Advanced Strong Hybrid and Plug-In Hybrid Engineering Evaluation and Cost Analysis

CARB Agreement 15CAR018

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DISCLAIMER

ACKNOWLEDGMENT

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Abstract

To improve vehicle fleet fuel efficiency and to meet emission standards, global automotive manufacturers have increased their strong HEV and PHEV portfolios. New technologies have been developed and deployed across many vehicle segments that claim to improve efficiency and overall vehicle performance while limiting the impact of increased costs. This study provides engineering evaluation and cost assessment of selected recent technologies available to support OEM hybridization strategies in the near and longer-term. 6 state-of-the-art systems that represent the most up-to-date technology were selected based on detailed review of OEM hybridization strategy, HEV/PHEV sales & forecast and advancements in vehicle architectures and hybrid technology in recent model years. Five of the selected technologies were related to electric powertrain and the sixth related to heating and cooling. The study highlights design improvements, and claimed advantages of the systems and then goes on to gain an understanding of the materials and manufacturing processes used to produce them. Direct and indirect costs for each component and assembly were then estimated. Finally, the report provides insights into emerging technologies to understand the potential cost reduction that may be achieved by 2025.

Executive Summary

To reduce greenhouse gas emissions, improve fuel economy, and meet zero-emission vehicle requirements in California and other regions, Original Equipment Manufacturer (OEMs) have introduced a mix of strong Hybrid Electric Vehicle (HEV) and Plug-in Hybrid Electric Vehicles (PHEVs) to their portfolios. Advancements in hybridization technology have been made, not only to meet regulations but also to improve vehicle driving and range performance while at the same time reducing overall vehicle costs. Customer acceptance is also increasing with annual HEV sale volumes around 400,000 units in the U.S. and a 63% increase in PHEV variants in the first six months of 2016. Most manufacturers are expecting a significant increase in hybrid vehicles, GM projects growth from 3 models in 2016 to more than 40 by 2025. In parallel, a six-fold increase in production volumes across HEV and PHEV models is projected. This study has been conducted to assess hybrid vehicle systems that present significant technological improvements that reduce weight, cost, improved efficiency, or performance, and are relevant for future mainstream vehicle markets within the U.S. A detailed cost estimate analysis was conducted by disassembling each system to its component parts and then estimating the cost associated with the material, production processes, and labor to manufacture the parts and assemblies. As the study is forward-looking CARB requested that the cost models developed should use PHEV production volumes of 200k units per year. The Toyota Prius 47% market share is at or near this volume in the U.S. market but is approximately half of the total NA 2015 HEV sales volume. It should be noted that the resultant cost estimates for the non-Toyota systems will therefore already incorporate cost savings associated with the expected increase in future production volumes.

Improvements in strong hybrid and plug-in hybrid technologies were assessed through review of technical papers, vehicle sales data, and assessment of global OEM hybridization strategies and benchmarking of currently available HEV/PHEV vehicles within the U.S. While comparing and contrasting differences between hybrid vehicle architectures (including Series, parallel and power-split), key subsystems in selected vehicles brands and models have been evaluated. Attractive technologies were identified in newly introduced and bestselling vehicles/brands; these include General Motors, Toyota, Ford, Audi, and Volkswagen as part of the VW group. Although other manufacturers, such as Honda, have announced some new advanced technologies for relevant vehicles, these will not be launched in the U.S. until 2018, so have not been considered due to the unavailability of hardware for study.

The initial review of vehicle technologies provided insight into some common trends embedded into new designs across OEMs.

- Light weighting
- Part reduction by component integration
- Efficient thermal management
- Reduction of mechanical and electric losses
- Limiting exposure to potential supply chain volatility in rare earth materials

To get in-depth insights into technological improvements and cost saving opportunities, it was recommended that there be a full teardown and cost estimation on the following six subsystems:

(1) Motor/Generator (MY2016 Chevrolet Volt PHEV)
(2) Traction motor (MY2016 Toyota Prius HEV)
(3) Dual power inverter (MY2016 Toyota Prius HEV)
(4) Single power inverter (MY2016 Audi A3 e-Tron PHEV)
(5) Air-cooled DCDC converter (MY2016 FORD FUSION HEV and C-MAX Energi)
(6) Heat pump systems (MY2015 Volkswagen e-Golf BEV)

It became clear through preparing this report that innovation at the OEMs is continuing at a brisk pace, looking not only at discrete technical engineering solutions but also at broader commercial considerations. Both GM and Toyota have developed new yet different approaches to limit their exposure to supply chain risks associated with rare earth materials that are extensively used in many modern automotive electric traction motors. Global accessibility of these high-cost materials is limited, which restricts the opportunity for an alternative supply. GM made use of the extra packaging volume available in their application (Volt), to develop a new topology and electromagnetic design to leverage lower performing ferrite based magnets in their Permanent Magnet Assisted Synchronous Reluctance Machine (PMASRM) motor/generator. Toyota aggressively attacked the fundamental efficiency of the stator, rotor, and thermal management design to reduce the quantity of heavy rare earth materials used in their permanent magnet based traction motor.

In 2012 Ford adopted an air cooled Direct Current to Direct Current (DC/DC) Converter. This slow follower approach, concentrating on increasing the manufacturing volume to reduce cost, has been used on multiple products (Fusion and CMax) over a number of years. Audi and Toyota opted to reduce package size and cost by integrating systems into one unit. This brought synergies by simplifying external cooling loop hardware as the units shared a common cooling circuit and reduced the size and amount of material used to encase the power electronics. Audi combined their DC/DC converter, and inverter. They also used the relatively new Friction Stir Welding (FSW) technique to provide the coolant passage simplification and cost reduction of the cooling plate assembly. Toyota took integration one step further by combining not only the inverters and DC/DC converter, but also adding a battery voltage boost unit into a single package. The voltage boost unit does reduce electrical efficiency to the system but allows Toyota to adopt a smaller battery pack while still getting the benefits of a higher working voltage at the motors. Efficient thermal management is one of the important contributors to achieving CAFE and CO_2 standards.

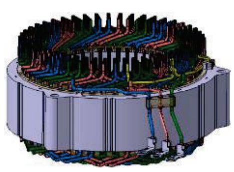
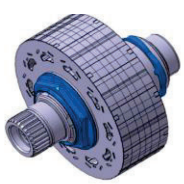
As BEV's generate relatively little heat, OEMs have developed heat pump thermal management systems that can efficiently move heat around the vehicle to heat the cabin on cold days. PHEV's are generally designed to use the Internal Combustion Engine (ICE) to provide heat to the cabin rather than using electric heating even when the battery has a reasonable level of charge. By effectively managing low-grade heat from the electric powertrain, OEMs could reduce the need or frequency of running the ICE to generate cabin heating allowing the vehicle to remain in electric mode longer. A well-designed and cost-effective heat pump system may improve the overall performance of PHEVs so the e-Golf's heat pump implementation was chosen for review.

Developing a suitable multi-valve manifold solution could also reduce the cost of such a system by 5%, approximately $22.

In the current generation of power electronics Silicon (Si) based insulated-gate bipolar transistor (IGBT) are utilized across all the systems. As Si's price performance ratio is starting to plateau, the OEMs are looking at different approaches to improving the price performance ratios of these systems. Wide Bandgap (WBG) technologies are starting to gain a foothold in lower power devices, such as audio systems, due to their fundamental material properties allowing for smaller, more efficient, and cheaper solutions. One of the challenges associated with bringing these technologies to high power devices (> 10 kW) is developing new high-temperature packaging materials and improving general manufacturing scale and quality. This is required to provide OEMs the ability to utilize them for higher power devices such as Inverters and DC/DC Converters. WBG costs are currently projected to be too high to be used in anything other than prestige level sectors over the next five years. Based on input from multiple sources, and assuming the technical challenges can be resolved by 2025, we can expect to see (1) WBG devices based on Silicon Carbide (SiC) with Inverters and DC/DC converters that are 25% to 35% smaller and lighter but 5% to 15% more expensive than current prices. (2) Gallium Nitride (GaN) achieve size and weight reductions of 35% to 45% in some applications. In addition, it is expected that in the near future GaN devices could achieve cost parity with Si based systems with a 5% to 20% cost reduction potential by 2025.

Although there is good evidence that OEMs are working hard to reduce PHEV costs, they are still faced with two difficult challenges: (i) the time required to provide surety that new technologies will meet the demands of warranty free operation for the 10 years, 150,000-mile design requirement and (ii) generating enough sales to justify investment in design and manufacturing capabilities needed to significantly reduce the cost of these systems. The scope of this report covered subsystem elements and components of strong hybrid powertrains, while further opportunities for cost reduction breakthroughs may be possible at the system level; these were beyond the scope of study for this report.

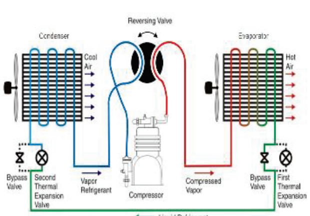
SUMMARY OF SELECTED SUBSYSTEMS

Recommended subsystems	Vehicle Powertrain	Attractiveness Improvements
1 **Motor A Generator**  	**MY 2016 Chevrolet Volt**  • PHEV • 2nd Generation	• Completely redesigned • Use of Ferrite Magnets • Weight and packaging reduction • Reduction of power and torque but increase of overall vehicle acceleration has been achieved • Attractive for cost – benefit • 48 kW, ~ $ 4/kW * • Analyzed weight 13.3 kg * (3.6 kW/kg *) • Package envelope 340 mm x 263 mm x 105 mm * (5.1 kW/L) • Cost Estimate with Mark-up * ~$192
2 **Traction Motor B**  	**MY 2016 Toyota Prius**  • HEV • 4th Generation	• Completely redesigned • Light weight traction motor • Reduction of rare-earth metals • Increase gravimetric power density • 53 kW, ~ $ 4/kW * • Analyzed weight 15.8 kg * (3.4 kW/kg *) • Package envelope 260 mm x 245 mm x 120 mm * (6.9 kW/L) • Cost Estimate with Mark-up * ~$221
3 **Dual Power Inverter** 	**MY 2016 Toyota Prius**  • HEV • 4th Generation	• Compact and better efficiency • Downsizing of the dual integrated liquid cooled AC inverters, boost converter, and DCDC converter • Improved volumetric power density • Analyzed weight 12.6 kg * • Package envelope 335 mm x 218 mm x 198 mm * (12.63 L) • Cost Estimate with Mark-up * ~$669

* Approximate values based on level of the sub-system analyzed, and where stated the electric motor kW rating, see Appendices for details

<table>
<tr><th>Recommended subsystems</th><th>Vehicle Powertrain</th><th>Attractiveness / Improvements</th></tr>
<tr><td>4 Single Power Inverter
</td><td>MY 2016 Audi A3 e-Tron

• PHEV
• 1st Generation</td><td>• Single integrated, liquid cooled AC Inverter/DCDC converter
• Weight reduction
• Improved performance
• Analyzed weight 10.2 kg *
• Package envelope 371 mm x 217 mm x 194 mm * (10.2 L)
• Cost Estimate with Mark-up * ~$752</td></tr>
<tr><td>5 DC/DC Converter
</td><td>MY 2016 Ford Fusion/CMAX


• HEV & PHEV
• 3rd Generation</td><td>• Air Cooled DCDC converter
• Cost reduction
• Analyzed weight 2.6 kg *
• Package envelope 313 mm x 155 mm x 79 mm * (3.8 L)
• Cost Estimate with Mark-up * ~$273</td></tr>
<tr><td>6 Heat pump system

</td><td>MY 2015 VW e-Golf

• BEV
• 1st Generation</td><td>• Improved cabin heating efficiency
• Improved electric range
• Suitable for PHEV but costly
• Analyzed weight 11 kg *
• Cost Estimate with Mark-up * ~$437</td></tr>
</table>

* Approximate values based on level of the sub-system analyzed, and where stated the electric motor kW rating, see Appendices for details

1 Introduction

1.1 Objective

The primary objective of the study is to identify HEV and PHEV electric drive powertrain technologies (excluding the battery pack and cells) that have undergone significant advancement in technology, cost, or efficiency since the assessment in the Joint Technical Support Document and the FEV, Inc. cost analysis study. Subsystems and technologies that meet the criteria mentioned above will be initially assessed and Ricardo recommended and defined the level of further analysis necessary on those selected subsystems. The scope of the study is limited to HEV and PHEV vehicles currently in production and available for sale in the U.S. To cover the broad spectrum of vehicle hybridization strategies, Ricardo assumed that new technologies were available in current bestselling vehicle brands as well as in most recent vehicles introduced in the U.S. market. Because of the differences in vehicle platforms, the team considered technologies available in Series, Parallel and Power-Split hybrid architectures. Ricardo also believes that design improvements in technologies such as heat pump systems available in some Battery Electric Vehicles (BEV) could reduce cost and make such subsystems an attractive option for cabin heating in a wide range of PHEVs.

1.2 Literature review

To evaluate the progress and improvements made in HEV and PHEVs, Ricardo first reviewed available public information, periodicals, OEMs websites, vehicle review web pages, and SAE papers. Information learned during this activity was used to validate hypotheses on OEM hybridization strategies. The Argonne National Laboratory (ANL) has provided HEV and PHEV sales data in the U.S. that has been collected since 2004. According to ANL, the Vehicle Technologies Office and its predecessor programs and/or offices within the Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy (DOE) have funded this work. Ricardo also used A2Mac1 Automotive Benchmarking Database to review selected vehicles in detail and to get initial insights on HEV and PHEV technology trends.

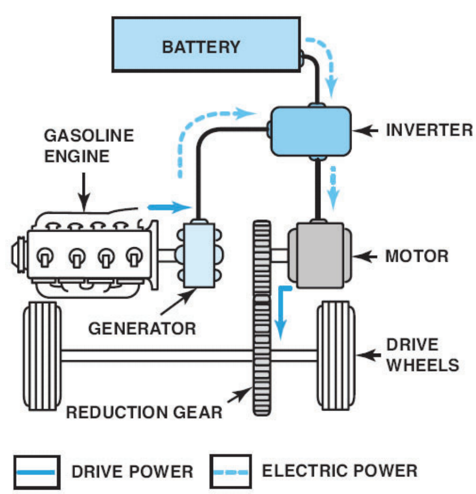
2 Current state of hybrid electric vehicle architecture

Both HEV and PHEV share some common principles. Motive power is typically provided by one or more electric motors in some combination an internal combustion engine (ICE). The ICE is designed to run on gasoline, biofuel or diesel fuel and a high voltage battery that provides electricity powers the electric motor. While a mid to long-range all-electric drive mode is not common in HEVs, PHEVs can run all-electric thanks to a larger capacity HV battery that can be recharged using an external electricity source. To combine and leverage the power flow of the ICE engine and electric motor, various vehicle architectures are available and generally classified as series, parallel, series-parallel or power split.

2.1 Series Hybrid Architecture

In a series hybrid, the ICE drives an electric generator to charge the battery and/or drive the traction motor, which propels the wheels as shown in Figure 2-1 the wheels. This vehicle configuration is less common today but found in some PHEVs, and it has been referred to as extended range electric vehicles (REX). For instance, the BMW i3 REX is designed around a series hybrid platform.

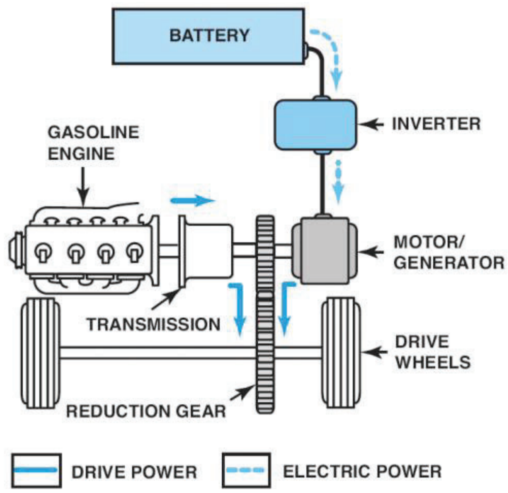
Figure 2-1 Power flow in series hybrid[1]



2.2 Parallel Hybrid Architecture

Parallel hybrid drive systems as shown in Figure 2-2 on p.18 involve the coupling of an ICE and an electric motor such that both are able to power the vehicle either individually or in tandem. In order to provide the power flow of both systems, a series of controlled clutches are typically included in the transmission to couple and decouple both the ICE and electric motor. The parallel hybrid architecture is widely used and the approach has been adopted in several vehicle models including BMW (X5, 330e, i8), Honda (Accord, Civic), VW Jetta, and Audi A3 e-Tron PHEV just to name few.

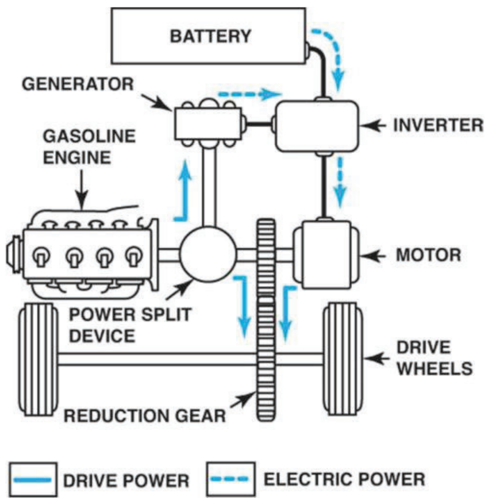
Figure 2-2 Power flow in parallel hybrids [1]



2.3 Series-Parallel or Power-split Hybrid Architecture

As the name describes, series-parallel and power-split hybrid configuration combine the operation of series and parallel hybrid. However, in a power-split architecture, the mechanical output of the ICE can be split to provide the motive force for the wheels and to drive a generator as shown in Figure 2-3 on p.19. The power splitter is usually a planetary gear set housed in the transmission and it allows the engine to both propel the vehicle and recharge the battery through the generator, though the latter can operate as a traction motor as well. The power-split architecture is usually used in "Twin Motor Drive" PHEVs and is implemented in the 2nd generation Chevrolet Volt as well as in several Toyota and Ford vehicle models.

Figure 2-3 Power flow in power-split hybrid[2]

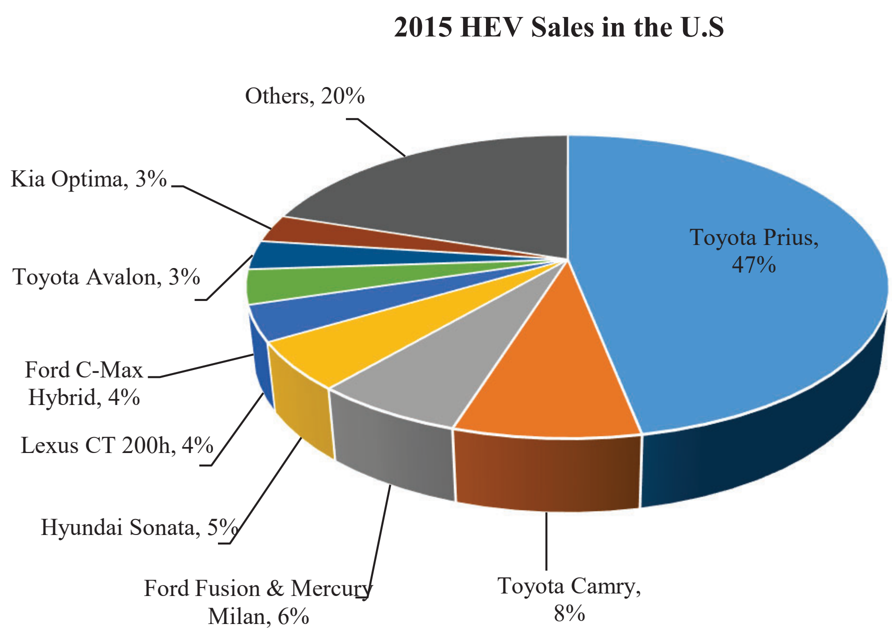


3 HEV / PHEV Market in the U.S.

3.1 Hybrid Electric Vehicles (HEV) Sales

Based on the data recorded by the Argonne National Laboratory, 384,400 Hybrid Electric Vehicles (HEV) were sold in the U.S. in 2015. A total of 40 vehicle models were available, with only 8 representing more than 80% of the market as illustrated in Figure 3-1. Toyota Prius HEV accounted for about half (47%) of total sales followed by the Toyota Camry (8%), Ford Fusion and Mercury Milan (6%), Hyundai Sonata (5%), Lexus CT 200h (4%), Ford C-Max Hybrid (4%), Toyota Avalon (3%) and Kia Optima (3%), all with single a digit market share. Clearly, the Toyota Prius HEV continues to dominate the market and leverage its brand recognition. Ricardo assumed that new cost efficient technologies available in MY2016 would certainly continue to keep Toyota ahead of the competition.

Figure 3-1 2015 HEV Sales in the U.S. (Market share %)[3]

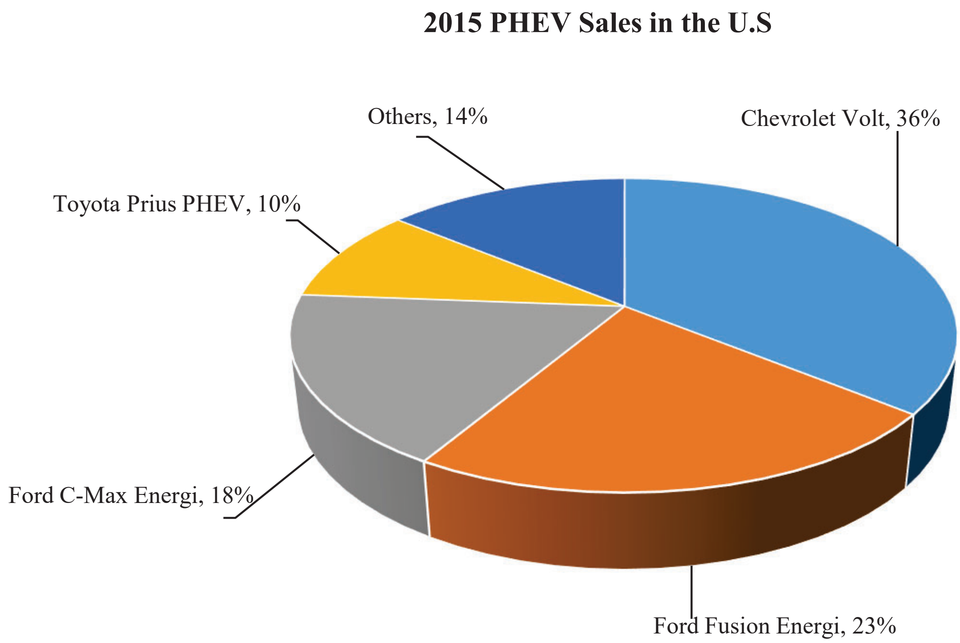


In the first six months of 2016, about 194,000 HEVs were sold in the U.S. (refer to Appendix A). Toyota Prius HEV continues to lead the market with 41% of sales. Sales of the newly introduced Toyota RAV 4 HEV is growing and the model represents about 12% of sales year-to-date.

3.2 Plug-In Hybrid Electric Vehicles (PHEV) Sales

In 2015, a total of 42,959 PHEVs were sold in the U.S. 13 vehicle models were available (refer to Appendix A for full list) but only 4 represented more than 80% of the market as illustrated in Figure 3-2. The Chevrolet Volt led the market with 36% share, followed by the Ford Fusion Energi (23%), Ford C-Max Energi (18%) and Toyota Prius PHEV (10%).

Figure 3-2 2015 PHEV Sales in the U.S. (Market share %)[3]



As of July 2016, about 36,500 PHEVs have been already sold since the beginning of the year, a 63% increase compared to the same period last year. This is not only due to the growing consumer acceptance of plug-in vehicles but also to the push from OEMs to increase their PHEV portfolio. European OEMs such as BMW, Volvo, Mercedes-Benz, and VW Group (Audi, VW, and Porsche) have introduced new PHEV models in the U.S. late 2015 and sales have steadily increased as illustrated in Appendix A.

In summary, sales data show that PHEV models are now being introduced as alternative and enhanced models compared to the same internal combustion engine powered version. Improvements in technologies, which often lead to cost reduction, could continue to make PHEV an attractive alternative. However, the vehicle architecture mix within strong HEV and PHEV differs among manufacturers and depends on OEM's electrification strategies.

4 Selected OEM Hybridization Strategies

4.1 Plug-in Hybrid Vehicle Technology Review

The current plug-in hybrid vehicle market was reviewed and six technologies were selected for additional detailed analysis. Each of the six selected technologies was analyzed to establish a "should cost" to manufacture and identify potential cost reductions for future plug-in hybrid vehicle system designs. The baseline cost of the current product is used to establish a delta cost to future design improvements. Cost reduction opportunities for future vehicles included design modifications, material substitutions, and processing improvements.

To select state-of-the-art systems that represent the most up-to-date technology, Ricardo reviewed technical papers, periodicals, equipment manufacturers' publications, advertisements, and public information on vehicle architectures and recent improvements in hybrid technology. In addition, Ricardo reviewed more than 18 months of U.S. HEV and PHEV sales data from January 2015 to July 2016. The team focused on the hybridization strategy of brands that comprise the top 80 percent of the global hybrid vehicle market with a dominant U.S. presence. It reviewed the technology trends in the brands' current production vehicles and compared series, parallel and power-split hybrid architectures. The Ricardo team also contrasted existing and new generation vehicle models using their own expertise and A2Mac1's large EV/hybrid benchmarking database.

MY2016 Chevrolet Volt PHEV	MY2014 Acura RLX Hybrid
MY2016 Toyota Prius HEV	MY2015 Honda Civic Hybrid
MY2013 Ford Fusion HEV	MY2016 Audi A3 e-Tron PHEV
MY2013 Ford C-Max Energi	MY2015 Volkswagen e-Golf BEV

The combination of hybridization strategy reviews and technology assessment validated the hypotheses that technologies available in selected vehicles are representative of the market environment and near-term vehicle development. Although Battery Electric Vehicles (BEV) were not in the scope, we believe that a well-designed and cost-effective heat pump system, which is available in the MY2015 Volkswagen e-Golf, provides advantages that can improve the performance of PHEVs as well BEVs.

4.2 Toyota Motor Corporation

4.2.1 Hybridization Strategy

Toyota offers a number of strong hybrids with power-split hybrid architecture based on the fourth generation Toyota Hybrid Synergy Drive (HSD)

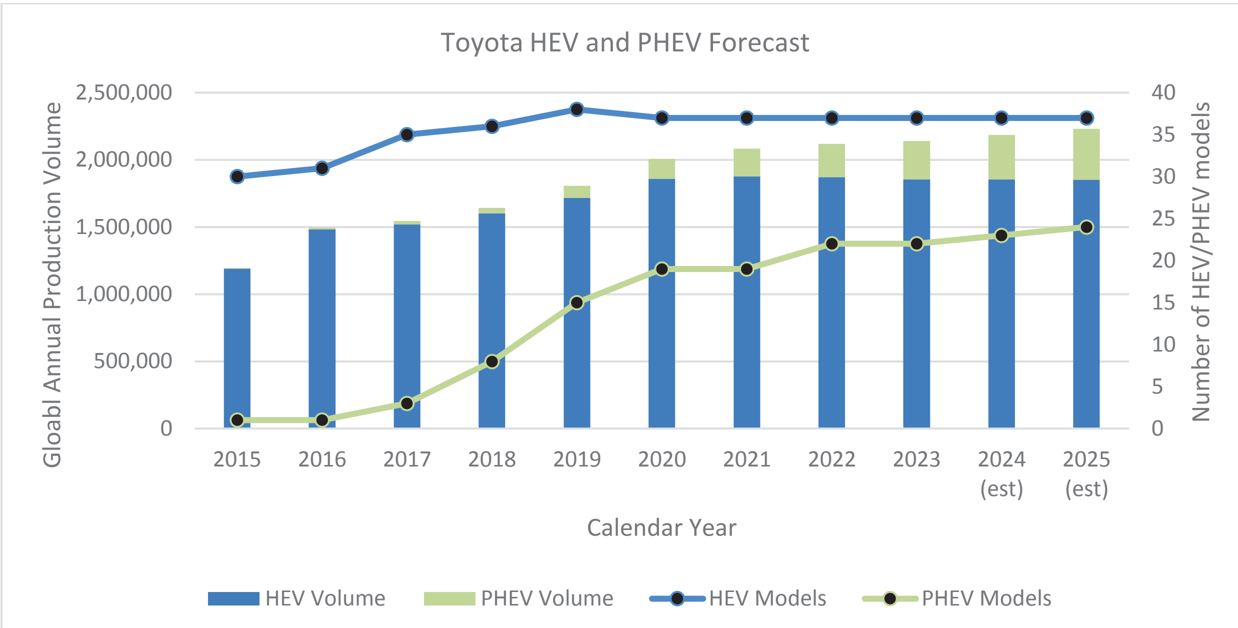
Currently, 12 HEV models are available across Toyota and Lexus as listed in Table 4-1 below. In front-wheel drive configuration such as in the MY2016 Toyota Prius Hybrid, the Toyota Hybrid Synergy Drive (HSD) consists of an internal combustion engine, a transaxle, two electric motors, an inverter-converter and high voltage battery[4]. In the all-wheel drive vehicle configuration, such as in the new MY2016 Rav4 Hybrid, a third electric motor is located in the rear-axle. In this configuration, there is no mechanical link between the engine in the front axle and the electric motor in the rear axle. We assume that the HSD all-wheel drive configuration will be available for Toyota Sport Utility Vehicles and within the Lexus brand.

Table 4-1 Toyota Current and Future Stated HEV/PHEV Model[4]

Model Year	Division	Nameplate	Powertrain	Vehicle Segment
2015	Toyota	Prius Plug-In (Production ended in 2015, new model in 2017)	PHEV	Mid-Size Vehicle
2016	Toyota	Camry	HEV	Full-Size Vehicle
2016	Toyota	Avalon	HEV	Full-Size Vehicle
2016	Toyota	Highlander	HEV	Sport Utility Vehicle
2016	Toyota	Prius	HEV	Mid-Size Vehicle
2016	Toyota	Prius c	HEV	Compact Vehicle
2016	Toyota	Prius v	HEV	Mid-Size Vehicle
2016	Toyota	RAV4 Hybrid	HEV	Sport Utility Vehicle
2016	Lexus	CTh	HEV	Compact Vehicle
2016	Lexus	GSh	HEV	Mid-Size Vehicle
2016	Lexus	Esh	HEV	Mid-Size Vehicle
2016	Lexus	LSh	HEV	Mid-Size Vehicle
2016	Lexus	RXh	HEV	Sport Utility Vehicle

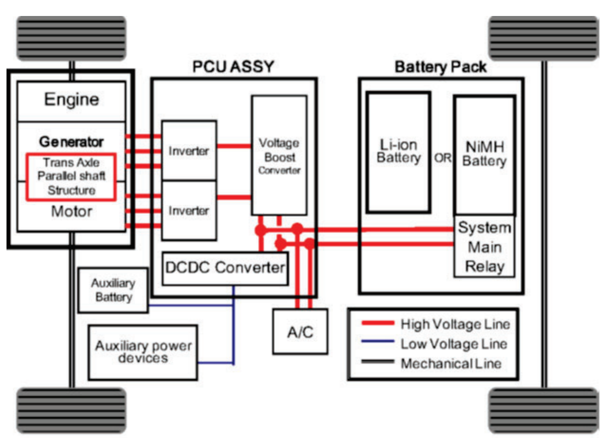
Nonetheless, we believe that Toyota will continue to widely adopt the same successful hybrid architecture available in the MY2016 Prius for other hybrid vehicles in its portfolio, especially for front wheel drive vehicles. Therefore, the bestselling Toyota Prius HEV will serve as a baseline for Toyota hybridization strategy. As Figure 4-1 shows, Toyota is projected to increase its global vehicle production to nearly 2.2M electrified vehicles by 2025. The Prius is forecast to represent more than 18% of total production in 2025. As the data in the figure below illustrates, Toyota will maintain the number of HEV models while steadily introducing new PHEV models.[10]

Figure 4-1 Toyota 2015 to 2025 PHEV & HEV Global Production Outlook [10]



The MY2016 Prius utilizes TOYOTA's new development strategy, TNGA (Toyota New Global Architecture) as shown in Figure 4-2 on p. 24. This architecture is also considered the baseline platform for future hybrid vehicles within the group.

Figure 4-2 Toyota New Global Architecture[5]



TNGA provides improvements in mechanical and electrical losses, size, and weight versus the previous generation core Prius, resulting in more than 14% combined city and highway fuel economy improvement.[5] The transaxle and electric motor have been redesigned to achieve better power-to-weight ratio. The total weight of the system was reduced by 9%[6] between 3rd and 4th generation designs.

Table 4-2 Comparison of 3rd and 4th Generation Prius [5]

Feature Comparison	**3rd Generation Prius**	**4th Generation Prius**
Engine	1.8L	1.8L
Engine Maximum Power	73kW	72kW
Engine Maximum Torque	142N-m	142N-m
Electric Motor	Synchronous AC Motor	Synchronous AC Motor
Electric Motor Maximum Power	60kW	53kW
Electric Motor Maximum Torque	207 N-m	163 N-m
Electric Motor Maximum Speed (rpm)	13,500	17,000

As Table 4-2 above shows, both the 3rd and 4th generation Prius utilize an inline 4 cylinder 1.8L internal combustion engine with comparable maximum power and torque. However, the synchronous AC Motor of the 4th generation Prius delivers about 12% less power and 21% less torque, but at a much higher maximum speed than the previous generation electric motor[5]. According to Toyota, the improvements made through proper selection and sizing of core components within the electric motor contributed not only to downsizing and weight reduction but also to a considerable reduction of electrical losses.

4.2.2 Toyota Selected Electric Powertrain Components

4.2.2.1 4th Generation Toyota Prius Electric Motor

Compared to the 3rd generation, the fourth-generation electric motor achieves a better power density. Although the latter delivers 12% less torque, its total weight has been reduced by more than 21%.[5] Additionally, improved design reduced electrical losses by more than 20%.[5] According to Toyota, the stator is designed with new features that include distributed winding with high packing space factor to minimize losses. In fact, Toyota moved from round to rectangular wires and the space factor improved by more than 15%.[5] Furthermore, the coil wire usage through segment winding reduced the use of copper. Figure 4-4 below shows a side-by-side comparison between the 4th and 3rd generation Toyota Prius stator.

Figure 4-3 MY2016 Prius HEV Highly Integrated Twin Motor / Gearbox[7]

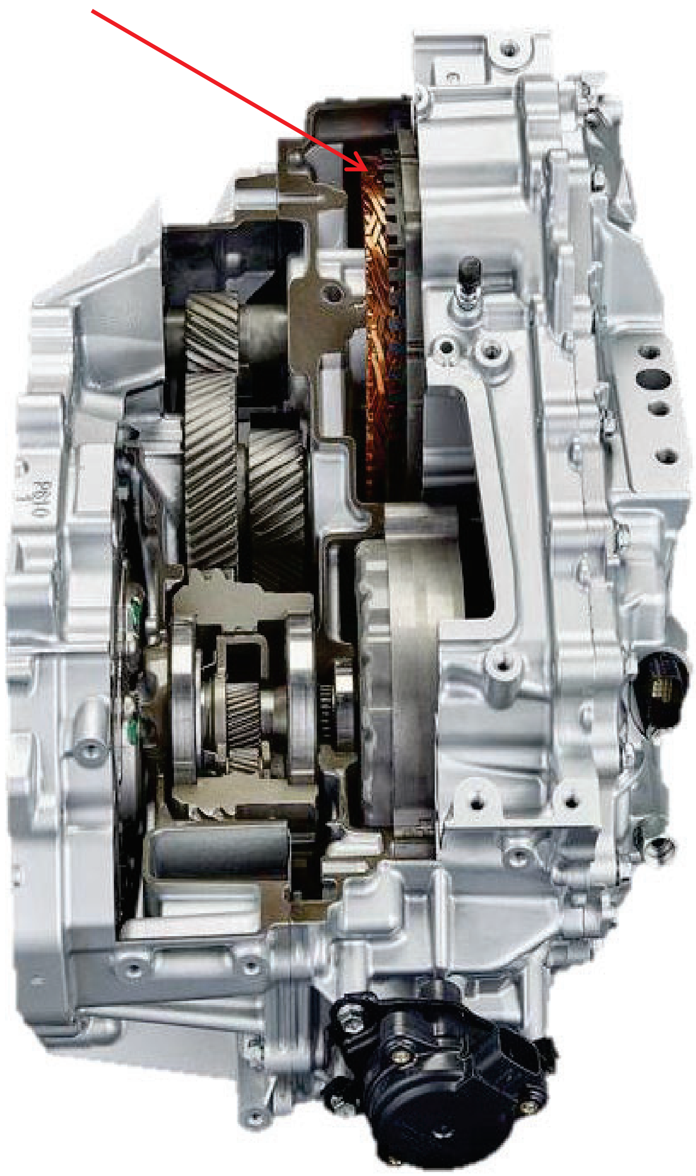
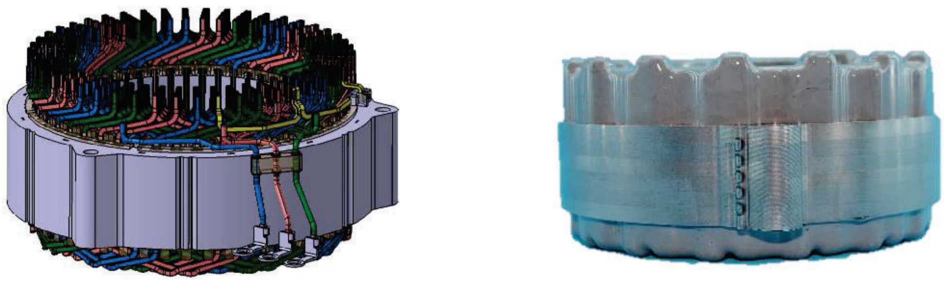


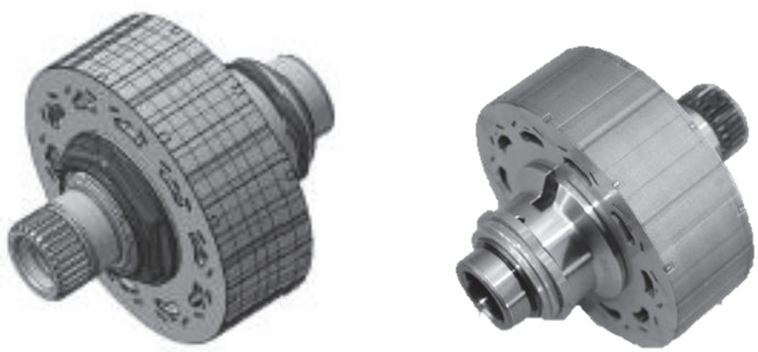
Figure 4-4 Comparison of Illustrative Stator MY2016 Prius HEV and MY2013 Prius HEV[5, 8]



The rotor was redesigned to reduce the rare-earth elements by more than 85%. In addition, Toyota state the magnet position was optimized providing further efficiency.

Figure 4-5 below depicts a side by comparison between the 4th and 3rd generation Prius rotor.

Figure 4-5 Comparison of Illustrative Rotor
MY2016 Prius HEV (left) and MY2013 Prius HEV (right)[5,8]

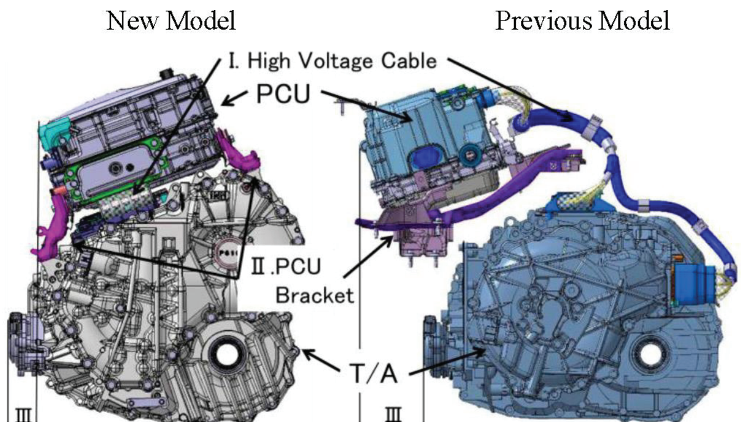


Changes made on both the rotor and stator of the 4th generation Toyota Prius HEV electric motor certainly play a key role in the overall improved vehicle performance.

4.2.2.2 4th Generation Toyota Prius Power Control Module

For improved performance, the 4th generation HSD Power Control Unit (PCU) has been redesigned as well around downsizing, weight, and electrical loss reduction. Compared to the previous generation, the weight, and volume of the PCU of the 4th generation MY2016 Prius has been reduced by 12% and 33% respectively while electrical losses have improved by 20%.[5] The smaller packaging, as shown in Figure 4-6 below allowed the PCU to be mounted directly on the transaxle to maximize vehicle space utilization and reduce high voltage cables. According to Toyota, introducing lightweight technology and downsizing of the control circuit board, reactor, capacitor module, current sensor, and DC/DC converter contributed the better performance. Also, improved sensing and faster processing enable improvement of controllability of high-voltage (allowing capacitor downsizing).[26]

Figure 4-6 Comparison of Power Control Unit of previous and new generation 2016 Toyota Prius[26]



As key functions, the Toyota PCU includes an inverter for the generator, an inverter for the traction motor, a boost converter, a DC/DC converter, and a cooling interface. All these key functions have been integrated into a single compact unit providing Toyota with the benefits mentioned above. Such a system is particularly attractive in "Twin-Motor Drive" hybrid system and necessitates further analysis. Ricardo recommends a full teardown and cost estimation the PCU unit and an assessment of the incremental cost/saving of system integration. Further analysis will also serve as a baseline to compare and contrast a dual power inverter with a single power inverter system commonly used in a "Single-Motor Drive" parallel hybrid architecture.

4.3 General Motors

4.3.1 Hybridization Strategy

Current and future trends show that GM is moving towards plug-in hybrids with a Power-split architecture as seen on the second-generation Chevrolet Volt

The MY2016 Volt is the second generation of the plug-in hybrid model and is considered best in class for a PHEV with 50+ miles all electric range. According to a study based on a survey of in-use operating data from more than 60,000 first generation Chevrolet Volts, it was determined that the trip initial ICE starts were reduced by 70% and Volt drivers were able to travel between 62% and 74% of their miles in all-electric mode without running the internal combustion engine. Based on this data, the same study concluded that second-generation Volt is projected to complete 80% of total miles driven using only electrical energy[9].

Since the first launch in 2010, the Volt has undergone several improvements, particularly in its powertrain. The Volt is significant not only as the best-selling plug-in hybrid in U.S., but also because its *Voltec* powertrain architecture is the basis for other GM HEVs and PHEV designs. The MY2016 Chevrolet Malibu and MY2017 Cadillac CT6 have been designed to use a similar architecture.

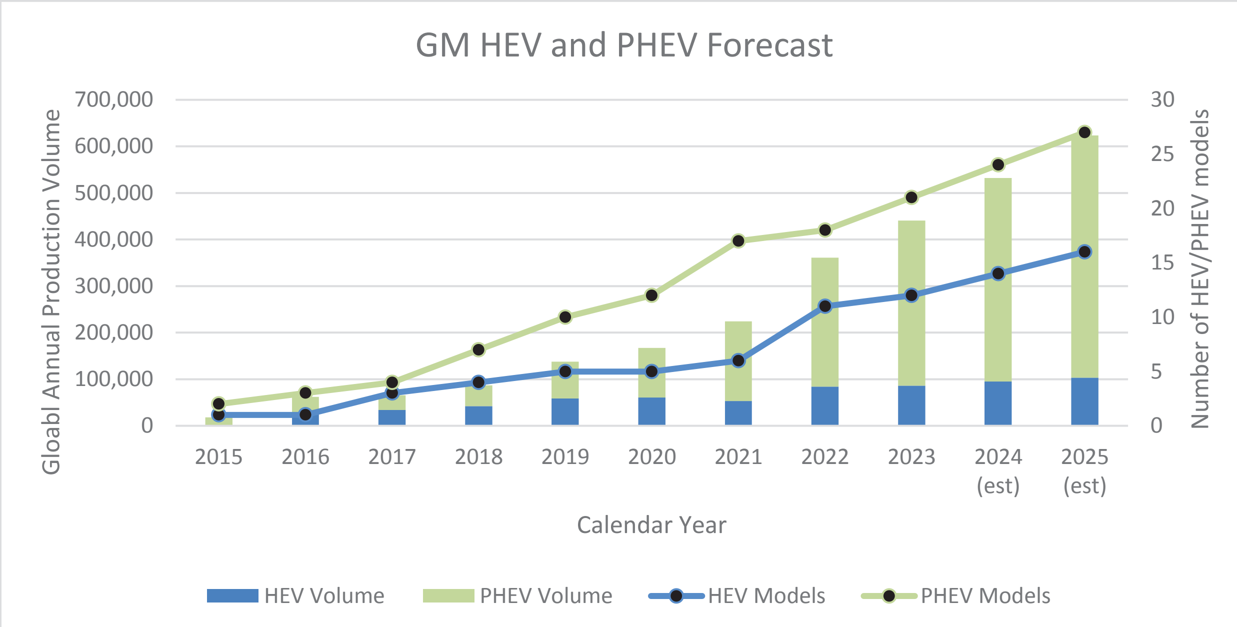
Table 4-3 Current and Future stated GM HEV/PHEV models

Model Year	Division	Nameplate	Powertrain	Vehicle Segment
2016	Chevrolet	Volt	PHEV	Compact sedan
2016	Chevrolet	Malibu	HEV	Mid-size sedan
2016	Cadillac	ELR (Out of Production)	PHEV	Full-size luxury sedan
2017	Cadillac	CT6	PHEV	Full-size luxury sedan

It is forecasted that Chevrolet Volt's power-split architecture will continue to be carried over to future HEV and PHEV GM models. GM's 2nd generation mild hybrid technology called eAssist, which is featured in the Buick LaCrosse, Buick Regal, Chevrolet Silverado and GMC Sierra, is predicted to be replaced with full and plug-in hybrids. The second generation MY2016 Chevrolet Malibu is an example, which has evolved from an eAssist mild hybrid to a full hybrid that is based on the *Voltec* powertrain architecture. The number of full HEV and PHEV models offered by GM is projected to grow from 3 in 2016 to more than 40 by 2025[10].

Furthermore, as Figure 4-7 below shows, GM is projected to increase its global HEV/PHEV vehicle production to approximately 167,000 units by 2020 at CAGR of 56%[10] for the Chevrolet, Buick, Cadillac and GMC brands combined. The Chevrolet Volt, which constitutes about 90% of GM HEV/PHEV production in 2015, is forecasted to represent more than 15% of total production by 2020 and is projected to remain one of the best-selling GM hybrids in the near term[10]. For further analysis, the bestselling MY2016 Chevrolet Volt will serve as a baseline for General Motors hybridization strategy.

Figure 4-7 General Motors 2015 to 2025 PHEV & HEV Global Production Outlook[10]



4.3.2 GM Selected Electric Powertrain Components

At a system and component level, several improvements have been made to optimize the power-split powertrain, particularly the redesign of the two electric machines to yield better performance, fuel economy and all-electric mode operation. GM's strategy for electric machine design is to reduce the use of rare earth metals in the permanent magnet rotors and thus reduce cost and mitigate uncertainty around rare earth prices. While several powertrain components are being shared across current HEV and PHEV platforms, electric machines are customized in different vehicles for best performance as illustrated in Table 4-4 below.

Table 4-4 Types of electric motor coupled with ICE in current GM full HEV and PHEV

Vehicle	**Type of electric motor coupled with ICE**
MY2016 Chevrolet Volt	Ferrite magnet (PM) e-machine
MY2016 Chevrolet Malibu	Lower grade neodymium (PM) e-machine
MY2017 Cadillac CT6	AC Induction e-machine

Figure 4-8 below depicts the difference between the Voltec powertrain configuration in the first and second generation Chevrolet Volt. Although both architectures utilize two motors there is a subtle difference in the way they are used. In the first generation, Motor A is a "generator" and Motor B is a "traction motor". GM has been able to reduce the power output, size, and cost of both motors combining their output in some modes to drive the wheels.

Figure 4-8 Schematics of 1st and 2nd Generation of Chevrolet Volt's Voltec System[11]

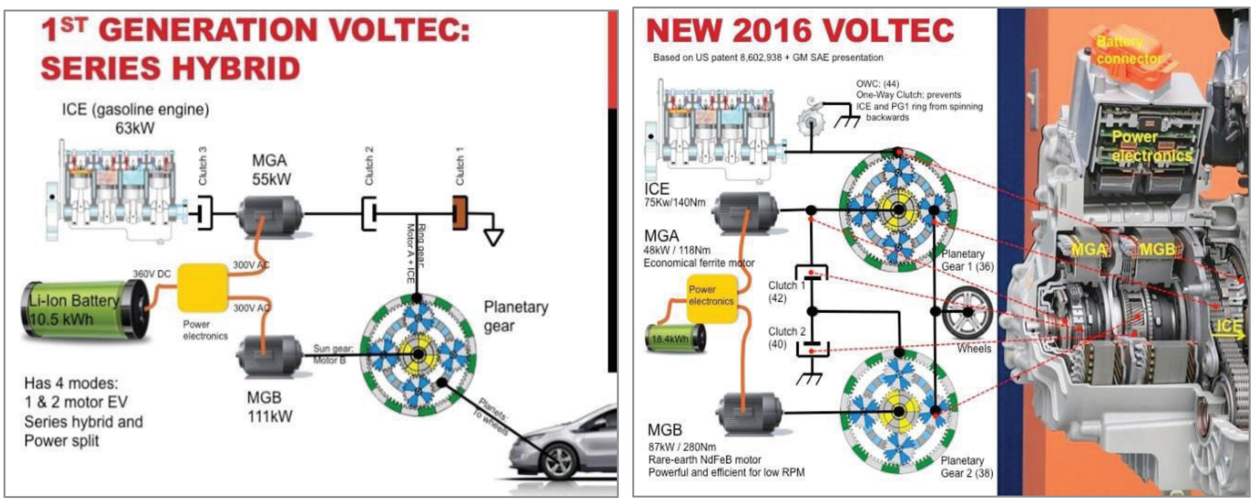
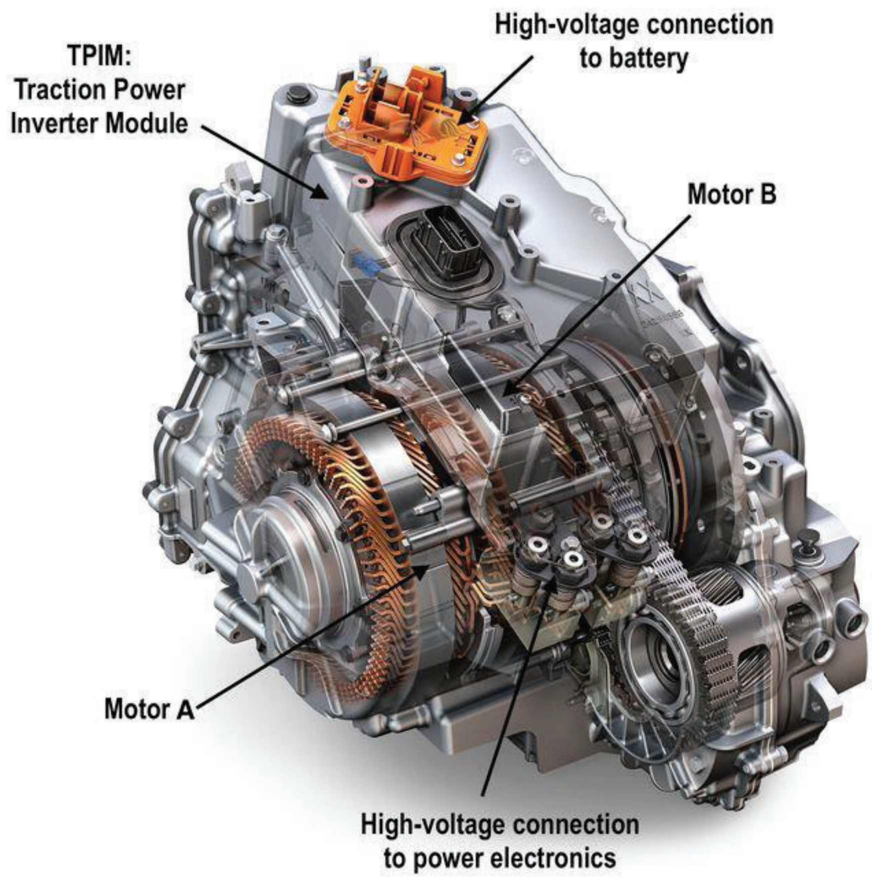


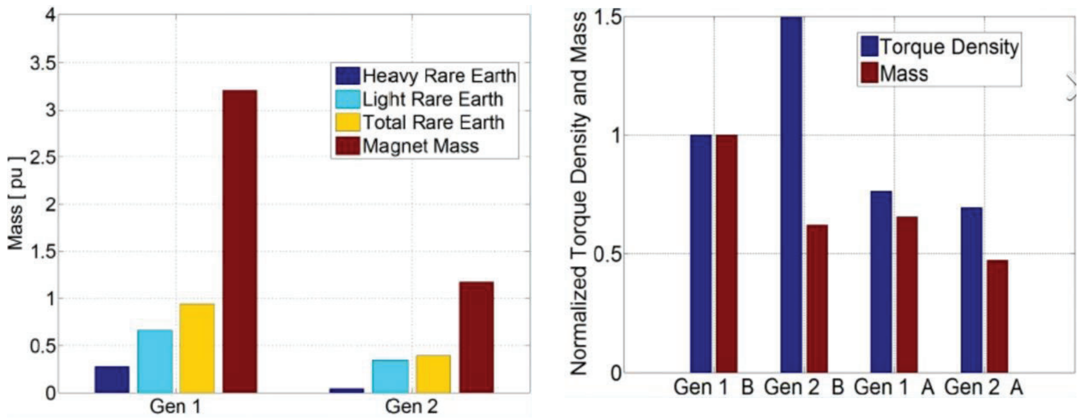
Figure 4-9 Gen 2 Voltec Drive Unit[15]



4.3.2.1 2nd Generation Chevrolet Volt Electric Motors

Because the Gen2 Voltec system can rely on both motor A and B for propulsion, the total torque and power output of each motor have been reduced by 15-20% (see Table 4-5 p. 34). As a result, the Gen2 system motor combined volume and mass have been reduced by 20% and 40% respectively compared to Gen114. Weight reduction has been achieved by minimizing the use of rare-earth metals such as Neodymium. In contrast to Gen1, the new Volt Motor A substitutes rare-earth magnets with ferrites magnets, while Motor B uses less Neodymium. In fact, the new design reduced heavy rare earth (Dy) usage by 80% and rare earth (Nd) by 50% from the two electric motors combined (Figure 4-10). Motor A has been redesigned with a weaker magnetic flux to minimize speed related losses at low loads and reduce costs. However, this design change is accompanied by reduced performance as is evident from the reduction in torque density of Motor A compared to its previous generation. In contrast, the continued use of rare earth magnets in an improved motor B design resulted in 50% increase in torque density.

Figure 4-10 (Left) Rare Earth Metal Usage; (Right) Motor Mass and Torque density comparison between Gen 1 and Gen 2 [12]



According to an SAE paper published by GM, the limited torque capability of ferrite magnets is enhanced by increasing reluctance torque component of the e-machine which is achieved by adding multiple magnets and air barriers to the motor[13]. The topology is often referred to as Permanent Magnet Assisted Synchronous Reluctance Machine (PMASRM). Although using ferrite magnets in a motor is not a new idea, its application has been limited to industrial uses where size, torque density, and operating temperature requirements are not as extreme as in automotive traction. While eliminating the use of rare-earth materials provides a pathway for cost reduction, it becomes necessary to design features to compensate for the decrease in performance that may potentially add some extra costs. Further investigation and cost assessment will provide insights on the state of ferrite based magnet technology as well as the cost benefits. Typically, this topology provides the following benefits.

- Power factor and inverter kVA requirement are comparable to an induction motor
- It can be operated stably down to zero speed at full load unlike an induction motor which may suffer overheating problems
- Can to be more efficient at low speed than an induction machine
- By adding appropriate amount of magnet into the rotor core, efficiency improves without having significant back-EMF and without change in the stator design. Because of the existence of flux barriers, demagnetization is hard to occur.
- Potential for lower bearing and winding temperatures

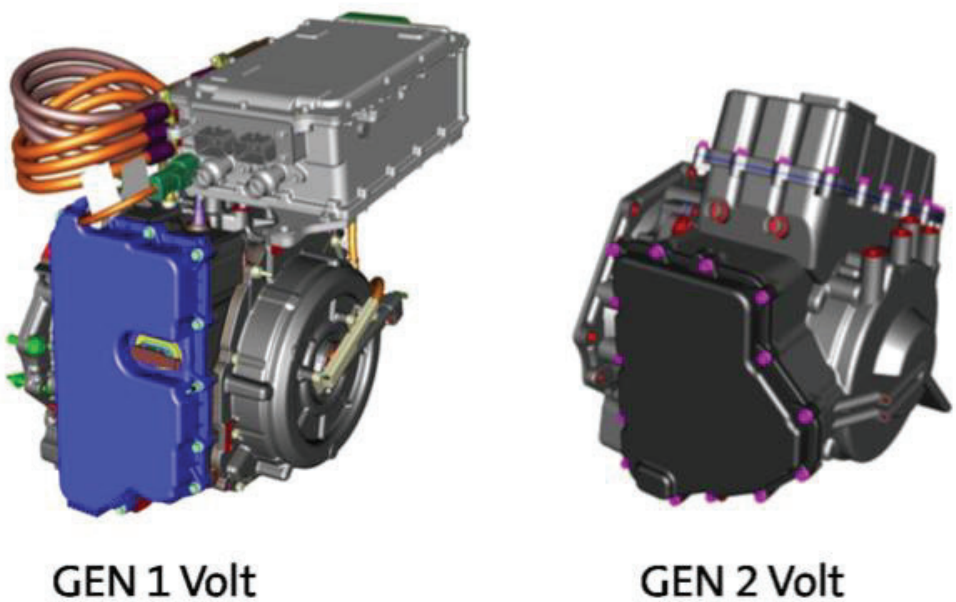
Table 4-5 Differences between first and second generation of Volt drivetrain[14]

Components	Gen 1 Chevrolet Volt	Gen 2 Chevrolet Volt
Motor A Type	Concentrated winding, NdFeB magnet	Distributed bar wound, Ferrite magnet
Motor A Power / Torque	55 kW / 186 Nm	48 kW / 118 Nm
Motor B Type	Distributed bar wound, NdFeB magnet	Distributed bar wound, NdFeB magnet
Motor B Power / Torque	111 kW / 370 Nm	87 kW / 280 Nm
Power Electronics	Separately mounted	Integrated
Total System Mass	164 kg	119 kg

4.3.2.2 2nd Generation Chevrolet Volt Power Inverter Module

The new Voltec transmission has an integrated Traction Power Inverter Module (TPIM), which is similar to the transmission in the 4th generation Toyota Prius HEV. As Figure 4-11 on p. 35 shows, integrating the TPIM with the drivetrain eliminates heavy current conducting cables and the overall volume has been reduced from 13.1L to 10.4L15. The TPIM consists of power inverter-A, power inverter B and a third inverter that runs an oil pump motor. In contrast, the DC/DC converter in the Toyota Prius is not integrated with the TPIM. According to data made public by GM, the TPIM uses Delphi's novel dual-side cooled Viper as the power device, which contains silicon IGBT and diode housed in an electrically isolated but thermally conductive package. This enables reduction of the silicon footprint, allowing for greater layout flexibility, and reduced cost[15].

Figure 4-11 Integrated power unit of Gen 2 Volt eliminates need for high voltage cables[12,15]



Although improvements were made on the TPIM, Ricardo will analyze the 4th generation Toyota Volt Power inverter that has similar features than the Volt but integrates a boost converter and a DCDC converter as well. We believe that integration will continue to be the focus in vehicle development and will require advanced technologies to enable compact design. Therefore, Ricardo believes that Toyota technology will provide comprehensive insights into power inverter technologies.

4.3.2.3 2nd Generation Chevrolet Volt Vehicle Parameters

Drivetrain improvements along with higher energy density battery pack and improved power-split architecture allows the Volt to maximize its electric only operation and extend all electric range from 38 miles in Gen1 to 53 miles in Gen2. Some key vehicle parameters include:

- 0-60 mph performance improved from 9.0 s to 8.3 s.
- Combined city/highway MPG in gas mode is up 11%.
- Combined city/highway MPGe in electric mode is up 4%.
- Curb weight reduced by 6.4%.
- MSRP is $1,000 less than the MY2015 Volt.

Table 4-6 Differences between first and second generation of Volt

Parameters	Gen 1 MY2015 Volt	Gen 2 MY2016 Volt
Base MRSP	$34,170	$33,170
Curb weight (lbs.)	3786	3543
Engine Size	1.4L 80 hp	1.5L 101 hp
Battery Size (kwh)	17.1	18.4
Vehicle horse power (hp.)	149	149
EPA Electric range (mile)	38	53
EPA (MPG / MPGe)	37 / 98	42 / 106
0 to 60 mph	9.0 s	8.3 s

4.3.2.4 Comparison between Chevrolet Volt PHEV and Malibu HEV drive unit

The Malibu Hybrid carries over the power inverter module, DC-DC converter, motor stators, and several other elements of the 2016 Volt powertrain as well as the power-split hybrid architecture. However, the motor rotor is a two-barrier interior permanent magnet design using NdFeB magnets[14]. The rotors are customized for HEV application and unlike the design used in the Volt. For example, Motor A in the Malibu uses NdFeB magnets instead of ferrite magnet used in Volt for better performance at the lower speeds of the hybrid drive cycle and less heat generation and losses under repeated high loads. Unlike in the Volt where both Motor A & B can power the wheels, in the Malibu, only the motor B is connected directly to the wheels while the Motor A acts as a generator to transmit engine power to the electrical drive.

Table 4-7 Drive Unit Specifications Comparing Volt (plug-in) and Malibu (HEV) [16]

Features	Volt	Malibu Hybrid
Motor A Type	Distributed bar wound, Ferrite magnet	Distributed bar wound, NdFeB magnet
Motor A Power	48 kW	55 kW
Motor B Type	Distributed bar wound, NdFeB magnet	Distributed bar wound, NdFeB magnet
Motor B Power	87 kW	76 kW
Power Electronics	Integrated	Integrated
Total System Mass	119 kg	116 kg

Despite being a larger vehicle than the Volt, the Malibu hybrid gets better fuel economy in gas hybrid mode than the Volt because of exhaust gas heat recovery, more efficient rare-earth PM motor, performance and tuning for gas operation mode. The EPA rated MPG of the hybrid Malibu is improved by 50% with more available power compared to the conventional ICE version. Because of similarities with the Volt and Prius, further analysis is not recommended on the Malibu drive unit.

4.4 Ford Motor Company

4.4.1 Hybridization Strategy

Ford offers a number of strong HEVs and PHEVs with a power-split architecture based on a 3rd generation system.

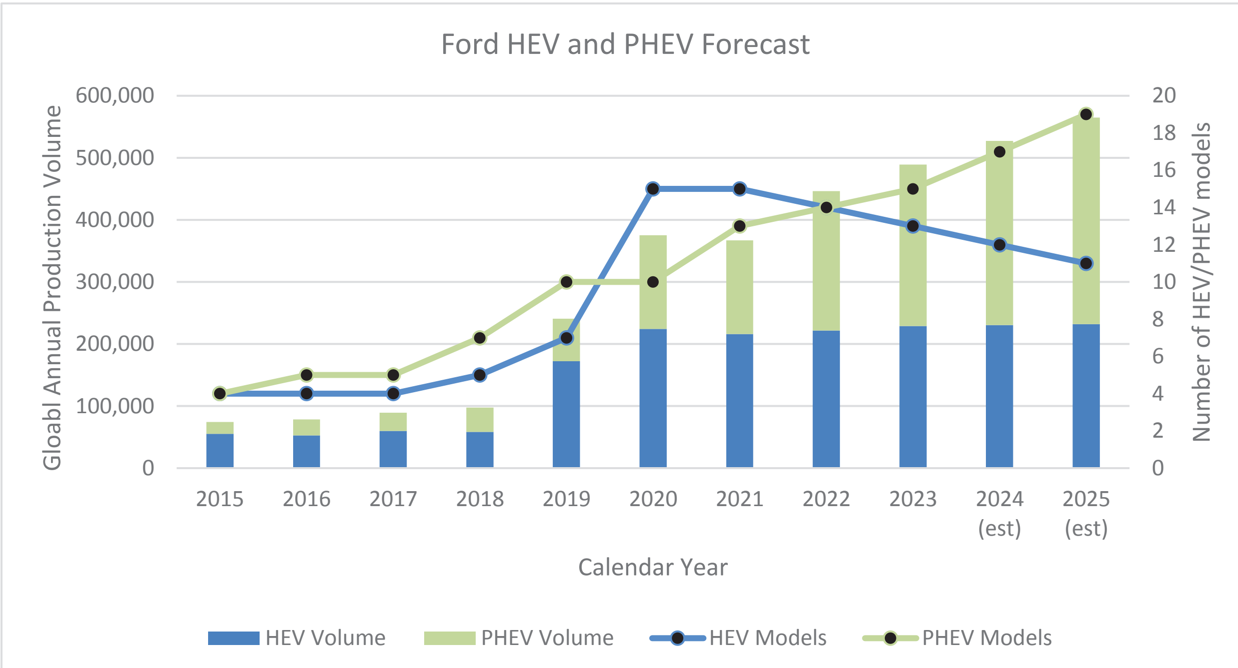
Ford Motor Company currently offers five hybrid vehicles in MY2016. The vehicles available include two plug-in hybrid electric vehicles, branded "Energi." and three hybrid electric vehicles as listed in Table 4-8 below.

Table 4-8 Ford Current HEV and PHEV vehicles[17]

Model Year	Division	Nameplate	Powertrain	Vehicle Segment
2016	Ford	Fusion Energi	PHEV	Mid-Size Vehicle
2016	Ford	CMAX Energi	PHEV	Full-Size Vehicle
2016	Ford	Fusion Hybrid	HEV	Sport Utility Vehicle
2016	Ford	CMAX Hybrid	HEV	Mid-Size Vehicle
2016	Lincoln	MKZ Hybrid	HEV	Mid-Size Vehicle

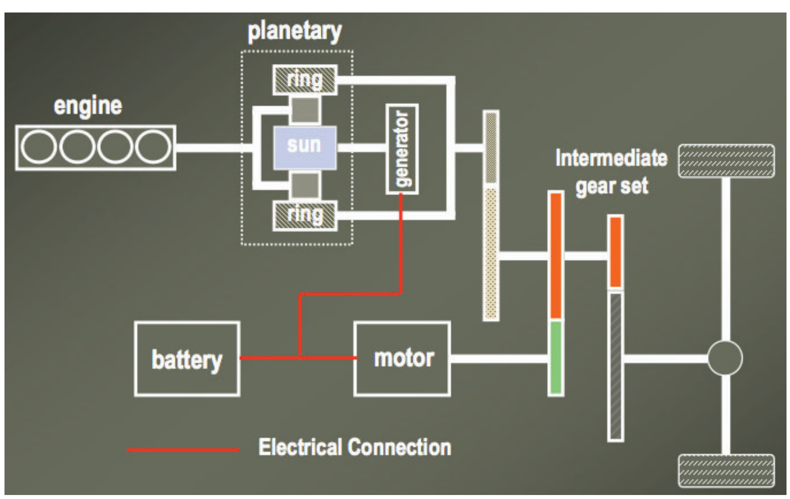
Ford's electrification strategy is based on a power-split platform architecture using downsized engines. Ford has made continuous efficiency improvements in different vehicle systems including engine, electrical A/C compressors, brakes, e-machines, power split transmission, high voltage battery, controls, and calibration.[18] Ford Fusion Energi PHEV has been Ford's best-selling PHEV since it was introduced in February 2013. In 2015, Ford Fusion Energi sold 9,750 units[3] (23% market share), second to the Chevrolet Volt with 36%. The 2015 Ford Fusion and CMAX electrified vehicles accounted for over 70% of total Ford HEV and PHEV global production.[10] Looking forward, Ford has stated that the company is investing $4.5B to increase vehicle electrification.[17] Ford production is forecasted to peak at about 594,000 electrified vehicles with 11 full hybrids and 19 plug-in hybrid vehicles produced globally by 2025. Ford anticipate a growing demand for PHEV products as indicated in Figure 4-12 below.[10]

Figure 4-12 Ford 2015 to 2025 PHEV & HEV Global Production Outlook[10]



The powertrain architecture in the Ford 3rd generation design follows a power-split system consisting of two electric machines connected to the engine and wheels through a planetary gear set as illustrated in Figure 4-13 below . The hybrid system offers four modes of operation including electric drive, engine drive with positive split, engine drive with negative split and regenerative braking.[18]

Figure 4-13 Ford Generation III Hybrid electric architecture[18]

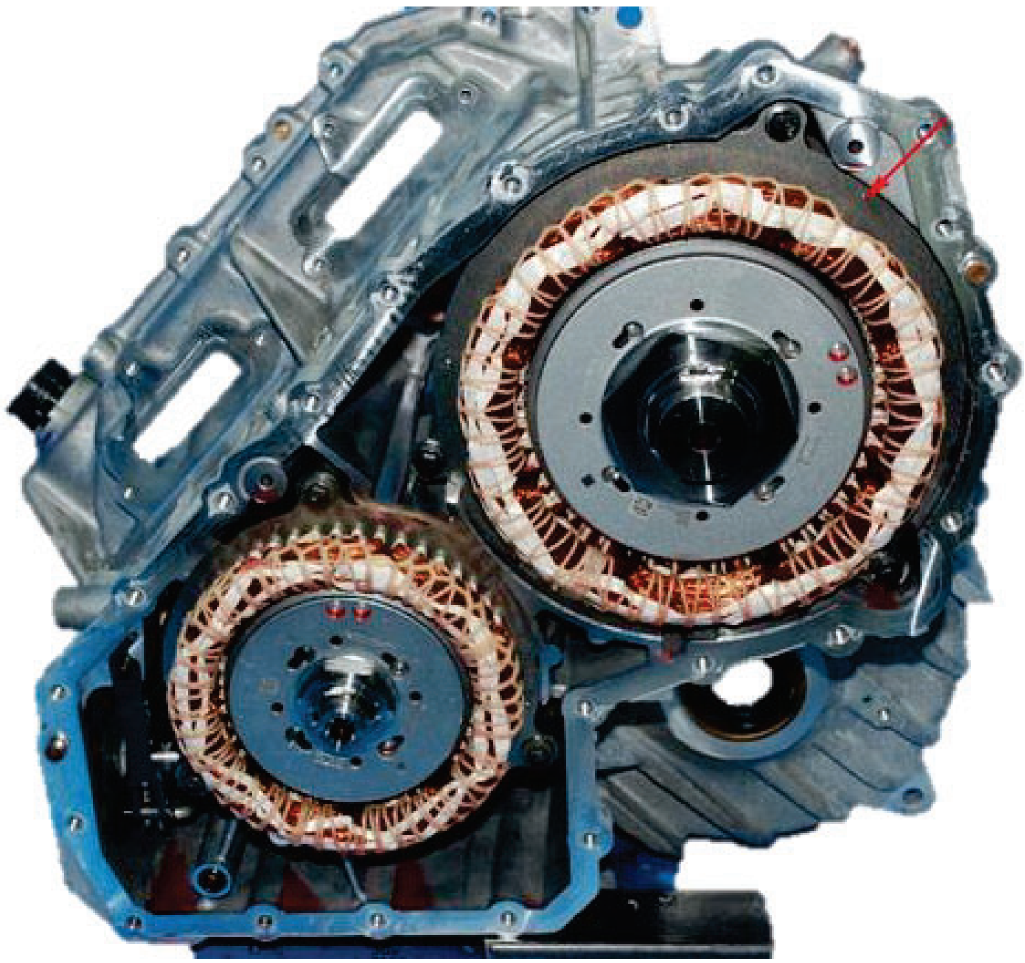


The generator in the Ford 3rd generation electrical architecture can provide battery charging during engine-on conditions and it is used as the engine starter. The ICE delivers torque under acceleration and steady state conditions when the battery charge is not required. The electric motor not only delivers torque and power under all-electric driving and acceleration modes but also provides battery charge during regenerative braking. [19]

In 2004, Ford made the decision to adopt a power split transmission in its HEV and PHEVs. The technology improvements from the Ford 1st and 2nd generation power split transmission resulted in 20% lower system cost. Further improvements led to additional 10% system cost reduction from the Ford 2nd and 3rd generation.[20] According to Ford, the power split strategy provides major benefits including improved packaging that maximizes space utilization while maintaining or improving peak horsepower and torque.

Over the three generations of hybrid electric systems, cost reduction strategy included managing the use of precious metals and identifying substitutes of costly rare-earths materials.[20] The 2013 Ford CMAX Energi Motor Generator is shown in Figure 4-14 on page 41. From Ford 2nd to 3rd generation electric architecture, Ford was able to develop measurable improvements. Cost reduction of power electronics was achieved by air-cooling versus liquid cooling in previous generations of hybrids.[21] In addition, the 3rd generation e-Drive system—with the inverter, controls, and electric machines— delivered nearly 5% efficiency improvements over three different operating points.[18]

Figure 4-14 2013 Ford CMAX Energi Motor Generator[8]



4.4.2 FORD Selected Electric Powertrain Components

4.4.2.1 3rd Generation FORD Electric Motors

The Ford CMAX and Fusion hybrid electric vehicle (HEV) utilizes a front-wheel drive 2-liter four-cylinder Atkinson cycle engine mated to a permanent magnet (PM) electric motor and powered by 1.4 kWh lithium-ion battery. Both vehicles output a total of 188 hp (140 kW) with an all-electric mode maximum speed of 62 mph (100 km/h). In hybrid mode, the CMAX and Fusion can achieve a maximum speed of 115 mph (185 km/h). [17]

Similarly, the CMAX Energi and Fusion Energi (both PHEV) deliver vehicle power of 188 hp (140 kW), however, a 7.6 kWh lithium-ion battery pack is used in the plug-in hybrid electric vehicles, more than 5 times the energy of that of the HEV variant. The traction electric motor in the Ford Energi plug-in hybrid electric vehicles can provide a top power of 68 kW and a total system power of 195 hp (150 kW) in charge-depleting mode (EV mode). The Ford Energi vehicles are also capable of reaching a top electric-only speed of 85 mph (137 km/h).[17] A comparison of Ford HEV and PHEV systems is found in Table 4-9 below.

Table 4-9 Comparison of Ford HEV & PHEV Systems

Features	**Ford Fusion / CMAX HEV**	**Ford Fusion / CMAX PHEV**
Battery Size	1.4 kWh	7.6kWh
Vehicle horsepower	188 hp	188 hp
Engine Displacement	2.0L	2.0L
Electric Drive	FWD	FWD
EPA-estimated EV Range	N/A	19 miles
Peak Voltage (during regeneration)	327 V	361 V
On Board Charger	N/A	3.3 kWh
Electric Mode Top Speed	62 mph	85 mph
Combined Power Charge Sustain Mode	188 hp (140 kW)	188 hp (140 kW)
Combined Power (hp) Charge Depletion Mode	N/A	195 (145 KW)

We assume that some attractive technologies in electric motors used by Ford is comparable to GM, Toyota and other major OEMs and therefore, we do not recommend further analysis on Ford electric motors.

4.4.2.2 Ford CMAX Energi & Fusion HEV DC/DC Converter

The 2013 Ford CMAX Energi utilizes an air-cooled standalone 2kW DC/DC Converter, as shown in Figure 4-15 below. The DC/DC converter is rated at about 145A at an output voltage of 14V. Ford's high-voltage to low-voltage DC/DC converter is stated to have 14% more power, 27% less volume, and 42% less weight than the previous design used by Ford Motor.[22]

Figure 4-15 2013 Ford CMAX DC/DC Converter (View: Front, Back and exploded)[8]

Ford claimed to reduce cost by using an air-cooled DCDC converter. Because the battery pack is air-cooled, the DCDC converter located inside the battery enclosure uses free airflow that circulates throughout the battery pack. Air-cooled DCDC converter is attractive and is different from the liquid-cooled approach provided by GM and Toyota. We recommend further analysis on the Ford DCDC converter. This will include a full teardown and cost estimation and an assessment of potential cost savings versus a similar liquid-cooled version. Comparing the Ford and Toyota DCDC converter will provide insights into cost saving opportunities.

4.5 Volkswagen Group

4.5.1 Hybridization Strategy

Volkswagen group offers a number of strong hybrids and Plug-in HEV across the Audi, VW, and Porsche brand.

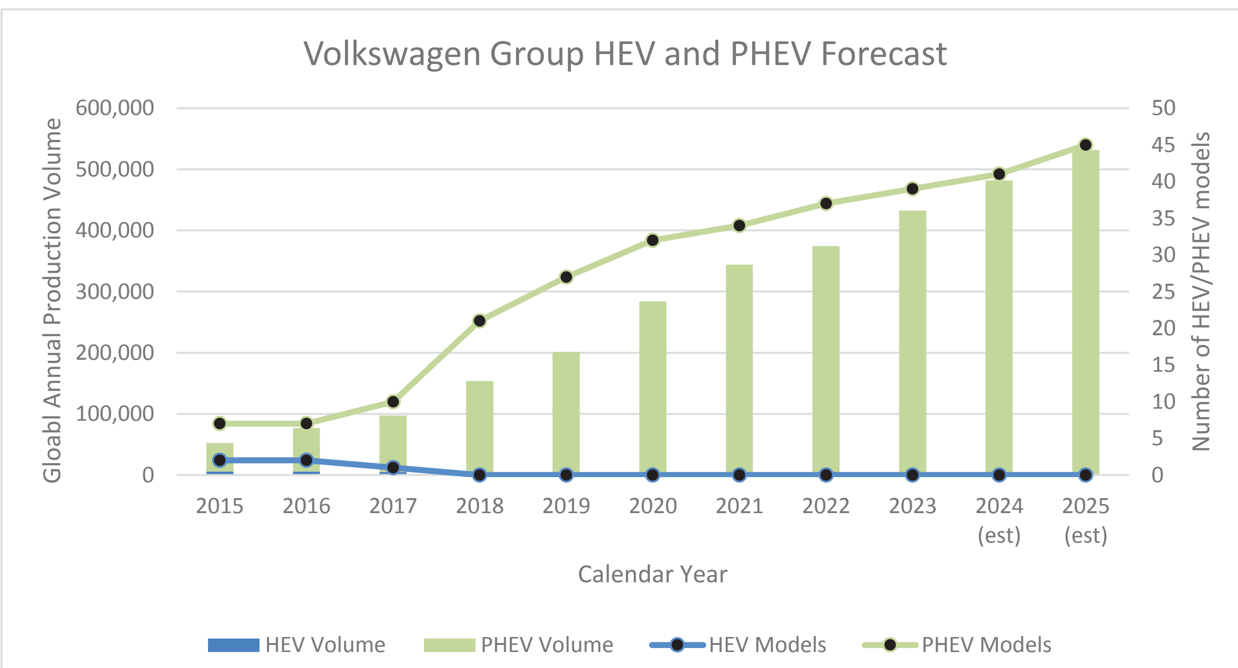
Introducing and promoting new hybrid and electric powertrains can help promote VW image after the recent violation of EPA and ARB emission regulations. As illustrated in Table 4-10 below, the VW Group currently offers five hybrid vehicle models in the U.S. as well as the pure electric e-Golf. Audi introduced the A3-eTron PHEV in the U.S. market this year and as of July 2016, more than 2,291 units (6% market share) have been sold[3]. During the same period, the luxury brand Porsche sold about 1,500 PHEVs, double the number of VW Jetta Hybrid sold last year (~750 units). Despite the aggressive push and marketing efforts, sales of the VW Jetta HEV is still falling short this year with only 356 vehicles sold as shown in Appendix A.

Table 4-10 Volkswagen Group HEV/PHEV Models

Model Year	Division	Nameplate	Powertrain	Vehicle Segment
2016	Audi	A3 e-Tron	PHEV	Compact Vehicle
2016	Audi	Q5 Hybrid	HEV	Sport Utility Vehicle
2016	Porsche	Cayenne S E-Hybrid	PHEV	Sport Utility Vehicle
2016	Porsche	Panamera S E-Hybrid	PHEV	Large size Vehicle
2016	VW	Jetta	HEV	Compact Vehicle
2016	VW	eGolf	BEV	Compact Vehicle

Over the next 10 years, we expect the group to phase-out its HEV models and increase its focus on PHEVs. As Figure 4-16 below shows, the Volkswagen group is forecasted to produce over 500,000 PHEVs by 2025, and more than 40 PHEV models sharing the same level technologies are expected to be available on the market[10].

Figure 4-16 Volkswagen Group 2015 to 2025 PHEV & HEV Global Production Outlook[10]



Last year, the Audi A3 e-Tron represented more than 30% of VW global PHEV production.[10] The A3 e-Tron is the first PHEV offered by the Audi brand in the U.S. With a front-wheel drive parallel hybrid architecture, the A3 e-Tron is powered by a 148-hp 1.4-L gasoline engine delivering 250 Nm of torque and a single 75-kW electric motor with 330-Nm of torque capability23. The electric machine can operate either as a traction motor or a generator, a “Single-Motor hybrid drive” architecture that is commonly used within the VW Group (VW, Audi, and Porsche), yet different from the” Twin-Motor hybrid drive” strategy offered by GM, Toyota, and Ford front-wheel drive systems. Because of the early success of the Audi A3 e-Tron (introduced in Europe in 2014) and the technology sharing policy within the VW group, industry experts believe that the platform will be carried over to several vehicle models within the VW group. To comply with both the “Modular Longitudinal Matrix” (MLB) vehicle construction strategy from Audi and Porsche brand as well as with the “Modular Transverse Matrix” of the VW brand. In fact, the MY2015 VW Golf GTE PHEV currently available in Europe shares the powertrain of the Audi A3 e-Tron[23].

According to Audi of America, the A3 e-Tron is part of the “*Audi energy”*, a comprehensive program designed to help improve the electric vehicle ownership experience and reduce the carbon footprint that comes with vehicle production, distribution, and driving[24]. As illustrated in Table 4-11 below the A3 e-Tron is not only more powerful than its conventional ICE-based counterpart model but also provides more than 20% better average fuel economy.

Table 4-11 Difference between Audi A3 e-Tron and A3 Conventional ICE

Parameter	**PHEV**	**Equivalent Conventional ICE**
Vehicle model	MY2016 A3 e-Tron	MY2016 A3
Base MRSP	\$37,900	\$30,900
Curb weight (lbs.)	3616	3175
Engine Size	1.4L, I4 Turbo	1.8L, I4 Turbo
Transmission Speed	6-Speed Dual Clutch	6-Speed Automatic
Battery Size (kwh)	8.8	-
Drive Type	FWD	FWD
Vehicle horse power (hp.)	204	170
Vehicle torque (Nm/ lb-ft)	330 / 243	272 / 200
EPA Electric range (mile)	16	-
EPA fuel economy (MPG/MPGe)	35 / 83	27 / -
Gas emissions (CO_2/mile)	158	328

4.5.2 VW Group Selected Electric Powertrain Components

4.5.2.1 1st Generation Audi A3 e-Tron Electric Motors

The electric drive of the A3 e-Tron is provided by a liquid-cooled AC permanent magnet synchronous electric motor producing 75kW (102 hp) and 258 lb-ft (350Nm) of torque. The disc-shaped electric motor is integrated between the flywheel and a dual-clutch 6-speed automatic transmission as shown in Figure 4-17 below. The high traction power electric machine is used to crank the internal combustion engine and work in tandem with the ICE to provide the propulsion force of the vehicle. Compared to the Chevrolet Volt or Toyota Prius HEV, not only does the A3 e-Tron use a more powerful electric machine, it also runs a much more powerful ICE engine delivering 110 kW (150 hp) and 250 N·m (184 lb-ft) to fit with the sports concept of the Audi brand. Although the technology sharing policy exists within the VW group, the electric machine is a component that is sizeable and varies across brands and vehicle models to fit the value proposition. We believe that the downsizing and light weight approach of the Chevrolet and Toyota electric machine better reflect the mainstream market and future trends. Therefore, the A3 e-Tron electric motor will not be recommended as a subject of further analysis.

Figure 4-17 Audi A3 e-Tron Powertrain[25]

4.5.2.2 Audi e-Tron AC Power Inverter Module

The VW Group "Single-Motor hybrid drive" parallel hybrid architecture incorporates a liquid-cooled pulse-controlled AC inverter that converts the DC voltage of the battery to alternating current necessary to drive the 75kw electric motor. To reduce the cost and maximize packaging, the DC/DC converter is directly integrated with the AC inverter and both units share a common dual face cooling plate.

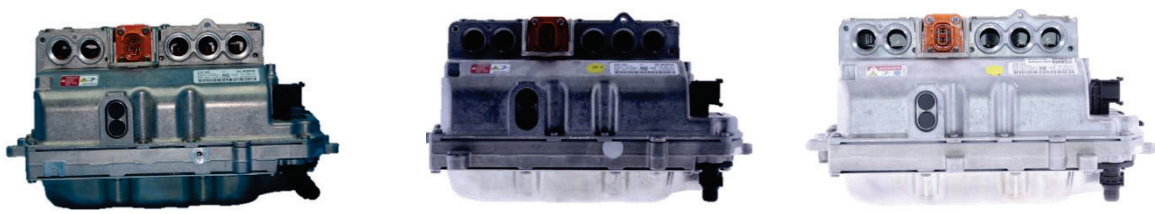
In MY2016 Audi A3 e-Tron, the compact single AC Power Inverter Module weighs 10 kg, just about 2kg lighter than the 4th Generation Toyota Prius Power Control Module (PCM weighs ~11.9 kg[26]) which includes a dual AC inverter to control the generator and the traction motor. However, with a volume of 6.8L, the Toyota PCU is 15% more compact than the A3's.

Table 4-12 Power Inverter Module: Differences between the Audi A3-eTron and Toyota Prius HEV

Parameter	MY2016 Audi e-Tron	MY2016 Toyota Prius HEV
Traction motor AC-Inverter	Integrated	Integrated
Generator AC-Inverter	N/A	Integrated
Boost Converter	N/A	Integrated
DC/DC Converter	Integrated	Integrated
Cooling	Liquid-cooled	Liquid-cooled
Volume	8 Liters[27]	6.8 Liters[26]
Weight	10 Kg[27]	11.9 kg[26]

Considering the technology sharing policy within the VW Group, Ricardo assumes that the Power Inverter Module used in the Audi A3 e-Tron will be carried over to several hybrid models within and across brands. In fact, the MY2016 Audi A3-eTron, the MY2015 VW e-Golf BEV and the MY2014 VW Jetta Hybrid seem to share a common power inverter design platform as shown in Figure 4-18 below.

Figure 4-18 AC Power Inverter Module (Left: Audi A3-eTron PHEV, Center: VW e-Golf BEV, Right: VW Jetta Hybrid)[8]



To compare and contrast the technologies in HEV and PHEV platforms and to get insights into the increment cost of power inverter modules designed for parallel vs. power-split hybrid applications, Ricardo recommended further analysis on both the Audi A3 e-Tron PHEV and Toyota Prius HEV power inverter module. The analysis will include a full teardown and component cost estimation.

4.6 Honda Motors

4.6.1 Honda Hybridization Strategy

Honda will offer a new generation of plug-in hybrids in its major core models starting with MY 2018 Honda Clarity while the existing Honda hybrids are being phased out gradually in the U.S.

Honda's parallel hybrid Integrator Motor Assist (IMA) system, which was first launched in 1999, has been phased out gradually. The last few vehicle models with the IMA system include the MY2014 Acura ILX, MY2014 Insight, MY2015 Civic and the most recent, MY2016 CR-Z. Besides the CR-Z, the only other hybrid offered by the Honda brand in the US today is the MY2017 Accord hybrid, which incorporates the second-generation I-MMD (Intelligent Multi-Mode Drive). This is a two-motor series-parallel hybrid system that made its first debut in the MY2014 Accord full hybrid and plug-in hybrid versions. The plug-in variant was not continued and the recent MY2017 full hybrid version will be discontinued.

While the number of hybrid models has been on the decline, Honda has announced that two-thirds of their vehicles will be electrified by 2030. In fact, the company will offer plug-in hybrids in major core models, starting with the MY 2018 Honda Clarity. The Clarity, which will replace the Accord hybrid, will offer an all-electric driving range of more than 40 miles. It will be the first vehicle in the world to be offered with hydrogen fuel-cell, battery-electric, and plug-in hybrid powertrains. Honda is collaborating with GM to develop plug-in hybrids in addition to their alliance for hydrogen fuel-cell vehicle technology joint venture called Fuel Cell System Manufacturing, LLC.

While other OEMs such as GM, Ford, Toyota, and VW have all recently refreshed their hybrid platforms and introduced new hybrid vehicle models, Honda is phasing out its existing hybrids in the US market to make room for new platforms. It seems that the launch of the Clarity plug-in hybrid in 2017 will mark the new generation of Honda's hybrid vehicles. The next generation Honda CR-V, which is due to be launched in 2017, is also likely to get a plug-in version[28]. Until then, Honda's new technologies will not be available in the U.S. market and Ricardo does not recommend further analysis on hybrid systems available in the outgoing Honda models.

The Acura brand, on the other hand, has adopted a different 3-motor all-wheel-drive hybrid system, which is a series-parallel architecture. It was released in the MY2014 RLX and is offered today in the RLX, NSX, and MDX Sport Hybrid. The 3-motor AWD hybrid system is a complex design and appears to be driven by performance rather than cost effectiveness. The benchmarking of the RLX electrified powertrain has not revealed advanced improvements in components such as electric motors or power electronics. Moreover, technological updates to Honda's hybrid platform may trickle down to Acura hybrid versions. Therefore, Acura's hybrid system does not appear to be attractive for detailed investigation of state-of-the-art technologies for mainstream market.

Table 4-13 Current and Future stated HEV/PHEV Honda and Acura models offered in US

Model Year	Division	Nameplate	Powertrain	Vehicle Segment
2016	Honda	CR-Z Hybrid (phased out)	HEV	Sport Utility Vehicle
2017	Honda	Accord Hybrid (phased out)	HEV	Full-size Vehicle
2017	Acura	MY 2017 Acura RLX Hybrid	HEV	Full-size luxury Vehicle
2017	Acura	MY 2017 Acura NSX Hybrid	HEV	Luxury sport Vehicle
2017	Acura	MY 2017 Acura MDX Sport Hybrid	HEV	Sport Utility Vehicle
2018	Honda	MY 2018 Honda Clarity	PHEV	Midsize Vehicle

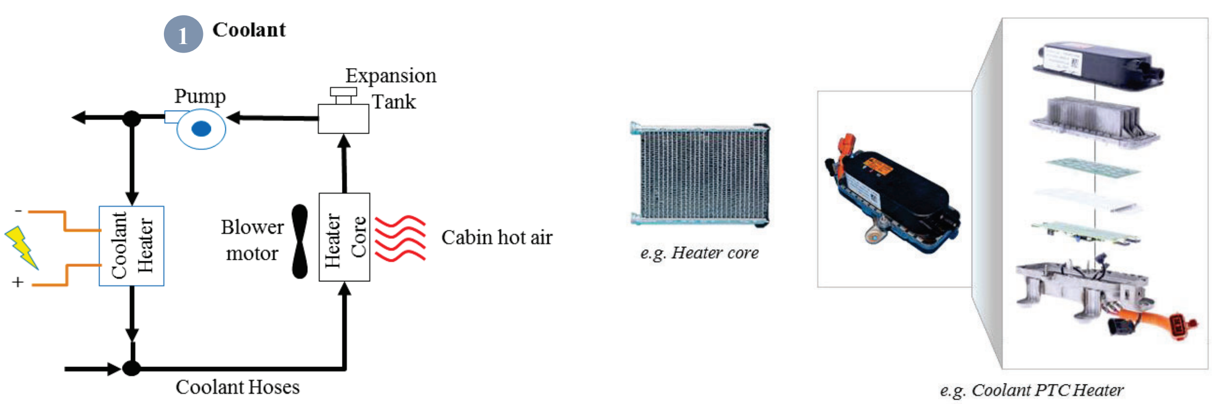
5 Cabin Heating Systems

In hybrid and BEV applications, cabin heating can be achieved using three solutions based on: (1) a coolant heater, (2) an air electric heater or (3) a heat pump system. Each system has pros and cons and the choice of one system versus the other depends on the vehicle architecture, the environmental conditions in which the vehicle will operate and the costs vs. benefits associated with each solution.

5.1 Coolant based cabin heating system

The coolant-based cabin heating approach is widely used in PHEV and BEV applications. The Chevrolet volt, Ford C-Max Energi, Audi A3 e-Tron as well as the VW eGolf all incorporate a coolant based cabin heating strategy. As depicted in Figure 5-1, the coolant heater (e.g. PTC heater) which can operate between 200-450V, draws electricity from the high voltage battery and heats up the coolant flowing through the heater core. The heat dissipated through the heater core is then blown inside the cabin to maintain the desired temperature.

Figure 5-1 Coolant based cabin heating system

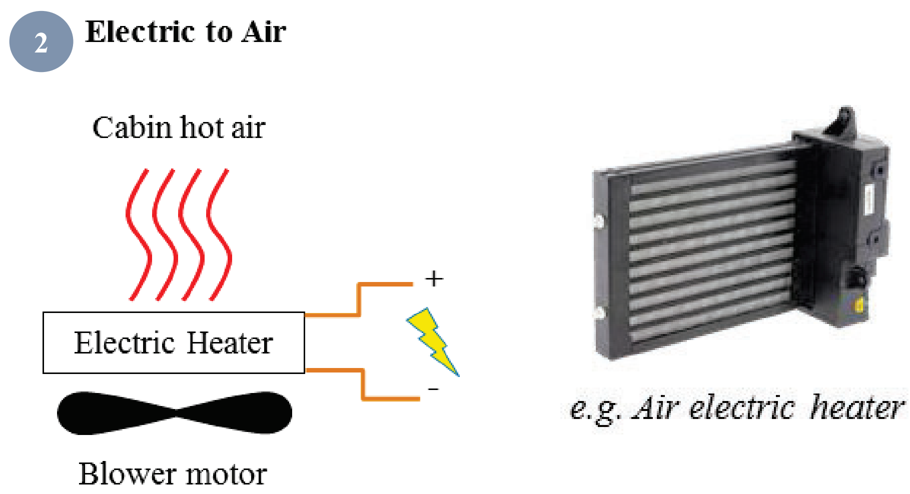


One of the benefits of combining the thermal management of the cabin with the power electronics described in Figure 5-1 is the use of the "free" heat transferred from the liquid-cooled power electronics to heat up the cabin. The system provides a very high controlled heat output, however, running the electric coolant heater adds load to the high voltage battery and consumes kilowatts of available energy that can be otherwise used to extend the vehicle electric range.

5.2 Electric cabin heating system

Using an electric heater reduces the complexity of the plumbing architecture (e.g. extra hoses, valves, pumps) as required with a coolant heater, solution (1). Instead, the electric system relies on the existing ambient airflow to control the cabin temperature.

Figure 5-2 Electric High Voltage Cabin Heating System

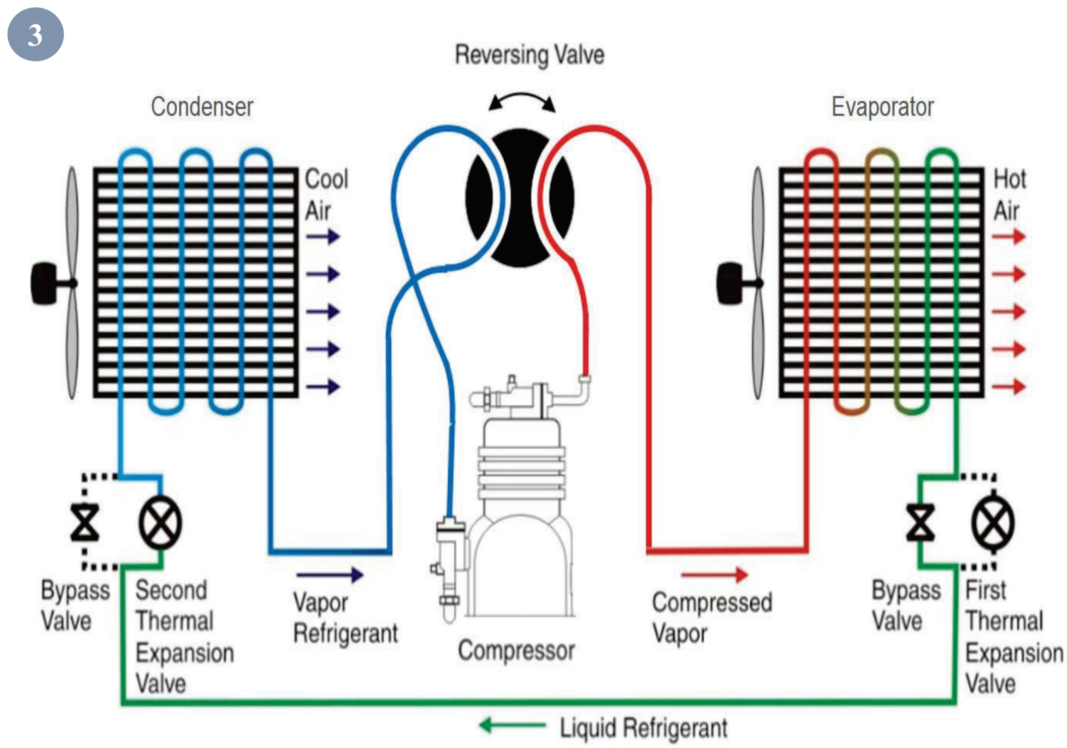


As shown Figure 5-2 above, the electric heater can directly heat the ambient air forced through using a blower motor and provide hot air through the cabin. However, the efficiency of such system is not optimal, especially in cold weather in PHEV and BEVs using liquid-cooled power electronics. Though the air electric heater usually operates at high voltage (e.g. 200-450V) some low voltage PTC electric heaters are also available. However, the latter requires a very high current to operate and uses considerable energy from the low voltage battery.

5.3 Heat pump system

In colder ambient temperatures, a heat pump system that uses the existing AC compressor, can reverse the refrigeration cycle and recover heat from the ambient air and from the vehicle power electronic components to manage the cabin heat. Figure 5-3 below depicts the system diagram of a heat pump system. Key components include the condenser, evaporator, high/low-pressure line, flow valves, and expansion valves.

Figure 5-3 Heat Pump System



The heat pump minimizes the use of the electric cabin heater and thus the overall energy consumption. This means in cold weather, the driving range in electric mode increases significantly. For instance, when operating in cold weather the driving range in the heat pump equipped VW e-Golf BEV has been estimated to increase by 30% when compared to a conventional heating system.[29] Although the heat pump provides range benefits, it does add extra cost in the vehicle thermal management but Ricardo believes that a well-designed system could reduce cost and increase market penetration. Ricardo believes that a heat pump system could be attractive for PHEVs applications.

6 Methods: Cost Analysis

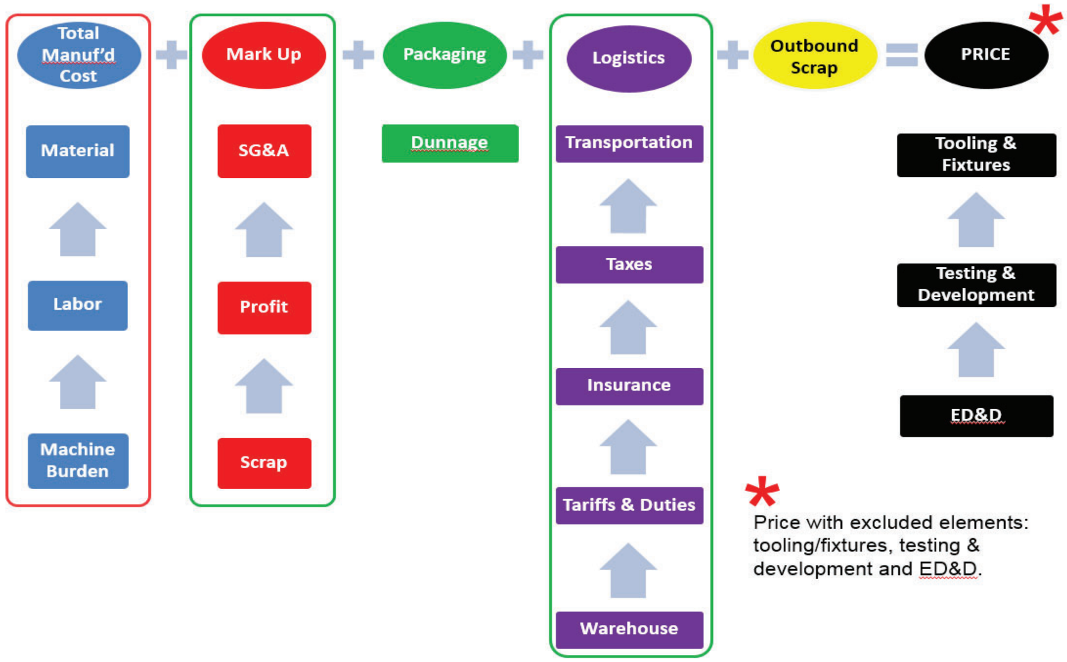
The scope of the project consisted of reviewing current PHEV technologies and assessing the state of the technologies in the 2020 to 2025 timeframe. The down-selected technologies were further analyzed to determine their relative cost based on current marketplace data. The baseline cost delta was estimated for future design iterations related to plug-in hybrid vehicles.

6.1 Costing Methodology

Munro and Associates use “bottom-up” costing to arrive at cost estimates for conceptual designs, with a detailed cost estimate that encompasses each stage of production, from primary processing to finished goods. In the cost analysis, various attributes of the parts are captured, including part weight, primary processing, machine features, and post-treatments/coatings. After the components are analyzed, they are put through Munro’s internal costing software analysis to develop the applicable sequence of manufacturing steps and process times. Throughout the process, numerous databases and internal cost models are used to feed essential data into Design Profit®, a proprietary software tool.

"Bottom-up" cost analysis is the most detailed of all cost-analysis techniques that deliver a complete “Total Accounted Should Cost” (TAC) analysis as outlined in Figure 6-1 below. Since each component is broken down into discrete process steps and all the assumptions are outlined, the product stakeholders can review and modify the inputs as necessary. Due to the rigor involved, it is one of the most accurate, reliable and easily performed methods available for obtaining useful results.

Figure 6-1 Total Accounted "Should Cost" Model Elements



Building strong element databases is critical to generating good cost estimates. Below are the elements in a standard TAC input database required to produce a final product price that spans the product lifecycle from raw materials to ready-to-ship product. It is important that these databases are kept up-to-date, especially in a volatile economy, as the information is fundamental to all cost assumptions made during analysis. These databases provide a means of ensuring transparency, accuracy, and consistency throughout the costing process. Munro updates its material and labor databases annually and its machine burden database bi-annually. Cost formulas and cost models are also required to generate TAC estimates. It takes several models to construct a total product "Should Cost" from primary processing to final deliverable product. Most models include cost elements and the hidden costs of quality and logistics. This is especially important when deciding to outsource or send operations to lower wage countries. Hidden costs associated with shipping and logistics, tariffs, duties, insurance and intellectual property protection become important cost elements as they can easily increase product costs 15 to 50 percent.

In addition, accurate models must be constructed and employed with some foundational intelligence. The information in the databases is researched thoroughly, and the embedded formulas in the cost models must represent current production capabilities. Both require regular updates and validation as economic conditions and technologies evolve.

Processing knowledge is also required develop the comprehensive cost models. Most parametric-based models have some built-in decision-making capabilities. However, every model has input cells that demand intelligent inputs to generate reasonable cost outputs. These inputs may include options such as, material choice, thickness, depth of cut, or number of slides. Presently, our current cost models do not ascertain if these inputs are intelligent. We rely on the expertise of our engineers to pass judgment on the inputs and the selected processing methods to ensure a viable and valid cost estimate is generated.

6.2 Supporting Cost Databases

Several costing databases and tools are used to support detailed and robust cost models. These include material, labor and machine burden calculators in which the underlying global and regional material, labor, and machine burden inputs are regularly updated. These inputs have defaults aligned with specific manufacturing and processing technologies, but they can be supplemented and overwritten as the need arises.

These input cells also have allowable ranges to avoid irrational inputs. In this manner, the cost models have cost information update capabilities on major inputs, including:

- Commodity price changes for key materials
- Price changes for commodity items such as, screws, greases or tape.
- Price changes for labor and machine burden rates (to enable sourcing strategies locally and globally)

6.3 Primary and Secondary Process Costing Methodology

A number of decisions go into the cost estimating process. The first is identifying the actual material used and the primary process for making the part. Once these have been identified, the appropriate costing tool is selected and the primary manufacturing cost is calculated. This is followed by capturing the secondary processes associated with the part, which is mapped in our proprietary Design Profit® software.

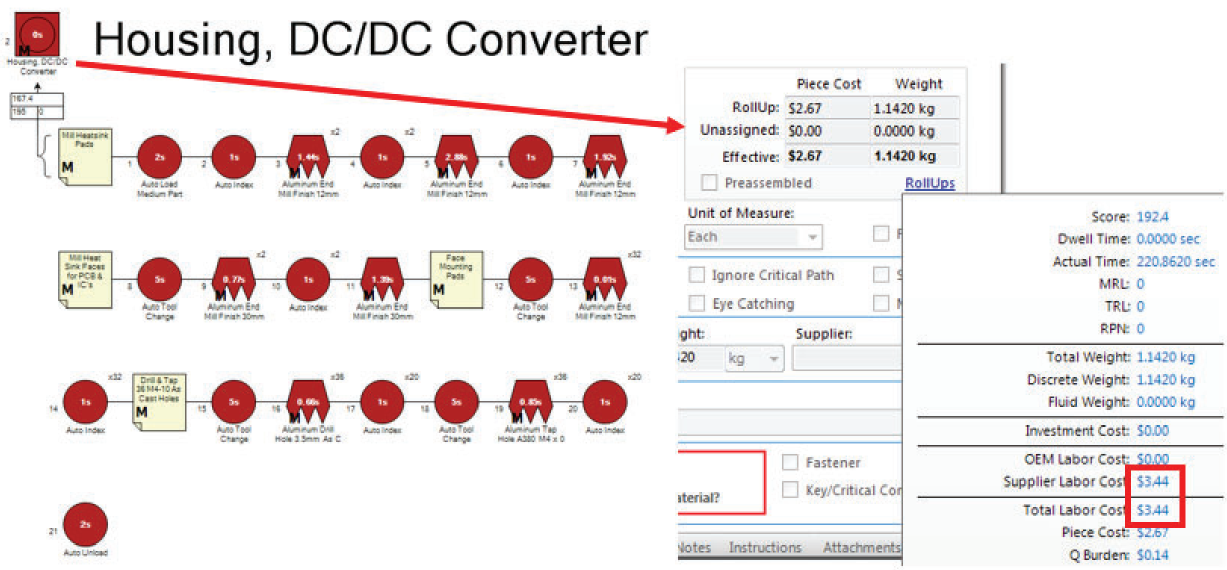
Once the primary material and manufacturing processes (primary and post) have been identified, the components can be cost estimated. To accomplish this, various parametric-based cost-estimating programs are utilized. These models provide various key outputs, including, cycle times and raw material costs for the parts for which estimates are being generated. All the models require a number of manual input parameters which may include some or all of the following, depending on the primary process selected: part length, width, height, weight (or volume), material, nominal wall thickness, material thickness, number of bends, number of punched holes, part projected area, part perimeter and the number of cavities.

Part variability is accounted for through a factoring methodology. These variables include tolerances, appearance, parting lines, complexity, number of planes, with die lock and profiles in the case of extrusions. The costs also take into account various material specifications including material density, tensile strengths, thermal diffusivity, injection pressures, die temperatures, mold temperatures, ejection temperatures, press sizes, press stroke rates, and extrusion rates.

After the primary process analysis has been completed, the cost of any required secondary processes is added. These include the costs associated with machining, surface treatments, and any joining methods. For example, the cost to produce a part made from bar stock material is developed in two steps. First, the cost of the raw material, based on the weight, gross envelope, and material type is calculated. Second, the cost of the machining and other process steps are added.

Diagram Figure 6-2 below is a snapshot of a machined component along with the roll-up of the total machining cost.

Figure 6-2 Example of Process Mapping for a Machined Component



The analysis does not include the assembly, manufacturing, dunnage, logistics or investment costs associated with purchased commodity components (examples listed below) coming into the manufacturing/assembly location. These components will be presented as a single-line purchased component cost.

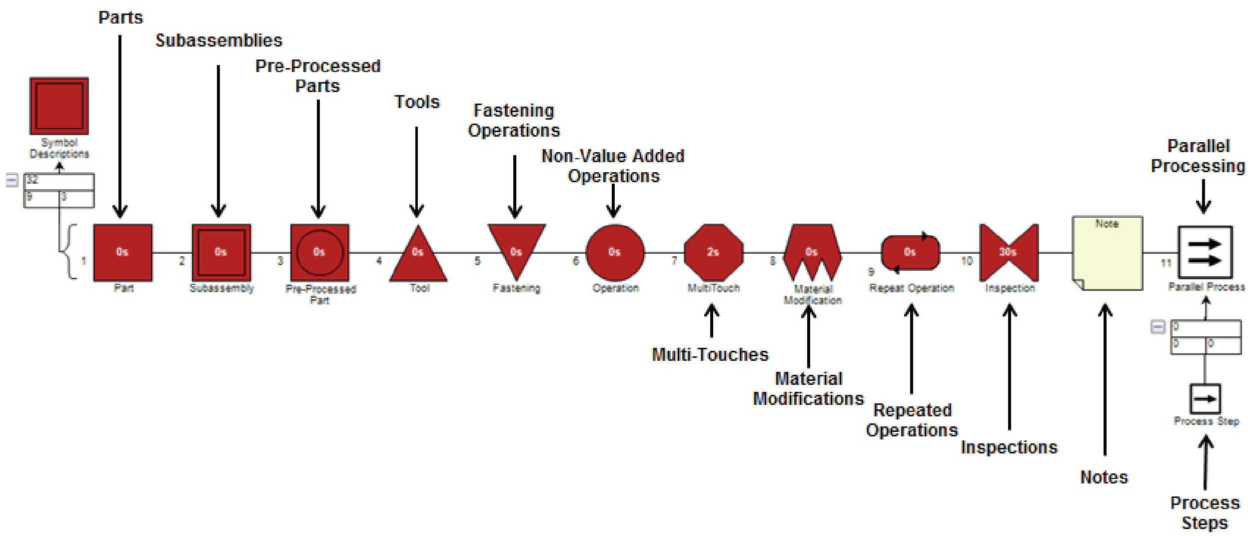
Commodity components:

Motors	Misc. Hardware: Pins, clamps, clips, ties, etc.
Pumps	Fasteners: nuts, bolts, washers, clamps, screws, etc.
Values	Ball Bearings
Snap Rings	Bushings
Springs	Solenoids, sensors, circuit breakers, switches
O-Rings and Seals	Greases and fluids
	Labels

Design Profit® software provides a detailed cost map analyzing every subassembly, part, operation and tool in the manufacturing process.

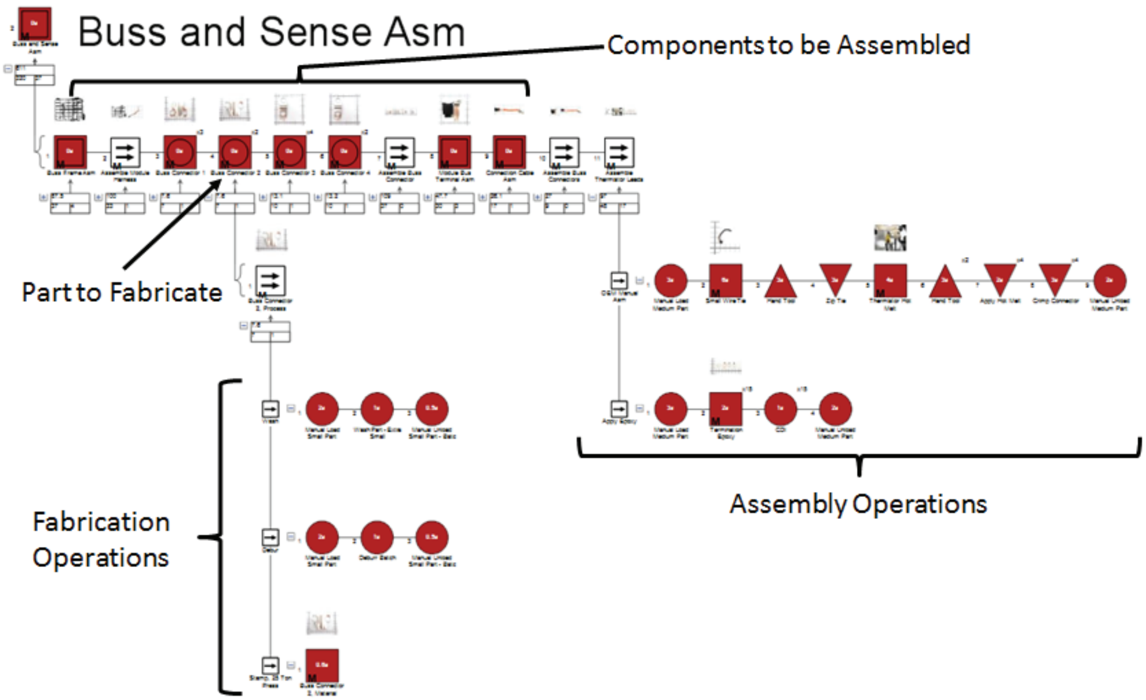
The various symbols shown below are used in a hierarchical diagram to quantify and compare design and manufacturing efficiencies and costs.

Figure 6-3 Design Profit Symbology



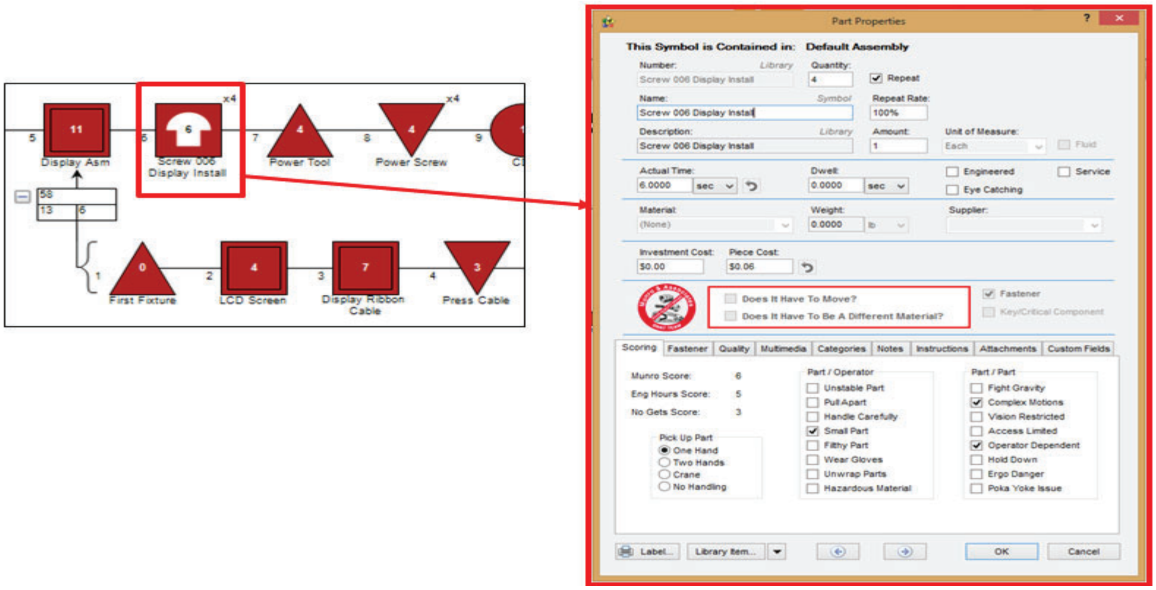
Each symbol is created by filling out a properties window, which allows us to assign penalty conditions and other information related to the symbol. From this, we can calculate the effect of handling difficulties on assembly time.

Figure 6-4 Properties Assigned to Symbols



The diagram shown in Figure 6-5 below, represents the level of detail that is used in the analysis. Each row above is assigned a specific cost center that relates to the activities that are occurring during each process step that the parts go through during manufacturing.

Figure 6-5 Example, Level of Analysis Detail Diagram



6.4 Cost Analysis

The following assumptions were made for the cost analysis:

- All processing was documented.
- All raw material prices are based on quotes and published information.
- All manufacturing processes include the man and machine to establish an hourly rate for a manufacturing work cell associated with each process used in creating the product. These work cell rates are used along with calculation of cycle time to generate the process costs of components. Machine rates are developed through an internal model accounting for all aspects of the primary and secondary equipment for the process. The operator rates are based on the specific industry labor rates and then assigned to a work cell with an adjustment for the number of operators in that cell.
- Common/basic component costs are determined as commodity items. These include: bearings, seals, fasteners and electronic components. These components are compared to numerous bills of materials to establish a purchased price.
- Electronic component costs are estimated using "Exclusion" costing methodologies.
- Machining cycle times are calculated using operations based on speeds and feeds from the standard Machinist Handbook.

6.4.1 Pricing Data Attainment Process

Pricing data is captured by various means depending on the item.

Munro publishes an internal 'Material Index Sheet' on a bi-monthly basis that contains current pricing data on more than 1,100 metal, resin, chemical, textile, and energy items. This data is aggregated from numerous free and paid sources.

6.4.2 Establish Work-Cell Rate

Cost centers for each work cell are built up to calculate the cost per hour for the equipment being used in each specific process. Equipment prices are obtained through quote requests from the manufacturers of the primary equipment. Inputs include the following:

- Investment costs: machine cost, interest, installation, start-up runs, etc.
- Facility costs: based on machine footprint and space for the operator.
- Utilities: energy, natural gas, compressed air, water, oil.
- Amortization: Each work cell is amortized using the IRS depreciation schedule (straight-line with zero value at end of life).

Table 6-1 Example of Spreadsheet Cost Calculation from Work Cell Analysis

Machinery Type	Manufacturer	Investment	Lifetime Use (years)	Salary Contribution	Machine Length (feet)	Machine Width (feet)	Energy Demand (KWH)	Natural Gas Demand (CFM)	Compressed Air (CFH)	Water Demands (gph)	Oil Demands (Gallons/Liter)	85% Eff & Actual % i.e. 81.99 Utilization Total Cost per hour (machine rate)
55 Ton	Mitsubishi	$77,000	11	1	13.7	2.4	13.8	-	-	-	-	$8.36
Dryer 50	Mitsubishi	$14,300	11	1	6.0	4.0	6	-	-	-	-	$2.70
Chiller 1 ton	Mitsubishi	$5,500	11	1	6.0	4.0	12	-	-	-	-	$2.95
TCU 3/4hp 9 KW (1)	Mitsubishi	$1,700	11	1	3.0	3.0	3	-	-	-	-	$1.14
Total including ancillary		$98,500										$15.15

Establishing the work cell rate depends on two basic assumptions: utility costs and working pattern. Assumptions for a work cell rate analysis are listed in Table 6-2 below.

Table 6-2 Example Work-cell Analysis

Utility Costs	
Electrical Energy $ KW/H	$ 0.0717
Natural Gas	$ 0.00664
Floor Space $/sq foot	$ 11.50
Interest	8.00 %
Water Cost per Gallon	$ 0.0035
Oil Cost	$ 0.02
Compressed Air Cost/CFM	$ 0.025
Plant Operating Pattern	
Work Days per Year	235
Hours per Shift	10
# of Shifts per Day	2
Total Hours per year	4700

Once the machine rate is established, the appropriate labor hours are added to the total cost of the work cell. The basic cost per labor hour is derived from the Bureau of Labor statistics and are based on specific industry classes as seen in Table 6-3 below. The cost per hour for labor includes direct labor plus all benefits. Indirect labor and MRO (maintenance, repair and other) are also included in the labor hours, both of which are calculated as a percentage of the total direct labor.

Table 6-3 Example Labor Rate for Supplier Job Descriptions

Supplier Job Description	US Rates
Inspection	$ 23.01
Furnace	$ 24.70
Plastics	$ 28.16
Plating cell	
Stamping	
Sand Casting	
Supplier General Assembly	
Machining	
Compression Molding	
Powdered Metal	

6.4.3 Defining Q Burden

Q Burden is short for Quality Burden. This is the additional cost burden carried by each unit of good product due to the actions were taken and additional material costs incurred from defects in parts as received or produced or in production processes. Q Burden is a key component of the "Cost of Quality" and may be considered equivalent to failure costs. The probability of a defect can be estimated from industry averages or can be based on company statistics.

Q Burden is calculated by adding the incident cost and the disposition cost for each defect and multiplying the sum by the probability of occurrence of a defect. ("Incident" is the set of actions that are taken immediately upon the discovery of a real or suspected defect.) Q Burden is calculated for any produced item including media, construction, manufactured goods, processed foods, and drugs. Types of incidents include those occurring during production, inspection and test failures, warranty returns, customer complaints, and externally directed recalls or shutdowns.

Q Burden reflects the variable cost of poor quality. The higher the rate at which defects occur and the higher the combined incident and disposition costs are, the higher the Q Burden.

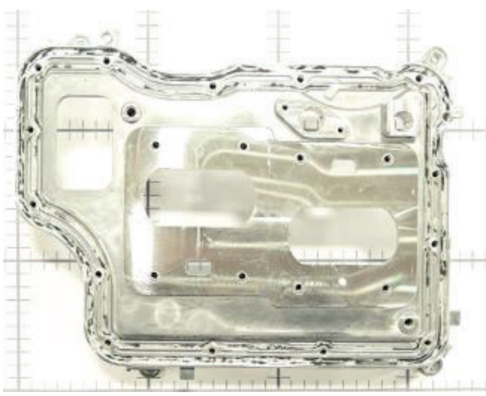
Q Burden does not include:

- Base overhead associated with quality organization (the amount required to assure compliance with industry and customer standards).
- Process documentation generally needed to communicate requirements and standards for production, inspection, and testing.
- Inspection and test equipment depreciation and consumables (unless needed for troubleshooting defective product(s)).
- Defect prevention activity (investment in new equipment, process improvement, mistake-proofing activities, redesign, Lean/Six Sigma activities, etc.).

6.4.4 Example Process Die-Casting

The die-casting process costs are calculated in an internal parametric-based cost-estimating sheet. The cells to the right are the material selection and dimensional values used to generate a material cost and processing cycle time. An image of the die-cast Top Plate part is on the left.

Figure 6-6 Example Primary Manufacturing Costing Module



Die Casting Material Costs & Cycle Times

Part Name: Top Plate, Top Plate w/Silicone Bead

Inputs:

	Die Casting Inputs:		
1	Height - Tool Draw	82	mm
2	Length - Longest	314	mm
3	Width - Shortest	250	mm
4	Max. Wall Thickness	5.5	mm
5	Weight of Part - Finished	0.738	kg
6	Percent Loss from Machining	7.00	%
7	Number of Cavities in Tool	2	
8	Number of Die Lock Features	0	
9	Material Number	7	

Material Name	Abbreviation	Cost ($/kg)
Al-9Si-3Cu(Fe)	A380	$2.27

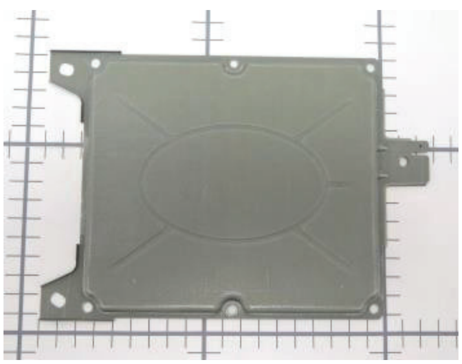
Outputs to DP:

	Die Casting Outputs:		
1	Min. Die Casting Machine	1927	tons
2	Die Casting Time	28.13	sec
3	Raw Material Weight	0.790	kg
4	Material Cost	$1.79	

6.4.5 Stamping Process

The sheet metal stamping process costs are calculated in an internal parametric-based cost-estimating sheet, an example of which is shown below in Figure 6-7. The cells to the right are the material selection and dimensional values and features used to generate a material cost and processing cycle time. An image of the stamped Bottom Cover part is on the left.

Figure 6-7 Example Primary Manufacturing Costing Module



Stamping Material Costs & Cycle Times

Part Name: Bottom Cover, Cell Control

Inputs:

	Stamping Inputs:		
	General Inputs:		
1	Stamping Quality: (Standard=1 , Fine Blanking=2)	1	
2	Parts per Hit (Side by Side Across Press Width)	1	
3	Material Number	6	
	Blanking Inputs:		
4	Shape Type: (Formed Sheet=1 , Drawn Box=2 , Drawn Cylinder=3)	1	
5	Part Height - Tool Draw	6.73	mm
6	Wrap Length - Longest	225	mm
7	Wrap Width - Shortest	150	mm
8	Sheet Thickness	0.65	mm
9	Number of Blanking Hits (If Unknown = 0)	0	
	Piercing Inputs:		
10	Number of Circular Holes	8	
11	Average Diameter of Circular Holes	5	mm
12	Number of Non-Circular Holes	2	
13	Total Perimeter of Non-Circular Holes	64	mm
14	Number of Piercing Hits (If Unknown = 0)	0	
	Bending Inputs:		
15	Number of Bends	0	
16	Total Length of Bend Lines	0	mm
17	Number of Bending Hits (If Unknown = 0)	0	
	Flanging Holes Inputs:		
18	Number of Flanged Holes	0	
19	Total Perimeter of Flanged Holes	0	mm
20	Number of Flanging Holes Hits (If Unknown = 0)	0	
	Forming Depression Inputs:		
21	Number of Depressions	1	
22	Total Perimeter of Depressions	560	mm
23	Number of Forming Depression Hits (If Unknown = 0)	0	
	Deep Drawing Inputs:		
24	Drawn Area Depth	0	mm
25	Drawn Area Length - Longest	0	mm
26	Drawn Area Width - Shortest	0	mm
27	Number of Deep Drawing Hits (If Unknown = 0)	0	

Material Name	Abbreviation	Cost ($/kg)
Medium Carbon Steel 1040 - Galvanized	AISI 1040 - Galva	$1.50

Outputs to DP:

	Stamping Outputs: (Progressive Die)		
1	Stamping Press	60	tons
2	Stamping Cycle Time	0.67	sec
3	Blank Weight	0.197	kg
4	Material Cost	$0.30	

6.4.6 Example Process Injection Molding

The injection molding process costs are calculated in an internal parametric-based cost-estimating sheet, like the one in Figure 6-8 below. The cells to the right are the material selection and dimensional values used to generate a material cost and processing cycle time. An image of an injection molded Vent Body part is on the left.

Figure 6-8 Primary Manufacturing Costing Module

Injection Molding Material Costs & Cycle Times

Part Name: Vent Body

Inputs:

	Injection Molding Inputs:			
1	Number of Injection Shots: (1, 2, & 3)	1		
2	Weight of Part	0.050	kg	
3	Number of Cavities in Tool	2		
4	Number of Die Lock Features	0		
5	Recycle Offal (1=Yes , 0=No)	0		
6	Height - Tool Draw	19.52	mm	
	Inputs for Each Injection Shot:	-	-	-
7	Injection Process: (Standard=1 , MuCell=2, & Foaming Agent=3)	1		
8	Length - Longest (mm)	105.4		
9	Width - Shortest (mm)	105.3		
10	Percentage of Part Area Used Based on Square Area of Length x Width	90.00		
11	Nominal Wall Thickness (mm)	2		
12	Material Number	59		

	Material Name	Abbreviation	Cost ($/kg)	Offal Value ($/kg)
-	Polypropylene (30% glass)	PP + GF30	$2.71	$0.00
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-

Outputs to DP:

	Injection Molding Outputs:			
1	Min. Injection Molding Press	103	tons	
	Outputs for Each Injection Shot:	PP + GF30	-	-
2	Injection Molding Time (sec)	7.29	-	-
3	Net Weight (kg)	0.050	-	-
4	Raw Material Weight (kg)	0.053	-	-
5	Raw Material Cost	$0.14	-	-

6.4.7 Tooling Estimates

A rough order of magnitude (ROM) estimate was utilized for calculating the tooling cost associated with making the various components found in the systems analyzed. The tooling, in this case, refers to the stamping dies, plastic injection molds, die-casting molds, and similar items. Because of the short timeframe of the project scope, a ROM estimate was used. To establish the ROM cost, each specific cost center was reviewed and two sets of numbers were generated. These two numbers represent a low complexity and high complexity cost for the tooling typically associated with the actual size of the machine with which it is associated. The high and low numbers were then averaged to establish a single tooling cost for each cost center in the analysis. Figure 6-9 below is a screen shot of the tooling estimator and its various inputs. Figure 6-10 on p.68 represents the outputs from the tooling cost estimator. Figure 6-10 on p.68 shows the results of a high and low tooling estimate for injection molding and the actual average tooling cost that is applied to the cost center.

Figure 6-9 Tooling Cost Module

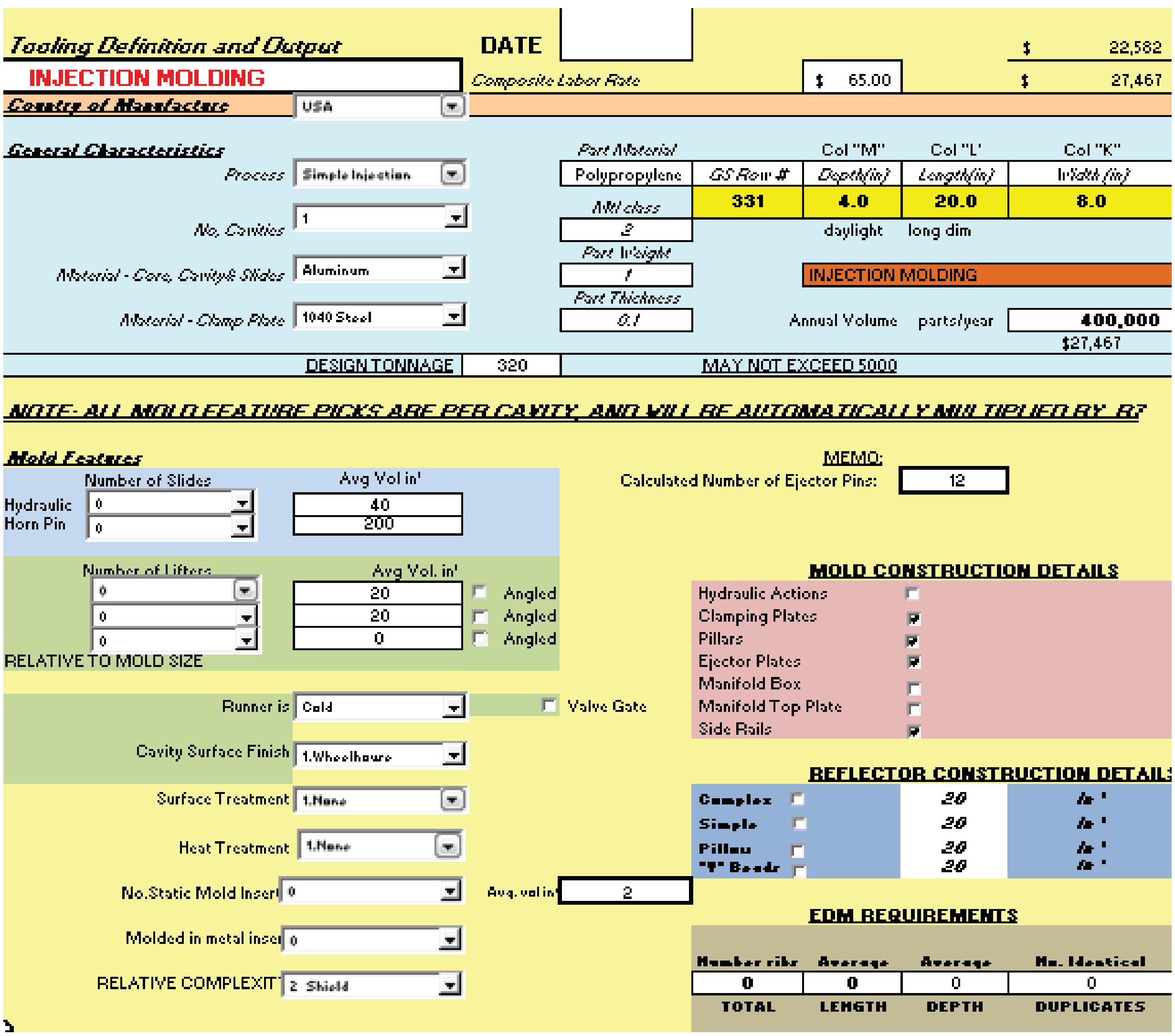


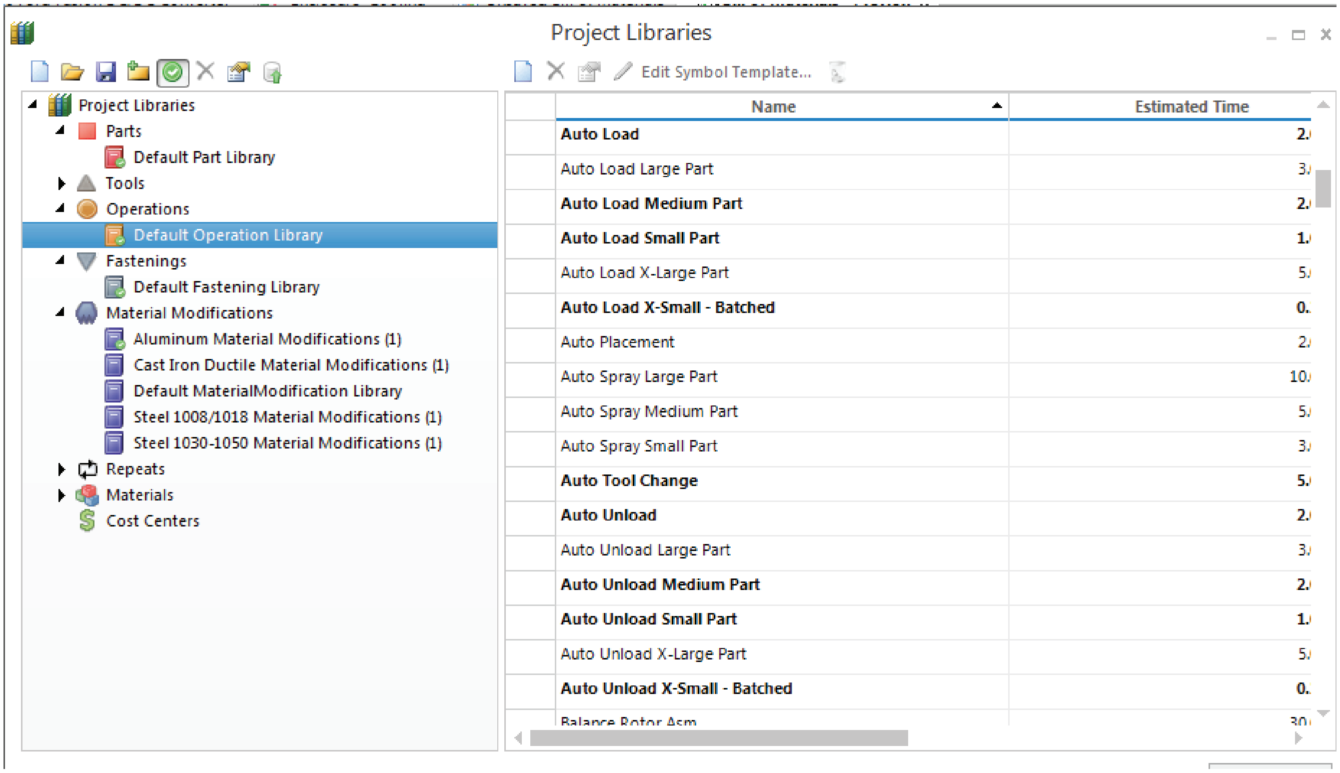
Figure 6-10 Tooling Cost Module

Figure 6-11 Tooling Cost Module

	United States			
Cost Center Description	Tooling Cost (High)	Tooling Cost (Low)	Tooling Cost (Average)	
Injection Mold Press, Inserts, 55 Ton	$65,896	$11,984	$38,941	$40,000
Injection Mold Press, Inserts, 110 Ton	$76,232	$15,713	$45,973	$45,000

As mentioned in the methodologies section all secondary processing of analyzed components is completely mapped out. Standard operating procedures are established and utilized throughout the project to ensure consistency. The basic operations include material modifications (machining – based on the machinist handbook for feeds and speeds), basic automated process steps, loading and unloading of components (automated and manual), standardized washing cycle times, fastening operations (for hand and power tools), welding operations, and pressing operations.

Figure 6-12 Screenshot of Operations Library



6.4.8 Example Layout Process Steps

The following example presents the steps involved in laying out the process for fabrication.

- Review part and application to determine fabrication steps to create the part.
- Typically, the work-cell associated with each process step is determined, based on part geometry.
- Each work cell is assigned its own specific burden rate, based on the equipment making up the cell.

Table 6-4 Part Fabrication: Right Read from the Bottom Up

Seq	Type	Name
1		Wash
2		Deburr
3		CNC Machining
4		Heat Treat Step 2
5		Heat Treat Step 1
6		Wash
7		Deburr
8		60 Ton Trim Press
9		2200 Ton Casting Press

6.4.9 Data Extraction Example

Each major system and sub-groupings "should cost" is developed with full details of all processing steps associated with the product. The summary shown in Table 6-5 below includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost with primary and secondary processes, Q-Burden (cost of quality for parts and processes), and total "should cost" before markups.

Table 6-5 Example Summary of System "Should Cost"

Design Profit®

EXECUTIVE SUMMARY
2016 Ford Fusion DC/DC

MUNRO & ASSOCIATES, INC.

	2016 Ford Fusion DC/DC Converter
Parts	587
Steps	1,779
Actual Time	2,843.46 sec
Fasteners	58
Total Weight	2.58 kg
Piece Cost	$184.69
Total Labor Cost	$40.95
Q Burden	$3.23
Total Cost	$228.88
Annual Production	200000

Each line item is explained as follows:

- Parts: The total number of discreet parts analyzed in the system.
- Steps: The total number of parts plus the number of processing steps accounted for.
- Actual time: roll-up of total time associated with all analyzed manufacturing processes.

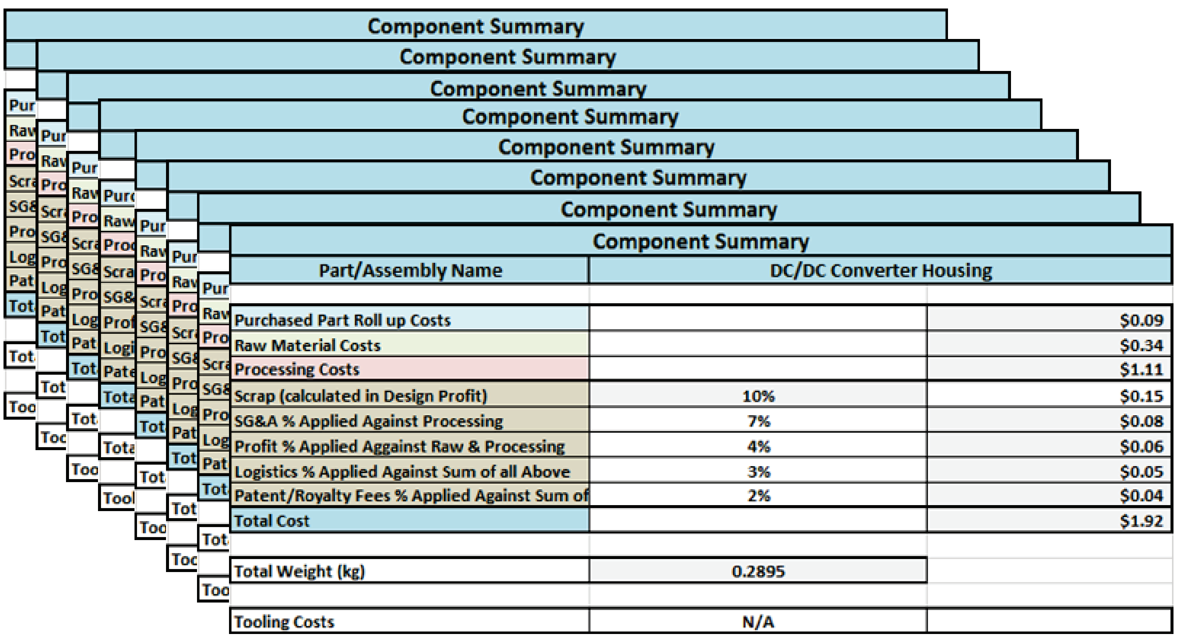
- Total weight: weight of system analyzed.
- Piece cost: The sum of commodity-based parts and raw materials for primary processing.
- Total labor costs: The sum of primary processing, secondary processing, and assembly.
- Q burden: The cost of quality commonly referred to as scrap. (Captures cost of incoming material and manufacturing, does not include cost of warranty and service issues.)
- Total cost: The sum of piece cost, total labor cost, and Q burden.
- Annual Production: agreed upon at project kickoff, 200k annually with five years of production.

Summaries of each major area, as well as a total roll-up cost, are imported where major groups were set up based on subsystem breakdown which is then totaled for the full total system cost. The analysis provides the "should cost" to make the part capturing material costs, processing and the cost of quality. The additional markups include sales and general administrative (SG&A) profit, logistics and patent and royalty fees. These additional markups represent the OEM's purchased price of the assemblies.

Table 6-6 below shows a typical stem summary with the markups rolling up into a total system/group cost.

Table 6-6 Example: Total System Costs with Markups

Component Summary		
Part/Assembly Name	DC/DC Converter Housing	
Purchased Part Roll up Costs		$0.09
Raw Material Costs		$0.34
Processing Costs		$1.11
Scrap (calculated in Design Profit)	10%	$0.15
SG&A % Applied Against Processing	7%	$0.08
Profit % Applied Aggainst Raw & Processing	4%	$0.06
Logistics % Applied Against Sum of all Above	3%	$0.05
Patent/Royalty Fees % Applied Against Sum of	2%	$0.04
Total Cost		$1.92
Total Weight (kg)	0.2895	
Tooling Costs	N/A	



Component Summary		
Part/Assembly Name	DC/DC Converter Housing	
Purchased Part Roll up Costs		$0.09
Raw Material Costs		$0.34
Processing Costs		$1.11
Scrap (calculated in Design Profit)	10%	$0.15
SG&A % Applied Against Processing	7%	$0.08
Profit % Applied Aggainst Raw & Processing	4%	$0.06
Logistics % Applied Against Sum of all Above	3%	$0.05
Patent/Royalty Fees % Applied Against Sum of	2%	$0.04
Total Cost		$1.92
Total Weight (kg)	0.2895	
Tooling Costs	N/A	

More specifically, each line item in the table can be understood by the following:

- Purchased Parts Roll-up Costs: Cost of all commodity-based parts.
- Raw Material Costs: Cost of all raw materials for primary processing of parts.
- Processing Costs: Cost of all primary and secondary manufacturing and assembly processes.
- Scrap (Design Profit Q-Burden: Estimated cost of quality for all incoming parts and processes.
- SG&A: Sales and general administrative, such factory overhead costs.
- Profit: The goal of a business.
- Logistics: Cost of incoming materials, shipping and handling.
- Patent/Royalty Fees: Cost of using intellectual property (IP).
- Total supplier manufacturing cost: Cost to manufacture the end-product analyzed. (This does not include tooling or outbound logistics.)
- Total Weight (Kg): Total weight of all parts analyzed.
- Annual Volume: Agreed upon at project kickoff.
- Product Life Years: Anticipated number of years a product will be in production.
- ROM Tooling Costs (1 set of Tools): Rough estimate of typical manufacturing tooling cost associated with making of specific system parts analyzed.
- Tooling Cost/part: Estimated ROM tooling cost per part. (Tooling cost divided by annual volume multiplied by product life.)
- ROM Tooling Costs (2 set of tools).

Figure 6-13 below is an example of the Cost Summary Sheet. Each major group includes the costs of raw materials, commodity items, and manufacturing processing costs. These line items roll up into the summary table. After final system process reviews are complete a value for scrap is established. The additional markups are calculated using the percentages shown in the table. The following methods are used for these markups: SG&A percentage is multiplied against processing costs; Profit percentage is multiplied by raw materials and processing costs; logistics percentage is multiplied by the sum of the line items above it; patent and royalty fees percentage is applied against the sum of the line items above it.

These line items are then summed up to provide a total cost assumed for manufacturing the system being analyzed. The total markup percentages will range from 15 percent to 30 percent. These percentages are in line with what is typically seen in the automotive industry. A rough order of magnitude tooling estimate was also established. The total tooling cost is then divided by the overall volume to establish what the estimated cost per system would be. The annual volume for the project was set at 200k units and a five-year product life span. The total tooling cost is not rolled up into the estimated purchased price.

Figure 6-13 Cost Summary Sheet

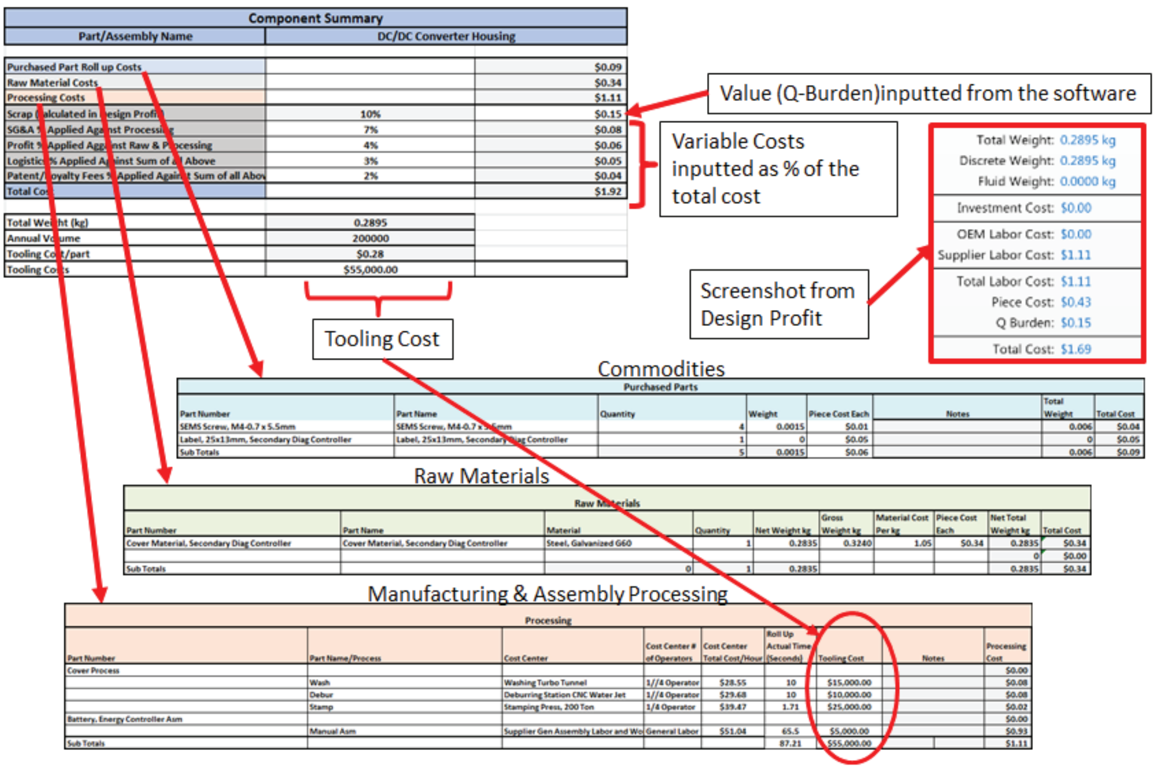
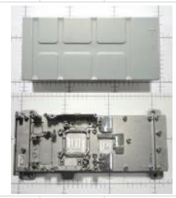


Table 6-7 below is an example showing the detailed costing analysis of the enclosure and the cooling group from the Ford DC to DC converter.

Table 6-7 Example Costing Analysis

Component Summary		
Part/Assembly Name	Enclosure & Cooling	
Purchased Part Roll up Costs		$0.09
Raw Material Costs		$3.01
Processing Costs		$4.68
Scrap (calculated in Design Profit)	4%	$0.32
SG&A % Applied Against Processing	7%	$0.33
Profit % Applied Aggainst Raw & Processing	4%	$0.31
Logistics % Applied Against Sum of all Above	3%	$0.26
Patent/Royalty Fees % Applied Against Sum of all Abc	2%	$0.18
Total Cost		$9.17



Total Weight:	1.4320 kg
Discrete Weight:	1.4320 kg
Fluid Weight:	0.0000 kg
Investment Cost:	$0.00
OEM Labor Cost:	$0.00
Supplier Labor Cost:	$4.68
Total Labor Cost:	$4.68
Piece Cost:	$3.10
Q Burden:	$0.32
Total Cost:	$8.10

Total Weight (kg)	1.4312
Annual Volume	200000
Tooling Cost/part	$0.00
Tooling Costs	$0.00

Purchased Parts

Part Number	Part Name	Quantity	Weight (kg)	Piece Cost Each	Notes	Total Weight	Total Cost
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	4	0.0014	$0.0100		0.0056	$0.0400
1444-44_02	Label, 25x13mm, DC/DC Converter	1	0.0001	$0.0500		0.0001	$0.0500
Sub Totals		5	0.0015	$0.0600		0.0057	$0.0900

Raw Materials

Part Number	Part Name	Material	Quantity	Net Weight kg	Gross Weight kg	Material Cost Per kg	Piece Cost Each	Net Total Weight kg	Total Cost
1444-44_01 Material	Material, Cover, DC/DC Converter	Steel, Galvanized G60	1	0.2835	0.3240	1.06	$0.34	0.2835	$0.34
1444-66_01 Material	Material, Housing, DC/DC Converter	Aluminum A380, Cast	1	1.1420	1.1770	2.27	$2.67	1.142	$2.67
Sub Totals		0	2	1.4255				1.4255	$3.01

Processing

Part Number	Part Name/Process	Cost Center	Cost Center # of Operators	Cost Center Total Cost/Hour	Roll Up Actual Time (Seconds)	Tooling Cost	Notes	Processing Cost
Cover, DC/DC Converter Processing								$0.00
	Spot Weld- Robotic	Spot Weld Sta, Auto, 1 Head, Sml-Med Parts	1/4 Operator	$25.28	17.8			$0.12
	Wash	Washing Turbo Tunnel	1//4 Operator	$28.55	10			$0.08
	Debur	Deburring Station CNC Water Jet	1//4 Operator	$29.68	10			$0.08
	Stamping Press, 200 Ton	Stamping Press, 200 Ton	1/4 Operator	$39.47	1.71			$0.02
Battery, Energy Controller Asm								$0.00
	Manual Asm	Supplier Gen Assembly Labor and Work Cell	General Labor	$51.04	65.50			$0.93
Housing, DC/DC Converter Processing								$0.00
	Wash	Washer Batch 12"x12"x16"	1/2 Operator	$12.63	10.00			$0.04
	Debur	Deburring Station CNC Water Jet	1//4 Operator	$29.68	10.00			$0.08
	Machining	Machining Center, Horiz, 41"x33"x38"	1//4 Operator	$39.17	167.35			$1.82
	Trim Press, 25 Ton	Trim Press, 25 Ton	1/2 Operator	$26.03	13.73			$0.10
	Die Cast, 1300 Ton	Die Cast Mach, 1300 Ton, Auto Load	2 Operators	$255.75	19.78			$1.41
Sub Totals					325.87	$0.00		$4.68

6.4.10 Materials and Processes

All components of the systems analyzed are captured in detail within the Design Profit software. The material and process assumptions are available in the appendix for each major grouping established i.e. Volt Motor includes a stator group and a rotor group. An example of the details provided for a group is shown in Table 6-8 below.

Table 6-8 Example Materials and Processes 12 of 56 Line Items

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Subassembly	717-1436_4	Stator Assembly	(None)
2	3	Subassembly	717-1436_5	Laminated Steel Stator Core	(None)
3	4	Preprocessed Part	717-1436_9	Laminated Steel	(None)
4	5	Manufacturing Steps		Laminated Steel Process	
5	6	Manufacturing Process		Wash	
6	6	Manufacturing Process		Debur	
7	6	Manufacturing Process		Stamping Press, 200 Ton	
8	7	Part	Material, 717-1436_9	Material, Laminated Steel	Electro Magnetic Steel
9	4	Part	717-1436_17	Paper Tube	Commodity Item
10	4	Manufacturing Steps		Laminated Steel Stator Core Assembly Process	
11	5	Manufacturing Process		Auto Assembly	
12	5	Manufacturing Process		Laminate Stacking Station	

The following describes each line item in Table 6-8 on page 76:

- Row: Row numbers are generated to ensure the number of line items extracted from Design Profit match up with the items in the report.
- Level: This represents an indented bill of material based on the assembly sequences identified during the analysis.
- Symbol Type: Denotes the type of symbol that is mapped in software. Subassembly includes the numerous parts that make up an end item. Preprocessed Part identifies whether a part was costed using a bottoms-up approach. Manufacturing Steps show the process steps that a preprocess part goes through. Part provides the material identified.
- Part Number: A unique part number is assigned to each part. There is no part number for any manufacturing processes.
- Name: This is the name assigned to each part/assembly/manufacturing process.
- Material Name: This is the assumed material for the parts. There is no material assigned to subassemblies and manufacturing processes.

6.4.11 Costed Bill of Material

All components of the systems analyzed are captured in detail within the Design Profit software. The bill of materials (BOM) are available in the appendix for each major grouping established i.e. Volt Motor includes a stator group and a rotor group. An example of the details provided for a group is shown in Table 6-9 on p. 78. Note the piece cost associated with the parts represents the cost to purchase commodity items or the cost of the raw materials to make the specific part. The BOM does not include the cost of processing materials or assembly of parts.

Table 6-9 Example Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Chevrolet Volt - Stator Assembly

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
717-1436_4	**Stator Asm**	**$59.19**	**1**	**$59.19**
717-1436_5	**Laminated Steel Stator Core**	**$30.58**	**1**	**$30.58**
717-1436_9	**Laminated Steel**	**$24.99**	**1**	**$24.99**
Material, 717-1436_9	Material, Laminated Steel	$0.21	119	$24.99
717-1436_17	Paper Tube	$0.02	288	$5.59
717-1436_23	**Hairpin Wire Asm**	**$26.89**	**1**	**$26.89**
717-1436_19 Paint	Paint, Unique Bar Wound Wire Connector 1 Asm.	$0.01	1	$0.01
717-1436_13 Paint	Paint, Unique Bar Wound Wire Connector 2	$0.01	1	$0.01
717-1436_14 Paint	Paint, Unique Bar Wound Wire Connector 3	$0.01	1	$0.01
717-1436_22 Paint	Paint, Unique Bar Wound Wire Connector 4	$0.01	1	$0.01
Material, 717-1436_6	Material, Commom Bar Wound Wire	$0.18	139	$25.02
Material, 717-1436_8	Material, Unique Inner Bar Wound Wire	$0.22	3	$0.66
Material, 717-1436_12	Material, Unique Bar Wound Wire Connector 1-A	$0.11	1	$0.11
Material, 717-1436_20	Material, Unique Bar Wound Wire Connector 1-B	$0.15	1	$0.15
Material, 717-1436_21	Material, Unique Bar Wound Wire Connector 1-C	$0.10	1	$0.10
Material, 717-1436_13	Material, Unique Bar Wound Wire Connector 2	$0.20	1	$0.20
Material, 717-1436_14	Material, Unique Bar Wound Wire Connector 3	$0.22	1	$0.22
Material, 717-1436_22	Material, Unique Bar Wound Wire Connector 4	$0.22	1	$0.22
Material, 717-1436_10	Material, Unique Bar Wound Wire Connector 4	$0.17	1	$0.17
717-1436_15	Inner Paper Ring	$0.34	1	$0.34
717-1436_16	Outer Paper Ring	$0.34	1	$0.34
717-1436_18	Insulating Varnish	$1.04	1	$1.04
717-1436_7	**Bar Wound Wire End Connectors**	**$0.69**	**1**	**$0.69**
Material, 717-1436_7	Material, Bar Wound Wire End Connectors	$0.23	3	$0.69
717-1436_1	**End Connector Housing Asm.**	**$1.20**	**1**	**$1.20**
717-1436_2	**End Connector Housing**	**$0.45**	**1**	**$0.45**
717-1436_2 Material	End Connector	$0.45	1	$0.45
717-1436_3	Quick Connector	$0.25	3	$0.75

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	7	Piece Cost (Total): $61.08	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	570		*Parts:*	*0*
Fasteners:	0		*Fasteners:*	*0*
Parts+Unanalyzed:	570		*Parts+Unanalyzed:*	*0*

The line items in Table 6-9 above include:

- Part Number: A unique number assigned to each part.
- Symbol Name: This is the name assigned to each part, assembly or manufacturing process.
- Piece Cost: The cost of manufacturing one part. This includes raw material and processing costs.
- Quantity: This shows the number of the same part being used in the subassembly.
- Piece Cost (Total): Total cost of manufacturing the part for the assigned quantity.

7 Results

The results of the study are broken down by systems, with the high-level teardown system observations along with the system makeup and cost estimates detailed for the first level. For the fully detailed cost breakdown of material and process, please refer to the relevant appendix.

7.1 Toyota Prius Traction Motor B Cost Analysis

The Toyota Prius motor was subdivided into two major groupings: the stator and the rotor. All parts were analyzed in detail to establish a "should cost" based on today's manufacturing practices. Each grouping is reported separately in the cost analysis detailing the "should cost" to manufacture and assemble the various components. The group costs are included in the total system cost. The stator group consists of the stamped electromagnet steel laminates, insulators, and copper windings. The rotor group contains the hub, stamped electromagnetic steel laminates, magnets, and end covers.

Figure 7-1 Toyota Prius Stator and Rotor

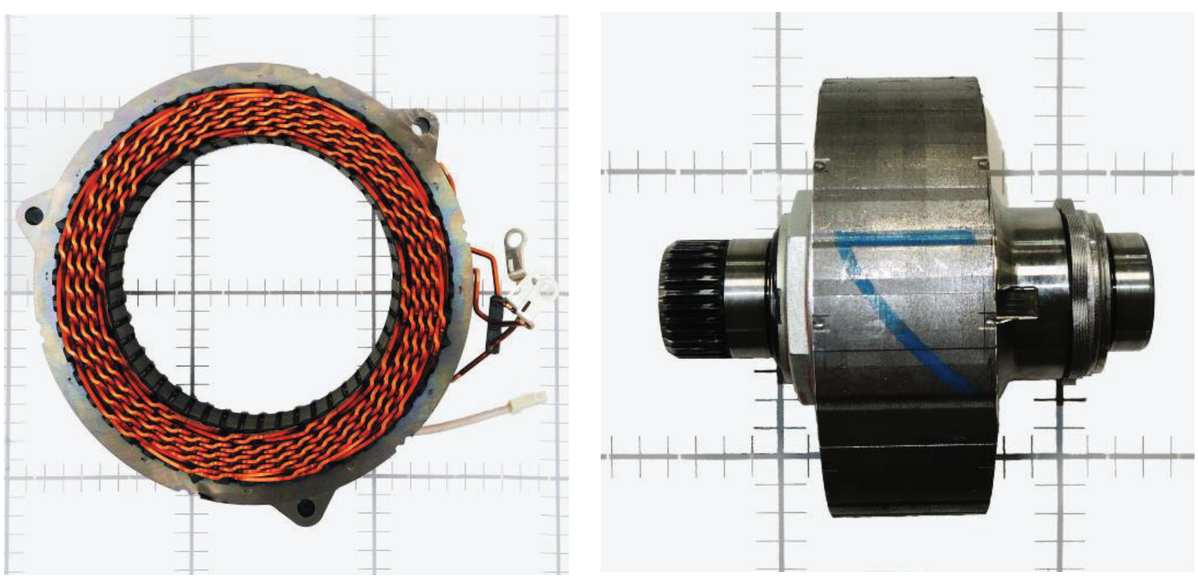
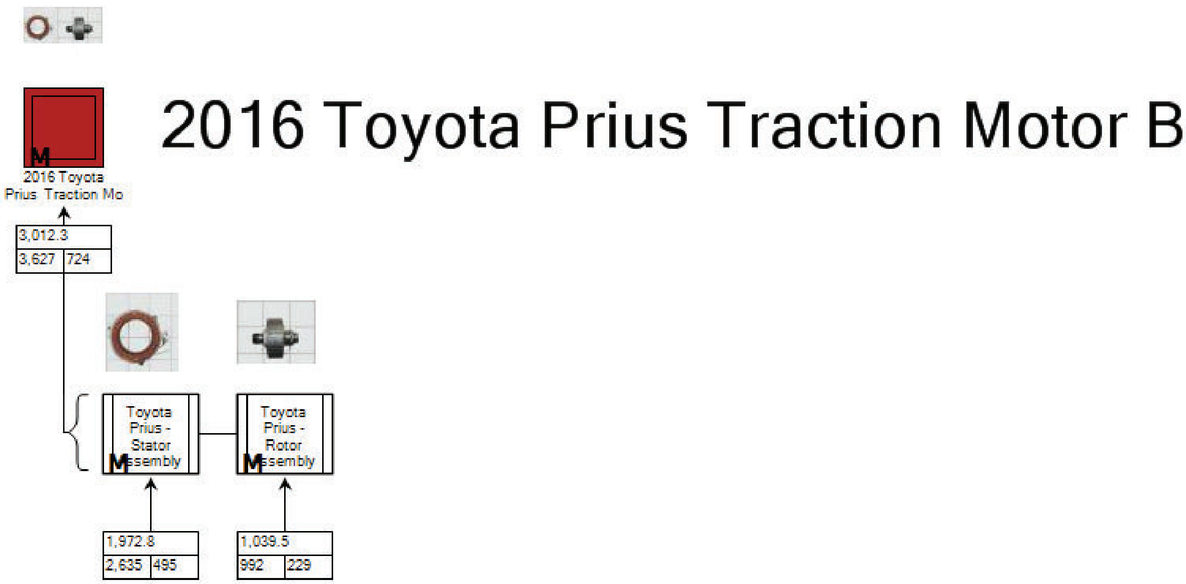


Figure 7-2 Toyota Prius Motor: Design Profit Cost Map—Major Groupings



The figure above is a screenshot of the major groupings of the motor assembly. The groupings will facilitate additional assessments that will identify higher cost drivers associated with the motor.

