F-Series Air Velocity Sensors
User Guide

DEGREE CONTROLS, INCORPORATED

18 Meadowbrook Drive

Milford, New Hampshire 03055 USA

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1   General Information

1.1   Overview

Thank you for your purchase of a DegreeC F-Series Sensor, a versatile and rugged, high-performance air velocity and temperature sensor with both analog and digital communication outputs.

Designed with conformal coated electronics and sealed enclosure, our F-series products are suitable for demanding applications, including those in corrosive or alkaline environments. With their robust, splash proof design and UV tolerant construction, the F-Series sensors are designed to handle a wide range of product and process control air flow applications. Additionally, the F-Series is configured to order, with a variety of velocity ranges, mechanical lengths, mounting option, and output communication styles available.

1.2   Features

1.2.1   Mechanical Features

- Two available mounting styles: Standard clamp or special gland fitting used for mounting sensor assembly, without need for screws, or hands inside the duct.
- Optimized flow geometry with segregation of velocity and temperature elements for highest accuracy.
- Aerodynamic cross section to minimize flow disturbance.
- Robust, sealed probe assembly uses corrosion and UV resistant materials.
- Printed insertion depth markers and flow direction arrow.
- Conformal coated sensing elements for environmental protection.
- Plenum-rated cabling suitable for HVAC, laboratory and process control applications.
- Remote head models available for compact applications or design-in embedded sensing needs.
- RoHS compliant
- Certified European (CE)

1.2.2   Electrical & Performance Features

- Industry-leading air velocity performance, with repeatability within ±1%.
- ±1°C temperature accuracy with repeatability within ±1°C.
- Quick Average velocity feature for fastest control system response.
- Best-in-class acceptance angle performance.
- Wide voltage input options 4.5 – 15 VDC, 19 – 29 VDC, or 22 – 26 V AC/DC.
- Multiple digital outputs available.
- Multi-sensor addressing capability.
- Intelligent, built-in customizable averaging/smoothing functions.
- <10 second start-up time and 400ms response time.

2 Product Specifications

2.1 General Specifications

Operating Temperature	0°C to 60°C (32°F to 140°F), **-10°C to 60°C (14°F to 140°F)***
Storage Temperature	-40°C to 105°C (-40°F - 221°F)
Air Velocity Range	Configurable, 0.15 m/s – 20 m/s (30 fpm – 4000 fpm)
Relative Humidity	5 – 95%
Acceptance Angle	± 30°
Repeatability	± 1% of reading (under identical conditions)
Temperature Accuracy	± 1°C**
Response Time	400ms
Airflow Averaging Time	Configurable (3 second default)
Start-up Time	<10 s
Alarm Output	Open drain, configurable trip point
Communication	I^2C (400KHz) or 3.3V UART
Cable Length	2 m (6 ft.)
Housing Construction	Polycarbonate (PC), UL94-V0 (head), UL94-HB (housing)
Plenum Rated Cable	22 AWG
Environmental Protection	IP65 electronics, including conformal coated sensing element
Standard Dimension	Selectable lengths **(See Section 2.3, Length)**

**A wider operating temperature range is possible with the F500 and F550 models only.*

***The air velocity sensor uses a hot bead algorithm, and at low velocities, the error in air temperature measuring grows due to self-heating effects. The air temperature accuracy is specified as a function of velocity:*
at velocities > 0.5 m/s [100 fpm] = ±1 °C [1.8 °F]
at velocities < 0.5 m/s [100 fpm] = ±2 °C [3.6 °F]

Repeatability ± 1% of reading (under identical conditions)

Air Velocity Range	Air Velocity Accuracy*
0.15 to 1.0 m/s (30 to 200 fpm)	± (1% of reading + 0.05 m/s [10 fpm])
0.5 to 10 m/s (100 to 2,000 fpm)	± (4% of reading + 0.10 m/s [20 fpm])
1.0 to 20 m/s (200 to 4,000 fpm)	± (5% of reading + 0.15 m/s [30 fpm])

*within compensation range

Temperature Compensation: The F-Series Air Velocity Sensor is a thermal airflow sensor; it is sensitive to changes in air density and measures velocity with reference to a set of standard conditions (21°C (70°F), 760mmHg (101.325kPa), and 0%RH). The F-Series Sensor has been designed and calibrated to automatically compensate for temperature effects up to 60°C.

2.2   Model Specifications

Degree Controls offers three models of the F-Series Air Velocity Sensor. The choice of model depends on the user's voltage range and current requirements, as noted below:

Name	Input Voltage Range	Current Consumption
F300	4.5 – 15 VDC	< 35mA nominal
F400	19 – 29 VDC	< 15mA nominal
F500	22 – 26 VDC/VAC	< 75mA nominal

Model Specifications Table 1: Input Voltage Range & Current Consumption

2.3   Hardware Configuration

	F300	F400	F500
Length	1 = 152mm [6.0"] max insertion depth = 110 mm [4.3"] 2 = 211mm [8.3"] max insertion depth = 169 mm [6.7"] 3 = 287mm [11.3"] max insertion depth = 245 mm [9.6"]	1 = 114mm [4.5"] max insertion depth = 72 mm [2.8"] 2 = 152mm [6.0"] max insertion depth = 110 mm [4.3"] 3 = 211mm [8.3"] max insertion depth = 169 mm [6.7"] 4 = 287mm [11.3"] max insertion depth = 245 mm [9.6"]	1 = 183mm [7.2"] max insertion depth = 140 mm [5.5"] 2 = 287mm [11.3"] max insertion depth = 245 mm [9.6"]
Velocity Profile	A = 0.15 to 1.0 m/s (30 to 200 fpm) B = 0.5 to 10 m/s (100 to 2,000 fpm) C = 1.0 to 20 m/s (200 to 4,000 fpm)		
Output Configuration	1 = 0 – 5 VDC air velocity output 2 = 0 – 5 VDC air temperature output 3 = 0 – 5 VDC air velocity and air temperature (dual outputs) 4 = 0 – 10 VDC air velocity output 5 = 0 – 10 VDC air temperature output		1 = 0 – 5 VDC air velocity output 2 = 0 – 5 VDC air velocity and air temperature (dual outputs) 3 = 0 – 10 VDC air velocity output 4 = 0 – 10 VDC air velocity

6 = 0 – 10 VDC air velocity and air temperature (dual outputs)	and air temperature (dual outputs)
7 = UART communication output	5 = 0 - 20 mA air velocity
8 = I^{2}C (3.3 VDC) communication output (addressing available)	6 = 0 - 20 mA air velocity and air temperature (dual outputs)
	7 = 4-20 mA air velocity
	8 = 4-20 mA air velocity and air temperature (dual outputs)
	9 = UART communication

Hardware Configuration Table 1: Ordering Information

3   Wiring Information

3.1   Configured with Dual Analog Output and UART Digital Communication

Wire Color	Wire Gauge	Description
Red		Power
Black		Ground
White		Velocity Analog Output
Green	22 AWG	Temperature Analog Output
Orange		UART Receive (RX)
Blue		UART Transmit (TX)
Brown*		Open Drain Alarm*

*While the F300, F400, and 500 can be configured as open drain switches; please see the Switch Series manual for purpose-built airflow switches.

3.2   Configured Only with UART Output

Wire Color	Wire Gauge	Description
Red		Power
Black	22 AWG	Ground
White		UART Receive (RX)
Green		UART Transmit (TX)

3.3   Configured Only with I^{2}C Output

Wire Color	Wire Gauge	Description
Red		Power
Black	22 AWG	Ground
White		SCL
Green		SDA

Caution:

The F300/400/500 sensors **do not** have polarity protection. **Do not** connect positive voltage to ground lead.

Notes:

1. For I^{2}C communication, external pull-up resistors to +3.3V for SDA and SCL are required. The F400 does not have internal pull-up resistors.
2. For RS232 communication, an external level shifter is required to convert 3.3V TTL to RS232 voltage levels. The F400 RX and TX signals are 3.3V TTL.

