Technical Note

SPI Communications with Honeywell Digital Output Force Sensors

1.0 INTRODUCTION

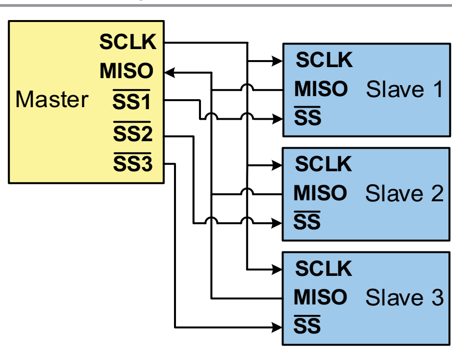
The Serial Peripheral Interface (SPI) is a simple bus system for synchronous serial communication between one master and one or more slaves. It operates either in full-duplex or half-duplex mode, allowing communication to happen in either both directions simultaneously, or in only one direction. The master device initiates an information transfer on the bus and generates clock and control signals. Slave devices are controlled by the master through individual slave select lines and are active only when selected.

Honeywell force sensors with SPI output operate in half-duplex mode only, with data transfer from the slave to the master (see Figure 1). For this data transmission three lines need to be used:

1. Slave Select (SS)
2. Signal Clock (SCLK)
3. Master In - Slave Out (MISO)

These three bus lines are all unidirectional. SCLK and SS and are controlled by the master while MISO is controlled by the slave.

Figure 1. SPI Bus Configuration



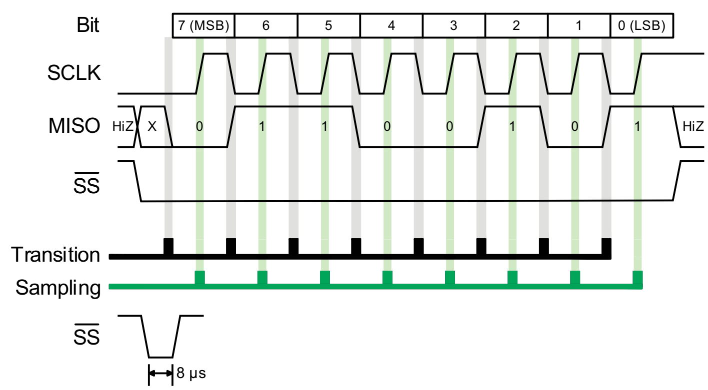
2.0 DATA TRANSFER WITH SPI OUTPUT FORCE SENSORS

Starting communication with Honeywell SPI output force sensors begins by deasserting the SS line. At this point, the sensor is no longer idle and will begin sending data once a clock is received.

Honeywell digital output force sensors are configured for operation such that data on the MISO line will transition during the falling edge of clock pulses. This means that the data on MISO should be sampled by the master device during the rising edge of the clock pulse.

Figure 2 shows an example of a one byte data transfer from the slave to the master. In this example, the data 101 (01100101 binary, or 65 hex) would be the result of the read.

