California Environmental Protection Agency
AIR RESOURCES BOARD

AIR QUALITY SURVEILLANCE BRANCH

STANDARD OPERATING PROCEDURES

FOR

RM YOUNG 81000
ULTRASONIC ANEMOMETERS

AQSB SOP 506
First Edition

MONITORING AND LABORATORY DIVISION

April 2017

California Environmental Protection Agency
AIR RESOURCES BOARD

Approval of Standard Operating Procedures (SOP)

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Date

TABLE OF CONTENTS

RM YOUNG 81000 ULTRASONIC ANEMOMETERS

		Page(s)	Date
1.0	**GENERAL INFORMATION**	**5 - 7**	04/17
1.1	Introduction	5	
1.2	General Principle of Operation	5	
1.3	Description of Ultrasonic Anemometers	5 - 7	
1.4	Interferences and Safety Considerations	7	
2.0	**INSTALLATION PROCEDURE (MODEL 81000)**	**9-17**	04/17
2.1	Installation Overview	9	
2.2	Equipment Required for Installation	9	
2.3	Mounting the Sensor onto Met Tower	9 - 10	
2.4	Sensor Alignment to True North	10 - 12	
2.5	Connecting to Data Loggers	12	
2.6	3D Sonic RS-232 Sensor Cable	12 - 14	
2.7	3D Sonic Sensor Configuration	14 - 17	
3.0	**CONFIGURATION**	**18 - 19**	04/17
3.1	CARBLogger Configuration	18 - 19	
4.0	**CALIBRATION INFORMATION**	**20**	04/17
4.1	RM Young 81000 Calibration Frequency	20	
5.0	**TROUBLESHOOTING**	**21**	04/17
5.1	General Troubleshooting	21	
6.0	**ROUTINE SERVICE CHECKS**	**22**	04/17
6.1	Daily Checks	22	
6.2	Weekly Checks	22	
6.3	Monthly Checks	22	
6.4	Semi-Annual Checks	22	
6.5	Annual Checks	22	

7.0 MAINTENANCE PROCEDURES **23** 04/17

7.1 General Information 23

FIGURES

Figure 1: RM Young Model 81000 Three Axis Ultrasonic Anemometer
Figure 2: Met Tower Assembly
Figure 3: Sensor Alignment Sticker
Figure 4: Sensor Installation
Figure 5: Sensor Mounting Collar
Figure 6: Checking Sensor Voltage
Figure 7: RM Young 81000 Manual Appendix A, RS-232 connections
Figure 8: RM Young 8100 RS-232 Wiring
Figure 9: RM Young Set-up menu
Figure 10: CARBLogger "Query" command
Figure 11: CARBLogger Report
Figure 12: Testing and Certification Report

APPENDICES

Appendix A: Analog connection of RM Young Model 81000 to ESC 88XX Data Logger

Appendix B: ESC 88XX Data Logger Channel Configurations for RM Young Model 81000 Anemometers

Appendix C: Model 81000 Programming for ESC 8800 Data Loggers

Appendix D: Model 81000 Programming for ESC 8816/32 Data Loggers

Appendix E: Monthly Maintenance Check Sheet for Ultrasonic Anemometers

Appendix F: RM Young Calibration Frequency Memo

1.0 GENERAL INFORMATION

1.1 Introduction:

This Standard Operating Procedure (SOP) describes procedures used by the California Air Resources Board (CARB) Air Quality Surveillance Branch (AQSB) to operate the RM Young 81000 ultrasonic anemometer for the measurement of meteorological parameters. This procedure was designed to supplement the manufacturer's instrument manual by describing any modifications in operating procedures, if any, implemented by the AQSB and is not intended to be a replacement for the instrument manual.

1.2 General Principle of Operation:

The RM Young Company Model 81000 Ultrasonic Anemometer (hence referred to as 3D Sonic or sensor) measures three dimensional wind speed, wind direction and speed of sound based on the transit time of ultrasonic acoustic signals. These signals are used to calculate the meteorological parameters which are a known function of the air temperature and composition. Sonic temperature (or virtual temperature) is derived from speed of sound which is corrected for crosswind effects.

The 3D Sonic has no on-board data storage. Therefore, should the data acquisition system connected to the sensor fail or stop logging; there is no method to recover meteorological data. Electrical connections to the sensor are made via an easily accessible junction box. The unit mounts on standard 1 inch pipe, outside diameter 1 ¼" O.D.

1.3 Description of RM Young 81000 Ultrasonic Anemometers

The 3D Sonic is a 3-axis, no moving parts wind sensor. It is well suited for applications requiring fast response with high resolution. The sensor features UV stabilized thermoplastic, stainless steel, and anodized aluminum components for excellent environmental resistance.

Measurement data are available as serial output using RS-232/485 or analog connections. Using serial connections (AQSB standard), multiple output formats are available. The custom format allows the user to construct an ASCII-printable serial output string and is easily set by the user via a standard serial communication program.

The standard custom output string for AQSB air monitoring operations is **"56789AB"** for UVW, 2D SPEED, 3D SPEED, Azimuth, Elevation, Speed of Sound, and Sonic Temperature where:

- UVW is the orthogonal u, v, and w wind velocities. Typically the 3D Sonic is oriented with u-axis aligned east-west and v-axis aligned north-south. In this orientation, +u values = wind from the east; +v values = wind from the north. Wind from below (updraft} = +w.

    - 2D SPEED is the wind magnitude in the u-v plane (the horizontal plane across the sensor).

    - 3D SPEED is wind magnitude in three dimensional space.

    - AZIMUTH is the 0.0-359.9" wind direction angle in the u-v plane. With the sensors junction box facing South. (0.0 degrees = North, 90.0 degrees = East, 180.0 degrees = South, and 270.0 degrees = West).

    - ELEVATION is the ± 90.0 degree wind elevation angle relative to the u-v plane. Values are positive when wind is from below (updraft) and negative when from above (downdraft). Effective elevation angle measurements are limited to ±60.0".

    - SOS is the speed of sound.

    - Sonic Temperature (Ts) is the virtual temperature derived from SOS.

If using analog connections, data are available via four analog voltage output channels in either Cartesian or Polar coordinates. The four analog outputs can be expressed as either UVW format or SPEED_AZIMUTH_ELEVATION format. The four output channels for the 3D Sonic in the SPEED_AZIMUTH_ELEVATION format are expressed as 3D Wind Speed (V1), Azimuth (V2), Elevation Angle (V3), and Sonic Temperature (V4) where:

- 3D Wind Speed – is the wind magnitude 3D space. The output range of the 3D wind speed channel V1 is 0 to 50 meters/sec (97.19 knots).

- Azimuth (Wind Direction Angle) – is the 0.0 to 359.9 wind direction angle relative to the u-v plane. When the 3D Sonic junction box is facing south, 0.0 degrees = North, 90 degrees = East, 180.0 = South and 270.0 degrees = West. The output range of the Azimuth channel (V2) is 0 to 540 degrees.

- Elevation – is the ± 90 degree wind elevation angle relative to the u-v plane. Values are positive when wind if from below (updraft) and negative with from above (downdraft). The output range of the Elevation channel (V3) is -60 to +60 degrees.

- Sonic Temperature – is the virtual temperature derived from the speed of sound. The output range of the Sonic Temperature channel (V4) is 220 to 320 degrees Kelvin (-53.2 to 46.8 degrees Celsius).

1.4 Interferences and Safety Considerations

High Wind Speed Measurements

For best measurement results, particularly at high wind speeds, always choose the lowest OUTPUT RATE possible. Lower output rates use a greater number of internal samples to generate the result and are more immune to outliers in the samples. If measuring for spectral content, carefully determine the needed sampling rate and use the lowest OUTPUT RATE necessary.