4   Mechanical Information

4.1   Probe Sensor Head Mechanical Drawing
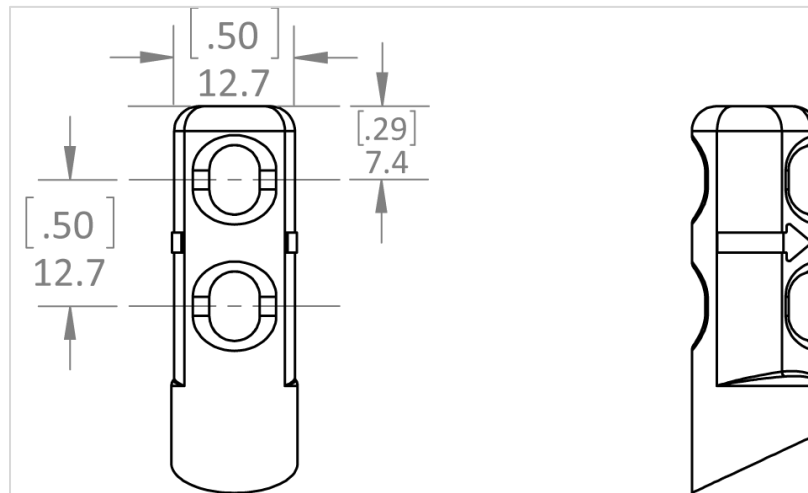
**Mechanical Figure 1: F-Series Sensor Head
(Directional)**

4.2   °C Clamp Mechanical Drawing
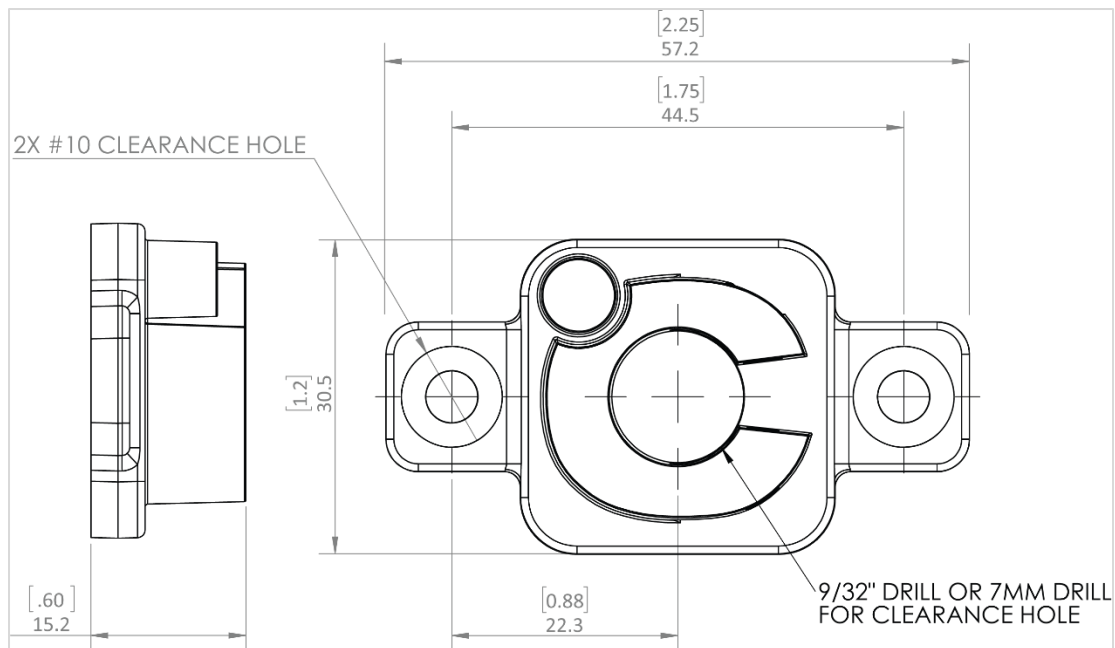
Mechanical Figure 2: °C Clamp

4.3   Remote Head Sensor

| Remote Extension to Sensor Head 1m (3') | Housing Length 197mm (7.75") | Cable Length 2m (6') |
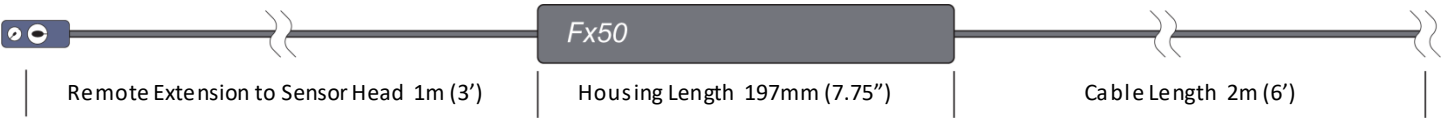
Mechanical Figure 3: F350/F450/F550 Tube & Wire Dimensions

6.5mm (1/4")

22mm (7/8")
Plastic .135 thick

5mm (1/5")

20mm (13/16")
Plastic .024 thick
Bead .065-.072 thick

4mm (1/6")

20mm (13/16")
Plastic .024 thick
Bead .065-.072 thick
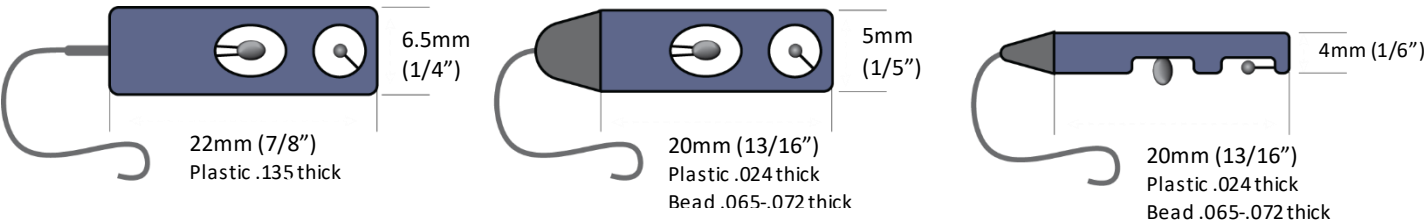
Mechanical Figure 4: Remote Sensor Head Dimensions

W

6.4mm (0.25")

3.2mm (0.127")

28.6mm (1.125")

19.86mm (0.782")

Ø 2.7mm (Ø 0.50")

Ø 2.7mm (Ø 0.50")
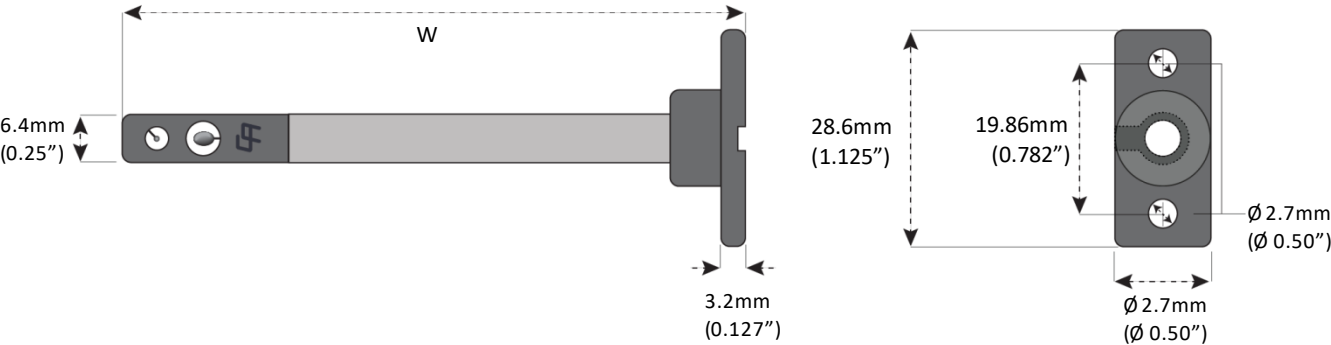
Mechanical Figure 5: Stainless Steel Wand Dimensions

4.4   RFS300 PCB Sensor

0.27" [6.9mm]

0.26" [6.6mm]

AIR DIRECTION

*3-dimensional STEP files available upon request

0.27" [6.9mm]

0.26" [6.6mm]

0.82" [20.8mm]

0.02" [0.5mm]