Figure 2. Example of a One Byte SPI Data Transfer with Honeywell Force Sensors

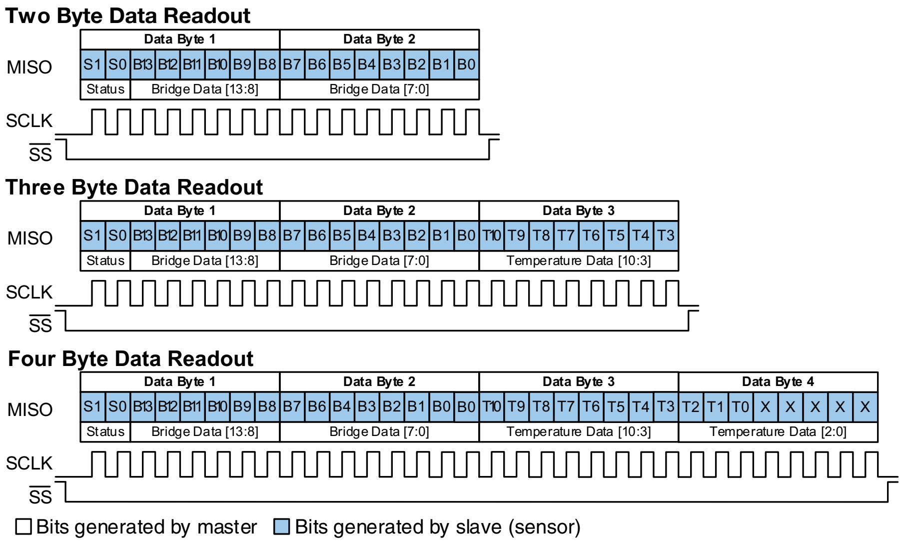


Once the clocking begins, Honeywell digital output force sensors are designed to output up to four bytes of data, depending on the sensor options and application needs. In all cases, the first two data bytes are the compensated force output, along with sensor status bits. The third and fourth bytes are for optional compensated temperature output.

2.1 Force Reading (see Figure 3)

To read out a compensated force reading, the master generates the necessary clock signal after activating the sensor with the slave select line. The sensor 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 can terminate the communication by stopping the clock and deactivating the slave select line.

Figure 3. SPI 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.

2.2 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.

2.3 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 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]
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 consists 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 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 digital output force 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

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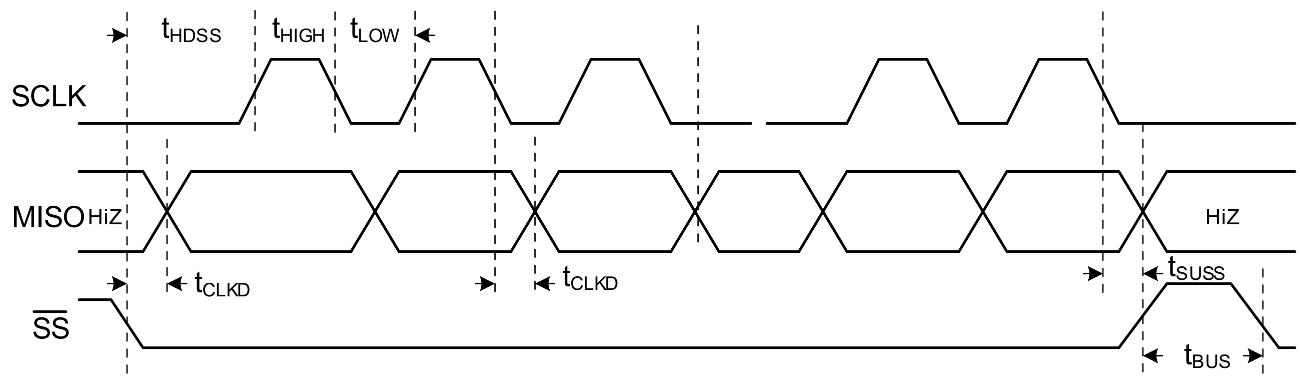
5.0 TIMING AND LEVEL PARAMETERS (See Figure 3)

Figure 3. SPI Bus Timing Diagram and Parameters



SPI Parameter	Symbol	Minimum	Typical	Maximum	Unit
SCLK clock frequency	f_{SCL}	50	—	800	kHz
SS drop to first clock edge	t_{HDSS}	2.5	—	—	µs
Minimum SCLK clock width[1]:					
low	t_{LOW}	0.6	—	—	µs
high	t_{HIGH}	0.6	—	—	µs
Clock edge to data transition	t_{CLKD}	0	—	—	µs
Rise of SS relative to last clock edge	t_{SSUS}	0.1	—	—	µs
Bus free time between rise and fall of SS	t_{BUS}	2	—	—	µs
Output level:					
low	Out_{LOW}	—	0	0.2	V_{DD}
high	Out_{HIGH}	0.8	1	—	V_{DD}

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

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008290-1-EN IL50
January 2016

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