Digital Output Description

This Application Note applies to the following pressure sensors:

- CCD Series 53D and 54D
- MAP Series 36D
- SLP Series 33D and 35D
- SPD Series 34D

Abstract:

This application note describes in detail the digital output format of Senphire's digital pressure sensors. The output is a one-wire output using pulse width modulation to represent 1's and 0's.

Design considerations as well as hints for writing interface firmware with an MCU are given

After reading this application note the user should be able to:

- Read and interpret the pulse width modulation coded output of 1's and 0's
- Write a simple firmware algorithm to read the output
- Calculate the transfer function for his/her respective sensor

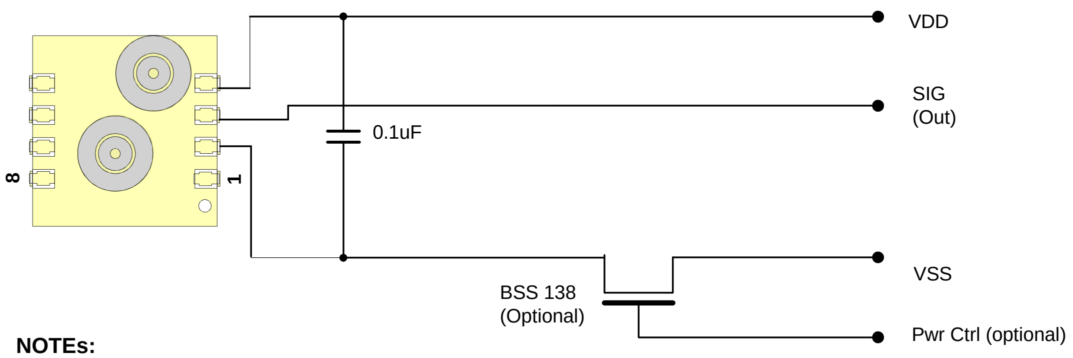
Digital Communication Parameters

Parameters	Min	Typ	Max	Unit	Remarks
Pull-Up Resistor (Internal)		30		kohm	Switched on in Output Mode
Rise Time			5	us	Any RC network connected in Out/SIG path must meet this rise time
Load Capacitance	0	1	15	nF	Including parasitic capacitance
Voltage Level - Low		0	0.2	VDD	Rail-to-rail CMOS Driver
Voltage Level - High	0.8	1		VDD	Rail-to-rail CMOS Driver

NOTEs:

- For the digital output no load resistors or capacitors should be placed on the output pin. No pull down resistor is allowed. It is strongly recommended that the OUT/SIG pin only be connected to a high impedance i/o of a microcontroller.
- The load for the OUT/SIG pin should be purely capacitive. In cases where a filter capacitor is absolutely necessary a maximum load capacitor of 2.2nF can be connected.
- Digital communication is achieved with internal pull up resistor of 30k ohm
- The output pin has an ESD protection of >4000V (HBM) and a latch-up protection of ±100mA or +8V/-4V (to VSS)

Application Circuit Example CCD 53D



NOTEs:

- A 0.1uF capacitor must be connected between Vdd and Vss
- For battery powered operation where power saving is required a BSS 138 Mosfet can be added to power down the device. The BSS 138 is a standard Enhancement Mosfet and will turn on when Pwr Ctrl = Logic 1
- Where power saving is not required Vss should be connected directly to the sensor with the BSS 138 and Pwr Ctrl omitted

Communication Interface (Digital Version Only)

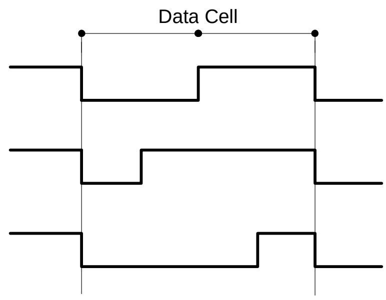
Pulse Width Modulation by a transition at the cell boundary is used to represent the binary values of pressure and temperature.

