

HV Series

Differential Low Pressure Sensors

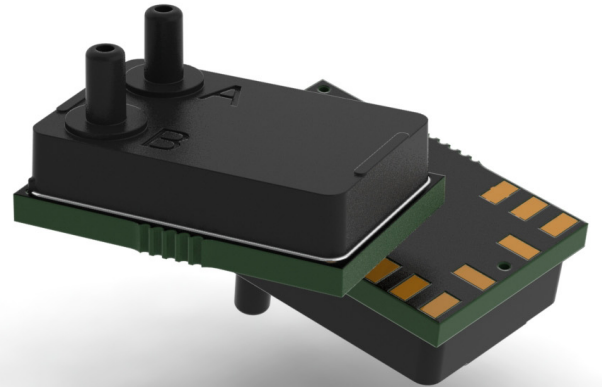
HVAC Applications

- Highly integrated sensor with ADC and DSP
- Selectable pressure range from 0.1 to 60 inH₂O
- Integrated 50/60Hz Notch Filter
- Selectable Bandwidth Filter from 0.1Hz to 10Hz
- Very High Accuracy +/- 0.1% of Selected Range
- Long Term Stability +/- 0.1% FSS
- Temperature Compensated 0°C to 50°C
- Supply Voltage Compensation
- Fully Integrated Compensation Math
- Standard I²C and SPI Interface

Product Summary

Superior Sensor Technology's HV Series Family offers the industry's highest performing and most flexible Differential Low Pressure Sensors for HVAC (Heating, Ventilation, and Air Conditioning) applications. Targeting pressure ranges from as low as 0.1" inH₂O (Water Column) to 60" inH₂O with industry leading 16 bits of resolution for each range supported. Competing solutions degrade as the pressure range is lowered; but, Superior's HV Series with the Multi-Range capability enabled maintains optimal performance from 60" inH₂O down to even 0.1" inH₂O.

The HV Series family employs Superior's proprietary NimbleSense™ architecture to create the industry's first generation of "Smart Sensors." NimbleSense™ provides very high dynamic range to enable a single device to cover the entire range of HVAC pressure requirements. For example, one Multi-Range enabled Superior Sensor device can replace three to five (or more) competing products greatly simplifying installation requirements and significantly lowering inventory costs. As an



example, an HV Series device installed in the ceiling vent can now be programmed to accommodate any pressure requirement without additional installation charges. For added performance, the HV Series has incorporated a 50/60Hz notch filter to minimize the impact of power noise spikes. The HV Series family provides a new level of integration combining an advanced piezoresistive sensing element with integrated amplification, ADC, DSP and digital interface which greatly simplifies customer integration efforts. The incorporation of advanced digital signal processing enables new functionality thus simplifying system development, manufacturing ease and increased reliability.

Constructed with a high reliability plastic enclosure, the HV Series family provides the ideal combination of very high performance and reliability while ensuring customers have a high volume cost effective solution optimized for their HVAC requirements.

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1 Maximum Ratings

Parameter	Sym	Min	Max	Units
Supply Voltage	V _{DDM}	Gnd-0.3	4.0	V
Voltage on I/O Pins	V _{DD} > 3.3V	Gnd-0.3	5.8	V
	V _{DD} ≤ 3.3V	Gnd-0.3	V _{DD} +2.5	V
I/O Current	I _{IOM}	-25	25	mA

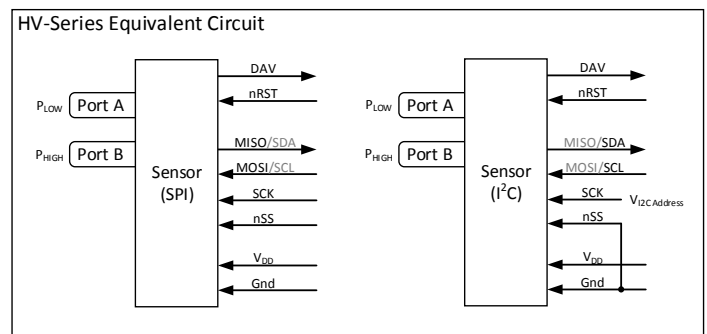
2 Suggested Operating Conditions

Parameter	Sym	Min	Max	Units
Supply Voltage	V _{DDOP}	2.8	3.5	V
Temperature	T _A	0	50	°C

3 Environmental

Parameter	Sym	Min	Max	Units	
Temperature Range	Compensated	T _{COMP}	0	50	°C
	Operating	T _{OP}	-20	85	°C
	Storage	T _{STG}	-40	85	°C
Humidity (Non-condensing)	RH _{OP}	0	95	% RH	
Vibration (10Hz-2kHz)	G _{VIBE}	-	15	g	
Shock (6 ms)	G _{SHOCK}	-	100	g	
Life	CY _{LIFE}	1M	-	Pressure Cycles	

4 Equivalent Circuit



5 Feature List

Parameter	Sym	HV160	HV120	HV110	HV210	Units	Notes
Number of FS Pressure Ranges	P _{NUM}	8	4	5	7	Each	
Specified FS Range Extents	P _{EXT}	±2.5 to ±60	±2.5 to ±20	±0.5 to ±10	±0.1 to ±10	inH ₂ O	
Number of BW Filter Corners	BW _{NUM}	7				Each	
BW Corner Frequency Extents	f _{BWEXT}	0.1 to 10				Hz	
Common Mode Pressure	P _{CM}	700	500	500	500	inH ₂ O	1
Proof Pressure	P _{PROOF}	400	40	40	40	inH ₂ O	2
Burst Pressure	P _{BURST}	480	120	120	120	inH ₂ O	3

- 1) Pressure applied to both ports simultaneously without incurring part damage.
- 2) Pressure at which the sensor will not suffer permanent damage.
- 3) Pressure if exceeded could cause permanent damage to the sensor.

6 Performance Characteristics

Note: Unless otherwise specified, characteristics specified with V_{DD} = 3.3V, T_A = 25C

Parameter	Sym	HV160			HV110/HV120			HV210			Units	Notes
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
Accuracy	P _{ACC}	-	0.05	0.1	-	0.05	0.1	-	0.05	0.1	% RNG	1, 2
Total Error Band	TEB	-	0.1	0.3	-	0.1	0.3	-	0.05	0.15	% FSS	3
Long Term Stability	LTS	-	0.1	0.25	-	0.1	0.25	-	0.05	0.1	% FSS/Yr	
Thermal Hysteresis	T _{HYS}	-	0.05	-	-	0.05	-	-	0.025	-	% FSS	
Pressure Hysteresis	P _{HYS}	-	0.05	-	-	0.05	-	-	0.05	-	% RNG	1
Position Sensitivity	P _{PS}	-	2.0	-	-	2.0	-	-	0.25	-	Pa	
Supply Rejection	P _{SR}	-	0.0005	-	-	0.0005	-	-	0.0005	-	Pa/mV	
Resolution	RES	-	16	-	-	16	-	-	16	-	bit	4
System ENOB	ENOB	-	17	-	-	19	-	-	19	-	Bit _{RMS}	5
Data Update Rate	f _{UPDATE}	108	111	114	108	111	114	108	111	114	Hz	6

- 1) Percentage of selected range.
- 2) Uncertainty limited by system noise for ranges of 0.5 inH₂O and below.
- 3) Includes errors of offset, span and thermal effects.
- 4) Each selected range has the specified resolution
- 5) ENOB stated for f_{BW} set to 0.1 Hz.
- 6) The internal update rate is fixed and does not change with range or filter settings. Sampling at lower data rates are possible provided the Nyquist frequency is observed. It is suggested to sample at least 3x the set f_{BW} frequency.