The total "should cost" to manufacture the Toyota Prius Motor is estimated and additional typical markups associated with component manufacturing added. (These additional markups are shown Table 7-2 on p. 82.)

Table 7-1 Toyota Prius Motor Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
2016 Toyota Prius Traction

MUNRO & ASSOCIATES, INC.

	2016 Toyota Prius Traction Motor B
Parts	724
Steps	4,641
Actual Time	3,016.19 sec
Fasteners	1
Total Weight	15.79 kg
Piece Cost	$131.79
Total Labor Cost	$56.43
Q Burden	$6.24
Total Cost	$194.46
Annual Production	200000

The summary shown in Table 7-1 above includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total "should cost" before markups.

Table 7-2 Toyota Prius Motor Cost Estimate Summary

Product Summary		
Part/Assembly Name:		2016 Toyota Prius Motor
Purchased Part Roll up Costs		$40.22
Raw Material Costs		$91.57
Processing Costs		$56.43
Scrap (Design Profit: Q-Burden)	3%	$6.24
SG&A % Applied Against Processing	7%	$3.95
Profit % Applied Against Raw & Processing	4%	$5.92
Logistics % Applied Against Sum of all Above	3%	$6.13
Patent/Royalty Fees % Applied Against Sum of all Above	5%	$10.52
Total Supplier Manufacturing Cost		$220.98
Total Weight (kg)		15.7875
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$960,000.00
Tooling Cost/part		$0.96
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,920,000.00
Tooling Cost/part		$1.92

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. As shown in Table 7-2 above, the markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown with each item. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

7.2 Toyota Prius Inverter Module Cost Analysis

The Toyota Prius Power Inverter Module provides three distinct functions. Provide motor control switching high voltage DC to three phase AC (Vehicle Traction Motor and Vehicle Motor Generator), convert high voltage three phase AC to high voltage DC (Motor Generator), and converting low voltage DC to high voltage DC (Boost Conversion) or high voltage DC to low voltage DC (Buck Conversion; 12-volt for typical vehicle electrical architecture). For reporting purposes, the module was broken down into three major groups. These groups include Enclosures & Cooling, DC/DC Buck Converter, and the Inverter, which includes the integrated Boost Converter. The two electrical groups DC/DC and Inverter systems were then separated into five sub-groups: Both electrical groups were analyzed using the following subgroups: Internal Housing, Bus Bars, Printed Circuit Board Assemblies (PCBA), Ferrites & Inductors (also includes capacitors for inverter), and Electrical Harnesses (wiring). Denso manufactured the module for Toyota.

Figure 7-3 Toyota Power Inverter

Figure 7-4 below is a screenshot of the major groupings of the Prius Power Inverter Module. The groupings will facilitate additional assessment that will identify higher cost drivers.

Figure 7-4 Toyota Power Inverter Module: Design Profit Cost Map-Major Groupings

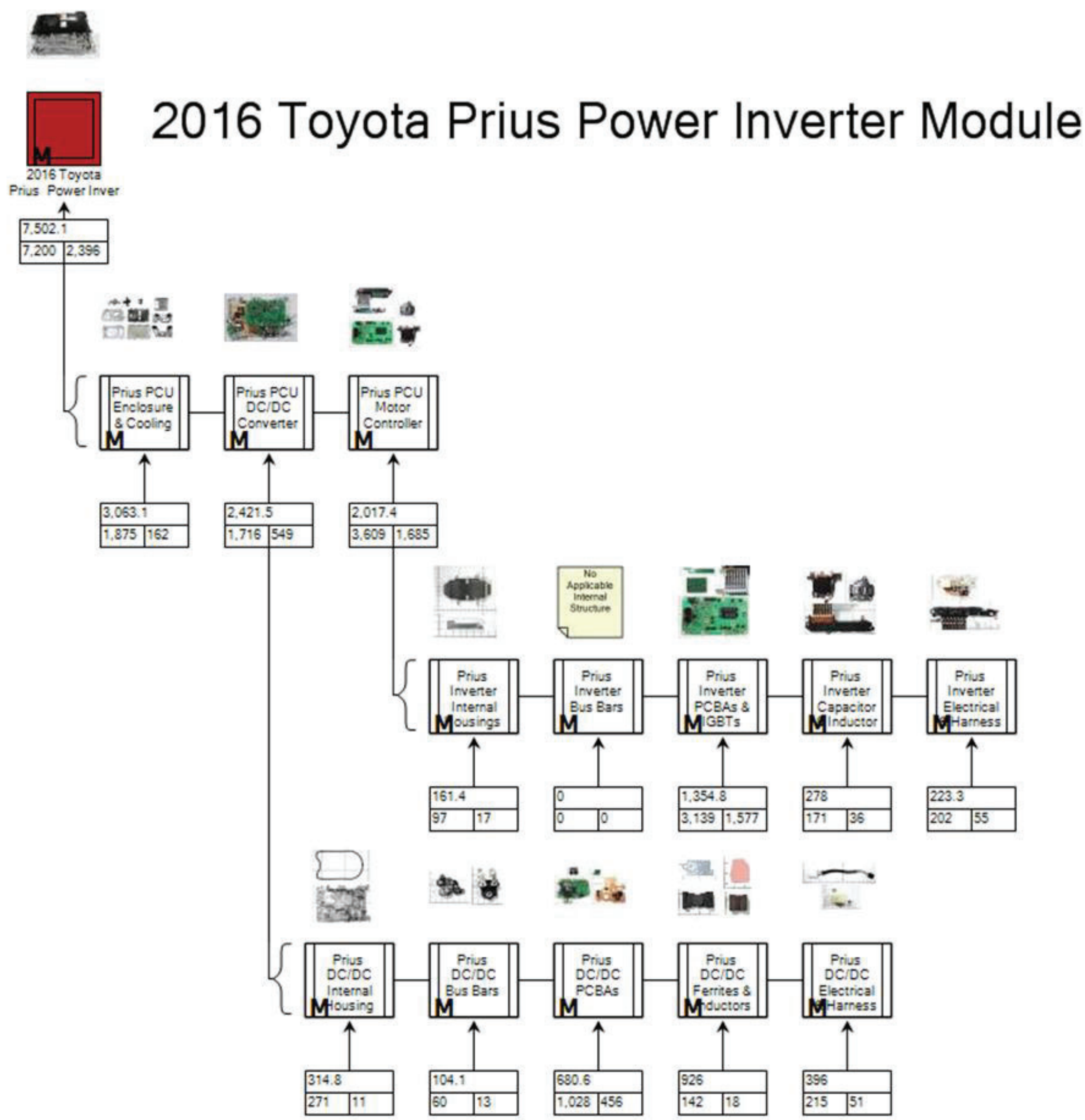


Table 7-3 Toyota Prius Power Inverter Module Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

2016 Toyota Prius Power

MUNRO & ASSOCIATES, INC.

	2016 Toyota Prius Power Inverter Module
Parts	2,521
Steps	8,405
Actual Time	8,972.67 sec
Fasteners	145
Total Weight	12.62 kg
Piece Cost	$419.62
Total Labor Cost	$136.42
Q Burden	$10.61
Total Cost	$566.64
Annual Production	200000

The summary shown in
Table 7-3 above includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total "should cost" before markups.

Table 7-4 Toyota Prius Power Inverter Module Cost Estimate Summary

Product Summary		
Part/Assembly Name:	2016 Toyota Prius Power Inverter Module	
Purchased Part Roll up Costs		$376.66
Raw Material Costs		$42.96
Processing Costs		$136.41
Scrap (Design Profit: Q-Burden)	2%	$10.61
SG&A % Applied Against Processing	7%	$9.55
Profit % Applied Against Raw & Processing	4%	$7.17
Logistics % Applied Against Sum of all Above	3%	$17.50
Patent/Royalty Fees % Applied Against Sum of all Above	11%	$68.21
Total Supplier Manufacturing Cost		$669.07
Total Weight (kg)		12.6159
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$5,310,000
Tooling Cost/part		$5.31
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$10,620,000
Tooling Cost/part		$10.62

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. As shown in, the markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown with each item. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

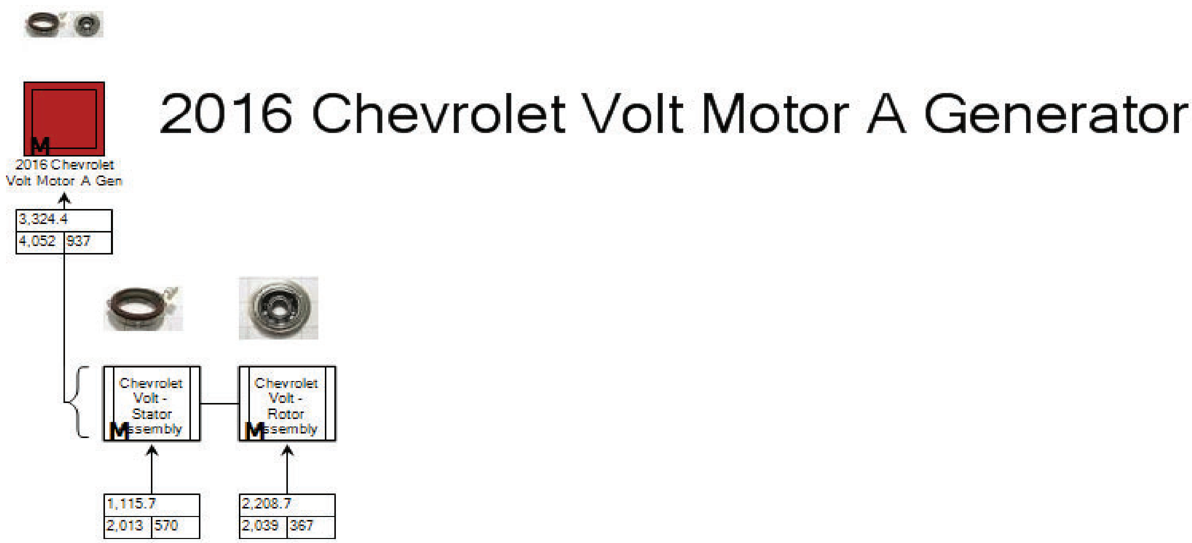
7.3 Chevy Volt Motor Cost Analysis

The Chevy Volt motor was subdivided into two major groupings: the stator and the rotor. All parts were analyzed in detail to establish a "should cost" based on today's manufacturing practices. Each grouping is reported separately in the cost analysis detailing the "should cost" to manufacture and assemble the various components. The group costs are included in the total system cost. The stator group consists of the stamped electromagnet steel laminates, insulators, and copper windings. The rotor group contains the hub, stamped electromagnetic steel laminates, magnets, and end covers.

Figure 7-5 Chevrolet Volt Stator and Rotor

The Figure 7-6 below is a screenshot of the major groupings of the motor assembly. The grouping facilitates additional assessment that will identify higher cost drivers associated with the motor.

Figure 7-6 Volt Motor: Design Profit Cost Map—Major Groupings



The total "should cost" to manufacture the Chevy Volt Motor is estimated and additional typical markups associated with component manufacturing added. (These additional markups are shown Table 7-6 on page 90.)

Table 7-5 Chevy Volt Motor: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
2016 Chevrolet Volt Motor A

MUNRO & ASSOCIATES, INC.

	2016 Chevrolet Volt Motor A Generator
Parts	937
Steps	4,097
Actual Time	3,595.73 sec
Fasteners	0
Total Weight	13.34 kg
Piece Cost	$105.01
Total Labor Cost	$58.62
Q Burden	$4.32
Total Cost	$167.95
Annual Production	200000

The summary shown in Table 7-5 above includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total cost before markups.

Table 7-6 The Chevy Volt Motor Cost Estimate Summary

Product Summary		
Part/Assembly Name:	2016 Chevy Volt Motor	
Purchased Part Roll up Costs		$27.02
Raw Material Costs		$77.99
Processing Costs		$58.62
Scrap (Design Profit: Q-Burden)	3%	$4.32
SG&A % Applied Against Processing	7%	$4.10
Profit % Applied Against Raw & Processing	4%	$5.46
Logistics % Applied Against Sum of all Above	3%	$5.33
Patent/Royalty Fees % Applied Against Sum of all Above	5%	$9.14
Total Supplier Manufacturing Cost		$191.99
Total Weight (kg)		13.3417
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$885,000.00
Tooling Cost/part		$0.89
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,770,000.00
Tooling Cost/part		$1.77

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. As shown above, in Table 7-6, the markups include sales and general administrative costs (SG&A), profit, logistics, and patent/royalty fees. The assumed percentages and cost calculations are shown with each item. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

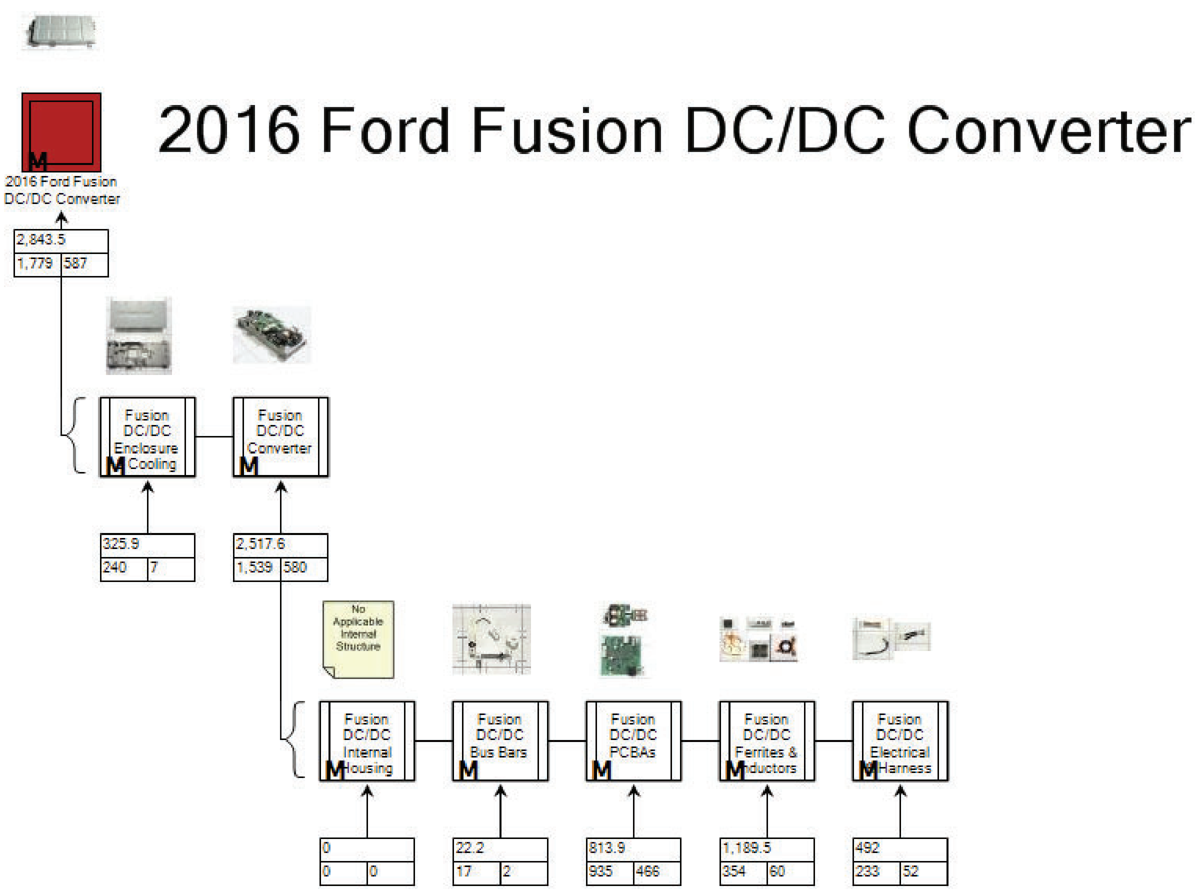
7.4 Ford Fusion DC/DC Converter Cost Analysis

The Ford DC to DC converter consists of the housing assembly and internal electronics converting the high voltage DC from the high voltage battery pack to 12-volts for the typical vehicle 12-volt systems. For reporting purposes, the assembly was broken down into two major groups Enclosures/cooling and electronics. The electrical system was then separated into five sub-groups: Internal Housing, Buss Bars, Printed Circuit Board Assemblies (PCBA), Ferrites & Inductors, and Harnesses (wiring). The DC to DC converter is manufactured by TDK and appears to be their Gen 4.7 which provides an output of 185 amps.

Figure 7-7 Ford Fusion DC to DC Converter

Figure 7-8 below is a screenshot of the major groupings of the Ford Fusion DC/DC Converter. The groupings will facilitate additional assessment that will identify higher cost drivers associated with the system.

Figure 7-8 Ford Fusion DC to DC Converter: Design Profit Cost Map—Major Groupings



The total "should cost" to manufacture the Ford DC/DC converter is estimated and additional typical markups associated with component manufacturing added. (These additional markups are shown Table 7-8 p. 94.

Table 7-7 Ford Fusion DC/DC Converter: Design Profit Summary

Design Profit® **EXECUTIVE SUMMARY**
2016 Ford Fusion DC/DC
MUNRO & ASSOCIATES, INC.

	2016 Ford Fusion DC/DC Converter
Parts	587
Steps	1,779
Actual Time	2,843.46 sec
Fasteners	58
Total Weight	2.58 kg
Piece Cost	$184.69
Total Labor Cost	$40.95
Q Burden	$3.23
Total Cost	$228.88
Annual Production	200000

The summary shown in Table 7-7 above includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total "should cost" before markups.

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. As shown below in Table 7-8, the markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown with each item. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

Table 7-8 Ford Fusion DC/DC Converter: Cost Estimate Summary

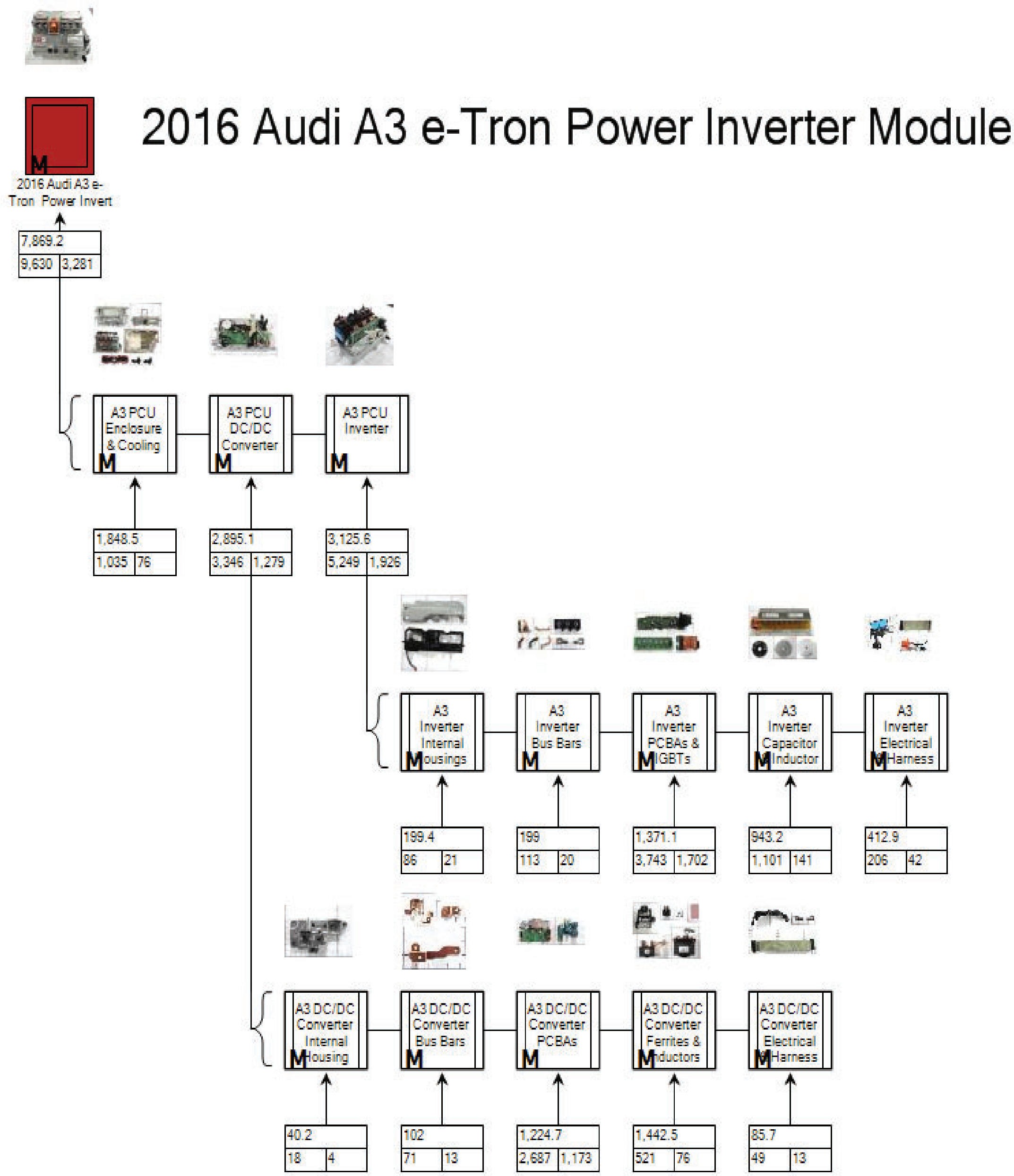
Product Summary		
Part/Assembly Name:	2016 Ford DC to DC Converter Assembly	
Purchased Part Roll up Costs		$177.36
Raw Material Costs		$7.30
Processing Costs		$40.96
Scrap (Design Profit: Q-Burden)	1%	$3.24
SG&A % Applied Against Processing	7%	$2.87
Profit % Applied Against Raw & Processing	4%	$1.93
Logistics % Applied Against Sum of all Above	3%	$7.01
Patent/Royalty Fees % Applied Against Sum of all Above	13%	$31.88
Total Supplier Manufacturing Cost		$272.55
Total Weight (kg)		2.5828
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,270,000
Tooling Cost/part		$1.27
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$2,540,000
Tooling Cost/part		$2.54

7.5 Audi A3 e-Tron Inverter Module Cost Analysis

The Audi A3 e-Tron Power Inverter Module is manufactured by Bosch. It provides two distinct functions; motor control switching of high voltage DC to three phase AC (Vehicle Traction Motor) and conversion of high voltage DC to low voltage DC (12-Volt for typical vehicle electrical architecture). For reporting purposes, the module was broken down into three major groups. These groups include Enclosures & Cooling, DC to DC Converter and the Inverter. The two electrical groups DC to DC and Inverter systems were then separated into five sub-groups: Both electrical groups were analyzed using the following subgroups: Internal Housing, Bus Bars, Printed Circuit Board Assemblies (PCBA), Ferrites & Inductors (also includes capacitors for inverter), and Electrical Harnesses (wiring).

Figure 7-9 Audi A3 e-Tron Power Inverter as Supplied by Bosch

Figure 7-10 Audi Power Inverter Module Design Profit Cost Map—Major Groupings



The groupings facilitate additional assessment that will identify higher cost drivers associated with the system. The higher cost components are then scrutinized to identify potential future cost savings.

Table 7-9 Audi Power Inverter Module: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

2016 Audi A3 e-Tron Power

MUNRO & ASSOCIATES, INC.

	2016 Audi A3 e-Tron Power Inverter Module
Parts	3,281
Steps	9,630
Actual Time	7,869.18 sec
Fasteners	126
Total Weight	10.19 kg
Piece Cost	$494.85
Total Labor Cost	$127.68
Q Burden	$10.34
Total Cost	$632.88
Annual Production	200000

The summary shown above in Table 7-9 includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table 7-10 Audi Power Inverter Module Cost Estimate Summary

Product Summary		
Part/Assembly Name:	2016 Audi A3 e-Tron Power Inverter Module	
Purchased Part Roll up Costs		$439.74
Raw Material Costs		$55.12
Processing Costs		$127.68
Scrap (Design Profit: Q-Burden)	2%	$10.34
SG&A % Applied Against Processing	7%	$8.94
Profit % Applied Against Raw & Processing	4%	$7.31
Logistics % Applied Against Sum of all Above	3%	$19.47
Patent/Royalty Fees % Applied Against Sum of all Above	12%	$83.29
Total Supplier Manufacturing Cost		$751.89
Total Weight (kg)		10.1853
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$7,752,500
Tooling Cost/part		$7.75
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$15,505,000
Tooling Cost/part		$15.51

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. As shown in Table 7-10 above, the markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown with each item. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

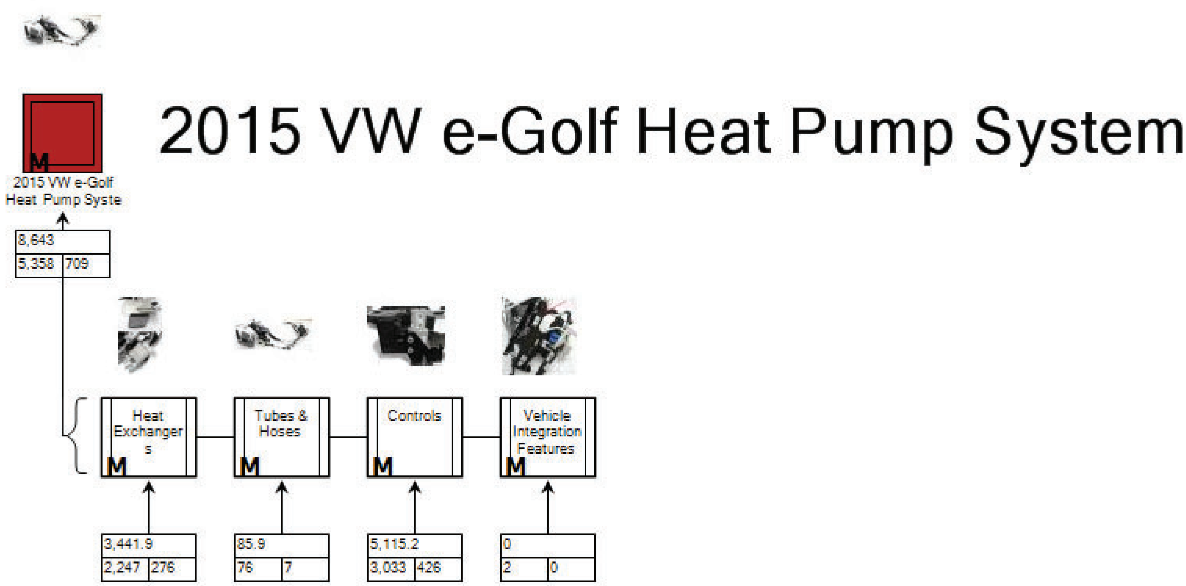
7.6 VW e-Golf Heat Pump System Cost Analysis

The VW e-Golf heat pump system provides two distinct functions, heating or cooling of the vehicle cabin. For reporting purposes, the system was broken down into four major groups. These groups include heat exchangers, Tubes & Hoses, Controls, and Vehicle integration features (mounting brackets). The heat exchanger section includes three components two of the heat exchangers are located inside the passenger compartment HVAC assembly while the third one resides in the engine compartment. The tubes and hoses group includes all plumbing associated with connecting all the discreet devices in the system. The controls group includes six electrically controlled valves (two different types). The vehicle integration features group includes a large stamped mounting bracket used to attach most of the valves associated with the system. The compressor, condenser, and drier bottle were excluded, as they would still be required in the typical AC system.

Figure 7-11 VW e-Golf Heat Pump System

Figure 7-12 below is a screenshot of the major groupings of the VW e-Golf heat pump system. The groupings will facilitate additional assessment that will identify higher cost drivers associated with the system.

Figure 7-12 VW e-Golf Heat Pump: Design Profit Cost Map-Major Groupings



The total "should cost" to manufacture the VW e-Golf Heat Pump System is estimated and additional typical markups associated with component manufacturing added. (These additional markups are shown in Table 7-12 p. 102.

Table 7-11 VW e-Golf Heat Pump System: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

2015 VW e-Golf Heat Pump

	2015 VW e-Golf Heat Pump System
Parts	1,102
Steps	8,503
Actual Time	17,084.51 sec
Fasteners	107
Total Weight	11.00 kg
Piece Cost	$131.32
Total Labor Cost	$236.55
Q Burden	$13.34
Total Cost	$381.22
Annual Production	200000

The summary shown in Table 7-11 above includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table 7-12 VW e-Golf Heat Pump System: Cost Estimate Summary

Component Summary		
Part/Assembly Name	2015 VW e-Golf Heat Pump System	
Purchased Part Roll up Costs		$78.26
Raw Material Costs		$53.07
Processing Costs		$236.55
Scrap (Design Profit: Q-Burden)	4%	$13.35
SG&A % Applied Against Processing	7%	$16.56
Profit % Applied Against Raw & Processing	4%	$11.58
Logistics % Applied Against Sum of all Above	3%	$12.28
Patent/Royalty Fees % Applied Against Sum of all Above	4%	$14.94
Total % Mark Up / Total Cost		$436.59
Total Weight (kg)		10.99
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$4,215,000
Tooling Cost/part		$4.22
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$8,430,000
Tooling Cost/part		$8.43

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. As shown above, in Table 7-12, the markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown with each item. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

8 Potential future state of hybrid electric vehicles

8.1 Objective

8.1.1 Technology enablers: how subsystems costs can be reduced

During the investigation in the current state of the art technologies in PHEV applications, the team has identified a number of components, systems, and architectural opportunities to reduce system costs. New technological breakthroughs may also open up new avenues to future cost reduction that are expected to achieve production viability in the coming years. These insights will be used to project how costs can be reduced in the 2020 and 2025-time frame. It is not within the scope of this project to fully develop new designs, but based on literature review, industry interviews and the team's expertise, the following design approaches can be considered a conservative view and provide design and manufacturing process options for achievable cost reductions. With the likelihood of new design and manufacturing advancements, further cost reduction opportunities are expected.

8.2 Summary of findings for potential future state

OEM's technology strategy will vary based on a number of factors, such as internal expertise, patents, existing infrastructure, new startup innovations, market forces, and legislation. The specific combination of factors will influence where development dollars are spent, as such, it is unlikely to be one discreet, industry-wide solution will prevail by 2025. During the preparation of this report, it became clear that along with technical advancements a large part of potential future cost savings come from increased production volumes and the associated competitive forces driving innovation in design and manufacturing. Other than the Toyota Prius, the current production volumes of the system analyzed are significantly less than the forward-looking 200k units per year used for this analysis and therefore better reflect the price of today's designs, manufactured at potential future HEV and PHEV production volumes.

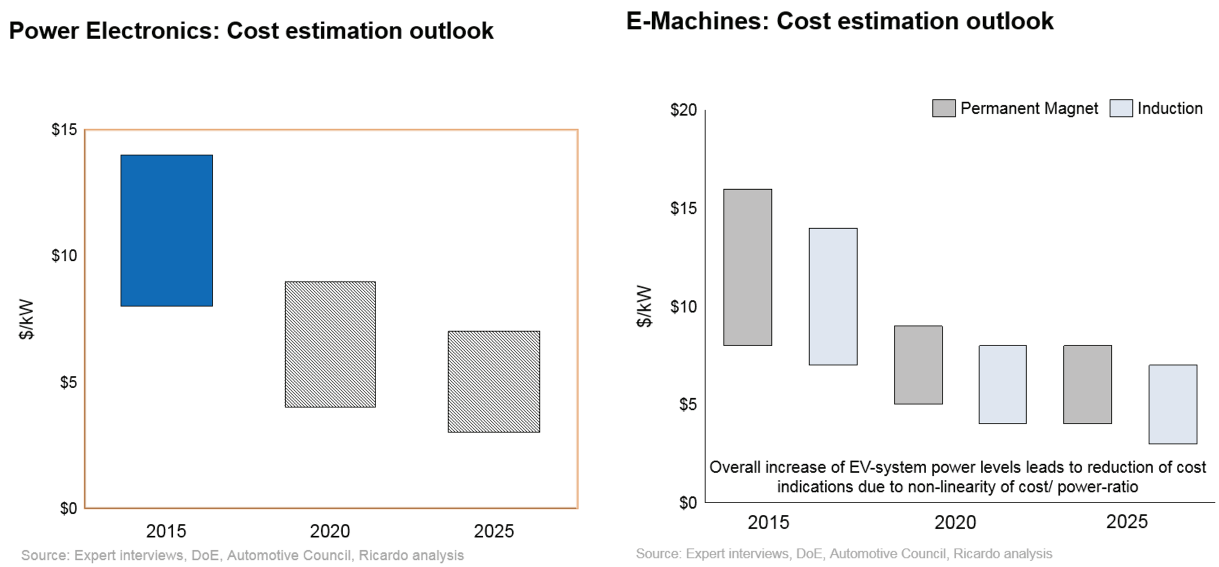
Based on expert interviews it was established that potential reduction in HEV and PHEV production costs would require production volume increases and manufacturing learning required to leverage the potential benefits of WBG technologies. As the actual engineering solutions have not been developed it is not possible to estimate these savings, but saving in terms of $/kW are likely to increase as EV-system power levels increase due to the non-linearity of cost to power ratio. Additional savings are likely to come from:

- Increased production volumes >500,000 to enable economies of scale
- Greater integration of systems especially as it relates to thermal management
- Widespread adoption of WBG semiconductors for high voltage application dramatically increases inverter efficiency – fewer devices required
  - Advancements in GaN and SiC manufacturing yield and uniformity
  - New high-temperature packaging materials for GaN and SiC devices
- Improved thermal management intelligently using heat as a resource that improves overall vehicle efficiency
- New topologies to leverage WBG capabilities

- High efficiency, high-temperature, and high switching frequencies
- Advances in controls to manage the noise, vibration and harshness historically developed by lower cost switched reluctance electric machines.

- Improved materials and manufacturing techniques
    - High-temperature packaging
    - Improve WBG device yield and consistency
    - Lower cost joining and sealing solutions such as friction stir welding

Figure 8-1 Potential Relative Future Cost Estimates



GM introduced the Silverado 1500 a mild hybrid Light-Duty Truck (LDT) in 2005 and full hybrid in 2008. Complaints about perceived poor drivability and cost to performance limited their uptake even at a time when the average NA gas price was at ~$4 per gallon. Current lower fuel costs and consumer market trends are driving product sales in larger SUV’s and LDT’s. This puts significant pressure on OEM’s attempts as they introduce smaller efficient vehicles to the market with sufficient volumes to significantly impact fuel economy and CO_2 levels of the fleet. As mentioned above the relative costs for EV systems goes down as the power of the system increases. Over the last 10 years, the OEMs have made significant improvements in their understanding and ability to harness the potential benefits offered by HEV and PHEV technologies. Drivability, fuel economy and cost is becoming acceptable and even successful in the marketplace as demonstrated by the Prius family and Volt. As user acceptance has improved, it would be interesting to investigate how the application of modern HEV and PHEV technologies might impact larger vehicles, such as SUV’s and LDT’s.

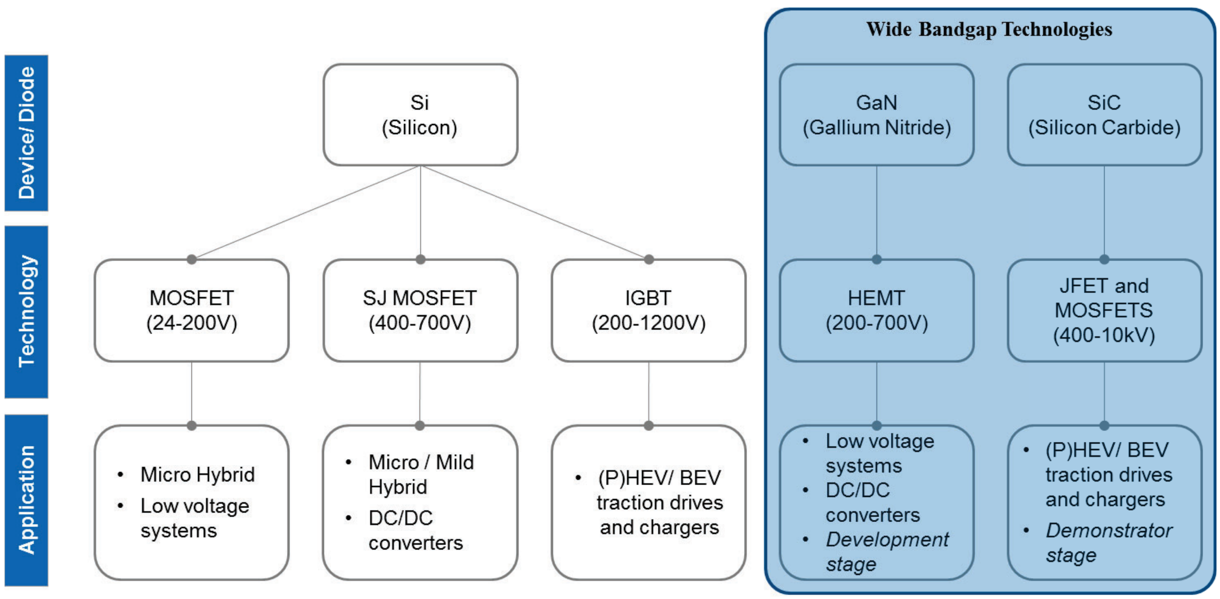
During the development of this report, challenges of breaking down key metrics to use for comparisons where identified. In order to meet the demanding targets, set by regulations and the marketplace, OEM's have moved away from considering a vehicle as a group of sub-systems. There is a need to view the vehicle as a holistic integrated entity that requires multifaceted bi-directional interactions across every system. For example, for traditional internal combustion engine vehicles (non-HEV or PHEV) drivetrain components could be designed knowing that they would experience the majority of the torque events in a single direction. With the advent of regenerative braking, drivetrain components between the wheels and the electric machine, have a more demanding workload. These components now have to handle the torque of almost equal values in both directions without generating noise, vibration, or a poor driving experience without failing prematurely.

As has been seen in the selection of systems analyzed in this report, each OEM is developing their own engineering solutions for HEV and PHEV products. Comparing the relative merits of each approach at only, a sub-system level has limitations. Challenges associated with one technical approach may not exist in another system if a fundamentally different design solution is used. For example, GM's Volt will, during high torque, engage the generator as a motor to supplement the torque provided to the wheels where implementing a smooth transition is technically challenging. Audi do not have the same problem as the solution used in the Audi A3 only has one electric machine. This solution has its own challenges in achieving optimal efficiency over the entire operating range the drive system has to deal with. It is therefore recommended that a future study compares multiple HEV and PHEV vehicles from a complete system standpoint.

Literature review

Silicon power electronics, in the form of IGBTs and metal–oxide–semiconductor field-effect transistors (MOSFETs) have been the go-to technology for power electronics. Significant improvements over the last twenty years in quality and production costs have paved the way for PHEVs to come to market. Today, silicon wafer die sizes of 300 mm diameter are a commodity and the ability to grow even larger wafers have been demonstrated but the downstream infrastructure is not readily available in place to capitalize on the advancement. Even with thermal management, improvements in material quality, and die size, silicon is nearing the boundaries of its performance due to limited voltage, thermal tolerance, and switching frequency headroom. What technologies are available to drive down size, weight, and cost in the next generation of products? See Figure 8-2 Power Electronics: Technology Overview p. 106.

Figure 8-2 Power Electronics: Technology Overview



Source: Ricardo analysis

8.3 Wide Bandgap Technologies

Because of the intrinsic material properties, wide bandgap (WBG) power devices either Silicon Carbide (SiC) or Gallium Nitride (GaN) have lower specific on-resistance, higher switching speed, higher allowable operating temperature, and higher breakdown voltage compared to Silicon (Si) power devices. With higher operating switching frequency, the size of passive components such as the capacitors, inductors, and filters can be reduced. Therefore, the power density of power electronics converters can be improved. For example, a research design project for a 6.6kW onboard charger indicated that the size and weight could be reduced by 30%-50% with all GaN devices operating up to 1MHz switching frequency. Moreover, the switching and conduction losses of WBG is lower compared to Si devices. Therefore, very efficient power converters can be developed based on WBG devices. A 40 kVA SiC junction gate field-effect transistor (JFET) Inverter with natural convection cooling is designed with more than 99.5% efficiency [30]. The efficiency is at least 1% higher than that of the Si inverter. In addition, the allowable maximum junction temperature is higher, and therefore, the cooling system can be simplified or reduced. For example, a 30kVA inverter using SiC MOSFETs for 180˚C ambient temperature is demonstrated and verified [31].

Compared to Si, WBG devices are a relatively new development in power electronic and developing designs that can utilize their unique properties pose some challenges. One obstacle to designing power electronic solutions with WBG is the limited current rating per WBG device. The rated currents of most WBG devices are lower than 100 Amps though some are now becoming available at 180A. This means in high-power applications, such as PHEV traction motor inverters require many discrete devices configured in parallel to meet the required operating current. Managing device (die) to device (die) variation in circuit design is more arduous than using the higher current carrying Si devices as the increased paralleling of components increases the design complexity in multiple ways. Device matching, components layout, cooling and gate driver designs need to be developed with demonstrable reliability in real world applications. For example, inverters and converters can be affected if static and dynamic current sharing of devices is mismatched. Currently, the long-time reliability information of these devices in practical applications is not available[32], and during recent development of WBG power devices, some reliability issues were reported but subsequently resolved. More data is needed to provide the confidence required by automotive OEMs for full-scale deployment.

In addition, on a per Ampere basis, SiC is currently ten times more expensive than Si, which is a major barrier for the wide application of WBG devices in PHEVs. If production improvements in quality, die size continue, and production volumes increase then taking into account learning from the development of Si, the device's price is expected to drop to 25% - 30% of today’s pricing by 2025. Even so, the cost of SiC will still be 225% greater than Si. If we factor in the other benefits of SiC on the system design, there is an opportunity for the cost of the inductors, capacitors, and package size the devices will come down. WBG suppliers and OEM’s are continuing to conduct research and are gradually using these devices in special areas, such as aerospace and military and in some industrial applications where cost is not as sensitive.

Based on industry expert interviews, and this studies analysis power electronics for Inverters and DC/DC converters currently range between $10 to $20 per kW but with advances in system cooling, and the introduction of WBG technologies with new topologies these systems could drop to $5 to $12 per kW. The lower pricing requiring even higher production volumes than the 200k units per year used for this study.

WBG devices will grow more popular due to the intrinsic material and system level advantages, and this will increase the number of applications and manufacturing volume. With these changes, the cost of WBG devices is expected to reduce and be applied in the other more cost sensitive application areas such as the solar and automotive industries. For instance, a startup company HiQ Solar, are developing very compact, highly efficient all SiC based solar inverters. Based on the currently released information, it is expected that the automotive industry will adopt WBG devices for powertrain systems in limited markets in the 2020 timeframe. However, for more broad application, the industry will need to validate the reliability in an automotive environment.

8.3.1 New packaging technology for WBG

To gain even greater benefits from WBG technology, there is a need for increased capabilities in the WBG packaging materials. Today, the maximum junction temperature of most commercialized WBG devices is between 150˚C to 175˚C. Theoretically, the operating junction temperature of WBG devices can be much higher than 175˚C because of the wide energy bandgap of the material. Currently, the temperature limit of the package materials not WBG dies size constraint limits the maximum application temperature and module packaging accounts for approximately 50% of the module cost. To take advantage of high-temperature capability, high-temperature, low-cost packaging technology needs to be developed for WBG power devices. A double-side cooling packaging solution for a high power 3 phase SiC inverter with junction temperature over 220˚C has been presented by D. Woo, H. Yuan, J. Li, L. Bum and H. Zhang[33]. This novel packaging material can endure temperatures up to 220˚C when applied to the module. To develop power converters for high-temperature applications, a high-temperature gate driver Integrated Circuit (IC) is also required. Usually, the Silicon-On-Insulator technology is applied for the high-temperature gate driver IC[34]. However, the cost is too high for commercial applications. Therefore, affordable high-temperature packaging technology still needs to be developed.

8.3.2 Modular concept for power electronics converters:

One increasingly popular way of using lower power devices in high power electronic applications is to utilize a modular system approach. For example, the Tesla fast-charging station utilizes eight onboard chargers in parallel. By using this architecture, one converter design can be applied to two or more products, saving significant development costs reduced time to market. Moreover, the power rating of the fast-charging stations can be adjusted by varying the number of paralleled onboard chargers in use at any one time. Although this approach works there is some inefficiency in this design solution that is unlikely to yield the lowest total cost solution.

Interest in WBG solutions is not in short supply as a number of corporations have invested heavily in the development of WBG technologies such as fabrication, gate design, charges, inverters and DC/DC converters. Some of the leaders in these technology advancements include EPC, Global Power Technology, GaN Systems, Hitachi, Infineon, Panasonic, ROHM, Semikron, Transform, Toyota.

8.4 SiC

8.4.1 Overview

SiC devices have already been applied to lower power DC-DC converters and inverters. For instance, Infineon has a power module utilizing a SiC diode that can be used in boost converters and inverters. Vincotech also has power modules with SiC MOSFET's. In addition, a demonstration 55kW traction inverter for hybrid electric vehicles was built with hybrid Si IGBT and SiC anti-parallel diode[35]. The test results show that the loss is reduced by about 12% compared to the all-Si device-based inverter.

SiC n-type wafer production volumes are projected to increase to a value greater $100 million by 2020.

8.4.2 Benefits

- SiC has higher voltage range than Si or GaN
  From 900V to 15,000V
- SiC operating temperature rating
  200°C compared with 125°C for Si
- Sic has a potential of 10x the frequency response of Si

8.4.3 Obstacles

Currently, SiC is only being produced on relatively small dies ~ 150 mm diameter with work being carried out to develop a robust process at 150 mm but even then the yield is relatively low. When projecting a timeline, we would look to the Si Wafer history and see that the growth from 150mm diameter wafers to the current industry size of 300mm took approximately 21 years (1980 to 2001). The jump to 200mm was almost 11 years (1980 to 1991)[36]. It is estimated that the development time for SiC could be compressed to 50% of that required to mature Si to the current level.

- SiC high inductance than GaN which leads to higher losses
- Difficult to integrate into parallel systems required for high current devices

8.5 GaN

8.5.1 Overview

GaN holds promise to take over today’s silicon power devices as they reach their price and performance limits. The technology proponents claim that, at the system level, a GaN solution will be half the size and weight of an equivalent Si solution.

It is the team understands that at least one OEM will be introducing a GaN solution to one of their luxury brands in the 2018-2020 period. There are also white papers that provide reference design solutions that show promise. GaN has already started to make gain traction in low power devices. Overcoming some of the current limitations is the challenge faced by the industry. Many players are competing in the development of GaN-on-Si but there is also the potential for the development of GaN-on-GaN.

In the motor drive applications, a research indicates that the system efficiency (from electric power to mechanical output power) is around 2%-5% higher by using GaN devices for a 2kW drive system [37].

GaN power amplifiers support a wide range of frequency bandwidths and high breakdown voltages. The manufacturing process currently remains too costly to exploit these benefits on a large scale.

8.5.2 Benefits

- Operating voltage range falls between Si and SiC
  From ~100V to 650V with development approaching ~1200V
- ±10V Gate tolerance
- Operating temperature rating of 150°C limited by packaging
- Compared to Si and SiC:
  - Lower resistive losses
  - Lower switching losses
  - Lower switching delays
- Current rating up to 250A at 100V

Once the manufacturability issues have been resolved, GaN is likely to be less expensive per Ampere than SiC and theoretically could be at parity or better than Si

8.5.3 Obstacles

Manufacturability of GaN devices is not at the same level of maturity as Si. Currently, GaN devices are only being produced on relatively small dies ~ 100 mm diameter with work being carried out to develop a robust process at 150 mm but even then the yield is relatively low. Defect density is the biggest challenge large-scale productivity and improved pricing.

To make use of the higher switching frequency available to GaN solutions the traction motor design will have to change. This change will not be limited to just the base number of poles but also changes in the properties of the stack lamination materials and geometry to optimize the electromagnetics.

8.6 Hot Deformation Neodymium Magnets

8.6.1 Overview

Daido Steel and Honda have developed a magnet made from the light rare earth element Neodymium (NeFeB) that that does not contains any Dysprosium (Dy), Terbium (Tb) which are heavy rare earth elements and provide the high anisotropic magnetic fields needed to increase High Coercive Force (Hcj). The method outlined in Honda's press releases describe the process as "Hot Deformation" [38]. This process allows for a fine crystal grain structure that like the heavy rare earth elements protects the magnet properties from the impact of elevated temperatures [39]. This new neodymium magnet is a joint development between Daido Steel and Honda. Daido steel has improved the hot deformation technologies and Honda has revised the shape of the magnet. The new magnet is accommodated in a new motor design, which has a revised rotor shape to optimize the flow of magnetic flux. The new magnet and motor design will be deployed in the Honda Hybrid MY 2017 Freed i-DCD (Intelligent Dual Clutch Drive) system in Japan.

8.6.2 Benefits

The new magnet is claimed to have the all the strength of NeFeB magnets without the expense of Heavy REE, yet retain the heat resistance characteristic of Heavy REE. The new 'hot deformation' process and magnet design along with an altered motor design are collectively responsible for achieving torque output equivalent to motors with the conventional type of magnet. NeFeB magnets have the highest magnetic force among all permanent magnets and traditionally they are made high heat resistance by adding heavy rare-earth metals. This has led to rising rare earth metals demand while supply remains flat and unevenly distributed globally. This poses a risk of unstable prices and supply as demand soars. Therefore, reduction in the use of heavy rare earth elements has been a subject of interest in the industry.

8.6.3 Obstacles

Accessibility to this new process by Daido Steel is uncertain, as is whether there is a cost penalty associated with the new process. A positive sign from Daido Steel was the announcement in August of 2016 that they decided to invest several billion yen in a production plant in the U.S. [40]. This plant is planned to be up and running in 2019 to meet the demands of automakers. If this 'hot deformation' magnet is able to survive challenging duty cycles and high heat better than traditional neodymium magnets without heavy rare earth elements these would present a significant opportunity.

8.6.4 Potential Cost savings by application (Generator, Traction motor)

Removing the market volatility and cost of Heavy REE in magnet production reduces the cost contingencies due to financial uncertainty as the automotive industry moves forward in deploying new electrified vehicles.

8.7 Ribbon Electrical Interconnects

8.7.1 Overview

According to the US Department of Energy's Vehicle Technology Office, ribbon wire looks to be an attractive alternative to traditional round wire for use in electrical interconnects of IGBTs [41]. Power electronics rely on wire bonds to electrically connect dies, substrate's top metallization layer, and lead frames. Traditionally multiple round bond wires are used in parallel to meet demands of high current power modules, as the diameter of these wires are limited to 500 micrometers. Such interconnects do not sufficiently meet the requirements of latest inverters which perform at high frequencies, power densities, and temperatures. A ribbon interconnect provides a better alternative for handling such operating conditions.

Benefits

Ribbon interconnects allows for higher current densities with fewer connections, a lower profile due to loop height and reduced parasitic inductance. With a 40% reduction in the bond area, it also provides for SiC and GaN device interconnects as they mature. Ribbon interconnects exhibit similar reliability to wire interconnects under thermal aging, cycling and corrosion tests as reported by NREL[14]. Power ribbon bonding solution has been commercialized in portable device semiconductor and power module markets and can be beneficial to hybrid electric vehicles as well [42].

8.7.2 Obstacles

Ribbon lifetime is adversely affected under vibration conditions, which can be mitigated by keeping span length of the ribbon to a minimum.

8.7.3 Potential Cost savings by application (Invertor, DC/DC, SiC and GaN IGBTs)

Ribbon bonding solutions have an increased current carrying capacity; a single 2,000 µm x 300 µm ribbon can replace five 375µm diameter Aluminum (Al) wires. This is economical when considering that a single 300 Amp IGBT may have 20 round wire connections.

8.8 Carbon Nano Tube (CNT) – Copper (Cu) Composite Wire

8.8.1 Overview

Carbon Nano Tube (CNT) – Copper (Cu) Composite wire is a conductor based on the marriage of approximately 65% CNT with 35% Cu [43]. The resulting CNT-Cu composite is lightweight and can carry a very high current density compared to copper. Various research groups are looking into making this a feasible product. Teijin Aramid (a Japanese-Dutch company), GE Global Research and a few universities are investigating new carbon nanomaterials in electrical machine winding. But to date realization of a commercial product at an economical cost for automotive use is unknown.

8.8.2 Benefits

CNT-Cu holds the promise of a 50% reduction of conductor weight in an electrical machine. In addition, it also is being touted as a having 100 times the current density of copper wire. CNT yarns have one-dimensional and symmetric structure enabling charge carriers to travel along the nanotubes almost without 'scattering' leading to high current carrying capacity [44]. Despite high conductivity of copper, a major share of electric machine losses still occurs in the copper windings. This also reduces the thermal management concerns associated with high power electric machines. Highly conductive, lightweight, and strong CNT yarn have the potential to replace copper if it can be produced at competitive prices.

8.8.3 Obstacles

Currently production volumes, termination, and cost are major hurdles making it unsuitable for automotive use at this time. Also conductivity while improved in recent studies is still lagging that of Aluminum [45]. CNT-Cu wires can find application in highly weight-sensitive operations in the military or satellite launches where cost penalty of mass is very high. The technology has been studied for deep sea drilling operation [46]. At present, the cost is prohibitive for use in automotive sectors. However, if price declines by the same factor as Carbon fiber over the last ten years it is a possibility for the future and it is certainly a technology to watch.

8.8.4 Potential Cost savings by application (Invertor, DC/DC, SiC and GaN IGBTs)

No cost savings are possible at the current time of CNT-Cu development phase. If the technology should become comparable to copper then savings would be realized in power density, motor size, performance, weight, and complexity.

8.9 Friction Stir Welding

8.9.1 Overview

Friction stir welding (FSW) is a mature process used in a variety of industries where the ability to join soft metals by their faces is required. A non-consumable tool generates heat via friction by rotating a tool against the items to be joined. This leads to a softened region near the FSW tool. While the tool is moved along the joint line, the metals intermix and the tool pressure forges the hot softened materials together.

8.9.2 Benefits

Issues typical of traditional welding processes such as porosity and cracking are avoided. Following are some benefits[47]:

- High-quality welds with good mechanical properties
- Minimal distortion from the welding process
- Welds alloys typically not weldable by traditional welding processes
- Uses no consumables

8.9.3 Obstacles

FSW is less tolerant of fit issues, such as height differences between parts, due to the method of developing heat via friction. Supporting and clamping of the parts to be joined is also critical due to the pressures applied to the parts during the joining process.

8.9.4 Potential Cost savings by application (Inverter and Converter Coolant Housings)

Due to the difficulty of manufacturing die-castings with cores, most aluminum housings requiring coolant passages are constructed from two parts. One or both parts will have the coolant passaged formed during the die-casting process. To ensure a leak-free joint, the surface of the castings is typically machined, a seal or gasket is applied, and then the two parts are then joined with fasteners. FSW can eliminate the additional parts, such as gaskets, fasteners, and related machining operations. The Audi e-Tron is one such example of successful and economical usage of FSW.

8.10 Analyzed Systems Cost Reduction Opportunities

The savings identified in the following sections do not capture all potential savings and efficiency gains that come from interaction or combination with other vehicle systems such as the cooling system that would make this an attractive and viable option.

8.10.1 Toyota Prius Traction Motor B Cost Analysis

The Toyota Prius Traction Motor B is a 4th generation, state-of-the-art permanent magnet electrical machine, which has been designed to substantially reduce the content of rare-earth materials. Toyota elected to liquid cool the rotor to maximize the power and torque available while preventing the magnets from being exposed to a temperature that could result in demagnetization. The cooling approach also included drillings holes in the rotor shaft and utilizing a series of uniquely stamped laminations to allow routing of liquid behind the magnets and exiting radially back to the sump. This is a major departure from most PHEV traction motors, which typically have only one or two different lamination designs. This results in the multiple stamping tools and the associated cost that will be substantially more than a typical traction motor design.

During the teardown a set of magnets were provided to Magnet Applications, Inc. for analysis, to determine the grade used. The testing determined that the Prius was utilizing a Neo 42 magnet which incorporated improved design and manufacturing techniques to reduce the amount of expensive and difficult to source heavy rare earth materials. Unexpectedly, the rotor and stator laminations were of different materials, If the slightly reduced efficiency can be absorbed using the same lamination material across the stator and rotor, as is usual, would provide material cost saving by reducing scrap and the associated costs. Alternatively, using a segmented stator lamination design may achieve similar financial benefits. No further redesigns were proposed for the 2020-2025 timeframe. Although, in the future, incremental reduction of heavy rare earth materials by utilizing Daido Steel's Hot Deformation Ne Magnet technology, magnetically masked laminations, and inclusion of GE's Carbon Nano Tube (CNT) – Copper (Cu) composite wire may provide for a much smaller, more powerful and lighter machine that does not require a unique cooling strategy.

Table 8-1 Toyota Prius Traction Motor B Cost & Weight Potential Analysis

	Price Change % (original system 100%)	Price $ Reduction	Weight Improvement % (original system 100%)	Weight Improvement (kg)
Common lamination material	93% - 96%	$10 to $15	N/A	N/A
Total		$10 to $15		

8.10.2 Toyota Prius Inverter Module Cost Analysis

The Toyota Prius Inverter module is based on Si IGBTs. As a 4th generation Inverter module it was observed that the internal space was well optimized in large part, due to the unique cooling system for the double sided IGBT cooling. The Prius Inverter featured a DC/DC buck converter in the lower housing and a boost converter integrated into the Motor Invertor section, which resides in the upper housing.

An idea implemented in Audi's A3 e-Tron Inverter module is to employ friction stir welding of the die cast cooling plates to their die cast enclosures. The Prius DC/DC converter is one such area that could benefit from this technique. It would remove a gasket, several fasteners, and some material resulting in a weight savings of 0.11 kg and a $1.98 cost reduction.

Due to low switching frequencies of Si it is necessary to incorporate inductors and capacitors to smooth the output in both electrical machines. The quantity and size of the inductors and capacitors could be reduced if Silicon Carbide (SiC) used due to its higher switching frequency. For the purpose of this study, it was assumed each Si, SiC and GaN device were of equal power capability for a direct part for part substitution. Choosing a modest doubling of the switching frequency in the DC/DC buck converter and including the other identified component savings, the DC/DC buck converter costs were reduced as shown in Table 8-2 below

Table 8-2 Toyota Prius DC/DC buck converter Cost & Weight Potential Analysis

	Price Change % (original system 100%)	Price $ Reduction	Weight Improvement % (original system 100%)	Weight Improvement (kg)
Inductors and capacitors	70% - 75%	$7 to $9	~60%	~0.15 kg
Housings, covers and busbars	75% - 85%	$1.60 to $2.70	70% - 90%	~0.35 kg
Using SiC	225%	($-2.30) *	N/A	N/A
Using GaN	0%	$0.00	N/A	N/A
Total		$6.30 to $11.70		~0.4 kg

In the DC/DC boost converter and Motor Inverter houses 7 IGBT modules and has the highest concentration of the inductors and capacitors, moving to WBG technology offers the largest improvement in package space and weight reduction. Projecting forward to 2025 and substituting SiC or GaN into the DC/DC boost converter and Motor Invertor yields an estimated potential cost.

Table 8-3 Toyota Prius DC/DC, Boost Converter, Motor Inverter Cost & Weight Potential Analysis

	Price Change % (original system 100%)	Price $ Reduction	Weight Improvement % (original system 100%)	Weight Improvement (kg)
Inductors and capacitors	75% - 80%	$20 to $25	~60%	~1 kg
Housings, covers and busbars	75% - 85%	$8 to $11	80% - 85%	~1 kg
Using SiC	225%	($-105) *	N/A	N/A
Using GaN	0%	$0.00	N/A	N/A
Total		$28 to $36		~2 kg

* increase

Note, these Inverter savings do not capture potential savings and efficiency gains in the other systems such as cooling system and the electric motor that would make this an attractive and viable option.

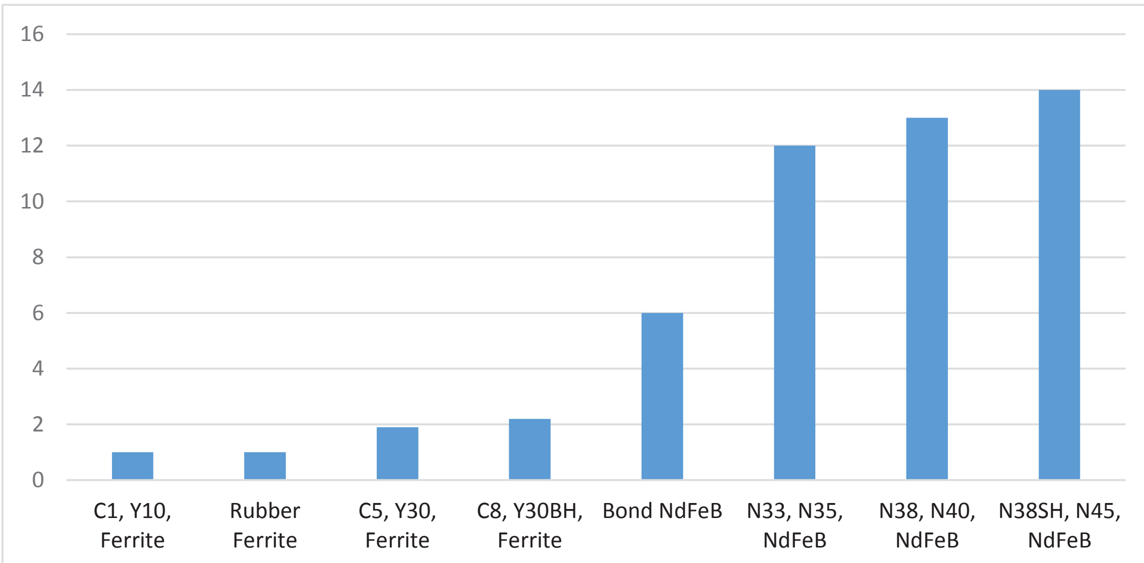
8.10.3 Chevy Volt Motor Cost Analysis

The Chevrolet Volt Motor A Generator is a state-of-the-art electrical machine, which has been designed to eliminate the use of rare earth metals. During the teardown, a set of magnets were provided to Magnet Applications, Inc. for analysis, to determine the grade used in the Volt motors. The testing determined that the Prius was utilizing a Neo 42 magnet while the Volt had a ferrite Ceramic (C)8. After reviewing alternatives, it was found that the ferrite magnets are the weaker of the magnet families as well as the cheapest overall compared to others. Additional research found that reducing the C8 to a lower grade, i.e. C5/C3 would reduce the power of the magnet and there were no additional advantages found. All of the ferrite magnets have a common max operating temperature range of 300 degrees Celsius. Based on this information it was concluded that the Volt is currently using one of the cheapest magnets available and no other reduced costs magnets were found to be available currently or in the future. The tables below were found at as a reference to the various grades and powers of magnets.

Table 8-4 The Characteristics, US MMPA0100-90 Standards.[48]

Grade	Br	Hc	Hci	(BH)max	Curie Temp.	Max. Op. Temp
	(KGs)	(KOe)	(KOe)	(MGOe)	(^{0}C)	(^{0}C)
Ceramic 1	2.2	1.86	3.25	1.1	450	300
Ceramic 5	3.8	2.4	2.5	1.1	450	300
Ceramic 7	3.4	3.25	4	2.75	450	300
Ceramic 8	3.85	2.95	3.2	3.5	450	300
Ceramic 10	4.2	2.95	3.05	4.2	450	300
THE CHARACTERISTICS: IEC, TDK, SJ/T10410-93 STANDARDS						

Figure 8-3 Magnetic Force by Material and Grade



The use of ferrites in the Permanent Magnet Assisted Synchronous Reluctance Machine (PMASRM) provides for a thermal operating range increase but conversely results in a loss of power and torque. These losses have been offset by a speed of rotation increase, slightly larger machine diameter, and a gear reduction change to the transaxle.

GM's Motor is designed specifically for this application making use of the package space near the engine to allow for a larger diameter lower power solution. Which allowed the use of lower power, lower cost magnets, yet maintain the required performance. This is the first in what is expected to be a completely new generation of motors in the PHEV space and no further redesigns were proposed for the 2020-2025 timeframe. Although, like the Prius, GM may benefit from, magnetically masked laminations and inclusion of GE's Carbon Nano Tube (CNT) – Copper (Cu) composite wire may provide for a much smaller, more powerful, and lighter machine that does not require a unique cooling strategy.

- Total estimated potential cost change: (0%)

8.10.4 Ford Fusion DC/DC Converter Cost Analysis

The Ford Fusion DC/DC Converter is based on Si MOSFETs. Due to their lower switching frequencies, the number and size of inductors and capacitors that could be reduced if Silicon Carbide (SiC) or Gallium Nitride (GaN) MOSFETs are used. Note: For the purpose of this study, it was assumed each Si, SiC and GaN device were of equal power capability for a direct part for part substitution.

If this approach is coupled with a modest doubling of the switching frequency this would yielded weight reduction and cost reduction over Si. Note: For the purpose of this study, it was assumed each Si, SiC and GaN device were of equal power capability for a direct part for part substitution.

Components of the DC/DC converter were reduced as follows:

Table 8-5 Ford Fusion DC/DC Converter Cost & Weight Potential Analysis

	Price Change % (original system 100%)	Price $ Reduction	Weight Improvement % (original system 100%)	Weight Improvement (kg)
Inductors and capacitors	70% - 75%	$10.5 to $12.7	~80%	~0.3 kg
Housings, covers and busbars	80% - 90%	$1 to $2	80% - 85%	~0.25 kg
Using SiC	225%	($-5.10) *	N/A	N/A
Using GaN	0%	$0.00	N/A	N/A
Total		$6.4 to $14.7		~0.55 kg

* increase

8.10.5 Audi A3 e-Tron Inverter Module Cost Analysis

The Audi A3 e-Tron Inverter module is based on Si IGBTs. It was observed that the internal space was well optimized with a DC/DC buck converter in the lower housing and the Invertor section residing in the upper housing.

The Inverter Module is a Bosch design released in 2013 that has a DC/DC converter design that utilizing individual dies and Wirebond interconnections. Using Ribbon wire to connect the dies could provide an estimated cost reduction of $1.89.

Due to the lower switching frequencies of Si, the size and volume of inductors and capacitors could be reduced if Silicon Carbide (SiC) switching is used. Using WBG devices over Si with a doubling of the switching frequency and including the other identified component savings, yields weight and cost reduction in the DC/DC converter.

Components of the DC/DC converter were reduced as follows:

Table 8-6 Audi A3 e-Tron DC/DC Converter Cost & Weight Potential Analysis

	Price Change % (original system 100%)	Price $ Reduction	Weight Improvement % (original system 100%)	Weight Improvement (kg)
Inductors and capacitors	70% - 75%	$13 to $15	~60%	~0.3 kg
Housings, covers and busbars	90% - 95%	$1 to $2	90%	~0.25 kg
Using SiC	225%	($-43)	N/A	N/A
Using GaN	0%	$0.00	N/A	N/A
Total		$14 to $17		~0.55 kg

* increase

In the Motor Inverter offered additional weight and cost reduction opportunities by using WBG technology over Si.

Components of the Motor Invertor were reduced as follows:

Table 8-7 Audi A3 e-Tron Inverter Cost & Weight Potential Analysis

	Price Change % (original system 100%)	Price $ Reduction	Weight Improvement % (original system 100%)	Weight Improvement (kg)
Inductors and capacitors	70% - 75%	$13 to $14	~60%	~0.5 kg
Housings, covers and busbars	85% - 90%	$7 to $10	85% - 90%	~0.4 kg
Using SiC	225%	($-43)	N/A	N/A
Using GaN	0%	$0.00	N/A	N/A
Total		$20 to $24		~0.9 kg

* increase

Note, similar to the Prius Inverter, there are potential savings and efficiency gains in the other systems such as cooling system and the electric motor that would make this an attractive and viable option.

8.10.6 VW e-Golf Heat Pump System Cost Analysis

The VW e-Golf's newly developed Heat Pump system is a state-of-the-art evolution of the traditional automotive A/C system. In addition to cooling the cabin, it will also heat the cabin with fine control for all HVAC requirements. The heat pump recovers heat from the ambient air and the heat given off by the drive system components, reducing the need for use of the IC engine to heat the passenger cabin. In looking for possible cost and complexity reductions, the focus is on opportunities in the valves, plumbing, and bracket components.

In looking at the actual implementation, it was observed that the designers utilized sophisticated valves with position feedback. All six of the valves use the same circuit board, motor, and gear train and provide feedback of the actual position of the valve. Three of the valves have a fine, variable opening capability and are being used to meter refrigerant flow while the remaining valves are primarily two positions, on or off devices. The idea is to replace the current position feedback sensor by utilizing the existing STMicroelectronics L9942 motor driver's "Stall" condition monitor when a positional stop is encountered. Knowing the starting position, that controller can effectively calculate the actual position. A recalibration cycle can be established during development. As such, the Hall sensor, support capacitors, and a magnet could be deleted from the build.

In addition, it was noted that five of the six valves are mounted on a common bracket near the firewall of the vehicle. These valves could be combined into a common valve manifold, which would allow for the removal of two "Y" connections from the refrigerant lines and provide for a reduction of tubing, fittings fasteners, and machining.

Utilizing a valve manifold would also allow for a substantial reduction in of the number of brackets as the manifold could be utilized to provide part of the structure, while, simplifying the plumbing and fastening requirements. See Table 8-8 below.

Table 8-8 VW e-Golf Heat Pump System Cost & Weight Potential Analysis

	Price Change % (original system 100%)	Price $ Reduction	Weight Improvement % (original system 100%)	Weight Improvement (kg)
Controls Hall Effect Sensor	98% to 99%	$4 to $5	~ 99%	~0.1 kg
Controls Valve Housing/Manifold	95% to 96%	$8 to $10	~ 97%	~0.3 kg
Vehicle Integration Features Brackets and Refrigerant Lines	40% to 50%	$9 to $10	~ 40%	~1.5 kg
Total		$21 to $25		~1.9 kg

GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

Abbreviation	Description
A/C	Air Conditioning
AC	Alternating Current
ANL	Argonne National Laboratory
BEV	Battery Electric Vehicle
DC	Direct Current
EPA	Environmental Protection Agency
FWD	Front Wheel Drive
HEV	Hybrid Electric Vehicle
HSD	Hybrid Synergy Drive
HV	High Voltage
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
IGBT	Insulated Gate Bipolar Transistor
IMA	Integrated Motor Assist
IMMD	Integrated Modular Motor Drive
NdFeB Magnets	Neodymium Iron Boron Magnets
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPG	Miles Per Gallon
OBC	On-board Charger
OEM	Original Equipment Manufacturer
PCBA	Printed Circuit Board Assembly

PCM	Powertrain Control Module
PCU	Power Control Unit
PHEV	Plug-In Hybrid Electric Vehicle
PM	Permanent magnet
PMASRM	Permanent Magnet Assisted Synchronous Reluctance Machine
REX	Range Extended
ROM	Rough Order of Magnitude
SG&A	Sales, General and Administrative
SJ MOSFET	Super Junction Metal Oxide Semiconductor Field Effect Transistor
TAC	Total Accounted Should Cost
TCU	Transmission Control Unit
TNGA	Toyota New Global Architecture
TPIM	Transmission Power Inverter Module

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[48] Hard ferrite (Ceramic) magnets http://strong-mag.com/Ferrite mag.htm

APPENDIX A

Table A-1 List of HEV models sold in the U.S. in 2015

Vehicle Model	Units sold (Year 2015)	Market Share
Toyota Prius	180,603	47%
Toyota Camry	30,640	8%
Ford Fusion & Mercury Milan	24,681	6%
Hyundai Sonata	19,908	5%
Lexus CT 200h	14,657	4%
Ford C-Max Hybrid	14,177	4%
Toyota Avalon	11,956	3%
Kia Optima	11,492	3%
Lexus LS ES Hybrid	11,241	3%
Honda Accord	11,065	3%
Lincoln MKZ	8,403	2%
Lexus RX 450h	7,722	2%
Subaru XV	5,589	1%
Honda Civic	4,887	1%
Buick Lacrosse	4,042	1%
Toyota Highlander	4,015	1%
Infiniti Q50	4,012	1%
Honda CR-z	3,073	1%
Lexus NX Hybrid	2,573	1%
Infiniti QX60	2,356	1%
Nissan Pathfinder Hybrid	2,245	1%
Toyota RAV4	1,494	<1%
Honda Insight	1,458	<1%
VW Jetta	740	<1%
Chevrolet Impala Hybrid	272	<1%
Acura RLX	250	<1%
Buick Regal	186	<1%
Infinity Q70 (formerly M Hybrid)	176	<1%
Audi Q5 Hybrid	97	<1%
Lexus GS 450h	91	<1%
BMW X6 & Active hybrid 3&5&7	63	<1%
Chevrolet Malibu	59	<1%
Mercedes E400h	53	<1%
Lexus LS 600h	47	<1%
Tahoe, Yukon, Escalade	25	<1%
Acura ILX	22	<1%
VW Touareg	16	<1%
Mercedes ML450	10	<1%
Chevrolet Silverado & GMC Sierra	3	<1%
Total	384,400	

Table A-2 List of HEV models sold in the U.S. YTD2016 (Jan-July)

Vehicle Model	Units sold (Jan-July 2016)	Market Share
Toyota Prius	80,053	41%
Toyota RAV4	23,943	12%
Ford Fusion & Mercury Milan	15,006	8%
Toyota Camry	12,494	6%
Hyundai Sonata	11,280	6%
Ford C-Max Hybrid	8,155	4%
Lexus RX 450h	5,414	3%
Lexus CT 200h	5,364	3%
Lexus LS ES Hybrid	4,935	3%
Toyota Avalon	4,650	2%
Lincoln MKZ	4,549	2%
Kia Optima	3,595	2%
Toyota Highlander	3,230	2%
Subaru XV	1,881	1%
Lexus NX Hybrid	1,594	1%
Honda CR-z	1,477	1%
Infiniti Q50	1,160	1%
Chevrolet Malibu	1,036	1%
Honda Accord	830	<1%
Honda Civic	767	<1%
Infiniti QX60	764	<1%
Buick Lacrosse	560	<1%
Nissan Pathfinder Hybrid	452	<1%
VW Jetta	356	<1%
Acura RLX	79	<1%
Infinity Q70 (formerly M Hybrid)	73	<1%
Lexus GS 450h	56	<1%
Honda Insight	53	<1%
Buick Regal	44	<1%
Chevrolet Impala Hybrid	35	<1%
Acura NSX	23	<1%
Lexus LS 600h	19	<1%
BMW X6 & Active hybrid 3&5&7	16	<1%
Audi Q5 Hybrid	15	<1%
Mercedes E400h	9	<1%
Acura ILX	1	<1%
VW Touareg	1	<1%
Total	193,969	-

Table A-3 List of PHEV models sold in the U.S. in 2015

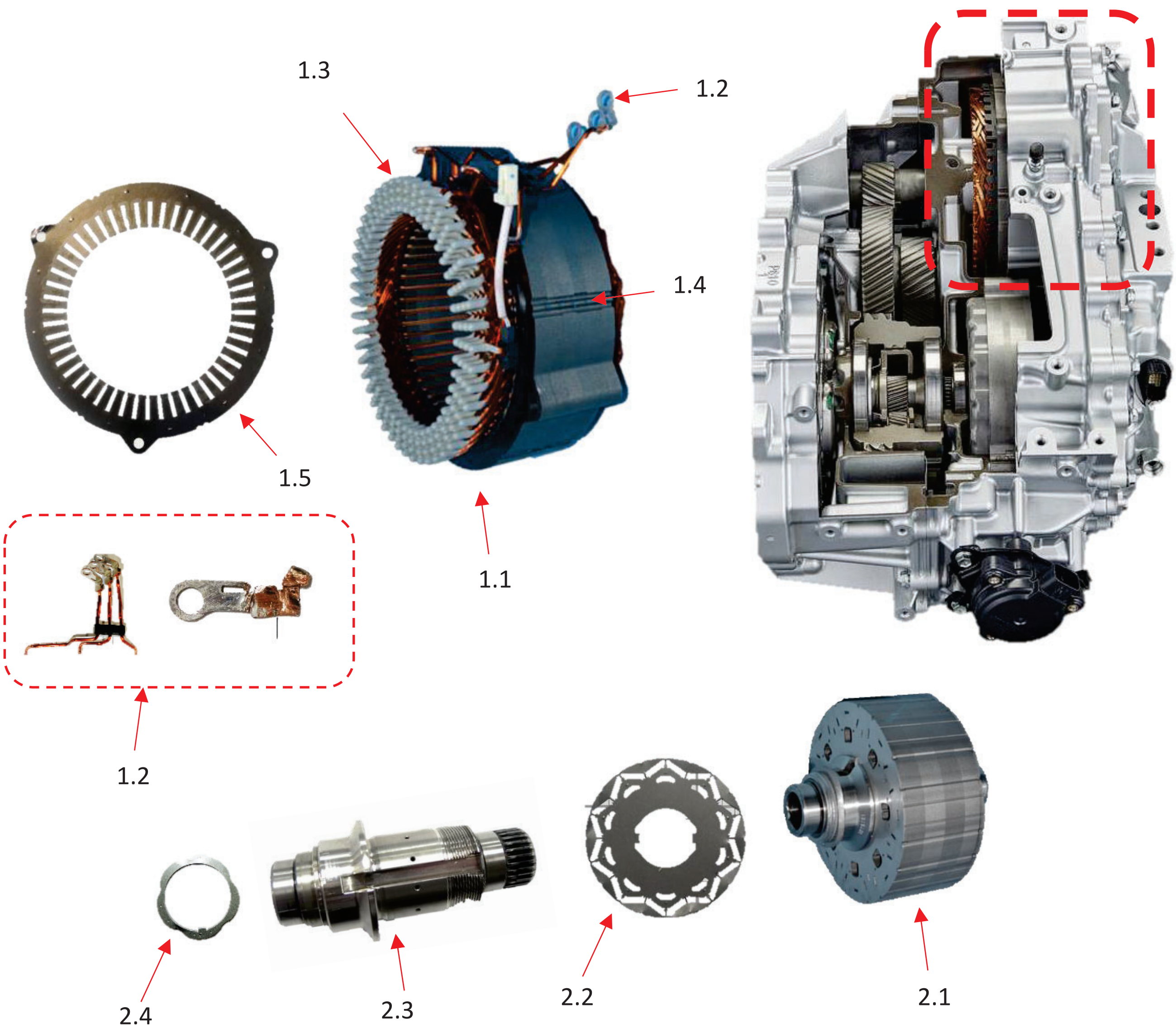
Vehicle Models	Units sold (2015)	Market Share
Chevrolet Volt	15,393	36%
Ford Fusion Energi	9,750	23%
Ford C-Max Energi	7,591	18%
Toyota Prius PHEV	4,191	10%
BMW i8	2,265	5%
Porsche Cayenne S E-hybrid	1,163	3%
Cadillac ELR	1,024	2%
BMW X5 PHEV	892	2%
Porsche Panamera S E-Hybrid	407	1%
Mercedes S550 Plug	118	<1%
Volvo-XC90 Plug In	86	<1%
Honda Accord	64	<1%
Hyundai Sonata Plug In	15	<1%
Total	42,959	

Table A-4 List of PHEV models sold in the U.S. YTD 2016 (Jan-July)

Vehicle Models	Units sold (Jan-July 2016)	Market Share
Chevrolet Volt	12,214	33%
Ford Fusion Energi	8,576	24%
Ford C-Max Energi	3,980	11%
BMW X5 PHEV	3,226	9%
Audi A3 Plug In	2,291	6%
Hyundai Sonata Plug In	1,700	5%
Porsche Cayenne S E-hybrid	1,314	4%
Volvo-XC90 Plug In	1,184	3%
BMW i8	786	2%
Cadillac ELR	511	1%
BMW 3-series Plug-In	228	1%
Mercedes S550 Plug	182	<1%
Porsche Panamera S E-Hybrid	177	<1%
Mercedes GLE 550e	49	<1%
Toyota Prius PHEV	46	<1%
Total	36,464	

APPENDIX B: Toyota Prius Traction Motor B

Figure B-1 Toyota Prius Motor B / Gearbox



Cost Estimate BOM			
1.1	Stator	2.1	Rotor
1.2	Spade Terminal	2.2	Rotor Laminate
1.3	Hairpin Segment	2.3	Rotor Hub
1.4	Stack Laser Weld Seam	2.4	Sensor Target Wheel
1.5	Stator Laminate		

Toyota Prius Stator

The Toyota Prius Stator group, pictured in Figure 3-6, consists of the laminate stack, copper windings, insulators, top and bottom plastic covers, temperature sensor and electrical interface connections. The laminations stack contains 240 electromagnetic steel stampings. The copper windings consist of 197 wire segments referred to as hairpin windings. Insulation of the coils is provided by a fabric layer inside the laminations. The electrical interfaces include three-phase terminals, three end connector wires and a spacer.

Figure B-2 Toyota Prius Stator Group

The total "should cost" to manufacture the Toyota Prius stator group is estimated and additional typical markups associated with component manufacturing added.

Table B-1 Toyota Prius Stator Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Toyota Prius - Stator Assembly

	Toyota Prius - Stator Assembly
Parts	495
Steps	2,635
Actual Time	1,723.23 sec
Fasteners	0
Total Weight	11.48 kg
Piece Cost	$79.31
Total Labor Cost	$39.30
Q Burden	$3.50
Total Cost	$122.11
Annual Production	200000

The summary shown includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (including primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total "should cost" before markups.

Table B-2 Toyota Prius Stator Group Estimate Summary

Component Summary		
Part/Assembly Name	Prius Stator	
Purchased Part Roll up Costs		$8.12
Raw Material Costs		$71.19
Processing Costs		$39.30
Scrap (Design Profit: Q-Burden)	3%	$3.50
SG&A % Applied Against Processing	7%	$2.75
Profit % Applied Against Raw & Processing	4%	$4.42
Logistics % Applied Against Sum of all Above	3%	$3.88
Patent/Royalty Fees % Applied Against Sum of all Above	5%	$6.66
Total % Mark Up / Total Cost	22%	$139.82
Total Weight (kg)		11.4804
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$450,000.00
Tooling Cost/part		$0.45
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$900,000.00
Tooling Cost/part		$0.90

The table above shows the "should cost" to manufacture the stator group parts and appropriate markup percentages that are applied to establish an estimated selling price. The markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown with each item. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

The Toyota Prius stator consists of 240 stamped electromagnet steel plates. The laminations are presorted and then pressed together to form the final stack. The stator outer profile also provides a means of mounting the finished assembly into the motor case (transmission). This is accomplished by using tabs in the outer diameter for through-hole mounting. The tabs add additional weight but not cost as they are positioned in the blanking scrap area and therefore do not add length or width to the blank sheet size.

Figure B-3 Toyota Prius Stator Laminate Segment

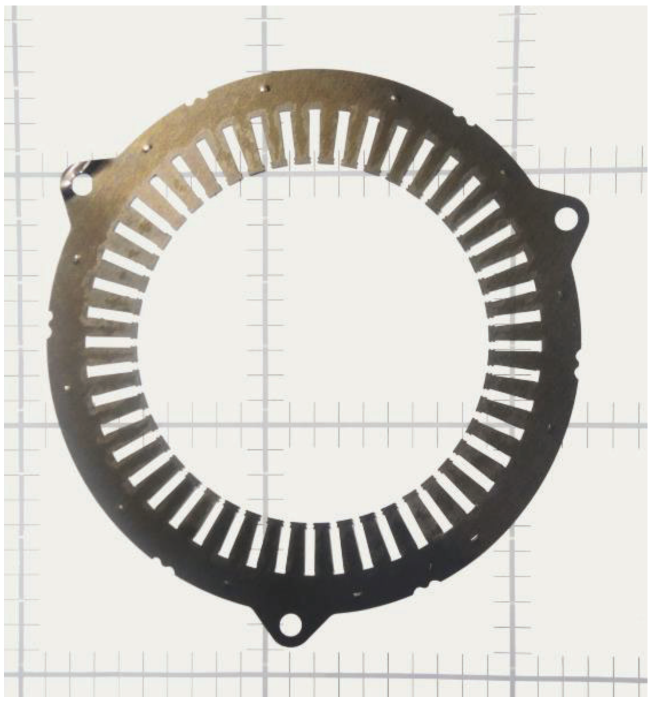


Figure B-4 Toyota Prius Stator Stack Laser-Welded Seams

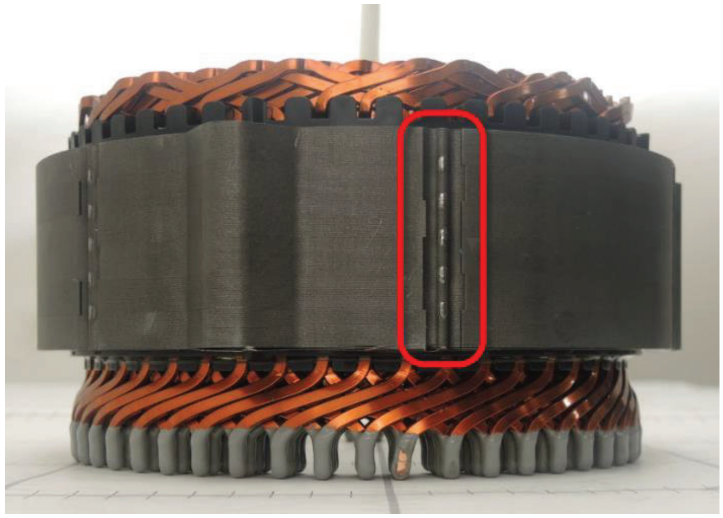
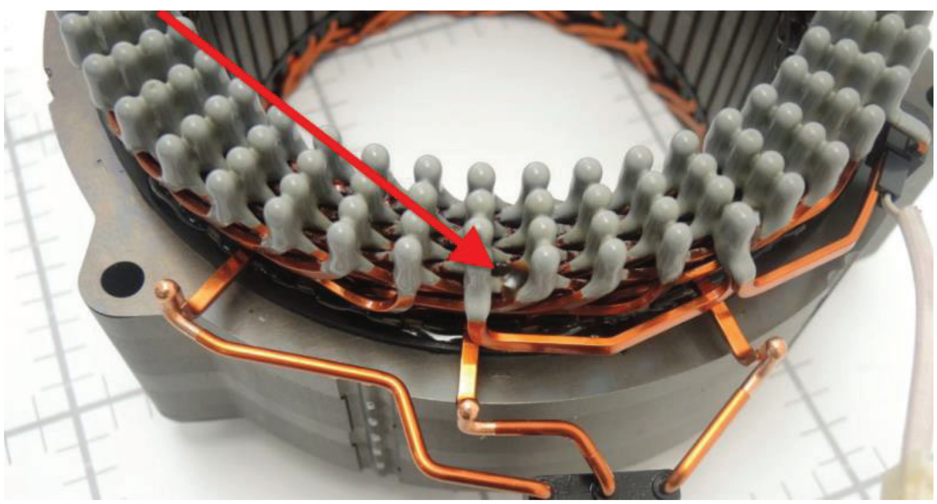
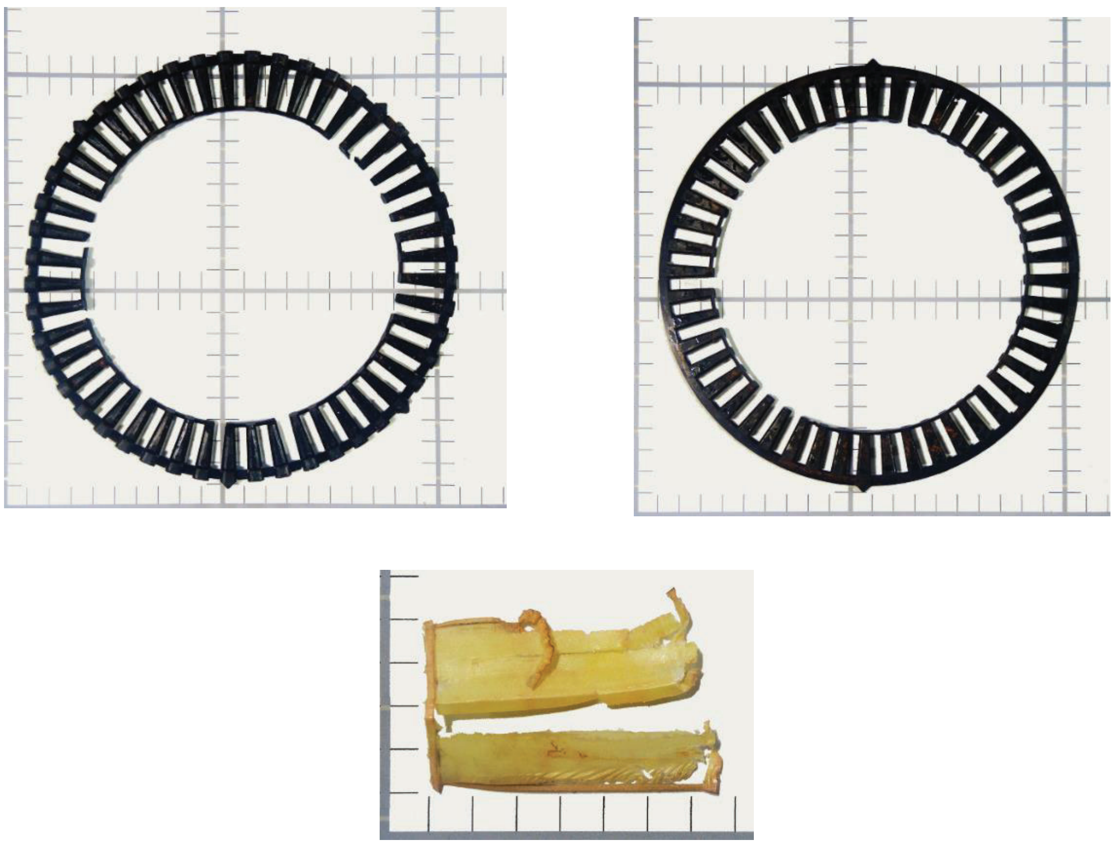


Figure B-4 Toyota Prius Stator Hairpin Windings



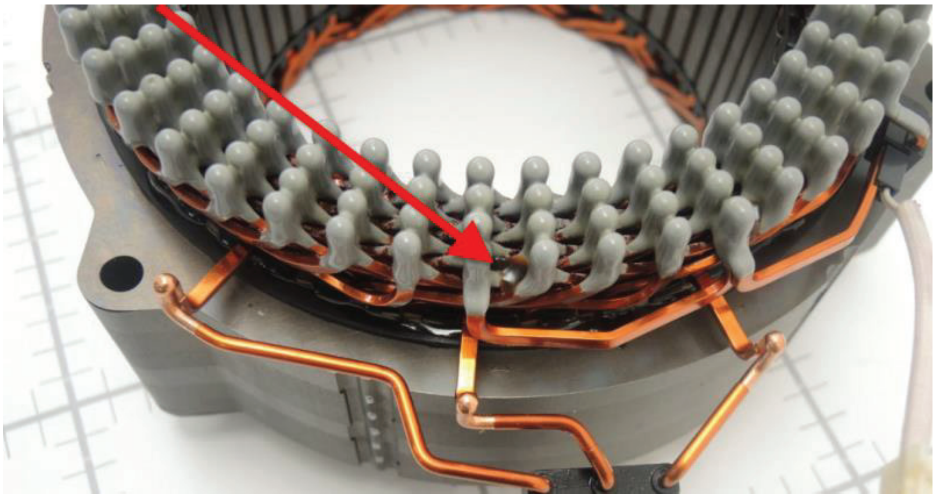
The design of the Toyota Prius stator copper coil, pictured is commonly referred to as a hairpin. In a hairpin design, the forming and installation of the wires into the rotor is assumed to be automated in a single manufacturing cell. It is also assumed that the copper wire stock is pre-coated, each wire segment stripped on each end and preformed for insertion into the stator, a single insulating layer is used by all the hairpins in the same slot as for preventing contact with the laminate stack, but not with one another. After pressing the wires into the laminate stack they are post-formed and the ends are welded together. After that, the welded heads are covered by a ceramic coat in a dipping process. These welded and dipped heads are indicated by the red arrow in Figure B-4 Toyota Prius Stator Hairpin Windings. A total of 197 wires are preformed into eight different profiles.

Figure B-5 Toyota Prius Stator Slot Insulators: slot insulator (top), plastic end cap insulators (bottom)



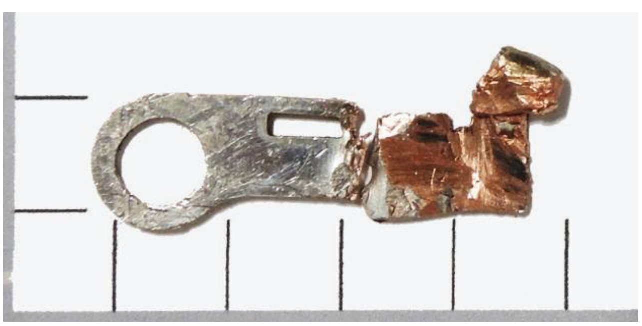
Insulation of the coils is provided by a 0.007" - Nomex Aramid Paper Sheet inside the laminate stack. Each pole slot contains one insulator. The stator coil is also assumed to be varnished trickle-coated after stator's assembly and before installation of end connectors. The three-phase wire leads from the motor and is dip-coated for additional insulation.

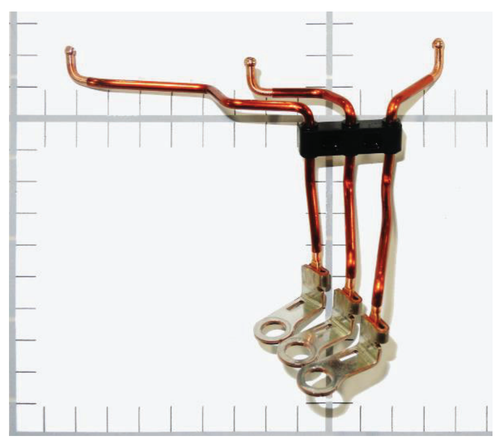
Figure B-6 Toyota Prius Stator Dip-Coated Hairpin Segments



The electrical interfaces include three end connector wires, three-phase eyelet terminals and a spacer. The spacer is over molded onto the three end connector wires. The three-phase spade terminals are stamped copper design crimped onto the end connector wire, which are then welded to the end of the copper lead coming from the stator.

Figure B-7 Toyota Prius Stator Spade Terminal (Left), Terminal Block (Right)





Toyota Prius Rotor

The Toyota Prius Rotor group consists of the main laminate stack, end plates, magnets, hub, smaller laminate stack, bearing insert, collar, nut and a spacer. The main laminate stack contains 174 electromagnetic steel stampings. The end plates close out each end of the rotor. A total of 40 magnets are installed inside slots in the laminate stack. The magnets are arranged into 10 poles with four magnets making up one pole, the two magnets are installed into a single slot (two slots per pole). During the technology selection phase, the magnets were found to be neodymium-based. A spacer and nut lock the laminate stack in place. The smaller laminate stack is kept in place by the collar. The Hub is a machined bar stock design with features for cooling the laminate stack. The rotor did contain 66 more laminations than the stator had in its stack.

Figure B- 9 Toyota Prius Rotor Assembly

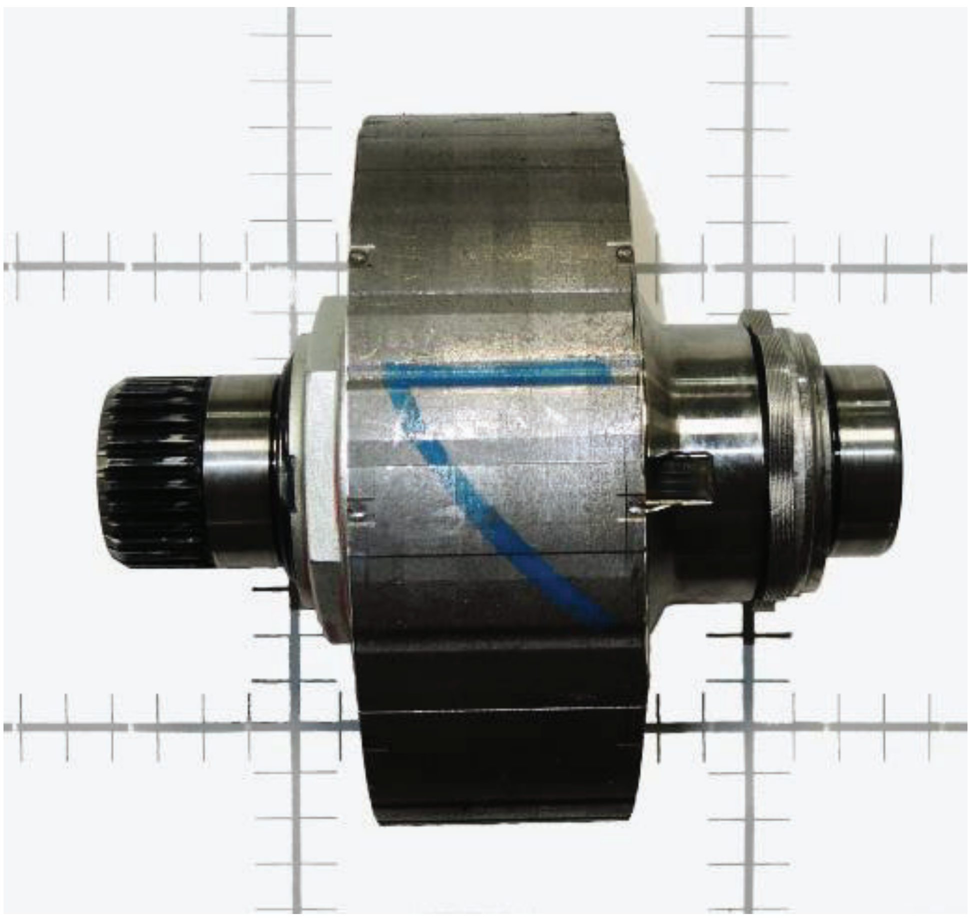


Table B- 3 Toyota Prius Rotor Group Design Profit Summary

Design Profit®

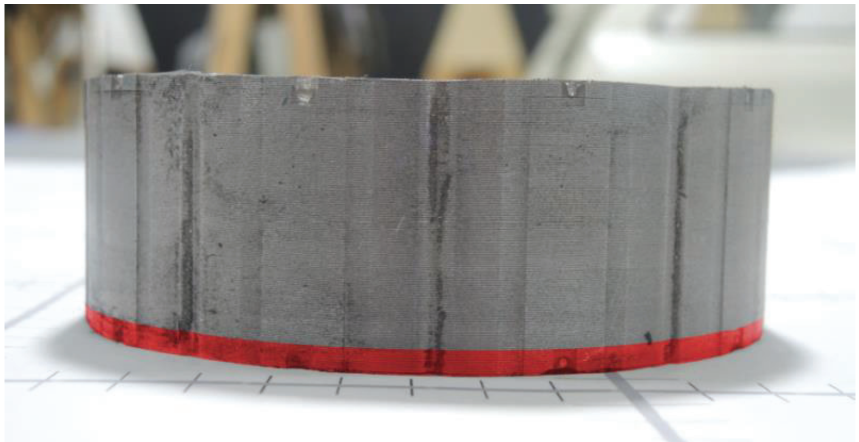
EXECUTIVE SUMMARY
Toyota Prius - Rotor Assembly

	Toyota Prius - Rotor Assembly
Parts	229
Steps	2,006
Actual Time	1,292.96 sec
Fasteners	1
Total Weight	4.31 kg
Piece Cost	$52.48
Total Labor Cost	$17.13
Q Burden	$2.74
Total Cost	$72.35
Annual Production	200000

Table B- 4 Toyota Prius Rotor Group Cost Summary

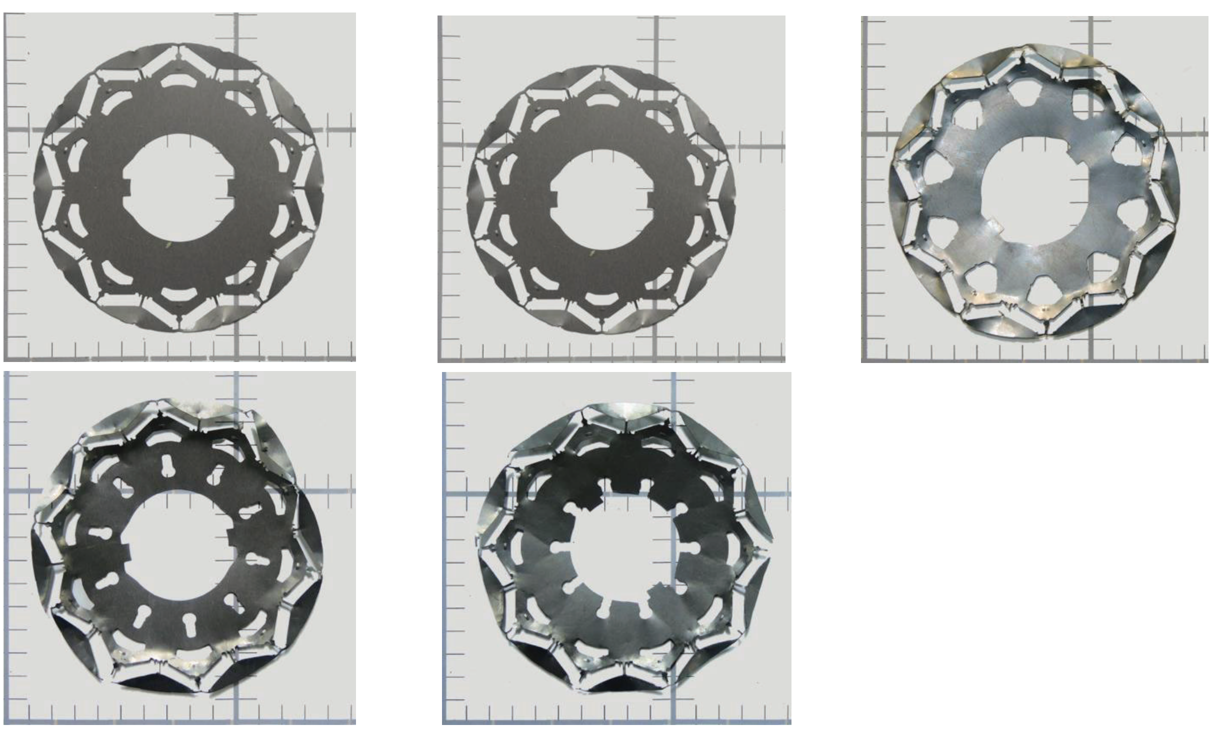
Component Summary		
Part/Assembly Name		Prius Rotor
Purchased Part Roll up Costs		$32.10
Raw Material Costs		$20.38
Processing Costs		$17.13
Scrap (Design Profit: Q-Burden)	4%	$2.74
SG&A % Applied Against Processing	7%	$1.20
Profit % Applied Against Raw & Processing	4%	$1.50
Logistics % Applied Against Sum of all Above	3%	$2.25
Patent/Royalty Fees % Applied Against Sum of all Above	5%	$3.87
Total % Mark Up / Total Cost	23%	$81.17
Total Weight (kg)		4.3071
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		510000
Tooling Cost/part		$0.51
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,020,000.00
Tooling Cost/part		$1.02

Figure B-10 Toyota Prius Rotor Laminate Stack



The Toyota Prius rotor laminate stack, pictured in Figure B-10, consists of 174 stamped electromagnetic steel plates. Which is less than the 240 laminations used in the stator. This arrangement is not typical in traction motor design as the rotor laminations are normally created from the center off-cut of the stator laminations. This approach allows Toyota to minimize the iron losses in the stator and rotor, but, unless they have another machine to make use of, the stator off-cut will result in higher material scrape cost. The laminations are presorted, then pressed together to form a finished laminate stack. The stator inner profile also provides a means for alignment when being pressed onto the hub. There are also five different laminate profiles which are used for internal cooling of the rotor via oil. This is unusual as this solution requires more complex tooling to produce the different passageways.

Figure B- 11 Toyota Prius Rotor Laminate Segments



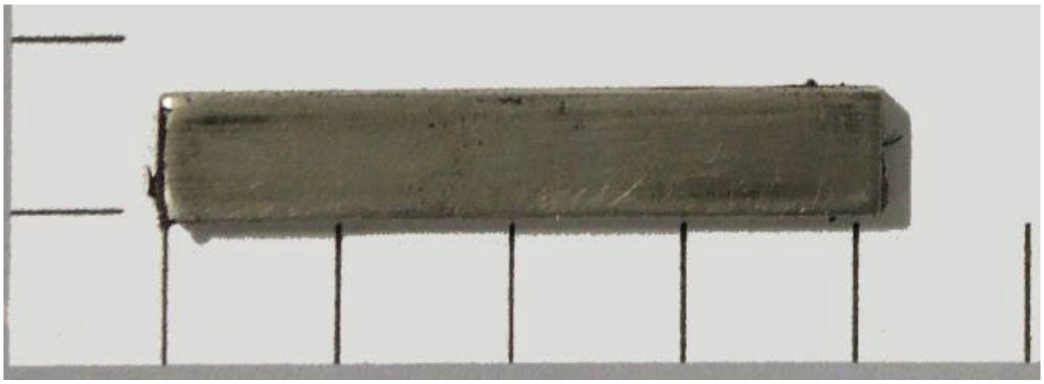
The rotor includes two cover plates, shown below, one on top and one on the bottom. The cover plates are set over the magnets. An orientation feature is included on the plates to facilitate installation.

Figure B- 12 Toyota Prius Rotor Top (left) and Bottom (right) Cover Plates

The rotors contain 10 poles with two identical magnets set into slot pairs for each pole section. The magnets reach end to end of the laminate stack. During the technology selection phase, the magnets were found to be neodymium-based (sintered Neo 42).

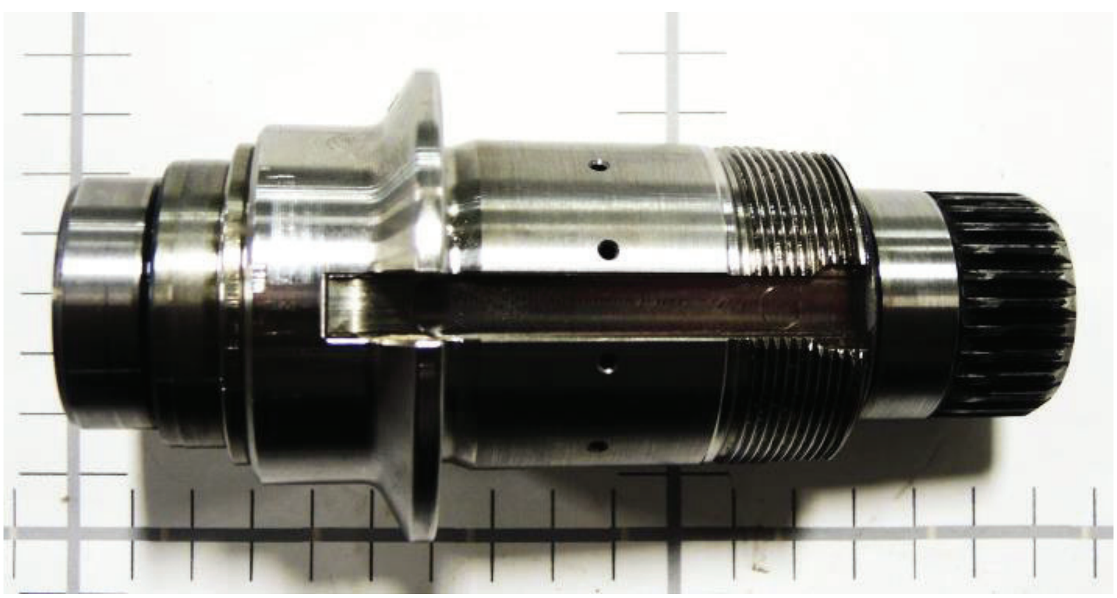
Figure B-13 Toyota Prius Rotor 10-Pole Magnet Configuration

Figure B- 14 Toyota Prius Rotor Magnet



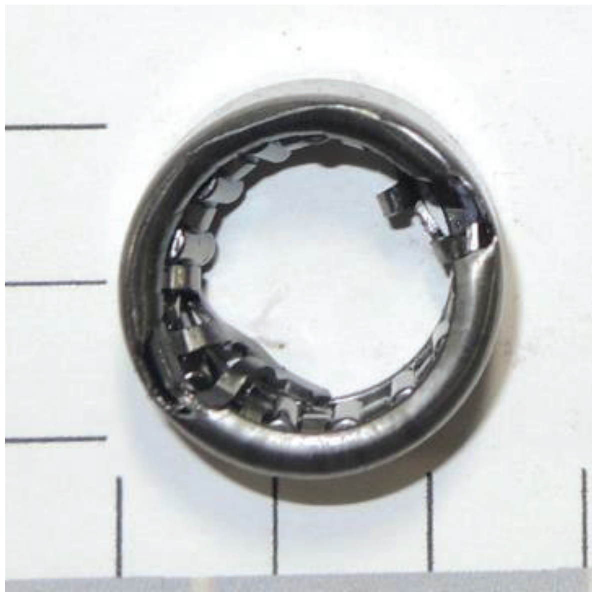
The Prius rotor hub, in Figure B-15 is manufactured from bar stock which is machined, deburred, induction hardened and then washed. The hub contains features for laminate stack press mounting, including key way alignment slots. Machined holes near the middle of the hub (cross drilled) align to cavities formed in the laminate stack for cooling.

Figure B- 15 Toyota Prius Rotor Hub



The Prius rotor hub also contains a bearing inside the ID of the shaft, as shown below. It is assumed this aligns to a component in the transmission. The bearing is considered a commodity item and is pressed into the end of the shaft.

Figure B- 16 Toyota Prius Rotor Hub Bearing



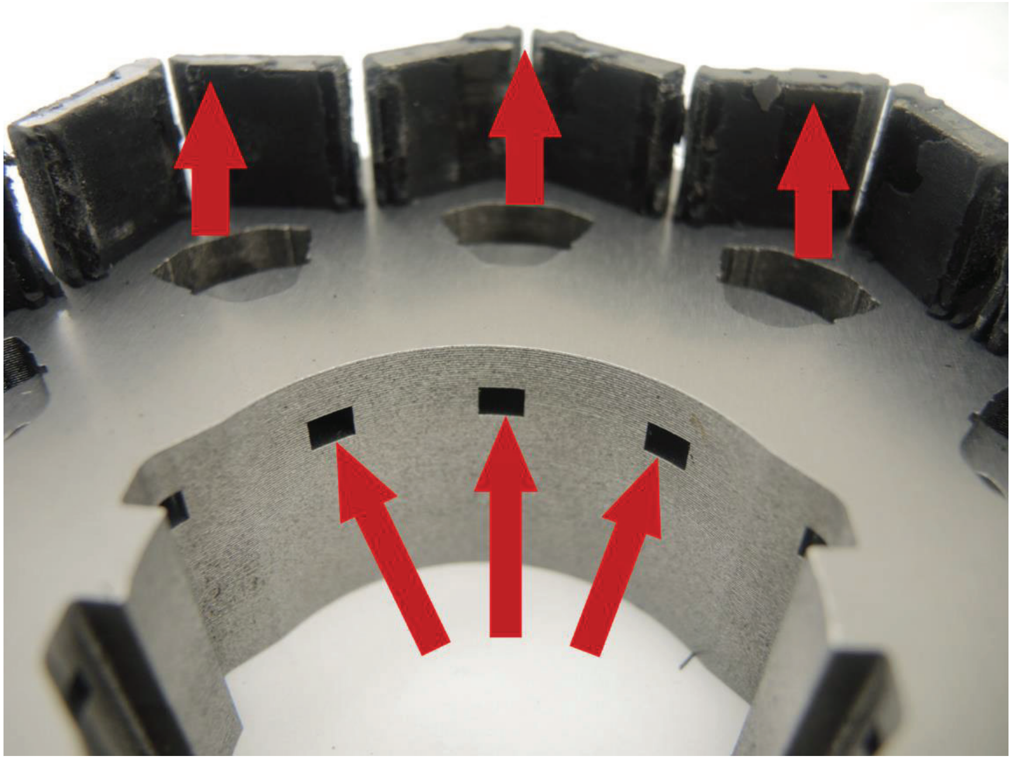
The Prius rotor hub contains a speed sensor target wheel on one end of the shaft. The target wheel consists of eight stamped laminations captured on the shaft by a press fit collar.

Figure B- 17 Toyota Prius Sensor Target Wheel

In Figure B-17, a close-up of the press fit collar is on the left. The image to the right shows a different view of the same collar on the shaft of the sensor target wheel.

The Prius rotor is internally cooled by oil. This is accomplished by cross-drilled holes in the hub aligned with pockets in the laminate stack. Different sets of laminations provide a mostly even distribution of oil in between the top and bottom sections.

Figure B-18 Toyota Prius Rotor Cooling



The arrows above demonstrate the distribution of oil within the rotor for internal cooling.

Table B-5 Toyota Prius Stator Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Subassembly	703-1510_11	Stator Assembly	(None)
2	3	Subassembly	703-1510_9	Laminated Steel Stator Core	(None)
3	4	Preprocessed Part	703-1510_14	Laminated Steel - Section 1	Electro Magnetic Steel
4	5	Manufacturing Steps		Laminated Steel Process	
5	6	Manufacturing Process		Wash	
6	6	Manufacturing Process		Deburr	
7	6	Manufacturing Process		Stamping Press, 200 Ton	
8	7	Part	Material, 703-1510_14	Material, Laminated Steel - Section 1	Electro Magnetic Steel
9	4	Preprocessed Part	703-1510_15	Laminated Steel - Section 2	Electro Magnetic Steel
10	5	Manufacturing Steps		Laminated Steel Process	
11	6	Manufacturing Process		Wash	
12	6	Manufacturing Process		Deburr	
13	6	Manufacturing Process		Stamping Press, 200 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
14	7	Part	Material, 703-1510_15	Material, Laminated Steel - Section 2	Electro Magnetic Steel
15	4	Preprocessed Part	703-1510_16	Laminated Steel - Section 3	Electro Magnetic Steel
16	5	Manufacturing Steps		Laminated Steel Process	
17	6	Manufacturing Process		Wash	
18	6	Manufacturing Process		Deburr	
19	6	Manufacturing Process		Stamping Press, 200 Ton	
20	7	Part	Material, 703-1510_16	Material, Laminated Steel - Section 3	Electro Magnetic Steel
21	4	Part	703-1510_21	Paper Tube	Commodity Item
22	4	Manufacturing Steps		Laminated Steel Stator Core Assembly Process	
23	5	Manufacturing Process		Auto Assembly	
24	5	Manufacturing Process		Laminate Stacking Station	
25	3	Preprocessed Part	703-1510_12	Top Plastic Cover	PBT CF30
26	4	Manufacturing Steps		Top Plastic Cover Processing	
27	5	Manufacturing Process		Injection Mold Press, 145 Ton	
28	6	Part	Material, 703-1510_12	Material, Top Plastic Cover	PBT CF30
29	3	Preprocessed Part	703-1510_13	Bottom Plastic Cover	PBT CF30
30	4	Manufacturing Steps		Top Plastic Cover Processing	
31	5	Manufacturing Process		Injection Mold Press, 145 Ton	
32	6	Part	Material, 703-1510_13	Material, Bottom Plastic Cover	PBT CF30
33	3	Preprocessed Part	703-1510_20	Hairpin Wire Asm.	Copper Cu (10200)
34	4	Manufacturing Steps		Wound Wire Process	
35	5	Manufacturing Process		Curing Oven	
36	5	Manufacturing Process		Dip Painting	
37	6	Part	703-1510_20-1 Coating	Coating, Hairpin Wire Asm.	Commodity Item
38	5	Manufacturing Process		Auto Assembly	
39	5	Manufacturing Process		Hairpin Installation	
40	6	Part	703-1510_10	Unique Wire Hairpin	Copper Cu (10200)
41	6	Part	703-1510_8	Single End Connector, Wire	Copper Cu (10200)
42	6	Part	703-1510_4	3 End Connectors, Hairpin Wire 1	Copper Cu (10200)
43	6	Part	703-1510_23	3 End Connectors, Hairpin Wire 2	Copper Cu (10200)
44	6	Part	703-1510_24	3 End Connectors, Hairpin Wire 3	Copper Cu (10200)
45	6	Part	Material, 703-1510_17	Material, Unique Outer Connector Bar Wound Wire	Copper Cu (10200)

Row	Level	Symbol Type	Number	Name	Material Name
46	6	Part	Material, 703-1510_18	Material, Unique Outer Short Connector Bar Wound W	Copper Cu (10200)
47	6	Part	Material, 703-1510_19	Material, Bar Wound Wire	Copper Cu (10200)
48	5	Manufacturing Process		Auto Assembly	
49	3	Part	703-1510_22	Insulating Varnish	Commodity Item
50	3	Manufacturing Steps		Stator Assembly	
51	4	Manufacturing Process		Varnish Trickle Process	
52	4	Manufacturing Process		Laser Etch	
53	4	Manufacturing Process		Laser Weld	
54	2	Subassembly	703-1510	3 End Connectors Asm.	(None)
55	3	Preprocessed Part	703-1510_3	End Connector	Copper Cu (10200)
56	4	Manufacturing Steps		End Connector Process	
57	5	Manufacturing Process		Wash	
58	5	Manufacturing Process		deburr	
59	5	Manufacturing Process		Stamping Press, 25 Ton	
60	6	Part	Material, 703-1510_3	Material, End Connector	Copper Cu (10200)
61	3	Manufacturing Steps		3 End Connectors Assembly	
62	4	Manufacturing Process		Auto Assembly	
63	4	Manufacturing Process		Injection Mold Press, Inserts, 18 Ton	
64	5	Part	Material, 703-1510_5	Material, 3 End Connectors, Spacer	PBT CF30
65	2	Subassembly	703-1510_2	Single End Connector Asm.	(None)
66	3	Part	703-1510_6	Single End Connector, Temperature Sensor	Commodity Item
67	3	Manufacturing Steps		Single End Connector Assembly	
68	4	Manufacturing Process		Injection Mold Press, Inserts, 10 Ton	
69	5	Part	Material, 703-1510_7	Material, Single End Connector, Housing	PBT CF30
70	2	Manufacturing Steps		Final Stator Assembly	
71	3	Manufacturing Process		TIG Weld Robotic	

Table B-6 Toyota Prius Stator Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Toyota Prius - Stator Assembly

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
703-1510_11	**Stator Assembly**	**$77.19**	**1**	**$77.19**
703-1510_9	**Laminated Steel Stator Core**	**$39.96**	**1**	**$39.96**
703-1510_14	**Laminated Steel - Section 1**	**$12.00**	**1**	**$12.00**
Material, 703-1510_14	Material, Laminated Steel - Section 1	$0.15	80	$12.00
703-1510_15	**Laminated Steel - Section 2**	**$12.00**	**1**	**$12.00**
Material, 703-1510_15	Material, Laminated Steel - Section 2	$0.15	80	$12.00
703-1510_16	**Laminated Steel - Section 3**	**$12.00**	**1**	**$12.00**
Material, 703-1510_16	Material, Laminated Steel - Section 3	$0.15	80	$12.00
703-1510_21	Paper Tube	$0.08	48	$3.96
703-1510_12	**Top Plastic Cover**	**$0.29**	**1**	**$0.29**
Material, 703-1510_12	Material, Top Plastic Cover	$0.29	1	$0.29
703-1510_13	**Bottom Plastic Cover**	**$0.23**	**1**	**$0.23**
Material, 703-1510_13	Material, Bottom Plastic Cover	$0.23	1	$0.23
703-1510_20	**Hairpin Wire Asm.**	**$34.63**	**1**	**$34.63**
703-1510_20-1 Coating	Coating, Hairpin Wire Asm.	$0.08	1	$0.08
703-1510_10	Unique Wire Hairpin	$0.04	1	$0.04
703-1510_8	Single End Connector, Wire	$0.06	1	$0.06
703-1510_4	3 End Connectors, Hairpin Wire 1	$0.08	1	$0.08
703-1510_23	3 End Connectors, Hairpin Wire 2	$0.06	1	$0.06
703-1510_24	3 End Connectors, Hairpin Wire 3	$0.06	1	$0.06
Material, 703-1510_17	Material, Unique Outer Connector Bar Wound Wire	$0.21	3	$0.62
Material, 703-1510_18	Material, Unique Outer Short Connector Bar Wound W	$0.18	3	$0.53
Material, 703-1510_19	Material, Bar Wound Wire	$0.18	186	$33.11
703-1510_22	Insulating Varnish	$2.08	1	$2.08
703-1510	**3 End Connectors Asm.**	**$0.11**	**1**	**$0.11**
703-1510_3	**End Connector**	**$0.10**	**1**	**$0.10**
Material, 703-1510_3	Material, End Connector	$0.03	3	$0.10
Material, 703-1510_5	Material, 3 End Connectors, Spacer	$0.01	1	$0.01
703-1510_2	**Single End Connector Asm.**	**$2.00**	**1**	**$2.00**
703-1510_6	Single End Connector, Temperature Sensor	$2.00	1	$2.00
Material, 703-1510_7	Material, Single End Connector, Housing	$0.00	1	$0.00

Assembly Totals

Analyzed Subs:	11
Unanalyzed Subs:	0
Parts:	495
Fasteners:	0
Parts+Unanalyzed:	495

Report Totals

Piece Cost (Total): $79.31

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

Table B-7 Toyota Prius Rotor Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Preprocessed Part	703-1460_5	Rotor Hub Shaft	Steel 1040 Cold Drawn or Cold Rolled
2	3	Manufacturing Steps		Rotor Hub Shaft Process	
3	4	Manufacturing Process		Wash	
4	4	Manufacturing Process		Deburr	
5	4	Manufacturing Process		Grinding Centerless	
6	4	Manufacturing Process		Spline Rolling	
7	4	Manufacturing Process		Induction Harden	
8	4	Manufacturing Process		CNC Machining	
9	4	Manufacturing Process		Cut Blank	
10	5	Part	703-1460_5 Material	Material, Rotor Hub Shaft	Steel 1040 Cold Drawn or Cold Rolled
11	2	Subassembly	703-1460_7	Laminated Steel Sensor Target Wheel Subasm	(None)
12	3	Preprocessed Part	703-1460_8	Laminated Steel	Electro Magnetic Steel
13	4	Manufacturing Steps		Laminate Process	
14	5	Manufacturing Process		Wash	
15	5	Manufacturing Process		Deburr	
16	5	Manufacturing Process		Stamping Press, 60 Ton	
17	6	Part	Material, 703-1460_8	Material, Laminated Steel Sensor Target Wheel	Electro Magnetic Steel
18	3	Manufacturing Steps		Laminate Assembly Process	
19	4	Manufacturing Process		Auto Assembly	
20	2	Preprocessed Part	703-1460_6	Rotor Hub Shaft Collar	Steel 1020 Hot Rolled
21	3	Manufacturing Steps		Rotor Hub Shaft Collar Process	
22	4	Manufacturing Process		Wash	
23	4	Manufacturing Process		Deburr	
24	4	Manufacturing Process		CNC Machine	
25	4	Manufacturing Process		Cut Blank	
26	5	Part	Material, 703-1460_6	Material, Rotor Hub Shaft Collar	Steel 1020 Hot Rolled
27	2	Part	703-1460_9	Bearing Insert	Commodity Item
28	2	Subassembly	703-1460_2	Laminated Steel Rotor Core Section	(None)
29	3	Preprocessed Part	703-1460_13	Welding Gap Laminated Steel	Electro Magnetic Steel
30	4	Manufacturing Steps		Welding Gap Laminated Steel Process	
31	5	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
32	5	Manufacturing Process		Deburr	
33	5	Manufacturing Process		Stamping Press, 25 Ton	
34	6	Part	Material, 703-1460_13	Material, Welding Gap Laminated Steel	Electro Magnetic Steel
35	3	Preprocessed Part	703-1460_12	Laminated Steel	Electro Magnetic Steel
36	4	Manufacturing Steps		Laminated Steel Process	
37	5	Manufacturing Process		Wash	
38	5	Manufacturing Process		Deburr	
39	5	Manufacturing Process		Stamping Press, 25 Ton	
40	6	Part	Material, 703-1460_12	Material, Laminated Steel	Electro Magnetic Steel
41	3	Preprocessed Part	703-1460_14	Internal Oil Distribution Laminated Steel-Outer	Electro Magnetic Steel
42	4	Manufacturing Steps		Internal Oil Distribution - Outer Laminate Process	
43	5	Manufacturing Process		Wash	
44	5	Manufacturing Process		Deburr	
45	5	Manufacturing Process		Stamping Press, 25 Ton	
46	6	Part	Material, 703-1460_14	Material, Internal Oil Distribution Laminated Steel	Electro Magnetic Steel
47	3	Preprocessed Part	703-1460_15	Internal Oil Distribution Laminated Steel-Middle	Electro Magnetic Steel
48	4	Manufacturing Steps		Internal Oil Distribution - Middle Laminate Process	
49	5	Manufacturing Process		Wash	
50	5	Manufacturing Process		Deburr	
51	5	Manufacturing Process		Stamping Press, 25 Ton	
52	6	Part	Material, 703-1460_15	Material, Internal Oil Distribution Laminated Steel	Electro Magnetic Steel
53	3	Preprocessed Part	703-1460_16	Internal Oil Distribution Laminated Steel-Oil	Electro Magnetic Steel
54	4	Manufacturing Steps		Internal Oil Distribution Laminate Process	
55	5	Manufacturing Process		Wash	
56	5	Manufacturing Process		Deburr	
57	5	Manufacturing Process		Stamping Press, 25 Ton	
58	6	Part	Material, 703-1460_16	Material, Internal Oil Distribution Laminated Steel	Electro Magnetic Steel
59	3	Part	703-1460_17	Magnet	Commodity Item
60	3	Manufacturing Steps		Laminated Steel Rotor Assembly Process	
61	4	Manufacturing Process		Auto Assembly	

Row	Level	Symbol Type	Number	Name	Material Name
62	4	Manufacturing Process		Weld Robotic	
63	4	Manufacturing Process		Motor Stacking	
64	2	Preprocessed Part	703-1460_10	Top Plate, Laminated Steel	Aluminum 6061
65	3	Manufacturing Steps		Top Plate, Laminated Steel Process	
66	4	Manufacturing Process		Wash	
67	4	Manufacturing Process		Deburr	
68	4	Manufacturing Process		Stamping Press, 25 Ton	
69	5	Part	Material, 703-1460_10	Material, Top Plate, Laminated Steel	Aluminum 6061
70	2	Preprocessed Part	703-1460_11	Bottom Plate, Laminated Steel	Aluminum 6061
71	3	Manufacturing Steps		Bottom Plate, Laminated Steel Process	
72	4	Manufacturing Process		Wash	
73	4	Manufacturing Process		Deburr	
74	4	Manufacturing Process		Stamping Press, 25 Ton	
75	5	Part	Material, 703-1460_11	Material, Bottom Plate, Laminated Steel	Aluminum 6061
76	2	Preprocessed Part	703-1460_3	Rotor Hub-Nut Spacer	Steel 1020 Hot Rolled
77	3	Manufacturing Steps		Rotor Hub-Nut Spacer Process	
78	4	Manufacturing Process		Wash	
79	4	Manufacturing Process		Deburr	
80	4	Manufacturing Process		Stamping Press, 25 Ton	
81	5	Part	Material, 703-1460_3	Material, Rotor Hub-Nut Spacer	Steel 1020 Hot Rolled
82	2	Part	703-1460_4	Rotor Hub Nut	Commodity Item
83	2	Manufacturing Steps		Rotor Assembly Process	
84	3	Manufacturing Process		Auto Assembly	
84	3	Manufacturing Process		Auto Assembly	
86	3	Manufacturing Process		Auto Assembly	

Table B- 8 Toyota Prius Rotor Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

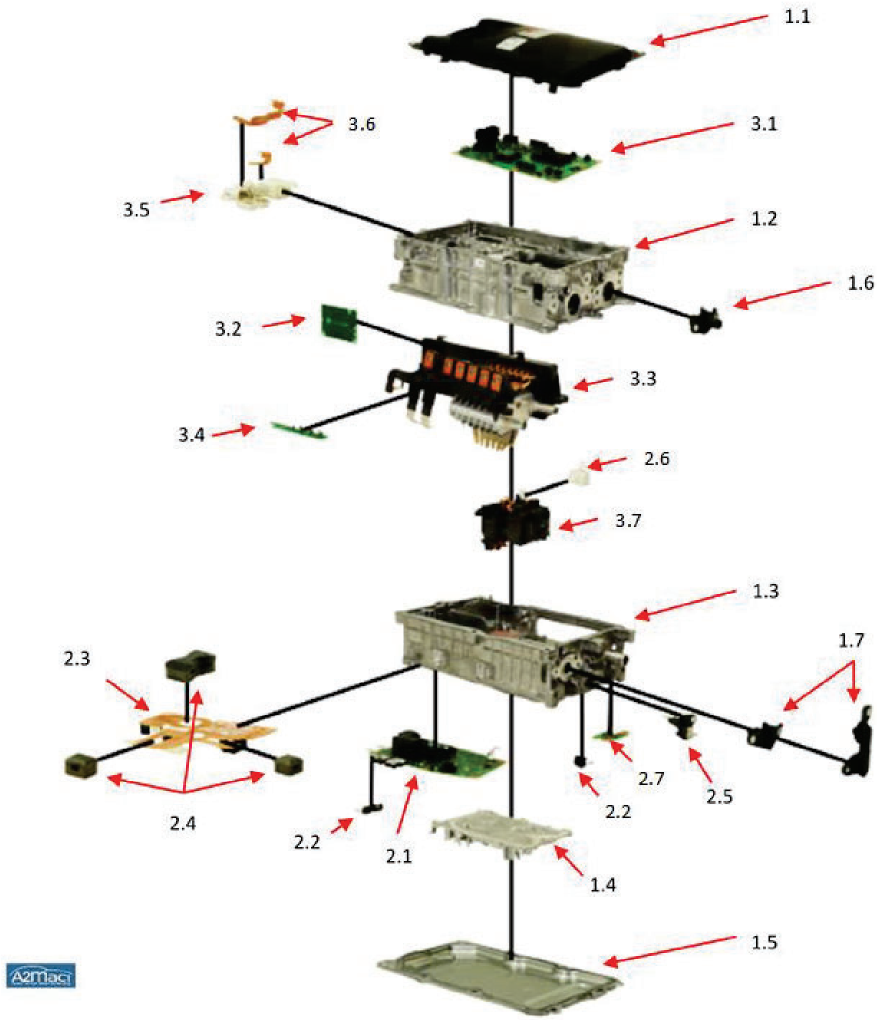
Toyota Prius - Rotor Assembly

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
703-1460_5	**Rotor Hub Shaft**	**$7.48**	**1**	**$7.48**
703-1460_5 Material	Material, Rotor Hub Shaft	$7.48	1	$7.48
703-1460_7	**Laminated Steel Sensor Target Wheel Subasm**	**$0.24**	**1**	**$0.24**
703-1460_8	**Laminated Steel**	**$0.24**	**1**	**$0.24**
Material, 703-1460_8	Material, Laminated Steel Sensor Target Wheel	$0.03	8	$0.24
703-1460_6	**Rotor Hub Shaft Collar**	**$0.04**	**1**	**$0.04**
Material, 703-1460_6	Material, Rotor Hub Shaft Collar	$0.04	1	$0.04
703-1460_9	Bearing Insert	$0.15	1	$0.15
703-1460_2	**Laminated Steel Rotor Core Section**	**$43.78**	**1**	**$43.78**
703-1460_13	**Welding Gap Laminated Steel**	**$2.10**	**1**	**$2.10**
Material, 703-1460_13	Material, Welding Gap Laminated Steel	$0.07	30	$2.10
703-1460_12	**Laminated Steel**	**$6.65**	**1**	**$6.65**
Material, 703-1460_12	Material, Laminated Steel	$0.07	95	$6.65
703-1460_14	**Internal Oil Distribution Laminated Steel-Outer**	**$1.26**	**1**	**$1.26**
Material, 703-1460_14	Material, Internal Oil Distribution Laminated Stee	$0.07	18	$1.26
703-1460_15	**Internal Oil Distribution Laminated Steel-Middle**	**$1.26**	**1**	**$1.26**
Material, 703-1460_15	Material, Internal Oil Distribution Laminated Stee	$0.07	18	$1.26
703-1460_16	**Internal Oil Distribution Laminated Steel-Oil**	**$0.91**	**1**	**$0.91**
Material, 703-1460_16	Material,Internal Oil Distribution Laminated Steel	$0.07	13	$0.91
703-1460_17	Magnet	$0.79	40	$31.60
703-1460_10	**Top Plate, Laminated Steel**	**$0.17**	**1**	**$0.17**
Material, 703-1460_10	Material, Top Plate, Laminated Steel	$0.17	1	$0.17
703-1460_11	**Bottom Plate, Laminated Steel**	**$0.17**	**1**	**$0.17**
Material, 703-1460_11	Material, Bottom Plate, Laminated Steel	$0.17	1	$0.17
703-1460_3	**Rotor Hub-Nut Spacer**	**$0.10**	**1**	**$0.10**
Material, 703-1460_3	Material, Rotor Hub-Nut Spacer	$0.10	1	$0.10
703-1460_4	Rotor Hub Nut	$0.35	1	$0.35

Assembly Totals		Report Totals	*Preassembled Totals*	
Analyzed Subs:	13	Piece Cost (Total): $52.48	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	229		*Parts:*	*0*
Fasteners:	1		*Fasteners:*	*0*
Parts+Unanalyzed:	229		*Parts+Unanalyzed:*	*0*

APPENDIX C: Toyota Prius Power Inverter Module

Figure C-1 Toyota Enclosures & Cooling Group

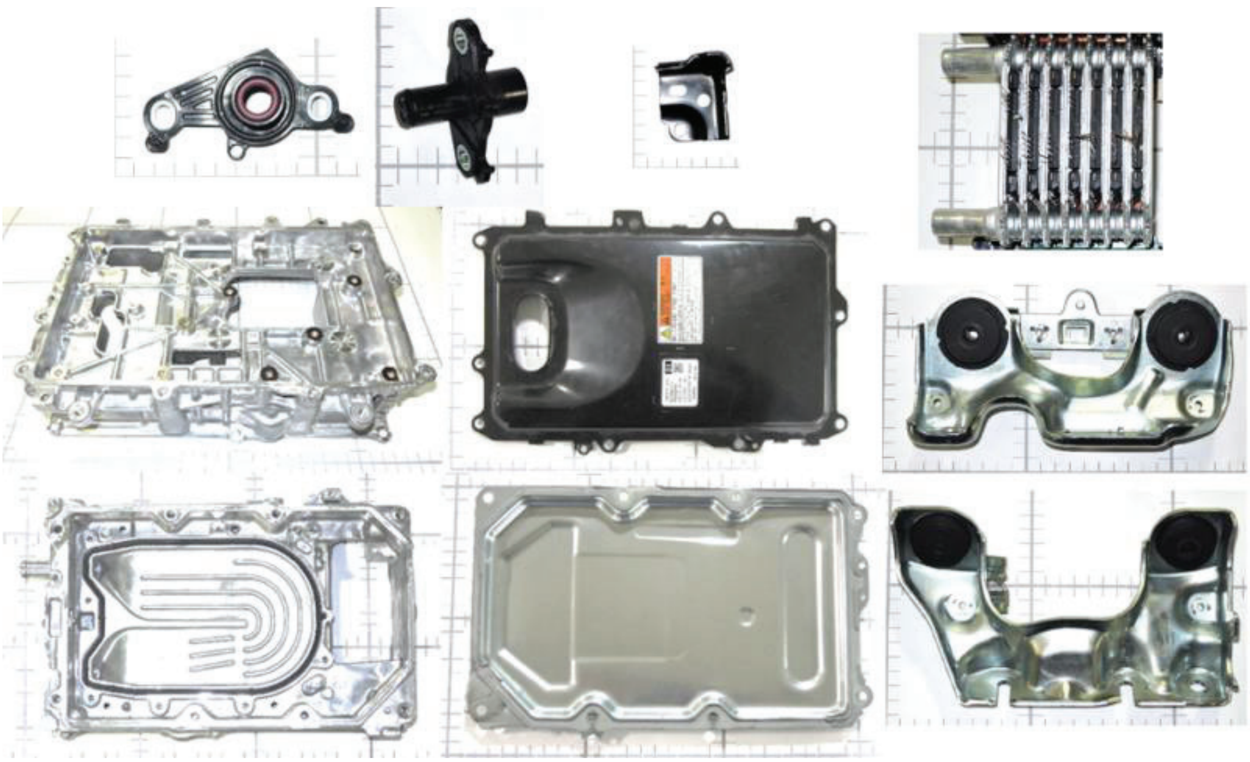


Cost Estimate BOM					
1.1	Top Cover	2.1	DC/DC Buck Converter Main Control Board	3.1	Inverter Main Controller Circuit Board
1.2	Enclosure Upper	2.2	DC/DC Buck Converter Bus Bar	3.2	Inverter Resistor Array Circuit Board
1.3	Enclosure Lower	2.3	DC/DC Buck Converter Inductor Circuit Board	3.3	IGBTs assembled to Cooler
1.4	Cooling Plate	2.4	Ferrites	3.4	Inverter Current Sensing Circuit Board
1.5	Bottom Cover	2.5	12V DC Outlet	3.5	Receptacle Cover Assembly
1.6	Coolant Inlet	2.6	Connector	3.6	Bus Bars
1.7	Coolant Passage Cover	2.7	Small Capacitor Board	3.7	Inductor Assembly

Toyota Enclosures and Cooling

The Toyota enclosures and cooling group includes the external housings, covers and components specific to cooling of internal components. The components within the group included the following: main enclosures on top and bottom both die cast aluminum, pair of covers both stamped steel, a pair of brackets for external fitment both stamped steel, IGBT cooler assembly, coolant line fittings, gaskets, and assorted hardware (silicone, screws, bushing, labels).

Figure C-2 Toyota Enclosures & Cooling Group



The summary shown in Table C-1 on p. 3 includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table C-1 Toyota Enclosure & Cooling: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Prius PCU Enclosure & Cooling

MUNRO & ASSOCIATES, INC.

	Prius PCU Enclosure & Cooling
Parts	141
Steps	1,800
Actual Time	3,017.76 sec
Fasteners	43
Total Weight	6.82 kg
Piece Cost	$25.94
Total Labor Cost	$47.31
Q Burden	$2.61
Total Cost	$75.86
Annual Production	200000

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. The markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown in the table below. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

Table C-2 Toyota Enclosure & Cooling: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU Enclosure & Cooling	
Purchased Part Roll up Costs		$11.54
Raw Material Costs		$14.40
Processing Costs		$47.31
Scrap (Design Profit: Q-Burden)	4%	$2.61
SG&A % Applied Against Processing	7%	$3.31
Profit % Applied Against Raw & Processing	4%	$2.47
Logistics % Applied Against Sum of all Above	3%	$2.45
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$1.68
Total % Mark Up / Total Cost	20%	$85.77
Total Weight (kg)		6.8171
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,960,000
Tooling Cost/part		$1.96
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$3,920,000
Tooling Cost/part		$3.92

There are 2 main enclosures, an upper and a lower. When assembled together they form the housing for the inverter. Both the enclosures were die cast aluminum components and the material was assumed to be aluminum A380. After casting the part is trimmed, machined, deburred and washed. The lower enclosure includes features for a cooling path, mounting the DC/DC mounting plate, electronics and connector/cable pass through holes. The lower enclosure is for mounting the DC/DC electronics and the upper enclosure is for the Motor Controller electronics.

Figure C-3 Toyota Upper Enclosure for Motor Controller Electronics

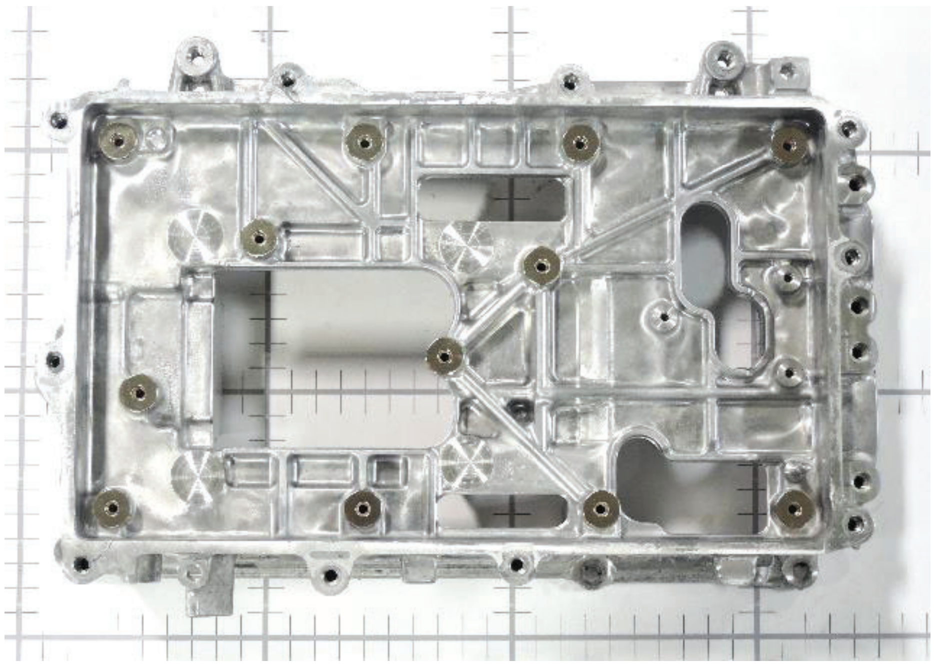
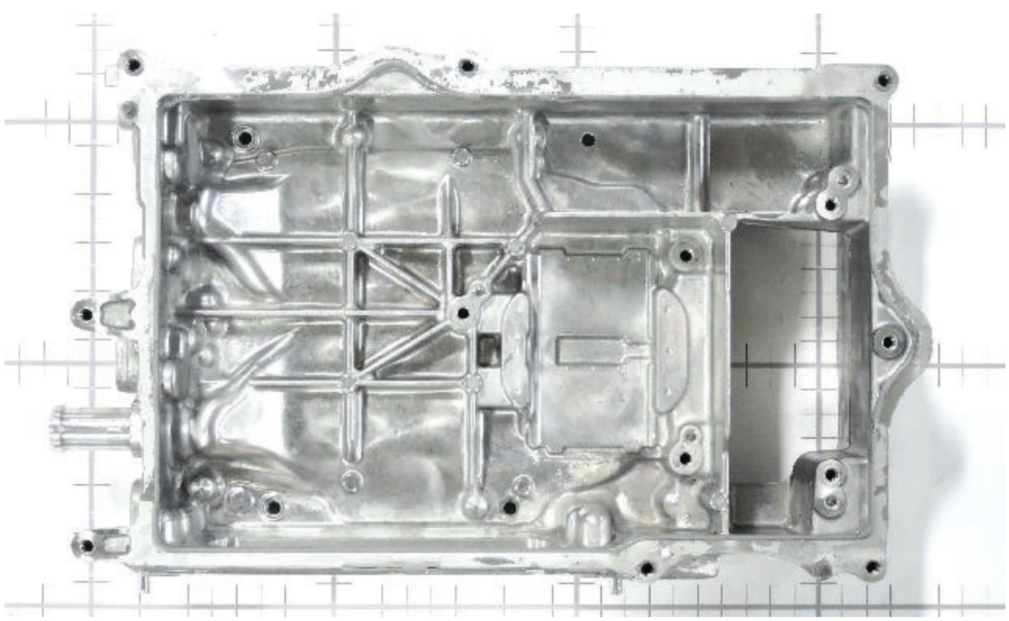


Figure C-4 Toyota Lower Enclosure for DC/DC Electronics

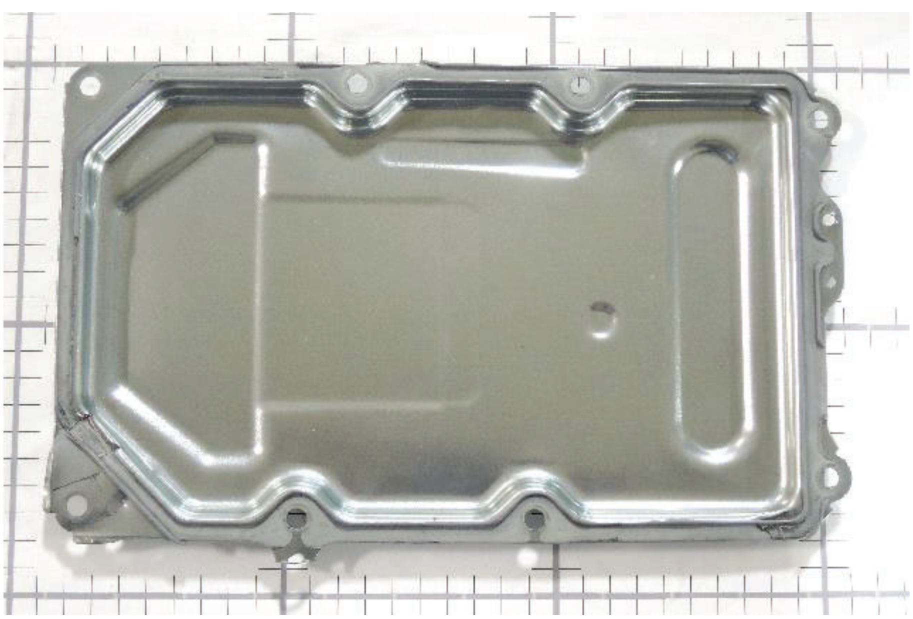


The top cover was assumed to be painted stamped steel plate. The part includes a feature for access to the connector on the motor controller side. A silicon based bead applied around the perimeter of the cover and is secured to the housing with threaded fasteners.

Figure C-5 Toyota Top Cover

The bottom cover was assumed to be a stamped galvanized steel plate. The cover is sealed using the same strategy as the top cover.

Figure C-6 Toyota Bottom Cover



IGBT Cooler assembly consists of the cooling plate assemblies, cooling pipes and the fins. The cooling plates are assumed to be stamped aluminum plates. The fins and divider are assumed to be aluminum and the manufacturing process is assumed to be roll forming. The fins and divider are placed in between the cooling plates and the cross section is shown below. There is a pair of cooling pipes which are attached to the ends of the cooling plate stack. There are eight sets of the cooling plate assembly which are stacked together. They accommodate the seven IGBTs; six for the two motors and one for the DC/DC Boost Converter which are slid in between each pair of cooling plates.

Figure C-7 Toyota IGBT Cooler Assembly

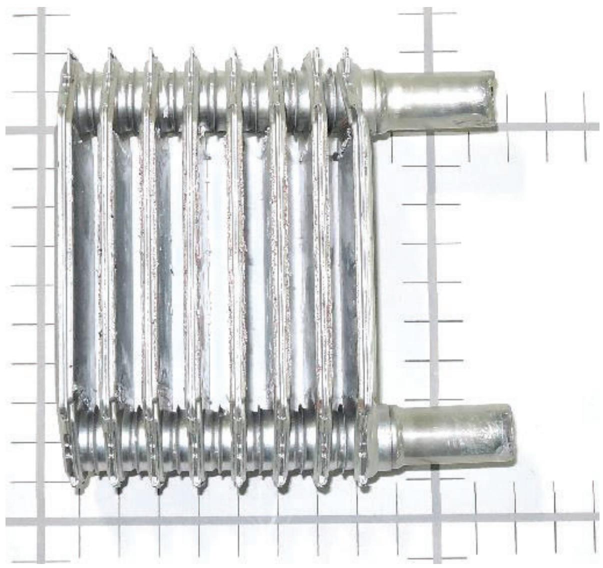
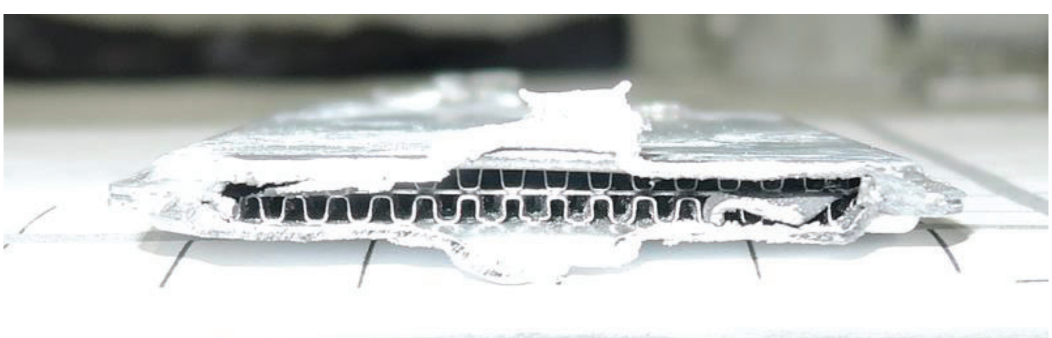


Figure C-8 Toyota IGBT Cooler Cross Section Showing Fins & Divider



Three coolant fittings are attached to the upper and lower enclosures. The fittings are injection molded glass filled nylon with a pair of anti-crush sleeves (for attachment with thread fasteners) and O-rings for sealing to the enclosure. One of the fittings is for interface to the vehicle coolant system. The other form an interface from the IGBT Cooler assembly inside the upper enclosure down to the lower enclosure for cooling of the DC/DC Buck Converter electronics.

Figure C-9 Toyota Coolant Fittings Mounted to Housing

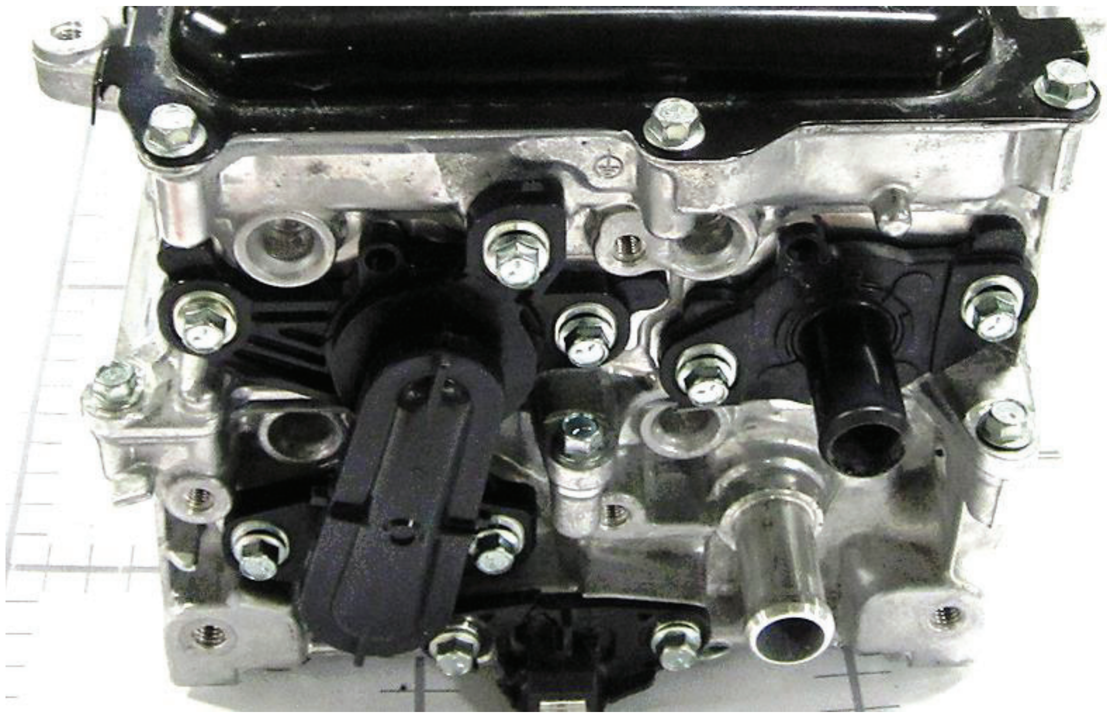
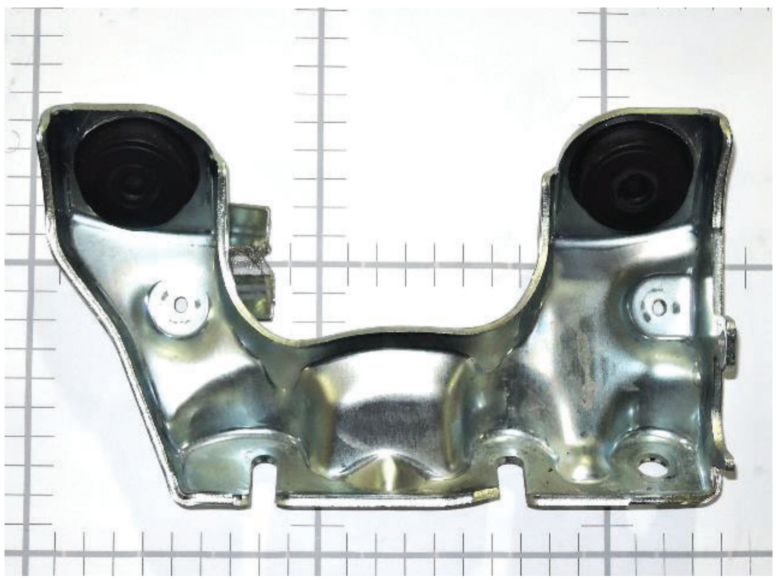
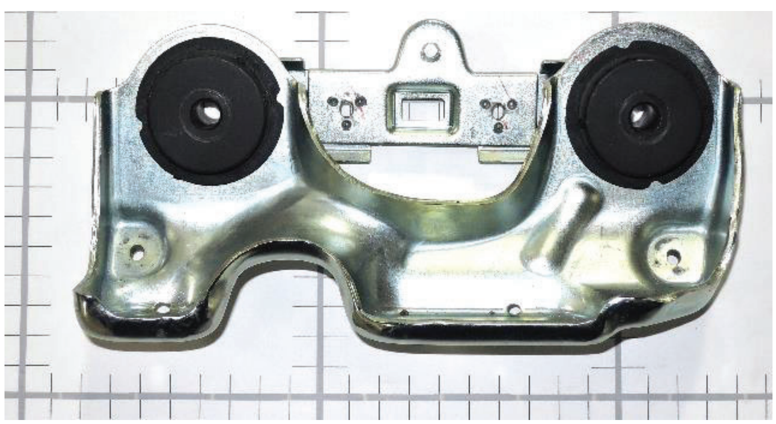


Figure C-10 Toyota Coolant Fittings: IGBT Cooler Interface (Top Left), DC/DC Cooling Interface (Top Right), IGBT to Vehicle Outlet Adapter (Bottom)

A pair of bracket assemblies are attached to the bottom enclosure for mounting the module to the vehicle. Each bracket assembly consists of a bracket, ground straps and mounting bushings. The brackets are assumed to be stamped steel. The bracket assemblies are fastened to the lower enclosure with threaded fasteners through the mounting bushings.

Figure C-11 Toyota Bracket Assemblies: Bracket at Coolant Fitting End (Top), Bracket at Electrical Connector End (Bottom)





Toyota DC/DC Buck Converter

The Toyota DC/DC Buck Converter group consists of five subgroups providing additional clarity in regards to system cost details. Each group in the Buck Converter will be reported on separately. Please note the DC/DC Boost Converter components are integrated into the Invertor assembly and will be reported upon in the Inverter section. The converter subgrouping consists of the following: Internal Housing, Buss Bars, Printed Circuit Board Assemblies (PCBA), Ferrites & Inductors, and Harnesses (wiring). The internal housing group includes any additional structural components found inside the unit once disassembled. The Buss Bars group includes any stamped metal components providing electrical connections between devices internal to the module. The PCBA group contains all of the printed circuit boards associated with the DC/DC converter. The ferrites and Inductors group includes additional electronic components associated with the DC/DC converter. The last group Harnesses includes all internal wiring components connecting the various components in the converter. High voltage DC comes in on the left side and the 12-volt DC output is on the right.

Figure C-12 Toyota DC/DC Converter

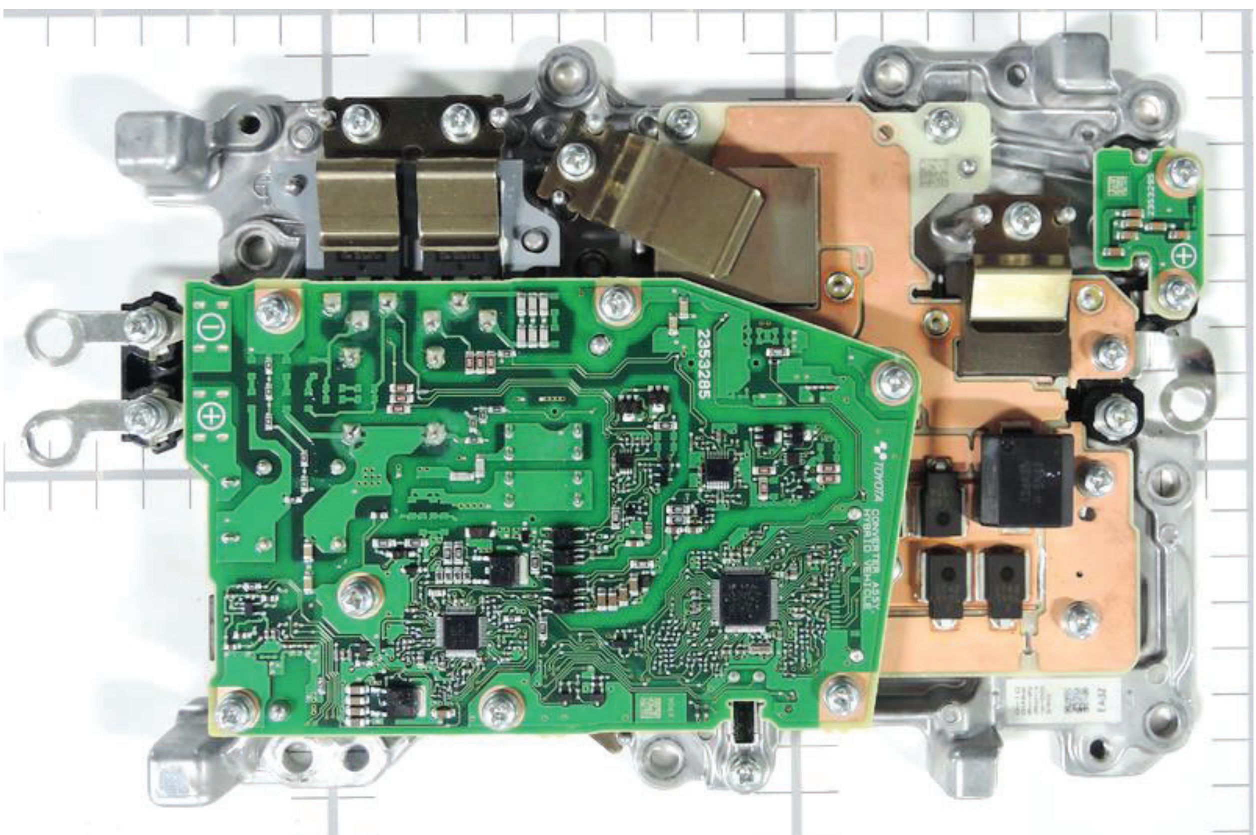


Figure C-13 Toyota DC/DC Buck Converter Assembled to Enclosure

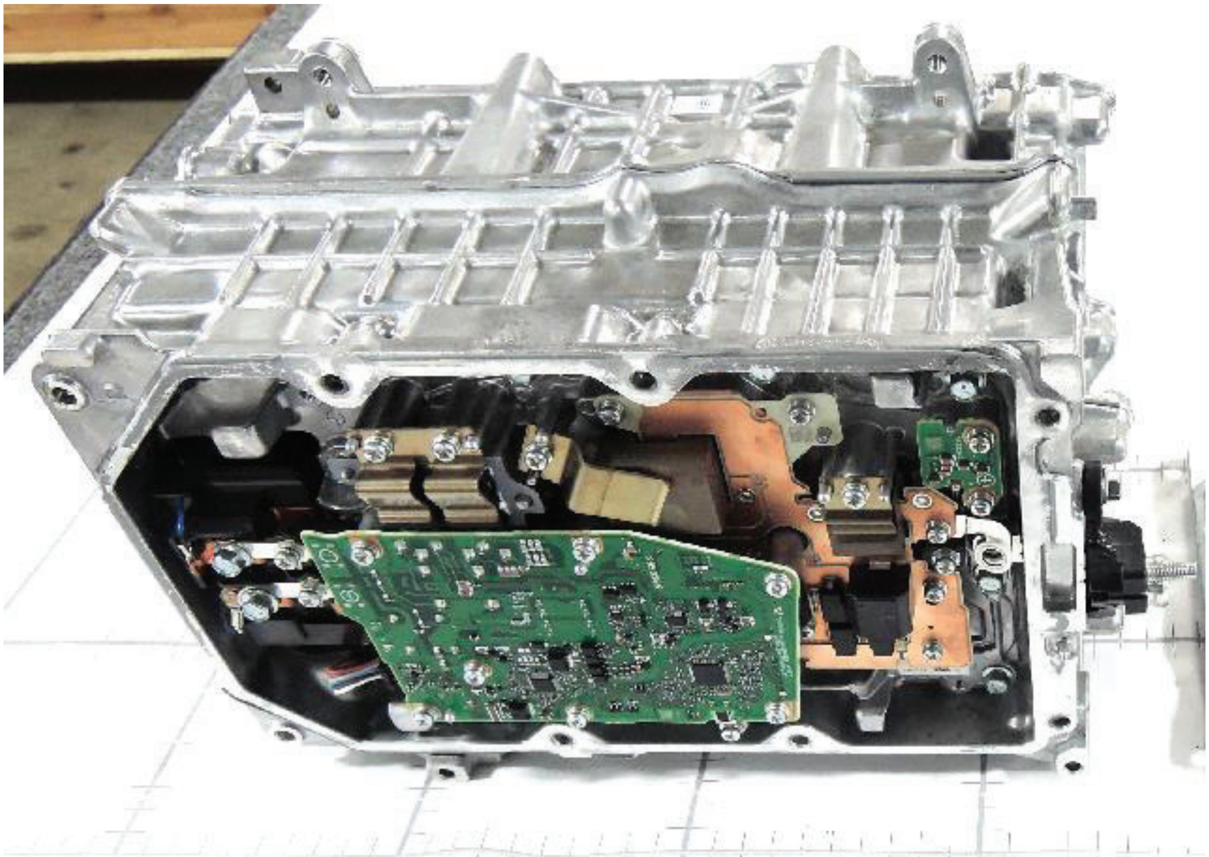


Table C-3 Toyota DC/DC Converter Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Prius PCU DC/DC Converter

MUNRO & ASSOCIATES, INC.

