UM-SJTU JI VE215 Lab #5

In this lab, we will evaluate some characteristics of second order circuit.

- Please hand in your post-lab assignment before the due date. Please do your post-lab assignment following the requirements in each problem. Both hand-written and printed are accepted.

- You are encouraged to print this lab manual and then finish the post-lab questions on it. For pictures or diagrams, you may print it in a paper, cut it down and paste on this worksheet.

- Always attach the pictures or screenshots of your waveforms if using the oscilloscope.

Instruments

Function Generator with coaxial cables

Oscilloscope with coaxial cables

Multi-meter

Breadboard and Wires

Capacitor of **820pF**

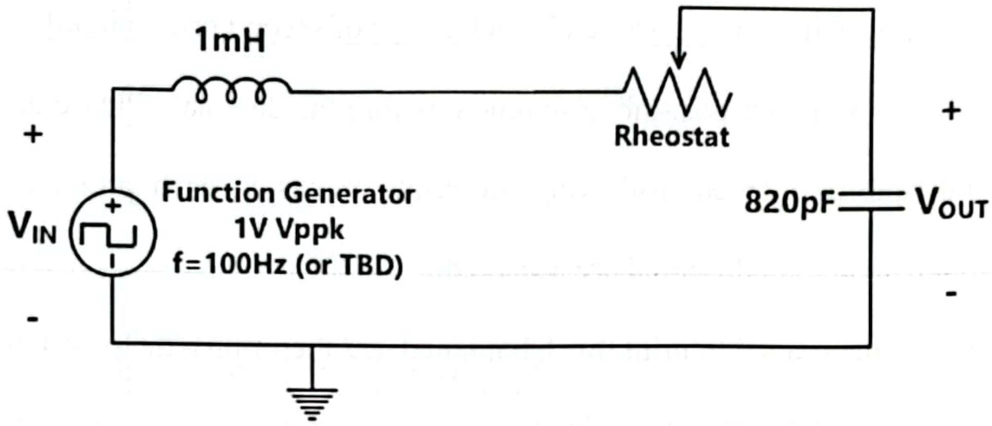
Inductor of **1mH**

Rheostat **0Ω~10kΩ**

$L \frac{di}{dt} + iR + \frac{1}{C}$

$V = \frac{Q}{C} \cdot \int$

Problem #1 Series-RLC 2nd Order Circuit



Please connect the circuit based on the Schematic above, turn on the function generator and then set a <u>square wave</u> at **1 Vppk** and **100 Hz.** **<u>Caution: Please set the output impedance of function generator to high-Z mode.</u>** Besides, <u>please use the oscilloscope to measure the voltages by monitoring the input signal in Channel 1 and the output in Channel 2</u>. You may adjust the frequency of function generator in order to let the capacitor can be fully charged or discharged during the half period of the input wave if necessary.

Then, please adjust the resistance of rheostat to generate the three kinds of response (over-damped, critical damped and under-damped) and then measure the <u>rise time (output voltage) of the first complete rising period</u>, <u>fall time (output voltage) of the first complete falling period</u>, the <u>time interval **ΔT** (output voltage) between two neighboring peaks (only for the under-damped cases)</u> and the <u>resistance of rheostat</u> corresponding to each cases. Please screenshot or take photos of your waveforms of three damping cases and complete the table in the next page during your measurement.

Damping Cases	Rise time	Fall time	ΔT	Resistance of rheostat
Over-Damped	11.8μs	11.6μs		6.07kΩ
Critical-Damped	1.82μs	1.84μs		1.11kΩ
Under-Damped	278μs	~~1.77~~ 2.46μs	5.90μs	3Ω