7 Electrical Characteristics

7.1 Supply Characteristics

Parameter	Sym	HV110/HV120/HV160			HV210			Units	Notes
		Min	Typ	Max	Min	Typ	Max		
Supply Current	I_{DD}	-	3.5	3.8	-	4.5	4.8	mA	
Supply Capacitance	C_{DD}	-	10	-	-	10	-	uF	1

1) Supply capacitance is provided within the part however it is recommended to include a 0.1 uF decoupling cap near the supply pads.

7.2 Reset Characteristics

Parameter	Sym	Condition	HV110 / HV120 / HV160/ HV210			Units	Notes
			Min	Typ	Max		
Power-On Reset Threshold	V_{PORR}	Rising Voltage on V_{DD}	-	1.4	-	V	
	V_{PORF}	Falling Voltage on V_{DD}	0.75	-	1.36	V	
Interface Detect Delay	t_{IOD}	From POR or External Reset	-	-	40	ms	
First Response Settling Time	t_{FRD}	From POR or External Reset	-	-	150	ms	1
External Reset Low	t_{RSTL}		15	-	-	us	
Input High Voltage	V_{IH}		$V_{DD}-0.6$	-	-		2
Input Low Voltage	V_{IL}		-	-	0.6		2
Internal Pull-Up Current	I_{PU}	$V_{IN} = 0V$	-	-10	-30	uA	2
Input Capacitance	C_{IN}		-	7	-	pF	2

1) The filter settling time to ensure the first reading is completely settled.

2) Input nRST

7.3 DAV Characteristics

Parameter	Sym	Condition	HV110 / HV120 / HV160/ HV210			Units	Notes
			Min	Typ	Max		
Output High Voltage	V_{OH}	$I_O = -3 \text{ mA}$	$V_{DD}-0.7$	-	-	V	
Output Low Voltage	V_{OL}	$I_O = 8 \text{ mA}$	-	-	0.6	V	

7.4 SPI Characteristics

Parameter	Sym	Condition	HV110 / HV120 / HV160/ HV210			Units	Notes
			Min	Typ	Max		
Output High Voltage	V _{OH}	I _O = -3 mA	V _{DD} -0.7	-	-	V	1
Output Low Voltage	V _{OL}	I _O = 8 mA	-	-	0.6	V	1
Input High Voltage	V _{IH}		V _{DD} -0.6	-	-		2, 3
Input Low Voltage	V _{IL}		-	-	0.6		2, 3
Internal Pull-Up Current	I _{PU}	V _{IN} = 0V	-	-10	-30	uA	2, 3
Time nSS to First SCK Edge	t _{SC}		150	-	-	us	
Clock Cycle Time	t _{CC}		8	-	-	us	
Byte to Byte Cycle Time	t _{BC}		150	-	-	us	
Time Last Clock to nSS High	t _{CN}		25	-	-	us	
Cycle Time nSS	t _{CS}		8	-	-	us	
Input Capacitance	C _{IN}		-	7	-	pF	2

- 1) Output MOSI
- 2) Inputs MISO, SCK, nSS
- 3) Inputs are 5V compliant.

7.5 I²C Characteristics

Parameter	Sym	Condition	HV110 / HV120 / HV160/ HV210			Units	Notes
			Min	Typ	Max		
SCL Clock Frequency	f _{SCL}		100	-	400	kHz	
Clock Stretch Time	t _{CKSTR}		-	15	150	us	
Input High Voltage	V _{IH}		V _{DD} -0.6	-	-		
Input Low Voltage	V _{IL}		-	-	0.6		
Output Low Voltage	V _{OL}	I _O = 8 mA	-	-	0.6	V	
Input Capacitance	C _{IO}		-	7	-	pF	

8 Materials

8.1 Wetted Materials

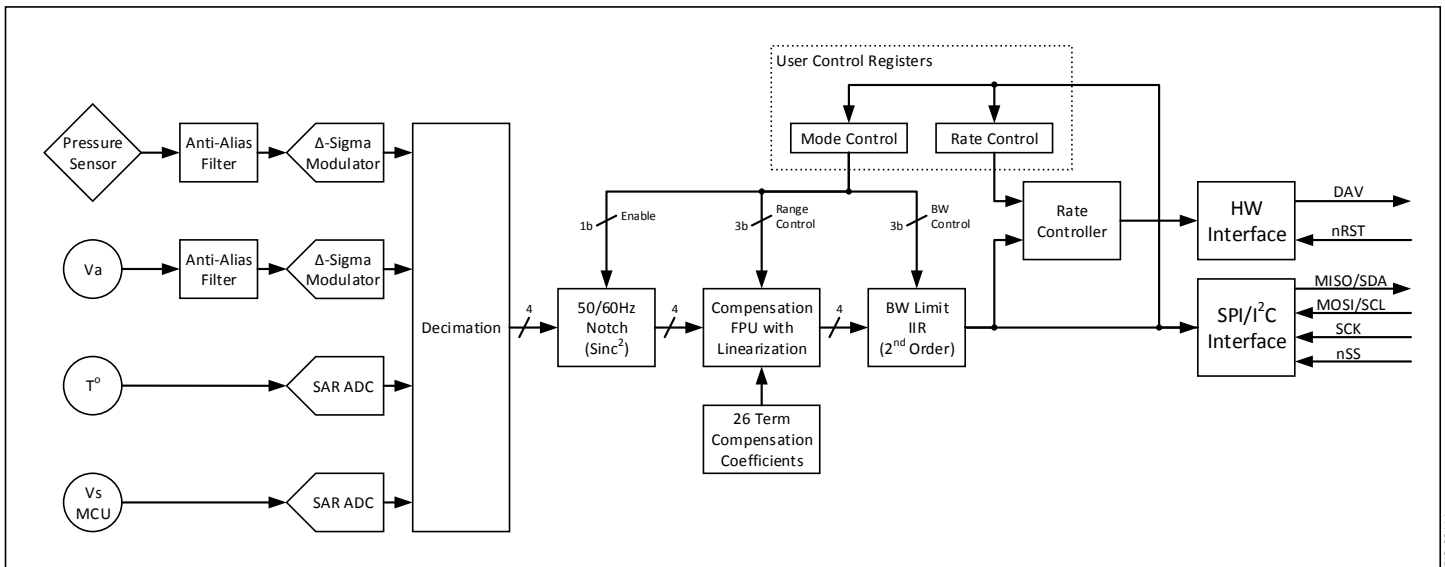
Parameter	Sym	HV110/HV120/HV160		HV210		Units	Notes
		P _A	P _B	P _A	P _B		
Wetted Materials	MAT _{WET}	Epoxy Nylon RTV Silicon	Epoxy Nylon RTV Silicon Gold Aluminum	Epoxy Nylon RTV Silicon Gold Aluminum	Epoxy Nylon RTV Silicon Gold Aluminum		