> **NOTE: AQSB standard configuration for the 3D Sonic is an output rate of two data points per minute. If the sensor's output rate is changed, CARBLogger may not properly process sub-minute data. Contact ODSS should the output rate need to be modified.**

Rain and Snow

Anything that blocks the acoustic signal path will degrade the measurement. If the path is blocked sufficiently, measurements cannot be made. The 3D Sonic can make accurate measurements in driving rain even at high OUTPUT RATES but light mist or heavy fog can allow droplets to accumulate on the transducer faces and block the measurement. Measurements may be made in driving snow although frost and snow that adheres to the transducer face may block the measurement. Similarly, freezing rain on the transducer face may block the measurement.

Power Connections

Supply power must be in the range of 12 to 24 VDC at the sensor junction box terminals in order for the sensor to operate properly. For long cables, be sure to allow for voltage drop due to wire resistance.

Met Tower Safety

Proper installation and siting of met towers determines the effectiveness of a system and ensures ease of maintenance and reliability. Climbing met towers to perform maintenance tasks is hazardous; use all necessary precautions as outlined in agency-specific Health and Safety Plans (HASPs).



Figure 1: RM Young Model 81000 3D Sonic Sensor

2.0 INSTALLATION PROCEDURE (RM YOUNG 81000 ANEMOMETERS)

2.1 Installation Overview:

The 3D Sonics arrive from the factory calibrated and ready to use. Prior to use, carefully unpack the sensor, inspect for physical damage, record the sensor's I.D information and date of last vendor calibration and test. Report any damage to the stockroom or the ODSS Instrument Laboratory personnel.

2.2 Equipment Required for Installation:

- RM Young 8100 Ultrasonic Anemometer
- Direct Current (DC) Power Supply, 12 to 24 VDC fixed output, and 500 mA minimum.
- Sufficient 18 to 24 gauge interconnect wiring to reach from the sensor mounting position to the power supply and data logger. The sensor interconnect will need an appropriate serial connector.
- Hand Tools, including, but not limited to the following:
    - Screwdrivers, flat and Phillips, numbers 0, 1, and 2
    - Wrenches, fixed SAE, and adjustable
    - Pliers, long nose
    - Pliers, diagonal cutting
    - Strippers, wire, 24 to 14 gauge
    - Bubble level
    - Magnetic Compass / Transit
- 1 ¼ inch OD pipe, to mount the 3D Sonic.
- Operator's Manuals for the 3D Sonic and the data logger in use.

2.3 Mounting the Sensor to an existing Meteorological Tower:

Proper operation of any meteorological instrument is directly related to siting of the sensor. An ideal installation is one where the operator can safely access the sensor, perform tests adjacent to the electronics and recorder, and re-install the sensor, alone within one hour. Site operators should review the U.S. Environmental Protection Agency (EPA), Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV to get a more detailed description of meteorological sensor siting requirements, installation procedures and safety considerations.

Prior to mounting sensor to tower, procure a serial cable of sufficient length to allow sensor to connect to data logger.

Secure a 1¼ inch O.D. alignment tube to meteorological tower or sled assembly. Mount the 3D Sonic to a vertical piece of 1¼ inch diameter rigid tubing and attach to cross arm. If co-locating with another wind sensor, keep the center of the 3D Sonic as close to the same elevation as the other sensor. Maintain at least one meter separation between sensors to minimize wake turbulence interference.

2.4 Sensor Alignment to True North:

The 3D Sonic must be oriented to True North to properly measure wind direction. The "**N**" indicator on the 3D Sonic alignment sticker must be facing True North to reference the sensor to True North. This can be accomplished when mounting the crossbar on which the sensor will be fixed onto the met mast. Mount the vertical stand to the crossbar, taking care to use a straight edge to align the RM Young mounting collar's southern protuberance to the 90 degree mark on the orthogonal joint.

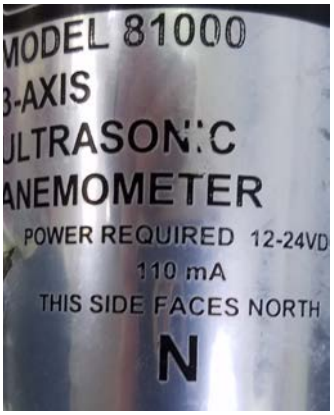


Figure 3: Alignment Sticker



Figure 4: Sensor Installation

Prior to installation, the station operator should be familiar with a site's magnetic declination and operation of a surveying compass. U.S EPA guidance require that the sensors be aligned to ≤2 degrees with respect to sensor mount (≤5 degrees absolute error for the installed system.)

NOTE: Compass readings can be affected by magnetic materials such as watches, belt buckles, knives, etc. All magnetic materials must be kept away from the compass when readings are taken.



Figure 5: Sensor Mounting Collar

3D Sonic sensors should be oriented to True North as follows:

1. Adjust a compass or pocket transit for proper site magnetic declination. Attach the ball and socket head to a tripod and attach the compass to the socket, secure with clamp.

2. Position the tripod where you can get a clear and safe view of the sensor. T**he best position is usually to the South of the met tower, in line with the mast, approximately 10 to 30 meters from mast facing North.**

3. Open the compass mirror to about a 45 degree angle and set the front site perpendicular to the case. Level the compass by using the circular bubble level. The compass is correctly sighted on the sensor when the

operator, while looking into mirror, sees the black center line of the mirror bisecting both the front site and the cross arm or orientation vane. Check the bubble in the circular level to confirm that it is still level. The North seeking end of the needle should be pointing to 0 degrees ± 0.5 degree. If the correct declination is used and the compass is properly sited, the cross arm or alignment vane should be aligned to True North. To confirm that the sensor is properly aligned, it is helpful to view the mast from the opposite side (180 degrees) of the orientation direction.

4. The use of an orientation pointer may make alignment of sensors to True North easier. If this is done, the pointer may appear parallel to the black bisecting centerline in the mirror.

5. Alignment of sensors is best done by two people, one person to orient the sensor and one person to read the compass.

2.5 Connecting to Data Loggers:

The RM Young 3D sonic can be configured for either digital or analog outputs. Currently, the AQSB's standard operation for the 3D sonic is to configure the instrument for digital output for the ARB's CARBLogger system.

Section's 2.7 and 3.1 of this document discusses 3D sonic sensor configuration and connections to CARBLogger.

Information for connecting the 3D Sonic to an analog data logger can be found in Appendix A of this document.

2.6 3D Sonic RS-232 Sensor Cable:

Prior to installing a 3D Sonic and connecting the sensor to CARBLogger, an RS-232 serial cable of sufficient length must be constructed. Sensor cables are typically assembled by the ODSS Instrument Lab at the request of field staff. Field staff should request a sensor cable with enough length to reach from CARBLogger to the top of met tower with extra for a drip line.

RM Young 81000 sensors purchased by the AQSB do not include a power supply. Hence, ODSS purchases a third-party adjustable 12 V power supply to provide power for the sensors. Power supplies for the 3D Sonics are configured by the ODSS Instrument Lab.
Some air monitoring sites in the network require long cable connections (greater than 100 feet). It is possible that the voltage produced by power supplies at these sites not be adequate to properly power the 3D Sonic. In these cases, it may require field staff to 1) measure the input voltage at the sensor and 2)

adjust/increase the voltage output from the power supply.

To check/verify input voltage to the 3D Sonic, plug in power supply to turn it on (power supplies are set to an output voltage of 12 volts by ODSS Instrument Lab). Connect a digital volt meter to the +PWR and PWR REF terminals of the 3D Sonic to check input voltage. The input voltage to the 3D Sonic should be at minimum 12 volts. If the voltage is not high enough, then the length of the cable may be causing an excessive voltage drop. Adjust the power supply potentiometer to increase its output voltage. Turn the power supply potentiometer clockwise to increase voltage, or counter-clockwise to decrease voltage.



