PCB PIEZOTRONICS
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TN-2

Series 3700 Capacitive Accelerometer Self-Test Feature

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Standard Series 3700 Capacitive Accelerometers (and many customized models for specific requirements) incorporate a built-in self-test feature. By simply applying a DC voltage to the self-test input conductor, the mechanical sensing element inside of the accelerometer is physically deflected. This deflection or "simulated acceleration" is detected by the built-in microelectronics and causes a proportional step change in the output voltage of the sensor. When monitored by readout equipment, such as a digital voltmeter or oscilloscope, this step change in the output voltage signal serves to verify the functionality of the mechanical sensing element and microelectronics. This feature may also be used for locating a specific measurement channel in multi-channel sensor array applications. The complete theory and operational details behind this valuable feature are quite simple and are explained in the following paragraphs.

Series 3700 Capacitive Accelerometers operate on a four-wire scheme: Power, Signal Out, Ground and Self-Test. The self-test conductor of the sensor is connected, through a resistor, to the lower electrode on the internal capacitive sensing element. (A mechanical diagram of the accelerometer is shown in Figure 1, while a simplified electrical schematic of the accelerometer is shown in Figure 2). By applying a DC voltage to the self-test input conductor, a charge (Q) forms across the sensing element according to the Law of Electrostatics:

$$Q = C_2 V_t, \qquad \textbf{Eq. 1}$$

where,

C_2 = Lower Sensing Element Capacitance
V_t = Self-Test DC Input Voltage

The accumulated charge results in an electrostatic force (F_e), which can be approximated by the following equation:

$$F_e = [A\varepsilon/2(d-X)^2] \bullet V_t^2 \qquad \textbf{Eq. 2}$$

where,

A = Electrode Area
ε = Permittivity of Air
d = Distance between Seismic Mass and Electrode Under 0g Condition
X = Distance Seismic Mass is Displaced During Self-Test
V_t = Self-Test Input Voltage

This electrostatic force attracts the electrically-grounded, seismic mass, which is supported by a flexible member, and causes it to physically deflect by some distance (X). As the distance between the mass and the electrodes changes, the built-in microelectronics sense the resulting change in capacitance of the air gap and provide a proportional step change in the output voltage signal. This step change in the DC output voltage will continue as long as the self-test voltage is applied.

While the self-test concept is simple and very reliable, there are a few operational precautions to be aware of:

1) Due to the fact that the self-test voltage is being applied to a capacitor, this input point naturally has a very high impedance. Therefore, very little current is required for proper operation and any low power DC voltage source can be used. However, for safety reasons and to avoid undue stress to the internal electronics, the self-test input voltage should not exceed 30 VDC. A convenient voltage

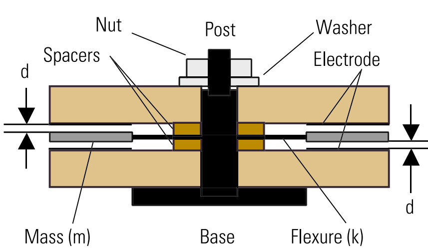

Figure 1a: Series 3700 Sensing Element in "0 g" Condition with Zero Self-Test Voltage

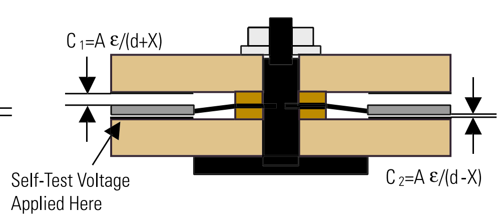

Figure 1b: Series 3700 Sensing Element in "0 g" Condition with +DC Self-Test Voltage Applied

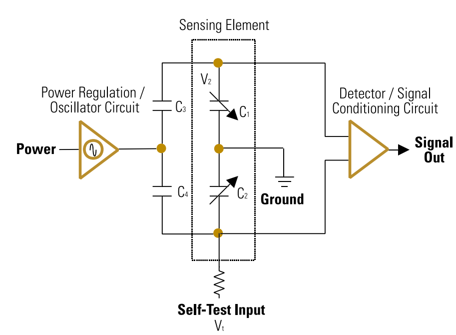

Figure 2: Electrical Schematic of a Series 3700 Variable Capacitance Accelerometer