8.2 Material Compliance

Parameter	Sym	HV110 / HV120 /HV160/ HV210	Units	Notes
RoHS	REG _{RoHS}	RoHS Compliant		
REACH	REG _{REAC}	REACH Compliant		

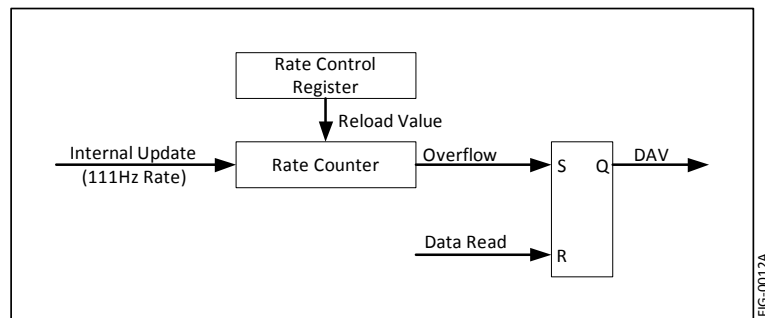
9 System Overview

The HV Series pressure sensor is a fully integrated pressure acquisition system in a sensor module. The acquisition system includes anti-alias filters, data acquisition, 50/60Hz notch filter, sensor compensation, bandwidth limiting and I/O functions. Refer to the figure below for the HV Series block diagram.



There are also two user controlled registers that tune the sensor to the specific user requirements. The first register is the Mode Control register that determines the output pressure range, the corner frequency of the bandwidth limiting filter and enables or disables the 50/60Hz notch filter.

The second register is the Rate Control register which controls the rate at which the Data Available (DAV) pin is asserted. The internal sensor data update rate is 111 Hz. This is generally much faster than the requirements of an HVAC transmitter so the Rate Control register will throttle down the rate at which the Data Available pin (DAV) is asserted. The DAV is reset upon each read of the pressure sensor. An internal model of the Rate Controller is illustrated in the figure to the right.



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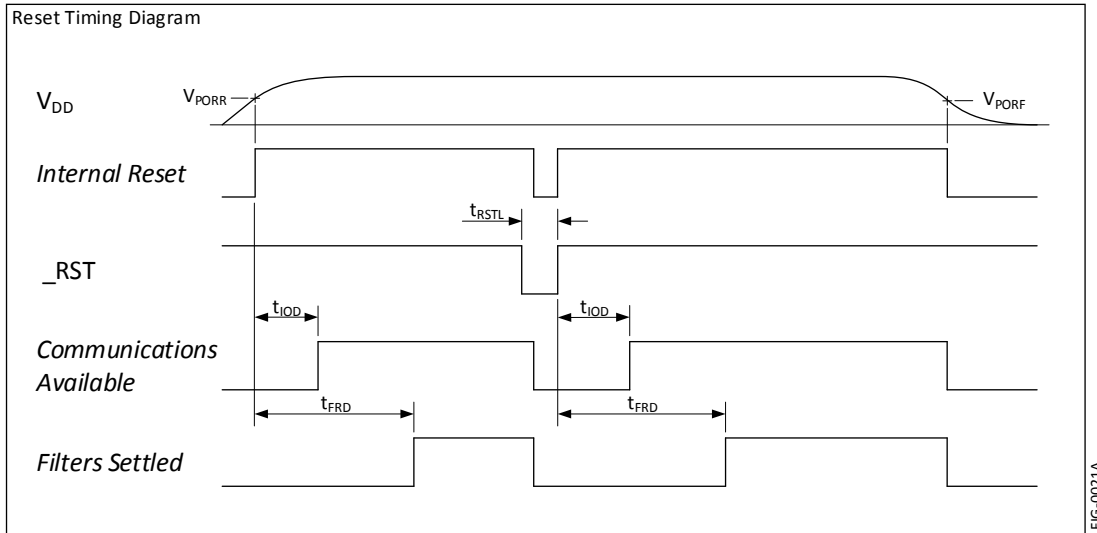
10 Interface

10.1 Reset

Reset timing is shown in the diagram below.

The communications method (SPI or I²C) is established during the time just after reset. During this time (t_{IOD}), no communications should take place.

Also, the internal filters are settling during the time t_{FRD} and data acquired during this time may not be fully settled.

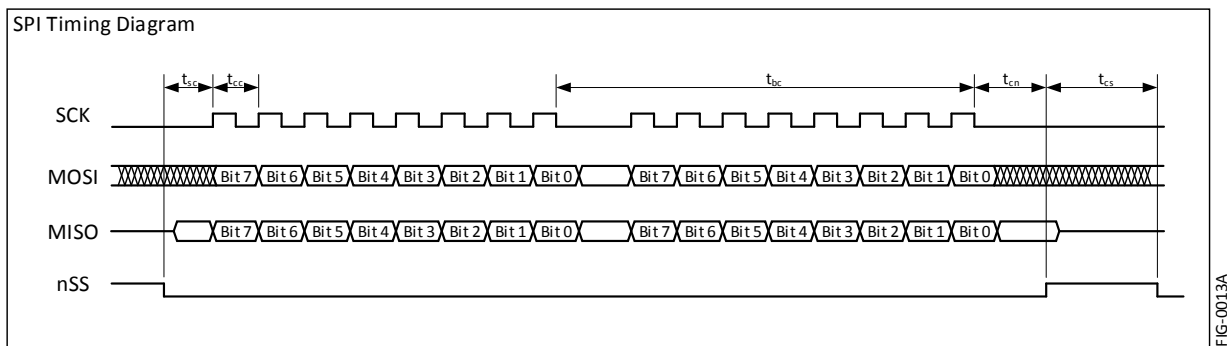


10.2 Communication Interface Selection

The communications interface is selected by interrogating the nSS pin after the internal power on reset delay. If nSS is high, the SPI interface will be selected otherwise (if low) the I²C interface will be selected. Grounding the nSS pin is an acceptable method for selecting the I²C interface. NOTE: The I²C interface supports 10 interface addresses. Refer to section 10.4.1 for the details on I²C address selection.

10.3 SPI Interface

The SPI interface uses a 16 bit transfer for all communications. Data is MSB first for both MOSI and MISO data transfers. Refer to the figure below for specific timing requirements.

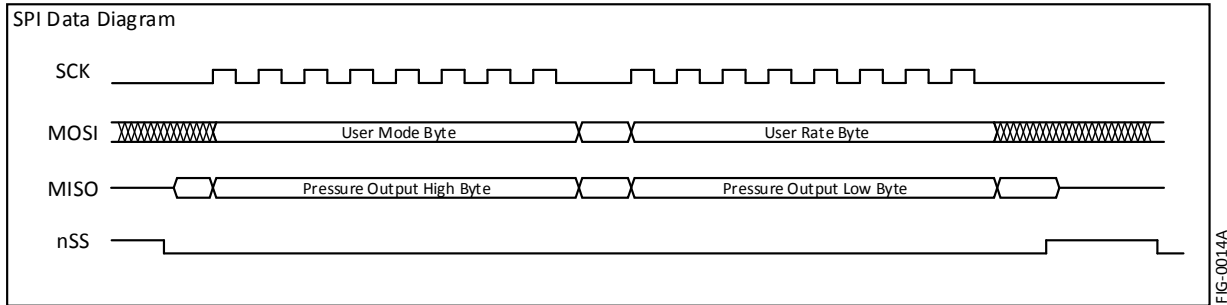


The data communications has been reduced to a simple 16 bit transfer model for reading the pressure output. Each communication cycle consists of master sending the Mode and Rate data to be placed into the sensor Mode Register and Rate Registers respectively. Simultaneously, the sensor sends the pressure data for the master to receive. Refer to the figure below for the data communication model of the HV Series sensor.

