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REPORT

Experiment 1: 分壓電路

NOTICE: PLEASE MARK APPROPRIATE "LABEL" ON YOUR SCHEMATIC

$R_{voltmeter} = \infty$			
	voltage（V_{R1}）		voltage（V_{R2}）
R_1=100Ω	5	R_2=100Ω	5
R_1=1MΩ	5	R_2=1MΩ	5

$R_{voltmeter} = \infty$, R1=R2=100 Ω

Fig1-1-1 schematic (測量 V_{R1} 使用的電路圖):

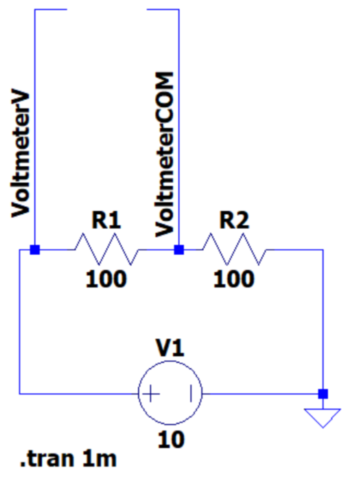
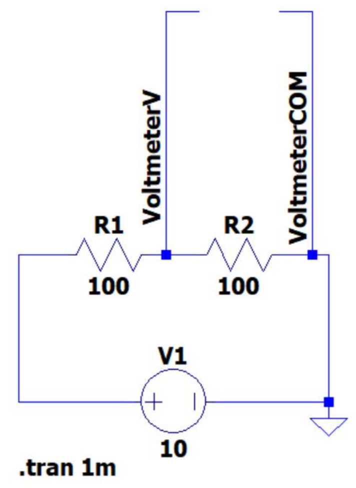


Fig1-1-2 schematic (測量 V_{R2} 使用的電路圖):



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$R_{voltmeter}$ = ∞, R1=R2=1 MΩ

Fig1-1-3 schematic (測量 V_{R1} 使用的電路圖):

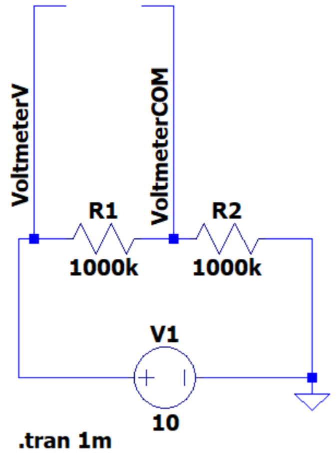
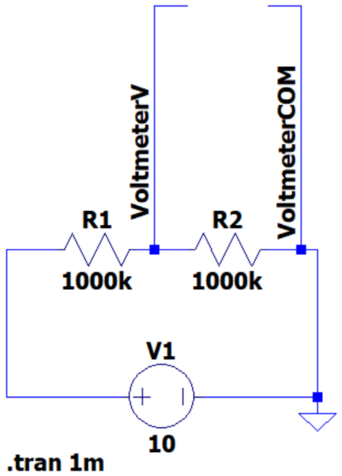


Fig1-1-4 schematic (測量 V_{R2} 使用的電路圖):



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$R_{voltmeter}$ = 1 MΩ			
	voltage（V_{R1}）		voltage（V_{R2}）
R_1=100Ω	4.9997	R_2=100Ω	4.9997
R_1=1MΩ	3.3333	R_2=1MΩ	3.3333

$R_{voltmeter}$ = 1 MΩ, R1=R2=100 Ω

Fig1-2-1 schematic (測量 V_{R1} 使用的電路圖):

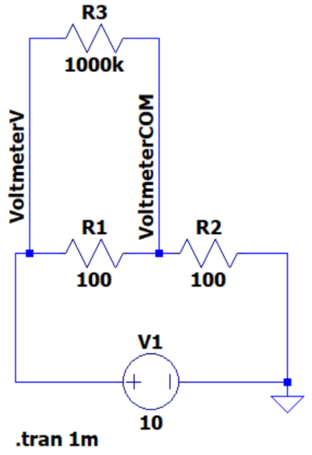
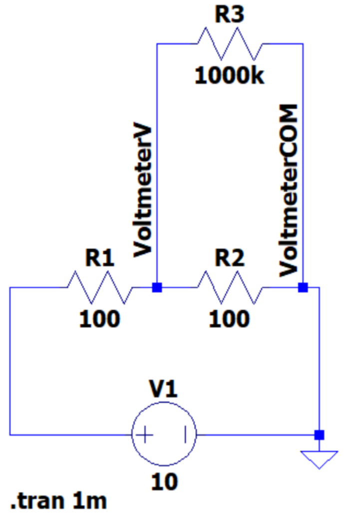


Fig1-2-2 schematic (測量 V_{R2} 使用的電路圖):



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$R_{voltmeter}$ = 1 MΩ, R1=R2=1 MΩ

Fig1-2-3 schematic (測量 V_{R1} 使用的電路圖):

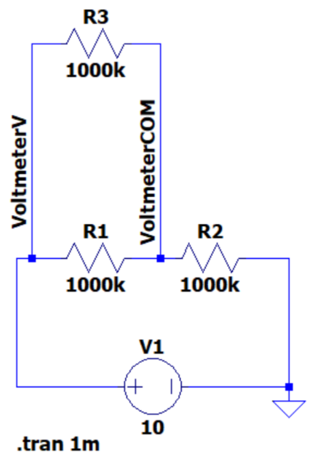
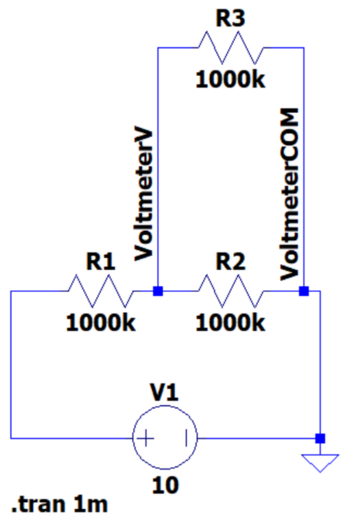


Fig1-2-4 schematic (測量 V_{R2} 使用的電路圖):



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$R_{voltmeter}$ = 10 MΩ			
	voltage（V_{R1}）		voltage（V_{R2}）
R_1=100Ω	4.99997	R_2=100Ω	4.99997
R_1=1MΩ	4.7619	R_2=1MΩ	4.7619

$R_{voltmeter}$ = 10 MΩ, R1=R2=100 Ω

Fig1-3-1 schematic (測量 V_{R1} 使用的電路圖):

