Technical Note

I^{2}C Communications with Honeywell Digital Output Pressure Sensors

1.0   Introduction

The I^{2}C bus is a simple, serial 8-bit oriented computer bus for efficient I^{2}C (Inter-IC) control. It provides good support for communication between different ICs across short circuit-board distances, such as interfacing microcontrollers with various low speed peripheral devices. For detailed specifications of the I^{2}C protocol, see Version 2.1 (January 2000) of the I^{2}C Bus Specification (source: NXP Semiconductor at (http://www.nxp.com/acrobat_download/literature/9398/39340011.pdf).

Each device connected to the bus is software addressable by a unique address and a simple master/slave relationship that exists at all times. The output stages of devices connected to the bus are designed around an open collector architecture. Because of this, pull-up resistors to +VDD must be provided on the bus. Both SDA and SCL are bidirectional lines, and it is important to system performance to match the capacitive loads on both lines. In addition, in accordance with the I^{2}C specification, the maximum allowable capacitance on either line is 400 pF to ensure reliable edge transitions at 400 kHz clock speeds (Figure 1).

When the bus is free, both lines are pulled up to +VDD. Data on the I^{2}C-bus can be transferred at a rate up to 100 kbit/s in the standard-mode, or up to 400 kbit/s in the fast-mode.

Figure 1. I^{2}C Bus Configuration
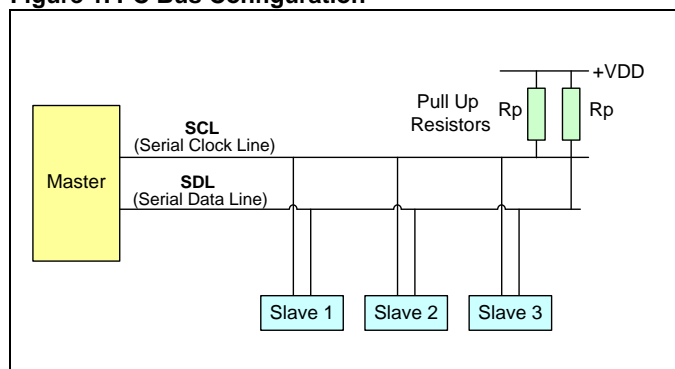
2.0   Data Transfer with I^{2}C Output Pressure Sensors

Honeywell's digital output pressure sensors are designed to work as slaves and will therefore only respond to requests from a master device. Following the address and read bit from the master, Honeywell digital output pressure sensors are designed to output up to 4 bytes of data, depending on the sensor options and the needs of the application. In all cases,

the first two data bytes are the compensated pressure output, along with sensor status bits. The third and fourth bytes are for optional compensated temperature output.

2.1   Sensor Address

Each sensor is referenced on the bus by a 7 bit slave address. The default address for Honeywell Pressure sensors is 40 (28 hex). Other available standard addresses are: 56 (38 hex), 72 (48 hex), 88 (58 hex), 104 (68 hex), 120 (78 hex), 136 (88 hex) and 152 (98 hex).

(Other custom values are available. Please contact Honeywell Customer Service with questions regarding custom slave addresses.)

2.2   Pressure Reading

To read out a compensated pressure reading, the master generates a START condition and sends the sensor slave address followed by a read bit (shown in Figure 2). After the sensor generates an acknowledge, it will transmit up to 4 bytes of data – the first two bytes containing the compensated pressure output, and the second two bytes containing the optional compensated temperature output. The master must acknowledge the receipt of each byte, and can terminate the communication by sending a Not Acknowledge (NACK) bit followed by a stop bit after receiving both bytes of data as show in Figure 2.

2.3   Temperature Reading

The optional corrected temperature data can be read out with either 8 bit or 11 bit resolution. By reading out the third byte of data from the sensor, the 8 bit compensated temperature value can be read. Further, by reading out the fourth byte of data, the complete 11 bit optional compensated temperature value can be read. The 8 bit value gives an approximate 0.8 °C resolution, while the 11 bit value gives an approximate 0.1 °C resolution.

When reading the full 11 bit resolution temperature output, the 5 least significant bits of the 4th data byte are "Do Not Care" and should be ignored.