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The requirement to send the Mode and Rate bytes on each data read cycle is intentional. The purpose is to force the master to send specific data for each communication and prevent inadvertent data from being sent to the sensor. Since a SPI interface will generally re-circulate data through its shift register, the intention is to prevent the pressure output from the sensor from being re-circulated back to the sensor and potentially causing unintended corruption of manufacturing data.



10.4 I²C Interface

The HV Series is compatible with the I²C protocol. For detailed information regarding the I²C protocol, please refer to the Philips I²C Bus Specification, Version 2.

10.4.1 I²C Address

R1 (kΩ)	R2 (kΩ)	Address (decimal)	Address (hex)
120	5.6	49	0x31
120	12	48	0x30
120	27	47	0x2F
120	51	46	0x2E
120	100	45	0x2D
56	100	44	0x2C
30	100	43	0x2B
15	100	42	0x2A
5.6	100	41	0x29
0	NoPop	40	0x28

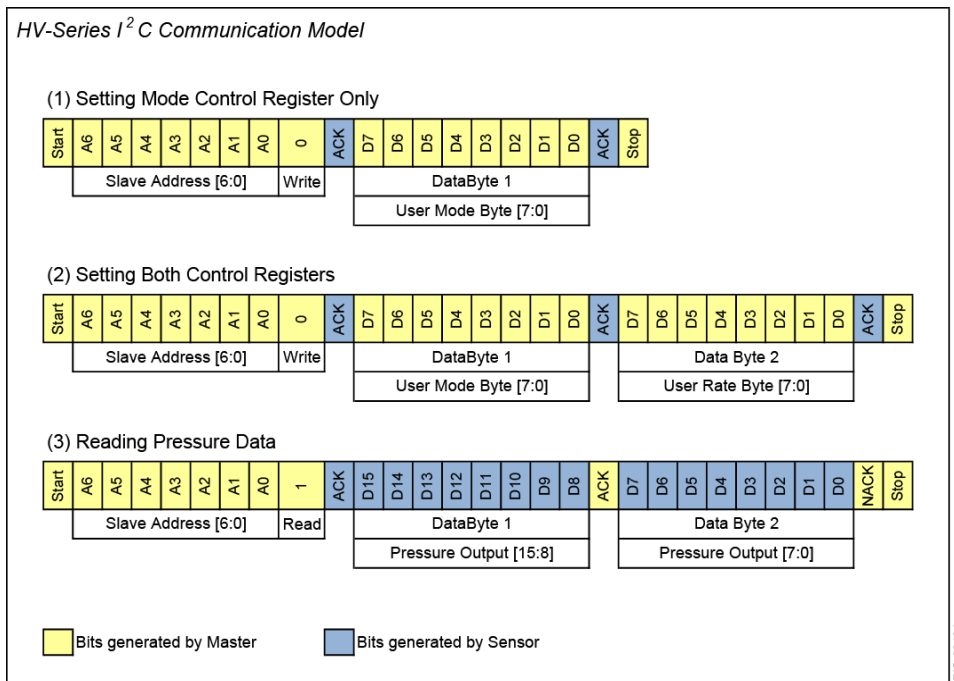
The I²C address is set to 0x28 by grounding the SCK line. Other I²C addresses can be established by applying a voltage to the SCK line by use of a resistor divider across the sensor supply voltage. The suggested resistor values and the respective I²C address are shown in the table to the left.

Note: R1 is the lower resistor of the divider where R2 is the upper resistor of the divider.

10.4.2 I²C Communications Model

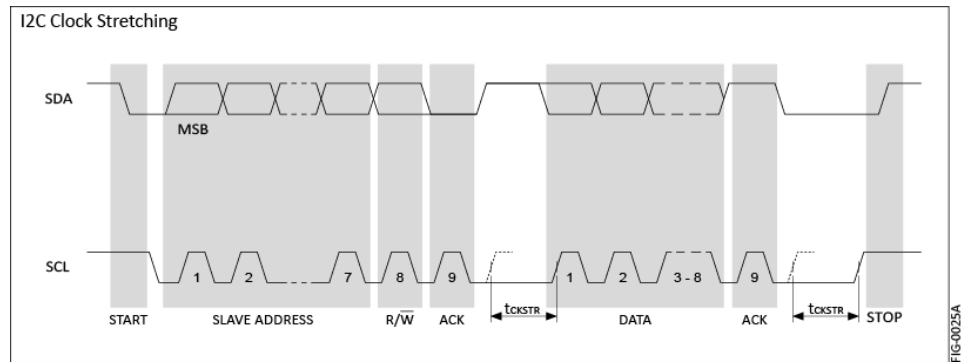
The sensor is configured as a slave device and as such, the communicating host must be configured as a master. There are two types of possible data transfers, data transfers from the master transmitter to an addressed sensor (WRITE), and data transfers from an addressed sensor to a master receiver (READ). The master device initiates both types of data transfers and provides the serial clock pulses on SCL.

The communications model for I²C is similar to that of SPI however, since I²C is a half-duplex protocol, the transfer of information to and from the sensor is separated into two separate communications. This is in contrast to the SPI interface where the transmitted and received data occurs simultaneously to and from the host. Refer to the figure to the right for the data communication model for the HV Series sensors.



10.4.3 I²C Clock Stretching

The figure to the right illustrates the I²C clock stretching by the sensor. At times, the sensor requires additional time to respond to the host and utilizes the clock stretching feature of the I²C protocol. This is accomplished by holding the SCL low after the ACK cycle of a data transfer. Refer to Section 7.5 for the clock stretching timing. Note, the maximum clock stretch time will generally only occur once during the three ACK cycles of a two byte transfer. That is, the balance of ACK's during a multi-byte transfer will generally include the typical clock stretching time.



10.4.4 I²C Bus Compatibility

The I²C specification allows any recessive voltage between 3.0 and 5.0 V. Different devices on the bus may operate at different voltage levels. However, the maximum voltage on any port pin must conform to the electrical characteristics specifications (See section 1). The bi-directional SCL (serial clock) and SDA (serial data) lines must be connected to a positive power supply voltage through a pull-up resistor or similar circuit. Every device connected to the bus must have an open-drain or open-collector output for both the SCL and SDA lines, so that both are pulled high (recessive state) when the bus is free.

10.5 Extended Data Acquisition

10.5.1 Available Extended Data

For either the SPI or I²C interface, additional data is available beyond the pressure. The means to access this extended data is to continue reading data (either SPI or I²C) beyond the first 16 bits of pressure information. The following table defines the order of the available data and respective format.

