RC and RL Circuits

RC Circuits

In this lab we study a simple circuit with a resistor and a capacitor from two points of view, one in time and the other in frequency. The viewpoint in time is based on a differential equation. The equation shows that the RC circuit is an approximate integrator or approximate differentiator. The viewpoint in frequency sees the RC circuit as a filter, either low-pass or high-pass.

Experiment 1, A capacitor stores charge*:*

Set up the circuit below to charge the capacitor to 5 volts. Disconnect the power supply and watch the trace decay on the 'scope screen. Estimate the decay time. It will be shown that this decay time, □ = RC, where R is the resistance in ohms and C is the capacitance in farads. From this estimate calculate an approximate value for the effective resistance in parallel with the capacitor. (This resistance is the parallel combination of the intrinsic leakage resistance within the capacitor and the input impedance of the 'scope.) [Ans.: about 1 s]

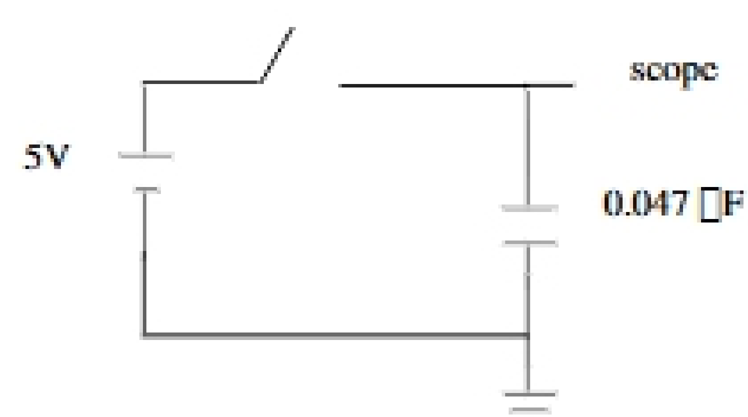

Figure 1: Capacitor charging circuit.

Next, replace the 0.047 μF capacitor by a 1000μF electrolytic capacitor [Pay attention to the capacitor polarity!] and watch the voltage across it after you disconnect the power supply. While you are waiting for something to happen, calculate the expected decay time. Come to a decision about whether you want to wait for something to happen. Act according to that decision.

Experiment 2, The RC integrator in time:

Consider the RC circuit in Figure 2 below:

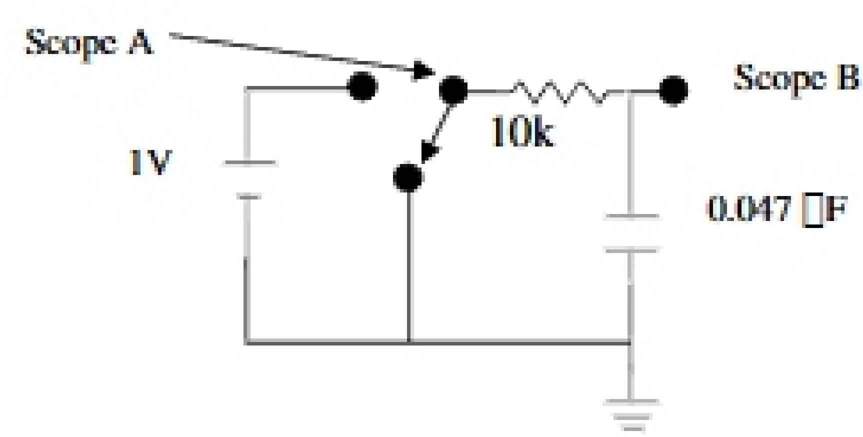

Figure 2: RC Circuit.

In lecture you will learn that this circuit can be described by a differential equation for q(t), the charge on the capacitor as a function of time. If you have time, you may wish to write down the equation and show that a solution for the voltage on the capacitor, V_C = q(t)/C, consistent with no initial charge on the capacitor, is:

$$V_c = 1 - e^{-t/\tau} \text{ where } \tau = RC.$$

Now build the circuit, replacing the battery and switch by a square wave generator. (Note: The square wave generator has positive and negative outputs, but this is the same as switching the battery with an added constant offset and a scale factor.)

Set the square wave frequency to 200 Hz, and observe the capacitor voltage.

