# ND Series

## Differential Pressure Sensors
## Industrial Applications

- Highly integrated sensor with ADC and DSP
- Up to 7 Selectable Pressure Ranges per Device
- Pressure ranges 0.25 inH$_2$O (62.5 Pa) to 5 psi (345 mBar)
- 16-bit resolution (each selected range)
- Exceptional Zero Stability
- Integrated 50/60Hz Notch Filter
- Selectable Bandwidth Filter from 1.0Hz to 200Hz
- Output Data Rate up to 444Hz
- Total Error Band less than 0.15% FSS
- Very High Accuracy +/- 0.05% of Selected Range
- Long Term Stability +/- 0.05% FSS
- Silicon gel protection on psi rated models
- Temperature Compensated -20°C to 85°C
- Supply Voltage Compensation
- Fully Integrated Compensation Math
- Standard I$^2$C and SPI Interface

## Product Summary

Based on Superior's NimbleSense™ architecture, the ND Series family extends the operating temperature down to -20°C and up to 85°C, while increasing pressures up to 5 psi (345mBar). Additionally, the ND utilizes the company's proprietary Multi-Range™ technology to create the industry's widest dynamic range. This wider dynamic range offers multiple pressure ranges in a single package thus minimizing the number of sensor variants required to support the demanding functional requirements of the various industrial market segments. For example, one Multi-Range enabled ND Sensor replaces up to 7 competing products greatly simplifying installation requirements and significantly lowering inventory costs.

Supporting pressure ranges as low as 0.25 inH2O to as high as 5 psi, the ND Series is ideal for a wide variety of industrial applications from air curtains to aeronautics, from environmental chambers to eye surgery equipment, and from UAVs to 3D Printing.

The ND Series measures dry air and non-aggressive gas pressure with very high accuracy and a stable zero point. Non-linearity is also industry leading which is typically 0.05% FSS. The ND Series has a selectable bandwidth filter from 1Hz to 200Hz, and 16-bit resolution. For added performance, the ND Series has incorporated a 50/60Hz notch filter to minimize the impact of power noise spikes. Finally, the ND Series is an excellent choice for applications requiring the utmost reliability.

The ND Series provides a new level of integration combining an advanced piezoresistive sensing element with integrated amplification, ADC, DSP and a digital interface which greatly simplifies customer integration efforts. Advanced digital processing enables new functionality thus simplifying system development, adding manufacturing ease and increasing reliability.

Constructed with a high reliability plastic enclosure, the ND Series family provides the ideal combination of very high performance and reliability at extended temperature ranges while ensuring customers have a high volume, cost effective solution optimized for a wide array of industrial requirements.

# ND Series
## Industrial Pressure Sensors

**Superior SENSOR TECHNOLOGY**

## Table of Contents

## 1 Maximum Ratings

| Parameter | Sym | Min | Max | Units |
|---|---|---|---|---|
| Supply Voltage | $V_{DDM}$ | Gnd-0.3 | 4.0 | V |
| Voltage on I/O Pins<br>$V_{DD} > 3.3V$<br>$V_{DD} \leq 3.3V$ | $V_{IOML}$<br>$V_{IOMH}$ | Gnd-0.3<br>Gnd-0.3 | 5.8<br>$V_{DD}$+2.5 | V<br>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 | $T_A$ | -20 | 85 | °C |

## 3 Environmental

| Parameter | Sym | Min | Max | Units |
|---|---|---|---|---|
| Temperature Range<br>Compensated<br>Operating<br>Storage | $T_{CMP}$<br>$T_{OP}$<br>$T_{STG}$ | -20<br>-20<br>-40 | 85<br>85<br>85 | °C<br>°C<br>°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 | - | Cycles |

## 4 Equivalent Circuit
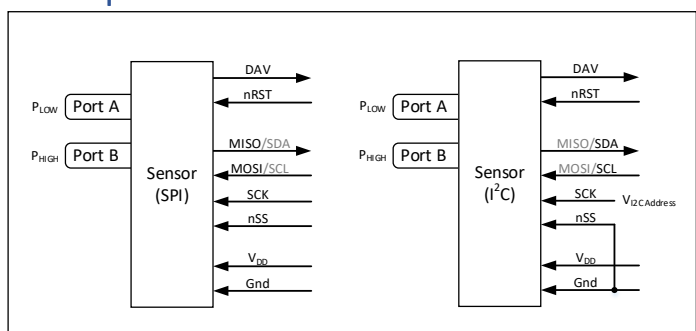
## 5  Feature List

Low Pressure (inH2O Ranges)

| Parameter | Sym | ND210 | ND110 | ND120 | ND130 | Units | Notes |
|---|---|---|---|---|---|---|---|
| Number of FS Pressure Ranges | $P_{NUM}$ | 7 | 6 | 7 | 7 | Each | |
| Specified FS Range Extents | $P_{EXT}$ | ±0.25 to ±10 | ±0.5 to ±10 | ±1.0 to ±20 | ±2.0 to ±30 | $inH_2O$ | |
| Number of BW Filter Corners | $BW_{NUM}$ | 8 | | | | Each | |
| BW Corner Frequency Extents | $f_{BWEXT}$ | 1.0 to 200 | | | | Hz | |
| Common Mode Pressure | $P_{CM}$ | 500 | 500 | 500 | 700 | $inH_2O$ | 1 |
| Proof Pressure | $P_{PROOF}$ | 40 | 40 | 40 | 100 | $inH_2O$ | 2 |
| Burst Pressure | $P_{BURST}$ | 120 | 120 | 120 | 200 | $inH_2O$ | 3 |