Data	Bytes	Format	Interpretation	Example
Pressure	1-2	2 byte, Signed Int	See Section 10.7	See Section 10.7
Temperature	3-4	2 byte, Signed Int	Fixed Decimal [8.8 bits], Upper 8 bits integer, lower 8 bits fractional. Temperature in °C	1880H (18.80H) = 24.5°C
Model	5-10	6 byte, ASCII, null terminated	Right reading ASCII with null termination	48H,56H,32H,31H,30H,00H = HV210
Serial Number	11-14	4 byte, Hex	Unique 4 byte serial for each part	2FD627A4H
Build Number	15-20	6 byte, ASCII, null terminated	Right reading ASCII with null termination	30H,30H,30H,33H,43H,00H = 0003C

10.5.2 SPI Extended Data Read

Reading the extended data while using the SPI interface is the same as shown in Section 10.3 with exception that the master continues to read during the same nSS sequence to read all 20 bytes of the extended data. Any portion of the 20 bytes can be read during the transfer. That is, for example, 4 bytes could be read to acquire only the pressure and temperature information. When reading the extended data, only the first two bytes sent to the sensor (User Mode and User Rate) are used to set the internal registers. The subsequent bytes (bytes 5 through 20) are ignored. Data read following the first 20 bytes is undefined.

10.5.3 I²C Extended Data Read

Reading the extended data via the I²C interface is similar to using the SPI interface where the master can simply continue to reading the sensor during the pressure reading transfer. The master continues Ack'ing until the number of desired bytes are read.

10.6 Control Registers

10.6.1 Mode Control Register

Default Value: 0xF6

Details of the Mode Control register are illustrated in the figure to the right.

Bits 0-2 control the output pressure range.

Bit 3 is the I/O Watchdog Enable bit. When set, the I/O watchdog is enabled. When enabled, the I/O watchdog will monitor the I/O activity. If I/O activity is not detected for the I/O Watchdog timeout time, the pressure sensor will reset itself. The I/O watchdog timeout time is determined by the currently active bandwidth setting. This is whether the bandwidth is selected directly or by using the Auto Select bandwidth.

Bits 4-6 control the BW Limit Filter. Note: When the BW bits are all set, the BW is automatically selected according to the selected pressure range (see table to right).

Bit 7 is the Notch Filter Enable bit. When enabled, the 50/60Hz notch filter is active.

Please note the available pressure ranges for the different sensor models are indicated in the table. For values where the pressure range is not available for the given sensor (high or low), the table is highlighted in light orange and indicates the given full scale value to use for pressure conversion. It is possible to use these values however, since they do effect the set sensor bandwidth when the Auto Select bandwidth value (BW Limit Select = 111b) is used.

It should also be noted that upon changing the Mode Control value, there is a one cycle latency before the new Mode Control value becomes valid. That is, the data of the communication cycle following a change to the Mode Control register will not reflect the change. It is not until the second communication cycle that the change in the Mode Control register will be reflected in the output data.

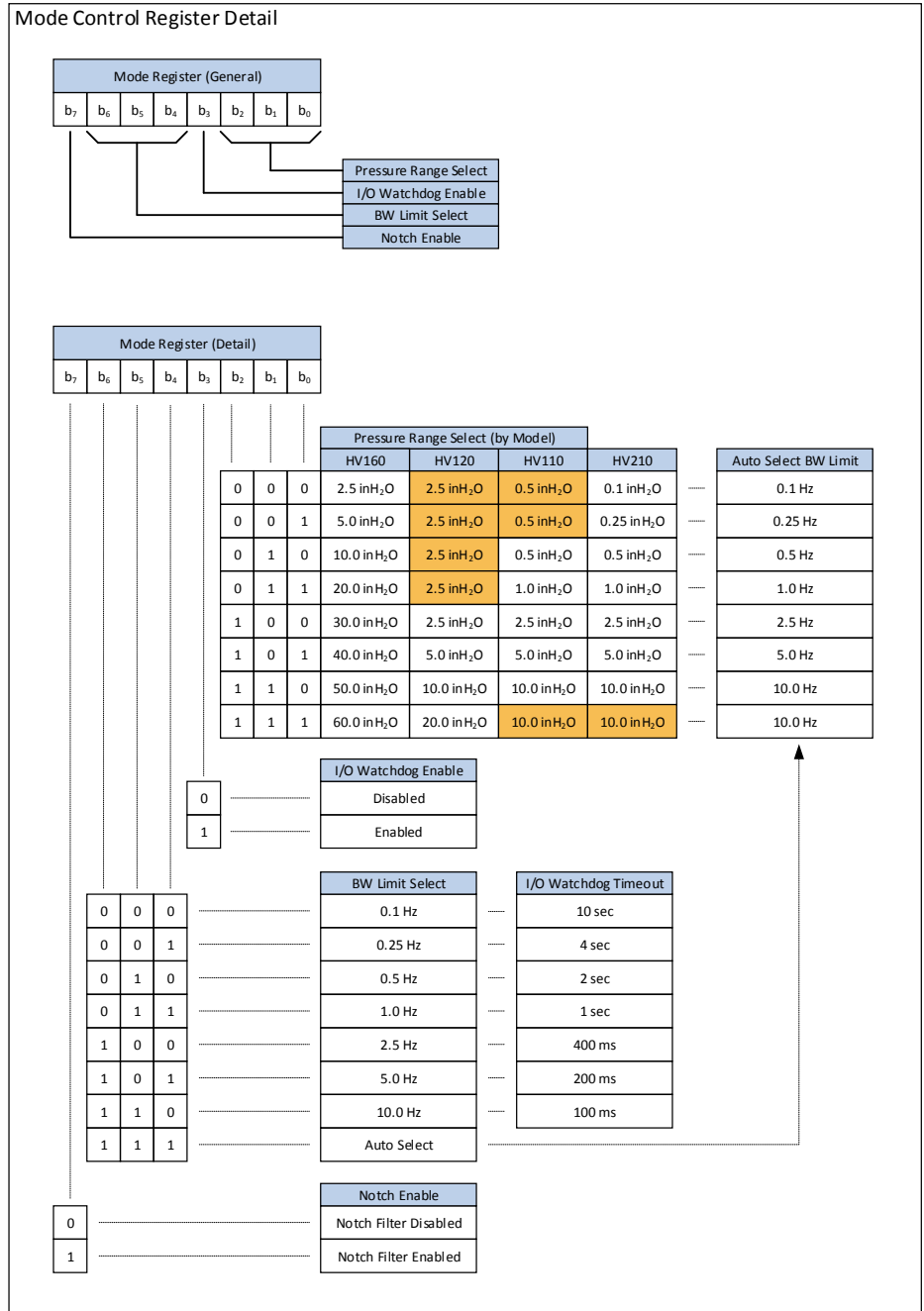


FIG-0023C

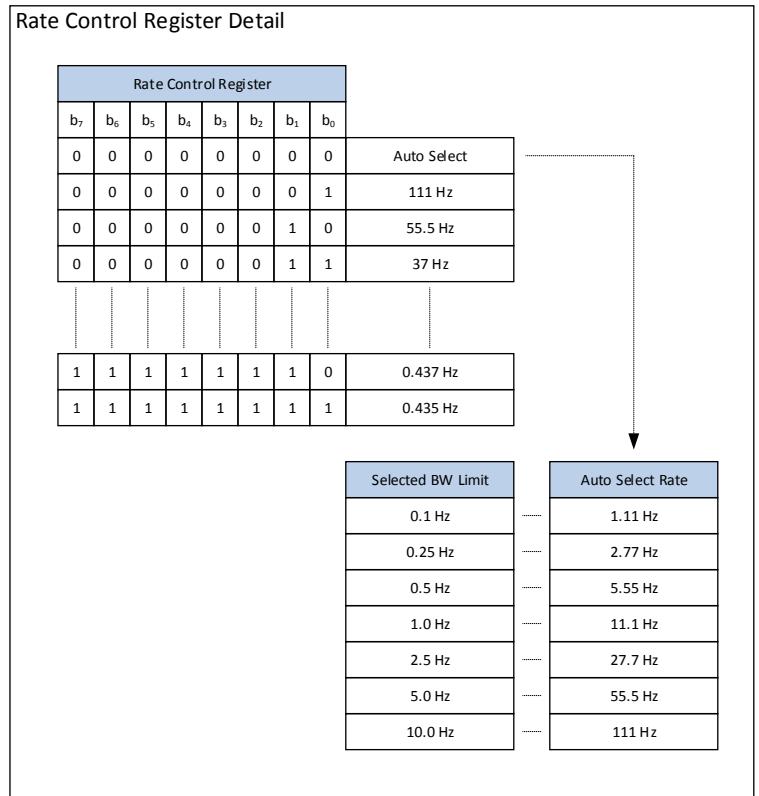
10.6.2 Rate Control Register

Default Value: 0x00

The Rate Control Register controls the rate at which the DAV pin is asserted indicating new data is available. This register is primarily used to throttle down the actual data transfer rate (when using the DAV as the trigger to sample) since the general HVAC requirement is less than the internal 111Hz update rate.

The function of this register is that it is the reload value of a data rate counter. The value of the Rate Control Register is the divisor of the 111 Hz internal data rate. Since a divisor of zero is not possible, a zero value will select the auto-select rate mode. In this mode, the rate is selected based on the selected bandwidth limit. The auto rate value is 11.1 times the corner frequency of the bandwidth limit in all auto selected rates.

Note: Start-up time for the sensor is approximately 250ms for the first sample to be settled. Requesting data during this time will result in invalid information. However, this start-up time can be used for configuring the Mode and Rate registers by performing a transfer with the desired Mode and Rate register values and discarding the received pressure data. After waiting the required start-up time, the sensor will respond with desired data since the Mode and Rate registers have been pre-established.



10.7 Computing Pressure

The pressure data is in the form of 16 bit signed integer sent in high byte then low byte order. This is a differential output by definition and the data range is $\pm 2^{15}$. There is a 10% margin in the output scaling and the selected full scale will reside in the 90% band of the total available output data range. Refer to Equation 1 (below) for the general model for computing the output pressure. As an example, if the sensor output is 3,647 counts and the selected pressure range is 1.0 inH₂O, then the output pressure is 0.124 inH₂O. Conversely, for a -3,647 count with the selected pressure range of 1.0 inH₂O, the computed output pressure is -0.124 inH₂O. Refer to Example 1 (below) for the specific example computation.

$$Eq\ 1: P_{inH_2O} = \frac{Out_{DIGITAL}}{90\% * 2^{15}} * Range_{SELECTED}$$

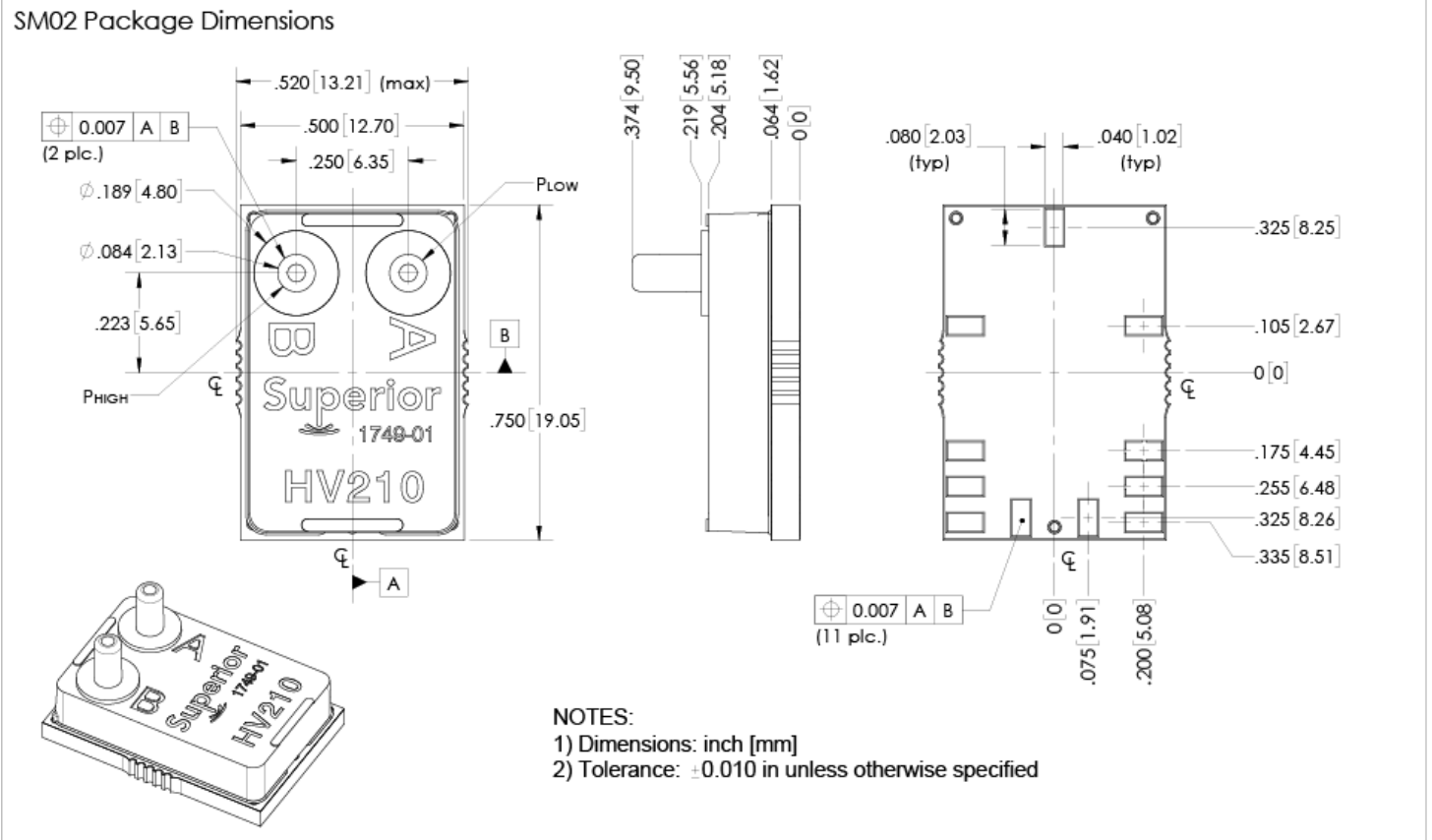
$$Example\ 1: P_{inH_2O} = \frac{3,647}{90\% * 2^{15}} * 1\ inH_2O = 0.124\ inH_2O$$