0.13" [3.3mm]
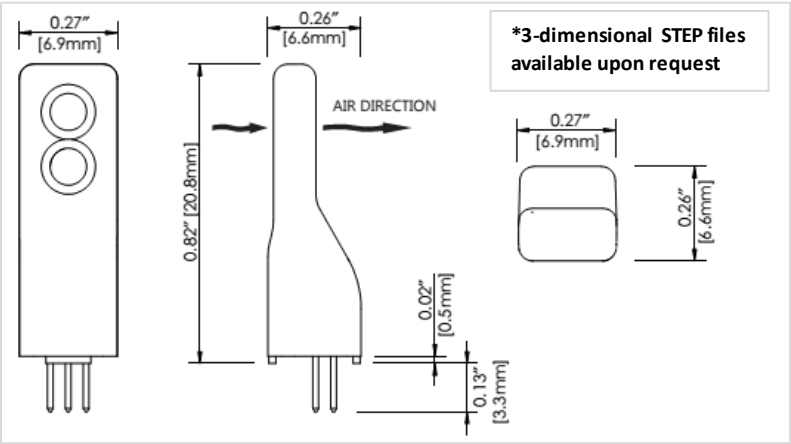
Mechanical Figure 6: RFS300 PCB Sensor Dimensions

5 Mounting and Positioning

5.1 Probe Style Sensors: F300, F400, F500
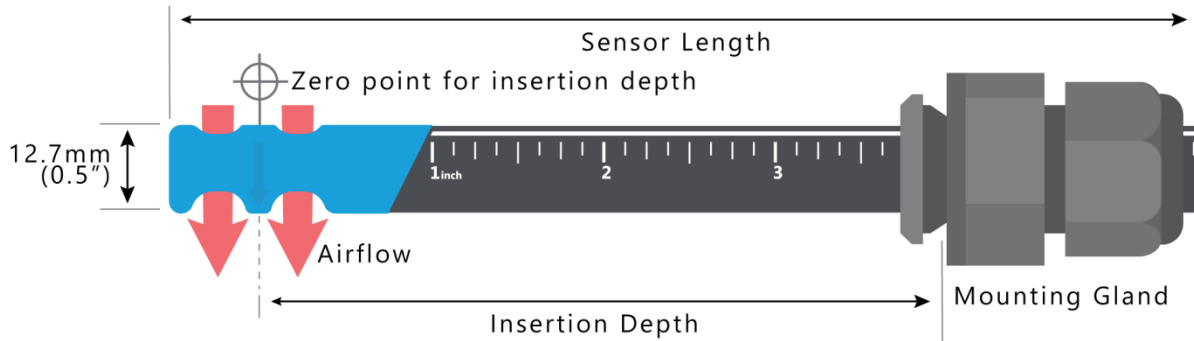
Mounting Figure 1: Sensor Dimensions

Note: Multiple sensor lengths are available to accommodate insertion depths of 30mm [1.25"] to 245mm [9.6"]. See **Mounting Figure 1** above for insertion "zero point" datum.

The F-Series Sensor utilizes either a °C Clamp or Gland fitting for installation. Please follow the below instructions for optimal installation:

5.1.1 Gland Installation

1. Drill a 13/16" (20mm) hole into the surface you wish to install the Sensor into.
   - Follow the below instructions to install the Sensor via Gland Fitting.
2. Adjust the Sensor's insertion depth (use the printed ruler on the Sensor's body for reference) and tighten the gland nut onto the Sensor body (**"A" in Figure 2 below**).
3. Insert the Sensor into the drilled hole wider flange first (**"B" in Figure 2 below**), then rotate into position, ensuring that the airflow indicators (arrows on the orange head; **see Figure 4 below**) are facing the correct direction.
4. Tighten the mounting nut (**"C" in Figure 2 below**) in the left-hand direction.

F-Series Sensor with Gland Fitting
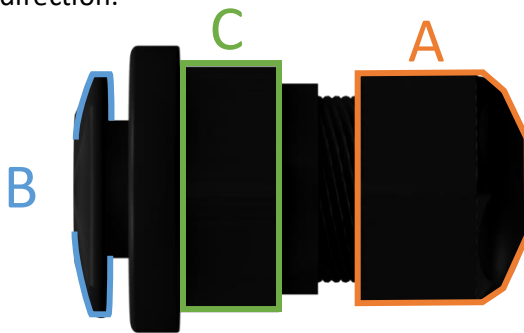
Side View

Front View

Mounting Figure 2: Gland Nut

5.1.2   °C Clamp Installation

1. Mark the sensor hole, and screw positions, per Step 1 of **Figure 4, below.**
2. Drill a 17/32" (14mm) hole through the surface you wish to install the Sensor.
3. Drill two pilot holes for the °C Clamp fastening screws.
4. Secure the °C Clamp with two screws.(not provided)
5. Insert the Sensor into the °C Clamp and adjust the Sensor's insertion depth (use the printed ruler on the Sensor's body for reference), ensuring that the airflow indicators (arrows on the blue or orange head**; see section 5.3 Airflow Direction**) are facing in the intended direction.
6. Using the provided screw, tighten and cinch the sensor into place.
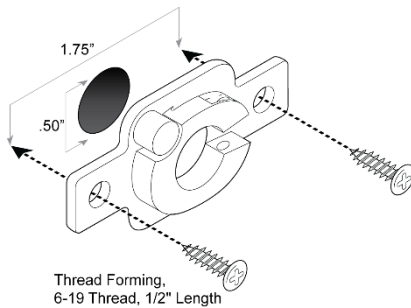
F-Series Sensor with °C Clamp Fitting

Mounting Figure 3: °C Clamp

Back View

Front View

Step 1

Step 2

1.75"

.50"

Thread Forming,
6-19 Thread, 1/2" Length
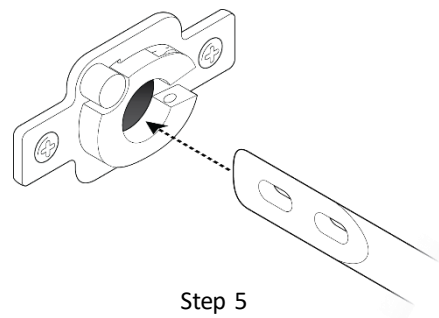
Step 3
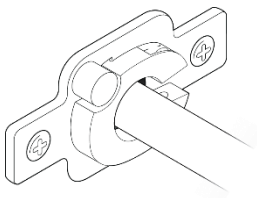
Step 4
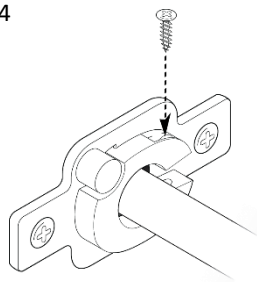
Step 5
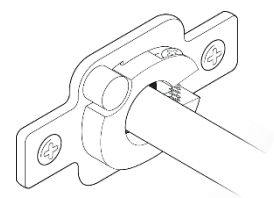
Mounting Figure 4: °C Clamp Installation

5.1.3   Airflow Direction

To ensure that the Sensor actuates within its published specifications, proper mounting precautions must be followed:

- The main airflow cavity that surrounds the flow thermistor must be orientated perpendicular to the airflow being monitored.
- When monitoring air velocity within a pipe or duct, mount the sensor so that the main flow cavity is in the center of the pipe or duct. Avoid mounting the sensor in turbulent locations caused by elbows, duct size changes, etc. If airflow turbulence causes excessive airflow reading variation, increasing the *Sample Time (index 63)* may solve the problem.
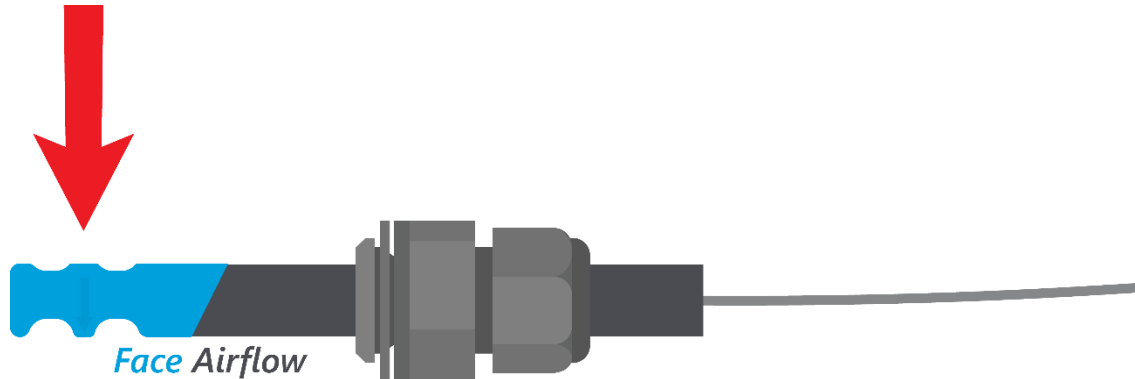
Airflow Figure 2: Direction of Airflow (Directional)