	Prius PCU DC/DC Converter
Parts	549
Steps	1,716
Actual Time	2,421.54 sec
Fasteners	34
Total Weight	1.31 kg
Piece Cost	$65.43
Total Labor Cost	$39.80
Q Burden	$2.33
Total Cost	$107.56
Annual Production	200000

Table C-4 Toyota DC/DC Converter Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU Module DC /DC Converter	
Purchased Part Roll up Costs		$60.30
Raw Material Costs		$5.13
Processing Costs		$39.79
Scrap (Design Profit: Q-Burden)	2%	$2.34
SG&A % Applied Against Processing	7%	$2.79
Profit % Applied Against Raw & Processing	4%	$1.80
Logistics % Applied Against Sum of all Above	3%	$3.36
Patent/Royalty Fees % Applied Against Sum of all Above	12%	$13.80
Total % Mark Up / Total Cost	28%	$129.31
Total Weight (kg)		1.3114
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,072,500
Tooling Cost/part		$1.07
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$2,145,000
Tooling Cost/part		$2.15

Toyota DC/DC Converter: Internal Housing

The Toyota DC/DC Internal Housing group consists of a single die cast aluminum cooling plate. The material for the cooling plate was assumed to be Aluminum A380. After casting the part is trimmed, machined, deburred and washed. The part contains the features for the cooling path on the bottom surface and the top surface has features to mount the electrical components. The part is fastened along with the circuit board attached to the bottom enclosure. A rubber gasket is placed in between the bottom enclosure and the cooling plate in order to ensure sufficient sealing between the two.

Figure C-14 Toyota DC/DC Converter: Cooling Plate

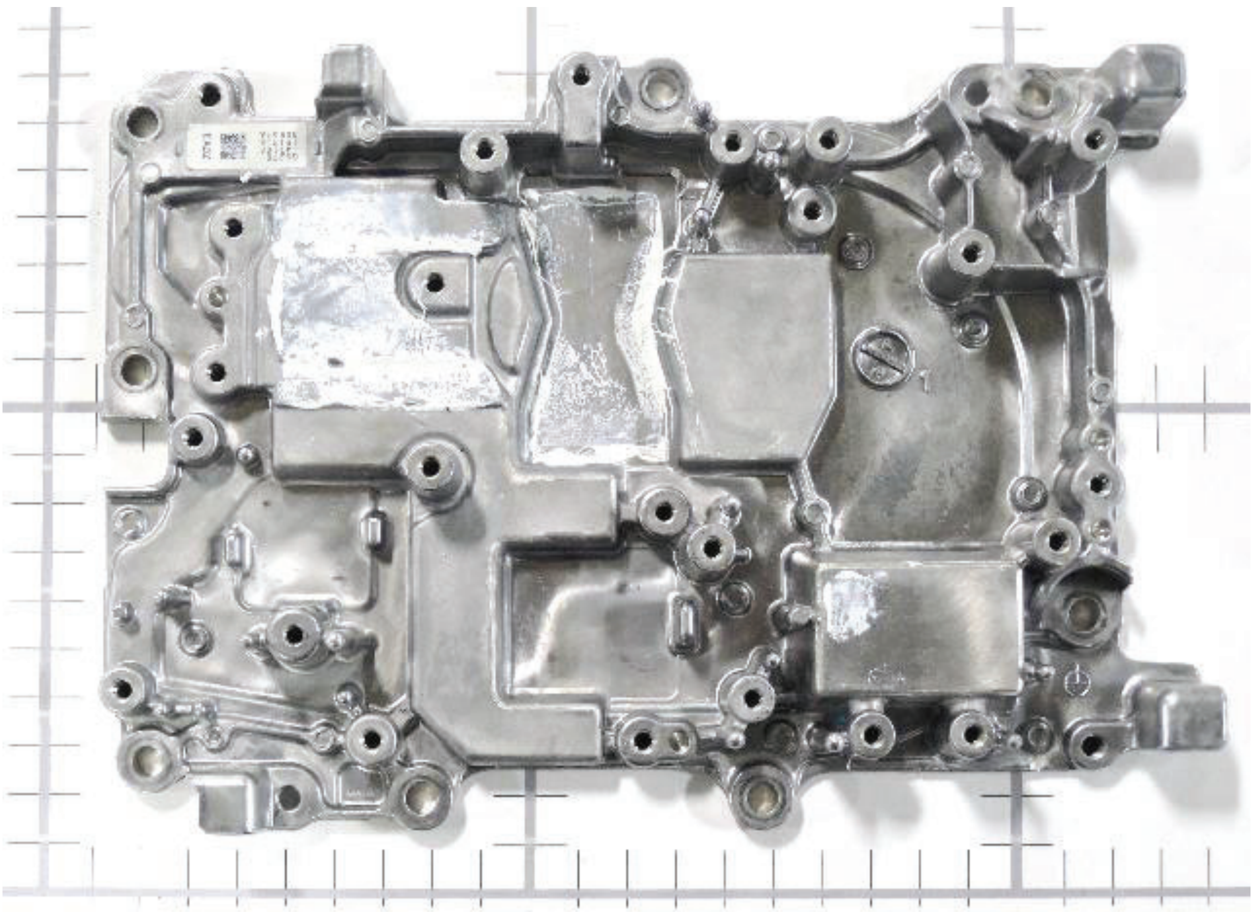


Figure C-15 Toyota DC/DC Converter: Gasket in Place on Lower Enclosure

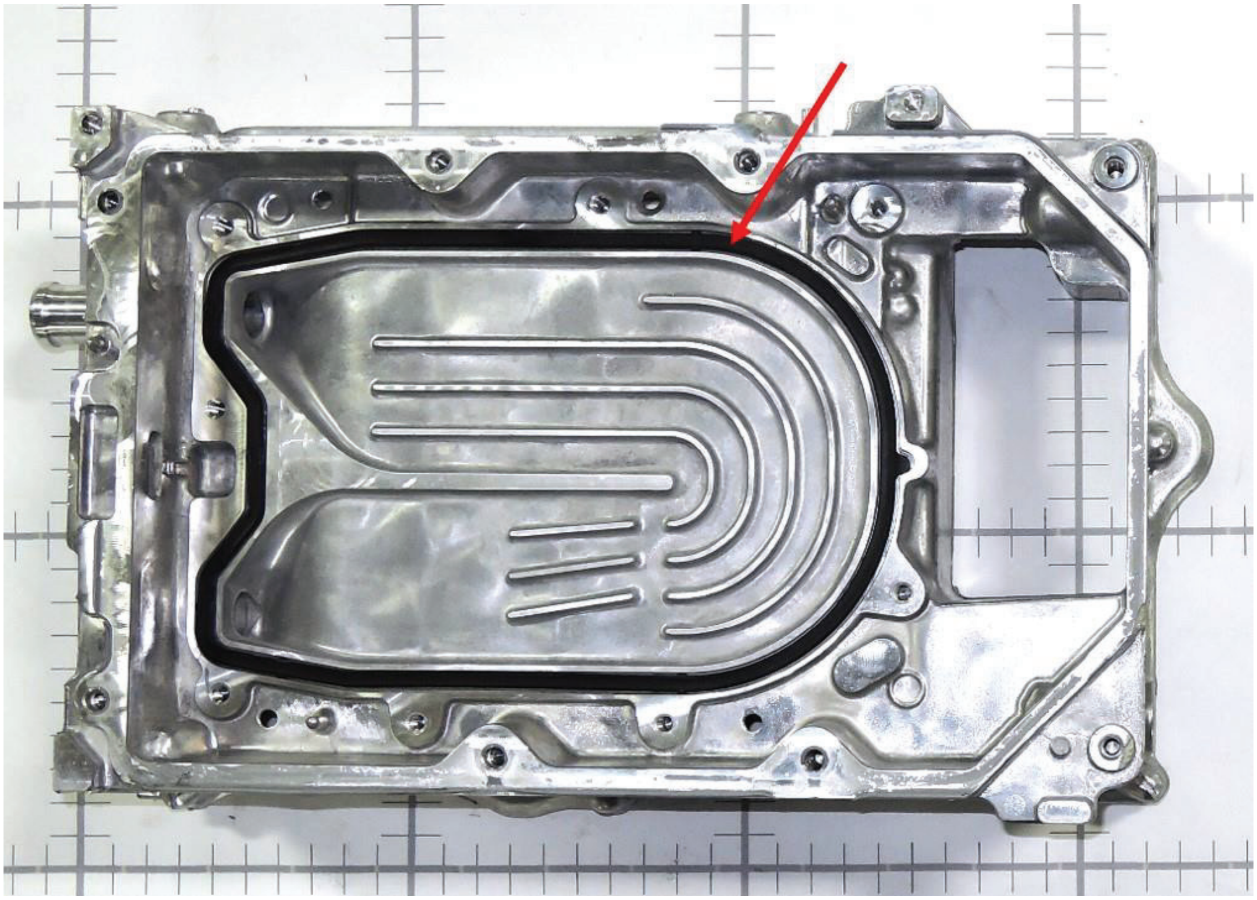


Table C-5 Toyota DC/DC Internal Housings Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Prius DC/DC Internal Housing

MUNRO & ASSOCIATES, INC.

	Prius DC/DC Internal Housing
Parts	11
Steps	271
Actual Time	314.82 sec
Fasteners	8
Total Weight	0.66 kg
Piece Cost	$1.73
Total Labor Cost	$5.50
Q Burden	$0.36
Total Cost	$7.59
Annual Production	200000
Cost Center's Tooling C	$220,000.00

Table C-6 Toyota DC/DC Internal Housings Group: Cost Estimate Summary

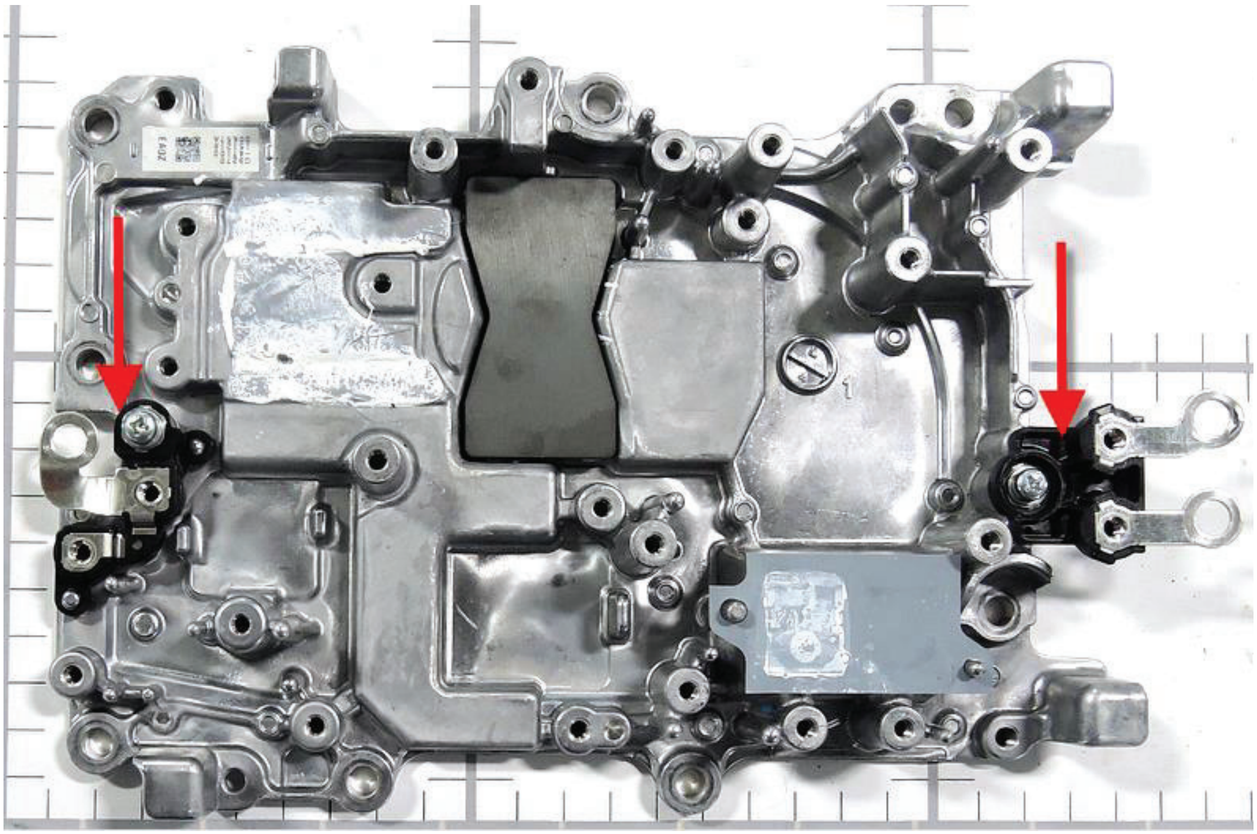
Component Summary		
Part/Assembly Name	Prius PCU DC/DC Internal Housing	
Purchased Part Roll up Costs		$0.21
Raw Material Costs		$1.52
Processing Costs		$5.50
Scrap (Design Profit: Q-Burden)	5%	$0.36
SG&A % Applied Against Processing	7%	$0.39
Profit % Applied Against Raw & Processing	4%	$0.28
Logistics % Applied Against Sum of all Above	3%	$0.25
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.17
Total % Mark Up / Total Cost	21%	$8.67
Total Weight (kg)		0.6625
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$220,000
Tooling Cost/part		$0.22
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$440,000
Tooling Cost/part		$0.44

Toyota DC/DC Converter: Bus Bars

The Toyota DC/DC Converter Bus Bars group consists of two bus bar connector assemblies. Both the bus bar connectors are insert injection molded. The assembly consists of stamped nickel plated copper terminals, nut and spacers. The plastic mold material is assumed to be glass filled Polybutylene Terephthalate. One assembly receives the high voltage DC and the other outputs the 12 volts DC from the DC/DC converter. Both the connectors are fastened to the DC/DC coolant plate with threaded fasteners.

Figure C-16 Toyota DC/DC Bus Bars Group

Figure C-17 Toyota DC/DC: Bus Bar Connectors in Place



The total "should cost" to manufacture the Toyota DC/DC converter Bus bars group is estimated and additional typical markups associated with component manufacturing added. (These additional markups are shown in Table C-8 on page 17.)

Table C-7 Toyota DC/DC Bus Bars Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Prius DC/DC Bus Bars

MUNRO & ASSOCIATES, INC.

	Prius DC/DC Bus Bars
Parts	13
Steps	60
Actual Time	104.08 sec
Fasteners	6
Total Weight	0.02 kg
Piece Cost	$0.98
Total Labor Cost	$0.77
Q Burden	$0.13
Total Cost	$1.88
Annual Production	200000

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. The markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown in the table below. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

Table C-8 Toyota DC/DC Bus Bars Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU DC /DC Bus Bars	
Purchased Part Roll up Costs		$0.36
Raw Material Costs		$0.62
Processing Costs		$0.77
Scrap (Design Profit: Q-Burden)	7%	$0.13
SG&A % Applied Against Processing	7%	$0.05
Profit % Applied Against Raw & Processing	4%	$0.06
Logistics % Applied Against Sum of all Above	3%	$0.06
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.04
Total % Mark Up / Total Cost	23%	$2.09
Total Weight (kg)		0.0224
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$205,000
Tooling Cost/part		$0.21
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$410,000
Tooling Cost/part		$0.41

Toyota DC/DC Converter: PCBAs

The Toyota DC/DC converter Printed Circuit Board Assemblies (PCBAs) group consists of an inductor circuit board, main DC/DC circuit board and a smaller capacitor circuit board. The inductor circuit board includes the diodes and a film capacitor and contains the space to place the ferrites in between to complete the circuit. The main DC/DC circuit board assembly contains all of the surface mount devices controlling the DC/DC converter. The smaller capacitor circuit board contains four capacitors and is connected to the output bus bar connector.

Figure C-18 Toyota DC/DC Converter: PCBAs Group

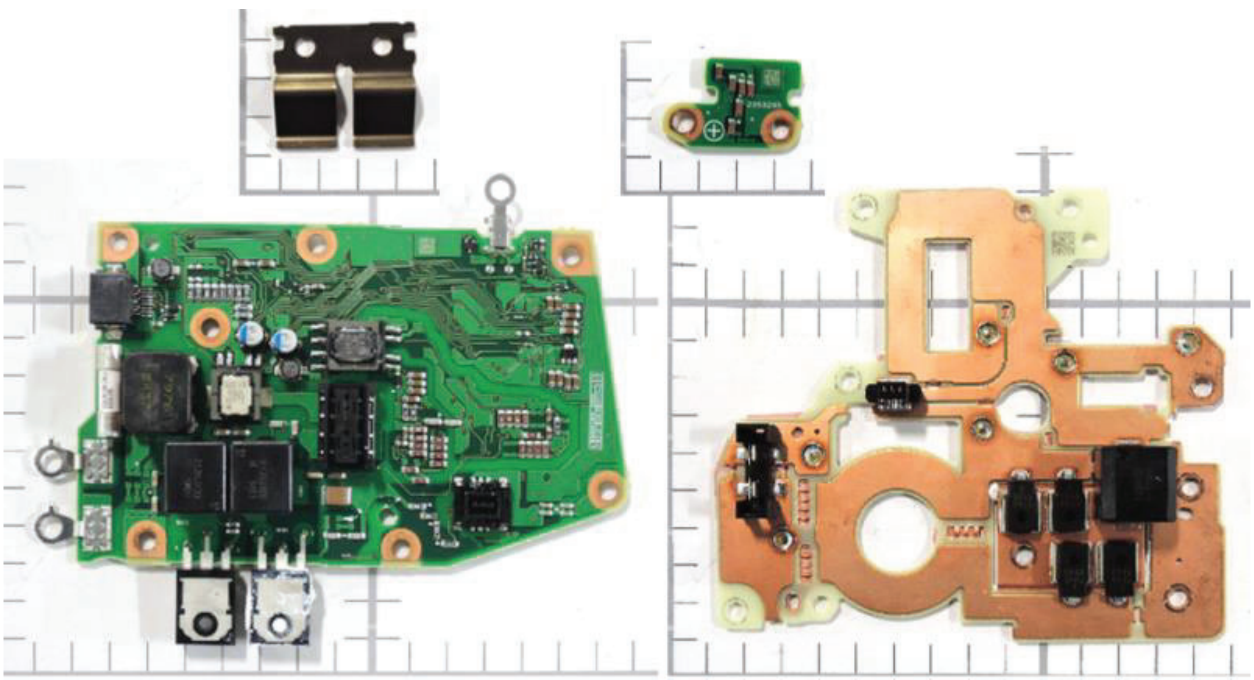


Table C-9 Toyota DC/DC PCBAs Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Prius DC/DC PCBAs

MUNRO & ASSOCIATES, INC.

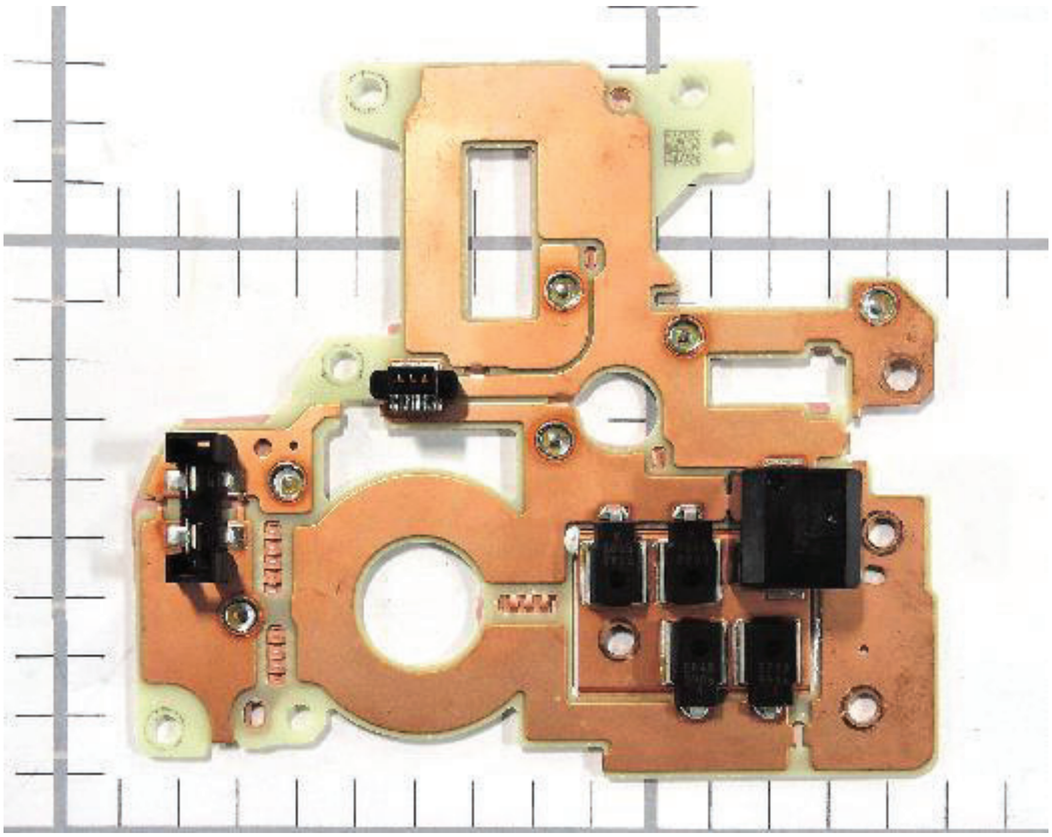
	Prius DC/DC PCBAs
Parts	456
Steps	1,028
Actual Time	680.64 sec
Fasteners	12
Total Weight	0.23 kg
Piece Cost	$56.08
Total Labor Cost	$13.98
Q Burden	$1.23
Total Cost	$71.30
Annual Production	200000

Table C-10 Toyota DC/DC PCBAs Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		Prius PCU DC /DC PCBAs
Purchased Part Roll up Costs		$54.80
Raw Material Costs		$1.28
Processing Costs		$13.98
Scrap (Design Profit: Q-Burden)	2%	$1.23
SG&A % Applied Against Processing	7%	$0.98
Profit % Applied Against Raw & Processing	4%	$0.61
Logistics % Applied Against Sum of all Above	3%	$2.19
Patent/Royalty Fees % Applied Against Sum of all Above	15%	$11.26
Total % Mark Up / Total Cost	31%	$86.33
Total Weight (kg)		0.2292
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$207,500
Tooling Cost/part		$0.21
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$415,000
Tooling Cost/part		$0.42

The inductor circuit board includes a FR4 Fiberglass material sandwiched between copper stampings. The FR4 material is glued on to the copper stampings. The circuit consists of 4 diodes and a film capacitor. The board has the space to accommodate the ferrite cores. The entire assembly is attached to the cooling plate using eight threaded fasteners. The inductor circuit board cost drivers are 1 – 10µF ±10% Film Capacitor, 4 - 48.4V TVS Diodes, 1 – 6 Terminal Board to Board Connector.

Figure C-19 Toyota DC/DC Converter: Inductor Circuit Board



The main DC-DC Control board included the following components which are were identified as having the highest cost: 1 - N-Ch 650 V 69 A MOSFET, 1 - Low Voltage 256 × 9 Synchronous FIFO Memory, 1 - 1mH 10kHz 2 Line Common Mode Choke, Printed 4 layer FR4 Circuit Board, 1 - 3.3V 32-bit RISC MCU w/192KB Flash 64-Pin device and 1 - 10uF 10% 50V Ceramic Capacitor w/J-Leads. Additional components found on the board include amplifiers, MOSFETS, transformers, voltage regulators, gate drivers, CAN Transceivers, flash memory, differential comparators and various smaller active and passive surface mount components. There is a stamped steel plate shown in Figure C-21 on p. 22 for holding the two power MOSFETs in place.

Figure C-20 Toyota DC/DC Converter: Main Control Board Top and Bottom Views

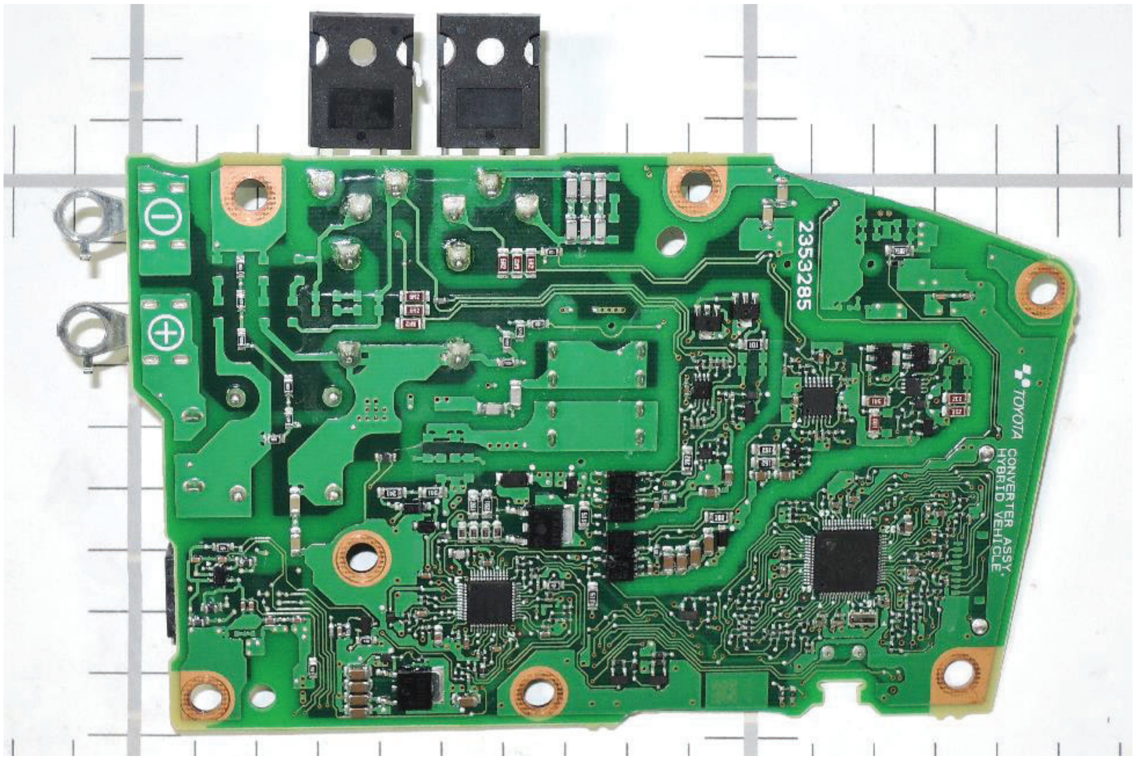
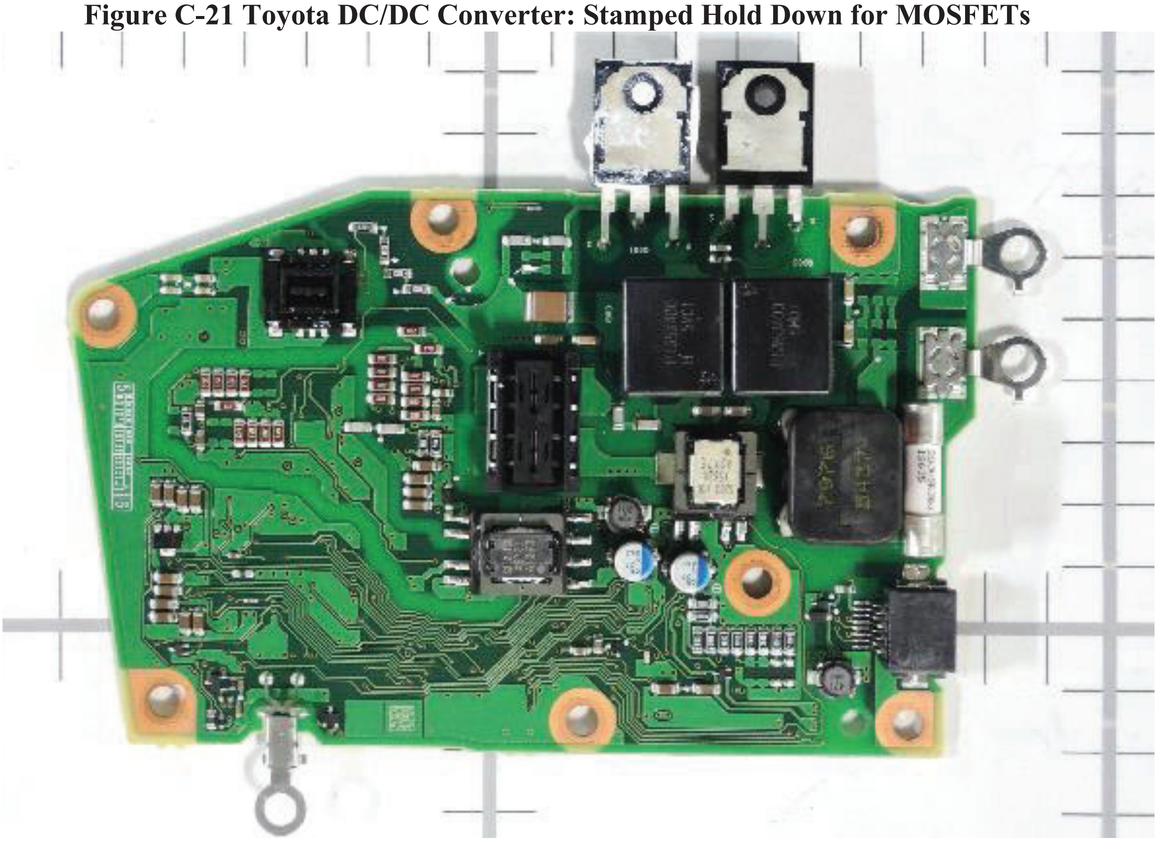
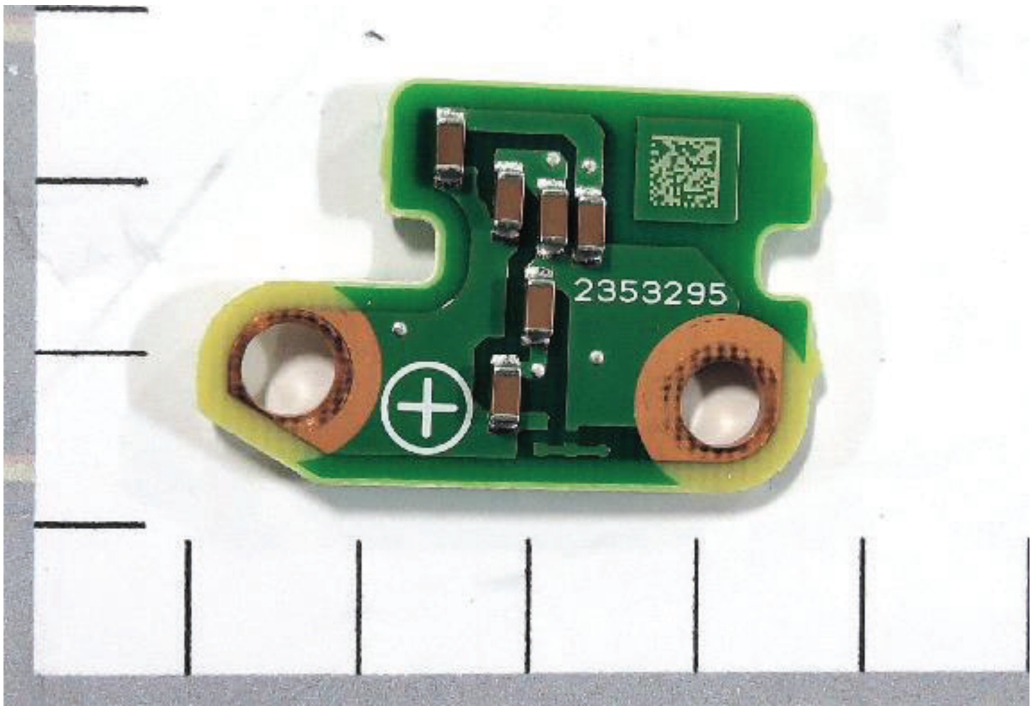


Figure C-21 Toyota DC/DC Converter: Stamped Hold Down for MOSFETs



The smaller capacitor circuit board contained six capacitors on one side of the board. The capacitors were identified as surface mounted Tolerance - 10%; 1206 (3216 Metric). The circuit board is a double layer FR4.

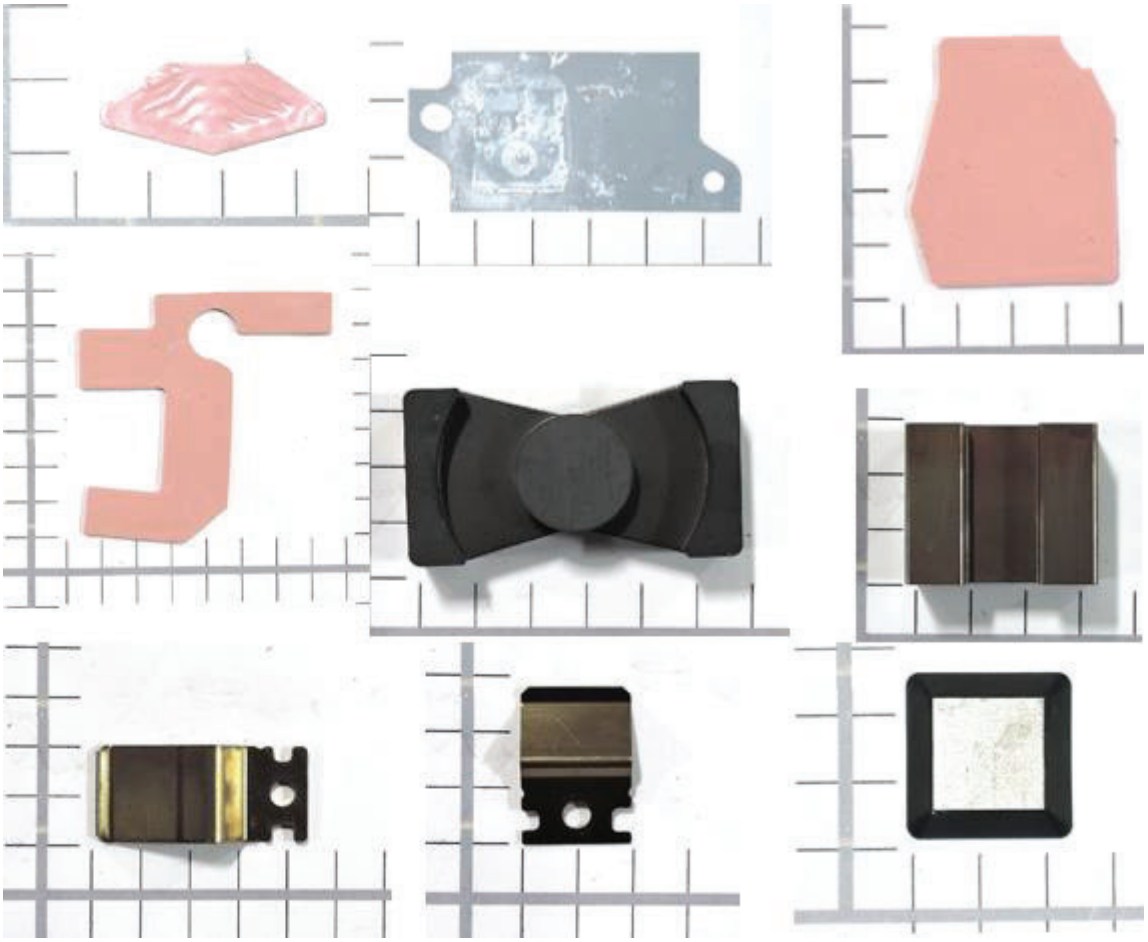
Figure C-22 Toyota DC/DC Converter: Small Capacitor Board



Toyota DC/DC Converter: Ferrites & Inductors

The Toyota DC/DC Ferrites & Inductors group consists of three ferrite cores, their holders and electrically insulating thermally conductive pads. The ferrites are a sintered powdered metal design. They are used on the high voltage input side of the circuitry and they are placed in between the inductor circuit board. The main DC-DC circuit board is placed on top of the ferrites cores. The electrically insulating thermally conductive pads are placed on the cooling plate where the ferrites are placed. The ferrite cores are held in place with help of holders which are fastened using threaded fasteners.

Figure C-23 Toyota DC/DC Converter: Ferrites & Inductors Group



The total “should cost” to manufacture the Toyota DC/DC Converter: Ferrites & Inductors group is estimated and additional typical markups associated with component manufacturing added. (These additional markups are shown Table C-12 on p. 26.)

The summary shown below in **Error! Reference source not found.** includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table C-11 Toyota DC/DC Ferrites & Inductors Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Prius DC/DC Ferrites &

MUNRO & ASSOCIATES, INC.

	Prius DC/DC Ferrites & Inductors
Parts	18
Steps	142
Actual Time	925.98 sec
Fasteners	3
Total Weight	0.32 kg
Piece Cost	$3.95
Total Labor Cost	$15.15
Q Burden	$0.20
Total Cost	$19.29
Annual Production	200000

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. The markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown in the table below. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

Table C-12 Toyota DC/DC Ferrites & Inductors Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU DC /DC Ferrites & Inductors	
Purchased Part Roll up Costs		$2.81
Raw Material Costs		$1.14
Processing Costs		$15.15
Scrap (Design Profit: Q-Burden)	1%	$0.20
SG&A % Applied Against Processing	7%	$1.06
Profit % Applied Against Raw & Processing	4%	$0.65
Logistics % Applied Against Sum of all Above	3%	$0.63
Patent/Royalty Fees % Applied Against Sum of all Above	10%	$2.16
Total % Mark Up / Total Cost	25%	$23.80
Total Weight (kg)		0.3161
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$285,000
Tooling Cost/part		$0.29
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$570,000
Tooling Cost/part		$0.57

The ferrites are two-piece powdered metal designs. The bottom ferrite cores, shown in Figure C-24 on p. 27 have flat base which sits on the cooling pad with a taper to the top surface. The top ferrite cores just below that image in Figure C-25 have a slot to be placed between the circuit boards. There is a unique stamped steel plate for each of the ferrite core assembly and is used as holder for the ferrite cores.

Figure C-24 Toyota DC/DC Converter: Bottom Ferrite Cores

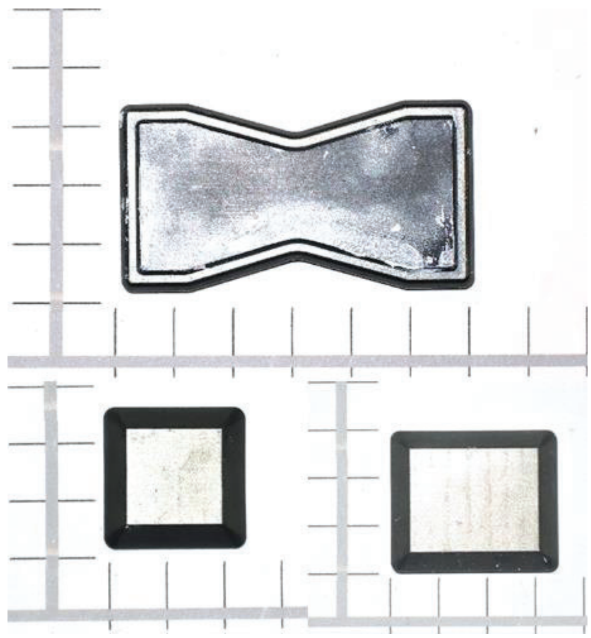


Figure C-25 Toyota DC/DC Converter: Top Ferrite Cores

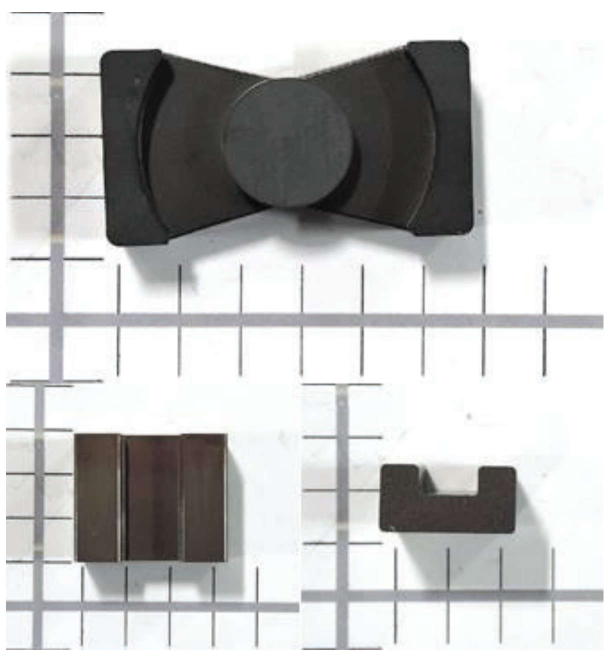
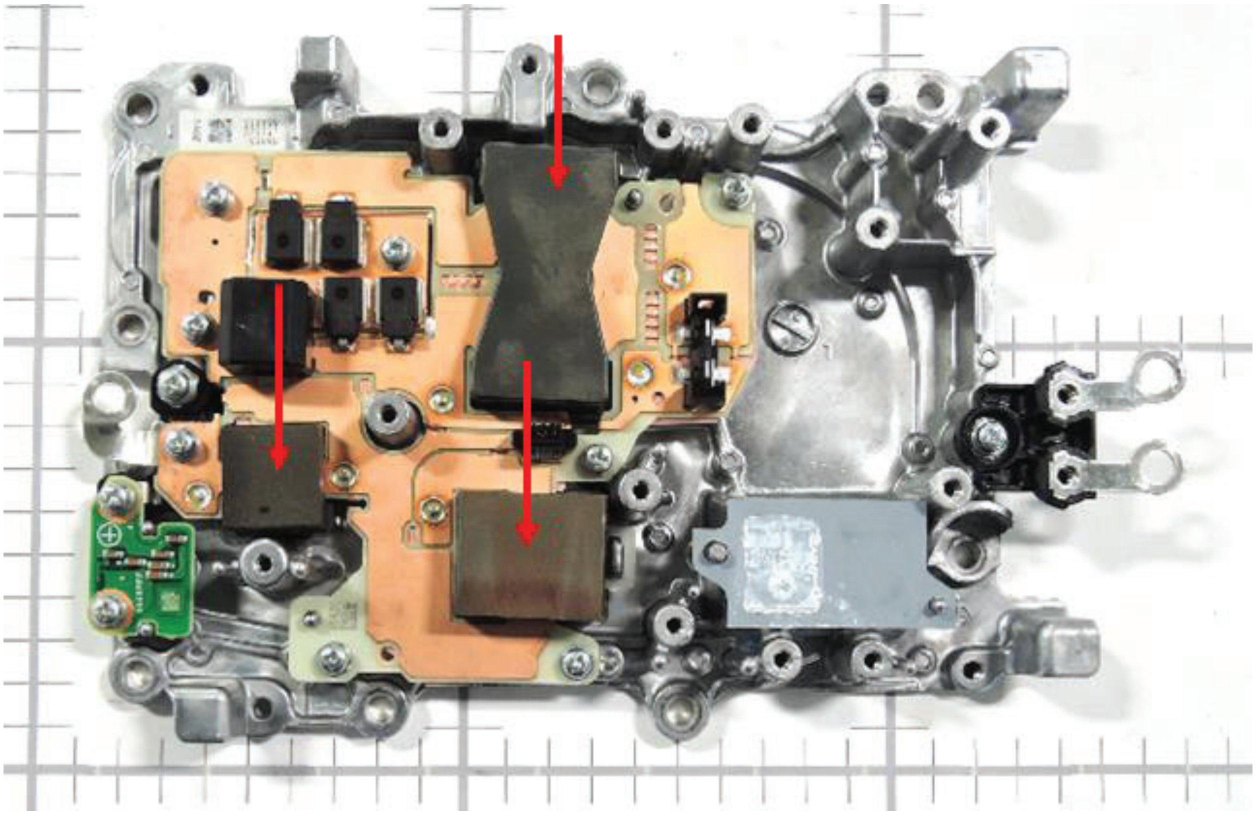


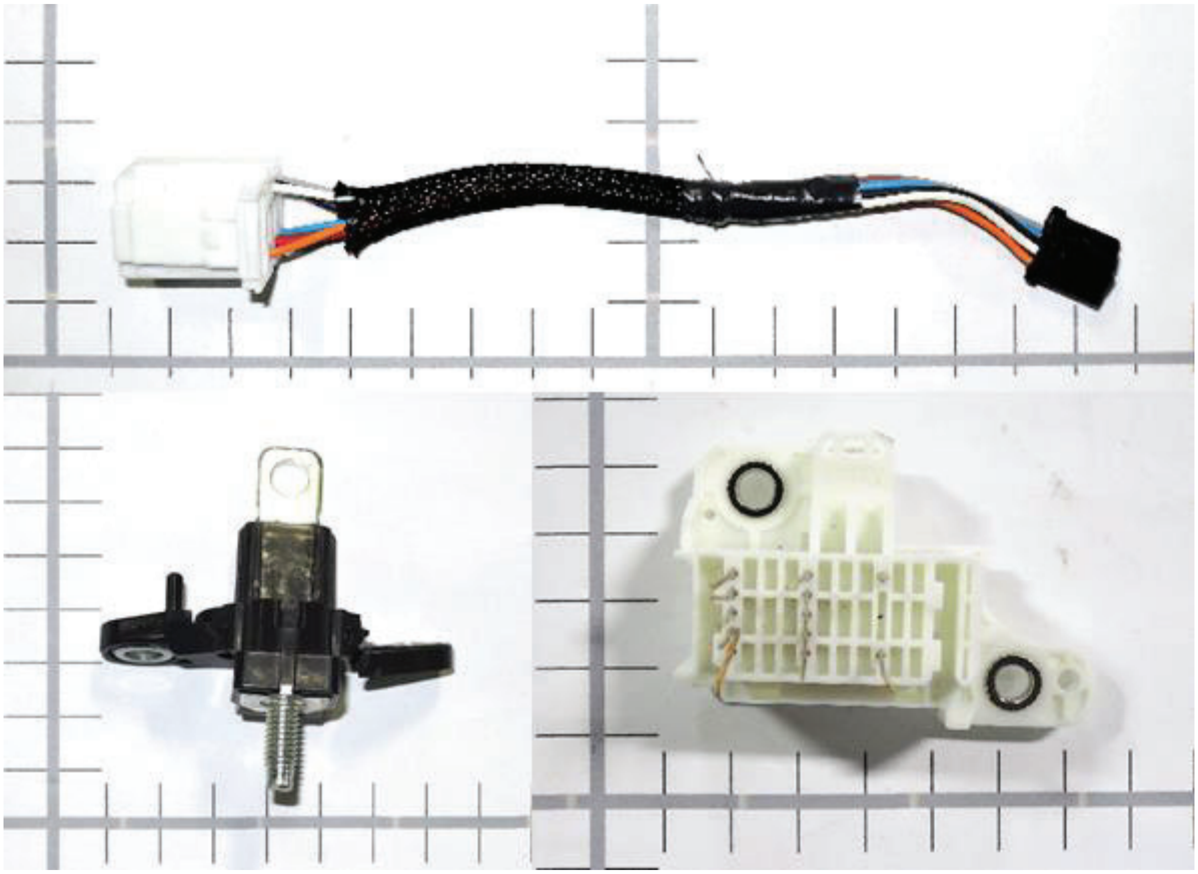
Figure C-26 Toyota DC/DC Converter: Ferrite Cores Assembled



Toyota DC/DC Converter: Electrical & Harness

The Toyota DC/DC Converter Electrical & Harness group consists of a 12 Volt DC outlet terminal lug mounted external to the housing, a harness which connects from the controller to the DC/DC board and a connector. The harness is connected to the main DC/DC circuit board on one end and to the connector on the other. The connector in turn gets connected to the motor controller circuit board on the other end.

Figure C-27 Toyota DC/DC Converter: Electrical & Harness Group



The total "should cost" to manufacture the Toyota DC/DC Converter Electrical & Harness group is estimated and additional typical markups associated with component manufacturing added. (These additional markups are shown Table C-14 on p.30.)

The summary shown on Table C-13 includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table C-13 Toyota DC/DC Electrical & Harness Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Prius DC/DC Electrical &

MUNRO & ASSOCIATES, INC.

	Prius DC/DC Electrical & Harness
Parts	51
Steps	215
Actual Time	396.01 sec
Fasteners	5
Total Weight	0.08 kg
Piece Cost	$2.69
Total Labor Cost	$4.39
Q Burden	$0.42
Total Cost	$7.50
Annual Production	200000

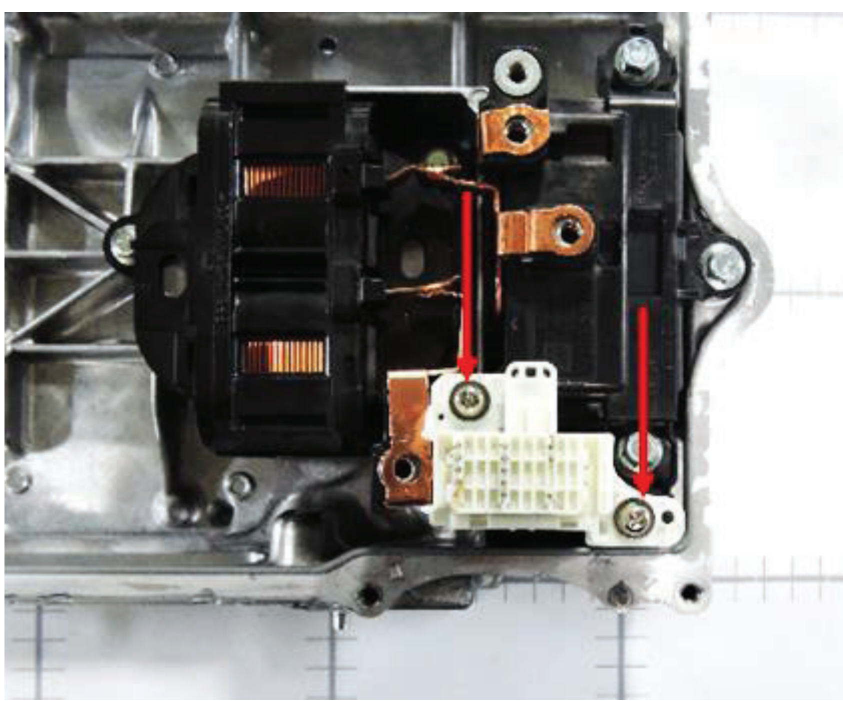
The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. The markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown in the table below. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

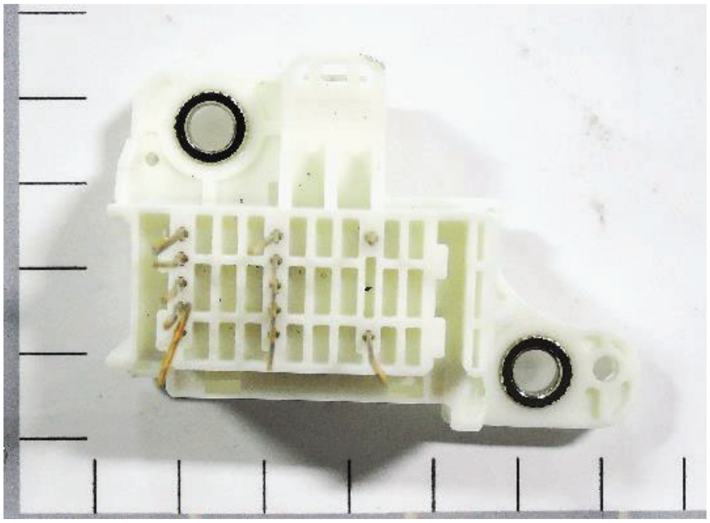
Table C-14 Toyota DC/DC Electrical & Harness Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU DC /DC Electrical Harnesses	
Purchased Part Roll up Costs		$2.12
Raw Material Costs		$0.57
Processing Costs		$4.39
Scrap (Design Profit: Q-Burden)	6%	$0.42
SG&A % Applied Against Processing	7%	$0.31
Profit % Applied Against Raw & Processing	4%	$0.20
Logistics % Applied Against Sum of all Above	3%	$0.24
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.16
Total % Mark Up / Total Cost	22%	$8.41
Total Weight (kg)		0.0812
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$155,000
Tooling Cost/part		$0.16
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$310,000
Tooling Cost/part		$0.31

The connector is an insert injection molded plastic part and the part includes connector pins, metal spacers and the connector body (housing). The housing is assumed to be made of glass filled Polybutylene Terephthalate.

Figure C-28 Toyota DC/DC Converter: Connector Assembled to Unit (Top), and Removed (Bottom)

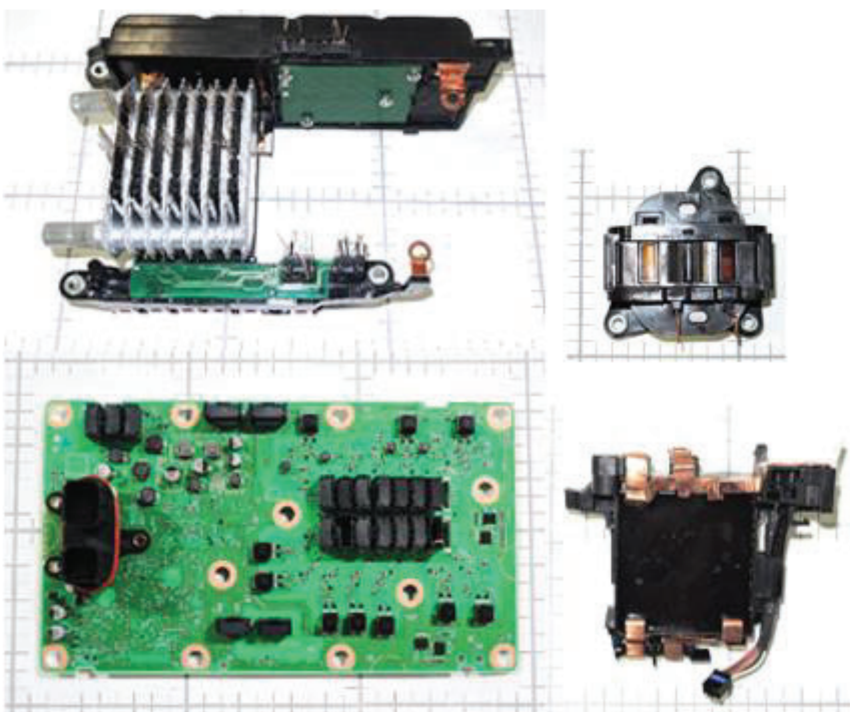




Toyota Inverter

The Toyota Inverter group consists of five subgroups providing additional clarity in regards to system cost details. Each group will be reported on separately. Please note the DC/DC Boost Converter components are integrated into the Invertor assembly and will be included in the following subgroups as well. The converter subgrouping consists of the following: Internal Housing, Buss Bars, Printed Circuit Board Assemblies (PCBA, also includes IGBTs), Inductors & Capacitors, and Harnesses (wiring). The internal housing group includes any additional structural components found inside the unit once disassembled. The Buss Bars group includes any stamped metal components providing electrical connections between devices internal to the module. The PCBA group contains all of the printed circuit boards associated with the inverter assembly. The Inductors and capacitors group includes additional electronic components associated with the inverter. The last group Harnesses includes all internal wiring components connecting the various components in the inverter.

Figure C-29 Toyota Inverter



The total “should cost” to manufacture the Toyota Inverter group is estimated and additional typical markups associated with component manufacturing added.

Table C-15 Toyota Inverter Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Prius PCU Motor Controller

MUNRO & ASSOCIATES, INC.

	Prius PCU Motor Controller
Parts	1,831
Steps	4,889
Actual Time	3,533.37 sec
Fasteners	68
Total Weight	4.49 kg
Piece Cost	$328.25
Total Labor Cost	$49.31
Q Burden	$5.66
Total Cost	$383.22
Annual Production	200000

Table C-16 Toyota Inverter Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		Prius PCU Inverter
Purchased Part Roll up Costs		$304.82
Raw Material Costs		$23.43
Processing Costs		$49.31
Scrap (Design Profit: Q-Burden)	1%	$5.66
SG&A % Applied Against Processing	7%	$3.45
Profit % Applied Against Raw & Processing	4%	$2.91
Logistics % Applied Against Sum of all Above	3%	$11.69
Patent/Royalty Fees % Applied Against Sum of all Above	13%	$52.72
Total % Mark Up / Total Cost	29%	$453.99
Total Weight (kg)		4.4874
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$2,277,500
Tooling Cost/part		$2.28
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$4,555,000
Tooling Cost/part		$4.56

Toyota Inverter: Internal Housing

The Toyota Inverter Internal Housing group consists of a load spring assembly and a spacer for the IGBT assembly. The load spring assembly safeguards the IGBT assembly during any vibrations. The spacers are placed in between the enclosure and the load spring to maintain the stiffness on the spring.

Figure C-30 Toyota Inverter: Internal Housing

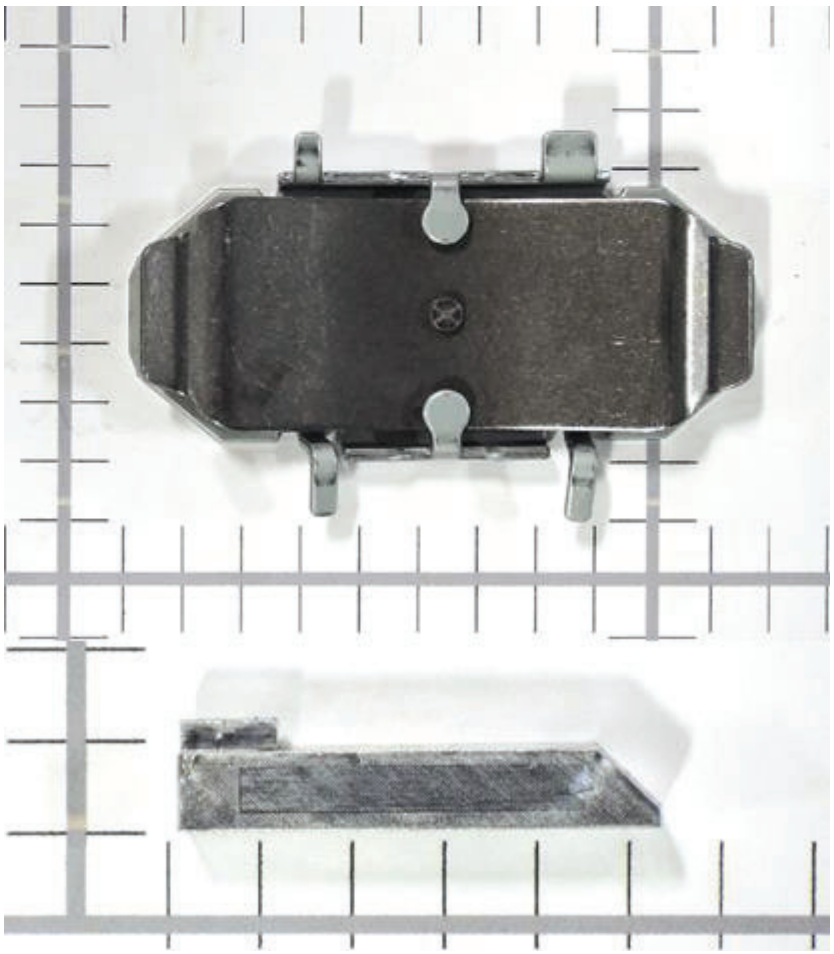


Table C-17 Toyota Inverter Internal Housings Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Prius Inverter Internal Housings

MUNRO & ASSOCIATES, INC.

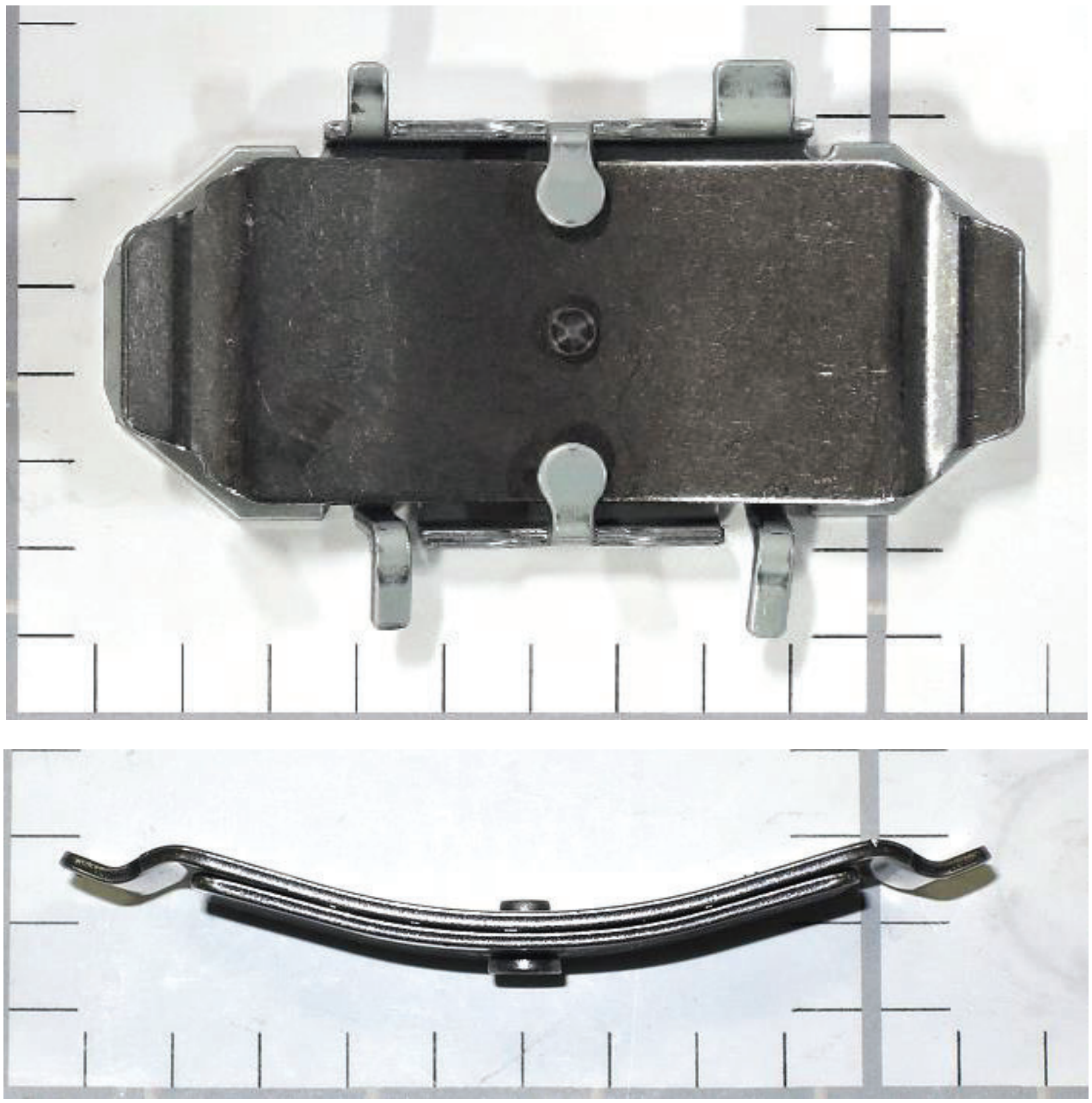
	Prius Inverter Internal Housings
Parts	17
Steps	97
Actual Time	161.43 sec
Fasteners	12
Total Weight	0.26 kg
Piece Cost	$0.84
Total Labor Cost	$2.05
Q Burden	$0.43
Total Cost	$3.33
Annual Production	200000

Table C-18 Toyota Inverter Internal Housings Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU Inverter Internal Housing	
Purchased Part Roll up Costs		$0.22
Raw Material Costs		$0.62
Processing Costs		$2.05
Scrap (Design Profit: Q-Burden)	15%	$0.43
SG&A % Applied Against Processing	7%	$0.14
Profit % Applied Against Raw & Processing	4%	$0.11
Logistics % Applied Against Sum of all Above	3%	$0.11
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.07
Total % Mark Up / Total Cost	31%	$3.76
Total Weight (kg)		0.2618
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$210,000
Tooling Cost/part		$0.21
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$420,000
Tooling Cost/part		$0.42

The load spring is an assembly consisting of 3 steel stamped plates and a rivet. Two of the plates are riveted together and the third plate acts as a bracket which allows the movement of the two plates within.

Figure C-31 Toyota Inverter: Internal Housings Cover and Frame: Load Spring Assembly (Top), and Load Spring Detail (Bottom)



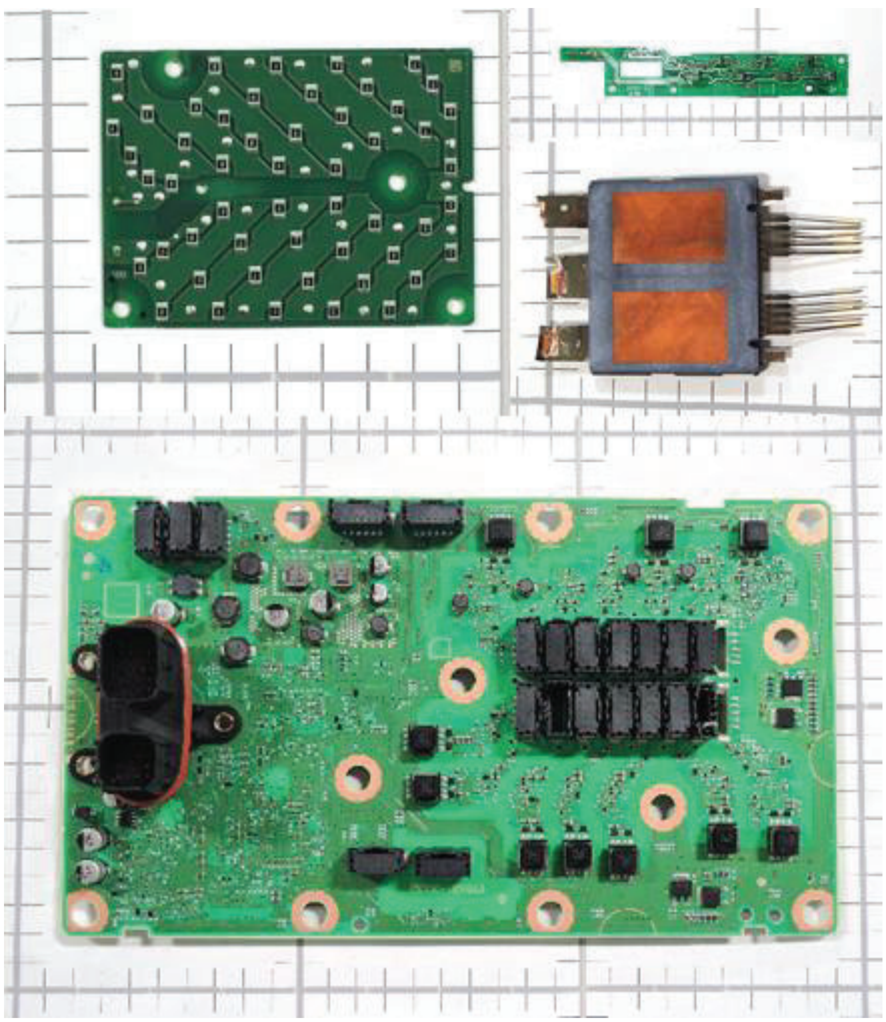
Toyota Inverter: Bus Bars

The Toyota inverter bus bar group consists of no additional components. The group was created for comparisons to similar groups analyzed in other portions of the project.

Toyota Inverter PCBAs & IGBTs

The Toyota Inverter Printed Circuit Board Assemblies (PCBAs) and IGBTs group consists of three printed circuit board assemblies and seven IGBTs. The three circuit boards are Current sensing board, main controller circuit board, resistor array board. There are 7 IGBTs; six for the two motors and one for the DC/DC Boost Converter that are slid in between the cooler assembly and are connected to the capacitor assembly.

Figure C-32 Toyota Inverter: PCBAs Group



The total "should cost" to manufacture the Toyota inverter PCBAs & IGBTs group is estimated and additional typical markups associated with component manufacturing added.

Figure C-33 Toyota Inverter PCBAs & IGBTs Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Prius Inverter PCBAs & IGBTs

MUNRO & ASSOCIATES, INC.

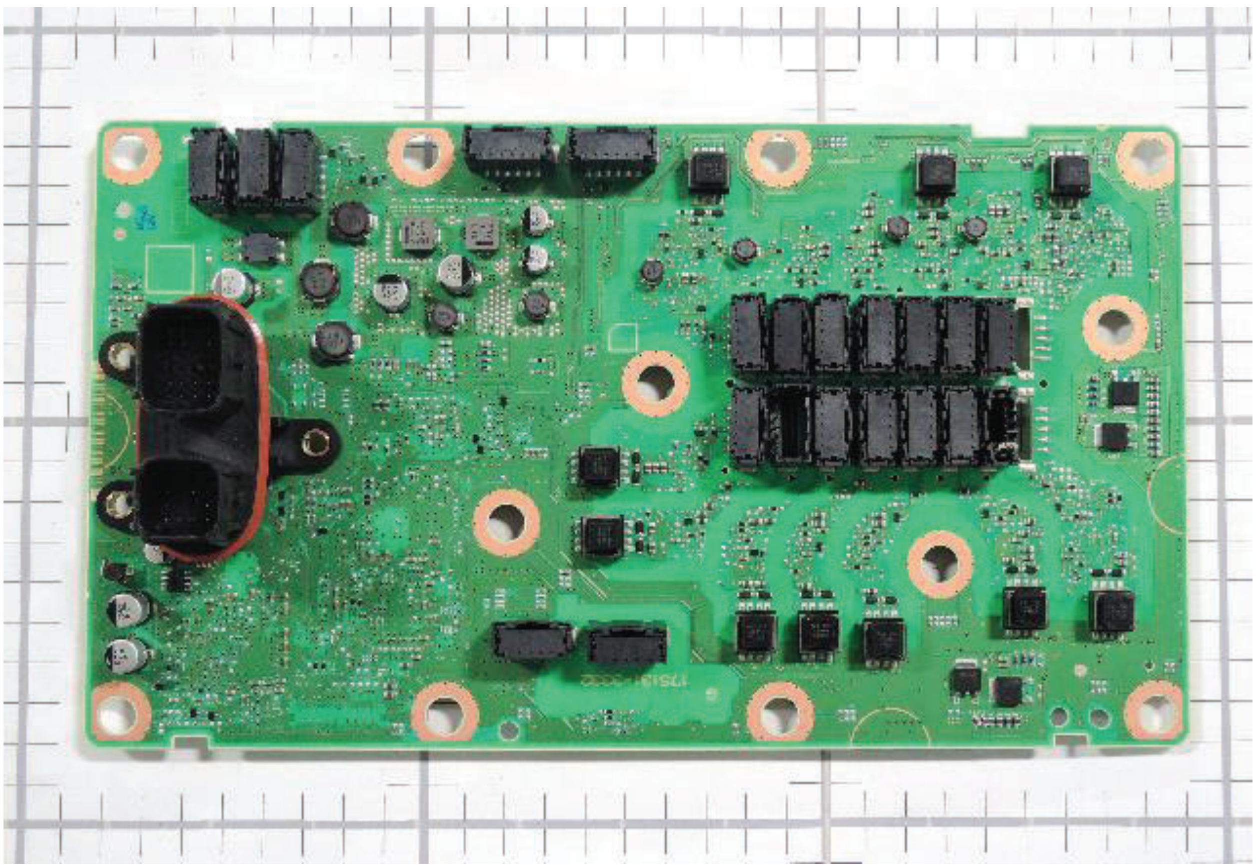
	Prius Inverter PCBAs & IGBTs
Parts	1,577
Steps	3,126
Actual Time	1,330.79 sec
Fasteners	21
Total Weight	1.01 kg
Piece Cost	$246.22
Total Labor Cost	$26.72
Q Burden	$2.58
Total Cost	$275.52
Annual Production	200000

Figure C-34 Toyota Inverter PCBAs & IGBTs Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU Inverter PCBAs & IGBTs	
Purchased Part Roll up Costs		$243.28
Raw Material Costs		$2.94
Processing Costs		$26.72
Scrap (Design Profit: Q-Burden)	1%	$2.58
SG&A % Applied Against Processing	7%	$1.87
Profit % Applied Against Raw & Processing	4%	$1.19
Logistics % Applied Against Sum of all Above	3%	$8.36
Patent/Royalty Fees % Applied Against Sum of all Above	15%	$43.04
Total % Mark Up / Total Cost	30%	$329.98
Total Weight (kg)		1.009
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$62,500
Tooling Cost/part		$0.06
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$125,000
Tooling Cost/part		$0.13

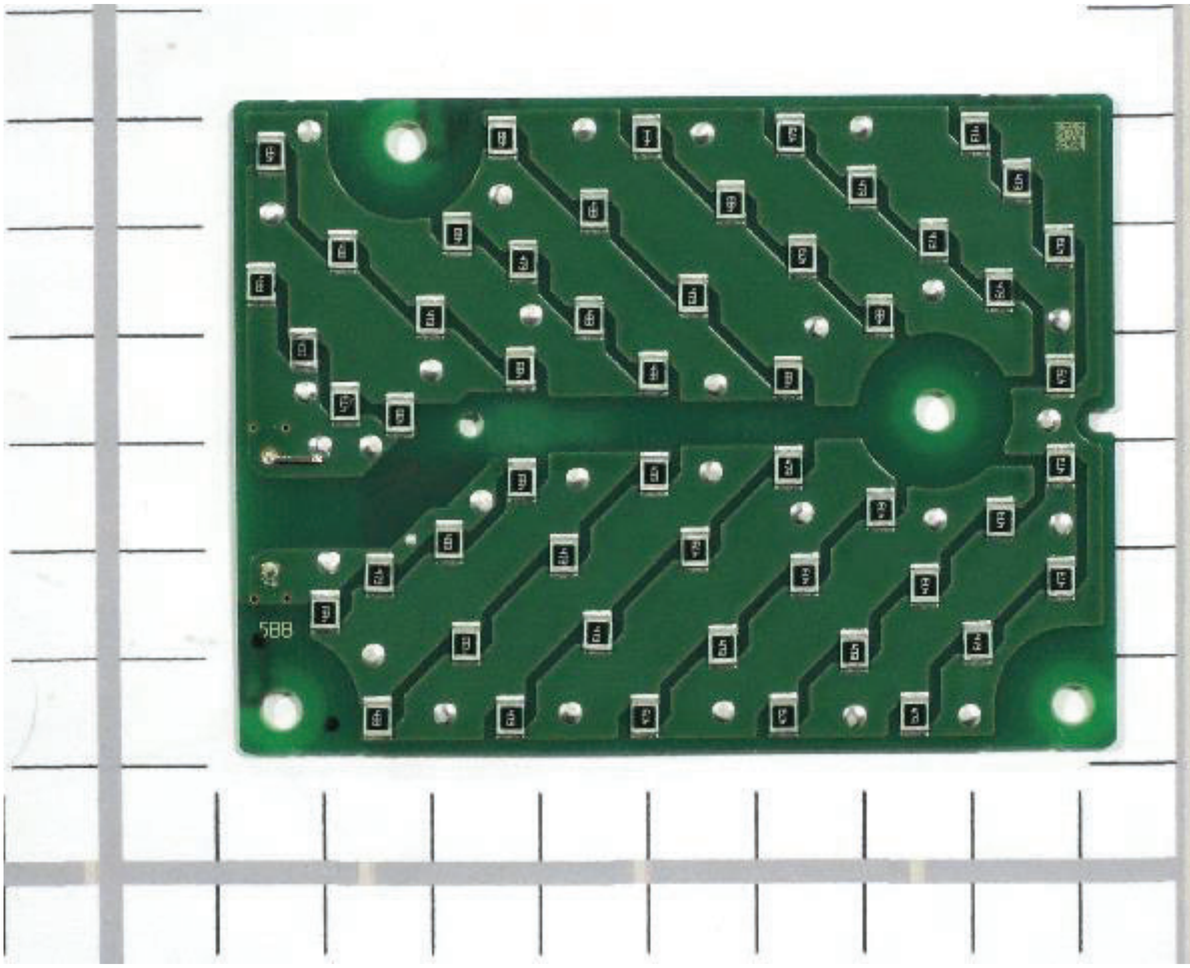
The main controller circuit board included the following components which are identified as the having the highest cost: 1 – 6 Layer FR4 Printed Circuit Board, 2 - 32-Bit 120MHz Microcontroller ICs, 1 - 16-bit H8S ROMLess MCU, 1 - Automotive 24 & 13 pin Dual Male Connector, 2 – Wide Range Synchronous Buck Controllers, 2 - 60V 22A N-CH MOSFETs. The board also has 21 hybrid automotive connectors by which the pins from the IGBTs, capacitor assembly and connector are connected. Additional components on the board include MOSFETs, inductors, rectifiers, resistors, capacitors and diodes. The dual connector can be seen on the left side of the image below.

Figure C-35 Toyota Inverter: Main Controller Circuit Board



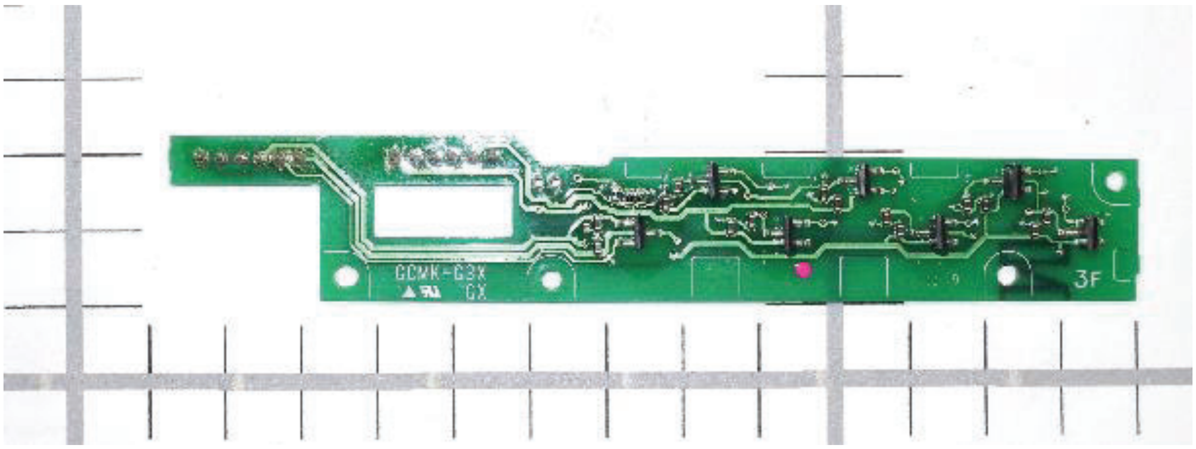
The resistor array circuit board included 1 - Dual Layer Printed FR4 Circuit Board, and 52 - 1210 5% Tolerance Resistors.

Figure C-36 Toyota Inverter: Resistor Array Circuit Board



The current sensing circuit board included the following components: 7 - Hall Effect Single Axis Sensors, 1 – Dual Layer Printed FR4 Circuit Board, 14 - 0603 0% Tolerance Capacitors and 3 – 0603 5% Tolorance Resistors.

Figure C-37 Toyota Inverter: Current Sensing Circuit Board



There are 7 Double Sided Cooled IGBTs which are slid in between the cooler assembly cooling plates. The image is shown in the image below. To ensure that the IGBTs transfer heat to the cooler Alumina Nitride (AlN) shims are placed on both sides of the IGBT, thus summing up to a total of 14 shims for the entire assembly. Heat sink compound is applied on the shims for increased heat transfer.

Figure C-38 Toyota Inverter: IGBTs Assembled to IGBT Cooler

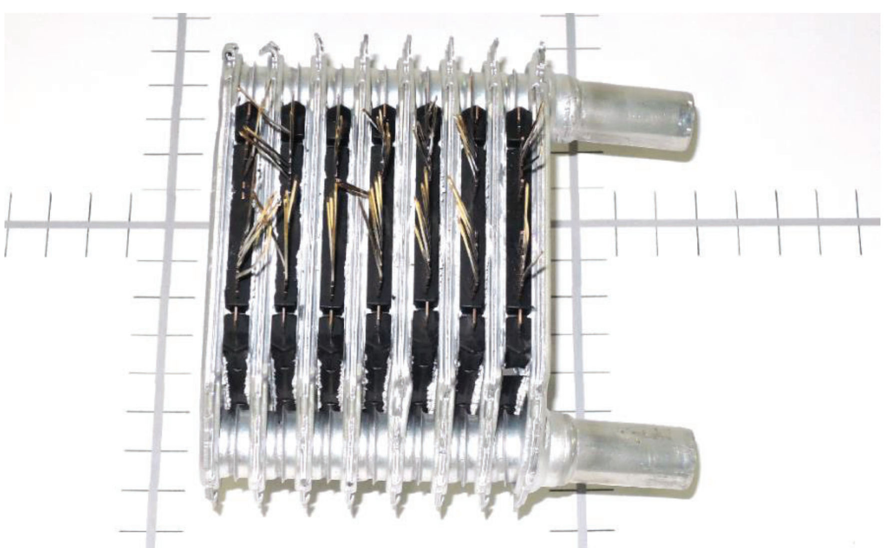
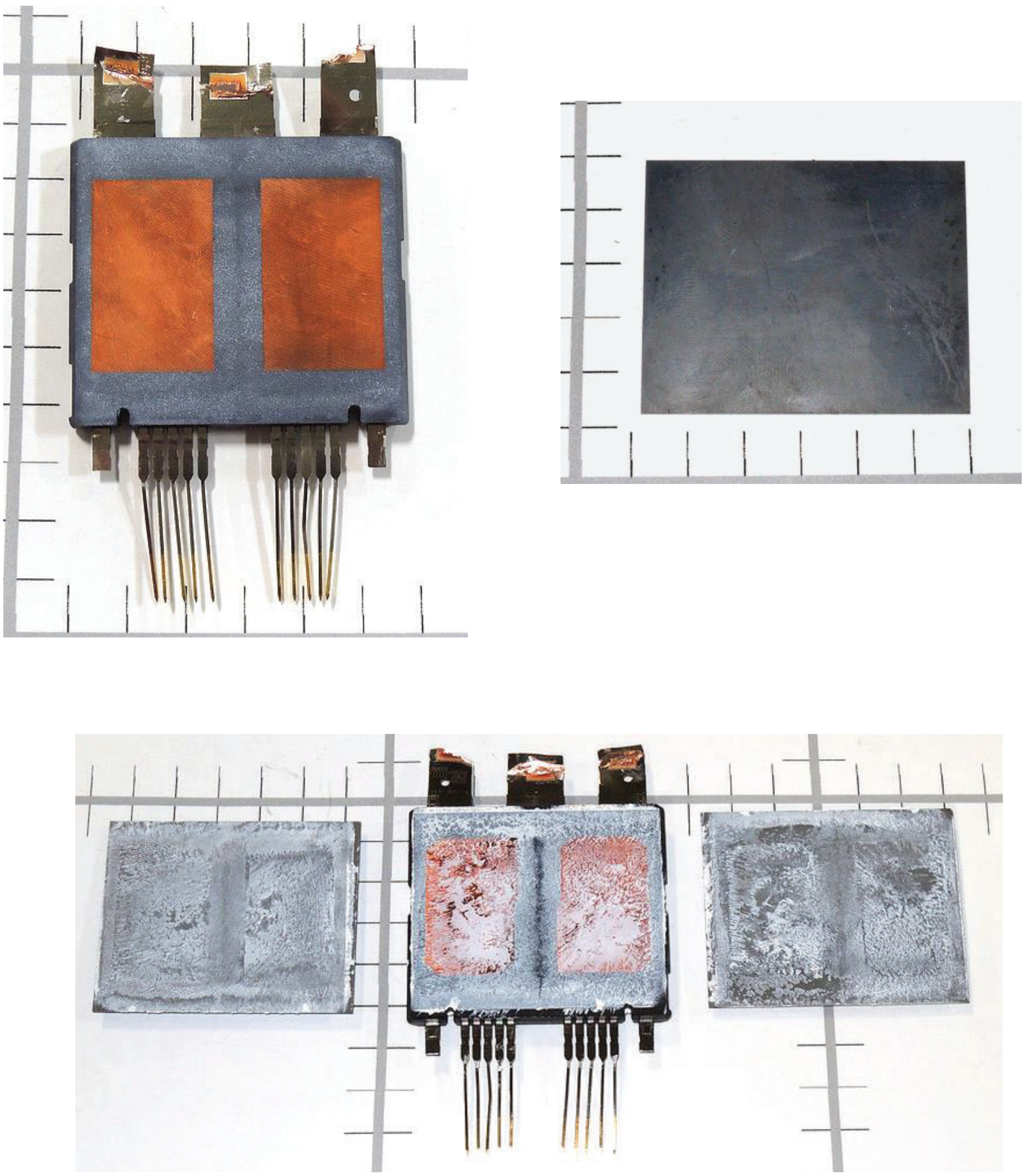


Figure C-39 Toyota Inverter: Dual Sided Cooling IGBT (Top Left), Alumina Nitride (AIN) Thermal Shim (Top Right), and IGBT with Shims Coated with Heat Sink Compound (Bottom)



Toyota Inverter Capacitor & Inductor

The Toyota inverter capacitor & inductors group consisted of two capacitor assemblies, and an inductor assembly. The capacitor assemblies are potted assemblies inside plastic housings. The inductor assembly is an over-molded assembly which has a pair of copper windings around a two-piece core.

Figure C-40 Toyota Inverter: Ferrites & Inductor Group

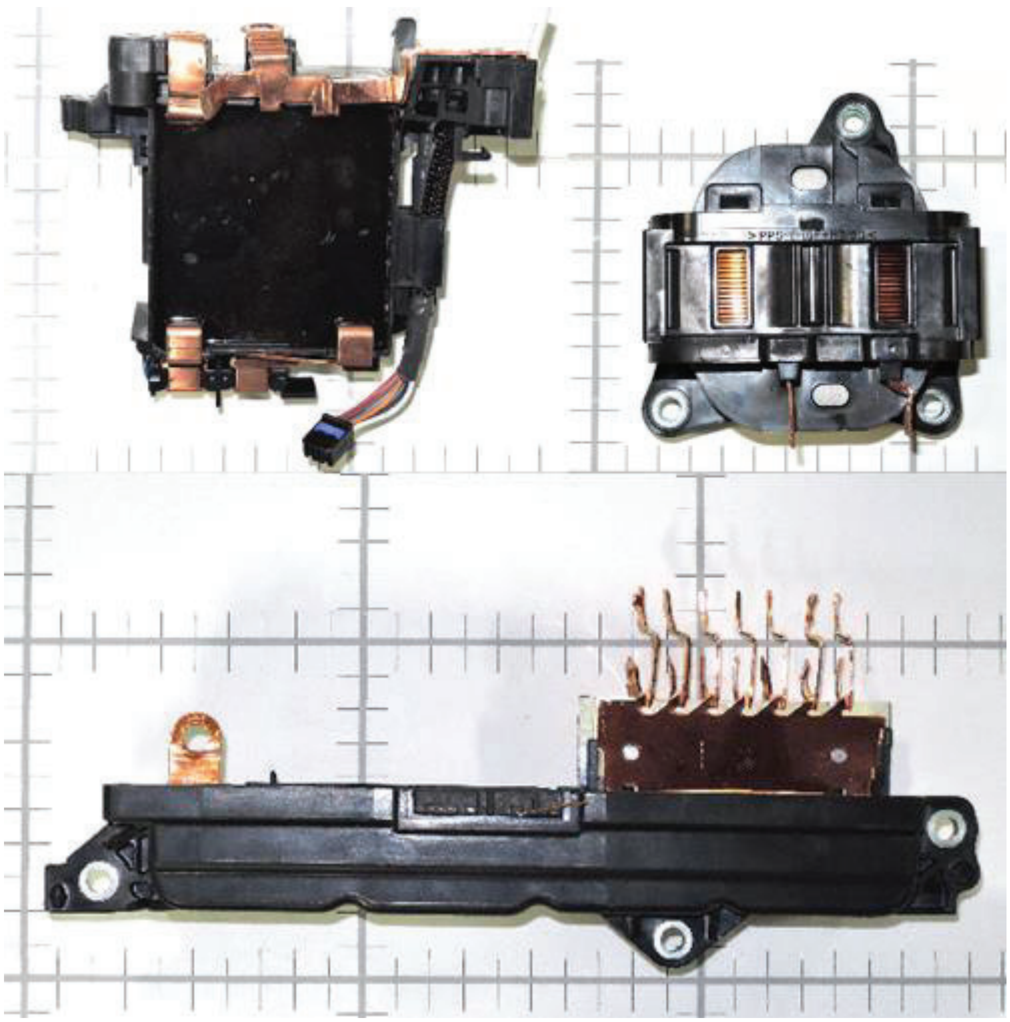


Table C-19 Toyota Inverter Capacitor & Inductor Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Prius Inverter Capacitor &

MUNRO & ASSOCIATES, INC.

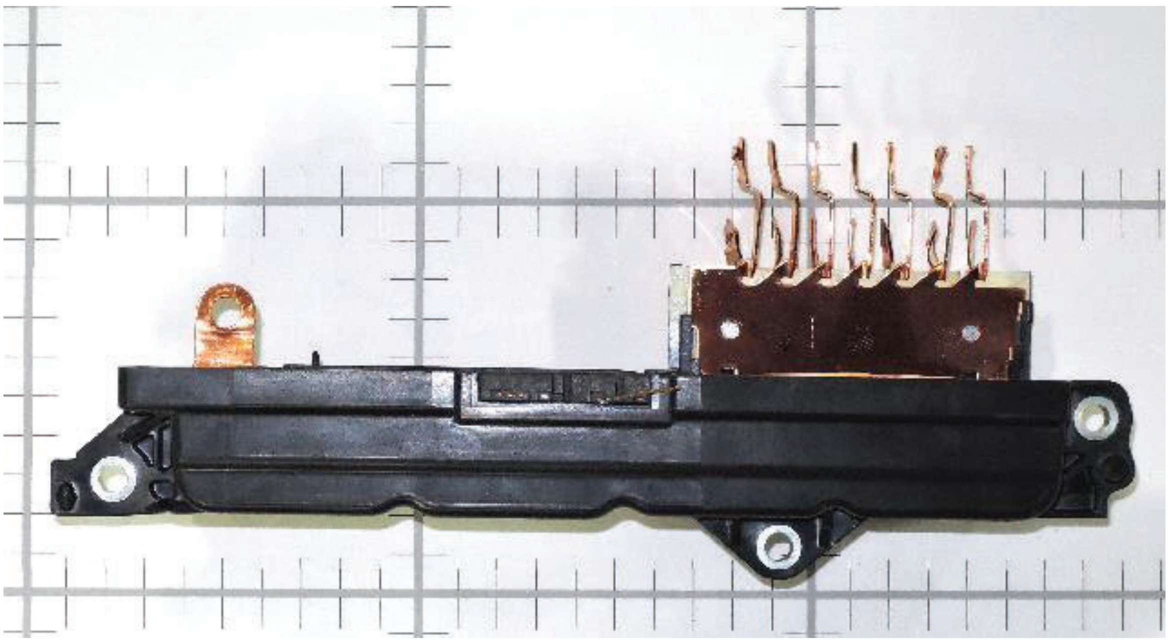
	Prius Inverter Capacitor & Inductor
Parts	72
Steps	480
Actual Time	1,198.63 sec
Fasteners	18
Total Weight	2.77 kg
Piece Cost	$73.56
Total Labor Cost	$13.29
Q Burden	$0.91
Total Cost	$87.76
Annual Production	200000

Table C-20 Toyota Inverter Capacitor & Inductor Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		Prius PCU Inverter Capacitor & Inductor
Purchased Part Roll up Costs		$59.71
Raw Material Costs		$13.85
Processing Costs		$13.29
Scrap (Design Profit: Q-Burden)	1%	$0.91
SG&A % Applied Against Processing	7%	$0.93
Profit % Applied Against Raw & Processing	4%	$1.09
Logistics % Applied Against Sum of all Above	3%	$2.69
Patent/Royalty Fees % Applied Against Sum of all Above	10%	$9.25
Total % Mark Up / Total Cost	25%	$101.72
Total Weight (kg)		2.7721
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,010,000
Tooling Cost/part		$1.01
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$2,020,000
Tooling Cost/part		$2.02

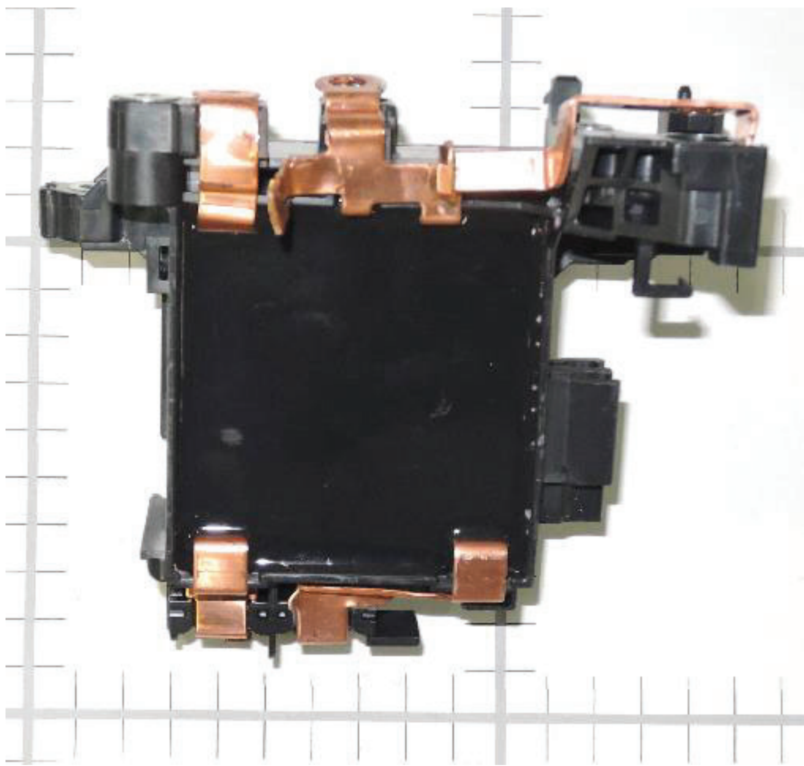
The main capacitor assembly included the capacitor pack, a plastic housing, stamped copper plates and epoxy potting compound in a plastic housing. The capacitor pack is a large metalized Polypropylene (PP) film design with four wound film capacitors connected in parallel. The capacitors are connected with stamped copper plates. Two plastic forms and a paper insulator are utilized to route and insulate the copper stampings. The capacitor housing is a 3-piece housing and is assumed to be injection molded >PPS GF MD<. The capacitor assembly is vacuum potted with epoxy after being placed in the housing.

Figure C-41 Toyota Inverter: Capacitor Assembly



The second capacitor assembly included the capacitor pack, a plastic housing, stamped copper plates and epoxy potting compound in a plastic housing. The capacitor pack is a large wound metalized Polypropylene (PP) film design. The metalized polymer is connected electrically with stamped copper plates. The capacitor housing is an injection molded >PPS GF MD<. The capacitor assembly is vacuum potted with epoxy after being placed in the housing.

Figure C-42 Toyota Inverter: Capacitor Assembly



The inductor assembly consists of a pair of copper windings which are wound around a pair of ferrites cores. The cores are assumed to be manufactured through a powdered metal process. The copper windings are wound around plastic bobbins. The cores then secured in place within the wound bobbins with the use of adhesive. This inductor assembly is then over-molded with >PPS GF MD< to form the housing.

Figure C-43 Toyota Inverter: Inductor

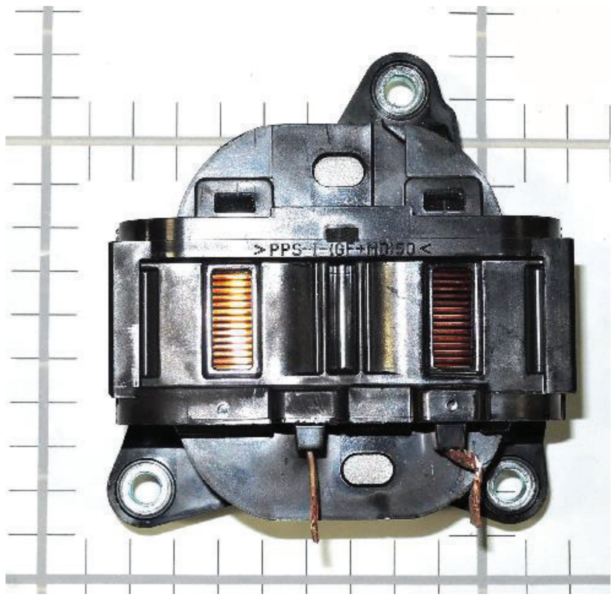
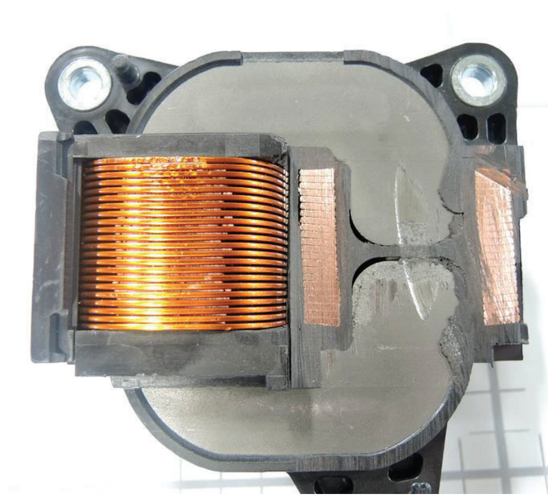


Figure C-44 Toyota Inverter: Inductor Section View



Toyota inverter: Electrical & Harness

The Toyota Inverter Electrical & Harness group consists of a receptacle cover assembly, a wire harness and a lead frame assembly. The harness connects the connector on the control board to the DC/DC main circuit board. The lead frame connects to the IGBTs, the motor controller and the current sensors.

Figure C-45 Toyota Inverter: Electrical & Harness Group

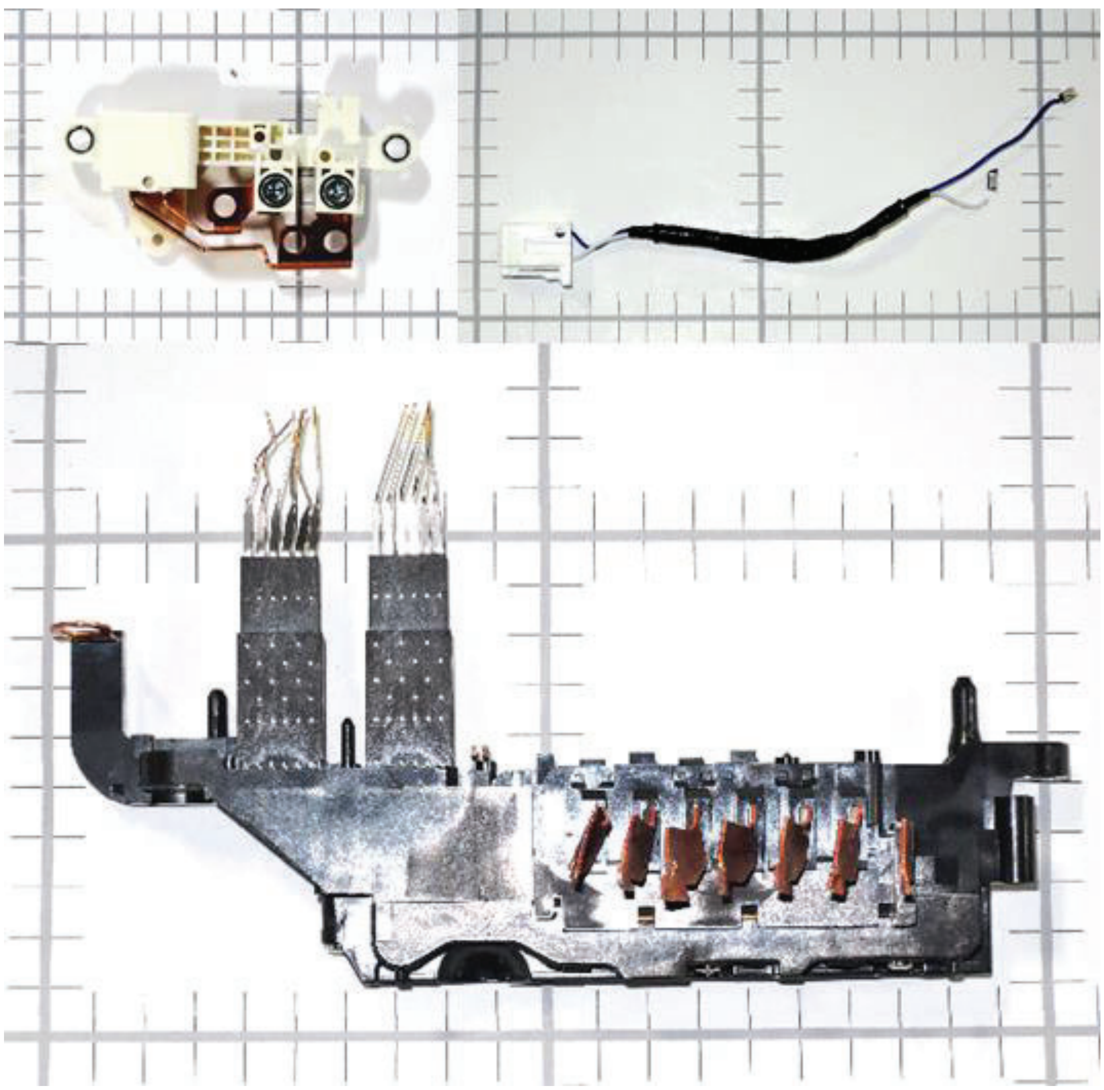


Table C-21 Toyota Inverter Electrical & Harness Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Prius Inverter Electrical &

MUNRO & ASSOCIATES, INC.

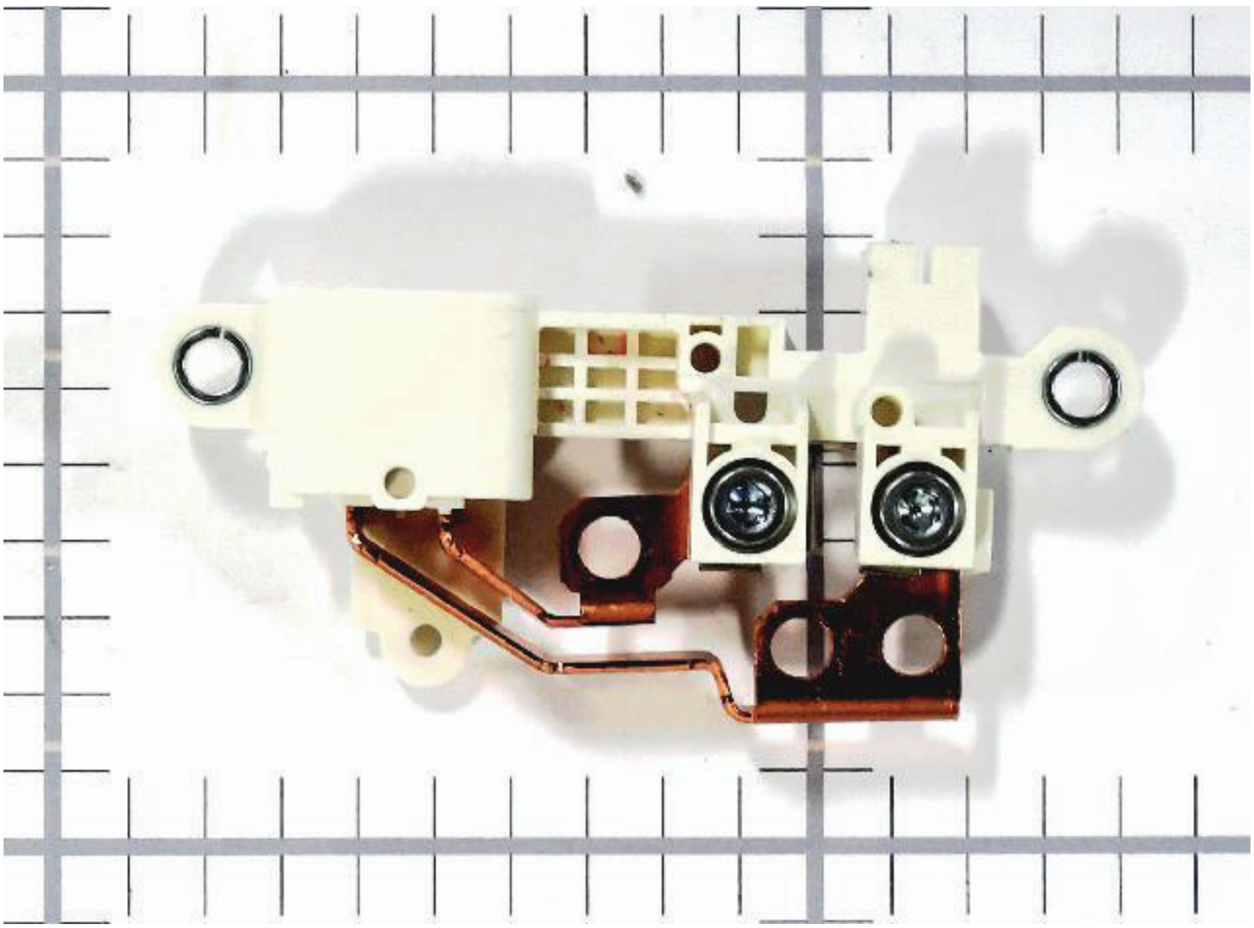
	Prius Inverter Electrical & Harness
Parts	165
Steps	1,186
Actual Time	842.52 sec
Fasteners	17
Total Weight	0.45 kg
Piece Cost	$7.62
Total Labor Cost	$7.25
Q Burden	$1.74
Total Cost	$16.61
Annual Production	200000

Table C-22 Toyota Inverter Electrical & Harness Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	Prius PCU Inverter Electrical & Harness	
Purchased Part Roll up Costs		$1.60
Raw Material Costs		$6.02
Processing Costs		$7.25
Scrap (Design Profit: Q-Burden)	12%	$1.74
SG&A % Applied Against Processing	7%	$0.51
Profit % Applied Against Raw & Processing	4%	$0.53
Logistics % Applied Against Sum of all Above	3%	$0.53
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.36
Total % Mark Up / Total Cost	28%	$18.54
Total Weight (kg)		0.4444
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$995,000
Tooling Cost/part		$1.00
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,990,000
Tooling Cost/part		$1.99

The receptacle cover consists of two copper bus bars, two connector plates, cover housing and fasteners to attach to the enclosure. The bus bars are assumed to be stamped copper plates. The connector plates are assumed to be stamped nickel coated copper plates. The plastic housing is considered to be injection molded out of glass filled Polybutylene Terephthalate.

Figure C-46 Toyota Inverter: Receptacle Cover Assembly



The lead frame assembly consists of stamped copper leads, connector pins and a plastic housing which also has stacked metal laminate cores over- molded. There are seven leads which are assumed to be stamped copper plates. There are 14 connector pins which connect to the current sensor board, 12 are connected to the main controller circuit board while the two remaining connector pins get connected to the IGBT circuit. There is also a plastic holder for the lead frame terminals which is assumed to be >PPS GF MD<. The housing for the lead frame is an injection molded >PPS GF MD< with seven laminated cores inserted and over-molded. Each core consists of 14 stamped steel plates pressed together.

Figure C-47 Toyota Inverter: Lead Frame Assembly

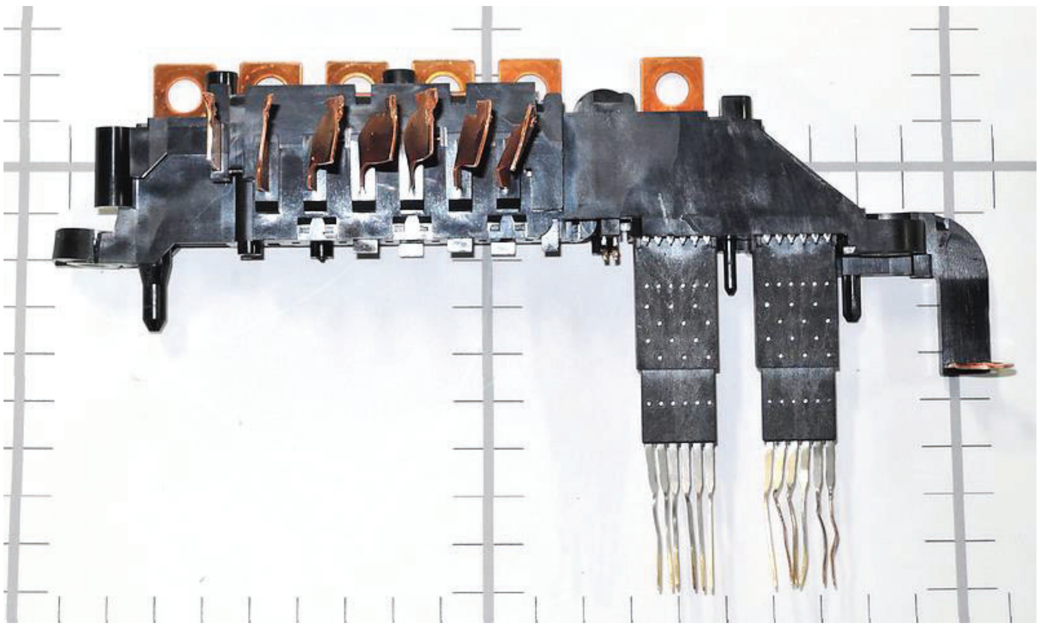


Figure C-48 Toyota Inverter: Lead Frame Sectioned with Laminated Cores. Note slot for Hall Current Sensor to be inserted

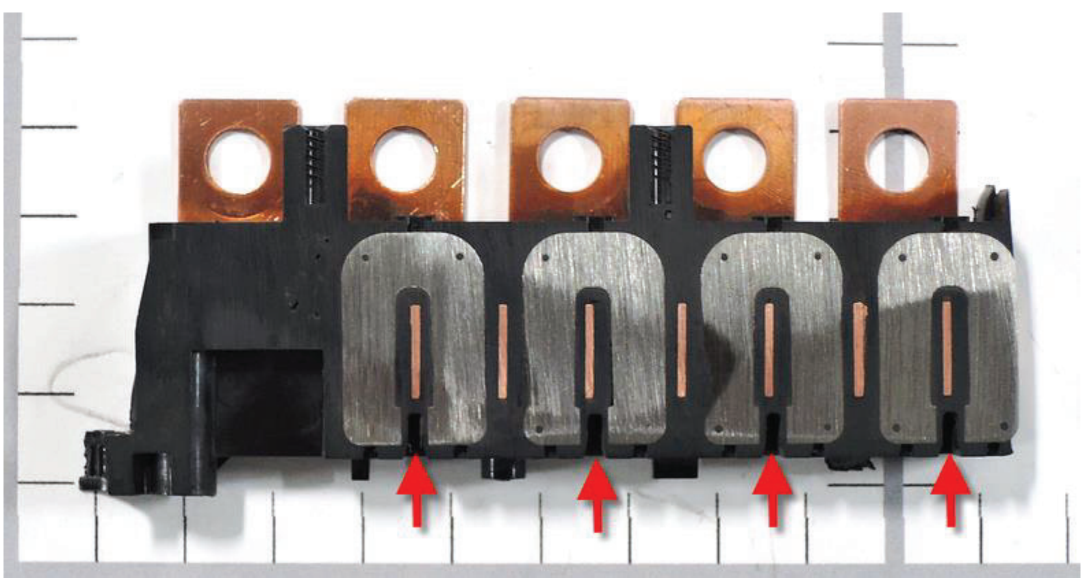


Table C-23 Toyota Power Inverter Enclosures & Cooling Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Preprocessed Part	1624-109	Enclosure Main 2	Aluminum A380, Cast
2	3	Manufacturing Steps		Enclosure Main 2 Processing	
3	4	Manufacturing Process		Wash	
4	4	Manufacturing Process		Debur	
5	4	Manufacturing Process		Machining	
6	4	Manufacturing Process		Trim Press	
7	4	Manufacturing Process		Die Cast, 840 Ton	
8	5	Part	1624-109 Material	Material, Enclosure Main 2	Aluminum A380, Cast
9	2	Subassembly	1624-103	Enclosure Main 1 Asm	(None)
10	3	Preprocessed Part	1624-103_1	Enclosure Main 1	Aluminum A380, Cast
11	4	Manufacturing Steps		Enclosure Main 1 Processing	
12	5	Manufacturing Process		Wash	
13	5	Manufacturing Process		Debur	
14	5	Manufacturing Process		Machining	
15	5	Manufacturing Process		Trim Press	
16	5	Manufacturing Process		Die Cast, 840 Ton	
17	6	Part	1624-103_1 Material	Material, Enclosure Main 1	Aluminum A380, Cast
18	3	Part	1624-103_2	M8x1.25, 7mm Reverse Thread Circular Standoff	Commodity Item
19	3	Manufacturing Steps		Assemble Enclosure Main Asm 1	
20	4	Manufacturing Process		Auto Assembly	
21	2	Preprocessed Part	1624-69	Enclosure Bottom Cover	Steel, Galvanized G60
22	3	Manufacturing Steps		Enclosure Bottom Cover Processing	
23	4	Manufacturing Process		Wash	
24	4	Manufacturing Process		Debur	
25	4	Manufacturing Process		Stamping Press 1000 Ton	
26	5	Part	1624-69 Material	Material, Enclosure Bottom Cover	Steel, Galvanized G60

Row	Level	Symbol Type	Number	Name	Material Name
27	2	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
28	2	Part	1624-69_3	Silicone Sealant	Commodity Item
29	2	Manufacturing Steps		Assemble Enclosure Bottom and Inverter Module	
30	3	Manufacturing Process		Auto Assembly	
31	2	Subassembly	1624-71	Coolant Passage Cover 2 Asm	(None)
32	3	Preprocessed Part	1624-71_1	Coolant Passage Cover 2	PA 610+PA 66- GF35
33	4	Manufacturing Steps		Coolant Passage Cover 2 Processing	
34	5	Manufacturing Process		Injection Mold Press, 55 Ton	
35	6	Part	1624-71_1 Material	Material, Coolant Passage Cover 2	PA 610+PA 66- GF35
36	3	Part	1624-71_2	O-Ring 14mm ID	Commodity Item
37	3	Part	1624-71_3	Plastic O-Ring 14mm ID	Commodity Item
38	3	Part	1624-71_5	O-Ring 33mm ID	Commodity Item
39	3	Part	1624-71_4	Metal Spacer	Commodity Item
40	3	Manufacturing Steps		Assemble Coolant Passage Cover 2 Asm	
41	4	Manufacturing Process		Manual Assembly	
42	4	Manufacturing Process		Auto Press Station	
43	2	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
44	2	Manufacturing Steps		Assemble Coolant Passage Cover 1 Asm & Power Inver	
45	3	Manufacturing Process		Auto Assembly	
46	2	Subassembly	1624-70	Coolant Passage Cover 1 Asm	(None)
47	3	Subassembly	1624-70_1	Coolant Passage Cover 1 Asm	(None)
48	4	Preprocessed Part	1624-70_1a	Coolant Passage Cover Top	PA 610+PA 66- GF35
49	5	Manufacturing Steps		Coolant Passage Cover Top Processing	
50	6	Manufacturing Process		Injection Mold Press, 55 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
51	7	Part	1624-70_1a Material	Material, Coolant Passage Cover 1 Top	PA 610+PA 66- GF35
52	4	Preprocessed Part	1624-70_1b	Coolant Passage Cover Bottom	PA 610+PA 66- GF35
53	5	Manufacturing Steps		Coolant Passage Cover Bottom Processing	
54	6	Manufacturing Process		Injection Mold Press, 55 Ton	
55	7	Part	1624-70_1b Material	Material, Coolant Passage Cover Bottom	PA 610+PA 66- GF35
56	4	Manufacturing Steps		Assemble Coolant Passage Cover Sub Asm	
57	5	Manufacturing Process		Auto Assembly	
58	3	Part	1624-70_2	O-Ring 14mm ID	Commodity Item
59	3	Part	1624-70_3	O-Ring 21mm ID	Commodity Item
60	3	Part	1624-71_4	Metal Spacer	Commodity Item
61	3	Manufacturing Steps		Assemble Coolant Passage Cover 1 Asm	
62	4	Manufacturing Process		Manual Assembly	
63	4	Manufacturing Process		Auto Press Station	
64	2	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
65	2	Manufacturing Steps		Assemble Coolant Passage Cover 1 & Power Inverter	
66	3	Manufacturing Process		Auto Assembly	
67	2	Subassembly	1624-72	Coolant Inlet/Outlet, Cover 2 Asm	(None)
68	3	Preprocessed Part	1624-72_1	Coolant Inlet/Outlet Cover	PA 610+PA 66- GF35
69	4	Manufacturing Steps		Coolant Inlet/Outlet Cover Processing	
70	5	Manufacturing Process		Injection Mold Press, 55 Ton	
71	6	Part	1624-72_1 Material	Material, Coolant Inlet/Outlet Cover	PA 610+PA 66- GF35
72	3	Part	1624-71_2	O-Ring 14mm ID	Commodity Item
73	3	Part	1624-71_3	Plastic O-Ring 14mm ID	Commodity Item
74	3	Part	1624-71_5	O-Ring 14mm ID	Commodity Item
75	3	Part	1624-71_4	Metal Spacer	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
76	3	Manufacturing Steps		Assemble Coolant Inlet/Outlet Cover Asm	
77	4	Manufacturing Process		Manual Assembly	
78	4	Manufacturing Process		Auto Press Station	
79	2	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
80	2	Manufacturing Steps		Assemble Coolant Inlet/Oulet Cover 2 to Inverter	
81	3	Manufacturing Process		Auto Assembly	
82	2	Preprocessed Part	1624-66_1	Enclosure Top Cover Bracket	Steel 1020 Cold Drawn or Cold Rolled
83	3	Manufacturing Steps		Enclosure Top Cover Brakcet Processing	
84	4	Manufacturing Process		Paint Curing	
85	4	Manufacturing Process		Paint	
86	5	Part	1624-66_1 Paint	Paint, Enclosure Top Cover Bracket	E Coat Black Protection Solids & Resins
87	4	Manufacturing Process		Wash	
88	4	Manufacturing Process		Debur	
89	4	Manufacturing Process		Stamping Press, 60 Ton	
90	5	Part	1624-66_1, Material	Material, Enclosure Top Cover Bracket	Steel 1020 Cold Drawn or Cold Rolled
91	2	Part	1624-66_2	M6 x 1.00, 20 mm, Self Threading Hex w/ Captured W	Commodity Item
92	2	Part	1624-66_5	Label 41x33mm, Enclosure Top Cover	Commodity Item
93	2	Part	1624-66_8	Label 41x33mm, Protective Film	Commodity Item
94	2	Part	1624-66_6	Label, 68x33mm, Enclosure Top Cover	Commodity Item
95	2	Preprocessed Part	1624-66	Enclosure Top Cover	Steel 1020 Cold Drawn or Cold Rolled
96	3	Manufacturing Steps		Enclosure Top Cover Processing	
97	4	Manufacturing Process		Paint Curing	
98	4	Manufacturing Process		Paint	
99	5	Part	1624-66 Paint	Paint, Enclosure Top Cover	E Coat Black Protection Solids & Resins

Row	Level	Symbol Type	Number	Name	Material Name
100	4	Manufacturing Process		Wash	
101	4	Manufacturing Process		Debur	
102	4	Manufacturing Process		Stamping Press, 300 Ton	
103	5	Part	1624-66, Material	Material, Enclosure Top Cover	Steel 1020 Cold Drawn or Cold Rolled
104	2	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
105	2	Part	1624-69_3	Silicone Sealant	Commodity Item
106	2	Manufacturing Steps		Assemble Enclosure Top Cover and Bracket	
107	3	Manufacturing Process		Manual Assembly	
108	3	Manufacturing Process		Auto Assembly	
109	2	Subassembly	703-1049	Power Inverter Bracket 1 Asm	(None)
110	3	Preprocessed Part	703-1049_2	Bracket 1	Steel 1010 Cold Drawn or Cold Rolled
111	4	Manufacturing Steps		Bracket 1 Processing	
112	5	Manufacturing Process		Wash	
113	5	Manufacturing Process		Debur	
114	5	Manufacturing Process		Stamping Press 300 Ton	
115	6	Part	703-1049_2 Material	Material, Bracket 1	Steel 1010 Cold Drawn or Cold Rolled
116	3	Subassembly	703-1049_3	Ground Strap Asm	(None)
117	4	Preprocessed Part	703-1049_3a	Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
118	5	Manufacturing Steps		Ground Strap A Processing	
119	6	Manufacturing Process		Wash	
120	6	Manufacturing Process		Debur	
121	6	Manufacturing Process		Stamping Press 25 Ton	
122	7	Part	703-1049_3a Material	Material, Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
123	4	Preprocessed Part	703-1049_3b	Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
124	5	Manufacturing Steps		Ground Strap B Processing	
125	6	Manufacturing Process		Wash	
126	6	Manufacturing Process		Debur	
127	6	Manufacturing Process		Stamping Press 25 Ton	
128	7	Part	703-1049_3b Material	Material, Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
129	4	Part	703-1049_3c	Wire Mesh	Commodity Item
130	4	Manufacturing Steps		Assemble Ground Strap	

Row	Level	Symbol Type	Number	Name	Material Name
131	5	Manufacturing Process		Auto Assembly	
132	3	Subassembly	703-1049_3	Ground Strap Asm	(None)
133	4	Preprocessed Part	703-1049_3a	Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
134	5	Manufacturing Steps		Ground Strap A Processing	
135	6	Manufacturing Process		Wash	
136	6	Manufacturing Process		Debur	
137	6	Manufacturing Process		Stamping Press 25 Ton	
138	7	Part	703-1049_3a Material	Material, Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
139	4	Preprocessed Part	703-1049_3b	Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
140	5	Manufacturing Steps		Ground Strap B Processing	
141	6	Manufacturing Process		Wash	
142	6	Manufacturing Process		Debur	
143	6	Manufacturing Process		Stamping Press 25 Ton	
144	7	Part	703-1049_3b Material	Material, Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
145	4	Part	703-1049_3c	Wire Mesh	Commodity Item
146	4	Manufacturing Steps		Assemble Ground Strap	
147	5	Manufacturing Process		Auto Assembly	
148	3	Preprocessed Part	703-1049_4a	Ground Strap Bracket	Steel 1010 Cold Drawn or Cold Rolled
149	4	Manufacturing Steps		Ground Strap Bracket Processing	
150	5	Manufacturing Process		Wash	
151	5	Manufacturing Process		Debur	
152	5	Manufacturing Process		Stamping Press 25 Ton	
153	6	Part	703-1049_4a Material	Material, Ground Strap Bracket	Steel 1010 Cold Drawn or Cold Rolled
154	3	Preprocessed Part	703-1049_4a	Ground Strap Bracket	Steel 1010 Cold Drawn or Cold Rolled
155	4	Manufacturing Steps		Ground Strap Bracket Processing	
156	5	Manufacturing Process		Wash	
157	5	Manufacturing Process		Debur	
158	5	Manufacturing Process		Stamping Press 25 Ton	
159	6	Part	703-1049_4a Material	Material, Ground Strap Bracket	Steel 1010 Cold Drawn or Cold Rolled
160	3	Part	703-1049_5	Rubber Coated Metal Bush, Small	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
161	3	Manufacturing Steps		Power Inverter Bracket 1 Asm Processing	
162	4	Manufacturing Process		Spot Weld	
163	4	Manufacturing Process		Auto Assembly	
164	2	Subassembly	703-1073	Power Inverter Bracket 2 Asm	(None)
165	3	Preprocessed Part	703-1073_1	Bracket 2	Steel 1010 Cold Drawn or Cold Rolled
166	4	Manufacturing Steps		Bracket 2 Processing	
167	5	Manufacturing Process		Wash	
168	5	Manufacturing Process		Debur	
169	5	Manufacturing Process		Stamping Press 200 Ton	
170	6	Part	703-1073_1 Material	Material, Bracket 2	Steel 1010 Cold Drawn or Cold Rolled
171	3	Preprocessed Part	703-1073_2	Support Bracket Left	Steel 1010 Cold Drawn or Cold Rolled
172	4	Manufacturing Steps		Support Bracket Left Processing	
173	5	Manufacturing Process		Wash	
174	5	Manufacturing Process		Debur	
175	5	Manufacturing Process		Stamping Press 200 Ton	
176	6	Part	703-1073_2 Material	Material, Support Bracket Left	Steel 1010 Cold Drawn or Cold Rolled
177	3	Preprocessed Part	703-1073_3	Support Bracket Right	Steel 1010 Cold Drawn or Cold Rolled
178	4	Manufacturing Steps		Support Bracket Right Processing	
179	5	Manufacturing Process		Wash	
180	5	Manufacturing Process		Debur	
181	5	Manufacturing Process		Stamping Press 60 Ton	
182	6	Part	703-1073_3 Material	Material, Support Bracket Right	Steel 1010 Cold Drawn or Cold Rolled
183	3	Subassembly	703-1073_4	Support Bracket Center Asm	(None)
184	4	Preprocessed Part	703-1073_4a	Support Bracket Center	Steel 1010 Cold Drawn or Cold Rolled
185	5	Manufacturing Steps		Support Bracket Center Processing	
186	6	Manufacturing Process		Wash	
187	6	Manufacturing Process		Debur	
188	6	Manufacturing Process		Stamping Press 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
189	7	Part	703-1073_4a Material	Material, Support Bracket Center	Steel 1010 Cold Drawn or Cold Rolled
190	4	Part	703-1073_4b	Support Bracket Center Stud	Commodity Item
191	4	Manufacturing Steps		Assemble Support Bracket and Stud	
192	5	Manufacturing Process		Spot Weld	
193	3	Subassembly	703-1049_3	Ground Strap Asm	(None)
194	4	Preprocessed Part	703-1049_3a	Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
195	5	Manufacturing Steps		Ground Strap A Processing	
196	6	Manufacturing Process		Wash	
197	6	Manufacturing Process		Debur	
198	6	Manufacturing Process		Stamping Press 25 Ton	
199	7	Part	703-1049_3a Material	Material, Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
200	4	Preprocessed Part	703-1049_3b	Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
201	5	Manufacturing Steps		Ground Strap B Processing	
202	6	Manufacturing Process		Wash	
203	6	Manufacturing Process		Debur	
204	6	Manufacturing Process		Stamping Press 25 Ton	
205	7	Part	703-1049_3b Material	Material, Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
206	4	Part	703-1049_3c	Wire Mesh	Commodity Item
207	4	Manufacturing Steps		Assemble Ground Strap	
208	5	Manufacturing Process		Auto Assembly	
209	3	Subassembly	703-1049_3	Ground Strap Asm	(None)
210	4	Preprocessed Part	703-1049_3a	Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
211	5	Manufacturing Steps		Ground Strap A Processing	
212	6	Manufacturing Process		Wash	
213	6	Manufacturing Process		Debur	
214	6	Manufacturing Process		Stamping Press 25 Ton	
215	7	Part	703-1049_3a Material	Material, Strap A Bracket	Steel 1010 Cold Drawn or Cold Rolled
216	4	Preprocessed Part	703-1049_3b	Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
217	5	Manufacturing Steps		Ground Strap B Processing	
218	6	Manufacturing Process		Wash	
219	6	Manufacturing Process		Debur	

Row	Level	Symbol Type	Number	Name	Material Name
220	6	Manufacturing Process		Stamping Press 25 Ton	
221	7	Part	703-1049_3b Material	Material, Strap B Bracket	Steel 1010 Cold Drawn or Cold Rolled
222	4	Part	703-1049_3c	Wire Mesh	Commodity Item
223	4	Manufacturing Steps		Assemble Ground Strap	
224	5	Manufacturing Process		Auto Assembly	
225	3	Part	703-1073_5	Rubber Coated Metal Bush, Large	Commodity Item
226	3	Manufacturing Steps		Power Inverter Bracket 2 Asm Processing	
227	4	Manufacturing Process		Spot Weld	
228	4	Manufacturing Process		Auto Assembly	
229	4	Manufacturing Process		Spot Weld	
230	2	Part	703-1049_1	M8 x 1.25, 40 mm Flanged Bolt	Commodity Item
231	2	Manufacturing Steps		Assemble Power Inverter Bracket 1 and 2	
232	3	Manufacturing Process		Auto Assembly	
233	2	Subassembly	1624-98_10	IGBT Cooler Asm	(None)
234	3	Preprocessed Part	1624-98_10a1	End Cooling Plate	Aluminum 6061
235	4	Manufacturing Steps		End Cooling Plate Processing	
236	5	Manufacturing Process		Laser Etch	
237	5	Manufacturing Process		Wash	
238	5	Manufacturing Process		Debur	
239	5	Manufacturing Process		Stamping Press, 25 Ton	
240	6	Part	1624-98_10a1 Material	Material, End Cooling Plate	Aluminum 6061
241	3	Preprocessed Part	1624-98_10a2	Cooling Plate A	Aluminum 6061
242	4	Manufacturing Steps		Cooling Plate A Processing	
243	5	Manufacturing Process		Wash	
244	5	Manufacturing Process		Debur	
245	5	Manufacturing Process		Stamping Press, 25 Ton	
246	6	Part	1624-98_10a2 Material	Material, Cooling Plate A	Aluminum 6061
247	3	Preprocessed Part	1624-98_10a3	Cooling Plate B	Aluminum 6061
248	4	Manufacturing Steps		Cooling Plate B Processing	
249	5	Manufacturing Process		Wash	
250	5	Manufacturing Process		Debur	
251	5	Manufacturing Process		Stamping Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
252	6	Part	1624-98_10a3 Material	Material, Cooling Plate B	Aluminum 6061
253	3	Preprocessed Part	1624-98_10a5	Cooling Center Plate	Aluminum 6061
254	4	Manufacturing Steps		Cooling Center Plate Processing	
255	5	Manufacturing Process		Wash	
256	5	Manufacturing Process		Debur	
257	5	Manufacturing Process		Stamping Press, 25 Ton	
258	6	Part	1624-98_10a5 Material	Material, Cooling Center Plate	Aluminum 6061
259	3	Preprocessed Part	1624-98_10a4	Cooling Pipe	Aluminum 6061
260	4	Manufacturing Steps		Cooling Pipe Processing	
261	5	Manufacturing Process		Wash	
262	5	Manufacturing Process		Debur	
263	5	Manufacturing Process		Saw Cut	
264	6	Part	1624-98_10a4 Material	Material, Cooling Pipe	Aluminum 6061
265	3	Preprocessed Part	1624-98_10a6	Waffle Fin Structure	Aluminum 3003-O, Coil
266	4	Manufacturing Steps		Waffle Fin Structure Processing	
267	5	Manufacturing Process		Roll-Form Fins	
268	6	Part	1624-98_10a6 Material	Material, Waffle Fin Structure	Aluminum 3003-O, Coil
269	3	Manufacturing Steps		Assemble Cooling Pipe Asm	
270	4	Manufacturing Process		Wash	
271	4	Manufacturing Process		Braze Oven	
272	4	Manufacturing Process		Oven Dry Station	
273	4	Manufacturing Process		Flux Application	
274	4	Manufacturing Process		Degrease	
275	4	Manufacturing Process		Cooling Pipe Assembly Line	
276	4	Manufacturing Process		Auto Press Station	
277	4	Manufacturing Process		Manual Assembly	

Table C-24 Toyota Power Inverter Enclosures & Cooling Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius PCU Enclosure & Cooling

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-109	**Enclosure Main 2**	**$4.65**	**1**	**$4.65**
1624-109 Material	Material, Enclosure Main 2	$4.65	1	$4.65
1624-103	**Enclosure Main 1 Asm**	**$7.41**	**1**	**$7.41**
1624-103_1	**Enclosure Main 1**	**$4.65**	**1**	**$4.65**
1624-103_1 Material	Material, Enclosure Main 1	$4.65	1	$4.65
1624-103_2	M8x1.25, 7mm Reverse Thread Circular Standoff	$0.23	12	$2.76
1624-69	**Enclosure Bottom Cover**	**$0.39**	**1**	**$0.39**
1624-69 Material	Material, Enclosure Bottom Cover	$0.39	1	$0.39
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	8	$0.16
1624-69_3	Silicone Sealant	$0.19	1	$0.19
1624-71	**Coolant Passage Cover 2 Asm**	**$0.40**	**1**	**$0.40**
1624-71_1	**Coolant Passage Cover 2**	**$0.14**	**1**	**$0.14**
1624-71_1 Material	Material, Coolant Passage Cover 2	$0.14	1	$0.14
1624-71_2	O-Ring 14mm ID	$0.04	2	$0.08
1624-71_3	Plastic O-Ring 14mm ID	$0.03	1	$0.03
1624-71_5	O-Ring 33mm ID	$0.05	1	$0.05
1624-71_4	Metal Spacer	$0.05	2	$0.10
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	2	$0.04
1624-70	**Coolant Passage Cover 1 Asm**	**$0.50**	**1**	**$0.50**
1624-70_1	**Coolant Passage Cover 1 Asm**	**$0.25**	**1**	**$0.25**
1624-70_1a	**Coolant Passage Cover Top**	**$0.06**	**1**	**$0.06**
1624-70_1a Material	Material, Coolant Passage Cover 1 Top	$0.06	1	$0.06
1624-70_1b	**Coolant Passage Cover Bottom**	**$0.19**	**1**	**$0.19**
1624-70_1b Material	Material, Coolant Passage Cover Bottom	$0.19	1	$0.19
1624-70_2	O-Ring 14mm ID	$0.04	1	$0.04
1624-70_3	O-Ring 21mm ID	$0.06	1	$0.06
1624-71_4	Metal Spacer	$0.05	3	$0.15
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	3	$0.06
1624-72	**Coolant Inlet/Outlet, Cover 2 Asm**	**$0.39**	**1**	**$0.39**
1624-72_1	**Coolant Inlet/Outlet Cover**	**$0.13**	**1**	**$0.13**
1624-72_1 Material	Material, Coolant Inlet/Outlet Cover	$0.13	1	$0.13
1624-71_2	O-Ring 14mm ID	$0.04	2	$0.08
1624-71_3	Plastic O-Ring 14mm ID	$0.03	1	$0.03
1624-71_5	O-Ring 14mm ID	$0.05	1	$0.05
1624-71_4	Metal Spacer	$0.05	2	$0.10
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	2	$0.04
1624-66_1	**Enclosure Top Cover Bracket**	**$0.22**	**1**	**$0.22**
1624-66_1 Paint	Paint, Enclosure Top Cover Bracket	$0.01	1	$0.01
1624-66_1, Material	Material, Enclosure Top Cover Bracket	$0.21	1	$0.21
1624-66_2	M6 x 1.00, 20 mm, Self Threading Hex w/ Captured W	$0.16	1	$0.16
1624-66_5	Label 41x33mm, Enclosure Top Cover	$0.10	1	$0.10
1624-66_8	Label 41x33mm, Protective Film	$0.10	1	$0.10
1624-66_6	Label, 68x33mm, Enclosure Top Cover	$0.10	1	$0.10
1624-66	**Enclosure Top Cover**	**$0.76**	**1**	**$0.76**
1624-66 Paint	Paint, Enclosure Top Cover	$0.10	1	$0.10

Table C-25 Prius PCU Enclosure and Cooling

Prius PCU Enclosure & Cooling

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-66, Material	Material, Enclosure Top Cover	$0.66	1	$0.66
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	10	$0.20
1624-69_3	Silicone Sealant	$0.40	1	$0.40
703-1049	**Power Inverter Bracket 1 Asm**	**$3.95**	**1**	**$3.95**
703-1049_2	**Bracket 1**	**$1.21**	**1**	**$1.21**
703-1049_2 Material	Material, Bracket 1	$1.21	1	$1.21
703-1049_3	**Ground Strap Asm**	**$0.08**	**1**	**$0.08**
703-1049_3a	**Strap A Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3a Material	Material, Strap A Bracket	$0.02	1	$0.02
703-1049_3b	**Strap B Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3b Material	Material, Strap B Bracket	$0.02	1	$0.02
703-1049_3c	Wire Mesh	$0.04	1	$0.04
703-1049_3	**Ground Strap Asm**	**$0.08**	**1**	**$0.08**
703-1049_3a	**Strap A Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3a Material	Material, Strap A Bracket	$0.02	1	$0.02
703-1049_3b	**Strap B Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3b Material	Material, Strap B Bracket	$0.02	1	$0.02
703-1049_3c	Wire Mesh	$0.04	1	$0.04
703-1049_4a	**Ground Strap Bracket**	**$0.04**	**1**	**$0.04**
703-1049_4a Material	Material, Ground Strap Bracket	$0.04	1	$0.04
703-1049_4a	**Ground Strap Bracket**	**$0.04**	**1**	**$0.04**
703-1049_4a Material	Material, Ground Strap Bracket	$0.04	1	$0.04
703-1049_5	Rubber Coated Metal Bush, Small	$1.25	2	$2.50
703-1073	**Power Inverter Bracket 2 Asm**	**$4.42**	**1**	**$4.42**
703-1073_1	**Bracket 2**	**$0.94**	**1**	**$0.94**
703-1073_1 Material	Material, Bracket 2	$0.94	1	$0.94
703-1073_2	**Support Bracket Left**	**$0.10**	**1**	**$0.10**
703-1073_2 Material	Material, Support Bracket Left	$0.10	1	$0.10
703-1073_3	**Support Bracket Right**	**$0.09**	**1**	**$0.09**
703-1073_3 Material	Material, Support Bracket Right	$0.09	1	$0.09
703-1073_4	**Support Bracket Center Asm**	**$0.13**	**1**	**$0.13**
703-1073_4a	**Support Bracket Center**	**$0.05**	**1**	**$0.05**
703-1073_4a Material	Material, Support Bracket Center	$0.05	1	$0.05
703-1073_4b	Support Bracket Center Stud	$0.08	1	$0.08
703-1049_3	**Ground Strap Asm**	**$0.08**	**1**	**$0.08**
703-1049_3a	**Strap A Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3a Material	Material, Strap A Bracket	$0.02	1	$0.02
703-1049_3b	**Strap B Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3b Material	Material, Strap B Bracket	$0.02	1	$0.02
703-1049_3c	Wire Mesh	$0.04	1	$0.04
703-1049_3	**Ground Strap Asm**	**$0.08**	**1**	**$0.08**
703-1049_3a	**Strap A Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3a Material	Material, Strap A Bracket	$0.02	1	$0.02
703-1049_3b	**Strap B Bracket**	**$0.02**	**1**	**$0.02**
703-1049_3b Material	Material, Strap B Bracket	$0.02	1	$0.02
703-1049_3c	Wire Mesh	$0.04	1	$0.04
703-1073_5	Rubber Coated Metal Bush, Large	$1.50	2	$3.00
703-1049_1	M8 x 1.25, 40 mm Flanged Bolt	$0.18	4	$0.72
1624-98_10	**IGBT Cooler Asm**	**$0.58**	**1**	**$0.58**
1624-98_10a1	**End Cooling Plate**	**$0.02**	**1**	**$0.02**

Table C-26 Prius PCU Enclosure and Cooling

Prius PCU Enclosure & Cooling

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-98_10a1 Material	Material, End Cooling Plate	$0.02	1	$0.02
1624-98_10a2	**Cooling Plate A**	**$0.16**	**1**	**$0.16**
1624-98_10a2 Material	Material, Cooling Plate A	$0.02	8	$0.16
1624-98_10a3	**Cooling Plate B**	**$0.14**	**1**	**$0.14**
1624-98_10a3 Material	Material, Cooling Plate B	$0.02	7	$0.14
1624-98_10a5	**Cooling Center Plate**	**$0.08**	**1**	**$0.08**
1624-98_10a5 Material	Material, Cooling Center Plate	$0.01	8	$0.08
1624-98_10a4	**Cooling Pipe**	**$0.02**	**1**	**$0.02**
1624-98_10a4 Material	Material, Cooling Pipe	$0.01	2	$0.02
1624-98_10a6	**Waffle Fin Structure**	**$0.16**	**1**	**$0.16**
1624-98_10a6 Material	Material, Waffle Fin Structure	$0.01	16	$0.16

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	43	Piece Cost (Total): $25.94	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	141		*Parts:*	*0*
Fasteners:	43		*Fasteners:*	*0*
Parts+Unanalyzed:	141		*Parts+Unanalyzed:*	*0*

Toyota DC/DC Converter Subgroups

Table C-27 Toyota DC/DC Internal Housing Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-97	DC/DC Mounting Plate Asm	(None)
2	4	Preprocessed Part	1624-97_4	Mounting Plate	Aluminum A380, Cast
3	5	Manufacturing Steps		Mounting Plate Processing	
4	6	Manufacturing Process		Wash	
5	6	Manufacturing Process		Debur	
6	6	Manufacturing Process		Machining	
7	6	Manufacturing Process		Trim Press, 25 Ton	
8	6	Manufacturing Process		Aluminum Die Casting	
9	7	Part	1624-97_4 Material	Material, Mounting Plate	Aluminum A380, Cast
10	4	Part	1624-97_2	Mounting Plate Barcode Label	Commodity Item
11	4	Manufacturing Steps		Assemble Barcode Label to Plate	
12	5	Manufacturing Process		Manual Asm	
13	3	Preprocessed Part	1624-97_1	Enclosure Main 2 Gasket	EPDM GP
14	4	Manufacturing Steps		Enclosure Main 2 Gasket Processing	
15	5	Manufacturing Process		Injection Mold Press, 55 Ton	
16	6	Part	1624-97_1 Material	Material, Enclosure Main 2 Gasket	EPDM GP
17	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
18	3	Manufacturing Steps		Enclosure Main 2 Gasket to Enclosure Main 2	
19	4	Manufacturing Process		Auto Asm	

Table C-28 Toyota DC/DC Internal Housing Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius DC/DC Internal Housing

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-97	**DC/DC Mounting Plate Asm**	**$1.53**	**1**	**$1.53**
1624-97_4	**Mounting Plate**	**$1.48**	**1**	**$1.48**
1624-97_4 Material	Material, Mounting Plate	$1.48	1	$1.48
1624-97_2	Mounting Plate Barcode Label	$0.05	1	$0.05
1624-97_1	**Enclosure Main 2 Gasket**	**$0.04**	**1**	**$0.04**
1624-97_1 Material	Material, Enclosure Main 2 Gasket	$0.04	1	$0.04
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	8	$0.16

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	3	Piece Cost (Total): $1.73	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	11		*Parts:*	*0*
Fasteners:	8		*Fasteners:*	*0*
Parts+Unanalyzed:	11		*Parts+Unanalyzed:*	*0*

Table C-29 Toyota DC/DC Buss Bars Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-92	Bus Bar Connector 2 Asm	(None)
2	4	Preprocessed Part	1624-92_1	Connector 2 Stamping 1	Copper Nickel Plated
3	5	Manufacturing Steps		Connector 2 Stamping 1 Processing	
4	6	Manufacturing Process		Wash	
5	6	Manufacturing Process		Debur	
6	6	Manufacturing Process		Stamping Press, 25 Ton	
7	7	Part	1624-92_1 Material	Material, Connector 2 Stamping 1	Copper Nickel Plated
8	4	Preprocessed Part	1624-92_2	Connector 2 Stamping 2	Copper Nickel Plated
9	5	Manufacturing Steps		Connector 2 Stamping 2 Processing	
10	6	Manufacturing Process		Wash	
11	6	Manufacturing Process		Debur	
12	6	Manufacturing Process		Stamping Press, 25 Ton	
13	7	Part	1624-92_2-Material	Material, Connector 2 Stamping 2	Copper Nickel Plated
14	4	Part	1624-92_3	M4 PEM nut	Commodity Item
15	4	Part	1624-92_4	PEM Spacer	Commodity Item
16	4	Manufacturing Steps		Bus Bar Connector 2 Assembly	
17	5	Manufacturing Process		Injection Mold Press, 55 Ton	
18	6	Part	1624-92_5-Material	Material, Connector 1 Asm	PBT GF30
19	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
20	3	Subassembly	1624-90	Bus Bar Connector 1 Asm	(None)
21	4	Preprocessed Part	1624-90_1	Connector 1 Stamping 1	Copper Nickel Plated
22	5	Manufacturing Steps		Connector 1 Stamping 1 Processing	
23	6	Manufacturing Process		Wash	
24	6	Manufacturing Process		Debur	

Row	Level	Symbol Type	Number	Name	Material Name
25	6	Manufacturing Process		Stamping Press, 25 Ton	
26	7	Part	1624-90_1-Material	Material, Connector 1 Stamping 1	Copper Nickel Plated
27	4	Part	1624-92_3	M4 PEM nut	Commodity Item
28	4	Part	1624-92_4	PEM Spacer	Commodity Item
29	4	Manufacturing Steps		Bus Bar Connector 1 Assembly	
30	5	Manufacturing Process		Injection Mold Press, 55 Ton	
31	6	Part	1624-92_5-Material	Material, Connector 1 Asm	PBT GF30
32	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
33	3	Manufacturing Steps		Install Bus Bars	
34	4	Manufacturing Process		Auto Asm	

Table C-30 Toyota DC/DC Buss Bars Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius DC/DC Bus Bars

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-92	**Bus Bar Connector 2 Asm**	**$0.50**	**1**	**$0.50**
1624-92_1	**Connector 2 Stamping 1**	**$0.14**	**1**	**$0.14**
1624-92_1 Material	Material, Connector 2 Stamping 1	$0.14	1	$0.14
1624-92_2	**Connector 2 Stamping 2**	**$0.24**	**1**	**$0.24**
1624-92_2-Material	Material, Connector 2 Stamping 2	$0.24	1	$0.24
1624-92_3	M4 PEM nut	$0.05	2	$0.10
1624-92_4	PEM Spacer	$0.01	1	$0.01
1624-92_5-Material	Material, Connector 1 Asm	$0.01	1	$0.01
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	1	$0.07
1624-90	**Bus Bar Connector 1 Asm**	**$0.34**	**1**	**$0.34**
1624-90_1	**Connector 1 Stamping 1**	**$0.22**	**1**	**$0.22**
1624-90_1-Material	Material, Connector 1 Stamping 1	$0.22	1	$0.22
1624-92_3	M4 PEM nut	$0.05	2	$0.10
1624-92_4	PEM Spacer	$0.01	1	$0.01
1624-92_5-Material	Material, Connector 1 Asm	$0.01	1	$0.01
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	1	$0.07

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	5	Piece Cost (Total): $0.98	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	13		*Parts:*	*0*
Fasteners:	6		*Fasteners:*	*0*
Parts+Unanalyzed:	13		*Parts+Unanalyzed:*	*0*

Table C-31 Toyota DC/DC PCBAs Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-88	Small Capacitor Circuit Board	(None)
2	4	Manufacturing Steps		Small Capacitor Circuit Board assembly	
3	5	Manufacturing Process		Laser Etch	
4	5	Manufacturing Process		Functional Test	
5	5	Manufacturing Process		De-Panel	
6	5	Manufacturing Process		PCB - Low Content	
7	6	Part	1624-88_1	DC/DC FR4 Circuit Board 2	Commodity Item
8	7	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
9	7	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
10	7	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item
11	7	Part	1206 Capacitors-1	Tolerance - 10%; 1206 (3216 Metric) 0.126" L x 0.0	Commodity Item
12	7	Part	1206 Capacitors-1	Tolerance - 10%; 1206 (3216 Metric) 0.126" L x 0.0	Commodity Item
13	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
14	3	Manufacturing Steps		Assemble DC/DC Circuit Boards 2 to Asm	
15	4	Manufacturing Process		Auto Asm	
16	3	Subassembly	1624-86	Inductor Circuit Board	(None)
17	4	Manufacturing Steps		Inductor Circuit Board Assembly	
18	5	Manufacturing Process		Functional Test	
19	5	Manufacturing Process		PCB - Low Content	
20	6	Subassembly	1624-86-2	PCB, DC/DC Circuit Board 3	(None)

Row	Level	Symbol Type	Number	Name	Material Name
21	7	Preprocessed Part	1624-86-5	Cu, Bottom Circuit Stamping, 0.020" Thick	Copper Cu (10200)
22	8	Manufacturing Steps		Bottom Cu Circuit Processing	
23	9	Manufacturing Process		Wash	
24	9	Manufacturing Process		Debur	
25	9	Manufacturing Process		Stamping Press, 25 Ton	
26	10	Part	1624-86-5 Material	Material, Cu, Bottom Circuit Stamping, 0.020" Thic	Copper Cu (10200)
27	7	Part	1624-86-3	PCB Material, FR4 Fiberglass, 0.020" Thick	Commodity Item
28	7	Preprocessed Part	1624-86-4	Cu, Top Circuit Stamping, 0.020" Thick	Copper Cu (10200)
29	8	Manufacturing Steps		Top Cu Circuit Processing	
30	9	Manufacturing Process		Wash	
31	9	Manufacturing Process		Debur	
32	9	Manufacturing Process		Stamping Press, 25 Ton	
33	10	Part	1624-86-4 Material	Material, Cu, Top Circuit Stamping, 0.020" Thick	Copper Cu (10200)
34	7	Part	Epoxy, Cu to Fiberglass	Epoxy, Cu to Fiberglass	Commodity Item
35	7	Manufacturing Steps		Board Assembly Processing	
36	8	Manufacturing Process		Laser Etch	
37	8	Manufacturing Process		Trim Press, 25 Ton	
38	8	Manufacturing Process		Automated Adhesive Curing	
39	8	Manufacturing Process		Auto Asm	
40	8	Manufacturing Process		Adhesive Coating Apply	
41	8	Manufacturing Process		De-Panel	
42	7	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
43	7	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
44	7	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
45	8	Part	SM8S30AHE3/2D	TVS DIODE 30VWM 48.4VC DO218AB	Commodity Item
46	7	Part	B32926J3106K000	10µF ±10% Film Capacitor 305V Polypropylene (PP),	Commodity Item
47	7	Part	Connector Small, 2 Terminals	Board to Board Connector Small, 2 Terminals	Commodity Item
48	7	Part	Connector Large, 6 Terminals	Board to Board Connector Large, 6 Terminals	Commodity Item
49	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
50	3	Manufacturing Steps		Assemble DC/DC Circuit Boards 3 to Asm	
51	4	Manufacturing Process		Auto Asm	
52	3	Subassembly	1624-80	Main DC-DC Circuit Board	(None)
53	4	Manufacturing Steps		Main DC-DC Circuit Board Assembly	
54	5	Manufacturing Process		Functional Test	
55	5	Manufacturing Process		Automated Thru Hole Placement	
56	7	Part	DF40C-30DS-0.4V	30 Position Connector Receptacle, Center Strip Con	Commodity Item
57	7	Part	MKP385513040JKM2T0	MKP385 1.3uF 5% 400VDC PITCH 27.5	Commodity Item
58	7	Part	BK/ABC-30-R	FUSE CERM 30A 250VAC 125VDC 3AB	Commodity Item
59	7	Part	#7448031501	1mH 10kHz 2 Line Common Mode Choke Thru Hole 15A D	Commodity Item
60	5	Manufacturing Process		De-Panel	
61	5	Manufacturing Process		PCB - Low Content	
62	6	Part	1624-80_3	DC/DC FR4 Printed Circuit 1	Commodity Item
63	7	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
64	7	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
65	7	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item
66	8	Part	2SA1162S-Y	TRANS PNP 50V 0.15A S-MINI	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
67	8	Part	MMBT2222ALT1G	TRANS NPN 40V 0.6A SOT23	Commodity Item
68	8	Part	BZT52H-C2V4	Zener Diode 2.4V 375mW 5% Surface Mount SOD-123F	Commodity Item
69	8	Part	BZD27C200P	Zener Diodes 200 Volt 0.8 Watt 5%	Commodity Item
70	8	Part	RJK6026DPE	Trans MOSFET N-CH 600V 5A 3-Pin TO-263 Embossed	Commodity Item
71	8	Part	STW78N65M5	MOSFET N-Ch 650 V 0.033 Ohm 69 A	Commodity Item
72	8	Part	STW19NM60N	MOSFET N-Ch 600 V 0.27 Ohm 13 A	Commodity Item
73	8	Part	1SS355VMTE	Diode Standard 80V 100mA Surface Mount UMD2	Commodity Item
74	8	Part	BZX585-C11	Zener Diodes DIODE ZENER 5 PCT	Commodity Item
75	8	Part	SML4761-E3	Zener Diodes 75 Volt 1.0W 10%	Commodity Item
76	8	Part	1206 Capacitors-2	1206 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	Commodity Item
77	8	Part	0805 Capacitors-2	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
78	8	Part	0603 Capacitors-3	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
79	8	Part	C2220C106K5R1C-AUTO7186	10uF 10% 50V Ceramic Capacitor X7R 2220 (5750 Metr	Commodity Item
80	8	Part	LTF4022T-100M-D	Fixed Inductors 10uH 0.16ohms 0.95A	Commodity Item
81	8	Part	LGJ7045TC-471M-D	Fixed Inductors 470uH 1.42ohms 0.43A 150 Deg C	Commodity Item
82	8	Part	1206 Resistors-2	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
83	8	Part	0603 Resistors-4	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
84	8	Part	10120666-101LF	CONN MINI SAS HD VERT 1X1	Commodity Item
85	8	Part	BM08B-ZESS-TBT	8 Pos Header, Shrouded Connector 0.059" (1.50mm) S	Commodity Item
86	8	Part	42037-1	Ring Terminal Connector 8 Stud Oval 18-22 AWG Crim	Commodity Item
87	8	Part	1416-04	Ground Lug Terminal, 4, M2.5, Brass	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
88	8	Part	UCL1E561MNL1GS	560uF 25V Aluminum Capacitors Radial, Can - SMD 20	Commodity Item
89	8	Part	B82801B0305A125	Current Sensing Transformer, 1:125, 6.5 ohm, 3 mH,	Commodity Item
90	8	Part	SPC560P34L1CEFBR	MCU 32-bit e200 RISC 192KB Flash 3.3V 64-Pin LQFP	Commodity Item
91	8	Part	LM2901YPT	Comparator General Purpose CMOS, TTL 14-TSSOP	Commodity Item
92	8	Part	BZD27C200P	Zener Diodes 200 Volt 0.8 Watt 5%	Commodity Item
93	8	Part	2SC5824T100Q	TRANS NPN 60V 3A SOT-89	Commodity Item
94	8	Part	2SC5876T106Q	TRANS NPN 60V 0.5A SOT-323	Commodity Item
95	8	Part	NCV2903DMR2G	Comparator Gen Purp CMOS, Open-Collector, TTL Micr	Commodity Item
96	8	Part	TLP185	Optoisolator Transistor O/P 3750Vrms 1 Ch 6-SO, 4	Commodity Item
97	8	Part	2SC2712-GR	TRANS NPN 50V 0.15A S-MINI	Commodity Item
98	8	Part	2SA1162S-Y	TRANS PNP 50V 0.15A S-MINI	Commodity Item
99	8	Part	BU4346G	Supervisor Push-Pull, Totem Pole 1 Channel 5-SSOP	Commodity Item
100	8	Part	MM3Z2V4T1G	Zener Diode 2.4V 300mW 8% Surface Mount SOD-323	Commodity Item
101	8	Part	RT9018B	LVR IC Pos Fixed or Adjustable 1 Output 1.8V, 3A 8	Commodity Item
102	8	Part	RJK0629DPE	Trans MOSFET N-CH 60V 85A	Commodity Item
103	8	Part	2SC5103TLQ	TRANS NPN 60V 5A SOT-428	Commodity Item
104	8	Part	PZU6.8BA	Zener Diodes 40W SNGL 200mA 7.14V Single Zener dio	Commodity Item
105	8	Part	1SS355VMTE	Diode Standard 80V 100mA Surface Mount UMD2	Commodity Item
106	8	Part	BZX384-C6V8	Zener Diode 6.8V 300mW 5% Surface Mount SOD-323	Commodity Item
107	8	Part	SD103BW-E3-08	Schottky Diodes & Rectifiers 5uA 30Volt 15A IFSM	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
108	8	Part	727-CY7C4201V-15AXC	FIFO 256 X9 LO VLTG SYNC FIFO COM	Commodity Item
109	8	Part	RB501VM-40TE-17	Diode Schottky 40V 100mA Surface Mount UMD2	Commodity Item
110	8	Part	1206 Resistors-2	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
111	8	Part	0603 Resistors-4	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
112	8	Part	0805 Resistors-3	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
113	8	Part	0402 Resistors-2	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
114	8	Part	1206 Capacitors-2	1206 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	Commodity Item
115	8	Part	0805 Capacitors-2	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
116	8	Part	0603 Capacitors-3	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
117	8	Part	0402 Capacitors-2	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
118	7	Part	9C-60.000MBBK-T	60MHz 50ppm Crystal 20pF 60 Ohm -20C-70 C Surface	Commodity Item
119	3	Preprocessed Part	1624-80_1	Circuit Ferrite Holder	Steel 1060 Cold Drawn or Cold Rolled Annealed
120	4	Manufacturing Steps		Circuit Ferrite Holder Processing	
121	5	Manufacturing Process		Wash	
122	5	Manufacturing Process		Debur	
123	5	Manufacturing Process		Stamping Press, 25 Ton	
124	6	Part	1624-80_1-Material	Material, Circuit Ferrite Holder	Steel 1060 Cold Drawn or Cold Rolled Annealed
125	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
126	3	Manufacturing Steps		Assemble DC/DC Circuit 1 and Ferrite Holder to Asm	
127	4	Manufacturing Process		Auto Asm	

