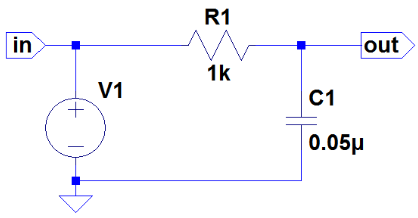
REPORT

Experiment 1: RC Circuit



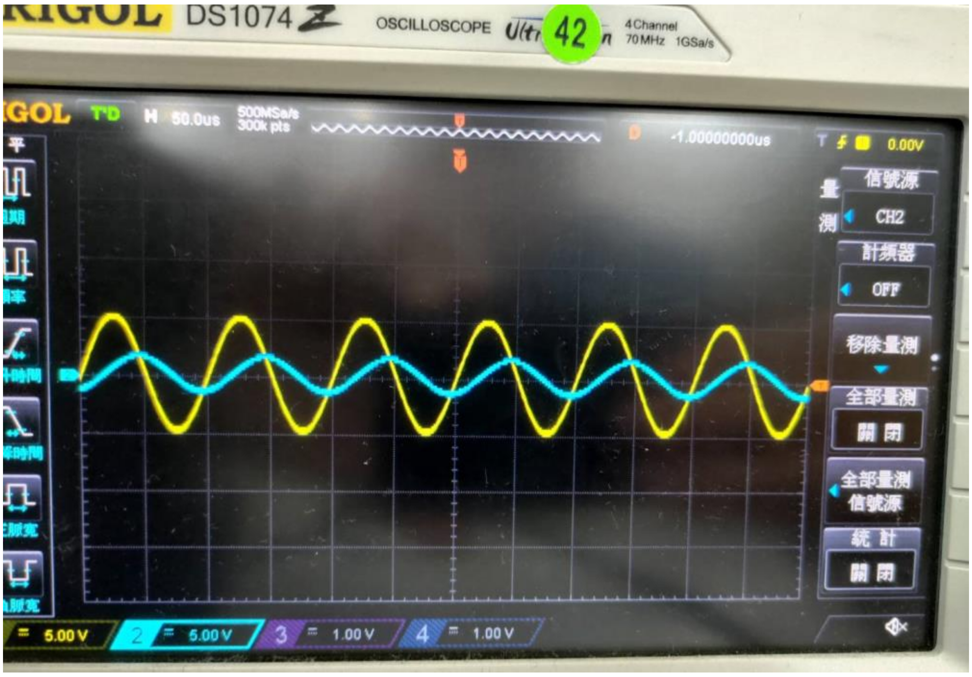
1.

Frequency (Hz)	5K	10K	15K
$V_{out,pp}$(V)	5.40	3.40	2.24

ADJUST THE OSCILLOSCOPE APPROPRIATELY

5k Hz V_{in} and V_{out} waveform

10k Hz V_{in} and V_{out} waveform



15k Hz V_{in} and V_{out} waveform

2.

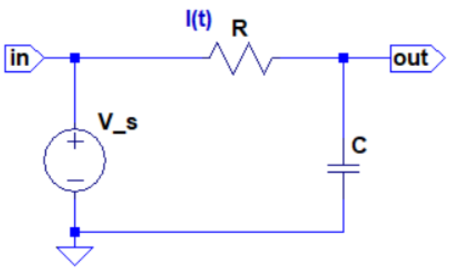
V_{in} and V_{out} waveform

time constant =$\Delta t = \Delta x$ = ____ $50\mu s$ _____ second (i.e. the value you use "cursor" function to measure)

Question:

Please use KVL and KCL to derive v_{out} function. (You need to show full solving process. NOT ONLY THE ANSWER)

Charge RC circuit:



Assume there are q charge store in the capacitor.

By KVL:

$$V_S - IR - \frac{q}{C} = 0 \qquad ...(1)$$

Substitute with $I = \frac{dq}{dt}$ into (1), we have:

$$R\frac{dq}{dt} + \frac{q}{C} = V_S \qquad ...(2)$$

Divided by R on both sides, and we have an ODE:

$$\frac{dq}{dt} + \frac{q}{RC} = \frac{V_S}{R} \qquad ...(3)$$

To solve (3) on the above, we have integral factor:

$$F(t) = e^{\int \frac{1}{RC}dt} = e^{\frac{t}{RC}} \qquad ...(4)$$

Then the solution of (3) is:

$$q(t) = \frac{1}{F(t)}\left[\int_0^t F(t)\cdot\frac{V_S}{R}dt + k\right], k \text{ is a const} \qquad ...(5)$$

Substitute with $F(t) = e^{\frac{t}{RC}}$ into (5):

$$q(t) = e^{\frac{-t}{RC}}\left[\int_0^t e^{\frac{t}{RC}}\cdot\frac{V_S}{R}dt + k\right] = CV_S\left(1 - e^{\frac{-t}{RC}}\right) + ke^{\frac{-t}{RC}} \qquad ...(6)$$

With the boundary condition of capacitor: $\lim_{t\to\infty} q(t) = CV_S$

$$\lim_{t\to\infty} CV_S\left(1 - e^{\frac{-t}{RC}}\right) + ke^{\frac{-t}{RC}} = CV_S \Rightarrow k = 0 \qquad ...(7)$$

Therefore, the solution of q is:

$$q(t) = CV_S\left(1 - e^{\frac{-t}{RC}}\right) \qquad ...(8)$$

Differentiate (8) with time:

$$I(t) = \frac{dq(t)}{dt} = \frac{V_S}{R} e^{\frac{-t}{RC}} \qquad ...(9)$$

Finally, we can get $V_{out} = V_S - I(t) \cdot R$, substitute with $I(t)$ in (9), we have:

$$V_{out} = V_S - \frac{V_S}{R} e^{\frac{-t}{RC}} \cdot R = V_S\left(1 - e^{\frac{-t}{RC}}\right) \qquad ...(10)$$

Define time constant $\tau = RC$, we have:

$$V_{out} = V_S\left(1 - e^{\frac{-t}{\tau}}\right) \qquad ...(11)$$

By (11), we can learn more about the circuit. When time pass a time constant $t = \tau = RC$, then V_{out} will rise from 0 to $V_S\left(1 - \frac{1}{e}\right)$, Note that $\frac{1}{e} \approx 0.368$. Therefore, $V_{out}(\tau) = V_S(1 - 0.368) = 0.632V_S$. That's the reason why we can use cursor to mark at $0.632V_S$, and get the time constant of the circuit.

Please use variable to answer what the time constant is equal to.

