

# Introduction to Charge Mode Accelerometers

Dytran charge mode accelerometers are designed to measure shock and vibration phenomena over a broad temperature range. These accelerometers, unlike the Low Impedance Voltage Mode (LIVM) types, contain no built-in amplifiers. Dytran's charge mode accelerometers utilize high sensitivity piezoceramic crystals, of the lead zirconate titanate (PZT) family, to produce a relatively high charge output in response to stress created by input vibration or shock acting upon the seismic system.

Because of the high impedance level of the charge mode signal generated by the crystals, a special type of amplifier, called a charge amplifier, is used to extract the very high impedance electrostatic charge signal from the crystals. The charge amplifier has the ability to convert the charge signal to a low impedance voltage mode signal without modifying it.

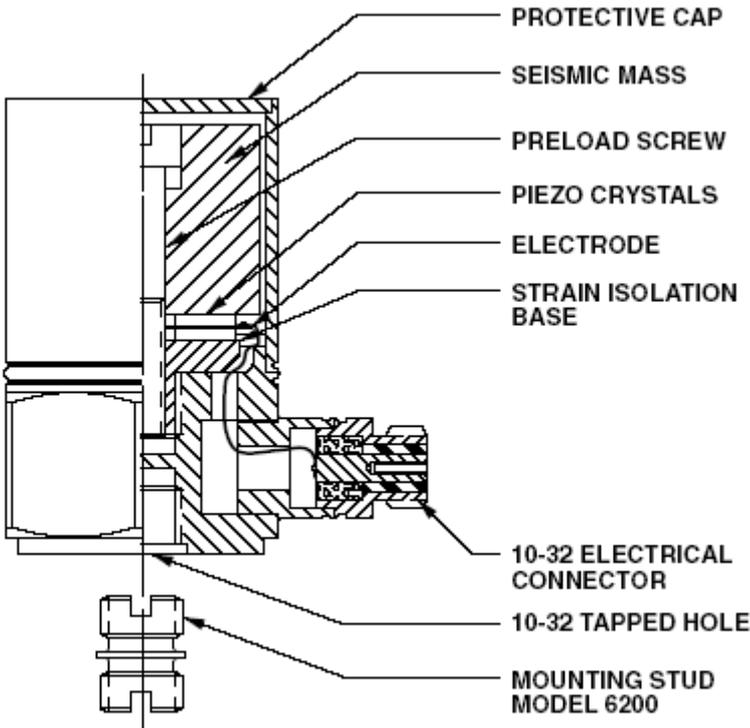


Figure 1: Typical compression design, charge mode accelerometer

Figure 1 is a cross-section of a typical charge mode compression design accelerometer, model 3100C6. The sensitivity is 100 pC/g (pC = pico coulomb =  $1 \times 10^{-12}$  Coulomb) and the useful frequency range is up to 5 kHz. The 3100C6 operates at temperatures up to +500°F.

A heavy metal seismic mass is preloaded against the piezoceramic crystals with an elastic preload screw. The mass converts the input acceleration into analogous stress on the crystals producing an output charge signal in direct proportion to instantaneous acceleration.

# When to Use Charge Mode Accelerometers

The question may be asked, “When should I consider using charge mode accelerometers vs. LIVM types with built-in electronics?”

Charge mode accelerometers should be considered:

1. when making measurements at temperatures above +250°F, the maximum temperature for most LIVM instruments,
2. when the versatility of the laboratory charge amplifier is desired for system standardization, ranging, filtering, integrating for velocity and displacement, etc. and,
3. when adding or replacing accelerometers where existing charge amplifiers must be used for economic or other reasons.

## Two System Concepts

Charge mode accelerometers may be combined with a variety of electronic components to create two basic measurement system classifications:

1. The conventional charge mode system, and
2. The Hybrid system.

The conventional charge mode system utilizes a sophisticated laboratory charge amplifier while the hybrid system features simple dedicated range miniature in-line charge and voltage amplifiers operating in conjunction with LIVM current source power units.

## The Conventional Charge Mode System

The versatile laboratory charge amplifier is the main feature of the conventional charge mode system. This section will familiarize you with the theory, operating characteristics and features of the basic laboratory charge amplifier.

