DEGREE CONTROLS, INC.

F200 Air Velocity Sensor

User Guide

DEGREE CONTROLS, INCORPORATED
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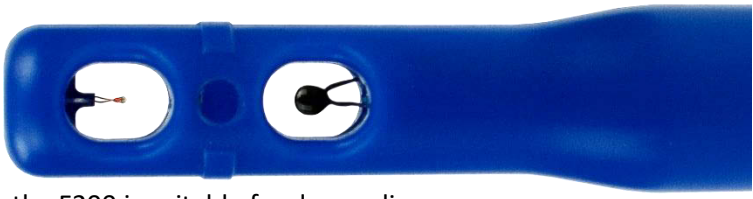
1 General Information

1.1 Overview

Thank you for your purchase of a DegreeC F200 Sensor, a versatile and rugged, high-performance air velocity and air temperature sensor with digital interface.



Designed with conformal coated electronics and sealed enclosure, the F200 is suitable for demanding applications, including those in corrosive or alkaline environments. With its robust, splash proof design, and UV tolerant construction, the F200 is designed to handle a wide range of product and process control air flow applications. The F200 is configured to order, with a variety of velocity ranges and either UART or I^2C communication styles available. The F200 is intended for new product designs, where the designer can take advantage of the digital communication. (If analog output signals are required, please see the F300, F400, and F500 velocity sensors.)

1.2 Features

1.2.1 Mechanical Features

- Easy duct mounting, with two bracket options (parallel and perpendicular to sensor).
- Push-wire connector for fastest connections.
- 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.
- RoHS compliant
- CE certified

1.2.2 Electrical & Performance Features

- Industry-leading air velocity performance, with repeatability within ±1%.
- ±1°C temperature accuracy
- Best- in-class acceptance angle performance.
- 4.5 – 15 VDC voltage input.
- Factory configured UART or I^2C
- More than 15 useful read addresses available
- In-situ calibration available.
- Multiple digital outputs available.
- I^2C addressing capability for multiple sensors
- Ideal with Arduino, Raspberry Pi, and all major microcontrollers and development boards.
- Configurable velocity averaging for smoothing sensor response.
- <10 second start-up time and 400ms response time.
- May be configured as an airflow switch with open drain output.

2 Product Specifications

2.1 General Specifications

Air Velocity Range	Configurable, 0.15m/s – 20m/s (30 fpm – 4000 fpm)
Operating Temperature	0°C to 60°C (32°F to 140°F)
Storage Temperature	-40°C to 105°C (-40°F - 220°F)
Relative Humidity	5 – 95%
Response Time	400ms
Temperature Accuracy	± 1°C*
Start-up Time	<10 s
Digital Output	UART or I^2C available for flow and temperature information
Alarm Output	3.3V TTL, programmable trip point (**see Section 4.1**)
Communication	I^2C (400KHz) or 3.3V UART (19.2Kbps)
Housing Construction	UL94-V0
Wire Gauge	18 – 24 AWG Max conductor 1.05mm Max insulation 2.1mm
Environmental Protection	IP65 electronics, including conformal coated sensing element

**The air velocity sensor uses a hot bead algorithm, and at extremely low velocities, the error in air temperature measuring can grow 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 F200 is a thermal airflow sensor; it is sensitive to changes in air density and indicates velocity with reference to a set of standard conditions (21°C (70°F), 760mmHg (101.325kPa), and 0%RH). The F200 has been designed so that when used over the stated temperature compensation range, the sensor indicates very close to actual air velocity and minimal compensation is only required to account for changes in barometric pressure or altitude.

2.2 Model Specifications

The F200 Sensor is offered with a single input voltage range. The voltage range and current requirements are noted below:

Name	Input Voltage Range	Current Consumption
F200	4.5 – 12 VDC	< 35mA nominal

Model Specifications Table 1: Input Voltage Range & Current Consumption

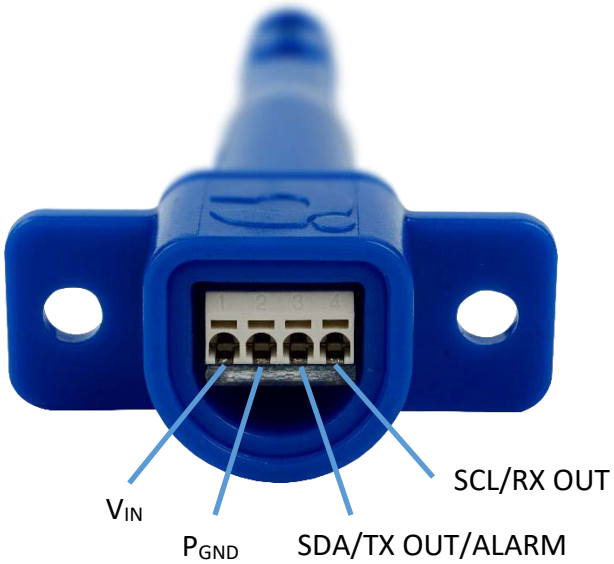
2.3 Hardware Configuration

The F200 Sensor may be configured with one of three velocity profile's and with either UART or I^2C communication output.

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	UART and I^2C communication output • For multi-sensor addressing, select I^2C

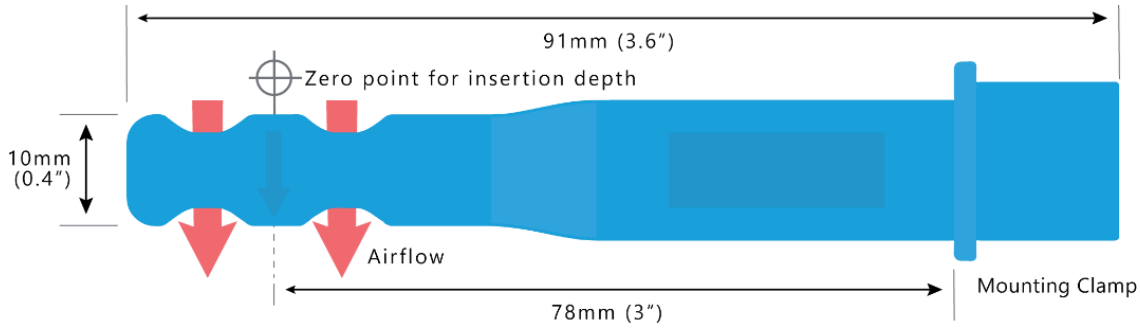
Hardware Configuration Table 1: Ordering Information

2.4 Connector Information



Note: For I^2C communication, external pull-up resistors to +3.3V for SDA and SCL are required. The F200 does not have internal pull-up resistors.