Table C-32 Toyota DC/DC PCBAs Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius DC/DC PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-88	**DC/DC Circuit Board 2**	**$0.88**	**1**	**$0.88**
1624-88_1	DC/DC FR4 Circuit Board 2	$0.10	1	$0.10
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.01	1	$0.01
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.00	1	$0.00
1206 Capacitors-1	Tolerance - 10%; 1206 (3216 Metric) 0.126" L x 0.0	$0.06	6	$0.39
1206 Capacitors-1	Tolerance - 10%; 1206 (3216 Metric) 0.126" L x 0.0	$0.06	6	$0.39
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	2	$0.14
1624-86	**DC/DC Circuit Board 3**	**$9.97**	**1**	**$9.97**
1624-86-2	**PCB, DC/DC Circuit Board 3**	**$1.90**	**1**	**$1.90**
1624-86-5	**Cu, Bottom Circuit Stamping, 0.020" Thick**	**$0.62**	**1**	**$0.62**
1624-86-5 Material	Material, Cu, Bottom Circuit Stamping, 0.020" Thic	$0.62	1	$0.62
1624-86-3	PCB Material, FR4 Fiberglass, 0.020" Thick	$0.04	1	$0.04
1624-86-4	**Cu, Top Circuit Stamping, 0.020" Thick**	**$0.62**	**1**	**$0.62**
1624-86-4 Material	Material, Cu, Top Circuit Stamping, 0.020" Thick	$0.62	1	$0.62
Epoxy, Cu to Fiberglass	Epoxy, Cu to Fiberglass	$0.31	2	$0.62
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.00	1	$0.00
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.00	1	$0.00
SM8S30AHE3/2D	TVS DIODE 30VWM 48.4VC DO218AB	$1.31	4	$5.22
B32926J3106K000	10µF ±10% Film Capacitor 305V Polypropylene (PP),	$1.79	1	$1.79
Connector Small, 2 Terminals	Board to Board Connector Small, 2 Terminals	$0.22	1	$0.22
Connector Large, 6 Terminals	Board to Board Connector Large, 6 Terminals	$0.82	1	$0.82
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	8	$0.56
1624-80	**DC/DC Circuit 1**	**$44.36**	**1**	**$44.36**
DF40C-30DS-0.4V	30 Position Connector Receptacle, Center Strip Con	$0.45	1	$0.45
MKP385513040JKM2T0	MKP385 1.3uF 5% 400VDC PITCH 27.5	$0.97	2	$1.94
BK/ABC-30-R	FUSE CERM 30A 250VAC 125VDC 3AB	$0.48	1	$0.48
#7448031501	1mH 10kHz 2 Line Common Mode Choke Thru Hole 15A D	$3.86	1	$3.86
1624-80_3	DC/DC FR4 Printed Circuit 1	$3.24	1	$3.24
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.02	1	$0.02
LF318 Solder Paste	LF318 Solder Paste	$0.23	1	$0.23
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.07	1	$0.07
2SA1162S-Y	TRANS PNP 50V 0.15A S-MINI	$0.02	1	$0.02
MMBT2222ALT1G	TRANS NPN 40V 0.6A SOT23	$0.01	1	$0.01
BZT52H-C2V4	Zener Diode 2.4V 375mW 5% Surface Mount SOD-123F	$0.03	2	$0.06
BZD27C200P	Zener Diodes 200Volt 0.8 Watt 5%	$0.07	1	$0.07

Prius DC/DC PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
RJK6026DPE	Trans MOSFET N-CH 600V 5A 3-Pin TO-263 Embossed	$0.63	1	$0.63
STW78N65M5	MOSFET N-Ch 650 V 0.033 Ohm 69 A	$9.35	1	$9.35
STW19NM60N	MOSFET N-Ch 600 V 0.27 Ohm 13 A	$1.43	1	$1.43
1SS355VMTE	Diode Standard 80V 100mA Surface Mount UMD2	$0.02	1	$0.02
BZX585-C11	Zener Diodes DIODEZENER 5 PCT	$0.04	1	$0.04
SML4761-E3	Zener Diodes 75Volt 1.0W 10%	$0.08	1	$0.08
1206 Capacitors-2	1206 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	$0.06	28	$1.80
0805 Capacitors-2	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	14	$0.42
0603 Capacitors-3	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	5	$0.06
C2220C106K5R1CAUTO 7186	10uF 10% 50V Ceramic Capacitor X7R 2220 (5750 Metr	$1.99	1	$1.99
LTF4022T-100M-D	Fixed Inductors 10uH 0.16ohms 0.95A	$0.42	1	$0.42
LGJ7045TC-471M-D	Fixed Inductors 470uH 1.42ohms 0.43A 150 Deg C	$1.72	1	$1.72
1206 Resistors-2	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.00	36	$0.11
0603 Resistors-4	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	5	$0.01
10120666-101LF	CONN MINI SAS HD VERT 1X1	$1.21	1	$1.21
BM08B-ZESS-TBT	8 Pos Header, Shrouded Connector 0.059" (1.50mm) S	$0.40	1	$0.40
42037-1	Ring Terminal Connector 8 Stud Oval 18-22 AWG Crim	$0.03	1	$0.03
1416-04	Ground Lug Terminal, 4, M2.5, Brass	$0.16	2	$0.32
UCL1E561MNL1GS	560uF 25V Aluminum Capacitors Radial, Can - SMD 20	$0.21	2	$0.42
B82801B0305A125��	Current Sensing Transformer, 1:125, 6.5 ohm, 3 mH,	$0.36	2	$0.71
SPC560P34L1CEFBR	MCU 32-bit e200 RISC 192KB Flash 3.3V 64-Pin LQFP	$2.93	1	$2.93
LM2901YPT	Comparator General Purpose CMOS, TTL 14-TSSOP	$0.09	1	$0.09
BZD27C200P	Zener Diodes 200Volt 0.8 Watt 5%	$0.07	3	$0.21
2SC5824T100Q	TRANS NPN 60V 3A SOT-89	$0.13	4	$0.54
2SC5876T106Q	TRANS NPN 60V 0.5A SOT-323	$0.10	3	$0.29
NCV2903DMR2G	Comparator Gen Purp CMOS, Open-Collector, TTL Micr	$0.16	1	$0.16
TLP185	Optoisolator Transistor O/P 3750Vrms 1 Ch 6-SO, 4	$0.13	4	$0.50
2SC2712-GR	TRANS NPN 50V 0.15A S-MINI	$0.02	2	$0.03
2SA1162S-Y	TRANS PNP 50V 0.15A S-MINI	$0.02	1	$0.02
BU4346G	Supervisor Push-Pull, Totem Pole 1 Channel 5-SSOP	$0.12	2	$0.25
MM3Z2V4T1G	Zener Diode 2.4V 300mW 8% Surface Mount SOD-323	$0.01	2	$0.02
RT9018B	LVR IC Pos Fixed or Adjustable 1 Output 1.8V, 3A 8	$0.16	1	$0.16
RJK0629DPE	Trans MOSFET N-CH 60V 85A	$0.46	1	$0.46
2SC5103TLQ	TRANS NPN 60V 5A SOT-428	$0.34	1	$0.34
PZU6.8BA	Zener Diodes 40W SNGL 200mA 7.14V Single Zener dio	$0.02	1	$0.02

Prius DC/DC PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1SS355VMTE	Diode Standard 80V 100mA Surface Mount UMD2	$0.02	1	$0.02
BZX384-C6V8	Zener Diode 6.8V 300mW 5% Surface Mount SOD-323	$0.02	1	$0.02
SD103BW-E3-08	Schottky Diodes & Rectifiers 5uA 30Volt 15A IFSM	$0.03	1	$0.03
727-CY7C4201V-15AXC	FIFO 256 X9 LO VLTG SYNC FIFO COM	$4.08	1	$4.08
RB501VM-40TE-17	Diode Schottky 40V 100mA Surface Mount UMD2	$0.03	1	$0.03
1206 Resistors-2	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.00	22	$0.07
0603 Resistors-4	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	12	$0.03
0805 Resistors-3	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.00	19	$0.02
0402 Resistors-2	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	106	$0.06
1206 Capacitors-2	1206 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	$0.06	21	$1.35
0805 Capacitors-2	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	11	$0.33
0603 Capacitors-3	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	34	$0.43
0402 Capacitors-2	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	33	$0.12
9C-60.000MBBK-T	60MHz 50ppm Crystal 20pF 60 Ohm -20C-70�C Surface	$0.17	1	$0.17
1624-80_1	**Circuit Ferrite Holder**	**$0.04**	**1**	**$0.04**
1624-80_1-Material	Material, Circuit Ferrite Holder	$0.04	1	$0.04
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	2	$0.14

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	7	Piece Cost (Total): $56.08	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	456		*Parts:*	*0*
Fasteners:	12		*Fasteners:*	*0*
Parts+Unanalyzed:	456		*Parts+Unanalyzed:*	*0*

Table C-33 Toyota DC/DC Ferrites & Inductors Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Part	1624_4	Heat Sink Compound	Commodity Item
2	3	Part	1624-86_1	Thermal Insulation Compound	Commodity Item
3	3	Part	1624-86_2	Thermal Insulation Compound	Commodity Item
4	3	Part	1624-86_3	Thermal Insulation Compound	Commodity Item
5	3	Manufacturing Steps		Apply Thermal and Heat Sink Compund	
6	4	Manufacturing Process		Auto Asm	
7	3	Part	1624-97_3	Cooling Plate Circuit Insulator Pad	Commodity Item
8	3	Manufacturing Steps		Install Insulator to Mount Plate	
9	4	Manufacturing Process		Auto Asm	
10	3	Preprocessed Part	1624-82_3	Ferrite 1 Bottom	Mn-Zn Soft Ferrite Powder
11	4	Manufacturing Steps		Ferrite 1 Bottom Processing	
12	5	Manufacturing Process		Wash	
13	5	Manufacturing Process		Mill Face	
14	5	Manufacturing Process		Oven Sintering Furnace	
15	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
16	6	Part	1624-82_3 Material	Material, Ferrite 1 Bottom	Mn-Zn Soft Ferrite Powder
17	3	Preprocessed Part	1624-84_4	Ferrite 2 Bottom	Mn-Zn Soft Ferrite Powder
18	4	Manufacturing Steps		Ferrite 2 Bottom Processing	
19	5	Manufacturing Process		Wash	
20	5	Manufacturing Process		Mill Face	
21	5	Manufacturing Process		Oven Sintering Furnace	
22	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
23	6	Part	1624-84_4 Material	Material, Ferrite 2 Bottom	Mn-Zn Soft Ferrite Powder
24	3	Part	1624-84_3	Ferrite 2 Insulator Pad	Commodity Item
25	3	Preprocessed Part	1624-85_4	Ferrite 3 Bottom	Mn-Zn Soft Ferrite Powder
26	4	Manufacturing Steps		Ferrite 3 Bottom Processing	

27	5	Manufacturing Process		Wash	
28	5	Manufacturing Process		Mill Face	
29	5	Manufacturing Process		Oven Sintering Furnace	
30	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
31	6	Part	1624-85_4 Material	Material, Ferrite 3 Bottom	Mn-Zn Soft Ferrite Powder
32	3	Manufacturing Steps		Assemble Ferrite Bottoms to Cooling Plate Asm	
33	4	Manufacturing Process		Auto Asm	
34	3	Preprocessed Part	1624-82_2	Ferrite 1 Top	Mn-Zn Soft Ferrite Powder
35	4	Manufacturing Steps		Ferrite 1 Top Processing	
36	5	Manufacturing Process		Wash	
37	5	Manufacturing Process		Mill Face	
38	5	Manufacturing Process		Oven Sintering Furnace	
39	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
40	6	Part	1624-82_2 Material	Material, Ferrite 1 Top	Mn-Zn Soft Ferrite Powder
41	3	Preprocessed Part	1624-84_2	Ferrite 2 Top	Mn-Zn Soft Ferrite Powder
42	4	Manufacturing Steps		Ferrite 2 Top Processing	
43	5	Manufacturing Process		Wash	
44	5	Manufacturing Process		Mill Face	
45	5	Manufacturing Process		Oven Sintering Furnace	
46	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
47	6	Part	1624-84_2 Material	Material, Ferrite 2 Top	Mn-Zn Soft Ferrite Powder
48	3	Preprocessed Part	1624-85_3	Ferrite 3 Top	Mn-Zn Soft Ferrite Powder
49	4	Manufacturing Steps		Ferrite 3 Top Processing	
50	5	Manufacturing Process		Wash	
51	5	Manufacturing Process		Mill Face	
52	5	Manufacturing Process		Oven Sintering Furnace	
53	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
54	6	Part	1624-85_3 Material	Material, Ferrite 3 Top	Mn-Zn Soft Ferrite Powder
55	3	Manufacturing Steps		Assemble Ferrite Tops to Asm	
56	4	Manufacturing Process		Auto Asm	

57	3	Preprocessed Part	1624-82_1	Ferrite Holder 1	Steel 1060 Cold Drawn or Cold Rolled Annealed
58	4	Manufacturing Steps		Ferrite Holder 1 Processing	
59	5	Manufacturing Process		Wash	
60	5	Manufacturing Process		Debur	
61	5	Manufacturing Process		Stamping Press, 25 Ton	
62	6	Part	1624-82_1 Material	Material, Ferrite Holder 1	Steel 1060 Cold Drawn or Cold Rolled Annealed
63	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
64	3	Preprocessed Part	1624-84_1	Ferrite Holder 2	Steel 1060 Cold Drawn or Cold Rolled Annealed
65	4	Manufacturing Steps		Ferrite Holder 2 Processing	
66	5	Manufacturing Process		Wash	
67	5	Manufacturing Process		Debur	
68	5	Manufacturing Process		Stamping Press, 25 Ton	
69	6	Part	1624-84_1 Material	Material, Ferrite Holder 2	Steel 1060 Cold Drawn or Cold Rolled Annealed
70	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
71	3	Preprocessed Part	1624-85_1	Ferrite Holder 3	Steel 1060 Cold Drawn or Cold Rolled Annealed
72	4	Manufacturing Steps		Ferrite Holder 3 Processing	
73	5	Manufacturing Process		Wash	
74	5	Manufacturing Process		Debur	
75	5	Manufacturing Process		Stamping Press, 25 Ton	
76	6	Part	1624-85_1 Material	Material, Ferrite Holder 3	Steel 1060 Cold Drawn or Cold Rolled Annealed
77	3	Part	1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	Commodity Item
78	3	Manufacturing Steps		Assemble Ferrite Holders to Asm	
79	4	Manufacturing Process		Auto Asm	
80					
81					
82					

Table C-34 Toyota DC/DC Ferrites & Inductors Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius DC/DC Ferrites & Inductors

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624_4	Heat Sink Compound	$0.08	1	$0.08
1624-86_1	Thermal Insulation Compound	$0.13	1	$0.13
1624-86_2	Thermal Insulation Compound	$0.66	1	$0.66
1624-86_3	Thermal Insulation Compound	$1.41	1	$1.41
1624-97_3	Cooling Plate Circuit Insulator Pad	$0.27	1	$0.27
1624-82_3	**Ferrite 1 Bottom**	**$0.23**	**1**	**$0.23**
1624-82_3 Material	Material, Ferrite 1 Bottom	$0.23	1	$0.23
1624-84_4	**Ferrite 2 Bottom**	**$0.13**	**1**	**$0.13**
1624-84_4 Material	Material, Ferrite 2 Bottom	$0.13	1	$0.13
1624-84_3	Ferrite 2 Insulator Pad	$0.04	1	$0.04
1624-85_4	**Ferrite 3 Bottom**	**$0.06**	**1**	**$0.06**
1624-85_4 Material	Material, Ferrite 3 Bottom	$0.06	1	$0.06
1624-82_2	**Ferrite 1 Top**	**$0.29**	**1**	**$0.29**
1624-82_2 Material	Material, Ferrite 1 Top	$0.29	1	$0.29
1624-84_2	**Ferrite 2 Top**	**$0.25**	**1**	**$0.25**
1624-84_2 Material	Material, Ferrite 2 Top	$0.25	1	$0.25
1624-85_3	**Ferrite 3 Top**	**$0.10**	**1**	**$0.10**
1624-85_3 Material	Material, Ferrite 3 Top	$0.10	1	$0.10
1624-82_1	**Ferrite Holder 1**	**$0.03**	**1**	**$0.03**
1624-82_1 Material	Material, Ferrite Holder 1	$0.03	1	$0.03
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	1	$0.07
1624-84_1	**Ferrite Holder 2**	**$0.04**	**1**	**$0.04**
1624-84_1 Material	Material, Ferrite Holder 2	$0.04	1	$0.04
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	1	$0.07
1624-85_1	**Ferrite Holder 3**	**$0.01**	**1**	**$0.01**
1624-85_1 Material	Material, Ferrite Holder 3	$0.01	1	$0.01
1624-80_2	SEMs Screw, M4 x 0.70, 8.5 mm	$0.07	1	$0.07

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	9	Piece Cost (Total): $3.95	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	18		*Parts:*	*0*
Fasteners:	3		*Fasteners:*	*0*
Parts+Unanalyzed:	18		*Parts+Unanalyzed:*	*0*

Table C-35 Toyota DC/DC Electrical & Harnesses Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-74	Receptacle Cover 2 Asm w/Gasket	(None)
2	4	Subassembly	1624-74_1	Receptacle Cover 2 Asm	(None)
3	5	Part	1624-74_1a	Steel Spacer	Commodity Item
4	5	Preprocessed Part	1624-74_1b	Copper Plate	Copper Cu (10200)
5	6	Manufacturing Steps		Copper Plate Processing	
6	7	Manufacturing Process		Electroplating	
7	8	Part	1624-74_1b Plating	Plating, Copper Plate	Commodity Item
8	7	Manufacturing Process		Wash	
9	7	Manufacturing Process		Debur	
10	7	Manufacturing Process		Stamping Press, 25 Ton	
11	8	Part	1624-74_1b Material	Material, Copper Plate	Copper Cu (10200)
12	5	Part	1624-74_1c	Bolt M6x1 15mm	Commodity Item
13	5	Manufacturing Steps		Receptacle Cover 2 Asm Processing	
14	6	Manufacturing Process		Injection Mold Press, 55 Ton	
15	7	Part	1624-74_1 Material	Material, Receptacle Cover 2	PPS-GF-MD
16	4	Preprocessed Part	1624-74_2	Gasket	EPDM GP
17	5	Manufacturing Steps		Gasket Processing	
18	6	Manufacturing Process		Injection Mold Press, 55 Ton	
19	7	Part	1624-74_2 Material	Material, Gasket	EPDM GP
20	4	Manufacturing Steps		Assemble Receptacle Cover 2 Asm	
21	5	Manufacturing Process		Manual Asm	
22	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
23	3	Manufacturing Steps		Receptacle Cover 2 Asm to Inverter Module	
24	4	Manufacturing Process		Auto Asm	
25	3	Subassembly	1624-106	Receptacle 3 Asm	(None)
26	4	Preprocessed Part	1624-106_1	Receptacle Housing	PBT GF30
27	5	Manufacturing Steps		Receptacle Housing Processing	

Row	Level	Symbol Type	Number	Name	Material Name
28	6	Manufacturing Process		Laser Etch	
29	6	Manufacturing Process		Injection Mold Press 55 Ton	
30	7	Part	1624-106_1 Material	Material, Receptacle Housing	PBT GF30
31	4	Part	1624-106_2	Metal Spacer	Commodity Item
32	4	Part	1624-106_3	Connector Pin	Commodity Item
33	4	Manufacturing Steps		Receptacle 3 Assembly	
34	5	Manufacturing Process		Auto Asm	
35	3	Part	1624-77_4	SEMs Screw, M4 x 0.70, 11.5 mm	Commodity Item
36	3	Manufacturing Steps		Receptacle 3 Asm to DC/DC Converter Module	
37	4	Manufacturing Process		Manual Asm	
38	3	Subassembly	1624-107_3	Control PCB to DC/DC Harness	(None)
39	4	Part	1624-107_4A	AWG 20 (0.8mm D) Wire, Blue	Commodity Item
40	4	Part	1624-107_4B	AWG 20 (0.8mm D) Wire, Brown	Commodity Item
41	4	Part	1624-107_4C	AWG 20 (0.8mm D) Wire, Red	Commodity Item
42	4	Part	1624-107_4D	AWG 20 (0.8mm D) Wire, Orange	Commodity Item
43	4	Part	1624-107_4E	AWG 20 (0.8mm D) Wire, White	Commodity Item
44	4	Part	1624-107_4F	AWG 20 (0.8mm D) Wire, Black	Commodity Item
45	4	Part	1624-107_4G	AWG 20 (0.8mm D) Wire, Grey	Commodity Item
46	4	Part	1624-107-4H	Connector, Small, 8 Terminals, 1 TPA	Commodity Item
47	4	Part	1624-107_4I	Connector, Large, 10 Terminals, 2 TPA	Commodity Item
48	4	Part	1624-107_4J	Braided Polyester Sleeve, Black Covering	Commodity Item
49	4	Part	1624-107_4K	Tape 8.5"	Commodity Item
50	4	Part	1624-107_4L	Female Terminal, Gold tip, 18-20 AWG, 0.64mm	Commodity Item
51	4	Part	1624-107_4M	Female Terminal Small, 18-20 AWG, Gold, 0.5m	Commodity Item
52	4	Manufacturing Steps		Assemble Harness, 7 Leads	
53	5	Manufacturing Process		Auto Asm	
54	5	Manufacturing Process		Auto Asm	
55	5	Manufacturing Process		Auto Asm	

Row	Level	Symbol Type	Number	Name	Material Name
56	5	Manufacturing Process		Auto Asm	
57	3	Manufacturing Steps		Assemble PCB-DC/DC Harness to Capacitor Asm	
58	4	Manufacturing Process		Manual Asm	

Table C-36 Toyota DC/DC Electrical & Harnesses Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius DC/DC Electrical & Harness

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-74	**Receptacle Cover 2 Asm w/Gasket**	**$0.60**	**1**	**$0.60**
1624-74_1	**Receptacle Cover 2 Asm**	**$0.60**	**1**	**$0.60**
1624-74_1a	Steel Spacer	$0.02	2	$0.04
1624-74_1b	**Copper Plate**	**$0.31**	**1**	**$0.31**
1624-74_1b Plating	Plating, Copper Plate	$0.01	1	$0.01
1624-74_1b Material	Material, Copper Plate	$0.30	1	$0.30
1624-74_1c	Bolt M6x1 15mm	$0.02	1	$0.02
1624-74_1 Material	Material, Receptacle Cover 2	$0.23	1	$0.23
1624-74_2	**Gasket**	**$0.00**	**1**	**$0.00**
1624-74_2 Material	Material, Gasket	$0.00	1	$0.00
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	2	$0.04
1624-106	**Receptacle 3 Asm**	**$1.18**	**1**	**$1.18**
1624-106_1	**Receptacle Housing**	**$0.04**	**1**	**$0.04**
1624-106_1 Material	Material, Receptacle Housing	$0.04	1	$0.04
1624-106_2	Metal Spacer	$0.03	2	$0.06
1624-106_3	Connector Pin	$0.09	12	$1.08
1624-77_4	SEMs Screw, M4 x 0.70, 11.5 mm	$0.06	2	$0.12
1624-107_3	**Control PCB to DC/DC Harness**	**$0.75**	**1**	**$0.75**
1624-107_4A	AWG 20 (0.8mm D) Wire, Blue	$0.01	1	$0.01
1624-107_4B	AWG 20 (0.8mm D) Wire, Brown	$0.01	1	$0.01
1624-107_4C	AWG 20 (0.8mm D) Wire, Red	$0.01	1	$0.01
1624-107_4D	AWG 20 (0.8mm D) Wire, Orange	$0.01	1	$0.01
1624-107_4E	AWG 20 (0.8mm D) Wire, White	$0.01	1	$0.01
1624-107_4F	AWG 20 (0.8mm D) Wire, Black	$0.01	1	$0.01
1624-107_4G	AWG 20 (0.8mm D) Wire, Grey	$0.01	1	$0.01
1624-107-4H	Connector, Small, 8 Terminals, 1 TPA	$0.14	1	$0.14
1624-107_4I	Connector, Large, 10 Terminals, 2 TPA	$0.20	1	$0.20
1624-107_4J	Braided Polyester Sleeve, Black Covering	$0.03	1	$0.03
1624-107_4K	Tape 8.5"	$0.01	1	$0.01
1624-107_4L	Female Terminal, Goldtip, 18-20 AWG, 0.64mm	$0.02	7	$0.16
1624-107_4M	Female Terminal Small, 18-20 AWG, Gold, 0.5m	$0.02	7	$0.14

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	7	Piece Cost (Total): $2.69	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	51		*Parts:*	*0*
Fasteners:	5		*Fasteners:*	*0*
Parts+Unanalyzed:	51		*Parts+Unanalyzed:*	*0*

Table C-37 Toyota Inverter: Internal Housings Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-98_2	Load Spring Asm	(None)
2	4	Preprocessed Part	1624-98_2a	Load Spring Outer Bracket	Steel 1020 Cold Drawn or Cold Rolled - Galvanized
3	5	Manufacturing Steps		Load Spring Outer Bracket Processing	
4	6	Manufacturing Process		Wash	
5	6	Manufacturing Process		Debur	
6	6	Manufacturing Process		Stamping Press, 200 Ton	
7	7	Part	1624-98_2a Material	Material, Load Spring Outer Bracket	Steel 1020 Cold Drawn or Cold Rolled - Galvanized
8	4	Preprocessed Part	1624-98_2b	Load Spring Center Plate	Steel 1040 Cold Drawn or Cold Rolled
9	5	Manufacturing Steps		Load Spring Center Plate Processing	
10	6	Manufacturing Process		Wash	
11	6	Manufacturing Process		Debur	
12	6	Manufacturing Process		Stamping Press, 25 Ton	
13	7	Part	1624-98_2b Material	Material, Load Spring Center Plate	Steel 1040 Cold Drawn or Cold Rolled
14	4	Preprocessed Part	1624-98_2c	Load Spring Outer Plate	Steel 1010 Cold Drawn or Cold Rolled
15	5	Manufacturing Steps		Load Spring Outer Plate Processing	
16	6	Manufacturing Process		Wash	
17	6	Manufacturing Process		Debur	
18	6	Manufacturing Process		Stamping Press, 60 Ton	
19	7	Part	1624-98_2c Material	Material, Load Spring Outer Plate	Steel 1040 Cold Drawn or Cold Rolled

Row	Level	Symbol Type	Number	Name	Material Name
20	4	Part	1624-98_2d	Load Spring Rivet	Commodity Item
21	4	Manufacturing Steps		Assemble Load Spring Asm	
22	5	Manufacturing Process		Auto Asm	
23	3	Preprocessed Part	1624-98_1	IGBT Asm Spacer	Aluminum A380, Cast
24	4	Manufacturing Steps		IGBT Asm Spacer Processing	
25	5	Manufacturing Process		Machining	
26	6	Part	1624-98_1 Material	Material, IGBT Asm Spacer	Aluminum A380, Cast
27	3	Preprocessed Part	1624-98_1	IGBT Asm Spacer	Aluminum A380, Cast
28	4	Manufacturing Steps		IGBT Asm Spacer Processing	
29	5	Manufacturing Process		Machining	
30	6	Part	1624-98_1 Material	Material, IGBT Asm Spacer	Aluminum A380, Cast
31	3	Manufacturing Steps		Install Load Spring & Spacers to Cooling Stack	
32	4	Manufacturing Process		Manual Asm	
33	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
34	3	Manufacturing Steps		Motor Controller Sub Asm to DC/DC Convertor SubAsm	
35	4	Manufacturing Process		Auto Asm	

Table C-38 Toyota Inverter: Internal Housings Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius Inverter Internal Housings

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-98_2	**Load Spring Asm**	**$0.50**	**1**	**$0.50**
1624-98_2a	**Load Spring Outer Bracket**	**$0.28**	**1**	**$0.28**
1624-98_2a Material	Material, Load Spring Outer Bracket	$0.28	1	$0.28
1624-98_2b	**Load Spring Center Plate**	**$0.09**	**1**	**$0.09**
1624-98_2b Material	Material, Load Spring Center Plate	$0.09	1	$0.09
1624-98_2c	**Load Spring Outer Plate**	**$0.13**	**1**	**$0.13**
1624-98_2c Material	Material, Load Spring Outer Plate	$0.13	1	$0.13
1624-98_2d	Load Spring Rivet	$0.00	1	$0.00
1624-98_1	**IGBT Asm Spacer**	**$0.06**	**1**	**$0.06**
1624-98_1 Material	Material, IGBT Asm Spacer	$0.06	1	$0.06
1624-98_1	**IGBT Asm Spacer**	**$0.06**	**1**	**$0.06**
1624-98_1 Material	Material, IGBT Asm Spacer	$0.06	1	$0.06
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	11	$0.22

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	6	Piece Cost (Total): $0.84	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	17		*Parts:*	*0*
Fasteners:	12		*Fasteners:*	*0*
Parts+Unanalyzed:	17		*Parts+Unanalyzed:*	*0*

Toyota Inverter: Bus Bars Materials and Processing Assumptions

The Toyota inverter bus bar group consists of no additional components. The group was created for comparisons to similar groups analyzed in other portions of the project.

Table C-39 Toyota Inverter: Bus Bars Bill of Materials

Toyota Inverter: PCBAs & IGBTs Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-77	Main Controller Circuit Board	(None)
2	5	Part	1150819	Automotive Dual Connector 24/13 pin Male	Commodity Item
3	4	Manufacturing Steps		Printed Circuit Board Assembly	
4	5	Manufacturing Process		Functional Test	
5	5	Manufacturing Process		Conformal Coat	
6	6	Part	Conformal Coat, PCBA-3	Conformal Coat, PCBA	Commodity Item
7	5	Manufacturing Process		Manual Thru Hole Placement	
8	5	Manufacturing Process		De-Panel	
9	5	Manufacturing Process		PCB - High Content	
10	6	Part	1624-77-1	Printed FR4, 6 Layer Circuit Board	Commodity Item
11	7	Part	EF2210 VOC Free Flux-1	EF2210 VOC Free Flux	Commodity Item
12	7	Part	LF318 Solder Paste-1	LF318 Solder Paste	Commodity Item
13	7	Part	Loctite Chipbonder 3627-1	Loctite Chipbonder 3627	Commodity Item
14	8	Part	NRVB1H100SFT3G	Diode Schottky 100V 1A Automotive 2-Pin SOD-123FL	Commodity Item
15	8	Part	TJ8S06M3L(T6L1,NQ)	MOSFET P-Ch MOS -8A -60V 27W 890pF 0.104	Commodity Item
16	8	Part	TK8S06K3L(T6L1,NQ)	MOSFET N-Ch MOS 8A 60V 25W 400pF 0.054	Commodity Item
17	8	Part	BAV99W,115	Diodes, Power, Switching SW 75V SOT323/SC70	Commodity Item
18	8	Part	2SA1586-GR,LF	Bipolar Transistors - BJT PNP Transistor -50V	Commodity Item
19	8	Part	MMST2907A-7-F	TRANS PNP 60V 0.6A SC70-3	Commodity Item
20	8	Part	DAN202KT146-1	Diodes - General Purpose, Power, Switching 80V 100	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
21	8	Part	BC817-40W,115	Bipolar Transistors - BJT NPN 45V 500mA	Commodity Item
22	8	Part	BR35H640FJ-WCE2	EEPROM EEPROM Serial-SPI 64Kb SOP-J8	Commodity Item
23	8	Part	NSV1SS400T1G	Diodes - Automotive, Switching SWDI 100V TR SOD-52	Commodity Item
24	8	Part	MM3Z27VT1G	Zener Diode 27V 300mW �5% Surface Mount SOD-323	Commodity Item
25	8	Part	BZX585-C2V7,135	Diode Zener Single 2.705V 5% 300mW 2-Pin SOD-523 T	Commodity Item
26	8	Part	805	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
27	8	Part	603	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
28	8	Part	402	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
29	8	Part	HZC686M050F24VT-F	Aluminum Organic Polymer Capacitors 68uF 50V 20%	Commodity Item
30	8	Part	HZC686M035X16T-F	Aluminum Organic Polymer Capacitors 68uF 35V 20%	Commodity Item
31	8	Part	HZC336M050X16T-F	Aluminum Organic Polymer Capacitors 33uF 50 Volts	Commodity Item
32	8	Part	EMVH500ADA470MHA0G	Aluminum Capacitors Radial, Can 47�F 50V	Commodity Item
33	8	Part	HZC157M035F24T-F	Aluminum Organic Polymer Capacitors 150uF 35 Volts	Commodity Item
34	8	Part	TGM-H251NFLF	Pulse Transformers ISO MOD SMD GullWing	Commodity Item
35	8	Part	CLF6045NIT-151M-D	Fixed Inductors 150uH 0.48ohms 0.53A 20% AEC-Q200	Commodity Item
36	8	Part	CLF7045NIT-470M-D	Ind Power Shielded Wirewound 47uH 20% 100KHz Ferri	Commodity Item
37	8	Part	ETQ-P3M1R5YFN	Fixed Inductors PCC 1.5uH 20% AEC-Q200	Commodity Item
38	8	Part	CLF10040T-470M	Ind Power Shielded Wirewound 47uH 20% 100KHz Ferri	Commodity Item
39	8	Part	ACM9070-701-2PL-TL01	Electromechanical Filter 700Ohm 10ADC	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
40	8	Part	805-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
41	8	Part	603-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
42	8	Part	A 15375	Hybrid Automotive Connector 6 pin Male/Female Lock	Commodity Item
43	8	Part	B 15466	Hybrid Automotive Connector 7 pin Male/Female Lock	Commodity Item
44	8	Part	NRVB1H100SFT3G	Diode Schottky 100V 1A Automotive 2-Pin SOD-123FL	Commodity Item
45	8	Part	TLP2309(TPL,E)	High Speed Optocouplers 3.3V 5V Supply Volt 30V 1A	Commodity Item
46	8	Part	TLP183(TPL,E	Optocoupler AC-IN 1-CH Transistor DC-OUT 4-Pin SO	Commodity Item
47	8	Part	DRV8702QRHBRQ1	Half-Bridge Gate Driver IC 32-VQFN (5x5)	Commodity Item
48	8	Part	DMN2019UTS-13	MOSFET BVDSS: 8V-24V 24V TSSOP-8 T&R 2.5K	Commodity Item
49	8	Part	BZX585-C2V7,135	Diode Zener Single 2.705V 5% 300mW 2-Pin SOD-523 T	Commodity Item
50	8	Part	DDZX18C-7	Zener Diode 18V 300mW �3% Surface Mount SOT-23-3	Commodity Item
51	8	Part	TJ8S06M3L(T6L1,NQ)	MOSFET P-Ch MOS -8A -60V 27W 890pF 0.104	Commodity Item
52	8	Part	FDB035AN06A0_F085	MOSFET N-CH 60V 22A TO-263AB	Commodity Item
53	8	Part	BAV99W,115	Diodes, Power, Switching SW 75V	Commodity Item
54	8	Part	MM3Z27VT1G	Zener Diode 27V 300mW �5% Surface Mount SOD-323	Commodity Item
55	8	Part	ACZRW5233B-G	Zener Diodes ZENER 0.35W 6V AEC-Q101	Commodity Item
56	8	Part	RB088NS150FHTL	Schottky Rectifier, 150 V, 10 A, Dual Com Cathode,	Commodity Item
57	8	Part	SML4750A-E3/61	Zener Diode 27V 1W �5% Surface Mount DO-214AC (SMA	Commodity Item
58	8	Part	D12363VF33V	MCU 16-bit H8S CISC ROMLess 3.3V 128-Pin PQFP	Commodity Item
59	8	Part	LM2904YST	General Purpose Amplifier 2 Circuit 8-MiniSO	Commodity Item
60	8	Part	CMH01(TE12L,Q,M)	Rectifiers 200V Vrrm 3.0A IF 0.98 VFM 40A IFSM SOD	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
61	8	Part	TMS320F28075PTPQ	Microcontroller IC 32-Bit 120MHz 512KB (256K x 16)	Commodity Item
62	8	Part	EB16E2G2H-25.000M	Standard Clock Oscillators 25MHz 1.8Vdc 100ppm	Commodity Item
63	8	Part	MMST2907A-7-F	TRANS PNP 60V 0.6A SC70-3	Commodity Item
64	8	Part	DAN202KT146-1	Diodes - General Purpose, Power, Switching 80V 100	Commodity Item
65	8	Part	2SA1586-GR,LF	Bipolar Transistors - BJT PNP Transistor -50V	Commodity Item
66	8	Part	UMR11NTR	Diodes - General Purp, Power, SW DIODE SOT-363-6	Commodity Item
67	8	Part	DTC114EUAT106	Bipolar Transistors - Pre-Biased NPN 50V 50MA SOT-	Commodity Item
68	8	Part	DTA114EEBTL	Bipolar Transistors - Pre-Biased TRANSISTORS 100MA	Commodity Item
69	8	Part	2SC4081UBTLR	Bipolar Transistors - BJT GP NPN Trans 50V 0.15A U	Commodity Item
70	8	Part	BD750L2FP-CE2	LDO Voltage Reg IC Pwr Linear Single Output TO-252	Commodity Item
71	8	Part	NSV1SS400T1G	Diodes - Automotive, Switching SWDI 100V TR SOD-52	Commodity Item
72	8	Part	LM5117PMHX/NOPB	Switching Controllers Sync Buck Cntlr 20-HTSSOP	Commodity Item
73	8	Part	805	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
74	8	Part	603	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
75	8	Part	402	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
76	8	Part	ACT45L-201-2P-TL000-1	Filter, Common Mode Choke 200�H @ 100kHz 2 Line	Commodity Item
77	8	Part	805-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
78	8	Part	603-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
79	8	Part	57201	Hybrid Automotive Connector 6 pin Female Lock	Commodity Item
80	8	Part	57152	Hybrid Automotive Connector 7 pin Female Lock	Commodity Item
81	3	Part	1624-77_1	Shoulder Screw, M4 x 0.70, 8.25 mm	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
82	3	Part	1624-77_2	Shoulder Screw O-Ring	Commodity Item
83	3	Part	1624-77_3	Flat Washer	Commodity Item
84	3	Part	1624-77_4	SEMs Screw, M4 x 0.70, 11.5 mm	Commodity Item
85	3	Manufacturing Steps		Circuit Board 1 Asm to Inverter Module	
86	4	Manufacturing Process		Manual Asm	
87	3	Subassembly	1624-98_3	Resistor Array Circuit Board	(None)
88	4	Manufacturing Steps		Resistor Array Circuit Board Assembly	
89	5	Manufacturing Process		Laser Etch	
90	5	Manufacturing Process		Functional Test	
91	5	Manufacturing Process		De-Panel	
92	5	Manufacturing Process		PCB - Low Content	
93	6	Part	Printed FR4 Circuit Board	Printed FR4 Circuit Board	Commodity Item
94	7	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
95	7	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
96	7	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item
97	7	Part	1210 Resistors	Tolerance - 5%; 1210 (3225 Metric) 0.126" L x 0.09	Commodity Item
98	3	Part	1624-98_4	Phillips Screw, M3 x 0.5, 7.6 mm	Commodity Item
99	3	Manufacturing Steps		Circuit Board 1 to Capacitor Asm	
100	4	Manufacturing Process		Auto Asm	
101	3	Subassembly	1624-98_5	Current Sensing Circuit Board	(None)
102	4	Manufacturing Steps		Current Sensing Circuit Board Assembly	
103	5	Manufacturing Process		Functional Test	
104	5	Manufacturing Process		De-Panel	
105	5	Manufacturing Process		PCB - Low Content	
106	6	Part	Printed FR4 Circuit Board-1	Printed FR4 Circuit Board	Commodity Item
107	7	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
108	7	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
109	7	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item
110	7	Part	OHS3151U	Hall Effect Sensor Single Axis TO-92-3	Commodity Item
111	7	Part	0603 Capacitors-2	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
112	7	Part	0603 Resistors-3	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	Commodity Item
113	3	Part	1624-98_6	Phillips Screw, M2 x 0.4, 7.6 mm	Commodity Item
114	3	Manufacturing Steps		Circuit Board 2 to Leadframe	
115	4	Manufacturing Process		Auto Asm	
116	3	Part	1624-98_7	IGBT	Commodity Item
117	3	Preprocessed Part	1624-98_11	Shim, Alumina, IGBT	Aluminum Nitride (AlN) (Default Material Library)
118	4	Manufacturing Steps		Ferrite 1 Processing	
119	5	Manufacturing Process		Wash	
120	5	Manufacturing Process		Oven Sintering Furnace	
121	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
122	6	Part	1624-98_11 Material	Material, Shim, Alumina, IGBT	Aluminum Nitride (AlN) (Default Material Library)
123	3	Part	1624_4	Heat Sink Compound	Commodity Item
124	3	Manufacturing Steps		Assemble IGBT Cooler Asm	

Table C-40 Toyota Inverter: PCBAs & IGBTs Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-77	**Circuit Board 1 Asm**	**$129.42**	**1**	**$129.42**
1150819	Automotive Dual Connector 24/13 pin Male	$2.02	1	$2.02
Conformal Coat, PCBA-3	Conformal Coat, PCBA	$0.77	1	$0.77
1624-77-1	Printed FR4, 6 Layer Circuit Board	$13.97	1	$13.97
EF2210 VOC Free Flux-1	EF2210 VOC Free Flux	$0.06	1	$0.06
LF318 Solder Paste-1	LF318 Solder Paste	$0.80	1	$0.80
Loctite Chipbonder 3627-1	Loctite Chipbonder 3627	$0.23	1	$0.23
NRVB1H100SFT3G	Diode Schottky 100V 1A Automotive 2-Pin SOD-123FL	$0.13	20	$2.60
TJ8S06M3L(T6L1,NQ)	MOSFET P-Ch MOS-8A -60V 27W 890pF 0.104	$0.24	2	$0.48
TK8S06K3L(T6L1,NQ)	MOSFET N-Ch MOS8A 60V 25W 400pF 0.054	$0.27	2	$0.54
BAV99W,115	Diodes, Power, Switching SW 75V SOT323/SC70	$0.01	14	$0.14
2SA1586-GR,LF	Bipolar Transistors - BJT PNP Transistor -50V	$0.01	3	$0.03
MMST2907A-7-F	TRANS PNP 60V 0.6A SC70-3	$0.01	2	$0.02
DAN202KT146-1	Diodes - General Purpose, Power, Switching 80V 100	$0.01	2	$0.02
BC817-40W,115	Bipolar Transistors - BJT NPN 45V 500mA	$0.01	4	$0.04
BR35H640FJ-WCE2	EEPROM EEPROM Serial-SPI 64Kb SOP-J8	$0.39	1	$0.39
NSV1SS400T1G	Diodes - Automotive, Switching SWDI 100V TR SOD-52	$0.02	6	$0.12
MM3Z27VT1G	Zener Diode 27V 300mW �5% Surface Mount SOD-323	$0.01	3	$0.03
BZX585-C2V7,135	Diode Zener Single 2.705V 5% 300mW 2-Pin SOD-523 T	$0.02	2	$0.04
805	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	75	$2.16
603	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	214	$2.53
402	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	115	$0.38
HZC686M050F24VT-F	Aluminum Organic Polymer Capacitors 68uF 50V 20%	$0.21	2	$0.42
HZC686M035X16T-F	Aluminum Organic Polymer Capacitors 68uF 35V 20%	$0.54	1	$0.54
HZC336M050X16T-F	Aluminum Organic Polymer Capacitors 33uF 50 Volts	$0.49	2	$0.98
EMVH500ADA470MHA0G	Aluminum Capacitors Radial, Can 47�F 50V	$0.19	1	$0.19
HZC157M035F24T-F	Aluminum Organic Polymer Capacitors 150uF 35 Volts	$0.13	2	$0.26
TGM-H251NFLF	Pulse Transformers ISO MOD SMD GullWing	$1.10	10	$11.00
CLF6045NIT-151M-D	Fixed Inductors 150uH 0.48ohms 0.53A 20% AEC-Q200	$0.29	5	$1.45
CLF7045NIT-470M-D	Ind Power Shielded Wirewound 47uH 20% 100KHz Ferri	$0.33	2	$0.66
ETQ-P3M1R5YFN	Fixed Inductors PCC 1.5uH 20% AEC-Q200	$0.48	2	$0.96

Prius Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
CLF10040T-470M	Ind Power Shielded Wirewound 47uH 20% 100KHz Ferri	$0.28	3	$0.84
ACM9070-701-2PL-TL01	Electromechanical Filter 700Ohm 10ADC	$0.32	1	$0.32
805-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.00	19	$0.02
603-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	28	$0.05
A 15375	Hybrid Automotive Connector 6 pin Male/Female Lock	$0.42	19	$7.98
B 15466	Hybrid Automotive Connector 7 pin Male/Female Lock	$0.48	2	$0.96
NRVB1H100SFT3G	Diode Schottky 100V 1A Automotive 2-Pin SOD-123FL	$0.13	29	$3.77
TLP2309(TPL,E)	High Speed Optocouplers 3.3V 5V Supply Volt 30V 1A	$0.41	17	$6.97
TLP183(TPL,E	Optocoupler AC-IN 1-CH Transistor DC-OUT 4-Pin SO	$0.06	14	$0.84
DRV8702QRHBRQ1	Half-Bridge Gate Driver IC 32-VQFN (5x5)	$0.96	14	$13.44
DMN2019UTS-13	MOSFET BVDSS: 8V-24V 24V TSSOP-8 T&R 2.5K	$0.09	3	$0.27
BZX585-C2V7,135	Diode Zener Single 2.705V 5% 300mW 2-Pin SOD-523 T	$0.02	4	$0.08
DDZX18C-7	Zener Diode 18V 300mW �3% Surface Mount SOT-23-3	$0.02	2	$0.04
TJ8S06M3L(T6L1,NQ)	MOSFET P-Ch MOS-8A -60V 27W 890pF 0.104	$0.24	3	$0.72
FDB035AN06A0_F085	MOSFET N-CH 60V 22A TO-263AB	$1.35	2	$2.70
BAV99W,115	Diodes, Power, Switching SW 75V	$0.01	9	$0.09
MM3Z27VT1G	Zener Diode 27V 300mW �5% Surface Mount SOD-323	$0.01	5	$0.05
ACZRW5233B-G	Zener Diodes ZENER 0.35W 6V AEC-Q101	$0.02	1	$0.02
RB088NS150FHTL	Schottky Rectifier, 150V, 10 A, Dual Com Cathode,	$0.58	1	$0.58
SML4750A-E3/61	Zener Diode 27V 1W �5% Surface Mount DO-214AC (SMA	$0.11	2	$0.22
D12363VF33V	MCU 16-bit H8S CISC ROMLess 3.3V 128-Pin PQFP	$6.81	1	$6.81
LM2904YST	General Purpose Amplifier 2 Circuit 8-MiniSO	$0.09	2	$0.18
CMH01(TE12L,Q,M)	Rectifiers 200V Vrrm 3.0A IF 0.98 VFM 40A IFSM SOD	$0.20	3	$0.60
TMS320F28075PTPQ	Microcontroller IC 32-Bit 120MHz 512KB (256K x 16)	$10.65	2	$21.30
EB16E2G2H-25.000M	Standard Clock Oscillators 25MHz 1.8Vdc 100ppm	$0.48	2	$0.96
MMST2907A-7-F	TRANS PNP 60V 0.6A SC70-3	$0.01	2	$0.02
DAN202KT146-1	Diodes - General Purpose, Power, Switching 80V 100	$0.01	1	$0.01
2SA1586-GR,LF	Bipolar Transistors - BJT PNP Transistor -50V	$0.01	1	$0.01
UMR11NTR	Diodes - General Purp, Power, SW DIODE SOT-363-6	$0.08	1	$0.08
DTC114EUAT106	Bipolar Transistors - Pre-Biased NPN 50V 50MA SOT-	$0.01	2	$0.02
DTA114EEBTL	Bipolar Transistors - Pre-Biased TRANSISTORS 100MA	$0.02	1	$0.02
2SC4081UBTLR	Bipolar Transistors - BJT GP NPN Trans 50V 0.15A U	$0.02	1	$0.02

Prius Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
BD750L2FP-CE2	LDO Voltage Reg IC Pwr Linear Single Output TO-252	$0.50	2	$1.00
NSV1SS400T1G	Diodes - Automotive, Switching SWDI 100V TR SOD-52	$0.02	6	$0.12
LM5117PMHX/NOPB	Switching Controllers Sync Buck Cntlr 20-HTSSOP	$2.02	2	$4.04
805	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	111	$3.20
603	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	185	$2.18
402	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	330	$1.09
ACT45L-201-2P-TL000-1	Filter, Common Mode Choke 200♦H @ 100kHz 2 Line	$0.90	2	$1.80
805-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.00	35	$0.04
603-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	10	$0.02
57201	Hybrid Automotive Connector 6 pin Female Lock	$0.10	19	$1.90
57152	Hybrid Automotive Connector 7 pin Female Lock	$0.11	2	$0.22
1624-77_1	Shoulder Screw, M4 x 0.70, 8.25 mm	$0.04	12	$0.48
1624-77_2	Shoulder Screw O-Ring	$0.04	12	$0.48
1624-77_3	Flat Washer	$0.01	12	$0.12
1624-77_4	SEMs Screw, M4 x 0.70, 11.5 mm	$0.06	3	$0.18
1624-98_3	**IGBT Circuit Board 1**	**$1.69**	**1**	**$1.69**
Printed FR4 Circuit Board	Printed FR4 Circuit Board	$0.59	1	$0.59
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.03	1	$0.03
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.01	1	$0.01
1210 Resistors	Tolerance - 5%; 1210 (3225 Metric) 0.126" L x 0.09	$0.02	52	$1.06
1624-98_4	Phillips Screw, M3x 0.5, 7.6 mm	$0.01	4	$0.04
1624-98_5	**IGBT Circuit Board 2**	**$8.73**	**1**	**$8.73**
Printed FR4 Circuit Board-1	Printed FR4 Circuit Board	$0.36	1	$0.36
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.01	1	$0.01
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.00	1	$0.00
OHS3151U	Hall Effect Sensor Single Axis TO-92-3	$1.16	7	$8.15
0603 Capacitors-2	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	$0.01	14	$0.19
0603 Resistors-3	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	3	$0.01
1624-98_6	Phillips Screw, M2x 0.4, 7.6 mm	$0.05	2	$0.10
1624-98_7	IGBT	$14.47	7	$101.29
1624-98_11	**Shim, Alumina, IGBT**	**$2.94**	**1**	**$2.94**
1624-98_11 Material	Material, Shim, Alumina, IGBT	$0.21	14	$2.94
1624_4	Heat Sink Compound	$0.03	28	$0.75

Prius Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	4	Piece Cost (Total): $246.22	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	1,577		*Parts:*	*0*
Fasteners:	21		*Fasteners:*	*0*
Parts+Unanalyzed:	1,577		*Parts+Unanalyzed:*	*0*

Table C-41 Toyota Inverter: Capacitor & Inductor Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-98_9	Capacitor Sub Asm 1	(None)
2	4	Part	1624-98_9e	PP Capacitor Film	Commodity Item
3	4	Preprocessed Part	1624-98_9a	Copper Stamping 1, Longer	Copper Cu (10200)
4	5	Manufacturing Steps		Copper Stamping 1, Longer - Processing	
5	6	Manufacturing Process		Wash	
6	6	Manufacturing Process		Debur	
7	6	Manufacturing Process		Stamping Press, 60 Ton	
8	7	Part	1624-98_9a Material	Material, Copper Stamping 1, Longer	Copper Cu (10200)
9	4	Preprocessed Part	1624-98_9b	Copper Stamping 2, Shorter	Copper Cu (10200)
10	5	Manufacturing Steps		Copper Stamping 2, Shorter - Processing	
11	6	Manufacturing Process		Wash	
12	6	Manufacturing Process		Debur	
13	6	Manufacturing Process		Stamping Press, 60 Ton	
14	7	Part	1624-98_9b Material	Material, Copper Stamping 2, Shorter	Copper Cu (10200)
15	4	Preprocessed Part	1624-98_9h	Plastic, Top Section - Vertical	PPS-GF-MD
16	5	Manufacturing Steps		Plastic, Top Section - Vertical Processing	
17	6	Manufacturing Process		Injection Mold, 55 Ton	
18	7	Part	1624-98_9h Material	Material, Plastic, Top Section - Vertical	PPS-GF-MD
19	4	Part	1624-98_9j	Plastic Insulating Paper	Commodity Item
20	4	Manufacturing Steps		Capacitor Sub Asm Process	
21	5	Manufacturing Process		Manual Assembly	
22	5	Manufacturing Process		Manual Asm	
23	4	Subassembly	1624-98_9c	Outer Casing, Capacitor Sub Asm 1	(None)
24	5	Part	1624-98_9d	Insert, Metal Spacer	Commodity Item
25	5	Manufacturing Steps		Outer Casing, Capacitor Sub Asm 1 - Processing	
26	6	Manufacturing Process		Laser Etching	

Row	Level	Symbol Type	Number	Name	Material Name
27	6	Manufacturing Process		Injection Mold Press, 150 Ton w/Inserts	
28	7	Part	1624-98_9 Material	Material, Outer Casing, Capacitor Sub Asm 1	PPS-GF-MD
29	4	Manufacturing Steps		Capacitor Sub to Case	
30	5	Manufacturing Process		Automated Assembly	
31	4	Subassembly	1624-98_9i	Small Lead Frame Asm	PPS-GF-MD
32	5	Preprocessed Part	1624-98_9k	Stamped Copper, Longer	Copper Nickel Plated
33	6	Manufacturing Steps		Stamped Copper, Longer - Processing	
34	7	Manufacturing Process		Wash	
35	7	Manufacturing Process		Debur	
36	7	Manufacturing Process		Stamping Press, 25 Ton	
37	8	Part	1624-98_9k Material	Material, Stamped Copper - Longer	Copper Nickel Plated
38	5	Preprocessed Part	1624-98_9l	Stamped Copper, Shorter	Copper Nickel Plated
39	6	Manufacturing Steps		Stamped Copper, Shorter - Processing	
40	7	Manufacturing Process		Wash	
41	7	Manufacturing Process		Debur	
42	7	Manufacturing Process		Stamping Press, 25 Ton	
43	8	Part	1624-98_9l Material	Material, Stamped Copper, Shorter	Copper Nickel Plated
44	5	Manufacturing Steps		Plastic, Side Section Processing	
45	6	Manufacturing Process		Injection Mold, 55 Ton	
46	7	Part	1624-98_9i Material	Material, Plastic, Side Section	PPS-GF-MD
47	4	Preprocessed Part	1624-98_9g	Plastic, Top Section - Horizontal	PPS-GF-MD
48	5	Manufacturing Steps		Plastic, Top Section - Horizontal Processing	
49	6	Manufacturing Process		Injection Mold, 55 Ton	
50	7	Part	1624-98_9g Material	Material, Plastic Top Section - Horizontal	PPS-GF-MD
51	4	Manufacturing Steps		Insert Lead Frame and Cover	
52	5	Manufacturing Process		Auto Asm	

Row	Level	Symbol Type	Number	Name	Material Name
53	4	Part	1624-98_9f	Epoxy Potting, Capacitor Sub Asm 1	Commodity Item
54	4	Manufacturing Steps		Processing and Curing Process	
55	5	Manufacturing Process		Inspection	
56	5	Manufacturing Process		Curing Oven 8'x8'	
57	5	Manufacturing Process		Vacuum Potting & Encapsulation	
58	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
59	3	Manufacturing Steps		Install Capacitor Asm	
60	4	Manufacturing Process		Spot Weld	
61	4	Manufacturing Process		Auto Asm	
62	3	Part	1624-109_1	Thermal Insulation Compound	Commodity Item
63	3	Manufacturing Steps		Thermal Insulation Compound to Enclosure Main 2	
64	4	Manufacturing Process		Auto Asm	
65	3	Subassembly	1624-107_1	Capacitor Asm	(None)
66	4	Preprocessed Part	1624-107_1a	Copper Stamping 1	Copper Cu (10200)
67	5	Manufacturing Steps		Copper Stamping 1 Processing	
68	6	Manufacturing Process		Wash	
69	6	Manufacturing Process		Debur	
70	6	Manufacturing Process		Stamping Press, 25 Ton	
71	7	Part	1624-107_1a Material	Material, Copper Stamping 1	Copper Cu (10200)
72	4	Preprocessed Part	1624-107_1b	Copper Stamping 2	Copper Cu (10200)
73	5	Manufacturing Steps		Copper Stamping 2 Processing	
74	6	Manufacturing Process		Wash	
75	6	Manufacturing Process		Debur	
76	6	Manufacturing Process		Stamping Press, 25 Ton	
77	7	Part	1624-107_1b Material	Material, Copper Stamping 2	Copper Cu (10200)
78	4	Preprocessed Part	1624-107_1c	Copper Stamping 3	Copper Cu (10200)
79	5	Manufacturing Steps		Copper Stamping 3 Processing	

Row	Level	Symbol Type	Number	Name	Material Name
80	6	Manufacturing Process		Wash	
81	6	Manufacturing Process		Debur	
82	6	Manufacturing Process		Stamping Press, 60 Ton	
83	7	Part	1624-107_1c Material	Material, Copper Stamping 3	Copper Cu (10200)
84	4	Subassembly	1624-107_1j	Capacitor Outer Casing Asm	(None)
85	5	Part	1624-107_1e	Metal Spacer, Insert 4	Commodity Item
86	5	Part	1624-107_1f	M4 x 0.7, Flanged Nut, Insert 1	Commodity Item
87	5	Part	1624-107_1g	M3 x 0.7, Nut, Insert 2	Commodity Item
88	5	Part	1624-107_1h	M4 x 0.7, Nut, Insert 3	Commodity Item
89	5	Manufacturing Steps		Capacitor Outer Casing Asm Processing	
90	6	Manufacturing Process		Auto Asm	
91	6	Manufacturing Process		Laser Etching	
92	6	Manufacturing Process		Injection Mold Press, 110 Ton w/Inserts	
93	7	Part	1624-107_1 Material	Material, Capacitor Asm	PPS-GF-MD
94	4	Part	1624-107_1i	PP, Metalized Film Capacitor	Commodity Item
95	4	Manufacturing Steps		Capacitor Asm Processing	
96	5	Manufacturing Process		Auto Asm	
97	5	Manufacturing Process		Manual Asm	
98	4	Part	1624-107_1d	Epoxy Potting, Capacitor Asm	Commodity Item
99	4	Manufacturing Steps		Potting & Curing Process	
100	5	Manufacturing Process		Inspection	
101	5	Manufacturing Process		Curing Oven 8x8'	
102	5	Manufacturing Process		Vacuum Potting & Encapsulation	
103	3	Subassembly	1624-107_2	Inductor Assy	(None)
104	4	Subassembly	1624-107_2G	Core/Coil Assy	(None)
105	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
106	6	Manufacturing Steps		Injection Molding Process	
107	7	Manufacturing Process		Injection Mold Press, 55 Ton	
108	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
109	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
110	6	Manufacturing Steps		Injection Molding Process	
111	7	Manufacturing Process		Injection Mold Press, 110 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
112	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
113	5	Manufacturing Steps		Spacer Assy	
114	6	Manufacturing Process		Manual Asm	
115	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
116	6	Manufacturing Steps		Injection Molding Process	
117	7	Manufacturing Process		Injection Mold Press, 55 Ton	
118	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
119	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
120	6	Manufacturing Steps		Injection Molding Process	
121	7	Manufacturing Process		Injection Mold Press, 110 Ton	
122	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
123	5	Manufacturing Steps		Spacer Assy	
124	6	Manufacturing Process		Manual Asm	
125	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
126	6	Manufacturing Steps		Injection Molding Process	
127	7	Manufacturing Process		Injection Mold Press, 55 Ton	
128	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
129	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
130	6	Manufacturing Steps		Injection Molding Process	
131	7	Manufacturing Process		Injection Mold Press, 110 Ton	
132	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
133	5	Manufacturing Steps		Spacer Assy	
134	6	Manufacturing Process		Manual Asm	
135	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
136	6	Manufacturing Steps		Injection Molding Process	
137	7	Manufacturing Process		Injection Mold Press, 55 Ton	
138	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
139	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
140	6	Manufacturing Steps		Injection Molding Process	
141	7	Manufacturing Process		Injection Mold Press, 110 Ton	
142	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
143	5	Manufacturing Steps		Spacer Assy	
144	6	Manufacturing Process		Manual Asm	

Row	Level	Symbol Type	Number	Name	Material Name
145	5	Part	1624-107_2C-1	Material, Flat Copper Wire, Coated	Commodity Item
146	5	Manufacturing Steps		Copper Winding Assy Process	
147	6	Manufacturing Process		Coil Winding w/Insulator	
148	6	Manufacturing Process		Coil Winding w/Insulator	
149	5	Preprocessed Part	1624-107_2B	Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
150	6	Manufacturing Steps		Magnetic Core, C Block, Processing	
151	7	Manufacturing Process		Wash	
152	7	Manufacturing Process		Oven Sintering Furnace	
153	7	Manufacturing Process		Powdered Metal Press, 100 Ton	
154	8	Part	1624-107_2B-1 Material	Material, Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
155	5	Part	1624-107_2H	Alumina Spacers	Commodity Item
156	5	Part	1624-107_2E	Adhesive Magnetic Core	Commodity Item
157	5	Manufacturing Steps		Core and Coil Assy Process	
158	6	Manufacturing Process		Auto Asm	
159	5	Preprocessed Part	1624-107_2B	Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
160	6	Manufacturing Steps		Magnetic Core, C Block, Processing	
161	7	Manufacturing Process		Wash	
162	7	Manufacturing Process		Oven Sintering Furnace	
163	7	Manufacturing Process		Powdered Metal Press, 100 Ton	
164	8	Part	1624-107_2B-1 Material	Material, Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
165	5	Part	1624-107_2E	Adhesive Magnetic Core	Commodity Item
166	5	Manufacturing Steps		Core and Coil Assy Process	
167	6	Manufacturing Process		Spot Weld	
168	6	Manufacturing Process		Auto Asm	
169	5	Preprocessed Part	1624-107_2D	Inductor Housing Retainer	PPS-GF-MD
170	6	Manufacturing Steps		Injection Molding Process	
171	7	Manufacturing Process		Injection Mold Press, 55 Ton	
172	8	Part	1624-107_2D Material	Material, Inductor Housing Retainer	PPS-GF-MD
173	5	Preprocessed Part	1624-107_2D	Inductor Housing Retainer	PPS-GF-MD
174	6	Manufacturing Steps		Injection Molding Process	
175	7	Manufacturing Process		Injection Mold Press, 55 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
176	8	Part	1624-107_2D Material	Material, Inductor Housing Retainer	PPS-GF-MD
177	5	Manufacturing Steps		Coil Support and Retainer Process	
178	6	Manufacturing Process		Auto Asm	
179	4	Part	1624-107_2A	Steel Spacer	Commodity Item
180	4	Manufacturing Steps		Inductor Over Mold Assy Process	
181	5	Manufacturing Process		Injection Mold Press, 55 Ton	
182	6	Part	1624-107_2I Material	Material, Inductor Housing	PPS-GF-MD
183	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
184	3	Manufacturing Steps		Capacitor & Inductor Asm to Enclosure Main 2	
185	4	Manufacturing Process		MIG Weld	
186	4	Manufacturing Process		Auto Asm	

Table C-42 Toyota Inverter: Capacitor & Inductor Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius Inverter Capacitor & Inductor

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-98_9	**Capacitor Sub Asm 1**	**$33.89**	**1**	**$33.89**
1624-98_9e	PP Capacitor Film	$4.32	4	$17.26
1624-98_9a	**Copper Stamping 1, Longer**	**$1.46**	**1**	**$1.46**
1624-98_9a Material	Material, Copper Stamping 1, Longer	$1.46	1	$1.46
1624-98_9b	**Copper Stamping 2, Shorter**	**$0.93**	**1**	**$0.93**
1624-98_9b Material	Material, Copper Stamping 2, Shorter	$0.93	1	$0.93
1624-98_9h	**Plastic, Top Section - Vertical**	**$0.07**	**1**	**$0.07**
1624-98_9h Material	Material, Plastic, Top Section - Vertical	$0.07	1	$0.07
1624-98_9j	Plastic Insulating Paper	$0.03	1	$0.03
1624-98_9c	**Outer Casing, Capacitor Sub Asm 1**	**$1.16**	**1**	**$1.16**
1624-98_9d	Insert, Metal Spacer	$0.05	3	$0.15
1624-98_9 Material	Material, Outer Casing, Capacitor Sub Asm 1	$1.01	1	$1.01
1624-98_9i	**Small Lead Frame Asm**	**$0.23**	**1**	**$0.23**
1624-98_9k	**Stamped Copper, Longer**	**$0.10**	**1**	**$0.10**
1624-98_9k Material	Material, Stamped Copper - Longer	$0.10	1	$0.10
1624-98_9l	**Stamped Copper, Shorter**	**$0.06**	**1**	**$0.06**
1624-98_9l Material	Material, Stamped Copper, Shorter	$0.06	1	$0.06
1624-98_9i Material	Material, Plastic, Side Section	$0.07	1	$0.07
1624-98_9g	**Plastic, Top Section - Horizontal**	**$0.71**	**1**	**$0.71**
1624-98_9g Material	Material, Plastic Top Section - Horizontal	$0.71	1	$0.71
1624-98_9f	Epoxy Potting, Capacitor Sub Asm 1	$12.04	1	$12.04
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	3	$0.06
1624-109_1	Thermal Insulation Compound	$2.18	1	$2.18
1624-107_1	**Capacitor Asm**	**$26.49**	**1**	**$26.49**
1624-107_1a	**Copper Stamping 1**	**$0.31**	**1**	**$0.31**
1624-107_1a Material	Material, Copper Stamping 1	$0.31	1	$0.31
1624-107_1b	**Copper Stamping 2**	**$0.40**	**1**	**$0.40**
1624-107_1b Material	Material, Copper Stamping 2	$0.40	1	$0.40
1624-107_1c	**Copper Stamping 3**	**$1.15**	**1**	**$1.15**
1624-107_1c Material	Material, Copper Stamping 3	$1.15	1	$1.15
1624-107_1j	**Capacitor Outer Casing Asm**	**$1.89**	**1**	**$1.89**
1624-107_1e	Metal Spacer, Insert 4	$0.05	3	$0.15
1624-107_1f	M4 x 0.7, Flanged Nut, Insert 1	$0.01	4	$0.04
1624-107_1g	M3 x 0.7, Nut, Insert 2	$0.09	2	$0.18
1624-107_1h	M4 x 0.7, Nut, Insert 3	$0.10	1	$0.10
1624-107_1 Material	Material, Capacitor Asm	$1.42	1	$1.42
1624-107_1i	PP, Metalized Film Capacitor	$12.29	1	$12.29
1624-107_1d	Epoxy Potting, Capacitor Asm	$10.45	1	$10.45
1624-107_2	**Inductor Assy**	**$10.79**	**1**	**$10.79**
1624-107_2G	**Core/Coil Assy**	**$8.32**	**1**	**$8.32**
1624-107_2F	**Coil Insulator Support**	**$0.09**	**1**	**$0.09**
1624-107_2F-1 Material	Material, Coil Insulator Support	$0.09	1	$0.09
1624-107_2L	**Coil Winding Support**	**$0.17**	**1**	**$0.17**
1624-107_2L Material	Material, Coil Winding Support	$0.17	1	$0.17
1624-107_2F	**Coil Insulator Support**	**$0.09**	**1**	**$0.09**
1624-107_2F-1 Material	Material, Coil Insulator Support	$0.09	1	$0.09

Prius Inverter Capacitor & Inductor

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-107_2L	**Coil Winding Support**	**$0.17**	**1**	**$0.17**
1624-107_2L Material	Material, Coil Winding Support	$0.17	1	$0.17
1624-107_2F	**Coil Insulator Support**	**$0.09**	**1**	**$0.09**
1624-107_2F-1 Material	Material, Coil Insulator Support	$0.09	1	$0.09
1624-107_2L	**Coil Winding Support**	**$0.17**	**1**	**$0.17**
1624-107_2L Material	Material, Coil Winding Support	$0.17	1	$0.17
1624-107_2F	**Coil Insulator Support**	**$0.09**	**1**	**$0.09**
1624-107_2F-1 Material	Material, Coil Insulator Support	$0.09	1	$0.09
1624-107_2L	**Coil Winding Support**	**$0.17**	**1**	**$0.17**
1624-107_2L Material	Material, Coil Winding Support	$0.17	1	$0.17
1624-107_2C-1	Material, Flat Copper Wire, Coated	$3.40	1	$3.40
1624-107_2B	**Magnetic Core C Block**	**$1.23**	**1**	**$1.23**
1624-107_2B-1 Material	Material, Magnetic Core C Block	$1.23	1	$1.23
1624-107_2H	Alumina Spacers	$0.17	2	$0.34
1624-107_2E	Adhesive Magnetic Core	$0.09	4	$0.37
1624-107_2B	**Magnetic Core C Block**	**$1.23**	**1**	**$1.23**
1624-107_2B-1 Material	Material, Magnetic Core C Block	$1.23	1	$1.23
1624-107_2E	Adhesive Magnetic Core	$0.09	4	$0.37
1624-107_2D	**Inductor Housing Retainer**	**$0.17**	**1**	**$0.17**
1624-107_2D Material	Material, Inductor Housing Retainer	$0.17	1	$0.17
1624-107_2D	**Inductor Housing Retainer**	**$0.17**	**1**	**$0.17**
1624-107_2D Material	Material, Inductor Housing Retainer	$0.17	1	$0.17
1624-107_2A	Steel Spacer	$0.05	3	$0.15
1624-107_2I Material	Material, Inductor Housing	$2.32	1	$2.32
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	8	$0.16

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	28	Piece Cost (Total): $73.56	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	72		*Parts:*	*0*
Fasteners:	18		*Fasteners:*	*0*
Parts+Unanalyzed:	72		*Parts+Unanalyzed:*	*0*

Table C-43 Toyota Inverter: Electrical & Harness Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624_3	Receptacle Cover 2 Asm w/Bus Bars	(None)
2	4	Subassembly	1624-101	Receptacle Cover 2 Asm	(None)
3	5	Preprocessed Part	1624-101_1	Receptacle Cover 2	PBT LG20
4	6	Manufacturing Steps		Receptacle Cover 2 Processing	
5	7	Manufacturing Process		Injection Mold Press, 55 Ton	
6	8	Part	1624-101_1 Material	Material, Receptacle Cover 2	PBT LG20
7	5	Part	1624-101_3	Metal Spacer 1	Commodity Item
8	5	Part	1624-101_6	Metal Spacer 2	Commodity Item
9	5	Manufacturing Steps		Assemble Receptacle Cover 2 Asm	
10	6	Manufacturing Process		Automated Press Station	
11	4	Preprocessed Part	1624-99	Bus Bar 1	Copper Cu (10200)
12	5	Manufacturing Steps		Bus Bar 1 Processing	
13	6	Manufacturing Process		Plating	
14	7	Part	1624-99 Plating-Nickel	1624-99 Plating-Nickel	Commodity Item
15	6	Manufacturing Process		Wash	
16	6	Manufacturing Process		Debur	
17	6	Manufacturing Process		Stamping Press, 200 Ton	
18	7	Part	1624-99 Material	Material, Bus Bar 1	Copper Cu (10200)
19	4	Preprocessed Part	1624-100	Bus Bar 2	Copper Cu (10200)
20	5	Manufacturing Steps		Bus Bar 2 Processing	
21	6	Manufacturing Process		Plating	

Row	Level	Symbol Type	Number	Name	Material Name
22	7	Part	1624-99 Plating-Nickel	1624-100 Plating-Nickel	Commodity Item
23	6	Manufacturing Process		Wash	
24	6	Manufacturing Process		Debur	
25	6	Manufacturing Process		Stamping Press, 25 Ton	
26	7	Part	1624-100 Material	Material, Bus Bar 2	Copper Cu (10200)
27	4	Subassembly	1624-101_4	Connector Plate 1 Sub Asm	(None)
28	5	Preprocessed Part	1624-101_4a	Connector Plate 1	Copper Nickel Plated
29	6	Manufacturing Steps		Connector Plate 1 Processing	
30	7	Manufacturing Process		Wash	
31	7	Manufacturing Process		Debur	
32	7	Manufacturing Process		Stamping Press, 25 Ton	
33	8	Part	1624-101_4a Material	Material, Connector Plate 1	Copper Nickel Plated
34	5	Part	1624-101_2	Connector Pin	Commodity Item
35	5	Manufacturing Steps		Assemble Connector Plate 1 and Connector Pin	
36	6	Manufacturing Process		Spot Weld	
37	6	Manufacturing Process		Auto Asm	
38	4	Subassembly	1624-101_5	Connector Plate 2 Sub Asm	(None)
39	5	Preprocessed Part	1624-101_5a	Connector Plate 2	Copper Nickel Plated
40	6	Manufacturing Steps		Connector Plate 2 Processing	
41	7	Manufacturing Process		Wash	
42	7	Manufacturing Process		Debur	
43	7	Manufacturing Process		Stamping Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
44	8	Part	1624-101_5a Material	Material, Connector Plate 2	Copper Nickel Plated
45	5	Part	1624-101_2	Connector Pin	Commodity Item
46	5	Manufacturing Steps		Assemble Connector Plate 2 and Connector Pin	
47	6	Manufacturing Process		Spot Weld	
48	6	Manufacturing Process		Auto Asm	
49	4	Part	1624-99_1	Allen Bolt M6x1 10mm	Commodity Item
50	4	Part	1624-99_2	Cap Nut M6	Commodity Item
51	4	Manufacturing Steps		Assemble Receptacle Cover 2 and Bus Bars	
52	5	Manufacturing Process		Auto Asm	
53	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
54	3	Manufacturing Steps		Receptacle Cover 2 Asm to Main Enclosure	
55	4	Manufacturing Process		Auto Asm	
56	3	Subassembly	1624-98_8	Lead Frame Sub Asm	(None)
57	4	Subassembly	1624-98_8a	Lead Frame Sub Asm 1	(None)
58	5	Preprocessed Part	1624-98_8a1	Copper Stamping Lead 1	Copper Cu (10200)
59	6	Manufacturing Steps		Copper Stamping 1 processing	
60	7	Manufacturing Process		Wash	
61	7	Manufacturing Process		Debur	
62	7	Manufacturing Process		Stamping Press, 60 Ton	
63	8	Part	1624-98_8a1-Material	Material, Copper Stamping Lead 1	Copper Cu (10200)
64	5	Preprocessed Part	1624-98_8a2	Copper Stamping Lead 2	Copper Cu (10200)
65	6	Manufacturing Steps		Copper Stamping 2 processing	
66	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
67	7	Manufacturing Process		Debur	
68	7	Manufacturing Process		Stamping Press, 25 Ton	
69	8	Part	1624-98_8a2-Material	Material, Copper Stamping Lead 2	Copper Cu (10200)
70	5	Preprocessed Part	1624-98_8a3	Copper Stamping Lead 3	Copper Cu (10200)
71	6	Manufacturing Steps		Copper Stamping 3 processing	
72	7	Manufacturing Process		Wash	
73	7	Manufacturing Process		Debur	
74	7	Manufacturing Process		Stamping Press, 25 Ton	
75	8	Part	1624-98_8a3-Material	Material, Copper Stamping Lead 3	Copper Cu (10200)
76	5	Preprocessed Part	1624-98_8a4	Copper Stamping Lead 4	Copper Cu (10200)
77	6	Manufacturing Steps		Copper Stamping 4 processing	
78	7	Manufacturing Process		Wash	
79	7	Manufacturing Process		Debur	
80	7	Manufacturing Process		Stamping Press, 25 Ton	
81	8	Part	1624-98_8a4-Material	Material, Copper Stamping Lead 4	Copper Cu (10200)
82	5	Preprocessed Part	1624-98_8a5	Copper Stamping Lead 5	Copper Cu (10200)
83	6	Manufacturing Steps		Copper Stamping 5 processing	
84	7	Manufacturing Process		Wash	
85	7	Manufacturing Process		Debur	
86	7	Manufacturing Process		Stamping Press, 25 Ton	
87	8	Part	1624-98_8a5-Material	Material, Copper Stamping Lead 5	Copper Cu (10200)

Row	Level	Symbol Type	Number	Name	Material Name
88	5	Preprocessed Part	1624-98_8a6	Copper Stamping Lead 6	Copper Cu (10200)
89	6	Manufacturing Steps		Copper Stamping 6 processing	
90	7	Manufacturing Process		Wash	
91	7	Manufacturing Process		Debur	
92	7	Manufacturing Process		Stamping Press, 25 Ton	
93	8	Part	1624-98_8a6-Material	Material, Copper Stamping Lead 6	Copper Cu (10200)
94	5	Preprocessed Part	1624-98_8a11	Copper Stamping Lead 7	Copper Cu (10200)
95	6	Manufacturing Steps		Copper Stamping 7 processing	
96	7	Manufacturing Process		Wash	
97	7	Manufacturing Process		Debur	
98	7	Manufacturing Process		Stamping Press, 25 Ton	
99	8	Part	1624-98_8a11-Material	Material, Copper Stamping Lead 7	Copper Cu (10200)
100	5	Part	1624-98_8a7	Metal Spacer	Commodity Item
101	5	Part	1624-98_8a8	Connector Pins	Commodity Item
102	5	Part	1624-98_8a9	IGBT Circuit Connector Pins	Commodity Item
103	5	Subassembly	1624-98_8a12	Laminate Assembly	(None)
104	6	Preprocessed Part	1624-98_8a13	Laminate Plate	Electro Magnetic Steel
105	7	Manufacturing Steps		Laminate Plate Processing	
106	8	Manufacturing Process		Wash	
107	8	Manufacturing Process		Deburr	
108	8	Manufacturing Process		Stamping Press, 25 Ton	
109	9	Part	1624-98_8a13-Material	Material, Laminate Plate	Electro Magnetic Steel
110	6	Manufacturing Steps		Laminate Asm Assembly	

Row	Level	Symbol Type	Number	Name	Material Name
111	7	Manufacturing Process		Automated Press Station	
112	5	Subassembly	1624-98_8a12	Laminate Assembly	(None)
113	6	Preprocessed Part	1624-98_8a13	Laminate Plate	Electro Magnetic Steel
114	7	Manufacturing Steps		Laminate Plate Processing	
115	8	Manufacturing Process		Wash	
116	8	Manufacturing Process		Deburr	
117	8	Manufacturing Process		Stamping Press, 25 Ton	
118	9	Part	1624-98_8a13-Material	Material, Laminate Plate	Electro Magnetic Steel
119	6	Manufacturing Steps		Laminate Asm Assembly	
120	7	Manufacturing Process		Automated Press Station	
121	5	Subassembly	1624-98_8a12	Laminate Assembly	(None)
122	6	Preprocessed Part	1624-98_8a13	Laminate Plate	Electro Magnetic Steel
123	7	Manufacturing Steps		Laminate Plate Processing	
124	8	Manufacturing Process		Wash	
125	8	Manufacturing Process		Deburr	
126	8	Manufacturing Process		Stamping Press, 25 Ton	
127	9	Part	1624-98_8a13-Material	Material, Laminate Plate	Electro Magnetic Steel
128	6	Manufacturing Steps		Laminate Asm Assembly	
129	7	Manufacturing Process		Automated Press Station	
130	5	Subassembly	1624-98_8a12	Laminate Assembly	(None)
131	6	Preprocessed Part	1624-98_8a13	Laminate Plate	Electro Magnetic Steel
132	7	Manufacturing Steps		Laminate Plate Processing	
133	8	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
134	8	Manufacturing Process		Deburr	
135	8	Manufacturing Process		Stamping Press, 25 Ton	
136	9	Part	1624-98_8a13-Material	Material, Laminate Plate	Electro Magnetic Steel
137	6	Manufacturing Steps		Laminate Asm Assembly	
138	7	Manufacturing Process		Automated Press Station	
139	5	Subassembly	1624-98_8a12	Laminate Assembly	(None)
140	6	Preprocessed Part	1624-98_8a13	Laminate Plate	Electro Magnetic Steel
141	7	Manufacturing Steps		Laminate Plate Processing	
142	8	Manufacturing Process		Wash	
143	8	Manufacturing Process		Deburr	
144	8	Manufacturing Process		Stamping Press, 25 Ton	
145	9	Part	1624-98_8a13-Material	Material, Laminate Plate	Electro Magnetic Steel
146	6	Manufacturing Steps		Laminate Asm Assembly	
147	7	Manufacturing Process		Automated Press Station	
148	5	Subassembly	1624-98_8a12	Laminate Assembly	(None)
149	6	Preprocessed Part	1624-98_8a13	Laminate Plate	Electro Magnetic Steel
150	7	Manufacturing Steps		Laminate Plate Processing	
151	8	Manufacturing Process		Wash	
152	8	Manufacturing Process		Deburr	
153	8	Manufacturing Process		Stamping Press, 25 Ton	
154	9	Part	1624-98_8a13-Material	Material, Laminate Plate	Electro Magnetic Steel
155	6	Manufacturing Steps		Laminate Asm Assembly	

Row	Level	Symbol Type	Number	Name	Material Name
156	7	Manufacturing Process		Automated Press Station	
157	5	Subassembly	1624-98_8a12	Laminate Assembly	(None)
158	6	Preprocessed Part	1624-98_8a13	Laminate Plate	Electro Magnetic Steel
159	7	Manufacturing Steps		Laminate Plate Processing	
160	8	Manufacturing Process		Wash	
161	8	Manufacturing Process		Deburr	
162	8	Manufacturing Process		Stamping Press, 25 Ton	
163	9	Part	1624-98_8a13-Material	Material, Laminate Plate	Electro Magnetic Steel
164	6	Manufacturing Steps		Laminate Asm Assembly	
165	7	Manufacturing Process		Automated Press Station	
166	5	Manufacturing Steps		Assemble Lead Frame Sub Asm 1	
167	6	Manufacturing Process		Injection Mold Press, 55 Ton	
168	7	Part	1624-98_8a10-Material	Material, Lead Frame Outer Casing	PPS-GF-MD
169	4	Preprocessed Part	1624-98_8b	Lead Frame Terminal Holder Bracket	PPS-GF-MD
170	5	Manufacturing Steps		Lead Frame Terminal Holder Processing	
171	6	Manufacturing Process		Laser Etch	
172	6	Manufacturing Process		Injection Mold Press, 55 Ton	
173	7	Part	1624-98_8b Material	Material, Lead Frame Terminal Holder Bracket	PPS-GF-MD
174	4	Part	1624-98_8c	M6 x 1.00, Flanged Nut	Commodity Item
175	4	Part	1624-98_8d	M3 x 0.5, 9.5 mm Philips Screw	Commodity Item
176	4	Manufacturing Steps		Assemble Lead Frame Sub Asm	
177	5	Manufacturing Process		Auto Asm	
178	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
179	3	Manufacturing Steps		Install Leadframe Asm	
180	4	Manufacturing Process		Spot Weld	
181	4	Manufacturing Process		Auto Asm	
182	3	Subassembly	1624-107_5	Capacitor Asm to Control PCB Harness	(None)
183	4	Part	1624-107_5A	AWG 22 (0.64mm D) Wire, Blue	Commodity Item
184	4	Part	1624-107_5B	AWG 22 (0.64mm D) Wire, White	Commodity Item
185	4	Part	1624-107_5C	Connector, White, 10 Terminals, 2 TPA	Commodity Item
186	4	Part	1624-107_5D	Female Terminal, Gold tip, 20-22 AWG, 0.64mm	Commodity Item
187	4	Part	1624-107_5E	Spade Terminal, 6.8mm W	Commodity Item
188	4	Part	1624-107_5F	Braided Polyester Sleeve, Black Covering	Commodity Item
189	4	Part	1624-107_5G	Tape 6.65" secring wires and sleeve	Commodity Item
190	4	Part	1624-107_5H	Tape 1.5" securing wires	Commodity Item
191	4	Manufacturing Steps		Assemble Harness, 2 Leads	
192	5	Manufacturing Process		Auto Asm	
193	5	Manufacturing Process		Auto Asm	
194	5	Manufacturing Process		Auto Asm	
195	5	Manufacturing Process		Auto Asm	
196	3	Manufacturing Steps		Assemble Capacitor - PCB Harness to Capacitor Asm	
197	4	Manufacturing Process		Manual Assembly	

Table C-44 Toyota Inverter: Electrical & Harness Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Prius Inverter Electrical & Harness

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624_3	**Receptacle Cover 2 Asm w/Bus Bars**	**$2.05**	**1**	**$2.05**
1624-101	**Receptacle Cover 2 Asm**	**$0.18**	**1**	**$0.18**
1624-101_1	**Receptacle Cover 2**	**$0.10**	**1**	**$0.10**
1624-101_1 Material	Material, Receptacle Cover 2	$0.10	1	$0.10
1624-101_3	Metal Spacer 1	$0.03	2	$0.06
1624-101_6	Metal Spacer 2	$0.01	2	$0.02
1624-99	**Bus Bar 1**	**$0.67**	**1**	**$0.67**
1624-99 Plating-Nickel	1624-99 Plating-Nickel	$0.00	1	$0.00
1624-99 Material	Material, Bus Bar 1	$0.67	1	$0.67
1624-100	**Bus Bar 2**	**$0.33**	**1**	**$0.33**
1624-99 Plating-Nickel	1624-100 Plating-Nickel	$0.00	1	$0.00
1624-100 Material	Material, Bus Bar 2	$0.33	1	$0.33
1624-101_4	**Connector Plate 1 Sub Asm**	**$0.29**	**1**	**$0.29**
1624-101_4a	**Connector Plate 1**	**$0.28**	**1**	**$0.28**
1624-101_4a Material	Material, Connector Plate 1	$0.28	1	$0.28
1624-101_2	Connector Pin	$0.01	1	$0.01
1624-101_5	**Connector Plate 2 Sub Asm**	**$0.34**	**1**	**$0.34**
1624-101_5a	**Connector Plate 2**	**$0.33**	**1**	**$0.33**
1624-101_5a Material	Material, Connector Plate 2	$0.33	1	$0.33
1624-101_2	Connector Pin	$0.01	1	$0.01
1624-99_1	Allen Bolt M6x1 10mm	$0.06	2	$0.12
1624-99_2	Cap Nut M6	$0.06	2	$0.12
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	2	$0.04
1624-98_8	**Lead Frame Sub Asm**	**$5.08**	**1**	**$5.08**
1624-98_8a	**Lead Frame Sub Asm 1**	**$4.29**	**1**	**$4.29**
1624-98_8a1	**Copper Stamping Lead 1**	**$0.88**	**1**	**$0.88**
1624-98_8a1-Material	Material, Copper Stamping Lead 1	$0.88	1	$0.88
1624-98_8a2	**Copper Stamping Lead 2**	**$0.25**	**1**	**$0.25**
1624-98_8a2-Material	Material, Copper Stamping Lead 2	$0.25	1	$0.25
1624-98_8a3	**Copper Stamping Lead 3**	**$0.23**	**1**	**$0.23**
1624-98_8a3-Material	Material, Copper Stamping Lead 3	$0.23	1	$0.23
1624-98_8a4	**Copper Stamping Lead 4**	**$0.22**	**1**	**$0.22**
1624-98_8a4-Material	Material, Copper Stamping Lead 4	$0.22	1	$0.22
1624-98_8a5	**Copper Stamping Lead 5**	**$0.23**	**1**	**$0.23**
1624-98_8a5-Material	Material, Copper Stamping Lead 5	$0.23	1	$0.23
1624-98_8a6	**Copper Stamping Lead 6**	**$0.24**	**1**	**$0.24**
1624-98_8a6-Material	Material, Copper Stamping Lead 6	$0.24	1	$0.24
1624-98_8a11	**Copper Stamping Lead 7**	**$0.31**	**1**	**$0.31**
1624-98_8a11-Material	Material, Copper Stamping Lead 7	$0.31	1	$0.31
1624-98_8a7	Metal Spacer	$0.05	2	$0.10
1624-98_8a8	Connector Pins	$0.01	12	$0.16
1624-98_8a9	IGBT Circuit Connector Pins	$0.00	2	$0.00
1624-98_8a12	**Laminate Assembly**	**$0.14**	**1**	**$0.14**
1624-98_8a13	**Laminate Plate**	**$0.14**	**1**	**$0.14**
1624-98_8a13-Material	Material, Laminate Plate	$0.01	14	$0.14
1624-98_8a12	**Laminate Assembly**	**$0.14**	**1**	**$0.14**

Prius Inverter Electrical & Harness

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1624-98_8a13	**Laminate Plate**	**$0.14**	**1**	**$0.14**
1624-98_8a13-Material	Material, Laminate Plate	$0.01	14	$0.14
1624-98_8a12	**Laminate Assembly**	**$0.14**	**1**	**$0.14**
1624-98_8a13	**Laminate Plate**	**$0.14**	**1**	**$0.14**
1624-98_8a13-Material	Material, Laminate Plate	$0.01	14	$0.14
1624-98_8a12	**Laminate Assembly**	**$0.14**	**1**	**$0.14**
1624-98_8a13	**Laminate Plate**	**$0.14**	**1**	**$0.14**
1624-98_8a13-Material	Material, Laminate Plate	$0.01	14	$0.14
1624-98_8a12	**Laminate Assembly**	**$0.14**	**1**	**$0.14**
1624-98_8a13	**Laminate Plate**	**$0.14**	**1**	**$0.14**
1624-98_8a13-Material	Material, Laminate Plate	$0.01	14	$0.14
1624-98_8a12	**Laminate Assembly**	**$0.14**	**1**	**$0.14**
1624-98_8a13	**Laminate Plate**	**$0.14**	**1**	**$0.14**
1624-98_8a13-Material	Material, Laminate Plate	$0.01	14	$0.14
1624-98_8a12	**Laminate Assembly**	**$0.14**	**1**	**$0.14**
1624-98_8a13	**Laminate Plate**	**$0.14**	**1**	**$0.14**
1624-98_8a13-Material	Material, Laminate Plate	$0.01	14	$0.14
1624-98_8a10-Material	Material, Lead Frame Outer Casing	$0.69	1	$0.69
1624-98_8b	**Lead Frame Terminal Holder Bracket**	**$0.28**	**1**	**$0.28**
1624-98_8b Material	Material, Lead Frame Terminal Holder Bracket	$0.28	1	$0.28
1624-98_8c	M6 x 1.00, Flanged Nut	$0.06	6	$0.36
1624-98_8d	M3 x 0.5, 9.5 mm Philips Screw	$0.05	3	$0.15
1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	$0.02	2	$0.04
1624-107_5	**Capacitor Asm to Control PCB Harness**	**$0.41**	**1**	**$0.41**
1624-107_5A	AWG 22 (0.64mm D) Wire, Blue	$0.01	1	$0.01
1624-107_5B	AWG 22 (0.64mm D) Wire, White	$0.01	1	$0.01
1624-107_5C	Connector, White, 10 Terminals, 2 TPA	$0.20	1	$0.20
1624-107_5D	Female Terminal, Goldtip, 20-22 AWG, 0.64mm	$0.02	2	$0.05
1624-107_5E	Spade Terminal, 6.8mm W	$0.04	2	$0.08
1624-107_5F	Braided Polyester Sleeve, Black Covering	$0.05	1	$0.05
1624-107_5G	Tape 6.65" secring wires and sleeve	$0.01	2	$0.01
1624-107_5H	Tape 1.5" securing wires	$0.00	2	$0.00

Assembly Totals

Analyzed Subs:	34
Unanalyzed Subs:	0
Parts:	165
Fasteners:	17
Parts+Unanalyzed:	165

Report Totals

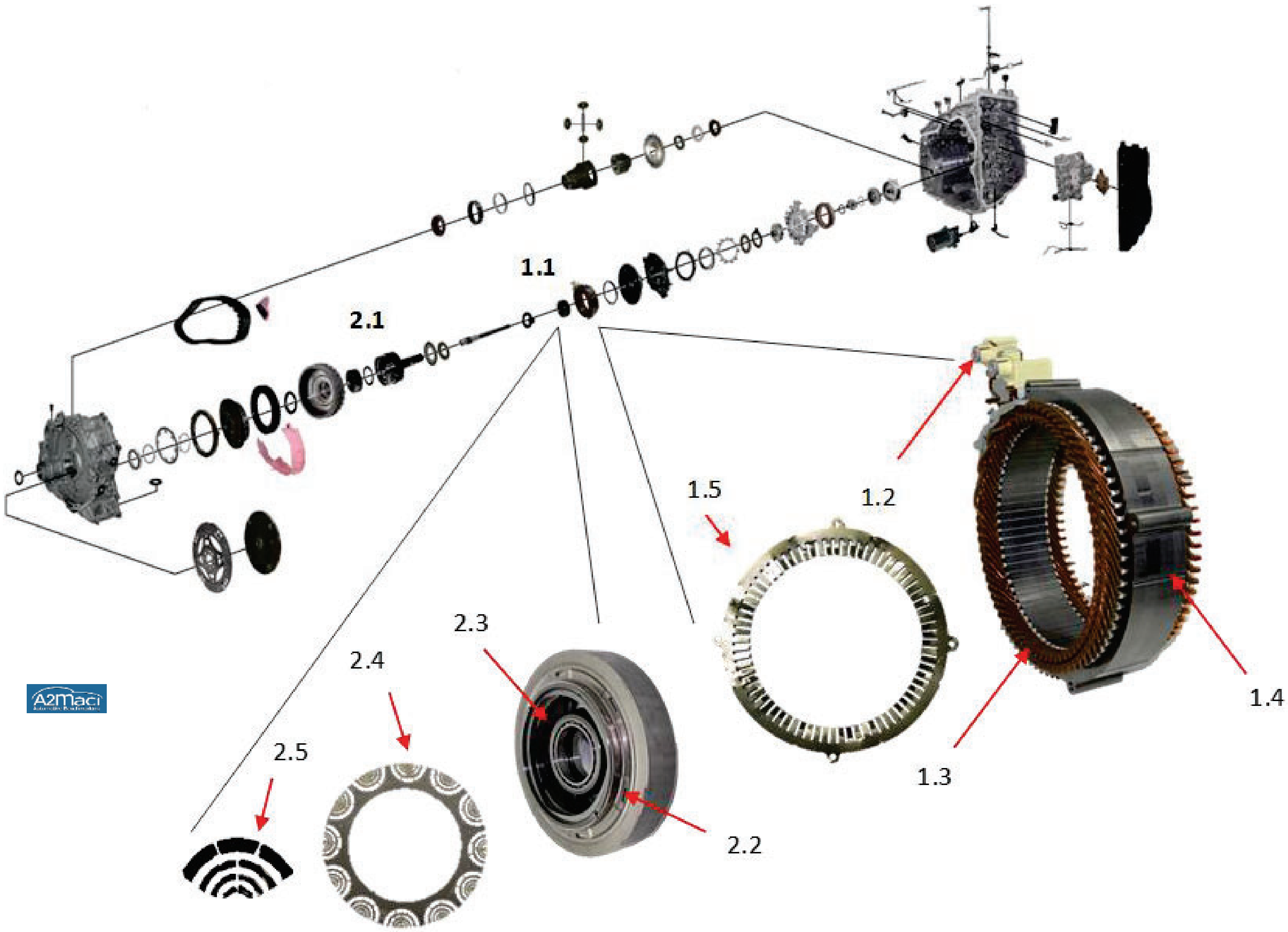
Piece Cost (Total): $7.62

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

APPENDIX D: Chevy Volt Motor

Figure D-1 The Chevy Volt Motor / Gearbox



Cost Estimate BOM			
1.1	Stator Group	2.1	Rotor Assembly
1.2	Spade Terminal Block	2.2	Rotor Top Cover Plate
1.3	Hairpin Windings	2.3	Rotor Hub & Bearing
1.4	Stack Laser-Weld Seam	2.4	Rotor Laminate
1.5	Stator Laminate	2.5	Rotor Ferrite Magnets

Chevy Volt Stator

The Chevy Volt Stator group consists of the laminate stack, copper windings, insulators and electrical interface connections. The laminates stack contains 119 electromagnetic steel stampings. The copper windings consist of 149 wire segments referred to as hairpin windings. Insulation of the coils is provided by a fabric layer inside the laminates. The three-phase wire leads from the motor receive additional insulation from a dip coating. The electrical interfaces include three-phase terminals, conductor standoff and mounting block.

Figure D-2 The Chevy Volt Stator Group

Table D-1 Chevy Volt Stator Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Chevrolet Volt - Stator

	Chevrolet Volt - Stator Assembly
Parts	570
Steps	2,058
Actual Time	1,299.37 sec
Fasteners	0
Total Weight	7.59 kg
Piece Cost	$61.08
Total Labor Cost	$30.43
Q Burden	$3.25
Total Cost	$94.76
Annual Production	200000

Table D-2 The Chevy Volt Stator Group Estimate Summary

Component Summary		
Part/Assembly Name		Chevy Volt Stator
Purchased Part Roll up Costs		$8.10
Raw Material Costs		$52.98
Processing Costs		$30.43
Scrap (Design Profit: Q-Burden)	4%	$3.25
SG&A % Applied Against Processing	7%	$2.13
Profit % Applied Against Raw & Processing	4%	$3.34
Logistics % Applied Against Sum of all Above	3%	$3.01
Patent/Royalty Fees % Applied Against Sum of all Above	5%	$5.16
Total % Mark Up / Total Cost	23%	$108.40
Total Weight (kg)		7.593
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$225,000.00
Tooling Cost/part		$0.23
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$450,000.00
Tooling Cost/part		$0.45

The Chevy Volt stator consists of 119 stamped electromagnet steel plates. The laminates are presorted and then pressed together to form the final stack. The stator outer profile also provides a means of mounting the finished assembly into the motor case (transmission). This is accomplished by using tabs in the outer diameter for through-hole mounting. The tabs add additional weight but not cost as they are positioned in the blanking scrap area and therefore do not add length or width to the blank sheet size.

Figure D-3 The Chevy Volt Stator Laminate Segment

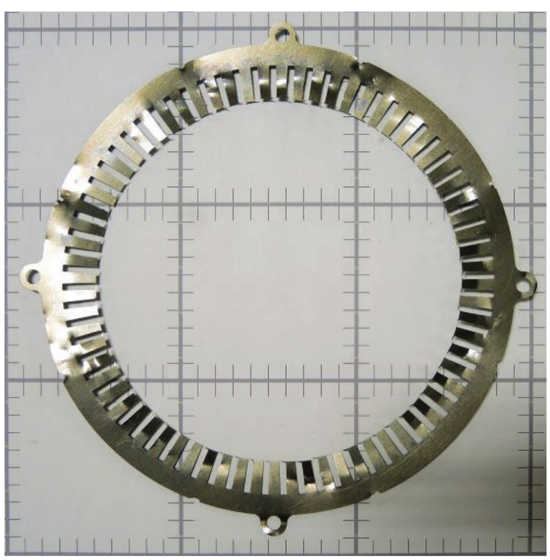


Figure D-4 The Chevy Volt Stator Stack

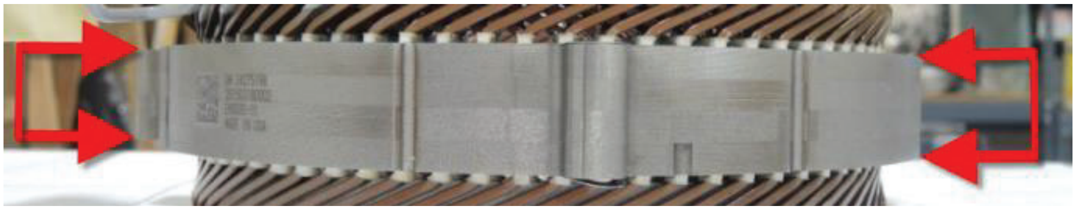
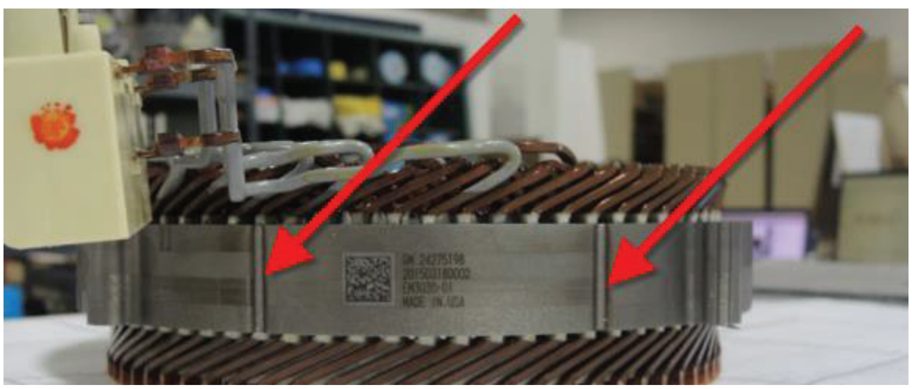
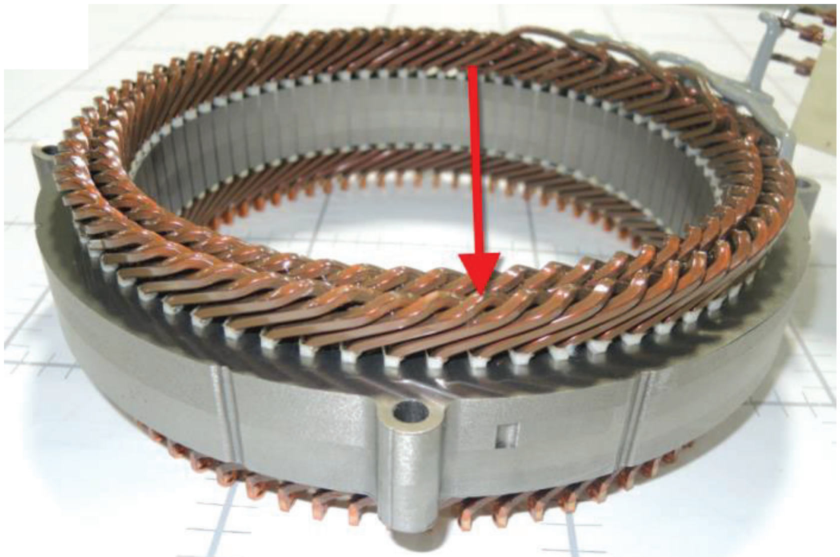


Figure D-4 Chevy Volt Stator Stack Laser-Welded Seams



The design of the Chevy Volt stator copper coil is commonly referred to as a hairpin. In a hairpin design, the forming and installation of the wires into the rotor is assumed to be automated in a single manufacturing cell. It is also assumed that the copper wire stock is pre-coated, each wire segment stripped on each end and preformed for insertion into the stator along with the insulating layer. After pressing the wires into the laminate stack they are post-formed and the ends are welded together. A total of 149 wires are preformed into nine different profiles.

Figure D-5 Chevy Volt Stator Hairpin Windings



Insulation of the coils is provided by a 0.007" - Nomex Aramid Paper Sheet inside the laminate stake. Each pole slot contains two insulators, one on the outer diameter of the slot, and one in the inner diameter. The stator coil is also assumed to be varnished dip-coated after final assembly. The three-phase wire leads from the motor and is dip-coated for additional insulation.

Figure D-6 Chevy Volt Stator Slot Insulator

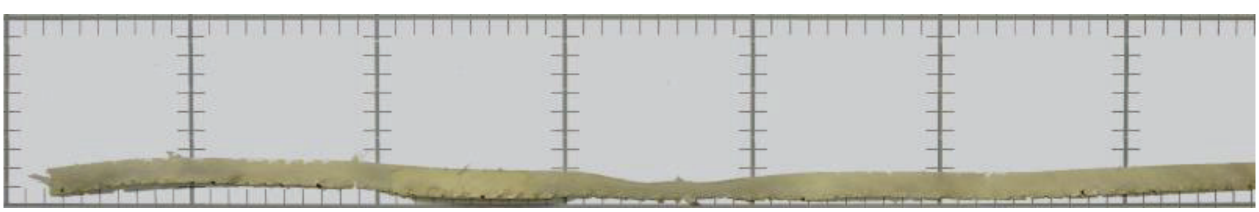
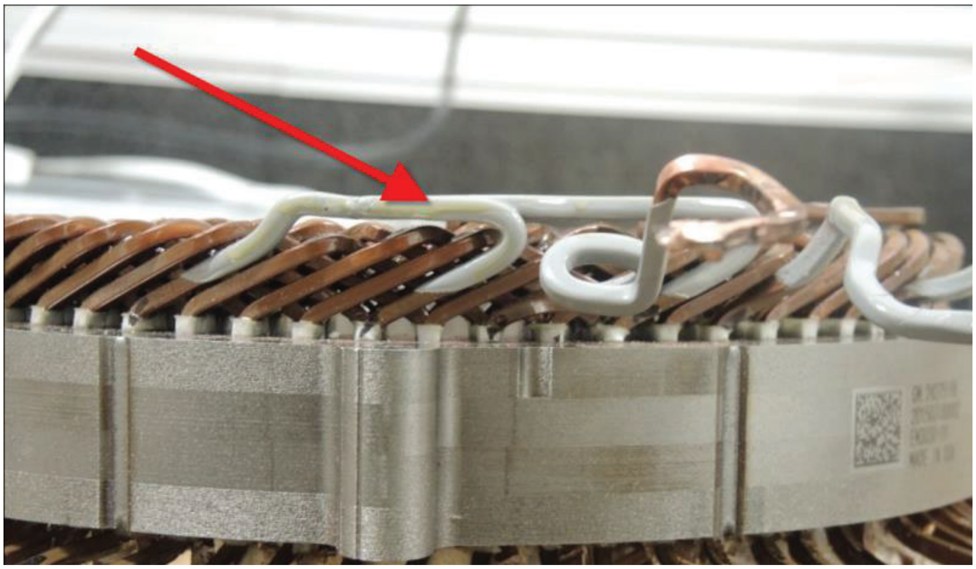


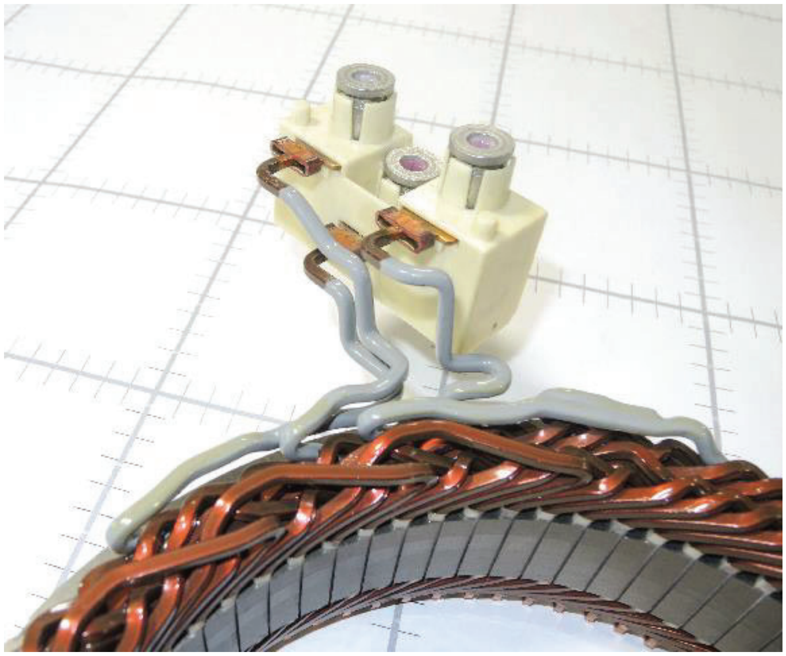
Figure D-7 Chevy Volt Stator Dip-Coated Hairpin Segments



The electrical interfaces include three-phase spade terminals, conductor standoff and mounting block. The three-phase spade terminal is a stamped copper design crimped onto the end of the copper lead coming from the stator. The spade terminals are inserted into a plastic injection molded retainer block. The block also includes three metal stand-off sleeves, presumably for ease in final installation.

Figure D-8 Chevy Volt Stator Spade Terminal

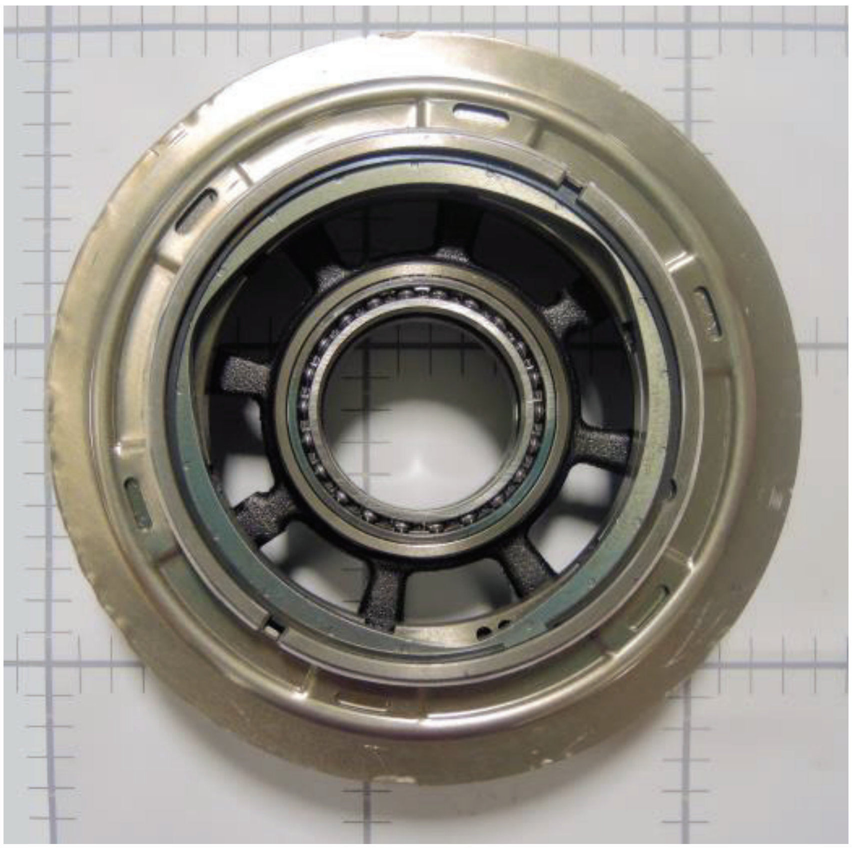
Figure D-9 Chevy Volt Stator Terminal Block



Chevy Volt Rotor

The Chevy Volt Rotor group consists of the laminate stack, end plates, magnets, hub and bearings. The laminate stack contains 128 electromagnetic steel stampings. The end plates close out each end of the rotor and include a smaller laminate stack, presumably for the speed sensor target.

Figure D-10 Chevy Volt Rotor Assembly



A total of 216 magnets are installed inside slots in the laminate stack. The magnets are arranged in into 12 poles with 18 magnets making up one pole. The 18 magnets are installed in four arched rows using four unique sizes. During the technology down-select phase, the magnets were found to be ferrite based. The Hub is a cast-machined design with features for pressing on the laminate stack and bearings. The rotor did contain nine more laminates than the stator had in its stack. The cost of the material in the first 119 stampings is assumed to be shared between the stator and rotor. The last nine plates cost is assigned to the rotor only. The total "should cost" to manufacture the Chevy Volt rotor group is estimated and additional typical markups that are part of component manufacturing. The last nine plates cost is assigned to the rotor only. The total "should cost" to manufacture the Chevy Volt rotor group is estimated and additional typical markups that are part of component manufacturing.

Table D-3 Chevy Volt Rotor Group Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Chevrolet Volt - Rotor Assembly

MUNRO & ASSOCIATES, INC.

	Chevrolet Volt - Rotor Assembly
Parts	367
Steps	2,039
Actual Time	2,296.37 sec
Fasteners	0
Total Weight	5.75 kg
Piece Cost	$43.93
Total Labor Cost	$28.19
Q Burden	$1.07
Total Cost	$73.19
Annual Production	200000

The summary above includes the number of parts analyzed, the number of processing steps for manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total cost before markups.

Table D-4 The Chevy Volt Rotor Group Cost Summary

Component Summary		
Part/Assembly Name	Chevy Volt Rotor	
Purchased Part Roll up Costs		$18.92
Raw Material Costs		$25.01
Processing Costs		$28.19
Scrap (Design Profit: Q-Burden)	1%	$1.07
SG&A % Applied Against Processing	7%	$1.97
Profit % Applied Against Raw & Processing	4%	$2.13
Logistics % Applied Against Sum of all Above	3%	$2.32
Patent/Royalty Fees % Applied Against Sum of all Above	5%	$3.98
Total % Mark Up / Total Cost	20%	$83.59
Total Weight (kg)		5.7487
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		660000
Tooling Cost/part		$0.66
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,320,000.00
Tooling Cost/part		$1.32

The Chevy Volt rotor laminate stack consists of 128 stamped electromagnetic steel plates. The laminates are presorted, then pressed together to form finished laminate stack. The stator inner profile also provides a means for alignment when being pressed onto the hub.

Figure D-11 The Chevy Volt Rotor Laminate Stack

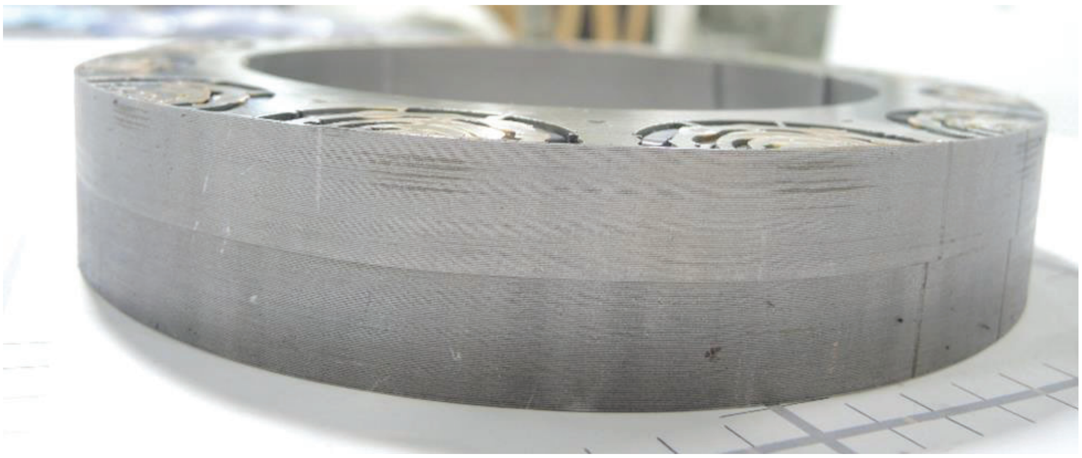
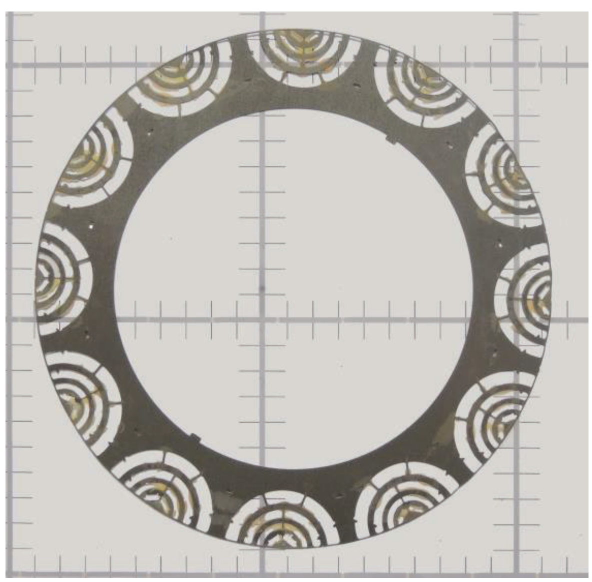


Figure D-12 The Chevy Volt Rotor Laminate Segment



The rotor includes three end plates, two on top and one on the bottom. The top end plates include a flat stamped stainless steel setting over the magnets with a second stamped aluminum plate with additional form features for component mounting.

Figure D-13 Chevy Volt Rotor Top Cover Plates

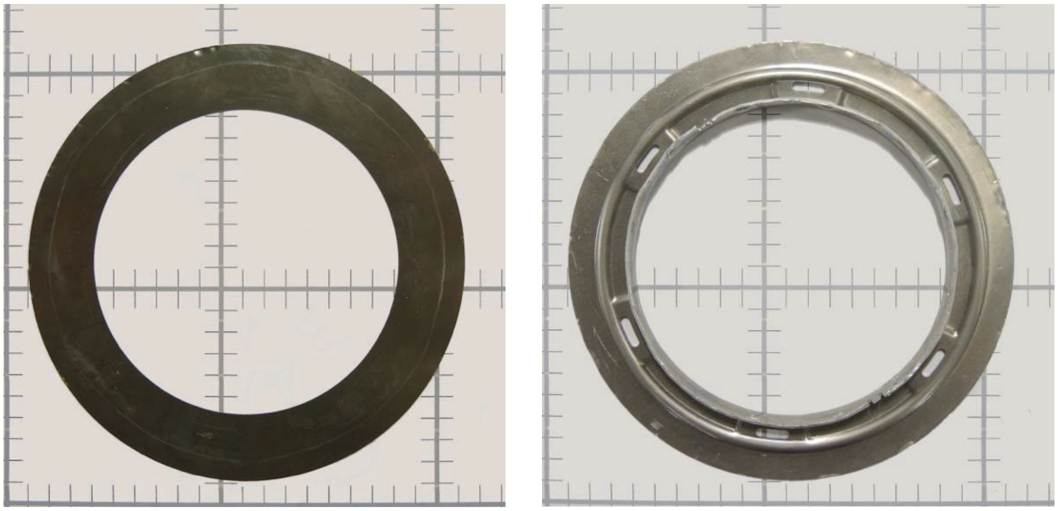


Figure D-14 Chevy Volt Rotor Bottom Cover Plates

The rotors contain 12 poles with 18 magnets set into four arched slots for each pole section. The magnets cover half the height of the laminate stack and consist of two sets of nine magnets. In addition, each row uses its own unique size of magnet with the three smaller rows using a pair of identical magnets and the one larger row using three magnets that are identical to each other. During the technology selection phase the magnets were found to be ferrite-based.

Figure D-15 Chevy Volt Rotor 12 Pole -Magnet Configuration

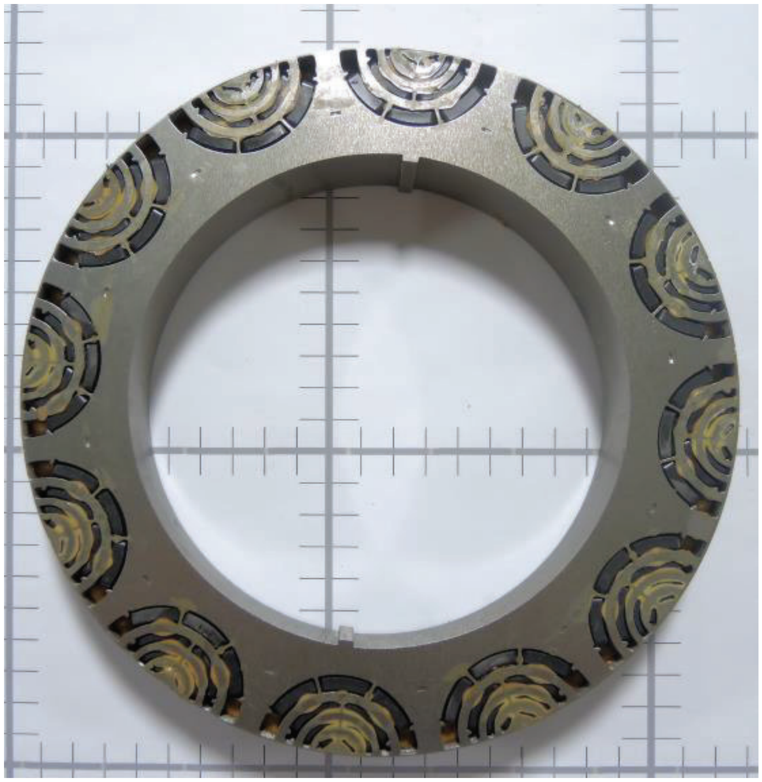
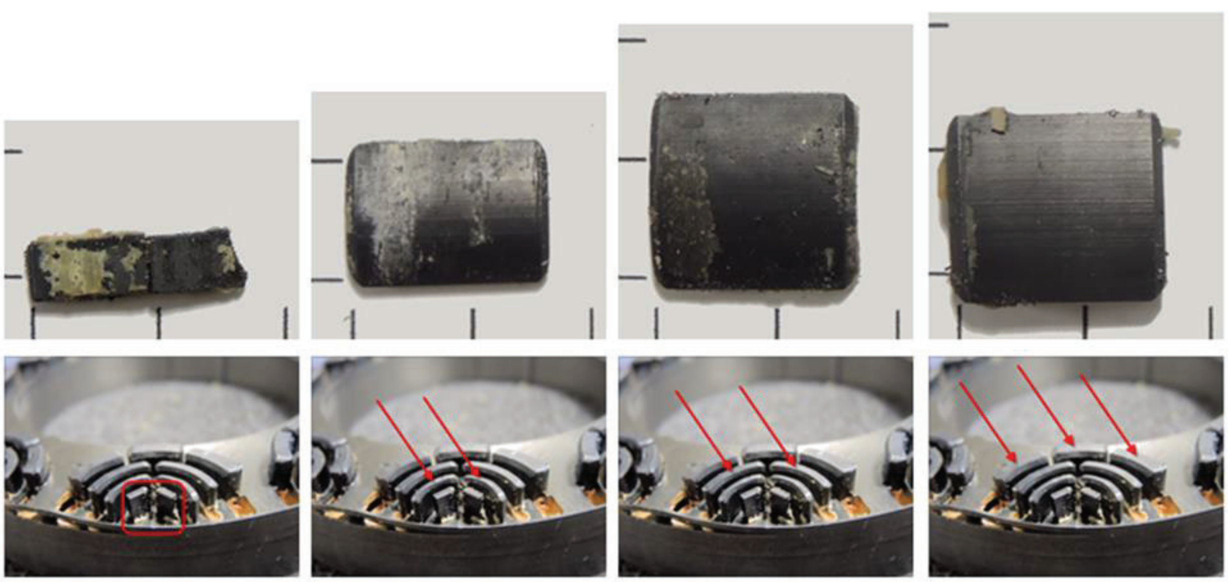


Figure D-16 Chevy Volt Rotor Unique Magnet Sizes



The Volt's rotor hub is a cast design presumably made of ductile cast iron. After casting, it is machined, deburred and washed. The hub contains features for laminate stack press mounting including key way alignment slots, bearing mount pockets, snap ring retainer grooves and eight drilled and tapped holes for mounting during final assembly. Two identical support bearings are pressed into the inner diameter on opposite ends of the hub. Bearings are an open-cage ball design.

Figure D-17 Chevy Volt Rotor Hub

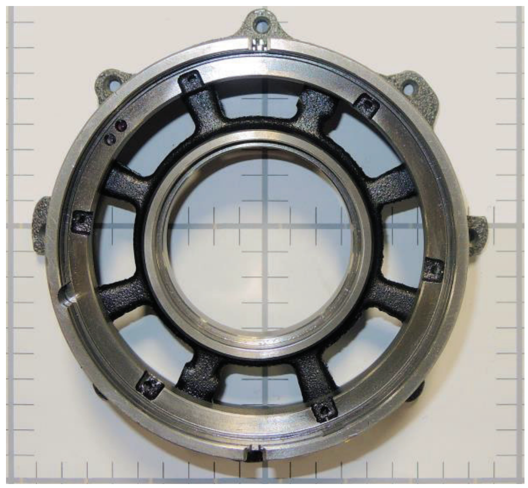


Figure D-18 Chevy Volt Rotor Hub Bearing

Table D-5 Chevy Volt Stator Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Subassembly	717-1436_4	Stator Assembly	(None)
2	3	Subassembly	717-1436_5	Laminated Steel Stator Core	(None)
3	4	Preprocessed Part	717-1436_9	Laminated Steel	(None)
4	5	Manufacturing Steps		Laminated Steel Process	
5	6	Manufacturing Process		Wash	
6	6	Manufacturing Process		Debur	
7	6	Manufacturing Process		Stamping Press, 200 Ton	
8	7	Part	Material, 717-1436_9	Material, Laminated Steel	Electro Magnetic Steel
9	4	Part	717-1436_17	Paper Tube	Commodity Item
10	4	Manufacturing Steps		Laminated Steel Stator Core Assembly Process	
11	5	Manufacturing Process		Auto Assembly	
12	5	Manufacturing Process		Laminate Stacking Station	
13	3	Preprocessed Part	717-1436_23	Hairpin Wire Assembly	(None)
14	4	Manufacturing Steps		Wound Wire Process	
15	5	Manufacturing Process		Curing Oven	
16	5	Manufacturing Process		Dip Painting	
17	6	Part	717-1436_19 Paint	Paint, Unique Bar Wound Wire Connector 1 Assembly.	Commodity Item
18	6	Part	717-1436_13 Paint	Paint, Unique Bar Wound Wire Connector 2	Commodity Item
19	6	Part	717-1436_14 Paint	Paint, Unique Bar Wound Wire Connector 3	Commodity Item
20	6	Part	717-1436_22 Paint	Paint, Unique Bar Wound Wire Connector 4	Commodity Item
21	5	Manufacturing Process		Hairpin Installation	

Row	Level	Symbol Type	Number	Name	Material Name
22	6	Part	Material, 717-1436_6	Material, Common Bar Wound Wire	Copper Cu (10200)
23	6	Part	Material, 717-1436_8	Material, Unique Inner Bar Wound Wire	Copper Cu (10200)
24	6	Part	Material, 717-1436_12	Material, Unique Bar Wound Wire Connector 1-A	Copper Cu (10200)
25	6	Part	Material, 717-1436_20	Material, Unique Bar Wound Wire Connector 1-B	Copper Cu (10200)
26	6	Part	Material, 717-1436_21	Material, Unique Bar Wound Wire Connector 1-C	Copper Cu (10200)
27	6	Part	Material, 717-1436_13	Material, Unique Bar Wound Wire Connector 2	Copper Cu (10200)
28	6	Part	Material, 717-1436_14	Material, Unique Bar Wound Wire Connector 3	Copper Cu (10200)
29	6	Part	Material, 717-1436_22	Material, Unique Bar Wound Wire Connector 4	Copper Cu (10200)
30	6	Part	Material, 717-1436_10	Material, Unique Bar Wound Wire Connector 4	Copper Cu (10200)
31	5	Manufacturing Process		TIG Weld Robotic	
32	3	Part	717-1436_15	Inner Paper Ring	Commodity Item
33	3	Part	717-1436_16	Outer Paper Ring	Commodity Item
34	3	Part	717-1436_18	Insulating Varnish	Commodity Item
35	3	Manufacturing Steps		Stator Assembly	
36	4	Manufacturing Process		Varnish Trickle Process	
37	4	Manufacturing Process		Laser Etch	
38	4	Manufacturing Process		Laser Weld	
39	2	Preprocessed Part	717-1436_7	Bar Wound Wire End Connectors	(None)
40	3	Manufacturing Steps		Bar Wound Wire End Connectors Process	
41	4	Manufacturing Process		Wash	
42	4	Manufacturing Process		deburr	
43	4	Manufacturing Process		Stamping Press, 200 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
44	5	Part	Material, 717-1436_7	Material, Bar Wound Wire End Connectors	Copper Cu (10200)
45	2	Manufacturing Steps		Bar Wound Wire End Connectors Installation	
46	3	Manufacturing Process		Auto Assembly	
47	2	Subassembly	717-1436_1	End Connector Housing Asm.	(None)
48	3	Preprocessed Part	717-1436_2	End Connector Housing	(None)
49	4	Manufacturing Steps		End Connecter Housing Processing	
50	5	Manufacturing Process		Injection Mold Press, 55 Ton	
51	6	Part	717-1436_2 Material	End Connector	PEI GP
52	3	Part	717-1436_3	Quick Connector	Commodity Item
53	3	Manufacturing Steps		End Connector Housing Assembly	
54	4	Manufacturing Process		Auto Assembly	
55	2	Manufacturing Steps		End Connector Housing Installation	
56	3	Manufacturing Process		Auto Assembly	

Table D-6 Chevy Volt Stator Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Chevrolet Volt - Stator Assembly

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
717-1436_4	**Stator Asm**	**$59.19**	**1**	**$59.19**
717-1436_5	**Laminated Steel Stator Core**	**$30.58**	**1**	**$30.58**
717-1436_9	**Laminated Steel**	**$24.99**	**1**	**$24.99**
Material, 717-1436_9	Material, Laminated Steel	$0.21	119	$24.99
717-1436_17	Paper Tube	$0.02	288	$5.59
717-1436_23	**Hairpin Wire Asm**	**$26.89**	**1**	**$26.89**
717-1436_19 Paint	Paint, Unique Bar Wound Wire Connector 1 Asm.	$0.01	1	$0.01
717-1436_13 Paint	Paint, Unique Bar Wound Wire Connector 2	$0.01	1	$0.01
717-1436_14 Paint	Paint, Unique Bar Wound Wire Connector 3	$0.01	1	$0.01
717-1436_22 Paint	Paint, Unique Bar Wound Wire Connector 4	$0.01	1	$0.01
Material, 717-1436_6	Material, Commom Bar Wound Wire	$0.18	139	$25.02
Material, 717-1436_8	Material, Unique Inner Bar Wound Wire	$0.22	3	$0.66
Material, 717-1436_12	Material, Unique Bar Wound Wire Connector 1-A	$0.11	1	$0.11
Material, 717-1436_20	Material, Unique Bar Wound Wire Connector 1-B	$0.15	1	$0.15
Material, 717-1436_21	Material, Unique Bar Wound Wire Connector 1-C	$0.10	1	$0.10
Material, 717-1436_13	Material, Unique Bar Wound Wire Connector 2	$0.20	1	$0.20
Material, 717-1436_14	Material, Unique Bar Wound Wire Connector 3	$0.22	1	$0.22
Material, 717-1436_22	Material, Unique Bar Wound Wire Connector 4	$0.22	1	$0.22
Material, 717-1436_10	Material, Unique Bar Wound Wire Connector 4	$0.17	1	$0.17
717-1436_15	Inner Paper Ring	$0.34	1	$0.34
717-1436_16	Outer Paper Ring	$0.34	1	$0.34
717-1436_18	Insulating Varnish	$1.04	1	$1.04
717-1436_7	**Bar Wound Wire End Connectors**	**$0.69**	**1**	**$0.69**
Material, 717-1436_7	Material, Bar Wound Wire End Connectors	$0.23	3	$0.69
717-1436_1	**End Connector Housing Asm.**	**$1.20**	**1**	**$1.20**
717-1436_2	**End Connector Housing**	**$0.45**	**1**	**$0.45**
717-1436_2 Material	End Connector	$0.45	1	$0.45
717-1436_3	Quick Connector	$0.25	3	$0.75

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	7	Piece Cost (Total): $61.08	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	570		*Parts:*	*0*
Fasteners:	0		*Fasteners:*	*0*
Parts+Unanalyzed:	570		*Parts+Unanalyzed:*	*0*

Table D-7 Chevy Volt Rotor Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Preprocessed Part	717-1456_5	Rotor Hub	(None)
2	3	Manufacturing Steps		Rotor Hub Processing	
3	4	Manufacturing Process		Wash	
4	4	Manufacturing Process		Debur	
5	4	Manufacturing Process		Machine	
6	4	Manufacturing Process		Machine	
7	4	Manufacturing Process		Trim Press, 60 Ton	
8	4	Manufacturing Process		Remove Sand	
9	4	Manufacturing Process		Sand Casting	
10	5	Part	717-1456_5 Material	Material, Rotor Hub	Cast Iron Ductile or Nodular (120/150)
11	5	Part	Lost Sand, 717-1456_5-1	Lost Sand, Rotor Hub	(None)
12	5	Part	Melt Energy, 717-1456_5-1-1	Melt Energy, Rotor Hub	(None)
13	4	Manufacturing Process		Core Making	
14	5	Part	Core, 717-1456_5-1	Core, Rotor Hub	Cast Iron Ductile or Nodular (120/150)
15	2	Subassembly	717-1456_6	Laminated Steel Rotor Core Section	(None)
16	3	Part	717-1456_12	Inner Magnet, Laminated Steel	Commodity Item
17	3	Part	717-1456_13	Second to Inner Magnet, Laminated Steel	Commodity Item
18	3	Part	717-1456_14	Second to Outer Magnet, Laminated Steel	Commodity Item
19	3	Part	717-1456_15	Outer Magnet, Laminated Steel	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
20	3	Preprocessed Part	717-1456_11	Lamited Steel	Electro Magnetic Steel
21	4	Manufacturing Steps		Lamited Steel Process	
22	5	Manufacturing Process		Wash	
23	5	Manufacturing Process		Debur	
24	5	Manufacturing Process		Stamping Press, 200 Ton	
25	6	Part	717-1456_11 Material	Material, Lamited Steel	Electro Magnetic Steel
26	6	Part	717-1456_11 Material-Remaining	Material, Lamited Steel	Electro Magnetic Steel
27	3	Manufacturing Steps		Laminated Steel Rotor Core Section Assembly	
28	4	Manufacturing Process		Auto Assembly	
29	4	Manufacturing Process		Auto Assembly	
30	4	Manufacturing Process		Auto Assembly	
31	4	Manufacturing Process		Auto Assembly	
32	4	Manufacturing Process		Apply Epoxy	
33	4	Manufacturing Process		Laminate Stacking Station	
34	2	Preprocessed Part	717-1456_8	Top Plate, Laminated Steel	Stainless Steel 304
35	3	Manufacturing Steps		Top Plate Process	
36	4	Manufacturing Process		Wash	
37	4	Manufacturing Process		Deburr	
38	4	Manufacturing Process		Stamping Press, 300 Ton	
39	5	Part	717-1456_8 Material	Material, Top Plate, Laminated Steel	Stainless Steel 304
40	2	Preprocessed Part	717-1456_9	Bottom Plate, Lamited Steel	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
41	3	Manufacturing Steps		Bottom Plate Process	
42	4	Manufacturing Process		Wash	
43	4	Manufacturing Process		Deburr	
44	4	Manufacturing Process		Stamping Press, 300 Ton	
45	5	Part	717-1456_9 Material	Material, Bottom Plate, Laminated Steel	Aluminum 6061
46	2	Preprocessed Part	717-1456_10	Top Cover, Lamited Steel	Aluminum 6061
47	3	Manufacturing Steps		Top Cover Process	
48	4	Manufacturing Process		Wash	
49	4	Manufacturing Process		Deburr	
50	4	Manufacturing Process		Stamping Press, 600 Ton	
51	5	Part	717-1456_10 Material	Material, Top Cover, Laminated Steel	Aluminum 6061
52	2	Manufacturing Steps		Top Cover, Lamited Steel & Plates Installation	
53	3	Manufacturing Process		Auto Assembly	
54	2	Part	717-1456_3	Bearing Support Asm.	Commodity Item
55	2	Manufacturing Steps		Bearing Support Asm. Installation	
56	3	Manufacturing Process		Auto Press Station	
57	2	Subassembly	717-1456_2	Outer Laminates Asm.	(None)
58	3	Preprocessed Part	717-1456_4	Outer Laminates	Electro Magnetic Steel
59	4	Manufacturing Steps		Outer Laminates Process	
60	5	Manufacturing Process		Wash	
61	5	Manufacturing Process		deburr	

Row	Level	Symbol Type	Number	Name	Material Name
62	5	Manufacturing Process		Stamping Press, 200 Ton	
63	6	Part	717-1456_4 Material	Material, Outer Laminates	Electro Magnetic Steel
64	3	Manufacturing Steps		Outer Laminates Assembly	
65	4	Manufacturing Process		Laser Etch	
66	4	Manufacturing Process		Auto Assembly	
67	2	Manufacturing Steps		Outer Laminates Asm. Installation	
68	3	Manufacturing Process		Auto Assembly	
69	2	Part	717-1456_1	Set Ring	Commodity Item
70	2	Manufacturing Steps		Set Ring Installation	
71	3	Manufacturing Process		Auto Assembly	

Table D-7 Chevy Volt Rotor Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

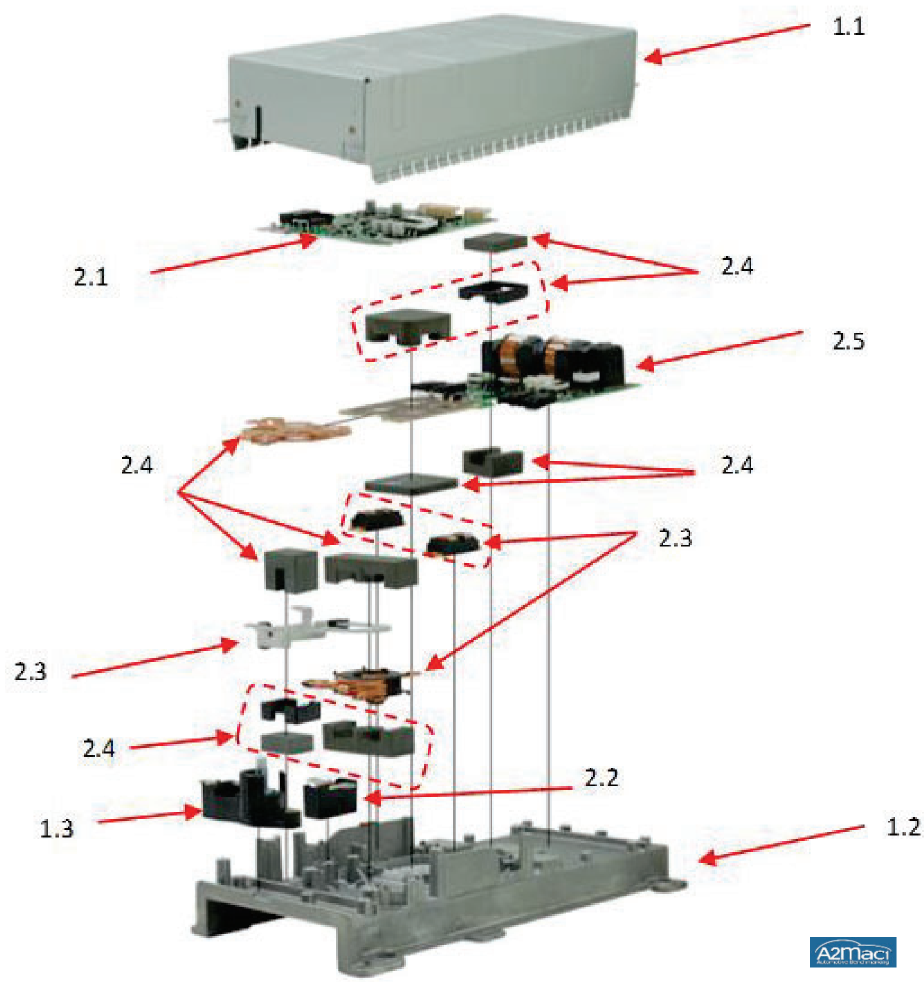
Chevrolet Volt - Rotor Assembly

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
717-1456_5	**Rotor Hub**	**$4.40**	**1**	**$4.40**
717-1456_5 Material	Material, Rotor Hub	$3.78	1	$3.78
Lost Sand, 717-1456_5-1	Lost Sand, Rotor Hub	$0.11	1	$0.11
Melt Energy, 717-1456_5-1-1	Melt Energy, Rotor Hub	$0.26	1	$0.26
Core, 717-1456_5-1	Core, Rotor Hub	$0.25	1	$0.25
717-1456_6	**Laminated Steel Rotor Core Section**	**$27.02**	**1**	**$27.02**
717-1456_12	Inner Magnet	$0.01	48	$0.48
717-1456_13	Second to Inner Magnet	$0.03	48	$1.30
717-1456_14	Second to Outer Magnet	$0.05	48	$2.59
717-1456_15	Outer Magnet	$0.08	72	$5.40
717-1456_11	**Lamited Steel**	**$17.25**	**1**	**$17.25**
717-1456_11 Material	Material, Lamited Steel	$0.12	119	$14.28
717-1456_11 Material-Remaining	Material, Lamited Steel	$0.33	9	$2.97
717-1456_8	**Top Plate, Laminated Steel**	**$0.28**	**1**	**$0.28**
717-1456_8 Material	Material, Top Plate, Laminated Steel	$0.28	1	$0.28
717-1456_9	**Bottom Plate, Lamited Steel**	**$0.68**	**1**	**$0.68**
717-1456_9 Material	Material, Bottom Plate, Laminated Steel	$0.68	1	$0.68
717-1456_10	**Top Cover, Lamited Steel**	**$0.58**	**1**	**$0.58**
717-1456_10 Material	Material, Top Cover, Laminated Steel	$0.58	1	$0.58
717-1456_3	Bearing Suppor Asm.	$4.50	2	$9.00
717-1456_2	**Outer Laminates Asm.**	**$1.82**	**1**	**$1.82**
717-1456_4	**Outer Laminates**	**$1.82**	**1**	**$1.82**
717-1456_4 Material	Material, Outer Laminates	$0.14	13	$1.82
717-1456_1	Set Ring	$0.15	1	$0.15

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	8	Piece Cost (Total): $43.93	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	367		*Parts:*	*0*
Fasteners:	0		*Fasteners:*	*0*
Parts+Unanalyzed:	367		*Parts+Unanalyzed:*	*0*

Appendix E: Ford Fusion DC/DC Converter

Figure E-1 Ford Fusion Base



Cost Estimate BOM			
1.1	Top Cover	2.1	DC/DC Controls Diagnostics Board
1.2	Base	2.2	Capacitor
1.3	Receptacle	2.3	DC/DC Bus Bar
		2.4	DC/DC Converter Ferrite
		2.5	DC/DC High Voltage Board

__Ford Fusion DC-DC Converter Enclosures and Cooling__

The Ford Fusion DC to DC converter enclosures group contains two primary components; the stamped steel cover enclosing the electronics and a die cast aluminum base. The converter has no direct cooling features other than fins along the bottom of the base casting. It is assumed the air flow for cooling is provided from the same system that is used to cool the battery pack. No additional cooling components were included for this reason.

Figure E-2 Ford Fusion Cover

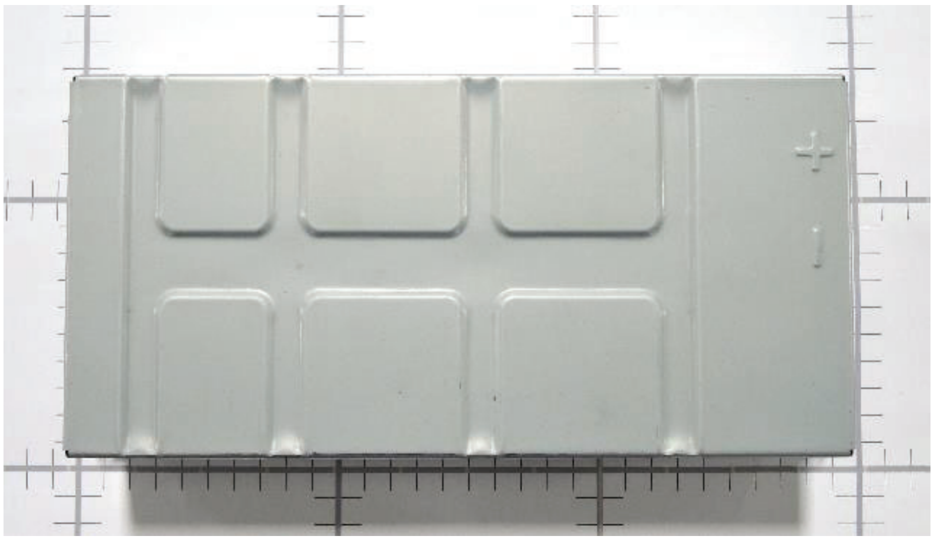
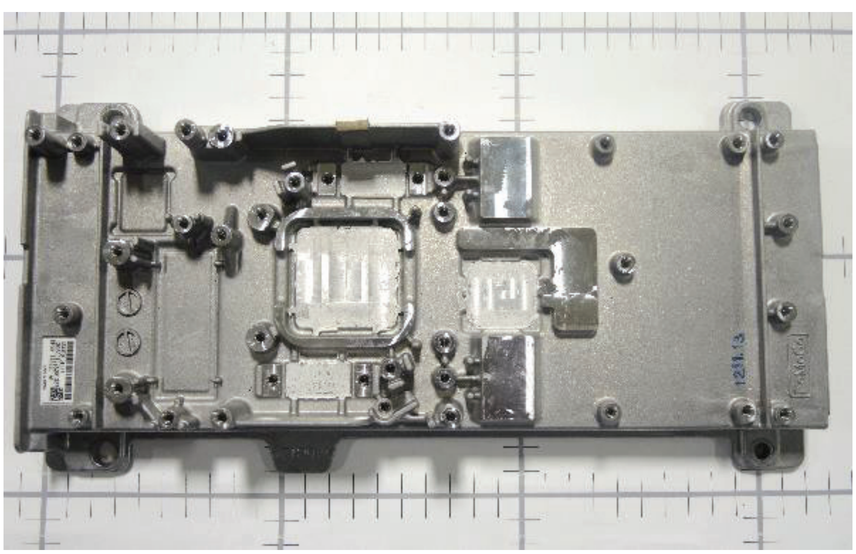


Figure E-3 Ford Fusion Base



The total "should cost" to manufacture the Ford enclosure and cooling group is estimated and additional typical markups associated with component manufacturing added. The summary shown in Table E-1 below includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table E-1 Ford Fusion DC/DC Enclosure & Cooling Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Fusion DC/DC Enclosure &

MUNRO & ASSOCIATES, INC.

	Fusion DC/DC Enclosure & Cooling
Parts	7
Steps	240
Actual Time	325.87 sec
Fasteners	4
Total Weight	1.43 kg
Piece Cost	$3.62
Total Labor Cost	$4.68
Q Burden	$0.32
Total Cost	$8.62
Annual Production	200000

Once complete the "should-cost" data is exported to a spreadsheet and percentages are applied to establish an estimated selling price. The markups include SG&A, profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown. Additional data at the bottom of the table includes total weight of the system analyzed, annual production volume, and approximate order of magnitude tooling costs. Tooling costs per part are not included in the total cost of the part. The base was assumed to be die cast aluminum A380. The casting then receives additional processing: including trimming of gates, machining, deburring and washing. The base machined features included heat sink pads, component mount pads and 32 tapped holes.

Table E-2 Ford DC/DC Enclosures & Cooling Group Estimate Summary

Component Summary		
Part/Assembly Name	Ford DC/DC Enclosures & Cooling	
Purchased Part Roll up Costs		$0.61
Raw Material Costs		$3.01
Processing Costs		$4.68
Scrap (Design Profit: Q-Burden)	4%	$0.32
SG&A % Applied Against Processing	7%	$0.33
Profit % Applied Against Raw & Processing	4%	$0.31
Logistics % Applied Against Sum of all Above	3%	$0.28
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.19
Total % Mark Up / Total Cost	20%	$9.72
Total Weight (kg)		1.4312
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$340,000
Tooling Cost/part		$0.34
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$680,000
Tooling Cost/part		$0.68

Figure E- 4 Ford Fusion Base Electronics Side

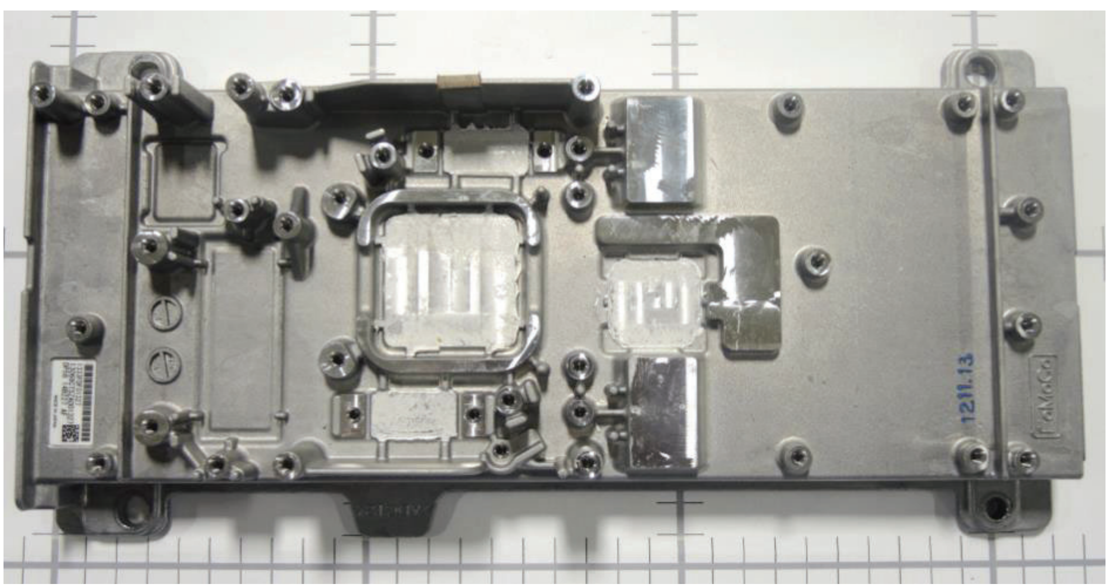
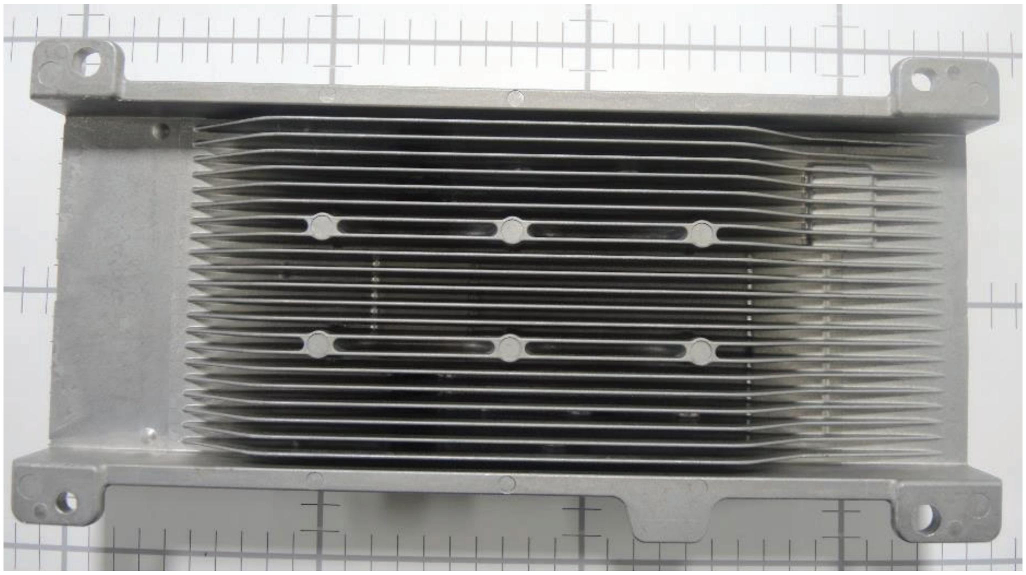
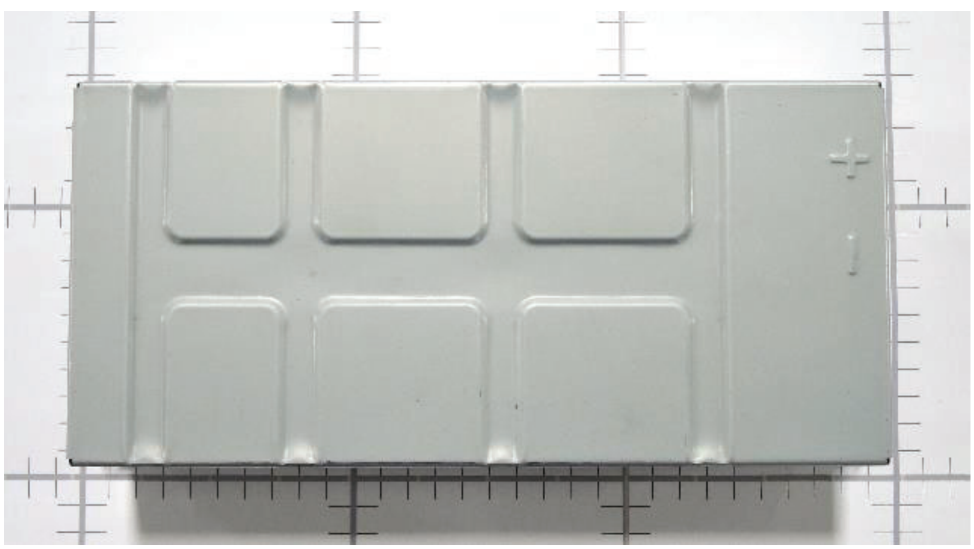


Figure E- 5 Ford Fusion Base Cooling Fin Side



The cover was assumed to be stamped galvanized low carbon steel. It is attached to the assembly with four threaded fasteners and has a label applied to it.

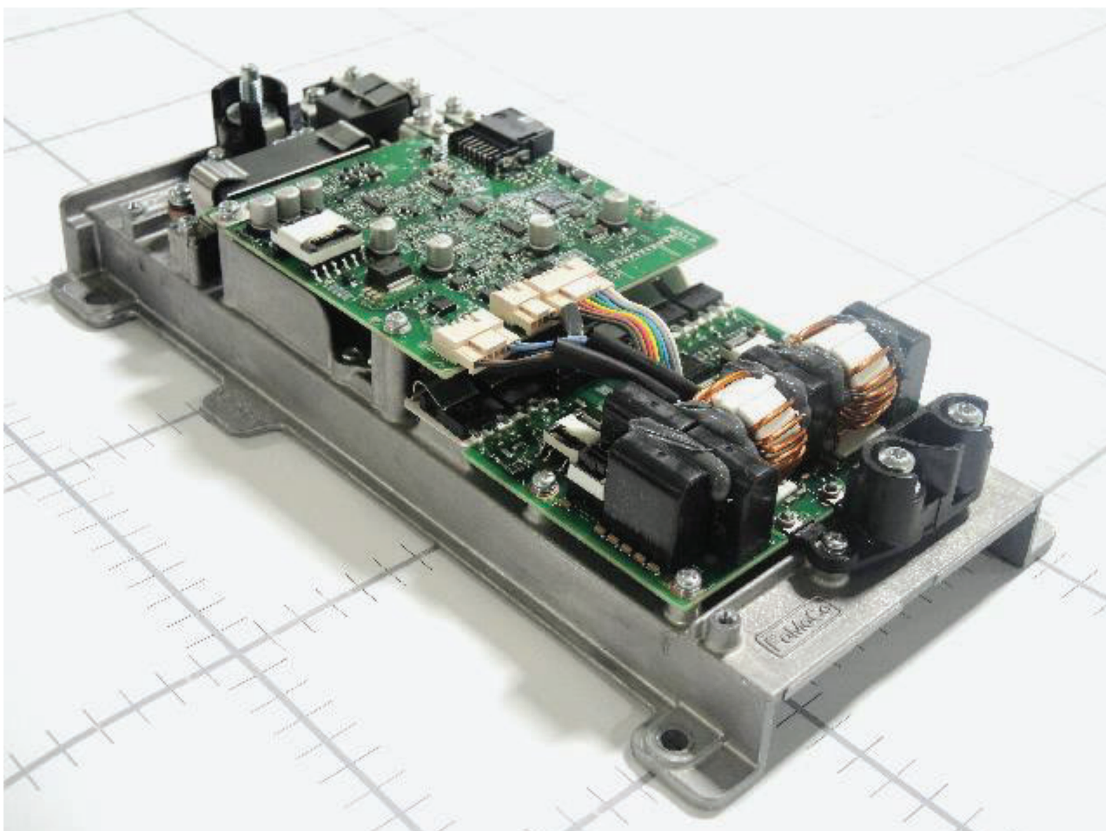
Figure E-6 Ford Fusion DC to DC Converter Cover



Ford Fusion DC/DC Converter

The Ford Fusion DC/DC Converter group consists of five subgroups providing additional clarity in regards to system cost details. Each group will be reported on separately. The converter subgrouping consists of the following: Internal Housing, Buss Bars, Printed Circuit Board Assemblies (PCBA), Ferrites & Inductors, and Harnesses (wiring). The internal housing group includes any additional structural components found inside the unit once disassembled. The Buss Bars group includes any stamped metal components providing electrical connections between devices internal to the module. The PCBA group contains all of the printed circuit boards associated with the DC to DC converter. The ferrites and Inductors group includes additional electronic components associated with the DC to DC converter. The last group Harnesses includes all internal wiring components connecting the various components in the converter.

Figure E-7 Ford Fusion DC/DC Converter



The total "should cost" to manufacture the Ford Fusion DC/DC Converter group is estimated and additional typical markups associated with component manufacturing added. The summary shown includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table E- 3 Ford Fusion DC/DC Converter Group Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Fusion DC/DC Converter

MUNRO & ASSOCIATES, INC.

	Fusion DC/DC Converter
Parts	580
Steps	1,539
Actual Time	2,517.59 sec
Fasteners	54
Total Weight	1.15 kg
Piece Cost	$181.07
Total Labor Cost	$36.28
Q Burden	$2.91
Total Cost	$220.27
Annual Production	200000

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. The markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown in the table below. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

Table E- 4 Ford Fusion DC/DC Converter Group Cost Summary

Component Summary		
Part/Assembly Name	Ford DC /DC Converter	
Purchased Part Roll up Costs		$176.75
Raw Material Costs		$4.29
Processing Costs		$36.28
Scrap (Design Profit: Q-Burden)	1%	$2.92
SG&A % Applied Against Processing	7%	$2.54
Profit % Applied Against Raw & Processing	4%	$1.62
Logistics % Applied Against Sum of all Above	3%	$6.73
Patent/Royalty Fees % Applied Against Sum of all Above	14%	$31.69
Total % Mark Up / Total Cost	29%	$262.83

Total Weight (kg)	1.15
Annual Volume	200000
Product Life: Years	5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)	$930,000
Tooling Cost/part	$0.93
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)	$1,860,000
Tooling Cost/part	$1.86

Ford Fusion DC/DC Internal Housing

The Ford Fusion DC/DC Internal Housing group consists of no additional components. The group was created for comparisons to similar groups analyzed in the Inverter/Converter portion of the project.

Ford Fusion DC/DC Bus Bars

The Ford Fusion DC/DC Bus Bars group consists of a single component connecting the 12-volt output to a pair of capacitors.

Figure E- 8 Ford Fusion DC/DC Bus Bars Group

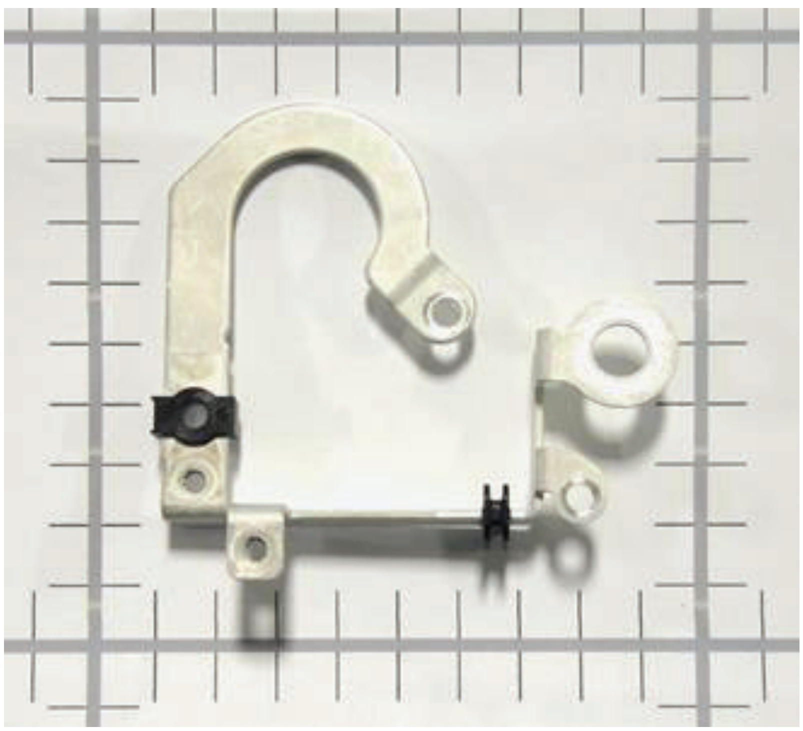


Table E- 5 Ford Fusion DC/DC Bus Bars Group Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Fusion DC/DC Bus Bars

MUNRO & ASSOCIATES, INC.

	Fusion DC/DC Bus Bars
Parts	2
Steps	17
Actual Time	22.19 sec
Fasteners	0
Total Weight	0.04 kg
Piece Cost	$0.12
Total Labor Cost	$0.19
Q Burden	$0.02
Total Cost	$0.33
Annual Production	200000

Table E-6 Ford Fusion DC/DC Bus Bars Group Cost Summary

Component Summary		
Part/Assembly Name		Ford DC /DC Bus Bars
Purchased Part Roll up Costs		$0.00
Raw Material Costs		$0.12
Processing Costs		$0.19
Scrap (Design Profit: Q-Burden)	6%	$0.02
SG&A % Applied Against Processing	7%	$0.01
Profit % Applied Against Raw & Processing	4%	$0.01
Logistics % Applied Against Sum of all Above	3%	$0.01
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.01
Total % Mark Up / Total Cost	22%	$0.37
Total Weight (kg)		0.0358
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$85,000
Tooling Cost/part		$0.09
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$170,000
Tooling Cost/part		$0.17

The Ford Fusion DC/DC Bus Bar connected between the 12-volt output and a capacitor was assumed to be a stamped formed part. The bus bar is made from 6000 series aluminum and has two over molded features. The molded features provide isolation and a means of securing the part during assembly.