5.2   Sidewall & Inline Sensor: F350, F450, F550

The Sidewall and optional Inline Sensor assemblies are used when it is not desirable to place a Probe style velocity sensor into the overhead ducting of a pressurized cabinet or fume hood. The Sidewall/Inline sensors measure the negative pressure of the cabinet, by installing them in an airflow path created by cutting a through-hole in the side of the cabinet, which, due to negative pressure, pulls in laboratory air. This measured airflow self-correlates to face velocity.
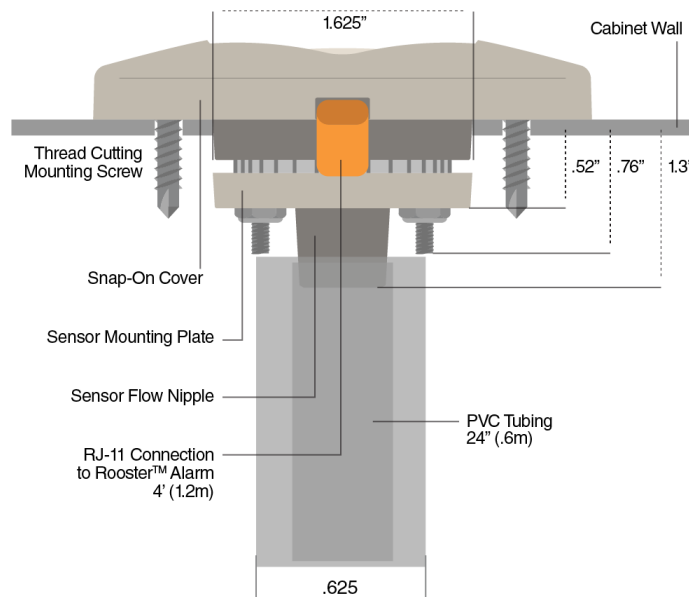
Sidewall & Inline Sensor Figure 1: Sidewall Sensor

The Sidewall sensor has been designed for single and dual wall cabinet installations. In a dual wall installation, the airflow path is made using the supplied 24" (.6m) of supplied PVC tubing and plastic end cap. In a single wall installation, no tubing or end cap is required. In a single wall cabinet, the side wall sensor is placed on the front or side of the unit, above the sash operating height by at least 4" (100mm). If cutting through the side of the cabinet, the hole should be roughly halfway to the back of the cabinet. In a dual wall cabinet, the sensor assembly is generally placed on the front of the cabinet, and connected to the through hole via the PVC tubing.
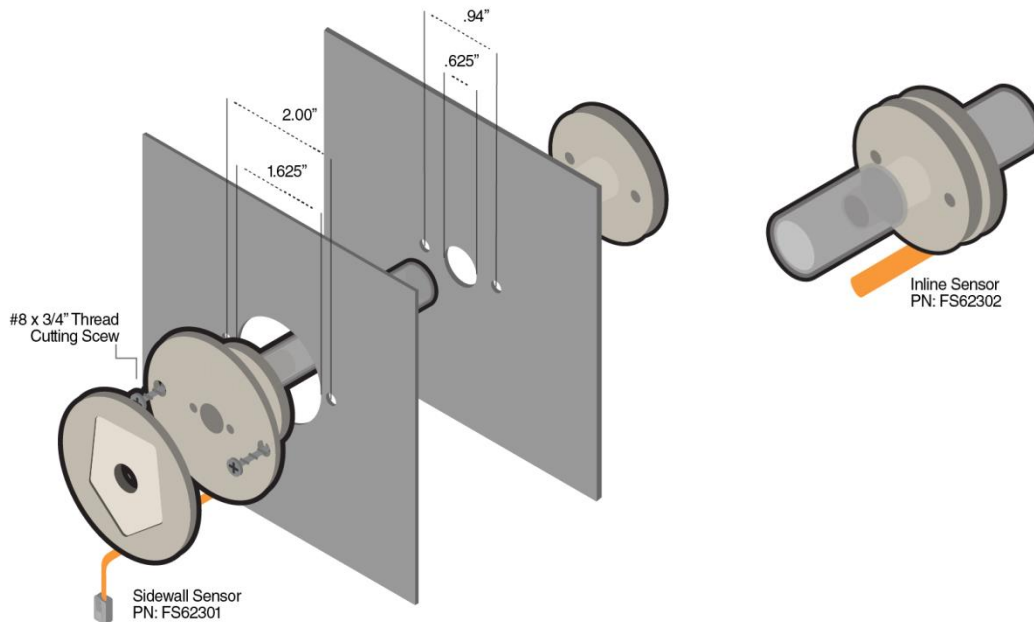
Sidewall & Inline Sensor Figure 2: Sidewall Sensor & Inline Sensor

5.3 Remote Head PCB Sensor

DegreeC Board Mount Sensor products can be mounted onto a PCB assembly by way of a simple socket insertion procedure or a no-clean soldering process.

5.3.1 Surface Mount Socketed Install

1. Insert sensor pins into corresponding mounting sockets on printed circuit board as depicted below.

5.3.2 RoHs-Compliant No-Wash Solder

1. Before soldering a F660, F661, or RFS300 sensor directly onto your circuit board surface, we advise you to follow best practices (ANSI/J-STD-001) during layout and processing to ensure optimal performance. Given the design of the nylon housing utilized in our board-mount sensors, DegreeC's board mount sensors must be soldered using a no-wash application method to prevent damage to sensor electronics.
2. In all instances, the soldering iron temperature must not exceed 480° F.
3. We recommend a manual hand-cleaning only after assembly is completed for user projects with tighter constraints.
4. For proper device soldering, please consult the mechanical drawings below and in the previous section for recommended drill diameter, pitch, and silk screen outline dimensions. Silk screen outline and Pin 1 should be marked as indicated. The stencil thickness and the aperture for soldering paste should be carefully dimensioned to allow clearance between the PCB and the package.

5. Before wave soldering, consult the table below for heating and cooling procedures. Do not expose product to temperatures in excess of the listed maximum.

Table: Thermal Profile

Maximum Temperature	Peak Duration	Δ Preheat Ramp	Δ Heat Ramp	Δ Ramp Down
260 °C	10 seconds across both waves	˄ *4 °C /sec*	˄ *200 °C /sec*	˅ *5 °C /sec*
500 °F	10 seconds across both waves	˄ *7.2 °F /sec*	˄ *360 °F /sec*	˅ *9 °F /sec*

