ANALYSIS ON CHOOSING THE APPROPRIATE ACCELEROMETER FOR TRANSPORT VEHICLE DIAGNOSTIC SYSTEMS

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A big variety of integral accelerometers is available nowadays. For the goal it is necessary to be made an accuracy analysis of the parameters of the separate presents that would had help at choice of accelerometer in concrete application. The head parameters of this analysis are frequency bandwidth, noise stable and sum error from the transduction.

Keywords: acceleration, analog output, pulse width modulation output, serial peripheral interface, automotive diagnostic, noise.

1. BASIC TYPES ACCELEROMETERS REVIEW

There exist a variety of now demanded integral dual-axis accelerometers. The most known company-manufacturers are Analogue Devices, ST Microelectronics, Parallax. As a leader it is notable the integrate accelerometer of Analog Devices. There are qualified a big set of accelerometers with different range of the measured acceleration, low consumption, low - pitched own noise and a different output interface - analogue output, an output with pulse-width modulation (PWM), as well as such with serial peripheral interface (SPI).

For objectivity of the made analysis, only representatives of one company - Analog Devices will be reviewed. The following three accelerometers of Analog Devices Company - ADXL 320, ADXL 210E and ADIS16003 are analyzed. First representative has the following characteristics: range of measured acceleration of ±5 g, analog output signal. The second - ADXL210E, respectively ±10g, output with pulse width modulation, ADIS16003 have range of ±1g and output with a serial peripheral interface.

1.1 Analog output accelerometers

The accelerometers with analog output have a possibility for limiting the frequency bandwidth of the output signal. This achieves by putting capacities at the Xout and Yout pins. By them it is realized a first-order frequency filter, decreasing it's own noise. The equation with which 3-dB upper frequency is being limited is presented by the following equation [4] :

$$F_{-3dB} = \frac{1}{(2\pi x R_{FLT} x C_{(X,Y)})} = \frac{1}{(2\pi (32k\Omega) x C_{(X,Y)})} = 5\mu F \frac{1}{C_{(X,Y)}}$$

The values of the filter capacitors for the desired frequency band are being obtained on the base of the equation. The output resistance R_{FLT} has a value 32kΩ and a tolerance up to ±15%, determinates the accuracy of frequency bandwidth.

Participating is essential on the capacitors, must not be less than 2000 pF as its value for the normal work.

Within measurement of a given process, it is necessary to limit the work frequency bandwidth to this own by the process. This will lead to the increasing of the resolution ability of the measurement. The possible highest frequency limit on this accelerometer is 2.5kHz. For an average value of the noise the company-manufacturer has given the following equation [4]:

$$rmsNoise = (250\mu g / \sqrt{Hz}).\sqrt{BW.1,6},$$

and for 50Hz it will lead to the follow:

$$rmsNoise = (250\mu g / \sqrt{Hz}).\sqrt{50.1,6} = 250\mu g.8,9 = 2,25mg$$

Frequency bandwidth [Hz]	C_X, C_Y [μF]	RMS – noise [mg]
10	0,470	1,00
50	0,100	2,25
100	0,047	3,20
500	0,010	7,10

Table 1

It can be observed from Table 1, that with increasing of frequency bandwidth, the noise increases itself too.

Sensitivity of the accelerometer is depended on the value of the power supply voltage. For this accelerometer with minimal power supply value Vs=2,4V, sensitivity is 135 mV/g, and at for its maximum value at Vs=5V is 312 mV/g. Due to the fact – noise level is not dependant to the power supply voltage, for achieving better resolution, it is necessary to use the highest possible supply voltage for this accelerometer.

The value of the output voltage at zero acceleration is the half of the power supply voltage [4]. For using the full range of ADC, it is necessary this voltage offset to be compensated, by means of a reference voltage source. This will lead itself to an additional error, due to the constancy of the reference voltage source.

1.2 Accelerometers with pulse-width modulation (PWM) output

The situation within the accelerometer with PWM is analogous to this with analog output – representative is ADXL210E. There are some special features, which distinguish it self to this with analog output. They should be clarified before the development of a system with such kind of sensor:

- the period of PWM defines the complete frequency bandwidth – which is ensured by external connected capacitors (fig. 1)
- the accuracy of duty cycle is dependable to the clock frequency of the used microcontroller [4].

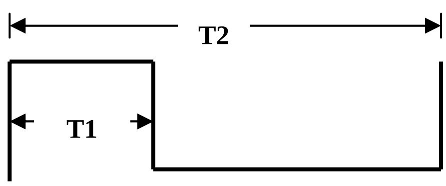

fig. 1

$$A(g) = 25.(\frac{T1}{T2} - 0,5) \quad (1)$$

$$0g = 50\% DutyCycle \quad (2)$$

$$\text{T2(s)=Rset/125M}\Omega \quad (3)$$

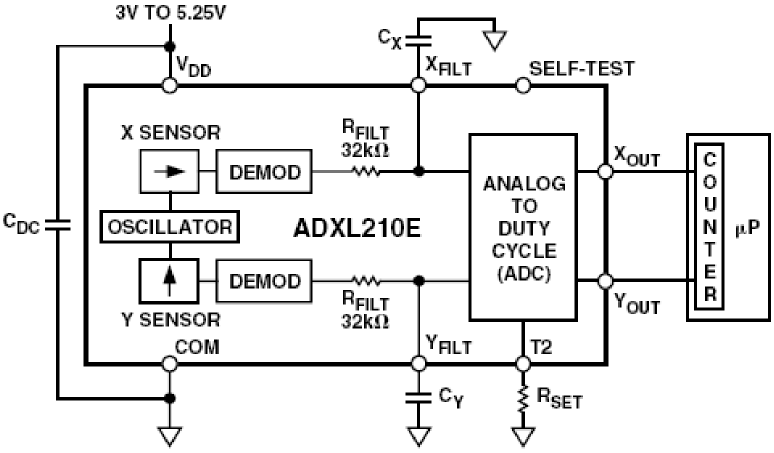

fig. 2

The noise level begins to give a change in the duty cycle of the PWM. In accordance with the documentation [5], the noise is defined by the follow:

$$rmsNoise = (200\mu g / \sqrt{Hz}).\sqrt{BW.1,6}$$

Within a comparison between this formula with analogy for the accelerometer with analog output, a smaller coefficient of the noise can be noticed . The value of the error is influenced by the number of bits of the timer system of used microcontroller, and also the frequency of incoming into it counting pulses.

For obtaining of real value of the acceleration from the raw data it is necessary a set of arithmetic calculation to be done (1). When the results should be processed in real time, the discretiozation frequency will be additionally reduced, due to the fact, it is partially dependable to the productivity of chosen microcontroller. The dependency between resolution and PWM period of the accelerometer and the frequency of counter pulses in the microcontroller is presented in table 2. The period T2 is defined by externally connected resistor Rset (fig. 2), which tolerance varies within ±15%. That tolerance impacts directly on the period T2, from where also to the precision of the defined upper frequency limit.

Table 2

Period T2 [ms]	Resistor for PWM [kΩ]	Counter frequency [MHz]	Number of pulses for a T2 period	Number of pulses for g	Resolution [mg]
1,0	124	2.0	2000	80	12.50
1,0	124	1.0	1000	40	25.00
1,0	124	0.5	500	20	50.00
5,0	625	2.0	10000	400	2.50
5,0	625	1.0	5000	200	5.00
5,0	625	0.5	2500	100	10.00
10,0	1250	2.0	20000	800	1.25
10,0	1250	1.0	10000	400	2.50
10,0	1250	0.5	5000	200	5.00

In analogy with the analog output accelerometers, it is necessary to limit the bandwidth. The higher frequency limit of the analog module is 5kHz. This signal could be lead to outputs, which the external filter capacitors are connected. The sensitivity at this analog outputs is 55mV/g at power supply voltage Vs=3V and 100mV/g at Vs=5V.

The transformation of that analog signal into PWM, leads to limiting of the frequency up to 500Hz[5]. For the normal operation of the accelerometer, the minimal value of externally connected capacitor is 10nF (Table 3).

Frequency bandwidth [Hz]	C_X, C_Y [μF]	RMS – noise [mg]
10	0,470	0.80
50	0,100	1,78
100	0,047	2,50
500	0,010	5,70

Table 3

The gained noise is presented by the follow equation [5]:

$$rmsNoise = (200\mu g/\sqrt{Hz}).\sqrt{BW.1,6}$$

It can be easily observed, that multiplier in ADXL210E has a value of $200\mu g/\sqrt{Hz}$ in contrast to ADXL320 which has value of $250\mu g/\sqrt{Hz}$. This leads to 20% lower noise at a same frequency band width. For band width of 50Hz the value of the noise is as follows:

$$rmsNoise = (200\mu g/\sqrt{Hz}).\sqrt{50.1,6} = 200\mu g.8,9 = 1,78mg$$

1.3 Accelerometer with serial peripheral interface (SPI)

ADIS16003 is a member of the accelerometers group with serial peripheral interface. The received from the measurement analog value is converted to digital and bring out through a standard digital interface - SPI.

The same way as within the previous mentioned two accelerometers, it is necessary to put additional external filter capacitors, which limit the frequency band width of the measurement. For this purpose the pins XFILT and YFILT are used. The dependence between used capacitor and 3dB – frequency band width is given by [6]:

$$F_{-3dB} = \frac{1}{(2\pi x R_{FLT} x(C_{(XFILT,YFILT))} + 2200pF))} =$$

$$= \frac{1}{(2\pi(32k\Omega)x(C_{(XFILT,YFILT))} + 2200pF))} =$$

$$= 5\mu F \frac{1}{(C_{(XFILT,YFILT))} + 2200pF)}$$

By contrast with previous reviewed accelerometers, that can operate without any additional connected external capacitors. In that case the maximum upper frequency limit for this accelerometer is 2,25 kHz. Additionally the limitation of the band width could achieved by externally connected capacitors.

The value of the noise for this accelerometer is given by the follow formula[6]:

$$rmsNoise = (110\mu g / \sqrt{Hz}).\sqrt{BW.1,6}$$

The value of noise's multiplier is vastly smaller than the preceding two accelerometers. For a band width of 50 Hz, for the noise level is :

$$rmsNoise = (110\mu g / \sqrt{Hz}).\sqrt{50.1,6} = 110.8,9 = 0.98mg$$

The dependency of frequency band width and noise level, by the externally connected capacitors is presented in Table 4.

Frequency bandwidth [Hz]	C_X, C_Y [μF]	RMS – noise [mg]
1	4,70	0.14
10	0,47	0.44
50	0,10	0,98
100	0,047	1,39
200	0,022	1,97
400	0,01	2.78
2250	0	6,60

Table 4

2. Conclusions

The accelerometer with analog output ADXL320 is with poorer properties than the other two, regarding parameters as noise and sensitivity. It is suitable for using in systems, where more than one accelerometer is used, and the output signals are passed to analog-to-digital-converter, through an analog multiplexer.

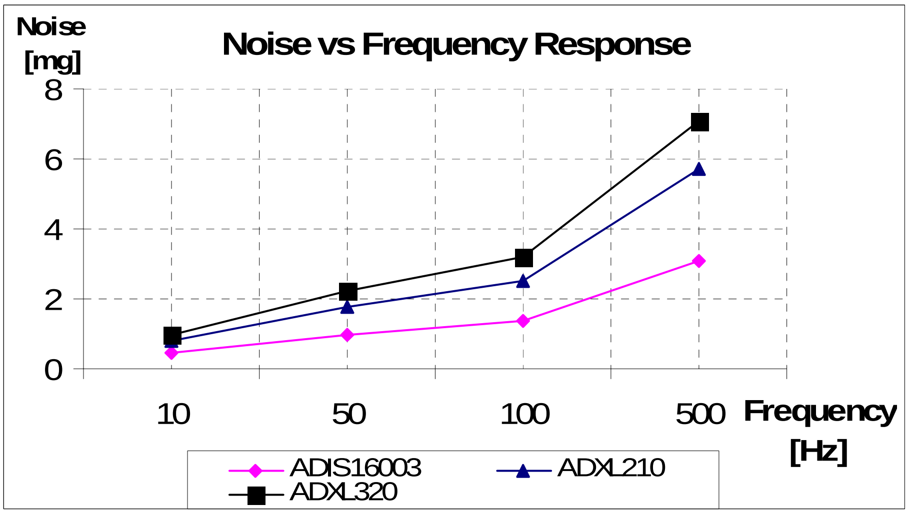

fig. 3

The accelerometer with PWM output ADXL210E has a lower noise level, but some disadvantages are presented within:

- limitation of the band width for the measured process by this of pulse width modulation.
- The result of the measurement is achieved as a result of complex set arithmetic operation.

The last reviewed accelerometer in present analysis - ADIS16003, possesses the best parameters – low noise (fig. 3), high frequency limit and possibility for additional temperature compensation.

3. REFERENCES

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