$\tau = RC$

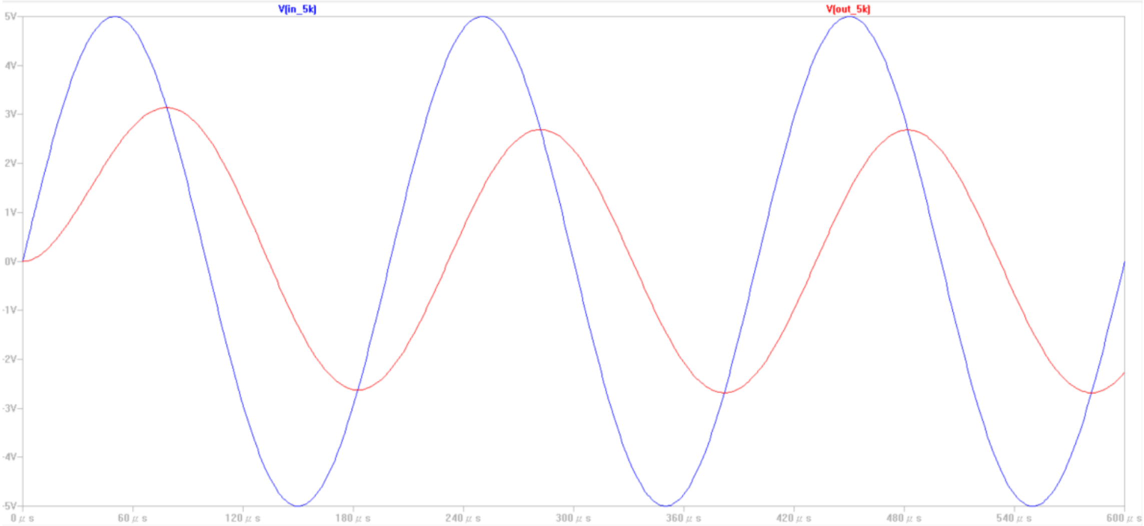
Please attach your LTSPICE simulation result for this experiment. (Both waveform and schematic)

Hint: Lab03

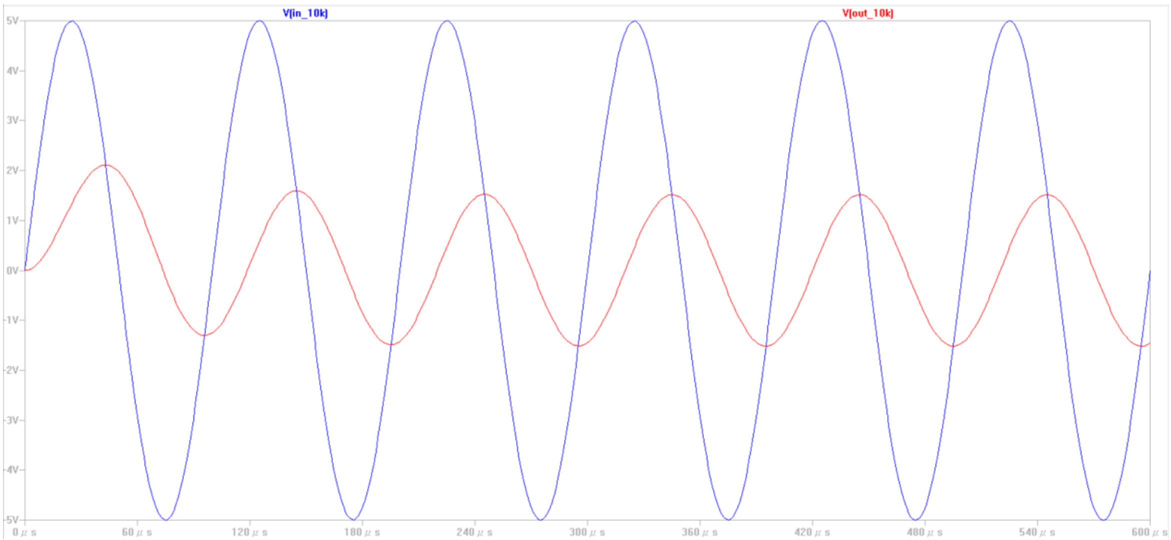
1.

