Oscilloscope and RC Circuits

APPARATUS

1. Tektronix Oscilloscope TDS1002 (see "Introduction to the Oscilloscope" on page 12)
2. Signal Generator
3. Electronic Voltmeter
4. Circuit Board (1 kΩ Resistor, 1 μF Capacitor - values approximate)
5. D. C. Power Cord

INTRODUCTION

This exercise consists of three parts:

(A) exploration of some properties of the oscilloscope,

(B) the charging and discharging of a capacitor as observed using the oscilloscope, and

(C) the measurement of the impedance of an electronic voltmeter by use of a capacitor discharge.

Study the circuit of Figure 1 and note that the switch can be connected to positions S1 or S2.
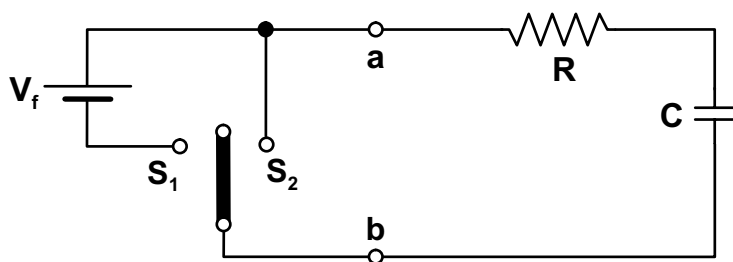

Figure 1: Circuit for charging/discharging a RC network

When you discuss RC circuits in class, you will study the charging and discharging of a capacitor in some detail. For our purposes, the following may be taken as experimental facts. When the capacitor in Figure 1 is initially uncharged and the switch is connected to S1 at $t = 0$, then the potential difference V across the capacitor C will increase with time according to:

$$V = V_f \left(1 - e^{-t/RC}\right)$$

where V_f is the constant supply potential. If after a time that is sufficiently long for V to approach V_f, the time is reset to t=0 and the switch is connected to S2, then V decreases with time according to

$$V = V_f \left(e^{-t/RC}\right)$$

In this case V decreases exponentially with time. Note that at $t = RC$, for both exponential rise and fall, the voltage has changed by approximately 63% of the maximum change ($1/e = 0.37$). This time, RC, is called the time constant of the circuit, and denoted by τ . If the switch is moved

alternately between S1 and S2 and back at a steady rate, then a square voltage wave would be applied across a-b. The voltage across the capacitor then would rise and fall exponentially. We will observe this by replacing the switch and battery by the signal generator and connecting the oscilloscope across the capacitor.

PROCEDURE

Part A: Exploration of the oscilloscope

1. Note the channel to which the cable has been connected. Set the corresponding trace to ON, using the CH1 MENU and CH2 MENU buttons. Other settings: SEC/DIV = 1 ms; VOLTS/DIV = 1 V

2. If you do not see a trace on the screen, then vary the POSITION of the corresponding trace. If no trace is seen, check the TRIGGER MENU, whether the trigger is set to AUTO. If still no trace is seen, check with your instructor. Vary the vertical and horizontal POSITION so that the trace lies along the center grid line and begins at the left edge of the grid.

3. Set the SEC/DIV to 10 ms and observe the behavior of the trace. Repeat at a setting of 100 ms. Describe your observations.

4. Connect the brown (ground) wire from the D.C. power cord to the black (ground) lead from the oscilloscope. Plug the D.C. power cord into the special socket. TOUCH the blue lead of the power cord to the red lead from the oscilloscope, **momentarily**. Repeat. Describe what you observe and explain.

5. Repeat 4 with the SEC/DIV set to 1 ms. Describe your observations. Why is the pattern so different from your previous observation?

6. Unplug the D.C. power cord and disconnect it from the oscilloscope. Set SEC/DIV to 10 ms and VOLTS/DIV to 100 mV. Describe the pattern that appears. Touch the red input wire with your finger and find the time between neighboring positive peaks. What is the frequency of this signal? What might be its source?