Middle Pressure (psi Ranges)

| Parameter | Sym | ND005D | Units | Notes |
|---|---|---|---|---|
| Number of FS Pressure Ranges | $P_{NUM}$ | 6 | Each | |
| Specified FS Range Extents | $P_{EXT}$ | ±0.5 to ±5.0 | psi | |
| Number of BW Filter Corners | $BW_{NUM}$ | 8 | Each | |
| BW Corner Frequency Extents | $f_{BWEXT}$ | 1.0 to 200 | Hz | |
| Common Mode Pressure | $P_{CM}$ | 25 | psi | 1 |
| Proof Pressure | $P_{PROOF}$ | 15 | psi | 2 |
| Burst Pressure | $P_{BURST}$ | 20 | psi | 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 | ND210 | | | ND110/ND120/ND130 | | | ND005D | | | Units | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | | |
| Accuracy | $P_{ACC}$ | - | 0.05 | 0.2 | - | 0.05 | 0.2 | - | 0.05 | 0.2 | % RNG | 1, 2 |
| Total Error Band | TEB | - | 0.10 | 0.3 | - | 0.15 | 0.75 | - | 0.07 | 0.5 | % FSS | 3 |
| TEB After AZ | $TEB_{AZ}$ | - | 0.07 | 0.2 | - | 0.10 | 0.5 | - | 0.05 | 0.3 | % FSS | 7 |
| Long Term Stability | LTS | - | 0.10 | 0.25 | - | 0.15 | 0.35 | - | 0.05 | 0.15 | % FSS/Yr | |
| Thermal Hysteresis | $T_{HYS}$ | - | 0.05 | - | - | 0.075 | - | - | 0.075 | - | % FSS | |
| Pressure Hysteresis | $P_{HYS}$ | - | 0.05 | - | - | 0.05 | - | - | 0.05 | - | % RNG | 1 |
| Position Sensitivity | $P_{PS}$ | - | 0.25 | - | - | 2.0 | - | - | 2.5 | - | Pa | |
| Supply Rejection | $P_{SR}$ | - | 0.0005 | - | - | 0.0005 | - | - | 0.0005 | - | Pa/mV | |
| Resolution | RES | - | 16 | - | - | 16 | - | - | 16 | - | bit | 4 |
| System ENOB | ENOB | - | 17 | - | - | 17 | - | - | 17 | - | $Bit_{RMS}$ | 5 |
| Data Update Rate | $f_{UPDATE}$ | 432 | 444 | 456 | 432 | 444 | 456 | 432 | 444 | 456 | Hz | 6 |

1) Percentage of selected range.
2) Uncertainty limited by system noise for ranges of 0.5 $inH_2O$ and below.
3) Includes errors of offset, span, hysteresis and thermal effects.
4) Each selected range has the specified resolution
5) ENOB stated for $f_{BW}$ set to 1.0 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) Total error band within 24 hours of a sensor auto-zero. Includes all error components of TEB.

# 7 Electrical Characteristics

## 7.1 Supply Characteristics

| Parameter | Sym | ND210 | | | ND110/ND120/ND130/ND005D | | | Units | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | | |
| Supply Current | $I_{DD}$ | - | 6.0 | 6.5 | - | 5.0 | 5.5 | 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 | All ND Series Parts | | | Units | Notes |
|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | | |
| Power-On Reset Threshold | $V_{PORR}$ $V_{PORF}$ | Rising Voltage on $V_{DD}$ Falling Voltage on $V_{DD}$ | - 0.75 | 1.4 - | - 1.36 | V V | |
| Interface Detect Delay | $t_{IOD}$ | From POR or External Reset | - | - | 40 | ms | |
| First Response Settling Time | $t_{FRD}$ | From POR or External Reset | - | - | 80 | 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 | All ND Series Parts | | | Units | Notes |
|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | | |
| Output High Voltage | $V_{OH}$ | $I_O$ = -3 mA | $V_{DD}$-0.7 | - | - | V | |
| Output Low Voltage | $V_{OL}$ | $I_O$ = 8 mA | - | - | 0.6 | V | |

## 7.4 I$^2$C Characteristics

| Parameter | Sym | Condition | All ND Series Parts | | | Units | Notes |
|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | | |
| SCL Clock Frequency | $f_{SCL}$ | | 100 | - | 400 | kHz | |
| Clock Stretch Time | $t_{CKSTR}$ | | - | 15 | 100 | 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 | |

## 7.5 SPI Characteristics

| Parameter | Sym | Condition | All ND Series Parts | | | 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 | $t_{SC}$ | | 100 | - | - | us | |
| Clock Cycle Time | $t_{CC}$ | | 6 | - | - | us | |
| Byte to Byte Cycle Time | $t_{BC}$ | | 100 | - | - | us | |
| Time Last Clock to nSS High | $t_{CN}$ | | 20 | - | - | us | |
| Cycle Time nSS | $t_{CS}$ | | 6 | - | - | us | |
| Input Capacitance | $C_{IN}$ | | - | 7 | - | pF | 2 |

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

## 8 Materials

## 8.1 Wetted Materials

| Parameter | Sym | ND210 | | ND110/ND120/ND130 | | ND005D | | Units | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | $P_A$ | $P_B$ | $P_A$ | $P_B$ | $P_A$ | $P_B$ | | |
| Wetted Materials | $MAT_{WET}$ | Epoxy Nylon RTV Silicon Gold Aluminum | Epoxy Nylon RTV Silicon Gold Aluminum | Epoxy Nylon RTV Silicon | Epoxy Nylon RTV Silicon Gold Aluminum | Epoxy Nylon RTV Silicon | Epoxy Nylon RTV Silicon Gold Sil-Gel | | |

## 8.2 Material Compliance

| Parameter | Sym | All ND Series Parts | Units | Notes |
|---|---|---|---|---|
| RoHS | $REG_{RoHS}$ | RoHS Compliant | | |
| REACH | $REG_{REAC}$ | REACH Compliant | | |