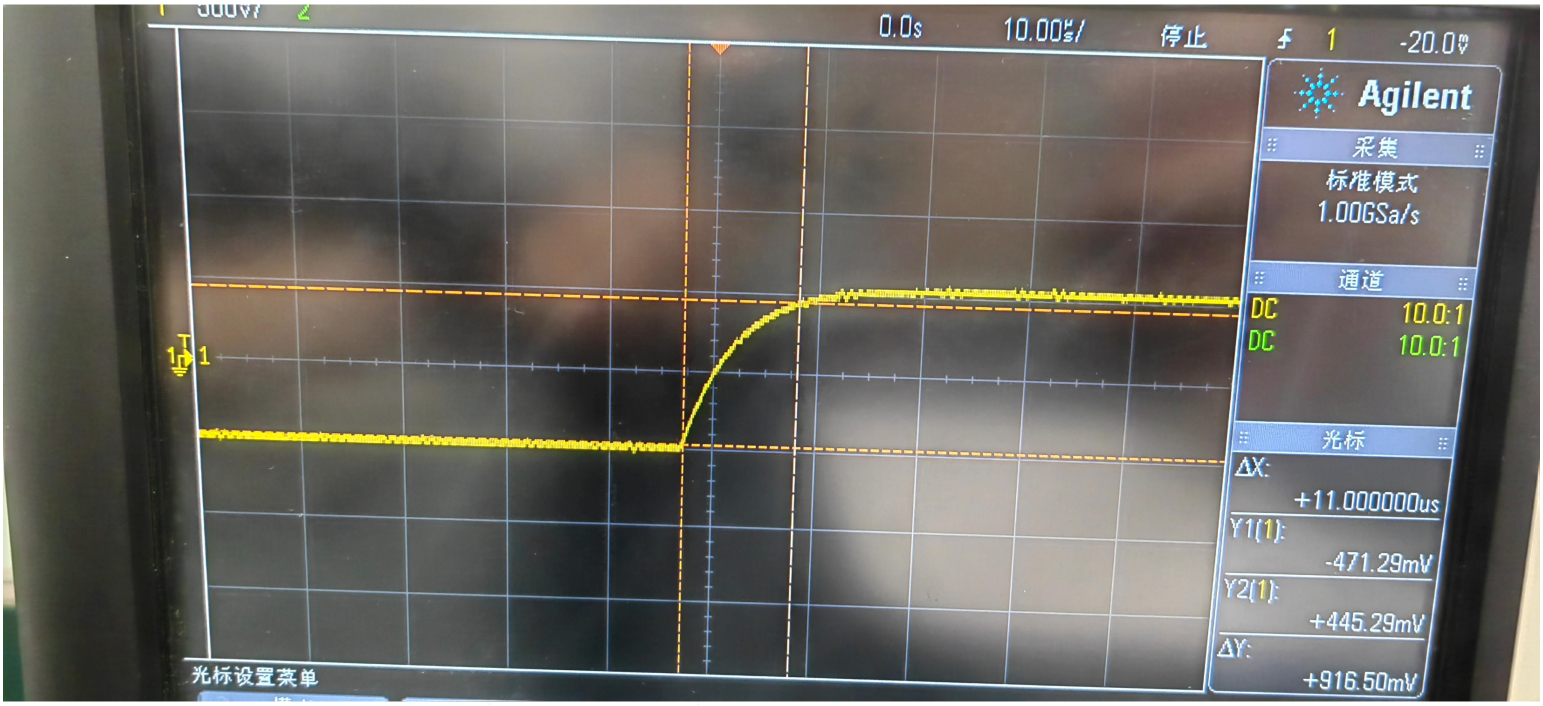
After that, please set your rheostat to **0Ω** (or short off the rheostat) and observe the waveform of output voltage you obtained. Similarly as before, please measure the rise time (output voltage) of the first complete rising period, fall time (output voltage) of the first complete falling period, the time interval ΔT (output voltage) between two neighboring peaks. Please screenshot or take photos of your waveform and complete the table.

