Honeywell

Technical Note

I^2C Communications with Honeywell Digital Output Force Sensors

1.0 INTRODUCTION

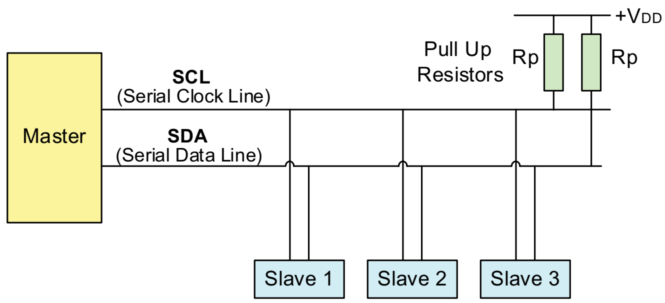
The I^2C bus is a simple, serial 8-bit oriented computer bus for efficient I^2C (Inter-IC) control. It provides good support for communication between different ICs across short circuit-board distances, such as interfacing microcontrollers with various low speed peripheral devices. For detailed specifications of the I^2C protocol, see Version 2.1 (January 2000) of the I^2C 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 $+V_{DD}$ must be provided on the bus. Both SDA and SCL (Serial Clock Line) 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^2C specification, the maximum allowable capacitance on either line is 400 pF to ensure reliable edge transitions at 400 kHz clock speeds (see Figure 1).

When the bus is free, both lines are pulled up to $+V_{DD}$. Data on the I^2C-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^2C Bus Configuration



2.0 DATA TRANSFER WITH I^2C OUTPUT FORCE SENSORS

Honeywell's digital output force 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 force sensors are designed to output up to four bytes of data, depending on the sensor options and application needs. In all cases, the first two data bytes are the compensated force 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 force 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.)

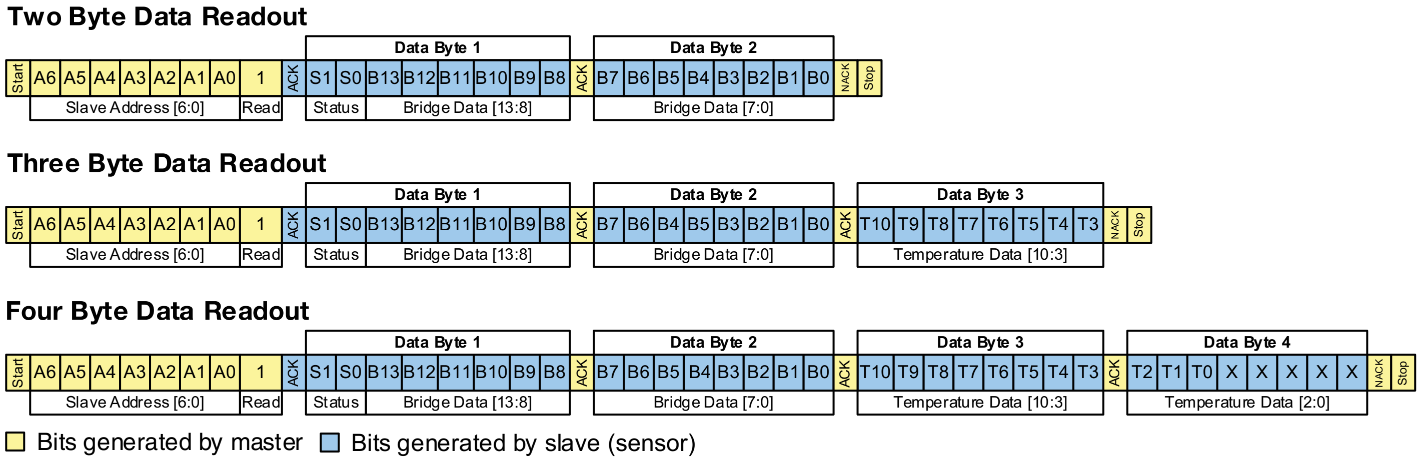
2.2 Force Reading (see Figure 2)

To read out a compensated force reading, the master generates a Start condition and sends the sensor slave address followed by a Read bit. After the sensor generates an Acknowledge (ACK), it will transmit up to four bytes of data: the first two bytes containing the compensated force 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.

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 five least significant bits of the fourth data byte are "Do Not Care" and should be ignored.

Figure 2. I²C Force and Temperature Measurement Packets Readout[1]



[1]For sensors that do not offer the optional compensated temperature output, the sensor will still output the third and fourth bytes of data; however, the information contained in these bytes is non-corrected data, and should not be used.

2.4 Status Bits

Honeywell digital output force 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 two status bits (see 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]
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

[1]Command mode is used for programming the sensor. This mode should not be seen during normal operation.

Standard diagnostics for Honeywell digital output force 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 content changes after calibration, a diagnostic condition will be flagged.

