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Electrical Characteristics of Endevco Variable Capacitance Accelerometers

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Introduction

The Endevco variable capacitance (VC) accelerometers are designed for measurement of relatively low-level accelerations in aerospace and automobile environments. The VC accelerometers feature low frequency measurement capability down to 0Hz, and operate on wide range of excitation voltage (e.g. 8-40V DC voltage for Model 7290G). They produce an output voltage of ±2 volts, often presented with a DC bias, and offer a versatile signal output arrangement allowing for differential or single-ended operation modes. The electrical characteristics of the Endevco VC accelerometers will be discussed in this article.

Excitation Voltage

An excitation voltage is used as input to power up the VC accelerometer. For the VC accelerometer model 7290G (Figure 1) as an example, it requires an excitation DC voltage from +8V to +40V. If the excitation voltage drops below the minimum specified voltage, the VC accelerometer will not operate. Exceeding the maximum voltage can cause permanent damage to the sensor.

The 7290G accelerometer features an internal voltage reference that regulates the input excitation to a constant and stable voltage reference to support the operation of other components of the sensor. A low noise DC voltage power supply with minimum ripples is recommended to use as excitation for the VC accelerometers. Certain care, such as cable shielding or proper elimination of nearby noise sources, should be taken to minimize noise pickup on the power wires of cabling to the accelerometer.

Figure 1. Model 7290G Variable Capacitance Accelerometer

Endevco VC accelerometers are ideally suited for operation with piezoresistive bridge signal conditioners found in many modern data acquisition systems. When using these accelerometers with a bridge signal conditioner, 10 Vdc excitation should be selected.

The input excitation voltage should be applied between the EXC (red) and GND (black) leads, as shown in Figure 2. The power supply ground should always be isolated from the AC line power ground. If the excitation voltage ground and power ground are common, this could result in excessive noise, unwanted ground loops and, in some cases, interaction between the excitation power line and signal amplifier.

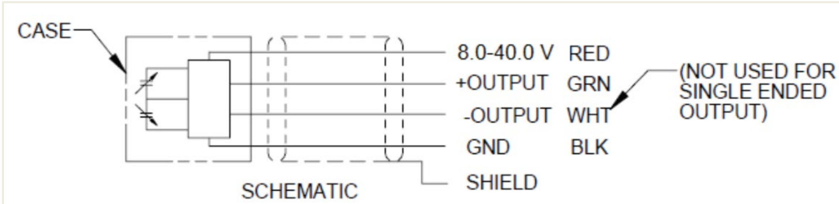

Figure 2. Wiring Diagram of VC Model 7290G

Unlike Piezoresistive accelerometers which use a passive resistance bridge as the sensing element and the sensitivity and zero characteristics are approximately ratio-metric to the excitation voltage applied to the device, the VC accelerometers have active electronics inside and its output is not ratio-metric to the excitation voltage, i.e., the excitation voltage can be operated anywhere within the specified range with no effect on the performance of the accelerometer.

ZMO

The Zero Measurand Output (ZMO) is the voltage output when the input to the accelerometer is 0g. VC accelerometers are DC devices, which means they will sense constant acceleration such as earth's gravity. When the accelerometer is positioned on its side (e.g. VC model 7290G as in Figure 3), the natural +1g gravity is perpendicular to the sensing direction of the accelerometer, the input to the accelerometer is 0g, ideally the output should read zero volts.

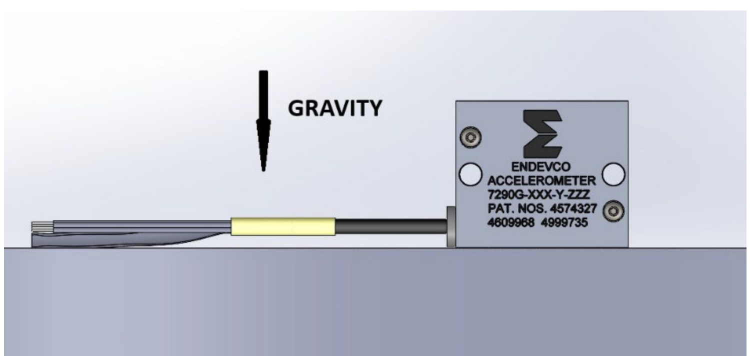

Figure 3. 0g position of Endevco VC accelerometer 7290G

While all Endevco VC accelerometers have their ZMO trimmed as close to zero volts output as possible, there will almost always be some voltage or ZMO present at the output. The ZMO can be considered as a constant error when measuring acceleration input, it can be manually subtracted from the voltage output for better measurement accuracy of the input acceleration. The ZMO can generally be further corrected with the zero-trimming function of the user's signal conditioner.

