UM-SJTU JI 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

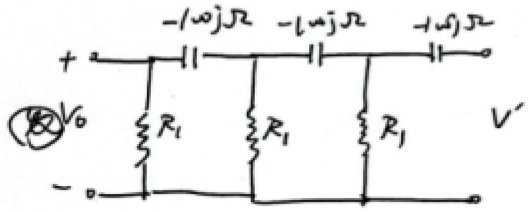
Three $\mathbf{0\Omega - 1000\Omega}$ Rheostats (or equivalent)

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 $\mathbf{1Vppk, 100Hz}$ 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.

$100\mu F \rightarrow \frac{1}{100\cdot 2\pi\cdot 100\mu\cdot j}\,\Omega \approx -100j\,\Omega$

$V' = V_1 \frac{R_1}{R_1 - 100j} = V\cancel{\frac{R(R+100j)}{R^2+10000}}\ \frac{R}{\sqrt{R^2+10000}} \angle -\tan^{-1}\left(\frac{100}{R}\right) \cdot V_1$

Thus, $V' = AV\angle 90°$, $\tan\left(\frac{100}{R}\right) = 30°$, $R_1 = 100\sqrt{3}\,\Omega$

$V' = AV\angle 180°$, $\tan\left(\frac{100}{R}\right) = 60°$, $R_1 = \frac{100\sqrt{3}}{3}\,\Omega$

(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 $\mathbf{180°}$?

$V' = AV\angle 90°$, $\left|\frac{V}{V_1}\right| = \frac{\sqrt{3}}{2}$, $A = \left(\frac{\sqrt{3}}{2}\right)^3 = \frac{3\sqrt{3}}{8} \approx 0.650$ $V' = AV\angle 180°$, $\left|\frac{V}{V_1}\right| = \frac{1}{2}$, $A = \left(\frac{1}{2}\right)^3 = \frac{1}{8} = 0.125$

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°	2.2375V	0.8062mV
180°	4.5125V	0.137mV

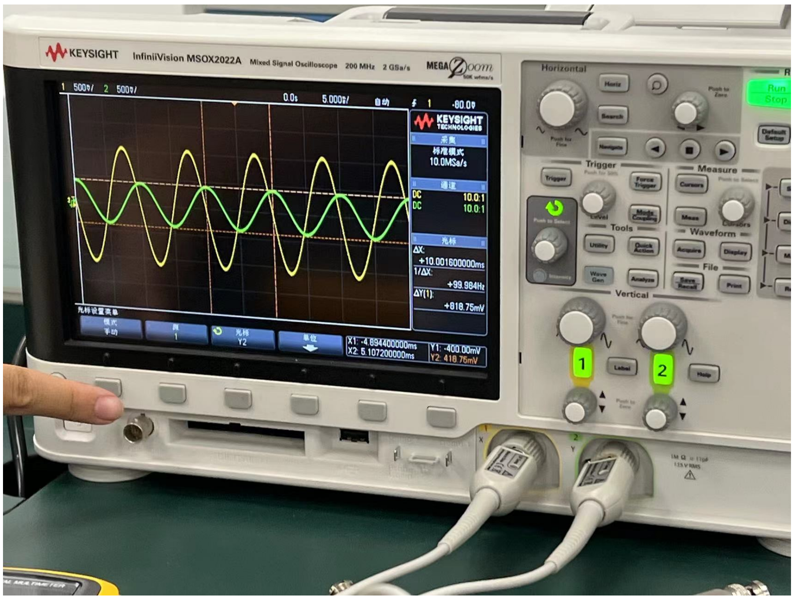
Then, please measure the phase difference by <u>one of the following two methods</u>.

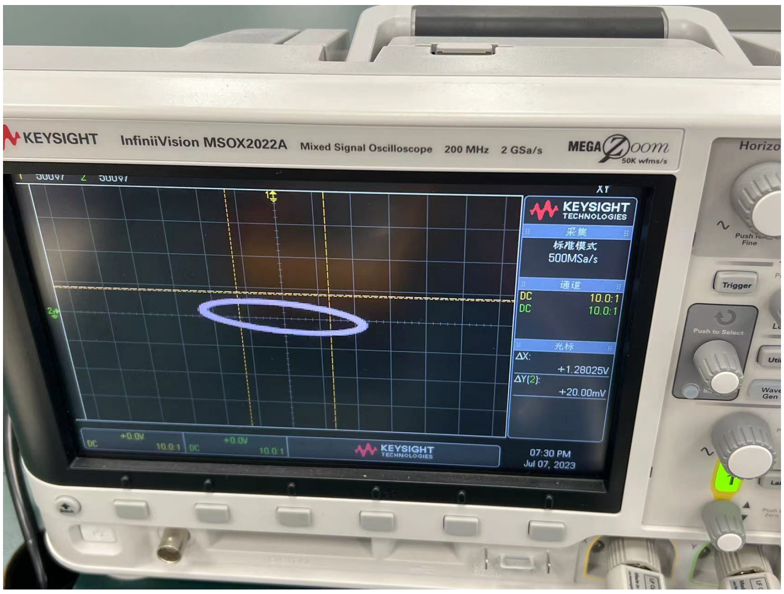
- Measure the time difference between the two signals directly and then calculate the phase difference
- Choose the X-Y channel and then display the Lissajous figures on the screen.