Waveform

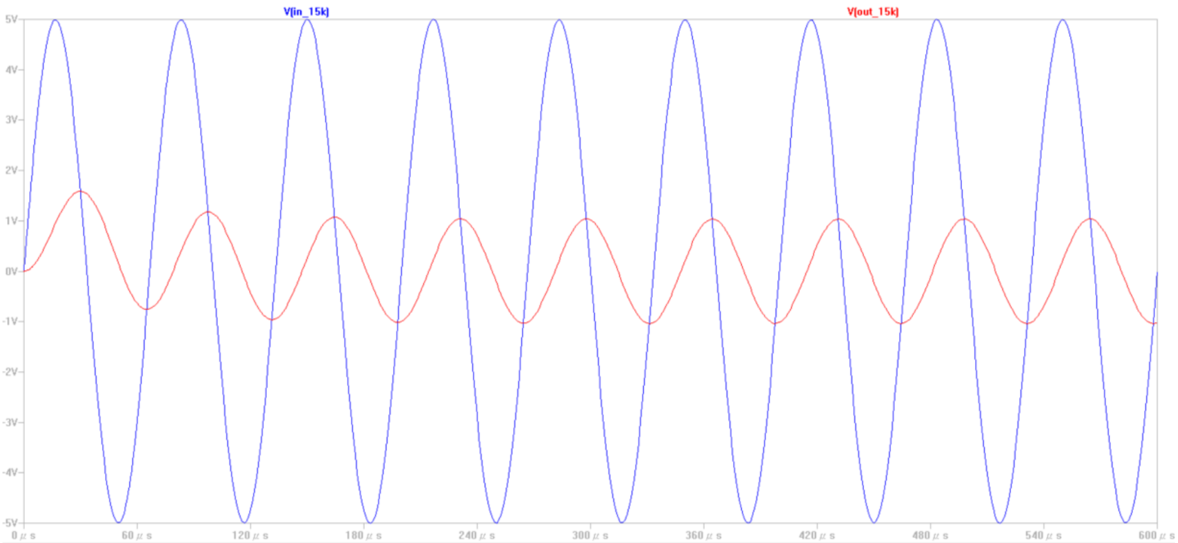
5k Hz V_{in} and V_{out} waveform



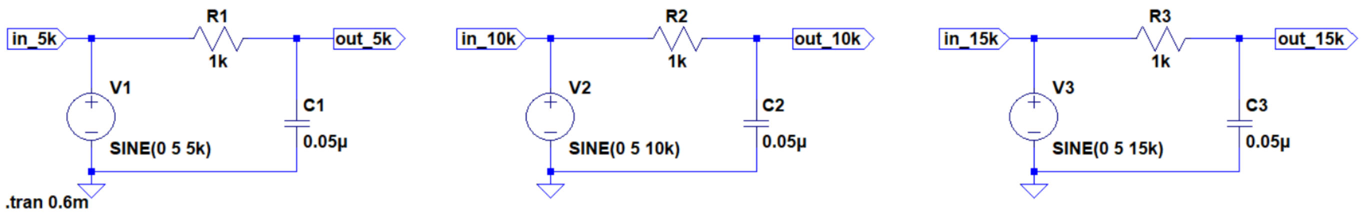
10k Hz V_{in} and V_{out} waveform



15k Hz V_{in} and V_{out} waveform

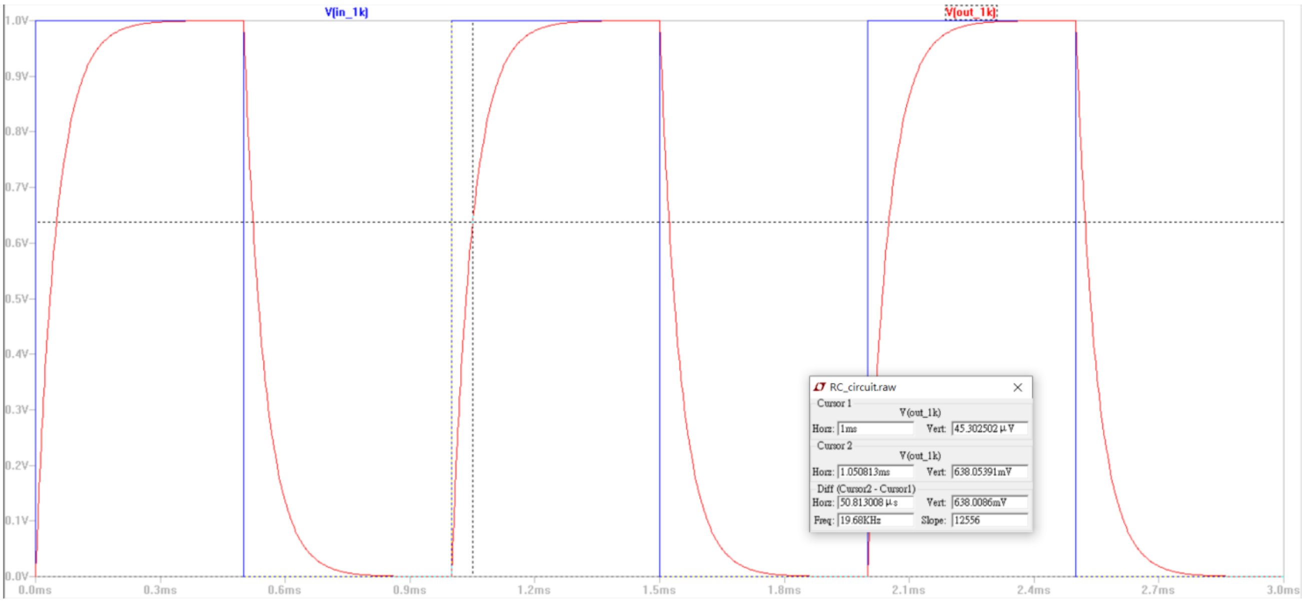


schematic

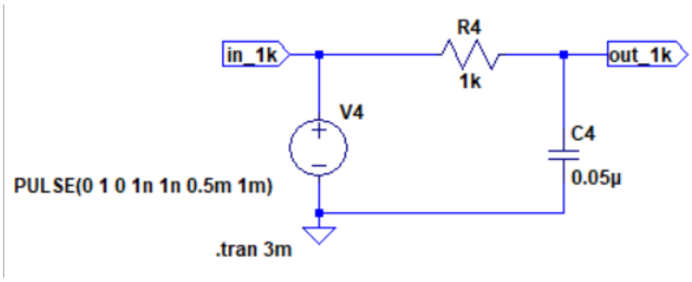


2.

Waveform



schematic



Please verify if the experiment data is satisfied with simulation results and hand calculations. Are there any differences?

My experiment data is almost the same as the LTspice simulation and my hand calculations. The time constant is almost $50\mu s$ same as the hand calculations.

Do you find anything about the relationship between output signal and input frequency?

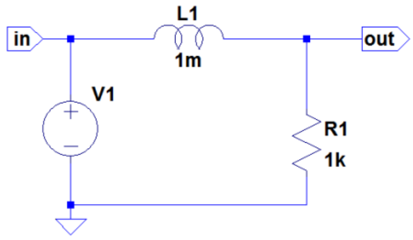
by (10), the relationship is: $V_{out} = 5\sin(2\pi ft)\left(1-e^{\frac{-t}{RC}}\right)$, differentiate by f:

$\frac{dV_{out}}{df} = 10\pi t\cos(2\pi ft)\left(1-e^{\frac{-t}{RC}}\right) = (10\pi t)\left(1-e^{\frac{-t}{RC}}\right)\cos(2\pi ft)$, we can figure that the V_{pp}^{out} is control

by $\cos(2\pi ft)$,which means that the value will not only increase but decrease as the frequency increase.

However, it might be a little wrong to induct the formula without considering the phase difference. Therefore, the result might be different to the above formula.

Experiment 2: RL Circuit

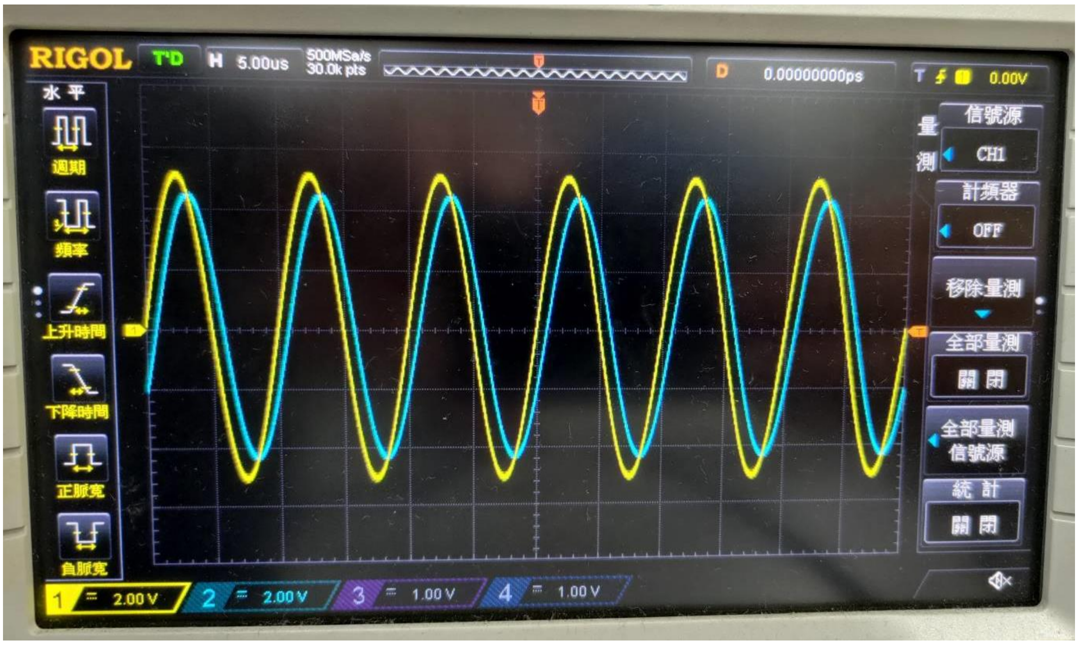


1.

Frequency (Hz)	100K	200K	300K
$V_{out,pp}$(V)	8.96	7.2	5.68

ADJUST THE OSCILLOSCOPE APPROPRIATELY

100k Hz V_{in} and V_{out} waveform



200k Hz V_{in} and V_{out} waveform

300k Hz V_{in} and V_{out} waveform

2.