Bit Encoding

Start Bit ⇨ 50% duty cycle used to set up strobe time

Logic 1 ⇨ 75% duty cycle

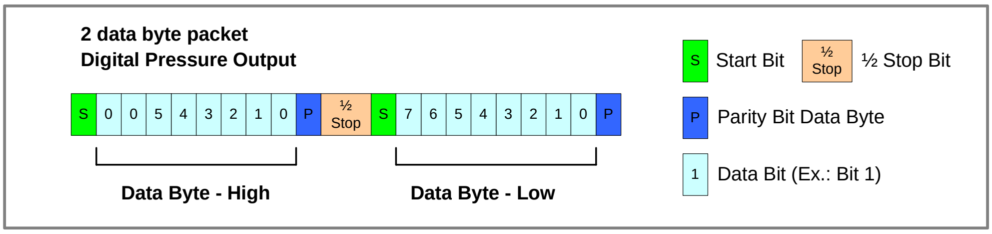
Logic 0 ⇨ 25% duty cycle



Read Operation

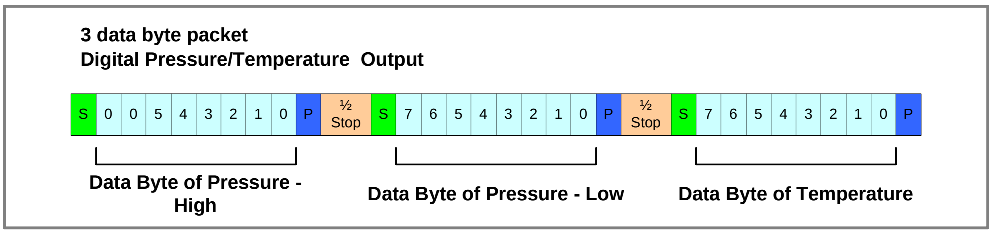
There are two modes (DPT digital pressure output with temperature, and DPO digital pressure out only) available for the output of this transducer.

In DPO mode, the transducer first transmits the high byte of pressure data followed by the low byte. The pressure data is 14-bits in resolution, so the upper two bits of the high byte are always zero padded. There is a stop bit in between the bytes of a pakcet. The period of the stop bit is half that of all the other bits and the signal level is always high for this duration.



DPO - Digital Pressure Output

For DPT mode, the pressure and an 8 bit temperature byte will be transmitted as 3 data packets. The temperature range is fixed from -50 to 150 °C.



DPT - Digital Pressure/Temperature Output

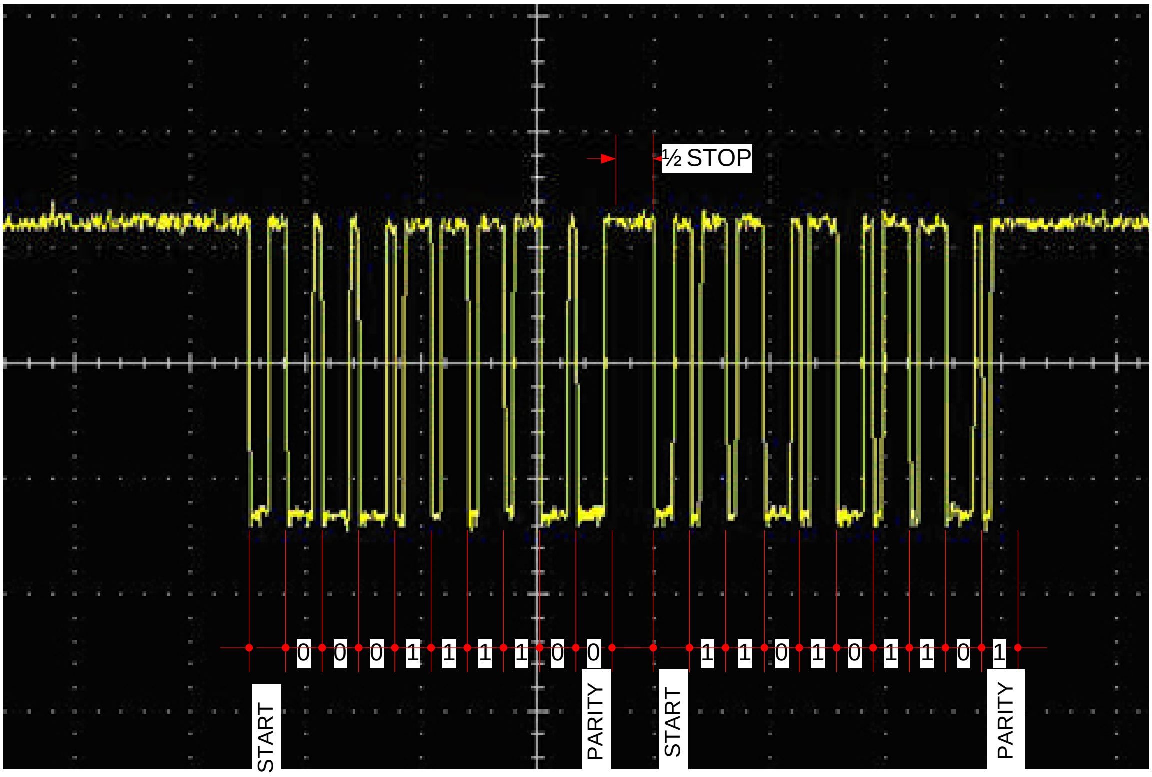
Note: DPT is available upon request. We do not guarantee the accuracy of the Temperature output but instead provide it as an added feature at no extra cost to customers.