Figure 6: Checking 3D Sonic input voltage

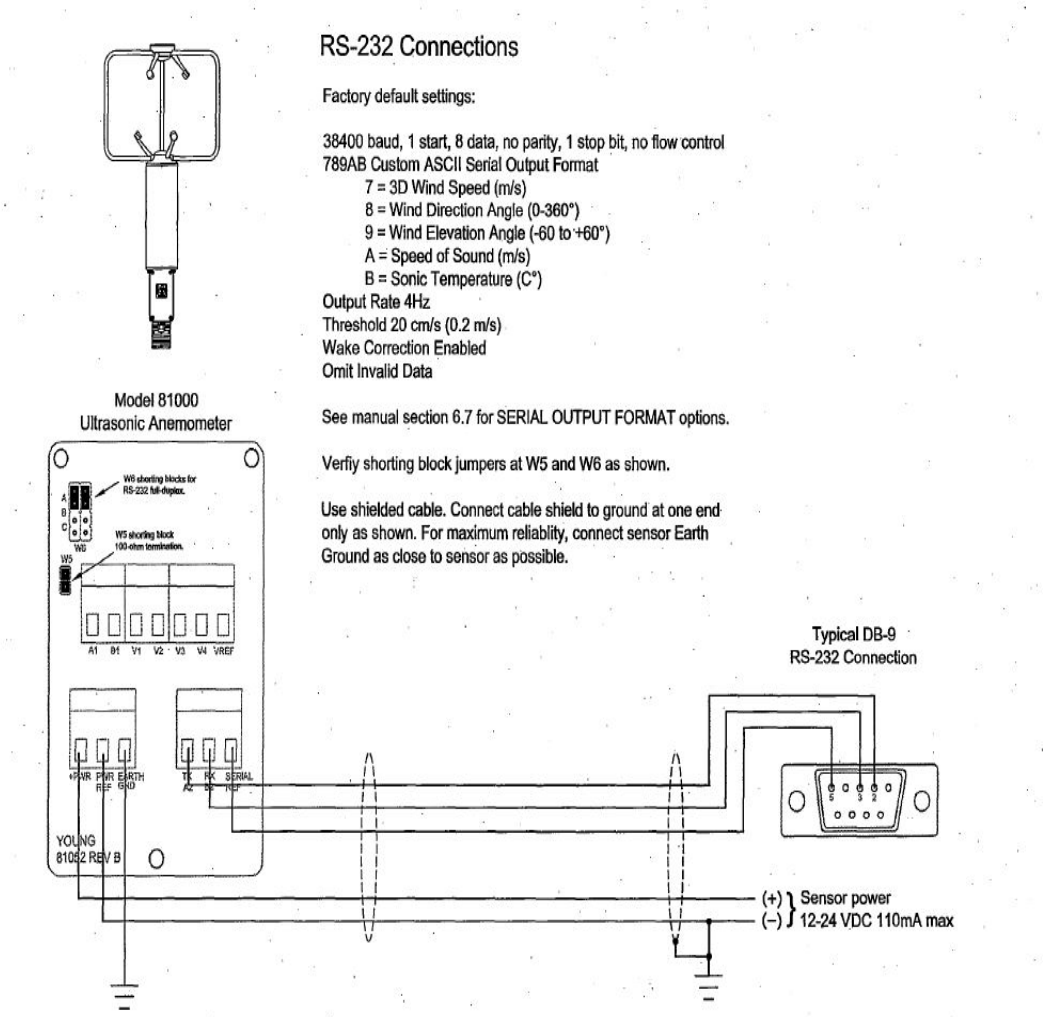


Figure 7: RM Young 81000 Manual Appendix A, RS-232 connections

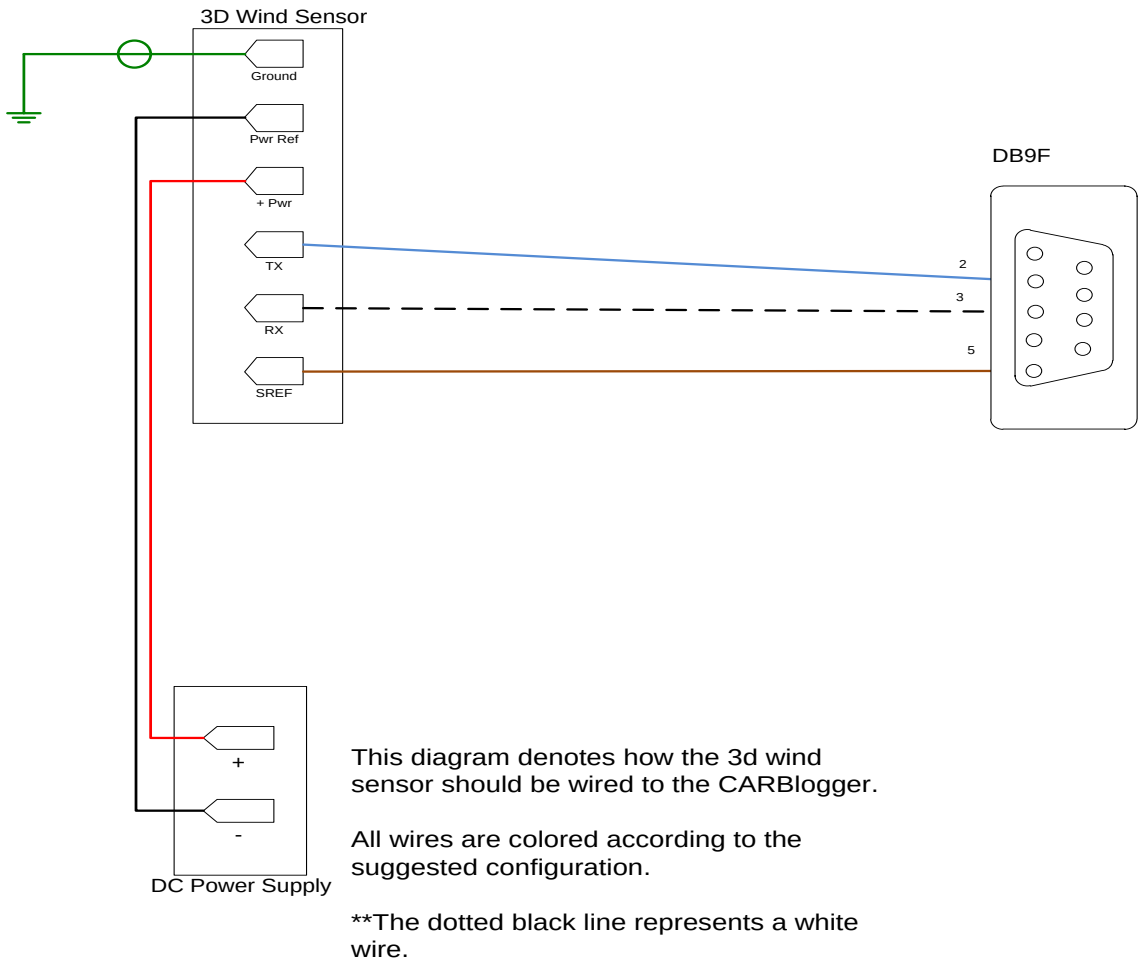


Figure 8: RM Young 3D Sonic RS-232 Wiring

2.7 3D Sonic Sensor Configuration

Prior to connecting the 3D sonic to a CARBLogger, there are several parameters that must be configured within the sensor. These parameters are typically set by the ODSS Instrument Laboratory staff before deploying a sensor. However, should staff need to configure a sensor or confirm a sensors settings the steps below describe that process. The following sensor parameters need to be set:

- Baud rate
- Output rate
- Serial out format
- Output data format
- Output units
- Error handling

Connect the 3D Sonic to a serial port of a laptop or computer and use a terminal program such as hyper-terminal, PuTTY, GtkTerm etc. This document illustrates using GtkTerm from the CARBLogger desktop. If you see data streaming onto the monitor or if the 3D Sonic displays a stream of garbage after connecting, then you have most likely found the right port.

