

# Laboratory 14

## Vibration Measurement With an Accelerometer

### **Required Special Equipment:**

- custom-made apparatus consisting of two sets of motors/shafts/bearings mounted on an aluminum plate
- Endevco 2721B charge amp
- Endevco 2256M15 or 2211E accelerometer
- high current power supply (HP 6286A)

### **14.1 Objective**

The objective of this exercise will be to compare the vibration characteristics of a normal and a defective ball bearing turning under load. The vibrations will be sensed with two piezoelectric accelerometers. The oscilloscope spectrum analyzer will be used to compare vibrations from the two bearings to detect defects.

### **14.2 Background**

#### Vibration Measurement With Piezoelectric Crystals

Piezoelectric accelerometers are in wide use for measuring shock and vibration. Most accelerometers have a design similar to that illustrated in Figure 14.1. The mass (called the seismic mass) causes inertial loads in response to motion of the object to which the accelerometer is attached. The inertial loads cause strain of the piezoelectric crystal. Due to the piezoelectric properties of the crystal, the strain causes displacement charge which is sensed at the crystal conductive coatings. A charge amplifier and conditioning circuit can measure this charge and convert it to a voltage signal which represents the acceleration of the object. A pre-loaded spring is used to keep the crystal in compression resulting in more linear behavior of the crystal.

In general, piezoelectric accelerometers cannot measure constant or slowly changing acceleration since the crystals can only measure a change in force by sensing a change in strain. But they are excellent for dynamic measurements such as vibration and impacts.

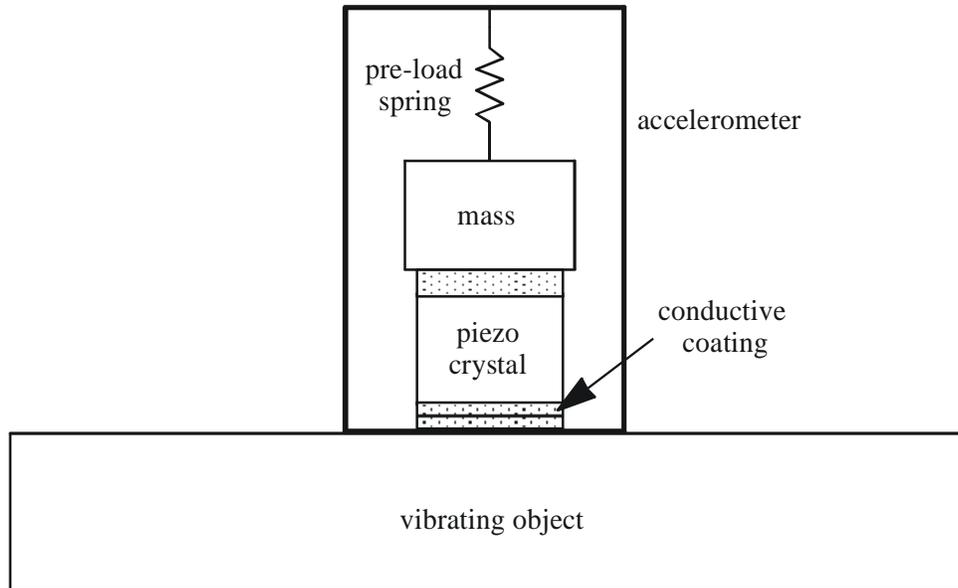


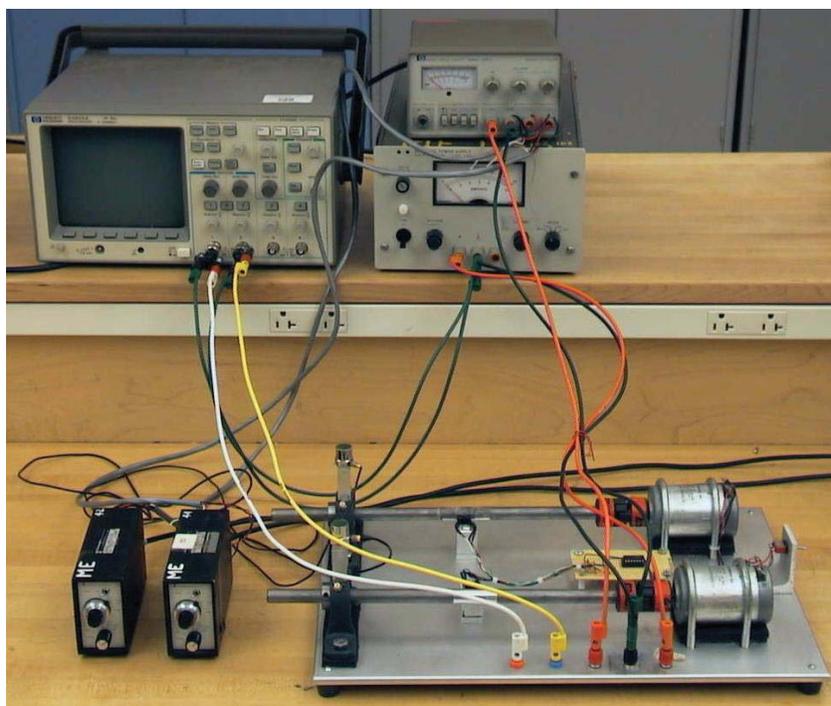
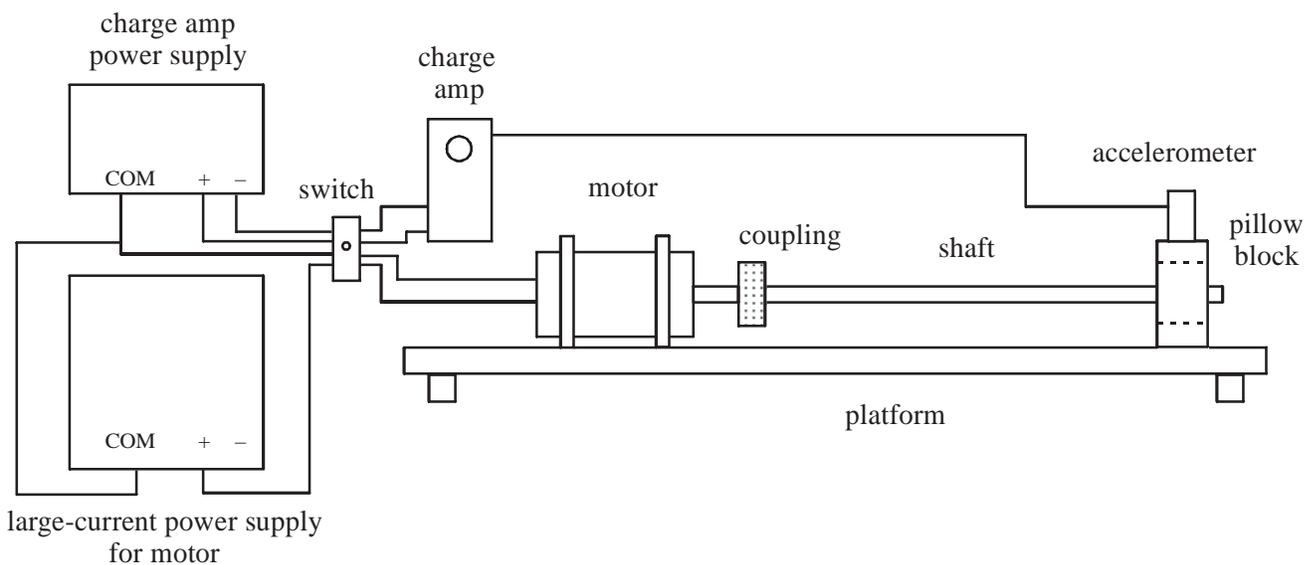
Figure 14.1 Piezoelectric Accelerometer Construction

