UM-SJTU JI 2024FA VE215 Lab #6

In this lab, we will build a tunable 3-stage phase shifter and evaluate the current-voltage relationship of it.

- Please hand in your post-lab assignment before the due date. Please do your post-lab assignment according to the requirements in each problem. Both hand-written and printed versions are OK.
- Always attach the pictures or screenshots of your waveforms if using the oscilloscope.

Instruments

Function Generator with coaxial cables

Oscilloscope with coaxial cables

Three capacitors of $\mathbf{100\mu F}$

Breadboard and wires

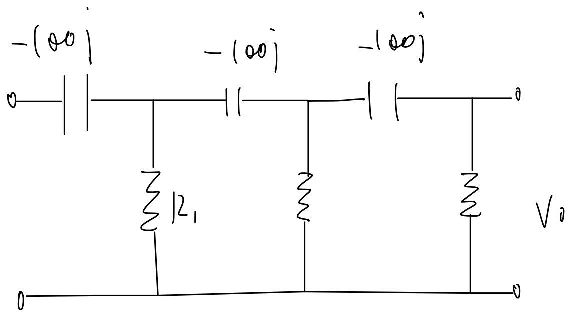
Three $\mathbf{0\Omega - 1000\Omega}$ Rheostats (or equivalent)

Problem #1 Design a 3-Stage Phase Shifter

Please design a tunable 3-stage RC phase shifter which can create $\mathbf{0^\circ - 180^\circ}$ phase difference between input voltage and output voltage if the operating frequency is $\mathbf{100Hz}$. (You can only using the instruments provided and you may change the shifting phase by adjusting the rheostats) After that, please build your circuit on breadboard. For the input voltage, please use the function generator to set a $\mathbf{1Vppk}$, $\mathbf{100Hz}$ sine wave.

Post-Lab Questions for (P1)

(1) Please draw the schematic of your design and mark all necessary values.



(2) Please state the working mechanism of your design. Then, state how to choose the resistances of the three rheostats in order to provide **90°** and **180°** phase difference between input and output voltages.

90°

$$\tilde{V}_o = V_i \frac{R}{\sqrt{R^2+(1/\omega C)^2}} \angle \arctan \frac{1}{\omega RC}.$$

$$\frac{1}{\omega RC} = \frac{\sqrt{3}}{3}$$

$$R = \frac{\sqrt{3}}{\omega C} = 173.2\,\Omega$$

180°.

$$\frac{1}{\omega RC} = \sqrt{3}.$$

$$R = \frac{1}{\sqrt{3}\,\omega C} = 57.7\,\Omega.$$

(3) According to your design, what are the ratios of the magnitudes between the input and output voltage signals when the shifting phases are $\mathbf{90°}$ and $\mathbf{180°}$?

$90°$ $\left(\frac{100\sqrt{3}}{\sqrt{(100\sqrt{3})^2+100^2}}\right)^3 = 65\%$.

$180°$ $\left(\frac{\frac{100}{\sqrt{3}}}{\sqrt{(\frac{100}{\sqrt{3}})^2+100^2}}\right)^3 = 12.5\%$

Problem #2 Evaluate Your Design

Please turn on the oscilloscope and then using the two channels to measure the input and output voltages of your circuit. Please display both channel signals (input and output) on the screen when the phase differences are $\mathbf{90°}$ and $\mathbf{180°}$.

Please measure the amplitude of the input and output voltages and then fill in the table:

Items	Amp of the input voltage	Amp of the output voltage
90°	3.42V.	98mV.
180°	4.22V	860mV.

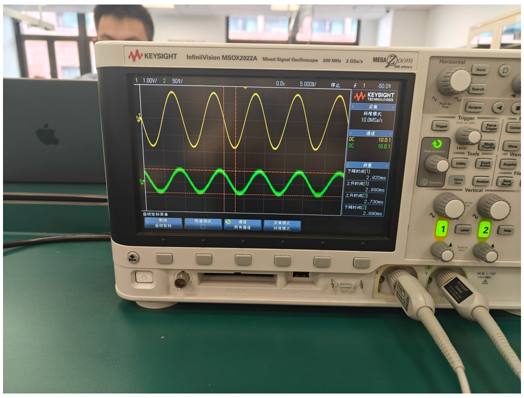
Then, please measure the phase difference by <u>one of the following two methods</u>.

- Measure the time difference between the two signals directly and then calculate the phase difference
- Choose the X-Y channel and then display the Lissajous figures on the screen.

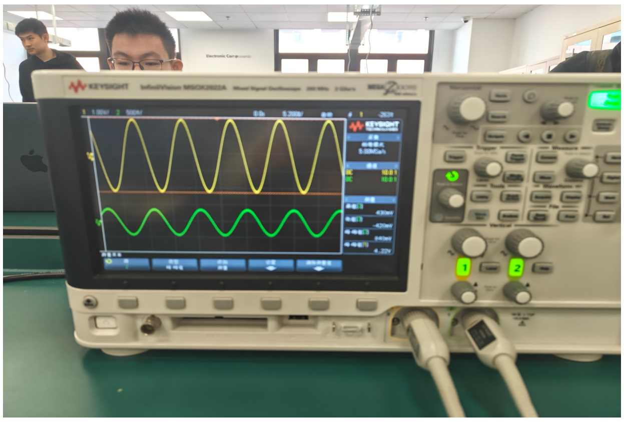
After that, please evaluate your design according to your results. Note that the for two $90°$ phase difference signals, the Lissajous figure is a circle. For two $180°$ phase difference signals, the Lissajous figure is a straight line segment.

Post-Lab Questions for (P2)

(1) Please attach the input and output waveforms (or Lissajous figures) of the $90°$ and $180°$ shifting cases.



90°



180°

(2) Please state how to calculate (or judge) the experimental values of phase difference according to your measurement. Then, please calculate the experimental values of phase differences for the two cases and compare them with the theoretical values.

We can use the oscillator to measure the phase difference.

According to the plot in last question, we can find the phase differences are respectively 90° and 180°, which aligns with our theoretical value.

(3) Please calculate the ratios of the magnitudes between the input and output voltage signals (experimental values) when the shifting phases are **90°** and **180°**. Then, please compare it with the theoretical values.

$90^\circ \quad \frac{98\times10^{-3}}{3.42} = 0.028.$

$180^\circ \quad \frac{860\times10^{-3}}{4.22} = 0.20.$

When it's 180°, it's close to the theoretical value, but when its 90°, error exists.