EG-52 Electromechanical Driver

Introduction

This small mechanical driver produces linear motion from an electrical signal. It is an excellent driver for acoustical experiments such as waves on a string or vibrations of membranes or plates. The driver can also be used to make fine adjustments in the position of components in an experimental setup. By installing the driver in a feedback loop that senses position, very precise position adjustments can be made. The static characteristics of a typical unit are shown in Fig.1. There is some hysteresis (sticking) in the motion of the drive shaft so that the shaft position when moving out is not coincident with the shaft moving in. When the driver is used as a harmonic drive, this hysteresis has no effect but if it is used for static positioning, this hysteresis many become important. The displacement range of the Drive shaft is much greater than shown in Fig.1. These data were limited by the contact micrometer used to make the measurement. The Electromechanical Driver can be driven from an EG-01 Function Generator or an EG-50 Audio Driver. Other audio oscillators can be used as well if they have a low impedance output. Most oscillators only have a high impedance output and this will not work satisfactorily. Check the audio oscillator specifications before connecting to the driver. The shaft motion is only linear so long as the voice moves in the uniform part of the magnetic field. Applying too much voltage will drive the coil out of the field so that the motion will no longer follow the driving signal.

Some assembly required:

Attach mounting bracket to generator.
Screw for mounting bracket is in the base of the generator. (See image)

Make sure to slide the tab to the unlock position to UNlock the generator when ready to use. (See image)

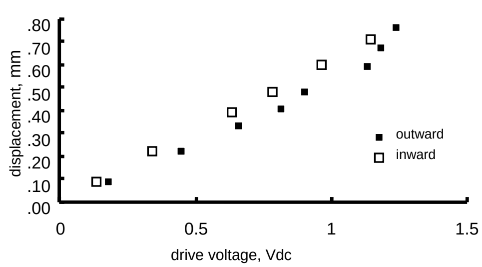


Figure 1. Static displacement.

This non-linearity problem can be solved by keeping the amplitude small. If any buzzing is heard, the coil is striking the bottom of the magnetic field structure and the amplitude should be reduced. The 1A fuse mounted beside the terminals is to protect the coil against greatly excessive drive currents. If you should blow the fuse, replace it with a 1A fast blow fuse. Anything larger will burn out the drive coil. The Electromechanical Driver has a mechanical resonance at low frequencies. The actual resonance depends on the characteristics of the load attached to it. A typical response curve is shown in Fig.2.

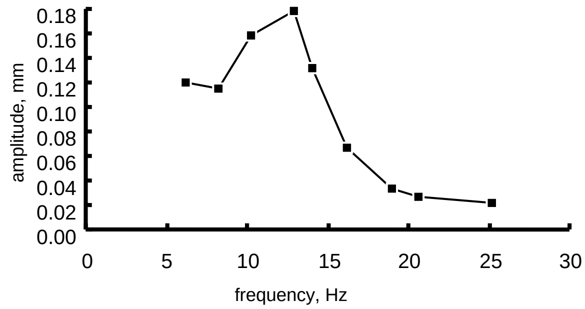


Figure 2. Amplitude vs frequency.

These values were obtained using a contact micrometer touching the top of the driver shaft while the drive frequency was changed. The micrometer finger loaded the driver and dropped the resonant frequency somewhat. The electrical impedance rises at the resonance and can be used to show the unloaded resonance of the driver. A typical curve is shown in Fig. 3.

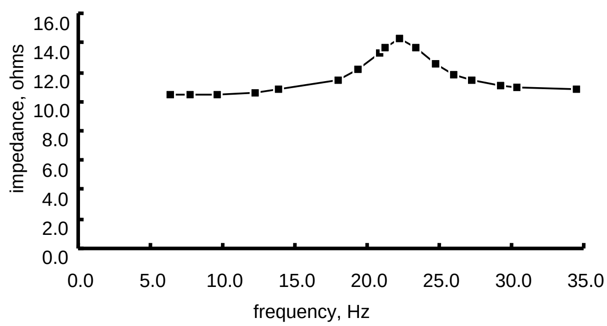


Figure 3. Electrical Impedance vs frequency.

It shows an unloaded resonance between 21 and 22Hz. The input impedance is quite constant outside this range. These curves illustrate the effect of the load on the response of the system. The driver becomes a part of the total mechanical system so that resonant frequencies shift depending upon the load.

