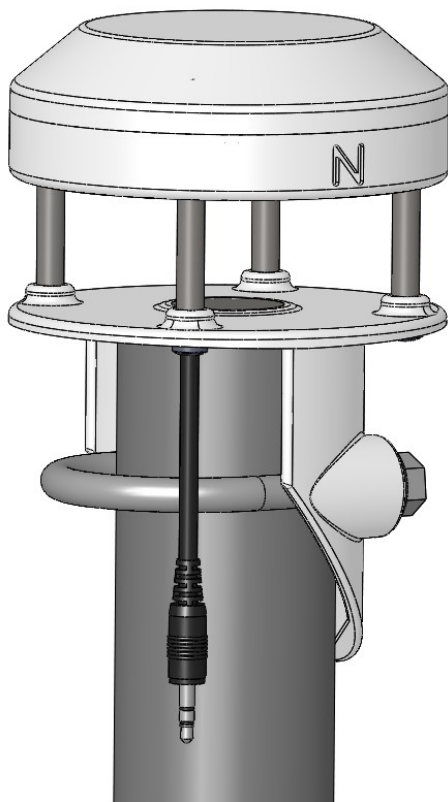


# DS-2

## Sonic Anemometer

Operator's Manual



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# 1 Introduction

Thank you for choosing Decagon's DS-2 Sonic Anemometer for measuring wind speed and direction. This manual will help you understand your instrument features and how to use this device successfully.

## 1.1 Customer Support

If you ever need assistance with your DS-2 or have any questions or feedback, there are several ways to contact us. Decagon has customer service representatives available to speak with you Monday through Friday, between 7 am and 5 pm Pacific time.

*Note: If you purchased your anemometer through a distributor, please contact them for assistance.*

Email:

**support@decagon.com** or **sales@decagon.com**

Phone:

509-332-5600

Fax:

509-332-5158

If contacting us by email or fax, please include as part of your message your instrument serial number, your name, address, phone, fax number, and a description of your problem or question.

## 1.2 About This Manual

Please read these instructions before operating your instrument to ensure that it performs to its full potential.

### 1.3 Warranty

The sensor has a 30-day satisfaction guarantee and a one-year warranty on parts and labor. Your warranty is automatically validated upon receipt of the instrument.

### 1.4 Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from the date of receipt of equipment.

*Note: We do not consider the results of ordinary wear and tear, neglect, misuse, or accident as defects.*

The Seller's liability for defective parts shall in no event exceed the furnishing of replacement parts "freight on board" the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitutes Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise (including, but without limitation, the implied warranties of merchantability and fitness for a particular purpose), not expressly set forth herein.

### 1.5 About DS-2

Decagon designed the DS-2 Sonic Anemometer to measure wind speed, direction, and even wind gusts. It is a two dimensional ultrasonic anemometer with no moving parts that provides specified

accuracy for long-term installations. It outputs SDI-12, and is compatible with Decagon's Em50, Em50R, Em50G, and other loggers like those from Campbell Scientific.

## 1.6 Specifications

Wind Speed Range: 0 to 30 m/s

Wind Speed Resolution: 0.01 m/s

Wind Speed Accuracy: 0.30 m/s or  $< 3\%$ , whichever is larger

Wind Direction Range: 0 to 359 degrees

Wind Direction Resolution: 1 degree

Wind Direction Accuracy:  $\pm 3$  degrees

Operating Temperature Range:  $-40$  to  $50$  °C

Excitation Voltage: 3.6 to 15 VDC

Current: 0.03 ma quiescent, 0.5 ma; sampling,  $< 0.05$  ma typical

Communication: SDI-12

Diameter: 100 mm

Height (wind sensor): 75 mm

Height (total w/ mount): 155 mm

Maximum sampling speed<sup>1</sup>: 1 Hz

Output<sup>1</sup>: average speed, gust speed, direction, or vector

Connector types: 3.5 mm (stereo) plug or stripped & tinned lead wires (Pigtail)

Cable Length: Standard is 5 m, though we have custom cable lengths available upon request

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<sup>1</sup>If sampling rate is greater than 0.1 Hz, the anemometer reports the speed and direction at the time of sampling. If sampled less frequently, the anemometer samples every 10 seconds, averages the vector components of the wind, and keeps the maximum gust. When the logger samples, the anemometer reports the average wind speed, direction, and the maximum gust speed.