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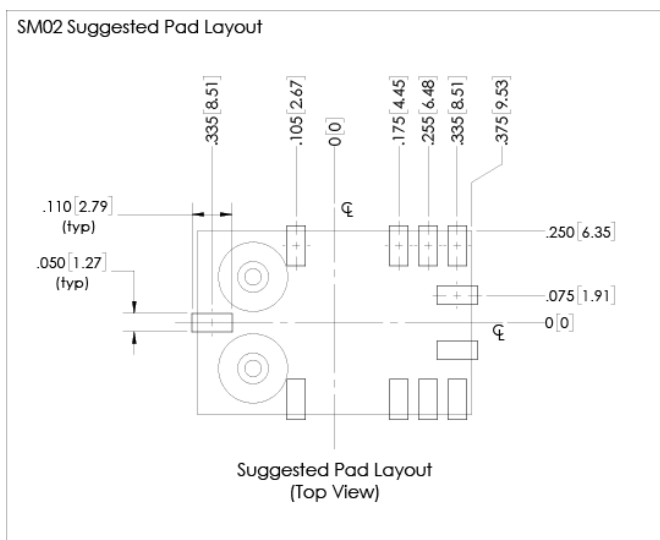
11 Mechanical and Manufacturing

11.1 Package Dimensions



11.2 Suggested Pad Layout

The suggested pad layout is shown in the figure below. An Eagle PCB symbol library is available with the shown pad dimensions. Please consult the factory to obtain the library.



11.3 Pinout

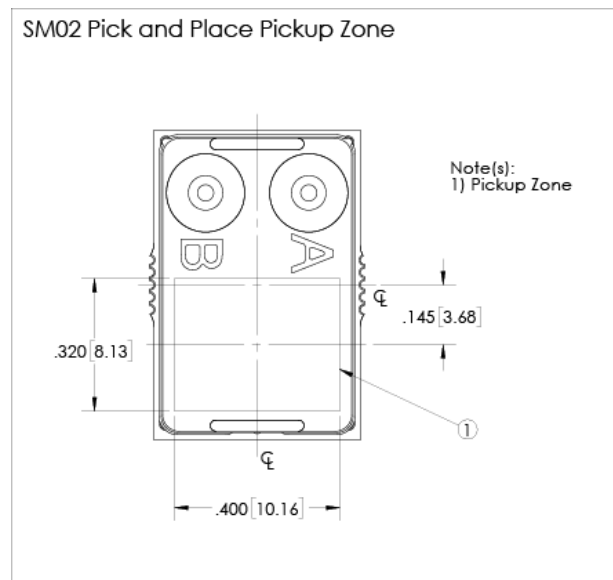
Pin	Sym	SPI	I ² C
1	nSS	Slave Select (active low)	Tie to Ground
2	MOSI/SCL	MOSI	SCL
3	MISO/SDA	MISO	SDA
4	SCK	Serial Clock	See Section 10.4.1
5	DNC	Do Not Connect	
6	DNC	Do Not Connect	
7	DNC	Do Not Connect	
8	Gnd	Ground	
9	V _{DD}	Sensor Supply	
10	nRST	Reset (active low)	
11	DAV	Data Available	



11.4 Reflow Soldering and Handling Conditions

Parameter	Sym	Val	Units
Soldering Specifications (Max)			
Preheat Ramp Rate	t _{PHRR}	3	°C/s
Soak Time	t _{SOAK}	3	min
Time Above 217C	t _{GT217}	50	s
Time Above 230C	t _{GT230}	40	s
Time Above 250C	t _{GT250}	15	s
Peak Temperature	t _{PT}	255	°C
Cooling Ramp Rate	t _{CRR}	-4	°C/s
Weight	W _{PRT}	3.5	gm
Moisture Sensitivity	MSL	3	
ESD (Human Body Model)	ESD	2	kV

