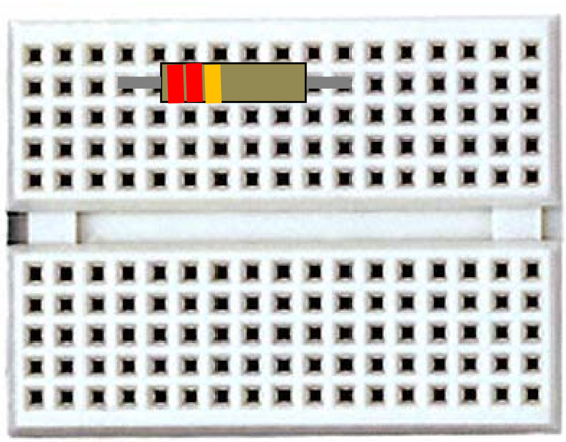
Charging and Discharging Capacitors

In this activity, we will see how energy storage elements like capacitors and inductors behave in circuits, by charging up and discharging a capacitor. Inductors also get charged and discharged, but it is current that is increased and decreased rather than charge. Capacitors are also easier to work with, so we will focus on them and then just point out how inductors behave by analogy.

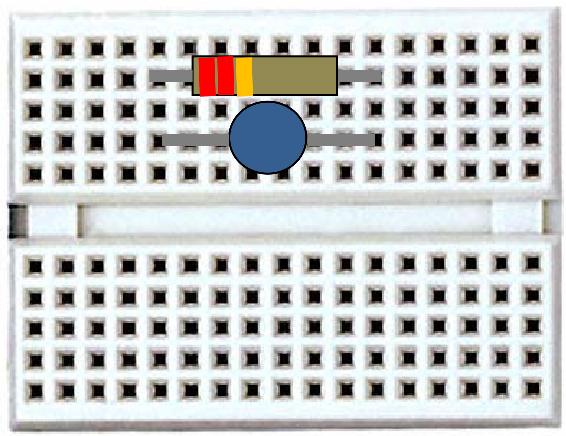
For this activity, we need a 9V battery, battery wires, a 470μF capacitor, a 33kΩ resistor, some wires with alligator clip connectors on them, a protoboard and the DMM.

The charging time for a capacitor is determined by the resistor the charging current must pass through. Batteries have a small internal resistance, so charging directly from a battery is quite fast.

1. Begin by inserting the 33kΩ resistor in your protoboard. This is shown generically below (the resistor is clearly not 33kΩ). Attach one end of two alligator clip wires to each end of the resistor. Connect the other end of one alligator clip wire to one of the DMM wires and the other end of the second alligator clip wire to the other DMM wire. Then set the dial on the DMM to measure 20V DC. This will set it up to measure the voltage across the resistor.



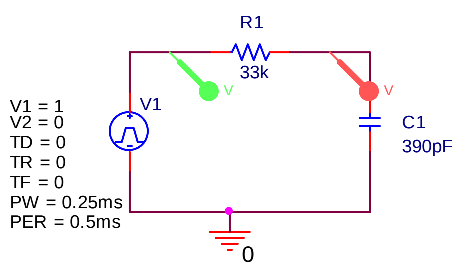
Next, charge up the 470μF capacitor to 9V by connecting it directly to the 9V battery. You can literally just touch the leads from the capacitor to the battery, hold it there for a few seconds and it will be fully charged. Making sure that the DMM is turned on, insert the charged capacitor in parallel with the resistor.



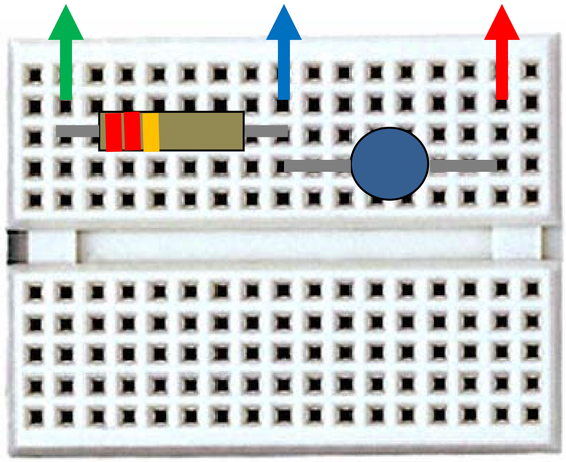
As soon as the capacitor is connected, you should see a voltage near 9V displayed on the DMM. It will start to decay toward zero. Calculate the time constant for this combination of resistor and capacitor. The time constant is the time it takes to decay to about a third of its initial value. To decay near to zero takes a few time constants. Once you have seen it decay, remove the capacitor, charge it up again, plug it back in and carefully time how long it takes to go below 1V. It should take a while but not minutes. For completeness, you should estimate the charging time by looking up the internal resistance of the battery. At the bottom of our webpage is a link to battery properties that we use in a course here at RPI called Electronic Instrumentation. You should find that the resistance is quite small so the charging time will also be small.

Now we want to show that this charging and discharging process can occur quite a bit faster than we can personally observe. Fortunately, tools like the Mobile Studio can follow much faster events than we can. To make the process faster, we will still use the 33kΩ resistor, but will replace the capacitor with one that is much smaller (390pF).

2. Build the circuit shown below. The source is the Mobile Studio AWG1.



The resistor and capacitor are now in series rather than in parallel.



There are three connections to make to the Mobile Studio board. Red should go to the ground next to AWG1 (pin #8). Green should go to AWG1 (pin #7). Blue should go to A2+ (pin #4). Set up the Mobile Studio to measure with the oscilloscope. Temporarily turn off channel 2. Select AWG1 as the source for channel 1. Select A2+ as the source for channel 2. Open the function generator. Set up Function Generator 1 (AWG1) with a frequency of 2kHz, with a peak-to-peak amplitude of 1V and an offset of 0.5V, and select square wave output. Click on the green Start button. This should produce a series of 1V pulses. For the horizontal scale, select 100µs per division to see them clearly. Choose Auto for your trigger. If it does not display, select the Set to 50% button. If you have problems, ask for help. Once you see the sequence of square pulses, you can turn on channel 2. It should look similar to channel 1 except that you should now be able to see the capacitor charging and discharging. For the 470µF capacitor, we found the time it takes to decay from about 9V to 1V. For this case, the same amount of decay will take the 1V pulses to about .11V. From the data shown by the Mobile Studio, determine this time. If everything worked well and you measured things correctly, the time to day for this experiment should be proportional to the change in capacitance or (390/470000) smaller. How did we do?

For inductors, the charging and decay time is proportional to the ratio of inductance to resistance, where the resistance is the sum of the inductor resistance and any other resistance in series with the inductor. Thus, the behavior is similar to capacitors.