## 2 Theory

The theory behind the sonic anemometer comes from Campbell and Unsworth (1979).<sup>2</sup> The speed  $c(m/s)$  of sound in still air depends on air temperature  $T(K)$ , vapor pressure  $e(kPa)$  and atmospheric pressure,  $p(kPa)$ , as seen in equation 1.

$$c = 20.067 \sqrt{T \left( 1 + \frac{0.32e}{p} \right)} \quad (1)$$

For a given sound path length,  $d$  (m), the number of wavelengths,  $n$  in still air is determined with equation 2.

$$n = \frac{\nu d}{c} \quad (2)$$

Here  $\nu$  is the frequency of the sound (Hz). When the air is moving, the sound speed is the sum of the wind speed and the speed of sound in still air. The anemometer transmits a sound pulse in a forward direction, and a similar pulse in the reverse direction, and computes the difference in  $n$  between the two. If the vector magnitude of the wind in the direction of the sound is  $u(m/s)$ , then:

$$\begin{aligned} n - \Delta n_+ &= \frac{\nu d}{c + u} \\ n - \Delta n_- &= \frac{\nu d}{c - u} \end{aligned} \quad (3)$$

for sound traveling with and against the wind. Subtracting the first from the second equation we obtain:

$$\Delta n = \Delta n_- - \Delta n_+ = \frac{2\nu d u}{c^2 - u^2} \quad (4)$$

Even at the maximum wind speeds for the anemometer,  $u^2$  is only about 1% of  $c^2$ , so for a good approximation write.

$$u \cong \frac{c^2}{2\nu d} \Delta n \quad (5)$$

---

<sup>2</sup>Cambell, G.S. and M.H. Unsworth (1979) An inexpensive sonic anemometer for eddy correlation. J. Appl. Meteor. 18:1072-1077.

This is the basic equation for the anemometer.  $\Delta n$  is proportional to the phase difference between the forward and reverse sound pulses. The sound comes from a 40 kHz ultrasonic transducer in the head of the anemometer. It is transmitted diagonally across the anemometer, bouncing off of a stainless steel disk in the center, and is received by another transducer in the anemometer head that is opposite the first. Once the sound pulse is received, the receiver becomes the transmitter and the process is repeated. Two more sensors, mounted at 90 degrees from the first two give the other horizontal component of the wind. The sound travels a total distance of about 72 mm from transmitter to receiver, but  $d$  in the equations is just the horizontal distance, which is 40 mm.

If we take  $u$  as the magnitude of the wind vector in the east-west direction (east +) and  $v$  as the magnitude in the north-south direction (north +), then compute wind speed with equation 6.

$$S = \sqrt{\overline{u^2} + \overline{v^2}} \quad (6)$$

Where the overbar indicates an average of the values sampled every ten seconds. Compute wind direction with equation 7.

$$\theta = \tan^{-1}(\overline{v}/\overline{u}) \quad (7)$$

The wind measurement requires 42 ms to complete. An additional 60 ms are required for the computations to determine phase differences. The anemometer samples every 10 seconds (or more often if requested). The gust speed reported is the highest instantaneous wind speed measured during the selected averaging interval. Cup anemometers average over a much longer interval than 42 ms, so the gusts measured with a sonic anemometer will have a larger peak to mean ratio than one would see with a cup anemometer.



### 3 Connecting the Anemometer

The DS-2 Sonic Anemometer is most easily used with Decagon's Em50, Em50R, and Em50G loggers (firmware version 2.11 or later).

*Note: The DS-2 requires continuous excitation, which is only available on Em50 loggers with serial numbers above EM20,000 and Em50G loggers above 5GOB1000. Please contact Decagon support if you need more information.*

They can also be used with other data loggers, such as those from Campbell Scientific, Inc. The DS-2 requires an excitation voltage in the range of 3.6 to 15 volts.

To download data to your computer from an Em50 logger, you will need to install ECH<sub>2</sub>O Utility or DataTrac 3 on your computer. The following software supports the DS-2 sensor:

Em50 Firmware version 2.11 or greater

ECH<sub>2</sub>O Utility 1.67 or greater

DataTrac 3.8 or greater

ProCheck hardware revision 'C' with firmware version 1.5.1

*Note: Please check your software version to ensure it will support the DS-2. To update your software to the latest versions, please visit Decagon's support site: <http://www.decagon.com/support/>.*

To use the DS-2 with your Em50 data logger, simply plug the stereo plug into one of the five ports on the data logger and use either ECH<sub>2</sub>O Utility, or DataTrac 3 software (see respective manuals) to configure that port for the DS-2 and set the measurement interval.

The Em50 and Em50R data loggers only allow logging at one minute intervals and the Em50G data loggers allow logging at five minute intervals. For any measurement made at frequencies longer than 10 seconds, the DS-2 will report 10 second averages. Thus, when using an Em50 or Em50R logging at one minute intervals, each reported value will be the average of six, 10 second averages from the instrument. When using an Em50G at five minute intervals, each reported

value will be the average of 30, 10 second averages. If customers desire temporal resolutions finer than one minute or wish to obtain samples without averages at frequencies of one to nine seconds, then they must use a Campbell Scientific or similar logger.