11.5 Pick and Place Pick-up Zone



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11.6 Packaging Options

11.6.1 Tray Packaging

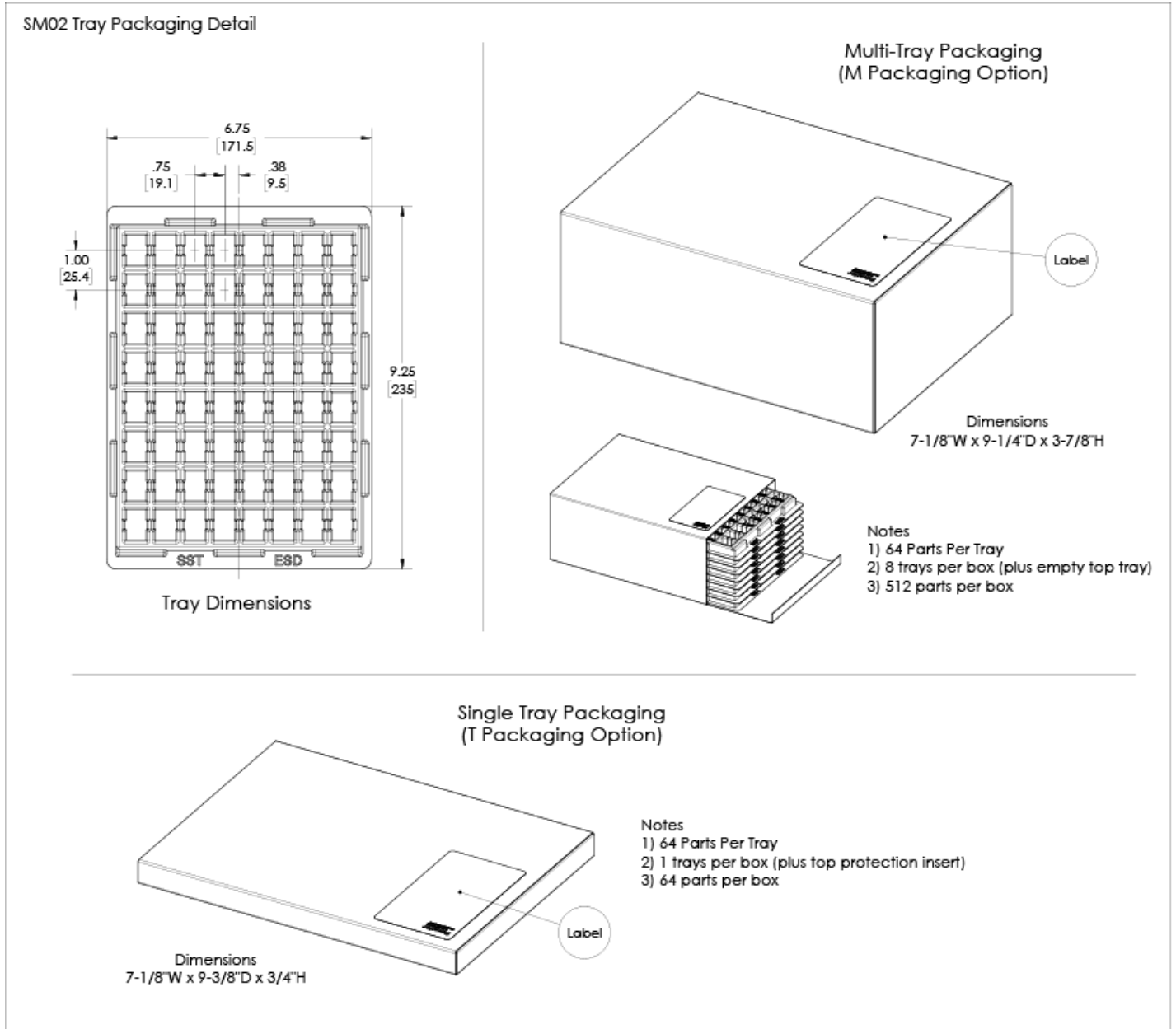


FIG-00228

11.6.2 Tape and Reel

SM02 Tape and Reel Detail

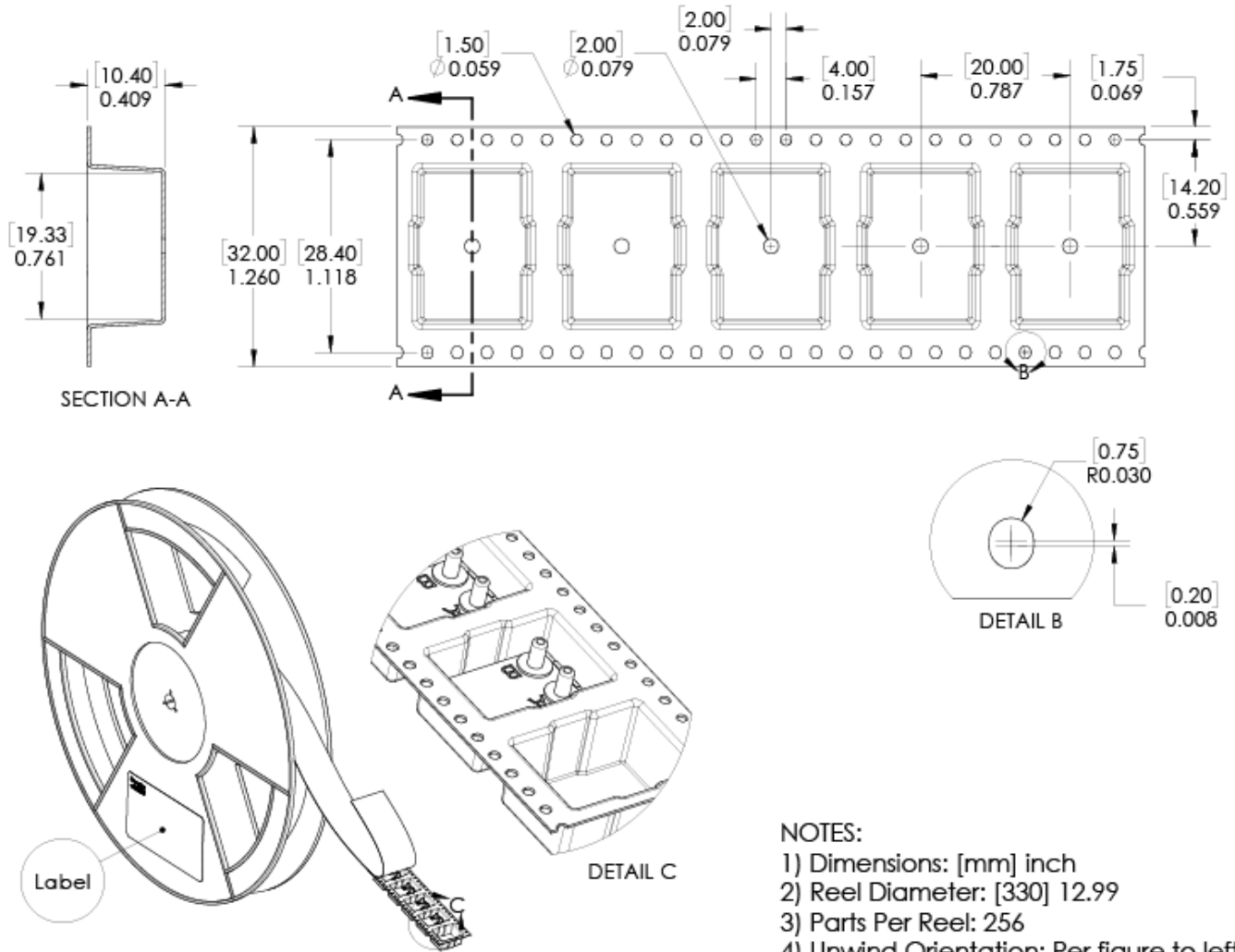
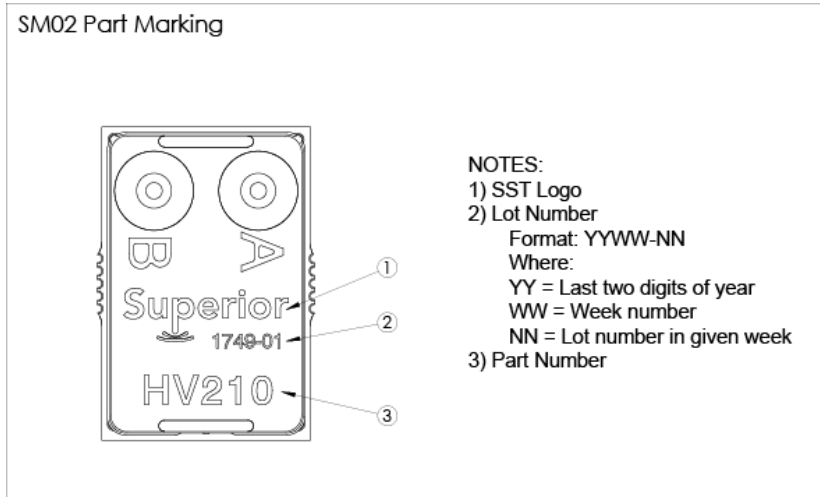


FIG-001.5A

HV Series

Differential Low Pressure Sensors

11.7 Part Identification



12 Packaging Labeling

Packaging labels are provided with barcode Code 128 symbology. The provided fields are Company Name, Part Number, Packaging ID and Quantity. The Packaging ID traces back to the Lot Number (or Lot Numbers) contained in the package. The purpose is to eliminate multiple labels (one for each included Lot Number) in the event of multiple Lot Numbers within a single package. This is for ease of customer tracking and maintenance. The Packaging ID is a 24 bit value printed in hexadecimal format.

13 Ordering Information

Part Number	Part Package	Packaging	Packaging Qty	Order Number
HV160-SM02	SM02	Tape and Reel	256	HV160-SM02-R
		Multi-Tray	512	HV160-SM02-M
		Single Tray	64	HV160-SM02-T
		Quarter Reel	64	HV160-SM02-Q
		Cut Tape	1-63	HV160-SM02-C
HV120-SM02	SM02	Tape and Reel	256	HV120-SM02-R
		Multi-Tray	512	HV120-SM02-M
		Single Tray	64	HV120-SM02-T
		Quarter Reel	64	HV120-SM02-Q
		Cut Tape	1-63	HV120-SM02-C
HV110-SM02	SM02	Tape and Reel	256	HV110-SM02-R
		Multi-Tray	512	HV110-SM02-M
		Single Tray	64	HV110-SM02-T
		Quarter Reel	64	HV110-SM02-Q
		Cut Tape	1-63	HV110-SM02-C
HV210-SM02	SM02	Tape and Reel	256	HV210-SM02-R
		Multi-Tray	512	HV210-SM02-M
		Single Tray	64	HV210-SM02-T
		Quarter Reel	64	HV210-SM02-Q
		Cut Tape	1-63	HV210-SM02-C