SubLab: Energy Harvesting

We are bathed in forms of energy. The sun lights up our world, radio transmissions completely surround us, vibrations from construction sites shake our homes, wind whips by, and so much more. Being able to capture some of this otherwise wasted energy would be like pulling free energy from the air. The process of doing this is called **Energy Harvesting**.

You may see an example of this as you walk around your neighborhood. Many people light their property with solar path lights. These little devices do not need to be hooked to power because they harvest their own, and store it for later use. The small solar cell on the light converts the sun's light into electricity which is stored in a small rechargeable battery. Then, when the sun goes down, the battery powers a small path light. This is an example of energy harvesting. Many road warning signs use this type of harvesting. They have bigger solar panels and batteries, but the process is the same.

There are many different ways to harvest energy depending on the energy source you are trying to harvest. Here are a few:

Solar and Wind energy collection - These are probably the most identifiable to most people. We have seen solar panels on homes and seen (or at least seen pictures) of wind farms where turbines are turning wind into electric power.

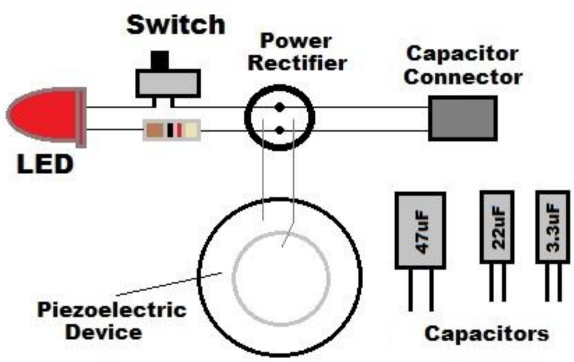
Thermoelectric – When two dissimilar metals are heated, there is a voltage developed at the junction. When many of these devices are arrayed together, it can generate electricity.

Kinetic Motion – Have you ever heard of a "self-winding" watch? There is a small pendulum inside that swings as you move your wrist when you walk and work. The energy is converted into a winding action which keeps the watch spring wound.

Piezoelectric – Crystals have a natural ability to generate a voltage when they are placed under pressure. We can take natural sources of force and harvest electricity through the use of a piezoelectric device. That is what this lab is going to do.

Have you ever seen little children running and their shoes are lighting up? This is accomplished with piezoelectric devices. Let's use one of these devices to replicate this effect.

Below is the setup of the harvester. The piezoelectric device (called piezo from now on) will generate electricity when vibrated or mechanically tapped. The LED is a light emitting diode that requires low amounts of energy to light. The switch



will connect or disconnect our LED from the circuit. The power rectifier converts the alternating wave produced by the piezo to a direct current for use in our system. The capacitors will be used to store energy and the capacitor connector is where we can connect our capacitors to the circuit.

Procedure: Light the LED

1) Do not connect the capacitors to the circuit yet. Slide the switch toward the LED position to connect it to the circuit.
2) Hold the device in your hand or place on a surface.
3) Tap the piezo and watch the response of the LED. See how different locations generate more or less energy. With two fingers, tap the outside circumference at two points located 180 degrees apart. Did this produce a bright flash?
4) Try different objects to see if it has an impact on the brightness of the LED.

The piezo is generating energy that the LED is using to light. Let’s use our system to store this energy.

Procedure: Store the Harvested Energy

1) Slide the switch away from the LED to remove it from the circuit and connect the capacitor socket to the piezo output. This will allow you to charge the capacitor from the piezo.
2) Take the capacitor marked 3.3uF and insert it into the capacitor socket. The capacitor has a white line aligned with one of its leads marking the negative side. Make sure this side goes into the Neg side of the socket. The value of the capacitor is proportional to the amount of charge it can hold. We are starting with the smallest value provided.
3) Tap repeatedly on the piezo in a way that you learned from the previous experiment that generates the most energy. Capacitors store electric charge on two plates. It will take a lot of tapping to get the capacitor charged sufficiently to light the LED.
4) After tapping for a while, turn the switch toward the LED and watch for it to light. The energy stored in the capacitor will discharge through the LED and give a quick flash. The flash will be brighter than the single tapping brightness because you have stored more energy in the capacitor than just the single tap.
5) Repeat the experiment steps 1 thru 4, but in step 2, use the 22uF and 47uF capacitors in turn. These capacitors have a greater capacity to hold charge and will take even longer to store enough energy to light the LED.

Capacitors are like rechargeable batteries in that they store energy for later use. Because they do not operate on a chemical process, they do not have memory effects or other problems associated with rechargeable batteries. They do however have a slight self discharge where the charge across the plates will slowly equalize over time. Modern capacitors have very low leakage but it is still noticeable over a long period of time. Try repeating the above procedure with the 3.3uF capacitor. Charge it up with a given amount of taps and look at the resulting light. Then, recharge it with the same amount of taps, but this time, wait 10 minutes to discharge the capacitor through the LED. Was there a difference? What if you use the 47uF capacitor?

There are many different ways to experiment with the harvester.

1) Set it up to charge the 47uF capacitor and place it on machinery that has significant vibration. After a while, switch to the LED position to see if you harvested enough to light the LED.
2) Try different materials to tap with. Is there a difference in the amount of energy produced if you tap with your finger or with the end of a ball point pen? What materials give the best response?
3) How many taps does it take to just make the LED light using a capacitor? Is the result related to the capacity of the capacitor?

Energy harvesting is a way to take what would be wasted energy and convert it into a usable form. Engineers and scientists are always studying ways to increase efficiency and save energy.