Differential Output Mode

The Endevco VC accelerometer offers a very versatile signal output arrangement allowing for differential output or single-ended output operations. (Figure 4)

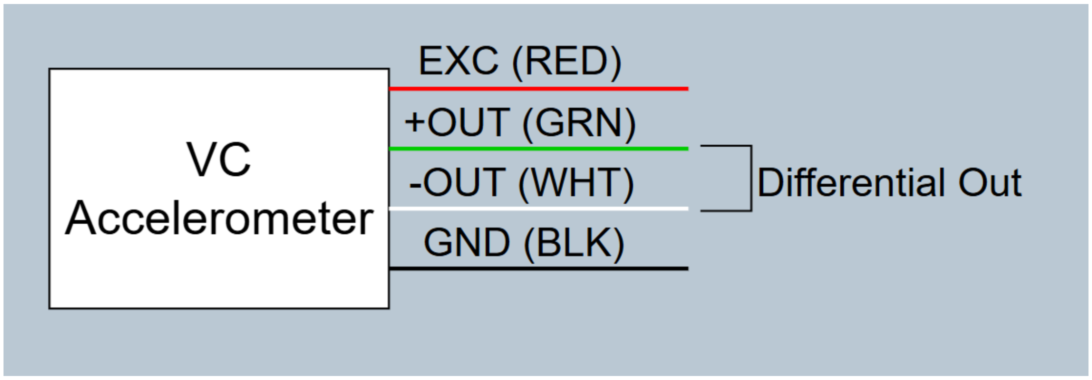

Figure 4. Differential Output Mode

In the differential output mode, the excitation voltage from the power supply is connected between the EXC and GND leads of the accelerometer, and the accelerometer output is measured between the +OUT and -OUT leads that are connected to oscilloscope, signal conditioner or data acquisition system. The voltage signal seen at +OUT or -OUT is an AC signal in response to the change of the input acceleration, coupled with a DC signal (bias). The bias remains constant and does not change with the input acceleration. In most Endevco VC accelerometers, such as model 7290G, the bias is +2.5V dc on both +OUT and -OUT. In differential mode of the accelerometer, the output is measured as the difference between +OUT and -OUT, their bias voltages are cancelled from each other leaving only the AC signal that's proportional to the acceleration input.

Here is an example of input acceleration calculation in the differential output mode:

Example:

If a 7290G VC accelerometer has a sensitivity of 10mV/g, and a ZMO of -20mV in differential mode, i.e. when sensor is at 0g position the voltage difference between the two output leads is ZMO = V(+OUT, 0g) – V(-OUT, 0g) = -20mV .

If the sensor sees a certain amount of input acceleration and the differential output measures between the +OUT and -OUT leads is Vout = V(+OUT) – V(-OUT) = 160mV, then the input acceleration can be derived by:

Input acceleration = (Vout – ZMO) / Sensitivity
= (160 mV – (-20mV)) / (10mV/g)
= 18 g

When the accelerometer is operated in differential mode, the common mode errors seen by the two output leads +OUT and -OUT owing to thermal variation or EMI interference can be greatly reduced or cancelled by each other which promises the most stable performance of the accelerometer over temperature and various test environments.

Single-ended Output Mode

Sometimes, due to instrumentation limitations, it is desirable to operate the accelerometer in the single-ended mode. The versatility of the 7290G does allow for single-ended operation without any modifications.

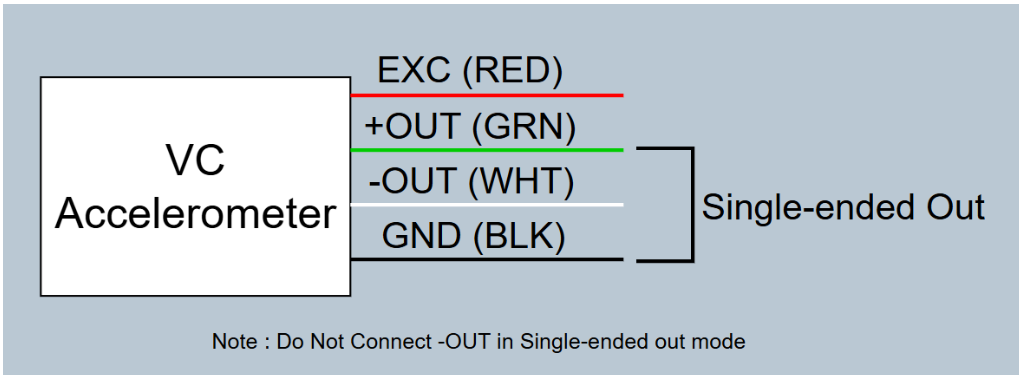

Figure 5. Single-ended Output Mode

In the single-ended mode, the excitation voltage from the power supply is connected between the EXC and GND leads of the accelerometer, the accelerometer output is measured between the +OUT and GND leads (Figure 5). The -OUT lead should be left float. Do not connect or ground the -OUT lead.

