Explanation of pressure sampling

Hardware equipment:

MCU: ATSAM21
Pressure Sensor: MP3H6115AC6T1

Hardware Spec:

MCU: One 12-bit, 350ksps Analog-to-Digital Converter (ADC) with up to 20 channels
Pressure Sensor: 15 to 115 kPa, Absolute, Integrated Pressure Sensor.

Table 3. Operating characteristics (V_S = 3.0 Vdc, T_A = 25 °C unless otherwise noted, P1 > P2.)

Characteristic	Symbol	Min	Typ	Max	Unit
Pressure range	P_{OP}	15	—	115	kPa
Supply voltage(1)	V_S	2.7	3.0	3.3	Vdc
Supply current	I_o	—	4.0	8.0	mAdc
Minimum pressure offset(2) (0 to 85 °C) @ V_S = 3.0 Volts	V_{off}	0.079	0.12	0.161	Vdc
Full-scale output(3) (0 to 85 °C) @ V_S = 3.0 Volts	V_{FSO}	2.780	2.82	2.861	Vdc
Full-scale span(4) (0 to 85 °C) @ V_S = 3.0 Volts	V_{FSS}	2.660	2.70	2.741	Vdc
Accuracy (0 to 85 °C)	—	—	—	±1.5	$\%V_{FSS}$
Sensitivity	V/P	—	27	—	mV/kPa
Response time(5)	t_R	—	1.0	—	ms
Warm-up time(6)	—	—	20	—	ms
Offset stability(7)	—	—	±0.25	—	$\%V_{FSS}$

Desired performance:

Sampling rate: more than 10Hz
Accuracy: 0.1 mBar/ 10 Pa -> 0.01% of 100kPa

Oversampling:

Oversampling is a cost-effective process of sampling the input signal at a much higher rate than the Nyquist frequency to increase the SNR and resolution (ENOB) that also relaxes the requirements on the antialiasing filter. As a general guideline, oversampling the ADC by a factor of four provides one additional bit of resolution, or a 6 dB increase in dynamic range. The number of samples required to get n bits of additional data precision is

$$number\ of\ samples = (2^n)^2 = 2^{2n}$$

The pressure resolution is calculated by

$$\frac{100kPa}{2^{16}div} = 1.5258\ Pa/div$$

Then the max measurement speed with 16bit is

$$\frac{350ksps}{2^{2*4}} = 1367sps(samples\ per\ second)$$

If we want 10Hz sampling rate, the maximum points we can get is

$$\frac{1367sps}{10Hz} = 136p$$

To improve the speed of MCU calculation and save some time for other process, we can use only 128 points.

The uncertainty of 128 pints average

$$\delta_{\bar{x}} = \frac{1}{\sqrt{n}}\delta_x = \frac{1}{\sqrt{128}} * 2\% = 0.176\%$$

If we need 0.01% accuracy, how many points should we have?

$$\frac{1}{\sqrt{x}} * 2\% = 0.01\%$$

$$x = 4000$$

So, we need at least 4000points to get 0.01% accuracy data.

Based on the test data I got recently, 1024 sample average with 1Hz will have 0.1mBar fluctuation, which means, no matter what frequency we want, 1024 points average should be enough.

Possible solutions:

- Use higher bits ADC. For example, 14-bit ADC. Each additional bit will save 2^2n times samples.
- Reduce dynamic range of the pressure sensor. Now the dynamic range of the sensor is 15 to 115 kPa. By adding a MOS, it could be reduced to about 85 kPa to 115kPa. Or use differential pressure sensor with 30 kPa range.
- Use better MCU with higher ADC sampling rate. Like 12-bit ADC with 2M sampling rate.

Recommendation:

Change the circuit design to add MOS (or AMP) for pressure sensor. So that the dynamic range is reduced to 1/4, then we don't need to use 16bit ADC data. Then we can use 14 bits oversampling and the sampling rate could be 2^4 times higher than before.

The disadvantage of this that, MOS is not perfectly linear. Since we are going to calibrate each sensor before deploying them, this disadvantage will be avoided.

Reduced dynamic range also reduced the data transfer rate through ZigBee network, which will increase the performance of the whole system.