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Figure 2. I²C Pressure and Temperature Measurement Packets Readout
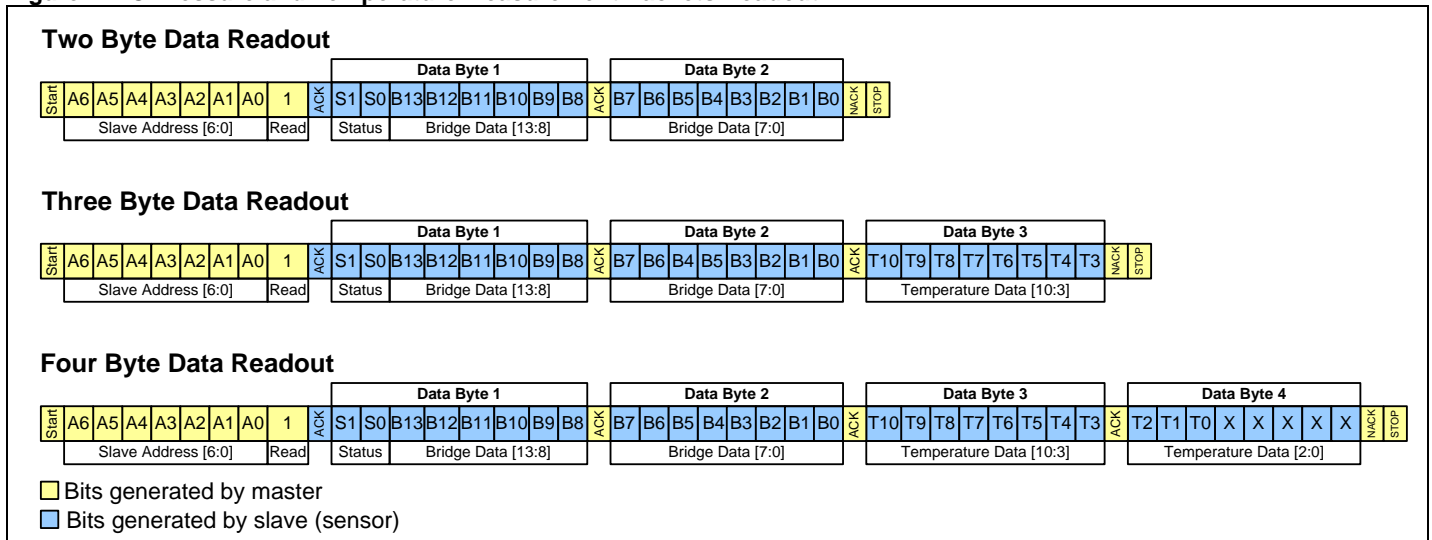
Note: For sensors that do not offer the optional compensated temperature output, the sensor will still output the third and fourth bytes of data, but the information contained in these bytes is non-corrected data, and should not be used.

2.4 Status Bits

Honeywell digital output pressure sensors offer both standard and optional diagnostics to ensure robust system operation in critical applications. The diagnostic states are indicated by the first two Most Significant Bits of Data Byte 1.

Four diagnostic states are indicated by the 2 status bits (Table 1).

Table 1. Diagnostic Conditions indicated by Status Bits

Status Bits		Definition
S1	S0	
0	0	normal operation, valid data
0	1	device in command mode*
1	0	stale data: data that has already been fetched since the last measurement cycle, or data fetched before the first measurement has been completed
1	1	diagnostic condition

Note: *Command mode is used for programming the sensor. This mode should not be seen during normal operation.

Standard diagnostics for Honeywell digital output pressure sensors consist of an EEPROM (Electrically Erasable Programmable Read-Only Memory) signature used to validate the EEPROM contents during startup. In the event that any EEPROM contents change after calibration, a diagnostic condition will be flagged.

Optional diagnostics for Honeywell digital output pressure sensors consist of:
- Loss of sense element connection
- Short circuit of sense element

When the two status bits are "11", one of the above mentioned diagnostic faults is indicated.

When the status bits read "10", "stale" data is indicated, this means that the data that already exists in the sensor's output buffer has already been fetched by the master, and has not yet been updated with the next data from the current measurement cycle. This can happen when the master polls the data quicker than the sensor can update the output buffer.

(Please contact Honeywell Customer Service with questions regarding the availability of optional Pressure Sensor diagnostics.)

3. 0 Calculation of the Pressure from the Digital Output

For Honeywell digital output pressure sensors, the output of the device can be expressed by the transfer function of the device as shown in Equation 1.

Equation 1: Pressure Sensor Transfer Function

$$Output = \frac{Output_{max} - Output_{min}}{P_{max} - P_{min}} \cdot (Pressure - P_{min}) + Output_{min}$$

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Rearranging this equation to solve for pressure, we get Equation 2:

Equation 2: Pressure Output Function

$$Pressure = \frac{(Output - Output_{min}) \cdot (Pressure_{max} - Pressure_{min})}{(Output_{max} - Output_{min})} + Pressure_{min}$$

Where:

Output$_{max}$ = output at max. pressure [counts]
Output$_{min}$ = output at min. pressure [counts]
Pressure$_{max}$ = max. value of pressure range [bar, psi, kPa, etc.]
Pressure$_{min}$ = min. value of pressure range [bar, psi, kPa, etc.]
Pressure = pressure reading [bar, psi, kPa, etc.]
Output = digital pressure reading [counts]

As an example, the pressure will be calculated for a -1 psi to 1 psi differential sensor with a 10% to 90% calibration and a pressure output of 1657 (decimal) counts:

Output$_{max}$ = 14745 counts (90% of 2^{14} counts or 0x3999)
Output$_{min}$ = 1638 counts (10% of 2^{14} counts or 0x0666)
Pressure$_{max}$ = 1 psi
Pressure$_{min}$ = -1 psi
Pressure = pressure in psi
Output = 1657 counts

$$Pressure = \left[\frac{(1657 - 1638) \cdot (1 - (-1))}{(14745 - 1638)}\right] + (-1)$$

$$Pressure = \left[\frac{(19) \cdot (2)}{13107}\right] + (-1)$$

$$Pressure = \left[\frac{38}{13107}\right] + (-1)$$

$$Pressure = (0.002899) + (-1)$$

$$Pressure = -0.997 \text{ psi}$$

4.0   Calculation of Optional Temperature from the Digital Output

For Honeywell digital output pressure sensors with the optional compensated temperature output, the output can be converted to °C using Equation 3:

Equation 3: Temperature Conversion Function

$$Temperature\,(°C) = \left(\frac{Output\,(dec)}{2047} \cdot 200\right) - 50$$

If the 8 bit temperature output is used, the data must first be shifted left by 3 bits and have the 3 Least Significant Bits set to "0's" for the equation to work.

As an example, the optional compensated temperature output will be calculated for a sensor with an 8 bit temperature output of 255:

Step 1: Left shift the above 8-bit value by 3 places and append the 3 LSBs with 0s:

Digital Temperature Output (8 – bit) = 255 = 11111111b
11111111000b = 2040

Step 2: Use the adjusted value and plug into Equation 3:

$$Temperature = \left(\frac{2040}{2047} \cdot 200\right) - 50$$

$$Temperature = 149.31\,°C$$

As a second example, the optional compensated temperature output will be calculated for a sensor with an 11 bit temperature output of 1456:

Step 1: Plug the digital temperature output value into Equation 3:

$$Temperature = \left(\frac{1456}{2047} \cdot 200\right) - 50$$

$$Temperature = 92.26\,°C$$

5.0   Timing and Level Parameters

**Table 2. Parameters for I^{2}C Bus Communication with Honeywell Digital Output Pressure Sensors**

I^{2}C Parameter	Sym.	Min.	Typ.	Max.	Unit
SCL clock frequency	f$_{SCL}$	100	-	400	kHz
Start condition hold time relative to SCL edge	t$_{HDSTA}$	0.1	-	-	µs
Minimum SCL clock low width*	t$_{LOW}$	0.6	-	-	µs
Minimum SCL clock high width*	t$_{HIGH}$	0.6	-	-	µs
Start condition set-up time relative to SCL edge	t$_{SUSTA}$	0.1	-	-	µs
Data hold time on SDA relative to SCL edge	t$_{HDDAT}$	0	-	-	µs
Data set-up time on SDA relative to SCL edge	t$_{SUDAT}$	0.1	-	-	µs
Stop condition setup time on SCL	t$_{SUSTO}$	0.1	-	-	µs
Bus free time between stop condition and start condition	t$_{BUS}$	2	-	-	µs
Output level low	Out$_{low}$	-	0	0.2	VDD
Output level high	Out$_{high}$	0.8	1	-	VDD
Pull-up resistance on SDA and SCL	Rp	1	-	50	kOhm

Note: *Combined low and high widths must equal or exceed minimum SCL period.

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Figure 3: I²C Bus Timing Diagram
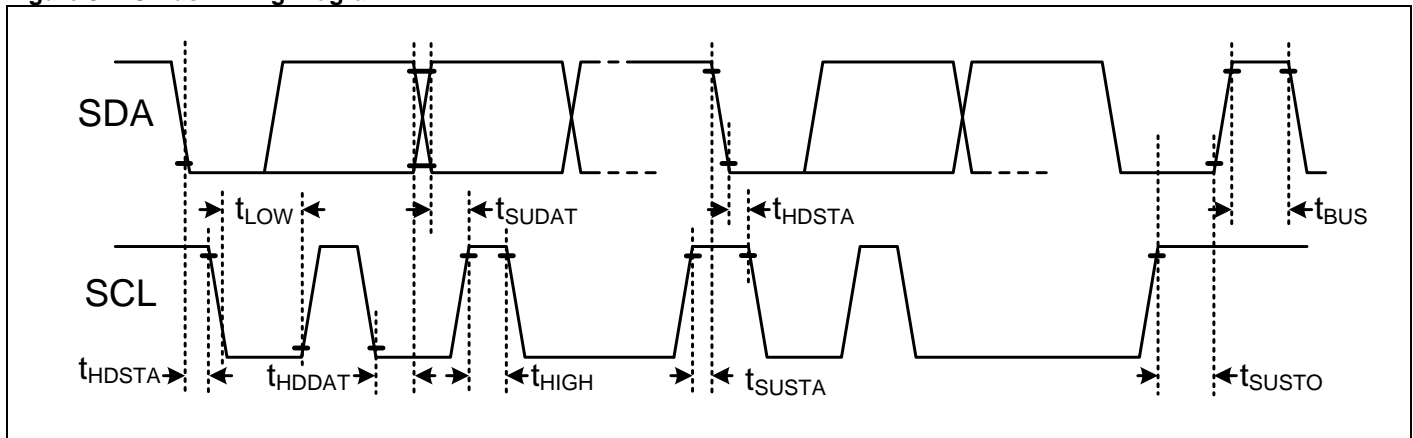
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