RC Circuit with Oscilloscope

Lab #5

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Objective

Use an oscilloscope to observe the time constant of an RC circuit experimentally.

1 Introduction

Recall from Lab #3 that the time constant τ of an RC circuit is the time during which the voltage decays to $1/e \approx 37\%$ of its value. The time constant is equal to RC.

An analog oscilloscope is an electronic device that plots voltage as a function of time by deflecting an electron beam in a cathode ray tube. It acts as a voltmeter.

2 Procedures and Results

We set up the circuit according to Figure 1, using an oscilloscope as a voltmeter and a function generator in place of a battery.

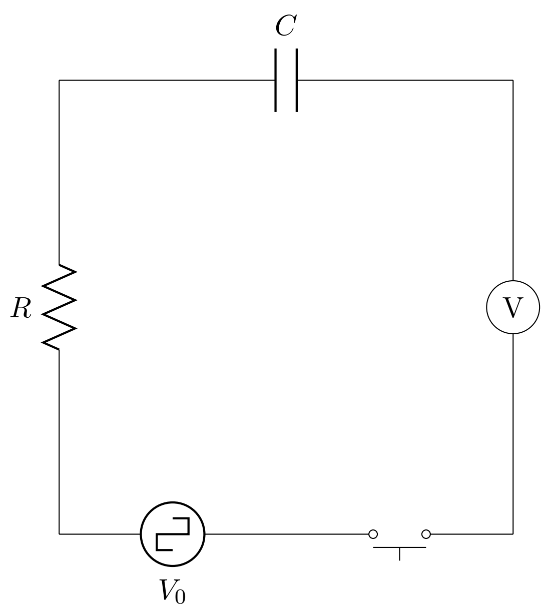
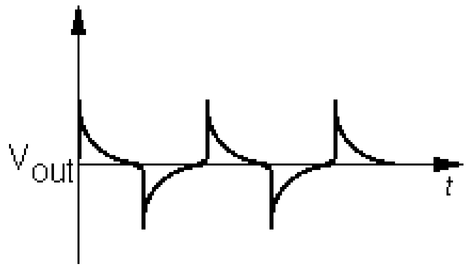
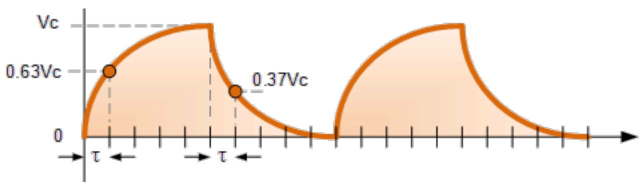


Figure 1: RC circuit

We set the function generator to produce a square wave and observed an output signal that looked like a series of spikes:



We then set the function generator to produce a triangle wave and observed an output signal that looked more like this:



which is more like the waveform we were told would appear. We adjusted the SEC/DIV knob of the oscilloscope until the image was frozen on the screen and adjusted VOLTS/DIV so that the waveform was 8 boxes high. Then, we measured the number of boxes across which the signal rose by 5 boxes.

Table 1: Oscilloscope measurements. Data courtesy of Margaret Burkart

Trial	Resistance	Capacitance	Divisions across	SEC/DIV
1	$10,920\,\Omega$	900 pF	1.2	$20\,\mu$s
2	$5,555\,\Omega$	900 pF	1.9	$20\,\mu$s
3	$1,111\,\Omega$	900 pF	1.9	$20\,\mu$s
4	$5,555\,\Omega$	100 pF	1.8	$20\,\mu$s
5	$5,555\,\Omega$	500 pF	1.9	$20\,\mu$s

3 Discussion

We calculated the observed time constant by multiplying the divisions across by the value of the SEC/DIV knob. A sample calculation is shown for Trial 1:

$$\tau_{observed} = 1.2 \times 20\,\mu\text{s} = 24\,\mu\text{s}$$

We calculated an accepted value for τ by multiplying the resistance by the capacitance:

$$\tau_{accepted} = 10,920\,\Omega \times 900\,\text{pF} = 9.828\,\mu\text{s}$$

Then, we calculated the percent error:

$$\% \, \text{error} = \frac{|\tau_{observed} - \tau_{accepted}|}{\tau_{accepted}} = \frac{|24 \, \mu\text{s} - 9.828 \, \mu\text{s}|}{9.828 \, \mu\text{s}} = 144\%$$

Table 2: Observed and accepted values of the time constants.

Trial	$\tau_{observed}$	$\tau_{accepted}$	% error
1	24 μs	9.828 μs	144 %
2	38 μs	4.9995 μs	660 %
3	38 μs	999.9 ns	3700%
4	36 μs	555.5 ns	6381%
5	38 μs	2.7775 μs	1268%

The circuit we built haphazardly—with the oscilloscope in series instead of parallel and a triangle wave as the input instead of a square wave—produced the same output as we would expect the prescribed circuit with a larger time constant to have. We believe that the large percent errors are due to the fact that we set up the circuit incorrectly, but we do not know exactly what caused it.

In the first setup with the square-wave input, the circuit was acting as a differentiator. One way to build a differentiator is to use an RC circuit with a time constant smaller than the period of the input waveform, and the accepted values of $\tau = RC$ were consistently smaller than the observed values of τ, which in turn is always smaller than the period of the input voltage signal.

4 Conclusion

When the time constant of an RC circuit is shorter than the period of the input signal, the circuit acts as a differentiator.