6. Contact technical support with any further questions at +1 (877) 334-7332.

5.3.3   Drill Diagram: PCB Sensor
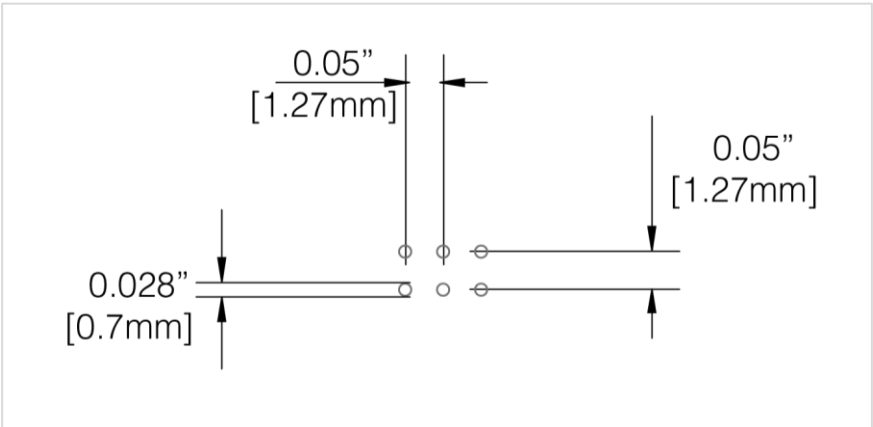
5.3.4   Silk Screen Outline: PCB Sensor
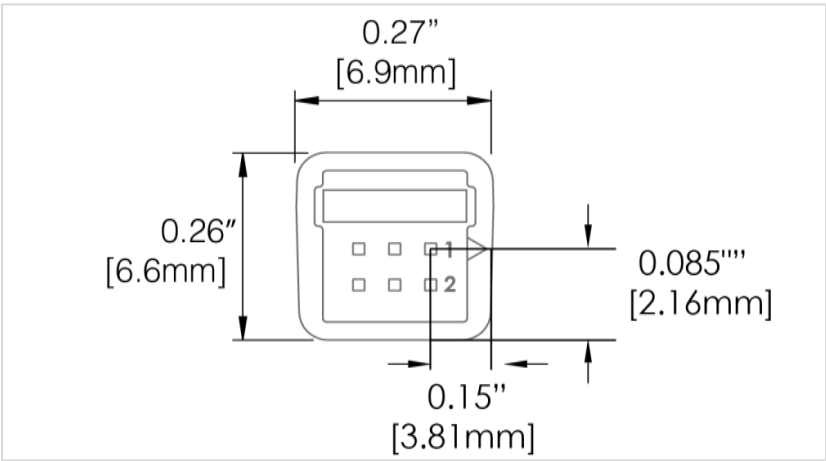
6   Communication

The F-Series Sensors support two methods of communication: UART and I^2C. The choice of communication is set up at DegreeC prior to shipment.

6.1   UART

The communication protocol described below is for communication between a master host and the slave Sensor product. This protocol is used to read/write configuration variables and to read process variables from the Sensor.

- The host can configure the Sensor by transmitting a "Memory Write" command which contains the memory index and the new data within the command.
- The host reads configuration variables using the "Memory Read" command.
- For multi-byte configuration variables, the data format is "little endian". The lowest address is the least significant byte.

Four process system variables (Velocity, Tamb, Power, and Raw Velocity) can also be read from the Sensor using the "Read Velocity", "Read Tamb", "Read Power", and "Read Raw Velocity" commands, as noted below:

Byte	1	2	3	4	1	2	3	4
Read Velocity	1	0	0	checksum	Velocity (Hi)	Velocity (Lo)	0	checksum
Read Tamb	2	0	0	checksum	Tamb (Hi)	Tamb (Lo)	0	checksum
Read Power	3	0	0	checksum	Power (Hi)	Power (Lo)	0	checksum
Memory Write	6	Memory Index	Data	checksum	Memory Index	Data	0	checksum
Memory Read	7	Memory Index	0	checksum	Memory Index	Data	0	checksum
Read Raw Velocity	9	0	0	checksum	Velocity Raw (Hi)	Velocity Raw (Lo)	0	checksum
RESET	12	0	0	checksum	n/a	n/a	n/a	checksum

UART Figure 1: Process System Variables

6.1.1   Hardware

The Sensor's UART RX and TX signals are digital signals from the internal processor's UART at 3.3V TTL voltage levels. To convert to true RS232 signals, an external level shifter is required.

6.1.2   Configuration

UART configuration is fixed at 19200 baud rate, 8 data bits, no parity, 1 stop bit.

Protocol

The sensor is a slave device and supports several different commands. Both transmit and reply command message lengths are four bytes. The fourth byte is a checksum byte to verify message integrity. The checksum byte is determined by performing an "exclusive or" logic operation of the first three bytes. The tables below define the seven host commands supported and the appropriate sensor reply.

Password Protection

Memory locations designated as (RWP) in the Memory Map require two consecutive Memory Write commands to change the setpoint.

- Command #1: Memory Write 0xAA to the Password (index 83).
- Command #2: Memory Write the new value to the password protected register. If valid, Sensor will accept the commands and write the new value. The Password (index 83) is automatically reset to 0xFF, the protected default state.

> **Caution:**
> - If the sensor receives a message with an invalid command byte or an invalid checksum, the message will be discarded and the Sensor will not reply.
> - If the sensor receives a partial message, the message will be discarded and the Sensor will not reply.
> - The host should use the "Read Velocity", "Read Tamb", "Read Power", and "Read Raw Velocity" commands to read these double byte variables.
> - When reading the double byte process variables Velocity (index 67), Raw Velocity (index 69), T Ambient Temperature (index 71), T Flow Temperature (index 73), Power Average (index 75), using the single byte "Memory Read" command, read the Low Byte first, then read the High Byte. This prevents a "byte mismatch" reading error.

6.2   I^{2}C

The communication protocol described below is for communication between the I^{2}C master host and the I^{2}C slave Sensor. This protocol is used to read/write configuration variables and to read process variables from the Sensor. Reading and writing to the Sensor uses the same protocol that is commonly used to read and write to EEPROM's. For multi-byte configuration and process variables, the data format is "little-endian", the low order byte of the number is stored in memory at the lower address.

6.2.1   Configuration

The protocol sequence is as follows:
- Each sensor starts out with a default Address of 192. This address may be changed to an arbitrary 8-bit value by writing to the sensor's I^{2}C address register and cycling power.
- The I^{2}C commands for the Sensors are defined as per the following tables:

1	7	1	1	8	1	8	1	1
S	Slave Address	Wr	A	Sub Address	A	Data Byte	A	P

S	=		Start bit
Slave Address	=		Sensor Address
Wr	=		0
A	=		Acknowledge from the Sensor
Sub Address	=		Index into the Sensor's Memory Map
Data Byte	=		Data written to the sensor at the Sub Address
P	=		Stop bit

I^{2}C Figure 1: Write Byte

1	7	1	1	8	1	1	8	1	1	8	1	1
S	Slave Address	Wr	A	Sub Address	A	S	Slave Address	Rd	A	Data Byte	A	P

S	=	Start bit
Slave Address	=	Sensor Address
Wr	=	0
Rd	=	1
A shaded	=	Acknowledge from the sensor (0 to indicate Ack)
Sub Address	=	Index into the sensor Memory Map
Data Byte	=	Data from the sensor at the Sub Address
A non-shaded	=	Acknowledge from the Host (1 to indicate end of read cycle)
P	=	Stop bit

I²C Figure 2: Write Byte

1	7	1	1	8	1	1	8	1	1	8	1	8	1	1
S	Slave Address	Wr	A	Sub Address	A	S	Slave Address	Rd	A	Data Lo Byte	A1	Data Hi Byte	A2	P

S	=	Start bit
Slave Address	=	Sensor Address
Wr	=	0
Rd	=	1
A shaded	=	Acknowledge from the Sensor (0 to indicate Ack)
Sub Address	=	Index into the Sensor Memory Map
Data Byte Lo	=	Data from the sensor at the Sub Address
A1 non-shaded	=	Acknowledge from the Host (0 to indicate read cycle continues if reading a second byte, 1 to indicate end of read cycle)
Data Byte Hi	=	Data at the next memory address (Only used if A1 was 0)
A2 non-shaded	=	Acknowledge from the Host (1 to indicate end of read cycle)
P	=	Stop bit

I²C Figure 3: Read Byte(s)

Caution:
If there is a communication failure in the midst of a read/write sequence, it is NECESSARY to issue a "Stop" bit before resuming communication with a new "Start" bit.

I²C Command Restrictions
- The write cycle only supports a single byte write cycle. Multiple byte write cycles are not supported.
- The read cycle supports a single and a double byte read cycle. Read cycles (greater than two) are not supported.

I²C Address
The sensor supports a 7-bit address which is shifted left to become the 7 most significant bits of the Slave Address Byte. The default value (after shifting) is 0xC0 (192) for write operations and 0xC1 (193) for read operations. This base address is password protected and can be changed by performing a "Write Byte" command to I²C Base Device Address (index 0) with the new base address. The new base address will become active after the next power cycle.

Password Protection

Setpoints designated as (RWP) in the Memory Map require two consecutive I^{2}C write commands to change the setpoint.

- Command #1: Write 0xAA to the Password (index 83).
- Command #2: Write the new value to the password protected register. If valid, the Sensor will accept the commands and write the new value. The Password (index 83) is automatically reset to 0xFF, the protected default state.

7 Analog Outputs

All 300, 400, and 500 series sensors have analog outputs for both velocity and temperature, which are determined by the configuration ordered by the customer. All analog outputs are scaled against a specific range and can be used in conjunction with digital communication.