3 Mounting and Positioning



Mounting Figure 1: Sensor Dimensions

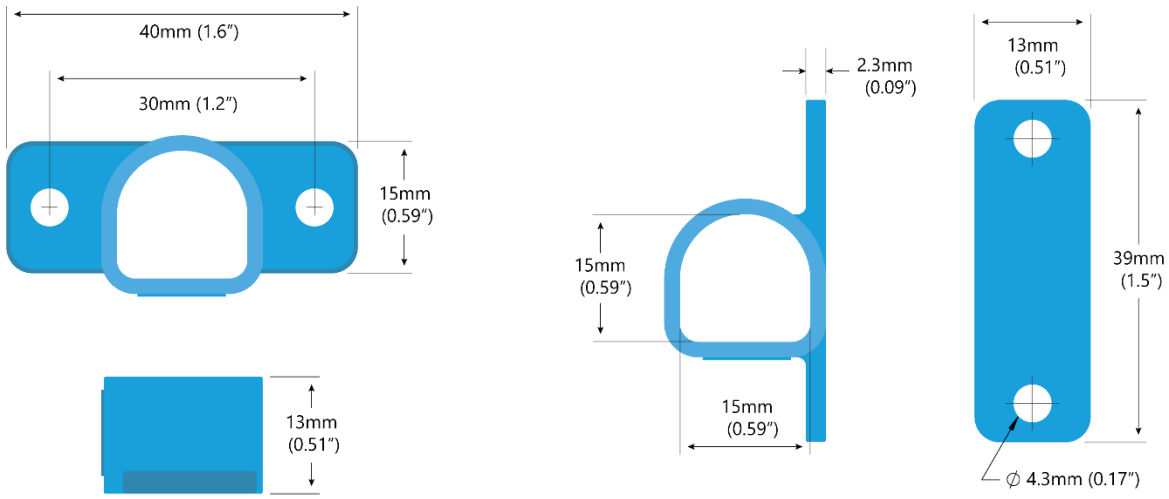
3.1 Airflow Direction

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

- The direction of airflow should be parallel to the axis of the thru hole in the sensor body.
- Deviation from this idealized flow vector is called angle of incidence, which should be less than 30˚ at all times.
- When monitoring air velocity within a pipe or duct, mount the sensor so that sensing elements are at the center of the pipe or duct (as shown above). 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)* will increase the averaging and smooth the readings.

3.2 Bracket Dimensions and Installation

The F200 can be configured with either a Parallel or Perpendicular bracket. Dimensions for both are below.
Using a drill bit properly suited to the surface type, drill a 13/16" (20mm) hole through the surface you wish to install the Sensor into. Drill two 4.3mm (0.17") pilot holes for the bracket. Insert the sensor into the bracket, and secure the bracket onto the surface using two screws.



Mounting Figure 2: Brackets – Parallel (left) and Perpendicular (right)

4 Communication

The F200 sensor supports two methods of communication: UART and I^2C. The choice of communication is configured at DegreeC prior to shipment.

4.1 Alarm Output

Via UART communication, the F200 may be configured to work as an airflow switch, with programmable trip point. The signal is a TTL output. Users can first use the F200 as a sensor to determine the required trip point, and then change the output behavior. DegreeC can pre-configure the F200 to operate in this mode. Contact degreeC at sales@degreeC.com for more information.

For customers interested in standard airflow switches with relay or open drain outputs, please see the S300 (5-12V nominal input), S400 (24VDC nominal input) products.

4.2 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

4.2.1 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.

4.2.2 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.

4.3 I^2C

The communication protocol described below is for communication between the I^2C master host and the I^2C 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.

4.3.1 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^2C address register and cycling power.
- The I^2C 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

I²C 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.

I^2C 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 I^2C 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^2C 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.

5 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:

5.1 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	RWP	1	**Communication Mode:** 5=UART 6=I²C	per Model P/N
2	0x02	RW	1	**Alarm Mode:** (bit mapped) bit 0: Enable VELOCITY_LOW_ALARM bit 1: Enable VELOCITY_HIGH_ALARM bit 2: Illegal bit 3: Illegal bit 4: Enable TEMPERATURE_LOW_ALARM bit 5: Enable TEMPERATURE_HIGH_ALARM bit 6: Illegal bit 7: Illegal Note: Only High or Low alarm can be set. Trying to set both disables alarm Alarms can be set for Velocity and Temperature Simultaneously	0
3	0x03	RW	2	**Velocity Alarm Low Setpoint:** Alarm Mode dependent … VELOCITY - Low Alarm Setpoint, (mm/s)	0
5	0x05	RW	2	**Velocity Alarm High Setpoint:** Alarm Mode dependent … VELOCITY - High Alarm Setpoint, (mm/s)	0
7	0x07	RW	1	**Power Up Alarm Delay Setpoint:** 0=DISABLE, (secs) At power-up the alarm timer is set to the Alarm Delay Setpoint and starts counting down to zero. While timing the alarm is set to the inactive state. At time-out, the alarm is serviced normally.	0
8	0x08	RW	1	**Alarm Trip Time:** The Alarm Trip Time parameter sets the number of consecutive seconds of velocity/temperature readings below the low threshold or above the high threshold to cause an alarm state change. Example: For an alarm condition compare of 5 seconds, set Alarm Trip Time to 5.	0
9	0x09	RW	1	**TX/SDA Pin State on Alarm:** Used to set the state of the TX/SDA/Alarm pin when the Alarm is active 0 = TX/SDA/Alarm pin is **shorted to GND** when **in alarm** (N.O). 1 = TX/SDA/Alarm pin is **floating** when **in alarm (** N.C).	0
10	0x0A	RW	1	**Configuration Flag:** (bit mapped) bit 0-6:Not Used bit 7: 0=Smart Averaging set to OFF 1=Smart Averaging set to ON	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	RO	1	**Reserved**	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	RW	2	**Temperature Alarm Low Setpoint:** Alarm Mode dependent … TEMPERATURE – Low Alarm Setpoint, (°C * 100)Reserved	0
44	0x2C	RW	2	**Temperature Alarm High Setpoint:** Alarm Mode dependent … TEMPERATURE – Low Alarm Setpoint, (°C * 100)Reserved	0
46	0x2E	RO	1	**Reserved**	CAL Data
47	0x2E	RO	1	**Reserved**	CAL Data
48	0x30	RO	1	**Reserved**	CAL Data
49	0x31	RO	1	**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	0x41	RO	2	**Reserved**	CAL Data
61	0x43	RO	2	**Reserved**	CAL Data
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**	Version 100
66	0x42	RO	1	**Status:** (bit mapped) bit 0: not used bit 1: Flow bead Control Error bit 2: not used bit 3: Ambient Temperature Sensor Error bit 4: Air Flow Temperature Sensor Error bit 5: not used bit 6: not used 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	**Reserved**	N/A
79	0x4F	RO	2	**Reserved**	N/A
81	0x51	RO	1	**Alarm Status:** (bit mapped) bit 0: VELOCITY_LOW_ALARM bit 1: VELOCITY_HIGH_ALARM bit 2: not used bit 3: not used bit 4: TEMPERATURE_LOW_ALARM bit 5: TEMPERATURE_HIGH_ALARM bit 6: not used bit 7: not used Alarms can be valid for Velocity and Temperature Simultaneously if enabled	N/A
82	0x52	RO	1	**Alarm Output:** -Reflects the state of the Alarm output 0= Alarm output floating 1=Alarm output shorted to ground	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.