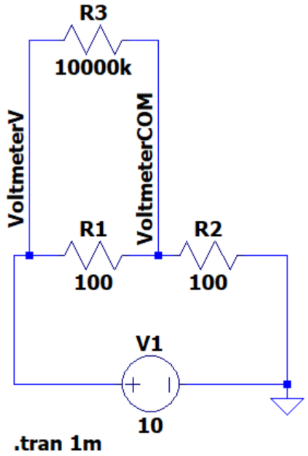
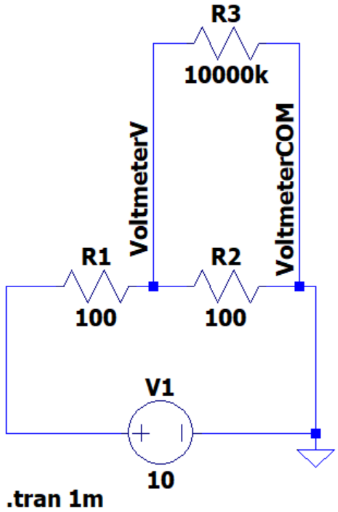


Fig1-3-2 schematic (測量 V_{R2} 使用的電路圖):



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$R_{voltmeter}$ = 10 MΩ, R1=R2=1 MΩ

Fig1-3-3 schematic (測量 V_{R1} 使用的電路圖):

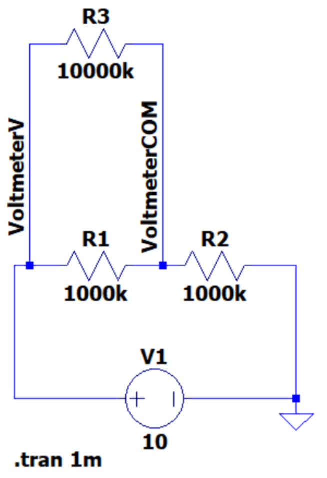
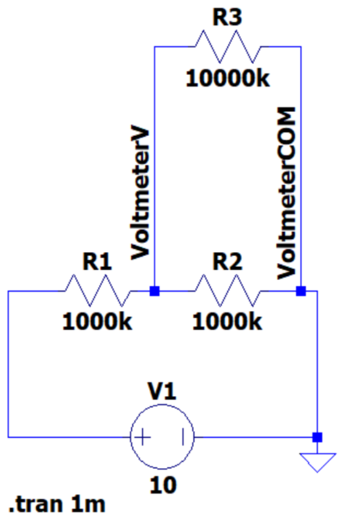


Fig1-3-4 schematic (測量 V_{R2} 使用的電路圖):



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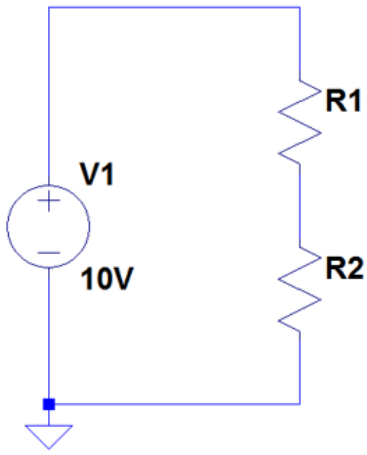
問題：

請與 lab01-exp3 結果比較並分析異同。

The following is a screenshot of Exp1-3 from my Lab1 report:

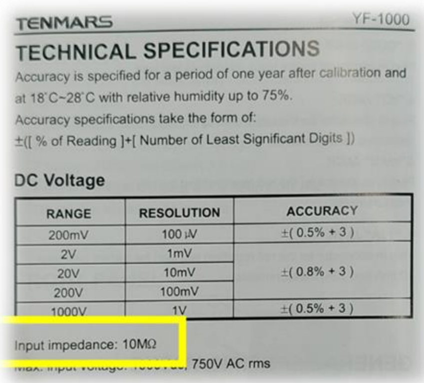
Experiment 3: The Effect Caused by the Internal Resistance of Multimeter



$$error = \frac{|V_S-(V_{R1}+V_{R2})|}{V_S} \times 100\%$$

	voltage (V_{R1})		voltage (V_{R2})	V_S	Error(%)
R_1=100Ω	4.99	R_2=100Ω	4.99	9.99	0.1%
R_1=1MΩ	4.78	R_2=1MΩ	4.74	9.99	4.7%

The multimeter I used was the TENMARS YF-1000. It has an internal resistance of 10MΩ.



TENMARS YF-1000

TECHNICAL SPECIFICATIONS

Accuracy is specified for a period of one year after calibration and at 18°C~28°C with relative humidity up to 75%.

Accuracy specifications take the form of:

±([% of Reading]+[Number of Least Significant Digits])

DC Voltage

RANGE	RESOLUTION	ACCURACY
200mV	100 μV	±(0.5% + 3)
2V	1mV	±(0.8% + 3)
20V	10mV	
200V	100mV	
1000V	1V	±(0.5% + 3)

Input impedance: 10MΩ

750V AC rms

The value measured is almost the same as what I got from LTspice simulation of 10M resistance voltmeter. This experiment once again shows that **a voltmeter must have high enough internal resistance to prevent the measurement result from being affected by the circuit it is connected to**. As it is not possible to achieve ∞ resistance, manufacturers had to settle with a relatively large value of 10M. However, if we were to measure a circuit with resistors that possess values comparable to 10M, the voltage measurements we get would be inaccurate. Just like what happened with the 1M voltmeter resistance simulation.