Analog Scaling:

The 300 and 400 series sensors have the temperature output scaled from 0-100C. The 500 series sensor has the temperature scaled from -25 to 75C.

The 300, 400 and 500 series sensors all have their velocity output scaled to the calibrated range, however it starts from 0 m/s, for convenience.

7.1 Velocity Analog Output (Voltage)

The calculated velocity is processed through the output configuration module. The sensor velocity is translated to an analog voltage with a configurable range. The output voltage that corresponds to the *Velocity High Range (index 52)* is determined by setting *Vout Maximum (index 59)* to the desired voltage, units are in millivolts. As the converted *Velocity (index 67)* goes from 0 mm/s to *Velocity High Range (index 52)*, Vout goes from 0 to *Vout Maximum (index 59)*.

Output voltage functionality at velocities exceeding the *Velocity High Range (index 52)* is configurable by setting bit 0 of the *Configuration Flag (index 10)*. With bit 0 set to 0, Vout is clamped at *Vout Maximum (index 59)*. With bit 0 set to 1, Voutput is not clamped and will continue to rise in a linear fashion at Velocities exceeding the *Velocity High Range (index 52)*. By default, bit 0 of the *Configuration Flag (index 10)* is set to 0 (clamped). **See Figure 1** below for the Voutput functionality as bit 0 is set to 0 (clamped) and 1 (not clamped):
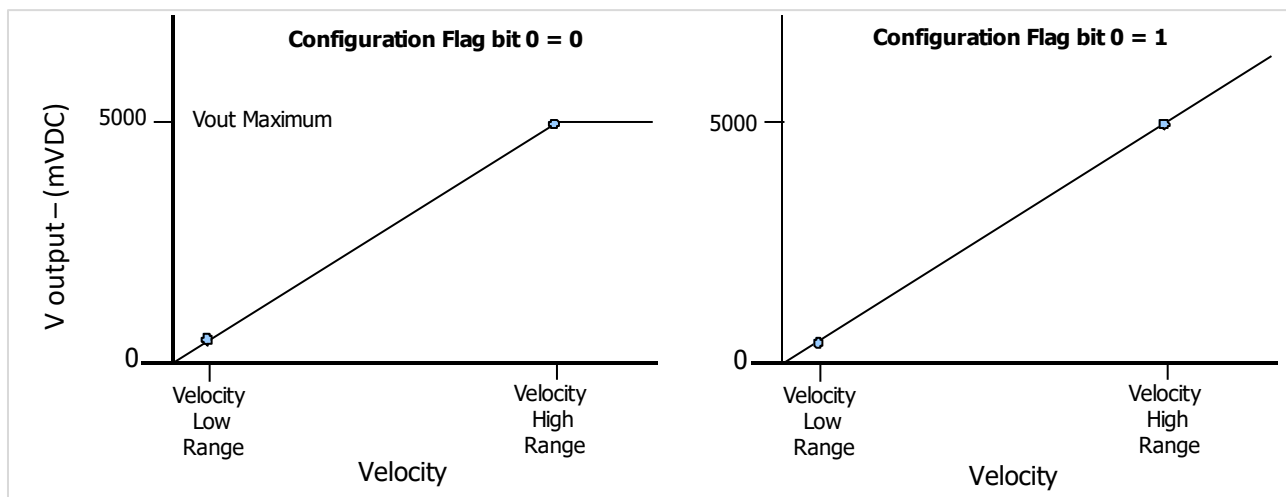
Velocity Analog Output Figure 1: Voutput (0 – 5V) with and without Clamping

For sensors without communications, the velocity can only be determined by measuring Voutput and calculating the velocity per the equation in **Figure 2** below:

$$\text{Velocity} = \frac{\text{Voutput} * \text{Velocity High Range}}{\text{Vout Maximum}}$$

Velocity Analog Output Figure 2: Velocity Calculation Equation using Voutput

The Velocity High Range and Vout Maximum can be obtained from the F400 Part Number. For example, if the sensor model is "F400–2–B-3", the Velocity High Range is 10160 mm/s and the Vout Maximum is 5V. In this case, if Voutput is 3.0VDC, then the velocity can be calculated per the following equation:

$$\text{Velocity} = \frac{\text{Voutput} * \text{Velocity High Range}}{\text{Vout Maximum}} = \frac{3000 * 10160}{5000} = 6096 \text{ mm/s}$$

Velocity Analog Output Figure 3: Velocity Calculation Example with Vout = 3.0V

Voutput: The Voutput value of the F400 sensor can also be obtained by the host reading *Voutput (index 77)* via the communication port. Units are in (mv).

> **Caution:**
> - Vout accuracy specification is only valid within the specified operational airflow range of the F400. Vout at velocities below Velocity Low Range (index 50), and velocities above Velocity High Range (index 52), are not guaranteed.
> - With the Voutput not clamped option, the output voltage is limited by the input supply voltage minus the internal operational amplifier VO output swing limit (typically .3V).

7.1.1 Velocity Analog Output (Voltage) Example

- Application airflow range is 100 – 2000 fpm.
- Output Voltage at 2000 fpm is 5.0V.
- At airflow velocities exceeding 2000 fpm, the output voltage should not exceed 5.0V.

For this application, the Velocity Range of 100 – 2000 fpm specifies a type "B" Velocity Profile, and the voltage of 5.0V specifies an Output Configuration Type "1" or "3". In this case let's assume this is an air velocity only output with an 8.3" tube, so the appropriate model is "F400-3-B-1". The figure below illustrates the Vout vs Velocity for this sensor model. The table below lists the internal register configuration for this model:

Name	Index (decimal)	Value	Description
Configuration Flag	10	0b00000000	Bit0=0, Vout clamped at Vout Maximum
Velocity Low Range	50,51	500	Standard Velocity Low Range of 500 mm/s
Velocity High Range	52,53	10000	Standard Velocity High Range of 10000 mm/s
Vout Maximum	59,60	5000	Sets Vout maximum when Velocity equals Velocity High Range
Velocity	67,68	6000	Velocity of last conversion is 6000 mm/s
Voutput	77,78	3000	Vout in (mv)

Velocity Analog Output Table 1: Internal Database Parameters for Analog Out Example
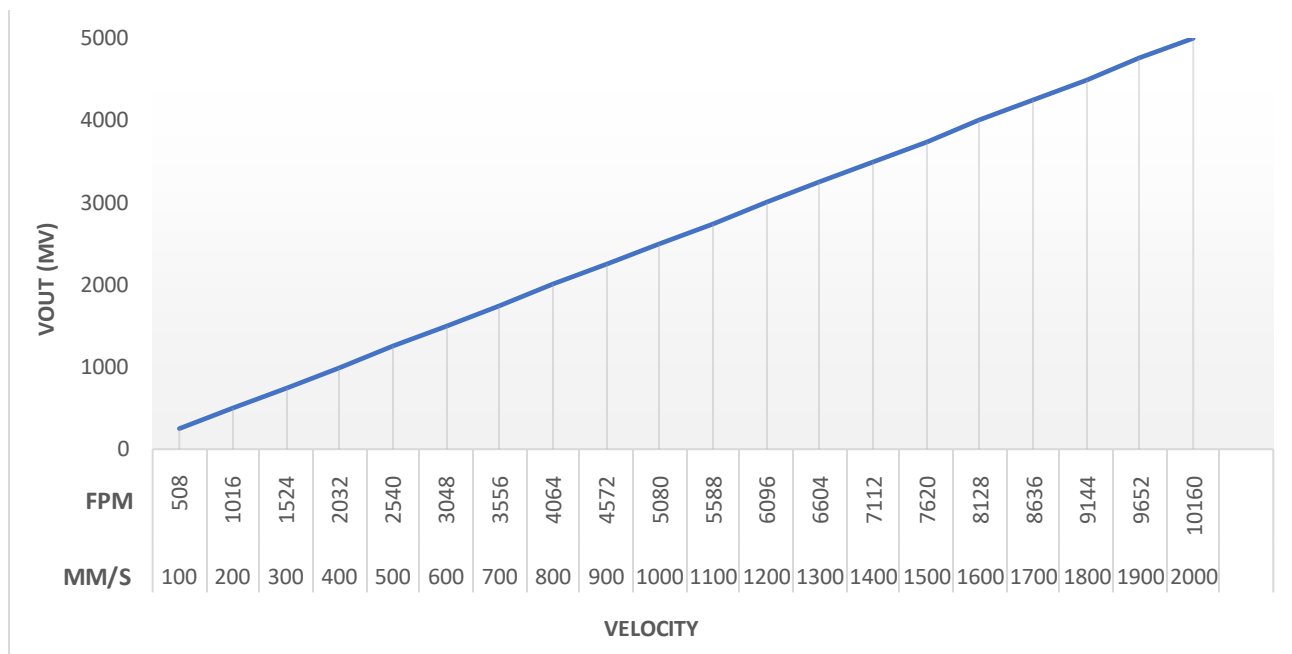
Velocity Analog Output Figure 4: Vout vs Velocity Example