Figure E-9 Ford Fusion DC/DC Bus Bar

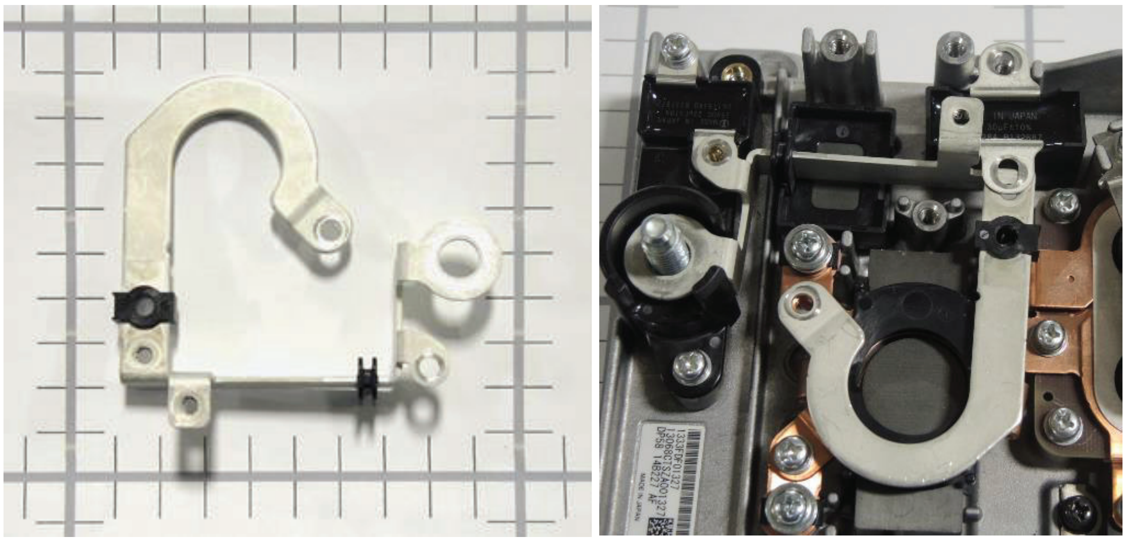
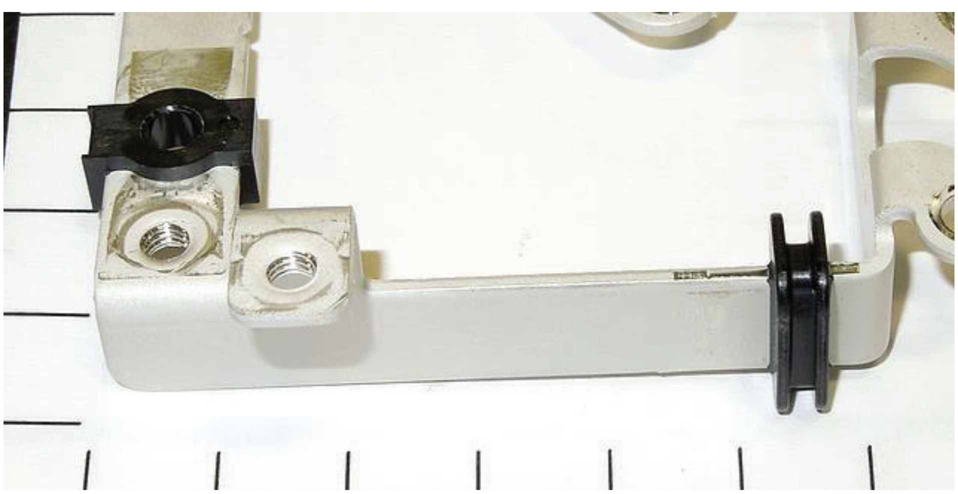


Figure E-10 Ford Fusion DC/DC Bus Bar over molded features



Ford Fusion DC/DC PCBAs

The Ford Fusion DC/DC Printed Circuit Board Assemblies (PCBAs) group consists of two components. One board is considered the high voltage board which converts the high voltage to low voltage for the vehicles 12 volt systems. The second board is the control/diagnostics board for the module.

Figure E-11 Ford Fusion DC/DC PCBAs Group

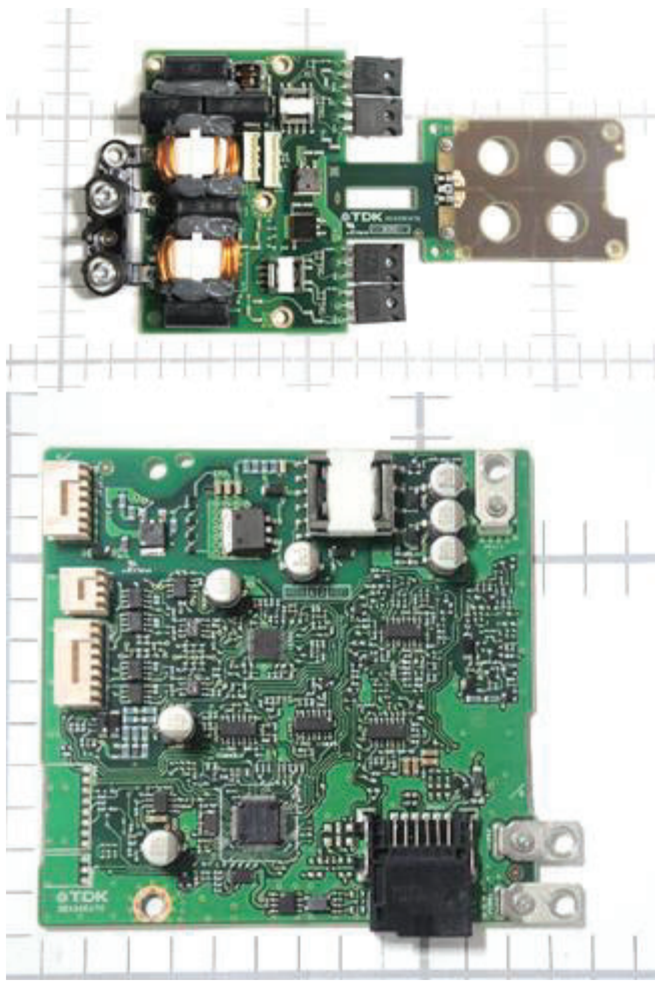


Table E- 7 Ford Fusion DC/DC PCBAs Group Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Fusion DC/DC PCBAs

MUNRO & ASSOCIATES, INC.

	Fusion DC/DC PCBAs
Parts	466
Steps	935
Actual Time	813.93 sec
Fasteners	30
Total Weight	0.43 kg
Piece Cost	$164.85
Total Labor Cost	$13.75
Q Burden	$1.54
Total Cost	$180.14
Annual Production	200000

Table E- 8 Ford Fusion DC/DC PCBAs Group Cost Summary

Component Summary		
Part/Assembly Name	Ford DC /DC Printed Circuit Board Assemblies	
Purchased Part Roll up Costs		$164.64
Raw Material Costs		$0.18
Processing Costs		$13.75
Scrap (Design Profit: Q-Burden)	1%	$1.54
SG&A % Applied Against Processing	7%	$0.96
Profit % Applied Against Raw & Processing	4%	$0.56
Logistics % Applied Against Sum of all Above	3%	$5.45
Patent/Royalty Fees % Applied Against Sum of all Above	15%	$28.06
Total % Mark Up / Total Cost	30%	$215.13
Total Weight (kg)		0.4295
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$165,000
Tooling Cost/part		$0.17
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$330,000
Tooling Cost/part		$0.33

Figure E-12 Ford Fusion DC/DC PCBAs Group

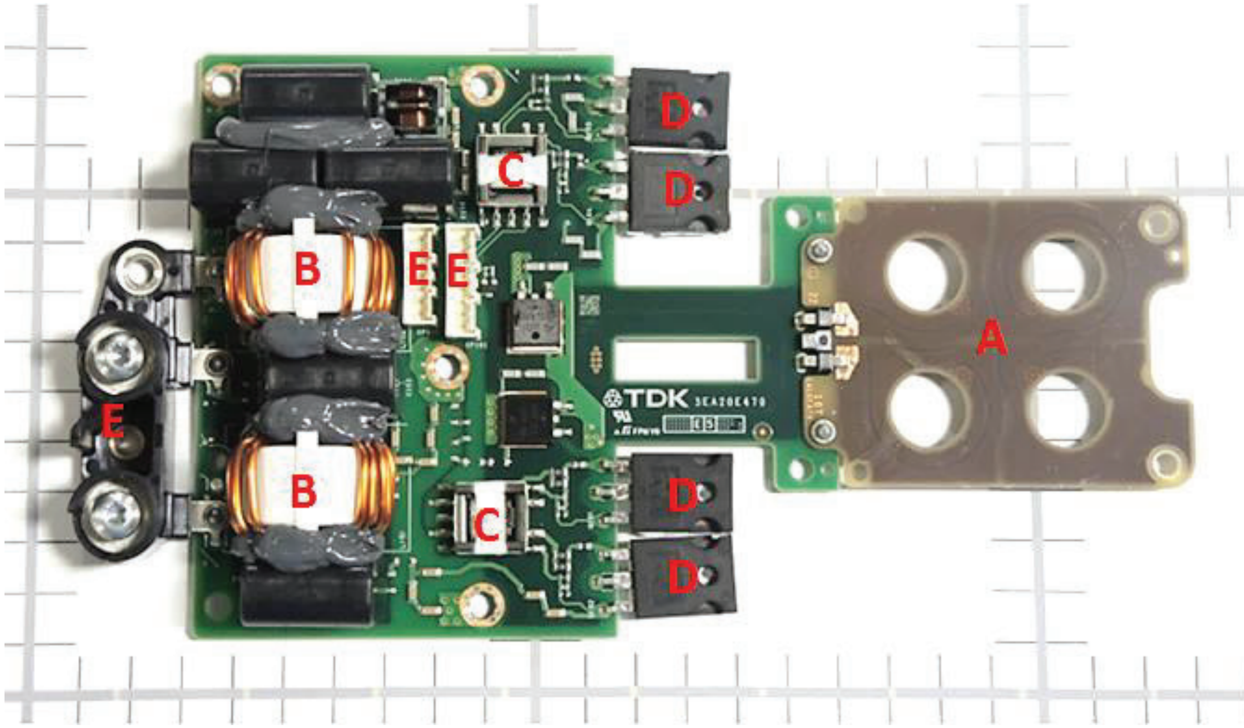


Table E- 9 Ford Fusion DC/DC PCBAs Group Summary- High Voltage Board

Part Label	Part Description	Comments
A	Coil	The coil is manufactured as a printed circuit board and then is riveted to the primary board completing circuit connections
B	Chokes	A pair of chokes for EMI suppression are seen on the left side of the board (copper wound ferrites)
C	Transformers	
D	MOFSETS	Four MOSFETs were identified as N-CH 600V 51A devices
E	Connector/Terminal Lugs	Terminal lugs for high current connections can be seen on the left of the board and a pair of low current connectors are located in the middle of the board

Figure E-13 Ford Fusion DC/DC PCBAs Group

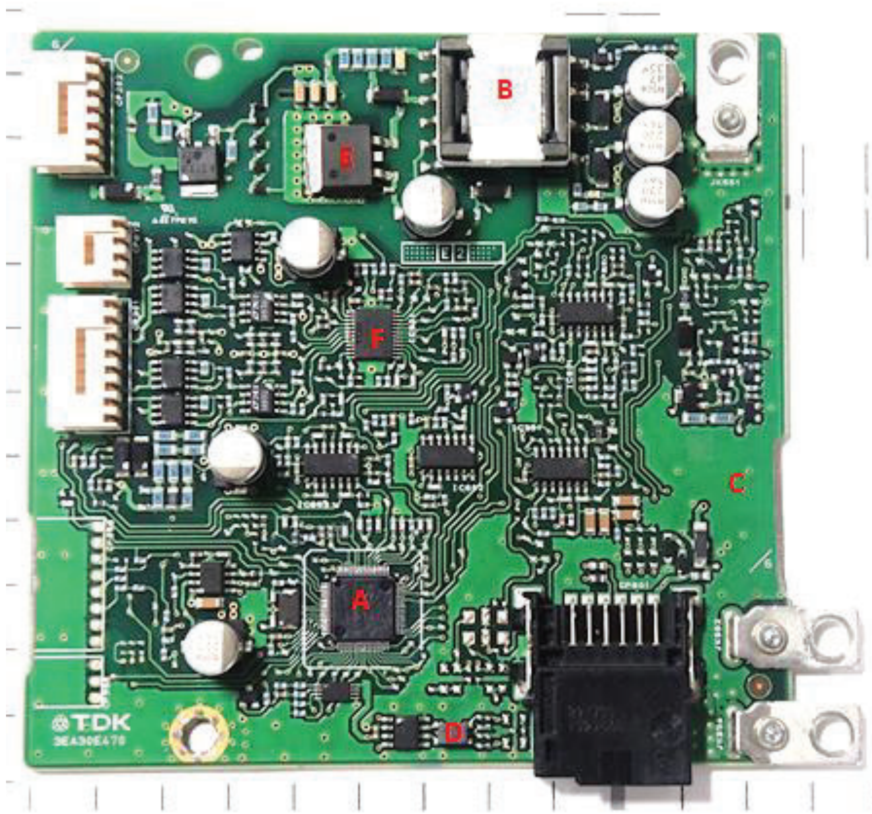


Table E- 10 Ford Fusion DC/DC PCBAs Group Summary-Control Diagnostic Board

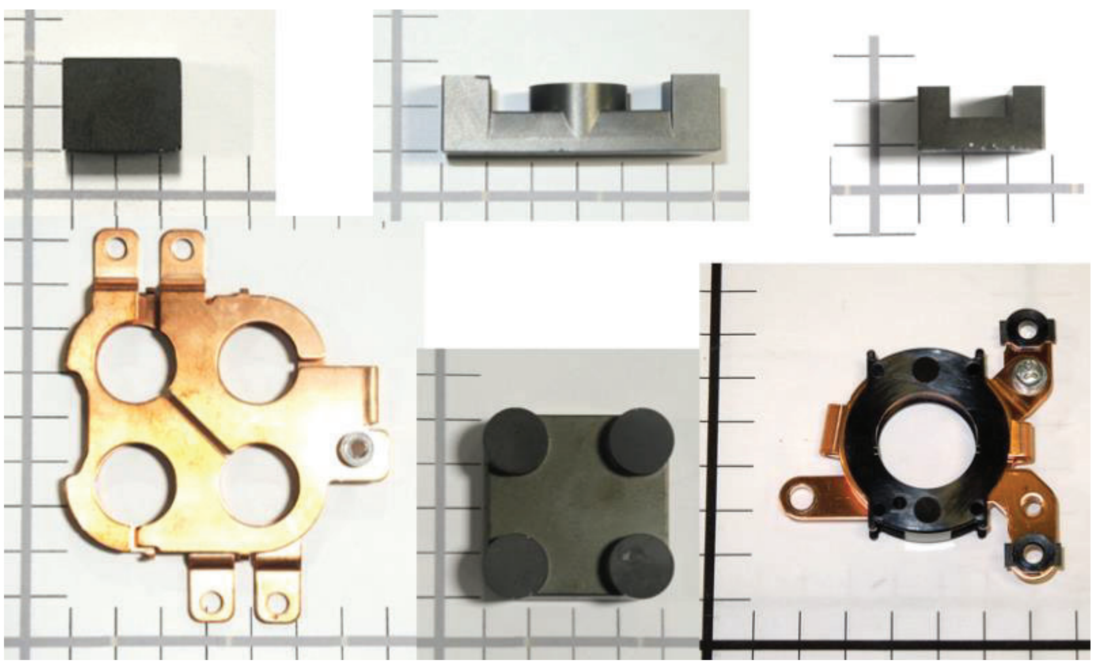
Part Label	Part Description	Comments
A	Integrated Circuit (IC) Micro Control Unit (MCU)	The main IC was identified as a 16 Bit MCU with 96KB flash in a 64LQFP package
B	Transformer	The transformer is a 36-60V flyback surface mount device
C	Printed Circuit Board (PCB)	The printed circuit board is a 2-layer design assumed to use a FR4 substrate
D	Filter	The Filter was found to be a 200µH Common Mode Choke
E	MOFSET	N-Channel 700V 9A device in a TO-263 package
F	Voltage Regulator	2 channel 5V-25V Switching-Step-Down regulator in a 24SOIC package

Additional components found on the board include connecter headers, EEPROM, CAN transceiver, electrolytic capacitors and various smaller active and passive surface mount components.

Ford Fusion DC/DC Ferrites & Inductors

The Ford Fusion DC/DC Ferrites & Inductors group consists of various ferrite cores, insulating pads and coils. The four ferrites are a sintered powdered metal design. Two ferrites are used on the 12-volt outlet side of the circuitry and one is associated with the high current input side. The third ferrite is trapped within the transformer area of the board along with the board internal coil and standalone cooper plate coil.

Figure E-14 Ford Fusion DC/DC Ferrites & Inductors Group



The total "should cost" to manufacture the Ford Fusion DC/DC Ferrites & Inductors group is estimated and additional typical markups associated with component manufacturing added. The summary shown includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table E- 11 Ford Fusion DC/DC Ferrites & Inductors Group Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
Fusion DC/DC Ferrites &

MUNRO & ASSOCIATES, INC.

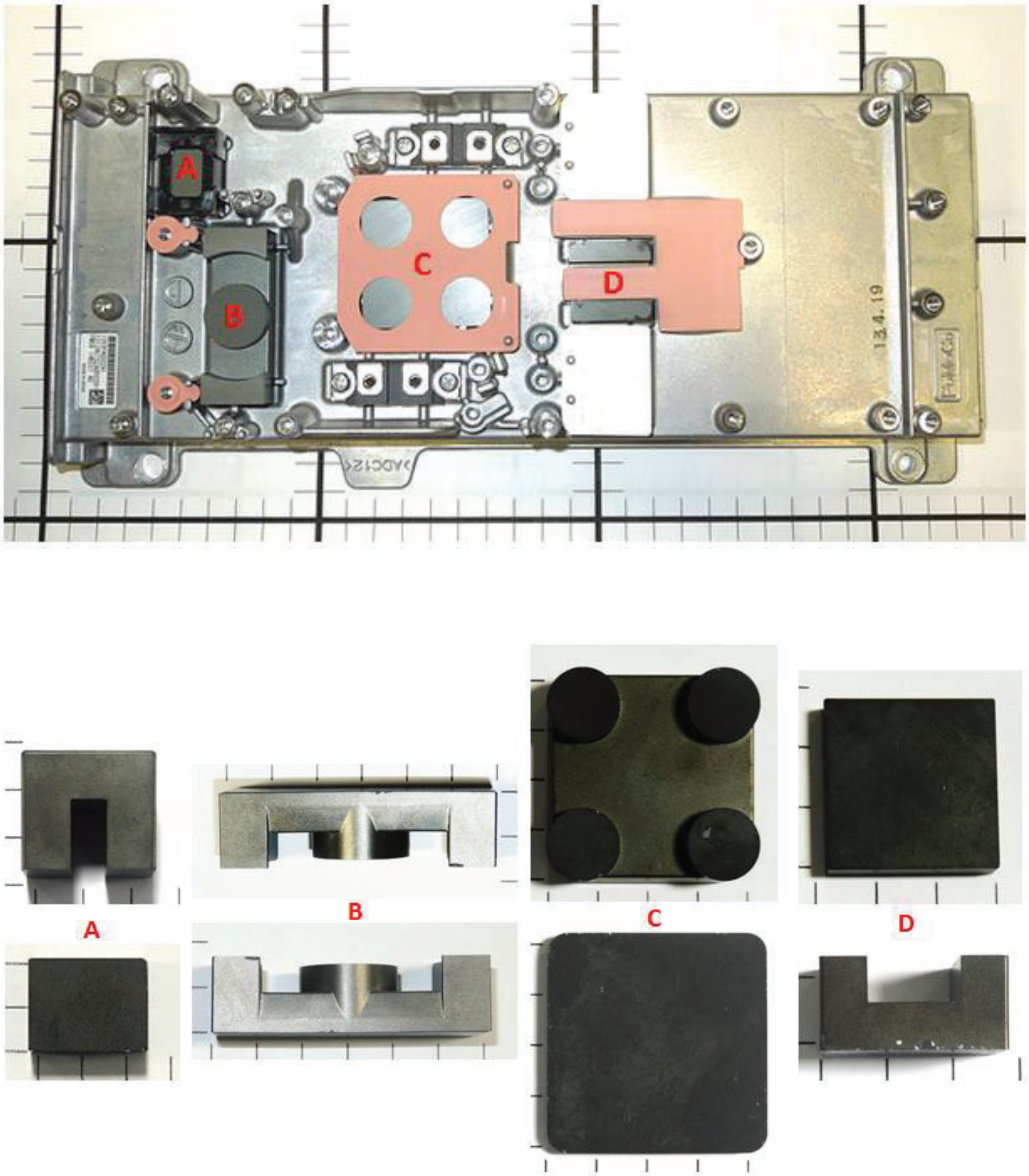
	Fusion DC/DC Ferrites & Inductors
Parts	60
Steps	354
Actual Time	1,189.46 sec
Fasteners	23
Total Weight	0.66 kg
Piece Cost	$13.44
Total Labor Cost	$16.95
Q Burden	$0.96
Total Cost	$31.35
Annual Production	200000

Table E- 12 Ford Fusion DC/DC Ferrites & Inductors Group Cost Summary

Component Summary		
Part/Assembly Name		Ford DC /DC Ferrites & Inductors
Purchased Part Roll up Costs		$9.45
Raw Material Costs		$3.99
Processing Costs		$16.95
Scrap (Design Profit: Q-Burden)	3%	$0.96
SG&A % Applied Against Processing	7%	$1.19
Profit % Applied Against Raw & Processing	4%	$0.84
Logistics % Applied Against Sum of all Above	3%	$1.00
Patent/Royalty Fees % Applied Against Sum of all Above	10%	$3.44
Total % Mark Up / Total Cost	27%	$37.81
Total Weight (kg)		0.6592
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$680,000
Tooling Cost/part		$0.68
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,360,000
Tooling Cost/part		$1.36

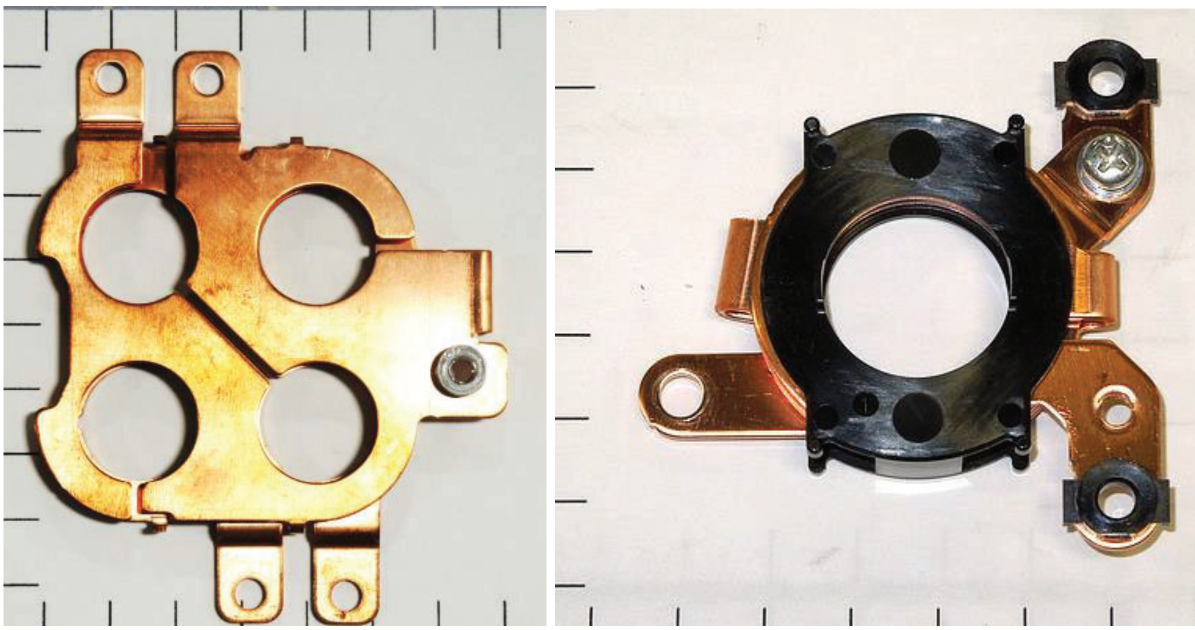
The ferrites are all sintered powdered metal. By design each ferrite core consists of two halves a top and bottom facilitating insertion of bus bars and coils. Two of the coils are U shaped (A & D) which wrap around a single buss bar while the other two are part of the two coil sets (B & C).

Figure E-15 Ford Fusion DC/DC Ferrites Cores



There are two coils associated with the ferrite cores a single coil and a quad coil. Both coils are found on the low voltage side of the unit. Both coils are a stamped formed copper design. The single coil also includes the plastic insulators one for the coil ring and two at the end of each terminal lug.

Figure E-16 Ford Fusion DC/DC Ferrites Cores



Ford Fusion DC/DC Electrical & Harness

The Ford Fusion DC/DC Electrical & Harness group consists of three different wire harnesses. Two of the harnesses connect the high voltage board to the control boards (jumper harnesses), while the third harness is actually a temp sensor which connects to the control board. The temp sensor is embedded into a barrel style connector with an eyelet for attachment to the base.

Figure E-17 Ford Fusion DC/DC Electrical & Harness Group

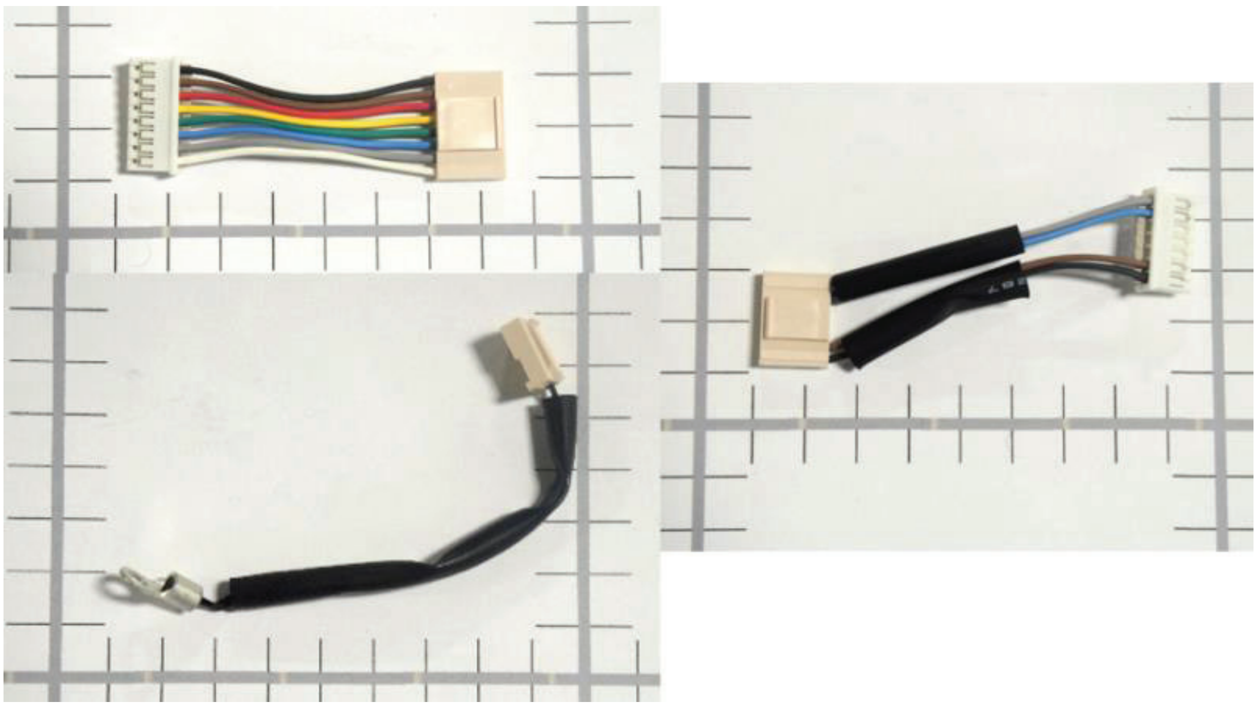


Table E- 13 Ford Fusion DC/DC Electrical & Harness Group Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Fusion DC/DC Electrical &

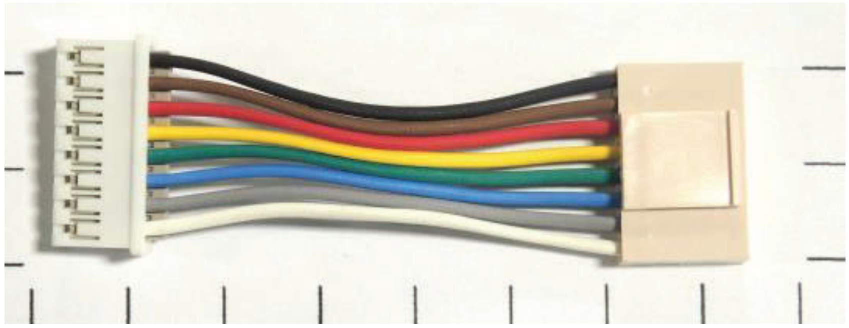
MUNRO & ASSOCIATES, INC.

	Fusion DC/DC Electrical & Harness
Parts	52
Steps	233
Actual Time	492.01 sec
Fasteners	1
Total Weight	0.03 kg
Piece Cost	$2.67
Total Labor Cost	$5.39
Q Burden	$0.40
Total Cost	$8.45
Annual Production	200000

Table E- 14 Ford Fusion DC/DC Electrical & Harness Group Cost Summary

Component Summary		
Part/Assembly Name	Ford DC /DC Electrical Harnesses	
Purchased Part Roll up Costs		$2.67
Raw Material Costs		$0.00
Processing Costs		$5.39
Scrap (Design Profit: Q-Burden)	5%	$0.40
SG&A % Applied Against Processing	7%	$0.38
Profit % Applied Against Raw & Processing	4%	$0.22
Logistics % Applied Against Sum of all Above	3%	$0.27
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.19
Total % Mark Up / Total Cost	21%	$9.51
Total Weight (kg)		0.0271
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$0
Tooling Cost/part		$0.00
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$0
Tooling Cost/part		$0.00

Figure E-18 Ford Fusion DC/DC Board to Board Jumper Harnesses



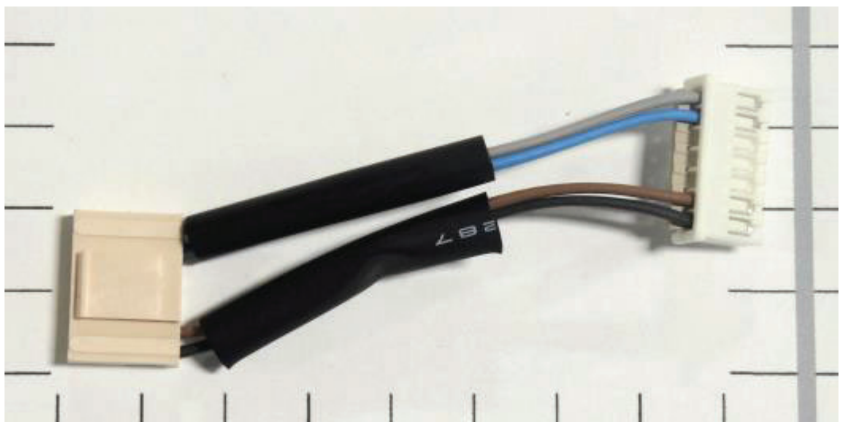


Figure E-19 Ford Fusion DC/DC Temp Sensor Harnesses

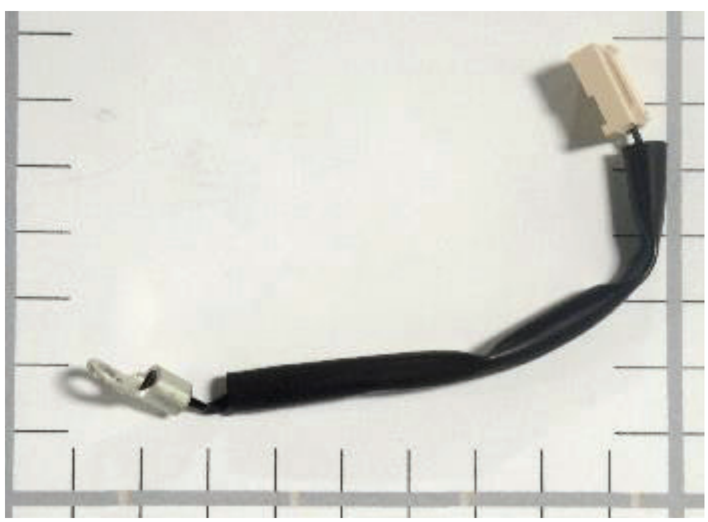


Table E-15 Ford Fusion DC/DC Enclosures & Cooling Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Preprocessed Part	1444-66_01	Housing, DC/DC Converter	Aluminum A380, Cast
2	3	Manufacturing Steps		Housing, DC/DC Converter Processing	
3	4	Manufacturing Process		Wash	
4	4	Manufacturing Process		Debur	
5	4	Manufacturing Process		Machining	
6	4	Manufacturing Process		Trim Press, 25 Ton	
7	4	Manufacturing Process		Die Cast, 1300 Ton	
8	5	Part	1444-66_01 Material	Material, Housing, DC/DC Converter	Aluminum A380, Cast
9	2	Preprocessed Part	1444-44_01	Cover, DC/DC Converter	Steel, Galvanized G60
10	3	Manufacturing Steps		Cover, DC/DC Converter Processing	
11	4	Manufacturing Process		Spot Weld- Robotic	
12	4	Manufacturing Process		Wash	
13	4	Manufacturing Process		Debur	
14	4	Manufacturing Process		Stamping Press, 200 Ton	
15	5	Part	1444-44_01 Material	Material, Cover, DC/DC Converter	Steel, Galvanized G60
16	2	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
17	2	Part	1624-66_01	Label, 25x13mm, DC/DC Converter	Commodity Item

Table E-16 Ford Fusion DC/DC Enclosures & Cooling Bill of Materials

Indented Bill of Materials — MUNRO & ASSOCIATES, INC.

Fusion DC/DC Enclosure & Cooling

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1444-66_01	**Housing, DC/DC Converter**	**$2.67**	**1**	**$2.67**
1444-66_01 Material	Material, Housing, DC/DC Converter	$2.67	1	$2.67
1444-44_01	**Cover, DC/DC Converter**	**$0.34**	**1**	**$0.34**
1444-44_01 Material	Material, Cover, DC/DC Converter	$0.34	1	$0.34
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	4	$0.56
1624-66_01	Label, 25x13mm, DC/DC Converter	$0.05	1	$0.05

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	2	Piece Cost (Total): $3.62	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	7		*Parts:*	*0*
Fasteners:	4		*Fasteners:*	*0*
Parts+Unanalyzed:	7		*Parts+Unanalyzed:*	*0*

Ford Fusion DC/DC Converter Subgroups

Table E-17 Ford Fusion DC/DC Internal Housing Materials and Processing Assumptions

The Ford Fusion DC/DC Internal Housing group consists of no additional components. The group was created for comparisons to similar groups analyzed in the Inverter/Converter portion of the project.

Table E-18 Ford Fusion DC/DC Internal Housing Bill of Materials

Indented Bill of Materials — MUNRO & ASSOCIATES, INC.

Fusion DC/DC Internal Housing

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	0	Piece Cost (Total): $0.00	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	0		*Parts:*	*0*
Fasteners:	0		*Fasteners:*	*0*
Parts+Unanalyzed:	0		*Parts+Unanalyzed:*	*0*

Table E-19 Ford Fusion DC/DC Buss Bars Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Preprocessed Part	HV Grnd Bar Asm, DC/DC Converter	1444-52_01	(None)
2	4	Manufacturing Steps	Ground Bar Processing		
3	5	Manufacturing Process	Injection Mold Press, 55 Ton		
4	6	Part	Overmolded Insulator, HV Grnd Bar	1444-52_01 Material 2	Polyphenylene Sulfide, (GF + MD) 65
5	5	Manufacturing Process	Wash		
6	5	Manufacturing Process	Debur		
7	5	Manufacturing Process	Machining		
8	5	Manufacturing Process	Stamping Press, 25 Ton		
9	6	Part	Material, HV Grnd Bar Asm, DC/DC Converter	1444-52_01 Material 1	Aluminum 6061

Table E-20 Ford Fusion DC/DC Buss Bars Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Fusion DC/DC Bus Bars

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1444-52_01	HV Grnd Bar Asm, DC/DC Converter	$0.12	1	$0.12
1444-52_01 Material 2	Overmolded Insulator, HV Grnd Bar	$0.01	1	$0.01
1444-52_01 Material 1	Material, HV Grnd Bar Asm, DC/DC Converter	$0.11	1	$0.11

Assembly Totals | **Report Totals** | ***Preassembled Totals***

Piece Cost (Total): $0.12

	Assembly Totals	Preassembled Totals
Analyzed Subs:	1	0
Unanalyzed Subs:	0	0
Parts:	2	0
Fasteners:	0	0
Parts+Unanalyzed:	2	0

Table E-21 Ford Fusion PCBAs Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1444-65_04	High Voltage PCB Asm, DC/DC Converter	(None)
2	4	Subassembly	1444-65_05	Binding Post , HV Cables	(None)
3	5	Part	1444-65_05A	Nut, Flanged, M4-0.7mm	Commodity Item
4	5	Part	1444-65_05B	Large Eyelet, 4mm	Commodity Item
5	5	Part	1444-65_05C	Small Eyelet, 4mm	Commodity Item
6	5	Part	1444-65_05D	Brass Spacer, 4mm	Commodity Item
7	5	Manufacturing Steps		Binding Post , HV Cables Processing	
8	6	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
9	7	Part	1444-65_05 Material	Material, Binding Post , HV Cables	Polyphenylene Sulfide, (GF + MD) 65
10	4	Part	1444-65_06	Material, HV Coil PCB, DC/DC Converter	Commodity Item
11	4	Part	1444-65_07	Rivet, 1/8 Dia .062-.125" Grip	Commodity Item
12	4	Part	1444-65_09	Connector, HV to Coil PCB, DC/DC Converter	Commodity Item
13	4	Manufacturing Steps		Assemble High Voltage PCB Asm, DC/DC Converter	
14	5	Manufacturing Process		Functional Test	
15	5	Manufacturing Process		Conformal Coat	
16	6	Part	Conformal Coat, PCBA-HV	Conformal Coat, PCBA-HV	Commodity Item
17	5	Manufacturing Process		Manual Thru Hole Placement	
18	5	Manufacturing Process		Automated Thru Hole	
19	7	Part	STW55NM60ND	MOSFET N-CH 600V 51A TO-247	Commodity Item
20	7	Part	R463R422050M2K	2.2µF Film Capacitor 310V 630V	Commodity Item
21	7	Part	PCB CHOKE VERT SMALL	PCB CHOKE VERT SMALL	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
22	7	Part	XFRMR FLYBACK, DC-DC, 14 x 14mm	XFRMR FLYBACK, DC-DC, 14 x 14mm	Commodity Item
23	7	Part	Connector, 7 Pin, Vertical, 2.5 mm Pitch, Male	Connector, 7 Pin, Vertical, 2.5 mm Pitch, Male	Commodity Item
24	7	Part	Connector, 8 Pin, Vertical, 2.5 mm Pitch, Male	Connector, 8 Pin, Vertical, 2.5 mm Pitch, Male	Commodity Item
25	5	Manufacturing Process		De-Panel	
26	5	Manufacturing Process		PCB Population - Low Content	
27	6	Part	HV PCB Asm, DC/DC Converter	HV PCB DC/DC Converter Board	Commodity Item
28	8	Part	SF20L60U-7600	Rectifiers VRM=600 IFSM=180, TO-220	Commodity Item
29	8	Part	DAN222TL	DIODE ARRAY 80V 100MA EMD3	Commodity Item
30	8	Part	Capacitor, Ceramic, 0603	Capacitor, Ceramic, 0603	Commodity Item
31	8	Part	Capacitor, Ceramic, 1206	Capacitor, Ceramic, 1206	Commodity Item
32	8	Part	Capacitor, Ceramic, 0805	Capacitor, Ceramic, 0805	Commodity Item
33	8	Part	Resistor, Ceramic, 0603	Resistor, Ceramic, 0603	Commodity Item
34	8	Part	Resistor, Ceramic, 0805	Resistor, Ceramic, 0805	Commodity Item
35	8	Part	Resistor, Ceramic, 1206	Resistor, Ceramic, 1206	Commodity Item
36	7	Part	B82801C565A100	Current Transformer	Commodity Item
37	4	Part	Silicone, RTV, Gray	Silicone, RTV, Gray	Commodity Item
38	4	Manufacturing Steps		Apply RTV to Capacitors	
39	5	Manufacturing Process		Manual Asm	
40	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
41	3	Part	1444-58_04	SEMS Screw, Black, M4-0.7 x 4.5mm	Commodity Item
42	3	Manufacturing Steps		Install HV PCB & Coil Asm, DC/DC Converter	
43	4	Manufacturing Process		Manual Asm	
44	3	Preprocessed Part	1444-65_08	Clip, MOSFET Retainer	Steel 4130
45	4	Manufacturing Steps		Clip, MOSFET Retainer Processing	

Row	Level	Symbol Type	Number	Name	Material Name
46	5	Manufacturing Process		Wash	
47	5	Manufacturing Process		Debur	
48	5	Manufacturing Process		Stamping Press, 25 Ton	
49	6	Part	1444-65_08 Material	Material, Clip, MOSFET Retainer	Steel 4130
50	3	Preprocessed Part	1444-65_08	Clip, MOSFET Retainer	Steel 4130
51	4	Manufacturing Steps		Clip, MOSFET Retainer Processing	
52	5	Manufacturing Process		Wash	
53	5	Manufacturing Process		Debur	
54	5	Manufacturing Process		Stamping Press, 25 Ton	
55	6	Part	1444-65_08 Material	Material, Clip, MOSFET Retainer	Steel 4130
56	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
57	3	Manufacturing Steps		Install Clip, MOSFET Retainer	
58	4	Manufacturing Process		Manual Asm	
59	3	Subassembly	1444-64_01	Diagnostic PCB Asm, DC/DC Converter	(None)
60	4	Part	1444-64_02	Terminal, Rivet, Screw & Soldered, PCB	Commodity Item
61	4	Part	1444-65_07	Rivet, 1/8 Dia .062-.125" Grip	Commodity Item
62	4	Manufacturing Steps		Assemble Diagnostic PCB Asm, DC/DC Converter	
63	5	Manufacturing Process		Functional Test	
64	5	Manufacturing Process		Conformal Coat	
65	6	Part	Conformal Coat, PCBA	Conformal Coat, PCBA	Commodity Item
66	5	Manufacturing Process		Manual Thru Hole Placement	
67	5	Manufacturing Process		Auto Thru Hole Placement	
68	7	Part	RIGHT ANGLE HDR 4P, GOLD, DF13-4P-1.25DS(50)	RIGHT ANGLE HDR 4P, GOLD, DF13-4P-1.25DS(50)	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
69	7	Part	RIGHT ANGLE HDR 8P, GOLD, DF13-8P-1.25DS(50)	RIGHT ANGLE HDR 8P, GOLD, DF13-8P-1.25DS(50)	Commodity Item
70	7	Part	RIGHT ANGLE HDR 7P, GOLD, DF13-7P-1.25DS(50)	RIGHT ANGLE HDR 7P, GOLD, DF13-7P-1.25DS(50)	Commodity Item
71	7	Part	1927688-3	Automotive Connectors ASSY, 1X6,GET RA HDR, KEY C	Commodity Item
72	5	Manufacturing Process		De-Panel	
73	5	Manufacturing Process		PCB Population - Low Content	
74	6	Part	Diagnostic PCB, DC/DC Converter	Diagnostic PCB, DC/DC Converter	Commodity Item
75	8	Part	M30291FAHP#U7A	IC MCU 16BIT 96KB FLASH 64LQFP	Commodity Item
76	8	Part	S-93C86BD4I-J8T1G	IC EEPROM 16KBIT 2MHZ 8SOP	Commodity Item
77	8	Part	CX5032GB20000H0PESZ Z	CRYSTAL 20MHZ 12PF SMD	Commodity Item
78	8	Part	SH8M3TB1	MOSFET N/P-CH 30V 5A/4.5A SOP8	Commodity Item
79	8	Part	L4993DTR	IC REG LDO 5V 0.15A 8SO	Commodity Item
80	8	Part	TLE6250G	IC TXRX CAN STD HI SPEED DSO-8	Commodity Item
81	8	Part	LTC1693-1IS8#PBF	Gate Driver IC Non-Inverting 8-SOIC	Commodity Item
82	8	Part	LM2901YDT	IC VOLT COMPARATOR QUAD 14-SOIC	Commodity Item
83	8	Part	LM2902YDT	IC VOLT COMPARATOR QUAD 14-SOIC	Commodity Item
84	8	Part	AOB9N70L	MOSFET NCH 700V 9A TO263	Commodity Item
85	8	Part	2SK3113-Z-E1-AZ	Trans MOSFET N-CH 600V 2A 3-Pin(2+Tab) TO-252 T/R	Commodity Item
86	8	Part	BCX52-10,115	TRANSISTOR PNP 60V 1A SOT89	Commodity Item
87	8	Part	2PB709ART,215	TRANS PNP 45V 0.1A SOT23-3	Commodity Item
88	8	Part	DAN202KT146	Diode Array Standard 80V 100mA SOT23-3	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
89	8	Part	D1FL20U-5053	Diode Rectifiers VRM=200 IFSM=20 DO214AC	Commodity Item
90	8	Part	RS1KL	Diode Rectifiers 1.0 Amp 800 Volt 150ns	Commodity Item
91	8	Part	D1FK60-5053	Diode Rectifiers 0.8 Amp 600 Volt	Commodity Item
92	8	Part	HZU12A1LTRF-E	Silicon Planar Zener Diode SOD323	Commodity Item
93	8	Part	BAS521,135	Diode 300V 250mA Surface Mount SOD-523	Commodity Item
94	8	Part	SMF22A-E3-08	TVS DIODE 22VWM 35.5VC SMF	Commodity Item
95	8	Part	AN33012UA-VB	Voltage Regulators- Switching-Step-Down 5V- 25V 2ch	Commodity Item
96	8	Part	Capacitor, Ceramic, 0603	Capacitor, Ceramic, 0603	Commodity Item
97	8	Part	Capacitor, Ceramic, 0805	Capacitor, Ceramic, 0805	Commodity Item
98	8	Part	Capacitor, Ceramic, 1206	Capacitor, Ceramic, 1206	Commodity Item
99	8	Part	ACH4518-332-TD01	LC (T-Type) EMI Filter 3rd Order Low Pass 1 Channe	Commodity Item
100	8	Part	ACT45L-201-2P-TL000	Filter, Common Mode Choke 200µH @ 100kHz 2 Line	Commodity Item
101	8	Part	Resistor, Ceramic, 0603	Resistor, Ceramic, 0603	Commodity Item
102	8	Part	Resistor, Ceramic, 0805	Resistor, Ceramic, 0805	Commodity Item
103	8	Part	Resistor, Ceramic, 1206	Resistor, Ceramic, 1206	Commodity Item
104	7	Part	B82802A12A315	TRANSFORMER FLYBACK 36-60V SMD	Commodity Item
105	7	Part	PCE5052TR-ND	CAP ALUM 47UF 35V 20% SMD	Commodity Item
106	7	Part	493-4454-2-ND	CAP ALUM 220UF 16V 20% SMD	Commodity Item
107	3	Part	Gasket, Fabric over Foam, 5x2mm	Gasket, Fabric over Foam, 5x2mm	Commodity Item
108	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
109	3	Manufacturing Steps		Install Diagnostic PCB	
110	4	Manufacturing Process		Manual Asm	

Row	Level	Symbol Type	Number	Name	Material Name
111	3	Part	1444-58_03	Diode Pair Module, 90V, DC/DC Converter	Commodity Item
112	3	Manufacturing Steps		Install Diode Pair	
113	4	Manufacturing Process		Manual Asm	

Table E-22 Ford Fusion PCBAs Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Fusion DC/DC PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1444-65_04	**High Voltage PCB Asm, DC/DC Converter**	**$74.99**	**1**	**$74.99**
1444-65_05	**Binding Post, HV Cables**	**$0.53**	**1**	**$0.53**
1444-65_05A	Nut, Flanged, M4-0.7mm	$0.03	2	$0.06
1444-65_05B	Large Eyelet, 4mm	$0.11	2	$0.22
1444-65_05C	Small Eyelet, 4mm	$0.05	1	$0.05
1444-65_05D	Brass Spacer, 4mm	$0.04	1	$0.04
1444-65_05 Material	Material, Binding Post, HV Cables	$0.16	1	$0.16
1444-65_06	Material, HV Coil PCB, DC/DC Converter	$1.74	1	$1.74
1444-65_07	Rivet, 1/8 Dia .062-.125" Grip	$0.01	5	$0.05
1444-65_09	Connector, HV to Coil PCB, DC/DC Converter	$0.84	1	$0.84
Conformal Coat, PCBA-HV	Conformal Coat, PCBA-HV	$0.21	1	$0.21
STW55NM60ND	MOSFET N-CH 600V 51A TO-247	$6.25	4	$25.00
R463R422050M2K	2.2µF Film Capacitor 310V 630V	$0.21	5	$1.05
PCB CHOKE VERT SMALL	PCB CHOKE VERT SMALL	$5.18	2	$10.36
XFRMR FLYBACK, DC-DC, 14 x 14mm	XFRMR FLYBACK, DC-DC, 14 x 14mm	$5.61	1	$5.61
Connector, 7 Pin, Vertical, 2.5 mm Pitch, Male	Connector, 7 Pin, Vertical, 2.5 mm Pitch, Male	$0.12	1	$0.12
Connector, 8 Pin, Vertical, 2.5 mm Pitch, Male	Connector, 8 Pin, Vertical, 2.5 mm Pitch, Male	$0.08	1	$0.08
HV PCB Asm, DC/DC Converter	HV PCB DC/DC Converter Board	$3.24	1	$3.24
SF20L60U-7600	Rectifiers VRM=600 IFSM=180, TO-220	$0.48	2	$0.96
DAN222TL	DIODE ARRAY 80V 100MA EMD3	$0.01	1	$0.01
Capacitor, Ceramic, 0603	Capacitor, Ceramic, 0603	$0.12	5	$0.60
Capacitor, Ceramic, 1206	Capacitor, Ceramic, 1206	$0.64	33	$21.12
Capacitor, Ceramic, 0805	Capacitor, Ceramic, 0805	$0.03	4	$0.12
Resistor, Ceramic, 0603	Resistor, Ceramic, 0603	$0.00	1	$0.00
Resistor, Ceramic, 0805	Resistor, Ceramic, 0805	$0.00	4	$0.00
Resistor, Ceramic, 1206	Resistor, Ceramic, 1206	$0.00	8	$0.02
B82801C565A100	Current Transformer	$1.62	2	$3.24
Silicone, RTV, Gray	Silicone, RTV, Gray	$0.08	1	$0.08
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	9	$1.26
1444-58_04	SEMS Screw, Black, M4-0.7 x 4.5mm	$0.07	4	$0.28
1444-65_08	**Clip, MOSFET Retainer**	**$0.01**	**1**	**$0.01**
1444-65_08 Material	Material, Clip, MOSFET Retainer	$0.01	1	$0.01
1444-65_08	**Clip, MOSFET Retainer**	**$0.01**	**1**	**$0.01**
1444-65_08 Material	Material, Clip, MOSFET Retainer	$0.01	1	$0.01
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	2	$0.28
1444-64_01	**Diagnostic PCB Asm, DC/DC Converter**	**$44.37**	**1**	**$44.37**
1444-64_02	Terminal, Rivet, Screw & Soldered, PCB	$0.05	3	$0.15
1444-65_07	Rivet, 1/8 Dia .062-.125" Grip	$0.01	3	$0.03
Conformal Coat, PCBA	Conformal Coat, PCBA	$0.18	1	$0.18
RIGHT ANGLE HDR 4P, GOLD, DF13-4P-1.25DS (50)	RIGHT ANGLE HDR 4P, GOLD, DF13-4P-1.25DS(50)	$0.18	1	$0.18

Fusion DC/DC PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
RIGHT ANGLE HDR 8P, GOLD, DF13-8P-1.25DS (50)	RIGHT ANGLE HDR 8P, GOLD, DF13-8P-1.25DS(50)	$0.30	1	$0.30
RIGHT ANGLE HDR 7P, GOLD, DF13-7P-1.25DS (50)	RIGHT ANGLE HDR 7P, GOLD, DF13-7P-1.25DS(50)	$0.29	1	$0.29
1927688-3	Automotive Connectors ASSY, 1X6,GET RA HDR, KEY C	$0.06	1	$0.06
Diagnostic PCB, DC/DC Converter	Diagnostic PCB, DC/DC Converter	$2.59	1	$2.59
M30291FAHP#U7A	IC MCU 16BIT 96KB FLASH 64LQFP	$7.78	1	$7.78
S-93C86BD4I-J8T1G	IC EEPROM 16KBIT 2MHZ 8SOP	$0.69	1	$0.69
CX5032GB20000H0PESZZ	CRYSTAL 20MHZ 12PF SMD	$0.43	1	$0.43
SH8M3TB1	MOSFET N/P-CH 30V 5A/4.5A SOP8	$0.21	5	$1.05
L4993DTR	IC REG LDO 5V 0.15A 8SO	$0.39	1	$0.39
TLE6250G	IC TXRX CAN STD HI SPEED DSO-8	$0.46	1	$0.46
LTC1693-1IS8#PBF	Gate Driver IC Non-Inverting 8-SOIC	$0.62	2	$1.24
LM2901YDT	IC VOLT COMPARATOR QUAD 14-SOIC	$0.06	2	$0.12
LM2902YDT	IC VOLT COMPARATOR QUAD 14-SOIC	$0.06	2	$0.12
AOB9N70L	MOSFET NCH 700V 9A TO263	$0.58	1	$0.58
2SK3113-Z-E1-AZ	Trans MOSFET N-CH 600V 2A 3-Pin (2+Tab) TO-252 T/R	$1.00	1	$1.00
BCX52-10,115	TRANSISTOR PNP 60V 1A SOT89	$0.04	1	$0.04
2PB709ART,215	TRANS PNP 45V 0.1A SOT23-3	$0.02	6	$0.12
DAN202KT146	Diode Array Standard 80V 100mA SOT23-3	$0.02	7	$0.14
D1FL20U-5053	Diode Rectifiers VRM=200 IFSM=20 DO214AC	$0.16	6	$0.96
RS1KL	Diode Rectifiers 1.0Amp 800 Volt 150ns	$0.01	1	$0.01
D1FK60-5063	Diode Rectifiers 0.8Amp 600 Volt	$0.01	1	$0.01
HZU12A1LTRF-E	Silicon Planar Zener Diode SOD323	$0.07	4	$0.28
BAS521,135	Diode 300V 250mA Surface Mount SOD-523	$0.12	1	$0.12
SMF22A-E3-08	TVS DIODE 22VWM 35.5VC SMF	$0.11	2	$0.22
AN33012UA-VB	Voltage Regulators-Switching-Step-Down 5V-25V 2ch	$0.88	1	$0.88
Capacitor, Ceramic, 0603	Capacitor, Ceramic, 0603	$0.12	84	$10.08
Capacitor, Ceramic, 0805	Capacitor, Ceramic, 0805	$0.03	4	$0.12
Capacitor, Ceramic, 1206	Capacitor, Ceramic, 1206	$0.64	9	$5.76
ACH4518-332-TD01	LC (T-Type) EMI Filter 3rd Order Low Pass 1 Channe	$0.15	1	$0.15
ACT45L-201-2P-TL000	Filter, Common Mode Choke 200µH @ 100kHz 2 Line	$1.09	1	$1.09
Resistor, Ceramic, 0603	Resistor, Ceramic, 0603	$0.00	144	$0.27
Resistor, Ceramic, 0805	Resistor, Ceramic, 0805	$0.00	17	$0.02
Resistor, Ceramic, 1206	Resistor, Ceramic, 1206	$0.01	22	$0.22
B82802A12A315	TRANSFORMER FLYBACK 36-60V SMD	$3.19	1	$3.19
PCE5052TR-ND	CAP ALUM 47UF 35V 20% SMD	$0.45	2	$0.90
493-4454-2-ND	CAP ALUM 220UF 16V 20% SMD	$0.43	5	$2.15
Gasket, Fabric over Foam, 5x2mm	Gasket, Fabric over Foam, 5x2mm	$0.08	1	$0.08
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	5	$0.70
1444-58_03	Diode Pair Module, 90V, DC/DC Converter	$21.43	2	$42.86

Fusion DC/DC PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	5	Piece Cost (Total): $164.85	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	466		*Parts:*	*0*
Fasteners:	30		*Fasteners:*	*0*
Parts+Unanalyzed:	466		*Parts+Unanalyzed:*	*0*

Table E-23 Ford Fusion Ferrites & Inductors Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Part	Heat Sink Compound	Heat Sink Compound	Commodity Item
2	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
3	3	Preprocessed Part	1444-74_01	Magnetic Core, U/I Block, Small, DC/DC Converter	Mn-Zn Soft Ferrite Powder
4	4	Manufacturing Steps		Magnetic Core, U/I Block, Small Processing	
5	5	Manufacturing Process		Wash	
6	5	Manufacturing Process		Mill Face	
7	5	Manufacturing Process		Oven Sintering Furnace	
8	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
9	6	Part	1444-74_01 Material	Material, Magnetic Core, U/I Block, Small, DC/DC C	Mn-Zn Soft Ferrite Powder
10	3	Preprocessed Part	1444-74_02	Carrier, U Block, DC/DC Converter	Polyphenylene Sulfide, (GF + MD) 65
11	4	Manufacturing Steps		Carrier, U/I Block Processing	
12	5	Manufacturing Process		Injection Mold Press, 55 Ton	
13	6	Part	1444-74_02 Material	Material, Carrier, U Block, DC/DC Converter	Polyphenylene Sulfide, (GF + MD) 65
14	3	Preprocessed Part	1444-75_01	Magnetic Core, E, Large, DC/DC Converter	Mn-Zn Soft Ferrite Powder
15	4	Manufacturing Steps		Magnetic Core, E, Large Processing	
16	5	Manufacturing Process		Wash	
17	5	Manufacturing Process		Mill Face	
18	5	Manufacturing Process		Oven Sintering Furnace	
19	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
20	6	Part	1444-75_01 Material	Material, Magnetic Core, E, Large, DC/DC Converter	Mn-Zn Soft Ferrite Powder
21	3	Preprocessed Part	1444-67_03	Magnetic Core, Double UR/I, Large	Mn-Zn Soft Ferrite Powder
22	4	Manufacturing Steps		Magnetic Core, Double UR/I, Large Processing	

Row	Level	Symbol Type	Number	Name	Material Name
23	5	Manufacturing Process		Wash	
24	5	Manufacturing Process		Mill Face	
25	5	Manufacturing Process		Oven Sintering Furnace	
26	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
27	6	Part	1444-67_03 Material	Material, Magnetic Core, Double UR/I, Large	Mn-Zn Soft Ferrite Powder
28	3	Preprocessed Part	1444-72_04	Magnetic Core, U Block, Small, DC/DC Converter	Mn-Zn Soft Ferrite Powder
29	4	Manufacturing Steps		Magnetic Core, U Block, Small Processing	
30	5	Manufacturing Process		Wash	
31	5	Manufacturing Process		Mill Face	
32	5	Manufacturing Process		Oven Sintering Furnace	
33	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
34	6	Part	1444-72_04 Material	Material, Magnetic Core, U Block, Small, DC/DC Con	Mn-Zn Soft Ferrite Powder
35	3	Part	1444-65_01	Thermal Pad, 0.015", DC/DC Converter	Commodity Item
36	3	Part	1444-65_02	Thermal Gap Pad, 0.08", DC/DC Converter	Commodity Item
37	3	Part	1444-65_03	Insulator Pad, Large, 0.009", High Perf	Commodity Item
38	3	Part	1444-57_03	Insulator Pad, Small, 0.009", High Perf	Commodity Item
39	3	Manufacturing Steps		Install Housing Components	
40	4	Manufacturing Process		Manual Asm	
41	3	Subassembly	1444-58	HV Coil Assembly, DC/DC Converter	(None)
42	4	Preprocessed Part	1444-58_01	HV Coil, DC/DC Converter	Copper Cu (10200)
43	5	Manufacturing Steps		HV Coil, DC/DC Converter Processing	
44	6	Manufacturing Process		Wash	
45	6	Manufacturing Process		Debur	
46	6	Manufacturing Process		Stamping Press, 60 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
47	7	Part	1444-58_01 Material	Material, HV Coil, DC/DC Converter	Copper Cu (10200)
48	4	Part	1444-58_02	Rivnut, M4-0.7mm, Shallow	Commodity Item
49	4	Manufacturing Steps		Assemble Coil & Rivnut	
50	5	Manufacturing Process		Manual Asm	
51	3	Manufacturing Steps		Assemble HV PCB & Coil	
52	4	Manufacturing Process		Manual Asm	
53	3	Subassembly	1444_01	Coil & Ground Assembly	(None)
54	4	Subassembly	1444-57_01	Ground Coil Assembly	(None)
55	5	Preprocessed Part	1444-57_01A	HV Grnd Coil A, DC/DC Converter	Copper Cu (10200)
56	6	Manufacturing Steps		HV Grnd Coil A, DC/DC Converter Processing	
57	7	Manufacturing Process		Wash	
58	7	Manufacturing Process		Debur	
59	7	Manufacturing Process		Machining	
60	7	Manufacturing Process		Stamping Press, 25 Ton	
61	8	Part	1444-57_01A Material	Material, Grnd Coil A, DC/DC Converter	Copper Cu (10200)
62	5	Preprocessed Part	1444-57_01B	HV Grnd Coil B, DC/DC Converter	Copper Cu (10200)
63	6	Manufacturing Steps		HV Grnd Coil B, DC/DC Converter Processing	
64	7	Manufacturing Process		Wash	
65	7	Manufacturing Process		Debur	
66	7	Manufacturing Process		Stamping Press, 25 Ton	
67	8	Part	1444-57_01B Material	Material, HV Grnd Coil B, DC/DC Converter	Copper Cu (10200)
68	5	Preprocessed Part	1444-57_01C	Carrier, HV Grnd Coil, DC/DC Converter	Polyphenylene Sulfide, (GF + MD) 65
69	6	Manufacturing Steps		Carrier, HV Grnd Coil, DC/DC Converter Processing	
70	7	Manufacturing Process		Injection Mold Press, 55 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
71	8	Part	1444-57_01C Material	Material, Carrier, HV Grnd Coil, DC/DC Converter	Polyphenylene Sulfide, (GF + MD) 65
72	5	Preprocessed Part	1444-57_02	Screw Isolator, HV Grnd Coil	Polyphenylene Sulfide, (GF + MD) 65
73	6	Manufacturing Steps		Screw Isolator, HV Grnd Coil Processing	
74	7	Manufacturing Process		Injection Mold Press, 55 Ton	
75	8	Part	1444-57_02 Material	Material, Screw Isolator, HV Grnd Coil	Polyphenylene Sulfide, (GF + MD) 65
76	5	Preprocessed Part	1444-57_02	Screw Isolator, HV Grnd Coil	Polyphenylene Sulfide, (GF + MD) 65
77	6	Manufacturing Steps		Screw Isolator, HV Grnd Coil Processing	
78	7	Manufacturing Process		Injection Mold Press, 55 Ton	
79	8	Part	1444-57_02 Material	Material, Screw Isolator, HV Grnd Coil	Polyphenylene Sulfide, (GF + MD) 65
80	5	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
81	5	Manufacturing Steps		Assemble Ground Coil Asm	
82	6	Manufacturing Process		Manual Asm	
83	4	Part	1444-53_01	Capacitor Asm, DC/DC Converter	Commodity Item
84	4	Subassembly	1444-50_01	12 Volt positive terminal lug	(None)
85	5	Part	1444-65_05D	Brass Spacer, 4mm	Commodity Item
86	5	Part	1444-50_01A	Capacitor, 2.2uF, 35VDC, Lugged	Commodity Item
87	5	Part	1444-50_01B	Brass Insert, 4-0.7mm	Commodity Item
88	5	Part	1444-50_01C	Stud Insert, M8-1.25, Knurled	Commodity Item
89	5	Manufacturing Steps		12 Volt Terminal Lug Processing	
90	6	Manufacturing Process		Injection Mold Press, 55 Ton	
91	7	Part	1444-50_01 Material	Material, 12V Terminal Lug	Polyphenylene Sulfide, (GF + MD) 65
92	4	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
93	4	Manufacturing Steps		Assemble Coil & 12 Volt Terminal Lug	
94	5	Manufacturing Process		Manual Asm	

Row	Level	Symbol Type	Number	Name	Material Name
95	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
96	3	Part	1444-57_04	SEMS Screw, M4-0.7 x 10mm	Commodity Item
97	3	Manufacturing Steps		Install HV Coil & Ground Asm	
98	4	Manufacturing Process		Manual Asm	
99	3	Preprocessed Part	1444-74_04	Magnetic Core, U Block, DC/DC Converter	Mn-Zn Soft Ferrite Powder
100	4	Manufacturing Steps		Magnetic Core, U Block, DC/DC Converter Processing	
101	5	Manufacturing Process		Wash	
102	5	Manufacturing Process		Mill Face	
103	5	Manufacturing Process		Oven Sintering Furnace	
104	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
105	6	Part	1444-74_04 Material	Material, Magnetic Core, U Block, DC/DC Converter	Mn-Zn Soft Ferrite Powder
106	3	Preprocessed Part	1444-75_01	Magnetic Core, E, Large, DC/DC Converter	Mn-Zn Soft Ferrite Powder
107	4	Manufacturing Steps		Magnetic Core, E, Large Processing	
108	5	Manufacturing Process		Wash	
109	5	Manufacturing Process		Mill Face	
110	5	Manufacturing Process		Oven Sintering Furnace	
111	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
112	6	Part	1444-75_01 Material	Material, Magnetic Core, E, Large, DC/DC Converter	Mn-Zn Soft Ferrite Powder
113	3	Part	1444-67_02	Insulator Sheet, Planar Coil	Commodity Item
114	3	Preprocessed Part	1444-67_01	Magnetic Core, Double UR, Large	Mn-Zn Soft Ferrite Powder
115	4	Manufacturing Steps		Magnetic Core, Double UR, Large Processing	
116	5	Manufacturing Process		Wash	
117	5	Manufacturing Process		Mill Face	
118	5	Manufacturing Process		Oven Sintering Furnace	

Row	Level	Symbol Type	Number	Name	Material Name
119	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
120	6	Part	1444-67_01 Material	Material, Magnetic Core, Double UR, Large	Mn-Zn Soft Ferrite Powder
121	3	Preprocessed Part	1444-72_03	Carrier, U/I Block	Polyphenylene Sulfide, (GF + MD) 65
122	4	Manufacturing Steps		Carrier, U/I Block Processing	
123	5	Manufacturing Process		Injection Mold Press, 55 Ton	
124	6	Part	1444-72_03 Material	Material, Carrier, U/I Block	Polyphenylene Sulfide, (GF + MD) 65
125	3	Preprocessed Part	1444-72_02	Magnetic Core, U/I Block, DC/DC Converter	Mn-Zn Soft Ferrite Powder
126	4	Manufacturing Steps		Magnetic Core, U/I Block Processing	
127	5	Manufacturing Process		Wash	
128	5	Manufacturing Process		Mill Face	
129	5	Manufacturing Process		Oven Sintering Furnace	
130	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
131	6	Part	1444-72_02 Material	Material, Magnetic Core, U/I Block, DC/DC Converter	Mn-Zn Soft Ferrite Powder
132	3	Manufacturing Steps		Install Planar Magnetic Core	
133	4	Manufacturing Process		Manual Asm	
134	3	Preprocessed Part	1444-72_01	Clip, Large, Ferrite Retainer	Steel 4130
135	4	Manufacturing Steps		Clip, Large, Ferrite Retainer Processing	
136	5	Manufacturing Process		Wash	
137	5	Manufacturing Process		Debur	
138	5	Manufacturing Process		Stamping Press, 60 Ton	
139	6	Part	1444-72_01 Material	Material, Clip, Large, Ferrite Retainer	Steel 4130
140	3	Preprocessed Part	1444-74_03	Clip, Med, Ferrite Retainer	Steel 4130
141	4	Manufacturing Steps		Clip, Med, Ferrite Retainer Processing	
142	5	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
143	5	Manufacturing Process		Debur	
144	5	Manufacturing Process		Stamping Press, 25 Ton	
145	6	Part	1444-74_03 Material	Material, Clip, Med, Ferrite Retainer	Steel 4130
146	3	Preprocessed Part	1444-74_03	Clip, Med, Ferrite Retainer	Steel 4130
147	4	Manufacturing Steps		Clip, Med, Ferrite Retainer Processing	
148	5	Manufacturing Process		Wash	
149	5	Manufacturing Process		Debur	
150	5	Manufacturing Process		Stamping Press, 25 Ton	
151	6	Part	1444-74_03 Material	Material, Clip, Med, Ferrite Retainer	Steel 4130
152	3	Preprocessed Part	1444-74_03	Clip, Med, Ferrite Retainer	Steel 4130
153	4	Manufacturing Steps		Clip, Med, Ferrite Retainer Processing	
154	5	Manufacturing Process		Wash	
155	5	Manufacturing Process		Debur	
156	5	Manufacturing Process		Stamping Press, 25 Ton	
157	6	Part	1444-74_03 Material	Material, Clip, Med, Ferrite Retainer	Steel 4130
158	3	Preprocessed Part	1444-75_02	Clip, Small, Ferrite Retainer	Steel 4130
159	4	Manufacturing Steps		Clip, Small, Ferrite Retainer Processing	
160	5	Manufacturing Process		Wash	
161	5	Manufacturing Process		Debur	
162	5	Manufacturing Process		Stamping Press, 25 Ton	
163	6	Part	1444-75_02 Material	Material, Clip, Small, Ferrite Retainer	Steel 4130
164	3	Preprocessed Part	1444-75_02	Clip, Small, Ferrite Retainer	Steel 4130
165	4	Manufacturing Steps		Clip, Small, Ferrite Retainer Processing	
166	5	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
167	5	Manufacturing Process		Debur	
168	5	Manufacturing Process		Stamping Press, 25 Ton	
169	6	Part	1444-75_02 Material	Material, Clip, Small, Ferrite Retainer	Steel 4130
170	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
115	3	Manufacturing Steps		Install Ferrite Clip	
116	4	Manufacturing Process		Manual Asm	
117	3	Part	Heat Sink Compound	Heat Sink Compound	Commodity Item
118	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
119	3	Preprocessed Part	1444-74_01	Magnetic Core, U/I Block, Small, DC/DC Converter	Mn-Zn Soft Ferrite Powder
120	4	Manufacturing Steps		Magnetic Core, U/I Block, Small Processing	
121	5	Manufacturing Process		Wash	
122	5	Manufacturing Process		Mill Face	
123	5	Manufacturing Process		Oven Sintering Furnace	
124	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
125	6	Part	1444-74_01 Material	Material, Magnetic Core, U/I Block, Small, DC/DC C	Mn-Zn Soft Ferrite Powder
126	3	Preprocessed Part	1444-74_02	Carrier, U Block, DC/DC Converter	Polyphenylene Sulfide, (GF + MD) 65
127	4	Manufacturing Steps		Carrier, U/I Block Processing	
128	5	Manufacturing Process		Injection Mold Press, 55 Ton	
129	6	Part	1444-74_02 Material	Material, Carrier, U Block, DC/DC Converter	Polyphenylene Sulfide, (GF + MD) 65
130	3	Preprocessed Part	1444-75_01	Magnetic Core, E, Large, DC/DC Converter	Mn-Zn Soft Ferrite Powder
131	4	Manufacturing Steps		Magnetic Core, E, Large Processing	
132	5	Manufacturing Process		Wash	
133	5	Manufacturing Process		Mill Face	
134	5	Manufacturing Process		Oven Sintering Furnace	

Row	Level	Symbol Type	Number	Name	Material Name
135	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
136	6	Part	1444-75_01 Material	Material, Magnetic Core, E, Large, DC/DC Converter	Mn-Zn Soft Ferrite Powder
137	3	Preprocessed Part	1444-67_03	Magnetic Core, Double UR/I, Large	Mn-Zn Soft Ferrite Powder
138	4	Manufacturing Steps		Magnetic Core, Double UR/I, Large Processing	
139	5	Manufacturing Process		Wash	
140	5	Manufacturing Process		Mill Face	
141	5	Manufacturing Process		Oven Sintering Furnace	
142	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
143	6	Part	1444-67_03 Material	Material, Magnetic Core, Double UR/I, Large	Mn-Zn Soft Ferrite Powder
144	3	Preprocessed Part	1444-72_04	Magnetic Core, U Block, Small, DC/DC Converter	Mn-Zn Soft Ferrite Powder
145	4	Manufacturing Steps		Magnetic Core, U Block, Small Processing	
146	5	Manufacturing Process		Wash	
147	5	Manufacturing Process		Mill Face	
148	5	Manufacturing Process		Oven Sintering Furnace	
149	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
150	6	Part	1444-72_04 Material	Material, Magnetic Core, U Block, Small, DC/DC Con	Mn-Zn Soft Ferrite Powder
151	3	Part	1444-65_01	Thermal Pad, 0.015", DC/DC Converter	Commodity Item
152	3	Part	1444-65_02	Thermal Gap Pad, 0.08", DC/DC Converter	Commodity Item
153	3	Part	1444-65_03	Insulator Pad, Large, 0.009", High Perf	Commodity Item
154	3	Part	1444-57_03	Insulator Pad, Small, 0.009", High Perf	Commodity Item
155	3	Manufacturing Steps		Install Housing Components	
156	4	Manufacturing Process		Manual Asm	
157	3	Subassembly	1444-58	HV Coil Assembly, DC/DC Converter	(None)
158	4	Preprocessed Part	1444-58_01	HV Coil, DC/DC Converter	Copper Cu (10200)

Row	Level	Symbol Type	Number	Name	Material Name
159	5	Manufacturing Steps		HV Coil, DC/DC Converter Processing	
160	6	Manufacturing Process		Wash	
161	6	Manufacturing Process		Debur	
162	6	Manufacturing Process		Stamping Press, 60 Ton	
163	7	Part	1444-58_01 Material	Material, HV Coil, DC/DC Converter	Copper Cu (10200)
164	4	Part	1444-58_02	Rivnut, M4-0.7mm, Shallow	Commodity Item
165	4	Manufacturing Steps		Assemble Coil & Rivnut	
166	5	Manufacturing Process		Manual Asm	
167	3	Manufacturing Steps		Assemble HV PCB & Coil	
168	4	Manufacturing Process		Manual Asm	
169	3	Subassembly	1444_01	Coil & Ground Assembly	(None)
170	4	Subassembly	1444-57_01	Ground Coil Assembly	(None)
171	5	Preprocessed Part	1444-57_01A	HV Grnd Coil A, DC/DC Converter	Copper Cu (10200)
172	6	Manufacturing Steps		HV Grnd Coil A, DC/DC Converter Processing	

Table E-24 Ford Fusion Ferrites & Inductors Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Fusion DC/DC Ferrites & Inductors

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
Heat Sink Compound	Heat Sink Compound	$0.08	1	$0.08
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	4	$0.56
1444-74_01	**Magnetic Core, U/I Block, Small, DC/DC Converter**	**$0.09**	**1**	**$0.09**
1444-74_01 Material	Material, Magnetic Core, U/I Block, Small, DC/DC C	$0.09	1	$0.09
1444-74_02	**Carrier, U Block, DC/DC Converter**	**$0.02**	**1**	**$0.02**
1444-74_02 Material	Material, Carrier, U Block, DC/DC Converter	$0.02	1	$0.02
1444-75_01	**Magnetic Core, E, Large, DC/DC Converter**	**$0.27**	**1**	**$0.27**
1444-75_01 Material	Material, Magnetic Core, E, Large, DC/DC Converter	$0.27	1	$0.27
1444-67_03	**Magnetic Core, Double UR/I, Large**	**$0.17**	**1**	**$0.17**
1444-67_03 Material	Material, Magnetic Core, Double UR/I, Large	$0.17	1	$0.17
1444-72_04	**Magnetic Core, U Block, Small, DC/DC Converter**	**$0.13**	**1**	**$0.13**
1444-72_04 Material	Material, Magnetic Core, U Block, Small, DC/DC Con	$0.13	1	$0.13
1444-65_01	Thermal Pad, 0.015", DC/DC Converter	$0.87	2	$1.74
1444-65_02	Thermal Gap Pad, 0.08", DC/DC Converter	$0.76	1	$0.76
1444-65_03	Insulator Pad, Large, 0.009", High Perf	$0.74	1	$0.74
1444-57_03	Insulator Pad, Small, 0.009", High Perf	$0.04	2	$0.09
1444-58	**HV Coil Assembly, DC/DC Converter**	**$0.90**	**1**	**$0.90**
1444-58_01	**HV Coil, DC/DC Converter**	**$0.89**	**1**	**$0.89**
1444-58_01 Material	Material, HV Coil, DC/DC Converter	$0.89	1	$0.89
1444-58_02	Rivnut, M4-0.7mm, Shallow	$0.01	1	$0.01
1444_01	**Coil & Ground Assembly**	**$5.03**	**1**	**$5.03**
1444-57_01	**Ground Coil Asembly**	**$1.35**	**1**	**$1.35**
1444-57_01A	**HV Grnd Coil A, DC/DC Converter**	**$0.64**	**1**	**$0.64**
1444-57_01A Material	Material, Grnd Coil A, DC/DC Converter	$0.64	1	$0.64
1444-57_01B	**HV Grnd Coil B, DC/DC Converter**	**$0.52**	**1**	**$0.52**
1444-57_01B Material	Material, HV Grnd Coil B, DC/DC Converter	$0.52	1	$0.52
1444-57_01C	**Carrier, HV Grnd Coil, DC/DC Converter**	**$0.03**	**1**	**$0.03**
1444-57_01C Material	Material, Carrier, HV Grnd Coil, DC/DC Converter	$0.03	1	$0.03
1444-57_02	**Screw Isolator, HV Grnd Coil**	**$0.01**	**1**	**$0.01**
1444-57_02 Material	Material, Screw Isolator, HV Grnd Coil	$0.01	1	$0.01
1444-57_02	**Screw Isolator, HV Grnd Coil**	**$0.01**	**1**	**$0.01**
1444-57_02 Material	Material, Screw Isolator, HV Grnd Coil	$0.01	1	$0.01
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	1	$0.14
1444-53_01	Capacitor Asm, DC/DC Converter	$1.53	1	$1.53
1444-50_01	**12 Volt positiver terminal lug**	**$1.73**	**1**	**$1.73**
1444-65_05D	Brass Spacer, 4mm	$0.04	2	$0.08
1444-50_01A	Capacitor, 2.2uF, 35VDC, Lugged	$1.28	1	$1.28
1444-50_01B	Brass Insert, 4-0.7mm	$0.02	1	$0.02
1444-50_01C	Stud Insert, M8-1.25, Knurled	$0.17	1	$0.17
1444-50_01 Material	Material, 12V Terminal Lug	$0.18	1	$0.18

Fusion DC/DC Ferrites & Inductors

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	3	$0.42
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	4	$0.56
1444-57_04	SEMS Screw, M4-0.7 x 10mm	$0.08	3	$0.24
1444-74_04	**Magnetic Core, U Block, DC/DC Converter**	**$0.19**	**1**	**$0.19**
1444-74_04 Material	Material, Magnetic Core, U Block, DC/DC Converter	$0.19	1	$0.19
1444-75_01	**Magnetic Core, E, Large, DC/DC Converter**	**$0.27**	**1**	**$0.27**
1444-75_01 Material	Material, Magnetic Core, E, Large, DC/DC Converter	$0.27	1	$0.27
1444-67_02	Insulator Sheet, Planar Coil	$0.05	1	$0.05
1444-67_01	**Magnetic Core, Double UR, Large**	**$0.36**	**1**	**$0.36**
1444-67_01 Material	Material, Magnetic Core, Double UR, Large	$0.36	1	$0.36
1444-72_03	**Carrier, U/I Block**	**$0.03**	**1**	**$0.03**
1444-72_03 Material	Material, Carrier, U/I Block	$0.03	1	$0.03
1444-72_02	**Magnetic Core, U/I Block, DC/DC Converter**	**$0.10**	**1**	**$0.10**
1444-72_02 Material	Material, Magnetic Core, U/I Block, DC/DC Converte	$0.10	1	$0.10
1444-72_01	**Clip, Large, Ferrite Retainer**	**$0.03**	**1**	**$0.03**
1444-72_01 Material	Material, Clip, Large, Ferrite Retainer	$0.03	1	$0.03
1444-74_03	**Clip, Med, Ferrite Retainer**	**$0.01**	**1**	**$0.01**
1444-74_03 Material	Material, Clip, Med, Ferrite Retainer	$0.01	1	$0.01
1444-74_03	**Clip, Med, Ferrite Retainer**	**$0.01**	**1**	**$0.01**
1444-74_03 Material	Material, Clip, Med, Ferrite Retainer	$0.01	1	$0.01
1444-74_03	**Clip, Med, Ferrite Retainer**	**$0.01**	**1**	**$0.01**
1444-74_03 Material	Material, Clip, Med, Ferrite Retainer	$0.01	1	$0.01
1444-75_02	**Clip, Small, Ferrite Retainer**	**$0.01**	**1**	**$0.01**
1444-75_02 Material	Material, Clip, Small, Ferrite Retainer	$0.01	1	$0.01
1444-75_02	**Clip, Small, Ferrite Retainer**	**$0.01**	**1**	**$0.01**
1444-75_02 Material	Material, Clip, Small, Ferrite Retainer	$0.01	1	$0.01
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	7	$0.98

Assembly Totals

Analyzed Subs:	26
Unanalyzed Subs:	0
Parts:	60
Fasteners:	23
Parts+Unanalyzed:	60

Report Totals

Piece Cost (Total): $13.44

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

Table E-25 Ford Fusion Electrical & Harnesses Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1444-48_01	Temp Sensor DC/DC Converter	(None)
2	4	Part	1444-48_01A	Thermister, Bead, w/Leads	Commodity Item
3	4	Part	1444-48_01B	Eyelet Terminal, Thermister, M4	Commodity Item
4	4	Part	1444-48_01C	Vinyl Tubing, 1/4" Diameter, Black	Commodity Item
5	4	Part	1444-48_01D	Female Terminal, Gold, 18-20 AWG, 1.0mm	Commodity Item
6	4	Part	1444-48_01E	Connector, Small, 4 Cavity, 1mm, OTP	Commodity Item
7	4	Part	1444-48_01F	Thermal Potting Epxoy, Black	Commodity Item
8	4	Manufacturing Steps		Assemble Temp Sensor DC/DC Converter	
9	5	Manufacturing Process		Manual Asm	
10	5	Manufacturing Process		Auto Asm	
11	5	Manufacturing Process		Auto Asm	
12	5	Manufacturing Process		Auto Asm	
13	3	Part	1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	Commodity Item
14	3	Subassembly	1444-56_01	Harness, 4 Leads, DC/DC Converter	(None)
15	4	Part	1444-56_01A	AWG 18 (0.8mm^2) Wire, Brown	Commodity Item
16	4	Part	1444-56_01B	AWG 18 (0.8mm^2) Wire, Blue	Commodity Item
17	4	Part	1444-56_01C	AWG 18 (0.8mm^2) Wire, Black	Commodity Item
18	4	Part	1444-56_01D	AWG 18 (0.8mm^2) Wire, Lt Grey	Commodity Item
19	4	Part	1444-48_01C	Vinyl Tubing, 1/4" Diameter, Black	Commodity Item
20	4	Part	1444-48_01D	Female Terminal, Gold, 18-20 AWG, 1.0mm	Commodity Item
21	4	Part	1444-56_01E	Connector, Small, 7 Cavity, 1mm, OTP	Commodity Item
22	4	Part	1444-56_01F	Female Terminal, 18-20 AWG, 1.0mm	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
23	4	Part	1444-56_01G	Connector, Small, 7 Cavity, 1mm	Commodity Item
24	4	Part	1444-56_01H	TPA, Connector, Small, 7 Cavity, 1mm	Commodity Item
25	4	Manufacturing Steps		Assemble Harness, 4 Leads, DC/DC Converter	
26	5	Manufacturing Process		Auto Asm	
27	5	Manufacturing Process		Auto Asm	
28	5	Manufacturing Process		Auto Asm	
29	5	Manufacturing Process		Auto Asm	
30	3	Subassembly	1444-59_01	Harness, 8 Leads, DC/DC Converter	(None)
31	4	Part	1444-56_01C	AWG 18 (0.8mm^2) Wire, Black	Commodity Item
32	4	Part	1444-56_01A	AWG 18 (0.8mm^2) Wire, Brown	Commodity Item
33	4	Part	1444-59_01A	AWG 18 (0.8mm^2) Wire, Red	Commodity Item
34	4	Part	1444-59_01B	AWG 18 (0.8mm^2) Wire, Yellow	Commodity Item
35	4	Part	1444-59_01C	AWG 18 (0.8mm^2) Wire, Green	Commodity Item
36	4	Part	1444-56_01B	AWG 18 (0.8mm^2) Wire, Blue	Commodity Item
37	4	Part	1444-56_01D	AWG 18 (0.8mm^2) Wire, Lt Grey	Commodity Item
38	4	Part	1444-59_01D	AWG 18 (0.8mm^2) Wire, White	Commodity Item
39	4	Part	1444-48_01D	Female Terminal, Gold, 18-20 AWG, 1.0mm	Commodity Item
40	4	Part	1444-59_01E	Connector, Small, 8 Cavity, 2.5mm Pitch	Commodity Item
41	4	Part	1444-56_01F	Female Terminal, 18-20 AWG, 1.0mm	Commodity Item
42	4	Part	1444-59_01F	Connector, Small, 8 Cavity, 1mm	Commodity Item
43	4	Part	1444-59_01G	TPA, Connector, Small, 8 Cavity, 1mm	Commodity Item
44	4	Manufacturing Steps		Assemble Harness, 8 Leads, DC/DC Converter	
45	5	Manufacturing Process		Auto Asm	
46	5	Manufacturing Process		Auto Asm	

Row	Level	Symbol Type	Number	Name	Material Name
47	5	Manufacturing Process		Auto Asm	
48	3	Manufacturing Steps		Install Temp Sensor & Harness	
49	4	Manufacturing Process		Manual Asm	

Table E-26 Ford Fusion Electrical & Harnesses Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

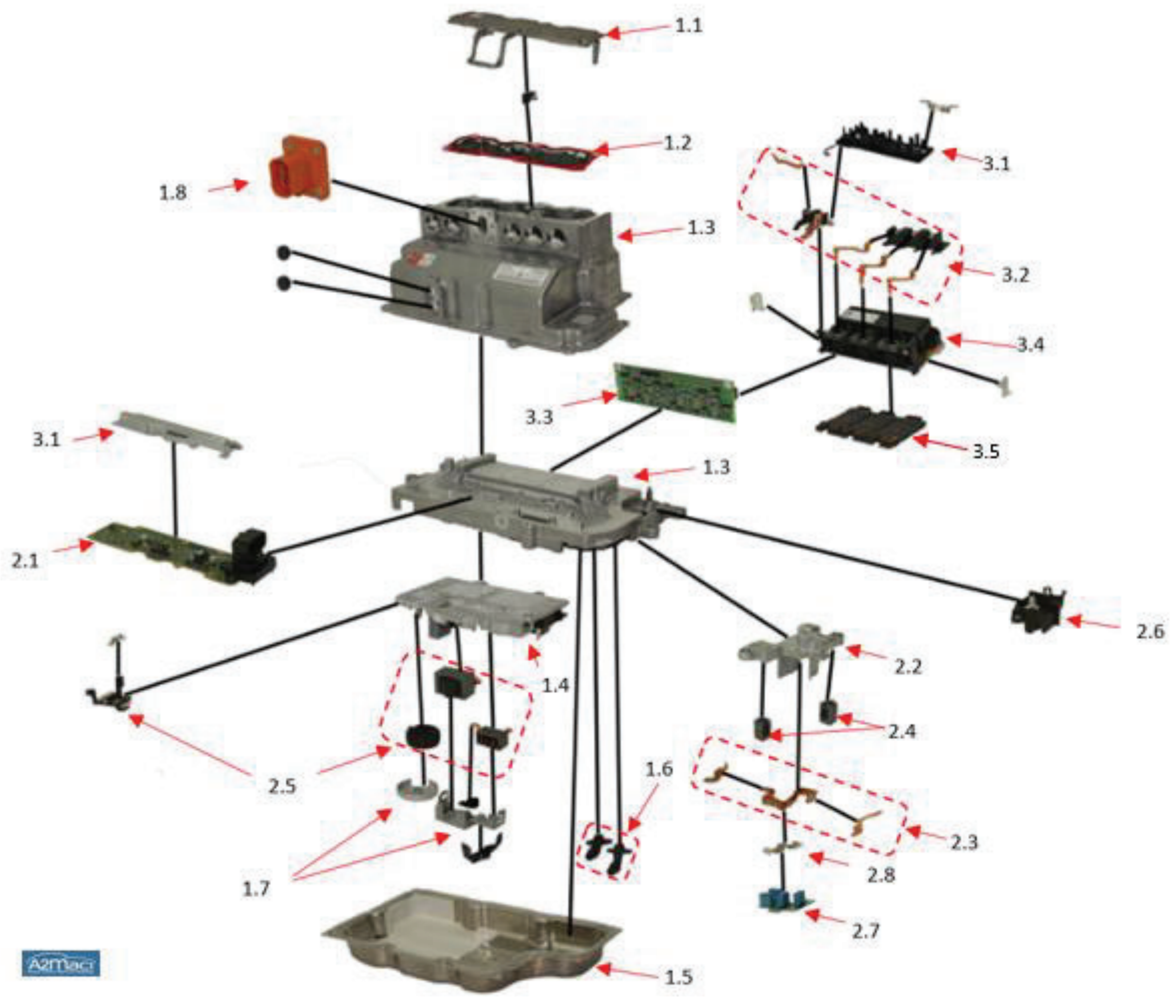
Fusion DC/DC Electrical & Harness

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1444-48_01	**Temp Sensor DC/DC Converter**	**$0.86**	**1**	**$0.86**
1444-48_01A	Thermister, Bead, w/Leads	$0.75	1	$0.75
1444-48_01B	Eyelet Terminal, Thermister, M4	$0.04	1	$0.04
1444-48_01C	Vinyl Tubing, 1/4" Diameter, Black	$0.01	1	$0.01
1444-48_01D	Female Terminal, Gold, 18-20 AWG, 1.0mm	$0.02	2	$0.04
1444-48_01E	Connector, Small, 4 Cavity, 1mm, OTP	$0.02	1	$0.02
1444-48_01F	Thermal Potting Epxoy, Black	$0.00	1	$0.00
1444-65_10	SEMS Screw, M4-0.7 x 5.5mm	$0.14	1	$0.14
1444-56_01	**Harness, 4 Leads, DC/DC Converter**	**$0.81**	**1**	**$0.81**
1444-56_01A	AWG 18 (0.8mm^2) Wire, Brown	$0.58	1	$0.58
1444-56_01B	AWG 18 (0.8mm^2) Wire, Blue	$0.00	1	$0.00
1444-56_01C	AWG 18 (0.8mm^2) Wire, Black	$0.00	1	$0.00
1444-56_01D	AWG 18 (0.8mm^2) Wire, Lt Grey	$0.00	1	$0.00
1444-48_01C	Vinyl Tubing, 1/4" Diameter, Black	$0.00	2	$0.01
1444-48_01D	Female Terminal, Gold, 18-20 AWG, 1.0mm	$0.02	4	$0.08
1444-56_01E	Connector, Small, 7 Cavity, 1mm, OTP	$0.03	1	$0.03
1444-56_01F	Female Terminal, 18-20AWG, 1.0mm	$0.01	4	$0.05
1444-56_01G	Connector, Small, 7 Cavity, 1mm	$0.03	1	$0.03
1444-56_01H	TPA, Connector, Small, 7 Cavity, 1mm	$0.02	1	$0.02
1444-59_01	**Harness, 8 Leads, DC/DC Converter**	**$0.85**	**1**	**$0.85**
1444-56_01C	AWG 18 (0.8mm^2) Wire, Black	$0.00	1	$0.00
1444-56_01A	AWG 18 (0.8mm^2) Wire, Brown	$0.46	1	$0.46
1444-59_01A	AWG 18 (0.8mm^2) Wire, Red	$0.00	1	$0.00
1444-59_01B	AWG 18 (0.8mm^2) Wire, Yellow	$0.00	1	$0.00
1444-59_01C	AWG 18 (0.8mm^2) Wire, Green	$0.00	1	$0.00
1444-56_01B	AWG 18 (0.8mm^2) Wire, Blue	$0.00	1	$0.00
1444-56_01D	AWG 18 (0.8mm^2) Wire, Lt Grey	$0.00	1	$0.00
1444-59_01D	AWG 18 (0.8mm^2) Wire, White	$0.00	1	$0.00
1444-48_01D	Female Terminal, Gold, 18-20 AWG, 1.0mm	$0.02	8	$0.16
1444-59_01E	Connector, Small, 8 Cavity, 2.5mm Pitch	$0.05	1	$0.05
1444-56_01F	Female Terminal, 18-20AWG, 1.0mm	$0.01	8	$0.10
1444-59_01F	Connector, Small, 8 Cavity, 1mm	$0.04	1	$0.04
1444-59_01G	TPA, Connector, Small, 8 Cavity, 1mm	$0.02	1	$0.02

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	3	Piece Cost (Total): $2.67	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	52		*Parts:*	*0*
Fasteners:	1		*Fasteners:*	*0*
Parts+Unanalyzed:	52		*Parts+Unanalyzed:*	*0*

APPENDIX F: Audi A3 e-Tron Inverter Module

Figure F-1 Audi A3 e-Tron Inverter Module

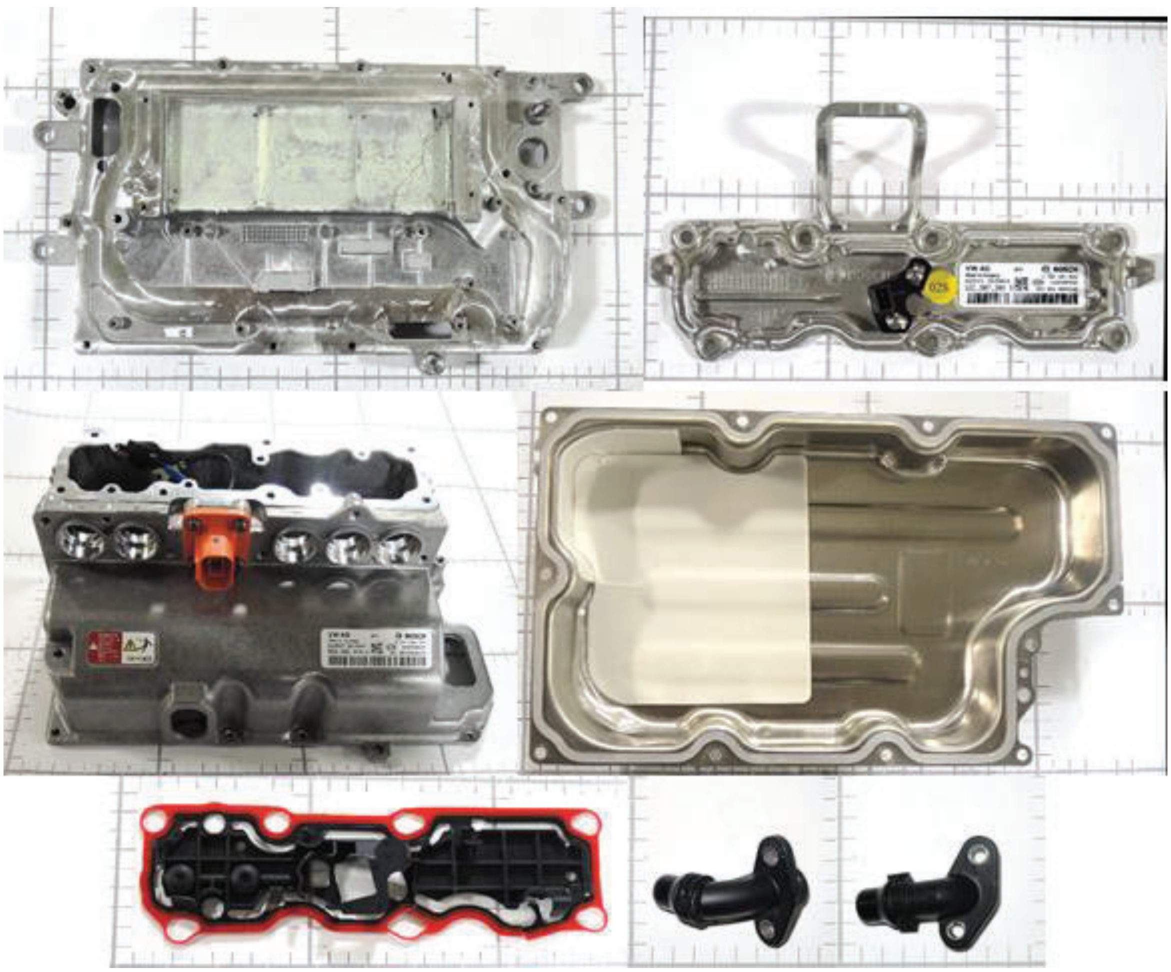


Cost Estimate BOM					
1.1	Top Cover	2.1	DC/DC Converter PCBA	3.1	Internal Housing Cover
1.2	Top Cover Gasket	2.2	DC/DC Converter Bus Bar Support	3.2	Inverter Bus Bar Group
1.3	Main Housing	2.3	DC/DC Converter Bus Bar	3.3	Inverter PCBA
1.4	Cooling Plate	2.4	DC/DC Converter Ferrite	3.4	Inverter Capacitor Group
1.5	Bottom Cover	2.5	DC/DC Converter Inductors	3.5	Inverter IGBT Half Bridge
1.6	Coolant Fittings	2.6	Receptacle		
1.7	Inductor Protection	2.7	Small Capacitor Board		
1.8	Receptacle	2.8	Ferrite Bracket		

Audi Enclosures and Cooling

The Audi enclosures and cooling group includes the external housings, covers and components specific to cooling of internal components. The components within the group included the following: two-piece cooling plate, main housing both die cast aluminum, pair of covers one die cast aluminum the other stamped aluminum, coolant line fittings, gaskets, and assorted hardware, such as screws, plugs, labels. (More detailed lists of the materials and processes that go into the enclosure & cooling group can be found in pp. 57 - 148 of this appendix.)

Figure F-2 Audi Enclosures and Cooling group



The total "should cost" to manufacture the Audi enclosure and cooling group is estimated and additional typical markups associated with component manufacturing added. The summary shown in Table F-1 below includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table F-1 Audi Enclosure & Cooling: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
A3 PCU Enclosure & Cooling

	A3 PCU Enclosure & Cooling
Parts	76
Steps	1,035
Actual Time	1,848.47 sec
Fasteners	36
Total Weight	5.00 kg
Piece Cost	$16.57
Total Labor Cost	$23.03
Q Burden	$1.68
Total Cost	$41.29
Annual Production	200000

Once complete the "should-cost" data is exported to a spreadsheet and percentages are applied to establish an estimated selling price. The markups include SG&A, profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown below in the total cost of the part.

Additional data at the bottom of the table includes total weight of the system analyzed, annual production volume, and approximate order of magnitude tooling costs. Tooling costs per part are not included in the total cost of the part.

Table F-2 Audi Enclosure & Cooling: Cost Estimate Summary

Component Summary		
Part/Assembly Name	A3 PCU Enclosure & Cooling	
Purchased Part Roll up Costs		$2.46
Raw Material Costs		$14.11
Processing Costs		$23.03
Scrap (Design Profit: Q-Burden)	4%	$1.68
SG&A % Applied Against Processing	7%	$1.61
Profit % Applied Against Raw & Processing	4%	$1.49
Logistics % Applied Against Sum of all Above	3%	$1.33
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.91
Total % Mark Up / Total Cost	20%	$46.63
Total Weight (kg)		4.9969
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,380,000
Tooling Cost/part		$1.38
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$2,760,000
Tooling Cost/part		$2.76

The cooling plate was assumed to be a die cast aluminum A380 two-piece design. Both castings manufacturing processes included casting, trimming of gates, machining, deburring and washing. After initial processing of the two parts they are then assembled and appear to be friction stir welded together. After welding post machining of the weld seam provides a sealing surface for final assembly. The cooling plate has machined pads (heat sinks) on both sides for the electronics. One side is for the DC to DC electronics and the opposite side is used to cool the IGBTs for the inverter.

Figure F-3 Audi Base, Invertor IGBT Cooling Side

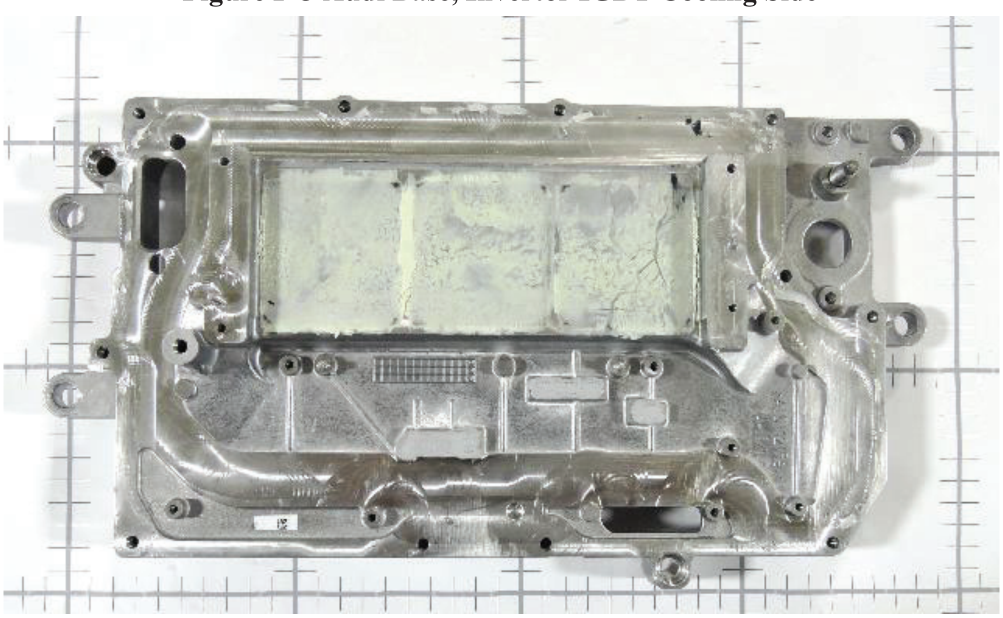
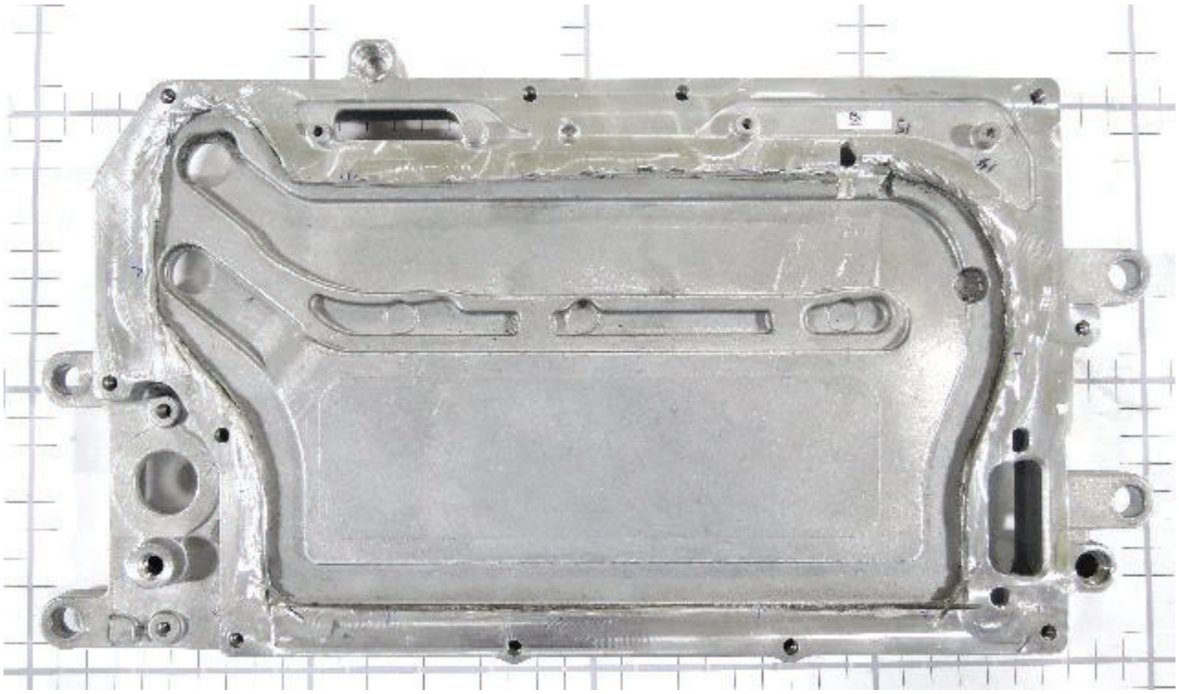


Figure F-4 Audi Base Cooling Plate, Interior Coolant Passage



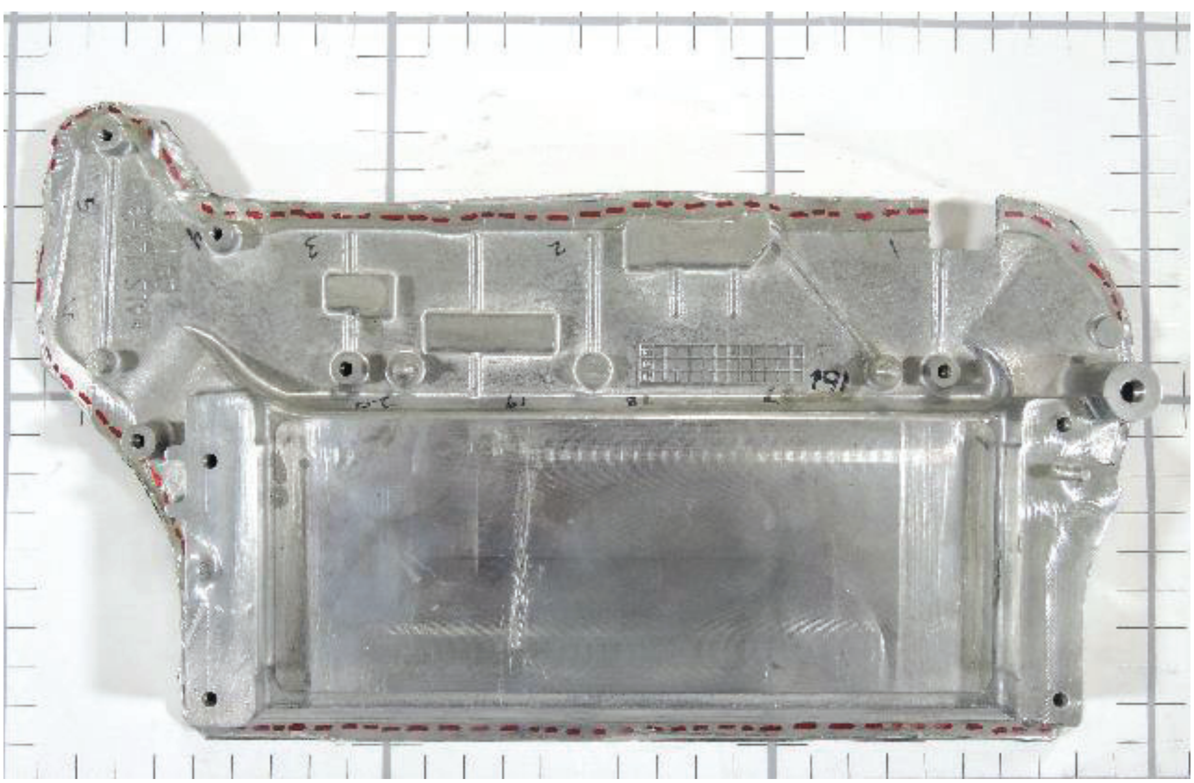


Figure F-5 Audi Base Cooling Plate, Coolant Passage Cover

The main housing is a large die cast aluminum component. The material was assumed to be aluminum A380. After casting the part is trimmed, machined, deburred and washed. The housing includes features for mounting the cooling plate, electronics and connector/cable pass through holes.

Figure F-6 Audi Main Housing

The top cover assembly included a cover plate, gasket/disconnect switch support bracket and a disconnect switch mounted to the inside face of the cover. The cover was assumed to be a die cast A380 aluminum machined plate with features for mounting the disconnect switch, and gasket/bracket assembly. The gasket/support bracket is a two-shot injection molded design with a silicon base gasket material and Polybutylene terephthalate (PBT) disconnect switch support bracket. The disconnect switch consisted of two terminals (assumed shorting bar) over molded in a PBT housing. The switch is fastened to the inside face of the cover with a pair of screws.

Figure F-7 Audi Top Cover with Disconnect Switch

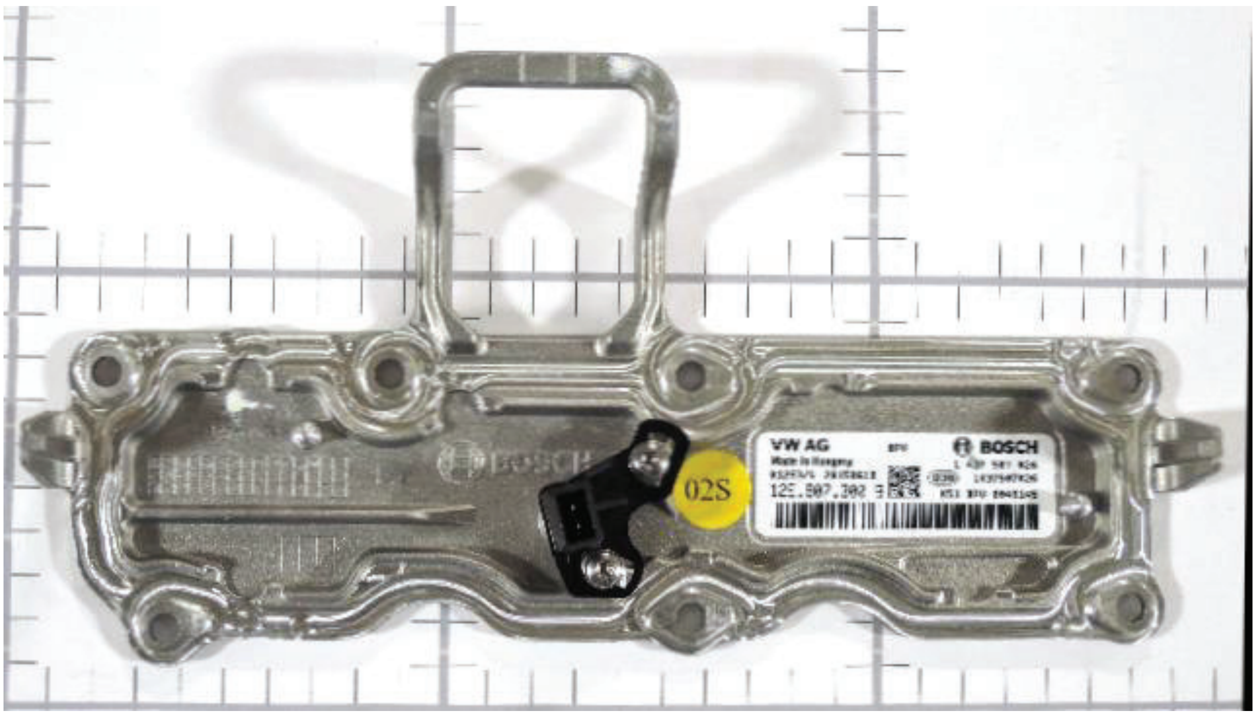
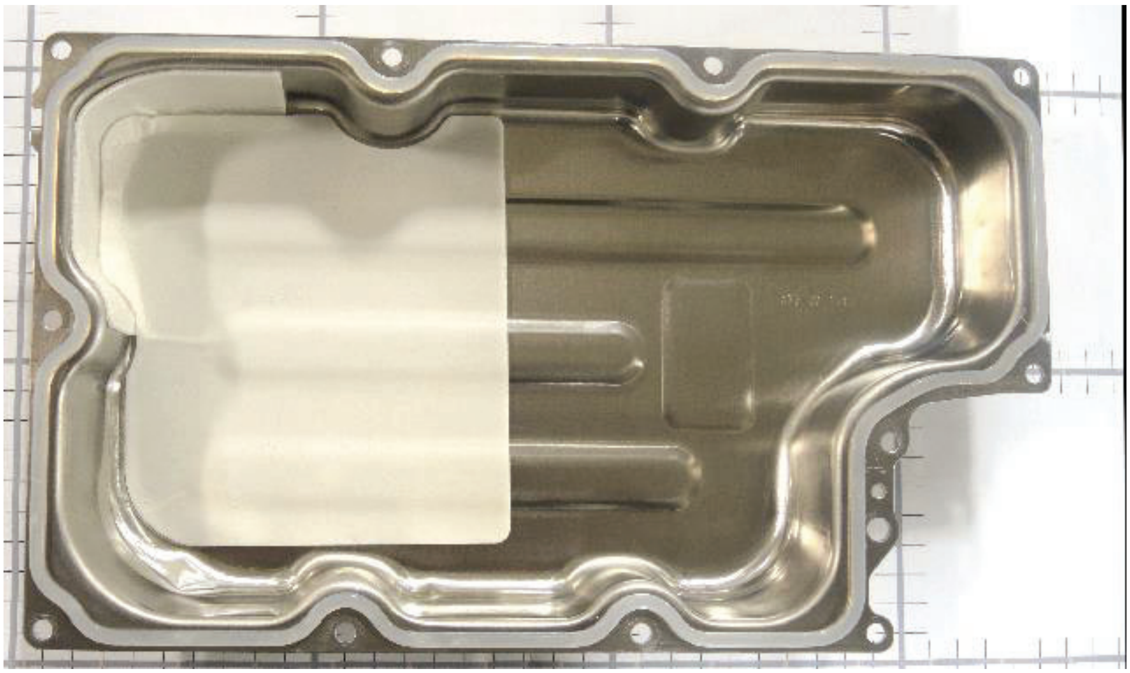


Figure F-8 Audi Top Cover Gasket and Support Bracket

Figure F-9 Audi Top Cover Disconnect Connector

The bottom cover assembly included the cover, gasket and a pair of foam pads. The cover was assumed to be a stamped aluminum. A pair of die cut peel and stick foam pads are placed on the inside surface of the cover. The cover is sealed with silicon based bead applied around the perimeter. The cover is secured to the housing with threaded fasteners around the perimeter.

Figure F-10 Audi Bottom Cover with Foam Pads and Silicon Seal



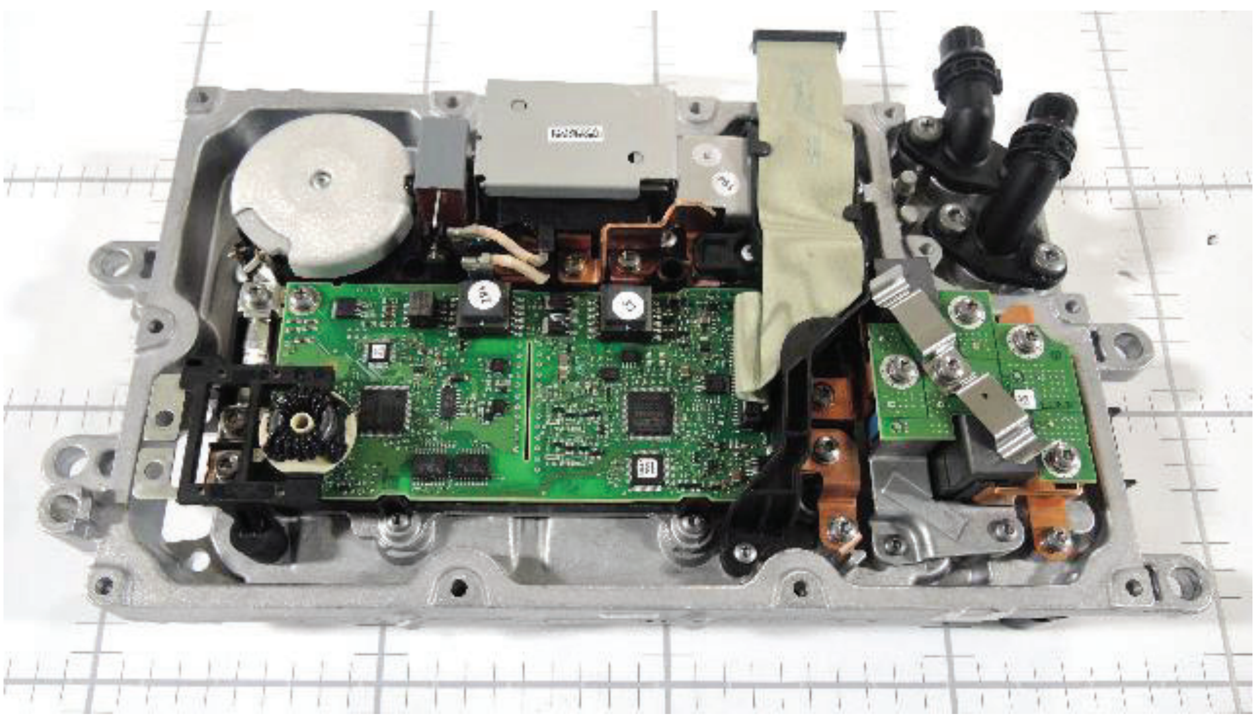
A pair of coolant fittings are attached to the cooling plate assembly for interface to the vehicle coolant system. The fittings are injection molded Glass-Filled Nylon with a pair of anti-crush sleeves (for attachment with thread fasteners) and an O-ring for sealing to the cooling plate

Figure F-11 Audi Coolant Fittings

Audi DC/DC Converter

The Audi DC/DC Converter group consists of five subgroups providing additional clarity in regards to system cost details. Each group will be reported on separately. The converter subgrouping consists of the following: Internal Housing, Bus Bars, Printed Circuit Board Assemblies (PCBA), Ferrites & Inductors, and Harnesses (wiring). The internal housing group includes any additional structural components found inside the unit once disassembled. The Bus Bars group includes any stamped metal components providing electrical connections between devices internal to the module. The PCBA group contains all of the printed circuit boards associated with the DC to DC converter. The ferrites and Inductors group includes additional electronic components associated with the DC to DC converter. The last group Harnesses includes all internal wiring components connecting the various components in the converter. High current DC comes in on the left side in the picture below and the 12-volt output is on the bottom right.

Figure F-12 Audi DC/DC Converter Assembly



The total "should cost" to manufacture the Audi DC/DC Converter group is estimated and additional typical markups associated with component manufacturing added. The summary shown below in Table F-3 includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table F-3 Audi DC/DC Converter Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
A3 PCU DC/DC Converter

MUNRO & ASSOCIATES, INC.

	A3 PCU DC/DC Converter
Parts	1,279
Steps	3,346
Actual Time	2,895.10 sec
Fasteners	39
Total Weight	1.72 kg
Piece Cost	$199.56
Total Labor Cost	$46.05
Q Burden	$3.44
Total Cost	$249.04
Annual Production	200000

The "should cost" to manufacture the parts is established and appropriate markup percentages are applied to establish an estimated selling price. The markups include sales and general administrative costs (SG&A), profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown in the table on page 12. Additional data at the bottom of the table includes the total weight of the system analyzed, annual production volume, and ROM tooling costs. Tooling cost/part is not included in the total cost of the part.

Table F-4 Audi DC/DC Converter: Cost Estimate Summary

Component Summary		
Part/Assembly Name	A3 PCU Module DC /DC Converter	
Purchased Part Roll up Costs		$188.75
Raw Material Costs		$10.81
Processing Costs		$46.05
Scrap (Design Profit: Q-Burden)	1%	$3.44
SG&A % Applied Against Processing	7%	$3.22
Profit % Applied Against Raw & Processing	4%	$2.27
Logistics % Applied Against Sum of all Above	3%	$7.64
Patent/Royalty Fees % Applied Against Sum of all Above	14%	$35.91
Total % Mark Up / Total Cost	29%	$298.09
Total Weight (kg)		1.7167
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$2,565,000
Tooling Cost/part		$2.57
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$5,130,000
Tooling Cost/part		$5.13

Audi DC/DC Converter: Internal Housing

The Audi DC/DC Internal Housing group consists of a single die cast aluminum bus bar support bracket. The bracket was assumed to be a cast aluminum A380 trimmed deburred and washed. All features are as cast with no additional machining evident. The part is attached with three threaded fasteners.

Figure F-13 Audi DC/DC Converter: Bus Bar Support Bracket

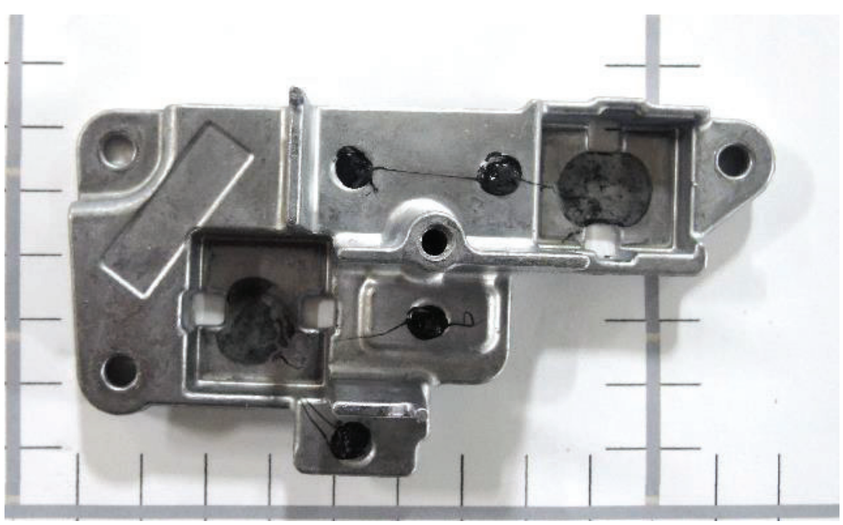


Table F-5 Audi DC/DC Internal Housings Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

A3 DC/DC Converter Internal

MUNRO & ASSOCIATES, INC.

	A3 DC/DC Converter Internal Housing
Parts	4
Steps	18
Actual Time	40.22 sec
Fasteners	3
Total Weight	0.04 kg
Piece Cost	$0.13
Total Labor Cost	$0.52
Q Burden	$0.11
Total Cost	$0.75
Annual Production	200000

Table F-6 Audi DC/DC Internal Housings: Cost Estimate Summary

Component Summary		
Part/Assembly Name	A3 PCU DC/DC Internal Housing	
Purchased Part Roll up Costs		$0.03
Raw Material Costs		$0.10
Processing Costs		$0.52
Scrap (Design Profit: Q-Burden)	17%	$0.11
SG&A % Applied Against Processing	7%	$0.04
Profit % Applied Against Raw & Processing	4%	$0.02
Logistics % Applied Against Sum of all Above	3%	$0.02
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.02
Total % Mark Up / Total Cost	33%	$0.86
Total Weight (kg)		0.0443
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$185,000
Tooling Cost/part		$0.19
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$370,000
Tooling Cost/part		$0.37

Audi DC/DC Converter: Bus Bars

The Audi DC/DC Converter Bus Bars group consists of three unique formed copper components. The smallest of the three below uses through-hole attachment only. The other two use a combination of through-hole and clinch nuts for attachment. The bus bars are located on the low voltage output end and are formed to accommodate component attachment and passing through ferrite cores.

Figure F-14 Audi DC/DC: Bus Bar Group

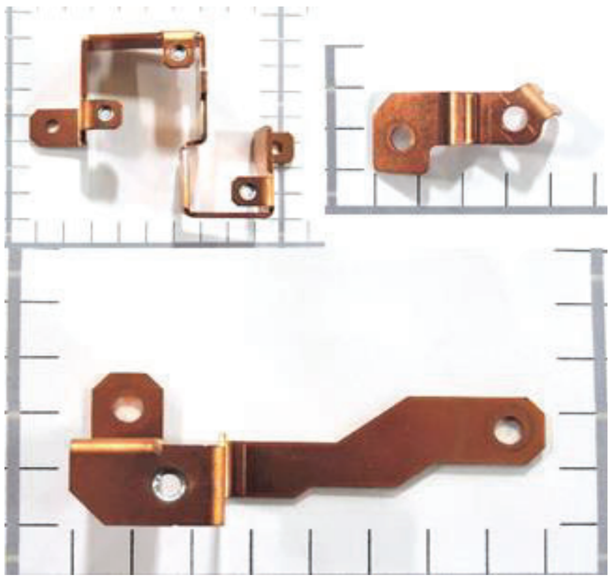


Figure F-15 Audi DC/DC: Bus Bars in Place

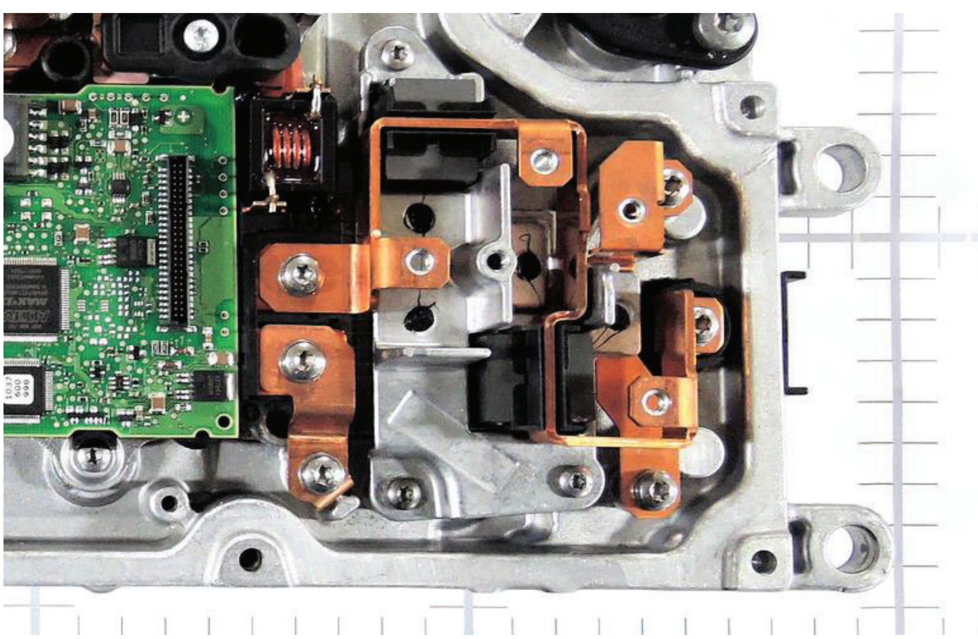


Table F-7 Audi DC/DC Bus Bars Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
A3 DC/DC Converter Bus Bars

MUNRO & ASSOCIATES, INC.

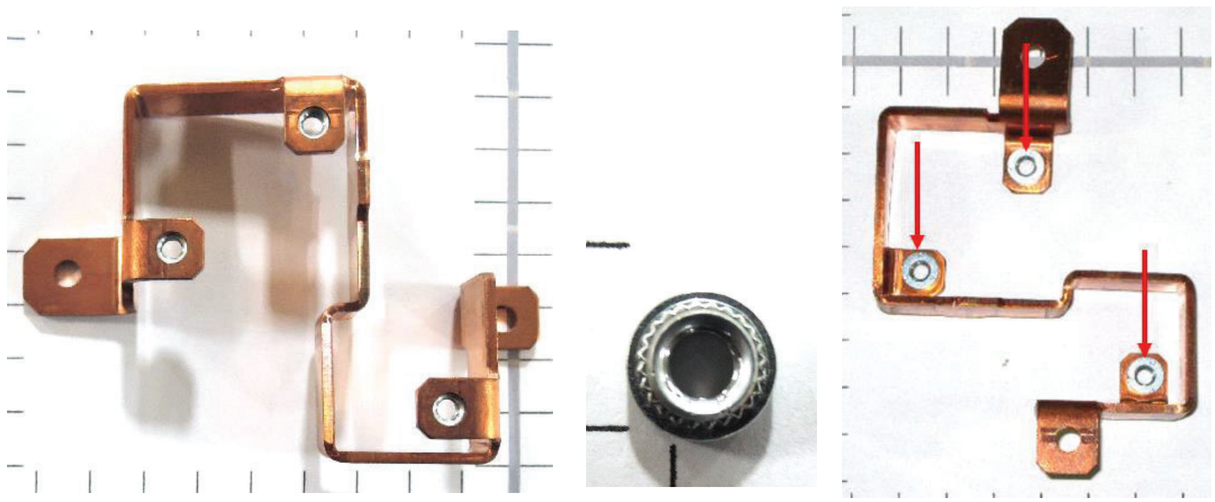
	A3 DC/DC Converter Bus Bars
Parts	13
Steps	71
Actual Time	101.98 sec
Fasteners	10
Total Weight	0.09 kg
Piece Cost	$2.48
Total Labor Cost	$0.95
Q Burden	$0.30
Total Cost	$3.72
Annual Production	200000

Table F-8 Audi DC/DC Bus Bars Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	A3 PCU DC /DC Bus Bars	
Purchased Part Roll up Costs		$0.26
Raw Material Costs		$2.22
Processing Costs		$0.95
Scrap (Design Profit: Q-Burden)	9%	$0.30
SG&A % Applied Against Processing	7%	$0.07
Profit % Applied Against Raw & Processing	4%	$0.13
Logistics % Applied Against Sum of all Above	3%	$0.12
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.08
Total % Mark Up / Total Cost	25%	$4.12
Total Weight (kg)		0.0894
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$220,000
Tooling Cost/part		$0.22
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$440,000
Tooling Cost/part		$0.44

The Audi DC/DC Converter bus bars are stamped from sheet stock copper and formed to shape. Shown below is the more complex stamping showing the use of three clinch nuts.

Figure F-16 Audi DC/DC Converter: Bus Bar Clinch Nuts



Audi DC/DC Converter: PCBAs

The Audi DC/DC converter Printed Circuit Board Assemblies (PCBAs) group consists of an IGBT assembly, main control circuit board and a smaller capacitor circuit board. The IGBT assembly includes two unique IGBTs, a complex over-molded lead frame and a heat sink plate. The printed circuit board assembly contains all of the surface mount devices controlling the DC to DC converter. The smaller capacitor circuit board contains four capacitors and uses through hole mounting to contact points.

Figure F-17 Audi DC/DC Converter: PCBAs Group

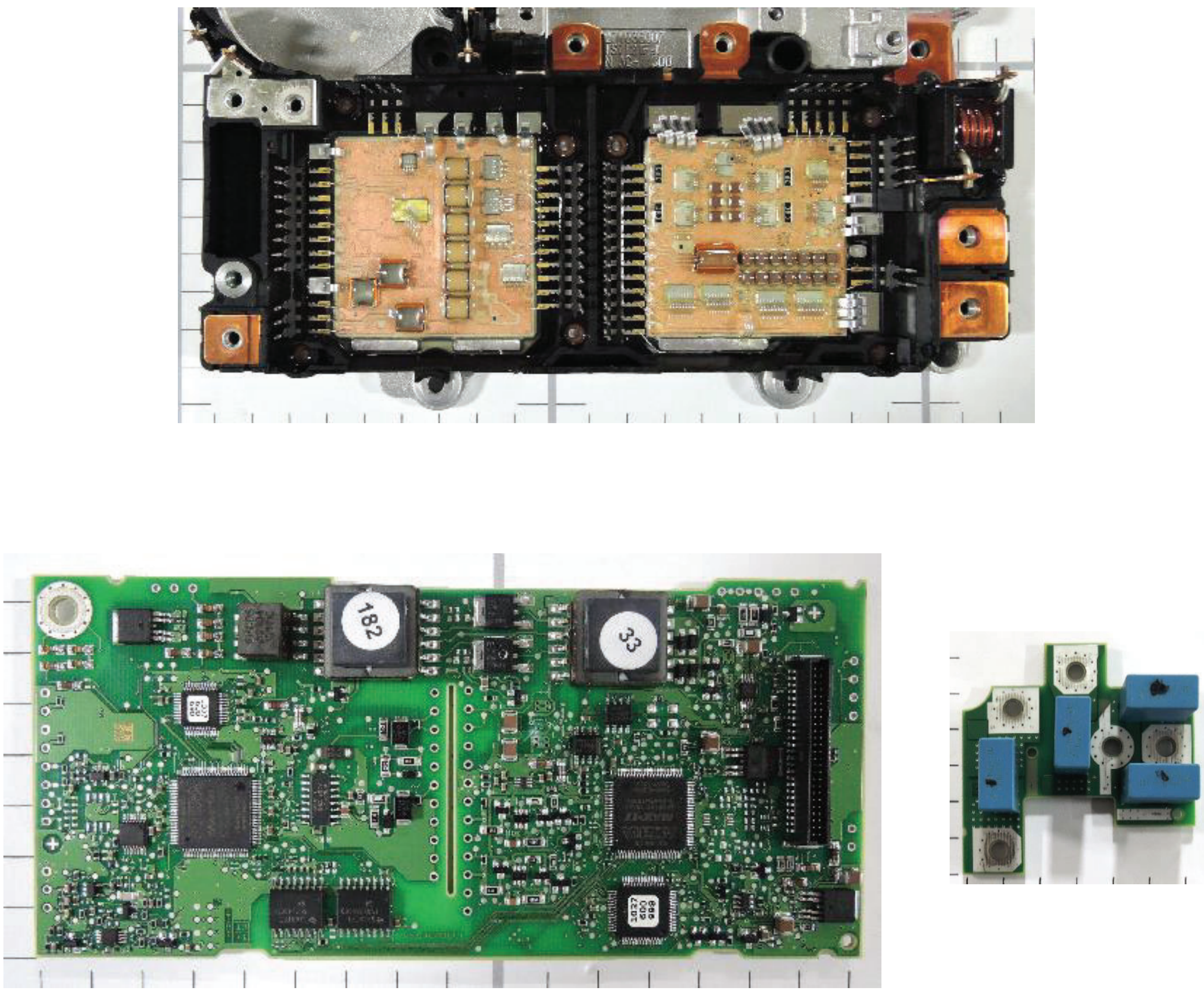


Table F-9 Audi DC/DC PCBAs Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
A3 DC/DC Converter PCBAs

MUNRO & ASSOCIATES, INC.

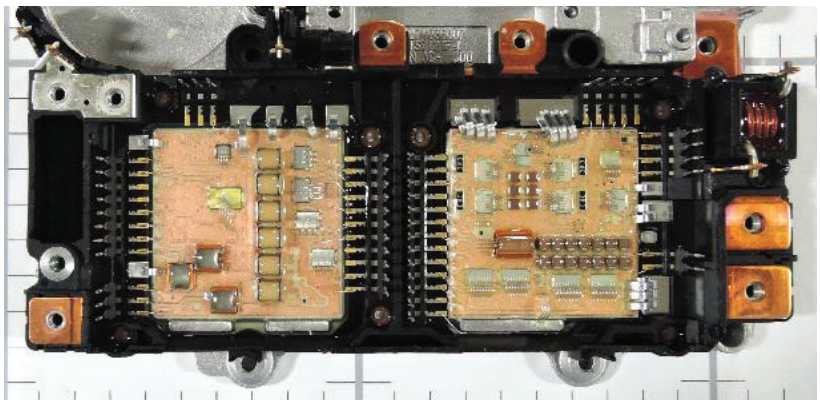
	A3 DC/DC Converter PCBAs
Parts	1,173
Steps	2,687
Actual Time	1,224.73 sec
Fasteners	9
Total Weight	0.72 kg
Piece Cost	$180.74
Total Labor Cost	$24.97
Q Burden	$1.94
Total Cost	$207.66
Annual Production	200000

Table F-10 Audi DC/DC PCBAs Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	A3 PCU DC /DC Printed Circuit Board Assemblies	
Purchased Part Roll up Costs		$176.49
Raw Material Costs		$4.25
Processing Costs		$24.97
Scrap (Design Profit: Q-Burden)	1%	$1.94
SG&A % Applied Against Processing	7%	$1.75
Profit % Applied Against Raw & Processing	4%	$1.17
Logistics % Applied Against Sum of all Above	3%	$6.32
Patent/Royalty Fees % Applied Against Sum of all Above	15%	$32.53
Total % Mark Up / Total Cost	30%	$249.42
Total Weight (kg)		0.7240
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$905,000
Tooling Cost/part		$0.91
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,810,000
Tooling Cost/part		$1.81

The IGBT Assembly includes two unique IGBT assemblies, a complex over-molded lead frame and a heat sink plate. The IGBT assemblies are bonded to the heat sink and then the lead frame is set in place and held by peened posts onto the heat sink. The IGBTs are connected to the lead frame with wire stitch bonding. The entire assembly is then attached to the cooling plate using thermally conductive paste and four threaded fasteners.

Figure F-18 Audi DC/DC Converter: IGBT Assembly



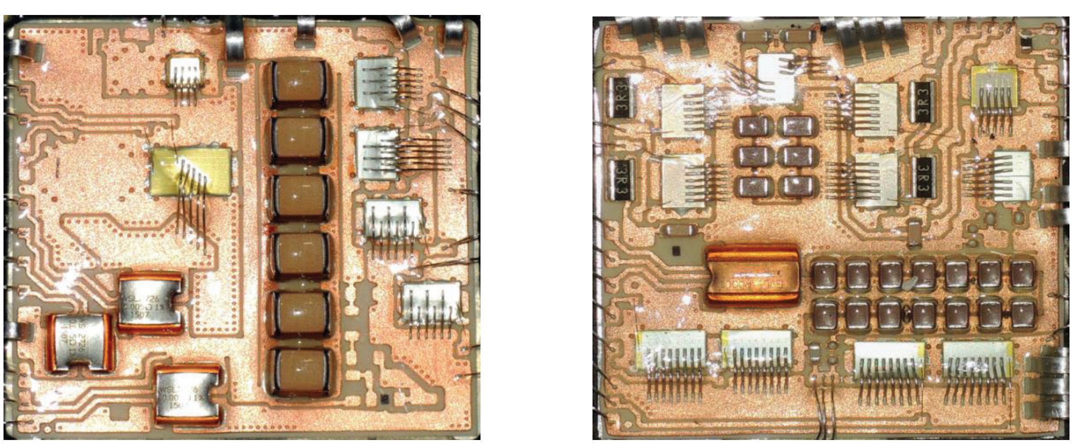
The two unique IGBTs, consist of surface mount device placed on an Alumina (Al) Copper (Cu) plated substrate.

The IGBT 1 cost drivers for the first IGBT assembly included 1 – IGBT 9.3 x 5.8mm Die, 4 - IGBTs, 6.5 x 4.9mm Die 1 - Diode, 4.2 x 4.1mm Die, 6 –Stacked Capacitors, 3 – Precision 0.005 OHM Resistors and the Al/Cu substrate.

The IGBT 2 cost drivers for the second IGBT assembly included 4 - IGBTs, 7.7 x 4.7mm Die, 4 - IGBTs, 6.4 x 4.9mm Die, 1 - IGBT, 5.3 x 5.2mm Die, 2 - Diodes, 6.4 x 4.3mm Die, 1 – Precision 0.0001 OHM Resistor and the Al/Cu substrate.

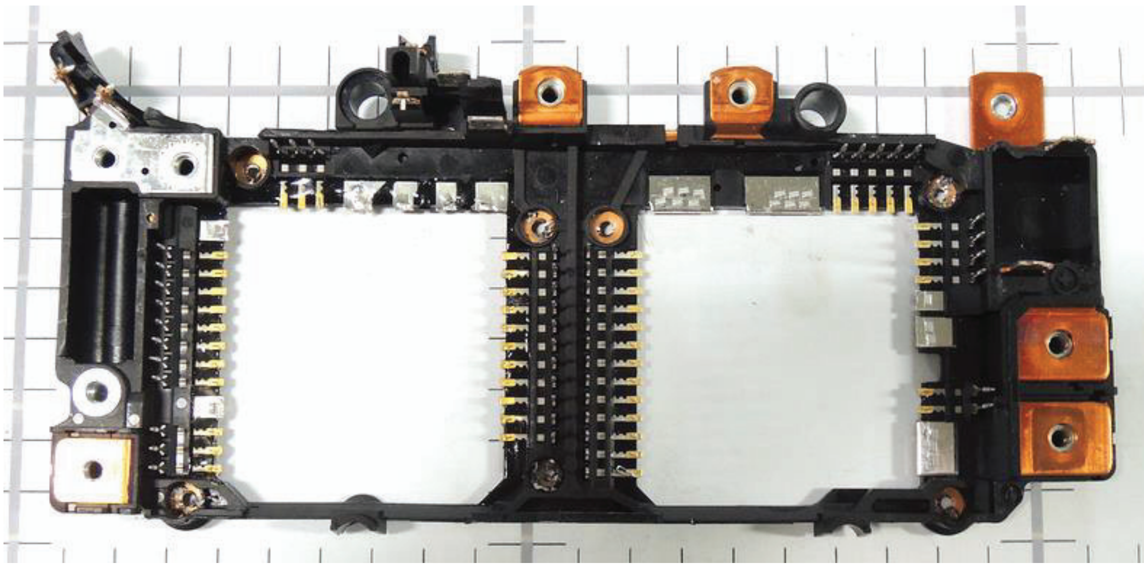
Both IGBT's use wire stitch bonding to connect the discreet components

Figure F-19 Audi DC/DC Converter: IGBT 1 Left, IGBT 2 Right



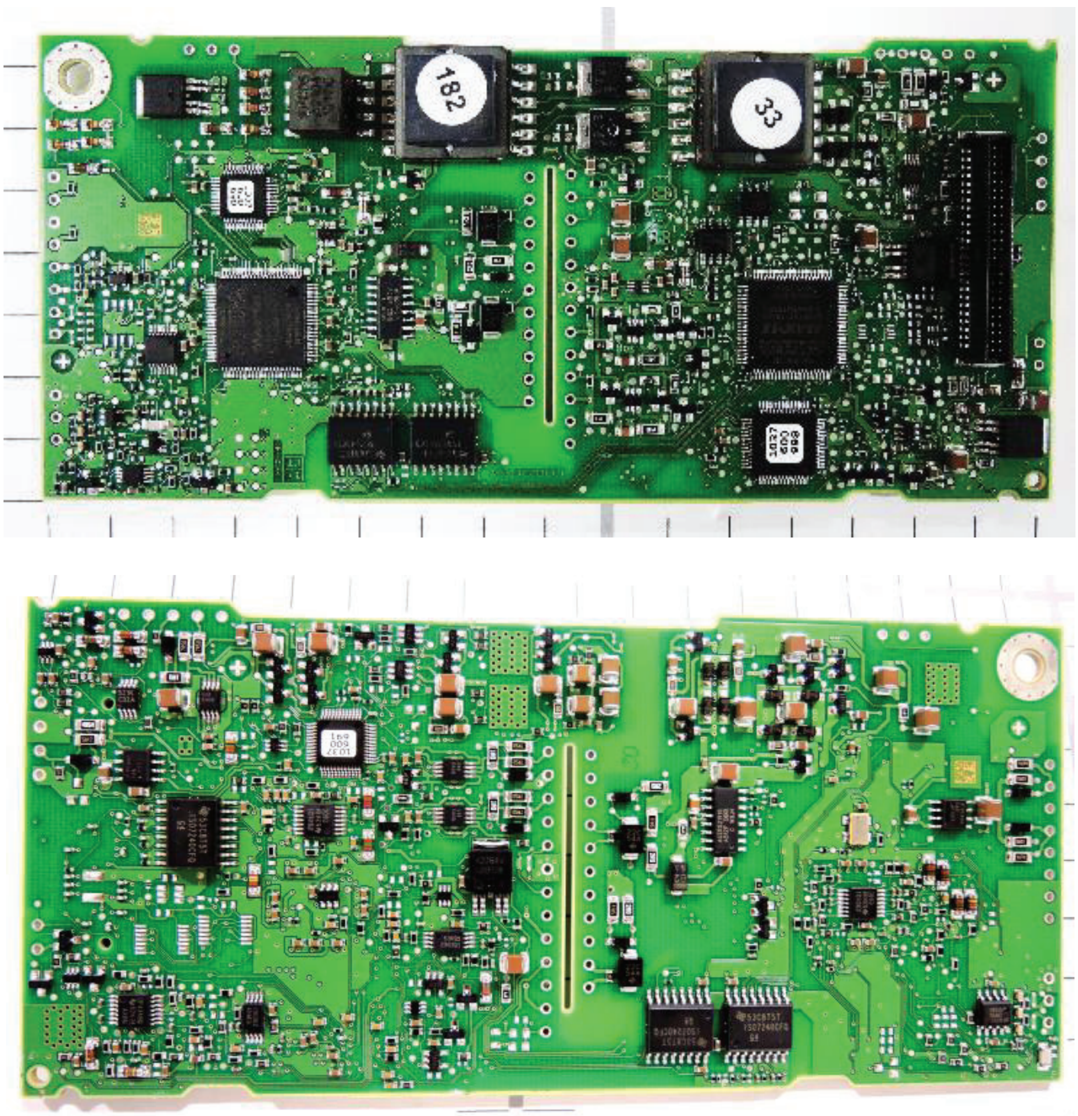
The IGBT lead frame is a complex over-molded component. A total of 76 individual parts are inserted into the mold prior to injecting the PBT plastic. The insert parts include copper and nickel plated copper bus bars, 49 compliant pin terminals and eight threaded nuts.

Figure F-20 Audi DC/DC Converter: IGBT Lead Frame



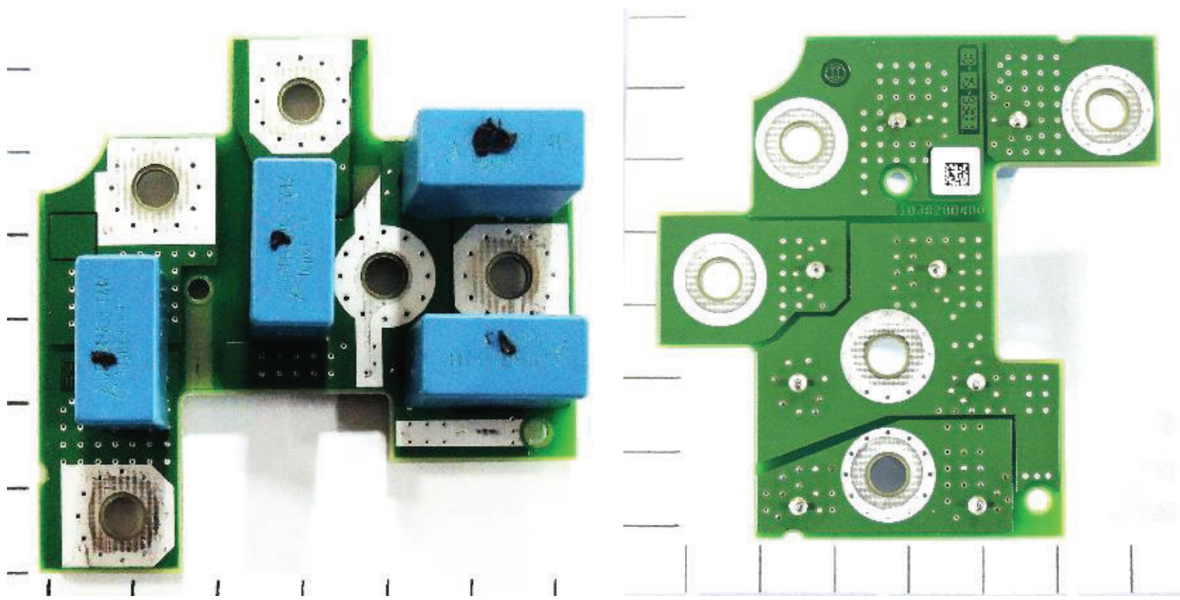
The main control board included the following components which are were identified as having the highest cost: 2 - Altera CPLD MAX II Family processers, 5 – Four Channel Digital Isolator Logic devices, 1 - 50 Position Shrouded Connector Header, 1 - 4 layer FR4 Printed Circuit Board, 1 – Freescale S12 16-bit MCU, and 1 – NXP S12 16-Bit MCU. Additional components found on the board include amplifiers, MOSFETS, transformers, voltage regulators, gate drivers, CAN Transceivers, flash memory, differential comparators and various smaller active and passive surface mount components.

Figure F-21 Audi DC/DC Converter: Main Control Board Top and Bottom Views



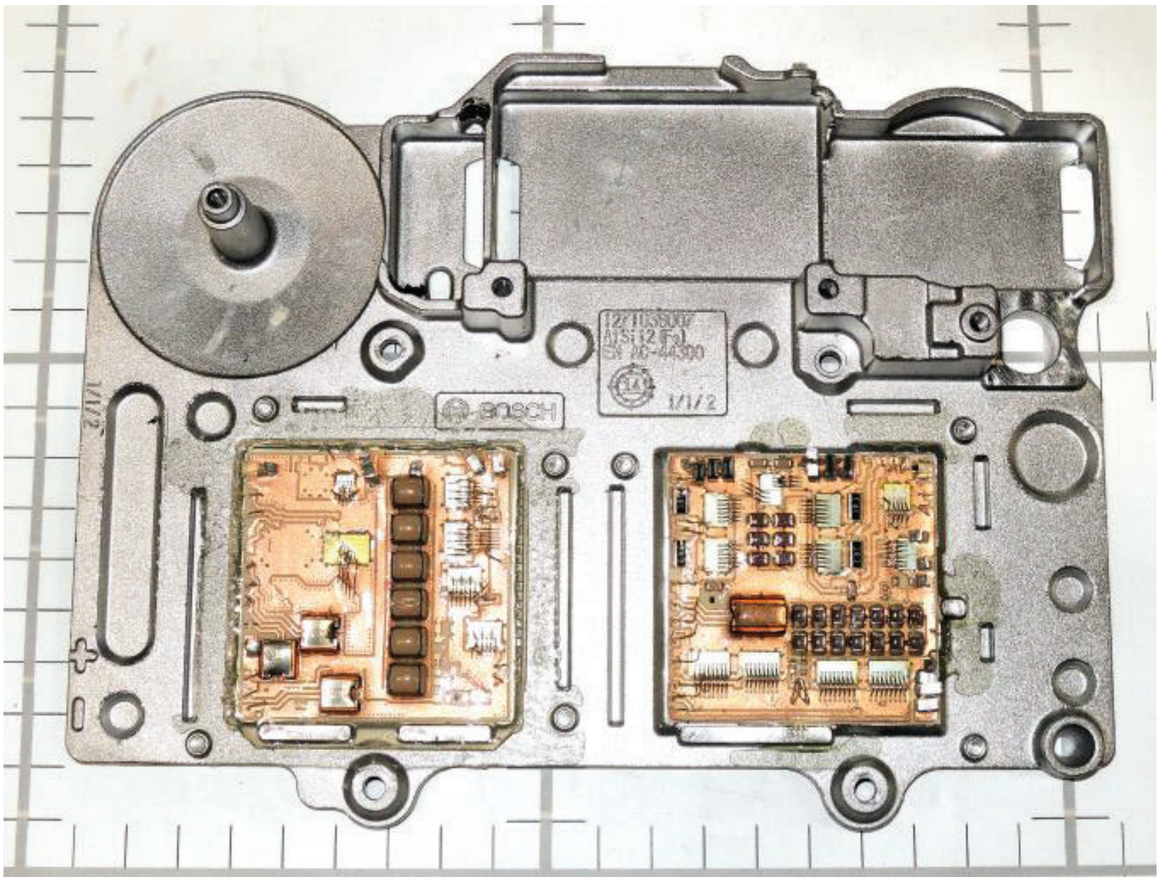
The smaller capacitor circuit board contained four capacitors. The capacitors were identified as through hole mounted 10µF Film Capacitor 40V 63V. The capacitor circuit board is a double layer FR4 with vias for capacitor leg pass through and contact pads for final assembly.

Figure F-22 Audi DC/DC Converter: Small Capacitor Board



The DC to DC heat sink is a die cast aluminum A380 plate. After casting the part was assumed to trimmed, shot peened, machined and washed. The part had minimal machining; the only machined features included the IGBT mount pads, four tapped holes and a pair of part locating lands.

Figure F-23 Audi DC/DC Converter: IGBT Assembly Heat Sink with PCBAs still attached



Audi DC/DC Converter: Ferrites & Inductors

The Audi DC/DC Ferrites & Inductors group consists of a pair of identical ferrite cores, and three inductors. The two ferrites are a sintered powdered metal design. They are both used on the high voltage input side of the circuitry with bus bars passing through them. The three inductors are all preassembled unique components. All three inductors use threaded fasteners for completing electrical circuit during assembly.

Figure F-24 Audi DC/DC Converter: Ferrites & Inductors Group

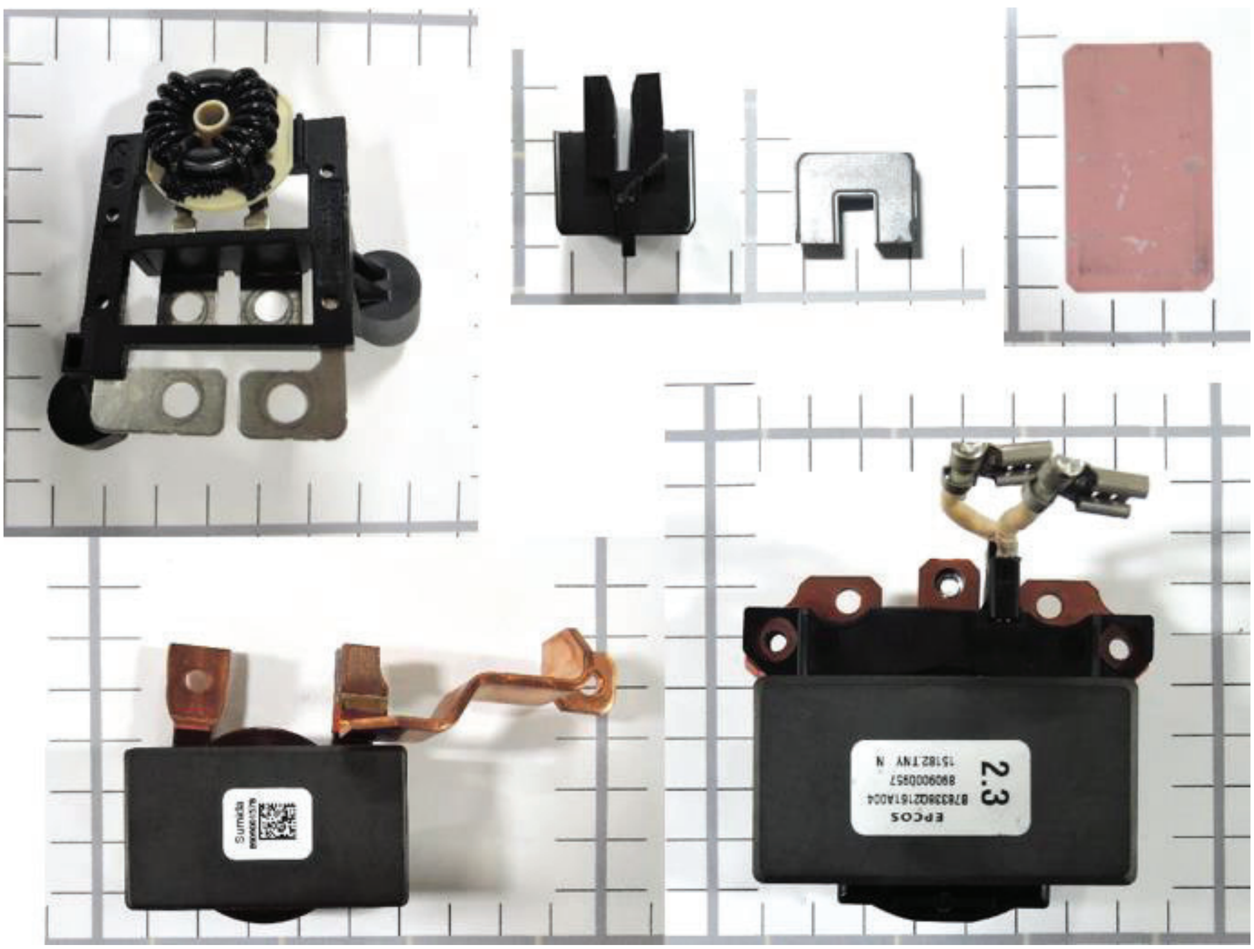


Table F-11 Audi DC/DC Ferrites & Inductors Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

A3 DC/DC Converter Ferrites &

MUNRO & ASSOCIATES, INC.

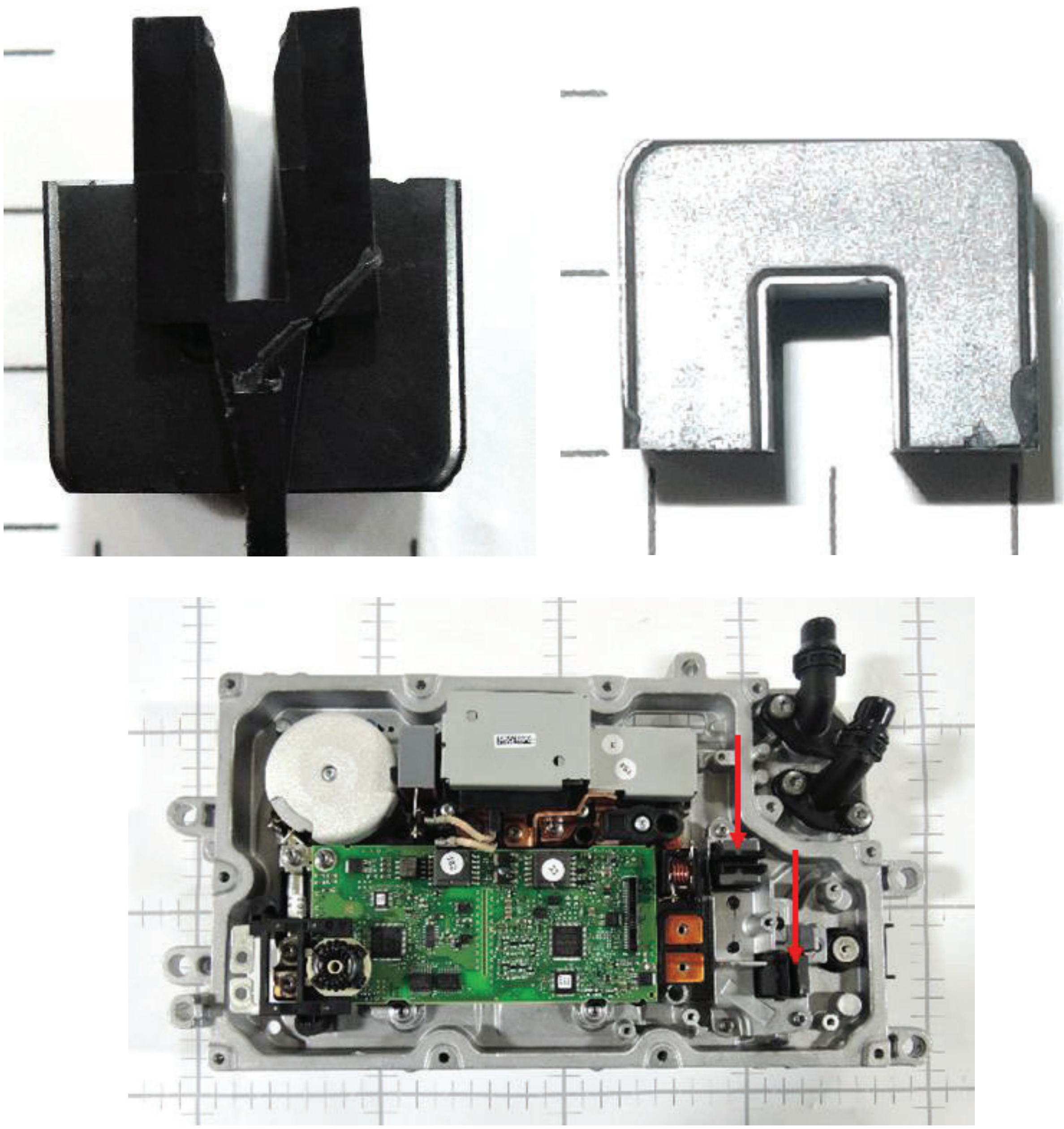
	A3 DC/DC Converter Ferrites & Inductors
Parts	76
Steps	521
Actual Time	1,442.48 sec
Fasteners	11
Total Weight	0.74 kg
Piece Cost	$8.14
Total Labor Cost	$18.70
Q Burden	$0.90
Total Cost	$27.74
Annual Production	200000

Table F-12 Audi DC/DC Ferrites & Inductors Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		A3 PCU DC /DC Ferrites & Inductors
Purchased Part Roll up Costs		$4.07
Raw Material Costs		$4.07
Processing Costs		$18.70
Scrap (Design Profit: Q-Burden)	3%	$0.90
SG&A % Applied Against Processing	7%	$1.31
Profit % Applied Against Raw & Processing	4%	$0.91
Logistics % Applied Against Sum of all Above	3%	$0.90
Patent/Royalty Fees % Applied Against Sum of all Above	10%	$3.09
Total % Mark Up / Total Cost	27%	$33.94
Total Weight (kg)		0.7363
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,135,000
Tooling Cost/part		$1.14
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$2,270,000
Tooling Cost/part		$2.27

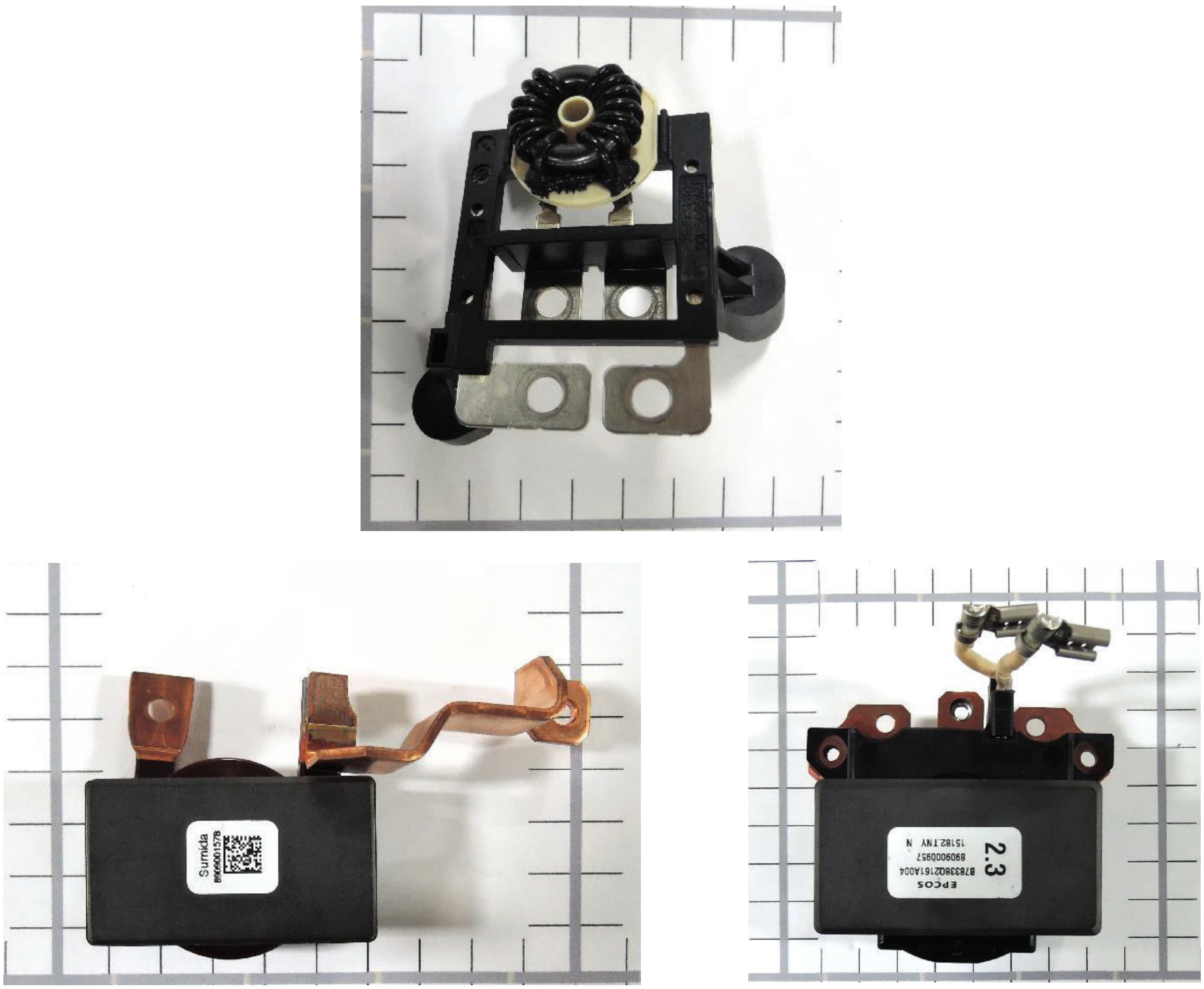
The two ferrites are identical two-piece powdered metal designs. The top and bottom ferrites are the same during installation the bottom ferrite has a plastic injection molded part snapped onto it. The plastic part provides insulation for the bus bar trapped between the two parts.

