PHSX 536: Homework #2

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Problem 1

If a complex voltage and current are related by the expression

$$v(t) = (-1 + j\sqrt{3})i(t)$$

what is the phase angle in degrees between the voltage and the current? Is the current leading or lagging the voltage?

Solution:

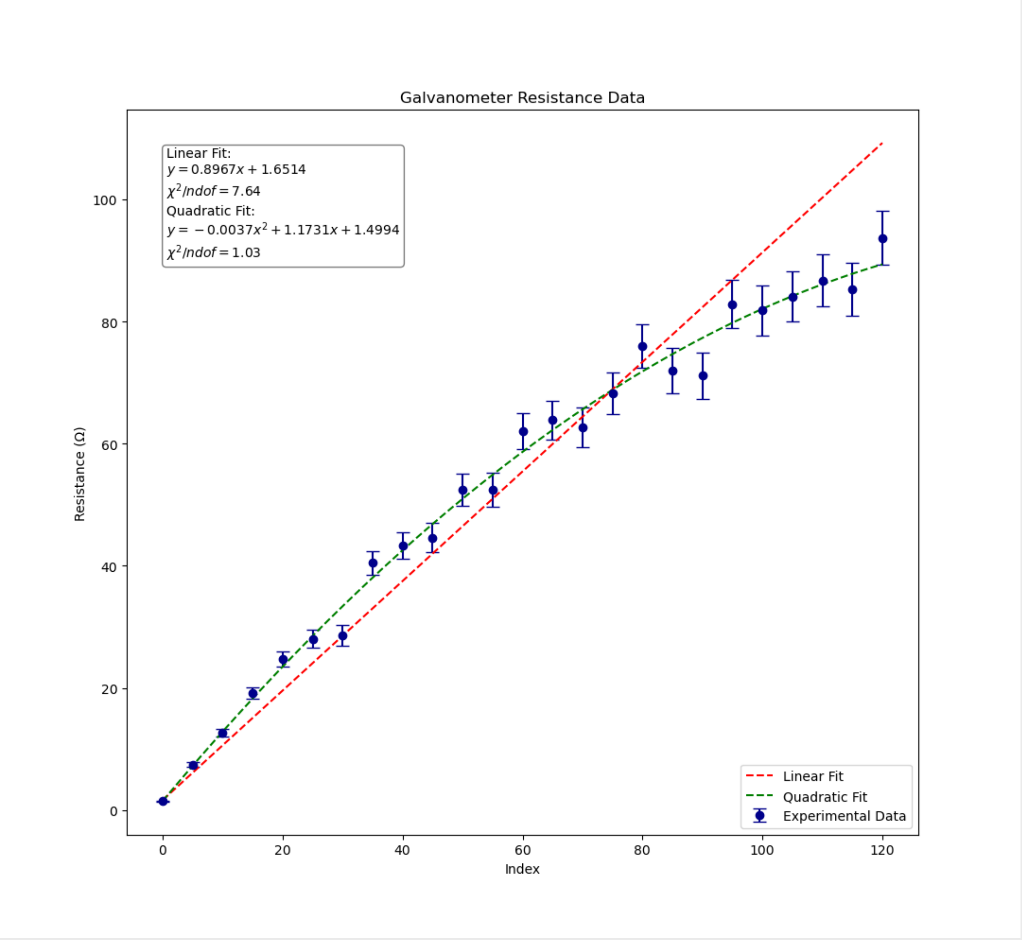
$$\theta = \tan^{-1}\left(\frac{\sqrt{3}}{-1}\right) = -60^\circ = 120^\circ$$

The current is lagging by 120 degrees.

Problem 2

You are given the following data for a potentiometer calibration. (Data file `potDat.txt` is in the same directory as this TEX file.)
Perform both linear and quadratic least-squares fits to the data and plot the results. Which function best describes the data? Based on the least-squares analyses, for each fit explain why the functional form is or is not consistent with the data assuming the uncertainties are purely statistical.

Solution:
This potentiometer is probably best modeled by the quadratic function. The linear model has a very high chisq value, indicating that it probably does not have enough parameters to fit the data well considering the uncertainties are purely statistical. If the linear model had fit this data better, the quadratic fit would not be correct since it would be overfitting. Considering the issues with the linear fit, and that we're seeing a chisq value near 1 with the quadratic model, my intuition tells me that the data is probably quadratic.



Problem 3

Use LTSpice to explore the transient response of the RC circuit to be studied in Experiment #3 (see the Week 3 video on BB titled "LTSpice Time Dependent Sources").

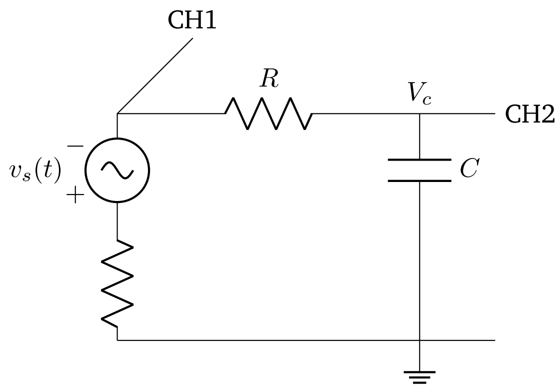


Figure 1: RC Circuit Diagram

Assume $v_s(t)$ varies as a step function that changes from -5V to 5V with a period of 10ms. Take $C = 10\,\mu$F and choose an R value that will result in a reasonable RC time constant for the laboratory measurement. You will want the capacitor to almost fully charge and discharge during one period.
Use **PROBE** to plot the voltage across the capacitor for $0 \leq t \leq 20$ ms. That is, plot the CH2 voltage as a function of time.