Typical Experiments

I. Vibrating Strings

An interesting experiment is to study the resonant frequencies of taut vibrating string and determine the factors that affect them. The length and the tension in the string are the primary variables. The mass per unit length of the string is also a variable, but it is less convenient to change.

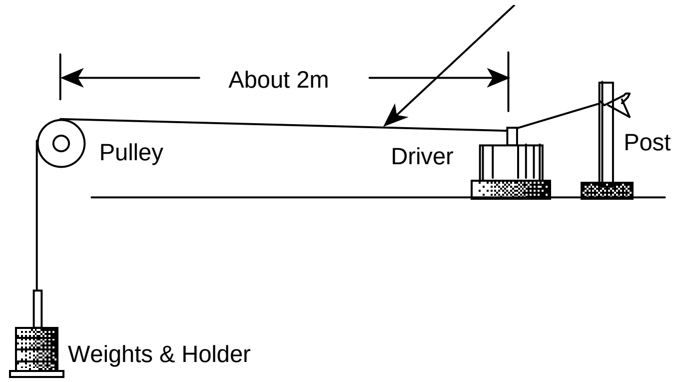


Figure 4

For this experiment, the length will stay fixed and the resonant frequencies will be measured as a function of the tension.

1. Fasten a smooth strong string to a fixed post.
2. Pass the string through the transverse hole in the top of the driver.
3. Fasten a pulley to a table edge about 2m from the fixed post.
4. Attach a weight holder to the free end of the string. Pass the string over the pulley so that it hangs clear of the table. Adding weights to the holder will supply the tension in the string.
5. Adjust the height of the attachment to the fixed post. It should be a little higher than the hole in the driver so that the string is deflected about 5° as it passes through the hole. This assures that when the driver shaft moves the string will move with it.
6. Add a 100g weight to the holder.
7. Adjust the driving frequency slowly until the string begins to vibrate in a single loop. Reduce the amplitude until the amplitude is about 3cm. Readjust the frequency until the maximum amplitude is reached. Record the value.

Theoretical considerations show that the frequency of a vibrating string is inversely proportional to the length of the string and directly proportional to the square root of the tension. The derivation of these relationships can be found in any text on acoustics such as Rossing, T.D., The Science of Sound Addison Wesley, Reading,, MA, (1982). The functional relationship between tension T, length L and frequency is shown in equation 1.

$$f_n = \{n/2L\} \sqrt{T/\mu} \quad (1)$$

In this equation, μ is the mass per unit length of the string.

Fig. 5 shows typical data using the EG-50 Audio Driver. Similar results obtained with the EG-01 Function Generator are shown in Fig.6.

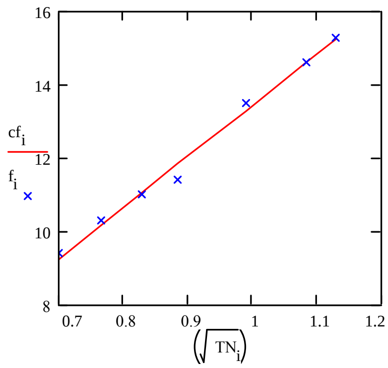


Figure 5

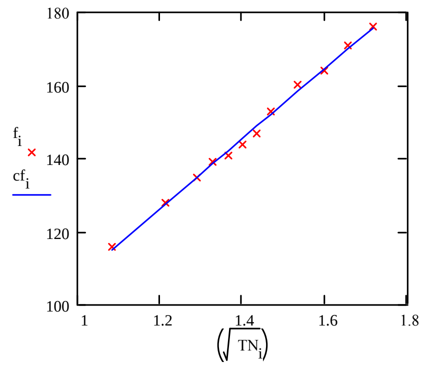


Figure 6

Effect of Length on Frequency

1. Replace the weights so that the tension is 130g.
For the EG-01, use 220g.
2. Measure the length of the string from the drive post on the Electromechanical Driver to the axle of the pulley.
3. Measure the resonant frequency for the length.
4. Plot the frequencies versus the reciprocal of the length. The relationship should be a straight line.

While adjusting the frequency to find resonance, you may find that the amplitude varies periodically from a few centimeters to near zero. This is the phenomenon of beats. Beats occur when the driving frequency is slightly different from the resonant frequency. When the two frequencies add together, the amplitude is large when the string's natural resonance and the driver's frequencies are in phase. The amplitude is small when their phases are opposite.