Figure F-25 Audi DC/DC Converter: Ferrite Cores



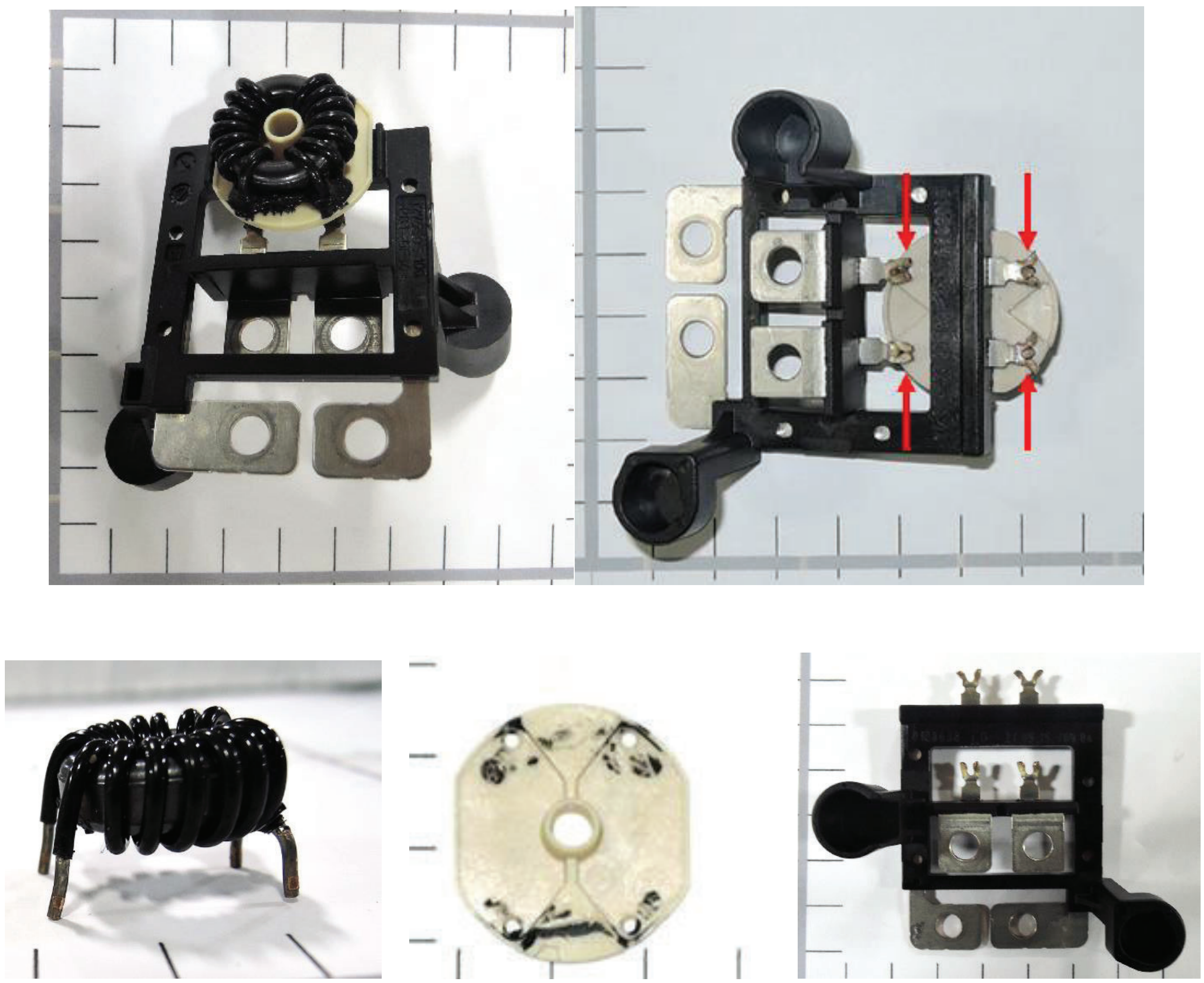
The three inductors are all preassembled unique components. All three inductors use threaded fasteners for completing electrical circuit during assembly. One inductor is known as a Toroidal wound device. One inductor uses unique wound flat stock. The third inductor is a transformer utilizing stamped conductors and a stranded copper wire.

Figure F-26 Audi DC/DC Converter: Toroid Top,
Flat Wound Inductor Lower Left,and Transformer Lower Right



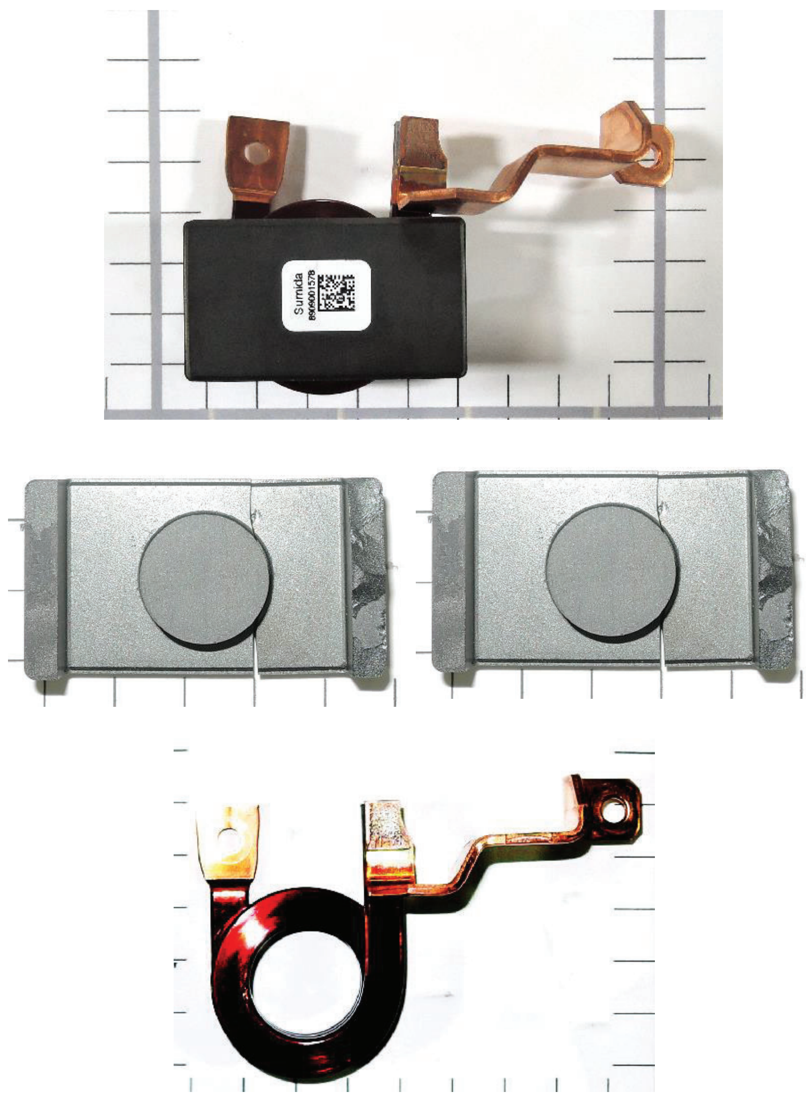
The Toroid inductor is mounted on an injection molded base and then attached to a frame with over-molded electrical terminals. The frame is an injection molded >PBT LG30< with four stamped terminals being over-molded.

Figure F-27 Audi DC/DC Converter: Assembled Toroid Inductor Top Left, Torrid to Lead Frame Connections Top Right, Wound Torrid Lower Left, Base Lower Center, Lead Frame Lower Right



The flat wound inductor uses a single piece coil formed from copper flat stock. A short terminal bar is welded onto one side. A pair of identical upper and lower ferrite cores are bonded together trapping the coil.

Figure F-28 Audi DC/DC Converter: Assembled Flat Wound Inductor Top, Ferrites Middle, and Coil Bottom



The transformer consisted of a combination of three formed copper plates with a wire wound section between each of the copper plates. The coils are assembled over a plastic injection molded part with plastic insulators between the copper wire and copper plates. After initial assembly the top cover is injection molded in place and the electrical lead side is then potted. The coil is then trapped by a pair of identical upper and lower ferrite cores bonded together.

Figure F-29 Audi DC/DC Converter: Assembled Transformer top, Ferrites Center right, Inductor Assembly minus Ferrites Center left, bottom: Stamped Copper Plates left, Copper Wire right

Audi DC/DC Converter: Electrical & Harness

The Audi DC/DC Converter Electrical & Harness group consists of ribbon cable with a plastic wire trough, the 12-volt outlet terminal lug mounted external to the housing, and the high voltage fuse. The plastic trough is used to route the ribbon cable inside the DC to DC converter. The cable is connected to the DC to DC main Control board and then passes through an opening in the heat sink. It is connected to the inverter side of the unit later during final assembly.

Figure F-30 Audi DC/DC Converter: Electrical & Harness Group,
Plastic Trough Top Left, High Voltage Fuse Top Right, and Ribbon Cable Bottom

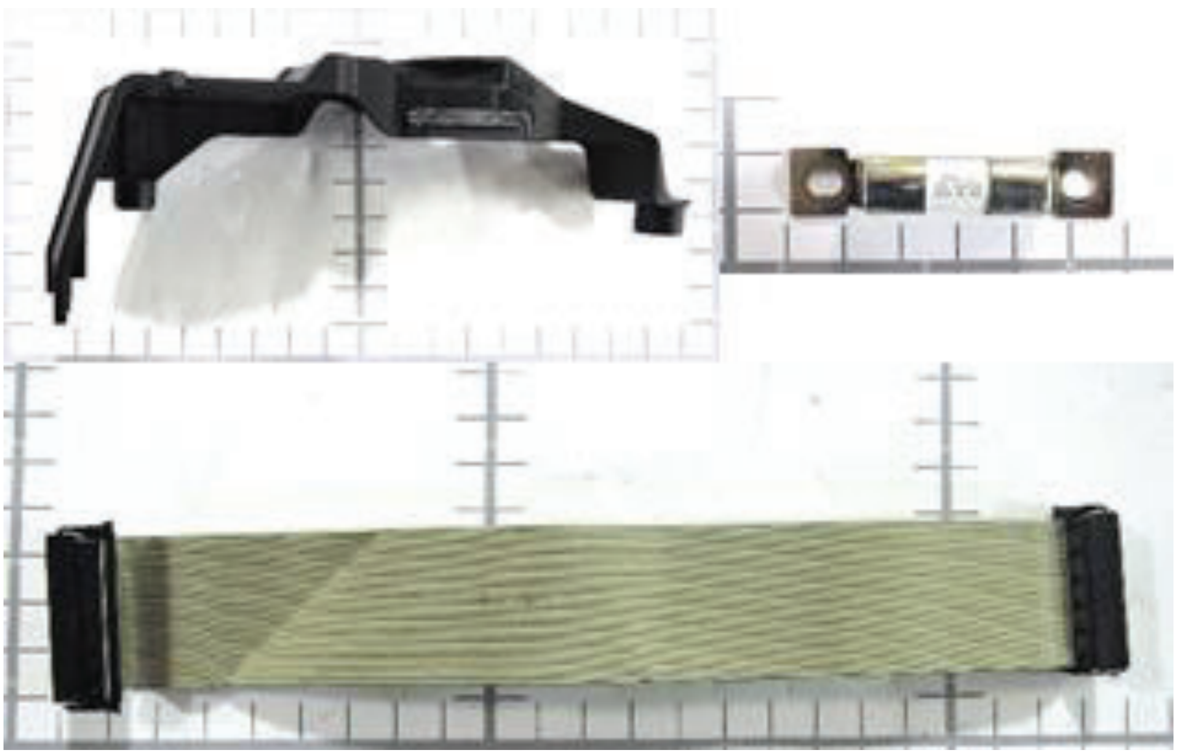


Table F-13 Audi DC/DC Electrical & Harness Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

A3 DC/DC Converter Electrical &

MUNRO & ASSOCIATES, INC.

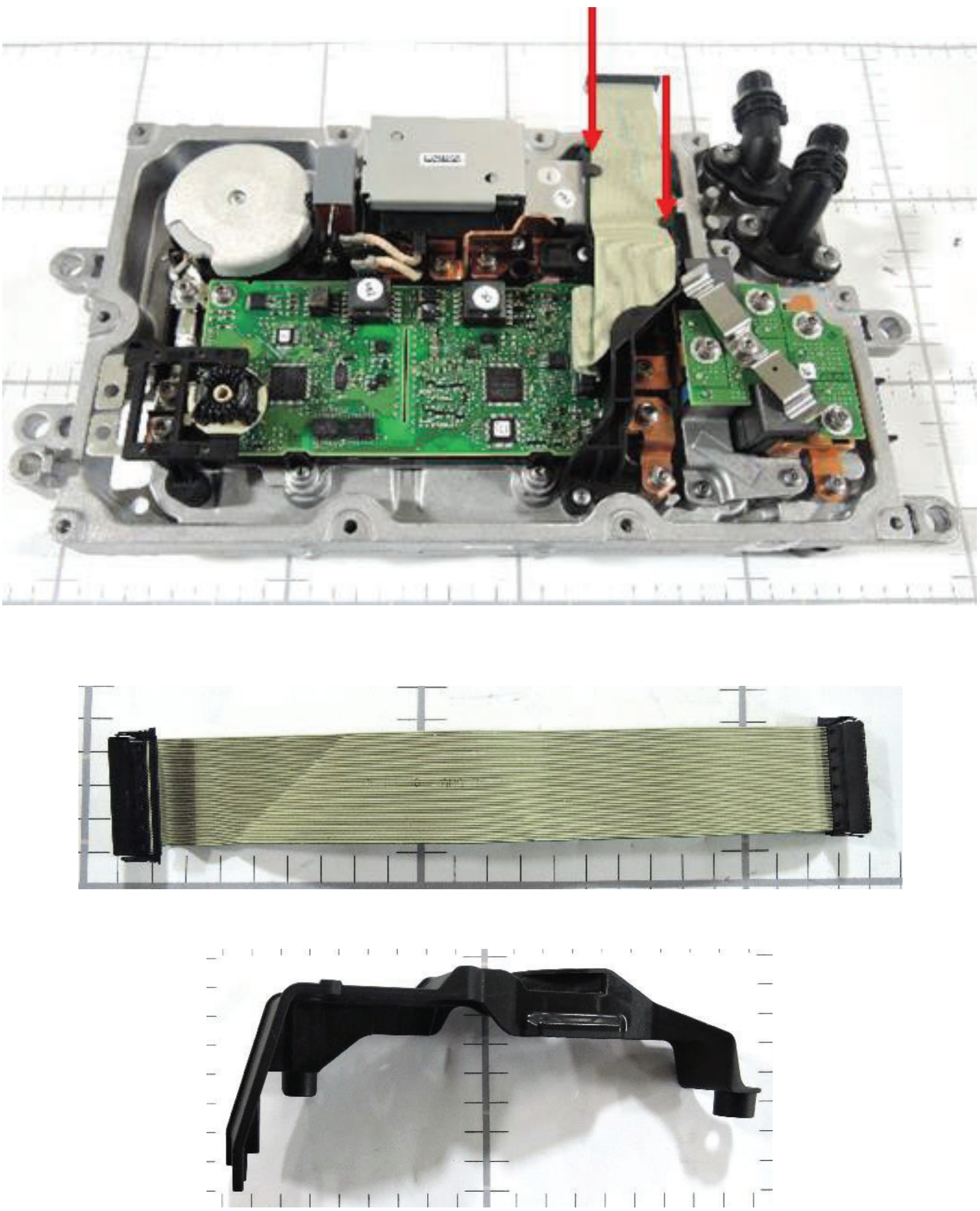
	A3 DC/DC Converter Electrical & Harness
Parts	13
Steps	49
Actual Time	85.69 sec
Fasteners	6
Total Weight	0.12 kg
Piece Cost	$8.07
Total Labor Cost	$0.91
Q Burden	$0.19
Total Cost	$9.17
Annual Production	200000

Component Summary		
Part/Assembly Name	A3 PCU DC /DC Electrical Harnesses	
Purchased Part Roll up Costs		$7.90
Raw Material Costs		$0.17
Processing Costs		$0.91
Scrap (Design Profit: Q-Burden)	2%	$0.19
SG&A % Applied Against Processing	7%	$0.06
Profit % Applied Against Raw & Processing	4%	$0.04
Logistics % Applied Against Sum of all Above	3%	$0.28
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.19
Total % Mark Up / Total Cost	18%	$9.75
Total Weight (kg)		0.1227
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$120,000
Tooling Cost/part		$0.12
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$240,000
Tooling Cost/part		$0.24

Table F-14 Audi DC/DC Electrical & Harness Group: Cost Estimate Summary

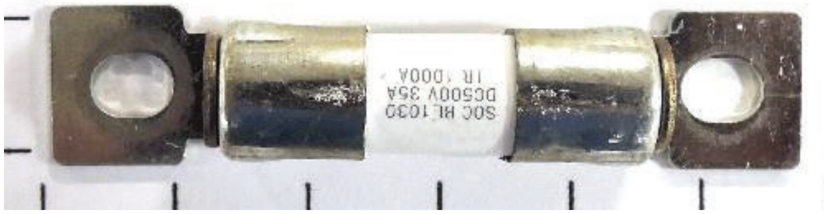
The ribbon cable trough is an injection molded component. Small tabs along the cable routing path are used to retain the ribbon cable.

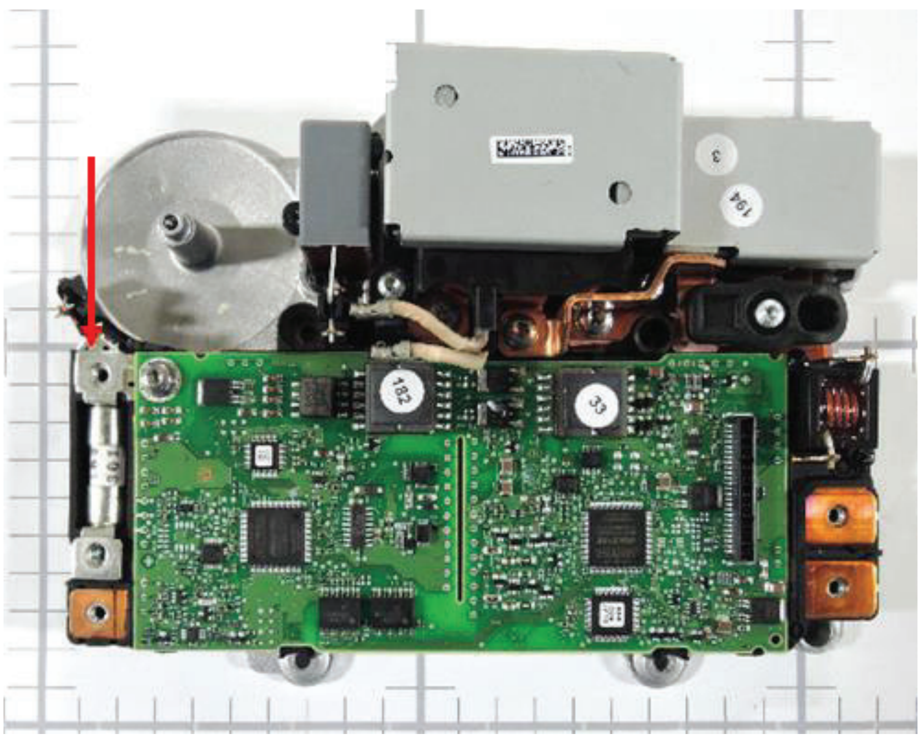
Figure F-31 Audi DC/DC Converter: Ribbon Cable and Trough Installed Top, Board to Board Ribbon Cable Center and Wire Trough Bottom



The DC to DC converter had a 35Amp, 500VDC voltage fuse located on the high voltage input side. It was retained to a set of tabs utilizing a pair of threaded fasteners.

Figure F-32 Audi DC/DC Converter: High Voltage Fuse and Installation Location





Audi Inverter

The Audi Inverter group consists of five subgroups providing additional clarity in regards to system cost details. Each group will be reported on separately. The converter subgrouping consists of the following: Internal Housing, Bus Bars, Printed Circuit Board Assemblies (PCBA, also includes IGBTs), Inductors & Capacitors, and Harnesses (wiring). The internal housing group includes any additional structural components found inside the unit once disassembled. The Bus Bars group includes any stamped metal components providing electrical connections between devices internal to the module. The PCBA group contains all of the printed circuit boards associated with the inverter assembly. The Inductors and capacitors group includes additional electronic components associated with the inverter. The last group Harnesses includes all internal wiring components connecting the various components in the inverter.

Figure F-33 Audi Inverter

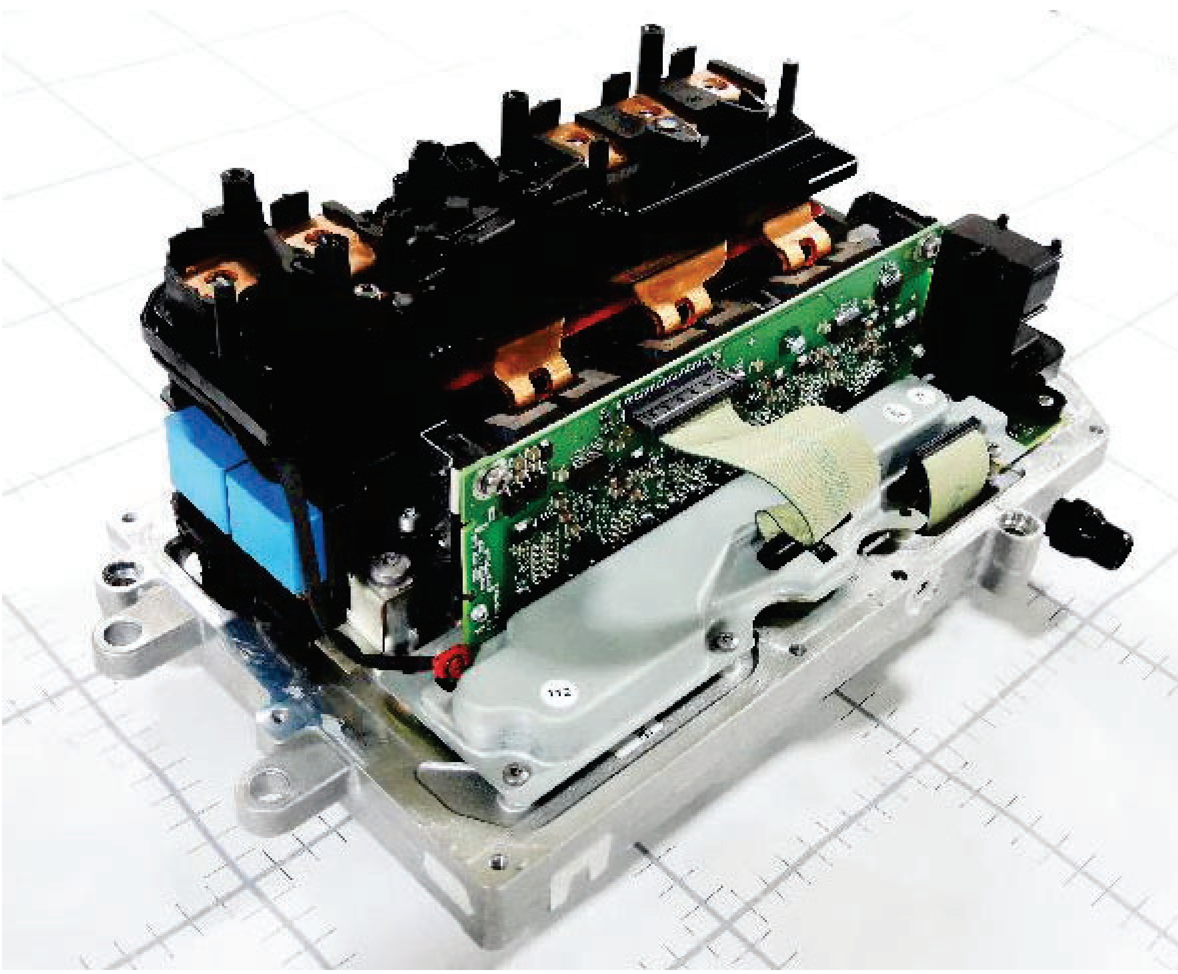


Table F-15 Audi Inverter Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
A3 PCU Inverter

MUNRO & ASSOCIATES, INC.

	A3 PCU Inverter
Parts	1,926
Steps	5,249
Actual Time	3,125.62 sec
Fasteners	51
Total Weight	3.47 kg
Piece Cost	$278.72
Total Labor Cost	$58.61
Q Burden	$5.22
Total Cost	$342.55
Annual Production	200000

Table F-16 Audi Inverter Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		A3 PCU Inverter
Purchased Part Roll up Costs		$248.53
Raw Material Costs		$30.20
Processing Costs		$58.60
Scrap (Design Profit: Q-Burden)	2%	$5.22
SG&A % Applied Against Processing	7%	$4.10
Profit % Applied Against Raw & Processing	4%	$3.55
Logistics % Applied Against Sum of all Above	3%	$10.51
Patent/Royalty Fees % Applied Against Sum of all Above	13%	$46.47
Total % Mark Up / Total Cost	28%	$407.17
Total Weight (kg)		3.4717
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$3,807,500
Tooling Cost/part		$3.81
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$7,615,000
Tooling Cost/part		$7.62

Audi Inverter: Internal Housing

The Audi Inverter Internal Housing group consists of a stamped steel cover and a plastic molded frame. The cover provides EMI shielding for one of the printed circuit boards. The plastic frame wraps around the AC and DC terminal lugs, and also includes circuitry for the disconnect feature in the top cover.

Figure F-34 Audi Inverter: Internal Housing

Table F-17 Audi Inverter Internal Housings Group

Design Profit®

EXECUTIVE SUMMARY
A3 Inverter Internal Housings

MUNRO & ASSOCIATES, INC.

	A3 Inverter Internal Housings
Parts	21
Steps	86
Actual Time	199.40 sec
Fasteners	8
Total Weight	0.23 kg
Piece Cost	$1.12
Total Labor Cost	$2.83
Q Burden	$0.35
Total Cost	$4.30
Annual Production	200000

Table F-18 Audi Inverter Internal Housings Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		A3 PCU Inverter Internal Housings
Purchased Part Roll up Costs		$0.54
Raw Material Costs		$0.58
Processing Costs		$2.83
Scrap (Design Profit: Q-Burden)	9%	$0.35
SG&A % Applied Against Processing	7%	$0.20
Profit % Applied Against Raw & Processing	4%	$0.14
Logistics % Applied Against Sum of all Above	3%	$0.14
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.10
Total % Mark Up / Total Cost	25%	$4.87
Total Weight (kg)		0.2265
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$175,000
Tooling Cost/part		$0.18
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$350,000
Tooling Cost/part		$0.35

The cover is a stamped galvanized low carbon steel and is attached with eight threaded fasteners around the perimeter. The plastic frame is an injection molded >PBT GF30<. The frame provides features for routing a pair of harnesses for the cover disconnect circuit and provides isolation of the motor three phase terminal lugs and DC high current terminal lugs.

Figure F-35 Audi Inverter: Internal Housings Cover Top, and Frame Below

Audi Inverter: Bus Bars

The Audi Inverter Bus Bars group consists of two sets of buss bars; one for the High Voltage DC circuits and a set for the motor three phase circuits. Additional components in the group include a terminal lug block and an additional buss bar connected in series with a high voltage fuse.

Figure F-36 Audi Inverter: Bus Bars Group

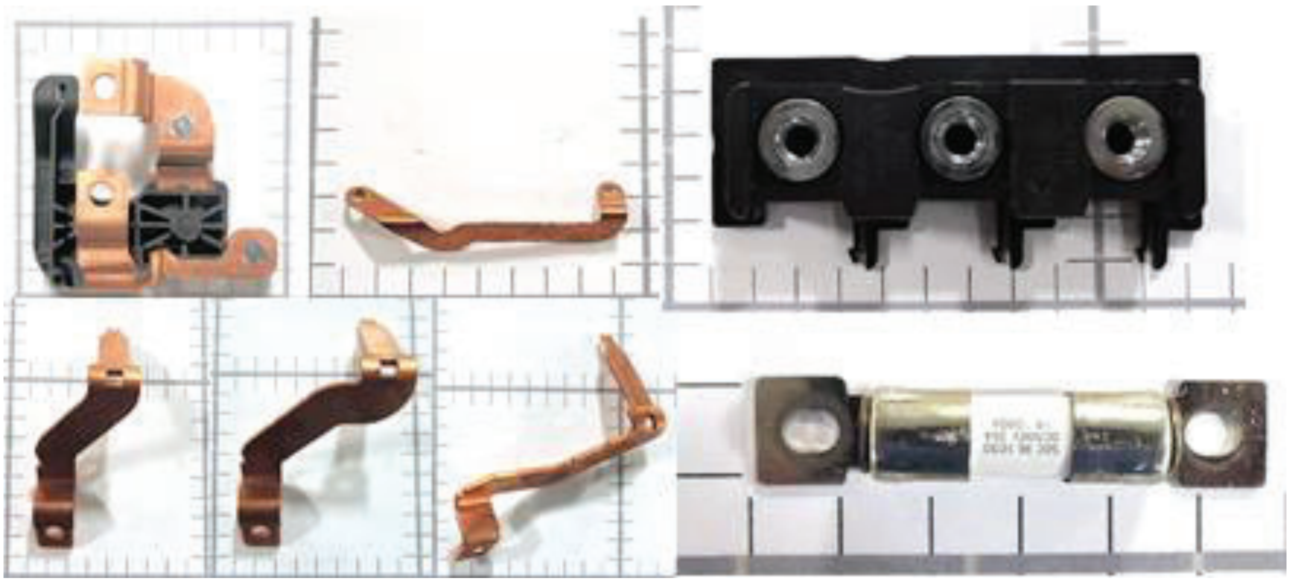


Table F-19 Audi Inverter Bus Bars Group: Design Profit Summary

Design Profit® — **EXECUTIVE SUMMARY**
A3 Inverter Bus Bars

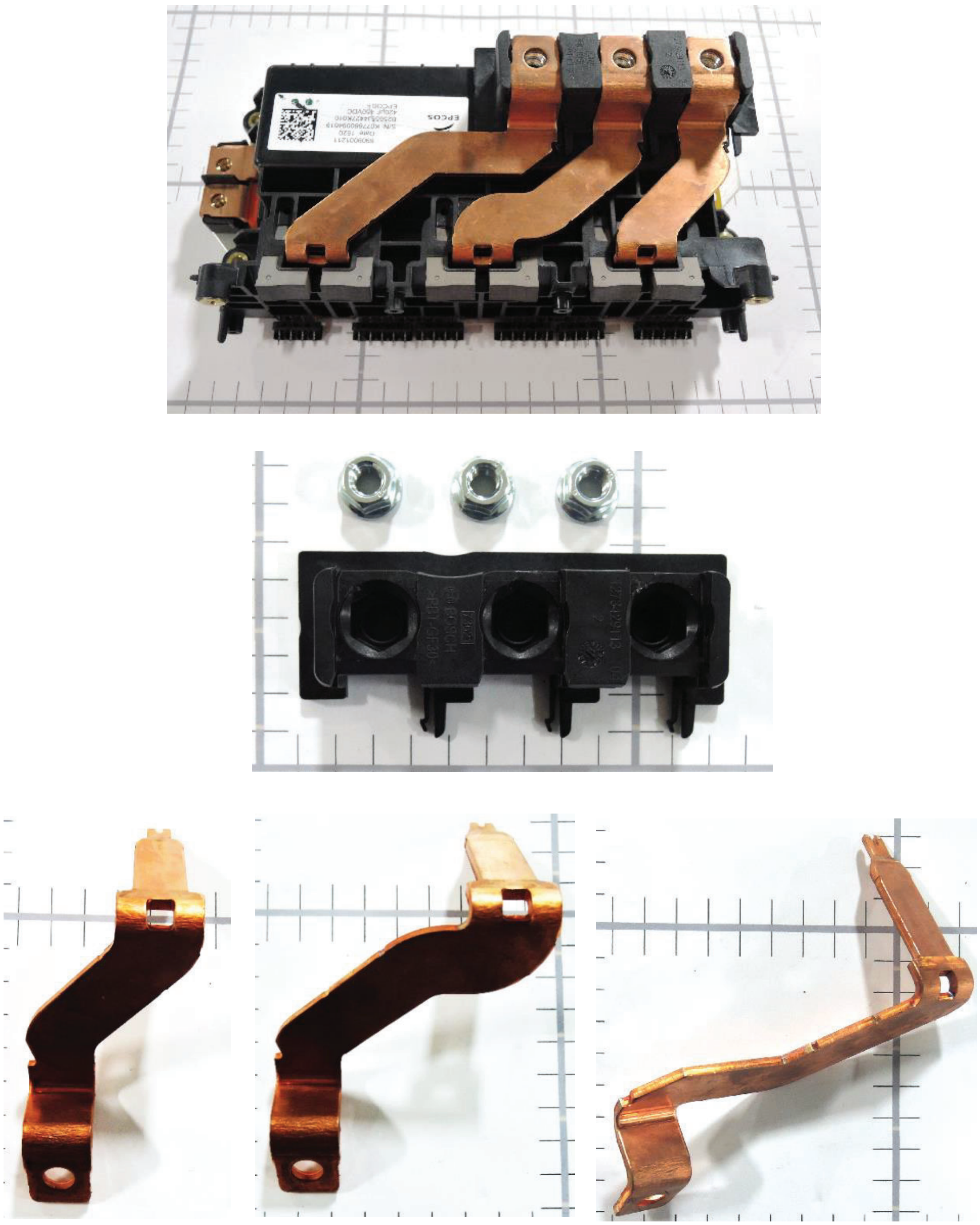
	A3 Inverter Bus Bars
Parts	20
Steps	113
Actual Time	199.04 sec
Fasteners	11
Total Weight	0.51 kg
Piece Cost	$18.63
Total Labor Cost	$1.91
Q Burden	$0.30
Total Cost	$20.85
Annual Production	200000

Table F-20 Audi Inverter Bus Bars Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	A3 PCU Inverter Bus Bars	
Purchased Part Roll up Costs		$6.13
Raw Material Costs		$12.50
Processing Costs		$1.91
Scrap (Design Profit: Q-Burden)	1%	$0.30
SG&A % Applied Against Processing	7%	$0.13
Profit % Applied Against Raw & Processing	4%	$0.58
Logistics % Applied Against Sum of all Above	3%	$0.65
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.44
Total % Mark Up / Total Cost	17%	$22.64
Total Weight (kg)		0.513
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$435,000
Tooling Cost/part		$0.44
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$870,000
Tooling Cost/part		$0.87

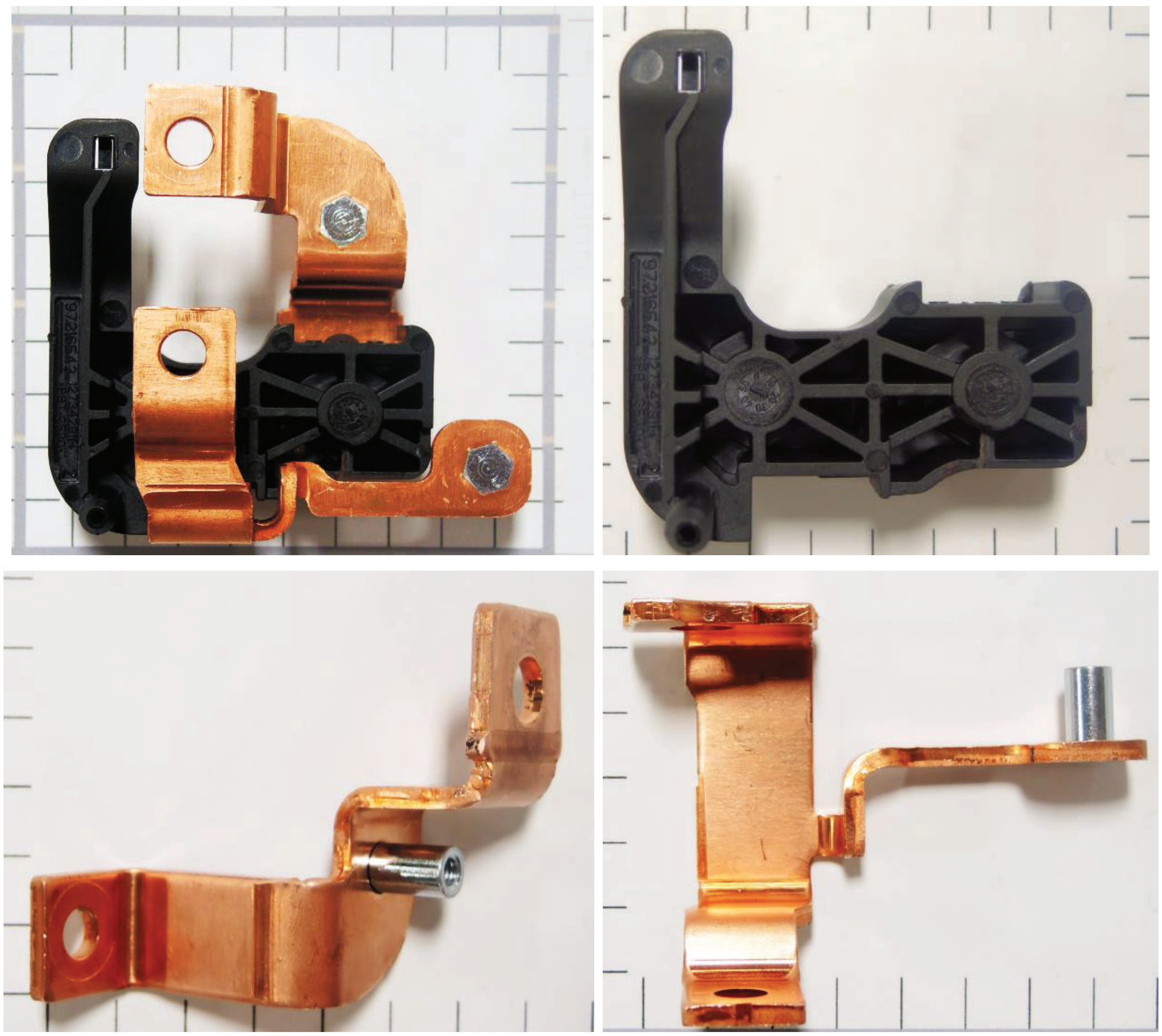
The Audi Inverter motor three phase bus bars consisted of three unique formed copper flat bars (one for each motor phase) and a molded plastic terminal lug bracket containing three threaded fasteners. One end of the bus bar connects to the external wiring via the terminal mount bracket while the other is a press fit to mating terminals below. The terminal lug bracket is an injection molded plastic >PBT GF30<.

Figure F-37 Audi Inverter: Motor Three Phase Bus Bars Installed Top, Lug Bracket with Nuts Center, and Bus Bars Below



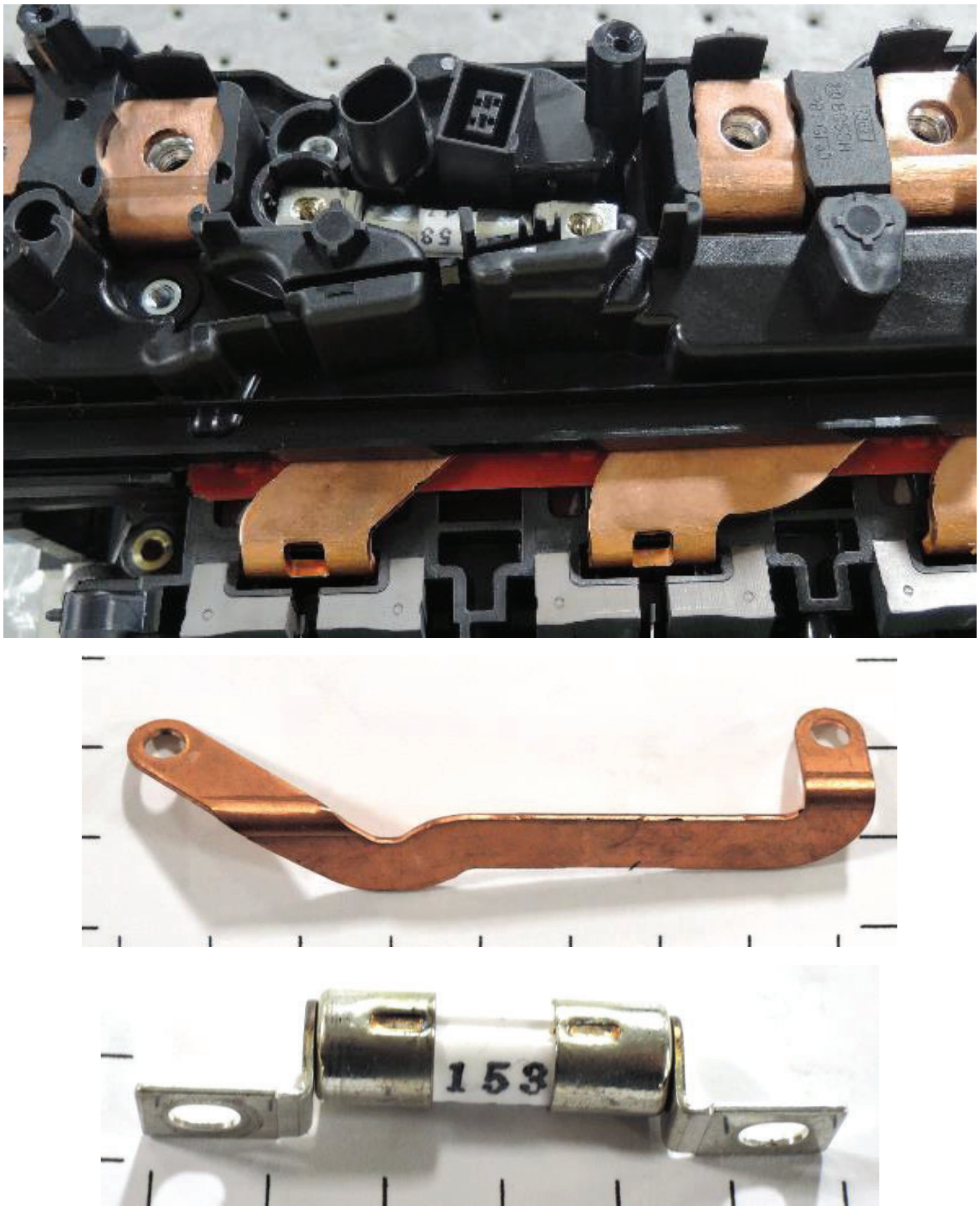
The Audi Inverter high voltage DC bus bars consisted of one sub assembly with a pair of buss bars. Both bus bars are formed flat stock copper and have a threaded standoff inserted. The buss bars snap into a plastic >PBT GF30< injection molded bracket.

Figure F-38 Audi Inverter: High Voltage DC Bus Bar Assembly Top Left, Plastic Bracket Top Right, Bus Bars Bottom



The Audi Inverter contained one unique bus bar connected in series with a 40Amp, 500VDC fuse between the AC and DC circuits connecting to components below. The buss bar is a preformed copper flat stock with on each end for fastener through-hole securing. The fuse used the same through-hole attachment.

Figure F-39 Audi Inverter: Bus Bar Installed Top, Unique Bus Bar Center, and 35 Amp 500VDC Fuse Bottom



Audi Inverter PCBAs & IGBTs

The Audi Inverter Printed Circuit Board Assemblies (PCBAs) and IGBTs group consists of two printed circuit board assemblies and three IGBTs. One PCBA is for IGBT control (motor/generator) and the other providing interface to the DC to DC board and the vehicle electrical system referred to as control/diagnostics board. Three IGBT's are mounted to a heat sink and all electrical connections are press fit.

Figure F-40 Audi Inverter: PCBAs Group

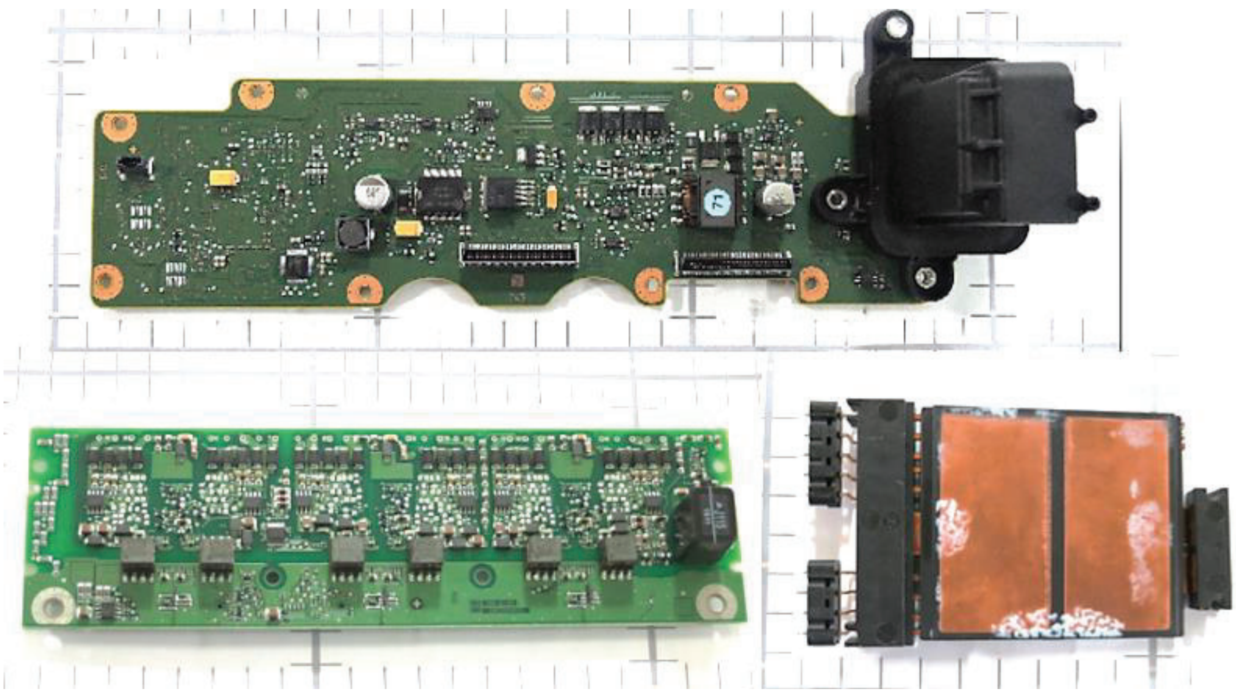


Table F-21 Audi Inverter PCBAs & IGBTs Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
A3 Inverter PCBAs & IGBTs

MUNRO & ASSOCIATES, INC.

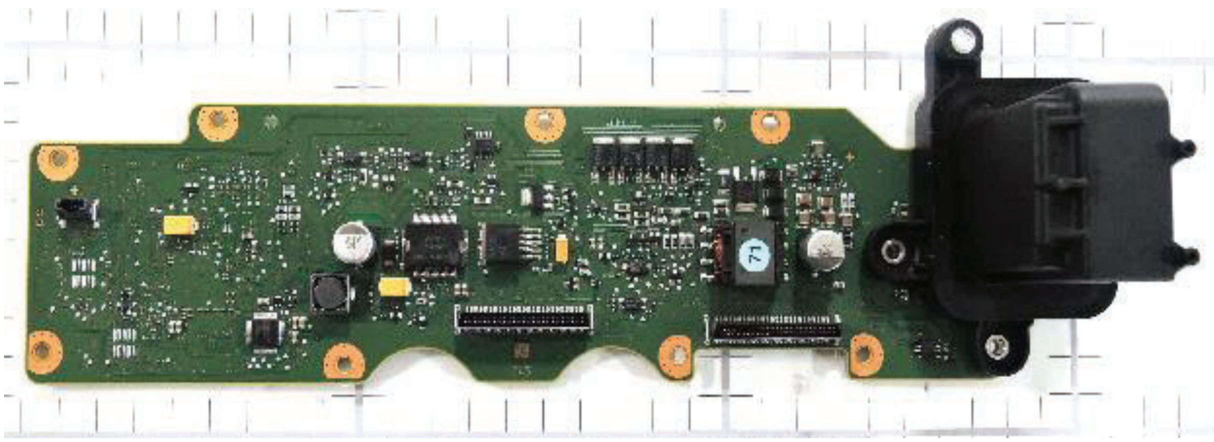
	A3 Inverter PCBAs & IGBTs
Parts	1,702
Steps	3,743
Actual Time	1,371.10 sec
Fasteners	10
Total Weight	0.85 kg
Piece Cost	$208.70
Total Labor Cost	$39.88
Q Burden	$2.64
Total Cost	$251.22
Annual Production	200000

Table F-22 Audi Inverter PCBAs & IGBTs Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		A3 PCU Inverter PCBAs & IGBTs
Purchased Part Roll up Costs		$207.76
Raw Material Costs		$0.94
Processing Costs		$39.88
Scrap (Design Profit: Q-Burden)	1%	$2.64
SG&A % Applied Against Processing	7%	$2.79
Profit % Applied Against Raw & Processing	4%	$1.63
Logistics % Applied Against Sum of all Above	3%	$7.67
Patent/Royalty Fees % Applied Against Sum of all Above	15%	$39.50
Total % Mark Up / Total Cost	30%	$302.81
Total Weight (kg)		0.845
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,825,000
Tooling Cost/part		$1.83
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$3,650,000
Tooling Cost/part		$3.65

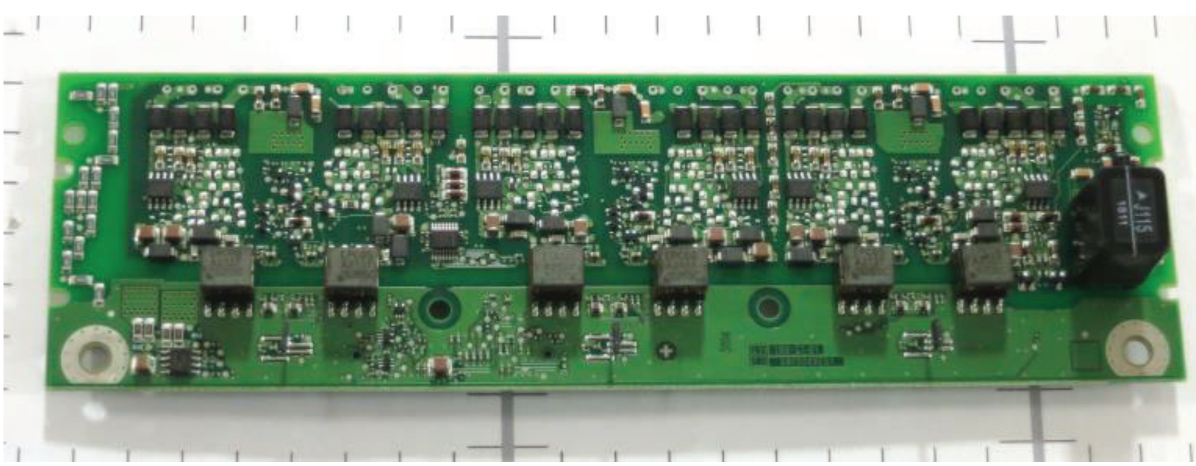
The control/diagnostics board included the following components which are were identified as having the highest cost: 1 - Altera CPLD MAX II Family processor, 1 – Resolver to Digital Converter IC, 1 - TriCore AURIX 32-Bit Microcontroller, 6 layer FR4 Printed Circuit Board, 1 – Bosch Automobile Engine Power Driver IC, and 1 - Current Sensing Transformer. Additional components found on the board include: connector headers, voltage regulators, amplifiers, CAN Transceivers, crystals, MOSFET's, comparators, and various smaller active and passive surface mount components.

Figure F-41 Audi Inverter: Control/Diagnostic PCBA



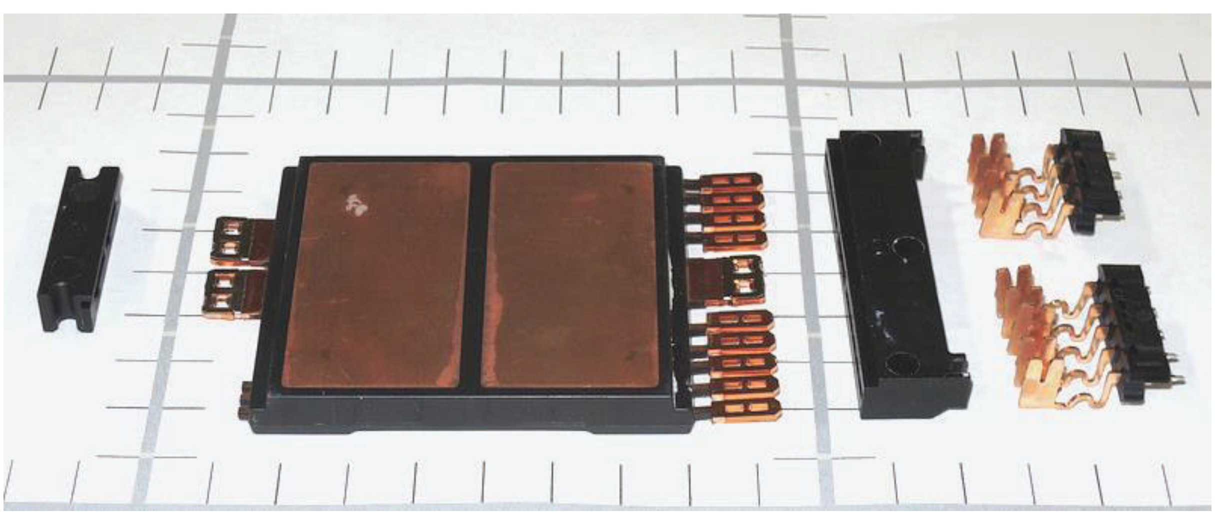
The IGBT Controls board included the following components which are were identified as having the highest cost: 6 Layer FR4 Printed Circuit Board, 1 – 50 Pin Connector, 1 - 12 Bit Analog to Digital Converter, 3 - Gate Drivers Dual Channel IGBT Driver IC, 1 - 560V PTC Resettable Fuse, and 2 - General Purpose 4 Channel Digital Isolator ICs. Additional components found on the board include connecter headers, transformers, voltage regulators and various smaller active and passive surface mount components.

Figure F-9 Audi Inverter: IGBT PCBA



The three IGBT assemblies consist each of 1 - Bosch 600V, 300A Half Bridge IGBT, 4 - Injection molded connectors and 9 Terminals.

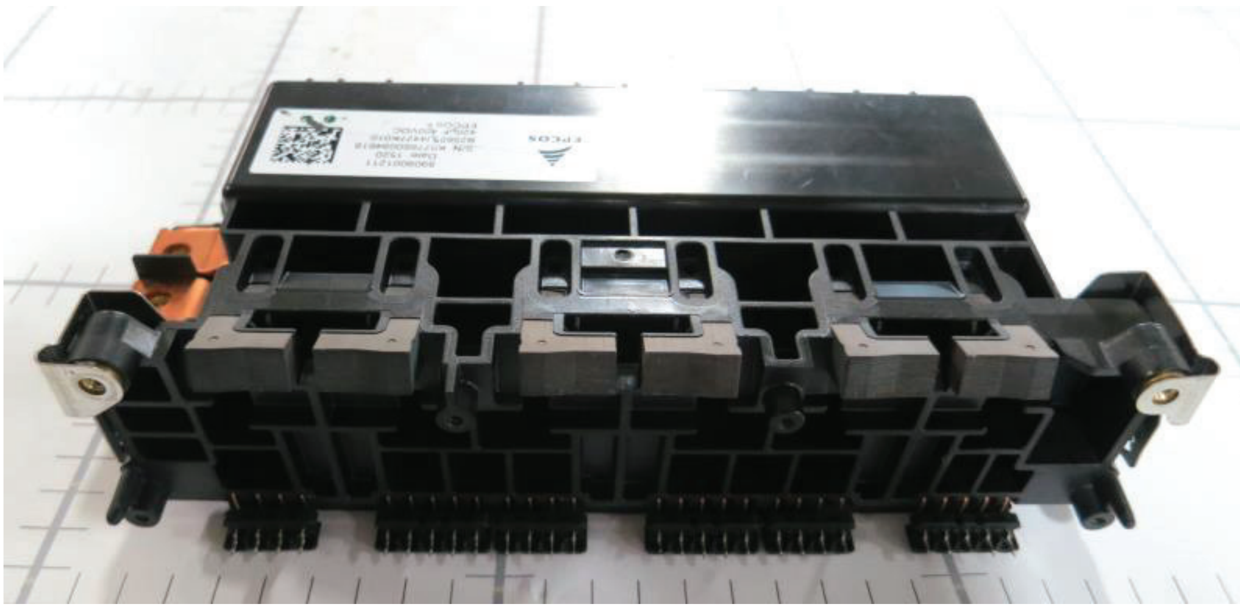
Figure F-42 Audi Inverter: IGBT Half Bridge Assembly (Top), IGBT with Connectors and Terminals (Bottom)



Audi Inverter Capacitor & Inductor

The Audi inverter capacitor & inductors group consisted of a large capacitor subassembly and a toroid inductor. The capacitor assembly included a plastic housing which also had stacked metal laminate cores over-molded with in it for the three phase buss bars.

Figure F-11 Audi Inverter: Capacitor & Inductor Group



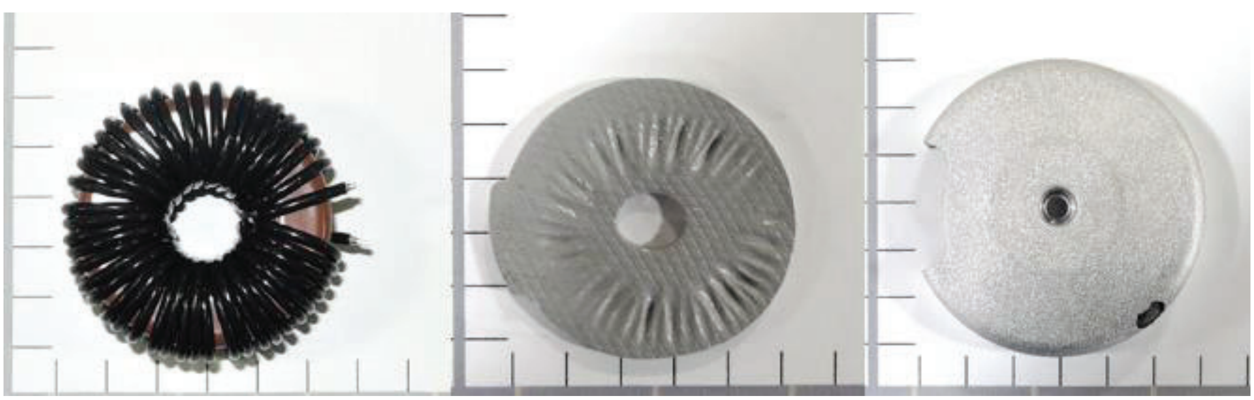


Table F-23 Audi Inverter Capacitor & Inductor Group: Design Profit Summary

Design Profit® EXECUTIVE SUMMARY
A3 Inverter Capacitor & Inductor
MUNRO & ASSOCIATES, INC.

	A3 Inverter Capacitor & Inductor
Parts	154
Steps	1,161
Actual Time	1,035.61 sec
Fasteners	18
Total Weight	1.81 kg
Piece Cost	$47.68
Total Labor Cost	$10.05
Q Burden	$1.49
Total Cost	$59.22
Annual Production	200000

Table F-24 Audi Inverter Capacitor & Inductor Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		A3 PCU Inverter Capacitor & Inductor
Purchased Part Roll up Costs		$31.76
Raw Material Costs		$15.92
Processing Costs		$10.05
Scrap (Design Profit: Q-Burden)	3%	$1.49
SG&A % Applied Against Processing	7%	$0.70
Profit % Applied Against Raw & Processing	4%	$1.04
Logistics % Applied Against Sum of all Above	3%	$1.83
Patent/Royalty Fees % Applied Against Sum of all Above	10%	$6.28
Total % Mark Up / Total Cost	27%	$69.07
Total Weight (kg)		1.8137
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$1,077,500
Tooling Cost/part		$1.08
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$2,155,000
Tooling Cost/part		$2.16

The capacitor assembly included the capacitor pack, a plastic housing which also had stacked metal laminate cores over-molded. The capacitor pack is a large metalized Polypropylene (PP) film design. The metalized polymer is connected with a combination copper and nickel plated copper stamped plates along with insulating layers. The capacitor housing is an injection molded >PPS GF MD< with the three cores inserted and over-molded. The cores consist of 31 stamped steel plates each pressed together.

Figure F-43 Audi Inverter: Capacitor Assembly

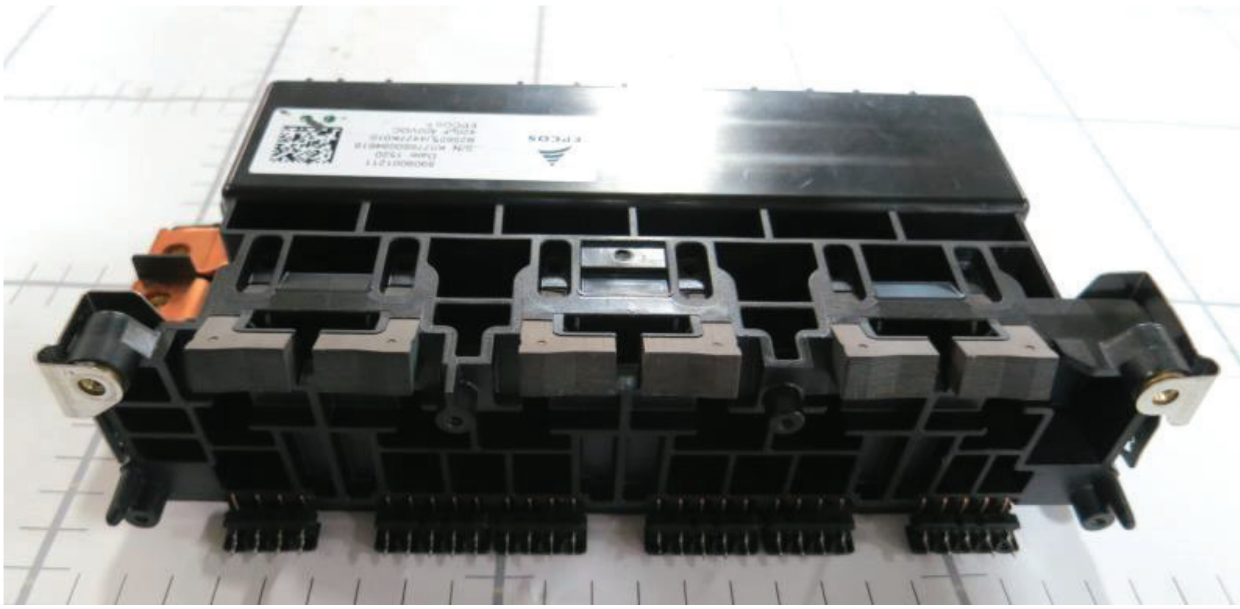


Figure F-44 Audi Inverter: Capacitor

Figure F-45 Audi Inverter: Capacitor Film Assembly Showing Metallized PP Film

Figure F-46 Audi Inverter: Capacitor Housing

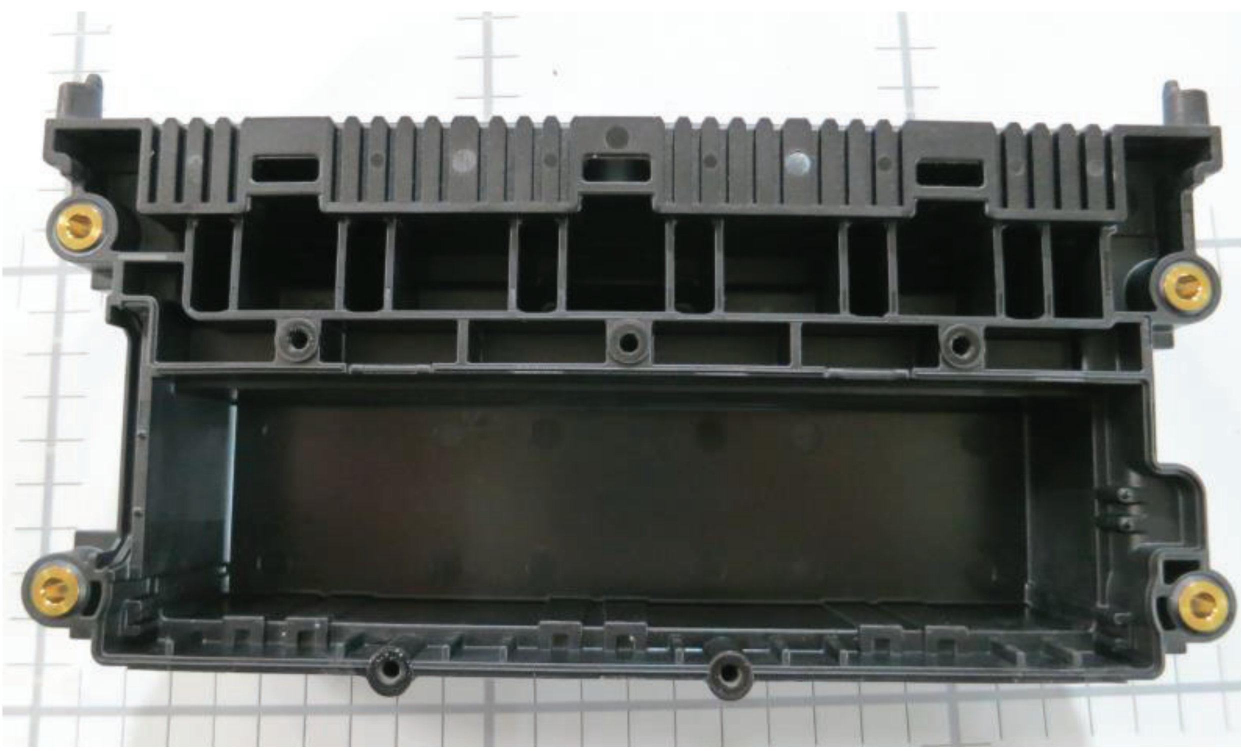
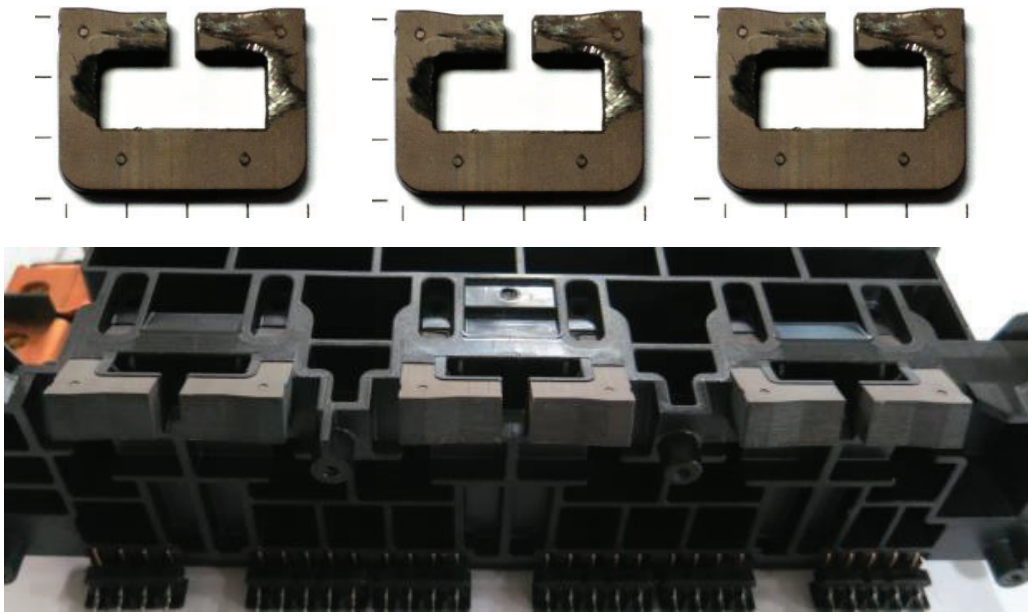


Figure F-47 Audi Inverter: Stamped Laminate Cores (Top), Housing with over-molded Cores (Bottom)



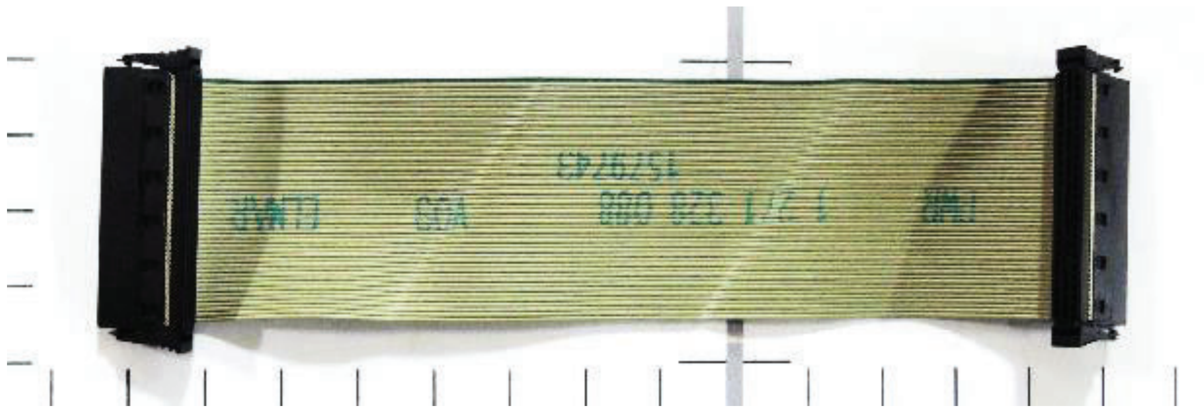
The Toroidal inductor consisted of a coated ferrite toroid core, coated magnet wire, an insulting pad and a die cast cover plate.

Figure F-48 Audi Inverter: Wound Inductor Top Left, Insulting Pad Top Center, Die Cast Cover Top Right, Coated Ferrite Toroid Lower Left, and Coated Magnet Wire Lower Right

Audi Inverter: Electrical & Harness

The Audi Inverter Electrical & Harness group consists of a ribbon cable and the high current electrical connector for interfacing with the vehicle electrical system.

Figure F-49 Audi Inverter: Electrical & Harness Group



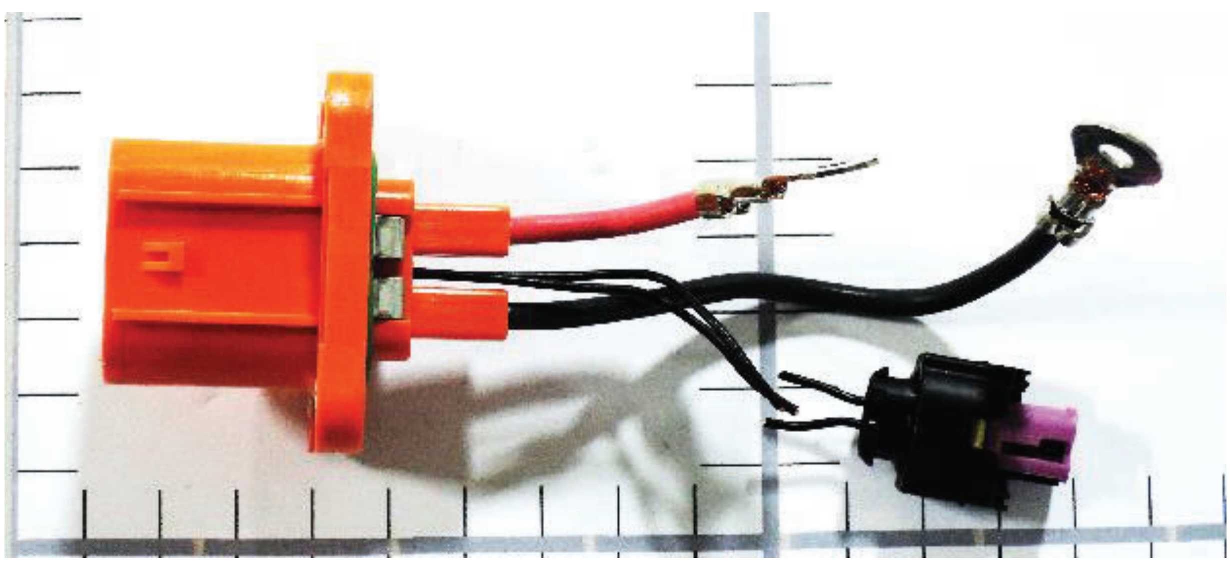


Table F-25 Audi Inverter Electrical & Harness Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

A3 Inverter Electrical & Harness

MUNRO & ASSOCIATES, INC.

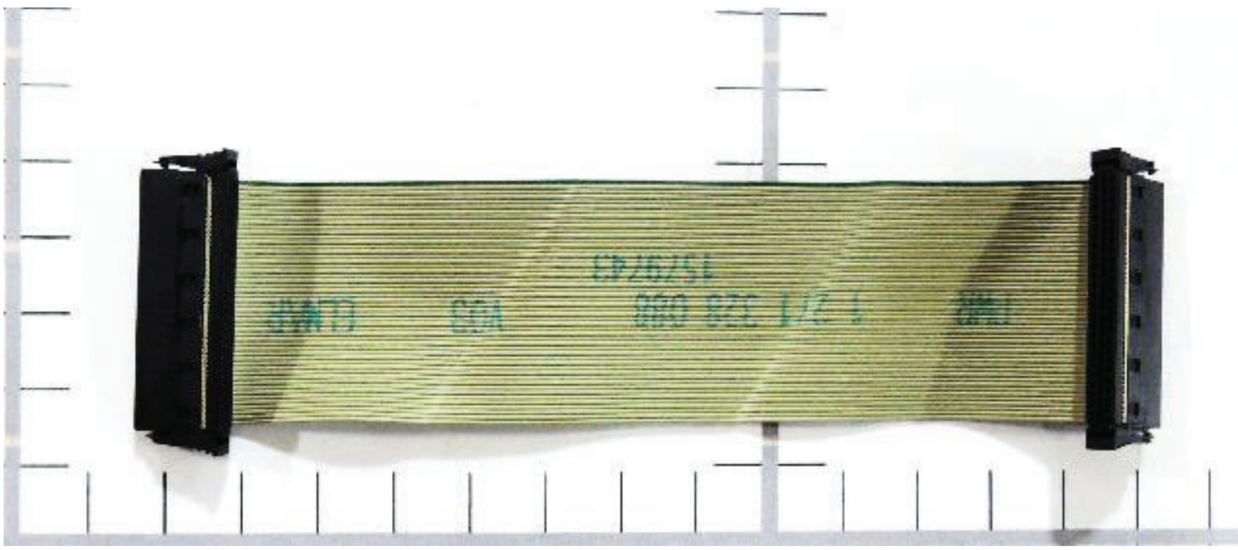
	A3 Inverter Electrical & Harness
Parts	29
Steps	146
Actual Time	320.47 sec
Fasteners	4
Total Weight	0.07 kg
Piece Cost	$2.60
Total Labor Cost	$3.93
Q Burden	$0.44
Total Cost	$6.97
Annual Production	200000

Table F-26 Audi Inverter Electrical & Harness Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		A3 PCU Inverter Electrical & Harness
Purchased Part Roll up Costs		$2.34
Raw Material Costs		$0.26
Processing Costs		$3.93
Scrap (Design Profit: Q-Burden)	7%	$0.44
SG&A % Applied Against Processing	7%	$0.28
Profit % Applied Against Raw & Processing	4%	$0.17
Logistics % Applied Against Sum of all Above	3%	$0.22
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.15
Total % Mark Up / Total Cost	23%	$7.79
Total Weight (kg)		0.0735
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$295,000
Tooling Cost/part		$0.30
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$590,000
Tooling Cost/part		$0.59

The ribbon cable is used to interconnect two circuit boards. Ribbon cables are considered a commodity item and costed accordingly.

Figure F-50 Audi Inverter: Board to Board Jumper Harnesses



The high voltage connector is mounted to the main housing and completes the circuitry connecting the high voltage DC circuits to the internal electronics (large heavy gauge cable. The connector also includes a safety disconnect circuit for protection during servicing of the system. The disconnect circuit is the small gauge which attach to the small black connector in the photo below. The main connector body (orange part in picture below) is injection molded glass filled nylon. The other feature within the connector is a metal connection plate witch interconnects to the shielding circuit with in the high current cable assemblies.

Figure F-51 Audi Inverter: High Voltage Cable Connector

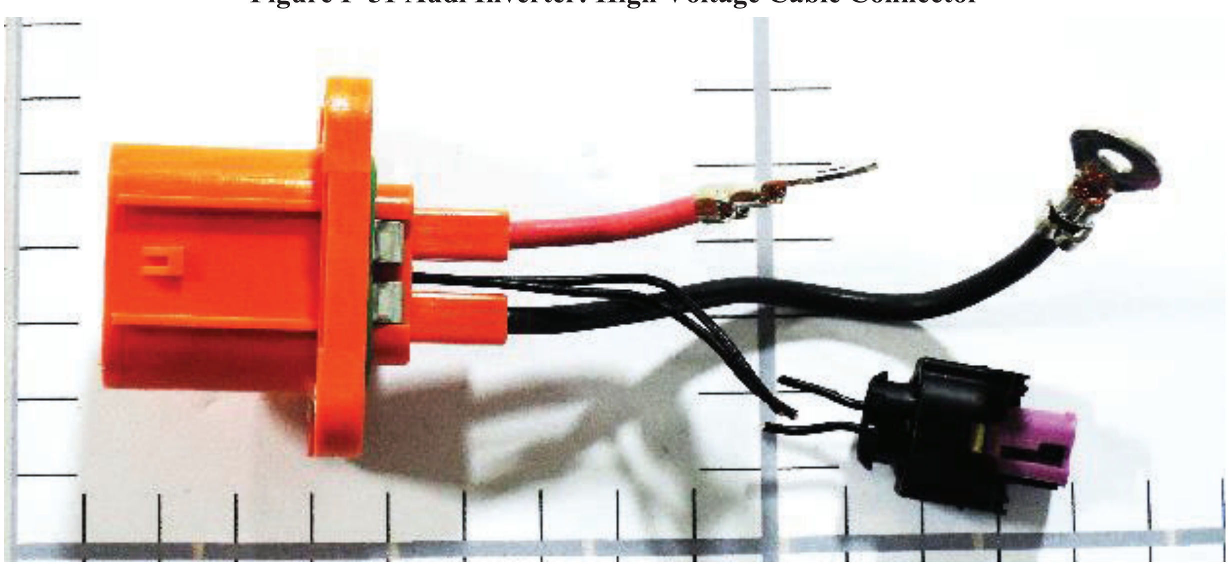


Table F-27 Audi Power Inverter Enclosures & Cooling Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Subassembly	1608-198_1	Cooling Plate Assembly	(None)
2	3	Preprocessed Part	1608-198_1-2-1/2	Cooling Plate Base	Aluminum A413.0, Cast
3	4	Manufacturing Steps		Cooling Plate Base Processing	
4	5	Manufacturing Process		Wash	
5	5	Manufacturing Process		CNC Water Jet Deburr	
6	5	Manufacturing Process		CNC Mill	
7	5	Manufacturing Process		Trim Press, 60 Ton	
8	5	Manufacturing Process		Die Cast, 1800 Ton	
9	6	Part	1608-198_1-2-1/2 Material	Material, Cooling Plate Base	Aluminum A413.0, Cast
10	3	Preprocessed Part	1608-198_1-4-11/1	Cooling Plate Close Out	Aluminum A413.0, Cast
11	4	Manufacturing Steps		Cooling Plate Close Out Processing	
12	5	Manufacturing Process		Wash	
13	5	Manufacturing Process		CNC Water Jet Deburr	
14	5	Manufacturing Process		CNC Mill	
15	5	Manufacturing Process		Trim Press, 60 Ton	
16	5	Manufacturing Process		Die Cast, 1050 Ton	
17	6	Part	1608-198_1-4-11/1 Material	Material, Cooling Plate Close Out	Aluminum A413.0, Cast
18	3	Part	1608-198_1-1	M8 x 1.25 Stud	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
19	3	Manufacturing Steps		Cooling Plate Assembly Processing	
20	4	Manufacturing Process		Manual Asm	
21	4	Manufacturing Process		Wash	
22	4	Manufacturing Process		CNC Water Jet Deburr	
23	4	Manufacturing Process		CNC Mill	
24	4	Manufacturing Process		CNC Mill	
25	4	Manufacturing Process		CNC Mill	
26	4	Manufacturing Process		CNC Mill	
27	4	Manufacturing Process		Friction Stir Weld	
28	2	Subassembly	1608-158_1	Coolant Outlet Asm	(None)
29	3	Preprocessed Part	1608-158_3	Coolant Outlet	PA 6/6 GF30
30	4	Manufacturing Steps		Coolant Outlet, Processing	
31	5	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
32	6	Part	1608-158_6	Metal Insert	Commodity Item
33	6	Part	1608-158_3 Material	Material, Coolant outlet	PA 6/6 GF30
34	3	Part	1608-158_5	Coolant Pipes O-Ring	Commodity Item
35	3	Manufacturing Steps		Coolant Outlet and O-Ring Assembly	
36	4	Manufacturing Process		Auto Asm	
37	2	Subassembly	1608-158_2	Coolant Inlet Asm	(None)
38	3	Preprocessed Part	1608-158_4	Coolant Inlet	PA 6/6 GF30

Row	Level	Symbol Type	Number	Name	Material Name
39	4	Manufacturing Steps		Coolant Inlet, Processing	
40	5	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
41	6	Part	1608-158_6	Metal Insert	Commodity Item
42	6	Part	1608-158_4 Material	Material, Coolant Inlet	PA 6/6 GF30
43	3	Part	1608-158_5	Coolant Pipes O-Ring	Commodity Item
44	3	Manufacturing Steps		Coolant Outlet and O-Ring Assembly	
45	4	Manufacturing Process		Auto Asm	
46	2	Part	1608-128_21	M6x1.00, 16.25 mm, Female Torx	Commodity Item
47	2	Manufacturing Steps		Coolant Inlet/Outlet to Enclosure Main 2 Assembly	
48	3	Manufacturing Process		Auto Asm	
49	2	Subassembly	1608_2	Main Housing Assembly	(None)
50	3	Subassembly	1608-116_1	Main Housing	(None)
51	4	Preprocessed Part	1608-116	Main Housing	Aluminum A413.0, Cast
52	5	Manufacturing Steps		Main Housing Processing	
53	6	Manufacturing Process		Wash	
54	6	Manufacturing Process		CNC Water Jet Deburr	
55	6	Manufacturing Process		Machine	
56	6	Manufacturing Process		Trim Press, 25 Ton	
57	6	Manufacturing Process		Die Cast, 530 Ton	
58	7	Part	1608-116 Material	Material, Main Housing	Aluminum A413.0, Cast
59	4	Part	1608-116_4	Supplier Reference Label	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
60	4	Part	1608-116_5	Barcode Label	Commodity Item
61	4	Part	1608-116_6	Inspection Label	Commodity Item
62	4	Part	524-1397_2O	Silicone RTV Clear	Commodity Item
63	4	Manufacturing Steps		Install Labels to Enclosure Main Asm	
64	5	Manufacturing Process		Apply Silicone	
65	5	Manufacturing Process		Manual Asm	
66	3	Subassembly	1608-122	Plug Asm	(None)
67	4	Preprocessed Part	1608-122_1	Plug w/ Filter	PBT GF30
68	5	Manufacturing Steps		Plug w/ Filter Processing	
69	6	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
70	7	Part	1608-122_4	Filter, Plug w/Filter	Commodity Item
71	7	Part	1608-122_1 Material	Material, Plug w/ Filter	PBT GF30
72	4	Preprocessed Part	1608-122_2	Plug Cap	PBT GF30
73	5	Manufacturing Steps		Plug Cap Processing	
74	6	Manufacturing Process		Injection Mold Press, 55 Ton	
75	7	Part	1608-122_2 Material	Material, Plug Cap	PBT GF30
76	4	Part	1608-122_3	Plug O-Ring	Commodity Item
77	4	Manufacturing Steps		Plug Assembly	
78	5	Manufacturing Process		Auto Asm	
79	3	Subassembly	1608-122	Plug Asm	(None)
80	4	Preprocessed Part	1608-122_1	Plug w/ Filter	PBT GF30
81	5	Manufacturing Steps		Plug w/ Filter Processing	

Row	Level	Symbol Type	Number	Name	Material Name
82	6	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
83	7	Part	1608-122_4	Filter, Plug w/Filter	Commodity Item
84	7	Part	1608-122_1 Material	Material, Plug w/ Filter	PBT GF30
85	4	Preprocessed Part	1608-122_2	Plug Cap	PBT GF30
86	5	Manufacturing Steps		Plug Cap Processing	
87	6	Manufacturing Process		Injection Mold Press, 55 Ton	
88	7	Part	1608-122_2 Material	Material, Plug Cap	PBT GF30
89	4	Part	1608-122_3	Plug O-Ring	Commodity Item
90	4	Manufacturing Steps		Plug Assembly	
91	5	Manufacturing Process		Auto Asm	
92	3	Manufacturing Steps		Assemble Main Housing	
93	4	Manufacturing Process		Auto Asm	
94	2	Part	1608-116_21	M5x0.80, 16mm, Female Torx	Commodity Item
95	2	Part	1608-137_6	M4x0.70, 10mm, Female Torx w/ Captured Washer	Commodity Item
96	2	Manufacturing Steps		Assemble Main Enclosures	
97	3	Manufacturing Process		Manual Asm	
98	3	Manufacturing Process		Auto Asm	
99	2	Preprocessed Part	1608-125	Lid Disconnect Support Gasket	(None)
100	3	Manufacturing Steps		Lid Disconnect Support Gasket, Processing	
101	4	Manufacturing Process		Injection Mold Press, 55 Ton 2 Shot	
102	5	Part	1608-125 Material	Material, Lid Disconnect Support Gasket	PBT CF20

Row	Level	Symbol Type	Number	Name	Material Name
103	5	Part	1608-125 Material-1	Material, Lid Disconnect Support Gasket	VMQ/MVQ Silicone
104	2	Subassembly	1608_1	Enclosure Top Asm	(None)
105	3	Subassembly	1608-128_1	Enclosure Top Asm	(None)
106	4	Preprocessed Part	1608-128	Enclosure Top	Aluminum A360
107	5	Manufacturing Steps		Enclosure Top Processing	
108	6	Manufacturing Process		Wash	
109	6	Manufacturing Process		Debur	
110	6	Manufacturing Process		Machine	
111	6	Manufacturing Process		Trim Press, 25 Ton	
112	6	Manufacturing Process		Die Cast, 840 Ton	
113	7	Part	1608-128 Material	Material, Enclosure Top	Aluminum A360
114	4	Part	1608-128_41	Supplier Reference Label	Commodity Item
115	4	Part	1608-128_5	Inspection Label	Commodity Item
116	4	Manufacturing Steps		Install Label	
117	5	Manufacturing Process		Manual Asm	
118	3	Preprocessed Part	1608-127	Lid Disconnect Switch	PBT CF30
119	4	Manufacturing Steps		Lid Disconnect Switch Processing	
120	5	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
121	6	Part	Insert Pins, Lid Disconnect Switch	Insert Pins, Lid Disconnect Switch	Commodity Item
122	6	Part	1608-127 Material	Material, Lid Disconnect Switch	PBT CF30
123	3	Part	1608-127_1	M4x.70, 9.75mm, Female Torx w/ Captured Washer	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
124	3	Manufacturing Steps		Enclosure Top Assembly	
125	4	Manufacturing Process		Auto Asm	
126	2	Part	1608-128_21	M6x1.00, 16.25 mm, Female Torx	Commodity Item
127	2	Manufacturing Steps		Top Enclosure and Gasket Assembly	
128	3	Manufacturing Process		Auto Asm	
129	2	Subassembly	1608-157	Enclosure Bottom	(None)
130	3	Preprocessed Part	1608-157_1	Enclosure Bottom	Aluminum 6061
131	4	Manufacturing Steps		Enclosure Bottom Processing	
132	5	Manufacturing Process		Wash	
133	5	Manufacturing Process		Debur	
134	5	Manufacturing Process		Stamping Press, 300 Ton	
135	6	Part	1608-157_1 Material	Material, Enclosure Bottom	Aluminum 6061
136	3	Preprocessed Part	1608-157_2	Foam Backing 1	Low Density Foam, Adhesive Backed
137	4	Manufacturing Steps		Foam Backing 1 Processing	
138	5	Manufacturing Process		Trim Press, 25 Ton	
139	6	Part	1608-157_2 Material	Material, Foam Backing 1	Low Density Foam, Adhesive Backed
140	3	Preprocessed Part	1608-157_3	Foam Backing 2	Low Density Foam, Adhesive Backed
141	4	Manufacturing Steps		Foam Backing 2 Processing	
142	5	Manufacturing Process		Trim Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
143	6	Part	1608-157_3 Material	Material, Foam Backing 2	Low Density Foam, Adhesive Backed
144	3	Part	524-1397_2O	Silicone	Commodity Item
145	3	Part	1608-185_6	Plain Label	Commodity Item
146	3	Manufacturing Steps		Enclosure Bottom Assembly	
147	4	Manufacturing Process		Auto Asm	
148	4	Manufacturing Process		Manual Asm	
149	2	Part	1608-116_21	M5x0.80, 16mm, Female Torx	Commodity Item
150	2	Manufacturing Steps		Assemble Enclosure Bottom	
151	3	Manufacturing Process		Auto Asm	
152	2	Part	1608-128_3	Caution label	Commodity Item
153	2	Manufacturing Steps		Install Caution Label to Module	
154	3	Manufacturing Process		Manual Asm	

Table F-28 Audi Power Inverter Enclosures & Cooling Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 PCU Enclosure & Cooling

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-198_1	**Cooling Plate Assembly**	**$6.61**	**1**	**$6.61**
1608-198_1-2-1/2	**Cooling Plate Base**	**$4.63**	**1**	**$4.63**
1608-198_1-2-1/2 Material	Material, Cooling Plate Base	$4.63	1	$4.63
1608-198_1-4-11/1	**Cooling Plate Close Out**	**$1.92**	**1**	**$1.92**
1608-198_1-4-11/1 Material	Material, Cooling Plate Close Out	$1.92	1	$1.92
1608-198_1-1	M8 x 1.25 Stud	$0.06	1	$0.06
1608-158_1	**Coolant Outlet Asm**	**$0.14**	**1**	**$0.14**
1608-158_3	**Coolant Outlet**	**$0.10**	**1**	**$0.10**
1608-158_6	Metal Insert	$0.02	2	$0.04
1608-158_3 Material	Material, Coolant outlet	$0.06	1	$0.06
1608-158_5	Coolant Pipes O-Ring	$0.04	1	$0.04
1608-158_2	**Coolant Inlet Asm**	**$0.15**	**1**	**$0.15**
1608-158_4	**Coolant Inlet**	**$0.11**	**1**	**$0.11**
1608-158_6	Metal Insert	$0.02	2	$0.04
1608-158_4 Material	Material, Coolant Inlet	$0.07	1	$0.07
1608-158_5	Coolant Pipes O-Ring	$0.04	1	$0.04
1608-128_21	M6x1.00, 16.25 mm, Female Torx	$0.02	4	$0.08
1608_2	**Main Housing Assembly**	**$4.89**	**1**	**$4.89**
1608-116_1	**Main Housing**	**$4.19**	**1**	**$4.19**
1608-116	**Main Housing**	**$3.75**	**1**	**$3.75**
1608-116 Material	Material, Main Housing	$3.75	1	$3.75
1608-116_4	Supplier Reference Label	$0.06	1	$0.06
1608-116_5	Barcode Label	$0.02	1	$0.02
1608-116_6	Inspection Label	$0.01	1	$0.01
524-1397_2O	Silicone RTV Clear	$0.36	1	$0.36
1608-122	**Plug Asm**	**$0.35**	**1**	**$0.35**
1608-122_1	**Plug w/ Filter**	**$0.31**	**1**	**$0.31**
1608-122_4	Filter, Plug w/Filter	$0.30	1	$0.30
1608-122_1 Material	Material, Plug w/Filter	$0.01	1	$0.01
1608-122_2	**Plug Cap**	**$0.01**	**1**	**$0.01**
1608-122_2 Material	Material, Plug Cap	$0.01	1	$0.01
1608-122_3	Plug O-Ring	$0.03	1	$0.03
1608-122	**Plug Asm**	**$0.35**	**1**	**$0.35**
1608-122_1	**Plug w/ Filter**	**$0.31**	**1**	**$0.31**
1608-122_4	Filter, Plug w/Filter	$0.30	1	$0.30
1608-122_1 Material	Material, Plug w/Filter	$0.01	1	$0.01
1608-122_2	**Plug Cap**	**$0.01**	**1**	**$0.01**
1608-122_2 Material	Material, Plug Cap	$0.01	1	$0.01
1608-122_3	Plug O-Ring	$0.03	1	$0.03
1608-116_21	M5x0.80, 16mm, Female Torx	$0.01	10	$0.10
1608-137_6	M4x0.70, 10mm, Female Torx w/ Captured Washer	$0.06	2	$0.12
1608-125	**Lid Disconnect Support Gasket**	**$0.21**	**1**	**$0.21**
1608-125 Material	Material, Lid Disconnect Support Gasket	$0.12	1	$0.12
1608-125 Material-1	Material, Lid Disconnect Support Gasket	$0.09	1	$0.09
1608_1	**Enclosure Top Asm**	**$0.80**	**1**	**$0.80**
1608-128_1	**Enclosure Top Asm**	**$0.73**	**1**	**$0.73**

A3 PCU Enclosure & Cooling

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-128	**Enclosure Top**	**$0.65**	**1**	**$0.65**
1608-128 Material	Material, Enclosure Top	$0.65	1	$0.65
1608-128_41	Supplier Reference Label	$0.06	1	$0.06
1608-128_5	Inspection Label	$0.02	1	$0.02
1608-127	**Lid Disconnect Switch**	**$0.05**	**1**	**$0.05**
Insert Pins, Lid Disconnect Switch	Insert Pins, Lid Disconnect Switch	$0.02	2	$0.04
1608-127 Material	Material, Lid Disconnect Switch	$0.01	1	$0.01
1608-127_1	M4x.70, 9.75mm, Female Torx w/ Captured Washer	$0.01	2	$0.02
1608-128_21	M6x1.00, 16.25 mm, Female Torx	$0.02	7	$0.14
1608-157	**Enclosure Bottom**	**$3.09**	**1**	**$3.09**
1608-157_1	**Enclosure Bottom**	**$2.74**	**1**	**$2.74**
1608-157_1 Material	Material, Enclosure Bottom	$2.74	1	$2.74
1608-157_2	**Foam Backing 1**	**$0.02**	**1**	**$0.02**
1608-157_2 Material	Material, Foam Backing 1	$0.02	1	$0.02
1608-157_3	**Foam Backing 2**	**$0.01**	**1**	**$0.01**
1608-157_3 Material	Material, Foam Backing 2	$0.01	1	$0.01
524-1397_2O	Silicone	$0.31	1	$0.31
1608-185_6	Plain Label	$0.01	1	$0.01
1608-116_21	M5x0.80, 16mm, Female Torx	$0.01	11	$0.11
1608-128_3	Caution label	$0.04	3	$0.13

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	25	**Piece Cost (Total):** $16.57	***Analyzed Subs:***	*0*
Unanalyzed Subs:	0		***Unanalyzed Subs:***	*0*
Parts:	76		***Parts:***	*0*
Fasteners:	36		***Fasteners:***	*0*
Parts+Unanalyzed:	76		***Parts+Unanalyzed:***	*0*

Table F-29 Audi DC/DC Internal Housing Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Preprocessed Part	1608-172	Bus Bar Assembly Support	Aluminum A413.0, Cast
2	4	Manufacturing Steps		Bus Bar Assembly Support Processing	
3	5	Manufacturing Process		Wash	
4	5	Manufacturing Process		Debur	
5	5	Manufacturing Process		Trim Press, 25 Ton	
6	5	Manufacturing Process		Aluminum Die Casting,	
7	6	Part	1608-172 Material	Material, Bus Bar Assembly Support	Aluminum A413.0, Cast
8	3	Part	1608-161_1	M4x0.70, 12 mm, Female Torx	Commodity Item
9	3	Manufacturing Steps		Bus Bar Assembly Support to Enclosure Main 2	
10	4	Manufacturing Process		Auto Asm	
11	3	Preprocessed Part	1608-172	Bus Bar Assembly Support	Aluminum A413.0, Cast
12	4	Manufacturing Steps		Bus Bar Assembly Support Processing	

Table F-30 Audi DC/DC Internal Housing Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 DC/DC Converter Internal Housing

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-172	**Bus Bar Assembly Support**	**$0.10**	**1**	**$0.10**
1608-172 Material	Material, Bus Bar Assembly Support	$0.10	1	$0.10
1608-161_1	M4x0.70, 12 mm, Female Torx	$0.01	3	$0.03

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	1	Piece Cost (Total): $0.13	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	4		*Parts:*	*0*
Fasteners:	3		*Fasteners:*	*0*
Parts+Unanalyzed:	4		*Parts+Unanalyzed:*	*0*

Table F-31 Audi DC/DC Buss Bars Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1608-168	Bus Bar 5 Asm	(None)
2	4	Preprocessed Part	1608-168_1	Bus Bar 5	Copper Cu (10200)
3	5	Manufacturing Steps		Bus Bar 5 Processing	
4	6	Manufacturing Process		Wash	
5	6	Manufacturing Process		Debur	
6	6	Manufacturing Process		Bending	
7	6	Manufacturing Process		Stamping Press, 300 Ton	
8	7	Part	1608-168_1 Material	Material, Bus Bar 5	Copper Cu (10200)
9	4	Part	1608-168_2	M4 PEM Nut	Commodity Item
10	4	Manufacturing Steps		Bus Bar 5 and PEM nuts Assembly	
11	5	Manufacturing Process		Automated Press	
12	3	Subassembly	1608-169_1	Bus Bar 6 Asm	(None)
13	4	Preprocessed Part	1608-169_1a	Bus Bar 6	Copper Cu (10200)
14	5	Manufacturing Steps		Bus Bar 6 Processing	
15	6	Manufacturing Process		Wash	
16	6	Manufacturing Process		Debur	
17	6	Manufacturing Process		Stamping Press, 60 Ton	
18	7	Part	1608-169_1 Material	Material, Bus Bar 6	Copper Cu (10200)
19	4	Part	1608-168_2	M4 PEM Nut	Commodity Item
20	4	Manufacturing Steps		Bus Bar 6 and PEM nuts Assembly	

Row	Level	Symbol Type	Number	Name	Material Name
21	5	Manufacturing Process		Automated Press	
22	3	Preprocessed Part	1608-186	Bus Bar 7	Copper Cu (10200)
23	4	Manufacturing Steps		Bus Bar 7 Processing	
24	5	Manufacturing Process		Wash	
25	5	Manufacturing Process		Debur	
26	5	Manufacturing Process		Stamping Press, 25 Ton	
27	6	Part	1608-186 Material	Material, Bus Bar 7	Copper Cu (10200)
28	3	Part	1608-127_1	M4x.70, 10 mm, Female Torx w/ Captured Washer	Commodity Item
29	3	Manufacturing Steps		Assemble Bus Bars	
30	4	Manufacturing Process		Auto Asm	

Table F-32 Audi DC/DC Buss Bars Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 DC/DC Converter Bus Bars

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-168	**Bus Bar 5 Asm**	**$1.80**	**1**	**$1.80**
1608-168_1	**Bus Bar 5**	**$1.65**	**1**	**$1.65**
1608-168_1 Material	Material, Bus Bar 5	$1.65	1	$1.65
1608-168_2	M4 PEM Nut	$0.05	3	$0.15
1608-169_1	**Bus Bar 6 Asm**	**$0.48**	**1**	**$0.48**
1608-169_1a	**Bus Bar 6**	**$0.43**	**1**	**$0.43**
1608-169_1 Material	Material, Bus Bar 6	$0.43	1	$0.43
1608-168_2	M4 PEM Nut	$0.05	1	$0.05
1608-186	**Bus Bar 7**	**$0.14**	**1**	**$0.14**
1608-186 Material	Material, Bus Bar 7	$0.14	1	$0.14
1608-127_1	M4x.70, 10 mm, Female Torx w/ Captured Washer	$0.01	6	$0.06

Assembly Totals

Analyzed Subs:	5
Unanalyzed Subs:	0
Parts:	13
Fasteners:	10
Parts+Unanalyzed:	13

Report Totals

Piece Cost (Total): $2.48

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

Table F-33 Audi DC/DC PCBAs Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1608-194	Circuit Board 4 Asm	(None)
2	4	Subassembly	1608-194_1	Circuit Board 4	(None)
3	5	Manufacturing Steps		Printed Circuit Board Assembly	
4	6	Manufacturing Process		Functional Test	
5	6	Manufacturing Process		De-Panel	
6	6	Manufacturing Process		PCB - Med Content	
7	7	Part	1608-194_1a	Printed FR4 Circuit Board	Commodity Item
8	8	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
9	8	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
10	8	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item
11	9	Part	0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
12	9	Part	0603 Resistors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
13	9	Part	0805 Resistors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
14	9	Part	1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
15	9	Part	CMA02040X2209GB300	RES SMD 22 OHM 2% 0.4W 0204	Commodity Item
16	9	Part	0402 Capacitor	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
17	9	Part	0603 Capacitor	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
18	9	Part	0805 Capacitor	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
19	9	Part	1206 Capacitor	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
20	9	Part	1210 Capacitor	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	Commodity Item
21	9	Part	TLE42764D V50	Linear Voltage Regulator IC Positive Fixed PG-TO25	Commodity Item
22	9	Part	EPM570T100A5N	Altera CPLD MAX II Family	Commodity Item
23	9	Part	ISO7221CQDRQ1	General Purpose Digital Isolator 4000Vpk 2	Commodity Item
24	9	Part	TJA1042T/3/118	High Speed CAN Transceiver	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
25	9	Part	BSS84PH6433XTMA1	Small Signal Transistor	Commodity Item
26	9	Part	DDZX43-7	Zener Diodes 300MW 43V	Commodity Item
27	9	Part	RP500N151A-TR-FE	Switching Regulators Buck DC/DC Converter	Commodity Item
28	9	Part	BZX84B6V8-7-F	Zener Diodes 350mW Prec Zener 2.7 to 39V 300mW	Commodity Item
29	9	Part	CMPT4401 TR	TRANS NPN 40V 0.6A SOT-23	Commodity Item
30	9	Part	BZX84B43-7-F	Zener Diodes 350mW Prec Zener 4.7V 5mA 3uA	Commodity Item
31	9	Part	SSM3K7002KF	N-Ch MOSFET 60V 0.4A	Commodity Item
32	9	Part	S9S12G48F0MLH	MCU 16-bit 48KB Flash 3.3V/5V Automotive 48-Pin LQ	Commodity Item
33	9	Part	S-1133B00-I8T1U	LDO Voltage Regulators LDO REG HI 60uA Iq 300mA Io	Commodity Item
34	9	Part	AP2210N-3.3TRG1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	Commodity Item
35	9	Part	BZX585-B33	Zener Diodes DIODE ZENER 2 PCT	Commodity Item
36	9	Part	BB565H7902XTSA1	Diode VAR Cap Single 30V 18.5pF 2-Pin SCD-80 T/R	Commodity Item
37	9	Part	BZX84B18-7-F	Zener Diode 18V 300mW 2% Surface Mount SOT-23	Commodity Item
38	9	Part	BUK9275-100A	MOSFET N-CH 100V 21.7A DPAK	Commodity Item
39	9	Part	BZX84C2V4LT1G	Zener Diode 2.4V 225mW 8% Surface Mount SOT-23-3	Commodity Item
40	9	Part	AZ23C4V7-7-F	Zener Diode Array 4.7V 300mW 5% SOT-23-3	Commodity Item
41	9	Part	MUN5116DW1T1G	Bipolar Transistors - Pre-Biased 100mA 50V BRT Dua	Commodity Item
42	9	Part	ISO7240CFQDWRQ1	Dig Isolator Logic 4-CH 150Mbps Automotive 16-Pin	Commodity Item
43	9	Part	AUIRS2191STR	MOSFET DRVR 600V 3.5A 2-OUT Hi/Lo Non-Inv 16-Pin S	Commodity Item
44	9	Part	P4SMA22CA-E3/61	Transient Voltage Suppressor Diodes 400W, 22V, 5%	Commodity Item
45	9	Part	EDZVT2R4.3B	Zener Diode 4.3V 150mW 3% Surface Mount EMD2	Commodity Item
46	9	Part	PT7M7433TAEX	Supervisor Push-Pull, Totem Pole 1 Channel SOT-23-	Commodity Item
47	9	Part	LMV762MM	Comparator General Purpose Push-Pull 8-VSSOP	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
48	9	Part	S9S12GN16F0MLF	MCU 16-bit S12 CISC 16KB Flash 3.3V/5V 48-Pin LQFP	Commodity Item
49	9	Part	OPA4348AQPWRQ1	General Purpose Amplifier 4 Circuit Rail-to-Rail 1	Commodity Item
50	9	Part	#15110502601000	50 Positions Header, Shrouded Connector 0.050" (1.	Commodity Item
51	9	Part	PA1281NLT	Transformers Audio & Signal SMD HiFreq WireWound 3	Commodity Item
52	9	Part	POE300F-19LB	Pulse Transformer, 1:0.56, 42 µH, 0.06 ohm, 1.5 kV	Commodity Item
53	9	Part	0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
54	9	Part	0603 Resistors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
55	9	Part	0805 Resistors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
56	9	Part	1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
57	9	Part	CMA02040X2209GB300	RES SMD 22 OHM 2% 0.4W 0204	Commodity Item
58	9	Part	0402 Capacitor	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
59	9	Part	0603 Capacitor	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
60	9	Part	0805 Capacitor	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
61	9	Part	1206 Capacitor	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
62	9	Part	1210 Capacitor	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	Commodity Item
63	9	Part	S-1133B00-I8T1U	LDO Voltage Regulators LDO REG HI 60uA Iq 300mA Io	Commodity Item
64	9	Part	ISO7221CQDRQ1	General Purpose Amplifier 4 Circuit Rail-to-Rail 1	Commodity Item
65	9	Part	S9S12GN16F0MLF-1	MCU 16-bit S12 CISC 16KB Flash 3.3V/5V 48-Pin LQFP	Commodity Item
66	9	Part	BB565H7902XTSA1	Diode VAR Cap Single 30V 18.5pF 2-Pin SCD-80 T/R	Commodity Item
67	9	Part	BZX84B18-7-F	Zener Diode 18V 300mW 2% Surface Mount SOT-23	Commodity Item
68	9	Part	SSM3K7002KF	N-Ch MOSFET 60V 0.4A	Commodity Item
69	9	Part	AZ23C4V7-7-F	Zener Diode Array 4.7V 300mW 5% SOT-23-3	Commodity Item
70	9	Part	BZX84C2V4LT1G	Zener Diode 2.4V 225mW 8% Surface Mount SOT-23-3	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
71	9	Part	AP2210N-3.3TRG1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	Commodity Item
72	9	Part	FAN7171M_F085	High-Side Gate Driver IC Non-Inverting 8-SOP	Commodity Item
73	9	Part	LMV762MM	Comparator General Purpose Push-Pull 8-VSSOP	Commodity Item
74	9	Part	S-1711A1J28-M6T1G	IC REG LINEAR 2.8V/2.85V SOT23	Commodity Item
75	9	Part	PBSS5160T	Bipolar Transistors - BJT TRANS BISS TAPE-7	Commodity Item
76	9	Part	TLE42764D V50	Linear Voltage Regulator IC Positive Fixed PG-TO25	Commodity Item
77	9	Part	LM2903DGKR	Comparator Differential CMOS, TTL 8-VSSOP	Commodity Item
78	9	Part	OPA4348AQPWRQ1	General Purpose Amplifier 4 Circuit Rail-to-Rail 1	Commodity Item
79	9	Part	BZX84B6V8-7-F	Zener Diodes 350mW Prec Zener 2.7 to 39V 300mW	Commodity Item
80	9	Part	BSS84PH6433XTMA1	Small Signal Transistor	Commodity Item
81	9	Part	BCR192TE6327XT	Trans Digital BJT PNP 50V 100mA Automotive 3-Pin S	Commodity Item
82	9	Part	BAS21-7-F	Diode Standard 200V 200mA Surface Mount SOT-23-3	Commodity Item
83	9	Part	SM6K2T110	MOSFET 2N-CH 60V 0.2A SOT-457	Commodity Item
84	9	Part	74AHC1G08GV	AND Gate IC 1 Channel 5-TSOP	Commodity Item
85	9	Part	SN74AUC2G06DBVR	Inverter IC 2 Channel Open Drain SOT-23-6	Commodity Item
86	9	Part	BZX585-B33	Zener Diodes DIODE ZENER 2 PCT	Commodity Item
87	9	Part	ISO7240CFQDWRQ1	Dig Isolator Logic 4-CH 150Mbps Automotive 16-Pin	Commodity Item
88	9	Part	LM2901AVQDRQ1	Comparator Differential CMOS, Open-Collector, 14-S	Commodity Item
89	9	Part	EDZVT2R4.3B	Zener Diode 4.3V 150mW 3% Surface Mount EMD2	Commodity Item
90	9	Part	AUIRS2191STR	MOSFET DRVR 600V 3.5A 2-OUT Hi/Lo Non-Inv 16-Pin S	Commodity Item
91	9	Part	P4SMA22CA-E3/61	Transient Voltage Suppressor Diodes 400W, 22V, 5%	Commodity Item
92	9	Part	2SC5084YTE85LF	RF Transistor NPN 12V 80mA 7GHz 150mW SC-59	Commodity Item
93	9	Part	CMPT4401 TR	TRANS NPN 40V 0.6A SOT-23	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
94	9	Part	LMP8601EDRQ1	Current Sense Amplifier 1 Circuit 8-SOIC	Commodity Item
95	8	Part	7M-50.000MAAJ-T	50MHz 30ppm Crystal 18pF 60 Ohm -20°C to 70°C Surf	Commodity Item
96	4	Subassembly	1608-194_2	IGBT 2 Asm	(None)
97	5	Preprocessed Part	1608-194_2a	Heatsink, IGBT 2 Asm	Aluminum A413.0, Cast
98	6	Manufacturing Steps		Heatsink, IGBT 2 Asm Processing	
99	7	Manufacturing Process		Wash	
100	7	Manufacturing Process		Debur	
101	7	Manufacturing Process		CNC Mill	
102	7	Manufacturing Process		Trim Press, 25 Ton	
103	7	Manufacturing Process		Aluminum Die Casting, 1050 Ton	
104	8	Part	1608-194_2a Material	Material, Heatsink, IGBT 2 Asm	Aluminum A413.0, Cast
105	5	Subassembly	1608-194_2b	Power PCBA 1, IGBT 2 Asm	(None)
106	6	Manufacturing Steps		IGBT Module Assembly	
107	7	Manufacturing Process		Functional Test	
108	7	Manufacturing Process		Wire Bonding (0.10mm D)	
109	8	Part	1608-194_2q	Al Bondwire, 0.10mm (0.005”)	Commodity Item
110	8	Part	1608-194_2q	Al Bondwire, 0.10mm (0.005”)	Commodity Item
111	7	Manufacturing Process		Wire Bonding (0.28mm D)	
112	8	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
113	8	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
114	8	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
115	8	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
116	8	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
117	8	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
118	7	Manufacturing Process		PCB Population, Low Content	
119	8	Part	1608-194_2t	Substrate, AlN, Cu Plated, PCBA 1	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
120	10	Part	1608-194_2t.5	Solder Preform, SnAgCu 1.2054mm^3	Commodity Item
121	10	Part	1608-194_2t.4	Solder Preform, SnAgCu 2.2295mm^3	Commodity Item
122	10	Part	1608-194_2t.6	Solder Preform, SnAgCu 3.7758mm^3	Commodity Item
123	10	Part	1608-194_2t.1	Diode, 4.2 x 4.1mm Die	Commodity Item
124	10	Part	1608-194_2t.2	IGBT, 6.5 x 4.9mm Die	Commodity Item
125	10	Part	1608-194_2t.3	IGBT, 9.3 x 5.8mm Die	Commodity Item
126	10	Part	1608-194_2s.10-1	RES SMD 0.005 OHM 1% 3W 2726 (4-Terminal)	Commodity Item
127	9	Part	WSL27265L000FEB	RES SMD 0.0001 OHM 1% 5W 4027	Commodity Item
128	5	Subassembly	1608-194_2c	Power PCBA 2, IGBT 2 Asm	(None)
129	6	Manufacturing Steps		IGBT Module Assembly	
130	7	Manufacturing Process		Functional Test	
131	7	Manufacturing Process		Wire Bonding (0.10mm D)	
132	8	Part	1608-194_2q	Al Bondwire, 0.10mm (0.005”)	Commodity Item
133	8	Part	1608-194_2q	Al Bondwire, 0.10mm (0.005”)	Commodity Item
134	8	Part	1608-194_2q	Al Bondwire, 0.10mm (0.005”)	Commodity Item
135	7	Manufacturing Process		Wire Bonding (0.39mm D)	
136	8	Part	1608-194_2r	Al Bondwire, 0.39mm (0.015”)	Commodity Item
137	8	Part	1608-194_2r	Al Bondwire, 0.39mm (0.015”)	Commodity Item
138	8	Part	1608-194_2r	Al Bondwire, 0.39mm (0.015”)	Commodity Item
139	8	Part	1608-194_2r	Al Bondwire, 0.39mm (0.015”)	Commodity Item
140	8	Part	1608-194_2r	Al Bondwire, 0.39mm (0.015”)	Commodity Item
141	8	Part	1608-194_2r	Al Bondwire, 0.39mm (0.015”)	Commodity Item
142	8	Part	1608-194_2r	Al Bondwire, 0.39mm (0.015”)	Commodity Item
143	7	Manufacturing Process		PCB Population, Low Content	
144	8	Part	1608-194_2s	Substrate, AlN, Cu Plated, PCBA 2	Commodity Item
145	10	Part	1608-194_2s.3	Solder Preform, SnAgCu 1.9264mm^3	Commodity Item
146	10	Part	1608-194_2s.2	Solder Preform, SnAgCu 1.9262mm^3	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
147	10	Part	1608-194_2s.1	Solder Preform, SnAgCu 2.1952mm^3	Commodity Item
148	10	Part	1608-194_2s.4	Solder Preform, SnAgCu 2.5333mm^3	Commodity Item
149	10	Part	1608-194_2s.5	Diode, 6.4 x 4.3mm Die	Commodity Item
150	10	Part	1608-194_2s.6	IGBT, 5.3 x 5.2mm Die	Commodity Item
151	10	Part	1608-194_2s.7	IGBT, 6.4 x 4.9mm Die	Commodity Item
152	10	Part	1608-194_2s.8	IGBT, 7.7 x 4.7mm Die	Commodity Item
153	10	Part	1608-194_2s.10	Capacitor, 10%, 1206 (3216 Metric) 0.126" L x 0.06	Commodity Item
154	10	Part	1608-194_2s.11	Capacitor, 10%, 1210 (3225 Metric) 0.126" L x 0.0	Commodity Item
155	10	Part	1608-194_2s.12	Capacitor, 10%, 0805 (2012 Metric) 0.079" L x 0.04	Commodity Item
156	10	Part	CRCW20103R30FKEFHP	RES SMD 3.3 OHM 1% 1W 2010	Commodity Item
157	10	Part	1608-194_2s.9	Resistor, 5%, 0805 (2012 Metric) 0.079" L x 0.049"	Commodity Item
158	9	Part	ISOTEK BVL 4027	RES SMD 0.0001 OHM 1% 5W 4027	Commodity Item
159	5	Part	1608-194_2p	Thermal Adhesive, Power Electronics	Commodity Item
160	5	Manufacturing Steps		PCBA Adhesive Apply Station	
161	6	Manufacturing Process		Curing Oven 8x8'	
162	6	Manufacturing Process		Adhesive Apply Station Adhesive Apply Station	
163	5	Part	1608-194_2h	Insulator Pad, IGBT 2 Asm	Commodity Item
164	5	Subassembly	1608-194_2e	Lead Frame Asm, IGBT 2 Asm	(None)
165	6	Subassembly	1608-194_2e1	Stamped Copper Lead 1 Asm	(None)
166	7	Preprocessed Part	1608-194_2e17	Stamped Copper Lead 1	Copper Cu (10200)
167	8	Manufacturing Steps		Stamped Copper Lead 1, Processing	
168	9	Manufacturing Process		Plating	
169	10	Part	1608-194_2e1 Plating	Stamped Copper Lead 1 Plating	Commodity Item
170	9	Manufacturing Process		Wash	
171	9	Manufacturing Process		Debur	
172	9	Manufacturing Process		Stamping Press, 60 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
173	10	Part	1608-194_2e17 Material	Material, Stamped Copper Lead 1	Copper Cu (10200)
174	7	Preprocessed Part	1608-194_2e2	Stamped Copper Lead 2	Copper Nickel Plated
175	8	Manufacturing Steps		Stamped Copper Lead 2, Processing	
176	9	Manufacturing Process		Wash	
177	9	Manufacturing Process		Debur	
178	9	Manufacturing Process		Stamping Press, 25 Ton	
179	10	Part	1608-194_2e2 Material	Material, Stamped Copper Lead 2	Copper Nickel Plated
180	7	Part	1608-194_2e15	M4 x 0.70, PEM Nut	Commodity Item
181	7	Manufacturing Steps		Assemble Stamped Copper Lead 1 Asm	
182	8	Manufacturing Process		Tog-L-Loc	
183	8	Manufacturing Process		Automated Press	
184	6	Preprocessed Part	1608-194_2e3	Stamped Copper Lead 3	Copper Nickel Plated
185	7	Manufacturing Steps		Stamped Copper Lead 3, Processing	
186	8	Manufacturing Process		Wash	
187	8	Manufacturing Process		Debur	
188	8	Manufacturing Process		Stamping Press, 25 Ton	
189	9	Part	1608-194_2e3 Material	Material, Stamped Copper Lead 3	Copper Nickel Plated
190	6	Preprocessed Part	1608-194_2e4	Stamped Copper Lead 4	Copper Cu (10200)
191	7	Manufacturing Steps		Stamped Copper Lead 4, Processing	
192	8	Manufacturing Process		Plating	
193	9	Part	1608-194_2e4 Plating	Stamped Copper Lead 1 Plating	Commodity Item
194	8	Manufacturing Process		Wash	
195	8	Manufacturing Process		Debur	
196	8	Manufacturing Process		Stamping Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
197	9	Part	1608-194_2e4 Material	Material, Stamped Copper Lead 4	Copper Cu (10200)
198	6	Preprocessed Part	1608-194_2e5	Stamped Copper Lead 5	Copper Cu (10200)
199	7	Manufacturing Steps		Stamped Copper Lead 5, Processing	
200	8	Manufacturing Process		Plating	
201	9	Part	1608-194_2e5 Plating	Stamped Copper Lead 5 Plating	Commodity Item
202	8	Manufacturing Process		Wash	
203	8	Manufacturing Process		Debur	
204	8	Manufacturing Process		Stamping Press, 25 Ton	
205	9	Part	1608-194_2e5 Material	Material, Stamped Copper Lead 5	Copper Cu (10200)
206	6	Preprocessed Part	1608-194_2e6	Stamped Copper Lead 6	Copper Nickel Plated
207	7	Manufacturing Steps		Stamped Copper Lead 6, Processing	
208	8	Manufacturing Process		Plating	
209	9	Part	1608-194_2e6 Plating	Stamped Copper Lead 6 Plating	Commodity Item
210	8	Manufacturing Process		Wash	
211	8	Manufacturing Process		Debur	
212	8	Manufacturing Process		Stamping Press, 25 Ton	
213	9	Part	1608-194_2e6 Material	Material, Stamped Copper Lead 6	Copper Nickel Plated
214	6	Preprocessed Part	1608-194_2e7	Stamped Copper Lead 7	Copper Nickel Plated
215	7	Manufacturing Steps		Stamped Copper Lead 7, Processing	
216	8	Manufacturing Process		Wash	
217	8	Manufacturing Process		Debur	
218	8	Manufacturing Process		Stamping Press, 25 Ton	
219	9	Part	1608-194_2e7 Material	Material, Stamped Copper Lead 7	Copper Nickel Plated
220	6	Preprocessed Part	1608-194_2e8	Stamped Copper Lead 8	Copper Nickel Plated

Row	Level	Symbol Type	Number	Name	Material Name
221	7	Manufacturing Steps		Stamped Copper Lead 8, Processing	
222	8	Manufacturing Process		Wash	
223	8	Manufacturing Process		Debur	
224	8	Manufacturing Process		Stamping Press, 25 Ton	
225	9	Part	1608-194_2e8 Material	Material, Stamped Copper Lead 8	Copper Nickel Plated
226	6	Preprocessed Part	1608-194_2e9	Stamped Copper Lead 9	Copper Nickel Plated
227	7	Manufacturing Steps		Stamped Copper Lead 9, Processing	
228	8	Manufacturing Process		Wash	
229	8	Manufacturing Process		Debur	
230	8	Manufacturing Process		Stamping Press, 25 Ton	
231	9	Part	1608-194_2e9 Material	Material, Stamped Copper Lead 9	Copper Nickel Plated
232	6	Preprocessed Part	1608-194_2e10	Stamped Copper Lead 10	Copper Nickel Plated
233	7	Manufacturing Steps		Stamped Copper Lead 10, Processing	
234	8	Manufacturing Process		Wash	
235	8	Manufacturing Process		Debur	
236	8	Manufacturing Process		Stamping Press, 25 Ton	
237	9	Part	1608-194_2e10 Material	Material, Stamped Copper Lead 10	Copper Nickel Plated
238	6	Preprocessed Part	1608-194_2e11	Stamped Copper Lead 11	Copper Nickel Plated
239	7	Manufacturing Steps		Stamped Copper Lead 11, Processing	
240	8	Manufacturing Process		Wash	
241	8	Manufacturing Process		Debur	
242	8	Manufacturing Process		Stamping Press, 25 Ton	
243	9	Part	1608-194_2e11 Material	Material, Stamped Copper Lead 11	Copper Nickel Plated

Row	Level	Symbol Type	Number	Name	Material Name
244	6	Preprocessed Part	1608-194_2e12	Stamped Copper Lead 12	Copper Nickel Plated
245	7	Manufacturing Steps		Stamped Copper Lead 12, Processing	
246	8	Manufacturing Process		Wash	
247	8	Manufacturing Process		Debur	
248	8	Manufacturing Process		Stamping Press, 25 Ton	
249	9	Part	1608-194_2e12 Material	Material, Stamped Copper Lead 12	Copper Nickel Plated
250	6	Preprocessed Part	1608-194_2e13	Stamped Copper Lead 13	Copper Cu (10200)
251	7	Manufacturing Steps		Stamped Copper Lead 13, Processing	
252	8	Manufacturing Process		Plating	
253	9	Part	1608-194_2e13 Plating	Stamped Copper Lead 13 Plating	Commodity Item
254	8	Manufacturing Process		Wash	
255	8	Manufacturing Process		Debur	
256	8	Manufacturing Process		Stamping Press, 25 Ton	
257	9	Part	1608-194_2e13 Material	Material, Stamped Copper Lead 13	Copper Cu (10200)
258	6	Part	1608-194_2e14	Copper Ground Plates	Commodity Item
259	6	Part	1608-194_2e16	M4 x 0.70, 11 mm, Closed PEM nut	Commodity Item
260	6	Part	1608-194_2o	Compliant Bondwire/PCB Pin	Commodity Item
261	6	Subassembly	1608-194_2l	Molded Lead Frame Body, IGBT 2 Asm	PBT GF30
262	7	Manufacturing Steps		Molded Leadframe, Processing	
263	8	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
264	9	Part	1608-194_2l Material	Material, Molded Lead Frame Body	PBT GF30
265	5	Manufacturing Steps		Install Leadframe & Wirebond	
266	6	Manufacturing Process		Wire Bonding (Ribbonwire)	
267	7	Part	1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"”)	Commodity Item
268	7	Part	1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"”)	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
269	7	Part	1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"”)	Commodity Item
270	7	Part	1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"”)	Commodity Item
271	7	Part	1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"”)	Commodity Item
272	7	Part	1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"”)	Commodity Item
273	6	Manufacturing Process		Wire Bonding (0.28mm D)	
274	7	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
275	7	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
276	7	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
277	7	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
278	7	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
279	7	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
280	7	Part	1608-194_2j	Al Bondwire, 0.28mm (0.011”)	Commodity Item
281	6	Manufacturing Process		Auto Asm	
282	5	Part	1608-194_2d	Silicone Potting Gel	Commodity Item
283	5	Manufacturing Steps		Potting & Curing Process	
284	6	Manufacturing Process		Inspection	
285	6	Manufacturing Process		Vacuum Potting & Encapsulation	
286	5	Part	1608-194_2f	Capacitor 15uF, 475VDC, IGBT 2 Asm	Commodity Item
287	5	Subassembly	1608-194_2g	Inductor Asm, IGBT 2 Asm	(None)
288	6	Part	1.5MM Metric Wire, 203mm L 1.77mm T	1.5MM Metric Wire, 203mm L 1.77mm T	Commodity Item
289	6	Manufacturing Steps		Wound Coil Process	
290	7	Manufacturing Process		Bend & Strip Ends	
291	7	Manufacturing Process		Coil Winding	
292	6	Part	Ferrite Cores EP 17	Ferrite Cores EP 17	Commodity Item
293	6	Manufacturing Steps		Ferrite bar and wound coil Asm process	
294	7	Manufacturing Process		Fix Coil and Ferrite bar	

Row	Level	Symbol Type	Number	Name	Material Name
295	6	Part	1608-195_14	Epoxy Potting Compound	Commodity Item
296	6	Manufacturing Steps		Potting & Curing Process	
297	7	Manufacturing Process		Inspection	
298	7	Manufacturing Process		Curing Oven 8x8'	
299	7	Manufacturing Process		Vacuum Potting & Encapsulation	
300	5	Part	1608-178_11	Black RTV Adhesive	Commodity Item
301	5	Manufacturing Steps		Assemble Capacitor & Coil to Base	
302	6	Manufacturing Process		Apply Black RTV Adhesive	
303	6	Manufacturing Process		Manual Asm	
304	5	Part	1608-194_2i	Label, IGBT 2 Asm	Commodity Item
305	5	Manufacturing Steps		Final Test & Install Label	
306	6	Manufacturing Process		Manual Asm	
307	6	Manufacturing Process		Functional Test	
308	4	Part	1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	Commodity Item
309	4	Manufacturing Steps		Install Circuit Board to IGBT	
310	5	Manufacturing Process		Manual Asm	
311	3	Part	1608-161_1	M4x0.70, 12 mm, Female Torx	Commodity Item
312	3	Part	Heat Sink Compound	Heat Sink Compound	Commodity Item
313	3	Manufacturing Steps		Assemble Circuir Board 4 Asm to Housing	
314	4	Manufacturing Process		Auto Asm	
315	3	Subassembly	1608-164	Circuit Board 3 Asm	(None)
316	4	Manufacturing Steps		Printed Circuit Board Assembly	
317	5	Manufacturing Process		Auto Label Apply	
318	6	Part	1608-164_1	Barcode Label	Commodity Item
319	5	Manufacturing Process		Functional Test	

Row	Level	Symbol Type	Number	Name	Material Name
320	5	Manufacturing Process		Automated Thru Hole Placement	
321	7	Part	B32522C106K189	10µF Film Capacitor 40V 63V	Commodity Item
322	5	Manufacturing Process		De-Panel	
323	6	Part	1608-164_2	Printed FR4 Circuit Board	Commodity Item
324	3	Part	1608-127_1	M4x.70, 10 mm, Female Torx w/ Captured Washer	Commodity Item
325	3	Manufacturing Steps		Assemble Circuit Board 3 Asm to Housing	
326	4	Manufacturing Process		Auto Asm	

Table F-34 Audi DC/DC PCBAs Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 DC/DC Converter PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-194	**Circuit Board 4 Asm**	**$174.40**	**1**	**$174.40**
1608-194_1	**Circuit Board 4**	**$87.40**	**1**	**$87.40**
1608-194_1a	Printed FR4 Circuit Board	$1.72	1	$1.72
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.03	1	$0.03
LF318 Solder Paste	LF318 Solder Paste	$0.44	1	$0.44
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.13	1	$0.13
0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	36	$0.02
0603 Resistors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	80	$0.15
0805 Resistors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.00	13	$0.01
1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.00	12	$0.04
CMA02040X2209GB300	RES SMD 22 OHM 2% 0.4W 0204	$0.08	17	$1.29
0402 Capacitor	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	46	$0.16
0603 Capacitor	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	51	$0.61
0805 Capacitor	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	6	$0.18
1206 Capacitor	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.07	1	$0.07
1210 Capacitor	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	$0.12	7	$0.86
TLE42764D V50	Linear Voltage Regulator IC Positive Fixed PG-TO25	$0.54	3	$1.61
EPM570T100A5N	Altera CPLD MAXII Family	$20.13	2	$40.26
ISO7221CQDRQ1	General Purpose Digital Isolator 4000Vpk 2	$1.12	1	$1.12
TJA1042T/3/118	High Speed CAN Transceiver	$0.33	1	$0.33
BSS84PH6433XTMA1	Small Signal Transistor	$0.01	6	$0.06
DDZX43-7	Zener Diodes 300MW 43V	$0.02	1	$0.02
RP500N151A-TR-FE	Switching Regulators Buck DC/DC Converter	$0.32	2	$0.64
BZX84B6V8-7-F	Zener Diodes 350mW Prec Zener 2.7 to 39V 300mW	$0.01	1	$0.01
CMPT4401 TR	TRANS NPN 40V 0.6A SOT-23	$0.09	1	$0.09
BZX84B43-7-F	Zener Diodes 350mW Prec Zener 4.7V 5mA 3uA	$0.01	4	$0.05
SSM3K7002KF	N-Ch MOSFET 60V0.4A	$0.01	4	$0.06
S9S12G48F0MLH	MCU 16-bit 48KB Flash 3.3V/5V Automotive 48-Pin LQ	$1.48	1	$1.48
S-1133B00-I8T1U	LDO Voltage Regulators LDO REG HI 60uA Iq 300mA Io	$0.28	1	$0.28
AP2210N-3.3TRG1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	$0.05	1	$0.05
BZX585-B33	Zener Diodes DIODE ZENER 2 PCT	$0.02	4	$0.09
BB565H7902XTSA1	Diode VAR Cap Single 30V 18.5pF 2-Pin SCD-80 T/R	$0.03	3	$0.09
BZX84B18-7-F	Zener Diode 18V 300mW 2% Surface Mount SOT-23	$0.01	1	$0.01

A3 DC/DC Converter PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
BUK9275-100A	MOSFET N-CH 100V 21.7A DPAK	$0.23	2	$0.46
BZX84C2V4LT1G	Zener Diode 2.4V 225mW 8% Surface Mount SOT-23-3	$0.01	1	$0.01
AZ23C4V7-7-F	Zener Diode Array 4.7V 300mW 5% SOT-23-3	$0.03	2	$0.06
MUN5116DW1T1G	Bipolar Transistors - Pre-Biased 100mA 50V BRT Dua	$0.02	1	$0.02
ISO7240CFQDWRQ1	Dig Isolator Logic 4-CH 150Mbps Automotive 16-Pin	$2.39	2	$4.78
AUIRS2191STR	MOSFET DRVR 600V 3.5A2-OUT Hi/Lo Non-Inv 16-Pin S	$1.11	1	$1.11
P4SMA22CA-E3/61	Transient Voltage Suppressor Diodes 400W, 22V, 5%	$0.10	2	$0.21
EDZVT2R4.3B	Zener Diode 4.3V 150mW 3% Surface Mount EMD2	$0.02	1	$0.02
PT7M7433TAEX	Supervisor Push-Pull, Totem Pole 1 Channel SOT-23-	$0.18	2	$0.37
LMV762MM	Comparator General Purpose Push-Pull 8-VSSOP	$0.24	1	$0.24
S9S12GN16F0MLF	MCU 16-bit S12 CISC 16KB Flash 3.3V/5V 48-Pin LQFP	$0.16	1	$0.16
OPA4348AQPWRQ1	General Purpose Amplifier 4 Circuit Rail-to-Rail 1	$0.42	1	$0.42
#15110502601000	50 Positions Header, Shrouded Connector 0.050" (1.	$2.22	1	$2.22
PA1281NLT	Transformers Audio & Signal SMD HiFreq WireWound 3	$0.93	2	$1.87
POE300F-19LB	Pulse Transformer, 1:0.56, 42 µH, 0.06 ohm, 1.5 kV	$0.57	1	$0.57
0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	35	$0.02
0603 Resistors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	126	$0.24
0805 Resistors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.00	12	$0.01
1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.00	20	$0.06
CMA02040X2209GB300	RES SMD 22 OHM 2% 0.4W 0204	$0.08	14	$1.06
0402 Capacitor	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	64	$0.22
0603 Capacitor	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	81	$0.96
0805 Capacitor	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	13	$0.39
1206 Capacitor	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.07	2	$0.13
1210 Capacitor	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	$0.12	19	$2.34
S-1133B00-I8T1U	LDO Voltage Regulators LDO REG HI 60uA Iq 300mA Io	$0.28	3	$0.84
ISO7221CQDRQ1	General Purpose Amplifier 4 Circuit Rail-to-Rail 1	$1.12	1	$1.12
S9S12GN16F0MLF-1	MCU 16-bit S12 CISC 16KB Flash 3.3V/5V 48-Pin LQFP	$1.57	1	$1.57
BB565H7902XTSA1	Diode VAR Cap Single 30V 18.5pF 2-Pin SCD-80 T/R	$0.03	8	$0.24
BZX84B18-7-F	Zener Diode 18V 300mW 2% Surface Mount SOT-23	$0.01	1	$0.01
SSM3K7002KF	N-Ch MOSFET 60V 0.4A	$0.01	4	$0.06

A3 DC/DC Converter PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
AZ23C4V7-7-F	Zener Diode Array 4.7V 300mW �5% SOT-23-3	$0.03	2	$0.06
BZX84C2V4LT1G	Zener Diode 2.4V225mW 8% Surface Mount SOT-23-3	$0.01	1	$0.01
AP2210N-3.3TRG1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	$0.05	1	$0.05
FAN7171M_F085	High-Side Gate Driver IC Non-Inverting 8-SOP	$0.40	2	$0.79
LMV762MM	Comparator General Purpose Push-Pull 8-VSSOP	$0.24	1	$0.24
S-1711A1J28-M6T1G	IC REG LINEAR 2.8V/2.85V SOT23	$0.07	2	$0.15
PBSS5160T	Bipolar Transistors - BJT TRANS BISS TAPE-7	$0.09	1	$0.09
TLE42764D V50	Linear Voltage Regulator IC Positive Fixed PG-TO25	$0.54	1	$0.54
LM2903DGKR	Comparator Differential CMOS, TTL 8-VSSOP	$0.06	2	$0.11
OPA4348AQPWRQ1	General Purpose Amplifier 4 Circuit Rail-to-Rail 1	$0.42	1	$0.42
BZX84B6V8-7-F	Zener Diodes 350mW Prec Zener 2.7 to 39V 300mW	$0.01	1	$0.01
BSS84PH6433XTMA1	Small Signal Transistor	$0.01	3	$0.03
BCR192TE6327XT	Trans Digital BJT PNP 50V 100mA Automotive 3-Pin S	$0.03	1	$0.03
BAS21-7-F	Diode Standard 200V200mA Surface Mount SOT-23-3	$0.01	2	$0.02
SM6K2T110	MOSFET 2N-CH 60V 0.2A SOT-457	$0.08	1	$0.08
74AHC1G08GV	AND Gate IC 1 Channel 5-TSOP	$0.02	2	$0.04
SN74AUC2G06DBVR	Inverter IC 2 Channel Open Drain SOT-23-6	$0.10	1	$0.10
BZX585-B33	Zener Diodes DIODEZENER 2 PCT	$0.02	8	$0.18
ISO7240CFQDWRQ1	Dig Isolator Logic 4-CH 150Mbps Automotive 16-Pin	$2.39	3	$7.17
LM2901AVQDRQ1	Comparator Differential CMOS, Open-Collector, 14-S	$0.13	2	$0.26
EDZVT2R4.3B	Zener Diode 4.3V 150mW 3% Surface Mount EMD2	$0.02	1	$0.02
AUIRS2191STR	MOSFET DRVR 600V 3.5A 2-OUT Hi/Lo Non-Inv 16-Pin S	$1.11	1	$1.11
P4SMA22CA-E3/61	Transient Voltage Suppressor Diodes 400W, 22V, 5%	$0.10	2	$0.21
2SC5084YTE85LF	RF Transistor NPN 12V 80mA 7GHz 150mW SC-59	$0.03	12	$0.41
CMPT4401 TR	TRANS NPN 40V 0.6A SOT-23	$0.09	1	$0.09
LMP8601EDRQ1	Current Sense Amplifier 1 Circuit 8-SOIC	$1.06	1	$1.06
7M-50.000MAAJ-T	50MHz 30ppm Crystal 18pF 60 Ohm -20�C to 70�C Surf	$0.41	1	$0.41
1608-194_2	**IGBT 2 Asm**	**$86.94**	**1**	**$86.94**
1608-194_2a	**Heatsink, IGBT 2 Asm**	**$0.85**	**1**	**$0.85**
1608-194_2a Material	Material, Heatsink, IGBT 2 Asm	$0.85	1	$0.85
1608-194_2b	**Power PCBA 1, IGBT 2 Asm**	**$23.38**	**1**	**$23.38**
1608-194_2q	Al Bondwire, 0.10mm (0.005")	$0.03	2	$0.06
1608-194_2q	Al Bondwire, 0.10mm (0.005")	$0.03	4	$0.12
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.02	4	$0.10
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.04	5	$0.19
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.03	9	$0.28

A3 DC/DC Converter PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.03	9	$0.23
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.05	3	$0.14
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.04	3	$0.12
1608-194_2t	Substrate, AlN, Cu Plated, PCBA 1	$1.05	1	$1.05
1608-194_2t.5	Solder Preform, SnAgCu 1.2054mm^3	$0.04	1	$0.04
1608-194_2t.4	Solder Preform, SnAgCu 2.2295mm^3	$0.04	4	$0.16
1608-194_2t.6	Solder Preform, SnAgCu 3.7758mm^3	$0.04	1	$0.04
1608-194_2t.1	Diode, 4.2 x 4.1mm Die	$1.22	1	$1.22
1608-194_2t.2	IGBT, 6.5 x 4.9mm Die	$2.12	4	$8.48
1608-194_2t.3	IGBT, 9.3 x 5.8mm Die	$4.23	1	$4.23
1608-194_2s.10-1	RES SMD 0.005 OHM 1% 3W 2726 (4-Terminal)	$0.77	6	$4.62
WSL27265L000FEB	RES SMD 0.0001 OHM 1% 5W 4027	$0.77	3	$2.31
1608-194_2c	**Power PCBA 2, IGBT 2 Asm**	**$49.60**	**1**	**$49.60**
1608-194_2q	Al Bondwire, 0.10mm (0.005")	$0.03	4	$0.12
1608-194_2q	Al Bondwire, 0.10mm (0.005")	$0.03	4	$0.12
1608-194_2q	Al Bondwire, 0.10mm (0.005")	$0.04	4	$0.16
1608-194_2r	Al Bondwire, 0.39mm (0.015")	$0.02	6	$0.11
1608-194_2r	Al Bondwire, 0.39mm (0.015")	$0.02	12	$0.18
1608-194_2r	Al Bondwire, 0.39mm (0.015")	$0.02	12	$0.18
1608-194_2r	Al Bondwire, 0.39mm (0.015")	$0.02	5	$0.09
1608-194_2r	Al Bondwire, 0.39mm (0.015")	$0.02	6	$0.10
1608-194_2r	Al Bondwire, 0.39mm (0.015")	$0.02	16	$0.28
1608-194_2r	Al Bondwire, 0.39mm (0.015")	$0.02	16	$0.28
1608-194_2s	Substrate, AlN, Cu Plated, PCBA 2	$1.05	1	$1.05
1608-194_2s.3	Solder Preform, SnAgCu 1.9264mm^3	$0.04	2	$0.08
1608-194_2s.2	Solder Preform, SnAgCu 1.9262mm^3	$0.04	1	$0.04
1608-194_2s.1	Solder Preform, SnAgCu 2.1952mm^3	$0.04	4	$0.16
1608-194_2s.4	Solder Preform, SnAgCu 2.5333mm^3	$0.04	4	$0.16
1608-194_2s.5	Diode, 6.4 x 4.3mm Die	$3.48	2	$6.96
1608-194_2s.6	IGBT, 5.3 x 5.2mm Die	$3.65	1	$3.65
1608-194_2s.7	IGBT, 6.4 x 4.9mm Die	$3.78	4	$15.12
1608-194_2s.8	IGBT, 7.7 x 4.7mm Die	$4.45	4	$17.80
1608-194_2s.10	Capacitor, 10%, 1206 (3216 Metric) 0.126" L x 0.06	$0.07	4	$0.26
1608-194_2s.11	Capacitor, 10%, 1210 (3225 Metric) 0.126" L x 0.0	$0.06	20	$1.28
1608-194_2s.12	Capacitor, 10%, 0805 (2012 Metric) 0.079" L x 0.04	$0.03	1	$0.03
CRCW20103R30FKEFHP	RES SMD 3.3 OHM 1% 1W 2010	$0.05	4	$0.19
1608-194_2s.9	Resistor, 5%, 0805 (2012 Metric) 0.079" L x 0.049"	$0.00	1	$0.00
ISOTEK BVL 4027	RES SMD 0.0001 OHM 1% 5W 4027	$1.19	1	$1.19
1608-194_2p	Thermal Adhesive, Power Electronics	$0.25	2	$0.50
1608-194_2h	Insulator Pad, IGBT 2 Asm	$0.06	1	$0.06
1608-194_2e	**Lead Frame Asm, IGBT 2 Asm**	**$5.39**	**1**	**$5.39**
1608-194_2e1	**Stamped Copper Lead 1 Asm**	**$0.89**	**1**	**$0.89**
1608-194_2e17	**Stamped Copper Lead 1**	**$0.61**	**1**	**$0.61**
1608-194_2e1 Plating	Stamped Copper Lead 1 Plating	$0.00	1	$0.00
1608-194_2e17 Material	Material, Stamped Copper Lead 1	$0.61	1	$0.61
1608-194_2e2	**Stamped Copper Lead 2**	**$0.23**	**1**	**$0.23**

A3 DC/DC Converter PCBAs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-194_2e2 Material	Material, Stamped Copper Lead 2	$0.23	1	$0.23
1608-194_2e15	M4 x 0.70, PEM Nut	$0.05	1	$0.05
1608-194_2e3	**Stamped Copper Lead 3**	**$0.19**	**1**	**$0.19**
1608-194_2e3 Material	Material, Stamped Copper Lead 3	$0.19	1	$0.19
1608-194_2e4	**Stamped Copper Lead 4**	**$0.17**	**1**	**$0.17**
1608-194_2e4 Plating	Stamped Copper Lead 1 Plating	$0.00	1	$0.00
1608-194_2e4 Material	Material, Stamped Copper Lead 4	$0.17	1	$0.17
1608-194_2e5	**Stamped Copper Lead 5**	**$0.19**	**1**	**$0.19**
1608-194_2e5 Plating	Stamped Copper Lead 5 Plating	$0.00	1	$0.00
1608-194_2e5 Material	Material, Stamped Copper Lead 5	$0.19	1	$0.19
1608-194_2e6	**Stamped Copper Lead 6**	**$0.26**	**1**	**$0.26**
1608-194_2e6 Plating	Stamped Copper Lead 6 Plating	$0.00	1	$0.00
1608-194_2e6 Material	Material, Stamped Copper Lead 6	$0.26	1	$0.26
1608-194_2e7	**Stamped Copper Lead 7**	**$0.13**	**1**	**$0.13**
1608-194_2e7 Material	Material, Stamped Copper Lead 7	$0.13	1	$0.13
1608-194_2e8	**Stamped Copper Lead 8**	**$0.13**	**1**	**$0.13**
1608-194_2e8 Material	Material, Stamped Copper Lead 8	$0.13	1	$0.13
1608-194_2e9	**Stamped Copper Lead 9**	**$0.15**	**1**	**$0.15**
1608-194_2e9 Material	Material, Stamped Copper Lead 9	$0.15	1	$0.15
1608-194_2e10	**Stamped Copper Lead 10**	**$0.25**	**1**	**$0.25**
1608-194_2e10 Material	Material, Stamped Copper Lead 10	$0.25	1	$0.25
1608-194_2e11	**Stamped Copper Lead 11**	**$0.35**	**1**	**$0.35**
1608-194_2e11 Material	Material, Stamped Copper Lead 11	$0.35	1	$0.35
1608-194_2e12	**Stamped Copper Lead 12**	**$0.35**	**1**	**$0.35**
1608-194_2e12 Material	Material, Stamped Copper Lead 12	$0.35	1	$0.35
1608-194_2e13	**Stamped Copper Lead 13**	**$0.11**	**1**	**$0.11**
1608-194_2e13 Plating	Stamped Copper Lead 13 Plating	$0.00	1	$0.00
1608-194_2e13 Material	Material, Stamped Copper Lead 13	$0.11	1	$0.11
1608-194_2e14	Copper Ground Plates	$0.01	7	$0.07
1608-194_2e16	M4 x 0.70, 11 mm, Closed PEM nut	$0.05	8	$0.40
1608-194_2o	Compliant Bondwire/PCB Pin	$0.03	49	$1.47
1608-194_2l	**Molded Lead Frame Body, IGBT 2 Asm**	**$0.28**	**1**	**$0.28**
1608-194_2l Material	Material, Molded Lead Frame Body	$0.28	1	$0.28
1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"")	$0.04	5	$0.21
1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"")	$0.07	1	$0.07
1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"")	$0.04	6	$0.25
1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"")	$0.07	6	$0.40
1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"")	$0.04	7	$0.31
1608-194_2k	Al Ribbonwire, 1.95mm x 0.35mm (0.077 x 0.014"")	$0.07	3	$0.20
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.04	10	$0.41
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.05	4	$0.20
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.04	4	$0.17
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.05	3	$0.15
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.04	10	$0.41
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.04	6	$0.25

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-194_2j	Al Bondwire, 0.28mm (0.011")	$0.04	4	$0.17
1608-194_2d	Silicone Potting Gel	$0.25	1	$0.25
1608-194_2f	Capacitor 15uF, 475VDC, IGBT 2 Asm	$2.68	1	$2.68
1608-194_2g	**Inductor Asm, IGBT 2 Asm**	**$0.99**	**1**	**$0.99**
1.5MM Metric Wire, 203mm L 1.77mm T	1.5MM Metric Wire, 203mm L 1.77mm T	$0.04	1	$0.04
Ferrite Cores EP17	Ferrite Cores EP17	$0.42	2	$0.84
1608-195_14	Epoxy Potting Compound	$0.11	1	$0.11
1608-178_11	Black RTV Adhesive	$0.03	1	$0.03
1608-194_2i	Label, IGBT 2 Asm	$0.02	1	$0.02
1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	$0.06	1	$0.06
1608-161_1	M4x0.70, 12 mm, Female Torx	$0.01	4	$0.04
Heat Sink Compound	Heat Sink Compound	$0.08	1	$0.08
1608-164	**Circuit Board 3 Asm**	**$6.18**	**1**	**$6.18**
1608-164_1	Barcode Label	$0.01	1	$0.01
B32522C106K189	10µF Film Capacitor 40V 63V	$1.41	4	$5.64
1608-164_2	Printed FR4 Circuit Board	$0.53	1	$0.53
1608-127_1	M4x.70, 10 mm, Female Torx w/ Captured Washer	$0.01	4	$0.04

Assembly Totals

Analyzed Subs:	24
Unanalyzed Subs:	0
Parts:	1,173
Fasteners:	9
Parts+Unanalyzed:	1,173

Report Totals

Piece Cost (Total): $180.74

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

Table F-35 Audi DC/DC Ferrites & Inductors Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1608-173	Ferrite Asm	(None)
2	4	Preprocessed Part	1608-173_1	Ferrite 1	Mn-Zn Soft Ferrite Powder
3	5	Manufacturing Steps		Ferrite 1 Processing	
4	6	Manufacturing Process		Wash	
5	6	Manufacturing Process		Mill Face	
6	6	Manufacturing Process		Oven Sintering Furnace	
7	6	Manufacturing Process		Powdered Metal Press, 100 Ton	
8	7	Part	1608-173_1 Material	Material, Ferrite 1	Mn-Zn Soft Ferrite Powder
9	4	Preprocessed Part	1608-173_2	Ferrite Holder	PC GP
10	5	Manufacturing Steps		Ferrite Holder Processing	
11	6	Manufacturing Process		Injection Mold Press, 55 Ton	
12	7	Part	1608-173_2 Material	Material, Ferrite Holder	PC GP
13	4	Manufacturing Steps		Assemble Ferrite 1 with Ferrite Holder	
14	5	Manufacturing Process		Auto Asm	
15	3	Subassembly	1608-173	Ferrite Asm	(None)
16	4	Preprocessed Part	1608-173_1	Ferrite 1	Mn-Zn Soft Ferrite Powder
17	5	Manufacturing Steps		Ferrite 1 Processing	
18	6	Manufacturing Process		Wash	
19	6	Manufacturing Process		Mill Face	
20	6	Manufacturing Process		Oven Sintering Furnace	
21	6	Manufacturing Process		Powdered Metal Press, 100 Ton	
22	7	Part	1608-173_1 Material	Material, Ferrite 1	Mn-Zn Soft Ferrite Powder

Row	Level	Symbol Type	Number	Name	Material Name
23	4	Preprocessed Part	1608-173_2	Ferrite Holder	PC GP
24	5	Manufacturing Steps		Ferrite Holder Processing	
25	6	Manufacturing Process		Injection Mold Press, 55 Ton	
26	7	Part	1608-173_2 Material	Material, Ferrite Holder	PC GP
27	4	Manufacturing Steps		Assemble Ferrite 1 with Ferrite Holder	
28	5	Manufacturing Process		Auto Asm	
29	3	Part	1608-178_11	Black RTV Adhesive	Commodity Item
30	3	Manufacturing Steps		Install Ferrite Asm	
31	4	Manufacturing Process		Auto Asm	
32	3	Preprocessed Part	1608-173_1	Ferrite 1	Mn-Zn Soft Ferrite Powder
33	4	Manufacturing Steps		Ferrite 1 Processing	
34	5	Manufacturing Process		Wash	
35	5	Manufacturing Process		Mill Face	
36	5	Manufacturing Process		Oven Sintering Furnace	
37	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
38	6	Part	1608-173_1 Material	Material, Ferrite 1	Mn-Zn Soft Ferrite Powder
39	3	Preprocessed Part	1608-173_1	Ferrite 1	Mn-Zn Soft Ferrite Powder
40	4	Manufacturing Steps		Ferrite 1 Processing	
41	5	Manufacturing Process		Wash	
42	5	Manufacturing Process		Mill Face	
43	5	Manufacturing Process		Oven Sintering Furnace	
44	5	Manufacturing Process		Powdered Metal Press, 100 Ton	
45	6	Part	1608-173_1 Material	Material, Ferrite 1	Mn-Zn Soft Ferrite Powder

Row	Level	Symbol Type	Number	Name	Material Name
46	3	Preprocessed Part	1608-162	Ferrite Bracket	Steel 4130
47	4	Manufacturing Steps		Ferrite Bracket Processing	
48	5	Manufacturing Process		Wash	
49	5	Manufacturing Process		Debur	
50	5	Manufacturing Process		Stamping Press, 60 Ton	
51	6	Part	1608-162 Material	Material, Ferrite Bracket	Steel 4130
52	3	Part	1608-127_1	M4x.70, 10 mm, Female Torx w/ Captured Washer	Commodity Item
53	3	Manufacturing Steps		Assemble Ferrite and Ferrite Bracket	
54	4	Manufacturing Process		Auto Asm	
55	3	Subassembly	1608-178	Inductor 1 Asm	(None)
56	4	Subassembly	1608-178_1	Inductor 1 Bracket	(None)
57	5	Preprocessed Part	1608-178_3	Inductor 1 Bracket 1	Steel 1010 Cold Drawn or Cold Rolled
58	6	Manufacturing Steps		Inductor 1 Bracket 1 Processing	
59	7	Manufacturing Process		Wash	
60	7	Manufacturing Process		Debur	
61	7	Manufacturing Process		Stamping Press, 25 Ton	
62	8	Part	1608-178_3 Material	Material, Inductor 1 Bracket 1	Steel 1010 Cold Drawn or Cold Rolled
63	5	Preprocessed Part	1608-178_4	Inductor 1 Bracket 2	Steel 1010 Cold Drawn or Cold Rolled
64	6	Manufacturing Steps		Inductor 1 Bracket 2 Processing	
65	7	Manufacturing Process		Wash	
66	7	Manufacturing Process		Debur	
67	7	Manufacturing Process		Stamping Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
68	8	Part	1608-178_4 Material	Material, Inductor 1 Bracket 2	Steel 1010 Cold Drawn or Cold Rolled
69	5	Preprocessed Part	1608-178_5	Inductor 1 Bracket 3	Steel 1010 Cold Drawn or Cold Rolled
70	6	Manufacturing Steps		Inductor 1 Bracket 3 Processing	
71	7	Manufacturing Process		Wash	
72	7	Manufacturing Process		Debur	
73	7	Manufacturing Process		Stamping Press, 25 Ton	
74	8	Part	1608-178_5 Material	Material, Inductor 1 Bracket 3	Steel 1010 Cold Drawn or Cold Rolled
75	5	Preprocessed Part	1608-178_6	Inductor 1 Bracket 4	Steel 1010 Cold Drawn or Cold Rolled
76	6	Manufacturing Steps		Inductor 1 Bracket 4 Processing	
77	7	Manufacturing Process		Wash	
78	7	Manufacturing Process		Debur	
79	7	Manufacturing Process		Stamping Press, 25 Ton	
80	8	Part	1608-178_6 Material	Material, Inductor 1 Bracket 4	Steel 1010 Cold Drawn or Cold Rolled
81	5	Manufacturing Steps		Inductor 1 Bracket Processing	
82	6	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
83	7	Part	1608-178_1 Material	Material, Inductor 1 Bracket	PBT LG30
84	4	Subassembly	1608-178_2	Inductor 1 Sub Asm	(None)
85	5	Part	1608-178_7	Ferrite Toroid	Commodity Item
86	5	Part	1608-178_8	Magnet Wire 1.25mm D, 176.3mm L	Commodity Item
87	5	Manufacturing Steps		Coil Wounding on Toroid	
88	6	Manufacturing Process		Strip Wire Parts	
89	6	Manufacturing Process		Coil Winding	
90	5	Preprocessed Part	1608-178_10	Toroid Mounting Base	PA6 LG20

Row	Level	Symbol Type	Number	Name	Material Name
91	6	Manufacturing Steps		Toroid Mounting Case Processing	
92	7	Manufacturing Process		Injection Mold Press, 55 Ton	
93	8	Part	1608-178_10 Material	Material, Toroid Mounting Base	PA6 LG20
94	5	Part	1608-178_11	Black RTV Adhesive	Commodity Item
95	5	Manufacturing Steps		Assemble Wound Toroid to Base	
96	6	Manufacturing Process		Apply Black RTV Adhesive	
97	6	Manufacturing Process		Manual Assembly	
98	4	Manufacturing Steps		Assemble Inductor and Bracket	
99	5	Manufacturing Process		Manual Asm	
100	3	Part	1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	Commodity Item
101	3	Manufacturing Steps		Inductor 1 Asm to Crcuit Board 4 Assembly	
102	4	Manufacturing Process		Auto Asm	
103	3	Part	1608-194_3	Thermal Gap Pad 1	Commodity Item
104	3	Part	1608-194_4	Thermal Gap Pad 2	Commodity Item
105	3	Part	1608-194_5	Thermal Gap Pad 3	Commodity Item
106	3	Manufacturing Steps		Assemble Thermal Pads	
107	4	Manufacturing Process		Manual Asm	
108	3	Subassembly	1608-192	Inductor 2 Asm	(None)
109	4	Preprocessed Part	1608-192_1	Magnetic Core	Mn-Zn Soft Ferrite Powder
110	5	Manufacturing Steps		Magnetic Core Processing	
111	6	Manufacturing Process		Wash	
112	6	Manufacturing Process		Mill Face	
113	6	Manufacturing Process		Oven Sintering Furnace	
114	6	Manufacturing Process		Powdered Metal Press, 100 Ton	
115	7	Part	1608-192_1 Material	Material, Magnetic Core	Mn-Zn Soft Ferrite Powder

Row	Level	Symbol Type	Number	Name	Material Name
116	4	Preprocessed Part	1608-192_1	Magnetic Core	Mn-Zn Soft Ferrite Powder
117	5	Manufacturing Steps		Magnetic Core Processing	
118	6	Manufacturing Process		Wash	
119	6	Manufacturing Process		Mill Face	
120	6	Manufacturing Process		Oven Sintering Furnace	
121	6	Manufacturing Process		Powdered Metal Press, 100 Ton	
122	7	Part	1608-192_1 Material	Material, Magnetic Core	Mn-Zn Soft Ferrite Powder
123	4	Subassembly	1608-192_2	HV Coil Asm	(None)
124	5	Preprocessed Part	1608-192_3	Flat Wire Coil, Coated	Mn-Zn Soft Ferrite Powder
125	6	Manufacturing Steps		Flat Wire Coil Processing	
126	7	Manufacturing Process		CNC Lathe TL25 4 Axis Twin Spindle-Auto Load	
127	7	Manufacturing Process		Automated Press	
128	7	Manufacturing Process		Bend and Strip Ends	
129	7	Manufacturing Process		Coil Edge Winding	
130	8	Part	1608-192_3 Material	Material, Flat Wire Coil, Coated	Copper Cu (10200)
131	5	Preprocessed Part	1608-192_5	Terminal Bar	Copper Cu (10200)
132	6	Manufacturing Steps		Terminal Bar Processing	
133	7	Manufacturing Process		Stamping Press, 25 Ton	
134	8	Part	1608-192_5 Material	Material, Terminal Bar	Copper Cu (10200)
135	5	Manufacturing Steps		HV Coil Assembly	
136	6	Manufacturing Process		MIG Weld	
137	4	Part	1608-192_4	Barcode Label	Commodity Item
138	4	Part	1608-192_6	Adhesive Magnetic Core	Commodity Item
139	4	Manufacturing Steps		Inductor 2 Assembly	
140	5	Manufacturing Process		Manual Asm	

