Notes on Experiment #11

You should be able to finish this experiment very quickly.

This week we will do experiment 11 almost AS IS. Your data will be the graphical images on the display of the scope. So, BRING GRAPH PAPER! cm X cm is best since that is the actual scale of the scope display. You will be sketching the transient response of a RC circuit. We will also take a look at the capacitor as an integrating device.

Procedure

Part 1

Set up the circuit as shown in the lab manual with C = 0.01uF and R =27K. Set the amplitude of the square wave to 6 volts peak-to-peak (NOT the 20 volts indicated in the lab manual.). It is important that the frequency of the 6 volt (peak-to-peak) be exactly 200 Hz. Do not trust the scales on the function generator. The scope scales are much more accurate. So, do this:

1. Set the time base to 0.5msec/DIV.
2. Adjust the frequency control dial on the function gen. so that there is one complete cycle of the input and output in exactly the 10 horizontal divisions. (i.e. one cycle is 5msec and therefore f = 200Hz.)
3. Draw a large (half page at least) accurate sketch of the input VS(t) and output VC(t) (on the same sketch) just as you see it on the scope.
4. Repeat steps 1 to 3 with C = 0.02uF and C = 0.068uF.

Now we will be making an estimation of the values of the RC time constants (tau) for each sketch of VC(t). To understand how to do this consider the following explanation.

For the part of VC(t) that starts up at t = 0:

VC(t) = VCSS(t) + [VC(0) - VCSS(0)]e^ut/RC where VCSS(t) = -3 Volts (a constant for all time).

The slope of the tangent line to VC(t) can be found by taking the derivative of VC(t)

\[ \frac{d[VC(t)]}{dt} = (-1/RC)[VC(0) - VCSS(0)]e^{uRC} \]

At t = 0 this becomes

\[ \left. \frac{d[VC(t)]}{dt} \right|_{t=0} = (1/RC)[ VCSS(0) - VC(0)] \]

So, for a vertical change of VCSS(0) - VC(0) the horizontal change is RC which is tau.
Note if $V_{\text{CSS}}(t)$ is constant then $V_{\text{CSS}}(0) = V_{\text{CSS}}(\infty) = V_{C}(\infty)$.

If you sketch the tangent line of $V_{C}(t)$ from the point $t = 0$ to the -3 Volt line the amount of horizontal change must be $\tau$. Project that amount of change up to the $t$ axis and you have graphically found the value of $\tau$. See Figure 1.

![Figure 1](image)

**Part 2**

Let $R = 100K$ and $C = 1uF$.

At 200 Hz $V_C$ will be very small compared to $V_S$ as required. Use only one trial of $V_S(t)$ for this part:

$V_S(t) = 3\cos(400(\pi)t)$

Is $V_C(t)$ approximately $1/RC$ times the integral of $3\cos(400(\pi)t)$?

Verify this by checking the amplitude and phase of $V_C(t)$.

Do not use the square wave and triangle wave for input as suggested in the lab manual.

**Circuit Analysis**

**Part 1**
Use the model in the lab manual (with voltage sources at 3 volts and not 10 volts) to find the general expression for $V_C(t)$. Calculate the expected value of $\tau$ for each capacitor.

**Part 2**

Show that if $V_C(t)$ is very tiny compared to $V_S(t)$ then $V_C(t)$ approximately $1/RC$ times the integral of $V_S(t)$. (Hint: if $V_C(t)$ is very small then $i_C(t)$ is approximately $V_S(t)/R$)

Read and know the setup of this experiment and have fun!
ECE 225 Experiment #11

RC Circuits

Purpose: To illustrate properties of capacitors and their operation in R-C circuits

Equipment: Agilent 54622A Oscilloscope, Agilent function generator, Universal Breadbox.

I. R-C step response

Set up the circuit in Figure 1 below. Adjust the function generator to provide a 200 Hz square wave, with zero DC offset, and 6 volts peak-to-peak. After these adjustments you can visualize the generator as the switching circuit shown illustrated below the circuit.

![Diagram of R-C circuit](image)

Connect the scope to display $V_C(t)$ on CH1 and $V_S(t)$ on CH2. Ground both displays (with the GND selection) to set the traces at the center of the display; then select the DC presentation, and display $V_C(t)$ and $V_S(t)$ simultaneously and with the same vertical sensitivity (VOLTS/DIV) for each channel. Record the input and output time functions. Measure the time constant by the method discussed in the notes, and compare it with the value calculated from the values of R and C. In order to measure the time constant accurately, you may have to alter the function generator's frequency. Record and comment upon your observations. Repeat the experiment with all values of C provided by your instructor.

Notice that $V_S(t)$ at the output terminals of the function generator is not a perfect square wave. Why? Record the waveforms accurately, especially the "imperfection" in $V_S(t)$.

II. An RC circuit as an integrator
Using the same circuit from part I, if $V_C(t)$ is much less than then $V_R(t)$ is almost equal to $V_S(t)$ and therefore $i_C(t)$ is almost equal to $V_S(t)/R$. Under this condition, $V_C(t) = 1/RC$ times the integral of $V_S(t)$, and thus the system with can be viewed as an integrator.

Use a square wave of frequency 200 Hz and amplitude 4 V peak-to-peak, and use $C = 1$ uF. Are the approximations mentioned above valid under these conditions? Display $V_S(t)$ and $V_C(t)$ simultaneously on the scope as in part 1, except that since $V_C(t)$ is much smaller than $V_C(t)$ you will have to use different vertical sensitivities (VOLTS/DIV) for the two channels. Try the sinusoidal and triangle waveforms. Record your observations.

Comment on the quality of this circuit as an integrator.

What is the integral of a square wave? Of a sinusoidal wave? Of a triangle wave? (Hints: the square wave is a succession of constants; what function $g(t)$ is the integral of the constant function $f(t) = +3$? $f(t) = -3$? The sinusoid is easy, from a basic calculus course. The triangle wave resembles the function $f(t) = K_1*t + K_2$; what function $g(t)$ is the integral of that?)