Damping Cases	Rise time	Fall time	ΔT	Resistance of rheostat
No Damping	2.14μs	2.16μs	5.92μs	**0Ω**

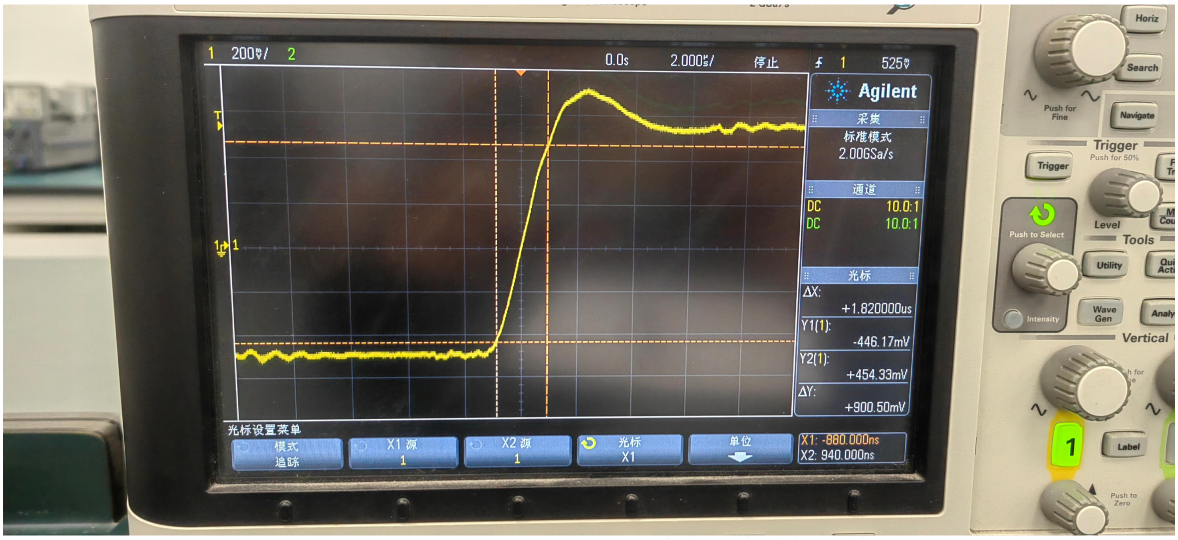
Post-Lab Questions for (P1)

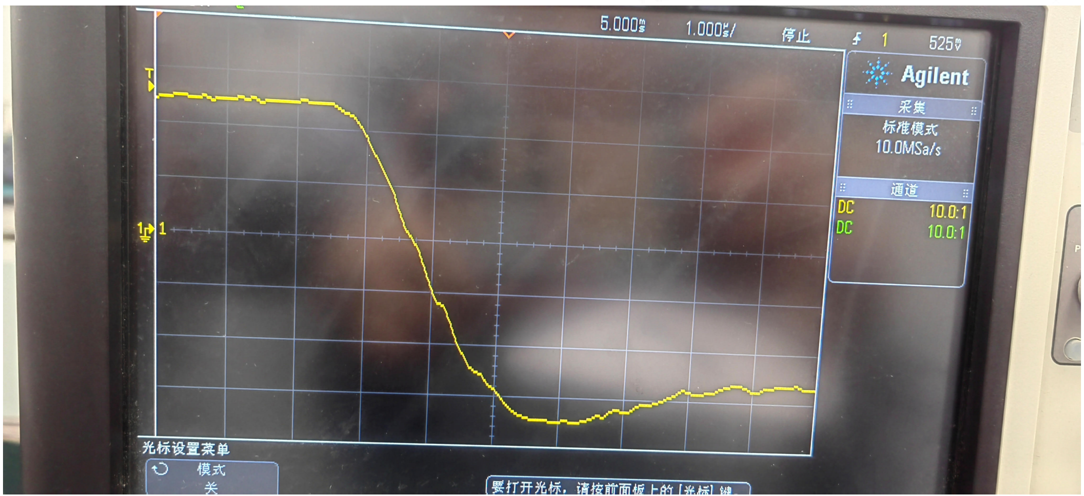
(1) Please attach three photos of your waveform (over-damped case, critical damped case and under-damped case) as well as the data table in the post-lab assignment.