# ND Series
## Industrial Pressure Sensors

## 9  System Overview

The ND 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 ND Series block diagram.
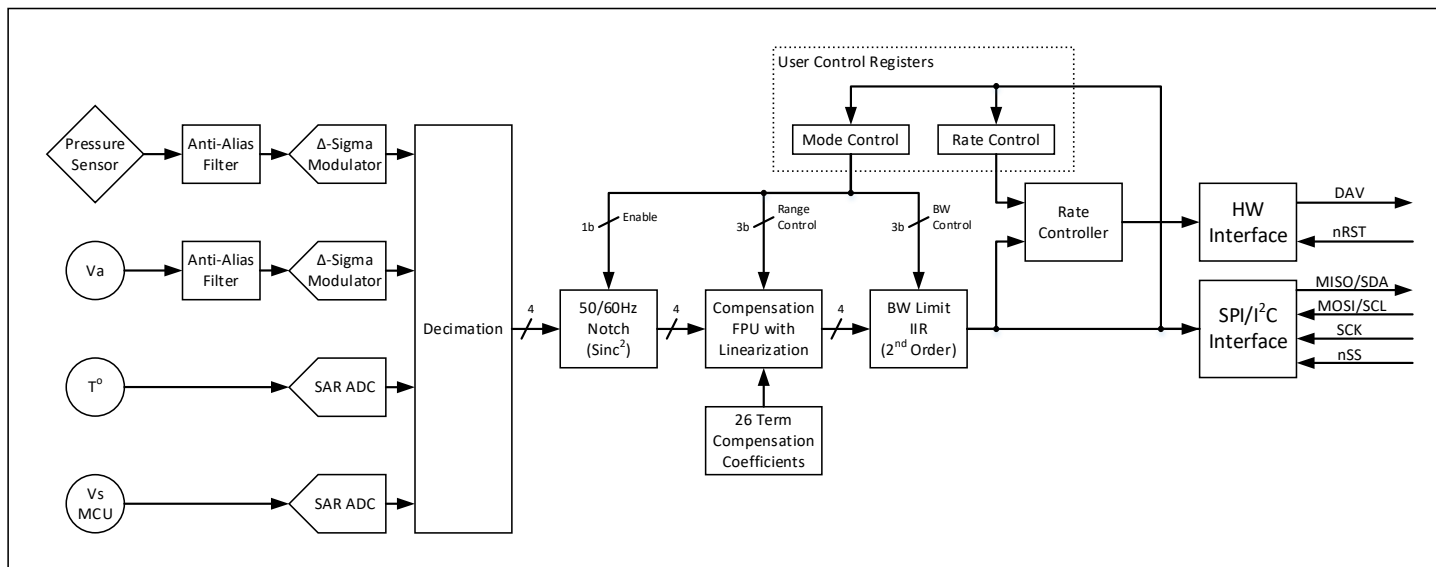


There are also two user controlled registers that tune the sensor to the specific user requirements.  The first register is the Mode Control register that determines the output pressure range, the corner frequency of the bandwidth limiting filter and enables or disables the 50/60Hz notch filter.

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 of 444 Hz is often much faster than industrial requirements so the Rate Control register can 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.
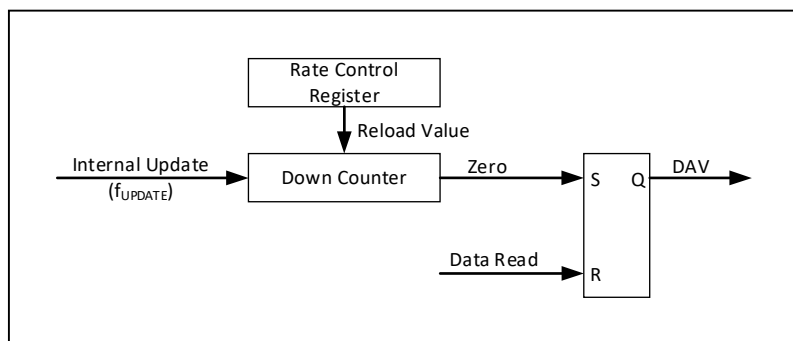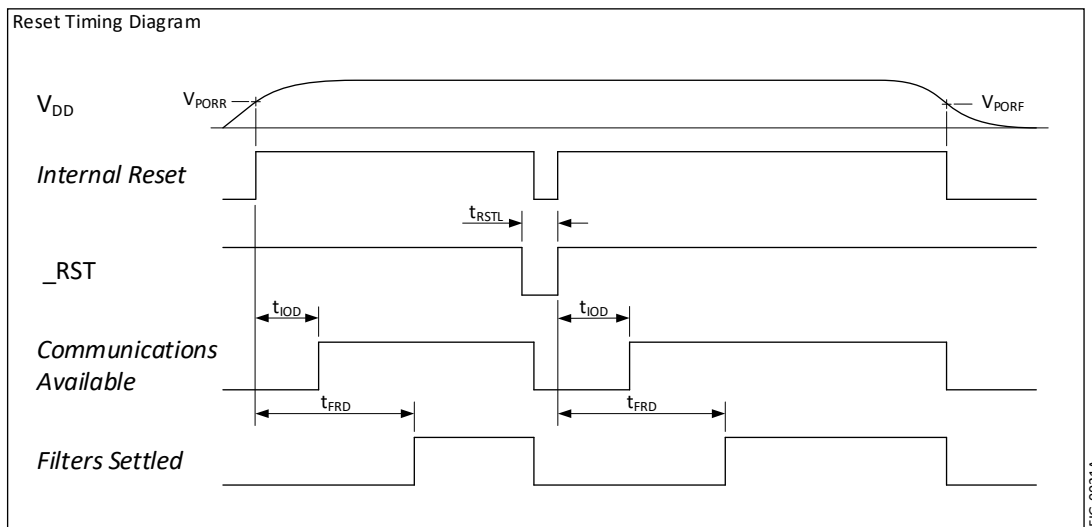
# 10 Interface

## 10.1 Reset

Reset timing is shown in the diagram below.

The communications method (SPI or I$^2$C) 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 I$^2$C interface will be selected. Grounding the nSS pin is an acceptable method for selecting the I$^2$C interface. NOTE: The I$^2$C interface supports 10 interface addresses. Refer to section 10.4.1 for the details on I$^2$C 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.
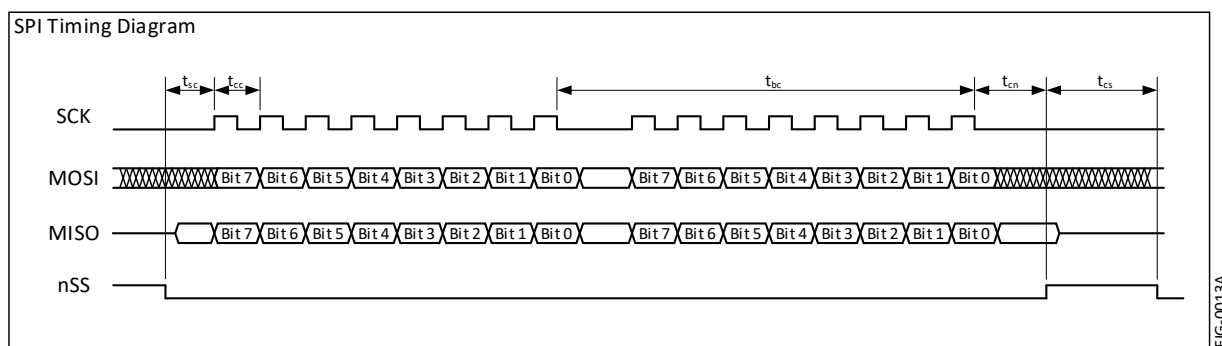


The data communications has been reduced to a simple 16 bit transfer model for reading the pressure output. Each communication cycle consists of master sending the Mode and Rate data to be placed into the sensor Mode Register and Rate Registers respectively. Simultaneously, the sensor sends the pressure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

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 the intended mode register.



