NEW METHOD AND TECHONOLGY FOR MEASURE OF ACCELERATION

Marius ARDELEAN
University Politehnica Timisoara, Faculty of Engineering Hunedoara
marius_a@fih.upt.ro

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Abstract: The utilization of sensor presupposes conversion of information from the physical world in a measure which can be easy quantificated, as a rule an electric signal. Thus the aim of kinematic parameter measure (acceleration, speed etc.) is to measure as a matter of fact a tension (or else a logical signal 1 or 0) what is converted further. Exist a lot of methods for measure kinematics parameters, each with the advantages and her disadvantages. In next paragraphs is presented a few type of accelerometer, especially the iMEMS® accelerometer (integrated Micro-Electro-Mechanical-System).

1. INTRODUCTION

Pendulum accelerometers. Use the principle that a pendulum with a mass m is detected a certain angle from its rest position when acceleration occurs. One problem with this type of accelerometer is getting an accurate measurement of the angle, especially for small accelerations, due to friction. Another problem is the size of the sensor, since it tends to be impractically large. The pendulous accelerometer is very seldom used. It is included only as a good example of the general principle of all accelerometers, i.e. using the inertia of masses to measure acceleration (which, of course, is a direct implication of inertia itself).

Pendulum accelerometer with incorporate gyroscope. Use a gyroscope in order to a measure a pendulum moment of rotation, the acceleration results from this. This type of accelerometer can measure a large range of accelerations, but he is very expensive.

Force rebalances accelerometers. Use a mass connected to a damping unit and a spring to measure acceleration. The displacement of the mass can be converted into acceleration by classical mechanics. These accelerometers are mainly used to measure very high accelerations.

Measure acceleration with piezoelectric sensor. Instruments based on piezoelectric crystals measure the dynamic or in change events, how is for instance the dynamic acceleration, but don't measure the static acceleration (g), [3]. This accelerometer can measure level of accelerations in area 0,0001g up to 100g (g= 9,81m/s^2)

For generated a signal these sensors are based on piezoelectric effect. Where the piezoelectric element is loaded with exterior forces, the electric loads are accumulated to the opposite parts of surface of the crystal, as per next figure.

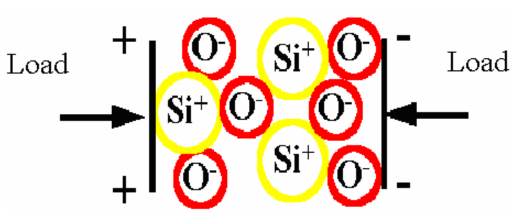


Figure 1 Work principle of piezoelectric element

As a piezoelectric element is used the crystals of quartz - natural piezoelectric materials and ceramic polycrystals artificial polarized. The used piezoelectric materials are of different forms and sizes, as per the figure 2.

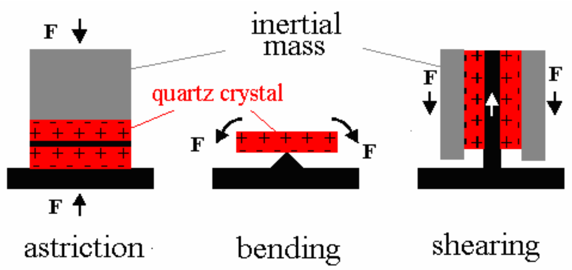


Figure 2 Ways of dispose the crystals of quartz and inertial table

Differential capacitor accelerometers. Come in two subtypes and both are a downsized version of the force rebalancing accelerometer above. The accelerometer is made of silicon and very small. The accelerometer we use in this report is a deferential capacity accelerometer. These accelerometers are based upon the fact that the capacitance between two plates is dependant on the distance between them. The accelerometer is a mass held up by springs etched out of silicon. A part of the mass makes up the middle plate of three plates, thus creating two different capacitors. The shift in position of the mass alters the distance between the plates, making one longer and one shorter. In the firsts subtype of differential capacitor accelerometers the difference in capacitance produces a current that is converted to an output voltage by logic control. The principal function can be seen in figure 3.

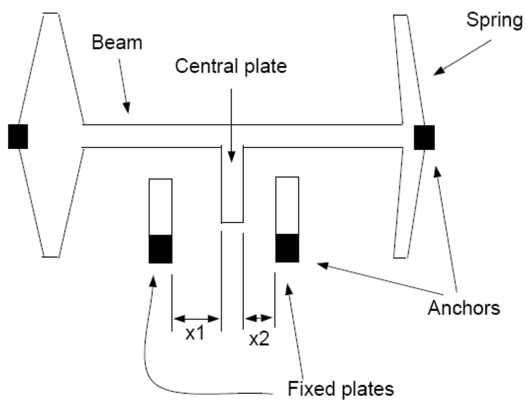


Figure 3 The principal function of differential capacitor accelerometers

Vibrating beam accelerometers. Use the physics of a violin string. The resonance frequency of the string changes when it is subject to more or less tension. Vibrating beam accelerometers produced in silicon use two vibrating beams that vibrate 180 degrees out of phase and in plane to lower the loss of energy from forces and shear through the mounting. Electrical circuits keep the beams vibrating at their resonance frequency. The resonance frequency is measured and converted to acceleration.