Over-damped case:

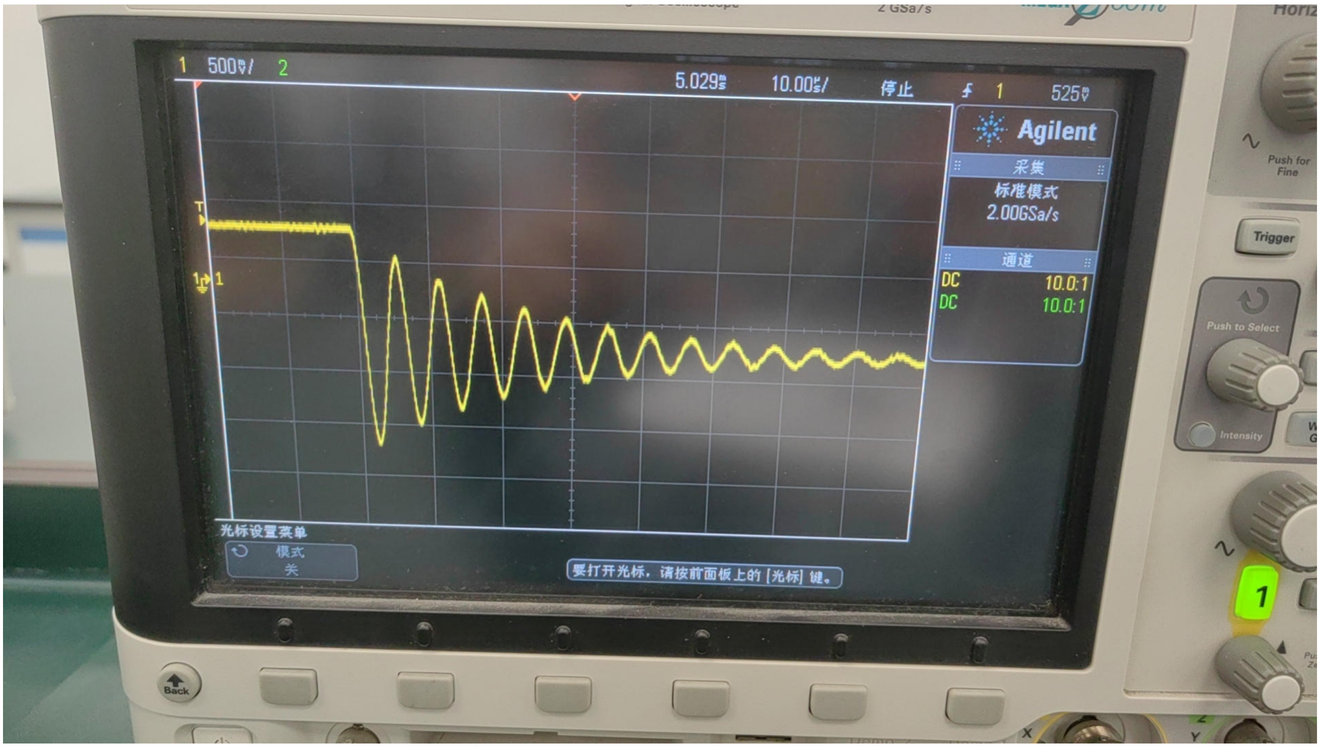


Critical-damped case

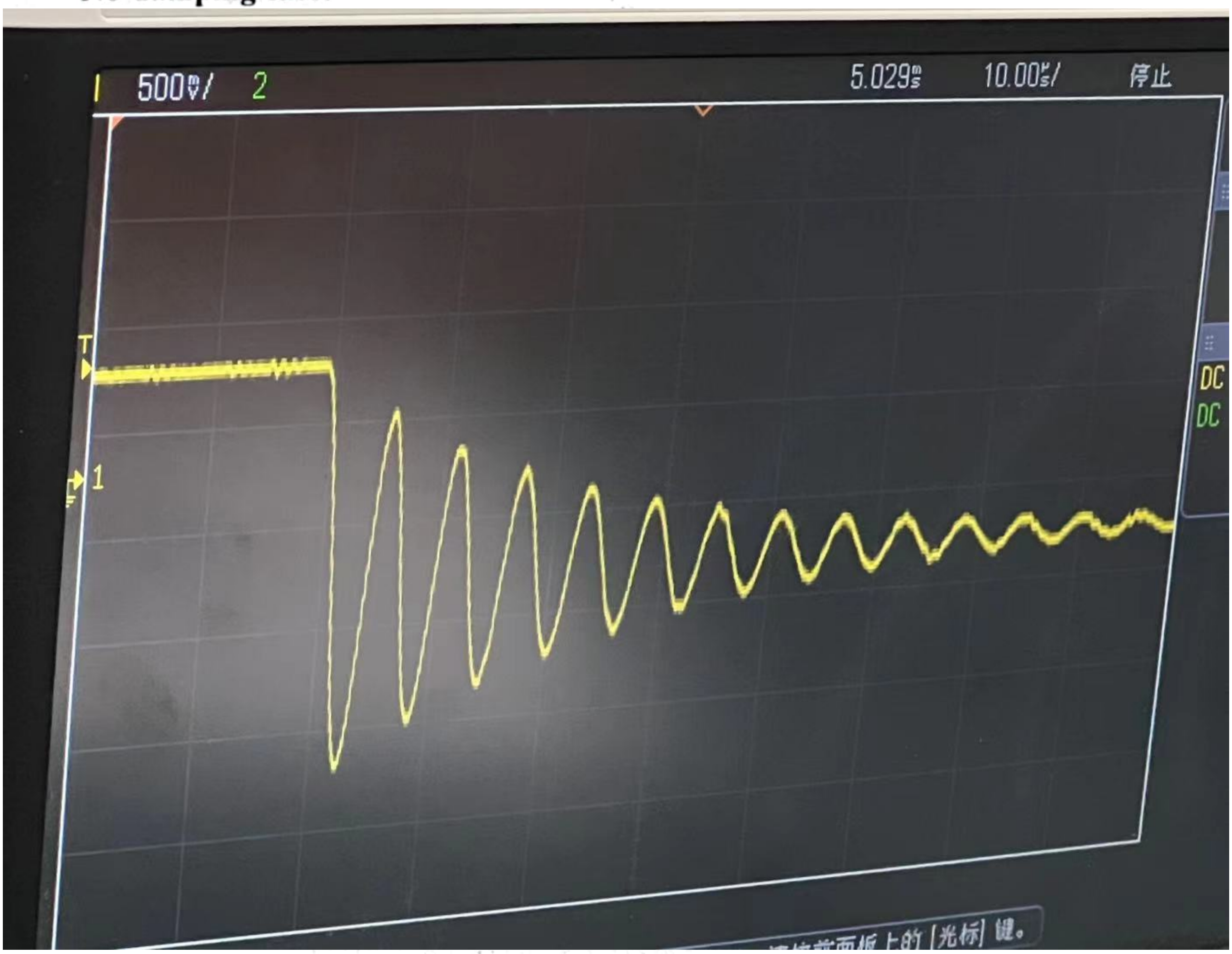




Under-damped case:



No-damping case:



(2) What are the theoretical values of the rise time (output voltage) of the first complete rising period, fall time (output voltage) of the first complete falling period, the time interval **ΔT** (output voltage) between two neighboring peaks of the under-damped case according to the rheostat resistance you choose? Please compare them with the experimental results and list some possible reasons if they are not the same.