SPI Data Diagram
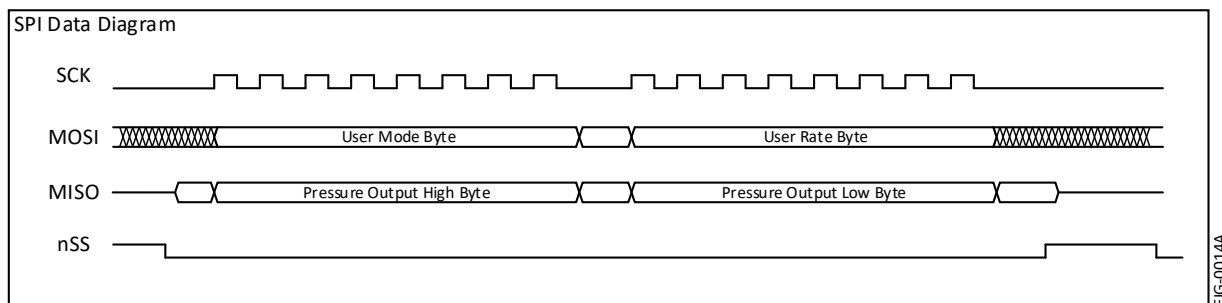
## 10.4 I$^2$C Interface

The ND Series is compatible with the I$^2$C protocol. For detailed information regarding the I$^2$C protocol, please refer to the Philips I$^2$C Bus Specification, Version 2.

### 10.4.1 I$^2$C Address

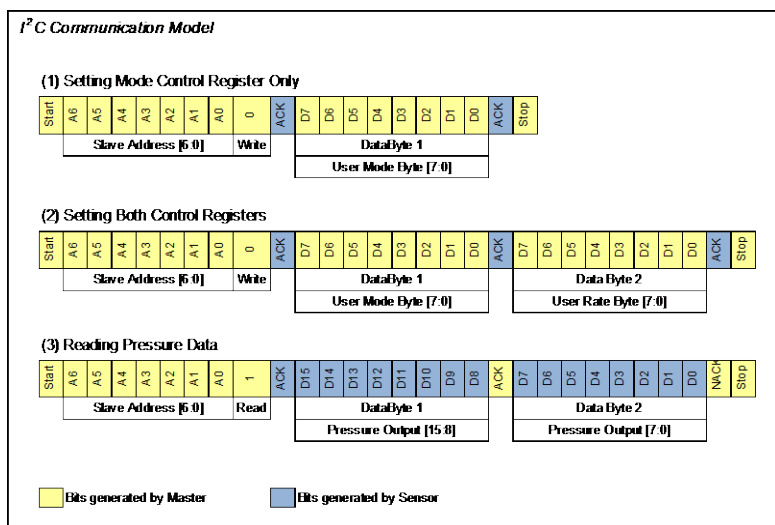| I2C Address Selection Table | | | |
|---|---|---|---|
| R1 (kΩ) | R2 (kΩ) | Address (decimal) | Address (hex) |
| 120 | 5.6 | 49 | 0x31 |
| 120 | 12 | 48 | 0x30 |
| 120 | 27 | 47 | 0x2F |
| 120 | 51 | 46 | 0x2E |
| 120 | 100 | 45 | 0x2D |
| 56 | 100 | 44 | 0x2C |
| 30 | 100 | 43 | 0x2B |
| 15 | 100 | 42 | 0x2A |
| 5.6 | 100 | 41 | 0x29 |
| 0 | NoPop | 40 | 0x28 |

The I$^2$C address is set to 0x28 by grounding the SCK line. Other I$^2$C 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 I$^2$C address are shown in the table to the left.

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

### 10.4.2 I$^2$C 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 I$^2$C is similar to that of SPI however, since I$^2$C 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 ND 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 7.4 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.
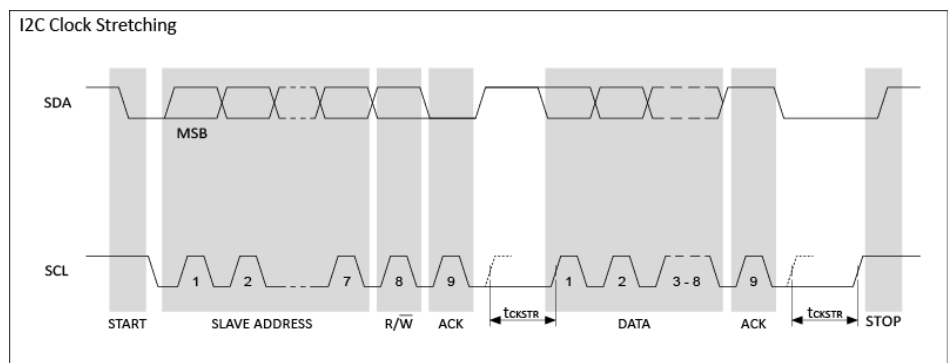