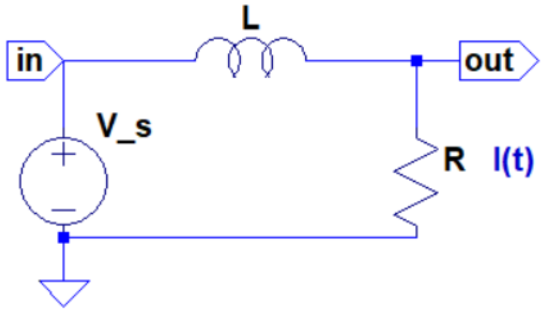
V_{in} and V_{out} waveform

time constant =$\Delta t = \Delta x =$ __$960ns = 0.96\mu s \sim 1\mu s$__ second (i.e. the value you use "cursor" function to measure)

Question:

Please use KVL and KCL to derive v_{out} function. (You need to show full solving process. NOT ONLY THE ANSWER)

Charge RL circuit:



By KVL, we have:

$$V_S - L\frac{dI}{dt} - IR = 0 \quad ...(12)$$

Divided by L on the both sides:

$$\frac{dI}{dt} + \frac{R}{L}I = \frac{V_S}{L} \quad ...(13)$$

To solve (13) on the above, we have integral factor:

$$F = e^{\int \frac{R}{L}dt} = e^{\frac{R}{L}t} \quad ...(14)$$

Then the solution of (13) is:

$$I(t) = \frac{1}{F(t)}\left[\int_0^t F(t)\cdot\frac{V_S}{L}dt + k\right], k \text{ is const} \quad ...(15)$$

Substitute with $F(t) = e^{\frac{R}{L}t}$ into (15):

$$I(t) = e^{-\frac{R}{L}t}\left[\int_0^t e^{\frac{R}{L}t}\cdot\frac{V_S}{L}dt + k\right] = \frac{V_S}{R}\left(1 - e^{-\frac{R}{L}t}\right) + ke^{-\frac{R}{L}t} \quad ...(16)$$

With the boundary condition of inductor: $I(0) = 0$

$$\frac{V_S}{R}\left(1 - e^{-\frac{R}{L}0}\right) + ke^{-\frac{R}{L}0} = 0 \Rightarrow k = 0 \quad ...(17)$$

Therefore, the solution of I is:

$$I(t) = \frac{V_S}{R}\left(1 - e^{-\frac{R}{L}t}\right) \quad ...(18)$$

Finally, we can get $V_{out} = I(t)\cdot R$, substitute with $I(t)$ in (18), we have:

$$V_{out} = \left[\frac{V_S}{R} \left(1 - e^{-\frac{R}{L}t} \right) \right] \cdot R = V_S \left(1 - e^{-\frac{R}{L}t} \right) \qquad ...(19)$$

Define time constant $\tau = \frac{L}{R}$, we have:

$$V_{out} = V_S \cdot \left(1 - e^{-\frac{t}{\tau}} \right) \qquad ...(20)$$

By (20), we can learn more about the circuit. When time pass a time constant $t = \tau = \frac{L}{R}$, then V_{out} will rise from 0 to $V_S\left(1-\frac{1}{e}\right)$, Note that $\frac{1}{e} \approx 0.368$. Therefore, $V_{out}(\tau) = V_S(1-0.368) = 0.632V_S$. That's the reason why we can use cursor to mark at $0.632V_S$, and get the time constant of the circuit.

Please use variable to answer what the time constant is equal to.

$\tau = \frac{L}{R}$

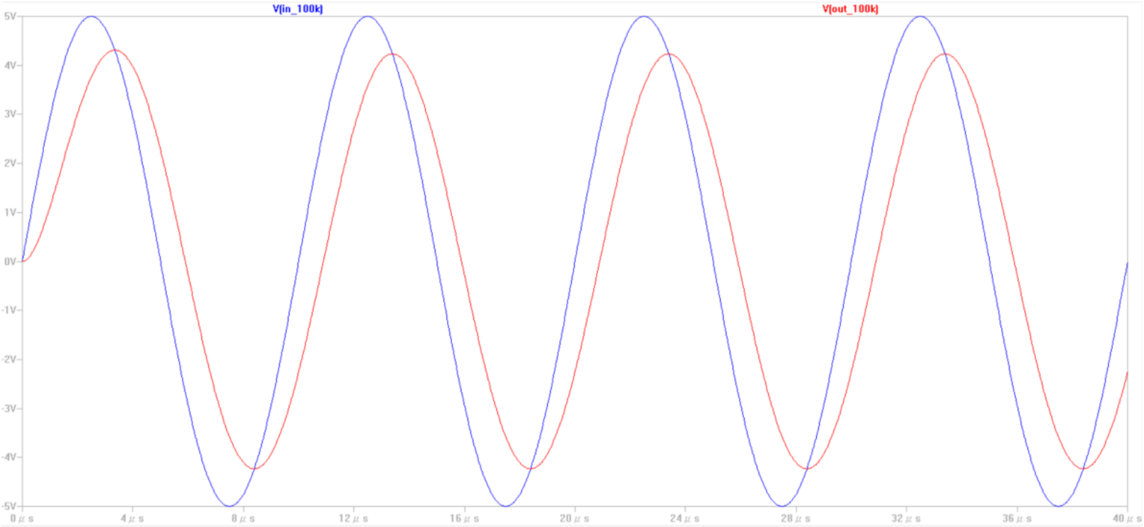
Please attach your LTSPICE simulation result for this experiment. (Both waveform and schematic)

Hint: Lab03

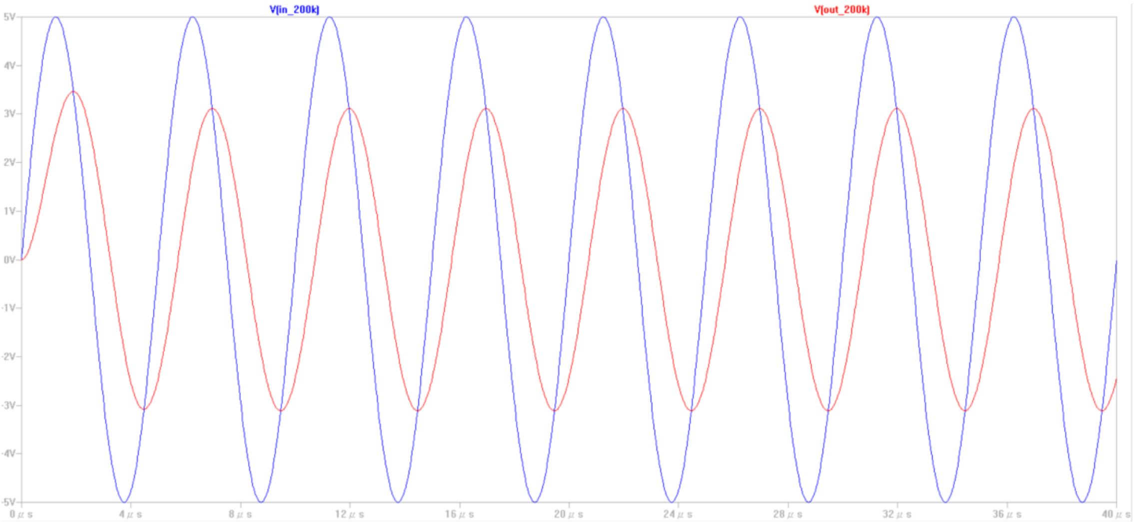
1.

