

Transient Response

Ph 261 Lab 11

Charles Kankelborg

December 1, 2011

1 Purpose

In this lab, you will measure the response of RC circuits to a sudden change in voltage.

2 Prelab

The transient response of an RC circuit can be written

$$V(t) = (V_i - V_f)e^{-t/T} + V_f, \quad (1)$$

where V_i is the voltage at $t = 0$, and V_f is the value that is approached asymptotically as $t \rightarrow \infty$.

Assume the output resistance of the function generator (R_{Th} in figure 1) is 50Ω , and

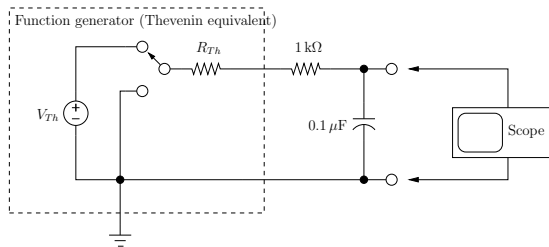


Figure 1: Function generator, set up to deliver a square wave output, connected to an RC circuit.

$V_{Th} = 8\text{ V}$. The voltage $V(t)$ across the capacitor is measured by the oscilloscope.

1. Calculate the time constant, $T = RC$, of the circuit.
2. If the switch is moved from the lower to the upper position at time $t=0$, calculate $V(t)$ and plot the result.
3. If the switch is moved from the upper to the lower position at $t = 0$, calculate and plot $V(t)$.
4. Consider two data points satisfying equation 1, $V_1(t_1)$ and $V_2(t_2)$. Show that the time constant is given by

$$T = \frac{t_1 - t_2}{\ln\left(\frac{V_2 - V_f}{V_1 - V_f}\right)}. \quad (2)$$

3 Equipment Required

- 1 Digital Multimeter
- 1 RCL Meter (shared)
- 1 Function Generator
- 1 Oscilloscope
- 2 Scope Probes
- 1 Protoboard
- 1 $0.1\ \mu\text{F}$ Capacitor
- 1 $0.47\ \mu\text{F}$ Capacitor
- 1 $1\ \text{k}\Omega$ Resistor

4 Procedure

Verify that the output resistance of your function generator is $50\ \Omega$. Usually there is a label indicating the value on the device.

1. Set up the function generator for a square wave at $50\ \text{Hz}$, $8\ \text{V}$ peak to peak, with no DC offset. Verify this output with the oscilloscope.
2. Build the RC circuit of figure 1 on a proto-board, connecting the function generator and oscilloscope as indicated. Also use the second channel to monitor the output of the function generator. It may be best to trigger off this signal.
3. Adjust the scope controls so that the decaying exponential waveform of the capacitor voltage (showing the transition from $8\ \text{V}$ to $0\ \text{V}$) is as large as possible, and zoom in so that you see only about 1-2 time constants on the horizontal axis.
4. Download the capacitor voltage trace from the oscilloscope to the computer, and print it out. Use the printout to graphically estimate the time constant, T , using equation

2. For measurements made from the graph, estimate your uncertainties.

5. Repeat steps 3-4 for the rising transition of the waveform.
6. Determine the actual capacitance value using the RCL meter. Compare this to the values you obtain by taking the time constant (as determined above) divided by the resistance.
7. Place the $0.47\ \mu\text{F}$ capacitor in parallel with the $0.1\ \mu\text{F}$. Predict the time constant, and check your prediction with a measurement. Report the percent error between your measurement and the predicted time constant.
8. Repeat step 7 with the two capacitors in series.

5 Conclusion

In your conclusion, comment on the accuracy of the method used to measure the time constants. What are the sources of error?