### 10.4.4  I²C Bus Compatibility

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 | 5-12 | 8 byte, ASCII, null terminated | Right reading ASCII with null termination | 4EH,44H,32H,31H,30H,00H,xxH,xxH = ND210<br>4EH,44H,30H,30H,35H,44H,00H,xxH = ND005D |
| Serial Number | 13-16 | 4 byte, Hex | Unique 4 byte serial for each part | 2FD627A4H |
| Software Number | 17-22 | 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 22 bytes of the extended data. Any portion of the 22 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 22) are ignored. Data read following the first 22 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.
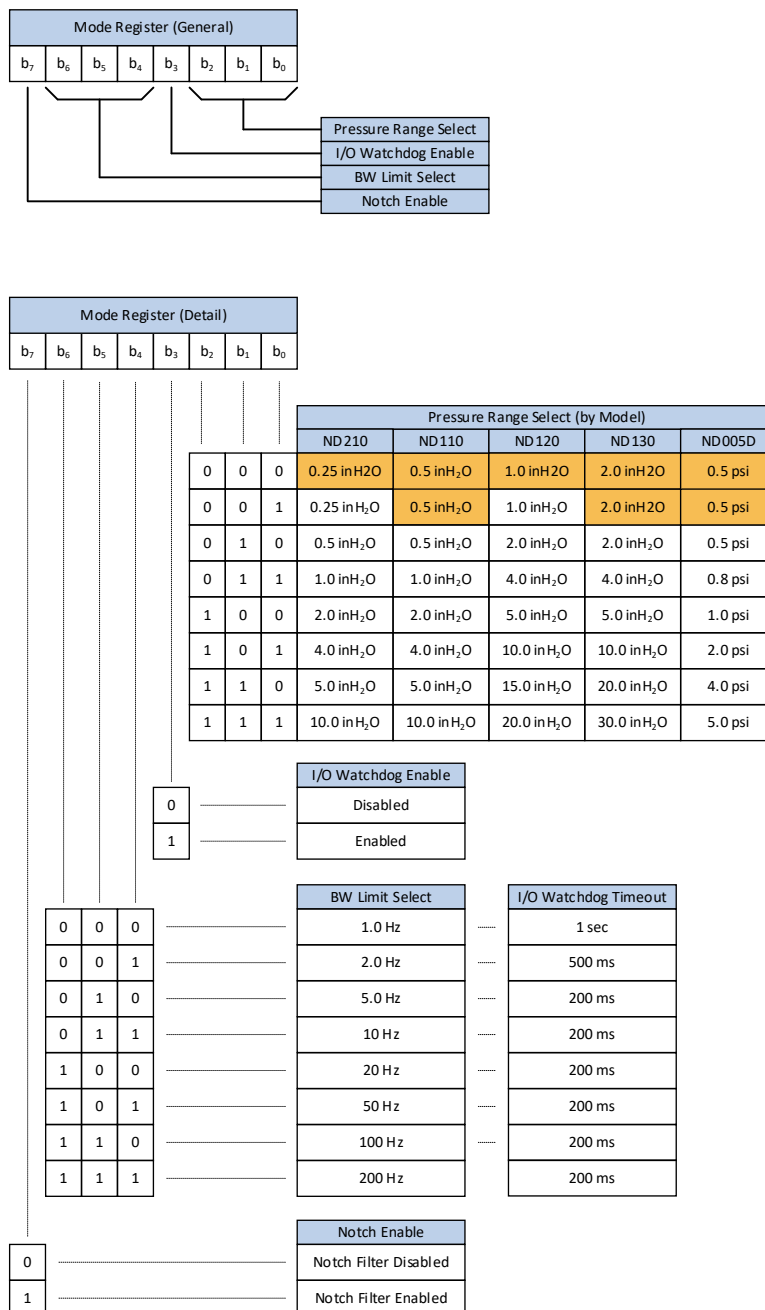
Bits 4-6 control the BW Limit Filter.

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.

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.

Mode Control Register Detail



Mode Register (General)

| b_7 | b_6 | b_5 | b_4 | b_3 | b_2 | b_1 | b_0 |

Pressure Range Select
I/O Watchdog Enable
BW Limit Select
Notch Enable

Mode Register (Detail)

| b_7 | b_6 | b_5 | b_4 | b_3 | b_2 | b_1 | b_0 |

| Pressure Range Select (by Model) | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | | ND210 | ND110 | ND120 | ND130 | ND005D |
| 0 | 0 | 0 | 0.25 inH2O | 0.5 inH$_2$O | 1.0 inH2O | 2.0 inH2O | 0.5 psi |
| 0 | 0 | 1 | 0.25 inH$_2$O | 0.5 inH$_2$O | 1.0 inH$_2$O | 2.0 inH2O | 0.5 psi |
| 0 | 1 | 0 | 0.5 inH$_2$O | 0.5 inH$_2$O | 2.0 inH$_2$O | 2.0 inH$_2$O | 0.5 psi |
| 0 | 1 | 1 | 1.0 inH$_2$O | 1.0 inH$_2$O | 4.0 inH$_2$O | 4.0 inH$_2$O | 0.8 psi |
| 1 | 0 | 0 | 2.0 inH$_2$O | 2.0 inH$_2$O | 5.0 inH$_2$O | 5.0 inH$_2$O | 1.0 psi |
| 1 | 0 | 1 | 4.0 inH$_2$O | 4.0 inH$_2$O | 10.0 inH$_2$O | 10.0 inH$_2$O | 2.0 psi |
| 1 | 1 | 0 | 5.0 inH$_2$O | 5.0 inH$_2$O | 15.0 inH$_2$O | 20.0 inH$_2$O | 4.0 psi |
| 1 | 1 | 1 | 10.0 inH$_2$O | 10.0 inH$_2$O | 20.0 inH$_2$O | 30.0 inH$_2$O | 5.0 psi |

| I/O Watchdog Enable | |
| --- | --- |
| 0 | Disabled |
| 1 | Enabled |

| BW Limit Select | | | | I/O Watchdog Timeout |
| --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 1.0 Hz | 1 sec |
| 0 | 0 | 1 | 2.0 Hz | 500 ms |
| 0 | 1 | 0 | 5.0 Hz | 200 ms |
| 0 | 1 | 1 | 10 Hz | 200 ms |
| 1 | 0 | 0 | 20 Hz | 200 ms |
| 1 | 0 | 1 | 50 Hz | 200 ms |
| 1 | 1 | 0 | 100 Hz | 200 ms |
| 1 | 1 | 1 | 200 Hz | 200 ms |

| Notch Enable | |
| --- | --- |
| 0 | Notch Filter Disabled |
| 1 | Notch Filter Enabled |

FIG-0083A

### 10.6.2 Rate Control Register

<u>Default Value: 0x00</u>

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 industrial requirement is less than the internal 444 Hz 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 444 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 roughly 3x the corner frequency of the selected bandwidth limit in all auto selected rates (where possible).

Note: Start-up time for the sensor is approximately 80ms 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.