7.2   Velocity Analog Output (Current)

7.2.1   0-20 mA
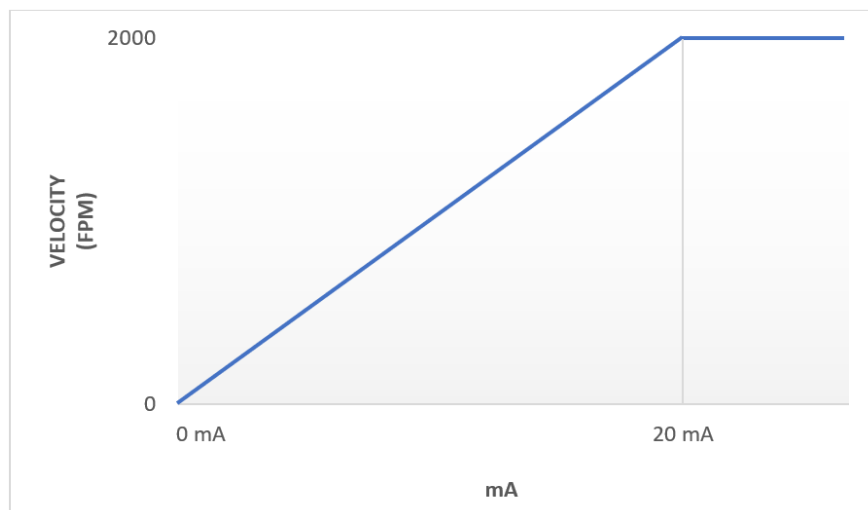
Velocity Analog Output Figure 5: 0-20 mA Example

$$\text{Velocity} = \frac{(\text{Vout Maximum}) * (\text{mA Reading})}{20}$$

Velocity Analog Output Figure 6: 0-20 mA Calculation Equation

7.2.2   4-20 mA
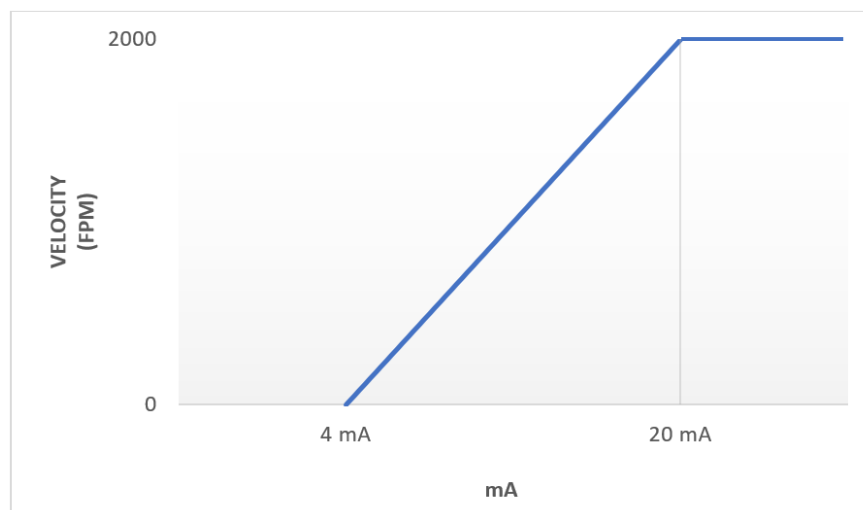
Velocity Analog Output Figure 7: 4-20 mA Example

$$\text{Velocity} = \frac{(\text{Vout Maximum}) * (\text{mA Reading} - 4)}{16}$$

Velocity Analog Output Figure 8: 4-20 mA Calculation Equation

7.2.3   Velocity Analog Output (Current) Example

For a B Cal. Range solution when utilizing 4-20 mA output, simply plug in the values found in the Calibration Range Chart on the next page, along with the measured mA reading:

If the mA reading is 11 mA for example:

- B Cal. Range Vout Maximum is 10 m/s

Plug in the numbers into the 4-20 mA formula as follows:

$$\text{Velocity} = \frac{(10 \text{ m/s}) * (11 \text{ mA} - 4)}{16}$$

Velocity is therefore **4.375 m/s**.

Calibration Range	V$_{OUT}$ Max
A *0.15 – 1.0 m/s* *30 – 200 fpm*	1.0 m/s 200 fpm
B *0.5 – 10.0 m/s* *100 – 2,000 fpm*	10.0 m/s 2,000 fpm
C *1.0 – 20.0 m/s* *200 – 4,000 fpm*	20 m/s 4,000 fpm

Velocity Analog Output Table 2: Calibration Range Table

Note: If the current outputs are unable to drive the desired current, bit 6 in Memory Location 66 will be set. (However, only if the current output error bit is set in the config. register).

7.3 Temperature Analog Output

The calculated temperature is processed through the output configuration module. The sensor temperature is translated to an analog voltage with a fixed range. The output voltage that corresponds to the Temperature High Range (100 °C) is determined by setting *Tout Maximum (index 61)* to the desired voltage, units are in millivolts. As the converted *T Ambient Average (index 71)* goes from 0 °C to 100 °C, Tout goes from 0 to *Tout Maximum (index 61)*. The linear conversion graph for the (0 - 5V) and the (0 – 10V) ranges are displayed below:
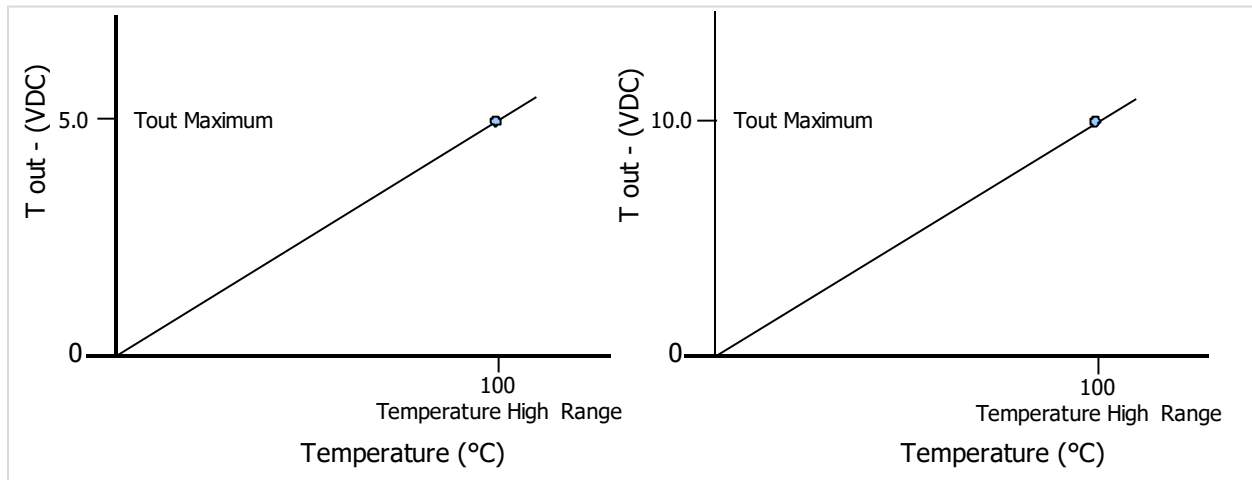
Temperature Analog Output Figure 1: Toutput for (0 – 5V) and (0 – 10V)

Note: For the F500, if Register 10 Bit 3 is set, the temperature is scaled from -25°C to 75°C.

