Biasing Internally Amplified Accelerometers

Accelerometers with integrated amplifiers are a popular alternative to those requiring external charge amplifiers. SigLab's top hatch access to the input signal conditioning circuitry makes building an internal accelerometer interface easy. This note describes a method of constructing an interface to accelerometers with internal amplifiers.

Overview

Bias Requirements

Many of today's accelerometers contain an integrated amplifier consisting of a FET, some bipolar transistors, and a few passive components. This scheme eliminates the need for a charge-to-voltage converter with its inherent problems, such as cable-induced noise. To use the integrated devices, a constant current bias must be applied to the amplifier, and the resulting dc offset component must be removed from the output signal.

The recommended range of a bias current is from 2 to 6 mA. The higher currents are needed for long cables, high signal levels, and high frequencies. For cables less than ten feet, 2 mA is sufficient for most applications (consult your accelerometer specifications). This bias current is injected into the center conductor of the coaxial cable which connects the accelerometer to SigLab. The return path for the bias current is through the coax shield.

The bias current causes a dc offset, called Bias Operating Voltage (V_{BOV}), between the center conductor and the shield. V_{BOV} is usually between 11 and 13 V but can be higher if the 6 mA bias current is used or if the accelerometer is cold.[1]

To maintain signal integrity, the bias source must supply a constant current at any accelerometer voltage (V_{Acc}) up to $V_{BOV} + V_{Signal}$. V_{Signal} is the level produced by the accelerometer responding to maximum anticipated acceleration. This level therefore depends on the anticipated maximum acceleration and the accelerometer sensitivity. This requirement is summarized by:

$$V_{Acc} \le (V_{BOV} + V_{Signal}) \qquad (1)$$

Constructing a Bias Source

Figure 1 illustrates a bias source constructed with three resistors, one capacitor, and one integrated current source (LM334). The largest positive power supply voltage, V_{PS}, available directly in SigLab is 15 V ± 3.5%. This sets an upper voltage limit for which the current source can supply a constant current. The current level supplied by the National Semiconductor LM334 is set by an external resistor between its R and -V pins. A 2 mA current is produced with a 33 ohm resistor. The LM334 requires almost a 1 V difference between its +V / -V pins to keep the current at 2 mA.

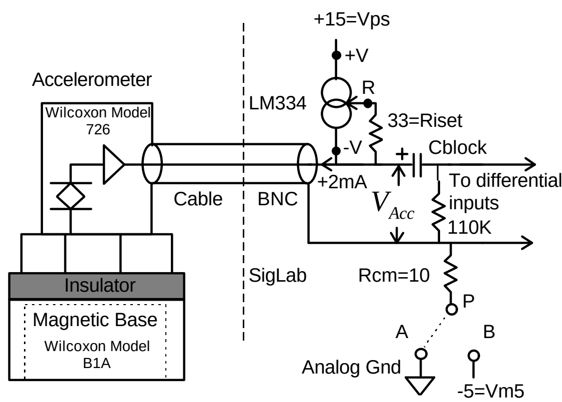

Figure 1 - SigLab Accelerometer Bias Source

Assuming a $V_{PS} = 14.5$ V and a 1 V drop across the LM334, the 2 mA current is supplied only if the center conductor voltage (with respect to the system ground) is less than 13.5 V:

$$V_{MAX} = V_{PS} - V_{LM334} = 13.5 \text{ V} \quad (2)$$

The dc component is removed with the capacitor, Cblock. The low frequency -3 dB point is set by this capacitor and the 110 K ohm resistor. SigLab's internal 1M ohm resistor appears in parallel with the 110 K hence the following:

$$f_{-3dB} = \frac{1}{2 \cdot p \cdot Cblock \cdot 10^5} \cdot \quad (3)$$

Therefore, a capacitor of 10 uF provides a low frequency -3 dB point of 0.16 Hz.

The accelerometer also has a low frequency roll-off. The value of Cblock should be chosen so that the f_{-3dB} point in (3) is lower than the accelerometer 3 dB frequency by a factor of about 4 or more. This insures that the accelerometer dynamics dominate the low frequency measurement behavior.

This note will now expand upon two measurement scenarios:

1. low level: $V_{Signal} \le 0.5$ V
2. high level: $V_{Signal} \le 5$ V

Only positive signal excursions are considered because negative excursions are not influenced by the bias supply.

Low Level Signals

In this configuration, the P-end of the Rcm resistor is returned to the system analog ground (the A position in Figure 1). Given the restriction of (2), and the fact that V_{BOV} can be 13 V, it becomes clear that there is not a great deal of range remaining for the signal:

$$V_{Signal} \le (V_{MAX} - V_{BOV})$$

$$V_{Signal} \le 0.5$$

This circuit's maximum signal level is therefore constrained by the high value of V_{BOV} in the accelerometer and the 15 V supply in SigLab.