1. Hit the [Esc] key, three times in rapid succession. This will cause a menu to appear.

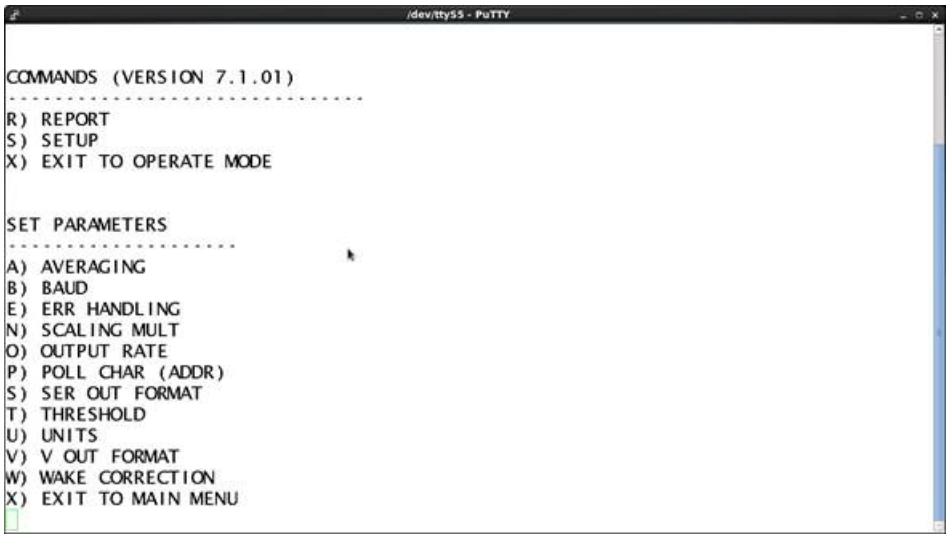


Figure 9: RM Young Model 81000 3D Sonic Set-up Menu

2. Next select [Setup] by typing “S”.

3. Select “Averaging” by typing “A”. Type “120” followed by enter to set an averaging interval of 120 samples

4. Select “Baud Rate” by typing “B”, and subsequently select 9600 by typing “D”. The sensor will respond by requesting a duplex setting, select “2” for FULL Duplex.

5. Select “Output Rate” by typing “O”, and subsequently select 4 Hz by typing “A”.

6. Set the “Serial Out Format” by selecting “S”, followed by”1” for “Custom”.

7. Choose the following options: “56789AB” for UVW, 2D SPEED, 3D SPEED, Azimuth, Elevation, Speed of Sound, Sonic Temp.

8. Select “Units” by typing “U”, and select “5” for knots, followed by enter.

9. Finally select “Err Handling” by typing “E”, then select “2” to omit invalid data.

The CARBLogger RM Young 81000 driver was programmed to accept data and correct for line/signal errors while omitting invalid sub minute data points. Should transmission be malformed (based on data observed to date), CARBLogger should drop that line of data.

For example, under optimal conditions, the following is a complete line of sub minute data which contains a check sum of “13” for the following values, the two digit hour, the two digit minute, the two digit second, the nano-second stamp (where 0 would be the bottom of the second, and 1 x 10^9 would be the top), U, V, W, 2D Speed, 3D Speed, Azimuth, Elevation, Speed of Sound, and Sonic temperature respectively:

13 14 55 33 609001231 2.0 -1.2 0.9 2.4 2.6 122.0 20.9 670.9 72.98

If the checksum doesn’t equal 13, or the speed of sound token is less than 600, that line will be discarded from the one minute average. As long as one to three sub-minute values are collected for any single minute, the average of all values will be recorded in the CARBLogger data record for that minute. The above file would be located at the following location:

“/home/aqdms/CARBLog/resources/RMYOUNG81000_drv/14/55.dat”

If no valid data points are collected for a single minute, no minute data is recorded to the CARBLogger data file, and an error is reported to the site operator letting them know why they missed that minutes data.

In cases of CARBLogger mis-configuration, the RMYoung driver may be unable to remove data files, hence causing too many lines of sub-m data to be collected. In this case, no minute data value is recorded, and an error is reported to the operator letting them know why they missed that minutes data.

NOTE: Should zero valid data points per minute or CARBLogger mis-configuration occur, CARBLogger will notify the operator with the following message *“The RMYoung data was not aggregated for this minute because of too few valid data points”*

3.0 CONFIGURATION

3.1 CARBLogger Configuration:

Prior to using the 3D Sonic, CARBLoggers the RM Young 81000 driver must be enabled. To select or verify that the 3D sonic driver is in use, select “Add Driver” from the CARBLogger user interface. The RM Young driver was developed evaluating various RS232 serial cable lengths and baud rates. For most if not all AQSB installations, a sensor output interval of two points per minute and 9600 baud rate are optimal. As normally configured, the 3D Sonic ideally collects 2 valid data points per minute. The following steps will allow operators to evaluate standard sensor configurations for their monitoring station. This test should be accomplished prior to installing the sensor to the met tower.

1. Connect the 3D Sonic to an available serial port on CARBLogger.

2. Start the CARBLogger with the 3D Sonic configured as discussed in Section 2.7 “3D Sonic Sensor Configuration” to an output rate of 2 points per minute.

   NOTE: AQSB standard configuration for the 3D Sonic is for an output rate of 2 points per minute. If the sensor’s output rate is changed to something other than 2 points per minute, CARBLogger may not properly process sub-minute data. Contact ODSS should the sensor’s output rate need to be modified.

3. Open a shell terminal by clicking on the Menu button, and choosing the “Terminal” icon.

4. Once in the terminal window, type the following command replacing [HH] with the present two digit hour (in PST). For instance, we ran this at 3:00 PM, so we replaced [HH] with “15”:

   ```
   sudo wc -l /home/aqdms/CARBLog/resources/RMYoung/[HH]/*.dat
   ```

   Figure 10: CARBLogger “Query” command

5. The output is a series of line count numbers adjacent to .dat file names as shown below.

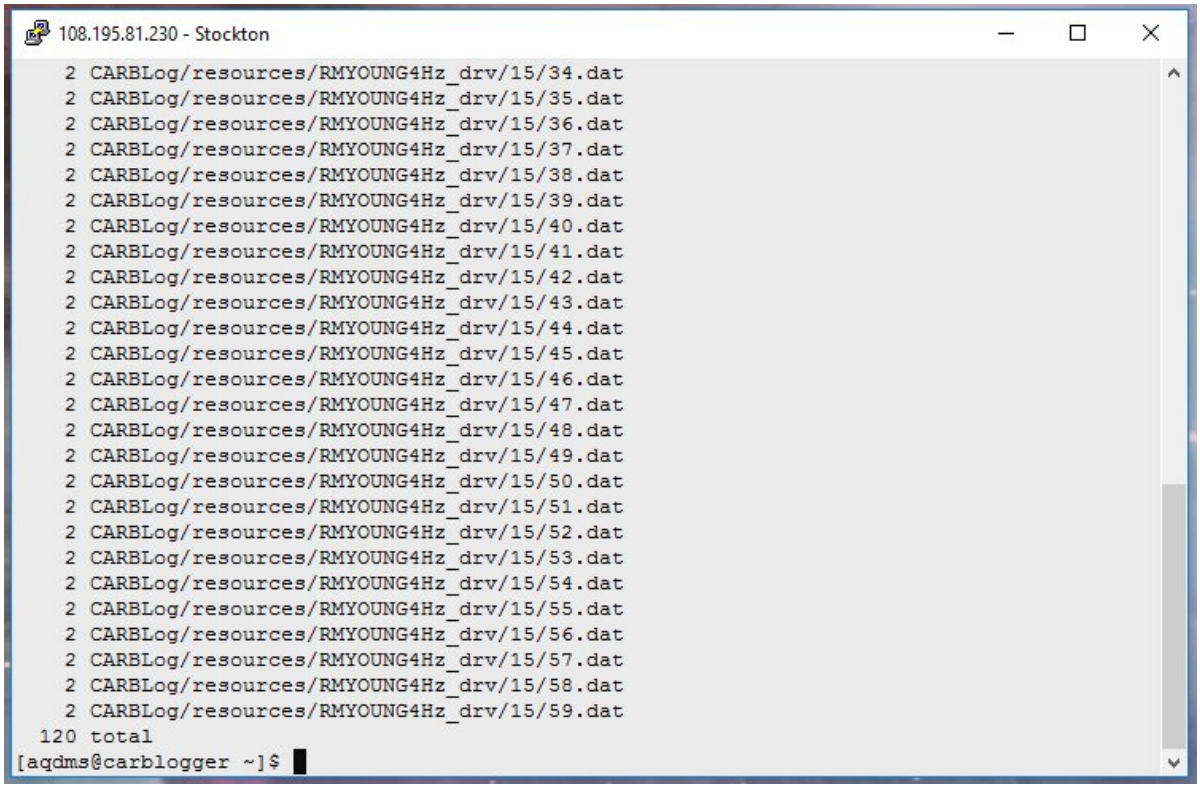


Figure 11: CARBLogger Display

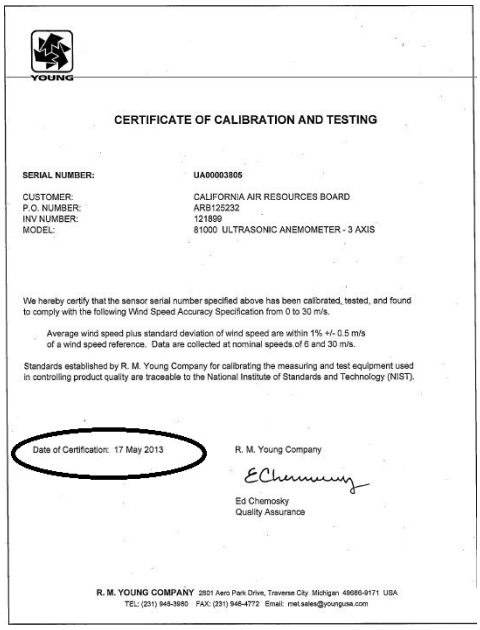
6. If the line count numbers you receive are from 1-3, then 2 points per minute and 9600 are the appropriate output rate and baud rates for your installation. If the line count number is greater than 3 or less than 1 (in which case the CARBLogger display shows that no data was received), then contact ODSS staff. The use of a shorter RS232 cable or the sensor's baud rate may need to be adjusted.

4.0 CALIBRATION INFORMATION

The 3D Sonics are calibrated and tested at the factory utilizing a wind tunnel and proprietary algorithms to compensate for certain inefficiencies in sampling. Wind tunnel calibrations are conducted at several wind speeds utilizing a NIST traceable wind speed standard. Accordingly, all 3D Sonics used in the AQSB ambient monitoring network must be returned to the manufacturer periodically to ensure and maintain proper operation of the sensor.

4.1 RM Young 81000 Calibration Frequency

Upon receipt of a new sensor or after return from factory for calibration, a Certificate of Calibration and Testing is received with each 3D Sonic sensor.



YOUNG

CERTIFICATE OF CALIBRATION AND TESTING

SERIAL NUMBER: UA00003805

CUSTOMER: CALIFORNIA AIR RESOURCES BOARD
P.O. NUMBER: ARB125232
INV NUMBER: 121899
MODEL: 81000 ULTRASONIC ANEMOMETER - 3 AXIS

We hereby certify that the sensor serial number specified above has been calibrated, tested, and found to comply with the following Wind Speed Accuracy Specification from 0 to 30 m/s.

Average wind speed plus standard deviation of wind speed are within 1% +/- 0.5 m/s of a wind speed reference. Data are collected at nominal speeds of 6 and 30 m/s.

Standards established by R. M. Young Company for calibrating the measuring and test equipment used in controlling product quality are traceable to the National Institute of Standards and Technology (NIST).

Date of Certification: 17 May 2013

R. M. Young Company

Ed Chernosky
Quality Assurance

R. M. YOUNG COMPANY 2801 Aero Park Drive, Traverse City Michigan 49686-9171 USA
TEL: (231) 946-3980 FAX: (231) 946-4772 Email: met.sales@youngusa.com

The Certificate of Calibration and Testing will display a date of certification. This date is the actual date the sensor was calibrated and tested by the manufacturer. Based on past sensor performance, amount of sensor usage, acceptable tolerance and manufacturer's recommendations: RM Young has stated ARB may establish a policy that the RM Young Model 81000 3D Sonic **Certificate of Calibration and Testing for ARB operated sensors is effective for TWO years after the date of certification**. However, RM Young recommends that sensors only be actively deployed to field locations for a period of one year.

Figure 12: Certification and Testing Report

Upon receiving a new or recently calibrated sensor, operators should check the certification date on the associated Certificate of Calibration and Testing document. The 3D sonic may be installed in the field anytime during the two year certification period but must not be used more than one year from the date of sensor installation. In addition, the one year field use period must be bracketed by the sensor's two year certification window.

5.0 TROUBLESHOOTING PROCEDURES

The 3D Sonic, having no moving parts, when properly configured is typically problem free and requires little if any maintenance. Most problems associated with the sensor manifest themselves as problems with the data (no data reported, data gaps or abnormal data readings). Most data related problems with the 3D Sonic are the result of improper configurations within CARBLogger and/or DMS. Refer to AQSB SOP 606 to address data issues relating to DMS.

Some common sensor issues field staff may encounter with the 3D Sonic are shown in the table below. In general, the solution to these issues are to inspect the sensor to verify that transducers are clean, all wires and connections are secure and power to the sensor is adequate. In addition, a review of CARBLogger diagnostic e-mails will indicate whether the sensor is generating enough sub-minute data to properly report meteorological data. Should field staff not identify a cause of a 3D Sonic sensor issue, contact ODSS for support.

Issue	Possible Problem(s)
Random missing 1-minute WS, WD or sonic temp data	• Obstructions to sensor's transducers • Poor power to sensor • Loose connections in sensor • Malfunctioning sensor
Large blocks of missing data	• Obstructions to sensor's transducers • Look for evidence of birds on sensor
Momentary or sudden drops in sonic temperature data	• Obstructions to sensor's transducers • Look for evidence of birds on sensor
Abnormal daily increases in WS or sonic Temp data	• Malfunctioning sensor

6.0 ROUTINE SERVICE CHECKS

6.1 Daily (or each time site is serviced) Checks:

Review data logger results from previous day(s) for consistency/believability.

6.2 Weekly Checks:

Visually check the sensor and/or sensor's transducers for physical damage or sensor orientation/alignment changes.

6.3 Monthly Checks:

Perform a visual check of current wind parameters. Estimate or measure wind speed and direction using a portable wind sensor and compare observations to data logger results. Results should be comparable within reason. If results are not comparable within reason, then the sensor should be checked for obstructions or damage and all cables and connections should be checked for problems. If no problems are observed, then the sensor should be replaced and/or sent to the manufacturer for repairs.

6.4 Semi-Annual Checks:

Sensor alignment with respect to True North should be checked. Alignment should be within +/- 5 degrees of true. If not, then sensor should be re-aligned. Sensor should be cleaned with a clean dry cloth and water.

6.5 Annual Checks:

Replace 3D Sonic with certified sensor and return "old" sensor to Operations and Data Support Section. The "new" sensors expiration date is TWO years from date indicated on the Certificate of Certification and Testing for the "new" sensor.