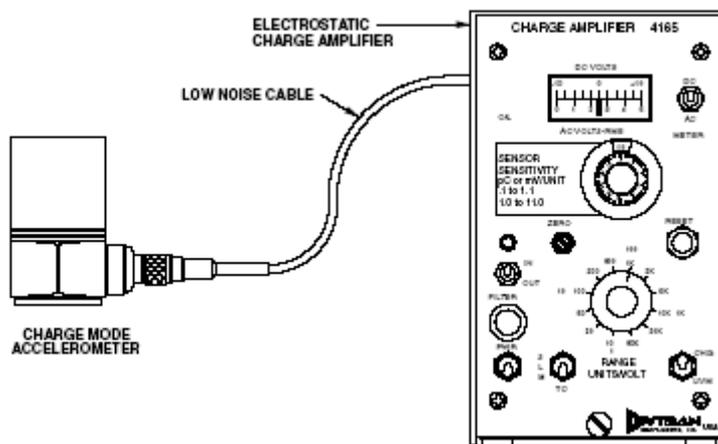


Figure 2 illustrates a laboratory charge amplifier, model 4165 in use with a model 3100C6 charge mode accelerometer. Series 6019A low-noise coaxial cable is used to minimize

triboelectric noise generated by cable motion. This is a very versatile system whose signal conditioning options include:

1. Standardization of system sensitivity
2. Full Scale range selection
3. Discharge time constant choices
4. Filter options
5. 0-10 VDC out for sinusoidal input
6. Overload indication
7. Instant system zeroing (or reset)
8. External calibrate signal insertion
9. Front panel meter for observation of DC level of output signal

## Charge Amplifier, Basic Theory

A charge amplifier is a special high gain, high input impedance inverting voltage amplifier with capacitive feedback. The amplifier is usually an operational amplifier (op-amp) with near infinite voltage gain.

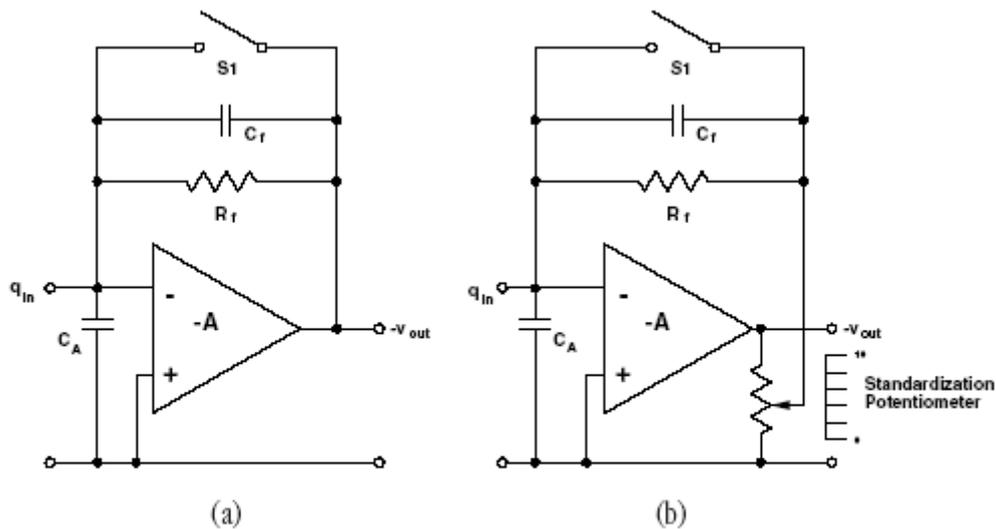


Figure 3: The charge amplifier

Referring to Figure 3, the input charge  $q_{in}$  is applied to the summing junction (inverting input) of the charge amplifier and is distributed to the input capacitance of the amplifier  $C_A$  and the feedback capacitor  $C_f$ . We may write the equation:

$$q_{in} = q_A + q_f \quad \text{Eq 1}$$

Using the electrostatic equation  $q = Cv$  and substituting in equation 1:

$$q_{in} = v_A C_A + v_f C_f \quad \text{Eq 2}$$

Using equation 2 and making the appropriate substitutions and solving for the output voltage of the amplifier in terms of input charge, amplifier loop gain, and input and feedback capacitance we have:

$$V_{out} = \frac{-q_{in}}{C_A / A + C_f (A + 1)} = \frac{-q_{in}}{C_f (1 + 1/A)} \times \frac{1}{1 + C_A / C_f (A + 1)} \quad \text{Eq 3}$$

where A is the open loop gain of the op-amp.

Now, letting gain A approach infinity, we have:

$$V_{out} = \frac{-q_{in}}{C_f} \quad \text{Eq 4}$$

This result (Eq 4) shows clearly that the transfer function (gain) of a charge amplifier is a function only of the value of the feedback capacitor Cf. Notice that input capacitance CA has no effect on the sensitivity of the charge amplifier. This means that cable capacitance, for example, has no effect on the sensitivity, a significant find when switching cable lengths and types.