6 Degree Controls Inc. Product Warranty

For a period of one (1) year following the date of delivery, and subject to the other provisions of this Warranty Section, DegreeC warrants that all new products that are both (a) manufactured by DegreeC and (b) purchased directly from DegreeC (or an authorized distributor of DegreeC) shall be free of material defects in materials and workmanship. Buyer's sole and exclusive remedy, and DegreeC's sole and exclusive obligation, in the event of any product defect shall be for DegreeC to, at its option, repair or replace such products free of charge. In no event shall DegreeC be liable for ordinary wear and tear. In order to get the benefit of the foregoing warranty, Buyer must examine the delivered products immediately upon receipt thereof and report to DegreeC, in writing, any visible defects within ten (10) working days of such receipt. Buyer's failure to report defects within the foregoing time period will be deemed an unqualified waiver of any and all of Buyer's rights to warranty claims. DegreeC does not provide any warranty for third party parts, components, or products that are not manufactured by DegreeC. Such parts, components, or products may be warranted by third parties on a "pass through" basis. The foregoing remedies shall not apply to any product failure caused in whole or in part by (i) Buyer's failure to operate, maintain, or service the products in accordance with DegreeC's documentation, (ii) any alteration, modification, or repair made to the products other than by DegreeC, or (iii) use of the products for a purpose other than that for which it is intended. THE FOREGOING EXPRESS WARRANTY extends only to the original customer of DegreeC or DegreeC's authorized distributor, as the case may be**.** THE CORRECTION OF ANY DEFECT IN, OR FAILURE OF, PRODUCTS BY REPAIR OR REPLACEMENT IN ACCORDANCE WITH DEGREEC'S POLICIES DESCRIBED HEREIN SHALL BE DEGREEC'S SOLE AND EXCLUSIVE OBLIGATION AND THE SOLE AND EXCLUSIVE REMEDY OF BUYER FOR ANY AND ALL LOSSES, DELAYS OR DAMAGES RESULTING FROM THE PURCHASE OR USE OF DEGREEC'S PRODUCTS. OTHER THAN THE LIMITED WARRANTY SPECIFICALLY STATED HEREIN, DEGREEC SPECIFICALLY DISCLAIMS ANY AND ALL OTHER WARRANTIES WITH RESPECT TO DEGREEC'S PRODUCTS, INCLUDING THE PERFORMANCE THEREOF AND ANY SERVICES PROVIDED TO BUYER, EITHER EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY WARRANTY ARISING FROM A COURSE OF DEALING OR USAGE OF TRADE, NON-INFRINGEMENT AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE OR USE.