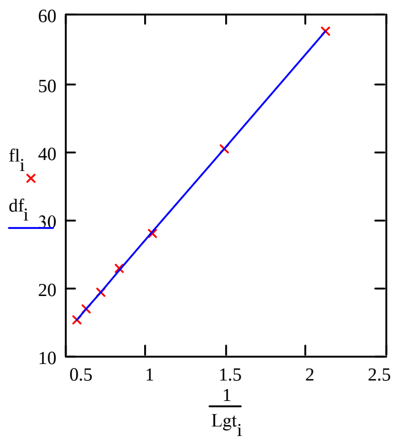


Figure 7

Beats are a good way to measure small frequency differences. If the amplitude fluctuates every 5s, the frequencies differ by 0.2Hz. To observe beats the drive amplitude should be as small as possible without the Electromechanical Driver stalling. If the drive amplitude is large, its amplitude overwhelms the resonance of the string. When adjusting the Audio Driver to find the resonance frequency, find the point where there are no beats. Typical results are shown in Fig.7 for the Audio Driver and Fig.8 for the Function Generator. In these figures, the resonant frequency is plotted against the reciprocal of the length. The straight line is a least squares fit to the data. It is clear from these figures that the data closely fits the theoretical prediction.

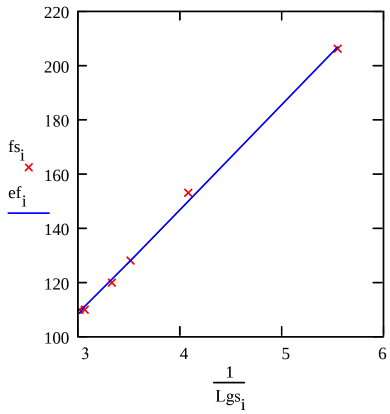


Figure 8

Harmonics

In equation 1 there is an integer n that describes the harmonic of the resonant frequency. The lowest frequency of the string has been the one that has been measured in the first part of the experiment. The string can vibrate in higher vibration modes as well. The second harmonic is shown in Fig.9.

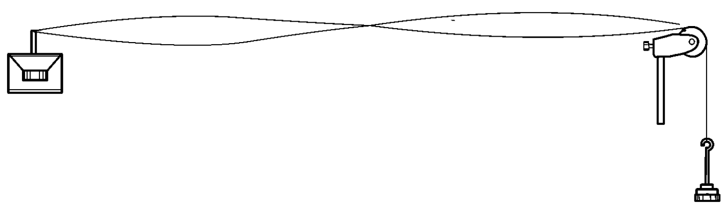


Figure 9

1. Increase the amplitude and then increase the driving frequency slowly until the string begins to vibrate in a double loop. This is the second harmonic. Reduce the amplitude until the amplitude is about 3cm. Readjust the frequency until the maximum amplitude is reached. Record the value.
2. Increase the amplitude and then increase the driving frequency until the string begins to vibrate in a triple loop. This is the third harmonic. Reduce the amplitude until the amplitude is about 3cm. Readjust the frequency until the maximum amplitude is reached. Record the value.
3. Add another 100g weight and repeat steps 7 to 10. Higher harmonics can also be found but they are more difficult to see and the chance of misidentifying the fourth for the fifth increases. The results are quite satisfying with three frequency measurements.The approximate appearance of the string when vibrating in its first three modes is illustrated in Fig.10.

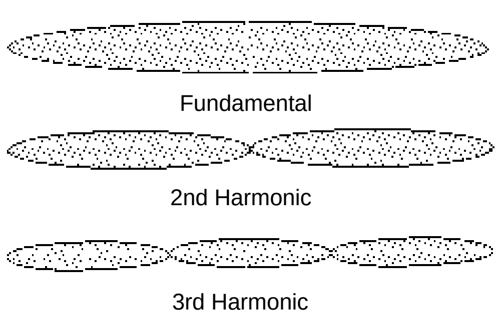


Figure 10. Approximate appearance of the vibrating string.

Typical results are shown in Fig.11. This graph shows the three resonant frequencies plotted against the square root of the tension. The theory of vibrations of a string says that the relationship is linear and from these data, it can be seen that it is.