### 3.1 3.5 mm Stereo Plug Wiring

DS-2 anemometers, used with Decagon loggers, come with a 3.5 mm stereo plug connector.(Figure 1 and 2) The stereo plug allows for rapid connection directly to Decagon's Em50 Series data loggers. Figure 3 shows the wiring configuration for this connector.



Figure 1: 3.5 mm Stereo Plug

### 3.2 Connecting to a Non-Decagon Logger

DS-2 Anemometers may be purchased for use with non-Decagon data loggers. These sensors typically come configured with stripped and tinned (pigtail) lead wires for use with SDI BUS terminals.(Figure 2 Refer to your particular logger manual for details on wiring. Our integrator's guide gives detailed instructions on connecting the DS-2 to non-Decagon loggers. Please visit <http://www.decagon.com/support> for the complete integrator's guide.

### 3.3 Pigtail End Wiring



Figure 2: Pigtail End Wiring

DS-2 sensors with the stripped and tinned cable option can be made with custom cable lengths (up to 305 meters) on a per meter fee basis. This option gets around the need for splicing wire (a possible failure point). Connect the wires to the data logger as shown, with the supply wire (white) connected to the excitation, the digital out wire (red) to a digital input, the bare ground wire to ground as seen in Figure 2.

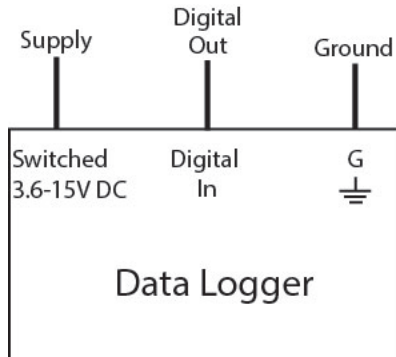


Figure 3: Wire Connections Diagram

*Note: The acceptable range of excitation voltages is from 3.6 to 15 VDC. If customers wish to read the DS-2 with Campbell Scientific Data Loggers, then you will need to power the sensors from a 12 V or switched 12 V port.*

If your DS-2 is equipped with the standard 3.5 mm plug, and you

wish to connect it to a non Decagon data logger, you have two options. First, you can clip off the plug on the sensor cable, strip and tin the wires, and wire it directly into the data logger. This has the advantage of creating a direct connection with no chance of the sensor becoming unplugged; however, it then cannot be easily used in the future with a Decagon data logger.

The other option is to obtain an adapter cable from Decagon. The 3-wire sensor adapter cable has a connector for the sensor jack on one end, and three wires on the other end for connection to a data logger (this is referred to as a “pigtail” adapter). Both the stripped and tinned adapter cable wires have the same termination as Figure 3; the white wire is excitation, red is data output, and the bare wire is ground.

*Note: Be extra careful to secure your stereo-to-pigtail adapter connections to ensure that your sensors do not become disconnected during use.*

## 4 Communication

The DS-2 Sonic Anemometer communicates using SDI-12 protocol. This chapter discusses the specifics of this method. For more information, please visit <http://www.decagon.com/support> for the complete integrators guide, which gives more detailed explanations and instructions.

### 4.1 SDI-12 Communication

The DS-2 Sonic Anemometer communicates using the SDI-12 protocol, a three-wire interface where all sensors are powered (white wire), grounded (bare wire), and communicate (red wire) on shared wires (for more info, go to [www.sdi-12.org](http://www.sdi-12.org)). There are some positive and negative elements of this protocol. On the positive side, multiple sensors can be connected to the same voltage supply and communication port on the data logger. This simplifies wiring because no multiplexer is necessary. On the negative side, one sensor problem can bring down the entire array (through a short circuit, etc.). To avoid this problem, we recommend the user make an independent junction box with wire harnesses where all sensor wires are connected to wire lugs so sensors can be disconnected if a problem arises. A single three-wire bundle can be run from the junction box to the data logger.

The SDI-12 protocol requires that all sensors have a unique address. DS-2 anemometers come from the factory with an SDI-12 address of 0. To add more than one SDI-12 sensor to a system, the sensor address must be changed to some value other than zero and all sensors on the bus must have unique addresses. Address options include {1..9, A..Z, a..z}.

There are two ways to set the SDI-12 sensor address. The best and easiest is to use Decagon's ProCheck (if the option is not available on your ProCheck, please upgrade to the latest version of firmware). SDI-12 addressing can be accessed in the "CONFIG" menu by selecting "SDI-12 Address" and pressing Enter. To change the SDI-12 address, press the up and down arrows until you see the desired

address and push Enter. SDI-12 communication allows many parameters to be communicated at once, so you can also see things like the sensor model, SDI-12 version, etc.