7.0 MAINTENANCE PROCEDURES

7.1 General Information:

Ultrasonic sensors should be checked periodically for any dirt or debris (aviary or insect) and gently cleaned if necessary using a clean dry cloth and water. Also, the sensors should be checked for physical damage to the array assembly, cable and cable connections. All transducers should be inspected to insure they are securely fastened.

Appendix A: Analog connection of RM Young Model 81000 to ESC 88XX Data Logger

Model 81000 sensors are wired directly into the data logger using an 8-conductor shielded cable. Table 1 shows the standard wiring to the sensor.

Table 1: Standard Wiring for Model 81000 Sensors

Connection	Description	Wire Color
V1	Wind Speed	Blue
V2	Wind Direction	Orange
V3	Elevation	Yellow
V4	Sonic Temp.	White
VREF	Common	Brown
+PWR	(+12VDC)	Red
PWR REF	(-12VDC)	Black
GND	Earth Ground	Green



Figure 1: Standard wiring for analog connection

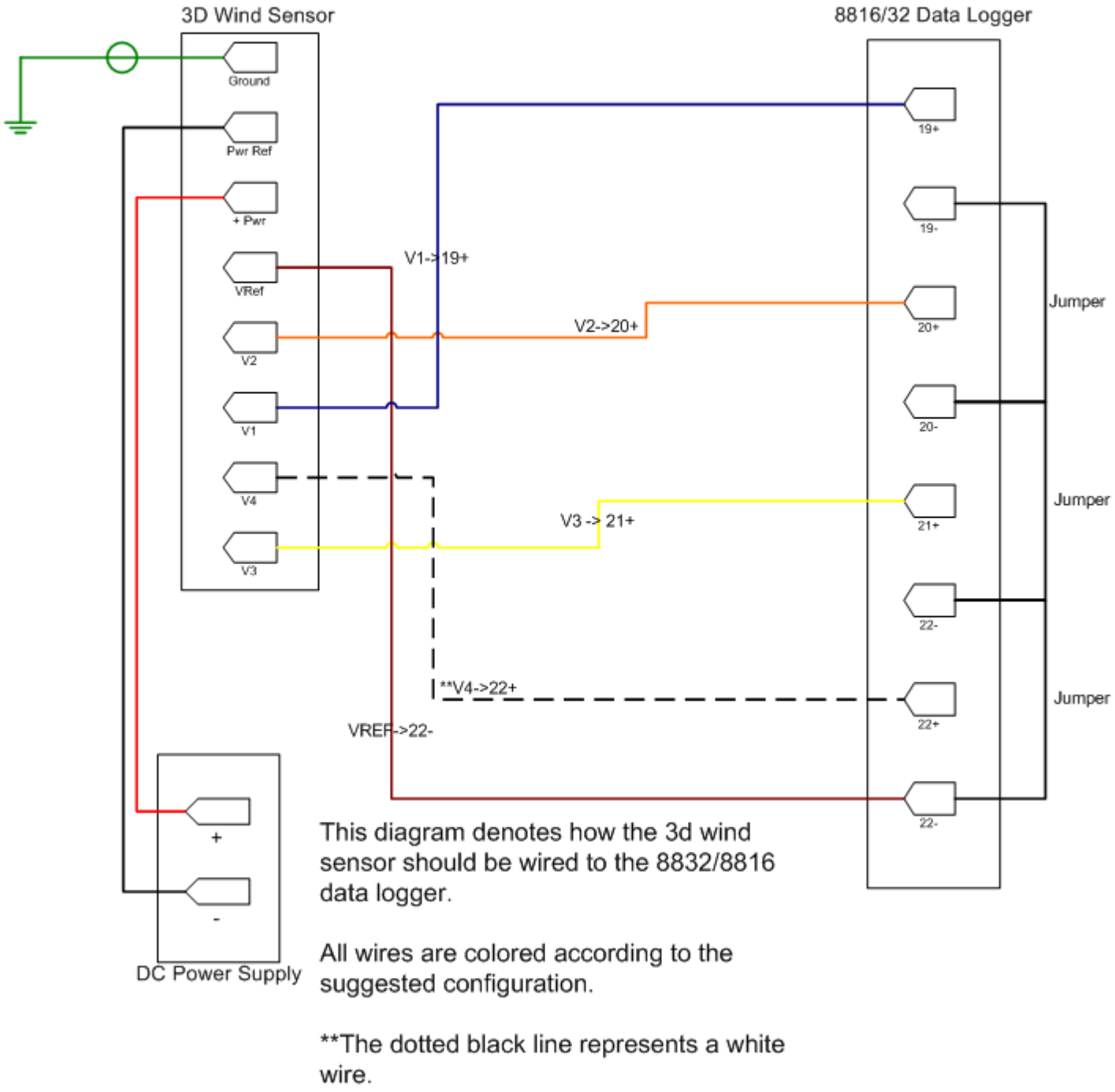


Figure 2: Model 81000 Wiring Diagram.

Appendix B: ESC 88XX Data Logger Channel Configurations for RM Young Model 81000 Anemometers:

The Model 81000 anemometer requires four data logger inputs. The AQSB standard configuration for Model 81000 inputs to the data logger will be as follows:

Table 2. Model 81000 Data Logger Channel Assignments

Channel	Channel Name	Channel Description
19	3DSWS	Scalar Wind Speed
20	3DSWD	Scalar Wind Direction
21	3DSE	Elevation Angle
22	3DST	Sonic Temperature
23	VERTWS	Vertical Wind Speed
24	3DRWS	Resultant Wind Speed
25	3DRWD	Resultant Wind Direction

3D Scalar Horizontal Wind Speed is expressed as:

*3DSWS = (V_{WS} / 5000) * 50 Meters per second*
Where V_{WS} is analog output voltage signal, in millivolts.

3DScalar Horizontal Wind Direction is expressed as:

*3DSWD = (V_{WD} / 5000) * 540 Degrees*
Where V_{WD} is analog output signal in millivolts.

3DElevation Angle in degrees is expressend as:

*3DSE = ((V_{SE} / 5000) * 120) – 60 Degrees*
Where V_{SE} is analog output voltage signal in millivolts.

To convert the Vertical Elevation value to Vertical Wind Speed, take the Tangent of the Angle, and multiply the result by the Horizontal Wind Speed:

*3DSVS = TAN (3DSE) * 3DSWS Meters per second*

As the 8816 / 8832 Data loggers express all Trigonometric functions in Radians, we must first convert Angles in Degrees to Radians:

$\Theta_{Radians} = \theta_{Degrees} * (2\pi / 360)$

So $SE_R = SE_D * 0.01745329$

Therefore:

*3DSVS = TAN (3DSE$_D$ * 0.0175) * 3DSWS Meters per second*

Changing the Slope and Intercept at the SWS Channel configuration to express Horizontal Wind Speed in Knots automatically expresses the Vertical Velocity in a range that must be described as Knots

Sonic Temperature is expressed as:
*3DST = (V_{ST} * 0.02) + 220 Kelvin*
Where V_{ST} is Sonic Temperature analog output in millivolts

Degrees Celsius = (Kelvin – 273.15)

Appendix C: Programming the ESC 8800 Data logger for Model 81000 Sensors

Use the following Channel Configuration setup for the **ESC 8800** series data logger. Channel numbers shown are AQSB defaults, but existing configurations already selected for your site may require selecting other channels. Resultant Wind Speed (channel 24) and Resultant Wind Direction (channel 25) should be programmed into the data logger prior to programming the Scalar Wind Speed (channel 19) and Scalar Wind Direction (channel 20). The RM Young Model 81000 sensor must be set to factory defaults.