$$L\frac{di}{dt} + iR + \oint V = 0$$

$$\frac{d^2 i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{LC} i = 0$$

Under-damped:

$$s^2 + 3\times10^3 s + 1.22\times10^{12} = 0$$

$$\Rightarrow i = e^{-1500}(C_1 \cos 1.10\times10^6 t + \sin 1.10\times10^6 t)$$

$$T = \frac{2\pi}{1.10\times10^{6}} s = 5.71\mu s$$

5.71 μs compared with 5.90 μs, 1.97 μs compared with 1.84 μs, 11.1 μs compared with 11.6 μs. There is not much difference

Overdamped:

$$\frac{d^2 i}{dt^2} + 6.07\times10^6 \frac{di}{dt} + 1.22\times10^{12} i = 1$$

$$\Rightarrow i = Ae^{-2.08\times10^5 t} + A_2 e^{-5.86\times10^6 t}$$

$$i(0)=0,\ V(0)=1 \Rightarrow \frac{di}{dt}(0) = -1000$$

$$\Rightarrow i = 1.769\times10^{-4}(e^{-2.08\times10^5 t} + e^{-5.86\times10^6 t})$$

$$V = \frac{1}{C}\int_0^t i\,dt = \frac{-8.50\times10^{-10}}{820p} e^{-2.08\times10^5 t} + \frac{3.02\times10^{-11}}{820p} e^{-5.86\times10^6 t}\Big|_0^t$$

$$= 1.037(1-e^{-2.08\times10^5 t}) - 0.037(1-e^{-5.86\times10^6 t})$$

$V=0.1,\ t=6.77\times10^{-7}$ $V=0.9,\ t=1.18\times10^{-5}$

Thus, $t_r = 11.1\mu s$.

Critically damped:

$$s^2 + 1.11\times10^6 s + 1.22\times10^{12} = 0$$

$$\Rightarrow i = (A_1 + A_2 t)e^{-1.11\times10^6 t}$$

$$i(0)=0,\ V(0)=1 \rightarrow \frac{di}{dt}(0) = -1000$$

$$A_1 = 0,\ A_2 = -1000$$

$$i = -1000te^{-1.11\times10^6 t}$$

$$V = \frac{1}{C}\int_0^t i\,dt = \frac{(9.009\times10^{-4} t + 8.116\times10^{-10})e^{-1.11\times10^6 t}}{820p} - 8.116\times10^{-10}$$

$$= (1.098\times10^6 t + 1)e^{-1.11\times10^6 t} - 1$$

$V=0.1$ $t=9.49\times10^{-8}$ $V=0.9$ $t=2.07\times10^{-6}$

Thus, $t_r = 1.97\mu s$

(3) Please derive the time-domain function of output voltage $V_{OUT}(t)$ for the zero-damped case if $V_{IN}(t) = -0.5 + u(t)$, where $u(t)$ is the unit-step function. What's the damping frequency of $V_{OUT}(t)$?

$$s^2 + 1.22\times10^{12} = 0$$

$$\Rightarrow i = C_1 \cos 1.10\times10^6 t + C_2 \sin 1.10\times10^6 t$$

$$T = \frac{2\pi}{1.10\times10^6} = 5.71\,\mu s$$

$$f = \frac{1}{T} = 1.75\times10^5\ Hz.$$

(4) What is the relationship between the under-damped case and zero-damped case? What roles did the rheostat play as?

When R=0, under-damped case becomes zero-damped case

The rheostat playes as a little damp s.t. the current shall vanish

(5) According to the waveform of zero-damped case you obtained, could the waveform matches with the result you obtained in question(3)? If not, why? (Hint: the digital oscilloscope can measure a maximum frequency of 100 or 200MHz. For higher frequency, a network analyzer is needed)

No.

Because there is still some resistance in the circuit, so the current still vanishes after some time.

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) It is ~~most~~ mainly consistent with my analysis. However, due to the resistance in the circuit, the no-damping case is not shown.

(2) The AC source may include some DC components. Thus there may be some fluctuation in the waveform. Also, the experiment may fail because of bad contact between components.

References

[1] *Circuits Make Sense,* Alexander Ganago, Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor.