Back-to-Back Accelerometer Calibration

To calibrate a vibration accelerometer is to accurately determine its sensitivity (in mV/g or pC/g) at various frequencies of interest. The ISA approved back-to-back comparison method is probably the most convenient and least expensive technique.

At Dytran, back-to-back calibration involves coupling the test accelerometer directly to a (NIST) traceable double-ended calibration standard accelerometer and driving the coupled pair with a vibration exciter at various frequencies and acceleration (g) levels. The assumption here is that since the accelerometers are tightly coupled together, both will experience exactly the same motion, thus the calibration of the back-to-back standard accelerometer can be precisely "transferred" to the test accelerometer.

The Dytran model 3120BK vibration calibration system used in conjunction with a small electrodynamic shaker, a signal generator, a frequency meter and several other pieces of equipment provides an inexpensive means to set up a calibration facility. The 3120BK may also be used with more sophisticated computer driven automatic calibration systems.

The 3120BK Back-to-Back Calibration System

The model 3120BK vibration calibration system consists of a double ended calibration accelerometer, (model 3120B), a standardization amplifier, (model 4119B), and the necessary interconnect cables and accessories. (See figure 1).

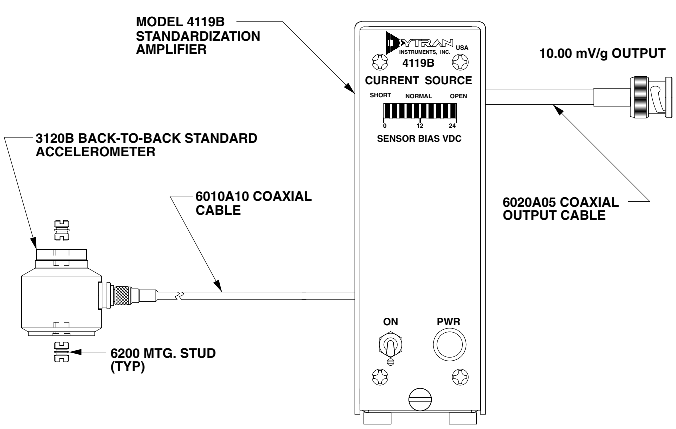

Figure 1: Model 3120BK system

Model 3120B Back-to-Back Standard Accelerometer

Figure 2 is a representative cross section of the model 3120B back-to-back standard accelerometer. This type of accelerometer is also known as a "double ended" standard because of its two mounting surfaces. The lower surface attaches to the shake table armature and the test accelerometer is attached to the upper surface.

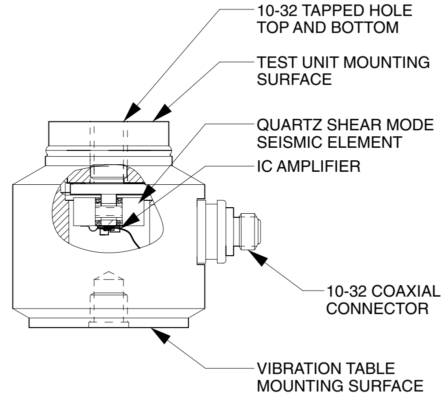

Figure 2: Model 3120B back-to-back calibration accelerometer

The quartz shear seismic element in the 3120B is mounted directly to the underside of the upper mounting surface to position it in closest possible proximity to the unit under test. This location ensures the tightest possible coupling to the test accelerometer. The excellent strain isolation of the quartz shear element serves to minimize the effect of the mass of the test accelerometer on the sensitivity of the standard. Subsequent sections of this article will address this phenomenon, known as "mass loading".

Within the 3120B, the electrical output of the self generating quartz shear seismic element is connected directly to the input of an integral IC impedance converting amplifier. (See the article "Introduction to LIVM Accelerometers" for a complete treatment of the Dytran internal amplifier concept). This amplifier buffers the signal making it impervious to outside interference and to cable generated noise.

The electrical connector of model 3120B is the convenient 10-32 coaxial type which has become the industry standard.

Model 4119B Standardization Amplifier

The line-powered model 4119B supplies constant current power to operate the IC amplifier in the 3120B and standardizes the system sensitivity to precisely 10.00 mV/g at 100 Hz. It also provides the necessary low-pass filtering to suppress the rising high frequency characteristic of the 3120B to provide flat frequency response to 10 kHz. (See Figure 3).

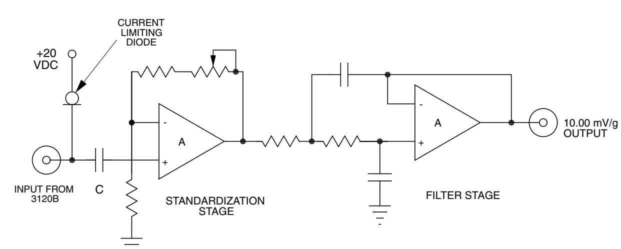

Figure 3: Block Diagram Model 4119B amplifier

The constant current source, a 2 mA current limiting diode, is powered by an internal 20 VDC power supply. A coupling capacitor C blocks the DC bias voltage which exists on the 3120B line, and connects the vibration signal (AC) to the input of the standardization stage.

This variable gain stage adjusts the system sensitivity to exactly 10.00 mV/g at the 100 Hz reference frequency. The next stage of the 4119B is a second order Butterworth low-pass filter with adjustable frequency characteristics. This filter is adjusted to exactly match the high frequency characteristics of the 3120B. The rolloff characteristics of the 4119B cancel the rising characteristics of the 3120B at higher frequencies.

Performing the Calibration

Assemble the system elements as shown in Figure 4. Couple the test accelerometer to the top surface of the 3120B. By setting the vibration frequency and the amplitude (using the output of the 3120BK system) a frequency response curve may be plotted for the test accelerometer. At each frequency, set the amplitude (in RMS g's) and read the corresponding amplitude from the test accelerometer (in RMS mV).

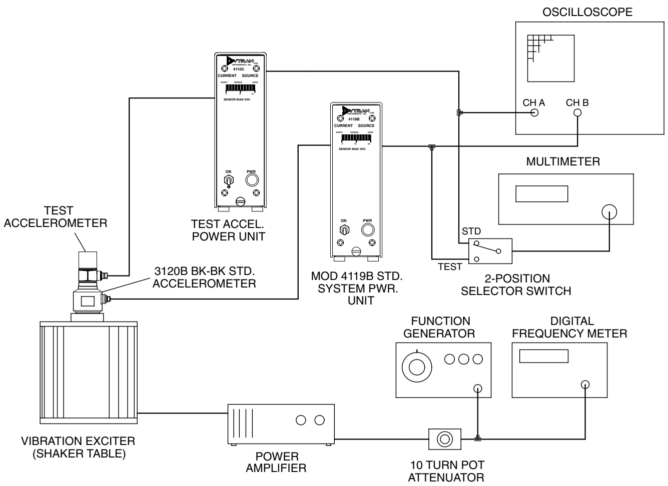

Figure 4: The complete calibration system

Mass Loading Compensation

It is appropriate at this time to discuss a very important but little emphasized phenomenon associated with back-to-back accelerometers known as "mass loading".

The 3120B is initially calibrated with a single ended accelerometer, model 3010B, which has been calibrated by an NIST certified calibration station. This accelerometer weighs 19 grams. When accelerometers (or velocity pickups), weighing considerable more that 19 grams, are placed atop the 3120B, the increased inertial loading due to the increase in mass, actually changes the effective sensitivity of the 3120B inserting a small calibration error. This error increases at higher frequencies.

These errors are negligible when calibrating units weighing up to 30 grams but over this weight, correction curves should be constructed to compensate for this effect. The following section shows how to establish the compensation curve for test units of varying weights.

Mass Loading Compensation Curves

The mass loading effect is frequency dependent as illustrated in Figure 5a. This figure shows a typical family of correction curves as plotted with various masses atop the 3120B.

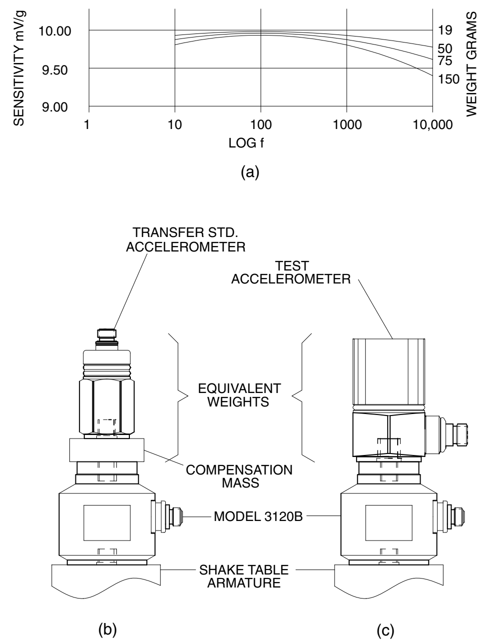

Figure 5: Typical correction curves and a compensation weight

To plot a mass loading correction curve for a model 3120BK system, proceed as follows:

1. Select a single-ended accelerometer to use as a transfer standard (preferably a model 3010B). Weigh the instrument precisely and record this weight, in grams.

2. Attach this accelerometer to the 3120B and determine its sensitivity at all frequencies of interest using the 3120B as the standard. Record the sensitivity at each frequency.

3. Weigh the new instrument to be calibrated. (If it weighs less than 30 grams, you do not need mass loading correction.

4. If it weighs more (say 50 grams) subtract the weight of the transfer standard from 50 grams and record. This is the needed weight of the compensation mass.

5. Calculate the dimensions of a steel (or tungsten) cylinder required to equal the result of step 4 and fabricate a compensation mass as shown in Figure 5b.

Note: It is important that the mating surfaces of the compensation mass be very flat (optical flatness is preferred). This degree of flatness is best obtained by a lapping process. Dytran has the equipment and skills to produce compensation masses at reasonable cost.

6. Attach the transfer accelerometer and compensation mass together as shown in Figure 5b, placing a light coating of silicone grease between all mating surfaces. Torque in place.

7. Using the sensitivity of the transfer standard (obtained in step 2) to determine the amplitude at each frequency point, determine the loaded sensitivity of the back-to-back standard accelerometer and record each of these values. These new sensitivity values plotted against frequency represent the correction curve for that particular mass of test instrument.

8. Mount the test instrument atop the 3120B, as shown in Figure 5c and, using the new values obtained in step 7, proceed to calibrate the test instrument by setting the amplitude at each frequency using the corrected output from the 3120BK system and reading the corresponding output from the test instrument at each frequency point.

NOTE: When using an RMS reading voltmeter to read amplitude values, you may convert to equivalent peak g levels by multiplying the RMS values by 1.414. This will only be necessary when calibrating velocity or displacement pickups.

Figure 6: System dimensions