### 14.3 Theory

A defective ball bearing will cause more vibration than an undamaged bearing. We can measure bearing vibration experimentally and determine whether a bearing is defective or not. To do this we must have a clear idea what the vibration characteristics of a good bearing are. A defective bearing will have more vibration components in the high frequency range than a non-defective bearing. This is due to scratches in the balls and imbalances in the high speed rotation of the shaft.

One method to analyze the frequency components of a bearing is to record the output of the accelerometer (which is attached to the bearing pillow block) over a given period of time. The Fourier transform of this waveform will convert the vibration data from amplitude vs. time to amplitude vs. frequency.

## 14.4 Laboratory Apparatus



**Figure 14.2** Schematic and Photograph of Bearing Signature Analysis Apparatus

The apparatus in the laboratory consists of a good and a defective bearing each supporting a shaft driven by a DC motor. You will have to determine which bearing is defective after you have completed the procedures listed below.

The accelerometers are mounted on plexiglass blocks which are in turn rigidly attached to the bearing pillow block. The accelerometers are connected to charge amplifiers.

Only one motor should be operated at a time in order to prevent cross-talk of vibration between the two bearings. The supply of the corresponding charge amplifier is selected with the help of the toggle switch.

A strobe light can be used to measure the shaft speed. By drawing an axial line on one side of the shaft and a transverse line on the other side, you can attain a reliable strobe light measurement. If the strobe is set to the shaft speed, one of the lines will be illuminated on each rotation of the shaft resulting in a stationary line image. If the strobe speed is set to half of the shaft speed, one of the lines will be illuminated on every second rotation of the shaft resulting in a dimmer image. If the strobe speed is set to twice the shaft speed, each line will be alternately illuminated on every half turn of the shaft resulting in a plus sign image. There are many more possibilities depending upon the shaft and strobe speeds, but a reliable method to acquire a good measurement is to start with a high strobe speed and decrease the speed until the image changes from a relatively bright stationary plus sign image to a bright single line stationary image.

As an alternative to the strobe light, you may use the reflective tape on the shaft and a retroreflective photosensor. The pulse train coming from the photosensor can be displayed on an oscilloscope and used to measure the frequency of revolution and thus the revolutions per second (rps) of the shaft.

**14.5 Laboratory Procedure / Summary Sheet**

Group: \_\_\_\_\_ Names: \_\_\_\_\_  
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- (1) Select the motor/bearing you want to take data from and set the toggle switch to the correct position.
- (2) Switch on the power supplies for the charge amplifier and the motors.
- (3) Set the motor speed to 3600 rpm with the aid of the strobe or retroreflective photosensor.
- (4) Look at the waveform you are getting on the oscilloscope.
- (5) Process the waveform using the Fast Fourier Transform (FFT) feature on the oscilloscope. To access this feature on an HP Digital oscilloscope, use the  $\pm$  button between the channel 1 and channel 2 buttons to access a menu that allows you to perform math on the signals. Turn on Function 2 and display the FFT menu (NOTE: this feature is available only on the HP54602A oscilloscopes equipped with the HP54657A Measurement/Storage module). Turn off the channel 1 and 2 displays (with the Channel buttons) so only Function 2 is on. This results in a clear line spectrum display. Sketch the vibration waveform and the FFT spectrum. Alternatively, acquire the data with LabView and the DAC hardware, and process it in MATLAB, MathCAD, or LabView to generate FFT spectrum plots.
- (6) Repeat the procedure for the other motor/bearing.

Compare the two sets of waveforms and spectrum plots. Try to draw conclusions about which bearing is in better shape. Submit the sketches and comments to the TA.