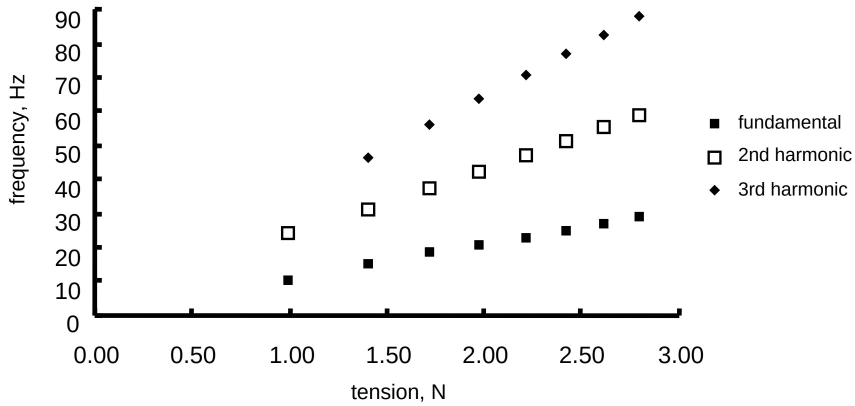


Figure 11. Vibrating string resonant frequencies.

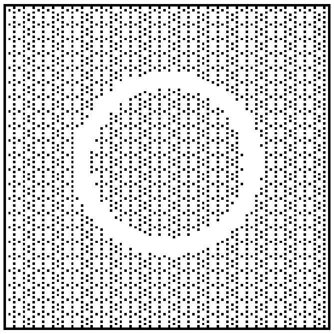
These lines when extended backward do not intersect the origin of the graph. This is due in part to the fact that the mass of the weight holder was not included when calculating the tension in the string. This example was designed to be a sample experiment. With care the fourth and fifth harmonics can also be observed. The amplitude will have to be
increased to the maximum for frequencies greater than 100Hz. There are many other factors that can be studied with the same data.

II. Chladni Plates

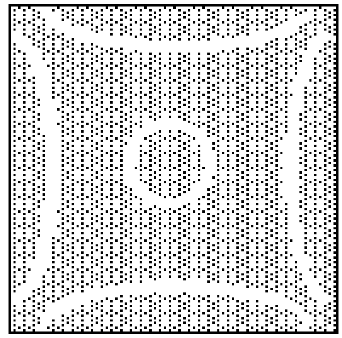
E.F. Chladni (1756-1827) devised a method for making visible the vibrations of a metal plate clamped at one point or supported at three or more points. Fine sand sprinkled on the plate comes to rest along the nodal lines where there is no motion. This experiment can easily be reproduced using the EG-52 Electromechanical Driver.

In this example, a square plate of aluminum .88mm thick and 13.3cm on a side was fastened to the top of the driver with a #4-40 x 1/4 machine screw and two #4 Split washers. The size governs the resonant frequencies but the phenomena can be observed for a considerable range of sizes.

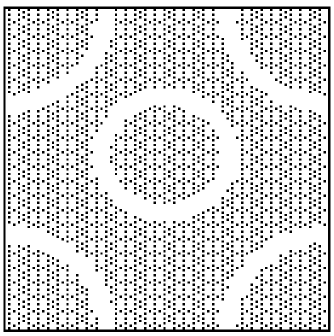
1. Attach the plate to the top of the Driver shaft with a #4-40 machine screw and a pair of lock washers. When tightening the screw, hold the end of the shaft with pliers to keep it from rotating while tightening the screw.
2. Turn on the Audio Driver and set the frequency to 100Hz and the amplitude about 1/3 from zero.
3. Increase the frequency slowly and listen for an increase in audible sound. The plate radiates much more sound at resonance than in between resonances.
4. When a resonance is found, reduce the amplitude and sprinkle a little clean dry sand onto the plate. The individual grains will dance on some parts of the plate and lie still at others. Turn up the amplitude a little until a good pattern is found. Sketch or photograph the pattern.
5. Increase the frequency slowly to find the next resonance. As the frequency is increased, the amplitude should be increased a little as well.



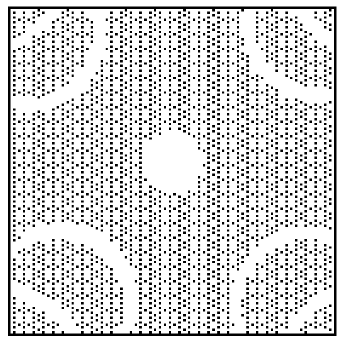
209 Hz



1054 Hz



567 Hz



1641 Hz

Chladni Patterns

Figure 12
The resonances are not as simply related as they are for a string, and the mathematical model, which describes the motion, is far more complex. Nevertheless, the patterns are interesting in themselves and give a clearer insight into how complex the vibrations of plates and panels can be.

Many interesting Chladni patterns can be found in the paperback Vibrations and Waves, French A.P., Norton and Co, New York (1971)