7. Set SEC/DIV to 1 ms and VOLTS/DIV to 1 V. Connect the signal generator so as to obtain a SQUARE WAVE, being careful to observe that GROUND leads are connected together. Connections vary with the type of generator: see the notes on Signal Generators at the end of the "Introduction to the Oscilloscope" section. Set the signal generator to a frequency of 100 Hz. This requires setting two controls, a frequency dial and a range (or multiplier). Note that 100 Hz = 1.0×10^2 Hz = 0.1 kHz.

8. Turn power ON for the signal generator. Adjust the AMPLITUDE of the generator until you get a pattern that is 5 divisions high on the screen. You may have to adjust the TRIGGER LEVEL knob on the oscilloscope to get a stable display.

9. Adjust the frequency of the signal generator until you get one complete cycle of a square wave on the screen. Wiggle the TRIGGER knob until the beginning of a cycle starts at the left of the screen. How much of a difference is there between the frequency setting of the signal generator and the frequency as calculated from the oscilloscope settings and display?

10. Turn OFF the signal generator, but do NOT alter any other settings on the generator or oscilloscope. These will be needed for part B.
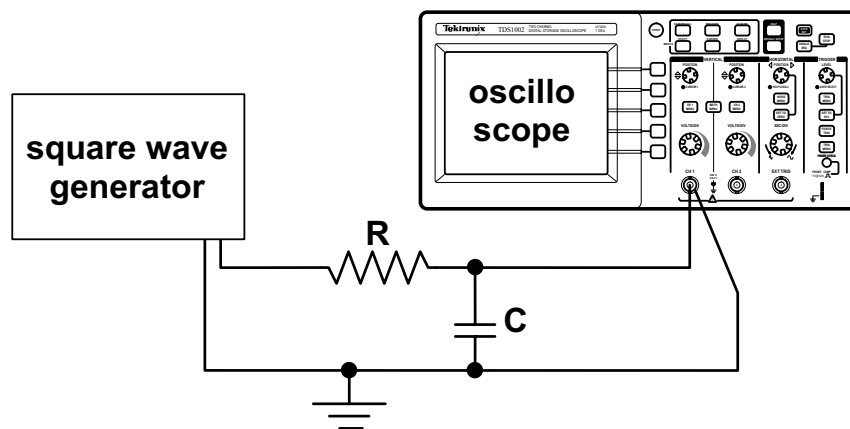
Part B: Charging and discharging of a capacitor

Figure 2: Measuring the characteristics of a RC network

1. Wire the circuit of Fig. 2 using the circuit board. Be careful to connect the GROUND terminal of the signal generator to the GROUND terminal of the oscilloscope. If in doubt, consult your instructor. Turn on the signal generator and increase the amplitude until you see a pattern with an amplitude of about 5 divisions on the oscilloscope.

2. Since you have left the frequency settings on the oscilloscope and signal generator unchanged from Part A, the pattern should just fill the grid, but it may be necessary to adjust the vertical position. You should see both the charging and discharging of the capacitor.

3. Sketch the pattern, showing a number of times and voltages.

4. Estimate the time constant of the RC circuit from your observations. Describe your reasoning.

5. Compare your value with that calculated from R and C. (The value of C in μF (microfarads) is marked, while the value of R has to be determined from its color coding. Assume that the only uncertainty is due to R (tolerance band) and compare the two values of the time constant. Do they agree?

Part C: Impedance of an electronic voltmeter

1. Turn off the signal generator and the oscilloscope. Remove the capacitor from the circuit.

2. Measure the terminal voltage of the DC leads from the special outlet using the electronic voltmeter. Be careful with any loose leads.

3. Charge the capacitor by connecting it for about a second to the DC leads. Be sure that the wires are not permitted to touch. Disconnect and unplug the DC leads from the outlet.

4. Connect the electronic voltmeter across the charged capacitor. When this connection is made, you have an RC circuit similar to Fig. 1 with switch S2 closed and R the resistance of the voltmeter. You can now measure the voltage as a function of time. Devise a method to estimate R. Indicate your result and describe your method.