

Implementing measurement and data processing with accelerometers

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1. Abstract

Acceleration is the rate of an object's velocity changes with time. With Newton's second law, force can be determined by the acceleration. So the study of acceleration becomes really important when understanding the behavior of a moving system. Accelerometers are the devices that measure the acceleration and output the acceleration in electrical form. The electrical signal from accelerometers can easily be processed with micro-controllers or some other displays.

2. Introduction

Accelerometers generally will contain a movable and a stationary part. The stationary part in the accelerometer will attach to the system and acting as the case of the accelerometer. The movable part will have spring load to balance the stationary part when no acceleration presents. When the accelerometer moves, the movable part will compress the spring until it reaches the same acceleration with the whole systems. By measuring the spring load, the acceleration can be studied. As shown in figure 1, in state A, the spring on both side of the mass hold it in the center. By comparing the electrical charge on both springs, the system have no voltage potential . In state B, the whole system move forward. Because of the moment of inertia on the mass, it will try to stay with it original state and compress the left spring until it achieve the same acceleration with the system; in other word, stationary with the system. The electrical potential between the left and right spring show the acceleration.

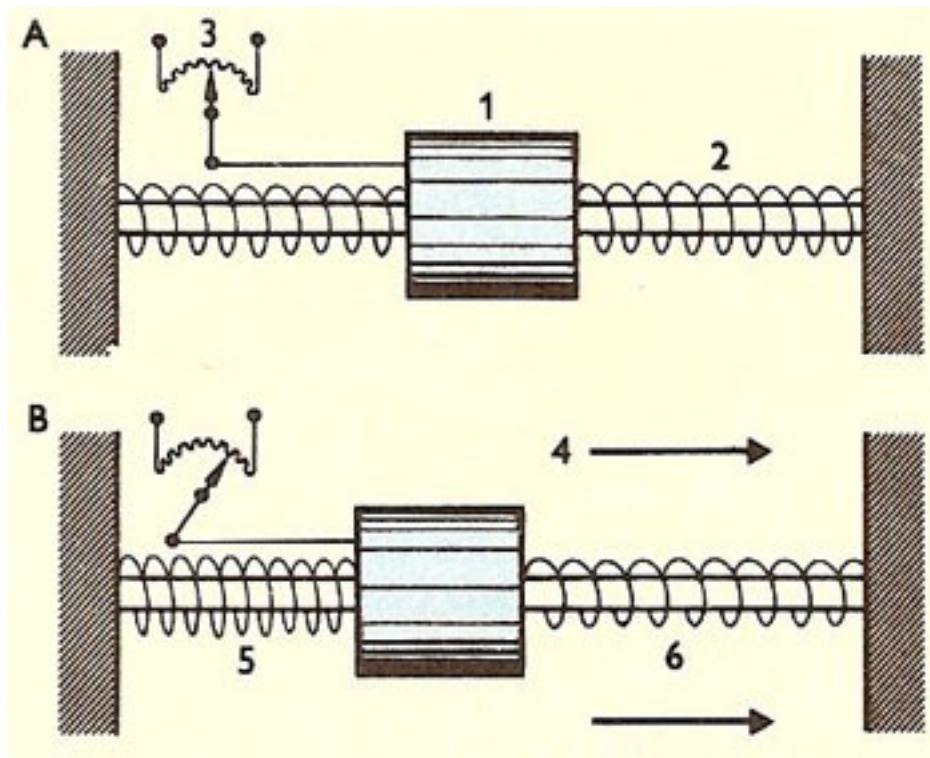


Figure 1

3. Accelerometer types

There are piezoelectric, piezoresistive and capacitive accelerometers for commercial uses.

Piezoelectric accelerometers are low weight, high frequency capacity, but expensive. This type of accelerometers have a flat response all the way up to 10,000Hz. Piezoelectric accelerometers rely on piezoceramics or single crystal. These piezoelectric material behaving as a pressure sensitive voltage source. As shown in figure 2, the output from the material feed into a ICP amplifier to amplify signal and reduce noise. This type of accelerometers are widely used in the laboratory, on the production floor, and as original equipment for measuring and recording dynamic changes in mechanical variables.