Optional diagnostics for Honeywell digital output force sensors consist of:

- Loss of sense element connection
- Short circuit of sense element

When the two status bits are “11”, one of the these two 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 force sensor diagnostics.)

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3. 0 CALCULATION OF FORCE FROM THE DIGITAL OUTPUT

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

Equation 1: Force Sensor Transfer Function

$$\text{Output} = \frac{(\text{Output}_{max.} - \text{Output}_{min.})}{\text{Rated Force Range}} \times (\text{Force}_{applied}) + \text{Output}_{min.}$$

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

Equation 2: Force Output Function

$$\text{Force} = \frac{(\text{Output} - \text{Output}_{min.})}{(\text{Output}_{max.} - \text{Output}_{min.})} \times \text{Rated Force Range}$$

Where:

$\text{Output}_{max.}$ = output at maximum force [counts]

$\text{Output}_{min.}$ = output at minimum force [counts]

Force_{rated} = maximum value of force range (N, lb, g, or kg)

$\text{Force}_{applied}$ = minimum value of force range (N, lb, g, or kg)

Force = force reading (N, lb, g, or kg)

Output = digital force reading [counts]

Example: The force is calculated for a 10 N force sensor with a 10% to 90% calibration and a force output of 6880 (decimal) counts:

$\text{Output}_{max.}$ = 14745 counts (90% of 2^{14} counts or 0x3999)

$\text{Output}_{min.}$ = 1638 counts (10% of 2^{14} counts or 0x0666)

Force_{rated} = 10 N

Force = force in N

Output = 6880 counts

$$\text{Force} = \frac{[(6880 - 1638) \times 10]}{(14745 - 1638)}$$

$$\text{Force} = \frac{(5242 \times 10)}{13107}$$

$$\text{Force} = 4 \text{ N}$$

4.0 CALCULATION OF OPTIONAL TEMPERATURE FROM THE DIGITAL OUTPUT

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

Equation 3: Temperature Conversion Function

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

If the 8-bit temperature output is used, the data must first be shifted left by three bits and have the three Least Significant Bits set to zeros for the equation to work.

Example: The optional compensated temperature output is calculated for a sensor with an 8-bit temperature output of 255:

Step 1: Left shift the above 8-bit value by three places and append the three LSBs with zeros:

Digital Temperature Output (8-bit) = 255 = 11111111b

11111111000b = 2040

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

$$\text{Temperature (°C)} = \left(\frac{2040}{2047} \times 200\right) - 50$$

Temperature = 149.31 °C

Example: The optional compensated temperature is calculated for a sensor with an 11-bit temperature output of 1456:

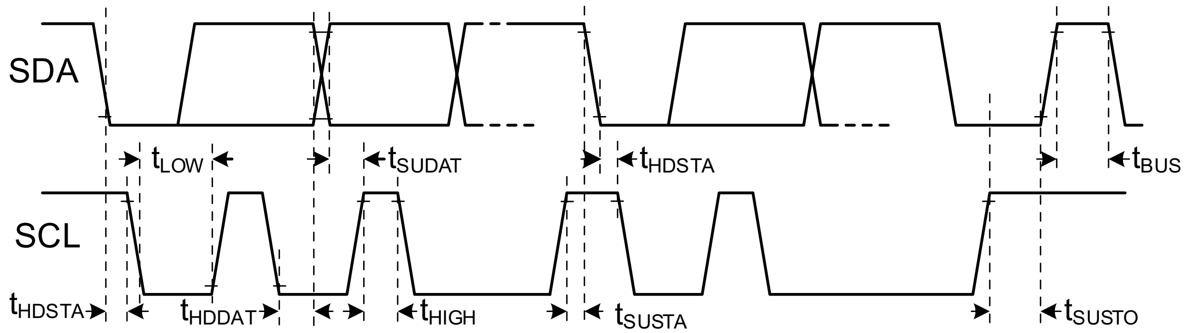
Step 1: Plug the digital temperature output value into Equation 3:

$$\text{Temperature (°C)} = \left(\frac{1456}{2047} \times 200\right) - 50$$

Temperature = 92.26 °C

5.0 TIMING AND LEVEL PARAMETERS (see Figure 3)

Figure 3. I²C Bus Timing Diagram and Parameters



I²C Parameter	Symbol	Minimum	Typical	Maximum	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 width[1]:					
low	t_{LOW}	0.6	—	—	µs
high	t_{HIGH}	0.6	—	—	µs
Start condition setup 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	V_{DD}
high	Out_{HIGH}	0.8	1	—	V_{DD}
Pull-up resistance on SDA and SCL	R_P	1	—	50	kOhm

[1]Combined low and high widths must equal or exceed minimum SCL period.

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008291-1-EN IL50
January 2016