Unlike the differential mode, the +2.5V dc bias on +OUT in single-ended mode is not cancelled from the voltage on GND, resulting a +2.5V dc ZMO when the accelerometer is positioned at 0g. The signal conditioner or data acquisition equipment should have sufficient offset to adjust for this bias and ZMO. In the single-ended mode, the ambient temperature should be reasonably stable to minimize the thermal effect on bias variation.

Here is an example of input acceleration calculation in the single-ended output mode:

Example:

If a 7290G VC accelerometer has a sensitivity of 10mV/g, and a ZMO of 2520 mV in single-ended mode, i.e. when sensor is at 0g position the voltage difference between the +OUT and GND leads is ZMO = V(+OUT, 0g) – GND = 2520mV .

If the sensor sees a certain amount of input acceleration and the single-ended output measures between the +OUT and GND leads is Vout = V(+OUT) – GND = 2780mV, then the input acceleration can be derived by:

Input acceleration = (Vout – ZMO) / Sensitivity
= (2780 mV – 2520mV) / (10mV/g)
= 26 g

Note: For ease of customer use, model 7290G can be ordered with "-D" standard option for differential mode calibration and "-S" option for single-ended mode calibration.

Check Basic Operation of VC Accelerometer

When the accelerometer is received or before use, it can be checked quickly on a test bench to verify its basic functionality. For VC model 7290G as an example, a +15V dc excitation is connected to EXC and GND leads to power up the accelerometer. The current consumption shown from the power supply is supposed to be 4-6mA. The voltage output V(+1g) is first measured at +1g static position of the accelerometer (Figure 6). The accelerometer is then flipped over to -1g static position on the test bench and a voltage measurement is taken again on the accelerometer output V(-1g).

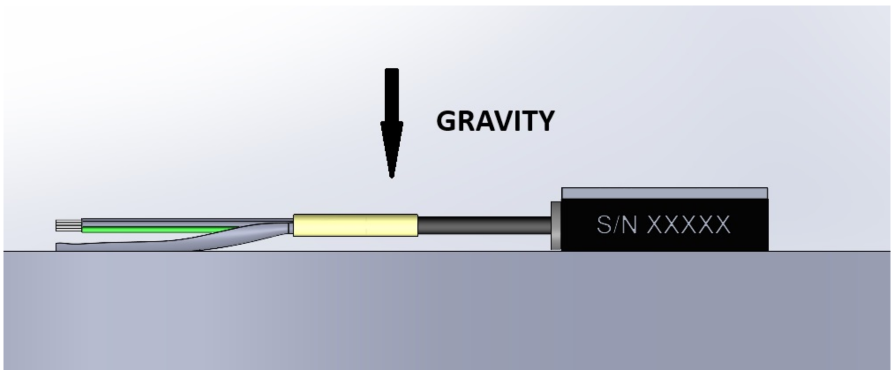

Figure 6. +1g position of Endevco VC accelerometer 7290G

The sensitivity and ZMO can be calculated by the formulas below. This calculation applies to either differential output mode or single-ended output mode.

$$\text{Sensitivity} = [V(+1g) - V(-1g)] / 2$$
$$\text{ZMO} = [V(+1g) + V(-1g)] / 2$$

Measurement Resolution and Noise

There is always a baseline noise presented at the output of a powered VC accelerometer due to the electronic noise of the internal components. The noise is a small amount of voltage signal that varies frequently over time as a meaningless output of the sensor. Any output in response to an acceleration input that's smaller than the baseline noise level would be buried within the noise and not be detected or measured by the accelerometer.

The measurement resolution of a VC accelerometer is the minimum input acceleration level that can be detected and measured by the accelerometer from the baseline noise. For instance, the measurement resolution of model 7290G-100 accelerometer is 0.01 g, which means the 7290G-100 has a full-scale measurement range of +/-100g, and it can detect input acceleration as low as +/-0.01 g. If measurement of an input of less than +/-0.01 g is needed in an application, a VC accelerometer model with lower measurement resolution, e.g., model 7290G-2 with a measurement resolution of 0.0002 g, should be used.

Additional output considerations

The user should observe the load requirements to obtain stable output and optimum performance of the accelerometer. For VC model 7290G as an example, the minimum resistive load is 10k Ω and the maximum capacitive load is 0.1uF. Any capacitive or resistive loads that are out of the specified range may cause an oscillating signal at the sensor output. Please refer to the datasheets for other electrical requirements of the Endevco VC accelerometers

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