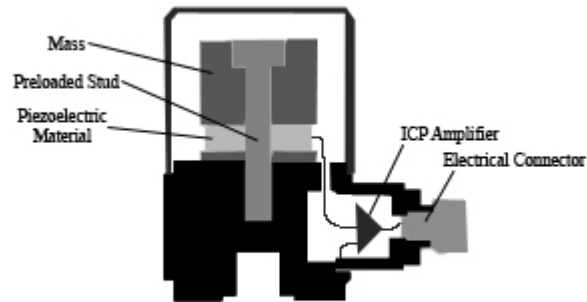


Figure 2

Piezoresistive accelerometers are for high shock use. This type of accelerometers rely on the piezoresistive effect, which is some of the material changes its electrical resistance under mechanical pressure. It will have a good and linear DC response and can operate up to 2,0000 m/s/s or higher. However, this type of accelerometer are relative expensive.

Capacitive accelerometers are cheap and good for low frequency applications. Most of capacitive accelerometers are a micro electro-mechanical systems (MEMS), which create a moving plate inside of the silicon chip with chemical reaction. As the figure 3 shown, the fixed outer plate have electrical charge, which create capacitance; while the movable plates moves in between the fixed plates and change the capacitance. By measuring the capacitance on the outer fixed plate, acceleration can be found. This type of accelerometers are widely used in the portable devices, eg. smartphones, step counter.