Row	Level	Symbol Type	Number	Name	Material Name
141	5	Manufacturing Process		Auto Asm	
142	3	Part	1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	Commodity Item
143	3	Manufacturing Steps		Assemble Inductor 2 to Circuit Board 4 Asm	
144	4	Manufacturing Process		Manual Asm	
145	3	Subassembly	1608-195	Inductor 4 Asm	(None)
146	4	Preprocessed Part	1608-195_1	Magnetic Core Large	Mn-Zn Soft Ferrite Powder
147	5	Manufacturing Steps		Magnetic Core Large Processing	
148	6	Manufacturing Process		Pad Printing	
149	6	Manufacturing Process		Wash	
150	6	Manufacturing Process		Mill Face	
151	6	Manufacturing Process		Oven Sintering Furnace	
152	6	Manufacturing Process		Powdered Metal Press, 100 Ton	
153	7	Part	1608-195_1 Material	Material, Magnetic Core Large	Mn-Zn Soft Ferrite Powder
154	4	Preprocessed Part	1608-195_1	Magnetic Core Large	Mn-Zn Soft Ferrite Powder
155	5	Manufacturing Steps		Magnetic Core Large Processing	
156	6	Manufacturing Process		Pad Printing	
157	6	Manufacturing Process		Wash	
158	6	Manufacturing Process		Mill Face	
159	6	Manufacturing Process		Oven Sintering Furnace	
160	6	Manufacturing Process		Powdered Metal Press, 100 Ton	
161	7	Part	1608-195_1 Material	Material, Magnetic Core Large	Mn-Zn Soft Ferrite Powder
162	4	Subassembly	1608-195_3	Current Sensor Coil Asm	(None)
163	5	Subassembly	1608-195_3a	Current Sensor Coil Sub Asm 1	(None)
164	6	Subassembly	1608-195_4	Copper Stamping 1 Asm	(None)
165	7	Preprocessed Part	1608-195_4a	Copper Stamping 1	Copper Cu (10200)

Row	Level	Symbol Type	Number	Name	Material Name
166	8	Manufacturing Steps		Copper Stamping 1 Processing	
167	9	Manufacturing Process		Wash	
168	9	Manufacturing Process		Debur	
169	9	Manufacturing Process		Stamping Press, 60 Ton	
170	10	Part	1608-195_4a Material	Material, Copper Stamping 1	Copper Cu (10200)
171	7	Part	1608-168_2	M4 PEM Nut	Commodity Item
172	7	Manufacturing Steps		Copper Stamping 1 and PEM nut Assembly	
173	8	Manufacturing Process		Automated Press	
174	6	Preprocessed Part	1608-195_5	Copper Stamping 2	Copper Cu (10200)
175	7	Manufacturing Steps		Copper Stamping 2 Processing	
176	8	Manufacturing Process		Wash	
177	8	Manufacturing Process		Debur	
178	8	Manufacturing Process		Stamping Press, 60 Ton	
179	9	Part	1608-195_5 Material	Material, Copper Stamping 2	Copper Cu (10200)
180	6	Preprocessed Part	1608-195_6	Copper Stamping 3	Copper Cu (10200)
181	7	Manufacturing Steps		Copper Stamping 3 Processing	
182	8	Manufacturing Process		Wash	
183	8	Manufacturing Process		Debur	
184	8	Manufacturing Process		Stamping Press, 25 Ton	
185	9	Part	1608-195_6 Material	Material, Copper Stamping 3	Copper Cu (10200)
186	6	Preprocessed Part	1608-195_6	Copper Stamping 3	Copper Cu (10200)
187	7	Manufacturing Steps		Copper Stamping 3 Processing	
188	8	Manufacturing Process		Wash	
189	8	Manufacturing Process		Debur	
190	8	Manufacturing Process		Stamping Press, 25 Ton	
191	9	Part	1608-195_6 Material	Material, Copper Stamping 3	Copper Cu (10200)

Row	Level	Symbol Type	Number	Name	Material Name
192	6	Part	1608-195_7	Copper Coil Winding, 72-0.10mm D Strands	Commodity Item
193	6	Preprocessed Part	1608-195_8	Coil Winding Shaft	PBT LG30
194	7	Manufacturing Steps		Coil Winding Shaft Processing	
195	8	Manufacturing Process		Injection Mold Press, 55 Ton	
196	9	Part	1608-195_8 Material	Material, Coil Winding Shaft	PBT LG30
197	6	Preprocessed Part	1608-195_9	Coil Winding Layer Support	PBT LG30
198	7	Manufacturing Steps		Coil Winding Shaft Processing	
199	8	Manufacturing Process		Injection Mold Press, 55 Ton	
200	9	Part	1608-195_9 Material	Material, Coil Winding Layer Support	PBT LG30
201	6	Part	1608-195_10	Coil Lead	Commodity Item
202	6	Part	1608-195_11	Coil Insulation Sleeve	Commodity Item
203	6	Manufacturing Steps		Current Sensor Coil Sub Asm 1 Processing	
204	7	Manufacturing Process		Auto Asm	
205	7	Manufacturing Process		Solder Stampings	
206	7	Manufacturing Process		Auto Asm	
207	7	Manufacturing Process		Coil Winding	
208	7	Manufacturing Process		Auto Asm	
209	7	Manufacturing Process		Coil Winding	
210	7	Manufacturing Process		Auto Asm	
211	7	Manufacturing Process		Coil Winding	
212	7	Manufacturing Process		Auto Asm	
213	5	Preprocessed Part	1608-195_3b	Current Sensor Coil Casing Asm	PBT LG30
214	6	Manufacturing Steps		Current Sensor Coil Casing Processing	
215	7	Manufacturing Process		Injection Mold Press, 110 Ton w/Inserts	
216	8	Part	1608-195_3 Material	Material Current Sensor Coil Casing Asm	PBT LG30
217	5	Part	1608-195_14	Epoxy Potting Compound	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
218	5	Manufacturing Steps		Potting & Curing Process	
219	6	Manufacturing Process		Inspection	
220	6	Manufacturing Process		Curing Oven 8x8'	
221	6	Manufacturing Process		Vacuum Potting & Encapsulation	
222	5	Part	1608-195_12	Spacer	Commodity Item
223	5	Part	1608-195_2	Thermal Gap Pad 4	Commodity Item
224	5	Manufacturing Steps		Current Sensor Coil Assembly	
225	6	Manufacturing Process		Auto Asm	
226	4	Part	1608-192_6	Adhesive Magnetic Core	Commodity Item
227	4	Part	1608-195_13	Supplier Label	Commodity Item
228	4	Manufacturing Steps		Inductor 4 Assembly	
229	5	Manufacturing Process		Auto Asm	
230	5	Manufacturing Process		Auto Asm	
231	3	Part	1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	Commodity Item
232	3	Part	1608-161_1	M4x0.70, 12 mm, Female Torx	Commodity Item
233	3	Manufacturing Steps		Assemble Inductor 4 to Circuit Board 4 Asm	
234	4	Manufacturing Process		Manual Asm	
235	3	Subassembly	1608-185	Ferrite Shield Asm	(None)
236	4	Preprocessed Part	1608-185_1	Ferrite Shield	Steel, Galvanized G60
237	5	Manufacturing Steps		Ferrite Shield Processing	
238	6	Manufacturing Process		Tog-L-loc	
239	6	Manufacturing Process		Wash	
240	6	Manufacturing Process		Debur	
241	6	Manufacturing Process		Stamping Press, 300 Ton	
242	7	Part	1608-185_1 Material	Material, Ferrite Shield	Steel, Galvanized G60
243	4	Part	1608-185_2	Foam Backing	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
244	4	Part	1608-185_3	Barcode Label	Commodity Item
245	4	Part	1608-185_4	Inspection Label 1	Commodity Item
246	4	Part	1608-185_5	Inspection Label 2	Commodity Item
247	4	Part	1608-185_6	Plain Label	Commodity Item
248	4	Manufacturing Steps		Assemble Ferrite Shield Asm	
249	5	Manufacturing Process		Manual Asm	
250	3	Preprocessed Part	1608-188	Bus Bar Protection	PA6 LG30
251	4	Manufacturing Steps		Bus Bar Protection Processing	
252	5	Manufacturing Process		Injection Mold Press, 55 Ton	
253	6	Part	1608-188 Material	Material, Bus Bar Protection	PA6 LG30
254	3	Part	1608-161_1	M4x0.70, 12 mm, Female Torx	Commodity Item
255	3	Manufacturing Steps		Assemble Bus Bar Protection and Ferrite Shield	
256	4	Manufacturing Process		Manual Asm	

Table F-36 Audi DC/DC Ferrites & Inductors Bill of Materials

A3 DC/DC Converter Ferrites & Inductors

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-173	**Ferrite Asm**	**$0.11**	**1**	**$0.11**
1608-173_1	**Ferrite 1**	**$0.10**	**1**	**$0.10**
1608-173_1 Material	Material, Ferrite 1	$0.10	1	$0.10
1608-173_2	**Ferrite Holder**	**$0.01**	**1**	**$0.01**
1608-173_2 Material	Material, Ferrite Holder	$0.01	1	$0.01
1608-173	**Ferrite Asm**	**$0.11**	**1**	**$0.11**
1608-173_1	**Ferrite 1**	**$0.10**	**1**	**$0.10**
1608-173_1 Material	Material, Ferrite 1	$0.10	1	$0.10
1608-173_2	**Ferrite Holder**	**$0.01**	**1**	**$0.01**
1608-173_2 Material	Material, Ferrite Holder	$0.01	1	$0.01
1608-178_11	Black RTV Adhesive	$0.01	1	$0.01
1608-173_1	**Ferrite 1**	**$0.10**	**1**	**$0.10**
1608-173_1 Material	Material, Ferrite 1	$0.10	1	$0.10
1608-173_1	**Ferrite 1**	**$0.10**	**1**	**$0.10**
1608-173_1 Material	Material, Ferrite 1	$0.10	1	$0.10
1608-162	**Ferrite Bracket**	**$0.01**	**1**	**$0.01**
1608-162 Material	Material, Ferrite Bracket	$0.01	1	$0.01
1608-127_1	M4x.70, 10 mm, Female Torx w/ Captured Washer	$0.01	1	$0.01
1608-178	**Inductor 1 Asm**	**$0.50**	**1**	**$0.50**
1608-178_1	**Inductor 1 Bracket**	**$0.08**	**1**	**$0.08**
1608-178_3	**Inductor 1 Bracket 1**	**$0.02**	**1**	**$0.02**
1608-178_3 Material	Material, Inductor 1 Bracket 1	$0.02	1	$0.02
1608-178_4	**Inductor 1 Bracket 2**	**$0.02**	**1**	**$0.02**
1608-178_4 Material	Material, Inductor 1 Bracket 2	$0.02	1	$0.02
1608-178_5	**Inductor 1 Bracket 3**	**$0.01**	**1**	**$0.01**
1608-178_5 Material	Material, Inductor 1 Bracket 3	$0.01	1	$0.01
1608-178_6	**Inductor 1 Bracket 4**	**$0.01**	**1**	**$0.01**
1608-178_6 Material	Material, Inductor 1 Bracket 4	$0.01	1	$0.01
1608-178_1 Material	Material, Inductor 1 Bracket	$0.02	1	$0.02
1608-178_2	**Inductor 1 Sub Asm**	**$0.42**	**1**	**$0.42**
1608-178_7	Ferrite Toroid	$0.40	1	$0.40
1608-178_8	Magnet Wire 1.25mm D, 176.3mm L	$0.00	2	$0.00
1608-178_10	**Toroid Mounting Base**	**$0.01**	**1**	**$0.01**
1608-178_10 Material	Material, Toroid Mounting Base	$0.01	1	$0.01
1608-178_11	Black RTV Adhesive	$0.01	1	$0.01
1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	$0.06	2	$0.12
1608-194_3	Thermal Gap Pad 1	$0.07	1	$0.07
1608-194_4	Thermal Gap Pad 2	$0.54	1	$0.54
1608-194_5	Thermal Gap Pad 3	$0.69	1	$0.69
1608-192	**Inductor 2 Asm**	**$1.35**	**1**	**$1.35**
1608-192_1	**Magnetic Core**	**$0.16**	**1**	**$0.16**
1608-192_1 Material	Material, Magnetic Core	$0.16	1	$0.16
1608-192_1	**Magnetic Core**	**$0.16**	**1**	**$0.16**
1608-192_1 Material	Material, Magnetic Core	$0.16	1	$0.16
1608-192_2	**HV Coil Asm**	**$0.92**	**1**	**$0.92**

A3 DC/DC Converter Ferrites & Inductors

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-192_3	**Flat Wire Coil, Coated**	**$0.58**	**1**	**$0.58**
1608-192_3 Material	Material, Flat Wire Coil, Coated	$0.58	1	$0.58
1608-192_5	**Terminal Bar**	**$0.34**	**1**	**$0.34**
1608-192_5 Material	Material, Terminal Bar	$0.34	1	$0.34
1608-192_4	Barcode Label	$0.02	1	$0.02
1608-192_6	Adhesive Magnetic Core	$0.09	1	$0.09
1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	$0.06	2	$0.12
1608-195	**Inductor 4 Asm**	**$3.87**	**1**	**$3.87**
1608-195_1	**Magnetic Core Large**	**$0.36**	**1**	**$0.36**
1608-195_1 Material	Material, Magnetic Core Large	$0.36	1	$0.36
1608-195_1	**Magnetic Core Large**	**$0.36**	**1**	**$0.36**
1608-195_1 Material	Material, Magnetic Core Large	$0.36	1	$0.36
1608-195_3	**Current Sensor Coil Asm**	**$3.01**	**1**	**$3.01**
1608-195_3a	**Current Sensor Coil Sub Asm 1**	**$1.80**	**1**	**$1.80**
1608-195_4	**Copper Stamping 1 Asm**	**$0.39**	**1**	**$0.39**
1608-195_4a	**Copper Stamping 1**	**$0.34**	**1**	**$0.34**
1608-195_4a Material	Material, Copper Stamping 1	$0.34	1	$0.34
1608-168_2	M4 PEM Nut	$0.05	1	$0.05
1608-195_5	**Copper Stamping 2**	**$0.34**	**1**	**$0.34**
1608-195_5 Material	Material, Copper Stamping 2	$0.34	1	$0.34
1608-195_6	**Copper Stamping 3**	**$0.31**	**1**	**$0.31**
1608-195_6 Material	Material, Copper Stamping 3	$0.31	1	$0.31
1608-195_6	**Copper Stamping 3**	**$0.31**	**1**	**$0.31**
1608-195_6 Material	Material, Copper Stamping 3	$0.31	1	$0.31
1608-195_7	Copper Coil Winding, 72-0.10mm D Strands	$0.22	1	$0.22
1608-195_8	**Coil Winding Shaft**	**$0.01**	**1**	**$0.01**
1608-195_8 Material	Material, Coil Winding Shaft	$0.01	1	$0.01
1608-195_9	**Coil Winding Layer Support**	**$0.08**	**1**	**$0.08**
1608-195_9 Material	Material, Coil Winding Layer Support	$0.01	8	$0.08
1608-195_10	Coil Lead	$0.05	2	$0.10
1608-195_11	Coil Insulation Sleeve	$0.02	2	$0.04
1608-195_3b	**Current Sensor Coil Casing Asm**	**$0.02**	**1**	**$0.02**
1608-195_3 Material	Material Current Sensor Coil Casing Asm	$0.02	1	$0.02
1608-195_14	Epoxy Potting Compound	$1.10	1	$1.10
1608-195_12	Spacer	$0.02	2	$0.04
1608-195_2	Thermal Gap Pad 4	$0.05	1	$0.05
1608-192_6	Adhesive Magnetic Core	$0.12	1	$0.12
1608-195_13	Supplier Label	$0.03	1	$0.03
1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	$0.06	2	$0.12
1608-161_1	M4x0.70, 12 mm, Female Torx	$0.01	2	$0.02
1608-185	**Ferrite Shield Asm**	**$0.25**	**1**	**$0.25**
1608-185_1	**Ferrite Shield**	**$0.16**	**1**	**$0.16**
1608-185_1 Material	Material, Ferrite Shield	$0.16	1	$0.16
1608-185_2	Foam Backing	$0.01	5	$0.05
1608-185_3	Barcode Label	$0.01	1	$0.01
1608-185_4	Inspection Label 1	$0.01	1	$0.01
1608-185_5	Inspection Label 2	$0.01	1	$0.01
1608-185_6	Plain Label	$0.01	1	$0.01

A3 DC/DC Converter Ferrites & Inductors

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-188	**Bus Bar Protection**	**$0.02**	**1**	**$0.02**
1608-188 Material	Material, Bus Bar Protection	$0.02	1	$0.02
1608-161_1	M4x0.70, 12 mm, Female Torx	$0.01	1	$0.01

Assembly Totals

Analyzed Subs:	39
Unanalyzed Subs:	0
Parts:	76
Fasteners:	11
Parts+Unanalyzed:	76

Report Totals

Piece Cost (Total): $8.14

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

Table F-37 Audi DC/DC Electrical & Harnesses Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Preprocessed Part	1608-161	Wire Harness Trough	PP LG30
2	4	Manufacturing Steps		Wire Harness Trough Processing	
3	5	Manufacturing Process		Injection Mold Press, 55 Ton	
4	6	Part	1608-161 Material	Material, Wire Harness Trough	PP LG30
5	3	Part	1608-161_1	M4x0.70, 12 mm, Female Torx	Commodity Item
6	3	Part	1608-160	Ribbon Cable 2	Commodity Item
7	3	Manufacturing Steps		Wire Trough And Ribbon Cable 2 Assembly	
8	4	Manufacturing Process		Manual Asm	
9	4	Manufacturing Process		Auto Asm	
10	3	Part	1608-189	Fuse 2	Commodity Item
11	3	Part	1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	Commodity Item
12	3	Manufacturing Steps		Install Fuse 2 to IGBT Asm	
13	4	Manufacturing Process		Auto Asm	
14	3	Preprocessed Part	1608-152	Receptacle Cover	PA 6/6 GP
15	4	Manufacturing Steps		Receptacle Cover, Processing	
16	5	Manufacturing Process		Injection Mold Press, 55 Ton	
17	6	Part	1608-152 Material	Material, Receptacle Cover	PA 6/6 GP
18	3	Subassembly	1608-176	Receptacle	(None)
19	4	Part	1608-116_8	Steel Spacer	Commodity Item
20	4	Part	1608-116_9	Stud Insert, Knurled	Commodity Item
21	4	Manufacturing Steps		Receptacle Assembly	
22	5	Manufacturing Process		Injection Mold Press, 110 Ton w/Inserts	
23	6	Part	1608-176, Material	Material, Receptacle	PA 66 GF50
24	3	Part	1608-116_21	M5x0.80, 16mm, Female Torx	Commodity Item
25	3	Manufacturing Steps		Receptacle, Cover and Enclosure Main 2 Assembly	
26	4	Manufacturing Process		Auto Asm	

Table F-38 Audi DC/DC Electrical & Harnesses Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 DC/DC Converter Electrical & Harness

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-161	**Wire Harness Trough**	**$0.06**	**1**	**$0.06**
1608-161 Material	Material, Wire Harness Trough	$0.06	1	$0.06
1608-161_1	M4x0.70, 12 mm, Female Torx	$0.01	2	$0.02
1608-160	Ribon Cable 2	$1.79	1	$1.79
1608-189	Fuse 2	$5.60	1	$5.60
1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	$0.06	1	$0.06
1608-152	**Receptacle Cover**	**$0.05**	**1**	**$0.05**
1608-152 Material	Material, Receptacle Cover	$0.05	1	$0.05
1608-176	**Receptacle**	**$0.47**	**1**	**$0.47**
1608-116_8	Steel Spacer	$0.02	2	$0.04
1608-116_9	Stud Insert, Knurled	$0.37	1	$0.37
1608-176, Material	Material, Receptacle	$0.06	1	$0.06
1608-116_21	M5x0.80, 16mm, Female Torx	$0.01	2	$0.02

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	3	Piece Cost (Total): $8.07	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	13		*Parts:*	*0*
Fasteners:	6		*Fasteners:*	*0*
Parts+Unanalyzed:	13		*Parts+Unanalyzed:*	*0*

Table F-39 Audi Inverter: Internal Housings Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Preprocessed Part	1608-181	Circuit Board 2 Shielding	Steel, Galvanized G60
2	4	Manufacturing Steps		Circuit Board 2 Shielding	
3	5	Manufacturing Process		Wash	
4	5	Manufacturing Process		Debur	
5	5	Manufacturing Process		Stamping Press, 60 Ton	
6	6	Part	1608-181 Material	Material, Circuit Board 2 Shielding	Steel, Galvanized G60
7	3	Part	1608-183_3	M4x0.70, 11.50 mm, Female Torx	Commodity Item
8	3	Manufacturing Steps		Motor Control Circuit Board Assembly	
9	4	Manufacturing Process		Manual Asm	
10	4	Manufacturing Process		Auto Asm	
11	3	Subassembly	1608-137	Lid Disconnect Housing Asm	(None)

Row	Level	Symbol Type	Number	Name	Material Name
12	4	Subassembly	1608-137_1	Lid Disconnect Housing Asm	(None)
13	5	Preprocessed Part	1608-137_1A	Lid Disconnect Housing	PBT GF30
14	6	Manufacturing Steps		Lid Disconnect Housing Processing	
15	7	Manufacturing Process		Injection Mold Press, 300 Ton	
16	8	Part	1608-137_1A, Material	Material, Lid Disconnect Housing	PBT GF30
17	5	Part	1608-137_1B	Insert M4 x 6.75	Commodity Item
18	5	Manufacturing Steps		Lid Disconnect Housing Assembly	
19	6	Manufacturing Process		Plastic Vibration Insertion	
20	4	Subassembly	1608-137_41	Harness 1 Sub Asm	(None)
21	5	Part	1608-137_4a	Wiring Harness	Commodity Item
22	5	Part	1608-137_4b	Harness Sleeve	Commodity Item
23	5	Part	1608-137_4c	Harness Connector Clip	Commodity Item
24	5	Part	1608-137_4d	Harness Connector Pin 1	Commodity Item
25	5	Part	1608-137_4e	Harness Connector Pin 2	Commodity Item
26	5	Manufacturing Steps		Harness 1 Assembly	
27	6	Manufacturing Process		Manual Asm	
28	4	Subassembly	1608-137_51	Harness 2 Sub Asm	(None)
29	5	Part	1608-137_5a	Wiring Harness Small	Commodity Item
30	5	Part	1608-137_4d	Harness Connector Pin 1	Commodity Item
31	5	Part	1608-137_4e	Harness Connector Pin 2	Commodity Item
32	5	Manufacturing Steps		Harness 2 Assembly	
33	6	Manufacturing Process		Manual Asm	
34	4	Manufacturing Steps		Assemble Lid Disconnect Housing	
35	5	Manufacturing Process		Manual Asm	
36	3	Manufacturing Steps		Install Lid Disconnect Housing	
37	4	Manufacturing Process		Manual Asm	

Table F-40 Audi Inverter: Internal Housings Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 Inverter Internal Housings

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-181	**Circuit Board 2 Shielding**	**$0.13**	**1**	**$0.13**
1608-181 Material	Material, Circuit Board 2 Shielding	$0.13	1	$0.13
1608-183_3	M4x0.70, 11.50 mm, Female Torx	$0.01	8	$0.08
1608-137	**Lid Disconnect Housing Asm**	**$0.91**	**1**	**$0.91**
1608-137_1	**Lid Disconnect Housing Asm**	**$0.57**	**1**	**$0.57**
1608-137_1A	**Lid Disconnect Housing**	**$0.45**	**1**	**$0.45**
1608-137_1A, Material	Material, Lid Disconnect Housing	$0.45	1	$0.45
1608-137_1B	Insert M4 x 6.75	$0.06	2	$0.12
1608-137_41	**Harness 1 Sub Asm**	**$0.25**	**1**	**$0.25**
1608-137_4a	Wiring Harness	$0.04	2	$0.07
1608-137_4b	Harness Sleeve	$0.02	1	$0.02
1608-137_4c	Harness Connector Clip	$0.08	1	$0.08
1608-137_4d	Harness Connector Pin 1	$0.04	1	$0.04
1608-137_4e	Harness Connector Pin 2	$0.04	1	$0.04
1608-137_51	**Harness 2 Sub Asm**	**$0.09**	**1**	**$0.09**
1608-137_5a	Wiring Harness Small	$0.01	1	$0.01
1608-137_4d	Harness Connector Pin 1	$0.04	1	$0.04
1608-137_4e	Harness Connector Pin 2	$0.04	1	$0.04

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	6	Piece Cost (Total): $1.12	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	21		*Parts:*	*0*
Fasteners:	8		*Fasteners:*	*0*
Parts+Unanalyzed:	21		*Parts+Unanalyzed:*	*0*

Table F-41 Audi Inverter: Bus Bars Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1608-143	Bus Bar Asm 2	(None)
2	4	Preprocessed Part	1608-143_1	Bus Bar Plastic Housing	PBT GF30
3	5	Manufacturing Steps		Bus Bar Plastic Housing Processing	
4	6	Manufacturing Process		Injection Mold Press, 55 Ton	
5	7	Part	1608-143_1 Material	Material, Bus Bar Plastic Housing	PBT GF30
6	4	Subassembly	1608-143_2	T+ Bus Bar Assembly	(None)
7	5	Preprocessed Part	1608-143_7	T+ Bus Bar	Copper Cu (10200)
8	6	Manufacturing Steps		T+ Bus Bar Processing	
9	7	Manufacturing Process		Wash	
10	7	Manufacturing Process		Debur	
11	7	Manufacturing Process		Stamping Press, 25 Ton	
12	8	Part	1608-143_7 Material	Material, T+ Bus Bar	Copper Cu (10200)
13	5	Part	1608-143_6	M4x0.7, 14mm, PEM Stand-Off	Commodity Item
14	5	Manufacturing Steps		T+ Bus Bar Assembly Processing	
15	6	Manufacturing Process		Automated Press Station	
16	4	Subassembly	1608-143_3	T- Bus Bar Assembly	(None)
17	5	Preprocessed Part	1608-143_8	T- Bus Bar	Copper Cu (10200)
18	6	Manufacturing Steps		T- Bus Bar Processing	
19	7	Manufacturing Process		Wash	
20	7	Manufacturing Process		Debur	
21	7	Manufacturing Process		Stamping Press, 25 Ton	
22	8	Part	1608-143_8 Material	Material, T- Bus Bar	Copper Cu (10200)
23	5	Part	1608-143_6	M4x0.7, 14mm, PEM Stand-Off	Commodity Item
24	5	Manufacturing Steps		T- Bus Bar Assembly Processing	
25	6	Manufacturing Process		Automated Press Station	
26	4	Part	1608-143_4	M8x1.25, 7.7mm,Nut	Commodity Item
27	4	Manufacturing Steps		Bus Bar Asm2 Assembly	
28	5	Manufacturing Process		Auto Asm	

Row	Level	Symbol Type	Number	Name	Material Name
29	3	Part	1608-143_5	M6x1.00, 18 mm, Female Torx w/ Captured Washer	Commodity Item
30	3	Manufacturing Steps		Bus Bar Asm2 Installation	
31	4	Manufacturing Process		Auto Asm	
32	3	Preprocessed Part	1608-137_2	Bus Bar 1	Copper Cu (10200)
33	4	Manufacturing Steps		Bus Bar 1 Processing	
34	5	Manufacturing Process		Wash	
35	5	Manufacturing Process		Debur	
36	5	Manufacturing Process		Stamping Press, 25 Ton	
37	6	Part	1608-137_2, Material	Material ,Bus Bar 1	Copper Cu (10200)
38	3	Part	1608-132	Fuse 1	Commodity Item
39	3	Part	1608-137_6	M4x0.70, 10mm, Female Torx w/ Captured Washer	Commodity Item
40	3	Manufacturing Steps		Assemble Bus Bar 1 & Fuse	
41	4	Manufacturing Process		Manual Asm	
42	3	Preprocessed Part	1608-149	Bus Bar 2	Copper Cu (10200)
43	4	Manufacturing Steps		Bus Bar 2 Processing	
44	5	Manufacturing Process		Wash	
45	5	Manufacturing Process		Debur	
46	5	Manufacturing Process		Stamping Press, 60 Ton	
47	6	Part	1608-149 Material	Material, Bus Bar 2	Copper Cu (10200)
48	3	Preprocessed Part	1608-150	Bus Bar 3	Copper Cu (10200)
49	4	Manufacturing Steps		Bus Bar 3 Processing	
50	5	Manufacturing Process		Wash	
51	5	Manufacturing Process		Debur	
52	5	Manufacturing Process		Stamping Press,60 Ton	
53	6	Part	1608-150 Material	Material, Bus Bar 3	Copper Cu (10200)
54	3	Preprocessed Part	1608-151	Bus Bar 4	Copper Cu (10200)
55	4	Manufacturing Steps		Bus Bar 2 Processing	
56	5	Manufacturing Process		Wash	
57	5	Manufacturing Process		Debur	
58	5	Manufacturing Process		Stamping Press, 60 Ton	
59	6	Part	1608-151 Material	Material, Bus Bar 4	Copper Cu (10200)
60	3	Subassembly	1608-144	Bus Bar Terminal Holder Asm	(None)

Row	Level	Symbol Type	Number	Name	Material Name
61	4	Preprocessed Part	1608-144_1	Bus Bar Terminal Holder Bracket	PBT SG30
62	5	Manufacturing Steps		Bus Bar Terminal Holder Bracket Processing	
63	6	Manufacturing Process		Injection Mold Press, 110 Ton	
64	7	Part	1608-144_1 Material	Material, Bus Bar Terminal Holder Bracket	PBT SG30
65	4	Part	1608-143_4	M8x1.25, 7.7mm,Nut	Commodity Item
66	4	Manufacturing Steps		Bus Bar Terminal holder Assembly	
67	5	Manufacturing Process		Auto Assembly	
68	3	Manufacturing Steps		Bus Bar Terminal Assembly	
69	4	Manufacturing Process		Manual Asm	

Table F-42 Audi Inverter: Bus Bars Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 Inverter Bus Bars

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-143	**Bus Bar Asm 2**	**$4.63**	**1**	**$4.63**
1608-143_1	**Bus Bar Plastic Housing**	**$0.11**	**1**	**$0.11**
1608-143_1 Material	Material, Bus Bar Plastic Housing	$0.11	1	$0.11
1608-143_2	**T+ Bus Bar Assembly**	**$1.79**	**1**	**$1.79**
1608-143_7	**T+ Bus Bar**	**$1.74**	**1**	**$1.74**
1608-143_7 Material	Material, T+ Bus Bar	$1.74	1	$1.74
1608-143_6	M4x0.7, 14mm, PEM Stand-Off	$0.05	1	$0.05
1608-143_3	**T- Bus Bar Assembly**	**$2.63**	**1**	**$2.63**
1608-143_8	**T- Bus Bar**	**$2.58**	**1**	**$2.58**
1608-143_8 Material	Material, T- Bus Bar	$2.58	1	$2.58
1608-143_6	M4x0.7, 14mm, PEM Stand-Off	$0.05	1	$0.05
1608-143_4	M8x1.25, 7.7mm,Nut	$0.05	2	$0.10
1608-143_5	M6x1.00, 18 mm, Female Torx w/ Captured Washer	$0.03	2	$0.06
1608-137_2	**Bus Bar 1**	**$0.59**	**1**	**$0.59**
1608-137_2, Material	Material ,Bus Bar 1	$0.59	1	$0.59
1608-132	Fuse 1	$5.60	1	$5.60
1608-137_6	M4x0.70, 10mm, Female Torx w/ Captured Washer	$0.06	2	$0.12
1608-149	**Bus Bar 2**	**$1.70**	**1**	**$1.70**
1608-149 Material	Material, Bus Bar 2	$1.70	1	$1.70
1608-150	**Bus Bar 3**	**$2.43**	**1**	**$2.43**
1608-150 Material	Material, Bus Bar 3	$2.43	1	$2.43
1608-151	**Bus Bar 4**	**$3.17**	**1**	**$3.17**
1608-151 Material	Material, Bus Bar 4	$3.17	1	$3.17
1608-144	**Bus Bar Terminal Holder Asm**	**$0.33**	**1**	**$0.33**
1608-144_1	**Bus Bar Terminal Holder Bracket**	**$0.18**	**1**	**$0.18**
1608-144_1 Material	Material, Bus Bar Terminal Holder Bracket	$0.18	1	$0.18
1608-143_4	M8x1.25, 7.7mm,Nut	$0.05	3	$0.15

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	12	Piece Cost (Total): $18.63	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	20		*Parts:*	*0*
Fasteners:	11		*Fasteners:*	*0*
Parts+Unanalyzed:	20		*Parts+Unanalyzed:*	*0*

Table F-43 Audi Inverter: PCBAs & IGBTs Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1608-183	Control/Diagnostics Board	(None)
2	4	Subassembly	1608-183_1	Connector Asm	(None)
3	5	Part	1608-183_1a	Connector Metal Spacer	Commodity Item
4	5	Part	1608-183_1b	Connector Pins	Commodity Item
5	5	Manufacturing Steps		Connector Asm Processing	
6	6	Manufacturing Process		Auto Assembly	
7	6	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
8	7	Part	1608-183_1 Material	Material, Connector Asm	PA 6/6 GF30
9	4	Manufacturing Steps		Printed Circuit Board Assembly	
10	5	Manufacturing Process		Laser Etch	
11	5	Manufacturing Process		Functional Test	
12	5	Manufacturing Process		Manual Through Hole Placement	
13	5	Manufacturing Process		De-Panel	
14	5	Manufacturing Process		PCB - Low Content	
15	6	Part	1608-183_2	Printed FR4 Control/Diagnostics Board	Commodity Item
16	7	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
17	7	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
18	7	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item
19	8	Part	TLE6250G V33	1/1 Transceiver Half CAN PG-DSO-8	Commodity Item
20	8	Part	LTC1871HMS	Step-Up/Step-Down DC-DC Controller IC 10-MSOP	Commodity Item
21	8	Part	BUK9222-55A,118	MOSFET N-CH 55V 48A DPAK	Commodity Item
22	8	Part	74AHC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	Commodity Item
23	8	Part	SM4T10CAY	TVS DIODE 8.5VWM 19.5VC SMA	Commodity Item
24	8	Part	NJVMJD44H11G	Bipolar Transistors - BJT BIP DPAK NPN 8A 80V	Commodity Item
25	8	Part	NDD03N60ZT4G	MOSFET N-CH 600V DPAK	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
26	8	Part	LM2903HYPT	Comparator Gen Purpose CMOS, Open-Collector, 8-TSS	Commodity Item
27	8	Part	TLE4251GXT	LDO Voltage Regulators Low Drop Voltage Tracker	Commodity Item
28	8	Part	BCP56-16T3G	TRANS NPN 80V 1A SOT-223	Commodity Item
29	8	Part	DDZX43-7-1	Zener Diodes 300MW 43V	Commodity Item
30	8	Part	AP2210N-3.3TRG1-1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	Commodity Item
31	8	Part	BZX84B18-7-F-1	Zener Diode 18V 300mW 2% Surface Mount SOT-23	Commodity Item
32	8	Part	BAS21-7-F-1	Diode Standard 200V 200mA Surface Mount SOT-23-3	Commodity Item
33	8	Part	MBR0540-TP	Schottky Diodes & Rectifier 0.5A 40V	Commodity Item
34	8	Part	FDS9958	MOSFET 2P-CH 60V 2.9A 8-SO	Commodity Item
35	8	Part	CMPT4401 TR-1	TRANS NPN 40V 0.6A SOT-23	Commodity Item
36	8	Part	40076	Automobile Engine Power Driver IC	Commodity Item
37	8	Part	EGF1D-E3/67A	Diode Standard 200V 1A Surface Mount DO-214BA	Commodity Item
38	8	Part	AD2S1210WDSTZRL7	R/D Converter 10, 12, 14, 16 bit Serial, Parallel	Commodity Item
39	8	Part	74LVC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	Commodity Item
40	8	Part	74LVC1G32GW,125	OR Gate IC 1 Channel 5-TSSOP	Commodity Item
41	8	Part	74LVC1G17GW-Q100,1	Buffer, Non-Inverting Push-Pull Output 5-TSSOP	Commodity Item
42	8	Part	AP7333-28SAG-7	LVR IC Positive Fixed 1 Output 2.8V 300mA SOT-23-3	Commodity Item
43	8	Part	T520C226M016ATE080	22uF 20% Molded Tantalum Polymer Capacitor 16V 231	Commodity Item
44	8	Part	T491D476K016AT	47uF 10% Molded Tantalum Capacitors 16V 2917 (7343	Commodity Item
45	8	Part	TCQD476M016R0070	47uF 20% Molded Tantalum Polymer Capacitor 16V 291	Commodity Item
46	8	Part	1210 Capacitors	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	Commodity Item
47	8	Part	0402 Capacitors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
48	8	Part	0805 Capacitors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
49	8	Part	0603 Capacitors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
50	8	Part	PE2010JKF070R03L	Current Sense Resistors - SMD 30 mOhms 100ppm 2010	Commodity Item
51	8	Part	1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
52	8	Part	0805 Resistors-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
53	8	Part	0603 Resistors-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
54	8	Part	0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
55	8	Part	#063210	Board to Board & Mezzanine Connectors 50P 1.27MM S	Commodity Item
56	8	Part	#234457	Headers & Wire Housings 3P 1.27MM SMT VERT MALE TY	Commodity Item
57	8	Part	B78334B1033A003	Current Sensing Transformer, 1:1:1:1, SMT	Commodity Item
58	8	Part	B82464P4474M	Fixed Inductors AEC-Q200	Commodity Item
59	8	Part	EMZA500ADA221MJA0G	220uF 50V Aluminum Capacitors Radial, Can - SMD 20	Commodity Item
60	8	Part	TC277T64F200SCAKXUMA1	TriCore AURIX Microcontroller IC 32-Bit 200MHz 4MB	Commodity Item
61	8	Part	EPM570T100A5N-1	CPLD MAX II Family	Commodity Item
62	8	Part	74LVC1G17GW-Q100,1	Buffer, Non-Inverting Push-Pull Output 5-TSSOP	Commodity Item
63	8	Part	74LVC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	Commodity Item
64	8	Part	74LVC1G32GW,125	OR Gate IC 1 Channel 5-TSSOP	Commodity Item
65	8	Part	BZX84C2V4LT1G-1	Zener Diode 2.4V 250mW 8% SMT SOT-23-3 (TO-236)	Commodity Item
66	8	Part	LM2903DGKR-1	Comparator Differential CMOS, Open-Collector, 8-VS	Commodity Item
67	8	Part	AD8617ARZ	General Purpose Amplifier 2 Circuit Rail-to-Rail 8	Commodity Item
68	8	Part	74HCT4066DB	Analog Switch ICs QUAD BILATERAL	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
69	8	Part	LM2901AVQDRQ1-1	Comparator Differential CMOS, Open-Collector, 14-S	Commodity Item
70	8	Part	MC33078YDT	General Purpose Amplifier 2 Circuit 8-SO	Commodity Item
71	8	Part	MC33204VDG	Operational Amplifier 1.8-12V Quad Rail to Rail -5	Commodity Item
72	8	Part	74HC366PW	Buffer, Inverting 6 Bit per Element Push-Pull O/P	Commodity Item
73	8	Part	DDZX43-7-1	Zener Diodes 300MW 43V	Commodity Item
74	8	Part	AP2210N-3.3TRG1-1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	Commodity Item
75	8	Part	2SK1828TE85LF	MOSFET N-CH 20V 50MA S-MINI	Commodity Item
76	8	Part	IPD50P04P4L-11	MOSFET P-CH 40V 50A TO252-3	Commodity Item
77	8	Part	BZX84B18-7-F-1	Zener Diode 18V 300mW 2% Surface Mount SOT-23	Commodity Item
78	8	Part	TLE6250G V33	1/1 Transceiver Half CAN PG-DSO-8	Commodity Item
79	8	Part	BSS84PH6433XTMA1-1	MOSFET P-CH 60V 170MA SOT-23	Commodity Item
80	8	Part	74AHC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	Commodity Item
81	8	Part	TPSMB16A	TVS Diodes 16V 600W 5% DO214AA	Commodity Item
82	8	Part	TPSMB33A	TVS Diodes 33V 600W 5% DO214AA	Commodity Item
83	8	Part	TAJA226K010RNJ	22uF 10% Molded Tantalum Capacitors 10V 1206 (3216	Commodity Item
84	8	Part	T491D476K016AT	47F 10% Molded Tantalum Capacitors 16V 2917 (7343	Commodity Item
85	8	Part	1210 Capacitors	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	Commodity Item
86	8	Part	0402 Capacitors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
87	8	Part	0805 Capacitors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item
88	8	Part	0603 Capacitors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
89	8	Part	CMA02040X2209GB300-1	RES SMD 22 OHM 2% 0.4W 0204	Commodity Item
90	8	Part	1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	Commodity Item
91	8	Part	0805 Resistors-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
92	8	Part	0603 Resistors-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	Commodity Item
93	8	Part	0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	Commodity Item
94	7	Part	NX5032GA-20.000M-STD-CSU-2	20MHz 50ppm Crystal 8pF 100 Ohm -40degC-150degC AE	Commodity Item
95	7	Part	DLW43MH201XK2L	200uH 100kHz 2 Line Common Mode Choke SMT 110mA DC	Commodity Item
96	3	Manufacturing Steps		Install Circuit Board 4 to Unit	
97	4	Manufacturing Process		Auto Asm	
98	3	Subassembly	1608-138	IGBT Control Board	(None)
99	4	Manufacturing Steps		Circuit Board Assembly	
100	5	Manufacturing Process		Laser Etch	
101	5	Manufacturing Process		Functional Test	
102	5	Manufacturing Process		Automated Through Hole Placement	
103	7	Part	B59219J130A20	PTC Resettable Fuse 560V Through Hole 4-Dip Cube	Commodity Item
104	5	Manufacturing Process		De-Panel	
105	5	Manufacturing Process		PCB - Low Content	
106	6	Part	1608-138 Printed FR4 Circuit Board-3	Printed FR4 IGBT Control Board	Commodity Item
107	7	Part	EF2210 VOC Free Flux	EF2210 VOC Free Flux	Commodity Item
108	7	Part	LF318 Solder Paste	LF318 Solder Paste	Commodity Item
109	7	Part	Loctite Chipbonder 3627	Loctite Chipbonder 3627	Commodity Item
110	8	Part	STTH102AY	Diodes - General Purpose, Power, Switching Auto Hi	Commodity Item
111	8	Part	IRF7478TRPBF	MOSFET N-CH 60V 7A 8-SOIC	Commodity Item
112	8	Part	1.5SMC18CA-E3/57T	TVS DIODE 15.3VWM 25.2VC DO214AB	Commodity Item
113	8	Part	P6SMB510A	TVS Diodes - Transient Voltage Suppressors TVS SUR	Commodity Item
114	8	Part	FAN3216TMX_F085	Low-Side Gate Driver IC Inverting 8-SOIC	Commodity Item
115	8	Part	P4SMA480A-E3/61	TVS DIODE 408VWM 658VC SMA	Commodity Item
116	8	Part	P4SMA51A-E3/61	TVS Diodes - Transient Voltage Suppressors 400W 51	Commodity Item
117	8	Part	BSS84PH6433XTMA1-2	MOSFET P-CH 60V 170MA SOT-23	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
118	8	Part	RT9818C-29GV	Supervisor Open Drain or Open Collector 1 Channel	Commodity Item
119	8	Part	BCR 185W H6327	Bipolar Transistors - Pre-Biased AF DIGITAL TRANSI	Commodity Item
120	8	Part	AP2210N-3.3TRG1-2	Linear Voltage Regulator IC Positive Fixed 1 Output	Commodity Item
121	8	Part	2SK1828TE85LF-1	MOSFET N-CH 20V 50MA S-MINI	Commodity Item
122	8	Part	74HC1G08GW,125	AND Gate IC 1 Channel 5-TSSOP	Commodity Item
123	8	Part	BAS40-05,215	Diode Array 1 Pair Common Cathode Schottky 40V 120	Commodity Item
124	8	Part	A1363LKTTN-10-T	Hall Effect Sensor Single Axis 4-SIP	Commodity Item
125	8	Part	P4SMA20CA-E3/61	TVS DIODE 17.1VWM 27.7VC SMA	Commodity Item
126	8	Part	ADS7841E/2K5	12 Bit Analog to Digital Converter 4 Input 1 SAR 1	Commodity Item
127	8	Part	BYG23M-E3/TR	Diode Avalanche 1000V (1kV) 1.5A Surface Mount DO-	Commodity Item
128	8	Part	BZX84-C18,235	Zener Diode 18V 250mW 5% Surface Mount SOT-23 (TO-	Commodity Item
129	8	Part	1210 Capacitors-1	Tolerance - 10%; 1210 (3225 Metric) 0.126" L x 0.0	Commodity Item
130	8	Part	1206 Capacitors	Tolerance - 10%; 1206 (3216 Metric) 0.126" L x 0.0	Commodity Item
131	8	Part	0805 Capacitors-1	Tolerance - 10%; 0805 (2012 Metric) 0.083" L x 0.0	Commodity Item
132	8	Part	0603 Capacitors-1	Tolerance - 10%; 0603 (1608 Metric) 0.064" L x 0.0	Commodity Item
133	8	Part	0402 Capacitors-1	Tolerance - 10%; 0402 (1005 Metric) 0.039" L x 0.0	Commodity Item
134	8	Part	CMA02040X2209GB300-2	RES SMD 22 OHM 2% 0.4W 0204	Commodity Item
135	8	Part	CMA02040X3300GB300	RES SMD 330 OHM 2% 0.4W 0204	Commodity Item
136	8	Part	CMA02040X1000GB300	RES SMD 100 OHM 2% 0.4W 0204	Commodity Item
137	8	Part	CMA02040X1509GB300	RES SMD 15 OHM 2% 0.4W 0204	Commodity Item
138	8	Part	1206 Resistors-1	Tolerance - 5%; 1206 (3216 Metric) 0.126" L x 0.06	Commodity Item
139	8	Part	0603 Resistors-2	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
140	8	Part	0805 Resistors-2	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	Commodity Item
141	8	Part	0402 Resistors-1	Tolerance - 5%; 0402 (1005 Metric) 0.039" L x 0.02	Commodity Item
142	8	Part	PA1281NLT-1	Transformers Audio & Signal SMD HiFreq WireWound 3	Commodity Item
143	8	Part	STTH102AY	Diodes - General Purpose, Power, Switching Auto Hi	Commodity Item
144	8	Part	SPB07N60C3	MOSFET N-CH 650V 7.3A D2PAK	Commodity Item
145	8	Part	TLE42642GHTSA2	Linear Voltage Regulator IC Positive Fixed 1 Outpu	Commodity Item
146	8	Part	BYG23M-E3/TR	Diode Avalanche 1000V (1kV) 1.5A Surface Mount DO-	Commodity Item
147	8	Part	RT9026GFP	Converter, DDR Bus Termination Regulator Voltage R	Commodity Item
148	8	Part	ADUM1401ARWZ-RL	General Purpose Digital Isolator 2500Vrms 4 Channe	Commodity Item
149	8	Part	LM2903DT	Comparator General Purpose CMOS, DTL, ECL, MOS, Op	Commodity Item
150	8	Part	SI1869DH-T1-E3	IC LOAD SW LVL SHIFT 20V SC70-6	Commodity Item
151	8	Part	P4SMA20CA-E3/61	TVS DIODE 17.1VWM 27.7VC SMA	Commodity Item
152	8	Part	BZX84-C18,235	Zener Diode 18V 250mW 5% Surface Mount SOT-23 (TO-	Commodity Item
153	8	Part	2SK1828TE85LF-1	MOSFET N-CH 20V 50MA S-MINI	Commodity Item
154	8	Part	RT9818C-29GV	Supervisor Open Drain or Open Collector 1 Channel	Commodity Item
155	8	Part	AP2210N-3.3TRG1-2	Linear Voltage Regulator IC Positive Fixed 1 Outpu	Commodity Item
156	8	Part	BSS84PH6433XTMA1-2	MOSFET P-CH 60V 170MA SOT-23	Commodity Item
157	8	Part	LT1460KCS3-3.3#TRPBF	Series Voltage Reference IC 0.5% 40mA SOT-23-3	Commodity Item
158	8	Part	2ED020I12FAXUMA2	Gate Drivers Dual Channel IGBT Driver IC +/-1200V	Commodity Item
159	8	Part	74HC1G08GW,125	AND Gate IC 1 Channel 5-TSSOP	Commodity Item
160	8	Part	SMBJ20A-E3/52	TVS DIODE 20VWM 32.4VC SMB	Commodity Item
161	8	Part	1210 Capacitors-1	Tolerance - 10%; 1210 (3225 Metric) 0.126" L x 0.0	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
162	8	Part	0805 Capacitors-1	Tolerance - 10%; 0805 (2012 Metric) 0.083" L x 0.0	Commodity Item
163	8	Part	0603 Capacitors-1	Tolerance - 10%; 0603 (1608 Metric) 0.064" L x 0.0	Commodity Item
164	8	Part	0402 Capacitors-1	Tolerance - 10%; 0402 (1005 Metric) 0.039" L x 0.0	Commodity Item
165	8	Part	CMA02040X3300GB300	RES SMD 330 OHM 2% 0.4W 0204	Commodity Item
166	8	Part	CMA02040X1000GB300	RES SMD 100 OHM 2% 0.4W 0204	Commodity Item
167	8	Part	CMA02040X3301GB300	RES SMD 3.3K OHM 2% 0.4W 0204	Commodity Item
168	8	Part	CMA02040X1509GB300	RES SMD 15 OHM 2% 0.4W 0204	Commodity Item
169	8	Part	1206 Resistors-1	Tolerance - 5%; 1206 (3216 Metric) 0.126" L x 0.06	Commodity Item
170	8	Part	0805 Resistors-2	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	Commodity Item
171	8	Part	0603 Resistors-2	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	Commodity Item
172	8	Part	0402 Resistors-1	Tolerance - 5%; 0402 (1005 Metric) 0.039" L x 0.02	Commodity Item
173	8	Part	B82432T1102K	1uH Unshielded Wirewound Inductor 1.3A 80 mOhm Max	Commodity Item
174	8	Part	63210	Board to Board & Mezzanine Connectors 50P 1.27MM S	Commodity Item
175	3	Preprocessed Part	1608-147	Circuit Board Bracket Right	Steel 1020 Cold Drawn or Cold Rolled - Galvanized
176	4	Manufacturing Steps		Capacitor Assembly Bracket Right Processing	
177	5	Manufacturing Process		Wash	
178	5	Manufacturing Process		Debur	
179	5	Manufacturing Process		Stamping Press, 25 Ton	
180	6	Part	1608-147, Material-1	Material, Capacitor Assembly Bracket Right	Steel 1020 Cold Drawn or Cold Rolled
181	3	Preprocessed Part	1608-145	Circuit Board Bracket Left	Steel 1020 Cold Drawn or Cold Rolled
182	4	Manufacturing Steps		Capacitor Assembly Bracket Left Processing	
183	5	Manufacturing Process		Wash	
184	5	Manufacturing Process		Debur	
185	5	Manufacturing Process		Stamping Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
186	6	Part	1608-145, Material	Material, Capacitor Assembly Bracket left	Steel 1020 Cold Drawn or Cold Rolled
187	3	Part	1608-138_1	M4x1.00, 10 mm Female Torx w/ Captured Washer	Commodity Item
188	3	Part	1608-138_2	M2x1.00, 8 mm Female Torx w/ Captured Washer	Commodity Item
189	3	Manufacturing Steps		Install Circuit Board	
190	4	Manufacturing Process		Manual Asm	
191	3	Subassembly	1608-139	IGBT Half Bridge Assembly	(None)
192	4	Part	1608-139_1	IGBT Half Bridge	Commodity Item
193	4	Preprocessed Part	1608-139_2	Terminal Block Large	PBT GF30
194	5	Manufacturing Steps		Terminal Block Large Processing	
195	6	Manufacturing Process		Injection Mold Press, 55 Ton	
196	7	Part	1608-139_2-Material	Material, Terminal Block Large	PBT GF30
197	4	Preprocessed Part	1608-139_3	Terminal Block Small	PBT GF30
198	5	Manufacturing Steps		Terminal Block Small Processing	
199	6	Manufacturing Process		Injection Mold Press, 55 Ton	
200	7	Part	1608-139_3-Material	Material, Terminal Block Small	PBT GF30
201	4	Manufacturing Steps		IGBT Half Bridge Asm	
202	5	Manufacturing Process		Automated Asm 5 parts	
203	4	Subassembly	1608-139_5	Terminal Asm 1	(None)
204	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
205	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
206	7	Manufacturing Process		Plating	
207	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
208	7	Manufacturing Process		Wash	
209	7	Manufacturing Process		Debur	
210	7	Manufacturing Process		Stamping Press, 25 Ton	
211	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
212	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
213	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
214	7	Manufacturing Process		Plating	
215	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
216	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
217	7	Manufacturing Process		Debur	
218	7	Manufacturing Process		Stamping Press, 25 Ton	
219	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
220	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
221	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
222	7	Manufacturing Process		Plating	
223	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
224	7	Manufacturing Process		Wash	
225	7	Manufacturing Process		Debur	
226	7	Manufacturing Process		Stamping Press, 25 Ton	
227	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
228	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
229	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
230	7	Manufacturing Process		Plating	
231	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
232	7	Manufacturing Process		Wash	
233	7	Manufacturing Process		Debur	
234	7	Manufacturing Process		Stamping Press, 25 Ton	
235	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
236	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
237	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
238	7	Manufacturing Process		Plating	
239	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
240	7	Manufacturing Process		Wash	
241	7	Manufacturing Process		Debur	
242	7	Manufacturing Process		Stamping Press, 25 Ton	
243	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
244	5	Manufacturing Steps		Terminal Asm1 Processing	
245	6	Manufacturing Process		Injection Molding, 55 Tons	
246	7	Part	1608-139_5-Material	Material, Terminal Asm 1	PBT GF30
247	4	Subassembly	1608-139_6	Terminal Asm 2	(None)
248	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
249	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
250	7	Manufacturing Process		Plating	

Row	Level	Symbol Type	Number	Name	Material Name
251	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
252	7	Manufacturing Process		Wash	
253	7	Manufacturing Process		Debur	
254	7	Manufacturing Process		Stamping Press, 25 Ton	
255	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
256	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
257	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
258	7	Manufacturing Process		Plating	
259	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
260	7	Manufacturing Process		Wash	
261	7	Manufacturing Process		Debur	
262	7	Manufacturing Process		Stamping Press, 25 Ton	
263	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
264	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
265	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
266	7	Manufacturing Process		Plating	
267	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
268	7	Manufacturing Process		Wash	
269	7	Manufacturing Process		Debur	
270	7	Manufacturing Process		Stamping Press, 25 Ton	
271	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
272	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
273	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
274	7	Manufacturing Process		Plating	
275	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
276	7	Manufacturing Process		Wash	
277	7	Manufacturing Process		Debur	
278	7	Manufacturing Process		Stamping Press, 25 Ton	
279	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
280	5	Manufacturing Steps		Terminal Asm2 Processing	
281	6	Manufacturing Process		Injection Molding, 55 ton	
282	7	Part	1608-139_6-Material	Material, Terminal Asm 2	PBT GF30
283	4	Manufacturing Steps		IGBT Half Bridge Asm Final	
284	5	Manufacturing Process		Automated Asm 5 parts	
285	3	Subassembly	1608-139	IGBT Half Bridge Assembly	(None)
286	4	Part	1608-139_1	IGBT Half Bridge	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
287	4	Preprocessed Part	1608-139_2	Terminal Block Large	PBT GF30
288	5	Manufacturing Steps		Terminal Block Large Processing	
289	6	Manufacturing Process		Injection Mold Press, 55 Ton	
290	7	Part	1608-139_2-Material	Material, Terminal Block Large	PBT GF30
291	4	Preprocessed Part	1608-139_3	Terminal Block Small	PBT GF30
292	5	Manufacturing Steps		Terminal Block Small Processing	
293	6	Manufacturing Process		Injection Mold Press, 55 Ton	
294	7	Part	1608-139_3-Material	Material, Terminal Block Small	PBT GF30
295	4	Manufacturing Steps		IGBT Half Bridge Asm	
296	5	Manufacturing Process		Automated Asm 5 parts	
297	4	Subassembly	1608-139_5	Terminal Asm 1	(None)
298	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
299	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
300	7	Manufacturing Process		Wash	
301	7	Manufacturing Process		Debur	
302	7	Manufacturing Process		Stamping Press, 25 Ton	
303	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
304	7	Manufacturing Process		Plating	
305	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
306	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
307	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
308	7	Manufacturing Process		Wash	
309	7	Manufacturing Process		Debur	
310	7	Manufacturing Process		Stamping Press, 25 Ton	
311	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
312	7	Manufacturing Process		Plating	
313	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
314	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
315	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
316	7	Manufacturing Process		Wash	
317	7	Manufacturing Process		Debur	
318	7	Manufacturing Process		Stamping Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
319	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
320	7	Manufacturing Process		Plating	
321	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
322	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
323	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
324	7	Manufacturing Process		Wash	
325	7	Manufacturing Process		Debur	
326	7	Manufacturing Process		Stamping Press, 25 Ton	
327	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
328	7	Manufacturing Process		Plating	
329	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
330	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
331	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
332	7	Manufacturing Process		Wash	
333	7	Manufacturing Process		Debur	
334	7	Manufacturing Process		Stamping Press, 25 Ton	
335	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
336	7	Manufacturing Process		Plating	
337	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
338	5	Manufacturing Steps		Terminal Asm1 Processing	
339	6	Manufacturing Process		Injection Molding, 55 Tons	
340	7	Part	1608-139_5-Material	Material, Terminal Asm 1	PBT GF30
341	4	Subassembly	1608-139_6	Terminal Asm 2	(None)
342	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
343	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
344	7	Manufacturing Process		Wash	
345	7	Manufacturing Process		Debur	
346	7	Manufacturing Process		Stamping Press, 25 Ton	
347	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
348	7	Manufacturing Process		Plating	
349	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
350	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
351	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
352	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
353	7	Manufacturing Process		Debur	
354	7	Manufacturing Process		Stamping Press, 25 Ton	
355	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
356	7	Manufacturing Process		Plating	
357	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
358	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
359	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
360	7	Manufacturing Process		Wash	
361	7	Manufacturing Process		Debur	
362	7	Manufacturing Process		Stamping Press, 25 Ton	
363	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
364	7	Manufacturing Process		Plating	
365	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
366	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
367	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
368	7	Manufacturing Process		Wash	
369	7	Manufacturing Process		Debur	
370	7	Manufacturing Process		Stamping Press, 25 Ton	
371	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
372	7	Manufacturing Process		Plating	
373	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
374	5	Manufacturing Steps		Terminal Asm2 Processing	
375	6	Manufacturing Process		Injection Molding, 55 ton	
376	7	Part	1608-139_6-Material	Material, Terminal Asm 2	PBT GF30
377	4	Manufacturing Steps		IGBT Half Bridge Asm Final	
378	5	Manufacturing Process		Automated Asm 5 parts	
379	3	Subassembly	1608-139	IGBT Half Bridge Assembly	(None)
380	4	Part	1608-139_1	IGBT Half Bridge	Commodity Item
381	4	Preprocessed Part	1608-139_2	Terminal Block Large	PBT GF30
382	5	Manufacturing Steps		Terminal Block Large Processing	
383	6	Manufacturing Process		Injection Mold Press, 55 Ton	
384	7	Part	1608-139_2-Material	Material, Terminal Block Large	PBT GF30
385	4	Preprocessed Part	1608-139_3	Terminal Block Small	PBT GF30
386	5	Manufacturing Steps		Terminal Block Small Processing	
387	6	Manufacturing Process		Injection Mold Press, 55 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
388	7	Part	1608-139_3-Material	Material, Terminal Block Small	PBT GF30
389	4	Manufacturing Steps		IGBT Half Bridge Asm	
390	5	Manufacturing Process		Automated Asm 5 parts	
391	4	Subassembly	1608-139_5	Terminal Asm 1	(None)
392	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
393	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
394	7	Manufacturing Process		Wash	
395	7	Manufacturing Process		Debur	
396	7	Manufacturing Process		Stamping Press, 25 Ton	
397	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
398	7	Manufacturing Process		Plating	
399	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
400	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
401	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
402	7	Manufacturing Process		Wash	
403	7	Manufacturing Process		Debur	
404	7	Manufacturing Process		Stamping Press, 25 Ton	
405	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
406	7	Manufacturing Process		Plating	
407	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
408	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
409	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
410	7	Manufacturing Process		Wash	
411	7	Manufacturing Process		Debur	
412	7	Manufacturing Process		Stamping Press, 25 Ton	
413	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
414	7	Manufacturing Process		Plating	
415	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
416	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
417	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
418	7	Manufacturing Process		Wash	
419	7	Manufacturing Process		Debur	
420	7	Manufacturing Process		Stamping Press, 25 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
421	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
422	7	Manufacturing Process		Plating	
423	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
424	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
425	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
426	7	Manufacturing Process		Wash	
427	7	Manufacturing Process		Debur	
428	7	Manufacturing Process		Stamping Press, 25 Ton	
429	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
430	7	Manufacturing Process		Plating	
431	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
432	5	Manufacturing Steps		Terminal Asm1 Processing	
433	6	Manufacturing Process		Injection Molding, 55 Tons	
434	7	Part	1608-139_5-Material	Material, Terminal Asm 1	PBT GF30
435	4	Subassembly	1608-139_6	Terminal Asm 2	(None)
436	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
437	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
438	7	Manufacturing Process		Wash	
439	7	Manufacturing Process		Debur	
440	7	Manufacturing Process		Stamping Press, 25 Ton	
441	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
442	7	Manufacturing Process		Plating	
443	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
444	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
445	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
446	7	Manufacturing Process		Wash	
447	7	Manufacturing Process		Debur	
448	7	Manufacturing Process		Stamping Press, 25 Ton	
449	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
450	7	Manufacturing Process		Plating	
451	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
452	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
453	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
454	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
455	7	Manufacturing Process		Debur	
456	7	Manufacturing Process		Stamping Press, 25 Ton	
457	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
458	7	Manufacturing Process		Plating	
459	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
460	5	Preprocessed Part	1608-139_4	Copper Stamping	Copper Cu (10200)
461	6	Manufacturing Steps		Terminal Asm Copper Stamping & Plating Processing	
462	7	Manufacturing Process		Wash	
463	7	Manufacturing Process		Debur	
464	7	Manufacturing Process		Stamping Press, 25 Ton	
465	8	Part	1608-139_4 Material	Material, Copper Stamping	Copper Cu (10200)
466	7	Manufacturing Process		Plating	
467	8	Part	1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	Commodity Item
468	5	Manufacturing Steps		Terminal Asm2 Processing	
469	6	Manufacturing Process		Injection Molding, 55 ton	
470	7	Part	1608-139_6-Material	Material, Terminal Asm 2	PBT GF30
471	4	Manufacturing Steps		IGBT Half Bridge Asm Final	
472	5	Manufacturing Process		Automated Asm 5 parts	
473	3	Preprocessed Part	1608-179_1	Rubber Insulator	VMQ/MVQ Silicone
474	4	Manufacturing Steps		Rubber Insulator Processing	
475	5	Manufacturing Process		Injection Mold Press, 110 Ton	
476	6	Part	1608-179_1, Material	Material, Rubber Insulator	VMQ/MVQ Silicone
477	3	Manufacturing Steps		Install IGBT To Capacitor Asm	
478	4	Manufacturing Process		Manual Asm	
479	3	Part	Motor Control Asm Fastener	M4x0.70, 25 mm, Female Torx	Commodity Item
480	3	Part	Heat Sink Compound	Heat Sink Compound	Commodity Item
481	3	Manufacturing Steps		Motor Control Assembly	
482	4	Manufacturing Process		Auto Asm	

Table F-44 Audi Inverter: PCBAs & IGBTs Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-183	**Control/Diagnostics Board**	**$93.34**	**1**	**$93.34**
1608-183_1	**Connector Asm**	**$0.84**	**1**	**$0.84**
1608-183_1a	Connector Metal Spacer	$0.01	3	$0.03
1608-183_1b	Connector Pins	$0.02	28	$0.56
1608-183_1 Material	Material, Connector Asm	$0.25	1	$0.25
1608-183_2	Printed FR4 Control/Diagnostics Board	$5.59	1	$5.59
EF2210 VOC FreeFlux	EF2210 VOC FreeFlux	$0.03	1	$0.03
LF318 Solder Paste	LF318 Solder Paste	$0.45	1	$0.45
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.13	1	$0.13
TLE6250G V33	1/1 Transceiver HalfCAN PG-DSO-8	$0.52	1	$0.52
LTC1871HMS	Step-Up/Step-Down DC-DC Controller IC 10-MSOP	$2.76	1	$2.76
BUK9222-55A,118	MOSFET N-CH 55V 48A DPAK	$0.28	1	$0.28
74AHC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	$0.04	1	$0.04
SM4T10CAY	TVS DIODE 8.5VWM 19.5VC SMA	$0.15	1	$0.15
NJVMJD44H11G	Bipolar Transistors - BJT BIP DPAK NPN 8A 80V	$0.23	2	$0.45
NDD03N60ZT4G	MOSFET N-CH 600V DPAK	$0.22	2	$0.45
LM2903HYPT	Comparator Gen Purpose CMOS, Open-Collector, 8-TSS	$0.43	4	$1.73
TLE4251GXT	LDO Voltage Regulators Low Drop Voltage Tracker	$0.90	1	$0.90
BCP56-16T3G	TRANS NPN 80V 1A SOT-223	$0.06	1	$0.06
DDZX43-7-1	Zener Diodes 300MW 43V	$0.02	12	$0.18
AP2210N-3.3TRG1-1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	$0.05	2	$0.11
BZX84B18-7-F-1	Zener Diode 18V 300mW 2% Surface Mount SOT-23	$0.01	2	$0.03
BAS21-7-F-1	Diode Standard 200V 200mA Surface Mount SOT-23-3	$0.01	1	$0.01
MBR0540-TP	Schottky Diodes & Rectifier 0.5A 40V	$0.03	2	$0.07
FDS9958	MOSFET 2P-CH 60V 2.9A 8-SO	$0.36	1	$0.36
CMPT4401 TR-1	TRANS NPN 40V 0.6A SOT-23	$0.11	1	$0.11
40076	Automobile Engine Power Driver IC	$4.98	1	$4.98
EGF1D-E3/67A	Diode Standard 200V 1A Surface Mount DO-214BA	$0.17	1	$0.17
AD2S1210WDSTZRL7	R/D Converter 10, 12, 14, 16 bit Serial, Parallel	$14.09	1	$14.09
74LVC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	$0.03	1	$0.03
74LVC1G32GW,125	OR Gate IC 1 Channel 5-TSSOP	$0.02	2	$0.04
74LVC1G17GW-Q100,1	Buffer, Non-Inverting Push-Pull Output 5-TSSOP	$0.03	1	$0.03
AP7333-28SAG-7	LVR IC Positive Fixed 1 Output 2.8V 300mA SOT-23-3	$0.08	1	$0.08
T520C226M016ATE080	22uF 20% Molded Tantalum Polymer Capacitor 16V 231	$0.34	1	$0.34
T491D476K016AT	47uF 10% Molded Tantalum Capacitors 16V 2917 (7343	$0.21	1	$0.21

A3 Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
TCQD476M016R0070	47uF 20% Molded Tantalum Polymer Capacitor 16V 291	$0.59	1	$0.59
1210 Capacitors	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	$0.12	6	$0.74
0402 Capacitors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	79	$0.26
0805 Capacitors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	15	$0.43
0603 Capacitors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	22	$0.26
PE2010JKF070R03L	Current Sense Resistors - SMD 30 mOhms 100ppm 2010	$0.14	1	$0.14
1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.00	21	$0.06
0805 Resistors-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.00	12	$0.01
0603 Resistors-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	14	$0.03
0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	85	$0.05
#063210	Board to Board & Mezzanine Connectors 50P 1.27MM S	$2.13	2	$4.26
#234457	Headers & Wire Housings 3P 1.27MM SMT VERT MALE TY	$1.46	1	$1.46
B78334B1033A003	Current Sensing Transformer, 1:1:1:1, SMT	$3.20	1	$3.20
B82464P4474M	Fixed Inductors AEC-Q200	$1.04	1	$1.04
EMZA500ADA221MJA0G	220uF 50V Aluminum Capacitors Radial, Can - SMD 20	$0.25	2	$0.51
TC277T64F200SCAKXUMA 1	TriCore AURIX Microcontroller IC 32-Bit 200MHz 4MB	$13.93	1	$13.93
EPM570T100A5N-1	CPLD MAX II Family	$20.62	1	$20.62
74LVC1G17GW-Q100,1	Buffer, Non-Inverting Push-Pull Output 5-TSSOP	$0.03	6	$0.16
74LVC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	$0.03	2	$0.05
74LVC1G32GW,125	OR Gate IC 1 Channel 5-TSSOP	$0.02	2	$0.04
BZX84C2V4LT1G-1	Zener Diode 2.4V 250mW 8% SMT SOT-23-3 (TO-236)	$0.01	4	$0.04
LM2903DGKR-1	Comparator Differential CMOS, Open-Collector, 8-VS	$0.07	2	$0.14
AD8617ARZ	General Purpose Amplifier 2 Circuit Rail-to-Rail 8	$0.83	1	$0.83
74HCT4066DB	Analog Switch ICs QUAD BILATERAL	$0.28	1	$0.28
LM2901AVQDRQ1-1	Comparator Differential CMOS, Open-Collector, 14-S	$0.18	1	$0.18
MC33078YDT	General Purpose Amplifier 2 Circuit 8-SO	$0.19	1	$0.19
MC33204VDG	Operational Amplifier 1.8-12V Quad Rail to Rail -5	$0.55	1	$0.55
74HC366PW	Buffer, Inverting 6 Bit per Element Push-Pull O/P	$0.13	4	$0.50
DDZX43-7-1	Zener Diodes 300MW 43V	$0.02	9	$0.14
AP2210N-3.3TRG1-1	LVR IC Positive Fixed 1 Output 3.3V 300mA SOT-23-3	$0.05	1	$0.05
2SK1828TE85LF	MOSFET N-CH 20V 50MA S-MINI	$0.04	2	$0.08
IPD50P04P4L-11	MOSFET P-CH 40V 50A TO252-3	$0.01	2	$0.03
BZX84B18-7-F-1	Zener Diode 18V 300mW 2% Surface Mount SOT-23	$0.01	1	$0.01

A3 Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
TLE6250G V33	1/1 Transceiver Half CAN PG-DSO-8	$0.52	1	$0.52
BSS84PH6433XTMA1-1	MOSFET P-CH 60V 170MA SOT-23	$0.02	1	$0.02
74AHC1G14GW-Q100,1	Inverter IC 1 Channel Schmitt Trigger 5-TSSOP	$0.04	1	$0.04
TPSMB16A	TVS Diodes 16V 600W 5% DO214AA	$0.12	1	$0.12
TPSMB33A	TVS Diodes 33V 600W 5% DO214AA	$0.12	1	$0.12
TAJA226K010RNJ	22uF 10% Molded Tantalum Capacitors 10V 1206 (3216	$0.05	1	$0.05
T491D476K016AT	47F 10% Molded Tantalum Capacitors 16V 2917 (7343	$0.21	1	$0.21
1210 Capacitors	1210 (3225 Metric) 0.126" L x 0.098" W (3.20mm x 2	$0.12	14	$1.72
0402 Capacitors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	126	$0.42
0805 Capacitors	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.03	19	$0.55
0603 Capacitors	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.01	51	$0.60
CMA02040X2209GB300-1	RES SMD 22 OHM 2% 0.4W 0204	$0.08	5	$0.40
1206 Resistors	1206 (3216 Metric) 0.126" L x 0.063" W (3.20mm x 1	$0.00	20	$0.06
0805 Resistors-1	0805 (2012 Metric) 0.079" L x 0.049" W (2.00mm x 1	$0.00	1	$0.00
0603 Resistors-1	0603 (1608 Metric) 0.063" L x 0.031" W (1.60mm x 0	$0.00	51	$0.10
0402 Resistors	0402 (1005 Metric) 0.039" L x 0.020" W (1.00mm x 0	$0.00	156	$0.09
NX5032GA-20. 000M-STD-CSU-2	20MHz 50ppm Crystal 8pF 100 Ohm -40degC-150degC AE	$0.48	1	$0.48
DLW43MH201XK2L	200uH 100kHz 2 Line Common Mode Choke SMT 110mADC	$0.59	3	$1.76
1608-138	**IGBT Control Board**	**$69.90**	**1**	**$69.90**
B59219J130A20	PTC Resettable Fuse 560V Through Hole 4-Dip Cube	$1.68	1	$1.68
1608-138 Printed FR4 Circuit Board-3	Printed FR4 IGBT Control Board	$3.10	1	$3.10
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.03	1	$0.03
LF318 Solder Paste	LF318 Solder Paste	$0.43	1	$0.43
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.13	1	$0.13
STTH102AY	Diodes - General Purpose, Power, Switching Auto Hi	$0.07	11	$0.81
IRF7478TRPBF	MOSFET N-CH 60V 7A 8-SOIC	$0.03	6	$0.19
1.5SMC18CA-E3/57T	TVS DIODE 15.3VWM 25.2VC DO214AB	$0.13	6	$0.78
P6SMB510A	TVS Diodes - Transient Voltage Suppressors TVS SUR	$0.10	6	$0.59
FAN3216TMX_F085	Low-Side Gate Driver IC Inverting 8-SOIC	$0.41	1	$0.41
P4SMA480A-E3/61	TVS DIODE 408VWM 658VC SMA	$0.10	6	$0.59
P4SMA51A-E3/61	TVS Diodes - Transient Voltage Suppressors 400W 51	$0.06	6	$0.34
BSS84PH6433XTMA1-2	MOSFET P-CH 60V 170MA SOT-23	$0.01	2	$0.02
RT9818C-29GV	Supervisor Open Drain or Open Collector 1 Channel	$0.06	7	$0.40
BCR 185W H6327	Bipolar Transistors - Pre-Biased AF DIGITAL TRANSI	$0.02	3	$0.05
AP2210N-3.3TRG1-2	Linear Voltage Regulator IC Positive Fixed 1 Outpu	$0.05	3	$0.15
2SK1828TE85LF-1	MOSFET N-CH 20V 50MA S-MINI	$0.03	3	$0.10

A3 Inverter PCBAs & IGBTs

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
74HC1G08GW,125	AND Gate IC 1 Channel 5-TSSOP	$0.02	3	$0.07
BAS40-05,215	Diode Array 1 Pair Common Cathode Schottky 40V 120	$0.02	3	$0.07
A1363LKTTN-10-T	Hall Effect Sensor Single Axis 4-SIP	$1.03	3	$3.08
P4SMA20CA-E3/61	TVS DIODE 17.1VWM 27.7VC SMA	$0.06	3	$0.19
ADS7841E/2K5	12 Bit Analog to Digital Converter 4 Input 1 SAR 1	$2.22	1	$2.22
BYG23M-E3/TR	Diode Avalanche 1000V (1kV) 1.5A Surface Mount DO-	$0.07	1	$0.07
BZX84-C18,235	Zener Diode 18V 250mW 5% Surface Mount SOT-23 (TO-	$0.01	2	$0.02
1210 Capacitors-1	Tolerance - 10%; 1210 (3225 Metric) 0.126" L x 0.0	$0.12	12	$1.48
1206 Capacitors	Tolerance - 10%; 1206 (3216 Metric) 0.126" L x 0.0	$0.07	8	$0.54
0805 Capacitors-1	Tolerance - 10%; 0805 (2012 Metric) 0.083" L x 0.0	$0.03	16	$0.46
0603 Capacitors-1	Tolerance - 10%; 0603 (1608 Metric) 0.064" L x 0.0	$0.01	17	$0.21
0402 Capacitors-1	Tolerance - 10%; 0402 (1005 Metric) 0.039" L x 0.0	$0.00	76	$0.26
CMA02040X2209GB300-2	RES SMD 22 OHM 2% 0.4W 0204	$0.08	18	$1.38
CMA02040X3300GB300	RES SMD 330 OHM 2% 0.4W 0204	$0.08	19	$1.44
CMA02040X1000GB300	RES SMD 100 OHM 2% 0.4W 0204	$0.08	6	$0.46
CMA02040X1509GB300	RES SMD 15 OHM 2% 0.4W 0204	$0.08	9	$0.69
1206 Resistors-1	Tolerance - 5%; 1206 (3216 Metric) 0.126" L x 0.06	$0.00	21	$0.06
0603 Resistors-2	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	27	$0.06
0805 Resistors-2	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	2	$0.00
0402 Resistors-1	Tolerance - 5%; 0402 (1005 Metric) 0.039" L x 0.02	$0.00	62	$0.04
PA1281NLT-1	Transformers Audio & Signal SMD HiFreq WireWound 3	$1.25	6	$7.48
STTH102AY	Diodes - General Purpose, Power, Switching Auto Hi	$0.07	8	$0.59
SPB07N60C3	MOSFET N-CH 650V 7.3A D2PAK	$0.71	7	$4.97
TLE42642GHTSA2	Linear Voltage Regulator IC Positive Fixed 1 Outpu	$0.55	6	$3.31
BYG23M-E3/TR	Diode Avalanche 1000V (1kV) 1.5A Surface Mount DO-	$0.07	6	$0.41
RT9026GFP	Converter, DDR Bus Termination Regulator Voltage R	$0.22	6	$1.32
ADUM1401ARWZ-RL	General Purpose Digital Isolator 2500Vrms 4 Channe	$1.49	2	$2.98
LM2903DT	Comparator General Purpose CMOS, DTL, ECL, MOS, Op	$0.06	1	$0.06
SI1869DH-T1-E3	IC LOAD SW LVL SHIFT 20V SC70-6	$0.09	6	$0.55
P4SMA20CA-E3/61	TVS DIODE 17.1VWM 27.7VC SMA	$0.06	3	$0.19
BZX84-C18,235	Zener Diode 18V 250mW 5% Surface Mount SOT-23 (TO-	$0.01	2	$0.02
2SK1828TE85LF-1	MOSFET N-CH 20V 50MA S-MINI	$0.03	9	$0.29
RT9818C-29GV	Supervisor Open Drain or Open Collector 1 Channel	$0.06	6	$0.34
AP2210N-3.3TRG1-2	Linear Voltage Regulator IC Positive Fixed 1 Outpu	$0.05	3	$0.15

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
BSS84PH6433XTMA1-2	MOSFET P-CH 60V 170MA SOT-23	$0.01	7	$0.08
LT1460KCS3-3.3#TRPBF	Series Voltage Reference IC 0.5% 40mA SOT-23-3	$1.33	2	$2.67
2ED020I12FAXUMA2	Gate Drivers Dual Channel IGBT Driver IC +/-1200V	$1.99	3	$5.96
74HC1G08GW,125	AND Gate IC 1 Channel 5-TSSOP	$0.02	4	$0.09
SMBJ20A-E3/52	TVS DIODE 20VWM 32.4VC SMB	$0.05	1	$0.05
1210 Capacitors-1	Tolerance - 10%; 1210 (3225 Metric) 0.126" L x 0.0	$0.12	31	$3.81
0805 Capacitors-1	Tolerance - 10%; 0805 (2012 Metric) 0.083" L x 0.0	$0.03	20	$0.58
0603 Capacitors-1	Tolerance - 10%; 0603 (1608 Metric) 0.064" L x 0.0	$0.01	28	$0.34
0402 Capacitors-1	Tolerance - 10%; 0402 (1005 Metric) 0.039" L x 0.0	$0.00	40	$0.14
CMA02040X3300GB300	RES SMD 330 OHM 2% 0.4W 0204	$0.08	8	$0.61
CMA02040X1000GB300	RES SMD 100 OHM 2% 0.4W 0204	$0.08	17	$1.30
CMA02040X3301GB300	RES SMD 3.3K OHM 2% 0.4W 0204	$0.07	60	$4.46
CMA02040X1509GB300	RES SMD 15 OHM 2% 0.4W 0204	$0.08	7	$0.54
1206 Resistors-1	Tolerance - 5%; 1206 (3216 Metric) 0.126" L x 0.06	$0.00	17	$0.05
0805 Resistors-2	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	1	$0.00
0603 Resistors-2	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	4	$0.01
0402 Resistors-1	Tolerance - 5%; 0402 (1005 Metric) 0.039" L x 0.02	$0.00	76	$0.05
B82432T1102K	1uH Unshielded Wirewound Inductor 1.3A 80 mOhm Max	$0.27	6	$1.60
63210	Board to Board & Mezzanine Connectors 50P 1.27MM S	$2.28	1	$2.28
1608-147	**Circuit Board Bracket Right**	**$0.01**	**1**	**$0.01**
1608-147, Material-1	Material, Capacitor Assembly Bracket Right	$0.01	1	$0.01
1608-145	**Circuit Board Bracket Left**	**$0.01**	**1**	**$0.01**
1608-145, Material	Material, Capacitor Assembly Bracket left	$0.01	1	$0.01
1608-138_1	M4x1.00, 10 mm Female Torx w/ Captured Washer	$0.13	2	$0.26
1608-138_2	M2x1.00, 8 mm Female Torx w/ Captured Washer	$0.05	4	$0.20
1608-139	**IGBT Half Bridge Assembly**	**$14.93**	**1**	**$14.93**
1608-139_1	IGBT Half Bridge	$14.72	1	$14.72
1608-139_2	**Terminal Block Large**	**$0.02**	**1**	**$0.02**
1608-139_2-Material	Material, Terminal Block Large	$0.02	1	$0.02
1608-139_3	**Terminal Block Small**	**$0.01**	**1**	**$0.01**
1608-139_3-Material	Material, Terminal Block Small	$0.01	1	$0.01
1608-139_5	**Terminal Asm 1**	**$0.10**	**1**	**$0.10**
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_5-Material	Material, Terminal Asm 1	$0.01	1	$0.01
1608-139_6	**Terminal Asm 2**	**$0.08**	**1**	**$0.08**
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_6-Material	Material, Terminal Asm 2	$0.00	1	$0.00
1608-139	**IGBT Half Bridge Assembly**	**$14.93**	**1**	**$14.93**
1608-139_1	IGBT Half Bridge	$14.72	1	$14.72
1608-139_2	**Terminal Block Large**	**$0.02**	**1**	**$0.02**
1608-139_2-Material	Material, Terminal Block Large	$0.02	1	$0.02
1608-139_3	**Terminal Block Small**	**$0.01**	**1**	**$0.01**
1608-139_3-Material	Material, Terminal Block Small	$0.01	1	$0.01
1608-139_5	**Terminal Asm 1**	**$0.10**	**1**	**$0.10**
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_5-Material	Material, Terminal Asm 1	$0.01	1	$0.01
1608-139_6	**Terminal Asm 2**	**$0.08**	**1**	**$0.08**
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_6-Material	Material, Terminal Asm 2	$0.00	1	$0.00
1608-139	**IGBT Half Bridge Assembly**	**$14.93**	**1**	**$14.93**
1608-139_1	IGBT Half Bridge	$14.72	1	$14.72
1608-139_2	**Terminal Block Large**	**$0.02**	**1**	**$0.02**
1608-139_2-Material	Material, Terminal Block Large	$0.02	1	$0.02
1608-139_3	**Terminal Block Small**	**$0.01**	**1**	**$0.01**
1608-139_3-Material	Material, Terminal Block Small	$0.01	1	$0.01
1608-139_5	**Terminal Asm 1**	**$0.10**	**1**	**$0.10**
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_5-Material	Material, Terminal Asm 1	$0.01	1	$0.01
1608-139_6	**Terminal Asm 2**	**$0.08**	**1**	**$0.08**
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_4	**Copper Stamping**	**$0.02**	**1**	**$0.02**
1608-139_4 Material	Material, Copper Stamping	$0.02	1	$0.02
1608-139_4-Nickel Plating	Ni Plating, Copper Stamping	$0.00	1	$0.00
1608-139_6-Material	Material, Terminal Asm 2	$0.00	1	$0.00
1608-179_1	**Rubber Insulator**	**$0.07**	**1**	**$0.07**
1608-179_1, Material	Material, Rubber Insulator	$0.07	1	$0.07
Motor Control Asm Fastener	M4x0.70, 25 mm, Female Torx	$0.01	4	$0.04
Heat Sink Compound	Heat Sink Compound	$0.08	1	$0.08

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	48	Piece Cost (Total): $208.70	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	1,702		*Parts:*	*0*
Fasteners:	10		*Fasteners:*	*0*
Parts+Unanalyzed:	1,702		*Parts+Unanalyzed:*	*0*

Table F-45 Audi Inverter: Capacitor & Inductor Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1608-179_2	Capacitor Assembly	(None)
2	4	Subassembly	1608-179_7	Capacitor	(None)
3	5	Preprocessed Part	1608-179_7a	Mounting Base, Capacitor	Aluminum 6061
4	6	Manufacturing Steps		Mounting Base Processing	
5	7	Manufacturing Process		Wash	
6	7	Manufacturing Process		Debur	
7	7	Manufacturing Process		Stamping Press, 200 Ton	
8	8	Part	1608-179_7a Material	Material, Mounting Base, Capacitor	Aluminum 6061
9	5	Part	1608-179_7c	Insulation 0.003", Self Adh, Base	Commodity Item
10	5	Subassembly	1608-179_7h	Capacitor & Leadframe Asm	(None)
11	6	Preprocessed Part	1608-197-7e	Lead Frame Asm, IGBT to Cap, 1	Copper Cu (10200)
12	7	Manufacturing Steps		Stamped Leadframe, Processing	
13	8	Manufacturing Process		Wash	
14	8	Manufacturing Process		Debur	
15	8	Manufacturing Process		Stamping Press, 200 Ton	
16	9	Part	1608-197-7e Material	Material, Lead Frame Asm, IGBT to Cap, 1	Copper Cu (10200)
17	6	Preprocessed Part	1608-197-7i	Contact Plate, Capacitor	Copper Nickel Plated
18	7	Manufacturing Steps		Stamped Contact, Processing	
19	8	Manufacturing Process		Wash	
20	8	Manufacturing Process		Debur	
21	8	Manufacturing Process		Stamping Press, 25 Ton	
22	9	Part	1608-197-7i Material	Material, Contact Plate, Capacitor	Copper Nickel Plated
23	6	Part	1608-179_7d	Insulation 0.003", Self Adh, Cap Base	Commodity Item
24	6	Manufacturing Steps		Assemble Cap Lead Frame 1	
25	7	Manufacturing Process		Manual Asm	
26	7	Manufacturing Process		Tog-L-loc	
27	6	Preprocessed Part	1608-197-7f	Lead Frame Asm, IGBT to Cap, 2	Copper Cu (10200)
28	7	Manufacturing Steps		Stamped Leadframe, Processing	

Row	Level	Symbol Type	Number	Name	Material Name
29	8	Manufacturing Process		Wash	
30	8	Manufacturing Process		Debur	
31	8	Manufacturing Process		Stamping Press, 200 Ton	
32	9	Part	1608-197-7f Material	Material, Lead Frame Asm, IGBT to Cap, 2	Copper Cu (10200)
33	6	Preprocessed Part	1608-197-7i	Contact Plate, Capacitor	Copper Nickel Plated
34	7	Manufacturing Steps		Stamped Contact, Processing	
35	8	Manufacturing Process		Wash	
36	8	Manufacturing Process		Debur	
37	8	Manufacturing Process		Stamping Press, 25 Ton	
38	9	Part	1608-197-7i Material	Material, Contact Plate, Capacitor	Copper Nickel Plated
39	6	Part	1608-179_7e	Insulation 0.003", Clear Self Adh, Cap Base	Commodity Item
40	6	Manufacturing Steps		Assemble Cap Lead Frame 2	
41	7	Manufacturing Process		Manual Asm	
42	7	Manufacturing Process		Tog-L-loc	
43	6	Part	1608-179_7b	PP, Metallized Film Capacitor	Commodity Item
44	6	Part	1608-179_7f	Sealer, Contact Plate, Cap Asm	Commodity Item
45	6	Manufacturing Steps		Assemble Lead Frames Asms to Cap	
46	7	Manufacturing Process		Automated Adhesive Curing	
47	7	Manufacturing Process		Adhesive Coating Apply	
48	7	Manufacturing Process		Manual Asm	
49	7	Manufacturing Process		Manual Asm	
50	7	Manufacturing Process		Manual Asm	
51	5	Manufacturing Steps		Install Insulator & Cap to Mount Plate	
52	6	Manufacturing Process		Manual Asm	
53	5	Subassembly	1608-197_7k	Molded Nut Plate, Capacitor	(None)
54	6	Part	1608-197-7m	Nutsert, Nutplate	Commodity Item
55	6	Manufacturing Steps		Molded Leadframe, Processing	
56	7	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
57	8	Part	1608-197_7k Material	Material, Molded Nutplate Body, Capacitor	PBT GF30

Row	Level	Symbol Type	Number	Name	Material Name
58	5	Preprocessed Part	1608-197_7n	Molded Connector Cover, Capacitor	PA6
59	6	Manufacturing Steps		Molded Leadframe, Processing	
60	7	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
61	8	Part	1608-197_7n-Material	Material, Molded Connector Cover, Capacitor	PA6
62	5	Preprocessed Part	1608-197_7o	Molded Busbsr Cover, Capacitor	VMQ/MVQ Silicone
63	6	Manufacturing Steps		Molded Leadframe, Processing	
64	7	Manufacturing Process		Injection Mold Press, 55 Ton w/Inserts	
65	8	Part	1608-197_7o Material	Material, Molded Busbar Cover, Capacitor	VMQ/MVQ Silicone
66	5	Manufacturing Steps		Install Nutplate and Covers	
67	6	Manufacturing Process		Auto Asm	
68	6	Manufacturing Process		Auto Asm	
69	5	Part	1608-197-7g.0	Label, Kondensator, Capacitor Asm	Commodity Item
70	5	Part	1608-197-7g.2	Label, Kleiner GmbH, Capacitor Asm	Commodity Item
71	5	Part	1608-197-7g.1	Label, Wickel, Capacitor Asm	Commodity Item
72	5	Manufacturing Steps		Install Labels	
73	6	Manufacturing Process		Manual Asm	
74	4	Preprocessed Part	1608-179_4	Foam Strip	Medium Density Foam
75	5	Manufacturing Steps		Trimming Processing	
76	6	Manufacturing Process		Trim Press, 25 Ton	
77	7	Part	1608-179_4, Material	Material, Foam Strip	Medium Density Foam
78	4	Preprocessed Part	1608-179_5	Plastic Strip	PC GP
79	5	Manufacturing Steps		Plastic Strip Injection Molding	
80	6	Manufacturing Process		Injection Mold Press, 200 Ton	
81	7	Part	1608-179_5, Material	Material, Plastic Strip	PC GP
82	4	Subassembly	1608-179_3	Capacitor Housing	(None)
83	5	Subassembly	1608-179_3E	Molded Housing	(None)
84	6	Subassembly	1608-179_3A	Laminate Assembly	(None)
85	7	Preprocessed Part	1608-179_3A1	Laminate Plate	Electro Magnetic Steel
86	8	Manufacturing Steps		Laminate Plate Processing	
87	9	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
88	9	Manufacturing Process		Deburr	
89	9	Manufacturing Process		Stamping Press, 25 Ton	
90	10	Part	1608-179_3A1 Material	Material, Laminate Plate	Electro Magnetic Steel
91	7	Manufacturing Steps		Laminate Asm Assembly	
92	8	Manufacturing Process		Automated Press Station	
93	6	Subassembly	1608-179_3A	Laminate Assembly	(None)
94	7	Preprocessed Part	1608-179_3A1	Laminate Plate	Electro Magnetic Steel
95	8	Manufacturing Steps		Laminate Plate Processing	
96	9	Manufacturing Process		Wash	
97	9	Manufacturing Process		Deburr	
98	9	Manufacturing Process		Stamping Press, 25 Ton	
99	10	Part	1608-179_3A1 Material	Material, Laminate Plate	Electro Magnetic Steel
100	7	Manufacturing Steps		Laminate Asm Assembly	
101	8	Manufacturing Process		Automated Press Station	
102	6	Subassembly	1608-179_3A	Laminate Assembly	(None)
103	7	Preprocessed Part	1608-179_3A1	Laminate Plate	Electro Magnetic Steel
104	8	Manufacturing Steps		Laminate Plate Processing	
105	9	Manufacturing Process		Wash	
106	9	Manufacturing Process		Deburr	
107	9	Manufacturing Process		Stamping Press, 25 Ton	
108	10	Part	1608-179_3A1 Material	Material, Laminate Plate	Electro Magnetic Steel
109	7	Manufacturing Steps		Laminate Asm Assembly	
110	8	Manufacturing Process		Automated Press Station	
111	6	Part	1608-179_3C	Insert Molded Standoff 4.45 mm ID	Commodity Item
112	6	Manufacturing Steps		Molded Housing Assembly	
113	7	Manufacturing Process		Injection Mold Press, 150 Ton w/Inserts	
114	8	Part	1608-179_3E, Material	Material, Molding Housing	PPS-GF-MD
115	5	Part	1608-179_3D	Label, Capacitor Housing	Commodity Item
116	5	Part	1608-179_3B	#6-32 Threaded Self-Tapping Insert	Commodity Item
117	5	Manufacturing Steps		Capacitor Housing Assembly	
118	6	Manufacturing Process		Apply Label	
119	6	Manufacturing Process		Install Inserts	
120	4	Part	M4x1.00, 16 mm	M4x1.00, 16 mm	Commodity Item
121	4	Manufacturing Steps		Assemble Capacitor Housing & Base	
122	5	Manufacturing Process		Auto Asm	
123	6	Part	M4x1.00, 16 mm	M4x1.00, 16 mm	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
124	3	Preprocessed Part	1608-166_1	Inductor Protection Cover	Aluminum A380, Cast
125	4	Manufacturing Steps		Inductor Protection Cover Processing	
126	5	Manufacturing Process		Wash	
127	5	Manufacturing Process		Debur	
128	5	Manufacturing Process		Trim Press, 25 Ton	
129	5	Manufacturing Process		Die Casting, 840 Ton	
130	6	Part	1608-166_1 Material	Material, Inductor Protection Cover	Aluminum A380, Cast
131	3	Part	1608-166_2	Inductor Protection Pad Top	Commodity Item
132	3	Part	1608-161_1	M4x0.70, 12 mm, Female Torx	Commodity Item
133	3	Subassembly	1608-193	Inductor 3	(None)
134	4	Part	1608-193-1	Toroid, Epoxy Coated, 46.7mm D x 18.0mm H	Commodity Item
135	4	Part	1608-193-2	AWG 12 (2.0mm^2) Wire, Black	Commodity Item
136	4	Manufacturing Steps		Toroid Inductor Assembly Process	
137	5	Manufacturing Process		Bend & Strip Ends	
138	5	Manufacturing Process		Coil Winding	
139	3	Part	1608-166_3	Inductor Protection Pad Bottom	Commodity Item
140	3	Manufacturing Steps		Assemble Inductor, Pads, Cover and Fuse	
141	4	Manufacturing Process		Auto Asm	
142	4	Manufacturing Process		Manual Asm	
143	3	Subassembly	1608-175	Capacitor Asm	(None)
144	4	Subassembly	1608-175_1	Capacitor Asm w/o Capacitor	(None)
145	5	Preprocessed Part	1608-175_4	Capacitor Bracket 1	Copper Nickel Plated
146	6	Manufacturing Steps		Capacitor Bracket 1 Processing	
147	7	Manufacturing Process		Wash	
148	7	Manufacturing Process		Debur	
149	7	Manufacturing Process		Stamping Press, 25 Ton	
150	8	Part	1608-175_4 Material	Material, Capacitor Bracket 1	Copper Nickel Plated
151	5	Preprocessed Part	1608-175_5	Capacitor Bracket 2	Copper Nickel Plated
152	6	Manufacturing Steps		Capacitor Bracket 2 Processing	
153	7	Manufacturing Process		Wash	
154	7	Manufacturing Process		Debur	
155	7	Manufacturing Process		Stamping Press, 25 Ton	
156	8	Part	1608-175_5 Material	Material, Capacitor Bracket 2	Copper Nickel Plated

Row	Level	Symbol Type	Number	Name	Material Name
157	5	Preprocessed Part	1608-175_6	Capacitor Bracket 3	Copper Nickel Plated
158	6	Manufacturing Steps		Capacitor Bracket 3 Processing	
159	7	Manufacturing Process		Wash	
160	7	Manufacturing Process		Debur	
161	7	Manufacturing Process		Stamping Press, 25 Ton	
162	8	Part	1608-175_6 Material	Material, Capacitor Bracket 3	Copper Nickel Plated
163	5	Part	1608-175_8	PEM Standoff	Commodity Item
164	5	Manufacturing Steps		Capacitor Asm w/o Capacitor Processing	
165	6	Manufacturing Process		Injection Mold Press, 55 Ton	
166	7	Part	1608-175_1 Material	Material, Capacitor Asm w/o Capacitor	PBT LG30
167	4	Part	B32024A3564M	0.56µF Film Capacitor 300V 1500V (1.5kV)	Commodity Item
168	4	Part	1608-175_2	Silicone RTV	Commodity Item
169	4	Manufacturing Steps		Assemble Capacitor Asm	
170	5	Manufacturing Process		Auto Asm	
171	3	Part	1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	Commodity Item
172	3	Part	1608-143_5	M6x1.00, 18 mm, Female Torx w/ Captured Washer	Commodity Item
173	3	Manufacturing Steps		Capacitor Asm Assembly	
174	4	Manufacturing Process		Auto Asm	

Table F-46 Audi Inverter: Capacitor & Inductor Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

A3 Inverter Capacitor & Inductor

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-179_2	**Capacitor Assembly**	**$32.40**	**1**	**$32.40**
1608-179_7	**Capacitor**	**$26.25**	**1**	**$26.25**
1608-179_7a	**Mounting Base, Capacitor**	**$0.76**	**1**	**$0.76**
1608-179_7a Material	Material, Mounting Base, Capacitor	$0.76	1	$0.76
1608-179_7c	Insulation 0.003", Self Adh, Base	$0.78	1	$0.78
1608-179_7h	**Capacitor & Leadframe Asm**	**$24.41**	**1**	**$24.41**
1608-197-7e	**Lead Frame Asm, IGBT to Cap, 1**	**$2.35**	**1**	**$2.35**
1608-197-7e Material	Material, Lead Frame Asm, IGBT to Cap, 1	$2.35	1	$2.35
1608-197-7i	**Contact Plate, Capacitor**	**$1.00**	**1**	**$1.00**
1608-197-7i Material	Material, Contact Plate, Capacitor	$1.00	1	$1.00
1608-179_7d	Insulation 0.003", Self Adh, Cap Base	$0.38	1	$0.38
1608-197-7f	**Lead Frame Asm, IGBT to Cap, 2**	**$1.69**	**1**	**$1.69**
1608-197-7f Material	Material, Lead Frame Asm, IGBT to Cap, 2	$1.69	1	$1.69
1608-197-7i	**Contact Plate, Capacitor**	**$1.00**	**1**	**$1.00**
1608-197-7i Material	Material, Contact Plate, Capacitor	$1.00	1	$1.00
1608-179_7e	Insulation 0.003", Clear Self Adh, Cap Base	$0.23	1	$0.23
1608-179_7b	PP, Metallized Film Capacitor	$17.51	1	$17.51
1608-179_7f	Sealer, Contact Plate, Cap Asm	$0.25	1	$0.25
1608-197_7k	**Molded Nut Plate, Capacitor**	**$0.18**	**1**	**$0.18**
1608-197-7m	Nutsert, Nutplate	$0.08	2	$0.16
1608-197_7k Material	Material, Molded Nutplate Body, Capacitor	$0.02	1	$0.02
1608-197_7n	**Molded Connector Cover, Capacitor**	**$0.03**	**1**	**$0.03**
1608-197_7n-Material	Material, Molded Connector Cover, Capacitor	$0.01	3	$0.03
1608-197_7o	**Molded Busbsr Cover, Capacitor**	**$0.03**	**1**	**$0.03**
1608-197_7o Material	Material, Molded Busbar Cover, Capacitor	$0.03	1	$0.03
1608-197-7g.0	Label, Kondensator, Capacitor Asm	$0.02	1	$0.02
1608-197-7g.2	Label, Kleiner GmbH, Capacitor Asm	$0.02	1	$0.02
1608-197-7g.1	Label, Wickel, Capacitor Asm	$0.02	1	$0.02
1608-179_4	**Foam Strip**	**$0.01**	**1**	**$0.01**
1608-179_4, Material	Material, Foam Strip	$0.01	1	$0.01
1608-179_5	**Plastic Strip**	**$0.08**	**1**	**$0.08**
1608-179_5, Material	Material, Plastic Strip	$0.02	4	$0.08
1608-179_3	**Capacitor Housing**	**$5.25**	**1**	**$5.25**
1608-179_3E	**Molded Housing**	**$5.09**	**1**	**$5.09**
1608-179_3A	**Laminate Assembly**	**$0.31**	**1**	**$0.31**
1608-179_3A1	**Laminate Plate**	**$0.31**	**1**	**$0.31**
1608-179_3A1 Material	Material, Laminate Plate	$0.01	31	$0.31
1608-179_3A	**Laminate Assembly**	**$0.31**	**1**	**$0.31**
1608-179_3A1	**Laminate Plate**	**$0.31**	**1**	**$0.31**
1608-179_3A1 Material	Material, Laminate Plate	$0.01	31	$0.31
1608-179_3A	**Laminate Assembly**	**$0.31**	**1**	**$0.31**
1608-179_3A1	**Laminate Plate**	**$0.31**	**1**	**$0.31**

A3 Inverter Capacitor & Inductor

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-179_3A1 Material	Material, Laminate Plate	$0.01	31	$0.31
1608-179_3C	Insert Molded Standoff 4.45 mm ID	$0.08	4	$0.32
1608-179_3E, Material	Material, Molding Housing	$3.84	1	$3.84
1608-179_3D	Label, Capacitor Housing	$0.06	1	$0.06
1608-179_3B	#6-32 Threaded Self-Tapping Insert	$0.05	2	$0.10
M4x1.00, 16 mm	M4x1.00, 16 mm	$0.09	5	$0.45
M4x1.00, 16 mm	M4x1.00, 16 mm	$0.09	4	$0.36
1608-166_1	**Inductor Protection Cover**	**$0.03**	**1**	**$0.03**
1608-166_1 Material	Material, Inductor Protection Cover	$0.03	1	$0.03
1608-166_2	Inductor Protection Pad Top	$2.41	1	$2.41
1608-161_1	M4x0.70, 12 mm, Female Torx	$0.01	1	$0.01
1608-193	**Inductor 3**	**$3.04**	**1**	**$3.04**
1608-193-1	Toroid, Epoxy Coated, 46.7mm D x 18.0mm H	$2.99	1	$2.99
1608-193-2	AWG 12 (2.0mm^2) Wire, Black	$0.05	1	$0.05
1608-166_3	Inductor Protection Pad Bottom	$3.21	1	$3.21
1608-175	**Capacitor Asm**	**$6.40**	**1**	**$6.40**
1608-175_1	**Capacitor Asm w/o Capacitor**	**$4.35**	**1**	**$4.35**
1608-175_4	**Capacitor Bracket 1**	**$1.74**	**1**	**$1.74**
1608-175_4 Material	Material, Capacitor Bracket 1	$1.74	1	$1.74
1608-175_5	**Capacitor Bracket 2**	**$1.65**	**1**	**$1.65**
1608-175_5 Material	Material, Capacitor Bracket 2	$1.65	1	$1.65
1608-175_6	**Capacitor Bracket 3**	**$0.71**	**1**	**$0.71**
1608-175_6 Material	Material, Capacitor Bracket 3	$0.71	1	$0.71
1608-175_8	PEM Standoff	$0.10	2	$0.20
1608-175_1 Material	Material, Capacitor Asm w/o Capacitor	$0.05	1	$0.05
B32024A3564M	0.56µF Film Capacitor 300V 1500V (1.5kV)	$1.01	2	$2.02
1608-175_2	Silicone RTV	$0.03	1	$0.03
1608-175_7	M4x0.70, 8 mm Female Torx w/ Captured Washer	$0.06	2	$0.12
1608-143_5	M6x1.00, 18 mm, Female Torx w/ Captured Washer	$0.03	2	$0.06

Assembly Totals		Report Totals	*Preassembled Totals*	
Analyzed Subs:	28	Piece Cost (Total): $47.68	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	154		*Parts:*	*0*
Fasteners:	18		*Fasteners:*	*0*
Parts+Unanalyzed:	154		*Parts+Unanalyzed:*	*0*

Table F-47 Audi Inverter: Electrical & Harness Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Part	1608-130	Ribbon Cable 1	Commodity Item
2	3	Manufacturing Steps		Install Ribbon Cable	
3	4	Manufacturing Process		Manual Asm	
4	3	Subassembly	1608-119	Receptacle w/ Wiring	(None)
5	4	Preprocessed Part	1608-119_6	Receptacle	PA 6/6 GF30
6	5	Manufacturing Steps		Receptacle Processing	
7	6	Manufacturing Process		Injection Mold Press, 110 Ton	
8	7	Part	1608-119_6, Material	Material, Receptacle	PA 6/6 GF30
9	4	Part	1608-119_5	Metal Ring	Commodity Item
10	4	Manufacturing Steps		Assemble Metal Rings	
11	5	Manufacturing Process		Auto Assembly	
12	4	Subassembly	1608-119_9	Small Black Wire Terminal	(None)
13	5	Part	1608-119_9A	Female Terminal 20-22 AWG, Small Black Wire	Commodity Item
14	5	Part	1608-119_9B	AWG 21 Wire, Small Black	Commodity Item
15	5	Preprocessed Part	1608-119_10D	Wiring Rubber Seal	EPDM GP
16	6	Manufacturing Steps		Wiring Rubber Seal Processing	
17	7	Manufacturing Process		Injection Mold Press, 55 Ton	
18	8	Part	1608-119_10D Material	Material, Wiring Rubber Seal	EPDM GP
19	5	Manufacturing Steps		Assembly Small Black Wire Terminal	
20	6	Manufacturing Process		Auto Asm	
21	4	Subassembly	1608-119_9	Small Black Wire Terminal	(None)
22	5	Part	1608-119_9A	Female Terminal 20-22 AWG, Small Black Wire	Commodity Item
23	5	Part	1608-119_9B	AWG 21 Wire, Small Black	Commodity Item
24	5	Preprocessed Part	1608-119_10D	Wiring Rubber Seal	EPDM GP

Row	Level	Symbol Type	Number	Name	Material Name
25	6	Manufacturing Steps		Wiring Rubber Seal Processing	
26	7	Manufacturing Process		Injection Mold Press, 55 Ton	
27	8	Part	1608-119_10D Material	Material, Wiring Rubber Seal	EPDM GP
28	5	Manufacturing Steps		Assembly Small Black Wire Terminal	
29	6	Manufacturing Process		Auto Asm	
30	4	Subassembly	1608-119_7	Red Wire Terminal	(None)
31	5	Part	1608-119_7A	Eyelet Terminal, Red Wire	Commodity Item
32	5	Part	1608-119_7B	Female Terminal, 8-10 AWG, Red Wire	Commodity Item
33	5	Part	1608-119_7C	AWG 9 Wire, Red	Commodity Item
34	5	Manufacturing Steps		Assembly Red Wire Terminal	
35	6	Manufacturing Process		Auto Asm	
36	4	Subassembly	1608-119_8	Black Wire Terminal	(None)
37	5	Part	1608-119_8A	Eyelet Terminal, Black Wire	Commodity Item
38	5	Part	1608-119_8B	Female Terminal, 8-10 AWG, Black Wire	Commodity Item
39	5	Part	1608_119_8C	AWG 9 Wire, Black	Commodity Item
40	5	Manufacturing Steps		Assembly Black Wire Terminal	
41	6	Manufacturing Process		Auto Asm	
42	4	Manufacturing Steps		Assemble Terminals	
43	5	Manufacturing Process		Manual Asm	
44	4	Subassembly	1608-119_10	Connector Asm	(None)
45	5	Preprocessed Part	1608-119_10A	Connector Housing	PA 66 MD40
46	6	Manufacturing Steps		Connector Housing Processing	
47	7	Manufacturing Process		Injection Mold Press, 55 Ton	
48	8	Part	1608-119_10A Material	Material, Connector Housing	PA 66 MD40
49	5	Preprocessed Part	1608-119_10B	Connector O-Ring	EPDM GP

Row	Level	Symbol Type	Number	Name	Material Name
50	6	Manufacturing Steps		Connector O-Ring Processing	
51	7	Manufacturing Process		Injection Mold Press, 55 Ton	
52	8	Part	1608-119_10B Material	Material, Connector O-Ring	EPDM GP
53	5	Preprocessed Part	1608-119_10C	Connector Clip	PA 6/6 GP
54	6	Manufacturing Steps		Connector Clip Processing	
55	7	Manufacturing Process		Injection Mold Press, 55 Ton	
56	8	Part	1608-119_10C Material	Material, Connector Clip	PA 6/6 GP
57	5	Manufacturing Steps		Connector Assembly	
58	6	Manufacturing Process		Manual Asm	
59	4	Manufacturing Steps		Assemble Connector Asm	
60	5	Manufacturing Process		Manual Asm	
61	4	Preprocessed Part	1608-119_3	Gasket	Rubber (Thermoset) Natural, Isoprene
62	5	Manufacturing Steps		Gasket Processing	
63	6	Manufacturing Process		Injection Mold Press, 55 Ton	
64	7	Part	1608-119_3 Material	Material, Gasket	Rubber (Thermoset) Natural, Isoprene
65	4	Preprocessed Part	1608-119_4	Metal Plug Support	Copper Nickel Plated
66	5	Manufacturing Steps		Metal Plug Support Processing	
67	6	Manufacturing Process		Wash	
68	6	Manufacturing Process		Debur	
69	6	Manufacturing Process		Stamping Press, 25 Ton	
70	7	Part	1608-119_4 Material	Material, Metal Plug Support	Copper Nickel Plated
71	4	Manufacturing Steps		Assemble Metal Rings, Plug Support and Gasket	
72	5	Manufacturing Process		Manual Asm	
73	3	Part	1608-119_1	M4x0.70, 14.75mm, Female Torx w/ Captured Washer	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
74	3	Manufacturing Steps		Install Receptacle to Enclosure	
75	4	Manufacturing Process		Manual Asm	

Table F-48 Audi Inverter: Electrical & Harness Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

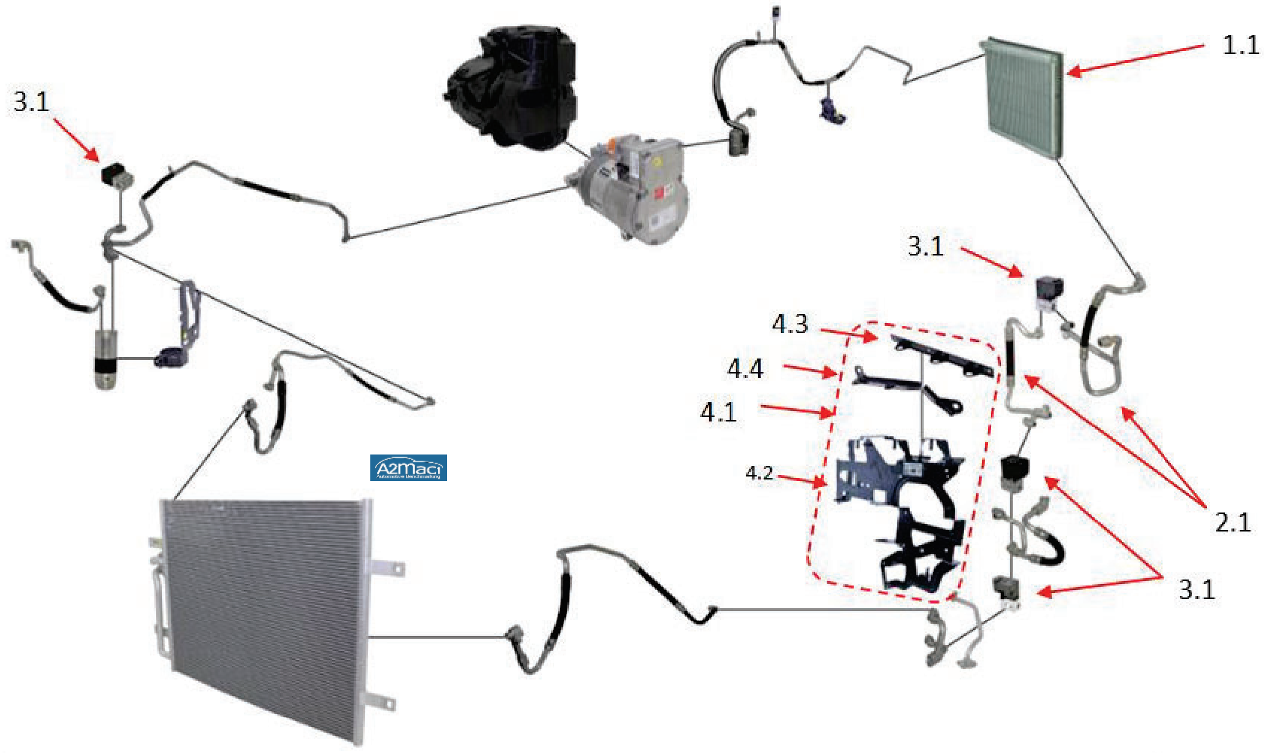
A3 Inverter Electrical & Harness

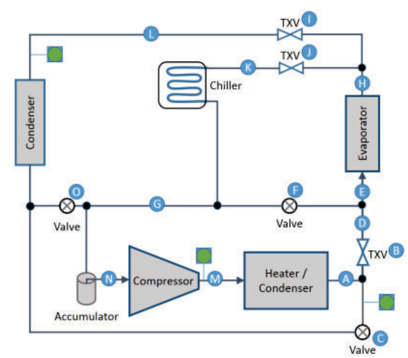
Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
1608-130	Ribbon Cable 1	$1.69	1	$1.69
1608-119	**Receptacle w/ Wiring**	**$0.83**	**1**	**$0.83**
1608-119_6	**Receptacle**	**$0.07**	**1**	**$0.07**
1608-119_6, Material	Material, Receptacle	$0.07	1	$0.07
1608-119_5	Metal Ring	$0.02	4	$0.08
1608-119_9	**Small Black Wire Terminal**	**$0.09**	**1**	**$0.09**
1608-119_9A	Female Terminal 20-22 AWG, Small Black Wire	$0.04	2	$0.08
1608-119_9B	AWG 21 Wire, Small Black	$0.00	1	$0.00
1608-119_10D	**Wiring Rubber Seal**	**$0.01**	**1**	**$0.01**
1608-119_10D Material	Material, Wiring Rubber Seal	$0.01	1	$0.01
1608-119_9	**Small Black Wire Terminal**	**$0.09**	**1**	**$0.09**
1608-119_9A	Female Terminal 20-22 AWG, Small Black Wire	$0.04	2	$0.08
1608-119_9B	AWG 21 Wire, Small Black	$0.00	1	$0.00
1608-119_10D	**Wiring Rubber Seal**	**$0.01**	**1**	**$0.01**
1608-119_10D Material	Material, Wiring Rubber Seal	$0.01	1	$0.01
1608-119_7	**Red Wire Terminal**	**$0.13**	**1**	**$0.13**
1608-119_7A	Eyelet Terminal, Red Wire	$0.04	1	$0.04
1608-119_7B	Female Terminal, 8-10 AWG, Red Wire	$0.05	1	$0.05
1608-119_7C	AWG 9 Wire, Red	$0.04	1	$0.04
1608-119_8	**Black Wire Terminal**	**$0.19**	**1**	**$0.19**
1608-119_8A	Eyelet Terminal, Black Wire	$0.04	1	$0.04
1608-119_8B	Female Terminal, 8-10 AWG, Black Wire	$0.05	1	$0.05
1608_119_8C	AWG 9 Wire, Black	$0.10	1	$0.10
1608-119_10	**Connector Asm**	**$0.03**	**1**	**$0.03**
1608-119_10A	**Connector Housing**	**$0.01**	**1**	**$0.01**
1608-119_10A Material	Material, Connector Housing	$0.01	1	$0.01
1608-119_10B	**Connector O-Ring**	**$0.01**	**1**	**$0.01**
1608-119_10B Material	Material, Connector O-Ring	$0.01	1	$0.01
1608-119_10C	**Connector Clip**	**$0.01**	**1**	**$0.01**
1608-119_10C Material	Material, Connector Clip	$0.01	1	$0.01
1608-119_3	**Gasket**	**$0.01**	**1**	**$0.01**
1608-119_3 Material	Material, Gasket	$0.01	1	$0.01
1608-119_4	**Metal Plug Support**	**$0.13**	**1**	**$0.13**
1608-119_4 Material	Material, Metal Plug Support	$0.13	1	$0.13
1608-119_1	M4x0.70, 14.75mm, Female Torx w/ Captured Washer	$0.02	4	$0.08

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	14	Piece Cost (Total): $2.60	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	29		*Parts:*	*0*
Fasteners:	4		*Fasteners:*	*0*
Parts+Unanalyzed:	29		*Parts+Unanalyzed:*	*0*

APPENDIX G: VW e-Golf Heat Pump System

Figure G-1 VW e-Golf Heat Pump System





Simplified System Schematic

Cost Estimate BOM			
1.1	Heat Exchanger-Evaporator Assembly	3.1	Control Valves
		4.1	Vehicle Integration Bracket Group
2.1	Hoses	4.2	Large Mounting Bracket
		4.3	Top Mounting Bracket
		4.4	Bottom Mounting Bracket

VW e-Golf Heat Exchangers

The VW e-Golf heat exchanger group includes three heat exchangers two in the vehicle cabin HVAC and the other in the engine compartment. One of the HVAC mounted heat exchangers uses micro channel extrusions while other uses more traditional flat stamped components. Both HVAC mounted heat exchangers have external fins for heat transfer. The chiller uses a combination of flat stampings and has internal fins for heat transfer. The HVAC heat exchangers provide heating/cooling transfer from the heat exchanger refrigerant to cabin air. The engine mounted chiller heating/cooling is from the heat exchanger refrigerant to the electrical coolant circuit.

Figure G-2 VW e-Golf Heat Exchangers

The summary shown in

Table G-1 below includes the number of parts analyzed, number of processing steps to manufacture, total time to manufacture, total weight, total piece cost, total labor cost (includes primary and secondary processes), Q-Burden (cost of quality for parts and processes) and total should cost before markups.

Table G-1 VW e-Golf Heat Exchangers Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
e-Golf Heat Exchangers

MUNRO & ASSOCIATES, INC.

	e-Golf Heat Exchangers
Parts	277
Steps	2,378
Actual Time	3,700.86 sec
Fasteners	4
Total Weight	2.67 kg
Piece Cost	$16.94
Total Labor Cost	$42.90
Q Burden	$3.22
Total Cost	$63.06
Annual Production	200000

Once complete the "should-cost" data is exported to a spreadsheet and percentages are applied to establish an estimated selling price. The markups include SG&A, profit, logistics and patent/royalty fees. The assumed percentages and cost calculations are shown in Table G-2 below. Additional data at the bottom of the table includes total weight of the system analyzed, annual production volume, and approximate order of magnitude tooling costs. Tooling costs per part are not included in the total cost of the part.

Table G-2 VW e-Golf Heat Exchangers Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	e-Golf Heat Pump System Heat Exchangers	
Purchased Part Roll up Costs		$2.29
Raw Material Costs		$14.65
Processing Costs		$42.90
Scrap (Design Profit: Q-Burden)	5%	$3.22
SG&A % Applied Against Processing	7%	$3.00
Profit % Applied Against Raw & Processing	4%	$2.30
Logistics % Applied Against Sum of all Above	3%	$2.05
Patent/Royalty Fees % Applied Against Sum of all Above	3%	$2.11
Total % Mark Up / Total Cost	22%	$72.53
Total Weight (kg)		2.6694
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$930,000
Tooling Cost/part		$0.93
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$1,860,000
Tooling Cost/part		$1.86

The heater/condenser assembly includes a heat exchanger subassembly, a pair of tubes and a common connection block. The sides of the heat exchanger assembly are wrapped with adhesive backed foam. The tubes in the assembly are assumed to be extruded aluminum. The heater assembly has 23 cooling fins sandwiched between 44 micro channel tubes through which the refrigerant passes through. The fins are assumed to be roll formed aluminum and the tubes are assumed to be cut from an extruded tube stock aluminum. There are caps on the top and bottom of the assembly (header plates). The top and bottom caps are assumed to be stamped Aluminum. The heater assembly is assumed to be oven brazed for the final assembly process. There is an end connector for external tubing connections which is assumed to be cut from an extruded bar stock aluminum and machined.

Figure G-3 VW e-Golf Heater/Condenser Assembly

Figure G-4 VW e-Golf Heater/Condenser Connector

The chiller assembly includes a connector, top and bottom plates, chiller plates, mounting plate and a pair of tubes for external connection. The top, bottom and mounting plates are assumed to be stamped Aluminum plates. There are 29 chiller plates and they are assumed to be stamped Aluminum plates. The chiller tubes are cut from extruded tube stock Aluminum. The chiller assembly is assumed to be oven brazed for the final assembly process.

Figure G-5 VW e-Golf Chiller Assembly

The evaporator assembly includes top and bottom plates, cooling fins, micro channel tubes, a tube connector, an intake tube and an exhaust tube. The sides of the heater assembly wrapped with an adhesive backed foam strip. The tubes in the assembly are assumed to be cut from an extruded tube stock Aluminum. The evaporator assembly has 42 cooling fins sandwiched between 82 micro channel tubes through which the coolant passes. The fins are assumed to be roll formed Aluminum and the tubes are assumed to be cut from an extruded tube stock Aluminum. There are caps on the top and bottom of the assembly. The top and bottom caps are assumed to be stamped Aluminum. The evaporator assembly is assumed to be oven brazed for the final assembly process. The connector is assumed to be cut from an extruded bar stock Aluminum and machined. The connector assembly has locator pins to ensure proper alignment when connecting to the external tubing.

Figure G-6 VW e-Golf Evaporator Assembly

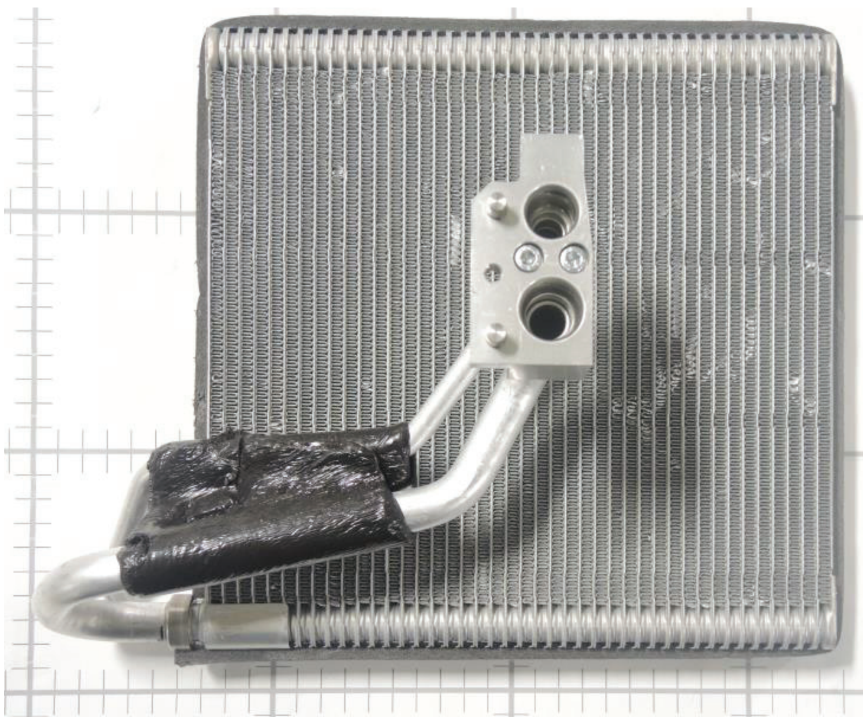
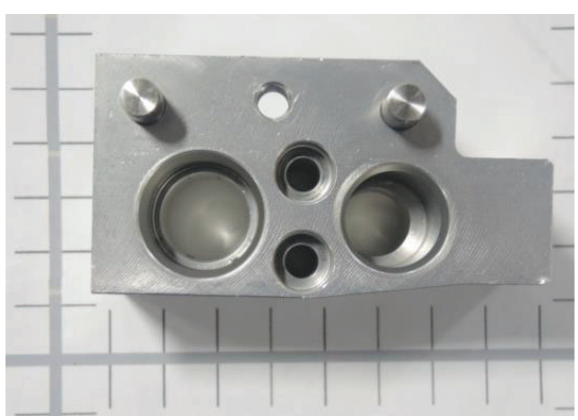


Figure G-7 VW e-Golf Evaporator Connector



VW E-Golf Tubes & Hoses

The VW e-Golf tubes and hoses group consists of a combination of fixed aluminum piping and flexible rubber hoses. All plumbing associated with the heat pump was analyzed. There are a total of 9 tube assemblies considered in this analysis. Four of the tube assemblies connect two components and five of them provide connections to three components. The solid sections of the tubing are assumed to be seamless aluminum tubes. The flexible sections of the tubes are assumed to be 3-layer extruded hoses with reinforced inner cords. The tubes have a combination of male and female fitting connections. They get connected to the valves, chiller, evaporator and the heater assembly.

Figure G-8 VW e-Golf Tubes & Hoses

Table G-3 VW e-Golf Tubes & Hoses Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY

Tubes & Hoses

MUNRO & ASSOCIATES, INC.

	Tubes & Hoses
Parts	200
Steps	2,338
Actual Time	6,420.08 sec
Fasteners	19
Total Weight	3.35 kg
Piece Cost	$28.28
Total Labor Cost	$93.64
Q Burden	$3.82
Total Cost	$125.73
Annual Production	200000

Table G-4 VW e-Golf Tubes & Hoses Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	e-Golf Heat Pump System Tubes & Hoses	
Purchased Part Roll up Costs		$8.70
Raw Material Costs		$19.58
Processing Costs		$93.64
Scrap (Design Profit: Q-Burden)	3%	$3.82
SG&A % Applied Against Processing	7%	$6.55
Profit % Applied Against Raw & Processing	4%	$4.53
Logistics % Applied Against Sum of all Above	3%	$4.10
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$2.82
Total % Mark Up / Total Cost	19%	$143.74
Total Weight (kg)		3.3452
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$145,000
Tooling Cost/part		$0.15
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$290,000
Tooling Cost/part		$0.29

VW e-Golf Controls

The VW e-Golf controls group consists of six valves total. Three of the valves are an open/close design (shut off valves) while the other three provide expansion valve functions providing pressure/temperature drops for system functionality. The valves are mounted to a support bracket with threaded fasteners.

Figure G-9 VW e-Golf Controls

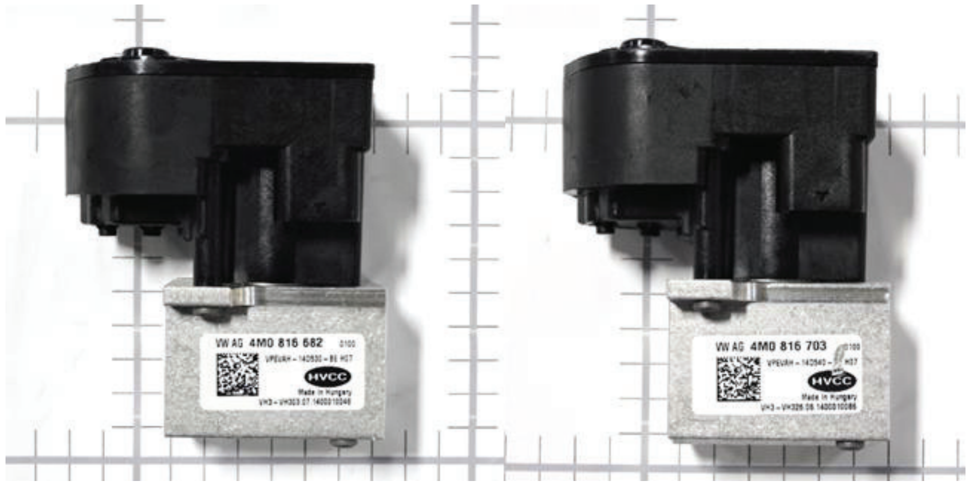


Figure G-10 VW e-Golf Controls Assembled

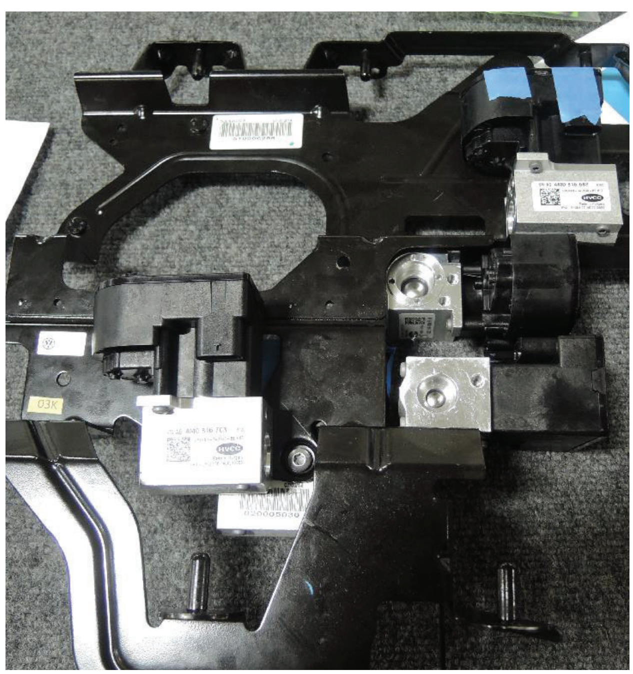


Table G-5 VW e-Golf Controls Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
e-Golf Controls

MUNRO & ASSOCIATES, INC.

	e-Golf Controls
Parts	597
Steps	3,626
Actual Time	6,270.49 sec
Fasteners	84
Total Weight	2.52 kg
Piece Cost	$78.93
Total Labor Cost	$92.63
Q Burden	$5.65
Total Cost	$177.21
Annual Production	200000

Table G-6 VW e-Golf Controls Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name	e-Golf Heat Pump System Controls	
Purchased Part Roll up Costs		$65.86
Raw Material Costs		$13.07
Processing Costs		$92.63
Scrap (Design Profit: Q-Burden)	3%	$5.65
SG&A % Applied Against Processing	7%	$6.48
Profit % Applied Against Raw & Processing	4%	$4.23
Logistics % Applied Against Sum of all Above	3%	$5.64
Patent/Royalty Fees % Applied Against Sum of all Above	5%	$9.68
Total % Mark Up / Total Cost	22%	$203.23
Total Weight (kg)		2.5176
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$2,940,000
Tooling Cost/part		$2.94
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$5,880,000
Tooling Cost/part		$5.88

The VW e-Golf uses three identical expansion valves. The expansion valve includes a control module and a control module body. The control module consists of a gear assembly, a 12VDC stepper motor, two PCBs, a stamped steel clip holding the assembly in place, a plastic housing and a plastic cover. The plastic cover and the housing are assumed to be injection molded glass filled Nylon. The gear assembly consists of plastic gears mounted on a stamped steel plate. The gears also have a small magnet inserted for position and directional sensing. The plastic gears are assumed to be injection molded Nylon. The control module body consists of a machined aluminum valve body, machined steel ball valve, sprocket assembly and an aluminum insert. The control module and the control body are fastened together with threaded fasteners.

Figure G-11 VW e-Golf Expansion Valves

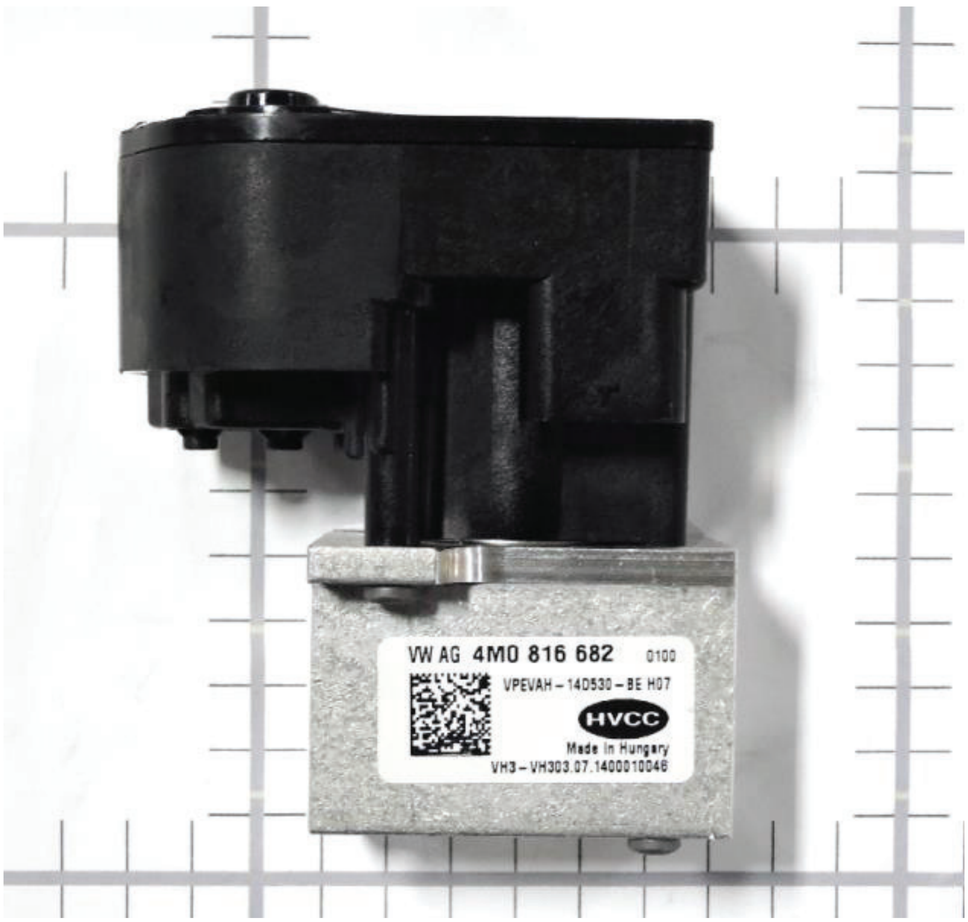


Figure G-12 VW e-Golf Control Module Components

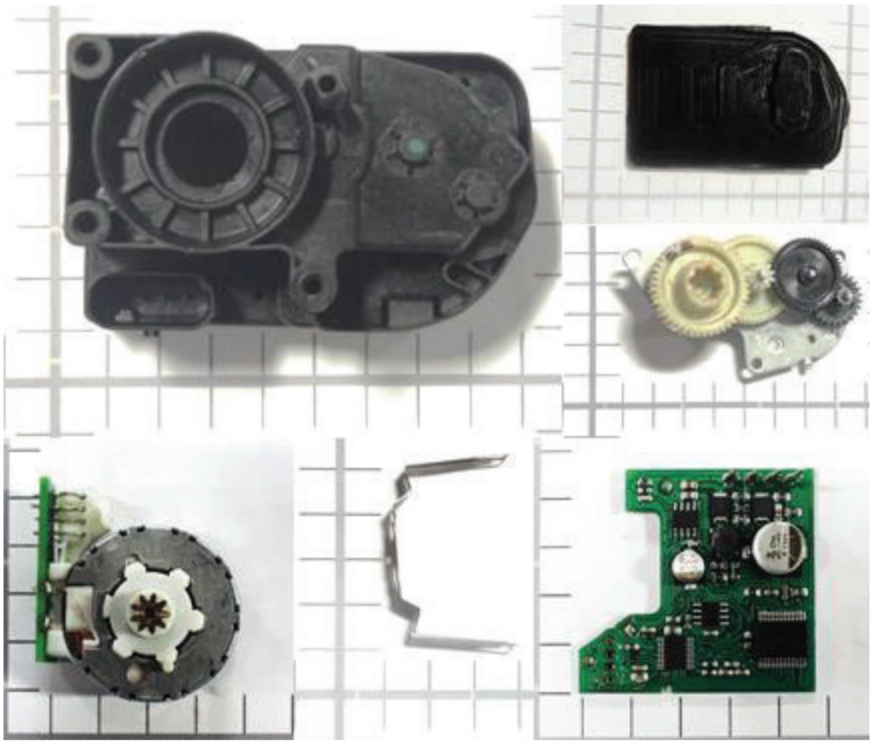


Figure G-13 VW e-Golf Control Module Body Components

The VW e-Golf uses three identical shut off valves. The shut valve includes a control module and a control module body. The control module consists of a gear assembly, a 12VDC stepper motor, two PCBs, a stamped steel clip holding the assembly in place, a plastic housing and a plastic cover. The plastic cover and the housing are assumed to be injection molded glass filled Nylon. The gear assembly consists of plastic gears mounted on a stamped steel plate. The gears also have a small magnet inserted for position and directional sensing. The plastic gears are assumed to be injection molded Nylon. The control module body consisted of a machined Aluminum valve body, machined steel ball valve, sprocket assembly and an Aluminum insert. The control module and the control body were fastened together with threaded fasteners.

Figure G-14 VW e-Golf Shut-off Valves

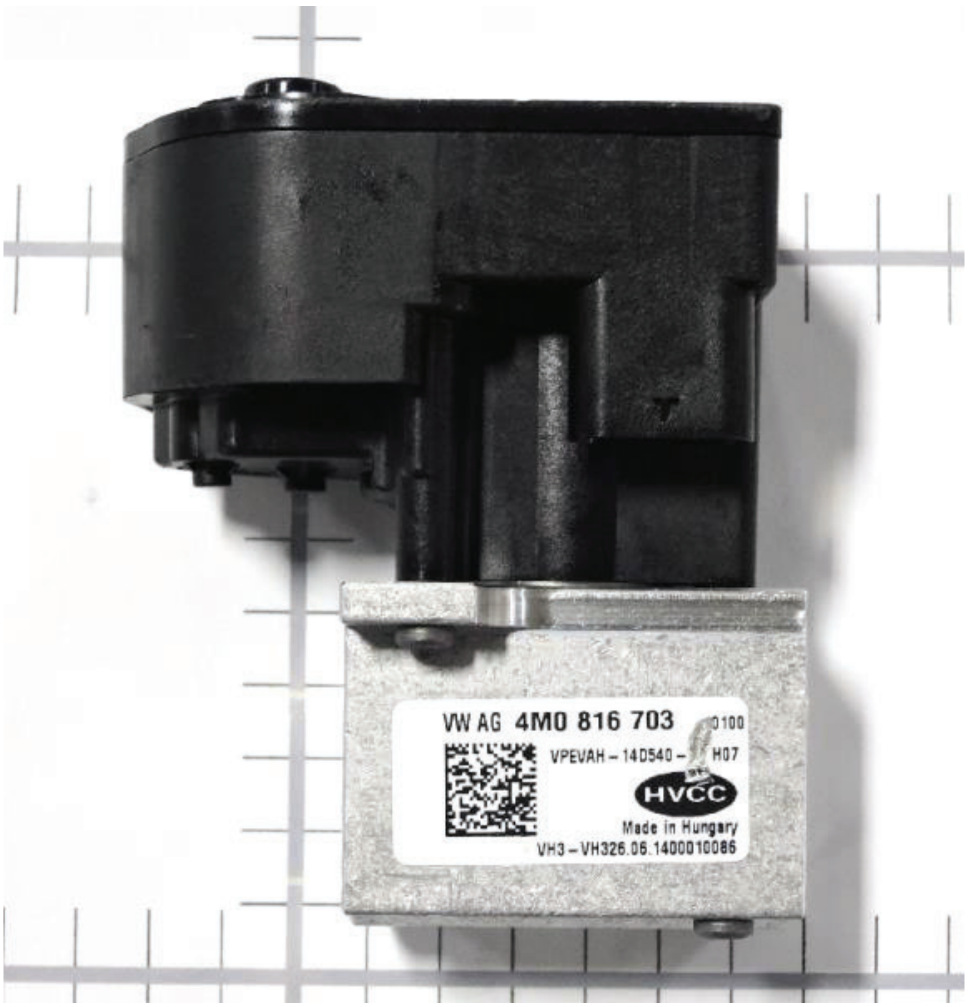


Figure G-15 VW e-Golf Control Module Components

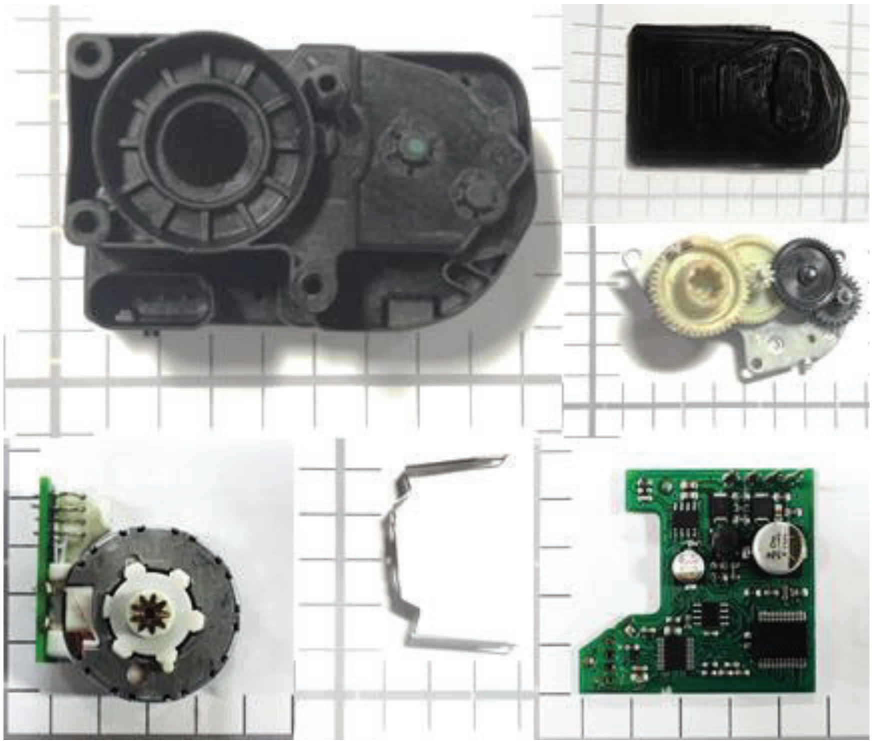


Figure G-16 VW e-Golf Control Module Body Components

VW e-Golf Vehicle Integration Features

The VW e-Golf vehicle integration features group consists of a large multi-piece stamped steel mounting bracket and a pair of smaller stamped parts with isolators. The main mount bracket consists of three stampings spot welled together. The two smaller mounting brackets contained features for rubber isolators which mount over posts on the main bracket. A majority of the valves and lines are attached to the large bracket which is mounted near the dash panel.

Figure G-17 VW e-Golf Vehicle Integration Bracket

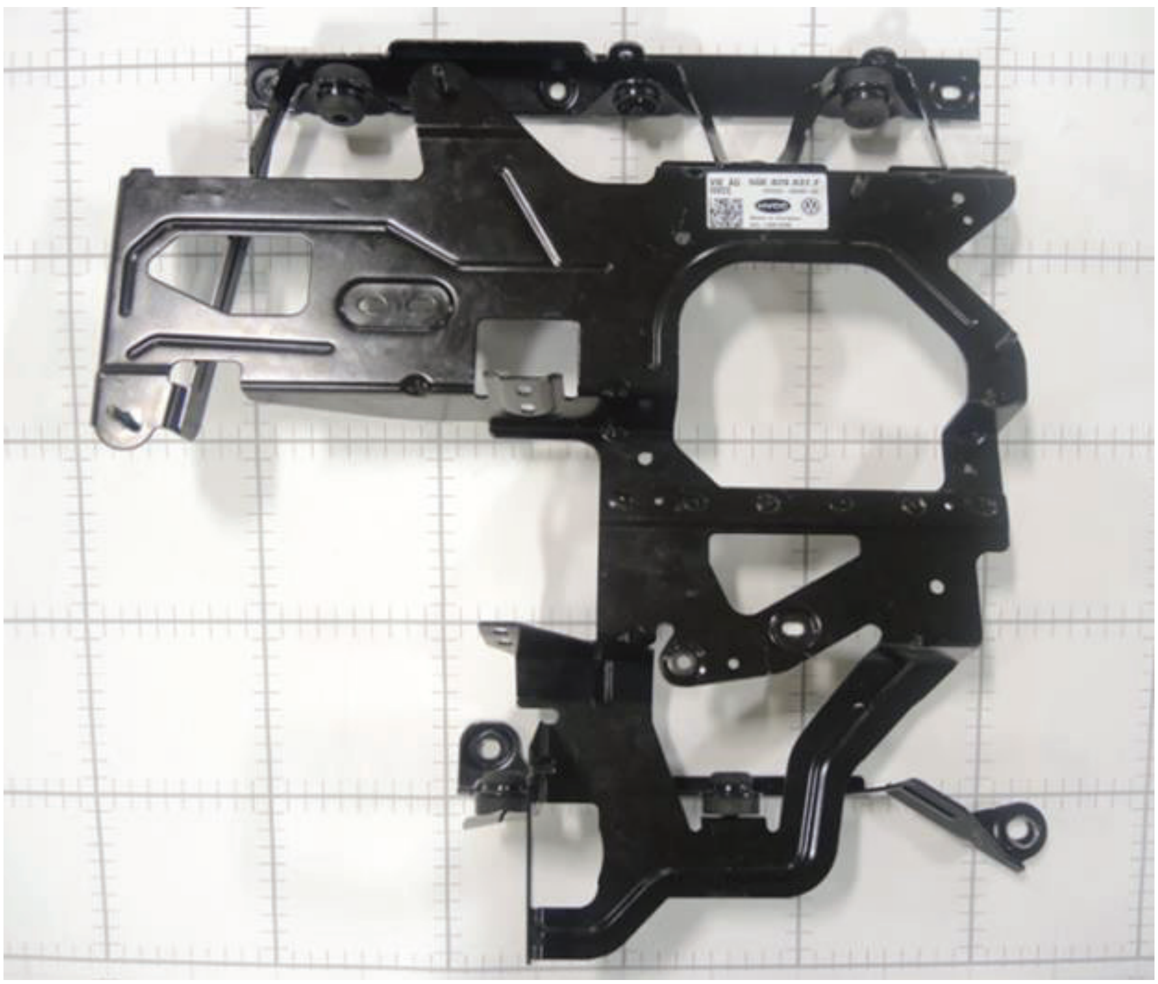


Table G-7 VW e-Golf Vehicle Integration Features Group: Design Profit Summary

Design Profit®

EXECUTIVE SUMMARY
e-Golf Vehicle Integration

MUNRO & ASSOCIATES, INC.

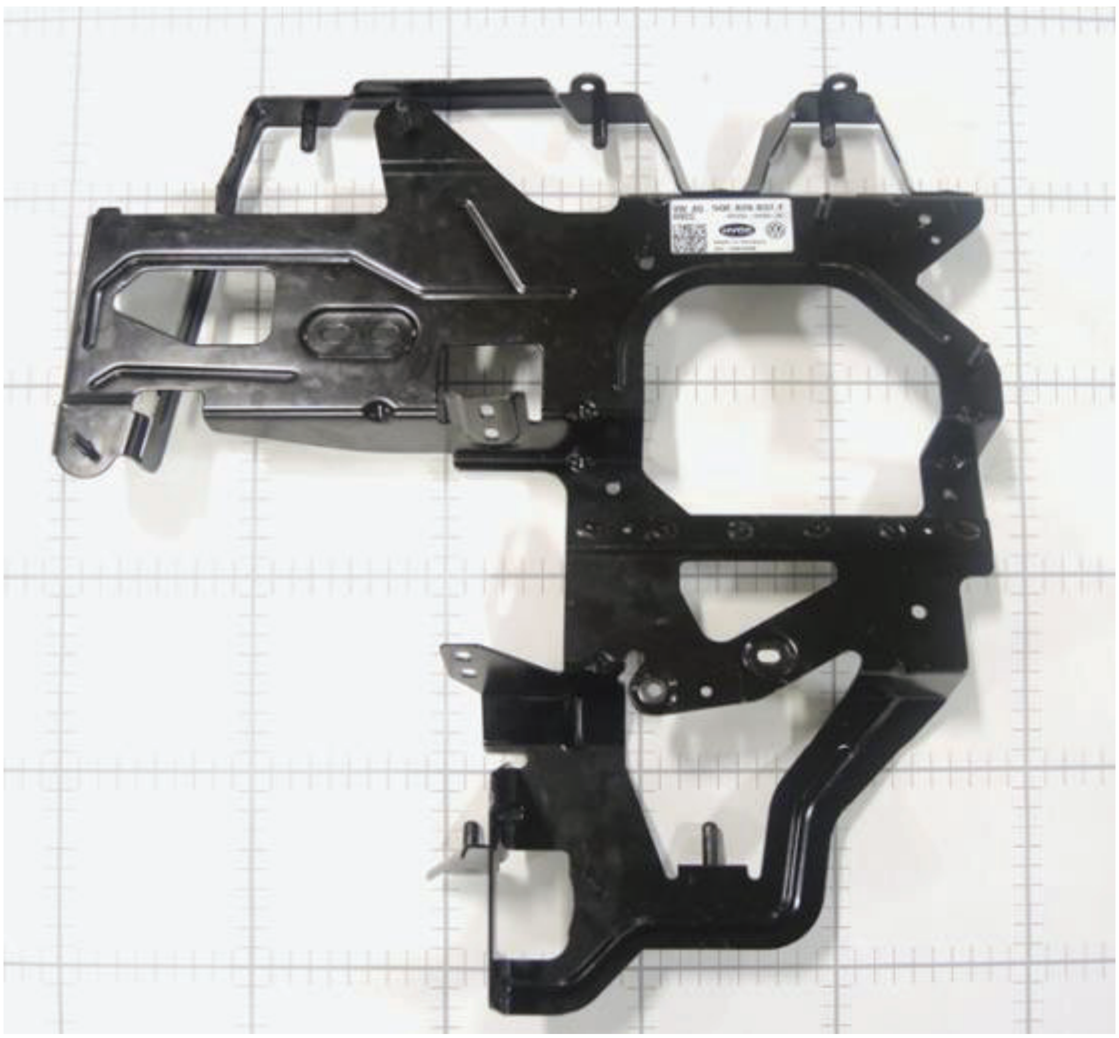
	e-Golf Vehicle Integration Features
Parts	28
Steps	161
Actual Time	693.07 sec
Fasteners	0
Total Weight	2.46 kg
Piece Cost	$7.18
Total Labor Cost	$7.38
Q Burden	$0.66
Total Cost	$15.22
Annual Production	200000

Table G-8 VW e-Golf Vehicle Integration Features Group: Cost Estimate Summary

Component Summary		
Part/Assembly Name		iolf Heat Pump System Vehicle Integration Featu
Purchased Part Roll up Costs		$1.41
Raw Material Costs		$5.77
Processing Costs		$7.38
Scrap (Design Profit: Q-Burden)	5%	$0.66
SG&A % Applied Against Processing	7%	$0.52
Profit % Applied Against Raw & Processing	4%	$0.53
Logistics % Applied Against Sum of all Above	3%	$0.49
Patent/Royalty Fees % Applied Against Sum of all Above	2%	$0.34
Total % Mark Up / Total Cost	21%	$17.09
Total Weight (kg)		2.4566
Annual Volume		200000
Product Life: Years		5
ROM Tooling Costs (1 set of Tools, single set- no provision for maintenance)		$200,000
Tooling Cost/part		$0.20
ROM Tooling Costs (2 set of Tools, 2nd set included for maintenance etc.)		$400,000
Tooling Cost/part		$0.40

The large mounting bracket is a three-piece welded bracket along with threaded and non-threaded weld studs (posts for isolator mounting). The brackets are assumed to be stamped steel brackets. The top and the center brackets are welded in four locations and the center is attached to the bottom bracket through six spot welds. The studs are then welded to the mounting bracket.

Figure G-18 VW e-Golf Large Mounting Bracket



The top mounting bracket is assumed to be stamped steel bracket. There are thee rubber bumpers attached to the bracket. They are used as the mounting points for this bracket to the large mounting bracket. They slid in to the non-threaded studs on the large mounting bracket.

Figure G-19 VW e-Golf Top Mounting Bracket

The bottom mounting bracket is assumed to be stamped steel bracket. There are two rubber bumpers attached to the bracket. They are used as the mounting points for this bracket to the large mounting bracket. They slid in to the non-threaded studs on the large mounting bracket.