**Rate Control Register Detail**

| Rate Control Register | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ | $b_0$ | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Auto Select |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 444 Hz |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 222 Hz |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 148 Hz |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1.75 Hz |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.74 Hz |

| Selected BW Limit | Auto Select Rate |
|---|---|
| 1.0 Hz | 3.0 Hz |
| 2.0 Hz | 6.0 Hz |
| 5.0 Hz | 15.3 Hz |
| 10 Hz | 31.7 Hz |
| 20 Hz | 63.4 Hz |
| 50 Hz | 148 Hz |
| 100 Hz | 444 Hz |
| 200 Hz | 444 Hz |

FIG-0084A

## 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 inH$_2$O, then the output pressure is 0.124 inH$_2$O. Conversely, for a -3,647 count with the selected pressure range of 1.0 inH$_2$O, the computed output pressure is -0.124 inH$_2$O. Refer to Example 1 (below) for the specific example computation.

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

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

## 11 Mechanical and Manufacturing

### 11.1 Package Dimensions



SM02 Package Dimensions

NOTES:
1) Dimensions: inch [mm]
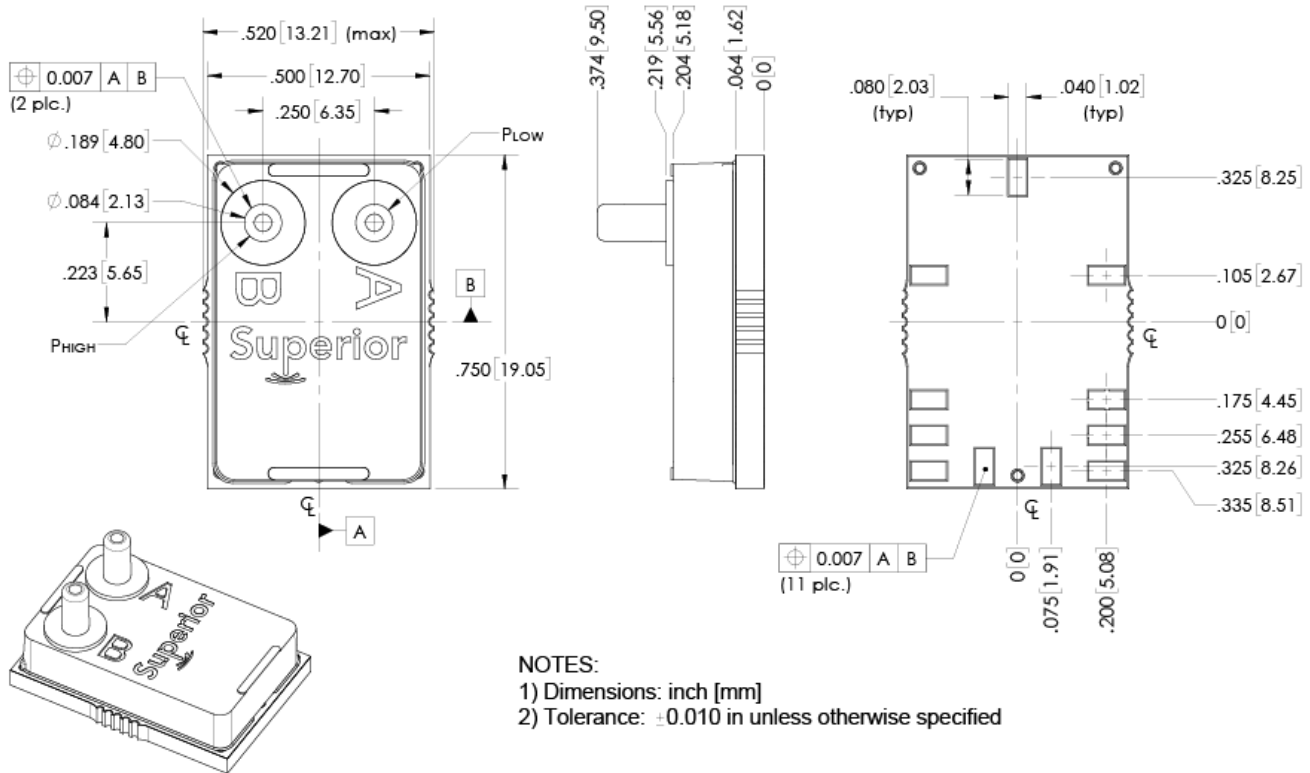2) Tolerance: ±0.010 in unless otherwise specified

### 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.
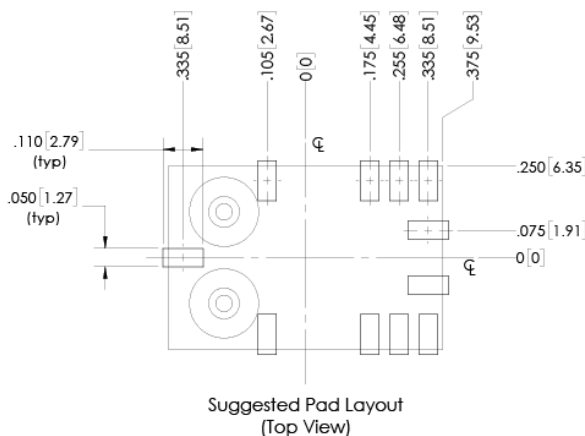


SM02 Suggested Pad Layout

Suggested Pad Layout
(Top View)

# ND Series
## Industrial Pressure Sensors

## 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 | |



SM02 Package Pinout

Pin Numbers (Top View)
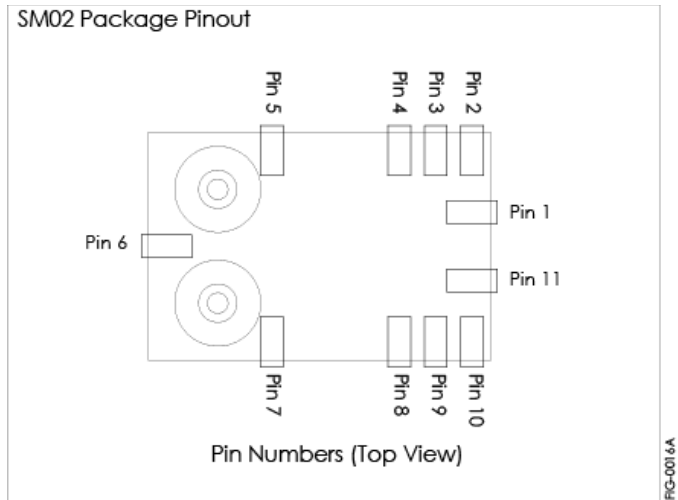
## 11.4 Reflow Soldering and Handling Conditions