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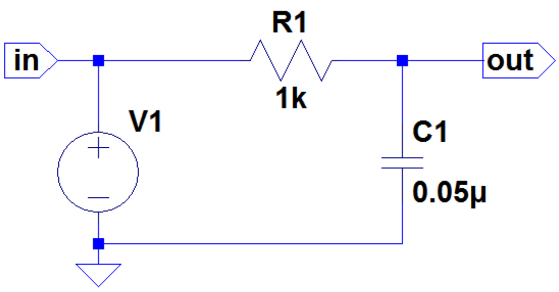
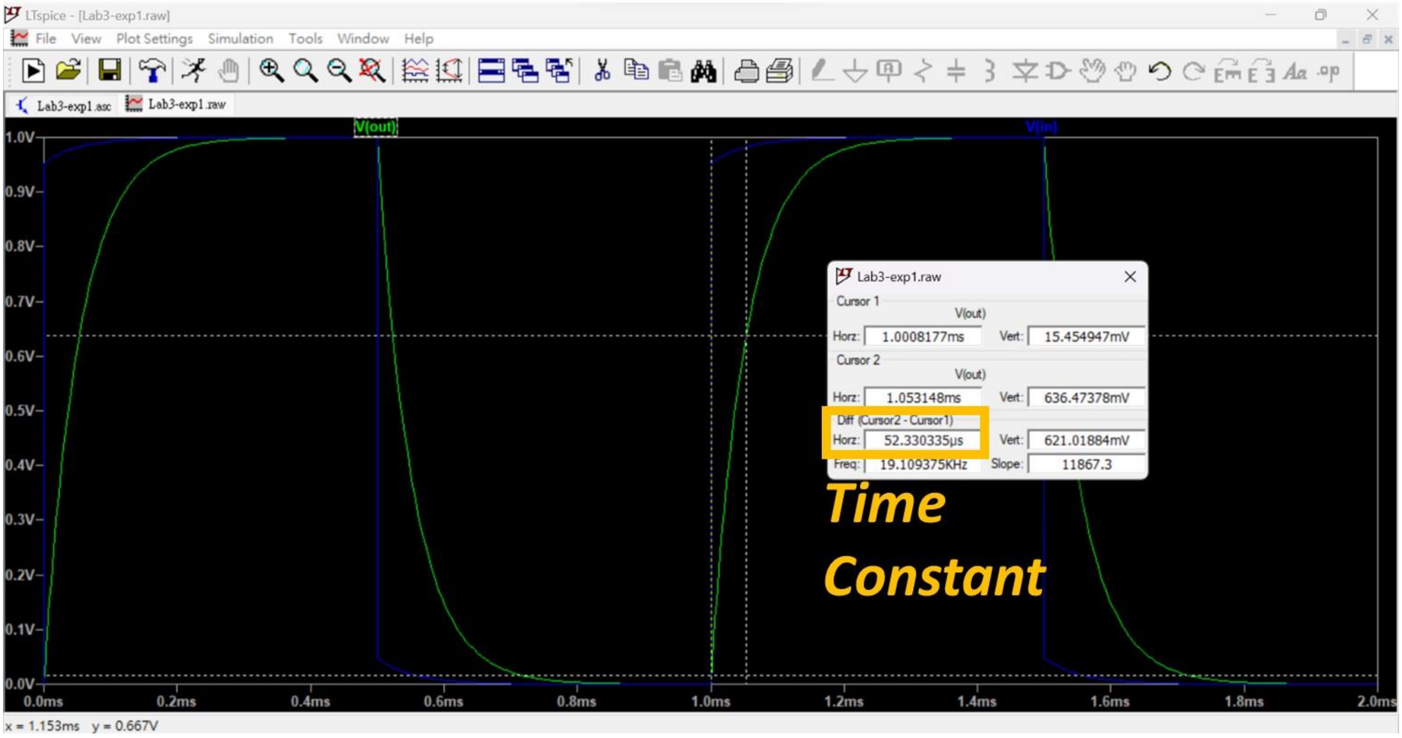
Experiment 2: RC 充放電電路



節點 in 與 out 的波形圖：

（請記得標示與時間常數有關的標籤）



其中，節點 in 為____藍____色（填寫顏色），節點 out 為____綠____色

$$V_c(t) = V_{in}(1 - e^{\frac{-t}{\tau}})$$

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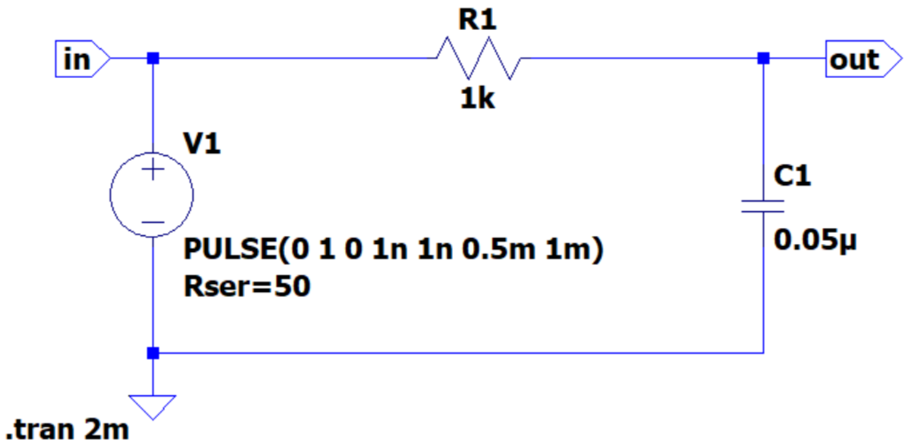
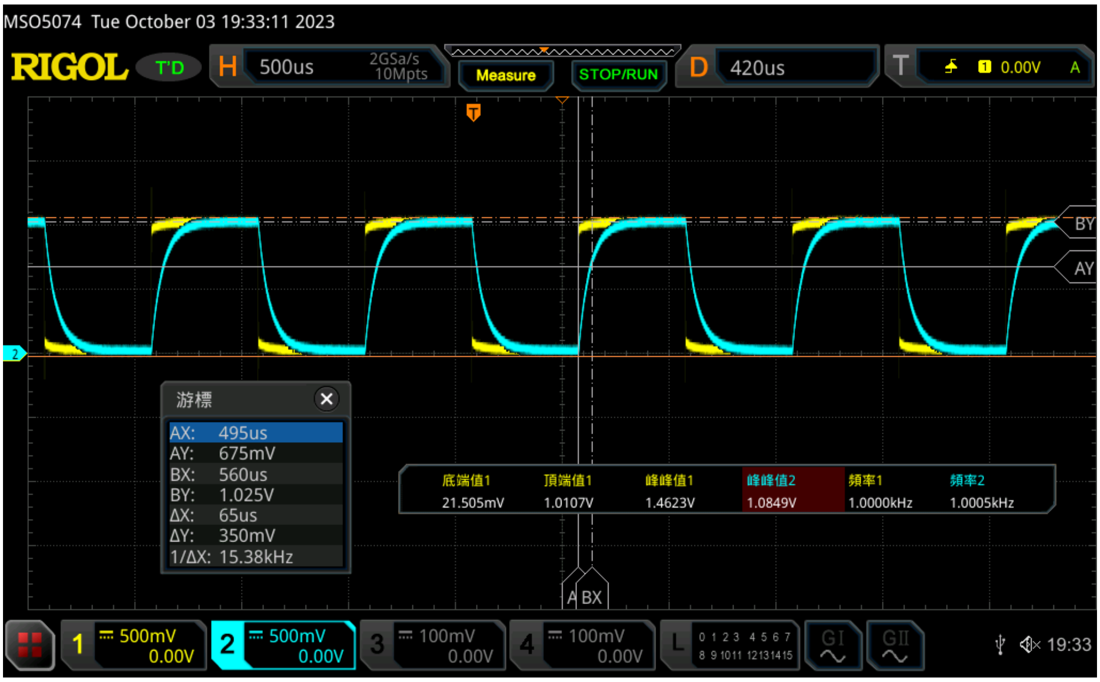
Schematic for RC circuit:



問題：

請與 lab03-exp1 結果比較並分析異同。

The following is the waveform screenshot I took for exp3-1:



During Exp3-1, I may have made some mistakes while measuring the time constant. It was supposed to be 50 μ s according to calculations. In fact, I simulated the experiment using LTspice at home while working on the report for Lab3, and I got 50 μ s. Therefore, if done correctly, the simulation result should **be almost the exact same as what we measured during Lab3.**

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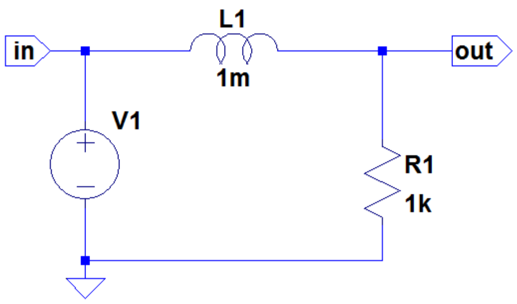
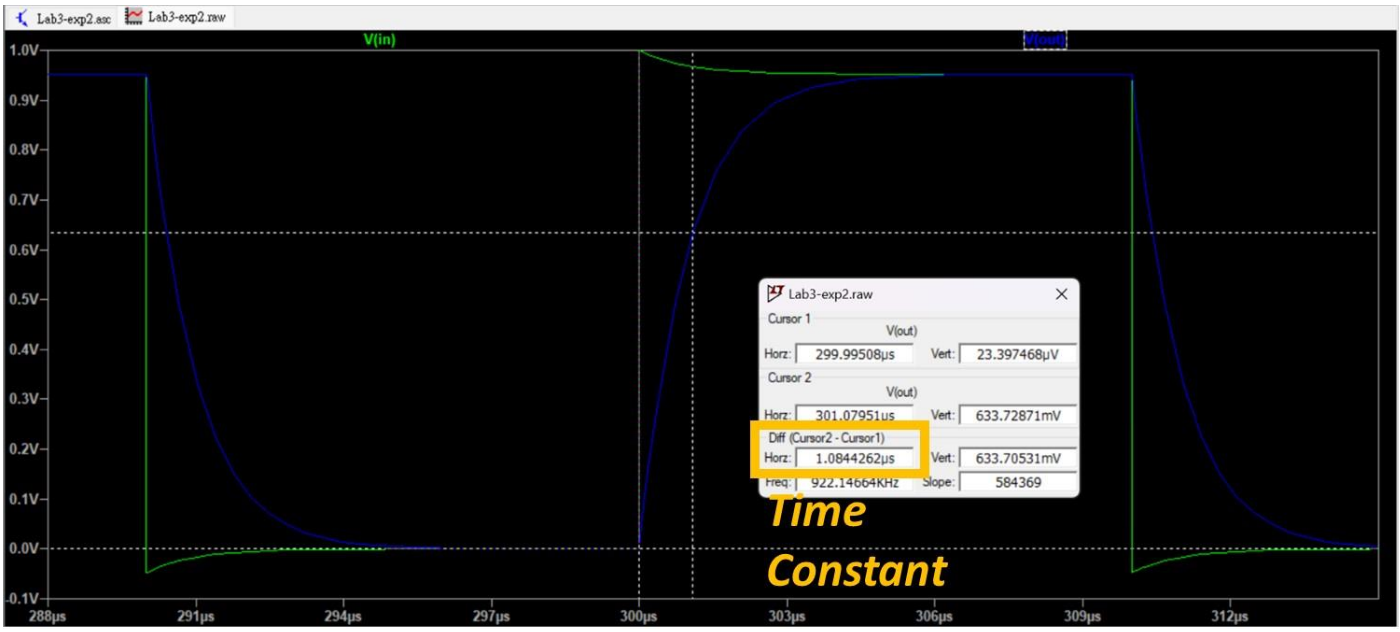
Experiment 3: RL 充放電電路

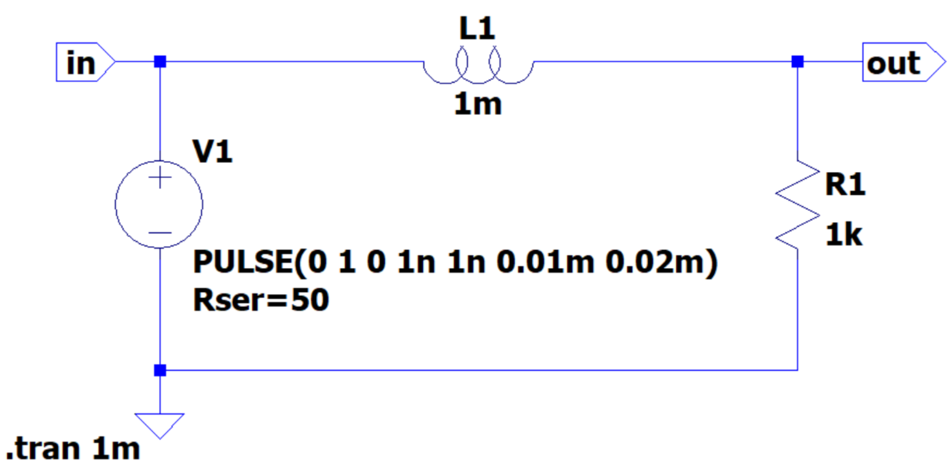


節點 in 與 out 的波形圖：
（請記得標示與時間常數有關的標籤）



其中，節點 in 為 綠 色（填寫顏色），節點 out 為 藍 色

Schematic for RC circuit:



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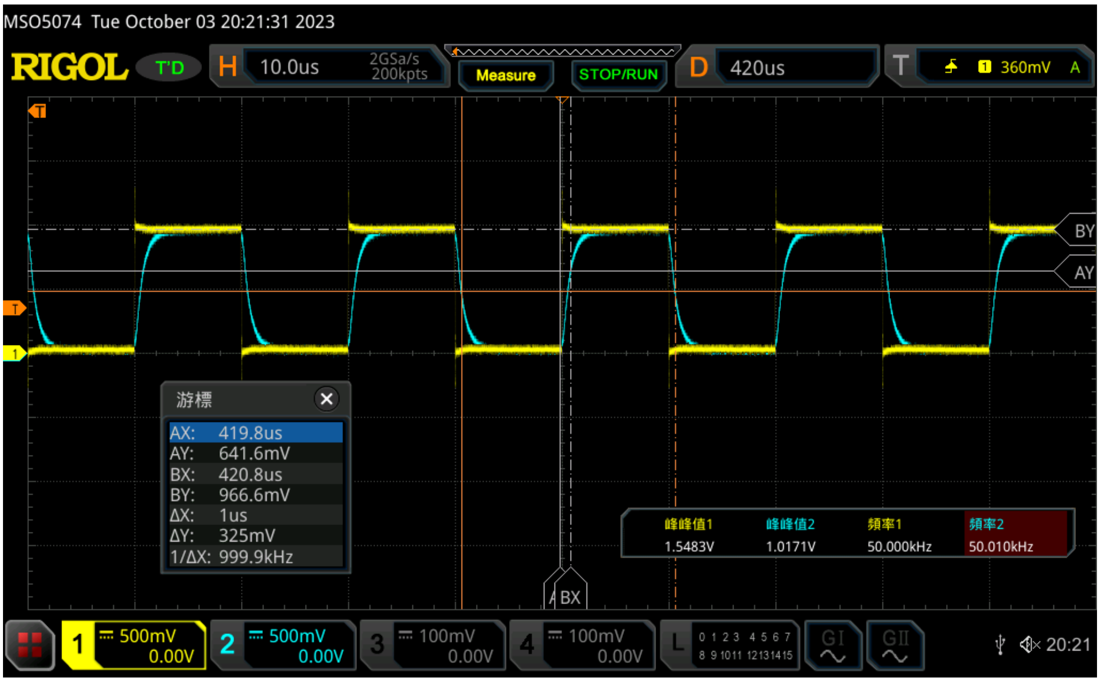
問題：

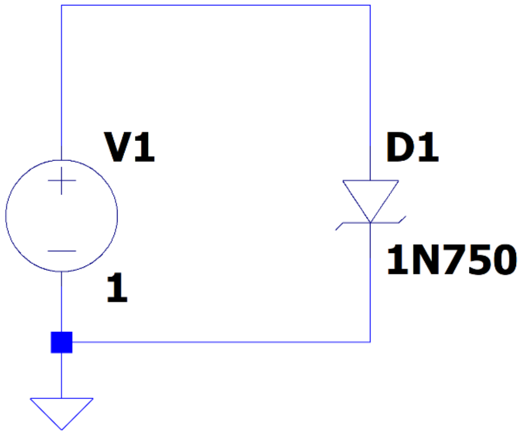
請與 lab03-exp2 結果比較並分析異同。

The following is the waveform screenshot I took for exp3-2:

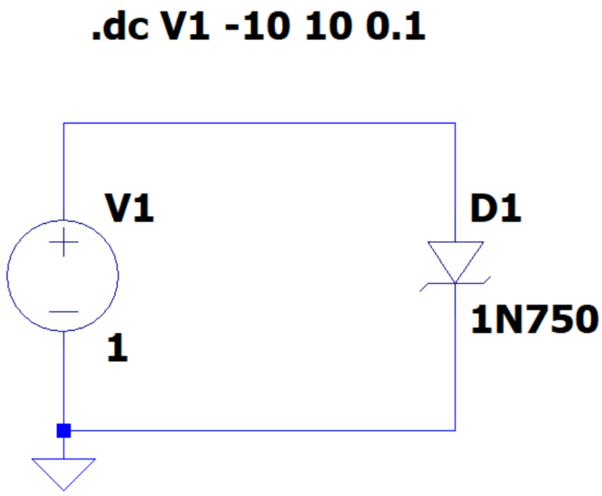


The simulation **aligns perfectly with what I measured in Exp3-2.** This demonstrates just how useful LTspice is. It might be wise to simulate future experiments beforehand if time permits. This will allow us to determine whether the results we acquire hands-on are accurate.

Experiment 4: 二極體特性曲線



schematic 圖（含所有需要使用的指令）:



IV curve of 1N750 Zener diode:

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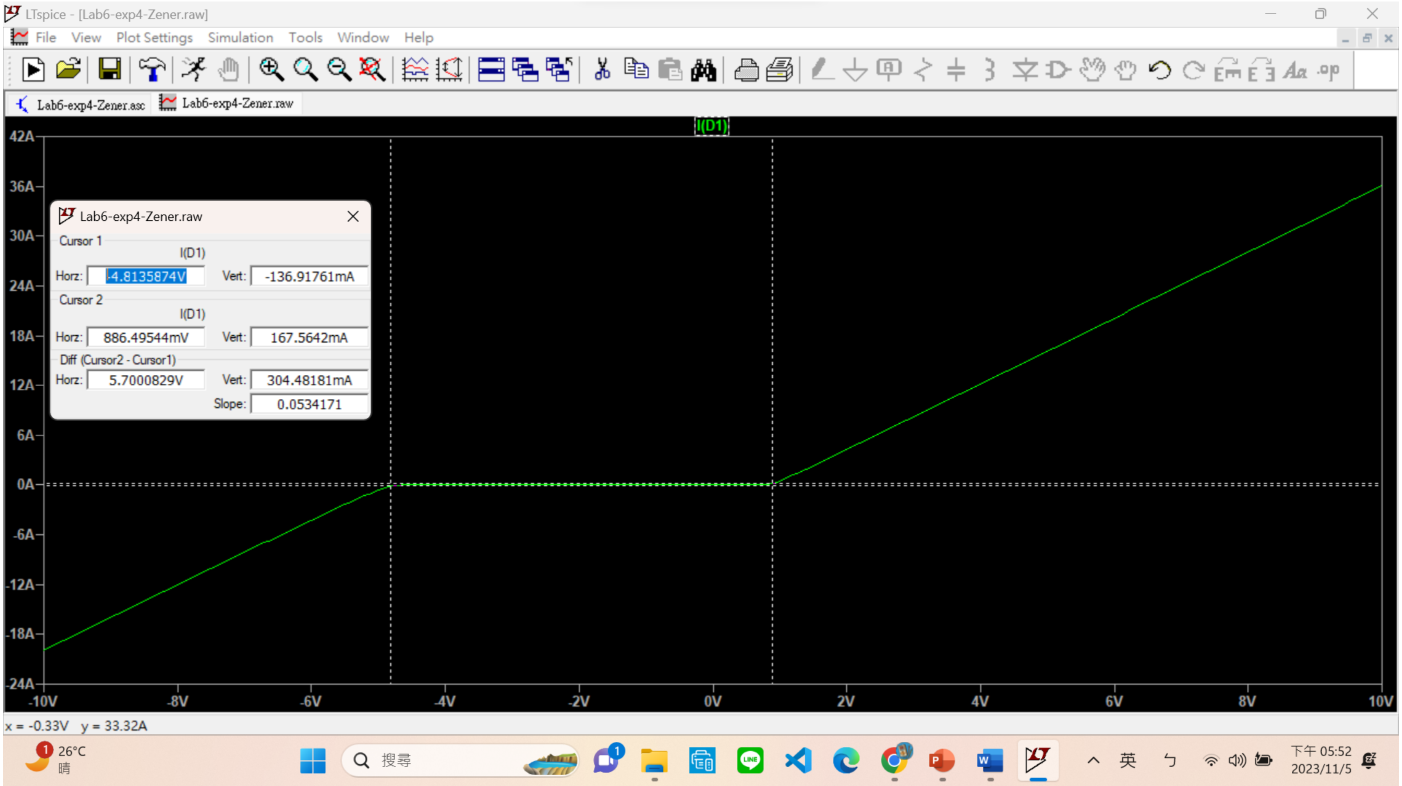
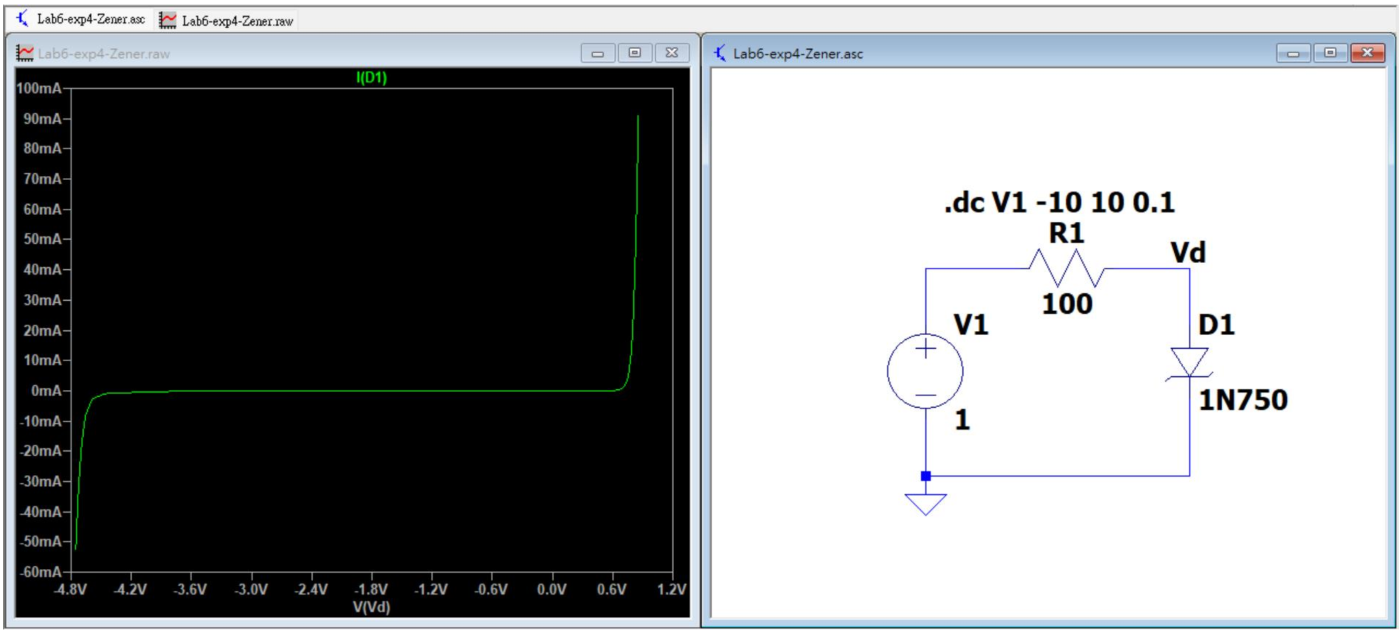


問題：

請嘗試描述圖中曲線的意義（可配合電子學內容）

The IV curve tells us that the diode has a cut-in voltage of 0.887V and a breakdown voltage of -4.814V. Before reaching either of these two voltage levels, it will not conduct current.

With **no resistor connected, the IV curve appears to be linear** past the cut-in/breakdown voltage. However, once a resistor is connected, we can observe a drastic change in the diode's behavior, the **voltage level remains nearly constant despite current change**. This characteristic allows the Zener diode to be used for voltage regulation.



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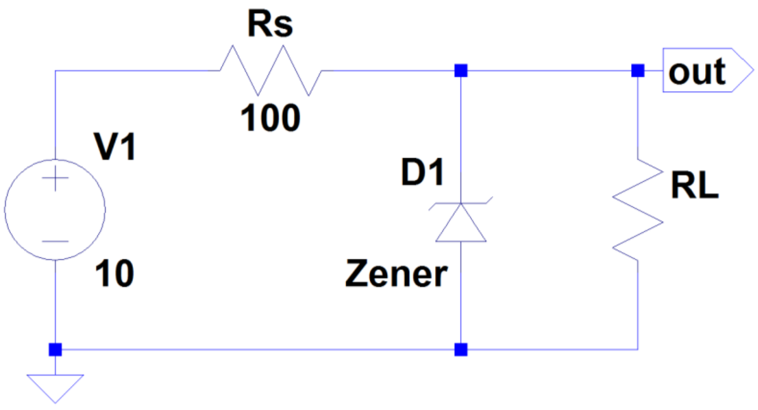
An example of this usage is the **shunt regulator** from part 1 of the midterm project. It **allows current to bypass the load when the input voltage exceeds the desired output voltage by providing a low-impedance path**.



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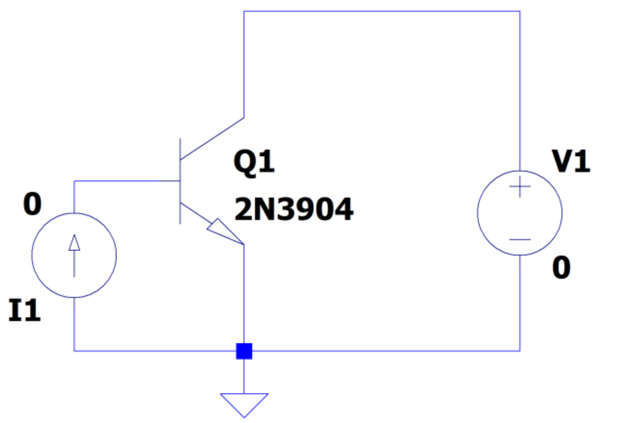
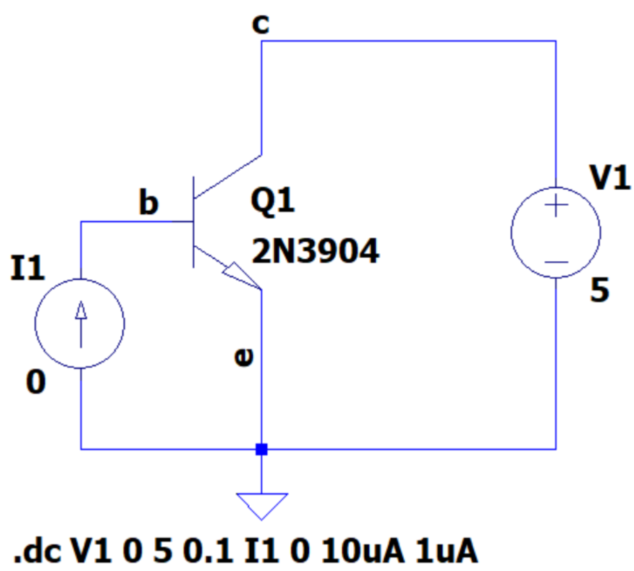
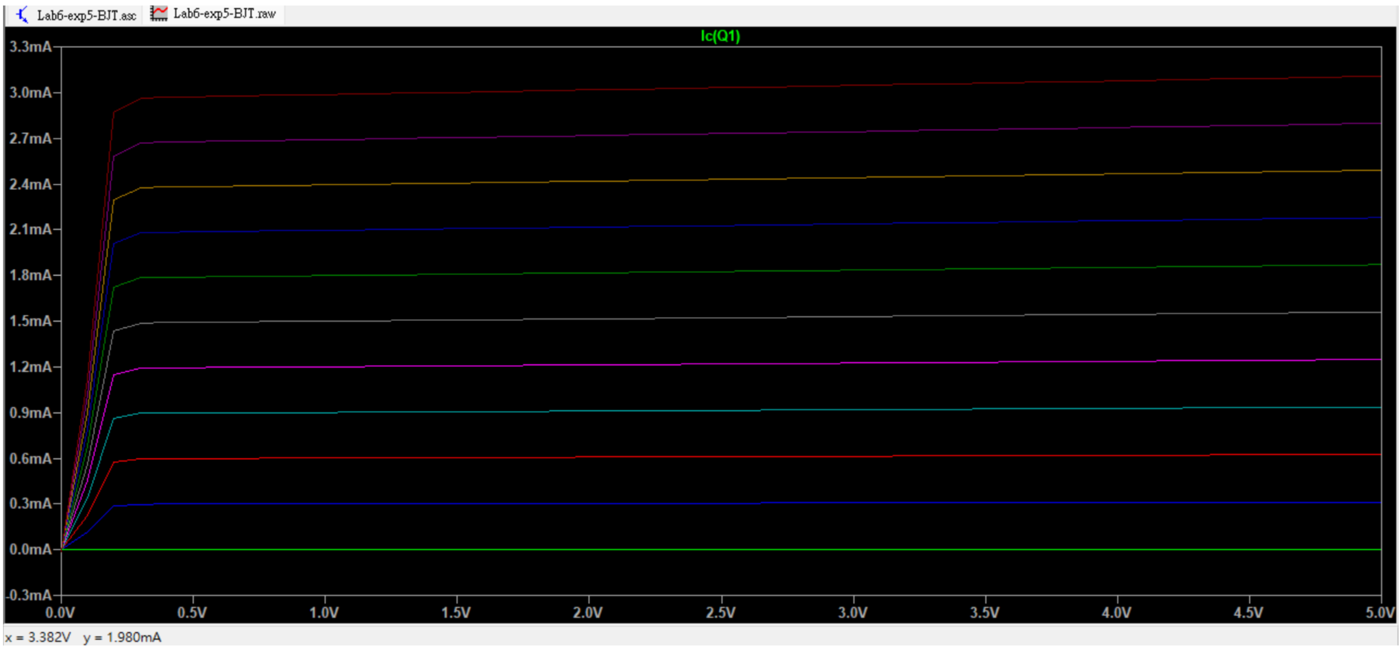
Experiment 5: BJT 特性曲線



schematic 圖（含所有需要使用的指令）：



IV curve of BJT 2N3904:



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問題：

請問 DC sweep 中，1st source 與 2nd source 分別對應到曲線圖上的哪些地方？

1st source: X-axis, voltage 0~5.0V, increasing at an interval of 0.1V

2nd source: Y-axis, current 0~10 μA, increasing at an interval of 0.1 μA

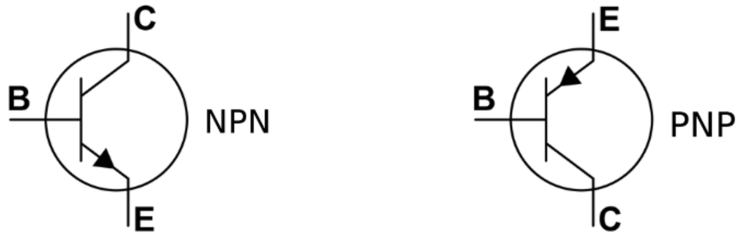
What are BJTs?

BJT stands for Bipolar Junction Transistor, and it is a type of semiconductor device. It is a **three-layer semiconductor** device made of two types of semiconductor material (typically silicon). The three layers are the **emitter, base, and collector**.