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.

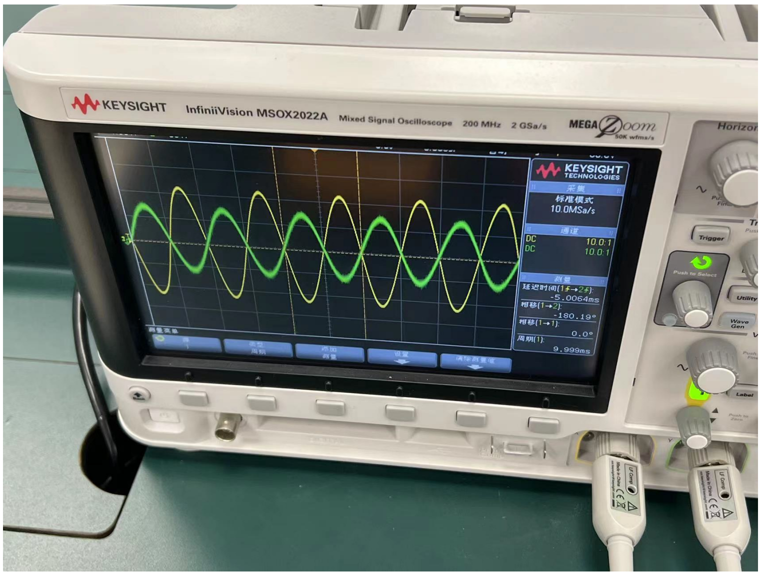
Post-Lab Questions for (P2)

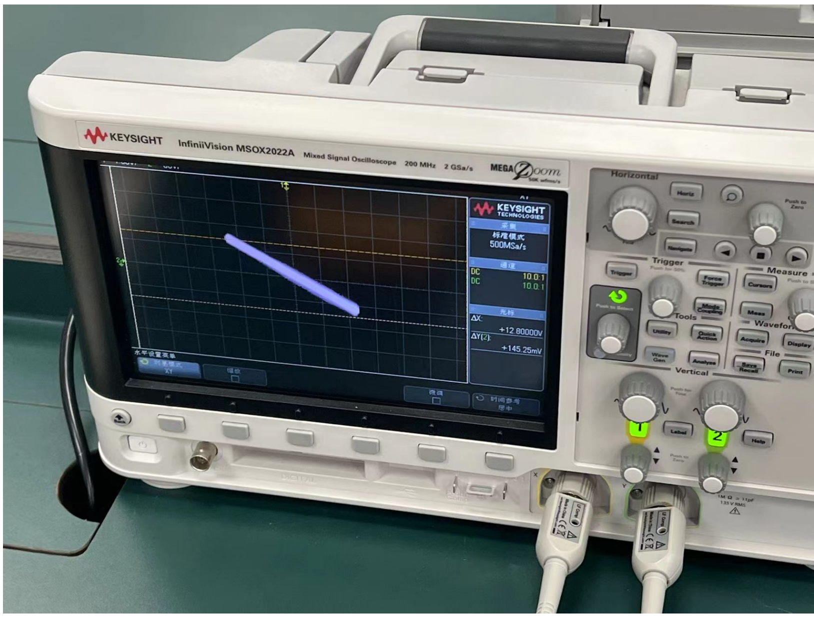
(1) Please attach the input and output waveforms (or Lissajous figures) of the $90°$ and $180°$ shifting cases.





90 degree





180 degree

(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.

The phase difference is directly shown in the oscillator. So, after carefully adjusting the phase difference to 90° and 180°, the phase difference is identical.

(3) Please calculate the ratios of the magnitudes between the input and output voltage signals (experimental values) when the shifting phases are $\mathbf{90^\circ}$ and $\mathbf{180^\circ}$. Then, please compare it with the theoretical values.

When the phase change is 90 degree:
0.8062mV/2.2375V=3.603*10^(-4)
When the phase change is 180 degree:
0.137mV/4.5125V=3.036*10^(-5)

3.603*10^(-4)<<0.650
3.036*10^(-5)<<0.125
There is huge error.

(4) What are the theoretical minimum and maximum shifting phases according to the design? How to adjust the rheostats to get the minimum and maximum phases?

The theoretical minimum shifting phase is 270°. If all rheostats becomes 0Ω, all the capacitors provides for a 90° phase change, so there is no phase difference, but there is no output voltage.

When the rheostats becomes 1000Ω, the phase change becomes arctan(100/1000)*3=17.13°

Post-Lab Reflection Questions

(1) Is your experimental result the same as your analysis (Need data as proof)? If not, how do you interpret this difference? What do you think is the source of the experimental error?

(2) What do you learn from this experiment? (e.g. what experimental procedures, how to debug, etc.)

(1)

No. Actually the three rheostats are not adjusted with identical resistance. Therefore, the phase shift in every step is not the same. The magnitude lift of a phase change (A_0/A_1)=cosα, where α is the phase change. And for any steps with different phase change s.t. α_1=α+λ, α_2=α-λ, cos(α+λ)cos(α-λ)=0.5(cos(2α)+cos(2λ))<cos^2(α). Thus, the magnitude is smaller due to the unbalanced phase change.

(2)

Call the TA and change the equipment whenever needed. QwQ