| 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



SM02 Pick and Place Pickup Zone

Note(s):
1) Pickup Zone

.145 [3.68]
.320 [8.13]
.400 [10.16]
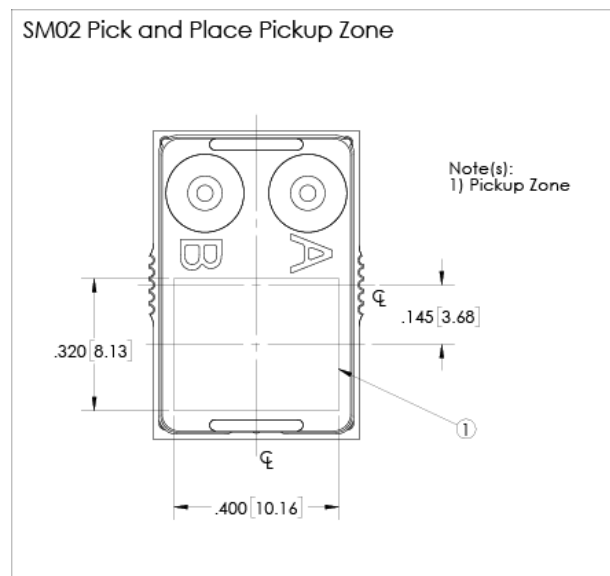
## 11.6 Packaging Options

### 11.6.1  Tray Packaging

SM02 Tray Packaging Detail



Tray Dimensions

Multi-Tray Packaging
(M Packaging Option)

Label

Dimensions
7-1/8"W x 9-1/4"D x 3-7/8"H

Notes
1) 64 Parts Per Tray
2) 8 trays per box (plus empty top tray)
3) 512 parts per box

Single Tray Packaging
(T Packaging Option)

Label

Notes
1) 64 Parts Per Tray
2) 1 trays per box (plus top protection insert)
3) 64 parts per box