Waveform

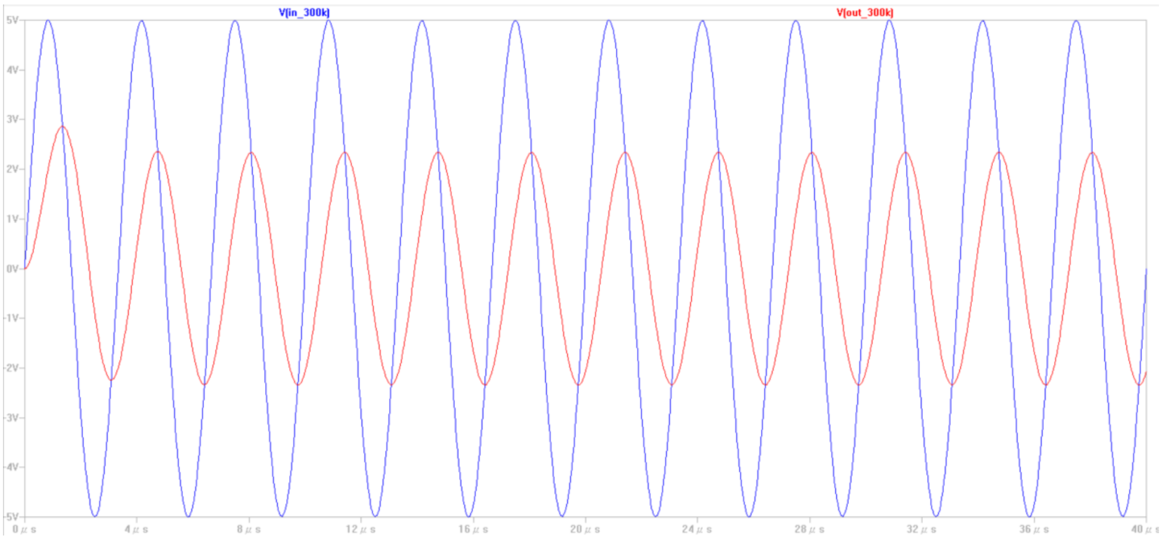
100k Hz V_{in} and V_{out} waveform



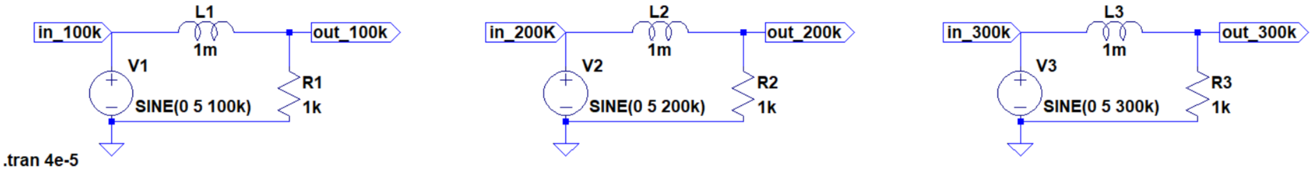
200k Hz V_{in} and V_{out} waveform



300k Hz V_{in} and V_{out} waveform

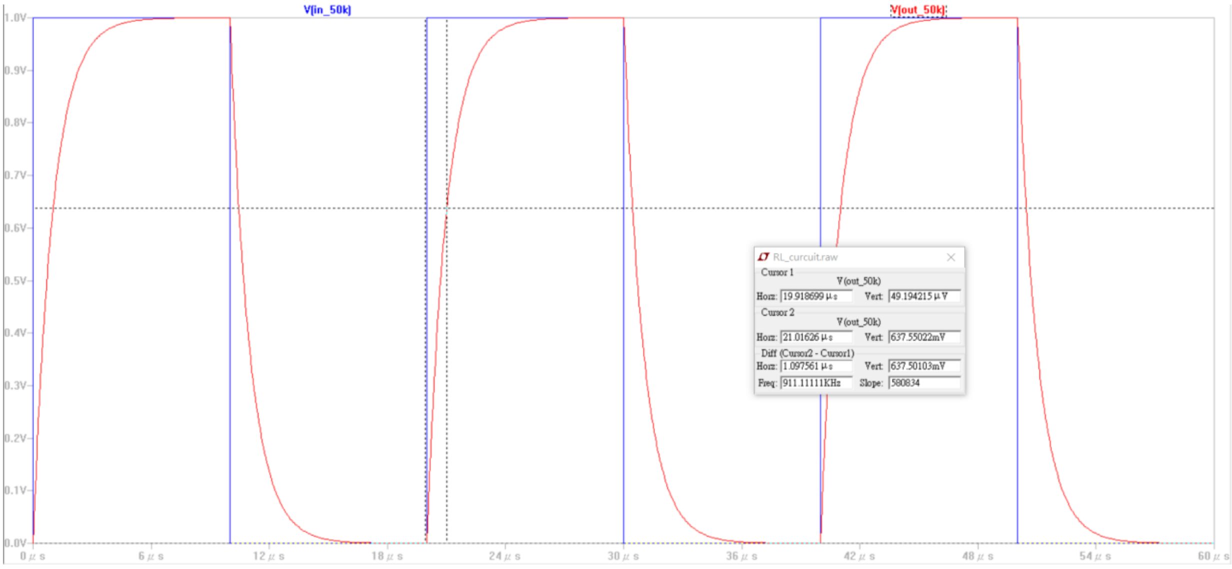


schematic

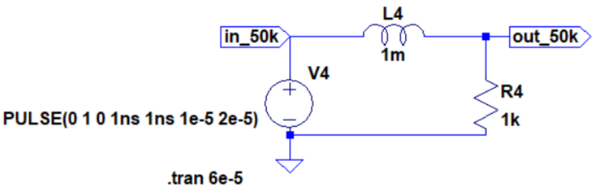


2.

Waveform



schematic



Please verify if the experiment data is satisfied with simulation results and hand calculations. Are there any differences?

In RL circuit, the output V_{pp} has a little different to the LTspice simulation. The trend of the both methods are almost the same. The difference might come from the characteristic of conductor in high frequency.

Do you find anything about the relationship between output signal and input frequency?

by $\ldots(19)$, the relationship is: $V_{out} = 5\sin(2\pi ft)\left(1-e^{-\frac{R}{L}t}\right)$, differentiate by f:

$\dfrac{dV_{out}}{df} = 10\pi t\cos(2\pi ft)\left(1-e^{-\frac{R}{L}t}\right) = (10\pi t)\left(1-e^{-\frac{R}{L}t}\right)\cos(2\pi ft)$, we can figure that the V_{pp}^{out} is control by $\cos(2\pi ft)$, which means that the value will not only increase but decrease as the frequency increase.

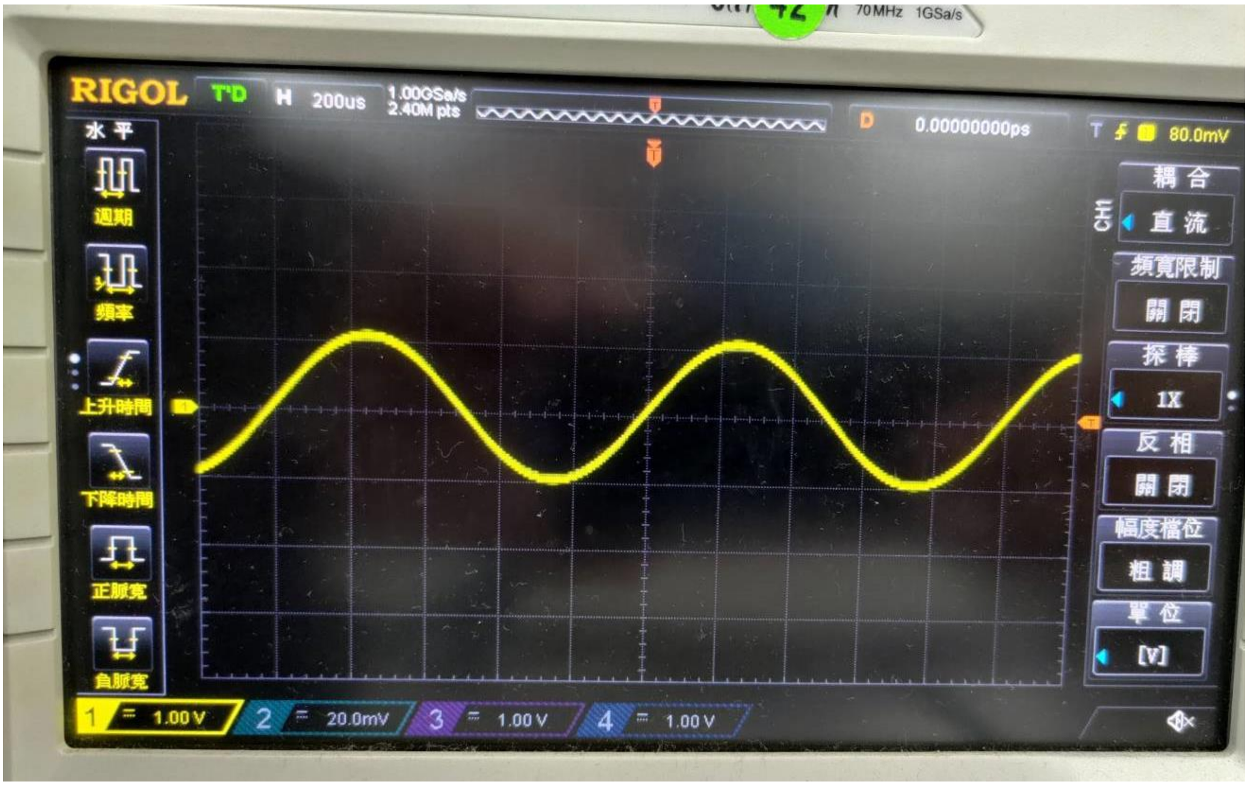
Same as above, I didn't consider phase difference in the inductive step, therefore, there might be a little different to the above formula.

Experiment 3: Speaker properties and signal sound

ADJUST THE OSCILLOSCOPE APPROPRIATELY

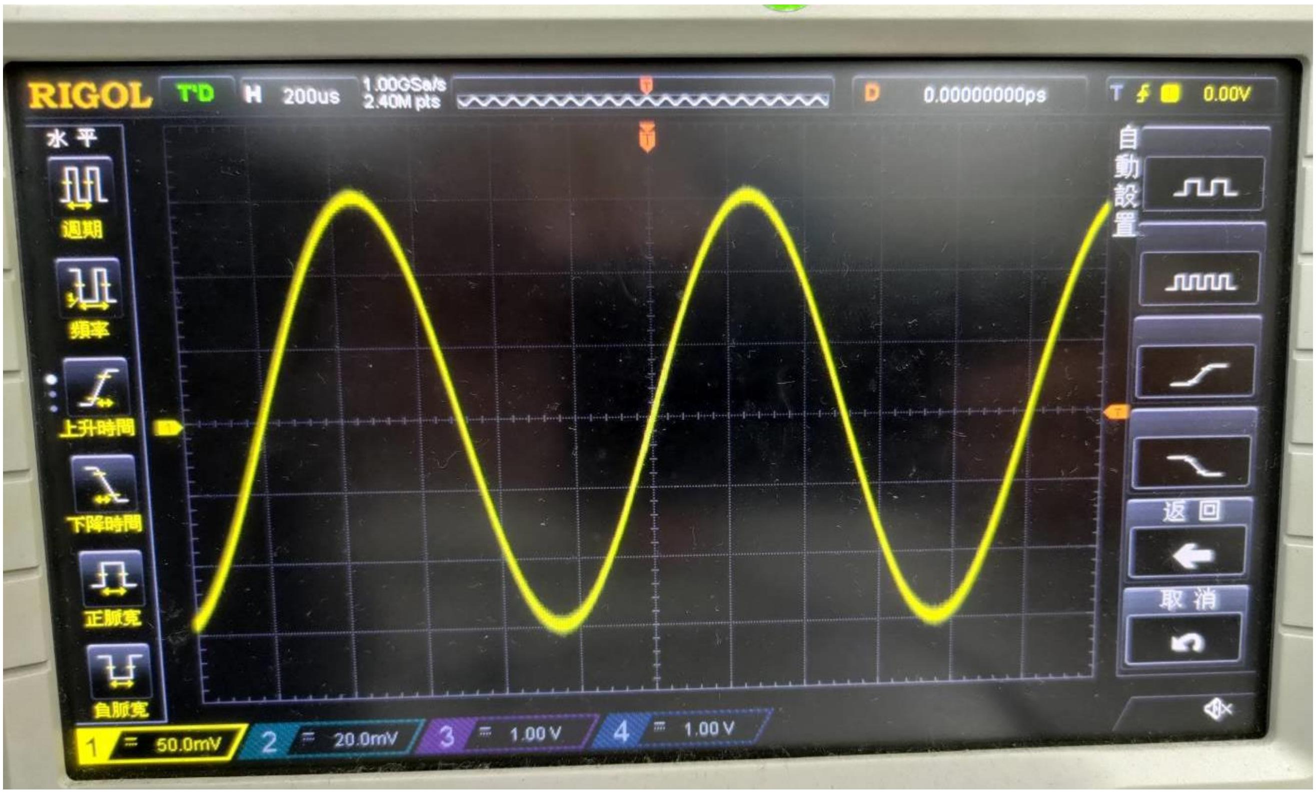
1.

waveform for FG + OSC



2.

waveform for FG + OSC + Speaker

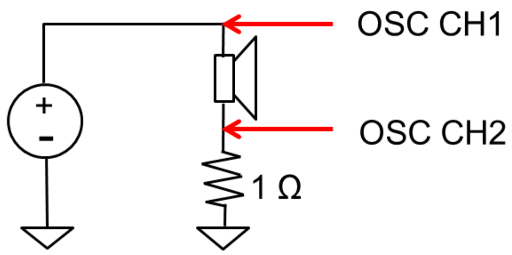


Configuration	V_{pp} of OSC CH1 (V)
FG + OSC	2
FG + OSC + Speaker	312mv

Question:
Are there any differences between these two connections?

For FG + OSC, the input directly deliver to output channel, and there is no other voltage drop between the input and output. Therefore, the V_{pp} of output channel is equal to input channel.

For FG + OSC + Speaker, there is a big voltage drop when current pass the speaker. Therefore, there is a huge drop of V_{pp} 。



3.

①

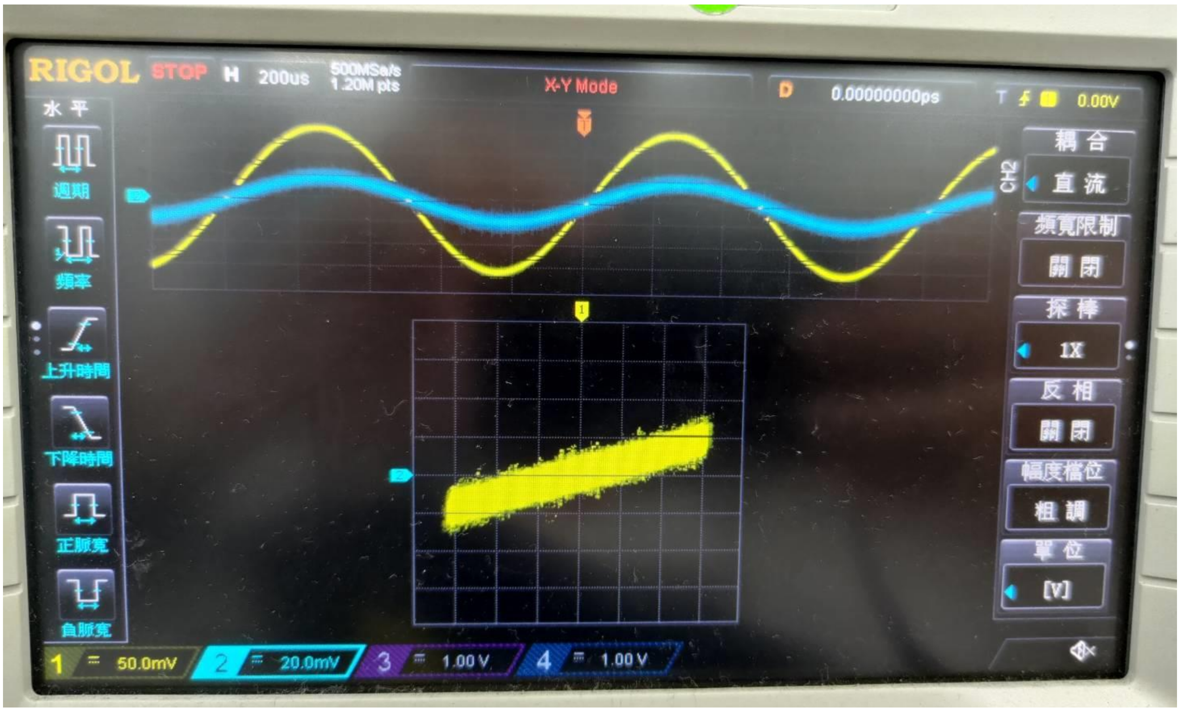
CH__1__ leads CH__2____ by __6.12____ degree.

Using measure on OSC, and get the rise time of the CH1 and CH2:

$$\phi = \frac{\Delta rise\ time}{T}\cdot 360 = \frac{(265-248)\cdot 10^{-6}s}{10^{-3}s}\cdot 360 = 6.12\,\text{degree}$$

CH1 and CH2 waveform (1 KHz)

X-Y mode plot



The Lissajous curve on the above can tell us that, the frequency of CH1 and CH2 is the same, however the phase difference is $\phi \sim 0$, since the curve is almost straight line.

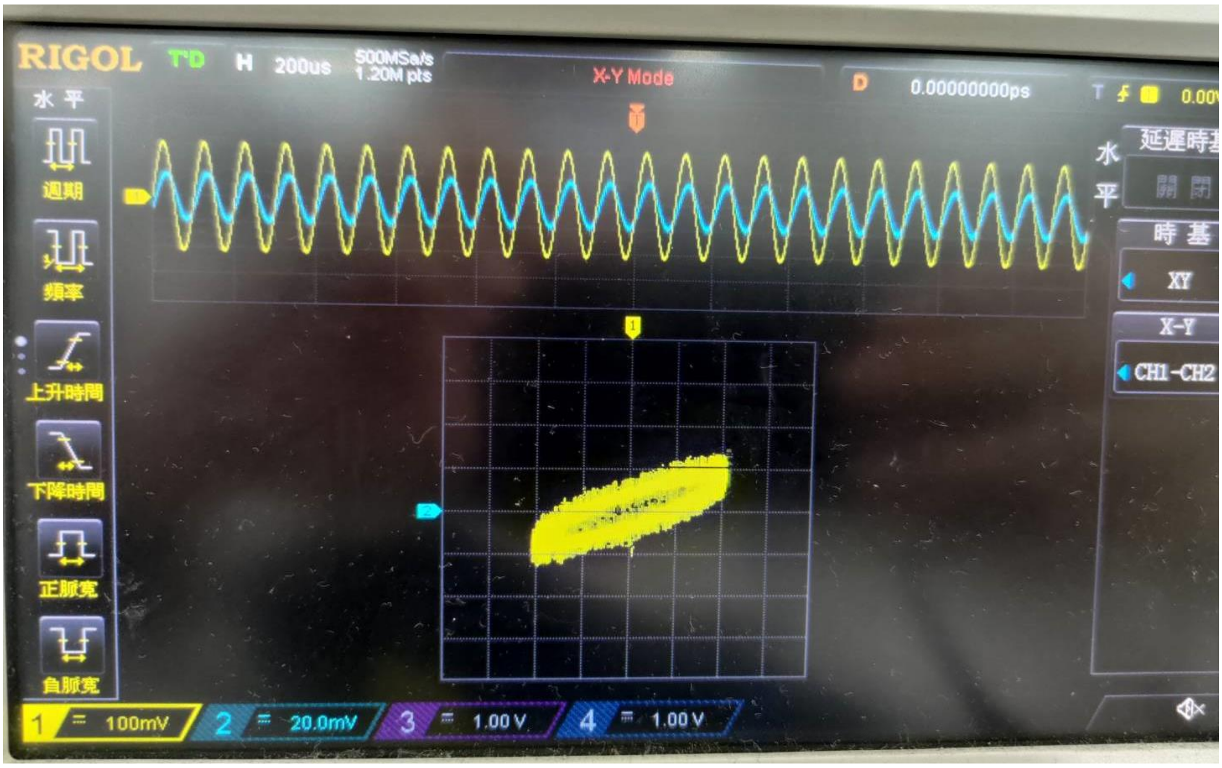
②

CH__1__ leads CH__2___ by __43.2___ degree.

$$\phi = \frac{\Delta rise\ time}{T} \cdot 360 = \frac{(36.8 - 24.8) \cdot 10^{-6} s}{10^{-4} s} \cdot 360 = 43.2 \,\text{degree}$$

CH1 and CH2 waveform (10 KHz)

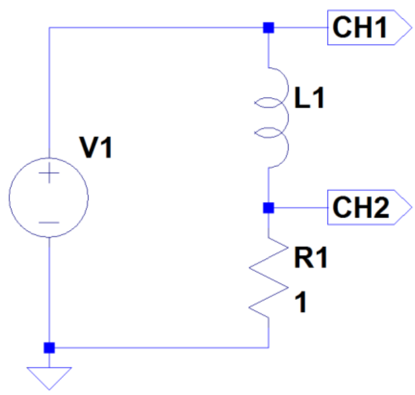
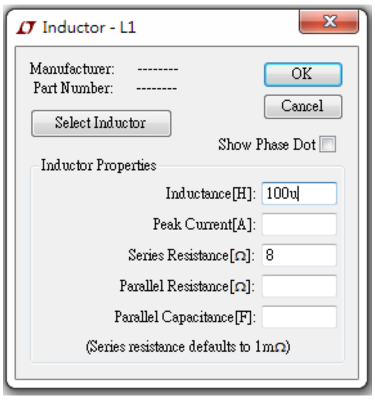
X-Y mode plot (10 KHz)



The Lissajous curve on the above can tell us that, the frequency of CH1 and CH2 is the same, however the phase difference is $0 < \phi < 90°$, since the curve is oval.

Question:

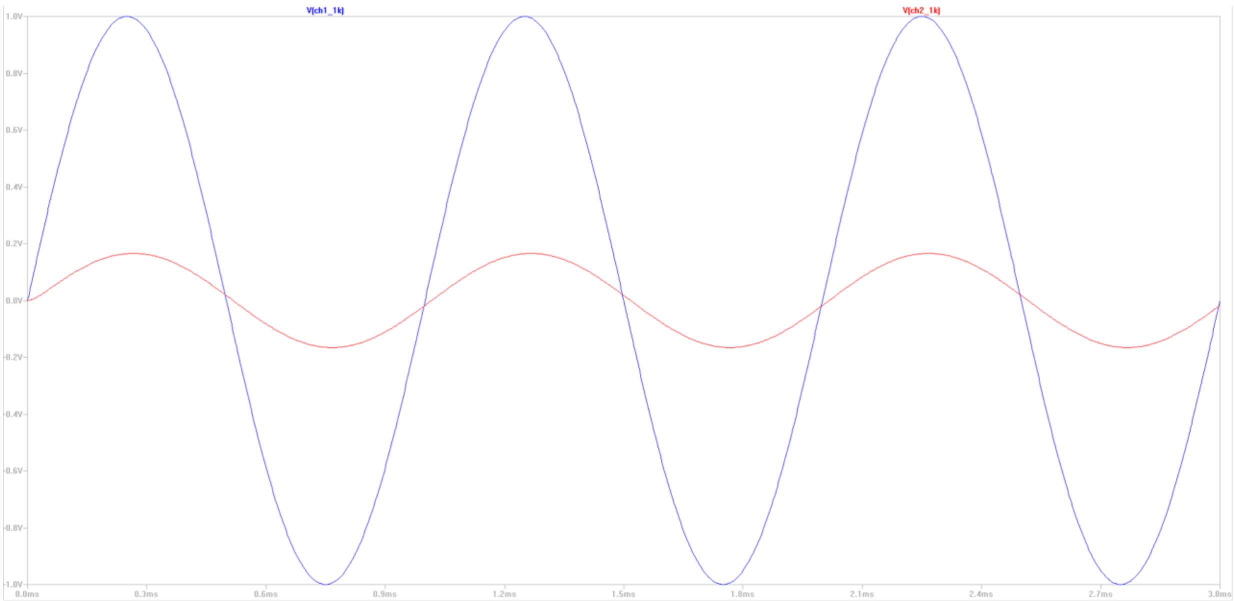
Use the following configurations to simulate Exp3-3① and Exp3-3②

Circuit Model	Inductor Attribute	Shape	Frequency (Hz)
		sine	1k
			10k

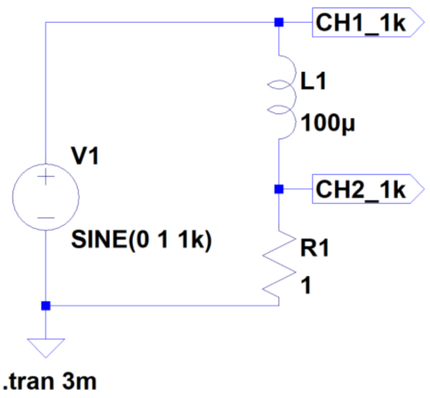
Please attach your LTSPICE simulation result for this experiment. (Both waveform and schematic)

Exp3-3①

waveform

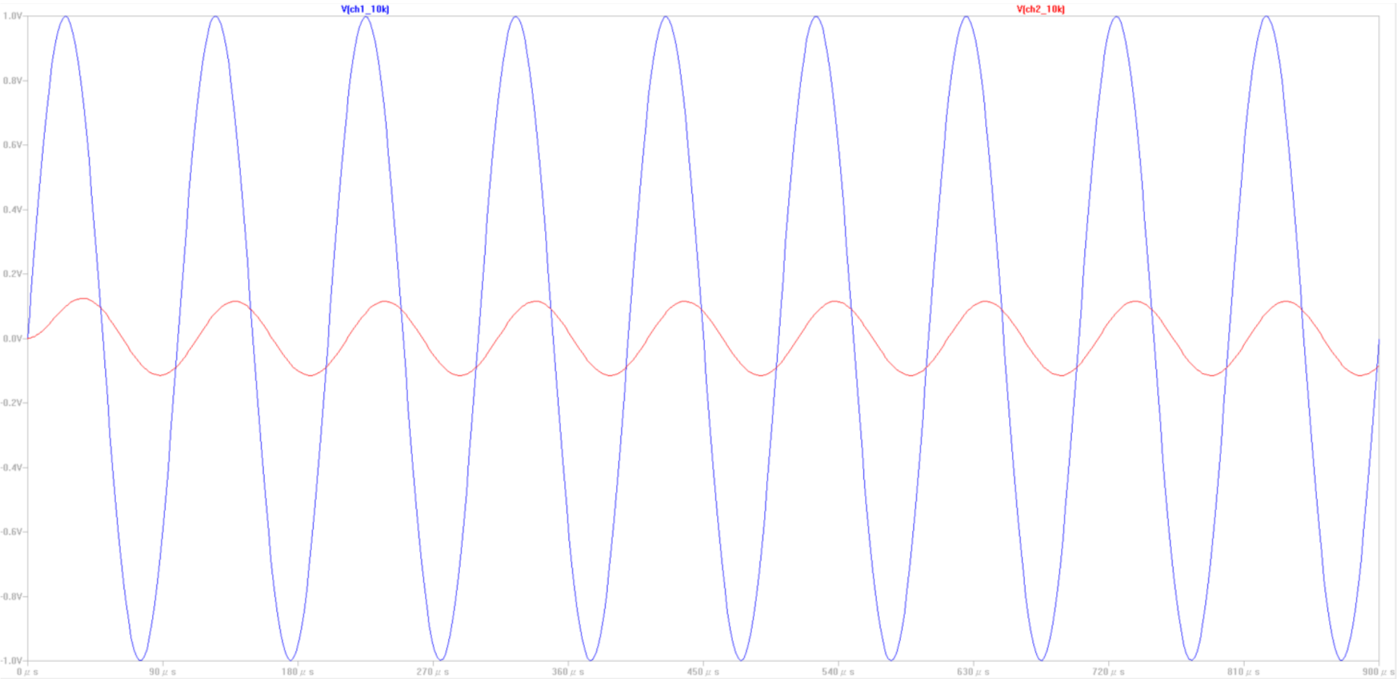


schematic

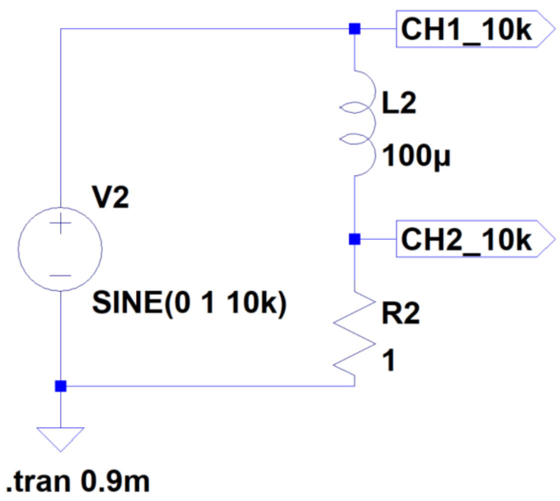


Exp3-3②

waveform



schematic



4.

Question:

Please describe the sound produced by different shape.

Sine: more fluent and smooth

Square: so annoy

Ramp: so anxious, noisy