Given the above restrictions, if the accelerometer has a sensitivity of 100 mV/g, accelerations of up to 5 g can be measured confidently. Often this signal level (0.5 V) is adequate if low levels of vibration are being measured or if the accelerometer has a low enough sensitivity.

Figure 2 illustrates severe signal clipping on positive peaks. Although it may not be obvious, the system is becoming nonlinear even below the 1.15 V clipping level. Measurements made on the accelerometer used indicated a V_{BOV} of 13 V. SigLab's power supply was found to be 14.75 V, so the guaranteed linear range would be up to the 0.75 V level.

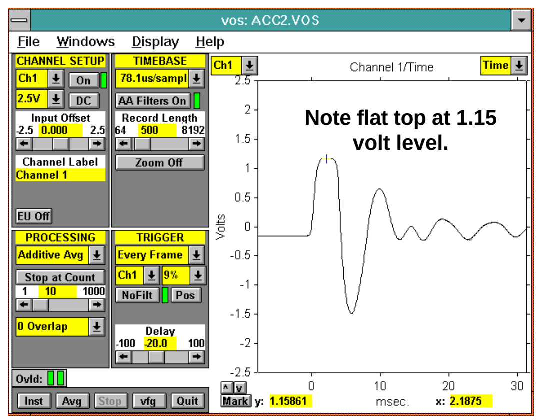

Figure 2 - Signal Clipping

A good way to insure that the results are always accurate is to set SigLab's full-scale voltage to any range below the maximum theoretically linear value. In this case, signals up to 0.75 V are assured to be accurately produced (linear) so the 0.62 V range (or lower) can be used. Doing this insures that SigLab's overload detectors are activated before there is any possibility of the acceleration measurement being non-linear.

Figure 3 illustrates an acceleration signal at a lower level. Notice the well-defined peak at 0.51 V. This is crude indication that the accelerometer is operating in a linear region.

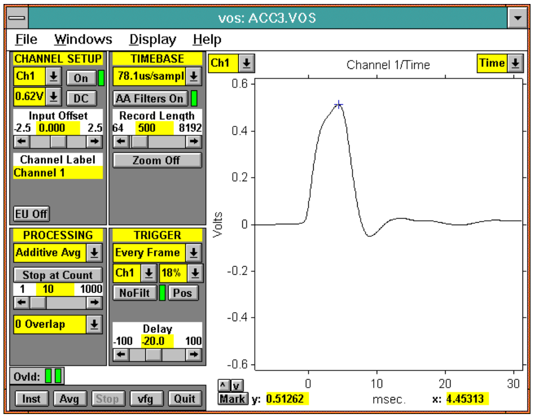

Figure 3 - Signal in Linear Range

Noise and Spurious Signals

The circuit in Figure 1 with a Wilcoxon Model 726 (100 mV/g) accelerometer was used to determine the noise performance of the accelerometer interface.

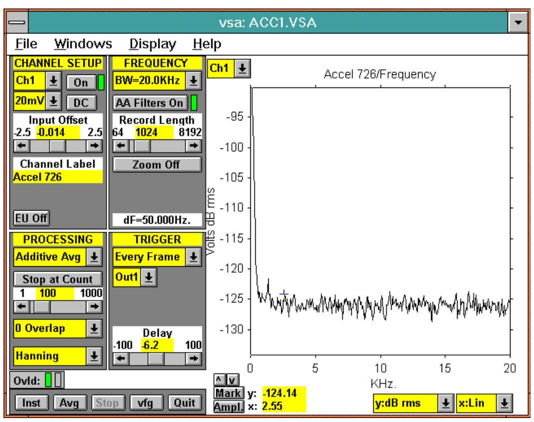

Figure 4 - Noise and Spurious Signals

Figure 4 illustrates the noise spectrum of the accelerometer using the bias source interface. The noise floor did not perceptibly change when a 50 ohm input termination resistor was replaced by the combination of the accelerometer and bias source. This validates that very little noise is generated by the accelerometer and bias source combination.

High Level Signals

The circuit in Figure 1 can be modified to handle accelerometer voltage outputs about 10 times as large as the previous version. This is possible because SigLab has a differential input amplifier. Instead of returning the P-end of the Rcm to analog ground, it can be returned to the -5 V power supply (the B position in Figure 1). This provides an effective $V_{PS} = 20$ V assuming nominal +15 and -5 V supplies. The -5 V dc term is then a common mode signal to the differential input and greatly attenuated. Applying equations (1) and (2) with nominal power supply values yields:

$$V_{MAX} = V_{PS} - V_{LM334} = 20 - 1 = 19 \text{ V}$$

$$V_{Signal} \le V_{MAX} - V_{BOV} = 19 - 13 \le 6 \text{ V}$$

The resulting $V_{Signal} \le 6$ V is a substantial improvement over the maximum value of the previous configuration.