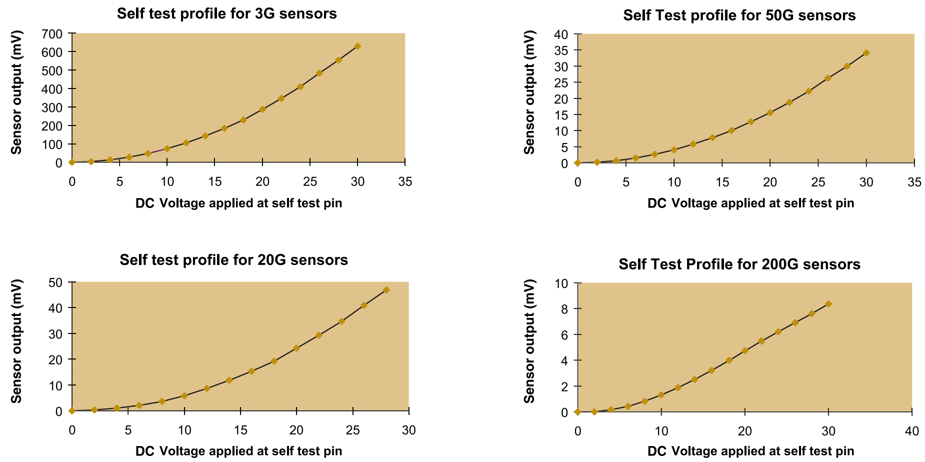

Figure 3: Step-Change in Output Voltage as a Function of Applied Self-Test Voltage for a Variety of Series 3700 Sensor Ranges

source is the same power supply used to power the sensor. The sensor power supply will provide more than adequate deflection of the sensing element to produce a noticeable (millivolts) output.

As one might intuitively believe, test results indicate that a larger self-test voltage will provide a larger step change in the output signal. It is important to monitor the change in DC voltage output signal and not the absolute level. The absolute output voltage can vary as it is affected by the orientation of the sensor in the Earth's Gravitational Field, the "zero-g" offset, and any signals due to sensed ambient vibration. In fact, the total output voltage will be the result of the algebraic sum of these factors and the "simulated acceleration" from the self-test voltage.

Figure 3 provides a general indication of the expected step change in output voltage for a variety of self-test input voltages. The actual numbers produced by the accelerometer may be slightly higher or lower as these values are affected by slight differences in the sensing element, which are inherent to the manufacturing process.

2) Since the self-test input is a high impedance point, noise sources, such as RFI, EMI or ESD, can cause charge to accumulate on the lower electrode. In turn, this will result in a drifting of the "zero-g offset" voltage of the sensor over time. Therefore, it is recommended that the self-test point be grounded when not in use. (All Series 445 and Series 478 Signal Conditioners offered by PCB automatically ground the self-test input to the sensor to avoid this problem).

3) Finally, it is important to note the self-test is not to be used for calibrating or verifying the calibration of a particular sensor. The step change in the output cannot be correlated with the sensitivity of the sensor. This results from the fact that the physical orientation of the sensor with respect to the Earth's gravity, the level of ambient vibration, the "zero-g" offset, and amount of applied DC voltage may all affect the output signal. Therefore, the feature serves only to verify operation and functionality of the components.

If a sensitivity check is required, the sensor can simply be "flipped" in the Earth's gravity to obtain a scaling factor. See Figure 4. This is accomplished by first placing the accelerometer on its side with its sensing axis perpendicular to the Earth's Gravity. The output from the sensor in this position is known as the "zero-g offset" voltage. Then, the sensor should be rotated so that its base rests on a surface parallel with the Earth. The sensor will now be experiencing +1g acceleration. By subtracting the "zero-g offset" voltage from this output voltage, the sensitivity of the sensor is determined.

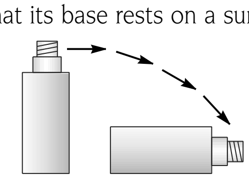

Figure 4: Sensor Flip Test

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