Sample Waveform Interpretation

A reading of a sample waveform is given below.

Note the stop bit which comes right after the parity bit of 0.

MSB is always transmitted first.



Sample Waveform Intepretation

Parity Checking

Where possible parity checking should be implemented by any firmware used to read the pressure output. The sensor output has an even parity applied to 1's.

Timing

Update Rate	Response Time	Baud Rate	Idle Time Between Data Packets
1000 Hz	1 ms	32kHz	1ms

The Baud rate of the pulse width modulation coded bit stream is 32kHz.

The Baud rate (32kHz) will vary +/- 15% from part to part, with the supply voltage and across temperature. Any firmware used the read the digital pressure and temperature readings should first use the **start bit** which is 50% high and 50% low to determine the exact frequency before decoding the digital output.

The idle time is the time in between data packets where no transmission occurs (the output is always high when idle).

Hints for Writing Firmware

Suggested Algorithm using Interrupts:

Connect the output of the sensor to a pin of a microcontroller capable of causing an interrupt on a falling edge. When the falling edge is detected this causes a branch into an ISR which is a counting loop incrementing until a rising edge is detected in the output. Now based on the number of counts the frequency can be determined.

After the frequency is known the ISR can simply wait for the appropriate time before sampling the other bits.

This methodology works on the concept that the idle time between data packets is 1ms much greater than the idle time between successive bits within each data packet 0.03ms (32kHz)

Suggested Algorithm for Real Time systems:

Real time systems might not able to tolerate the Senphire pressure sensor interrupting the system at a constant interval. This makes the system more complicated.

The solution here would be to use the BSS 138 and another I/O from the microcontroller to control the power to the sensor. After power on the sensor will respond with a pressure reading approximately 10 ms later. If during that time a higher priority interrupt occurs the microcontroller can simply power down the sensor and service the other interrupt.

A 2s warm up time is required to ensure the stated accuracy. It is thus recommended the sensor be kept ‘normally on’ and only have the power pulsed ‘off’ then ‘on’ to generate the pressure reading when required

This method is also useful for shutting down the power to provide a ‘standby’ mode useful for many battery powered applications.

Note it is possible to power the sensor using an I/O of a microcontroller but this is not recommended as a noise free power supply is needed to ensure all specifications of the pressure sensor are met.

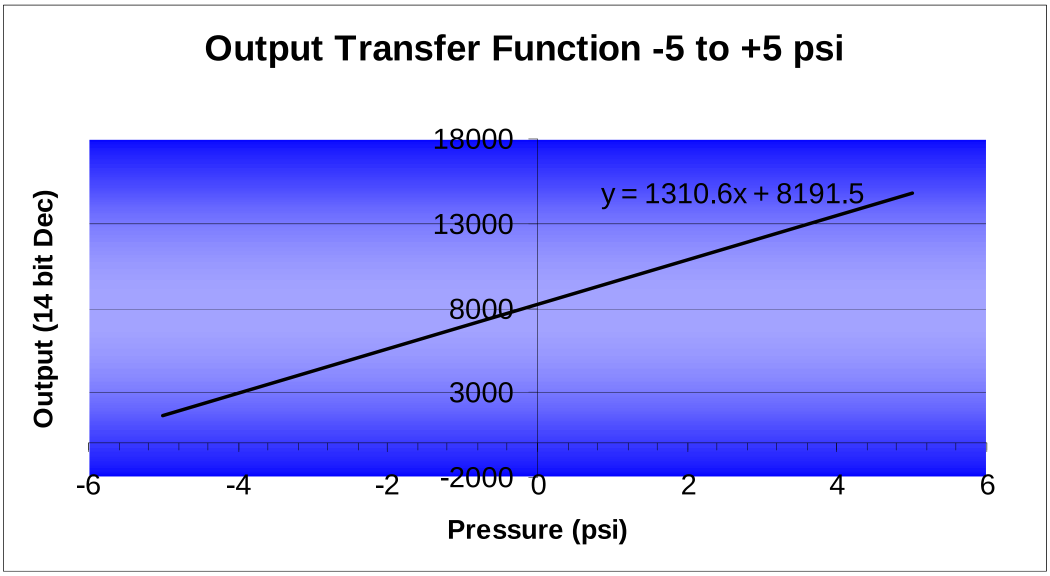
How to Interpret the Pressure/Temperature Value

All Senphire digital pressure sensors have been calibrated to a straight line transfer function. Temperature and non-linearity compensation are already included and are transparent to the user. The pressure value can be easily obtained by inserting the output into the transfer function. The process is explained below.

The pressure value is read out as a 14 bit word. The word corresponds to 0x0000 to 0x3FFF in Hex or 0 to 16383 in Decimal.

The first step is to convert the Hex value to Decimal. The calculator supplied with Microsoft Windows will easily do this.

The next step is to port the decimal value into the straight line function shown in the chart below.



The following example is for a -5 to +5 psi transfer function:

The output word is 0x1ABC.

The output word is translated into decimal which is 6844

The decimal word is then inserted into the equation which gives:

6844 = 1310.6x + 8191.5 where x is the pressure in psi

We then compute x = -1.028 psi

*Note: The transfer function varies for each pressure range. Make sure you use the correct function. If in doubt please email Senphire or our distributors for support

Transfer Function

To obtain the transfer function we start with the two parameters found in the sensor datasheet shown again below for convenience.

Parameters	Min	Typ	Max	Unit
Zero Output		0666		Hex
Full Scale Output		3999		Hex

Zero output = 0x0666 and Full Scale output = 0x3999.

The total output resolution is 14 bits or 0x3FFF.

We convert these into decimal for convenience:
Zero output = 1638, Full Scale output = 14745 and Total output resolution = 16383

Note that 1638 is 10% of total resolution and 14745 is 90% of total resolution so only 80% of the total 14 bit resolution is used to represent the required FS.

Now we correlate the outputs to the pressure range (see ordering guide in datasheet on how to specify pressure range). The example below refers to the output function on the previous page.

Parameter	Corresponding Pressure	Hex	Decimal
Zero Output	-5 psi	0x0666	1638
Full Scale Output	+ 5 psi	0x3999	14745

So taking the coordinates (-5 psi , 1638 counts) and (+5 psi, 14745 counts) we can calculate the corresponding straight line transfer function by calculating the gradient and Y-axis intercept.

In this case it is Y = 1310X + 8191 where Y=Digital output in Decimal and X= pressure in psi

Temperature Transfer Function (DPT only):

Temperature Range	Transfer Function
-50 to 150 °C	y = 1.275x + 63.75

Where y is temperature in °C and x is the output of the sensor in decimal (0 to 255)

Note: The temperature transfer function is the same regardless of the pressure range chosen. The temperature output is not intended for high accuracy measurements but is instead provided as an additional function at no extra cost.

Effective Resolution

While the resolution is stated as 14 bits in the datasheet it is impossible to attain this resolution in practice.

14 bits is merely the resolution of the internal Analog to Digital converter (ADC) of the ASIC used to achieve the digital compensation and output.

In practice its resolution will be lower than 14 bits with quantization noise and amplification errors that result in a non-perfect match of the input range of the ADC to the sensor being compensated.

Therefore the guaranteed resolution of Senphire sensors is 0.1% FS or 10 bits.

Noise Filtering

In most cases the software designed to read the pressure word should (where possible) allow for an averaging of 4-8 readings (the ideal being 8) to reduce noise. It is usually possible to get better resolution using an approach like this.

The recommended averaging algorithm is shown below:

$$\text{Current Reading} = \frac{\text{Latest Reading} + 7 * (\text{Previous Reading})}{8}$$

The formula above is for an average of 8 samples. The user should adapt it to the number of samples desired.

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