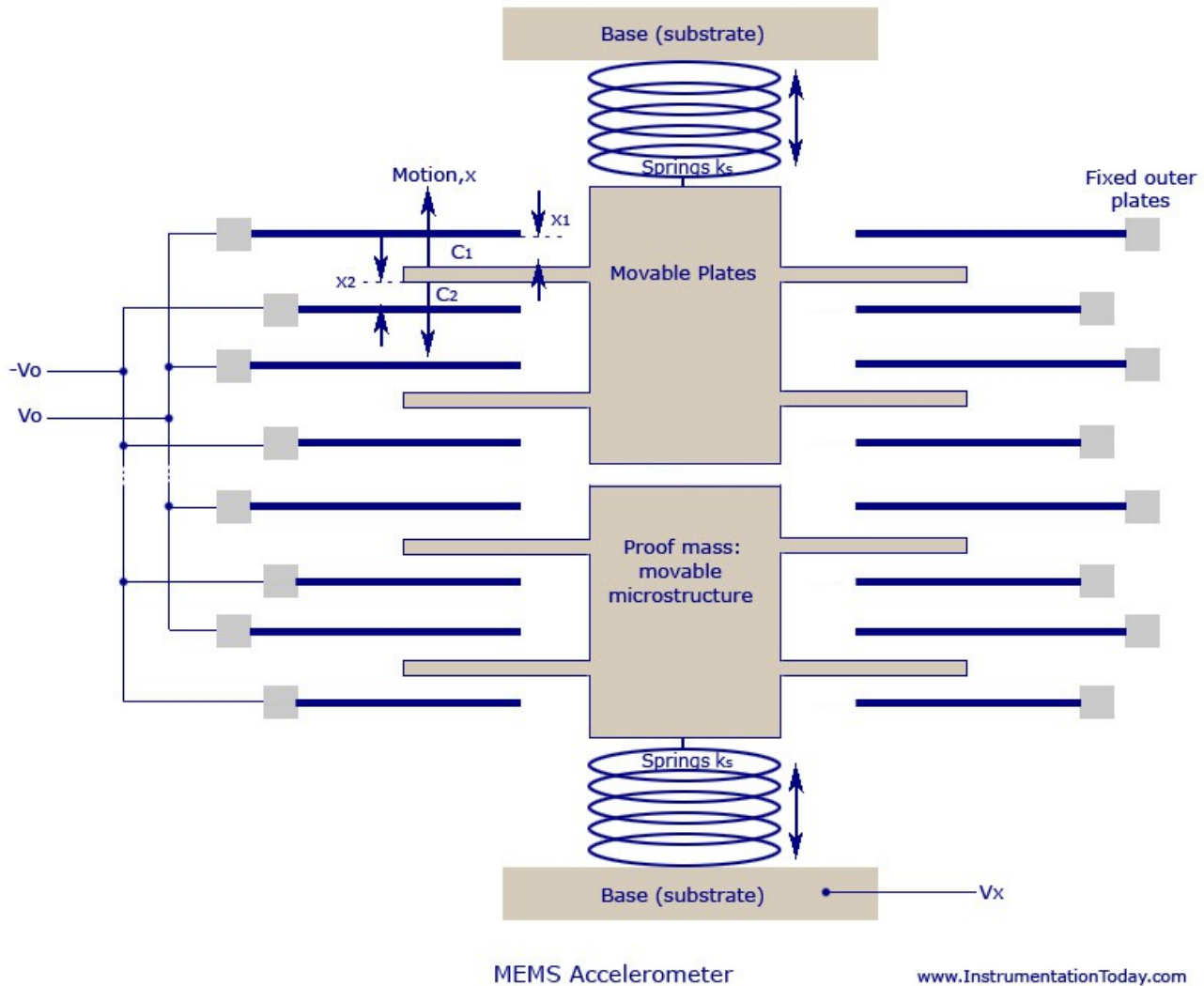


Figure 3

4. Accelerometer selections

As discussed in the previous section, the acceleration capacity and frequency response are the most important factors when selecting an accelerometer. These factors come down to the type of measurements for the accelerometers. The basic types of measurements are vibration, shock, motion, and seismic.

When measuring a vibration in a system, the frequency response of the accelerometer becomes the first priority. Depending on the frequency of the system, a piezoelectric accelerometer will be best for high frequency monitoring. This type of motion is often found in transportation and

aerospace environment.

For the shock measurement, the acceleration capacity became the first factor need to be considered. Most of the shock measurement felt in 5,000 m/s/s to 50,000 m/s/s acceleration range. In the case of a crash event, the acceleration can go up to 20,000 m/s/s. One more factor need to consider is the noise. A filter for the noise will be necessary in this application; however, a good frequency response accelerometer can pick up acceleration much easy, which require a fine tuned filter system.

Motion and seismic can be considered as a low frequency and low acceleration measurement.

Generally, a capacitive accelerometer will be used. The benefit on this accelerometer are less sensitive to the ambient temperature. Also, some other factors need to be considered.

Accelerometer is normally the core of a system, the right type of accelerometer make the system much easy to design and increase the usability.

5. Accelerometer signal processing

The signal from accelerometers are electrical voltage or some other forms of electrical signal. In order to got the desire acceleration value, a conversion between the electrical signal to the mechanical acceleration need to be preformed. The signal processing process depend on the accelerometer signal output.

Normally, an analog accelerometer will have a linear output during certain acceleration range, which was designed for specific usage. In our project, the Freescale MMA224KEG analog accelerometer will have a linear output at 4.75v-5v power supply. And the output voltage will be dividing the input, which 0g is set at 0.5Vdd. Although, in the spec sheet of the accelerometer have a internal filter for the high frequency noise, some noise still can be found on the receiver side of the micro-controller. An 2nd-order noise filter was used between the accelerometer and micro-controller. On the micro-controller side, an analog accelerometer will need to use the operation of analog to digital convertor (ADC) to convert the analog signal to

digital for future processing. The resolution of the convertor will effect on the accuracy of the final acceleration value. And the analog signal can easily interrupted by the outside noise, which can lead to an incorrect reading.

For the digital accelerometer, the data processing procedure will be easier. Because most of the digital accelerometer outputs a pulse width modulation (PWM) signal, micro-controller can easily pick-up the signal, count the width to calculate the resultant acceleration value. However, the digital accelerometer is a analog accelerometer with a ADC embedded in the accelerometer, which can also have the resolution issue. On the other hand, the signal is converted right after been generated, which less noise will be introduced. Depending on the applications, the signal processing will be different, and the accuracy of the result will need to be considered.

6. Accelerometer power consumption

In most cases, the power consumption of the accelerometer will not be considered; however, in a portable device, the consumption will be a big factor. In our application, we have the issue with the accelerometer consume a lot more power then the data sheet claimed. This can have a lot of factor in the design. Because the MEMS accelerometer is a capacitive one, which is a big capacitor changing all the time. The frequency of the sampling will changed the current drain on the accelerometer. With higher sampling frequency, the more power the accelerometer will consume. Under this condition, lower the sampling rate might need to be considered in order to reduce the power consumption.

7. References

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