Figure G-20 VW e-Golf Bottom Mounting Bracket

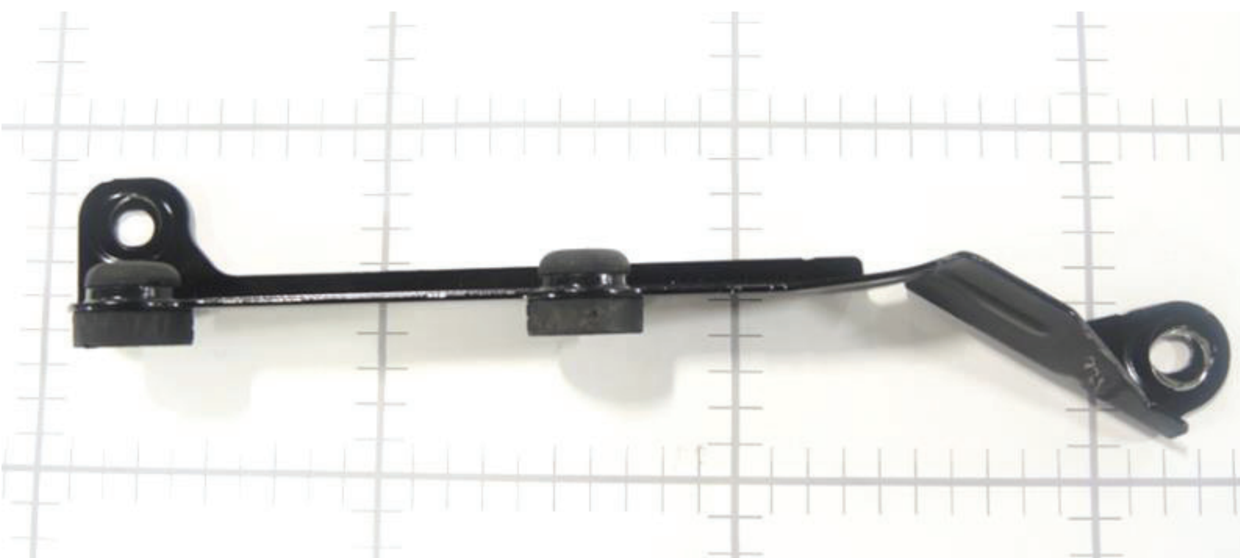


Table G-9 VW e-Golf Heat Pump System Heat Exchangers Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Subassembly	524-1437	Heater/Condenser Asm	(None)
2	3	Subassembly	524-1437-5	Heater Subassembly	(None)
3	4	Subassembly	524-1437-1	Top Cap Subassembly	(None)
4	5	Preprocessed Part	524-1437_1A	Top Cap, Heater Module Asm	Aluminum 3003-O, Coil
5	6	Manufacturing Steps		Top Cap Processing	
6	7	Manufacturing Process		Wash	
7	7	Manufacturing Process		Deburr	
8	7	Manufacturing Process		Stamping Press, 60 Ton	
9	8	Part	524-1437_1A Material	Material, Top Cap	Aluminum 3003-O, Coil
10	5	Preprocessed Part	524-1437_1E	Top Cap Mounting Plate, Heater Module Asm	Aluminum 3003-O, Coil
11	6	Manufacturing Steps		Top Cap Mtg Plate Processing	
12	7	Manufacturing Process		Wash	
13	7	Manufacturing Process		Deburr	
14	7	Manufacturing Process		Stamping Press, 60 Ton	
15	8	Part	524-1437_1E Material	Material, Top Cap Mounting Plate	Aluminum 3003-O, Coil
16	5	Manufacturing Steps		Top Cap Assembly Processing	
17	6	Manufacturing Process		Heat Exchanger Assembly	
18	4	Subassembly	524-1437-2	Bottom Cap Subassembly	(None)
19	5	Preprocessed Part	524-1437_1B	Bottom Cap, Heater Module Asm	Aluminum 3003-O, Coil
20	6	Manufacturing Steps		Bottom Cap Processing	
21	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
22	7	Manufacturing Process		Deburr	
23	7	Manufacturing Process		Stamping Press, 25 Ton	
24	8	Part	524-1437_1B Material	Material, Bottom Cap	Aluminum 3003-O, Coil
25	5	Preprocessed Part	524-1437_1F	Bottom Cap Mounting Plate, Heater Module Asm	Aluminum 3003-O, Coil
26	6	Manufacturing Steps		Bottom Cap Mounting Plate Processing	
27	7	Manufacturing Process		Wash	
28	7	Manufacturing Process		Deburr	
29	7	Manufacturing Process		Stamping Press, 60 Ton	
30	8	Part	524-1437_1F Material	Material, Bottom Cap Mounting Plate	Aluminum 3003-O, Coil
31	5	Manufacturing Steps		Bottom Cap Assembly Processing	
32	6	Manufacturing Process		Heat Exchanger Assembly	
33	4	Preprocessed Part	524-1437_1C	Cooling Fin, Heater Module Asm	Aluminum 3003-O, Coil
34	5	Manufacturing Steps		Cooling Fin Processing	
35	6	Manufacturing Process		Roll-Form Fins	
36	7	Part	524-1437_1C Material	Material, Cooling Fin	Aluminum 3003-O, Coil
37	4	Preprocessed Part	524-1437_1D	Cooling Tube, Heater Module Asm	Aluminum 3003-O, Coil
38	5	Manufacturing Steps		Cooling Tube Processing	
39	6	Manufacturing Process		Saw Cut	
40	7	Part	524-1437_1D Material	Material, Cooling Tube	Aluminum 3003-O, Coil
41	4	Subassembly	524-1437-4	Connector Subassembly	(None)
42	5	Preprocessed Part	524-1437_1P	Connector, Heater Module Asm	Aluminum 6061
43	6	Manufacturing Steps		Connector Processing	
44	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
45	7	Manufacturing Process		Deburr	
46	7	Manufacturing Process		CNC Machining	
47	7	Manufacturing Process		Saw Cut	
48	8	Part	524-1437_1P Material	Material, Connector	Aluminum 6061
49	5	Part	524-1437_1Q	Small Locating Pin, Heater Module Asm	Commodity Item
50	5	Part	524-1437_1R	Large Locating Pin, Heater Module Asm	Commodity Item
51	5	Manufacturing Steps		Connector Assembly Processing	
52	6	Manufacturing Process		Heat Exchanger Assembly	
53	4	Manufacturing Steps		Assemble Heater Processing	
54	5	Manufacturing Process		Wash	
55	5	Manufacturing Process		Braze, Oven	
56	5	Manufacturing Process		Intercooler Oven	
57	5	Manufacturing Process		Flux Application	
58	5	Manufacturing Process		Degrease	
59	5	Manufacturing Process		Intercooler Assembly	
60	3	Subassembly	524-1437-3	Intake Tube Subassembly	(None)
61	4	Preprocessed Part	524-1437_1L	Pipe, Intake, Heater Module Asm	Aluminum 3003 - Seamless Tube
62	5	Manufacturing Steps		Pipe, Intake Processing	
63	6	Manufacturing Process		Wash	
64	6	Manufacturing Process		Deburr	
65	6	Manufacturing Process		Tube Bending	
66	6	Manufacturing Process		CNC Tube Bending	
67	6	Manufacturing Process		Saw Cut	

Row	Level	Symbol Type	Number	Name	Material Name
68	7	Part	524-1437_1L Material	Material, Intake Tube	Aluminum 3003 - Seamless Tube
69	4	Preprocessed Part	524-1437_1N	Bushing, Heater Module Asm	Aluminum 6061
70	5	Manufacturing Steps		Bushing Processing	
71	6	Manufacturing Process		Wash	
72	6	Manufacturing Process		Deburr	
73	6	Manufacturing Process		CNC Machining	
74	6	Manufacturing Process		Saw Cut	
75	7	Part	524-1437_1N Material	Material, Bushing	Aluminum 6061
76	4	Manufacturing Steps		Intake Tube Assembly Processing	
77	5	Manufacturing Process		Heat Exchanger Assembly	
78	3	Subassembly	524-1437-6	Exhaust Tube Subassembly	(None)
79	4	Preprocessed Part	524-1437_1M	Pipe, Exhaust, Heater Module Asm	Aluminum 3003 - Seamless Tube
80	5	Manufacturing Steps		Tube, Exhaust Processing	
81	6	Manufacturing Process		Wash	
82	6	Manufacturing Process		Deburr	
83	6	Manufacturing Process		Tube Bending	
84	6	Manufacturing Process		CNC Tube Bending	
85	6	Manufacturing Process		Saw Cut	
86	7	Part	524-1437_1M Material	Material, Exhaust Pipe	Aluminum 3003 - Seamless Tube
87	4	Preprocessed Part	524-1437_1N	Bushing, Heater Module Asm	Aluminum 6061
88	5	Manufacturing Steps		Bushing Processing	
89	6	Manufacturing Process		Wash	
90	6	Manufacturing Process		Deburr	

Row	Level	Symbol Type	Number	Name	Material Name
91	6	Manufacturing Process		CNC Machining	
92	6	Manufacturing Process		Saw Cut	
93	7	Part	524-1437_1N Material	Material, Bushing	Aluminum 6061
94	4	Manufacturing Steps		Exhaust Tube Assembly Processing	
95	5	Manufacturing Process		Heat Exchanger Assembly	
96	3	Part	524-1437_1G	Foam, Heater Module Asm	Commodity Item
97	3	Part	524-1437_1S	Label, Valeo	Commodity Item
98	3	Part	524-1437_1T	Label, Orange	Commodity Item
99	3	Manufacturing Steps		Assemble Heater Tubing & Labels	
100	4	Manufacturing Process		Manual Assembly	
101	4	Manufacturing Process		Manual Assembly	
102	4	Manufacturing Process		Manual Assembly	
103	2	Subassembly	524-1359	Chiller Assembly	(None)
104	3	Preprocessed Part	524-1359_1	Chiller Connector	Aluminum 6061
105	4	Manufacturing Steps		524-1359_1 Processing	
106	5	Manufacturing Process		Wash	
107	5	Manufacturing Process		Deburr	
108	5	Manufacturing Process		CNC Machine	
109	5	Manufacturing Process		Saw Cut	
110	6	Part	524-1359_1 Material	Material, Chiller Connector	Aluminum 6061
111	3	Preprocessed Part	524-1359_2	Chiller Top Plate	Aluminum 6061
112	4	Manufacturing Steps		524-1359_2 Processing	
113	5	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
114	5	Manufacturing Process		Deburr	
115	5	Manufacturing Process		Stamping Press, 25 Ton	
116	6	Part	524-1359_2 Material	Material, Chiller Top Plate	Aluminum 6061
117	3	Preprocessed Part	524-1359_3	Chiller Plates	Aluminum 6061
118	4	Manufacturing Steps		524-1359_3 Processing	
119	5	Manufacturing Process		Wash	
120	5	Manufacturing Process		Deburr	
121	5	Manufacturing Process		Stamping Press, 25 Ton	
122	6	Part	524-1359_3 Material	Material, Chiller Plates	Aluminum 6061
123	3	Preprocessed Part	524-1359_4	Chiller Bottom Plate	Aluminum 6061
124	4	Manufacturing Steps		524-1359_4 Processing	
125	5	Manufacturing Process		Wash	
126	5	Manufacturing Process		Deburr	
127	5	Manufacturing Process		Stamping Press, 25 Ton	
128	6	Part	524-1359_4 Material	Material, Chiller Bottom Plate	Aluminum 6061
129	3	Preprocessed Part	524-1359_5	Chiller Mounting Plate	Aluminum 6061
130	4	Manufacturing Steps		524-1359_5 Processing	
131	5	Manufacturing Process		Wash	
132	5	Manufacturing Process		Deburr	
133	5	Manufacturing Process		Stamping Press, 25 Ton	
134	6	Part	524-1359_5 Material	Material, Chiller Mounting Plate	Aluminum 6061
135	3	Preprocessed Part	524-1359_6	Chiller Tube	Aluminum 3003 - Seamless Tube
136	4	Manufacturing Steps		524-1359_6 Processing	

Row	Level	Symbol Type	Number	Name	Material Name
137	5	Manufacturing Process		Wash	
138	5	Manufacturing Process		Deburr	
139	5	Manufacturing Process		CNC Tube Cutting	
140	6	Part	524-1359_6 Material	Material, Tube	Aluminum 3003 - Seamless Tube
141	3	Part	524-1359_8	Torx Screw M6x25 w/Captured Washer	Commodity Item
142	3	Part	524-1359_9	Foot Clamp	Commodity Item
143	3	Part	524-1359_7	Label SQE.819.030	Commodity Item
144	3	Part	524-1359_10	Inspection Label	Commodity Item
145	3	Manufacturing Steps		Chiller Assembly Processing	
146	4	Manufacturing Process		Manual Assembly	
147	4	Manufacturing Process		Braze, Oven	
148	4	Manufacturing Process		Manual Assembly	
149	2	Subassembly	524-1447	Evaporator Assembly	(None)
150	3	Subassembly	524-1447_1	Tube Interface Asm	(None)
151	4	Preprocessed Part	524-1447_1A	Tube Interface Bottom	Aluminum 3003-O, Coil
152	5	Manufacturing Steps		Tube Interface Btm Processing	
153	6	Manufacturing Process		Wash	
154	6	Manufacturing Process		Deburr	
155	6	Manufacturing Process		Stamping Press, 25 Ton	
156	7	Part	524-1447_1A Material	Material, Tube Interface Btm	Aluminum 3003-O, Coil
157	4	Preprocessed Part	524-1447_1B	Tuber Interface Top, Lager Hole	Aluminum 3003-O, Coil
158	5	Manufacturing Steps		Tube Interface Top, Large Hole Processing	
159	6	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
160	6	Manufacturing Process		Deburr	
161	6	Manufacturing Process		Stamping Press, 25 Ton	
162	7	Part	524-1447_1B Material	Material, Tube Interface Top, Large Hole	Aluminum 3003-O, Coil
163	4	Preprocessed Part	524-1447_1C	Tube Interface Top. Small Hole	Aluminum 3003-O, Coil
164	5	Manufacturing Steps		Tube Interface Top, Small Hole Processing	
165	6	Manufacturing Process		Wash	
166	6	Manufacturing Process		Deburr	
167	6	Manufacturing Process		Stamping Press, 25 Ton	
168	7	Part	524-1447_1C Material	Material, Tube Interface Top, Small Hole	Aluminum 3003-O, Coil
169	4	Manufacturing Steps		Assemble Tube Interface	
170	5	Manufacturing Process		Automated Asm	
171	3	Preprocessed Part	524-1447_2	Top Plate	Aluminum 3003-O, Coil
172	4	Manufacturing Steps		Top Plate Processing	
173	5	Manufacturing Process		Wash	
174	5	Manufacturing Process		Deburr	
175	5	Manufacturing Process		Stamping Press, 200 Ton	
176	6	Part	524-1447_2 Material	Material, Top Plate	Aluminum 3003-O, Coil
177	3	Preprocessed Part	524-1447_3	Bottom Plate	Aluminum 3003-O, Coil
178	4	Manufacturing Steps		Bottom Plate Processing	
179	5	Manufacturing Process		Wash	
180	5	Manufacturing Process		Deburr	
181	5	Manufacturing Process		Stamping Press, 200 Ton	
182	6	Part	524-1447_3 Material	Material, Bottom Plate	Aluminum 3003-O, Coil

Row	Level	Symbol Type	Number	Name	Material Name
183	3	Subassembly	524-1447_41	Micro Tube Asm	(None)
184	4	Preprocessed Part	524-1447_4a	Top Micro Tube	Aluminum 3003-O, Coil
185	5	Manufacturing Steps		Micro Tubes Processing	
186	6	Manufacturing Process		Wash	
187	6	Manufacturing Process		Deburr	
188	6	Manufacturing Process		Stamping Press, 25 Ton	
189	7	Part	524-1447_4 Material	Material, Micro Tubes	Aluminum 3003-O, Coil
190	4	Preprocessed Part	524-1447_4b	Bottom Micro Tube	Aluminum 3003-O, Coil
191	5	Manufacturing Steps		Bottom Micro Tube Processing	
192	6	Manufacturing Process		Wash	
193	6	Manufacturing Process		Deburr	
194	6	Manufacturing Process		Stamping Press, 25 Ton	
195	7	Part	524-1447_4 Material	Material, Micro Tubes	Aluminum 3003-O, Coil
196	4	Manufacturing Steps		Micro Tube Asm Processing	
197	5	Manufacturing Process		Auto Asm	
198	3	Preprocessed Part	524-1447_5	Cooling Fins	Aluminum 3003-O, Coil
199	4	Manufacturing Steps		Cooling Fins Processing	
200	5	Manufacturing Process		Roll Form Fins	
201	6	Part	524-1447_5 Material	Material, Cooling Fins	Aluminum 3003-O, Coil
202	3	Manufacturing Steps		Assemble Evaporator	
203	4	Manufacturing Process		Wash	
204	4	Manufacturing Process		Braze Oven	
205	4	Manufacturing Process		Intercooler Oven Dry Station	

Row	Level	Symbol Type	Number	Name	Material Name
206	4	Manufacturing Process		Flux Application	
207	4	Manufacturing Process		Degrease	
208	4	Manufacturing Process		Intercooler Asm	
209	3	Preprocessed Part	524-1447_11	Small Collar, Tube Interface Asm	Aluminum 6061
210	4	Manufacturing Steps		Small Collar, Tube Interface Asm Processing	
211	5	Manufacturing Process		Wash	
212	5	Manufacturing Process		Debur	
213	5	Manufacturing Process		Saw Cut	
214	6	Part	524-1447_11 Material	Material, Small Collar, Tube Interface Asm	Aluminum 6061
215	3	Preprocessed Part	524-1447_12	Big Collar, Tube Interface Asm	Aluminum 6061
216	4	Manufacturing Steps		Big Collar, Tube Interface Asm Processing	
217	5	Manufacturing Process		Wash	
218	5	Manufacturing Process		Debur	
219	5	Manufacturing Process		Saw Cut	
220	6	Part	524-1447_12 Material	Material, Big Collar, Tube Interface Asm	Aluminum 6061
221	3	Preprocessed Part	524-1447_13	16mm Tube, Tube Interface Asm	Aluminum 3003 - Seamless Tube
222	4	Manufacturing Steps		16mm Tube Processing	
223	5	Manufacturing Process		Wash	
224	5	Manufacturing Process		Deburr	
225	5	Manufacturing Process		Tube Bending	
226	5	Manufacturing Process		Saw Cut	
227	6	Part	524-1447_13 Material	Material, 16mm Tube	Aluminum 3003 - Seamless Tube
228	3	Preprocessed Part	524-1447_14	9.5mm Tube, Tube Interface Asm	Aluminum 3003 - Seamless Tube

Row	Level	Symbol Type	Number	Name	Material Name
229	4	Manufacturing Steps		9.50mm Tube Processing	
230	5	Manufacturing Process		Wash	
231	5	Manufacturing Process		Deburr	
232	5	Manufacturing Process		Tube Bending	
233	5	Manufacturing Process		Saw Cut	
234	6	Part	524-1447_14 Material	Material, 9.5 mm Tube	Aluminum 3003 - Seamless Tube
235	3	Part	524-1447_15	O-Ring	Commodity Item
236	3	Manufacturing Steps		Assemble Tube to Interface	
237	4	Manufacturing Process		Manual Assembly	
238	3	Subassembly	524-1447_6	Tube Connector	(None)
239	4	Preprocessed Part	524-1447_6B	Tube Connector	Aluminum 6061
240	5	Manufacturing Steps		Tube Connector Processing	
241	6	Manufacturing Process		Wash	
242	6	Manufacturing Process		Deburr	
243	6	Manufacturing Process		CNC Machining	
244	6	Manufacturing Process		Saw Cut	
245	7	Part	524-1447_6B Material	Material, Tube Connector	Aluminum 6061
246	4	Part	524-1447_6A	6mm Locating Pin	Commodity Item
247	4	Part	524-1447_6C	Company Label	Commodity Item
248	4	Part	524-1447_6D	Barcode Label	Commodity Item
249	4	Manufacturing Steps		Assembly of Tube Connector	
250	5	Manufacturing Process		Manual Assembly	
251	3	Preprocessed Part	524-1447_7	Tube Holder Support	Steel 1020 Cold Drawn or Cold Rolled

Row	Level	Symbol Type	Number	Name	Material Name
252	4	Manufacturing Steps		Tube Holder Support Processing	
253	5	Manufacturing Process		Wash	
254	5	Manufacturing Process		Deburr	
255	5	Manufacturing Process		CNC Machining	
256	5	Manufacturing Process		Stamping Press, 60 Ton	
257	6	Part	524-1447_7 Material	Material, Tube Holder Support	Steel 1020 Cold Drawn or Cold Rolled
258	3	Part	524-1447_8	M5 X 0.80, 35 mm Bolt	Commodity Item
259	3	Part	524-1447_10	Cover (Bull Wrap)	Commodity Item
260	3	Part	524-1447_16	Foam Strip	Commodity Item
261	3	Manufacturing Steps		Assemble Tube Connector	
262	4	Manufacturing Process		Manual Assembly	
263	4	Manufacturing Process		Manual Assembly	

Table G-10 VW e-Golf Heat Pump System Heat Exchangers Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

e-Golf Heat Exchangers

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1437	Heater/Condenser Asm	$5.52	1	$5.52
524-1437-5	Heater Subassembly	$3.89	1	$3.89
524-1437-1	Top Cap Subassembly	$0.21	1	$0.21
524-1437_1A	Top Cap, Heater Module Asm	$0.10	1	$0.10
524-1437_1A Material	Material, Top Cap	$0.10	1	$0.10
524-1437_1E	Top Cap Mounting Plate, Heater Module Asm	$0.11	1	$0.11
524-1437_1E Material	Material, Top Cap Mounting Plate	$0.11	1	$0.11
524-1437-2	Bottom Cap Subassembly	$0.21	1	$0.21
524-1437_1B	Bottom Cap, Heater Module Asm	$0.10	1	$0.10
524-1437_1B Material	Material, Bottom Cap	$0.10	1	$0.10
524-1437_1F	Bottom Cap Mounting Plate, Heater Module Asm	$0.11	1	$0.11
524-1437_1F Material	Material, Bottom Cap Mounting Plate	$0.11	1	$0.11
524-1437_1C	Cooling Fin, Heater Module Asm	$1.96	1	$1.96
524-1437_1C Material	Material, Cooling Fin	$0.09	23	$1.96
524-1437_1D	Cooling Tube, Heater Module Asm	$0.29	1	$0.29
524-1437_1D Material	Material, Cooling Tube	$0.01	44	$0.29
524-1437-4	Connector Subassembly	$1.23	1	$1.23
524-1437_1P	Connector, Heater Module Asm	$0.98	1	$0.98
524-1437_1P Material	Material, Connector	$0.98	1	$0.98
524-1437_1Q	Small Locating Pin, Heater Module Asm	$0.10	1	$0.10
524-1437_1R	Large Locating Pin, Heater Module Asm	$0.15	1	$0.15
524-1437-3	Intake Tube Subassembly	$0.57	1	$0.57
524-1437_1L	Pipe, Intake, Heater Module Asm	$0.46	1	$0.46
524-1437_1L Material	Material, Intake Tube	$0.46	1	$0.46
524-1437_1N	Bushing, Heater Module Asm	$0.11	1	$0.11
524-1437_1N Material	Material, Bushing	$0.11	1	$0.11
524-1437-6	Exhaust Tube Subassembly	$0.83	1	$0.83
524-1437_1M	Pipe, Exhaust, Heater Module Asm	$0.72	1	$0.72
524-1437_1M Material	Material, Exhaust Pipe	$0.72	1	$0.72
524-1437_1N	Bushing, Heater Module Asm	$0.11	1	$0.11
524-1437_1N Material	Material, Bushing	$0.11	1	$0.11
524-1437_1G	Foam, Heater Module Asm	$0.04	1	$0.04
524-1437_1S	Label, Valeo	$0.10	1	$0.10
524-1437_1T	Label, Orange	$0.10	1	$0.10
524-1359	Chiller Assembly	$2.83	1	$2.83
524-1359_1	Chiller Connector	$0.52	1	$0.52
524-1359_1 Material	Material, Chiller Connector	$0.52	1	$0.52
524-1359_2	Chiller Top Plate	$0.07	1	$0.07
524-1359_2 Material	Material, Chiller Top Plate	$0.07	1	$0.07
524-1359_3	Chiller Plates	$1.20	1	$1.20
524-1359_3 Material	Material, Chiller Plates	$0.03	40	$1.20
524-1359_4	Chiller Bottom Plate	$0.07	1	$0.07
524-1359_4 Material	Material, Chiller Bottom Plate	$0.07	1	$0.07
524-1359_5	Chiller Mounting Plate	$0.16	1	$0.16
524-1359_5 Material	Material, Chiller Mounting Plate	$0.16	1	$0.16

e-Golf Heat Exchangers

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1359_6	**Chiller Tube**	**$0.10**	**1**	**$0.10**
524-1359_6 Material	Material, Tube	$0.05	2	$0.10
524-1359_8	Torx Screw M6x25w/Captured Washer	$0.15	2	$0.30
524-1359_9	Foot Clamp	$0.15	2	$0.30
524-1359_7	Label SQE.819.030	$0.10	1	$0.10
524-1359_10	Inspection Label	$0.01	1	$0.01
524-1447	**Evaporator Assembly**	**$8.59**	**1**	**$8.59**
524-1447_1	**Tube Interface Asm**	**$0.09**	**1**	**$0.09**
524-1447_1A	**Tube Interface Bottom**	**$0.04**	**1**	**$0.04**
524-1447_1A Material	Material, Tube Interface Btm	$0.04	1	$0.04
524-1447_1B	**Tuber Interface Top, Lager Hole**	**$0.03**	**1**	**$0.03**
524-1447_1B Material	Material, Tube Interface Top, Large Hole	$0.03	1	$0.03
524-1447_1C	**Tube Interface Top. Small Hole**	**$0.02**	**1**	**$0.02**
524-1447_1C Material	Material, Tube Interface Top, Small Hole	$0.02	1	$0.02
524-1447_2	**Top Plate**	**$0.19**	**1**	**$0.19**
524-1447_2 Material	Material, Top Plate	$0.19	1	$0.19
524-1447_3	**Bottom Plate**	**$0.19**	**1**	**$0.19**
524-1447_3 Material	Material, Bottom Plate	$0.19	1	$0.19
524-1447_41	**Micro Tube Asm**	**$3.28**	**1**	**$3.28**
524-1447_4a	**Top Micro Tube**	**$1.64**	**1**	**$1.64**
524-1447_4 Material	Material, Micro Tubes	$0.04	41	$1.64
524-1447_4b	**Bottom Micro Tube**	**$1.64**	**1**	**$1.64**
524-1447_4 Material	Material, Micro Tubes	$0.04	41	$1.64
524-1447_5	**Cooling Fins**	**$2.52**	**1**	**$2.52**
524-1447_5 Material	Material, Cooling Fins	$0.06	42	$2.52
524-1447_11	**Small Collar, Tube Interface Asm**	**$0.00**	**1**	**$0.00**
524-1447_11 Material	Material, Small Collar, Tube Interface Asm	$0.00	1	$0.00
524-1447_12	**Big Collar, TubeInterface Asm**	**$0.01**	**1**	**$0.01**
524-1447_12 Material	Material, Big Collar, Tube Interface Asm	$0.01	1	$0.01
524-1447_13	**16mm Tube, TubeInterface Asm**	**$0.32**	**1**	**$0.32**
524-1447_13 Material	Material, 16mm Tube	$0.32	1	$0.32
524-1447_14	**9.5mm Tube, TubeInterface Asm**	**$0.19**	**1**	**$0.19**
524-1447_14 Material	Material, 9.5 mm Tube	$0.19	1	$0.19
524-1447_15	O-Ring	$0.08	1	$0.08
524-1447_6	**Tube Connector**	**$1.04**	**1**	**$1.04**
524-1447_6B	**Tube Connector**	**$0.59**	**1**	**$0.59**
524-1447_6B Material	Material, Tube Connector	$0.59	1	$0.59
524-1447_6A	6mm Locating Pin	$0.15	2	$0.30
524-1447_6C	Company Label	$0.10	1	$0.10
524-1447_6D	Barcode Label	$0.05	1	$0.05
524-1447_7	**Tube Holder Support**	**$0.11**	**1**	**$0.11**
524-1447_7 Material	Material, TubeHolder Support	$0.11	1	$0.11
524-1447_8	M5 X 0.80, 35 mm Bolt	$0.07	2	$0.14
524-1447_10	Cover (Bull Wrap)	$0.40	1	$0.40

e-Golf Heat Exchangers

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	43	Piece Cost (Total): $16.94	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	277		*Parts:*	*0*
Fasteners:	4		*Fasteners:*	*0*
Parts+Unanalyzed:	277		*Parts+Unanalyzed:*	*0*

Table G-11 VW e-Golf Tubes & Hoses Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Subassembly	524-1361	Tube K Assembly, AC System	(None)
2	3	Subassembly	524-1361_1	Tube K Assembly	(None)
3	4	Preprocessed Part	524-1361_1B	Connector 1, Tube K Assembly	Aluminum 6061
4	5	Manufacturing Steps		Connector 1, Processing	
5	6	Manufacturing Process		Wash	
6	6	Manufacturing Process		Deburr	
7	6	Manufacturing Process		CNC Machine	
8	6	Manufacturing Process		Cut Off	
9	7	Part	524-1361_1B, Material	Material, Connector 1	Aluminum 6061
10	4	Preprocessed Part	524-1361_1C	Connector 2, Tube K Assembly	Aluminum 6061
11	5	Manufacturing Steps		Connector 2, Processing	
12	6	Manufacturing Process		Wash	
13	6	Manufacturing Process		Deburr	
14	6	Manufacturing Process		CNC Machine	
15	6	Manufacturing Process		Cut Off	
16	7	Part	524-1361_1C, Material	Material, Connector 2, Tube K Assembly	Aluminum 6061
17	4	Preprocessed Part	524-1361_1E	End Tube Connector	Aluminum 6061
18	5	Manufacturing Steps		End Tube Connector, Processing	
19	6	Manufacturing Process		Wash	
20	6	Manufacturing Process		Deburr	
21	6	Manufacturing Process		CNC Machine	
22	6	Manufacturing Process		Cut Off	

Row	Level	Symbol Type	Number	Name	Material Name
23	7	Part	524-1361_1E, Material	Material, End Tube Connector	Aluminum 6061
24	4	Part	524-764_1C7	Guide Pin, Connector 1	Commodity Item
25	4	Preprocessed Part	524-1361_1A	Tube K	Aluminum 3003 - Seamless Tube
26	5	Manufacturing Steps		Tube K Process	
27	6	Manufacturing Process		Wash	
28	6	Manufacturing Process		Deburr	
29	6	Manufacturing Process		Tube Bending	
30	6	Manufacturing Process		Saw Cut	
31	7	Part	524-1361_1A, Material	Material, Tube K	Aluminum 3003 - Seamless Tube
32	4	Manufacturing Steps		Tube K Assembly	
33	5	Manufacturing Process		Manual Asm	
34	3	Part	524-1361_2	O-Rings	Commodity Item
35	3	Part	524-1361_3	Bar Code Label	Commodity Item
36	3	Part	524-1361_4	Label	Commodity Item
37	3	Manufacturing Steps		Assemble Tube K	
38	4	Manufacturing Process		Manual Asm	
39	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
40	2	Manufacturing Steps		Install Tube K Assembly, AC System	
41	3	Manufacturing Process		Manual Asm	
42	2	Subassembly	524-1396	Tube H Assembly, AC System	(None)
43	3	Subassembly	524-1396_1	Tube H Assembly	(None)
44	4	Subassembly	524-1396_1A	Section 1, Tube H	(None)
45	5	Subassembly	524-1396_1A1	Connector Hose Asm	(None)
46	6	Preprocessed Part	524-1396_1A1A	Connecting Tube	Aluminum 3003 - Seamless Tube

Row	Level	Symbol Type	Number	Name	Material Name
47	7	Manufacturing Steps		Connecting Tube Process	
48	8	Manufacturing Process		Wash	
49	8	Manufacturing Process		Tube Bending	
50	8	Manufacturing Process		Saw Cut	
51	9	Part	524-1396_1A1A Material	Material, Connecting Tube	Aluminum 3003 - Seamless Tube
52	6	Preprocessed Part	524-1396_1A1B	Connecting Block	Aluminum 6061
53	7	Manufacturing Steps		Connecting Block Process	
54	8	Manufacturing Process		Wash	
55	8	Manufacturing Process		Deburr	
56	8	Manufacturing Process		CNC Machine	
57	8	Manufacturing Process		Saw Cut	
58	9	Part	524-1396_1A1B Material	Material, Connecting Block	Aluminum 6061
59	6	Manufacturing Steps		Assemble Connector 1	
60	7	Manufacturing Process		Auto Asm	
61	5	Preprocessed Part	524-1396_1A2	20mm-OD Wrapped	(None)
62	6	Manufacturing Steps		20mm-OD Wrapped Hose Process	
63	7	Manufacturing Process		Extrusion	
64	8	Part	524-1396_1A2 Material 1	Material 1,Inner Rubber Layer,20 mm-OD W	_EPDM (Extrusion Grade)
65	8	Part	524-1396_1A2 Material 2	Material 2,Reinforcement Layer,20mm-OD	_PA Thread w/ PVC Coating
66	8	Part	524-1396_1A2 Material 3	Material 3,Outer Rubber Layer,14mm-OD Wrapped Hose	_EPDM (Extrusion Grade)
67	8	Part	524-1396_1A2 Material 4	Material 4,Outer EPDM Covering,20mm-OD Wrapped Hos	_EPDM Covering
68	5	Part	524-1396_1A4	20mm-OD Hose Sleeve	Commodity Item
69	5	Subassembly	524-1396_1A3	Branch Connector Asm	(None)
70	6	Preprocessed Part	524-1396_1A3B	Connecting Tube	Aluminum 3003 - Seamless Tube

Row	Level	Symbol Type	Number	Name	Material Name
71	7	Manufacturing Steps		Connecting Tube Process	
72	8	Manufacturing Process		Wash	
73	8	Manufacturing Process		Tube Bending	
74	8	Manufacturing Process		Saw Cut	
75	9	Part	524-1396_1A3 Material	Material, Branch Connector Asm	Aluminum 3003 - Seamless Tube
76	6	Preprocessed Part	524-1396_1A3A	Connector 2 Asm	Aluminum 6061
77	7	Manufacturing Steps		Connector 2 Process	
78	8	Manufacturing Process		Wash	
79	8	Manufacturing Process		Deburr	
80	8	Manufacturing Process		CNC Machine	
81	8	Manufacturing Process		Saw Cut	
82	9	Part	524-1396_1A3A Material	Material, Connector 2 Asm	Aluminum 6061
83	6	Manufacturing Steps		Branch Connector Asm	
84	7	Manufacturing Process		Auto Asm	
85	5	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061
86	6	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	
87	7	Manufacturing Process		Wash	
88	7	Manufacturing Process		Deburr	
89	7	Manufacturing Process		Saw Cut	
90	8	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
91	5	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061
92	6	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	
93	7	Manufacturing Process		Wash	
94	7	Manufacturing Process		Deburr	

Row	Level	Symbol Type	Number	Name	Material Name
95	7	Manufacturing Process		Saw Cut	
96	8	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
97	5	Manufacturing Steps		Assemble Hose Branch	
98	6	Manufacturing Process		Manual Asm	
99	4	Subassembly	524-1396_1B	Section 2, Tube H	(None)
100	5	Preprocessed Part	524-1396_1B1	Connecting Tube	Aluminum 3003 - Seamless Tube
101	6	Manufacturing Steps		Connecting Tube Process	
102	7	Manufacturing Process		Wash	
103	7	Manufacturing Process		Tube Bending	
104	7	Manufacturing Process		Saw Cut	
105	8	Part	524-1396_1B1 Material	Material, Connecting Tube	Aluminum 3003 - Seamless Tube
106	5	Preprocessed Part	524-1396_1B2	Connector Block 1	Aluminum 6061
107	6	Manufacturing Steps		Connector 2, Processing	
108	7	Manufacturing Process		Wash	
109	7	Manufacturing Process		Deburr	
110	7	Manufacturing Process		CNC Machine	
111	7	Manufacturing Process		Cut Off	
112	8	Part	524-1396_1B2 Material	Material, Connector Block 1	Aluminum 6061
113	5	Preprocessed Part	524-1396_1B3	End Tube Connector	Aluminum 6061
114	6	Manufacturing Steps		End Tube Connector, Processing	
115	7	Manufacturing Process		Wash	
116	7	Manufacturing Process		Deburr	
117	7	Manufacturing Process		CNC Machine	
118	7	Manufacturing Process		Cut Off	

Row	Level	Symbol Type	Number	Name	Material Name
119	8	Part	524-1361_1E, Material	Material, End Tube Connector	Aluminum 6061
120	5	Manufacturing Steps		Assemble Section 2	
121	6	Manufacturing Process		Auto Asm	
122	4	Manufacturing Steps		Assemble Section 1 & 2	
123	5	Manufacturing Process		Manual Asm	
124	3	Part	524-1396_2	O-Rings	Commodity Item
125	3	Part	524-1396_3	Bar Code Label	Commodity Item
126	3	Part	524-1396_4	Label	Commodity Item
127	3	Manufacturing Steps		Assmeble Tube H	
128	4	Manufacturing Process		Manual Asm	
129	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
130	2	Manufacturing Steps		Install Tube H Assembly, AC System	
131	3	Manufacturing Process		Manual Asm	
132	2	Subassembly	524-764	Tube L Assembly, AC System	(None)
133	3	Subassembly	524-764_1	Tube L Assembly	(None)
134	4	Subassembly	524-764_1A	Section 1, Tube L	(None)
135	5	Subassembly	524-764_1A1	Connector Hose Assembly	(None)
136	6	Preprocessed Part	524-764_1A1A	Connector Block	Aluminum 6061
137	7	Manufacturing Steps		Connector 1, Processing	
138	8	Manufacturing Process		Wash	
139	8	Manufacturing Process		Deburr	
140	8	Manufacturing Process		CNC Machine	
141	8	Manufacturing Process		Cut Off	
142	9	Part	524-764_1A1A Material	Material, Connector Block	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
143	6	Preprocessed Part	524-764_1A1B	Connecting Tube	Aluminum 6061
144	7	Manufacturing Steps		Connecting Tube Process	
145	8	Manufacturing Process		Wash	
146	8	Manufacturing Process		Deburr	
147	8	Manufacturing Process		Tube Bending	
148	8	Manufacturing Process		Saw Cut	
149	9	Part	524-764_1A1B Material	Material, Connecting Tube	Aluminum 6061
150	6	Part	524-764_1A1C	Heat Shrink Tubing	Commodity Item
151	6	Manufacturing Steps		Assmeble Connector Hose Assembly	
152	7	Manufacturing Process		Manual Asm	
153	5	Preprocessed Part	524-764_1A3	Hose Crimping Fitting	Aluminum 6061
154	6	Manufacturing Steps		Hose Crimp Fitting Process	
155	7	Manufacturing Process		Wash	
156	7	Manufacturing Process		Deburr	
157	7	Manufacturing Process		Saw Cut	
158	8	Part	524-764_1A3 Material	Material, Hose Crimping Fitting	Aluminum 6061
159	5	Preprocessed Part	524-764_1A4	25mm - OD Wrapped	(None)
160	6	Manufacturing Steps		25mm - OD Wraped Hose Process	
161	7	Manufacturing Process		Extrusion	
162	8	Part	524-764_1A4 Material 1	Material 1, Inner PA Layer, 25mm - OD Wrapped Hose	PA6
163	8	Part	524-764_1A4 Material 2	Material 2, Middle Layer Covering, 25mm - OD Wrapp	_EPDM (Extrusion Grade)
164	8	Part	524-764_1A4 Material 3	Material 3, Reinforcement Layer, 25mm - OD Wrapped	PA Thread w/ PVC Coat
165	8	Part	524-764_1A4 Material 4	Material 4, Outer Layer, 25mm - OD Wrapped Hose	_EPDM Covering
166	5	Part	524-764_1A5	Sleeve, 25mm - OD Wrapped	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
167	5	Manufacturing Steps		Assmeble Section 1, Tube L	
168	6	Manufacturing Process		Manual Asm	
169	4	Subassembly	524-764_1B	Section 2, Tube L	(None)
170	5	Preprocessed Part	524-764_1B1	Connecting Tube	Aluminum 6061
171	6	Manufacturing Steps		Connecting Tube Process	
172	7	Manufacturing Process		Wash	
173	7	Manufacturing Process		Deburr	
174	7	Manufacturing Process		Tube Bending	
175	7	Manufacturing Process		Saw Cut	
176	8	Part	524-764_1B1 Material	Material, Connecting Tube	Aluminum 6061
177	5	Preprocessed Part	524-764_1B2	Hose Crimping Fitting	Aluminum 6061
178	6	Manufacturing Steps		Hose Crimp Fitting Process	
179	7	Manufacturing Process		Auto Asm	
180	7	Manufacturing Process		Wash	
181	7	Manufacturing Process		Deburr	
182	7	Manufacturing Process		Saw Cut	
183	8	Part	524-764_1B2 Material	Material, Hose Crimping Fitting	Aluminum 6061
184	5	Preprocessed Part	524-764_1B2	Hose Crimping Fitting	Aluminum 6061
185	6	Manufacturing Steps		Hose Crimp Fitting Process	
186	7	Manufacturing Process		Auto Asm	
187	7	Manufacturing Process		Wash	
188	7	Manufacturing Process		Deburr	
189	7	Manufacturing Process		Saw Cut	
190	8	Part	524-764_1B2 Material	Material, Hose Crimping Fitting	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
191	5	Preprocessed Part	524-764_1B3	25mm - OD Wrapped	(None)
192	6	Manufacturing Steps		25mm - OD Wraped Hose Process	
193	7	Manufacturing Process		Extrusion	
194	8	Part	524-764_1B3 Material 1	Material 1, Inner PA Layer, 25mm - OD Wrapped Hose	PA6
195	8	Part	524-764_1B3 Material 2	Material 2, Middle Layer Covering, 25mm - OD Wrapp	_EPDM (Extrusion Grade)
196	8	Part	524-764_1B3 Material 3	Material 3, Reinforcement Layer, 25mm - OD Wrapped	PA Thread w/ PVC Coat
197	8	Part	524-764_1B3 Material 4	Material 4, Reinforcement Layer, 25mm - OD Wrapped	_EPDM Covering
198	5	Preprocessed Part	524-764_1B4	Hex Spacer	Aluminum 6061
199	6	Manufacturing Steps		Hex Spacer Process	
200	7	Manufacturing Process		Wash	
201	7	Manufacturing Process		Deburr	
202	7	Manufacturing Process		Saw Cut	
203	8	Part	524-764_1B4 Material	Material, Hex Spacer	Aluminum 6061
204	5	Preprocessed Part	524-764_1B4	Hex Spacer	Aluminum 6061
205	6	Manufacturing Steps		Hex Spacer Process	
206	7	Manufacturing Process		Wash	
207	7	Manufacturing Process		Deburr	
208	7	Manufacturing Process		Saw Cut	
209	8	Part	524-764_1B4 Material	Material, Hex Spacer	Aluminum 6061
210	5	Manufacturing Steps		Assmeble Section 2, Tube L	
211	6	Manufacturing Process		Manual Asm	
212	4	Subassembly	524-764_1C	Section 3, Tube L	(None)
213	5	Part	524-764_1C6	Heat Shrink Tubing	Commodity Item
214	5	Preprocessed Part	524-764_1C5	Hose Crimping Fitting	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
215	6	Manufacturing Steps		Hose Crimp Fitting Process	
216	7	Manufacturing Process		Auto Asm	
217	7	Manufacturing Process		Wash	
218	7	Manufacturing Process		Deburr	
219	7	Manufacturing Process		Saw Cut	
220	8	Part	524-764_1C5 Material	Material, Hose Crimping Fitting	Aluminum 6061
221	5	Preprocessed Part	524-764_1C1	Connector Block	Aluminum 6061
222	6	Manufacturing Steps		Sensor Process	
223	7	Manufacturing Process		Wash	
224	7	Manufacturing Process		Deburr	
225	7	Manufacturing Process		CNC Machine	
226	7	Manufacturing Process		Saw Cut	
227	8	Part	524-764_1C1Material	Material, Connector Block	Aluminum 6061
228	5	Part	524-764_1C7	Guide Pin	Commodity Item
229	5	Preprocessed Part	524-764_1C2	Connecting Tube 1	Aluminum 6061
230	6	Manufacturing Steps		Connecting Tube Process	
231	7	Manufacturing Process		Wash	
232	7	Manufacturing Process		Deburr	
233	7	Manufacturing Process		Tube Bending	
234	7	Manufacturing Process		Saw Cut	
235	8	Part	524-764_1C2 Material	Material, Connecting Tube 1	Aluminum 6061
236	5	Preprocessed Part	524-764_1C3	Sensor	Aluminum 6061
237	6	Manufacturing Steps		Sensor Process	
238	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
239	7	Manufacturing Process		Deburr	
240	7	Manufacturing Process		CNC Machine	
241	7	Manufacturing Process		Saw Cut	
242	8	Part	524-764_1C3 Material	Material, Sensor	Aluminum 6061
243	5	Preprocessed Part	524-764_1C4	Connecting Tube 2	Aluminum 6061
244	6	Manufacturing Steps		Connecting Tube 2 Process	
245	7	Manufacturing Process		Wash	
246	7	Manufacturing Process		Deburr	
247	7	Manufacturing Process		Tube Bending	
248	7	Manufacturing Process		Saw Cut	
249	8	Part	524-764_1C4 Material	Material, Connecting Tube 2	Aluminum 6061
250	5	Manufacturing Steps		Assmeble Section 3, Tube L	
251	6	Manufacturing Process		Manual Asm	
252	3	Part	524-764_2	QR Code Label	Commodity Item
253	3	Part	524-764_3	O-Ring, 14mm ID	Commodity Item
254	3	Part	524-764_4	O-Ring, 16mm ID	Commodity Item
255	3	Manufacturing Steps		Assmeble Tube L	
256	4	Manufacturing Process		Manual Asm	
257	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
258	2	Manufacturing Steps		Install Tube L Assembly, AC System	
259	3	Manufacturing Process		Manual Asm	
260	2	Subassembly	524-1360	Tube P Assmebly, AC System	(None)
261	3	Subassembly	524-1360_1	Tube P Asm	(None)
262	4	Subassembly	524-1360_1A	Section 1, Tube P Asm	(None)

Row	Level	Symbol Type	Number	Name	Material Name
263	5	Preprocessed Part	524-1360_1A1	Connector 1, Section 1	Aluminum 6061
264	6	Manufacturing Steps		Connector 1, Processing	
265	7	Manufacturing Process		Wash	
266	7	Manufacturing Process		Deburr	
267	7	Manufacturing Process		CNC Machine	
268	7	Manufacturing Process		Cut Off	
269	8	Part	524-1360_1A1 Material	Material, Connector #1	Aluminum 6061
270	5	Preprocessed Part	524-1360_1A2	Connecting Tube, Section 1	Aluminum 3003 - Seamless Tube
271	6	Manufacturing Steps		Connecting Tube Processing	
272	7	Manufacturing Process		Wash	
273	7	Manufacturing Process		Deburr	
274	7	Manufacturing Process		Tube Bending	
275	7	Manufacturing Process		Saw Cut	
276	8	Part	524-1360_1A2 Material	Material, Tube #1	Aluminum 3003 - Seamless Tube
277	5	Manufacturing Steps		Section 1 Processing	
278	6	Manufacturing Process		Manual Asm	
279	4	Subassembly	524-1360_1B	Section 2, Tube P Asm	(None)
280	5	Preprocessed Part	524-1360_1B1	Connector 2, Section 2	Aluminum 6061
281	6	Manufacturing Steps		Connector 2, Processing	
282	7	Manufacturing Process		Wash	
283	7	Manufacturing Process		Deburr	
284	7	Manufacturing Process		CNC Machine	
285	7	Manufacturing Process		Cut Off	
286	8	Part	524-1360_1B1 Material	Material, Connector 2, Section 2	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
287	5	Part	524-1360_1B4	Guide Pin	Commodity Item
288	5	Part	524-1360_1B5	Bar Code Label	Commodity Item
289	5	Part	524-1360_1B6	Label	Commodity Item
290	5	Manufacturing Steps		Connector 2 Processing	
291	6	Manufacturing Process		Manual Asm	
292	5	Preprocessed Part	524-1360_1B2	End Tube Connector, Section 2	Aluminum 6061
293	6	Manufacturing Steps		End Tube Connector, Section 2 Processing	
294	7	Manufacturing Process		Wash	
295	7	Manufacturing Process		Deburr	
296	7	Manufacturing Process		CNC Machine	
297	7	Manufacturing Process		Cut Off	
298	8	Part	524-1360_1B2 Material	Material, End Tube Connector, Section 2	Aluminum 6061
299	5	Preprocessed Part	524-1360_1B3	Connecting Tube, Section 2	Aluminum 3003 - Seamless Tube
300	6	Manufacturing Steps		Connecting Tube, Section 2 Processing	
301	7	Manufacturing Process		Wash	
302	7	Manufacturing Process		Deburr	
303	7	Manufacturing Process		Tube Bending	
304	7	Manufacturing Process		Saw Cut	
305	8	Part	524-1360_1B3 Material	Material, Connector Tube, Section 2	Aluminum 3003 - Seamless Tube
306	5	Manufacturing Steps		Section 2 Assembly	
307	6	Manufacturing Process		Manual Asm	
308	4	Preprocessed Part	524-1360_1C	Tube Connector, Tube P Asm	Aluminum 6061
309	5	Manufacturing Steps		Tube Connector, Processing	
310	6	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
311	6	Manufacturing Process		Deburr	
312	6	Manufacturing Process		CNC Machine	
313	6	Manufacturing Process		Cut Off	
314	7	Part	524-1360_1C, Material	Material, Connector 2, Tube P Assembly	Aluminum 6061
315	4	Manufacturing Steps		Tube P Processing	
316	5	Manufacturing Process		Manual Asm	
317	3	Part	524-1360_2	Threaded Stud	Commodity Item
318	3	Part	524-1360_3	Nut	Commodity Item
319	3	Part	524-1360_4	O-Rings	Commodity Item
320	3	Manufacturing Steps		Assemble Tube P	
321	4	Manufacturing Process		Manual Asm	
322	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
323	2	Manufacturing Steps		Install Tube P Assmebly, AC System	
324	3	Manufacturing Process		Manual Asm	
325	2	Subassembly	524-683	Tube N Assembly, AC System	(None)
326	3	Subassembly	524-683_1	Tube N Asm	(None)
327	4	Subassembly	524-683_1A	Section 1, Tube N Asm	(None)
328	5	Preprocessed Part	524-683_1A1	Connector 1, Section 1 Asm	Aluminum 6061
329	6	Manufacturing Steps		Connector 1,Section 1 Asm Processing	
330	7	Manufacturing Process		Wash	
331	7	Manufacturing Process		Deburr	
332	7	Manufacturing Process		CNC Machine	
333	7	Manufacturing Process		Cut Off	
334	8	Part	524-683_1A1 Material	Material, Connector 1, Section 1 Asm	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
335	5	Preprocessed Part	524-683_1A2	Connecting Tube, Section 1 Asm	Aluminum 3003 - Seamless Tube
336	6	Manufacturing Steps		Connecting Tube Process	
337	7	Manufacturing Process		Wash	
338	7	Manufacturing Process		Deburr	
339	7	Manufacturing Process		Tube Bending	
340	7	Manufacturing Process		Saw Cut	
341	8	Part	524-683_1A2 Material	Material, Connecting Tube, Section 1 Asm	Aluminum 3003 - Seamless Tube
342	5	Manufacturing Steps		Section 1 Assembly	
343	6	Manufacturing Process		Manual Asm	
344	4	Preprocessed Part	524-683_1B	25mm - OD Wraped	(None)
345	5	Manufacturing Steps		25mm - OD Wraped Hose Process	
346	6	Manufacturing Process		Extrusion	
347	7	Part	524-683_1B Material 1	Material 1, Inner PVC Layer, 25mm - OD Wrapped	PA6
348	7	Part	524-683_1B Material 2	Material 2, Middle Layer Covering, 25mm - OD Wrapp	_EPDM (Extrusion Grade)
349	7	Part	524-683_1B Material 3	Material 3, Reinforcement Layer, 25mm - OD Wrapped	PA Thread w/ PVC Coat
350	7	Part	524-684_1B Material 4	Material 4, Outer Layer, 25mm - OD Wrapped H	_EPDM Covering
351	4	Subassembly	524-683_1C	Section 3, Tube N Asm	(None)
352	5	Preprocessed Part	524-683_1C1	Connector 2, Section 3 Asm	Aluminum 6061
353	6	Manufacturing Steps		Connector 2,Section 3 Asm Processing	
354	7	Manufacturing Process		Wash	
355	7	Manufacturing Process		Deburr	
356	7	Manufacturing Process		CNC Machine	
357	7	Manufacturing Process		Cut Off	
358	8	Part	524-683_1C1 Material	Material, Connector 2, Section 3 Asm	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
359	5	Preprocessed Part	524-683_1C2	Connecting Tube, Section 3 Asm	Aluminum 3003 - Seamless Tube
360	6	Manufacturing Steps		Connecting Tube, Section 3 Asm Process	
361	7	Manufacturing Process		Wash	
362	7	Manufacturing Process		Deburr	
363	7	Manufacturing Process		Tube Bending	
364	7	Manufacturing Process		Saw Cut	
365	8	Part	524-683_1C2 Material	Material, Connecting Tube, Section 3 Asm	Aluminum 3003 - Seamless Tube
366	5	Manufacturing Steps		Section 3 Processing	
367	6	Manufacturing Process		Manual Asm	
368	4	Preprocessed Part	524-764_1A3	Hose Crimping Fitting	Aluminum 6061
369	5	Manufacturing Steps		Hose Crimp Fitting Process	
370	6	Manufacturing Process		Wash	
371	6	Manufacturing Process		Deburr	
372	6	Manufacturing Process		Saw Cut	
373	7	Part	524-764_1A3 Material	Material, Hose Crimping Fitting	Aluminum 6061
374	4	Part	524-683_1D	Barcode Label	Commodity Item
375	4	Part	524-683_1E	Inspection Label	Commodity Item
376	4	Manufacturing Steps		Tube Section Asm	
377	5	Manufacturing Process		Manual Asm	
378	5	Manufacturing Process		Manual Asm	
379	3	Part	524-683_2	O-Ring	Commodity Item
380	3	Manufacturing Steps		Tube N Assembly	
381	4	Manufacturing Process		Manual Asm	
382	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
383	2	Manufacturing Steps		Install Tube N Assembly, AC System	
384	3	Manufacturing Process		Manual Asm	
385	2	Subassembly	524-1387	Tube D & E Assembly, AC System	(None)
386	3	Subassembly	524-1387_1	Tube D & E Asm	(None)
387	4	Subassembly	524-1387_1A	Tube E Subassembly, Tube D & E Asm	(None)
388	5	Preprocessed Part	524-1387_1A2	Tube E, Tube E Subassembly	Aluminum 3003 - Seamless Tube
389	6	Manufacturing Steps		Tube E Process	
390	7	Manufacturing Process		Wash	
391	7	Manufacturing Process		Deburr	
392	7	Manufacturing Process		Tube Bending	
393	7	Manufacturing Process		Saw Cut	
394	8	Part	524-1387_1A2 Material	Material, Tube E	Aluminum 3003 - Seamless Tube
395	5	Preprocessed Part	524-1387_1A1	Tube E Connector	Aluminum 6061
396	6	Manufacturing Steps		Tube E Connector Process	
397	7	Manufacturing Process		Wash	
398	7	Manufacturing Process		Deburr	
399	7	Manufacturing Process		CNC Machine	
400	7	Manufacturing Process		Cut Off	
401	8	Part	524-1387_1A1 Material	Material, Tube E Connector	Aluminum 6061
402	5	Manufacturing Steps		Tube E Assembly Process	
403	6	Manufacturing Process		Manual Asm	
404	4	Preprocessed Part	524-1387_1B	Hose Subassembly, Tube D & E Asm	(None)
405	5	Manufacturing Steps		Hose Subassembly, Tube D & E Asm Processing	
406	6	Manufacturing Process		Extrusion	

Row	Level	Symbol Type	Number	Name	Material Name
407	7	Part	524-1387_1B Material 1	Material, Inner PA Layer, 25mm - OD Wrapped Ho	PA6
408	7	Part	524-1387_1B Material 2	Material, Middle Layer Covering, 25mm - OD Wrapped	_EPDM (Extrusion Grade)
409	7	Part	524-1387_1B Material 3	Material, Reinforcement Layer, 25mm - OD Wrapped H	PA Thread w/ PVC Coat
410	7	Part	524-1387_1B Material 4	Material, Outer Layer, 25mm - OD Wrapped H	_EPDM Covering
411	4	Subassembly	524-1387_1C	Tube D Subassembly, Tube D & E Asm	(None)
412	5	Preprocessed Part	524-1387_1C2	Tube D, Tube D Subassembly	Aluminum 3003 - Seamless Tube
413	6	Manufacturing Steps		Tube D Process	
414	7	Manufacturing Process		Wash	
415	7	Manufacturing Process		Deburr	
416	7	Manufacturing Process		Tube Bending	
417	7	Manufacturing Process		Saw Cut	
418	8	Part	524-1387_1C2 Material	Material, Tube D	Aluminum 3003 - Seamless Tube
419	5	Subassembly	524-1387_1C1	Tube D Connector	(None)
420	6	Preprocessed Part	524-1387_1C1A	Connector #1, Tube D Subassembly	Aluminum 6061
421	7	Manufacturing Steps		Connector #1 Process	
422	8	Manufacturing Process		Wash	
423	8	Manufacturing Process		Deburr	
424	8	Manufacturing Process		CNC Machine	
425	8	Manufacturing Process		Cut Off	
426	9	Part	524-1387_1C1A Material	Material, Connector #1	Aluminum 6061
427	6	Preprocessed Part	524-1387_1C1B	Connecting Tube, Tube D Subassembly	Aluminum 3003 - Seamless Tube
428	7	Manufacturing Steps		Connecting Tube Process	
429	8	Manufacturing Process		Wash	
430	8	Manufacturing Process		Deburr	

Row	Level	Symbol Type	Number	Name	Material Name
431	8	Manufacturing Process		Saw Cut	
432	9	Part	524-1387_1C1B Material	Material, Connecting Tube	Aluminum 3003 - Seamless Tube
433	6	Preprocessed Part	524-1387_1C1C	Connector #2, Tube D Subassembly	Aluminum 6061
434	7	Manufacturing Steps		Connector #2 Process	
435	8	Manufacturing Process		Wash	
436	8	Manufacturing Process		Deburr	
437	8	Manufacturing Process		CNC Machine	
438	8	Manufacturing Process		Cut Off	
439	9	Part	524-1387_1C1C Material	Material, Connector #2	Aluminum 6061
440	6	Manufacturing Steps		Tube D Connector Processing	
441	7	Manufacturing Process		Manual Asm	
442	5	Manufacturing Steps		Tube D Assembly Process	
443	6	Manufacturing Process		Manual Asm	
444	4	Preprocessed Part	524-1387_1A3	Hose Crimp Fitting 1, Section 1 Asm	Aluminum 6061
445	5	Manufacturing Steps		Hose Crimp Fitting Process	
446	6	Manufacturing Process		Wash	
447	6	Manufacturing Process		Deburr	
448	6	Manufacturing Process		Saw Cut	
449	7	Part	524-764_1A3 Material	Material, Hose Crimping Fitting	Aluminum 6061
450	4	Preprocessed Part	524-1387_1A3	Hose Crimp Fitting 1, Section 1 Asm	Aluminum 6061
451	5	Manufacturing Steps		Hose Crimp Fitting Process	
452	6	Manufacturing Process		Wash	
453	6	Manufacturing Process		Deburr	
454	6	Manufacturing Process		Saw Cut	

Row	Level	Symbol Type	Number	Name	Material Name
455	7	Part	524-764_1A3 Material	Material, Hose Crimping Fitting	Aluminum 6061
456	4	Part	524-1387_1D	Sleeve, 25mm - OD Wrapped	Commodity Item
457	4	Manufacturing Steps		Tube D & E Assembly Process	
458	5	Manufacturing Process		Manual Asm	
459	3	Part	524-1387_2	O-Ring Big	Commodity Item
460	3	Part	524-1387_3	O-Rings Small	Commodity Item
461	3	Part	524-1387_1C1D	Bar Code Label	Commodity Item
462	3	Part	524-1387_1C1E	Label	Commodity Item
463	3	Manufacturing Steps		Tube D & E Assembly	
464	4	Manufacturing Process		Manual Asm	
465	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
466	2	Manufacturing Steps		Install Tube D & E Assembly, AC System	
467	3	Manufacturing Process		Manual Asm	
468	2	Subassembly	524-1363	Tube A Assembly, AC System	(None)
469	3	Subassembly	524-1363_1	Tube A Asm	(None)
470	4	Subassembly	524-1363_1A	Section 1, Tube A Asm	(None)
471	5	Preprocessed Part	524-1363_1A1	Connector 1, Section 1	Aluminum 6061
472	6	Manufacturing Steps		Connector 1,Section 1 Processing	
473	7	Manufacturing Process		Wash	
474	7	Manufacturing Process		Deburr	
475	7	Manufacturing Process		CNC Machine	
476	7	Manufacturing Process		Cut Off	
477	8	Part	524-1363_1A1 Material	Material, Connector 1, Section 1	Aluminum 6061
478	5	Preprocessed Part	524-1363_1A2	Connecting Tube 1, Section 1	Aluminum 3003 - Seamless Tube

Row	Level	Symbol Type	Number	Name	Material Name
479	6	Manufacturing Steps		Connecting Tube 1, Section 1 Processing	
480	7	Manufacturing Process		Wash	
481	7	Manufacturing Process		Deburr	
482	7	Manufacturing Process		Tube Bending	
483	7	Manufacturing Process		Saw Cut	
484	8	Part	524-1363_1A2 Material	Material, Connecting Tube 1, Section 1	Aluminum 3003 - Seamless Tube
485	5	Manufacturing Steps		Section 1 Processing	
486	6	Manufacturing Process		Manual Asm	
487	4	Subassembly	524-1363_1B	Section 2, Tube A Asm	(None)
488	5	Preprocessed Part	524-1363_1B2	Connecting Tube 2, Section 2	Aluminum 3003 - Seamless Tube
489	6	Manufacturing Steps		Connecting Tube 2, Section 2 Processing	
490	7	Manufacturing Process		Wash	
491	7	Manufacturing Process		Deburr	
492	7	Manufacturing Process		Tube Bending	
493	7	Manufacturing Process		Saw Cut	
494	8	Part	524-1363_1B2 Material	Material, Connecting Tube 2, Section 2	Aluminum 3003 - Seamless Tube
495	5	Preprocessed Part	524-1363_1B1	Connector 2, Section 2	Aluminum 6061
496	6	Manufacturing Steps		Connector 2,Section 2 Processing	
497	7	Manufacturing Process		Wash	
498	7	Manufacturing Process		Deburr	
499	7	Manufacturing Process		CNC Machine	
500	7	Manufacturing Process		Cut Off	
501	8	Part	524-1363_1B1 Material	Material, Connector 2, Section 2	Aluminum 6061
502	5	Part	524-1363_1B4	Bar Code Label	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
503	5	Part	524-1363_1B5	Label	Commodity Item
504	5	Manufacturing Steps		Section 2 Processing	
505	6	Manufacturing Process		Manual Asm	
506	4	Preprocessed Part	524-1363_1C	20mm Wrapped Hose, Tube A Asm	(None)
507	5	Manufacturing Steps		21mm-OD Wrapped Hose Process	
508	6	Manufacturing Process		Extrusion	
509	7	Part	524-1363_1C Material 1	Material 1, 20mm Wrapped Hose, Tube A Asm	PA6 GP
510	7	Part	524-1363_1C Material 2	Material 2, 20mm Wrapped Hose, Tube A Asm	_EPDM (Extrusion Grade)
511	7	Part	524-1363_1C Material 3	Material 3, 20mm Wrapped Hose, Tube A Asm	PA Thread w/ PVC Coat
512	7	Part	524-1363_1C Material 4	Material 4, 20mm Wrapped Hose, Tube A Asm	_EPDM Covering
513	4	Subassembly	524-1363_1D	Section 3, Tube A Asm	(None)
514	5	Preprocessed Part	524-1363_1D1	Connector 3, Section 3	Aluminum 6061
515	6	Manufacturing Steps		Connector 3,Section 3 Processing	
516	7	Manufacturing Process		Wash	
517	7	Manufacturing Process		Deburr	
518	7	Manufacturing Process		CNC Machine	
519	7	Manufacturing Process		Cut Off	
520	8	Part	524-1363_1D1 Material	Material, Connector 3, Section 3	Aluminum 6061
521	5	Preprocessed Part	524-1363_1D2	Connecting Tube 3, Section 3	Aluminum 3003 - Seamless Tube
522	6	Manufacturing Steps		Connecting Tube 3, Section 3 Processing	
523	7	Manufacturing Process		Wash	
524	7	Manufacturing Process		Deburr	
525	7	Manufacturing Process		Tube Bending	
526	7	Manufacturing Process		Saw Cut	

Row	Level	Symbol Type	Number	Name	Material Name
527	8	Part	524-1363_1D2 Material	Material, Connecting Tube 3, Section 3	Aluminum 3003 - Seamless Tube
528	5	Manufacturing Steps		Section 3 Processing	
529	6	Manufacturing Process		Manual Asm	
530	4	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061
531	5	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	
532	6	Manufacturing Process		Wash	
533	6	Manufacturing Process		Deburr	
534	6	Manufacturing Process		Saw Cut	
535	7	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
536	4	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061
537	5	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	
538	6	Manufacturing Process		Wash	
539	6	Manufacturing Process		Deburr	
540	6	Manufacturing Process		Saw Cut	
541	7	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
542	4	Manufacturing Steps		Tube A Asm Processing	
543	5	Manufacturing Process		Manual Asm	
544	3	Part	524-1363_2	O-Rings	Commodity Item
545	3	Manufacturing Steps		Tube K Processing	
546	4	Manufacturing Process		Manual Asm	
547	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
548	2	Manufacturing Steps		Install Tube A Assembly, AC System	
549	3	Manufacturing Process		Manual Asm	
550	2	Subassembly	524-732	Tube G Assembly, AC System	(None)

Row	Level	Symbol Type	Number	Name	Material Name
551	3	Subassembly	524-732_1	Tube G Assembly	(None)
552	4	Subassembly	524-732_1A	Section 1, Tube G Asm	(None)
553	5	Preprocessed Part	524-732_1A2	Connecting Tube 1, Section 1	Aluminum 3003 - Seamless Tube
554	6	Manufacturing Steps		Connecting Tube 1, Section 1 Processing	
555	7	Manufacturing Process		Wash	
556	7	Manufacturing Process		Deburr	
557	7	Manufacturing Process		Tube Bending	
558	7	Manufacturing Process		Saw Cut	
559	8	Part	524-732_1A2 Material	Material, Connecting Tube 1, Section 1	Aluminum 3003 - Seamless Tube
560	5	Preprocessed Part	524-732_1A1	Connector 1, Section 1	Aluminum 6061
561	6	Manufacturing Steps		Connector 1,Section 1 Processing	
562	7	Manufacturing Process		Wash	
563	7	Manufacturing Process		Deburr	
564	7	Manufacturing Process		CNC Machine	
565	7	Manufacturing Process		Cut Off	
566	8	Part	524-732_1A1 Material	Material, Connector 1, Section 1	Aluminum 6061
567	5	Part	524-732_1A4	Bar Code Label	Commodity Item
568	5	Part	524-732_1A5	Label	Commodity Item
569	5	Manufacturing Steps		Assemble Section 1	
570	6	Manufacturing Process		Manual Asm	
571	4	Subassembly	524-732_1B	Section 2, Tube G Asm	(None)
572	5	Preprocessed Part	524-732_1B2	Connecting Tube 2, Section 2	Aluminum 3003 - Seamless Tube
573	6	Manufacturing Steps		Connecting Tube 2, Section 2 Processing	
574	7	Manufacturing Process		Wash	

Row	Level	Symbol Type	Number	Name	Material Name
575	7	Manufacturing Process		Deburr	
576	7	Manufacturing Process		Tube Bending	
577	7	Manufacturing Process		Saw Cut	
578	8	Part	524-732_1B2 Material	Material, Connecting Tube 2, Section 2	Aluminum 3003 - Seamless Tube
579	5	Part	524-732_1B3	Connecting Tube 2 Cover	Commodity Item
580	5	Subassembly	524-732_1B1	Connector 2, Section 2	(None)
581	6	Preprocessed Part	524-732_1B1C	Connecting Tube Small, Connector 2	Aluminum 3003 - Seamless Tube
582	7	Manufacturing Steps		Connecting Tube Small, Connector 2 Processing	
583	8	Manufacturing Process		Wash	
584	8	Manufacturing Process		Deburr	
585	8	Manufacturing Process		Tube Bending	
586	8	Manufacturing Process		Saw Cut	
587	9	Part	524-732_1B1C Material	Material, Connecting Tube Small, Connector 2	Aluminum 3003 - Seamless Tube
588	6	Preprocessed Part	524-732_1B1A	Connector A, Connector 2	Aluminum 6061
589	7	Manufacturing Steps		Connector A Processing	
590	8	Manufacturing Process		Wash	
591	8	Manufacturing Process		Deburr	
592	8	Manufacturing Process		CNC Machine	
593	8	Manufacturing Process		Cut Off	
594	9	Part	524-732_1B1A Material	Material, Connector A, Connector 2	Aluminum 6061
595	6	Preprocessed Part	524-732_1B1B	Connector B, Connector 2	Aluminum 6061
596	7	Manufacturing Steps		Connector B Processing	
597	8	Manufacturing Process		Wash	
598	8	Manufacturing Process		Deburr	

Row	Level	Symbol Type	Number	Name	Material Name
599	8	Manufacturing Process		CNC Machine	
600	8	Manufacturing Process		Cut Off	
601	9	Part	524-732_1B1B Material	Material, Connector B, Connector 2	Aluminum 6061
602	6	Manufacturing Steps		Connector 2 Processing	
603	7	Manufacturing Process		Auto Asm	
604	5	Part	524-732_1B4	Connecting Tube 2 Interface, Section 2	Commodity Item
605	5	Manufacturing Steps		Section 2 Processing	
606	6	Manufacturing Process		Auto Asm	
607	4	Preprocessed Part	524-732_1C	26mm OD Wrapped Hose, Tube G Asm	(None)
608	5	Manufacturing Steps		26mm-OD Wrapped Hose Process	
609	6	Manufacturing Process		Extrusion	
610	7	Part	524-732_1C Material 1	Material 1, 26mm OD Wrapped Hose, Tube G Asm	PA6
611	7	Part	524-732_1C Material 2	Material 2, 26mm OD Wrapped Hose, Tube G Asm	_EPDM (Extrusion Grade)
612	7	Part	524-732_1C Material 3	Material 3, 26mm OD Wrapped Hose, Tube G Asm	_EPDM Covering
613	7	Part	524-732_1C Material 4	Material 4, 26mm OD Wrapped Hose, Tube G Asm	PA Thread w/ PVC Coat
614	4	Preprocessed Part	524-764_1A3	Hose Crimping Fitting	Aluminum 6061
615	5	Manufacturing Steps		Hose Crimp Fitting Process	
616	6	Manufacturing Process		Auto Asm	
617	6	Manufacturing Process		Wash	
618	6	Manufacturing Process		Deburr	
619	6	Manufacturing Process		Saw Cut	
620	7	Part	524-764_1A3 Material	Material, Hose Crimping Fitting	Aluminum 6061
621	4	Preprocessed Part	524-764_1A3	Hose Crimping Fitting	Aluminum 6061
622	5	Manufacturing Steps		Hose Crimp Fitting Process	

Row	Level	Symbol Type	Number	Name	Material Name
623	6	Manufacturing Process		Auto Asm	
624	6	Manufacturing Process		Wash	
625	6	Manufacturing Process		Deburr	
626	6	Manufacturing Process		Saw Cut	
627	7	Part	524-764_1A3 Material	Material, Hose Crimping Fitting	Aluminum 6061
628	4	Manufacturing Steps		Assemble Tube G Section 1 & 2	
629	5	Manufacturing Process		Manual Asm	
630	3	Part	524-732_2	Tube Holder	Commodity Item
631	3	Part	524-732_3	Tube Cap	Commodity Item
632	3	Subassembly	524-732_4	Tube Bracket Support Asm	(None)
633	4	Preprocessed Part	524_732_4A	Tube Bracket Support	TPI GP
634	5	Manufacturing Steps		Tube Bracket Support Processing	
635	6	Manufacturing Process		Injection Mold Press, 110 Ton	
636	7	Part	524_732_4A Material	Material, Tube Bracket Support	TPI GP
637	4	Preprocessed Part	524_732_4B	Rubber Bushing	EPDM GP
638	5	Manufacturing Steps		Rubber Bushing Processing	
639	6	Manufacturing Process		Injection Mold Press, 55 Ton	
640	7	Part	524_732_4B Material	Material, Rubber Bushing	EPDM GP
641	4	Part	524_732_4C	Inspection Label	Commodity Item
642	4	Manufacturing Steps		Assemble Tube Support Bracket Asm	
643	5	Manufacturing Process		Manual Asm	
644	3	Part	524-732_5	O-Rings	Commodity Item
645	3	Manufacturing Steps		Tube G Assembly	
646	4	Manufacturing Process		Manual Asm	

Row	Level	Symbol Type	Number	Name	Material Name
647	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
648	2	Manufacturing Steps		Install Tube G Assembly, AC System	
649	3	Manufacturing Process		Manual Asm	
650	2	Subassembly	524-741	Tube M Assembly, AC System	(None)
651	3	Subassembly	524-741_1	Tube M Asm	(None)
652	4	Subassembly	524-741_1A	Section 1, Tube M Asm	(None)
653	5	Preprocessed Part	524-741_1A2	Connecting Tube 1, Section 1	Aluminum 3003 - Seamless Tube
654	6	Manufacturing Steps		Connecting Tube 1, Section 1 Processing	
655	7	Manufacturing Process		Wash	
656	7	Manufacturing Process		Deburr	
657	7	Manufacturing Process		Tube Bending	
658	7	Manufacturing Process		Saw Cut	
659	8	Part	524-741_1A2 Material	Material, Connecting Tube 1, Section 1	Aluminum 3003 - Seamless Tube
660	5	Preprocessed Part	524-741_1A1	Connector 1, Section 1	Aluminum 6061
661	6	Manufacturing Steps		Connector 1,Section 1 Processing	
662	7	Manufacturing Process		Wash	
663	7	Manufacturing Process		Deburr	
664	7	Manufacturing Process		CNC Machine	
665	7	Manufacturing Process		Cut Off	
666	8	Part	524-741_1A1 Material	Material, Connector 1, Section 1	Aluminum 6061
667	5	Part	524-741_1A4	Bar Code Label	Commodity Item
668	5	Manufacturing Steps		Section 1 Processing	
669	6	Manufacturing Process		Manual Asm	
670	4	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061

Row	Level	Symbol Type	Number	Name	Material Name
671	5	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	
672	6	Manufacturing Process		Wash	
673	6	Manufacturing Process		Deburr	
674	6	Manufacturing Process		Saw Cut	
675	7	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
676	4	Preprocessed Part	524-741_1D	24mm OD Wrapped	(None)
677	5	Manufacturing Steps		24mm-OD Wrapped Hose Process	
678	6	Manufacturing Process		Extrusion	
679	7	Part	524-741_1D Material 1	Material 1, 20mm OD Wrapped	PA6
680	7	Part	524-741_1D Material 2	Material 2, 20mm OD Wrapped	_EPDM (Extrusion Grade)
681	7	Part	524-741_1D Material 3	Material 3, 20mm OD Wrapped	PA Thread w/ PVC Coat
682	7	Part	524-741_1D Material 4	Material 2, 20mm OD Wrapped	_EPDM Covering
683	4	Part	524-741_1I	Heat Shield Section 1	Commodity Item
684	4	Part	524-741_5	Heat Shrink Tubing 1	Commodity Item
685	4	Preprocessed Part	524-741_1B1	Connecting Tube 2, Section 2	Aluminum 3003 - Seamless Tube
686	5	Manufacturing Steps		Connecting Tube 2, Section 2 Processing	
687	6	Manufacturing Process		Wash	
688	6	Manufacturing Process		Deburr	
689	6	Manufacturing Process		Tube Bending	
690	6	Manufacturing Process		Saw Cut	
691	7	Part	524-741_1B1 Material	Material, Connecting Tube 2, Section 2	Aluminum 3003 - Seamless Tube
692	4	Part	524-741_1I	Heat Shield Section 2	Commodity Item
693	4	Part	524-741_5	Heat Shrink Tubing 2	Commodity Item
694	4	Part	524-741_5	Heat Shrink Tubing 4	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
695	4	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061
696	5	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	
697	6	Manufacturing Process		Wash	
698	6	Manufacturing Process		Deburr	
699	6	Manufacturing Process		Saw Cut	
700	7	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
701	4	Manufacturing Steps		Assemble Section 1 to Section 2	
702	5	Manufacturing Process		Manual Asm	
703	4	Preprocessed Part	524-741_1E	Sensor Block	Aluminum 6061
704	5	Manufacturing Steps		Sensor Process	
705	6	Manufacturing Process		Wash	
706	6	Manufacturing Process		Deburr	
707	6	Manufacturing Process		CNC Machine	
708	6	Manufacturing Process		Saw Cut	
709	7	Part	524-741_1E Material	Material, Sensor Block	Aluminum 6061
710	4	Subassembly	524-741_1C	Section 3, Tube M Asm	(None)
711	5	Preprocessed Part	524-741_1C2	Connecting Tube 3, Section 3	Aluminum 3003 - Seamless Tube
712	6	Manufacturing Steps		Connecting Tube 3, Section 3 Processing	
713	7	Manufacturing Process		Wash	
714	7	Manufacturing Process		Deburr	
715	7	Manufacturing Process		Saw Cut	
716	8	Part	524-741_1C2 Material	Material, Connecting Tube 3, Section 3	Aluminum 3003 - Seamless Tube
717	5	Preprocessed Part	524-741_1C4	Spacer	Aluminum 6061
718	6	Manufacturing Steps		Hex Spacer Process	

Row	Level	Symbol Type	Number	Name	Material Name
719	7	Manufacturing Process		Wash	
720	7	Manufacturing Process		Deburr	
721	7	Manufacturing Process		Saw Cut	
722	8	Part	524-764_1B4 Material	Material, Hex Spacer	Aluminum 6061
723	5	Part	524-741_1C3	Schrader Valve, Section 3	Commodity Item
724	5	Manufacturing Steps		Section 3 Processing	
725	6	Manufacturing Process		Manual Asm	
726	4	Manufacturing Steps		Assemble Section 3 to Section 2	
727	5	Manufacturing Process		Manual Asm	
728	4	Preprocessed Part	524-741_1F	24mm OD Wrapped Tube	(None)
729	5	Manufacturing Steps		24mm-OD Wrapped Hose Process	
730	6	Manufacturing Process		Extrusion	
731	7	Part	524-741_1F Material 1	Material 1, 24mm OD Wrapped Tube	PA6
732	7	Part	524-741_1F Material 2	Material 1, 24mm OD Wrapped Tube	_EPDM (Extrusion Grade)
733	7	Part	524-741_1F Material 3	Material 3, 24mm OD Wrapped Tube	PA Thread w/ PVC Coat
734	7	Part	524-741_1F Material 4	Material 4, 24mm OD Wrapped Tube	_EPDM Covering
735	4	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061
736	5	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	
737	6	Manufacturing Process		Wash	
738	6	Manufacturing Process		Deburr	
739	6	Manufacturing Process		Saw Cut	
740	7	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
741	4	Preprocessed Part	524-1363_1B3	Hose Crimp Fittings	Aluminum 6061
742	5	Manufacturing Steps		Hose Crimp Fitting 1, Section 2 Processing	

Row	Level	Symbol Type	Number	Name	Material Name
743	6	Manufacturing Process		Wash	
744	6	Manufacturing Process		Deburr	
745	6	Manufacturing Process		Saw Cut	
746	7	Part	524-1363_1B3 Material	Material, Hose Crimp Fittings	Aluminum 6061
747	4	Subassembly	524-741_1G	Section 4, Tube M Asm	(None)
748	5	Preprocessed Part	524-741_1G2	Connecting Tube 4, Section 4	Aluminum 3003 - Seamless Tube
749	6	Manufacturing Steps		Connecting Tube 4, Section 4 Processing	
750	7	Manufacturing Process		Wash	
751	7	Manufacturing Process		Deburr	
752	7	Manufacturing Process		Tube Bending	
753	7	Manufacturing Process		Saw Cut	
754	8	Part	524-741_1G2 Material	Material, Connecting Tube 4, Section 4	Aluminum 3003 - Seamless Tube
755	5	Preprocessed Part	524-741_1G3	End Tube Connector, Section 4	Aluminum 6061
756	6	Manufacturing Steps		End Tube Connector, Section 4 Processing	
757	7	Manufacturing Process		Wash	
758	7	Manufacturing Process		Deburr	
759	7	Manufacturing Process		CNC Machine	
760	7	Manufacturing Process		Saw Cut	
761	8	Part	524-741_1G3 Material	Material, End Tube Connector, Section 4	Aluminum 6061
762	5	Manufacturing Steps		Section 4 Processing	
763	6	Manufacturing Process		Manual Asm	
764	4	Part	524-741_1I	Heat Shield Section 3	Commodity Item
765	4	Part	524-741_1I	Heat Shield Section 4	Commodity Item
766	4	Part	524-741_5	Heat Shrink Tubing 5	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
767	4	Manufacturing Steps		Assemble Section 4 and Hose to Section 3	
768	5	Manufacturing Process		Manual Asm	
769	4	Subassembly	524-741_1H	Section 5, Tube M Asm	(None)
770	5	Preprocessed Part	524-741_1H1	Connecting Tube 5, Section 5	Aluminum 3003 - Seamless Tube
771	6	Manufacturing Steps		Connecting Tube 5, Section 5 Processing	
772	7	Manufacturing Process		Wash	
773	7	Manufacturing Process		Deburr	
774	7	Manufacturing Process		Tube Bending	
775	7	Manufacturing Process		Saw Cut	
776	8	Part	524-741_1H1 Material	Material, Connecting Tube 5, Section 5	Aluminum 3003 - Seamless Tube
777	5	Preprocessed Part	524-741_1H2	Connector 2, Section 5	Aluminum 6061
778	6	Manufacturing Steps		Connector 2,Section 5 Processing	
779	7	Manufacturing Process		Wash	
780	7	Manufacturing Process		Deburr	
781	7	Manufacturing Process		CNC Machine	
782	7	Manufacturing Process		Cut Off	
783	8	Part	524-741_1H2 Material	Material, Connector 2, Section 5	Aluminum 6061
784	5	Preprocessed Part	524-741_1H3	Connecting Tube Spacer, Section 5	Aluminum 6061
785	6	Manufacturing Steps		Connecting Tube Spacer, Section 5 Process	
786	7	Manufacturing Process		Wash	
787	7	Manufacturing Process		Deburr	
788	7	Manufacturing Process		Saw Cut	
789	8	Part	524-741_1H3 Material	Material, Connecting Tube Spacer, Section 5	Aluminum 6061
790	5	Manufacturing Steps		Section 5 Processing	

Row	Level	Symbol Type	Number	Name	Material Name
791	6	Manufacturing Process		Manual Asm	
792	4	Part	524-741_5	Heat Shrink Tubing 6	Commodity Item
793	4	Manufacturing Steps		Assemble Section 5 to Section 4	
794	5	Manufacturing Process		Manual Asm	
795	3	Subassembly	524-741_2	Tube Holder Asm	(None)
796	4	Preprocessed Part	524-741_2A	Tube Holder Outer	PA 6/6 GP
797	5	Manufacturing Steps		Tube Holder Outer Processing	
798	6	Manufacturing Process		Injection Mold Press, 55 Ton	
799	7	Part	524-741_2A Material	Material, Tube Holder Outer	PA 6/6 GP
800	4	Preprocessed Part	524-741_2B	Tube Holder Inner	EPDM GP
801	5	Manufacturing Steps		Tube Holder Inner Processing	
802	6	Manufacturing Process		Injection Mold Press, 55 Ton	
803	7	Part	524-741_2B Material	Material, Tube Holder Inner	EPDM GP
804	4	Manufacturing Steps		Assemble Tube Holder Asm	
805	5	Manufacturing Process		Manual Asm	
806	3	Part	524-741_3	Tube Cap	Commodity Item
807	3	Part	524-741_4	O-Rings	Commodity Item
808	3	Manufacturing Steps		Tube M Assembly	
809	4	Manufacturing Process		Manual Asm	
810	2	Part	524-1399_1	Torx Screw M6x10	Commodity Item
811	2	Manufacturing Steps		Install Tube M Assmebly, AC System	
812	3	Manufacturing Process		Manual Asm	

Table G-12 Tubes & Hoses

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

Tubes & Hoses

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1361	**Tube K Assembly, AC System**	**$1.17**	**1**	**$1.17**
524-1361_1	**Tube K Assembly**	**$0.99**	**1**	**$0.99**
524-1361_1B	**Connector 1, Tube K Assembly**	**$0.26**	**1**	**$0.26**
524-1361_1B, Material	Material, Connector 1	$0.26	1	$0.26
524-1361_1C	**Connector 2, Tube K Assembly**	**$0.13**	**1**	**$0.13**
524-1361_1C, Material	Material, Connector 2, Tube K Assembly	$0.13	1	$0.13
524-1361_1E	**End Tube Connector**	**$0.02**	**1**	**$0.02**
524-1361_1E, Material	Material, End Tube Connector	$0.02	1	$0.02
524-764_1C7	Guide Pin, Connector 1	$0.01	1	$0.01
524-1361_1A	**Tube K**	**$0.57**	**1**	**$0.57**
524-1361_1A, Material	Material, Tube K	$0.57	1	$0.57
524-1361_2	O-Rings	$0.03	2	$0.06
524-1361_3	Bar Code Label	$0.10	1	$0.10
524-1361_4	Label	$0.02	1	$0.02
524-1399_1	Torx Screw M6x10	$0.10	2	$0.20
524-1396	**Tube H Assembly, AC System**	**$2.21**	**1**	**$2.21**
524-1396_1	**Tube H Assembly**	**$2.03**	**1**	**$2.03**
524-1396_1A	**Section 1, Tube H**	**$1.59**	**1**	**$1.59**
524-1396_1A1	**Connector Hose Asm**	**$0.48**	**1**	**$0.48**
524-1396_1A1A	**Connecting Tube**	**$0.14**	**1**	**$0.14**
524-1396_1A1A Material	Material, Connecting Tube	$0.14	1	$0.14
524-1396_1A1B	**Connecting Block**	**$0.34**	**1**	**$0.34**
524-1396_1A1B Material	Material, Connecting Block	$0.34	1	$0.34
524-1396_1A2	**20mm-OD Wrapped**	**$0.17**	**1**	**$0.17**
524-1396_1A2 Material 1	Material 1,Inner Rubber Layer,20 mm-OD W	$0.02	1	$0.02
524-1396_1A2 Material 2	Material 2,Reinforcement Layer, 20mm-OD	$0.06	1	$0.06
524-1396_1A2 Material 3	Material 3,Outer Rubber Layer, 14mm-OD Wrapped Hose	$0.02	1	$0.02
524-1396_1A2 Material 4	Material 4,Outer EPDM Covering, 20mm-OD Wrapped Hos	$0.07	1	$0.07
524-1396_1A4	20mm-OD Hose Sleeve	$0.21	1	$0.21
524-1396_1A3	**Branch Connector Asm**	**$0.71**	**1**	**$0.71**
524-1396_1A3B	**Connecting Tube**	**$0.45**	**1**	**$0.45**
524-1396_1A3 Material	Material, Branch Connector Asm	$0.45	1	$0.45
524-1396_1A3A	**Connector 2 Asm**	**$0.26**	**1**	**$0.26**
524-1396_1A3A Material	Material, Connector 2 Asm	$0.26	1	$0.26
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-1396_1B	**Section 2, Tube H**	**$0.44**	**1**	**$0.44**
524-1396_1B1	**Connecting Tube**	**$0.29**	**1**	**$0.29**
524-1396_1B1 Material	Material, Connecting Tube	$0.29	1	$0.29
524-1396_1B2	**Connector Block 1**	**$0.13**	**1**	**$0.13**
524-1396_1B2 Material	Material, Connector Block 1	$0.13	1	$0.13

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1396_1B3	**End Tube Connector**	**$0.02**	**1**	**$0.02**
524-1361_1E, Material	Material, End Tube Connector	$0.02	1	$0.02
524-1396_2	O-Rings	$0.03	2	$0.06
524-1396_3	Bar Code Label	$0.10	1	$0.10
524-1396_4	Label	$0.02	1	$0.02
524-1399_1	Torx Screw M6x10	$0.10	3	$0.30
524-764	**Tube L Assembly, AC System**	**$2.88**	**1**	**$2.88**
524-764_1	**Tube L Assembly**	**$2.72**	**1**	**$2.72**
524-764_1A	**Section 1, Tube L**	**$1.21**	**1**	**$1.21**
524-764_1A1	**Connector Hose Assembly**	**$0.47**	**1**	**$0.47**
524-764_1A1A	**Connector Block**	**$0.25**	**1**	**$0.25**
524-764_1A1A Material	Material, Connector Block	$0.25	1	$0.25
524-764_1A1B	**Connecting Tube**	**$0.13**	**1**	**$0.13**
524-764_1A1B Material	Material, Connecting Tube	$0.13	1	$0.13
524-764_1A1C	Heat Shrink Tubing	$0.09	1	$0.09
524-764_1A3	**Hose Crimping Fitting**	**$0.02**	**1**	**$0.02**
524-764_1A3 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-764_1A4	**25mm - OD Wrapped**	**$0.43**	**1**	**$0.43**
524-764_1A4 Material 1	Material 1, Inner PA Layer, 25mm - OD Wrapped Hose	$0.06	1	$0.06
524-764_1A4 Material 2	Material 2, Middle Layer Covering, 25mm - OD Wrapp	$0.11	1	$0.11
524-764_1A4 Material 3	Material 3, Reinforcement Layer, 25mm - OD Wrapped	$0.07	1	$0.07
524-764_1A4 Material 4	Material 4, Outer Layer, 25mm - OD Wrapped Hose	$0.19	1	$0.19
524-764_1A5	Sleeve, 25mm - OD Wrapped	$0.29	1	$0.29
524-764_1B	**Section 2, Tube L**	**$0.73**	**1**	**$0.73**
524-764_1B1	**Connecting Tube**	**$0.30**	**1**	**$0.30**
524-764_1B1 Material	Material, Connecting Tube	$0.30	1	$0.30
524-764_1B2	**Hose Crimping Fitting**	**$0.02**	**1**	**$0.02**
524-764_1B2 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-764_1B2	**Hose Crimping Fitting**	**$0.02**	**1**	**$0.02**
524-764_1B2 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-764_1B3	**25mm - OD Wrapped**	**$0.38**	**1**	**$0.38**
524-764_1B3 Material 1	Material 1, Inner PA Layer, 25mm - OD Wrapped Hose	$0.05	1	$0.05
524-764_1B3 Material 2	Material 2, Middle Layer Covering, 25mm - OD Wrapp	$0.10	1	$0.10
524-764_1B3 Material 3	Material 3, Reinforcement Layer, 25mm - OD Wrapped	$0.06	1	$0.06
524-764_1B3 Material 4	Material 4, Reinforcement Layer, 25mm - OD Wrapped	$0.17	1	$0.17
524-764_1B4	**Hex Spacer**	**$0.00**	**1**	**$0.00**
524-764_1B4 Material	Material, Hex Spacer	$0.00	1	$0.00
524-764_1B4	**Hex Spacer**	**$0.00**	**1**	**$0.00**
524-764_1B4 Material	Material, Hex Spacer	$0.00	1	$0.00
524-764_1C	**Section 3, Tube L**	**$0.78**	**1**	**$0.78**
524-764_1C6	Heat Shrink Tubing	$0.04	1	$0.04
524-764_1C5	**Hose Crimping Fitting**	**$0.02**	**1**	**$0.02**
524-764_1C5 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-764_1C1	**Connector Block**	**$0.39**	**1**	**$0.39**
524-764_1C1Material	Material, Connector Block	$0.39	1	$0.39

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-764_1C7	Guide Pin	$0.01	1	$0.01
524-764_1C2	**Connecting Tube 1**	**$0.08**	**1**	**$0.08**
524-764_1C2 Material	Material, Connecting Tube 1	$0.08	1	$0.08
524-764_1C3	**Sensor**	**$0.14**	**1**	**$0.14**
524-764_1C3 Material	Material, Sensor	$0.14	1	$0.14
524-764_1C4	**Connecting Tube 2**	**$0.10**	**1**	**$0.10**
524-764_1C4 Material	Material, Connecting Tube 2	$0.10	1	$0.10
524-764_2	QR Code Label	$0.10	1	$0.10
524-764_3	O-Ring, 14mm ID	$0.03	1	$0.03
524-764_4	O-Ring, 16mm ID	$0.03	1	$0.03
524-1399_1	Torx Screw M6x10	$0.10	1	$0.10
524-1360	**Tube P Assmebly, AC System**	**$1.80**	**1**	**$1.80**
524-1360_1	**Tube P Asm**	**$1.57**	**1**	**$1.57**
524-1360_1A	**Section 1, Tube P Asm**	**$0.76**	**1**	**$0.76**
524-1360_1A1	**Connector 1, Section 1**	**$0.26**	**1**	**$0.26**
524-1360_1A1 Material	Material, Connector #1	$0.26	1	$0.26
524-1360_1A2	**Connecting Tube, Section 1**	**$0.50**	**1**	**$0.50**
524-1360_1A2 Material	Material, Tube #1	$0.50	1	$0.50
524-1360_1B	**Section 2, Tube P Asm**	**$0.43**	**1**	**$0.43**
524-1360_1B1	**Connector 2, Section 2**	**$0.12**	**1**	**$0.12**
524-1360_1B1 Material	Material, Connector 2, Section 2	$0.12	1	$0.12
524-1360_1B4	Guide Pin	$0.01	1	$0.01
524-1360_1B5	Bar Code Label	$0.03	1	$0.03
524-1360_1B6	Label	$0.02	1	$0.02
524-1360_1B2	**End Tube Connector, Section 2**	**$0.11**	**1**	**$0.11**
524-1360_1B2 Material	Material, End Tube Connector, Section 2	$0.11	1	$0.11
524-1360_1B3	**Connecting Tube, Section 2**	**$0.14**	**1**	**$0.14**
524-1360_1B3 Material	Material, Connector Tube, Section 2	$0.14	1	$0.14
524-1360_1C	**Tube Connector, Tube P Asm**	**$0.38**	**1**	**$0.38**
524-1360_1C, Material	Material, Connector 2, Tube P Assembly	$0.38	1	$0.38
524-1360_2	Threaded Stud	$0.12	1	$0.12
524-1360_3	Nut	$0.05	1	$0.05
524-1360_4	O-Rings	$0.03	2	$0.06
524-1399_1	Torx Screw M6x10	$0.10	2	$0.20
524-683	**Tube N Assembly, AC System**	**$2.24**	**1**	**$2.24**
524-683_1	**Tube N Asm**	**$2.21**	**1**	**$2.21**
524-683_1A	**Section 1, Tube N Asm**	**$0.59**	**1**	**$0.59**
524-683_1A1	**Connector 1, Section 1 Asm**	**$0.35**	**1**	**$0.35**
524-683_1A1 Material	Material, Connector 1, Section 1 Asm	$0.35	1	$0.35
524-683_1A2	**Connecting Tube, Section 1 Asm**	**$0.24**	**1**	**$0.24**
524-683_1A2 Material	Material, Connecting Tube, Section 1 Asm	$0.24	1	$0.24
524-683_1B	**25mm - OD Wraped**	**$0.43**	**1**	**$0.43**
524-683_1B Material 1	Material 1, Inner PVC Layer, 25mm - OD Wrapped	$0.06	1	$0.06
524-683_1B Material 2	Material 2, Middle Layer Covering, 25mm - OD Wrapp	$0.11	1	$0.11
524-683_1B Material 3	Material 3, Reinforcement Layer, 25mm - OD Wrapped	$0.07	1	$0.07
524-684_1B Material 4	Material 4, Outer Layer, 25mm - OD Wrapped H	$0.19	1	$0.19
524-683_1C	**Section 3, Tube N Asm**	**$1.03**	**1**	**$1.03**

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-683_1C1	**Connector 2, Section 3 Asm**	**$0.65**	**1**	**$0.65**
524-683_1C1 Material	Material, Connector 2, Section 3 Asm	$0.65	1	$0.65
524-683_1C2	**Connecting Tube, Section 3 Asm**	**$0.38**	**1**	**$0.38**
524-683_1C2 Material	Material, Connecting Tube, Section 3 Asm	$0.38	1	$0.38
524-764_1A3	**Hose Crimping Fitting**	**$0.04**	**1**	**$0.04**
524-764_1A3 Material	Material, Hose Crimping Fitting	$0.02	2	$0.04
524-683_1D	Barcode Label	$0.10	1	$0.10
524-683_1E	Inspection Label	$0.02	1	$0.02
524-683_2	O-Ring	$0.03	1	$0.03
524-1399_1	Torx Screw M6x10	$0.10	1	$0.10
524-1387	**Tube D & E Assembly, AC System**	**$2.69**	**1**	**$2.69**
524-1387_1	**Tube D & E Asm**	**$2.48**	**1**	**$2.48**
524-1387_1A	**Tube E Subassembly, Tube D & E Asm**	**$0.55**	**1**	**$0.55**
524-1387_1A2	**Tube E, Tube E Subassembly**	**$0.21**	**1**	**$0.21**
524-1387_1A2 Material	Material, Tube E	$0.21	1	$0.21
524-1387_1A1	**Tube E Connector**	**$0.34**	**1**	**$0.34**
524-1387_1A1 Material	Material, Tube E Connector	$0.34	1	$0.34
524-1387_1B	**Hose Subassembly, Tube D & E Asm**	**$0.28**	**1**	**$0.28**
524-1387_1B Material 1	Material, Inner PA Layer, 25mm - OD Wrapped Ho	$0.04	1	$0.04
524-1387_1B Material 2	Material, Middle Layer Covering, 25mm - OD Wrapped	$0.07	1	$0.07
524-1387_1B Material 3	Material, Reinforcement Layer, 25mm - OD Wrapped H	$0.05	1	$0.05
524-1387_1B Material 4	Material, Outer Layer, 25mm - OD Wrapped H	$0.12	1	$0.12
524-1387_1C	**Tube D Subassembly, Tube D & E Asm**	**$1.38**	**1**	**$1.38**
524-1387_1C2	**Tube D, Tube D Subassembly**	**$0.30**	**1**	**$0.30**
524-1387_1C2 Material	Material, Tube D	$0.30	1	$0.30
524-1387_1C1	**Tube D Connector**	**$1.08**	**1**	**$1.08**
524-1387_1C1A	**Connector #1, Tube D Subassembly**	**$0.70**	**1**	**$0.70**
524-1387_1C1A Material	Material, Connector #1	$0.70	1	$0.70
524-1387_1C1B	**Connecting Tube, Tube D Subassembly**	**$0.03**	**1**	**$0.03**
524-1387_1C1B Material	Material, Connecting Tube	$0.03	1	$0.03
524-1387_1C1C	**Connector #2, Tube D Subassembly**	**$0.35**	**1**	**$0.35**
524-1387_1C1C Material	Material, Connector #2	$0.35	1	$0.35
524-1387_1A3	**Hose Crimp Fitting 1, Section 1 Asm**	**$0.02**	**1**	**$0.02**
524-764_1A3 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-1387_1A3	**Hose Crimp Fitting 1, Section 1 Asm**	**$0.02**	**1**	**$0.02**
524-764_1A3 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-1387_1D	Sleeve, 25mm - OD Wrapped	$0.23	1	$0.23
524-1387_2	O-Ring Big	$0.03	1	$0.03
524-1387_3	O-Rings Small	$0.03	2	$0.06
524-1387_1C1D	Bar Code Label	$0.10	1	$0.10
524-1387_1C1E	Label	$0.02	1	$0.02
524-1399_1	Torx Screw M6x10	$0.10	3	$0.30
524-1363	**Tube A Assembly, AC System**	**$2.20**	**1**	**$2.20**
524-1363_1	**Tube A Asm**	**$2.11**	**1**	**$2.11**
524-1363_1A	**Section 1, Tube A Asm**	**$0.62**	**1**	**$0.62**

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1363_1A1	**Connector 1, Section 1**	**$0.36**	**1**	**$0.36**
524-1363_1A1 Material	Material, Connector 1, Section 1	$0.36	1	$0.36
524-1363_1A2	**Connecting Tube 1, Section 1**	**$0.26**	**1**	**$0.26**
524-1363_1A2 Material	Material, Connecting Tube 1, Section 1	$0.26	1	$0.26
524-1363_1B	**Section 2, Tube A Asm**	**$0.56**	**1**	**$0.56**
524-1363_1B2	**Connecting Tube 2, Section 2**	**$0.05**	**1**	**$0.05**
524-1363_1B2 Material	Material, Connecting Tube 2, Section 2	$0.05	1	$0.05
524-1363_1B1	**Connector 2, Section 2**	**$0.39**	**1**	**$0.39**
524-1363_1B1 Material	Material, Connector 2, Section 2	$0.39	1	$0.39
524-1363_1B4	Bar Code Label	$0.10	1	$0.10
524-1363_1B5	Label	$0.02	1	$0.02
524-1363_1C	**20mm Wrapped Hose, Tube A Asm**	**$0.26**	**1**	**$0.26**
524-1363_1C Material 1	Material 1, 20mm Wrapped Hose, Tube A Asm	$0.03	1	$0.03
524-1363_1C Material 2	Material 2, 20mm Wrapped Hose, Tube A Asm	$0.03	1	$0.03
524-1363_1C Material 3	Material 3, 20mm Wrapped Hose, Tube A Asm	$0.10	1	$0.10
524-1363_1C Material 4	Material 4, 20mm Wrapped Hose, Tube A Asm	$0.10	1	$0.10
524-1363_1D	**Section 3, Tube A Asm**	**$0.65**	**1**	**$0.65**
524-1363_1D1	**Connector 3, Section 3**	**$0.51**	**1**	**$0.51**
524-1363_1D1 Material	Material, Connector 3, Section 3	$0.51	1	$0.51
524-1363_1D2	**Connecting Tube 3, Section 3**	**$0.14**	**1**	**$0.14**
524-1363_1D2 Material	Material, Connecting Tube 3, Section 3	$0.14	1	$0.14
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-1363_2	O-Rings	$0.03	3	$0.09
524-1399_1	Torx Screw M6x10	$0.10	3	$0.30
524-732	**Tube G Assembly, AC System**	**$4.53**	**1**	**$4.53**
524-732_1	**Tube G Assembly**	**$4.17**	**1**	**$4.17**
524-732_1A	**Section 1, Tube G Asm**	**$0.78**	**1**	**$0.78**
524-732_1A2	**Connecting Tube 1, Section 1**	**$0.40**	**1**	**$0.40**
524-732_1A2 Material	Material, Connecting Tube 1, Section 1	$0.40	1	$0.40
524-732_1A1	**Connector 1, Section 1**	**$0.26**	**1**	**$0.26**
524-732_1A1 Material	Material, Connector 1, Section 1	$0.26	1	$0.26
524-732_1A4	Bar Code Label	$0.10	1	$0.10
524-732_1A5	Label	$0.02	1	$0.02
524-732_1B	**Section 2, Tube G Asm**	**$2.95**	**1**	**$2.95**
524-732_1B2	**Connecting Tube 2, Section 2**	**$1.00**	**1**	**$1.00**
524-732_1B2 Material	Material, Connecting Tube 2, Section 2	$1.00	1	$1.00
524-732_1B3	Connecting Tube 2 Cover	$0.07	1	$0.07
524-732_1B1	**Connector 2, Section 2**	**$1.18**	**1**	**$1.18**
524-732_1B1C	**Connecting Tube Small, Connector 2**	**$0.09**	**1**	**$0.09**
524-732_1B1C Material	Material, Connecting Tube Small, Connector 2	$0.09	1	$0.09
524-732_1B1A	**Connector A, Connector 2**	**$0.26**	**1**	**$0.26**
524-732_1B1A Material	Material, Connector A, Connector 2	$0.26	1	$0.26
524-732_1B1B	**Connector B, Connector 2**	**$0.83**	**1**	**$0.83**
524-732_1B1B Material	Material, Connector B, Connector 2	$0.83	1	$0.83

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-732_1B4	Connecting Tube 2 Interface, Section 2	$0.70	1	$0.70
524-732_1C	**26mm OD Wrapped Hose, Tube G Asm**	**$0.40**	**1**	**$0.40**
524-732_1C Material 1	Material 1, 26mm OD Wrapped Hose, Tube G Asm	$0.05	1	$0.05
524-732_1C Material 2	Material 2, 26mm OD Wrapped Hose, Tube G Asm	$0.10	1	$0.10
524-732_1C Material 3	Material 3, 26mm OD Wrapped Hose, Tube G Asm	$0.18	1	$0.18
524-732_1C Material 4	Material 4, 26mm OD Wrapped Hose, Tube G Asm	$0.07	1	$0.07
524-764_1A3	**Hose Crimping Fitting**	**$0.02**	**1**	**$0.02**
524-764_1A3 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-764_1A3	**Hose Crimping Fitting**	**$0.02**	**1**	**$0.02**
524-764_1A3 Material	Material, Hose Crimping Fitting	$0.02	1	$0.02
524-732_2	Tube Holder	$0.08	1	$0.08
524-732_3	Tube Cap	$0.10	1	$0.10
524-732_4	**Tube Bracket Support Asm**	**$0.12**	**1**	**$0.12**
524_732_4A	**Tube Bracket Support**	**$0.07**	**1**	**$0.07**
524_732_4A Material	Material, Tube Bracket Support	$0.07	1	$0.07
524_732_4B	**Rubber Bushing**	**$0.04**	**1**	**$0.04**
524_732_4B Material	Material, Rubber Bushing	$0.01	4	$0.04
524_732_4C	Inspection Label	$0.01	1	$0.01
524-732_5	O-Rings	$0.03	2	$0.06
524-1399_1	Torx Screw M6x10	$0.10	3	$0.30
524-741	**Tube M Assembly, AC System**	**$6.67**	**1**	**$6.67**
524-741_1	**Tube M Asm**	**$6.46**	**1**	**$6.46**
524-741_1A	**Section 1, Tube M Asm**	**$0.95**	**1**	**$0.95**
524-741_1A2	**Connecting Tube 1, Section 1**	**$0.73**	**1**	**$0.73**
524-741_1A2 Material	Material, Connecting Tube 1, Section 1	$0.73	1	$0.73
524-741_1A1	**Connector 1, Section 1**	**$0.12**	**1**	**$0.12**
524-741_1A1 Material	Material, Connector 1, Section 1	$0.12	1	$0.12
524-741_1A4	Bar Code Label	$0.10	1	$0.10
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-741_1D	**24mm OD Wrapped**	**$0.18**	**1**	**$0.18**
524-741_1D Material 1	Material 1, 20mm OD Wrapped	$0.02	1	$0.02
524-741_1D Material 2	Material 2, 20mm OD Wrapped	$0.02	1	$0.02
524-741_1D Material 3	Material 3, 20mm OD Wrapped	$0.06	1	$0.06
524-741_1D Material 4	Material 2, 20mm OD Wrapped	$0.08	1	$0.08
524-741_1I	Heat Shield Section 1	$0.29	1	$0.29
524-741_5	Heat Shrink Tubing 1	$0.03	1	$0.03
524-741_1B1	**Connecting Tube 2, Section 2**	**$0.51**	**1**	**$0.51**
524-741_1B1 Material	Material, Connecting Tube2, Section 2	$0.51	1	$0.51
524-741_1I	Heat Shield Section 2	$0.55	1	$0.55
524-741_5	Heat Shrink Tubing 2	$0.05	1	$0.05
524-741_5	Heat Shrink Tubing 4	$0.03	1	$0.03
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-741_1E	**Sensor Block**	**$0.12**	**1**	**$0.12**
524-741_1E Material	Material, Sensor Block	$0.12	1	$0.12
524-741_1C	**Section 3, Tube M Asm**	**$0.95**	**1**	**$0.95**

Tubes & Hoses

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-741_1C2	**Connecting Tube 3, Section 3**	**$0.17**	**1**	**$0.17**
524-741_1C2 Material	Material, Connecting Tube 3, Section 3	$0.17	1	$0.17
524-741_1C4	**Spacer**	**$0.00**	**1**	**$0.00**
524-764_1B4 Material	Material, Hex Spacer	$0.00	1	$0.00
524-741_1C3	Schrader Valve, Section 3	$0.78	1	$0.78
524-741_1F	**24mm OD Wrapped Tube**	**$0.48**	**1**	**$0.48**
524-741_1F Material 1	Material 1, 24mm OD Wrapped Tube	$0.06	1	$0.06
524-741_1F Material 2	Material 1, 24mm OD Wrapped Tube	$0.05	1	$0.05
524-741_1F Material 3	Material 3, 24mm OD Wrapped Tube	$0.17	1	$0.17
524-741_1F Material 4	Material 4, 24mm OD Wrapped Tube	$0.20	1	$0.20
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-1363_1B3	**Hose Crimp Fittings**	**$0.01**	**1**	**$0.01**
524-1363_1B3 Material	Material, Hose Crimp Fittings	$0.01	1	$0.01
524-741_1G	**Section 4, Tube M Asm**	**$0.37**	**1**	**$0.37**
524-741_1G2	**Connecting Tube 4, Section 4**	**$0.24**	**1**	**$0.24**
524-741_1G2 Material	Material, Connecting Tube 4, Section 4	$0.24	1	$0.24
524-741_1G3	**End Tube Connector, Section 4**	**$0.13**	**1**	**$0.13**
524-741_1G3 Material	Material, End Tube Connector, Section 4	$0.13	1	$0.13
524-741_1I	Heat Shield Section 3	$0.77	1	$0.77
524-741_1I	Heat Shield Section 4	$0.59	1	$0.59
524-741_5	Heat Shrink Tubing 5	$0.03	1	$0.03
524-741_1H	**Section 5, Tube M Asm**	**$0.49**	**1**	**$0.49**
524-741_1H1	**Connecting Tube 5, Section 5**	**$0.13**	**1**	**$0.13**
524-741_1H1 Material	Material, Connecting Tube 5, Section 5	$0.13	1	$0.13
524-741_1H2	**Connector 2, Section 5**	**$0.35**	**1**	**$0.35**
524-741_1H2 Material	Material, Connector 2, Section 5	$0.35	1	$0.35
524-741_1H3	**Connecting Tube Spacer, Section 5**	**$0.01**	**1**	**$0.01**
524-741_1H3 Material	Material, Connecting Tube Spacer, Section 5	$0.01	1	$0.01
524-741_5	Heat Shrink Tubing 6	$0.03	1	$0.03
524-741_2	**Tube Holder Asm**	**$0.05**	**1**	**$0.05**
524-741_2A	**Tube Holder Outer**	**$0.03**	**1**	**$0.03**
524-741_2A Material	Material, Tube Holder Outer	$0.03	1	$0.03
524-741_2B	**Tube Holder Inner**	**$0.02**	**1**	**$0.02**
524-741_2B Material	Material, Tube Holder Inner	$0.02	1	$0.02
524-741_3	Tube Cap	$0.10	1	$0.10
524-741_4	O-Rings	$0.03	2	$0.06
524-1399_1	Torx Screw M6x10	$0.10	1	$0.10

Assembly Totals

Analyzed Subs:	134
Unanalyzed Subs:	0
Parts:	200
Fasteners:	19
Parts+Unanalyzed:	200

Report Totals

Piece Cost (Total): $28.28

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

Table G-13 VW e-Golf Controls Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	3	Subassembly	1624-98_9	Capacitor Sub Asm 1	(None)
2	4	Part	1624-98_9e	PP Capacitor Film	Commodity Item
3	4	Preprocessed Part	1624-98_9a	Copper Stamping 1, Longer	Copper Cu (10200)
4	5	Manufacturing Steps		Copper Stamping 1, Longer - Processing	
5	6	Manufacturing Process		Wash	
6	6	Manufacturing Process		Debur	
7	6	Manufacturing Process		Stamping Press, 60 Ton	
8	7	Part	1624-98_9a Material	Material, Copper Stamping 1, Longer	Copper Cu (10200)
9	4	Preprocessed Part	1624-98_9b	Copper Stamping 2, Shorter	Copper Cu (10200)
10	5	Manufacturing Steps		Copper Stamping 2, Shorter - Processing	
11	6	Manufacturing Process		Wash	
12	6	Manufacturing Process		Debur	
13	6	Manufacturing Process		Stamping Press, 60 Ton	
14	7	Part	1624-98_9b Material	Material, Copper Stamping 2, Shorter	Copper Cu (10200)
15	4	Preprocessed Part	1624-98_9h	Plastic, Top Section - Vertical	PPS-GF-MD
16	5	Manufacturing Steps		Plastic, Top Section - Vertical Processing	
17	6	Manufacturing Process		Injection Mold, 55 Ton	
18	7	Part	1624-98_9h Material	Material, Plastic, Top Section - Vertical	PPS-GF-MD
19	4	Part	1624-98_9j	Plastic Insulating Paper	Commodity Item
20	4	Manufacturing Steps		Capacitor Sub Asm Process	
21	5	Manufacturing Process		Manual Assembly	

Row	Level	Symbol Type	Number	Name	Material Name
22	5	Manufacturing Process		Manual Asm	
23	4	Subassembly	1624-98_9c	Outer Casing, Capacitor Sub Asm 1	(None)
24	5	Part	1624-98_9d	Insert, Metal Spacer	Commodity Item
25	5	Manufacturing Steps		Outer Casing, Capacitor Sub Asm 1 - Processing	
26	6	Manufacturing Process		Laser Etching	
27	6	Manufacturing Process		Injection Mold Press, 150 Ton w/Inserts	
28	7	Part	1624-98_9 Material	Material, Outer Casing, Capacitor Sub Asm 1	PPS-GF-MD
29	4	Manufacturing Steps		Capacitor Sub to Case	
30	5	Manufacturing Process		Automated Assembly	
31	4	Subassembly	1624-98_9i	Small Lead Frame Asm	PPS-GF-MD
32	5	Preprocessed Part	1624-98_9k	Stamped Copper, Longer	Copper Nickel Plated
33	6	Manufacturing Steps		Stamped Copper, Longer - Processing	
34	7	Manufacturing Process		Wash	
35	7	Manufacturing Process		Debur	
36	7	Manufacturing Process		Stamping Press, 25 Ton	
37	8	Part	1624-98_9k Material	Material, Stamped Copper - Longer	Copper Nickel Plated
38	5	Preprocessed Part	1624-98_9l	Stamped Copper, Shorter	Copper Nickel Plated
39	6	Manufacturing Steps		Stamped Copper, Shorter - Processing	
40	7	Manufacturing Process		Wash	
41	7	Manufacturing Process		Debur	
42	7	Manufacturing Process		Stamping Press, 25 Ton	
43	8	Part	1624-98_9l Material	Material, Stamped Copper, Shorter	Copper Nickel Plated
44	5	Manufacturing Steps		Plastic, Side Section Processing	
45	6	Manufacturing Process		Injection Mold, 55 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
46	7	Part	1624-98_9i Material	Material, Plastic, Side Section	PPS-GF-MD
47	4	Preprocessed Part	1624-98_9g	Plastic, Top Section - Horizontal	PPS-GF-MD
48	5	Manufacturing Steps		Plastic, Top Section - Horizontal Processing	
49	6	Manufacturing Process		Injection Mold, 55 Ton	
50	7	Part	1624-98_9g Material	Material, Plastic Top Section - Horizontal	PPS-GF-MD
51	4	Manufacturing Steps		Insert Lead Frame and Cover	
52	5	Manufacturing Process		Auto Asm	
53	4	Part	1624-98_9f	Epoxy Potting, Capacitor Sub Asm 1	Commodity Item
54	4	Manufacturing Steps		Processing and Curing Process	
55	5	Manufacturing Process		Inspection	
56	5	Manufacturing Process		Curing Oven 8'x8'	
57	5	Manufacturing Process		Vacuum Potting & Encapsulation	
58	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
59	3	Manufacturing Steps		Install Capacitor Asm	
60	4	Manufacturing Process		Spot Weld	
61	4	Manufacturing Process		Auto Asm	
62	3	Part	1624-109_1	Thermal Insulation Compound	Commodity Item
63	3	Manufacturing Steps		Thermal Insulation Compound to Enclosure Main 2	
64	4	Manufacturing Process		Auto Asm	
65	3	Subassembly	1624-107_1	Capacitor Asm	(None)
66	4	Preprocessed Part	1624-107_1a	Copper Stamping 1	Copper Cu (10200)
67	5	Manufacturing Steps		Copper Stamping 1 Processing	
68	6	Manufacturing Process		Wash	
69	6	Manufacturing Process		Debur	

Row	Level	Symbol Type	Number	Name	Material Name
70	6	Manufacturing Process		Stamping Press, 25 Ton	
71	7	Part	1624-107_1a Material	Material, Copper Stamping 1	Copper Cu (10200)
72	4	Preprocessed Part	1624-107_1b	Copper Stamping 2	Copper Cu (10200)
73	5	Manufacturing Steps		Copper Stamping 2 Processing	
74	6	Manufacturing Process		Wash	
75	6	Manufacturing Process		Debur	
76	6	Manufacturing Process		Stamping Press, 25 Ton	
77	7	Part	1624-107_1b Material	Material, Copper Stamping 2	Copper Cu (10200)
78	4	Preprocessed Part	1624-107_1c	Copper Stamping 3	Copper Cu (10200)
79	5	Manufacturing Steps		Copper Stamping 3 Processing	
80	6	Manufacturing Process		Wash	
81	6	Manufacturing Process		Debur	
82	6	Manufacturing Process		Stamping Press, 60 Ton	
83	7	Part	1624-107_1c Material	Material, Copper Stamping 3	Copper Cu (10200)
84	4	Subassembly	1624-107_1j	Capacitor Outer Casing Asm	(None)
85	5	Part	1624-107_1e	Metal Spacer, Insert 4	Commodity Item
86	5	Part	1624-107_1f	M4 x 0.7, Flanged Nut, Insert 1	Commodity Item
87	5	Part	1624-107_1g	M3 x 0.7, Nut, Insert 2	Commodity Item
88	5	Part	1624-107_1h	M4 x 0.7, Nut, Insert 3	Commodity Item
89	5	Manufacturing Steps		Capacitor Outer Casing Asm Processing	
90	6	Manufacturing Process		Auto Asm	
91	6	Manufacturing Process		Laser Etching	
92	6	Manufacturing Process		Injection Mold Press, 110 Ton w/Inserts	
93	7	Part	1624-107_1 Material	Material, Capacitor Asm	PPS-GF-MD

Row	Level	Symbol Type	Number	Name	Material Name
94	4	Part	1624-107_1i	PP, Metalized Film Capacitor	Commodity Item
95	4	Manufacturing Steps		Capacitor Asm Processing	
96	5	Manufacturing Process		Auto Asm	
97	5	Manufacturing Process		Manual Asm	
98	4	Part	1624-107_1d	Epoxy Potting, Capacitor Asm	Commodity Item
99	4	Manufacturing Steps		Potting & Curing Process	
100	5	Manufacturing Process		Inspection	
101	5	Manufacturing Process		Curing Oven 8x8'	
102	5	Manufacturing Process		Vacuum Potting & Encapsulation	
103	3	Subassembly	1624-107_2	Inductor Assy	(None)
104	4	Subassembly	1624-107_2G	Core/Coil Assy	(None)
105	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
106	6	Manufacturing Steps		Injection Molding Process	
107	7	Manufacturing Process		Injection Mold Press, 55 Ton	
108	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
109	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
110	6	Manufacturing Steps		Injection Molding Process	
111	7	Manufacturing Process		Injection Mold Press, 110 Ton	
112	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
113	5	Manufacturing Steps		Spacer Assy	
114	6	Manufacturing Process		Manual Asm	
115	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
116	6	Manufacturing Steps		Injection Molding Process	
117	7	Manufacturing Process		Injection Mold Press, 55 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
118	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
119	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
120	6	Manufacturing Steps		Injection Molding Process	
121	7	Manufacturing Process		Injection Mold Press, 110 Ton	
122	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
123	5	Manufacturing Steps		Spacer Assy	
124	6	Manufacturing Process		Manual Asm	
125	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
126	6	Manufacturing Steps		Injection Molding Process	
127	7	Manufacturing Process		Injection Mold Press, 55 Ton	
128	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
129	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
130	6	Manufacturing Steps		Injection Molding Process	
131	7	Manufacturing Process		Injection Mold Press, 110 Ton	
132	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
133	5	Manufacturing Steps		Spacer Assy	
134	6	Manufacturing Process		Manual Asm	
135	5	Preprocessed Part	1624-107_2F	Coil Insulator Support	PPS-GF-MD
136	6	Manufacturing Steps		Injection Molding Process	
137	7	Manufacturing Process		Injection Mold Press, 55 Ton	
138	8	Part	1624-107_2F-1 Material	Material, Coil Insulator Support	PPS-GF-MD
139	5	Preprocessed Part	1624-107_2L	Coil Winding Support	PPS-GF-MD
140	6	Manufacturing Steps		Injection Molding Process	
141	7	Manufacturing Process		Injection Mold Press, 110 Ton	

Row	Level	Symbol Type	Number	Name	Material Name
142	8	Part	1624-107_2L Material	Material, Coil Winding Support	PPS-GF-MD
143	5	Manufacturing Steps		Spacer Assy	
144	6	Manufacturing Process		Manual Asm	
145	5	Part	1624-107_2C-1	Material, Flat Copper Wire, Coated	Commodity Item
146	5	Manufacturing Steps		Copper Winding Assy Process	
147	6	Manufacturing Process		Coil Winding w/Insulator	
148	6	Manufacturing Process		Coil Winding w/Insulator	
149	5	Preprocessed Part	1624-107_2B	Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
150	6	Manufacturing Steps		Magnetic Core, C Block, Processing	
151	7	Manufacturing Process		Wash	
152	7	Manufacturing Process		Oven Sintering Furnace	
153	7	Manufacturing Process		Powdered Metal Press, 100 Ton	
154	8	Part	1624-107_2B-1 Material	Material, Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
155	5	Part	1624-107_2H	Alumina Spacers	Commodity Item
156	5	Part	1624-107_2E	Adhesive Magnetic Core	Commodity Item
157	5	Manufacturing Steps		Core and Coil Assy Process	
158	6	Manufacturing Process		Auto Asm	
159	5	Preprocessed Part	1624-107_2B	Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
160	6	Manufacturing Steps		Magnetic Core, C Block, Processing	
161	7	Manufacturing Process		Wash	
162	7	Manufacturing Process		Oven Sintering Furnace	
163	7	Manufacturing Process		Powdered Metal Press, 100 Ton	
164	8	Part	1624-107_2B-1 Material	Material, Magnetic Core C Block	Mn-Zn Soft Ferrite Powder
165	5	Part	1624-107_2E	Adhesive Magnetic Core	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
166	5	Manufacturing Steps		Core and Coil Assy Process	
167	6	Manufacturing Process		Spot Weld	
168	6	Manufacturing Process		Auto Asm	
169	5	Preprocessed Part	1624-107_2D	Inductor Housing Retainer	PPS-GF-MD
170	6	Manufacturing Steps		Injection Molding Process	
171	7	Manufacturing Process		Injection Mold Press, 55 Ton	
172	8	Part	1624-107_2D Material	Material, Inductor Housing Retainer	PPS-GF-MD
173	5	Preprocessed Part	1624-107_2D	Inductor Housing Retainer	PPS-GF-MD
174	6	Manufacturing Steps		Injection Molding Process	
175	7	Manufacturing Process		Injection Mold Press, 55 Ton	
176	8	Part	1624-107_2D Material	Material, Inductor Housing Retainer	PPS-GF-MD
177	5	Manufacturing Steps		Coil Support and Retainer Process	
178	6	Manufacturing Process		Auto Asm	
179	4	Part	1624-107_2A	Steel Spacer	Commodity Item
180	4	Manufacturing Steps		Inductor Over Mold Assy Process	
181	5	Manufacturing Process		Injection Mold Press, 55 Ton	
182	6	Part	1624-107_2I Material	Material, Inductor Housing	PPS-GF-MD
183	3	Part	1624-66_3	M5 x 0.80, 16 mm, Flanged Bolt	Commodity Item
184	3	Manufacturing Steps		Capacitor & Inductor Asm to Enclosure Main 2	
185	4	Manufacturing Process		MIG Weld	
186	4	Manufacturing Process		Auto Asm	

Table G-14 VW e-Golf Controls Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

e-Golf Controls

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1399	**Expansion Valve #682**	**$12.93**	**1**	**$12.93**
524-1397_2	**Control Module**	**$10.92**	**1**	**$10.92**
524-1399_2A	**Control Module Cover**	**$0.05**	**1**	**$0.05**
524-1397_2A Material	Material, Control Module Cover	$0.05	1	$0.05
524-1397_2E	**Steel Clip**	**$0.01**	**1**	**$0.01**
524-1397_2E Material	Material, Steel Clip	$0.01	1	$0.01
524-1397_2B	**Circut Board**	**$5.94**	**1**	**$5.94**
524-1397_2B1	Connector Pins	$0.08	4	$0.32
524-1397_2B2	Printed FR4 Circuit Board	$0.27	1	$0.27
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.02	1	$0.02
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.01	1	$0.01
MLX90363EDC-ABB-000 -SP	Hall Effect Sensor X, Y, Z Axis 8-SOIC	$1.35	1	$1.35
ATA6625C-TAQY	LIN Transceivers LIN System Basis Chip	$0.65	1	$0.65
L9942XP1TR	Motor / Motion / Ignition Controllers & Drivers In	$1.18	1	$1.18
STPS2L40U	Diode Schottky 40V 2A Surface Mount SMB	$0.08	2	$0.16
S9S08SG16E1CTLR	8 Bit Microcontrollers - MCU S08 16K FLASH	$1.30	1	$1.30
0805 Resistors-5	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	10	$0.01
0603 Resistors-6	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	6	$0.01
EEE-1VA221P	220�F 35V Aluminum Capacitors Radial, Can - SMD 20	$0.11	1	$0.11
EEE-HC1V220P	22�F 35V Aluminum Capacitors Radial, Can - SMD 300	$0.08	1	$0.08
0805 Capacitors-4	Tolerance - 10%; 0805 (2012 Metric) 0.079" L x 0.0	$0.03	6	$0.20
0603 Capacitors-5	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	$0.01	11	$0.16
SDR0604-471KL	Fixed Inductors 470uH 10% SMD 0604	$0.10	1	$0.10
524-1397_2C	**Motor Assembly**	**$4.32**	**1**	**$4.32**
524-1397_2C1	**PCB Board**	**$0.08**	**1**	**$0.08**
524-1397_2C3	Printed FR4 Circuit Board	$0.08	1	$0.08
524-1397_2C2	Stepper Motor 12VDC	$4.24	1	$4.24
524-1397_2M	Screw M4x10mm	$0.03	3	$0.09
524-1397_2D	**Gear Assembly**	**$0.27**	**1**	**$0.27**
524-1397_2G	**Steel Frame**	**$0.12**	**1**	**$0.12**
524-1397_2G1	**Steel Base Plate**	**$0.08**	**1**	**$0.08**
524-1397_2G1 Material	Material, Steel Frame	$0.08	1	$0.08
524-1397_2G2	**Gear Shaft 1**	**$0.01**	**1**	**$0.01**
524-1397_2G2 Material	Material, Gear Shaft 1	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_2G4	Bushing	$0.01	1	$0.01
524-1397_2H	**Big White Gear**	**$0.04**	**1**	**$0.04**
524-1397_2H2	Gear Shaft Insert	$0.01	1	$0.01
524-1397_2H Material	Material, Big White Gear	$0.03	1	$0.03
524-1397_2I	**Magnet Insert**	**$0.08**	**1**	**$0.08**
524-1397_2I1	Small Magnet	$0.03	1	$0.03
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2I2	**Magnet Holder**	**$0.01**	**1**	**$0.01**
524-1397_2I2 Material	Material, Magnet Holder	$0.01	1	$0.01
524-1397_2J	**Small White Gear**	**$0.02**	**1**	**$0.02**
524-1397_2J Material	Material, Small White Gear	$0.02	1	$0.02
524-1397_2K	**Big Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2K Material	Material, Big Black Gear	$0.01	1	$0.01
524-1397_2L	**Small Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2L Material	Material, Small Black Gear	$0.01	1	$0.01
524-1397_2N	O-Ring Insert	$0.02	1	$0.02
524-1397_2O	Silicone RTV Clear	$0.03	1	$0.03
524-1397_2F	**Control Module Housing**	**$0.19**	**1**	**$0.19**
524-1397_2F Material	Material, Control Module Housing	$0.19	1	$0.19
524-1399_4	**Control Module Body**	**$1.98**	**1**	**$1.98**
524-1399_5	**Valve Body Subassembly**	**$1.06**	**1**	**$1.06**
524-1399_1A	**Control Module Body 682**	**$0.91**	**1**	**$0.91**
524-1399_1A Material	Material, Control Module Body	$0.91	1	$0.91
524-1399_1B	**Control Module Ball Valve**	**$0.10**	**1**	**$0.10**
524-1399_1B Material	Material, Ball Valve	$0.10	1	$0.10
524-1399_1C	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1399_1C Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-5	**Insert Subassembly**	**$0.36**	**1**	**$0.36**
524-1397_1P	**Control Module Insert**	**$0.32**	**1**	**$0.32**
524-1397_1P Material	Material, Insert	$0.32	1	$0.32
524-1399_1C	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1397_1R Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-3	**Sprocket Subassembly**	**$0.51**	**1**	**$0.51**
524-1397_1D	**Control Module Wheel**	**$0.19**	**1**	**$0.19**
524-1397_1D Material	Material, Wheel	$0.19	1	$0.19
524-1397_1N	Control Module Small O-Ring	$0.03	2	$0.06
524-1397_1E	Control Module Large O-Ring	$0.03	1	$0.03
524-1397_1C	**Control Module Sprocket**	**$0.16**	**1**	**$0.16**
524-1397_1C Material	Material, Sprocket	$0.16	1	$0.16
524-1397_1F	**Control Module Cap**	**$0.01**	**1**	**$0.01**
524-1397_1F Material	Material, Cap	$0.01	1	$0.01
524-1397_1H	Control Module Washer	$0.01	1	$0.01
524-1397_1G	**Control Module Shaft**	**$0.03**	**1**	**$0.03**
524-1397_1G Material	Material, Shaft	$0.03	1	$0.03
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_1U	Control Module Label 5028	$0.02	1	$0.02
524-1397_1V	Contrl Module Label 816 682	$0.02	1	$0.02
524-1397_3	Long Screw M4x50mm	$0.01	2	$0.02
524-1397_4	Short Screw M4x15mm	$0.01	1	$0.01
524-1399	**Expansion Valve #682**	**$12.93**	**1**	**$12.93**
524-1397_2	**Control Module**	**$10.92**	**1**	**$10.92**
524-1399_2A	**Control Module Cover**	**$0.05**	**1**	**$0.05**
524-1397_2A Material	Material, Control Module Cover	$0.05	1	$0.05
524-1397_2E	**Steel Clip**	**$0.01**	**1**	**$0.01**
524-1397_2E Material	Material, Steel Clip	$0.01	1	$0.01
524-1397_2B	**Circut Board**	**$5.94**	**1**	**$5.94**
524-1397_2B1	Connector Pins	$0.08	4	$0.32
524-1397_2B2	Printed FR4 Circuit Board	$0.27	1	$0.27
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.02	1	$0.02
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.01	1	$0.01
MLX90363EDC-ABB-000 -SP	Hall Effect Sensor X, Y, Z Axis 8-SOIC	$1.35	1	$1.35
ATA6625C-TAQY	LIN Transceivers LIN System Basis Chip	$0.65	1	$0.65
L9942XP1TR	Motor / Motion / Ignition Controllers & Drivers In	$1.18	1	$1.18
STPS2L40U	Diode Schottky 40V 2A Surface Mount SMB	$0.08	2	$0.16
S9S08SG16E1CTLR	8 Bit Microcontrollers - MCU S08 16K FLASH	$1.30	1	$1.30
0805 Resistors-5	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	10	$0.01
0603 Resistors-6	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	6	$0.01
EEE-1VA221P	220�F 35V Aluminum Capacitors Radial, Can - SMD 20	$0.11	1	$0.11
EEE-HC1V220P	22�F 35V Aluminum Capacitors Radial, Can - SMD 300	$0.08	1	$0.08
0805 Capacitors-4	Tolerance - 10%; 0805 (2012 Metric) 0.079" L x 0.0	$0.03	6	$0.20
0603 Capacitors-5	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	$0.01	11	$0.16
SDR0604-471KL	Fixed Inductors 470uH 10% SMD 0604	$0.10	1	$0.10
524-1397_2C	**Motor Assembly**	**$4.32**	**1**	**$4.32**
524-1397_2C1	**PCB Board**	**$0.08**	**1**	**$0.08**
524-1397_2C3	Printed FR4 Circuit Board	$0.08	1	$0.08
524-1397_2C2	Stepper Motor 12VDC	$4.24	1	$4.24
524-1397_2M	Screw M4x10mm	$0.03	3	$0.09
524-1397_2D	**Gear Assembly**	**$0.27**	**1**	**$0.27**
524-1397_2G	**Steel Frame**	**$0.12**	**1**	**$0.12**
524-1397_2G1	**Steel Base Plate**	**$0.08**	**1**	**$0.08**
524-1397_2G1 Material	Material, Steel Frame	$0.08	1	$0.08
524-1397_2G2	**Gear Shaft 1**	**$0.01**	**1**	**$0.01**
524-1397_2G2 Material	Material, Gear Shaft 1	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_2G4	Bushing	$0.01	1	$0.01
524-1397_2H	**Big White Gear**	**$0.04**	**1**	**$0.04**
524-1397_2H2	Gear Shaft Insert	$0.01	1	$0.01
524-1397_2H Material	Material, Big White Gear	$0.03	1	$0.03
524-1397_2I	**Magnet Insert**	**$0.08**	**1**	**$0.08**
524-1397_2I1	Small Magnet	$0.03	1	$0.03
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2I2	**Magnet Holder**	**$0.01**	**1**	**$0.01**
524-1397_2I2 Material	Material, Magnet Holder	$0.01	1	$0.01
524-1397_2J	**Small White Gear**	**$0.02**	**1**	**$0.02**
524-1397_2J Material	Material, Small White Gear	$0.02	1	$0.02
524-1397_2K	**Big Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2K Material	Material, Big Black Gear	$0.01	1	$0.01
524-1397_2L	**Small Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2L Material	Material, Small Black Gear	$0.01	1	$0.01
524-1397_2N	O-Ring Insert	$0.02	1	$0.02
524-1397_2O	Silicone RTV Clear	$0.03	1	$0.03
524-1397_2F	**Control Module Housing**	**$0.19**	**1**	**$0.19**
524-1397_2F Material	Material, Control Module Housing	$0.19	1	$0.19
524-1399_4	**Control Module Body**	**$1.98**	**1**	**$1.98**
524-1399_5	**Valve Body Subassembly**	**$1.06**	**1**	**$1.06**
524-1399_1A	**Control Module Body 682**	**$0.91**	**1**	**$0.91**
524-1399_1A Material	Material, Control Module Body	$0.91	1	$0.91
524-1399_1B	**Control Module Ball Valve**	**$0.10**	**1**	**$0.10**
524-1399_1B Material	Material, Ball Valve	$0.10	1	$0.10
524-1399_1C	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1399_1C Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-5	**Insert Subassembly**	**$0.36**	**1**	**$0.36**
524-1397_1P	**Control Module Insert**	**$0.32**	**1**	**$0.32**
524-1397_1P Material	Material, Insert	$0.32	1	$0.32
524-1399_1C	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1397_1R Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-3	**Sprocket Subassembly**	**$0.51**	**1**	**$0.51**
524-1397_1D	**Control Module Wheel**	**$0.19**	**1**	**$0.19**
524-1397_1D Material	Material, Wheel	$0.19	1	$0.19
524-1397_1N	Control Module Small O-Ring	$0.03	2	$0.06
524-1397_1E	Control Module Large O-Ring	$0.03	1	$0.03
524-1397_1C	**Control Module Sprocket**	**$0.16**	**1**	**$0.16**
524-1397_1C Material	Material, Sprocket	$0.16	1	$0.16
524-1397_1F	**Control Module Cap**	**$0.01**	**1**	**$0.01**
524-1397_1F Material	Material, Cap	$0.01	1	$0.01
524-1397_1H	Control Module Washer	$0.01	1	$0.01
524-1397_1G	**Control Module Shaft**	**$0.03**	**1**	**$0.03**
524-1397_1G Material	Material, Shaft	$0.03	1	$0.03
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_1U	Control Module Label 5028	$0.02	1	$0.02
524-1397_1V	Contrl Module Label 816 682	$0.02	1	$0.02
524-1397_3	Long Screw M4x50mm	$0.01	2	$0.02
524-1397_4	Short Screw M4x15mm	$0.01	1	$0.01
524-1399	**Expansion Valve #682**	**$12.93**	**1**	**$12.93**
524-1397_2	**Control Module**	**$10.92**	**1**	**$10.92**
524-1399_2A	**Control Module Cover**	**$0.05**	**1**	**$0.05**
524-1397_2A Material	Material, Control Module Cover	$0.05	1	$0.05
524-1397_2E	**Steel Clip**	**$0.01**	**1**	**$0.01**
524-1397_2E Material	Material, Steel Clip	$0.01	1	$0.01
524-1397_2B	**Circut Board**	**$5.94**	**1**	**$5.94**
524-1397_2B1	Connector Pins	$0.08	4	$0.32
524-1397_2B2	Printed FR4 Circuit Board	$0.27	1	$0.27
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.02	1	$0.02
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.01	1	$0.01
MLX90363EDC-ABB-000 -SP	Hall Effect Sensor X, Y, Z Axis 8-SOIC	$1.35	1	$1.35
ATA6625C-TAQY	LIN Transceivers LIN System Basis Chip	$0.65	1	$0.65
L9942XP1TR	Motor / Motion / Ignition Controllers & Drivers In	$1.18	1	$1.18
STPS2L40U	Diode Schottky 40V 2A Surface Mount SMB	$0.08	2	$0.16
S9S08SG16E1CTLR	8 Bit Microcontrollers - MCU S08 16K FLASH	$1.30	1	$1.30
0805 Resistors-5	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	10	$0.01
0603 Resistors-6	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	6	$0.01
EEE-1VA221P	220�F 35V Aluminum Capacitors Radial, Can - SMD 20	$0.11	1	$0.11
EEE-HC1V220P	22�F 35V Aluminum Capacitors Radial, Can - SMD 300	$0.08	1	$0.08
0805 Capacitors-4	Tolerance - 10%; 0805 (2012 Metric) 0.079" L x 0.0	$0.03	6	$0.20
0603 Capacitors-5	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	$0.01	11	$0.16
SDR0604-471KL	Fixed Inductors 470uH 10% SMD 0604	$0.10	1	$0.10
524-1397_2C	**Motor Assembly**	**$4.32**	**1**	**$4.32**
524-1397_2C1	**PCB Board**	**$0.08**	**1**	**$0.08**
524-1397_2C3	Printed FR4 Circuit Board	$0.08	1	$0.08
524-1397_2C2	Stepper Motor 12VDC	$4.24	1	$4.24
524-1397_2M	Screw M4x10mm	$0.03	3	$0.09
524-1397_2D	**Gear Assembly**	**$0.27**	**1**	**$0.27**
524-1397_2G	**Steel Frame**	**$0.12**	**1**	**$0.12**
524-1397_2G1	**Steel Base Plate**	**$0.08**	**1**	**$0.08**
524-1397_2G1 Material	Material, Steel Frame	$0.08	1	$0.08
524-1397_2G2	**Gear Shaft 1**	**$0.01**	**1**	**$0.01**
524-1397_2G2 Material	Material, Gear Shaft 1	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_2G4	Bushing	$0.01	1	$0.01
524-1397_2H	**Big White Gear**	**$0.04**	**1**	**$0.04**
524-1397_2H2	Gear Shaft Insert	$0.01	1	$0.01
524-1397_2H Material	Material, Big White Gear	$0.03	1	$0.03
524-1397_2I	**Magnet Insert**	**$0.08**	**1**	**$0.08**
524-1397_2I1	Small Magnet	$0.03	1	$0.03
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2I2	**Magnet Holder**	**$0.01**	**1**	**$0.01**
524-1397_2I2 Material	Material, Magnet Holder	$0.01	1	$0.01
524-1397_2J	**Small White Gear**	**$0.02**	**1**	**$0.02**
524-1397_2J Material	Material, Small White Gear	$0.02	1	$0.02
524-1397_2K	**Big Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2K Material	Material, Big Black Gear	$0.01	1	$0.01
524-1397_2L	**Small Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2L Material	Material, Small Black Gear	$0.01	1	$0.01
524-1397_2N	O-Ring Insert	$0.02	1	$0.02
524-1397_2O	Silicone RTV Clear	$0.03	1	$0.03
524-1397_2F	**Control Module Housing**	**$0.19**	**1**	**$0.19**
524-1397_2F Material	Material, Control Module Housing	$0.19	1	$0.19
524-1399_4	**Control Module Body**	**$1.98**	**1**	**$1.98**
524-1399_5	**Valve Body Subassembly**	**$1.06**	**1**	**$1.06**
524-1399_1A	**Control Module Body 682**	**$0.91**	**1**	**$0.91**
524-1399_1A Material	Material, Control Module Body	$0.91	1	$0.91
524-1399_1B	**Control Module Ball Valve**	**$0.10**	**1**	**$0.10**
524-1399_1B Material	Material, Ball Valve	$0.10	1	$0.10
524-1399_1C	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1399_1C Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-5	**Insert Subassembly**	**$0.36**	**1**	**$0.36**
524-1397_1P	**Control Module Insert**	**$0.32**	**1**	**$0.32**
524-1397_1P Material	Material, Insert	$0.32	1	$0.32
524-1399_1C	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1397_1R Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-3	**Sprocket Subassembly**	**$0.51**	**1**	**$0.51**
524-1397_1D	**Control Module Wheel**	**$0.19**	**1**	**$0.19**
524-1397_1D Material	Material, Wheel	$0.19	1	$0.19
524-1397_1N	Control Module Small O-Ring	$0.03	2	$0.06
524-1397_1E	Control Module Large O-Ring	$0.03	1	$0.03
524-1397_1C	**Control Module Sprocket**	**$0.16**	**1**	**$0.16**
524-1397_1C Material	Material, Sprocket	$0.16	1	$0.16
524-1397_1F	**Control Module Cap**	**$0.01**	**1**	**$0.01**
524-1397_1F Material	Material, Cap	$0.01	1	$0.01
524-1397_1H	Control Module Washer	$0.01	1	$0.01
524-1397_1G	**Control Module Shaft**	**$0.03**	**1**	**$0.03**
524-1397_1G Material	Material, Shaft	$0.03	1	$0.03
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_1U	Control Module Label 5028	$0.02	1	$0.02
524-1397_1V	Contrl Module Label 816 682	$0.02	1	$0.02
524-1397_3	Long Screw M4x50mm	$0.01	2	$0.02
524-1397_4	Short Screw M4x15mm	$0.01	1	$0.01
524-1399_1	Torx Screw M6x10	$0.10	6	$0.60
524-1397	**On/Off Vale #703**	**$12.97**	**1**	**$12.97**
524-1397_2	**Control Module**	**$10.93**	**1**	**$10.93**
524-1399_2A	**Control Module Cover**	**$0.05**	**1**	**$0.05**
524-1397_2A Material	Material, Control Module Cover	$0.05	1	$0.05
524-1397_2E	**Steel Clip**	**$0.01**	**1**	**$0.01**
524-1397_2E Material	Material, Steel Clip	$0.01	1	$0.01
524-1397_2B	**Circut Board**	**$5.94**	**1**	**$5.94**
524-1397_2B1	Connector Pins	$0.08	4	$0.32
524-1397_2B2	Printed FR4 Circuit Board	$0.27	1	$0.27
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.02	1	$0.02
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.01	1	$0.01
MLX90363EDC-ABB-000 -SP	Hall Effect Sensor X, Y, Z Axis 8-SOIC	$1.35	1	$1.35
ATA6625C-TAQY	LIN Transceivers LIN System Basis Chip	$0.65	1	$0.65
L9942XP1TR	Motor / Motion / Ignition Controllers & Drivers In	$1.18	1	$1.18
STPS2L40U	Diode Schottky 40V 2A Surface Mount SMB	$0.08	2	$0.16
S9S08SG16E1CTLR	8 Bit Microcontrollers - MCU S08 16K FLASH	$1.30	1	$1.30
0805 Resistors-5	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	10	$0.01
0603 Resistors-6	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	6	$0.01
EEE-1VA221P	220�F 35V Aluminum Capacitors Radial, Can - SMD 20	$0.11	1	$0.11
EEE-HC1V220P	22�F 35V Aluminum Capacitors Radial, Can - SMD 300	$0.08	1	$0.08
0805 Capacitors-4	Tolerance - 10%; 0805 (2012 Metric) 0.079" L x 0.0	$0.03	6	$0.20
0603 Capacitors-5	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	$0.01	11	$0.16
SDR0604-471KL	Fixed Inductors 470uH 10% SMD 0604	$0.10	1	$0.10
524-1397_2C	**Motor Assembly**	**$4.32**	**1**	**$4.32**
524-1397_2C1	**PCB Board**	**$0.08**	**1**	**$0.08**
524-1397_2C3	Printed FR4 Circuit Board	$0.08	1	$0.08
524-1397_2C2	Stepper Motor 12VDC	$4.24	1	$4.24
524-1397_2M	Screw M4x10mm	$0.03	3	$0.09
524-1397_2D	**Gear Assembly**	**$0.27**	**1**	**$0.27**
524-1397_2G	**Steel Frame**	**$0.12**	**1**	**$0.12**
524-1397_2G1	**Steel Base Plate**	**$0.08**	**1**	**$0.08**
524-1397_2G1 Material	Material, Steel Frame	$0.08	1	$0.08
524-1397_2G2	**Gear Shaft 1**	**$0.01**	**1**	**$0.01**
524-1397_2G2 Material	Material, Gear Shaft 1	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_2G3 Material	Material, Gear Shaft 2	$0.01	1	$0.01
524-1397_2G4	Bushing	$0.01	1	$0.01
524-1397_2H	**Big White Gear**	**$0.04**	**1**	**$0.04**
524-1397_2H2	Gear Shaft Insert	$0.01	1	$0.01
524-1397_2H Material	Material, Big White Gear	$0.03	1	$0.03
524-1397_2I	**Magnet Insert**	**$0.08**	**1**	**$0.08**
524-1397_2I1	Small Magnet	$0.03	1	$0.03
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2I2	**Magnet Holder**	**$0.01**	**1**	**$0.01**
524-1397_2I2 Material	Material, Magnet Holder	$0.01	1	$0.01
524-1397_2J	**Small White Gear**	**$0.02**	**1**	**$0.02**
524-1397_2J Material	Material, Small White Gear	$0.02	1	$0.02
524-1397_2K	**Big Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2K Material	Material, Big Black Gear	$0.01	1	$0.01
524-1397_2L	**Small Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2L Material	Material, Small Black Gear	$0.01	1	$0.01
524-1397_2N	O-Ring Insert	$0.02	1	$0.02
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2F	**Control Module Housing**	**$0.19**	**1**	**$0.19**
524-1397_2F Material	Material, Control Module Housing	$0.19	1	$0.19
524-1397_1	**Control Module Body**	**$2.01**	**1**	**$2.01**
524-1397-4	**Valve Body Subassembly**	**$1.09**	**1**	**$1.09**
524-1397_1A	**Control Module Body**	**$0.91**	**1**	**$0.91**
524-1397_1A Material	Material, Control Module Body	$0.91	1	$0.91
524-1397_1B	**Control Module Ball Valve**	**$0.10**	**1**	**$0.10**
524-1397_1B Material	Material, Ball Valve	$0.10	1	$0.10
524-1397_1R	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1397_1R Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397_1T	Body O-Ring - Black	$0.03	1	$0.03
524-1397-5	**Insert Subassembly**	**$0.36**	**1**	**$0.36**
524-1397_1P	**Control Module Insert**	**$0.32**	**1**	**$0.32**
524-1397_1P Material	Material, Insert	$0.32	1	$0.32
524-1397_1Q	**Insert Seat**	**$0.01**	**1**	**$0.01**
524-1397_1Q Material	Material, Insert Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-3	**Sprocket Subassembly**	**$0.51**	**1**	**$0.51**
524-1397_1D	**Control Module Wheel**	**$0.19**	**1**	**$0.19**
524-1397_1D Material	Material, Wheel	$0.19	1	$0.19
524-1397_1N	Control Module Small O-Ring	$0.03	2	$0.06
524-1397_1E	Control Module Large O-Ring	$0.03	1	$0.03
524-1397_1C	**Control Module Sprocket**	**$0.16**	**1**	**$0.16**
524-1397_1C Material	Material, Sprocket	$0.16	1	$0.16
524-1397_1F	**Control Module Cap**	**$0.01**	**1**	**$0.01**
524-1397_1F Material	Material, Cap	$0.01	1	$0.01
524-1397_1H	Control Module Washer	$0.01	1	$0.01
524-1397_1G	**Control Module Shaft**	**$0.03**	**1**	**$0.03**
524-1397_1G Material	Material, Shaft	$0.03	1	$0.03
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1J	Control Module Label 4363	$0.02	1	$0.02
524-1397_1K	Control Module Label 816 703	$0.02	1	$0.02
524-1397_3	Long Screw M4x50mm	$0.01	2	$0.02
524-1397_4	Short Screw M4x15mm	$0.01	1	$0.01
524-1397	**On/Off Vale #703**	**$12.97**	**1**	**$12.97**
524-1397_2	**Control Module**	**$10.93**	**1**	**$10.93**
524-1399_2A	**Control Module Cover**	**$0.05**	**1**	**$0.05**
524-1397_2A Material	Material, Control Module Cover	$0.05	1	$0.05
524-1397_2E	**Steel Clip**	**$0.01**	**1**	**$0.01**
524-1397_2E Material	Material, Steel Clip	$0.01	1	$0.01
524-1397_2B	**Circut Board**	**$5.94**	**1**	**$5.94**
524-1397_2B1	Connector Pins	$0.08	4	$0.32
524-1397_2B2	Printed FR4 Circuit Board	$0.27	1	$0.27
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.02	1	$0.02
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.01	1	$0.01
MLX90363EDC-ABB-000 -SP	Hall Effect Sensor X, Y, Z Axis 8-SOIC	$1.35	1	$1.35
ATA6625C-TAQY	LIN Transceivers LIN System Basis Chip	$0.65	1	$0.65
L9942XP1TR	Motor / Motion / Ignition Controllers & Drivers In	$1.18	1	$1.18
STPS2L40U	Diode Schottky 40V 2A Surface Mount SMB	$0.08	2	$0.16
S9S08SG16E1CTLR	8 Bit Microcontrollers - MCU S08 16K FLASH	$1.30	1	$1.30
0805 Resistors-5	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	10	$0.01
0603 Resistors-6	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	6	$0.01
EEE-1VA221P	220�F 35V Aluminum Capacitors Radial, Can - SMD 20	$0.11	1	$0.11
EEE-HC1V220P	22�F 35V Aluminum Capacitors Radial, Can - SMD 300	$0.08	1	$0.08
0805 Capacitors-4	Tolerance - 10%; 0805 (2012 Metric) 0.079" L x 0.0	$0.03	6	$0.20
0603 Capacitors-5	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	$0.01	11	$0.16
SDR0604-471KL	Fixed Inductors 470uH 10% SMD 0604	$0.10	1	$0.10
524-1397_2C	**Motor Assembly**	**$4.32**	**1**	**$4.32**
524-1397_2C1	**PCB Board**	**$0.08**	**1**	**$0.08**
524-1397_2C3	Printed FR4 Circuit Board	$0.08	1	$0.08
524-1397_2C2	Stepper Motor 12VDC	$4.24	1	$4.24
524-1397_2M	Screw M4x10mm	$0.03	3	$0.09
524-1397_2D	**Gear Assembly**	**$0.27**	**1**	**$0.27**
524-1397_2G	**Steel Frame**	**$0.12**	**1**	**$0.12**
524-1397_2G1	**Steel Base Plate**	**$0.08**	**1**	**$0.08**
524-1397_2G1 Material	Material, Steel Frame	$0.08	1	$0.08
524-1397_2G2	**Gear Shaft 1**	**$0.01**	**1**	**$0.01**
524-1397_2G2 Material	Material, Gear Shaft 1	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft2	$0.01	1	$0.01
524-1397_2G4	Bushing	$0.01	1	$0.01
524-1397_2H	**Big White Gear**	**$0.04**	**1**	**$0.04**
524-1397_2H2	Gear Shaft Insert	$0.01	1	$0.01
524-1397_2H Material	Material, Big White Gear	$0.03	1	$0.03
524-1397_2I	**Magnet Insert**	**$0.08**	**1**	**$0.08**
524-1397_2I1	Small Magnet	$0.03	1	$0.03
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2I2	**Magnet Holder**	**$0.01**	**1**	**$0.01**
524-1397_2I2 Material	Material, Magnet Holder	$0.01	1	$0.01
524-1397_2J	**Small White Gear**	**$0.02**	**1**	**$0.02**
524-1397_2J Material	Material, Small White Gear	$0.02	1	$0.02
524-1397_2K	**Big Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2K Material	Material, Big Black Gear	$0.01	1	$0.01
524-1397_2L	**Small Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2L Material	Material, Small Black Gear	$0.01	1	$0.01
524-1397_2N	O-Ring Insert	$0.02	1	$0.02
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2F	**Control Module Housing**	**$0.19**	**1**	**$0.19**
524-1397_2F Material	Material, Control Module Housing	$0.19	1	$0.19
524-1397_1	**Control Module Body**	**$2.01**	**1**	**$2.01**
524-1397-4	**Valve Body Subassembly**	**$1.09**	**1**	**$1.09**
524-1397_1A	**Control Module Body**	**$0.91**	**1**	**$0.91**
524-1397_1A Material	Material, Control Module Body	$0.91	1	$0.91
524-1397_1B	**Control Module Ball Valve**	**$0.10**	**1**	**$0.10**
524-1397_1B Material	Material, Ball Valve	$0.10	1	$0.10
524-1397_1R	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1397_1R Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397_1T	Body O-Ring - Black	$0.03	1	$0.03
524-1397-5	**Insert Subassembly**	**$0.36**	**1**	**$0.36**
524-1397_1P	**Control Module Insert**	**$0.32**	**1**	**$0.32**
524-1397_1P Material	Material, Insert	$0.32	1	$0.32
524-1397_1Q	**Insert Seat**	**$0.01**	**1**	**$0.01**
524-1397_1Q Material	Material, Insert Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-3	**Sprocket Subassembly**	**$0.51**	**1**	**$0.51**
524-1397_1D	**Control Module Wheel**	**$0.19**	**1**	**$0.19**
524-1397_1D Material	Material, Wheel	$0.19	1	$0.19
524-1397_1N	Control Module Small O-Ring	$0.03	2	$0.06
524-1397_1E	Control Module Large O-Ring	$0.03	1	$0.03
524-1397_1C	**Control Module Sprocket**	**$0.16**	**1**	**$0.16**
524-1397_1C Material	Material, Sprocket	$0.16	1	$0.16
524-1397_1F	**Control Module Cap**	**$0.01**	**1**	**$0.01**
524-1397_1F Material	Material, Cap	$0.01	1	$0.01
524-1397_1H	Control Module Washer	$0.01	1	$0.01
524-1397_1G	**Control Module Shaft**	**$0.03**	**1**	**$0.03**
524-1397_1G Material	Material, Shaft	$0.03	1	$0.03
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1J	Control Module Label 4363	$0.02	1	$0.02
524-1397_1K	Control Module Label 816 703	$0.02	1	$0.02
524-1397_3	Long Screw M4x50mm	$0.01	2	$0.02
524-1397_4	Short Screw M4x15mm	$0.01	1	$0.01
524-1397	**On/Off Vale #703**	**$12.97**	**1**	**$12.97**
524-1397_2	**Control Module**	**$10.93**	**1**	**$10.93**
524-1399_2A	**Control Module Cover**	**$0.05**	**1**	**$0.05**
524-1397_2A Material	Material, Control Module Cover	$0.05	1	$0.05
524-1397_2E	**Steel Clip**	**$0.01**	**1**	**$0.01**
524-1397_2E Material	Material, Steel Clip	$0.01	1	$0.01
524-1397_2B	**Circut Board**	**$5.94**	**1**	**$5.94**
524-1397_2B1	Connector Pins	$0.08	4	$0.32
524-1397_2B2	Printed FR4 Circuit Board	$0.27	1	$0.27
EF2210 VOC Free Flux	EF2210 VOC Free Flux	$0.00	1	$0.00
LF318 Solder Paste	LF318 Solder Paste	$0.02	1	$0.02
Loctite Chipbonder 3627	Loctite Chipbonder 3627	$0.01	1	$0.01
MLX90363EDC-ABB-000 -SP	Hall Effect Sensor X, Y, Z Axis 8-SOIC	$1.35	1	$1.35
ATA6625C-TAQY	LIN Transceivers LIN System Basis Chip	$0.65	1	$0.65
L9942XP1TR	Motor / Motion / Ignition Controllers & Drivers In	$1.18	1	$1.18
STPS2L40U	Diode Schottky 40V 2A Surface Mount SMB	$0.08	2	$0.16
S9S08SG16E1CTLR	8 Bit Microcontrollers - MCU S08 16K FLASH	$1.30	1	$1.30
0805 Resistors-5	Tolerance - 5%; 0805 (2012 Metric) 0.079" L x 0.04	$0.00	10	$0.01
0603 Resistors-6	Tolerance - 5%; 0603 (1608 Metric) 0.063" L x 0.03	$0.00	6	$0.01
EEE-1VA221P	220�F 35V Aluminum Capacitors Radial, Can - SMD 20	$0.11	1	$0.11
EEE-HC1V220P	22�F 35V Aluminum Capacitors Radial, Can - SMD 300	$0.08	1	$0.08
0805 Capacitors-4	Tolerance - 10%; 0805 (2012 Metric) 0.079" L x 0.0	$0.03	6	$0.20
0603 Capacitors-5	Tolerance - 10%; 0603 (1608 Metric) 0.063" L x 0.0	$0.01	11	$0.16
SDR0604-471KL	Fixed Inductors 470uH 10% SMD 0604	$0.10	1	$0.10
524-1397_2C	**Motor Assembly**	**$4.32**	**1**	**$4.32**
524-1397_2C1	**PCB Board**	**$0.08**	**1**	**$0.08**
524-1397_2C3	Printed FR4 Circuit Board	$0.08	1	$0.08
524-1397_2C2	Stepper Motor 12VDC	$4.24	1	$4.24
524-1397_2M	Screw M4x10mm	$0.03	3	$0.09
524-1397_2D	**Gear Assembly**	**$0.27**	**1**	**$0.27**
524-1397_2G	**Steel Frame**	**$0.12**	**1**	**$0.12**
524-1397_2G1	**Steel Base Plate**	**$0.08**	**1**	**$0.08**
524-1397_2G1 Material	Material, Steel Frame	$0.08	1	$0.08
524-1397_2G2	**Gear Shaft 1**	**$0.01**	**1**	**$0.01**
524-1397_2G2 Material	Material, Gear Shaft 1	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**

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Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_2G3 Material	Material, Gear Shaft 2	$0.01	1	$0.01
524-1397_2G3	**Gear Shaft 2**	**$0.01**	**1**	**$0.01**
524-1397_2G3 Material	Material, Gear Shaft 2	$0.01	1	$0.01
524-1397_2G4	Bushing	$0.01	1	$0.01
524-1397_2H	**Big White Gear**	**$0.04**	**1**	**$0.04**
524-1397_2H2	Gear Shaft Insert	$0.01	1	$0.01
524-1397_2H Material	Material, Big White Gear	$0.03	1	$0.03
524-1397_2I	**Magnet Insert**	**$0.08**	**1**	**$0.08**
524-1397_2I1	Small Magnet	$0.03	1	$0.03
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2I2	**Magnet Holder**	**$0.01**	**1**	**$0.01**
524-1397_2I2 Material	Material, Magnet Holder	$0.01	1	$0.01
524-1397_2J	**Small White Gear**	**$0.02**	**1**	**$0.02**
524-1397_2J Material	Material, Small White Gear	$0.02	1	$0.02
524-1397_2K	**Big Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2K Material	Material, Big Black Gear	$0.01	1	$0.01
524-1397_2L	**Small Black Gear**	**$0.01**	**1**	**$0.01**
524-1397_2L Material	Material, Small Black Gear	$0.01	1	$0.01
524-1397_2N	O-Ring Insert	$0.02	1	$0.02
524-1397_2O	Silicone RTV Clear	$0.04	1	$0.04
524-1397_2F	**Control Module Housing**	**$0.19**	**1**	**$0.19**
524-1397_2F Material	Material, Control Module Housing	$0.19	1	$0.19
524-1397_1	**Control Module Body**	**$2.01**	**1**	**$2.01**
524-1397-4	**Valve Body Subassembly**	**$1.09**	**1**	**$1.09**
524-1397_1A	**Control Module Body**	**$0.91**	**1**	**$0.91**
524-1397_1A Material	Material, Control Module Body	$0.91	1	$0.91
524-1397_1B	**Control Module Ball Valve**	**$0.10**	**1**	**$0.10**
524-1397_1B Material	Material, Ball Valve	$0.10	1	$0.10
524-1397_1R	**Body Seat**	**$0.01**	**1**	**$0.01**
524-1397_1R Material	Material, Body Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397_1T	Body O-Ring - Black	$0.03	1	$0.03
524-1397-5	**Insert Subassembly**	**$0.36**	**1**	**$0.36**
524-1397_1P	**Control Module Insert**	**$0.32**	**1**	**$0.32**
524-1397_1P Material	Material, Insert	$0.32	1	$0.32
524-1397_1Q	**Insert Seat**	**$0.01**	**1**	**$0.01**
524-1397_1Q Material	Material, Insert Seat	$0.01	1	$0.01
524-1397_1S	Body Seat O-Ring	$0.03	1	$0.03
524-1397-3	**Sprocket Subassembly**	**$0.51**	**1**	**$0.51**
524-1397_1D	**Control Module Wheel**	**$0.19**	**1**	**$0.19**
524-1397_1D Material	Material, Wheel	$0.19	1	$0.19
524-1397_1N	Control Module Small O-Ring	$0.03	2	$0.06
524-1397_1E	Control Module Large O-Ring	$0.03	1	$0.03
524-1397_1C	**Control Module Sprocket**	**$0.16**	**1**	**$0.16**
524-1397_1C Material	Material, Sprocket	$0.16	1	$0.16
524-1397_1F	**Control Module Cap**	**$0.01**	**1**	**$0.01**
524-1397_1F Material	Material, Cap	$0.01	1	$0.01
524-1397_1H	Control Module Washer	$0.01	1	$0.01
524-1397_1G	**Control Module Shaft**	**$0.03**	**1**	**$0.03**
524-1397_1G Material	Material, Shaft	$0.03	1	$0.03

e-Golf Controls

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1L	Control Module Screw M4x9mm	$0.01	1	$0.01
524-1397_1M	Control Module Screw M4x10mm	$0.01	1	$0.01
524-1397_1J	Control Module Label 4363	$0.02	1	$0.02
524-1397_1K	Control Module Label 816 703	$0.02	1	$0.02
524-1397_3	Long Screw M4x50mm	$0.01	2	$0.02
524-1397_4	Short Screw M4x15mm	$0.01	1	$0.01
524-1399_1	Torx Screw M6x10	$0.10	6	$0.60

Assembly Totals

Analyzed Subs:	198
Unanalyzed Subs:	0
Parts:	597
Fasteners:	84
Parts+Unanalyzed:	597

Report Totals

Piece Cost (Total): $78.93

Preassembled Totals

Analyzed Subs:	*0*
Unanalyzed Subs:	*0*
Parts:	*0*
Fasteners:	*0*
Parts+Unanalyzed:	*0*

Table G-15 VW e-Golf Vehicle Integration Features Materials and Processing Assumptions

Row	Level	Symbol Type	Number	Name	Material Name
1	2	Subassembly	524-1402	Bracket Assembly Heat Pump	(None)
2	3	Subassembly	524-1402_1	Bracket Subassembly #1	(None)
3	4	Preprocessed Part	524-1402_1A	Center Welded Bracket	Steel 1010 Cold Drawn or Cold Rolled
4	5	Manufacturing Steps		Bracket Process	
5	6	Manufacturing Process		Wash	
6	6	Manufacturing Process		Deburr	
7	6	Manufacturing Process		Stamping Press, 2500 Ton	
8	7	Part	524-1402_1A Material	Material, Center Welded Bracket	Steel 1010 Cold Drawn or Cold Rolled
9	4	Preprocessed Part	524-1402_1B	Bottom Welded Bracket	Steel 1010 Cold Drawn or Cold Rolled
10	5	Manufacturing Steps		Bracket Process	
11	6	Manufacturing Process		Wash	
12	6	Manufacturing Process		Deburr	
13	6	Manufacturing Process		Stamping Press, 1800 Ton	
14	7	Part	524-1402_1B Material	Material, Bottom Welded Bracket	Steel 1010 Cold Drawn or Cold Rolled
15	4	Preprocessed Part	524-1402_1C	Top Welded Bracket	Steel 1010 Cold Drawn or Cold Rolled
16	5	Manufacturing Steps		Bracket Process	
17	6	Manufacturing Process		Wash	
18	6	Manufacturing Process		Deburr	
19	6	Manufacturing Process		Stamping Press, 4000 Ton	
20	7	Part	524-1402_1C Material	Material, Top Welded Bracket	Steel 1010 Cold Drawn or Cold Rolled
21	4	Part	524-1402_1D	Threaded Weld Studs	Commodity Item
22	4	Part	524-1402_1E	Weld Studs	Commodity Item

Row	Level	Symbol Type	Number	Name	Material Name
23	4	Manufacturing Steps		Subassembly #1 Assembly Process	
24	5	Manufacturing Process		Cure	
25	5	Manufacturing Process		Paint	
26	6	Part	524-1402 Dip Paint	Paint Material, Bracket Subassembly	Paint
27	5	Manufacturing Process		Wash	
28	5	Manufacturing Process		Mark Part	
29	5	Manufacturing Process		Projection Weld	
30	5	Manufacturing Process		Projection Weld	
31	5	Manufacturing Process		MIG Weld	
32	3	Subassembly	524-1402_2	Bottom Bracket Subassembly #2	(None)
33	4	Preprocessed Part	524-1402_2A	Bottom Bracket	Steel 1010 Cold Drawn or Cold Rolled
34	5	Manufacturing Steps		Bracket Processing	
35	6	Manufacturing Process		Cure	
36	6	Manufacturing Process		Paint	
37	7	Part	524-1402_2A Dip Paint	Paint Material, Bottom Bracket	Paint

Table G-16 VW e-Golf Vehicle Integration Features Bill of Materials

Indented Bill of Materials

MUNRO & ASSOCIATES, INC.

e-Golf Vehicle Integration Features

Number	Symbol Name	Piece Cost	Item Qty	Piece Cost (Total)
524-1402	**Backet Assembly Heat Pump**	**$7.18**	**1**	**$7.18**
524-1402_1	**Bracket Subassembly #1**	**$5.48**	**1**	**$5.48**
524-1402_1A	**Center Welded Bracket**	**$2.19**	**1**	**$2.19**
524-1402_1A Material	Material, Center Welded Bracket	$2.19	1	$2.19
524-1402_1B	**Bottom Welded Bracket**	**$1.64**	**1**	**$1.64**
524-1402_1B Material	Material, Bottom Welded Bracket	$1.64	1	$1.64
524-1402_1C	**Top Welded Bracket**	**$0.61**	**1**	**$0.61**
524-1402_1C Material	Material, Top Welded Bracket	$0.61	1	$0.61
524-1402_1D	Threaded Weld Studs	$0.08	4	$0.32
524-1402_1E	Weld Studs	$0.10	5	$0.50
524-1402 Dip Paint	Paint Material, Bracket Subassembly	$0.22	1	$0.22
524-1402_2	**Bottom Bracket Subassembly #2**	**$0.75**	**1**	**$0.75**
524-1402_2A	**Bottom Bracket**	**$0.55**	**1**	**$0.55**
524-1402_2A Dip Paint	Paint Material, Bottom Bracket	$0.05	1	$0.05
524-1402_2A Material	Material, Bottom Bracket	$0.50	1	$0.50
524-1402_4	Bumpers	$0.10	2	$0.20
524-1402_3	**Top Bracket Subassembly #3**	**$0.86**	**1**	**$0.86**
524-1402_3A	**Top Bracket**	**$0.56**	**1**	**$0.56**
524-1402_3A Dip Paint	Paint Material, Top Bracket	$0.03	1	$0.03
524-1402_3A Material	Material, Top Bracket	$0.53	1	$0.53
524-1402_4	Bumpers	$0.10	3	$0.30
524-1402_5	Label, 820.037.F	$0.02	1	$0.02
524-1402_6	Label, 0286	$0.02	1	$0.02
524-1402_7	Label, 820 905 C	$0.02	1	$0.02
524-1402_8	Label, 03K	$0.01	1	$0.01
524-1402_9	Label, Blue Dot	$0.01	1	$0.01
524-1402_10	Label, Yellow Dot	$0.01	1	$0.01

Assembly Totals		Report Totals	Preassembled Totals	
Analyzed Subs:	9	Piece Cost (Total): $7.18	*Analyzed Subs:*	*0*
Unanalyzed Subs:	0		*Unanalyzed Subs:*	*0*
Parts:	28		*Parts:*	*0*
Fasteners:	0		*Fasteners:*	*0*
Parts+Unanalyzed:	28		*Parts+Unanalyzed:*	*0*