Figure 5 shows a +5 V output signal produced by the same accelerometer and bias source used in Figures 2 & 3. The -5 V supply was used to increase the linear range.

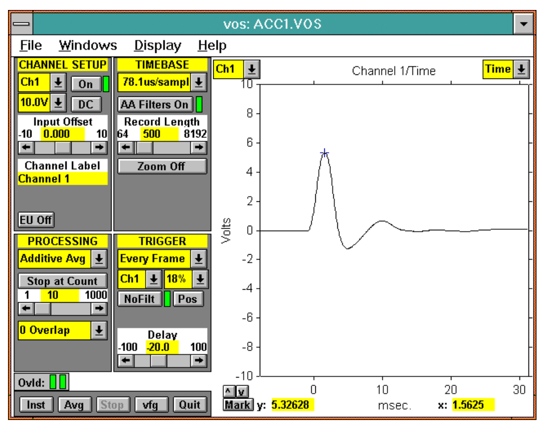

Figure 5 - Five Volt Signal Capability

The drawback of this approach is that the low side of the accelerometer is at -5 V with respect to SigLab's signal ground. When SigLab is operated from the ac mains, the case of the accelerometer is at a -5 V potential with respect to the “green” (or safety) ground return. Properly installed equipment (motor, machine, etc.) is always connected to this green ground return.

Therefore, a short circuit between the case of the accelerometer and a safety ground through the device being measured must be avoided. This is easily accomplished with an insulated mount such as the B1A from Wilcoxon Research shown in Figure 1. This insulated mount is useful in breaking ground loops (differences in voltage between the low side of the analyzer input and the machine being measured). Therefore an insulated mount is beneficial even when the low side of the accelerometer is grounded (the A position in Figure 1 or 7).

It should be noted that even with the insulated mount, the accelerometer must be handled with care. Its case must be prevented from inadvertently shorting to any metallic object with a ground return or, worse yet, an external power source (e.g. 110 Vac). The 10 ohm resistor (Rcm) is does not sufficiently limit the current into SigLab, and damage is likely

Common Mode Signals

A relatively low value for Rcm (10 ohms) is used in the bias source to minimize the pickup of unwanted ac signals through capacitive coupling. Although common mode signals are severely attenuated by the CMRR of SigLab's differential inputs, it is prudent to further minimize them with a low value of Rcm.

Physical Construction

Figure 7 illustrates a component layout on a 14-pin dual in-line component header. The A/B selection is accomplished by wiring the end of the 10 ohm resistor to the desired point (pin 12 for analog ground (A), pin 8 for -5 V (B)). The LM334 is in a plastic 3 leaded package, and the top view is shown in Figure 7.

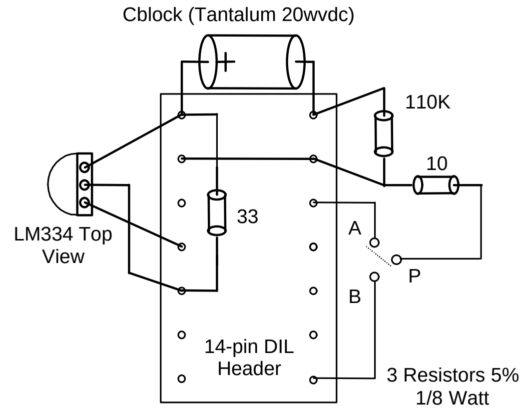

Figure 7 - Physical Construction of Bias Source on a 14-pin Header

Conclusion

The construction of a bias source for accelerometers with integrated amplifiers has been presented. Handling positive excursions of less than 0.5 V is easy. Handling larger excursions (up to 5 V) can be done with the same simple circuit, but there is some risk. Choosing the 5 V option requires some diligence on the part of the user in the mounting and handling of the accelerometer. More complicated schemes can be created using power conversion technology to provide a higher bias voltage, but the simple approach presented will satisfy a wide variety of real-world applications.

For more information contact:
Spectral Dynamics
1010 Timothy Drive
San Jose, CA 95133-1042
Phone: (408) 918-2577
Fax: (408) 918-2580
Email: siglabsupport@sd-star.com
www.spectraldynamics.com

---

[1] Accelerometers with a lower V_{BOV} can be ordered from Wilcoxon Research in Gaithersburg MD 20878, Tel: (301) 330-8811. This will increase the available positive swing.