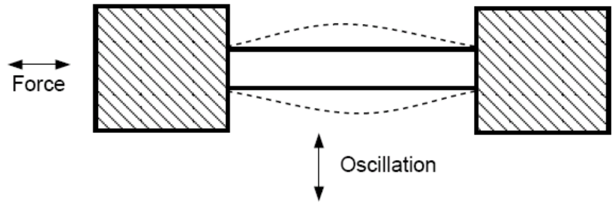


Figure 4 The principal function of vibrating beam accelerometers

In figure 4 the principal function of the accelerometer can be seen. Vibrating beam accelerometers can be made very precise and are to prefer before differential capacity accelerometers.

The last two types have in recent years been produced using a technology called silicon micromachining. These devices are so-called micro electro mechanical systems (MEMS). Capacitive-based MEMS accelerometers are actually to prefer before the piezoelectric accelerometers in many cases because they generally offer higher sensitivity and better resolution. The same is true for MEMS vibrating beam accelerometers. Also MEMS accelerometers do usually not have the problem that piezoelectric accelerometers have with low frequency components.

2. EXPERIMENTAL RESERCH

From viewpoint of acceleration order which measures it, these accelerometers are:

- accelerometers for lower accelerations (low-g accelerometers) which measures accelerations in domain ±1g up to ±20g;
- accelerometers for higher accelerations (high-g accelerometers) which measures accelerations in domain ±20g up to ±250g.

The *ADXL202JQC* accelerometer does part from the iMEMS® accelerometers (integrated Micro-Electro-Mechanical-System), who are revolutionized the market of miniaturization sensor, integrate on same circuits, and is presented in figure 5. Is a complete, dual-axis acceleration measurement system on a single monolithic IC. It contains a polysilicon surface micromachined sensor and signal conditioning circuitry to implement an open loop acceleration measurement architecture. For each axis, an output circuit converts the analog signal to a duty cycle modulated (DCM) digital signal that can be decoded with a counter/timer port on a microprocessor. The ADXL202 is capable of measuring both positive and negative accelerations to at least ±2 *g*. The accelerometer can measure static acceleration forces such as gravity, allowing it to be used as a tilt sensor, [4].

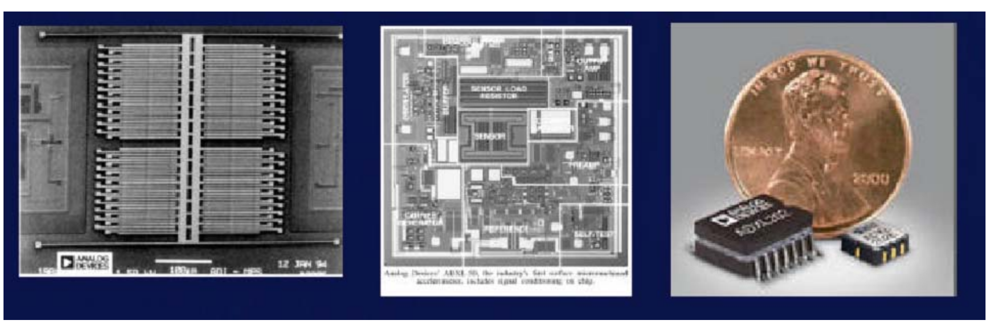


Figure 5 Detail of ADXL202JQC accelerometer

Decoding and calibration of accelerometer:

In the case which is used the digital output the acceleration is calculated using formula:

$$\mathbf{Accel.(in\,g)} = \frac{\mathbf{DUTY\,CYCLE - DUTY\,CYCLE\;0g}}{\mathbf{DUTY\,CYCLE\;\;g}} \qquad (1)$$

or

$$A(g) = \frac{(T_1/T_2) - 0{,}5}{12{,}5\%} \qquad (2)$$

where:

0 g = 50% duty cycle

12,5% = sensitivity factor;
T_1 – length of the "on" portion of the cycle;
T_2 - length of the total cycle;
T_1/T_2 – duty cycle ratio of the "on" time (T1) of the cycle to the total cycle (T2).
Thus an 0·g acceleration produces a nominal duty cycle of 50%.

The acceleration signal can be determined by measuring the length of the T1 and T2 pulses with a counter/timer or with a polling loop using a low cost microcontroller. An analog output voltage can be obtained either by buffering the signal from the X_{FILT} and Y_{FILT} pin, or by passing the duty cycle signal through an RC filter to reconstruct the DC value.

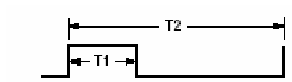


Figura 6 Typical Output Duty Cycle

For low *g* applications, the force of gravity is the most stable, accurate and convenient acceleration reference available. A reading of the 0·*g* point can be determined by orientating the device parallel to the earth's surface and then reading the output.

A more accurate calibration method is to make measurements at +1·*g* and –1·*g*. The sensitivity can be determined by the two measurements. To calibrate, the accelerometer's measurement axis is pointed directly at the earth. The 1·*g* reading is saved and the sensor is turned 180° to measure –1·*g*. Using the two readings, the sensitivity is:

Let A = Accelerometer output with axis oriented to +1·*g*

Let B = Accelerometer output with axis oriented to –1·*g then*:

$$Sensitivity = [A - B]/2\ g \qquad (3)$$

For example, if the +1 *g* reading (A) is 55% duty cycle and the –1·*g* reading (B) is 32% duty cycle, then:

$$Sensitivity = [55\% - 32\%]/2\ g = 11.5\%/g$$

These equations apply whether the output is analog or duty cycle. Application notes outlining algorithms for calculating acceleration from duty cycle and automated calibration routines are available from the factory, [2].

For construction of accelerometer, is made a print circuit which are mounted the components elements, and is incorporate ADXL202JQC circuit, the resistances for adjustment of duty cycle frequency and filter capacitor, as per figure 7.

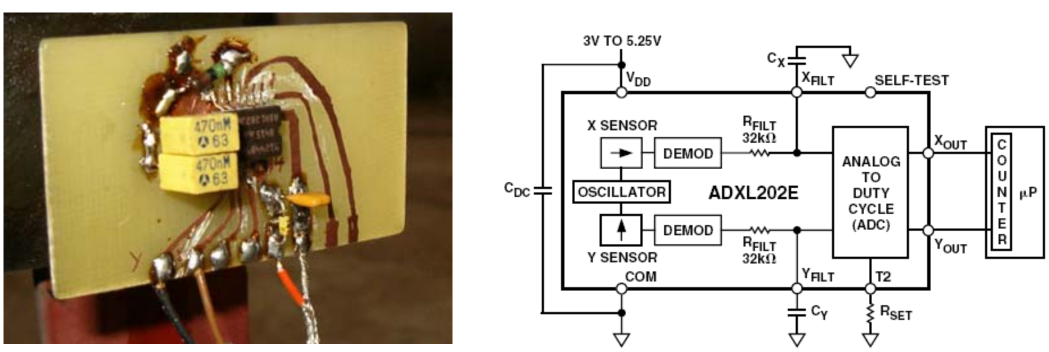


Figure 7 Print circuit and block diagram of accelerometer

For this accelerometer is providing also output for the digital and analogical signal. The input current of accelerometer is come from a direct current source of 4,5 V. For a quick and easy fixations in the opposite part of incorporate circuit are located a magnet.

Anterior establishment of this fixation mode is performed the experimentations in order to put in evidence eventually which influences can be produced of the magnetic field about comportment in operation of accelerometer. Were didn't evidence such interferential, therefore considered as this ways of fixation is most opportune in this case. Also, in order to don't obtain measure errors, the couple is fixed against the turning around self axes in operation time. The experimentations is accomplished on the experimental stand realized ate 1:1 scale after the model of next mechanism, [1].

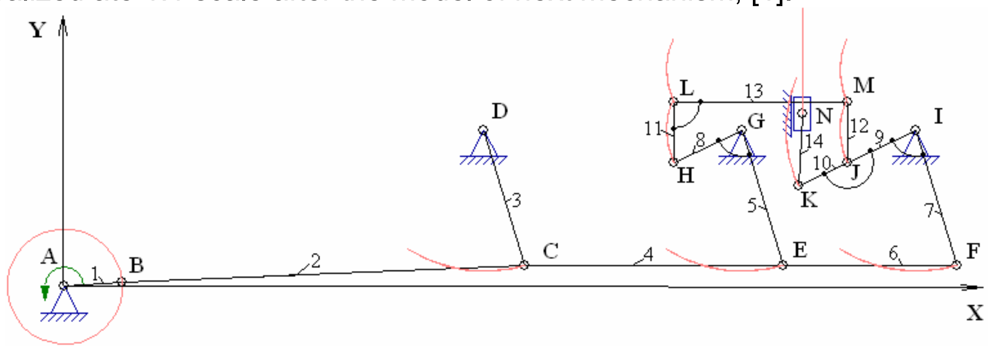


Figure 8 Kinematical scheme of mechanism

With this accelerometer and personal computer with acquisition data card is measured acceleration in couple of mechanism and in different point from cinematic element of mechanism. Figure 9 is presented the acceleration components raw data for each two axes of coordinates, and in figure 10 is presented variation of acceleration component for one cinematic cycle.

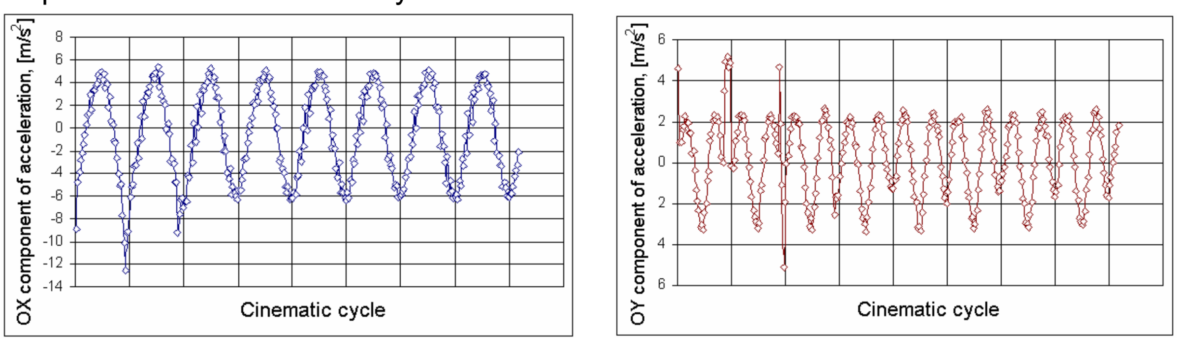
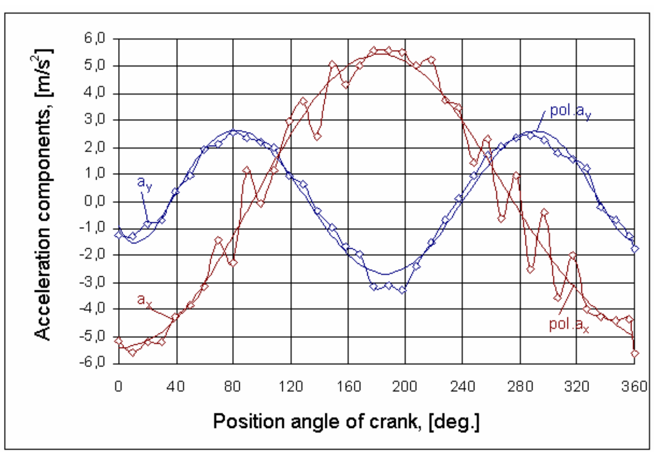


Figure 9 Acceleration components raw data for C couple



pol.a_y = 1E-12x6 - 1E-09x5 + 5E-07x4 - 9E-05x3 + 0.0068x2 - 0.1218x - 0.9046, R^2 = 0.9706
pol.a_x = -2E-13x6 + 2E-10x5 - 7E-08x4 + 7E-06x3 + 0.0005x2 + 0.0006x - 5.4039, R^2 = 0.9629

Figure 10 Acceleration components for C couple, for cinematic cycle

For each cinematic couples was measured the components of accelerations after two axes of reference system. The measure was made for many cinematic cycle, and it was selected a cinematic cycle in which don't put in evidence another disturbances (vibrations of ensemble, abnormal variations of acceleration by reason of shock or moving of couple, etc.).

Both component of acceleration is measured simultaneous, and is recorded with an acquisition data device. Data are processed in Excel with calculus routine. Starting of this data, can be obtained by integration expression of speed and course for studied cinematic couple.

3. CONCLUSIONS

These MEMS accelerometers are actually to prefer before the piezoelectric accelerometers in many cases because they generally offer higher sensitivity and better resolution.

Accelerometers is produced in a large range of models, for lower to very high acceleration, with application in a large field of application, from monitoring and measure (vibration, acceleration, tilt), robotics, auto industry (airbag sensor), navigation device (GPS device), and so on.

Resolution of this type of accelerometer is good, but for better result is need an electronic filtration of raw data. In this paper the variation of acceleration is represented with a polynomial regression curb.

With this type of accelerometer is possible to measure static and dynamic acceleration, and depend of models can be measure component of acceleration from all three axes of coordinate system simultaneous.

Can be realized a portable device for measure of acceleration, using a microcontroller.

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