Variants:

- NPN (Negative-Positive-Negative)
  - **Base requires positive** voltage turns on
  - Current flows from **Collector to Emitter**

- PNP (Positive-Negative-Positive)
  - **Base requires negative** voltage turns on
  - Current flows from **Emitter to Collector**



Operation:

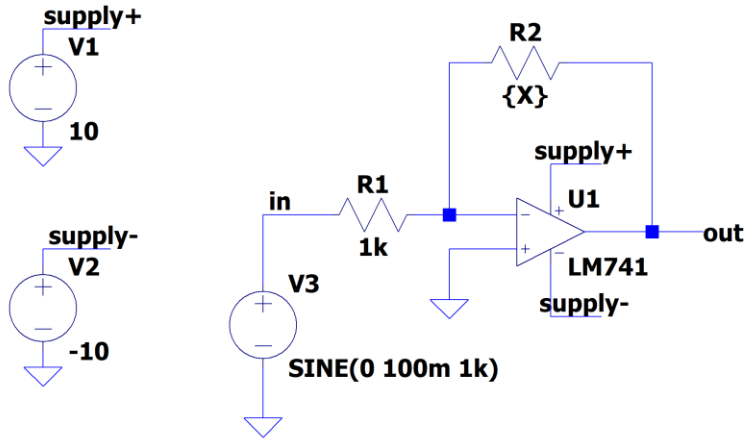
BJTs operate by controlling the flow of current between the collector and emitter terminals. The base terminal is used to control this current. **When a small current flows into the base-emitter junction, it allows a larger current to flow between the collector and emitter**. The transistor can amplify or switch signals depending on how it's configured in a circuit.

Applications:

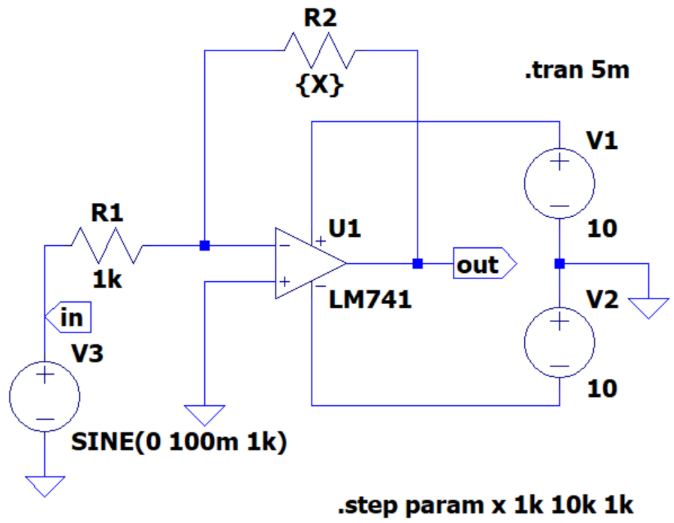
- Amplification: BJTs can be **used as amplifiers** to increase the strength of a weak signal. In this mode, they operate in the active region, where **a small change in the base current results in a larger change in the collector current**. This property makes them useful in applications like audio amplification.
- Switching: BJTs can also be **used as switches**, allowing current to flow between the collector and emitter when the base-emitter junction is forward-biased and turning off the current when it is

reverse-biased. This is known as the cut-off and saturation regions of operation and is useful for digital logic and switching applications.

Experiment 6: 有可變電阻的電路（.step param語法練習）



schematic 圖（含所有需要使用的指令）：



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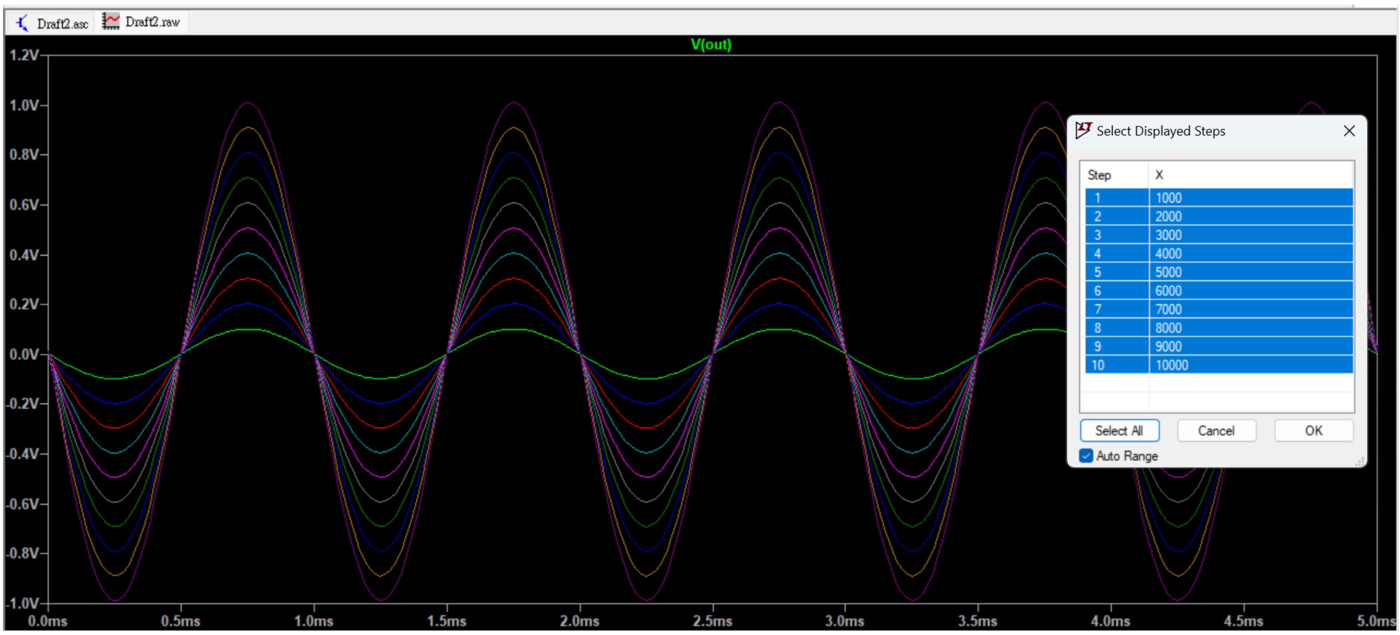
節點 out 的波形圖（含各種 R2 電阻標示）：



References:

1. All About Circuits: Introduction to Bipolar Junction Transistors (BJT)
   https://www.allaboutcircuits.com/textbook/semiconductors/chpt-4/bipolar-junction-transistors-bjt/
2. All About Circuits: What are Zener Diodes?
   https://www.allaboutcircuits.com/textbook/semiconductors/chpt-3/zener-diodes/