Introduction to LIVM Accelerometers

Construction

Low Impedance Voltage Mode (LIVM) accelerometers are designed to measure shock and vibration phenomena over a wide frequency range. They contain integral IC electronics that converts the high impedance signal generated by the piezo crystals to a low impedance voltage that can drive long cables with excellent noise immunity. These accelerometers utilize quartz and piezoceramic crystals in compression and shear mode.

Figure 1 is a representative cross section of a typical LIVM compression design accelerometer with central preload, strain isolation base and integral impedance converting IC amplifier. The amplifier utilizes a metal oxide silicon field effect transistor (MOSFET) in its input stage, coupled to a bipolar output transistor for improved line driving capability.

The LIVM concept eliminates the need for expensive charge amplifiers and low noise cable, allows the driving of long cables for field use and lowers the perchannel cost of the measurement system.

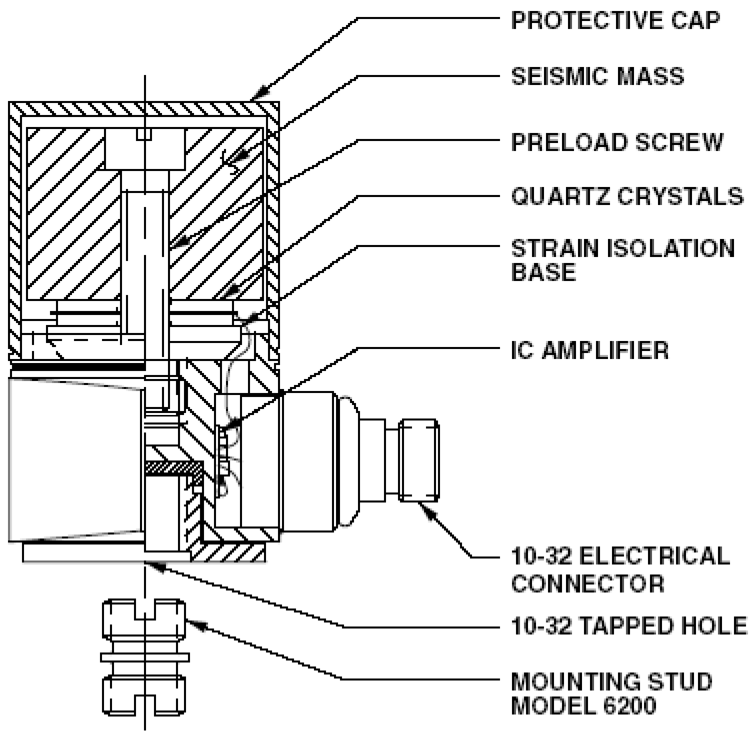

Figure 1: Compression design LIVM accelerometer.

Powering

All Dytran LIVM accelerometers may be powered by any constant current type power unit capable of providing 2 to 20 mA of constant current at a DC voltage (compliance) level of +18 to + 30 Volts. NEVER connect a power supply that has no current limiting to an LIVM accelerometer. This will immediately destroy the integral IC amplifier.

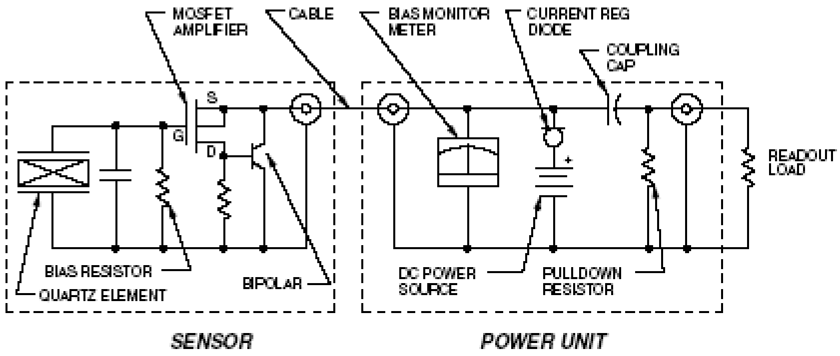

Figure 2: Typical LIVM system

The quiescent DC bias level (turn-on voltage), at the power input to the accelerometer, may fall within the range of +8 to +12 Volts DC, depending upon the specifications of the particular model. The actual measured value is reported on the calibration certificate supplied with each instrument. The dynamic signal from the accelerometer is superimposed on the DC bias level and is extracted in the power unit.

Each LIVM accelerometer is ranged to produce ±5 Volts output for ±full scale (g level) input. The magnitude of the DC voltage source (compliance voltage) in the power unit determines the overrange capability, i.e., the point where clipping will occur on the positive waveform.

System Low Frequency Response

Piezoelectric accelerometers are effectively AC coupled devices (see Figure 2) and as such, do not posses true DC response. However, with certain considerations and precautions, these devices may be used to measure events at frequencies as low as fractions of one Hertz.

The low frequency response of LIVM systems may be limited by the accelerometer or by the power unit but more likely by the combination of both. Referring again to Figure 2, it will be seen that an LIVM system contains two high pass first order RC filters in cascade as described here:

1. Inside the accelerometer, the shunt capacitor and bias resistor located at the gate of the amplifier and,

2. In the power unit, the coupling capacitor and the pulldown resistor/readout load in parallel. These low pass filters may be represented by the following equivalent circuit (see Figure 3).

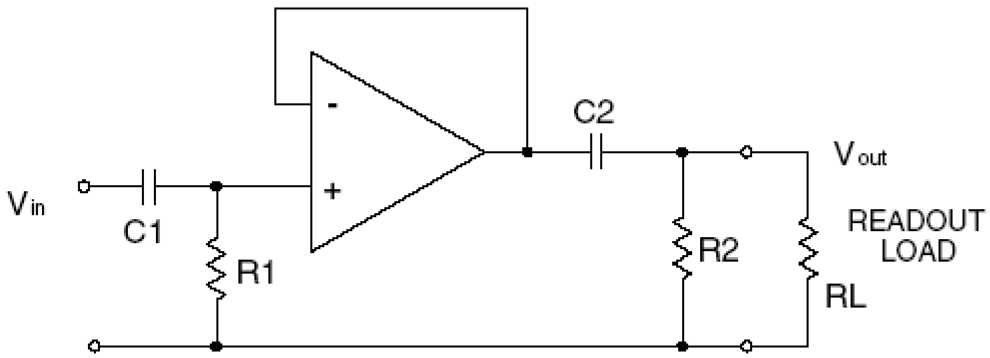

Figure 3: Equivalent LIVM system schematic.

While exact analysis of this circuit is well known, certain helpful observations can be quickly made. The time constant of each filter is the product of the appropriate R and C as follows:

τ_1 = R1 x C1 (Seconds) and τ_2 = R2 x C2 (Seconds)

Consider 3 possible relationships between τ_1 and τ_2:

1. $\tau_1 << \tau_2$ In this case, the lower cutoff (-3db) frequency for the system is:

$$f_0 = \frac{.16}{\tau_1} \quad \text{(Hz)} \qquad \text{(Eq. 1)}$$

The lower -5% frequency is:

$$f_{-5\%} = 3 \times f_0 \quad \text{(Hz)} \qquad \text{(Eq. 2)}$$

The sensor is controlling the low frequency entirely in this case.

2. $\tau_1 >> \tau_2$ In this case, the output load and coupling capacitor determine the low frequency response as follows:

The lower cutoff frequency (-3db) is:

$$f_0 = \frac{.16}{\tau_2} \quad \text{(Hz)} \qquad \text{(Eq. 3)}$$

The lower -5% frequency is:

$$f_{-5\%} = 3 \times f_0 \quad \text{(Hz)} \qquad \text{(Eq. 4)}$$

3. $\tau_1 = \tau_2$ In this case, where τ_1 and τ_2 are equal or close in value, the combined time constant, $\tau_3 = (\tau_1 + \tau_2) / 2$

The -6db frequency is:

$$f_{-6db} = \frac{.16}{\tau_3} \quad \text{(Hz)} \qquad \text{(Eq. 5)}$$

The -3db frequency is:

$$f_0 = 1.6 \text{ x } f_{-6db} \quad \text{(Hz)} \qquad \text{(Eq. 6)}$$

The -5% frequency is:

$$f_{-5\%} = 1.6 \text{ x } f_{-6db} \quad \text{(Hz)} \qquad \text{(Eq. 7)}$$

These values are approximate and are to be used as a guide only.

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Getting the Most From the Low Frequency Response of the Accelerometer

To measure ultra low frequencies with a very long TC LIVM accelerometer where the AC coupling TC of the power unit is the limiting factor, a DC coupled LIVM power unit (Model 4115B) is available. This unit utilizes a direct-coupled summing amplifier to null the DC bias of the accelerometer by summing an equal absolute value negative DC voltage at the input stage. The result is a zero DC voltage level at the output, achieved with no coupling capacitor.

Using this power unit, the accelerometer discharge time constant alone determines the low frequency response of the system in accordance with previously mentioned equations 1 and 2.

High Frequency Response

Another important consideration in selecting an accelerometer may be its high frequency response.

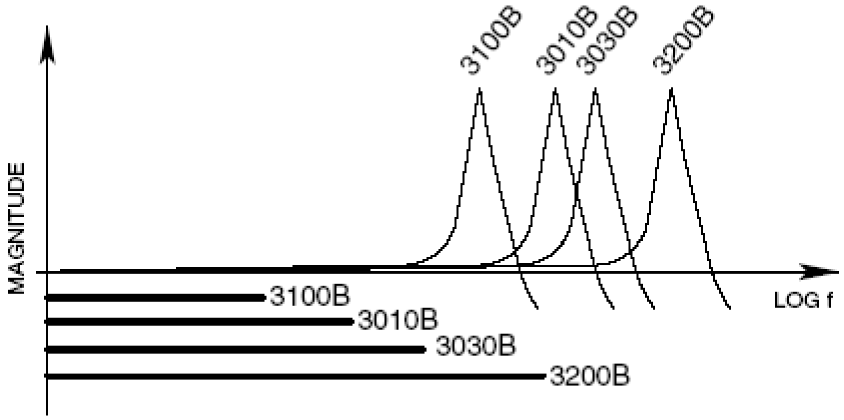

Figure 4: High Frequency Response Comparison

Figure 4 shows the typical high frequency characteristics of four Dytran accelerometers. These curves illustrate the undamped 2nd order system response characteristic of the accelerometers and the bar graphs illustrate the comparative useful frequency range of each model, the comparison criterion being the +5% deviation from the 100 Hz reference sensitivity.

The high frequency response of any accelerometer is sensitive to mounting techniques and may be modified by any anomaly that reduces the mechanical coupling between accelerometer and mounting surface such as the use of an adhesive, magnetic or ground isolation base, dirty or non-flat mounting surface and too thick glue lines in adhesive mount installations. Follow the mounting instructions outlined in the manual supplied with each accelerometer for best results.

Sensitivity Standardization

The reference sensitivity (mV/g) of all Dytran vibration accelerometers is measured at 100 Hz at an input amplitude of 1g, RMS unless otherwise specified. This is measured by the back-to-back comparison method. The sensitivity of shock accelerometers (such as series 3200B) is determined by a drop-shock technique developed by Dytran. All calibrations are NIST traceable.
“Standardized” models are considered to be those models whose sensitivities are specified to be within ±2% of the nominal sensitivity value at 100 Hz. Shock accelerometers, because of their nature, are not standardized. Consult the product data sheet to determine which units have standardized sensitivity.

Piezodyne™ Technology

Dytran has perfected an advanced patented concept in LIVM technology that increases the voltage output from piezo crystals using a feedback technique with the standard unity gain IC LIVM amplifier. This concept, called Piezodynetm, (Patent no. 4,816,713) spawned a line of miniature, high sensitivity, high resolution accelerometers.

Because there is no gain amplifier used in Piezodyne, output noise does not increase in proportion to the increase in output signal amplitude. The result is a 6db improvement in signal-to-noise ratio and up to 8 times increase in sensitivity.

RMS to Peak Conversion

The output voltage generated by an LIVM accelerometer has a direct correlation with input acceleration. A 1g RMS sinusoidal input will produce a 1g RMS output signal as illustrated in Figure 5. A 100 mV/g accelerometer (Model 3100B) is used here as an example. Refer to figure 5.

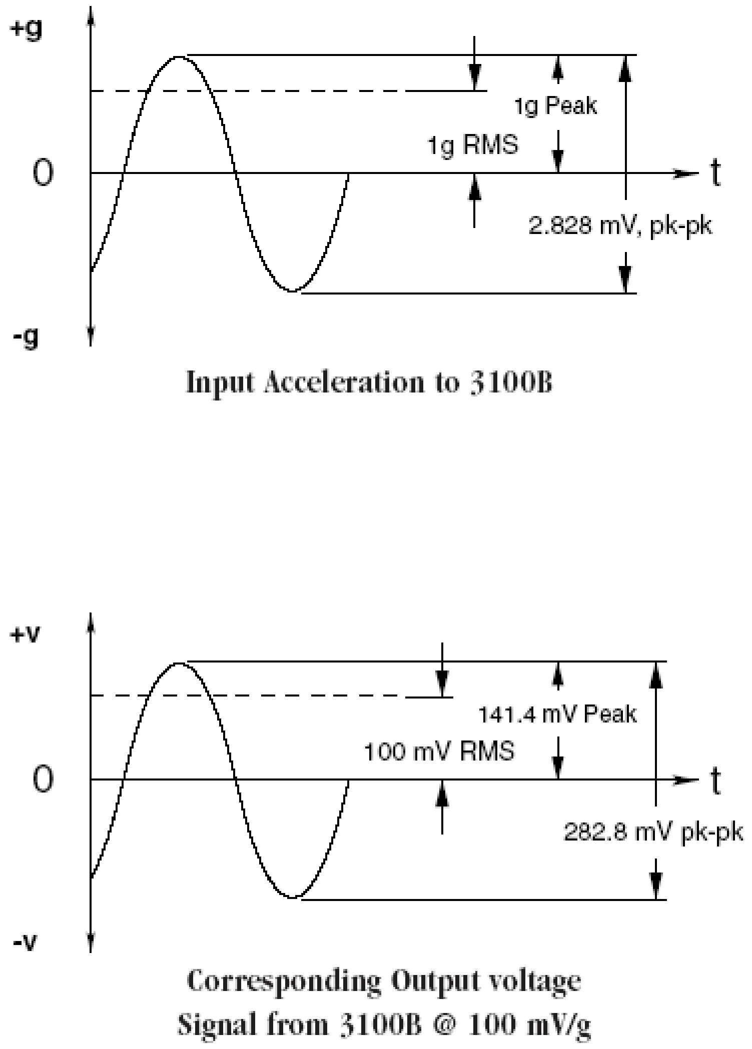

Figure 5: Input/Output Waveforms

For sinusoidal vibration input, it is convenient to read the output with a true RMS reading AC voltmeter. To convert this value to peak g's, simply multiply by 1.414. Example:

g's peak + 1.414 x g's RMS. and,
g's peak-to-peak = 2.828 x g's RMS

Shock Accelerometers

Shock accelerometers are designed to measure very rapidly changing high level unidirectional transient acceleration inputs as might be generated by pyrotechnic devices, crash tests, impact tests, etc. They are characterized by small size, high stiffness (for high natural frequency) and ruggedness. Model 3200B is one such accelerometer.

The resonant frequency of series 3200B shock accelerometers is greater than 100 kHz resulting in excellent rise time and minimal ringing. These rugged 6 gram instruments feature integral 10-32 or 1/4-28 threaded integral mounting studs (6 mm is also available) and hardened 17-4 steel housings. The sensing element utilizes an exclusive 2-piece element base for stain isolation and high natural frequency.