SDI-12 communication is also supported by Campbell Scientific data loggers like the CR10X, CR1000, CR3000, etc. Direct SDI-12 communication is supported in the “Terminal Emulator” mode under the Tools menu on the Connect screen. Detailed information on setting the address using CSI data loggers can be found on our website at <http://www.decagon.com/support/downloads/>.

Users can power the sensor using any voltage from 3.6 to 15 VDC. The SDI-12 protocol allows the sensors to be continuously powered, and we recommended that the power (white wire) be connected to a continuous 3.6 to 15 VDC source. The sensor can also be used with a switched power source to allow the sensor array to be reset if a problem arises, but the anemometer needs to be continuously powered so that it will sample at 10 second intervals and retain the gust speeds. Reading the DS-2 anemometer in SDI-12 mode using a CSI data logger requires a function call. An example program from Edlog and CRBasic can be found in the software section of <http://www.decagon.com/support/>.

Commands to which the DS-2 responds are:

R0 (or D0) returns average wind speed (m/s), wind direction (degrees) and air temperature (C). A typical R0 query is:

```
?R0!0+1.10+357+23.6
```

R3 (or D3) returns the average vector components of the wind (m/s) and the maximum gust speed since the last interrogation. A typical query is:

```
?R3!0 0.04 0.00 0.04
```

```
-.
```

The underscore at the end of R3 is an anemometer identifier. the period is a checksum, so changes depending on the output.

## 4.2 Campbell Scientific Programs

The DS-2 Sonic Anemometer is a SDI-12 compatible sensor. This makes programming for the sensor in CRBasic or Edlog straightforward. Simply choose the SDI-12 Recorder command and input the necessary parameters. As mentioned earlier, the sensor outputs three values, so be sure to define your array size as 3 in CRBasic (i.e. Public DS-2(3)) or leave room for two more parameters after your “Loc” call in Edlog. Example programs can be found at <http://www.decagon.com/support>.

## 5 Installing the DS-2

### 5.1 Attaching and leveling

The DS-2 is fitted with a U-bolt, allowing it to be mounted atop most posts, poles, tripods, etc. Depending on the application, the DS-2 should be mounted two to three meters above ground.

#### 5.1.1 Adjustable Length Pole

A telescoping pole is available for purchase to use with the DS-2. The pole consists of two tubes, which can be adjusted out to a length of approximately 2.38 meters. The large, outer tube has a diameter of approximately 5 cm, whereas the inner tube is approximately 4.5 cm in diameter.

Be sure to secure the telescoping pole to the ground by either auguring a hole (we recommend .6 m, or 2 foot depth, minimum), or by using the included base, anchors, and guy-wires.

#### 5.1.2 Leveling

You will need to adjust the anemometer so that it is level. Use a bubble level or other leveling device to ensure the anemometer is level(leveling device not included).

### 5.2 Orientation

For accurate wind direction measurements the DS-2 must be properly oriented. An N engraved on the side of the anemometer indicates which side of the sensor to point north. Be sure to direct the anemometer toward true north, not magnetic north.



### 5.3 Cleaning and Maintenance

Occasionally, the anemometer might become subject to interference from the environment. This could be due to miscellaneous environmental, animal or insect made debris. It is a good idea to check the anemometer every 1.5 to 2 months to ensure it is clear of such debris. You do not need to remove the anemometer from its mount to remove debris. Do take caution, however, to ensure that the sensor is oriented north, and that it is still level.

To clean the anemometer, take a warm damp cloth and scrub with light to medium pressure. Do not immerse the anemometer in water. After scrubbing with a damp cloth, use a dry cloth to remove excess water and completely dry the sensor.

*Note: Do not allow water to enter the sensors in the head, water will ruin them.*

### 5.4 Calibration

The anemometer calibration is based on fundamental physical principles and does not change with use. Recalibration should therefore not be necessary.

## 6 Troubleshooting

### **Problem #1: Sensor not responding:**

- Check power to the sensor
- Check sensor cable and 3.5 mm plug integrity
- Check data logger wiring to ensure

White - 3.6 to 15 V supply

Red - Digital out

Bare - Ground

If sensor does not respond, use the Pro-Check to make sure it is working satisfactorily.

## 7 Declaration of Conformity

Application of Council Directive:	2004/108/EC and 2011/65/EU
Standards to which conformity is declared:	EN 61326-1:2013 and EN 50581:2012
Manufacturer's Name:	Decagon Devices, Inc 2365 NE Hopkins Ct. Pullman, WA 99163 USA
Type of Equipment:	Wind speed and direction sensor
Model Number:	DS-2
Year of First Manufacture:	2012

This is to certify that the DS-2 anemometer, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

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