Scalar Wind Speed Configuration:
Channel Number: 19
CHANNEL NAME: 3DSWS
CHANNEL TYPE: 3
VECTOR AVERAGING: N
STORE HOURLY AVERAGES: Y
STORE HOURLY SIGMAS: N
STORE HOURLY % VALID: N
STORE HOURLY RANGE: N
STORE AUX AVERAGES: N
CHANNEL UNITS: KTS
VOLTS FULL SCALE: 5.0
SLOPE: 97.2
INTERCEPT: 0
DECIMAL POSITIONER: 0

Scalar Wind Direction Configuration:
Channel Number: 20
CHANNEL NAME: 3DSWD
CHANNEL TYPE: 4
VECTOR AVERAGING: N
STORE HOURLY AVERAGES: Y
STORE HOURLY SIGMAS: N
STORE HOURLY % VALID: N
STORE HOURLY RANGE: N
STORE AUX AVERAGES: N
CHANNEL UNITS: DEG
VOLTS FULL SCALE: 5.0
SLOPE: 540
INTERCEPT: 0
DECIMAL POSITIONER: 0

Elevation Angle Configuration:
Channel Number: 21
CHANNEL NAME: 3DSE
CHANNEL TYPE: 9
VECTOR AVERAGING: N
STORE HOURLY AVERAGES: Y
STORE HOURLY SIGMAS: N
STORE HOURLY % VALID: N
STORE HOURLY RANGE: N
STORE AUX AVERAGES: N
CHANNEL UNITS: DEG
VOLTS FULL SCALE: 5.0
SLOPE: 120
INTERCEPT: -60
DECIMAL POSITIONER: 1

Sonic Temperature Configuration:
Channel Number: 22
CHANNEL NAME: 3DST
CHANNEL TYPE: 9
VECTOR AVERAGING: N
STORE HOURLY AVERAGES: Y
STORE HOURLY SIGMAS: N
STORE HOURLY % VALID: N
STORE HOURLY RANGE: N
STORE AUX AVERAGES: N
CHANNEL UNITS: DEGC
VOLTS FULL SCALE: 5.0
SLOPE: 100
INTERCEPT: 0
DECIMAL POSITIONER: 1

Instructions for setting the Math Pak equation for Vertical Wind Speed determination:

SET EQUATION 1 TAN((C21)*.0175)*C19=

Vertical Wind Speed Configuration:
Channel Number: 23
CHANNEL NAME: VERTWS
CHANNEL TYPE: M
EQUATION NUMBER: 1
STORE HOURLY AVERAGES: Y
STORE HOURLY SIGMAS: N
STORE HOURLY % VALID: N
STORE HOURLY RANGE: N

STORE AUX AVERAGES: N
CHANNEL UNITS: KTS
DECIMAL POSITIONER: 1

Vector Wind Speed Configuration:
Channel Number: 24
CHANNEL NAME: 3DRWS
CHANNEL TYPE: 1
VECTOR AVERAGING: Y
WDR CHANNEL NUMBER: 19
STORE HOURLY AVERAGES: Y
STORE HOURLY SIGMAS: N
STORE HOURLY % VALID: N
STORE HOURLY RANGE: N
STORE AUX AVERAGES: N
CHANNEL UNITS: KTS
VOLTS FULL SCALE: 5.0
SLOPE: 97.2
INTERCEPT: 0
DECIMAL POSITIONER: 0

Vector Wind Direction Configuration:
Channel Number: 25
CHANNEL NAME: 3DRWD
CHANNEL TYPE: 2
VECTOR AVERAGING: Y
WSP CHANNEL NUMBER: 20
STORE HOURLY AVERAGES: Y
STORE HOURLY SIGMAS: N
STORE HOURLY % VALID: N
STORE HOURLY RANGE: N
STORE AUX AVERAGES: N
CHANNEL UNITS: DEG
VOLTS FULL SCALE: 5.0
SLOPE: 540
INTERCEPT: 0
DECIMAL POSITIONER: 0

Appendix D: Programming the ESC 8816/32 for RM Young Model 81000 Sensors

Use the following Channel Configuration setup for the **ESC 8816/32** series data loggers should be used to program the data logger to handle the 3D Sonic outputs in the SPPED_AZIMUTH_ELEVATION fomat. Channel numbers shown are AQSB defaults, but existing configurations already selected for your site may require selecting other channels. 3DRWS (channel 24) and 3DRWD (channel 25) should be programmed into the data logger prior to programming the 3DSWS (channel 19) and 3DSWD (channel 20). The RM Young Model 81000 sensor must be set to factory defaults.

This configuration string configures the data logger to receive the 3D Sonic (V1) channel and store the 3D scalar wind speed on DAS channel 19 in Knots.

ESC 8816 v5.34 ID:99 Wind Speed Config.
Instrument Name : 3DSWS
Report Channel Number : 19
Analog Input Number : 19
Volts Full Scale : 5
High Input : 5 V
Low Input : 0 V
High Output (E.U.s) : 97.2
Low Output (E.U.s) : 0
Units : KTS
Base Avg. Interval, Storage : 1m , 0s
Average #1 Interval, Storage: 15m , 0s
Average #2 Interval, Storage: 1h , 33d 13h
FINISHED (Configure Now) 11/30/07 09:48:39

ESC 8816 v5.34 ID:99 Config. Channel Options
Name (not editable) : 3DSWS
Chl Number (not editable) : 19
Decimal Positioner : 01
Span for Cal Err : (not set)
Round Precision : (none)

This configuration string configures the data logger to receive the 3D Sonic (V2)

channel and store the 3D scalar wind direction on DAS channel 20 in Degrees.

ESC 8816 v5.34 ID:99 Wind Direction Config.
Instrument Name : 3DSWD
Report Channel Number : 20
Analog Input Number : 20
Volts Full Scale : 5
High Input : 5 V
Low Input : 0 V
High Output (E.U.s) : 540
Low Output (E.U.s) : 0
Units : DEG
Base Avg. Interval, Storage : 1m , 0s
Average #1 Interval, Storage: 15m , 0s
Average #2 Interval, Storage: 1h , 33d 13h
FINISHED (Configure Now) 11/30/07 09:50:44

ESC 8816 v5.34 ID:99 Config. Channel Options
Name (not editable) : 3DSWD
Chl Number (not editable) : 20
Decimal Positioner : 01
Span for Cal Err : (not set)
Round Precision : (none)

This configuration string configures the data logger to receive the 3D Sonic (V3) channel and store the elevation angle on DAS channel 21 in degrees.

ESC 8816 v5.34 ID:99 Standard Channel Config.
Instrument Name : 3DSE
Analog Input Number : 21
Report Channel Number : 21
Volts Full Scale : 5
High Input : 5 V
Low Input : 0 V
High Output (E.U.s) : 60
Low Output (E.U.s) : -60
Units : DEG
Base Avg. Interval, Storage : 1m , 0s
Average #1 Interval, Storage: 15m , 0s
Average #2 Interval, Storage: 1h , 33d 13h
Use 40CFR75 Validation (Y/N): N
FINISHED (Configure Now) 11/30/07 09:53:04

ESC 8816 v5.34 ID:99 Config. Channel Options
Name (not editable) : 3DSE
Chl Number (not editable) : 21
Decimal Positioner : 01
Span for Cal Err : (not set)
Round Precision : (none)

This configuration string configures the data logger to receive the 3D Sonic (V4) channel and store the sonic temperature on DAS channel 22 in degrees Celsius.

ESC 8816 v5.34 ID:99 Standard Channel Config.
Instrument Name : 3DST
Analog Input Number : 22
Report Channel Number : 22
Volts Full Scale : 5
High Input : 5 V
Low Input : 0 V
High Output (E.U.s) : 46.85
Low Output (E.U.s) : -53.15
Units : DEGC
Base Avg. Interval, Storage : 1m , 0s
Average #1 Interval, Storage: 15m , 0s
Average #2 Interval, Storage: 1h , 33d 13h
Use 40CFR75 Validation (Y/N): N
FINISHED (Configure Now) 11/30/07 10:03:33

ESC 8816 v5.34 ID:99 Config. Channel Options
Name (not editable) : 3DST
Chl Number (not editable) : 22
Decimal Positioner : 01
Span for Cal Err : (not set)
Round Precision : (none)

This configuration string configures the data logger calculate the vertical wind speed from the elevation angle channel and store the vertical wind speed on DAS channel 23 in Knots.

