Laboratory 7: RC Circuits and Electronic Clocks

Today we will build a circuit that generates a signal with a fixed frequency. The timing all depends on the RC elements in the circuit, so we will investigate that first.

Our Tools and Concepts

Function Generator

We will use a function generator to take the RC circuit through its charging/discharging cycle. You will use it on the square wave setting (we will show you) for this part.

Oscilloscope

We will use the oscilloscope to measure the voltage across the capacitor. During the charging/discharging process, we will use the Cursor feature that allows us to get numerical values for the time and voltage. We also use the frequency counter.

Capacitor and Resistors

The *capacitor* (C, measured in Farads) stores electric charge, maintaining an electric field between its plates. The resistor (R, measured in Ohms) controls how quickly charge can run through circuit as the capacitor builds up or reduces its charge.

RC Time Constant

The combination RC gives the characteristic time of the circuit – the basic time scale that tells us how fast things happen in the circuit. This will provide the oscillation for our clock; the self-generated frequency of the clock will be a multiple of 1/RC.

Operational Amplifier Circuit

The complicated-looking assembly that supports the RC circuit is the power source for our oscillator, using an *operational amplifier*. This integrated chip has a set of transistors, resistors, and capacitors, all miniaturized to make them into a versatile module. If this were an electronics class, we would spend time figuring out what is inside and how it does what it does. But, that's not our agenda. For our purposes, think of it as something that provides a large voltage signal and uses that to amplify the oscillations of the circuit, whose frequency is determined by the RC circuit,

A. RC Circuit and Time Constant

We will help you take the resistor and capacitor out of the circuit to test them.

Using alligator clip wires, we will show you how to:

- Use an ohmmeter to measure the resistance, R,
- Connect the RC circuit to the function generator,
- Attach the oscilloscope probe to measure the capacitor voltage, V_C,
- Get the capacitor discharge voltage signal on the oscilloscope,
- Use the oscilloscope cursors to take a series of time/voltage measurements.

Your task is to get 6 or more [t, $V_C(t)$] points to analyze, in order to find RC and C. Make a table of your measurements for later analysis.

B. Op-Amp Multivibrator Circuit

As we said above, the only thing in this complicated mess on your bread board that has any time dependent behavior is the RC circuit, so that is the resonator for your clock. Everything else is on the breadboard is the power supply for your clock, and the frequency meter of the oscilloscope as your clock counter.

We have set up the circuit so that it should work. We will show you how to:

- Attach the oscilloscope probe to the clock output (White Wire),
- Power up the circuit, notice the cyclic pattern on the oscilloscope,
- Record the frequency that your clock is generating,
- Change resistances to change the RC time constant,
- Use an ohmmeter to measure each resistance you used.

Your task is to measure the clock frequency for three different resistances.
You will already know the capacitance from your analysis of Part A,
so knowing R will give you the time constant for that circuit.

C. Analysis

For Part A,

- Find the natural logarithms of your voltages and add that to your data table,
- Plot ln[V] *vs.* t,
- Find the best fit line for these data and the slope of that best fit line.
- Determine C from that slope, knowing that *slope = – 1/RC*.

For Part B,

- Find the expected time constant for each of your resistances,
- Compare the generated frequency to 1/RC. What multiple is it in each case?

Lab Write-up

Explain what you did, what conclusions you can draw from it.

Comment on the reliability of the results. For instance, did you notice the frequency on the oscilloscope jumping around much?

Write a few sentences in summary about how this method could be used to generate a clock signal of any chosen frequency, given the right circuit elements to choose from.