OBJECTIVES

Understand basic principles of operation of the piezo device – as both a sensor and output device. We will use this sensor to pickup vibrations required to trigger a MIDI signal which will drive a drum synthesizer. You will learn how different materials vibrate and how damping affects this vibration. You will also learn how to use an oscilloscope and catch single-shot signals automatically.

INTRODUCTION & BACKGROUND

Piezoelectric devices are able to generate an electric potential through the application of mechanical stress. These devices are used in many applications including picking up acoustic vibrations. For this reason they are commonly used as sensors in musical instrument pickups. A typical piezo disk is shown in Figure 1.

The Piezoelectric effect is also reversible. If you ever owned an early cell phone, you’ve probably heard a piezo buzzer generating the ringtone (albeit a fairly cheesy one).

In this lab, we will deal with time-changing waveforms that oscillate at certain frequencies. Frequency is defined as the number of occurrences of something over some unit of time. For example, your heart may beat 70 times per minute. From this, we can find the frequency value in units Hertz (Hz). Hz requires the format “occurrences per second.” Using factor-label, we find our heart beats at a frequency of:

\[
\left(\frac{70 \text{ beats}}{1 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ sec}}\right) = 1.167 \text{Hz}
\]

From frequency we can find out how long (in seconds) it takes for those occurrences (here the beats) to repeat again. This is the period of the signal. This is related to frequency by the simple relationship:

\[
T = \frac{1}{f}
\]

where T is the period in seconds and f is frequency in Hz.
So if you passed basic arithmetic, you can find that the period of a 1.167Hz signals is 0.86s. This means that every 0.86 seconds, your heart beats again. Every periodic signal has both a frequency and period. If something has a higher frequency, it has a smaller period and visa versa.

Piezo transducers cannot make static DC measurements (ones that stay at a constant of fixed value), since they can only generate a voltage output while moving. This corresponds to the sensor being a less ideal choice for slow changing, low frequency measurement. Of course, the actual lower bound is related to many things, such as the size of the sensor and what composition is used. All this means is that our sensor has to measure a vibration FASTER than its lower bandwidth limit. The response of the sensor is shown in Figure 2.

![Figure 2. Piezoelectric Sensor Frequency Response.](image)

In the figure above, you note that the x-axis is frequency (how ‘fast’ the vibration is), and the y-axis is the normalized amplitude of the sensor. Note that at lower frequencies, the sensor amplitude goes down. You may also note the large peak. This is the resonant frequency of the device and is the frequency where the device ‘likes’ to vibrate excessively.

These sensor signals will be used to trigger a drum synthesizer. The system is outlined in Figure 3.
Luckily, many of these blocks are prebuilt for you in an Analogue-to-MIDI converter.

To alter the natural response curve of the piezo, you can mount the sensor to different materials. These materials can be used for many things including: increasing or lowering vibration frequency, damping, increase the usable surface area of sensor, or even just to increase the ruggedness of the sensor.

You will use an oscilloscope to monitor the time-varying signal coming from the piezo when it is excited. An oscilloscope is an instrument used to display the time-changing nature of an electronic signal. You can think of it as a real-time plotter where the x-axis measures time and the y-axis measures amplitude, typically in voltage. You will be given hands-on instruction on how to use the oscilloscope by your instructor.

**EQUIPMENT & SOFTWARE**

- Piezo element
- Breadboard
- ¼" mono plug
- Oscilloscope
- Agilent Intuilink
- Assorted materials: wood, acrylic, foam, tape

**PROCEDURE**

The piezo disk must be mounted properly for 1) it not to be damaged and 2) vibrate freely.

- Mount the sensor on various materials and give it a tap to see if you can find the best balance of dynamics and volume for use as a drum. You can strike the surface of the material with your hand, but be consistent throughout the tests. When mounting the sensor be absolutely certain to create a simple
strain relief for the wiring to the sensor (the really thin wires). These can easily break and render the sensor useless.

- You can check the signal output of the piezo directly with the oscilloscope. Using a scope probe or appropriate cable, monitor the signal from the piezo for each mounting method/material you choose. Since the signal is only present when you tap it and dies off quickly, you need to set up a special single triggering method with the scope. This instruction will also be delivered in-class.

- Take scope screen shots of the output using Agilent Intuillink (in-class instructions will be given). Acquire enough screen shots to describe the differences in the vibration of the piezo and the characteristics of the material you mount the sensor to. I.e. some materials vibrate faster, some have more damping and may vibrate well at first then die off quickly with a fast decay, and some materials may vibrate and ring for a long time (low damping). You should be able to compare these intuitive material characteristics to the waveform you obtain from the piezo.

- For each screenshot find the approximate frequency of vibration by finding the signal’s period.

Now that you’ve found the best material and mounting strategy for the sensor, we can use it as an actual drum trigger! Each group’s trigger will be used to form all the components of a standard drum kit.

DELEIVERABLES

The following deliverables are REQUIRED components for your lab report. Answer any questions carefully and be certain to work in your full groups when writing the lab report:

- Oscilloscope screen-shots for each mounting strategy with descriptions of why the signals appear as they do.
- Piezo frequency and associated period (approximate) for each mounting strategy (can be found from scope screen shots).
- What materials and mounting strategies were used? Why was this particular strategy effective?
- Contributions to the project and lab report write-up by each student.
- EXTRA CREDIT: How could you find the resonant frequency of the piezo experimentally?

SAFETY & LAB PROTOCOL

- Return all cabling neatly to the racks
- Clean your workspace when finished your experiment
- No food or drink allowed in the lab
- Take extreme care handling the instruments

REFERENCES