ESC 8816 v5.34 ID:99 Math Channel Configuration
Instrument Name : VERTWS
Report Channel Number : 23
Equation : TAN(3DSE*0.01745329)*3DSWS
Units : KTS
Base Avg. Interval, Storage : 1m , 0s
Average #1 Interval, Storage: 15m , 0s
Average #2 Interval, Storage: 1h , 33d 13h
Round Constituents (Y/N) : N
Use 40CFR75 Validation (Y/N): N
FINISHED (Configure Now) 11/30/07 10:07:35

ESC 8816 v5.34 ID:99 Config. Channel Options
Name (not editable) : VERTWS
Chl Number (not editable) : 23
Decimal Positioner : 01
Span for Cal Err : (not set)
Round Precision : (none)

This configuration string configures the data logger calculate the 3D resultant wind speed from the 3D scalar wind speed channel and store the 3D RWS on DAS

channel 24 in Knots.

ESC 8816 v5.34 ID:99 Vector Wind Speed Config
Instrument Name : 3DRWS
Report Channel Number : 24
WDR Input Number : 20
WDR Volts Full Scale : 5
WDR High Input : 5 V
WDR Low Input : 0 V
WDR High Output (E.U.s) : 540
WDR Low Output (E.U.s) : 0
WSP Input Number : 19
WSP Volts Full Scale : 5
WSP High Input : 5 V
WSP Low Input : 0 V
WSP High Output (E.U.s) : 97.2
WSP Low Output (E.U.s) : 0
Units : KTS
Base Avg. Interval, Storage : 1m , 0s
Average #1 Interval, Storage: 15m , 0s
Average #2 Interval, Storage: 1h , 33d 13h
FINISHED (Configure Now) 11/30/07 10:11:27

ESC 8816 v5.34 ID:99 Config. Channel Options
Name (not editable) : 3DRWS
Chl Number (not editable) : 24
Decimal Positioner : 01
Span for Cal Err : (not set)
Round Precision : (none)

This configuration string configures the data logger calculate the 3D resultant wind direction from the 3D scalar wind direction channel and store the 3D RWD

on DAS channel 25 in degrees.

```
ESC 8816 v5.34  ID:99       Vector Wind Direction Config
   Instrument Name           :  3DRWD
   Report Channel Number      :  25
   WDR Input Number           :  20
   WDR Volts Full Scale       :  5
   WDR High Input             :  5 V
   WDR Low Input              :  0 V
   WDR High Output (E.U.s)    :  540
   WDR Low Output (E.U.s)     :  0
   WSP Input Number           :  19
   WSP Volts Full Scale       :  5
   WSP High Input             :  5 V
   WSP Low Input              :  0 V
   WSP High Output (E.U.s)    :  97.2
   WSP Low Output (E.U.s)     :  0
   Units                      :  DEG
   Base Avg. Interval, Storage :  1m  , 0s
   Average #1 Interval, Storage:  15m , 0s
   Average #2 Interval, Storage:  1h  , 33d 13h
   FINISHED (Configure Now)      11/30/07 10:13:25

ESC 8816 v5.34  ID:99       Config. Channel Options
   Name (not editable)        :  3DRWD
   Chl Number (not editable)  :  25
   Decimal Positioner         :  01
   Span for Cal Err           :  (not set)
   Round Precision            :  (none)
```

This configuration string configures the data logger calculate the hourly sigma of the 3D scalar wind speed from store the hourly sigma on DAS channel 26 in Knots.

```
ESC 8816 v5.34  ID:99       Sigma Channel Config.
   Instrument Name           :  SIG3DSWS
   Report Channel Number     :  26
   Analog Input Number       :  19
   Volts Full Scale          :  5
   High Input                :  5 V
   Low Input                 :  0 V
   High Output (E.U.s)       :  97.2
   Low Output (E.U.s)        :  0
   Units                     :  kts
   Base Avg. Interval, Storage :  1m  , 0s
   Average #1 Interval, Storage:  15m , 0s
   Average #2 Interval, Storage:  1h  , 33d 13h
   FINISHED (Configure Now)      03/12/08 14:29:57

ESC 8816 v5.34  ID:99     Config. Channel Options
   Name (not editable)       :  SIG3DSWS
   Chl Number (not editable)  :  26
   Decimal Positioner        :  01
   Span for Cal Err          :  (not set)
   Round Precision           :  (none)
```

This configuration string configures the data logger calculate the hourly sigma of the 3D scalar wind direction and store the hourly sigma on DAS channel 27 in Knots.

```
ESC 8816 v5.34  ID:99      Sigma Channel Config.
   Instrument Name           :  SIG3DSWD
    Report Channel Number      :  27
    Analog Input Number        :  20
    Volts Full Scale           :  5
    High Input                 :  5 V
    Low Input                  :  0 V
    High Output (E.U.s)        :  540
    Low Output (E.U.s)         :  0
    Units                      :  deg
    Base Avg. Interval, Storage :  1m  , 0s
    Average #1 Interval, Storage:  15m , 0s
    Average #2 Interval, Storage:  1h  , 33d 13h
    FINISHED (Configure Now)      03/12/08 14:31:37

ESC 8816 v5.34  ID:99     Config. Channel Options
    Name (not editable)        :  SIG3DSWD
    Chl Number (not editable)  :  27
    Decimal Positioner         :  00
    Span for Cal Err           :  (not set)
    Round Precision            :  (none)

          .
```

Appendix E: Monthly Maintenance Check Sheet for Ultrasonic Anemometers.

CALIFORNIA AIR RESOURCES BOARD
MONTHLY QUALITY MAINTENANCE CHECKSHEET
ULTRASONIC ANEMOMETERS

Location:_____ Month/Year:_____

Station Number:_____ Operator: _____

Property Number:_____ Agency:_____

OPERATOR'S INSTRUCTIONS:

1) Daily Checks: Review data logger results from previous day for consistency.

2) Weekly Checks: Visually check sensor, cables, met tower etc. for physical damage. Visually inspect sensor orientation/alignment.

3) Monthly Checks: Perform a visual check of current wind parameters. Estimate wind speed and direction and compare observations to data logger results. If results not within reason, then check for obstructions or damage. Check cables and connections for problems.

4) Semi-Annual Checks: Check sensor for alignment with respect to true north. If alignment is not within +/- 5 degrees of True, re-align sensor.

5) Annual Checks: Replace sensor and return to Operations and Data Support.

Sensor certification and testing date:_____

Sensor certification expiration date:_____

Sensor site installation date:_____

Date	Comments or Maintenance Performed

Reviewed by:_____ Date:_____

AQSB QC Form 506 (RM Young Model 81000) Jan 2017

Appendix F: RM Young Calibration Frequency Memo

R.M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA

1 October 2016

To Whom It May Concern

Subject: Frequency of Calibration for R.M. Young Company Manufactured Products

Unless otherwise stated in instruction manuals R.M. Young Company recommends a calibration frequency of one year from the date of previous calibration or from sensor installation date for all sensors manufactured/calibrated at our facility. This calibration frequency may be affected due to local governing bodies, amount of sensor usage, and the acceptable tolerance based on customer's requirements. We suggest that a recalibration not exceed one year from the date of installation or two years from the date of previous calibration.

Please feel free to contact us should you have further questions.

Sincerely,

Andy Oliver
Sales Manager

METEOROLOGICAL INSTRUMENTS
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