For sensors without communications the temperature can only be determined by measuring Tout and calculating the temperature per the equation below:

$$\text{Temperature (°C)} = \frac{\text{Tout} * \text{TemperatureRange(°C)}}{\text{ToutMaximum(VDC)}} = \frac{\text{Tout} * 100}{\text{ToutMaximum(VDC)}}$$

Temperature Analog Output Figure 2: Temperature Calculation Equation

Tout: The Tout value of the F400 sensor can also be obtained by the host reading *Toutput (index 79)* via the communication port. Units are in (mv).

> **Caution:**
> • Tout accuracy specification is only valid within the specified operational temperature range of the sensor.

7.3.1 Temperature Analog Example

Requirements:

- Application temperature range is 0 – 100 °C.
- Output Voltage at 100°C should be 5.0V.

In this example, the Tout signal measures 1.418 VDC. The equation below calculates the corresponding temperature. The table below lists the internal register configuration for this model:

$$\text{Temperature (°C)} = \frac{\text{Toutput} * 100}{\text{Tout Maximum}} = \frac{1.418 * 100}{5} = 28.36 \text{ °C}$$

Temperature Analog Output Figure 3: Tout vs Temperature Example

Name	Index (decimal)	Value	Description
Tout Maximum	61,62	5000	Sets Tout maximum when Temperature equals Temperature High Range (100 °C)
T Ambient Average	71,72	2836	Temperature of last conversion is 28.36°C
Toutput	77,78	1418	Tout in (mv)

Temperature Analog Output Table 1: Internal Database Parameters for Temperature Analog Example

8   Sensor Registers

The sensor setpoints and process parameters can be accessed by reading and writing into the memory map using the appropriate serial communications interface. The table below provides specific details for these parameters:

8.1   Memory Map

Index		Type	Size	Name/Description	Default
Dec	Hex				
0	0x00	RWP	1	**I²C Base Device Address:** (used in I2C Communication Mode Only).	0xC0
1	0x01	RO	1	**Communication Mode:** 5=UART 6=I²C	per Model P/N
2	0x02	RW	1	Reserved for Alarm Upgrade	0
3	0x03	RW	2	Reserved for Alarm Upgrade	0
5	0x05	RW	2	Reserved for Alarm Upgrade	0
7	0x07	RW	1	Reserved for Alarm Upgrade	0
8	0x08	RW	1	Reserved for Alarm Upgrade	0
9	0x09	RW	1	Reserved for Alarm Upgrade	0
10	0x0A	RW	1	**Configuration Flag:** (bit mapped) bit 0: 0=Vout clamped at VoutMaximum; 1=Vout NOT clamped at VoutMaximum bit 1: 0=Vout set to 0v if sensor failure detected; 1=Vout set to VoutMaximum if sensor failure detected bit 2: 0=Tout set to 0v if ambient sensor failure detected; 1=Tout set to ToutMaximum if ambient sensor failure detected bit 3 (F500 Only): 0: Tout Scaled from 0-100°C; 1: Tout Scaled from -25-75°C bit 5 (F500 Only): 0: 0-20mA current out; 1: 4-20mA current out bit 6 (F500 Only): 0: enable current output error; 1: disable current output error	0
11	0x0B	RO	1	**Calibrated** (0=UNCALIBRATED, 1=CALIBRATED)	1
12	0x0C	RO	4	**Reserved**	ID Data
16	0x10	RO	4	**Reserved**	ID Data
20	0x14	RO	4	**Serial Number:** Combination of the Date Code (aka Year Week; Index 24), Work Order (Index 30) number, and Serial Number (i.e. the order in which a particular sensor was processed on a Work Order.	ID Data
24	0x18	RO	6		ID Data
30	0x1E	RO	4		ID Data
34	0x22	RWP	4	**Multidrop UART Address:** 1 Byte Identifier which can be used as an address for support of multidrop UART communications protocol. A value of 0 means that mulitidrop messages will be ignored. In order to set this byte, Sensor Power Average (address 75) must be over 35mW.	0
35	0x23	RO	1	**Reserved**	CAL Data
36	0x24	RO	1	**Reserved**	CAL Data

37	0x25	RO	1	**Reserved**	CAL Data
38	0x26	RO	4	**Reserved**	CAL Data
42	0x2A	RO	4	**Reserved**	CAL Data
46	0x2E	RO	1	**Reserved**	CAL Data
47	0x2F	RO	1	**Tamb Velocity High Offset:** Used to calculate Tamb, (sbbb.bbbb)	CAL Data
48/49	0x30	RO	2	**Reserved**	CAL Data
50	0x32	RO	2	**Velocity Low Range:** From Model P/N, (mm/sec)	CAL Data
52	0x34	RO	2	**Velocity High Range:** From Model P/N, also used to determine V output, (mm/sec)	CAL Data
54	0x36	RO	1	**Reserved**	CAL Data
55	0x37	RO	1	**Reserved**	CAL Data
56	0x38	RO	1	**Reserved**	CAL Data
57	0x39	RO	1	**Reserved**	CAL Data
58	0x40	RO	1	**Reserved**	CAL Data
59	0x3B	RW	2	**Vout Maximum:** Vout maximum voltage, (mv) Defines Vout when Velocity reading equals Velocity High Range Set to 5000 for 0 − 5V output Set to 10000 for 0 − 10V output	Per Model P/N
61	0x3D	RW	2	**Tout Maximum:** Tout maximum voltage, (mv) Defines Tout when Temperature reading equals Temperature High Range, 100°C Set to 5000 for 0 − 5V output Set to 10000 for 0 − 10V output	Per Model P/N
63	0x3F	RW	1	**Sample Time:** Determines the sample time (sec) used to calculate the rolling average velocity. Value range is (0 to 9), results in sample times (0.4 sec to 9.0 sec). Examples: 0=.4 sec, 1=1.0 sec, 2=2.0 sec, 3=3.0 sec, 4=4.0 sec, 5=5.0 sec., 6=6.0 sec., 7=7.0 sec., 8=8.0 sec., 9=9.0 sec.	3
64	0x40	RO	2	**Firmware Version:** F300/F400 have same firmware; F500 different firmware.	TBD

66	0x42	RO	1	**Status:** (bit mapped) bit 0: not used bit 1: Flow bead Control Error bit 2: Voutput Control Error, disabled if VoutMaximum=0 bit 3: Ambient Temperature Sensor Error bit 4: Air Flow Temperature Sensor Error bit 5: Toutput Control Error, disabled if ToutMaximum=0 bit 6 (F500 Only): 0: current output drive error enabled; 1: current output drive error disabled bit 7: not used	N/A
67	0x43	RO	2	**Velocity:** Velocity measured from last conversion cycle, (mm/s)	N/A
69	0x45	RO	2	**Raw Velocity Reading:** Unfiltered velocity measurement (mm/s)	N/A
71	0x47	RO	2	**T Ambient Average:** Temperature measured from the last conversion cycle, (°C * 100) Example: A temperature of 31.2°C would be represented as 3120	N/A
73	0x49	RO	2	**T Flow Temperature:** Temperature of the flow thermistor, (°C * 100)	N/A
75	0x4B	RO	2	**Power Average:** Calculated power to maintain Tflow setpoint, (mw * 100) Example: A power value 28.62 mw would be represented as 2862	N/A
77	0x4D	RO	2	**Vout:** Voutput voltage, (mv)	N/A
79	0x4F	RO	2	**Tout:** Toutput voltage, (mv)	N/A
81	0x51	RO	1	Reserved for Alarm Upgrade	N/A
82	0x52	RO	1	Reserved for Alarm Upgrade	N/A
83	0x53	RW	1	**Password:** To write to RWP type items, this Password register must first be set to 0xAA. Then a second write command can write to the RWP item. Password is automatically reset to 0xFF after any command accessing index 0 thru 82.	0xFF

Table 1: Sensor Memory Map

Notes:

1 RW are Read/Write setpoint variables.
2 RWP are Read/Write setpoint variables that are Password protected.
3 RO are Read Only variables.
4 When sensor registers are referenced within this document, the sensor register Name and Index will be italicized with the index number displayed within parenthesis. For example, the Sample Time at index 63 would be depicted as *Sample Time (index 63)*. The index number will be in decimal format.

9   Degree Controls Inc. Product Warranty

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