Building a Charge Amplifier

1632 Corporate Landing Parkway, Virginia Beach, VA 23454 Phone: (757) 426-3678 Fax: (757) 426-3633 www.oceanasensor.com

Preamplifier Design

General Description

OST's high impedance accelerometer models (TR0AXN, PB0AXN, AP0AXN) require a preamplifier to convert the high impedance output of the piezoelectric element into a low impedance signal that is suitable for use with measuring and instrumentation devices. There are two basic types of preamplifiers that can be used with piezoelectric accelerometers:

1. Charge Preamplifiers
2. Voltage Preamplifiers

OST recommends the use of charge preamplifiers with its accelerometers because cable capacitance has little effect on the overall sensitivity of the system. Charge preamplifiers can be used with various cable lengths without the need for recalibration due to cable capacitance. Voltage preamplifiers require recalibration when different cable lengths are used because the sensitivity is directly related to cable capacitance. This application note will only describe charge preamplifiers.

Charge Preamplifiers

Charge preamplifiers produce an output voltage that is proportional to the charge input. A schematic of a charge-amplified system is shown below in Figure 1.

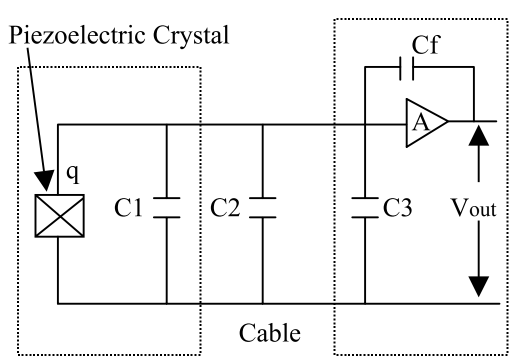

Figure 1. Charge Amplified System

The output voltage is dependent on the ratio of the input charge to the feedback capacitance as shown in Equation 1 below. Note that the capacitance due to the sensor, cable, and amplifier (C1, C2, C3) do not affect the system sensitivity.

$$Vout = \frac{q}{Cf} \qquad \text{(Eq. 1)}$$

Although cable capacitance does not affect the system sensitivity, low noise, shielded cable should be used to reduce charge generated by cable motion (triboelectric effect) and to reduce electrical noise induced by RFI and EMI.

General Purpose Preamplifier

Figure 2 shows a schematic of a charge preamplifier that can be used to convert the high impedance output of OST's high impedance accelerometer models into a low impedance signal.

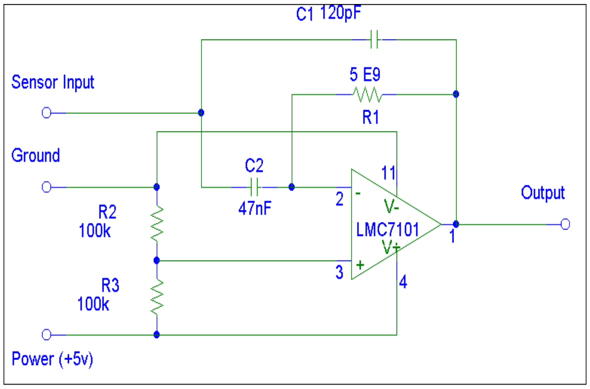

Figure 2. Charge Preamplifier

The component values are selected to produce the required output voltage sensitivity and set the low frequency response characteristics. The feedback capacitor (C1) defines the output voltage sensitivity of the charge-amplified system. Eq. 2 shows the voltage sensitivity of the circuit in Figure 2 when connected to OST's PB0AXN, which has a charge sensitivity of 13pC/g.

$$Vout = \frac{13pC/g}{120pF} = 108mV/g \qquad \text{(Eq. 2)}$$

The product of the feedback resistor (R1) and the feedback capacitor (C1) sets the overall system time constant (τ). The time constant defines the low frequency cutoff of the system as shown in Eq.3.

$$fc = \frac{1}{2\pi RC} = \frac{1}{2\pi\tau} \qquad \text{(Eq.3)}$$

The time constant (τ) for the charge preamplifier shown in Figure 2 is:

$$\tau = R_1 \times C_1 = 5E^9 \times 120E^{-12} = 0.6s \qquad \text{(Eq. 4)}$$

Using (τ) from Eq. 4, the low frequency cutoff is:

$$f_c = \frac{1}{2\pi\tau} = \frac{1}{2\pi \times 0.6} \cong 0.27Hz \qquad \text{(Eq. 5)}$$

The value of R1 and C1 can be adjusted to produce required time constants and output sensitivities.

Resistors R2 and R3 in Figure 2 are used to offset the output voltage by ½ the supply voltage so that positive and negative swings can be measured. This is an economical way of producing an offset voltage and should not be considered stable or accurate. If a stable, accurate offset is required for applications such as A/D conversion, a more robust method of offset generation should be used.

The operational amplifier used in Figure 2 is a low power, rail-to-rail, single supply op-amp. This op amp was selected for this application note because it can be used with several supply voltages and it has very low leakage current. When selecting operational amplifiers for charge pre-amplifier applications, it is essential to ensure that the input bias current is small. OST recommends typical values of 1 pA and maximum values less than 100 pA. It is also important to note that low power op amps are generally bandwidth limited, which can affect the high frequency characteristics of the system.

Feedback Resistor Concerns
It is important to note that the feedback resistance is generally very large (usually in the giga-ohm range). Because of this large resistance, leakage currents in the circuit can cause large voltage drops across the feedback resistor, which can cause amplifier saturation. For this reason, low leakage op-amps should be used and steps should be taken to ensure that there are no leakage paths caused by flux residue or other board contaminants. Circuit board material can also compromise circuit performance. The resistance of the board must be significantly higher than the feedback resistance to maintain the low frequency cutoff set by the feedback capacitor and resistor. Ceramic based substrates are recommended due to their extremely high resistance characteristics. FR4 glass epoxy boards generally have resistance lower than the feedback resistor and are not recommended.

Other Precautionary Notes
Dropping a piezoelectric accelerometer onto a concrete floor can produce a 10,000 g force. In an unpowered sensor, the charge generated from a drop appears on the input of the op-amp. Care should be taken to ensure that the maximum input voltage (ESD tolerance) of the op amp is not exceeded due to mishandling of the sensor.

Power supplies should be decoupled using appropriate methods to reduce electrical noise that can cause measurement errors.