Dimensions
7-1/8"W x 9-3/8"D x 3/4"H

FIG-0002B
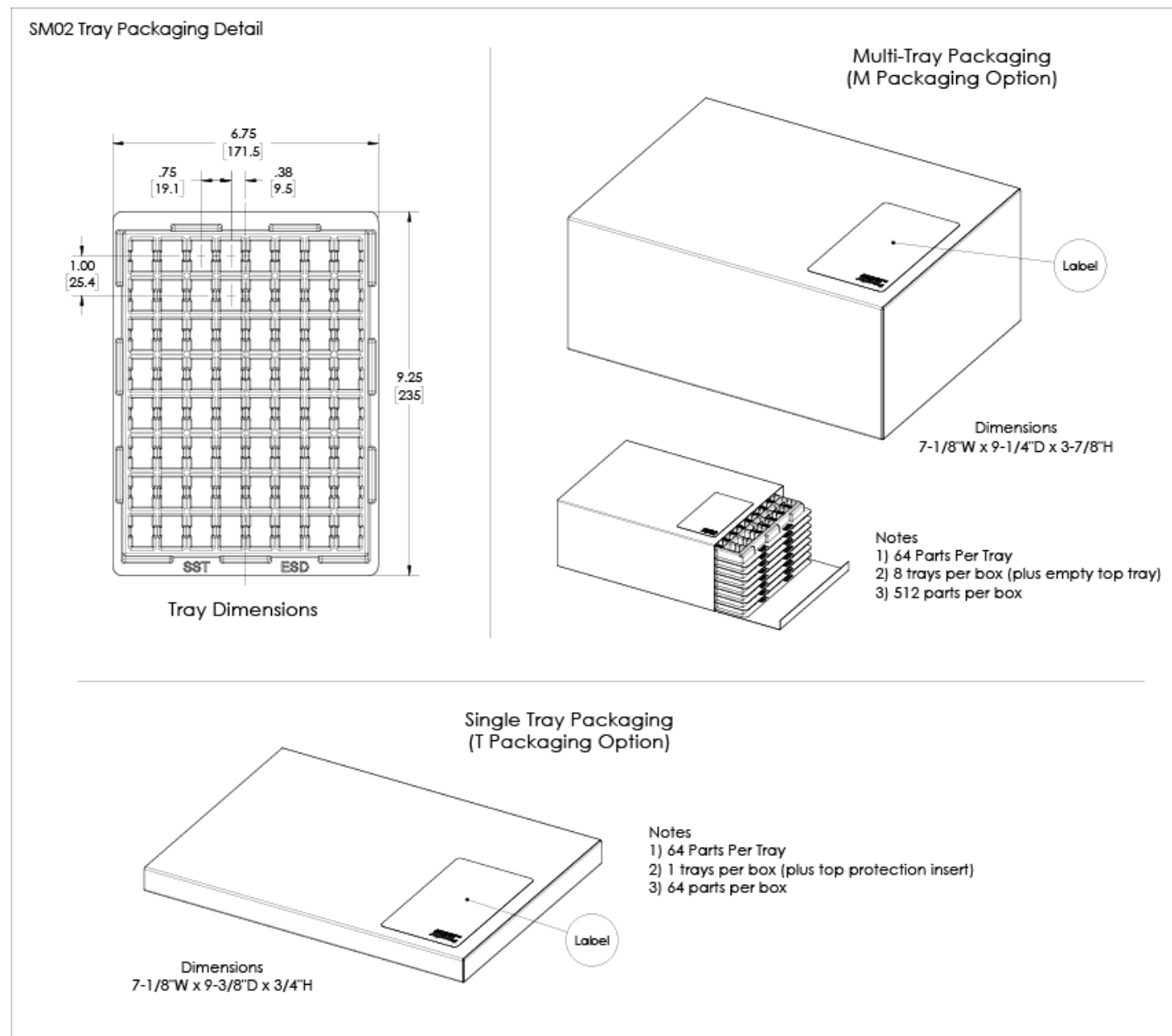
### 11.6.2 Tape and Reel

SM02 Tape and Reel Detail



SECTION A-A

DETAIL B

DETAIL C

Label

NOTES:
1) Dimensions: [mm] inch
2) Reel Diameter: [330] 12.99
3) Parts Per Reel: 256
4) Unwind Orientation: Per figure to left
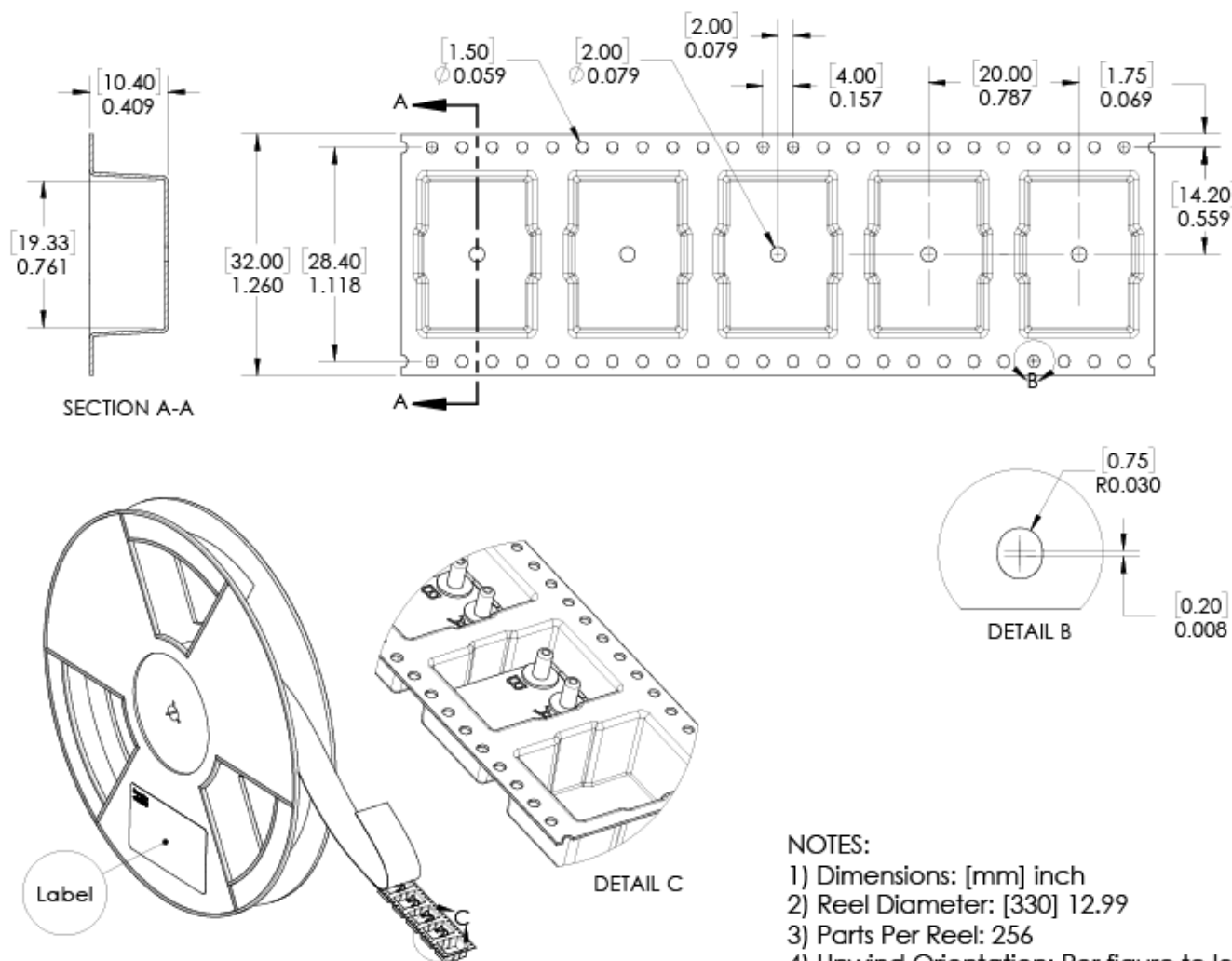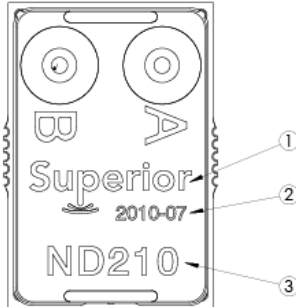
## 11.7 Part Identification



SM02 Part Marking

NOTES:
1) SST Logo
2) Lot Number
   Format: YYWW-NN
   Where:
   YY = Last two digits of year
   WW = Week number
   NN = Lot number in given week
3) Part Number

FIG-0085A



## 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 |
|---|---|---|---|---|
| ND210-SM02 | SM02 | Tape and Reel<br>Multi-Tray<br>Single Tray<br>Cut Tape | 256<br>512<br>64<br>1-63 | ND210-SM02-R<br>ND210-SM02-M<br>ND210-SM02-T<br>ND210-SM02-C |
| ND110-SM02 | SM02 | Tape and Reel<br>Multi-Tray<br>Single Tray<br>Cut Tape | 256<br>512<br>64<br>1-63 | ND110-SM02-R<br>ND110-SM02-M<br>ND110-SM02-T<br>ND110-SM02-C |
| ND120-SM02 | SM02 | Tape and Reel<br>Multi-Tray<br>Single Tray<br>Cut Tape | 256<br>512<br>64<br>1-63 | ND120-SM02-R<br>ND120-SM02-M<br>ND120-SM02-T<br>ND120-SM02-C |
| ND130-SM02 | SM02 | Tape and Reel<br>Multi-Tray<br>Single Tray<br>Cut Tape | 256<br>512<br>64<br>1-63 | ND130-SM02-R<br>ND130-SM02-M<br>ND130-SM02-T<br>ND130-SM02-C |
| ND005D-SM02 | SM02 | Tape and Reel<br>Multi-Tray<br>Single Tray<br>Cut Tape | 256<br>512<br>64<br>1-63 | ND005D-SM02-R<br>ND005D-SM02-M<br>ND005D-SM02-T<br>ND005D-SM02-C |

## 14 Revisions

| Rev | Change Description(s) | Date | By |
|-----|----------------------|------|-----|
| A | Initial Release | 1/4/21 | T.S. |

## 15 Warranty

Superior Sensor Technology and its subsidiaries warrant goods of its manufacture as being free of defective materials and faulty workmanship during the applicable warranty period. In all cases, Superior Sensor Technology's standard product warranty applies; please refer to your order acknowledgement or consult your local sales office for specific warranty details.

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