## Adding Versatility to The Charge Amplifier

Standardization of system sensitivity, say to exactly 10.00 or 100.00 mV/g is accomplished by adjusting the amount of feedback with a potentiometer as shown. Standardization is often necessary because accelerometers are rarely ever made to exact sensitivities. The use of a precision multi-turn potentiometer with turns counting dial allows the standardization of the system sensitivity by dialing in the accelerometer sensitivity.

Referring to Figure 3b, changing the range of the charge amplifier is accomplished by switching various values of feedback capacitor into the feedback path. This is accomplished with a rotary switch which has maybe 10 values of precision capacitor arrayed around it.

Again referring to Figure 3b, feedback resistor Rf gives DC stability to the circuit and establishes the discharge time constant (TC) of the amplifier thereby setting the low frequency response of the amplifier. A momentary reset switch (S1) discharges the residual charge in the feedback capacitor returning the system output to zero.

The circuit shown in Figure 3b represents only the first stage of a rudimentary charge amplifier. One or more stages of filtering, integration and other features can be added all in one compact package.

# The Hybrid System

A Dytran hybrid system combines charge mode accelerometers with miniature in-line fixed sensitivity charge amplifiers. These charge amplifiers are powered by standard 2-wire LIVM power units.

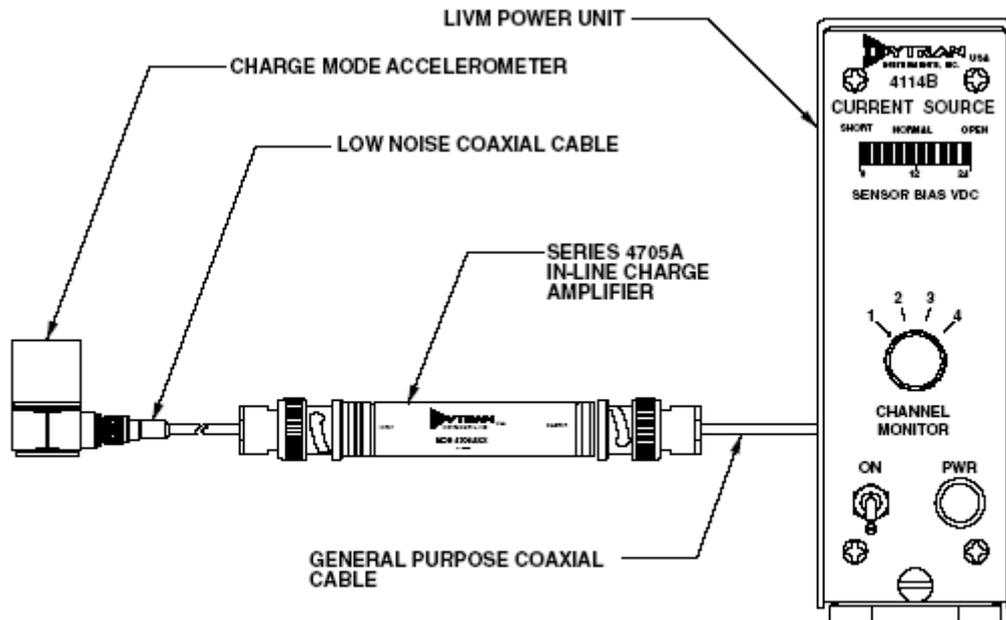


Figure 4: A hybrid system with in-line charge amplifier

The hybrid system, (refer to Figure 4) is ideal for field use because of its small size and rugged construction of the miniature charge amplifiers, for example, Models 4751B and 4505A. These amplifiers are powered by conventional LIVM constant current power units and transmit the output signal over the same two wires as do conventional LIVM systems. The power unit separates the signal information from the DC bias of the amplifier and couples it to the readout instrument. As with conventional charge mode systems, low noise coaxial cable is used to couple the accelerometer to the charge amplifier to minimize triboelectric noise.

## When to Use The Hybrid System

The hybrid system should be considered when:

1. The accelerometer is used to measure events at a temperature which is above that recommended for LIVM instruments, i.e., instruments that have built-in amplifiers and the environment is not favorable to laboratory charge amplifiers.
2. System cost is an important factor. Per channel cost of the hybrid system is a fraction of that for the conventional charge amplifier system.
3. LIVM current source power units are in-hand and must be utilized.

4. Ruggedness and small size of the measurement system is imperative.
5. A dedicated system without the versatility of a laboratory charge is sufficient for the measurement task.