Solution:
We define the RC time constant to be:

$$\tau = RC$$

with units time
I will choose to wait 5 times this so that it's very nearly fully charged such that

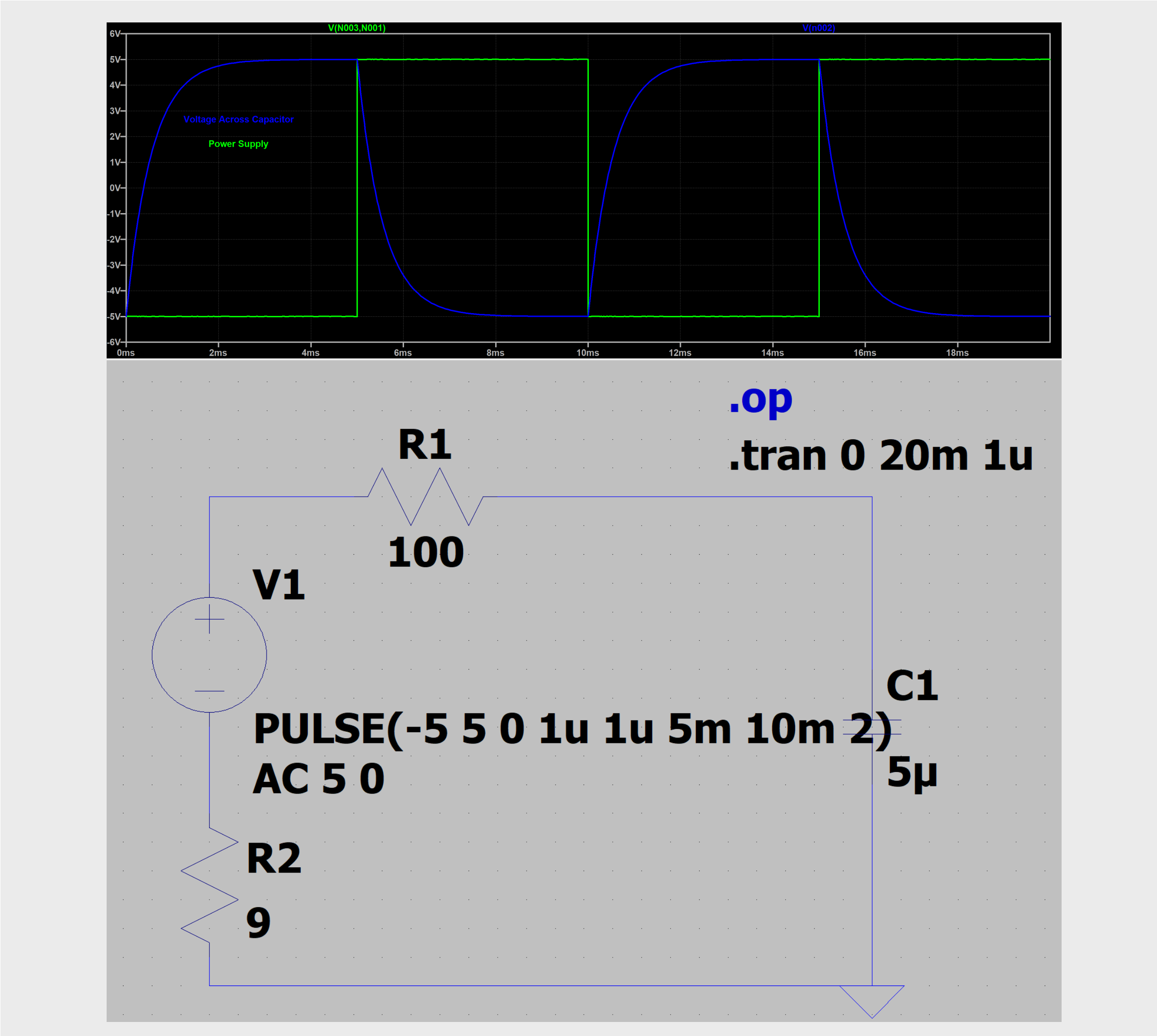
$$5\tau = T$$

We will then have R approximately:

$$5\left(R \cdot \left(10 \times 10^{-5}\right)\right) \approx 10 \times 10^{-3}$$
$$R \approx \frac{10 \times 10^{-3}}{5 \times 10^{-5}} = 200\ \Omega$$

I have not measured my power supply's internal resistance, but I expect it to have minimal effect on charging time given the large tolerance I have in my 5τ estimate. I have just set it to something small for simulation purposes.

Problem 3 continued on next page...


V(N003,N001)
V(n002)
Voltage Across Capacitor
Power Supply
6V
5V
4V
3V
2V
1V
0V
-1V
-2V
-3V
-4V
-5V
-6V
0ms
2ms
4ms
6ms
8ms
10ms
12ms
14ms
16ms
18ms
.op
.tran 0 20m 1u
R1
100
V1
PULSE(-5 5 0 1u 1u 5m 10m 2)
AC 5 0
C1
5µ
R2
9