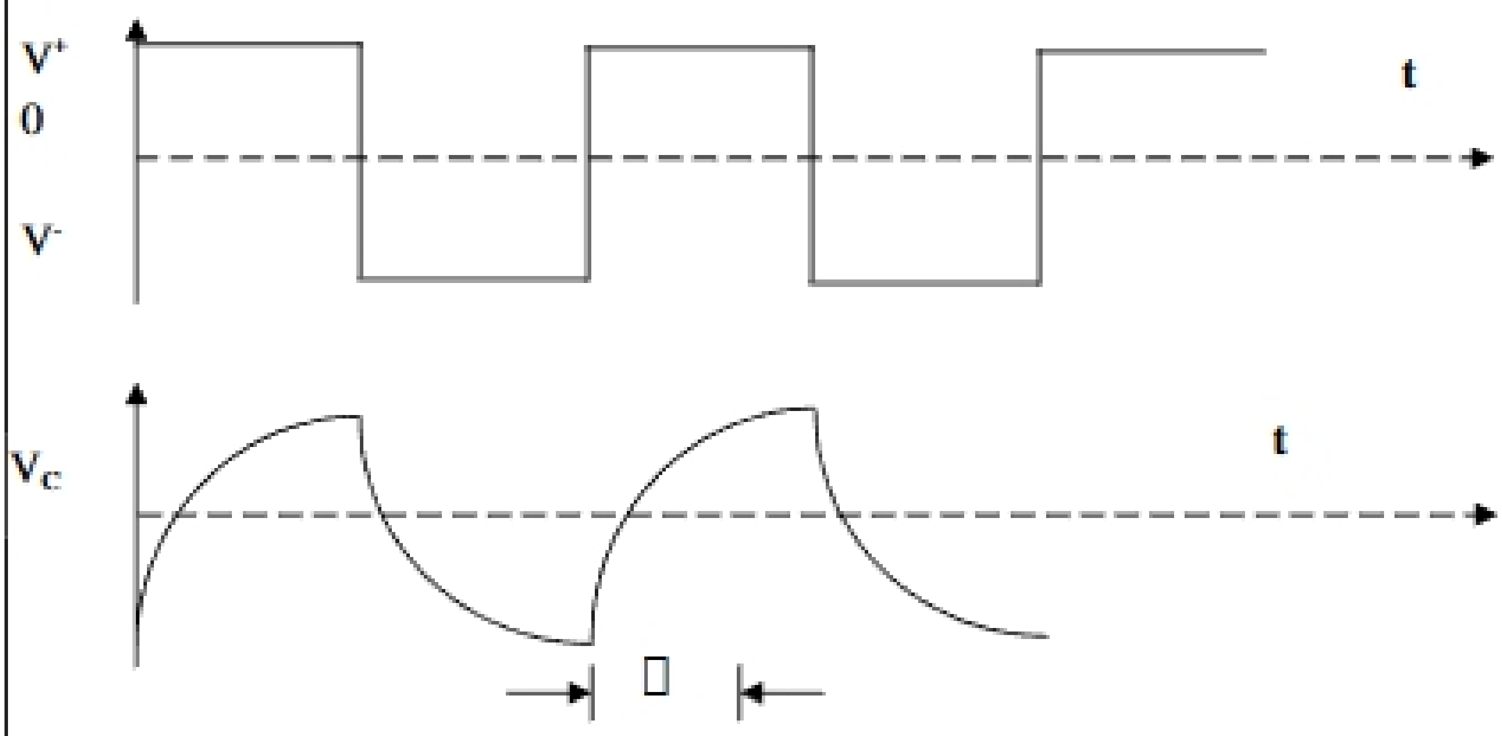

Figure 3: Square Wave and Integrator Output.

Use the 'scope to measure the time required to rise to a value of $(V_+ - V_-)(1-e^{-1})$. Accuracy in this measurement is improved if the pattern nearly fills the screen. This rise time must be equal to τ. Compare with the calculated value of τ.

Increase the square wave frequency to 900 Hz. Is the RC circuit a better approximation to a true integrator at this frequency? Sketch the response of a true integrator to a square-wave input.

Experiment 3, The RC differentiator in time:

Consider the RC circuit in Figure 4 below:

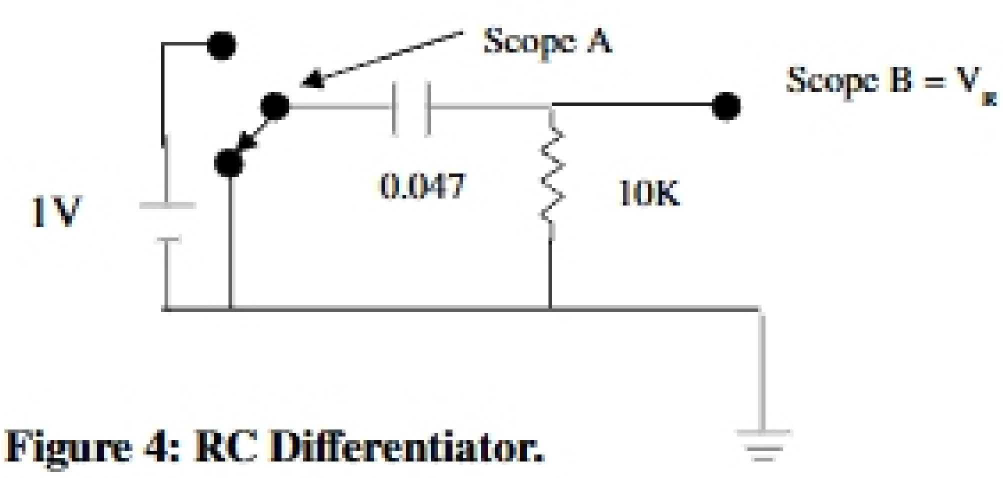

Figure 4: RC Differentiator.