Department of Electrical and Computer Engineering
University of Victoria
ELEC 300 - Linear Circuits II

LABORATORY REPORT

Experiment No.: ______________________________

Title: ______________________________

Date of Experiment: ______________________________

(should be as scheduled)

Report Submitted on: ______________________________

(should be within one week from the time of experiment)

To: ______________________________

Laboratory Group #: ______________________________

Names: (please print) ______________________________

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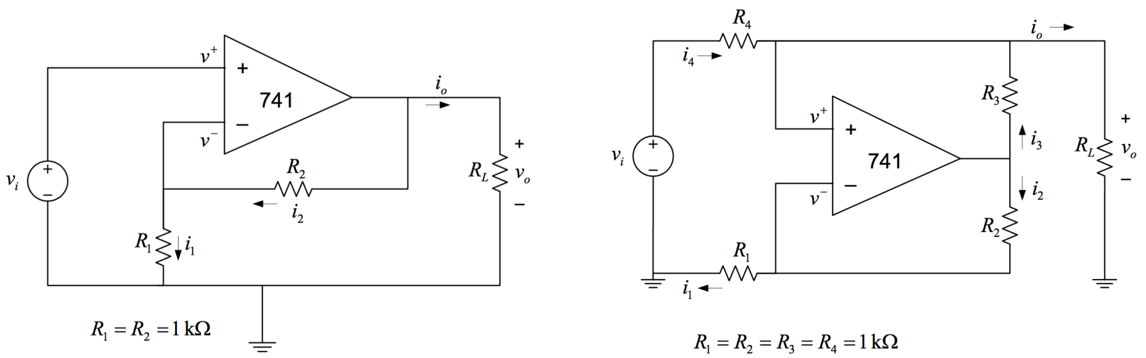
Fig. 0-1. The front page of a lab report

# 1 Objective

To create two variants of independent sources, both a voltage source and a current source, and analyze their behaviour compared to that expected from theory and calculations.

# 2 Introduction

Operational amplifiers (op amps) can be used to transform a fixed voltage source into a variable voltage or current source. The output gain, $K$, of the voltage or current is controlled by the feedback network for the op amp. A voltage-controlled voltage source (VCVS) (Fig. 1(a)) and a voltage-controlled current source (VCCS) (Fig. 1(b)) were created in this lab using an LN741 op amp.




(a) VCVS with $K = 2$

(b) VCCS with $K = 1$ when $R_L = 1\,\mathrm{k}\Omega$

Figure 1: Circuits constructed in this lab [1, p. 17]

Since the VCVS is constructed as a non-inverting amplifier its governing equation is:

$$V_0 = V_i \left( \frac{R_2}{R_1} + 1 \right) = KV_i. \tag{1}$$

Careful application of Kirchoff's Laws yields the following relation for the VCCS:

$$I_o = \frac{V_i}{R}$$

where $R_1 = R_2 = R_3 = R_4 = R$. The output voltage is constrained to:

$$\frac{R}{R_L} \cdot \frac{V_{cc}^-}{2} < V_i < \frac{V_{cc}^+}{2} \cdot \frac{R}{R_L} \tag{2}$$

# 3 Results

## 3.1 Voltage controlled voltage source (VCVS)

A VCVS was constructed following the schematic in Fig. 1(a). $\pm 10$ V was used as supply voltage for the op amp. The response of the output voltage to changes in input voltage is shown in Fig. 2.

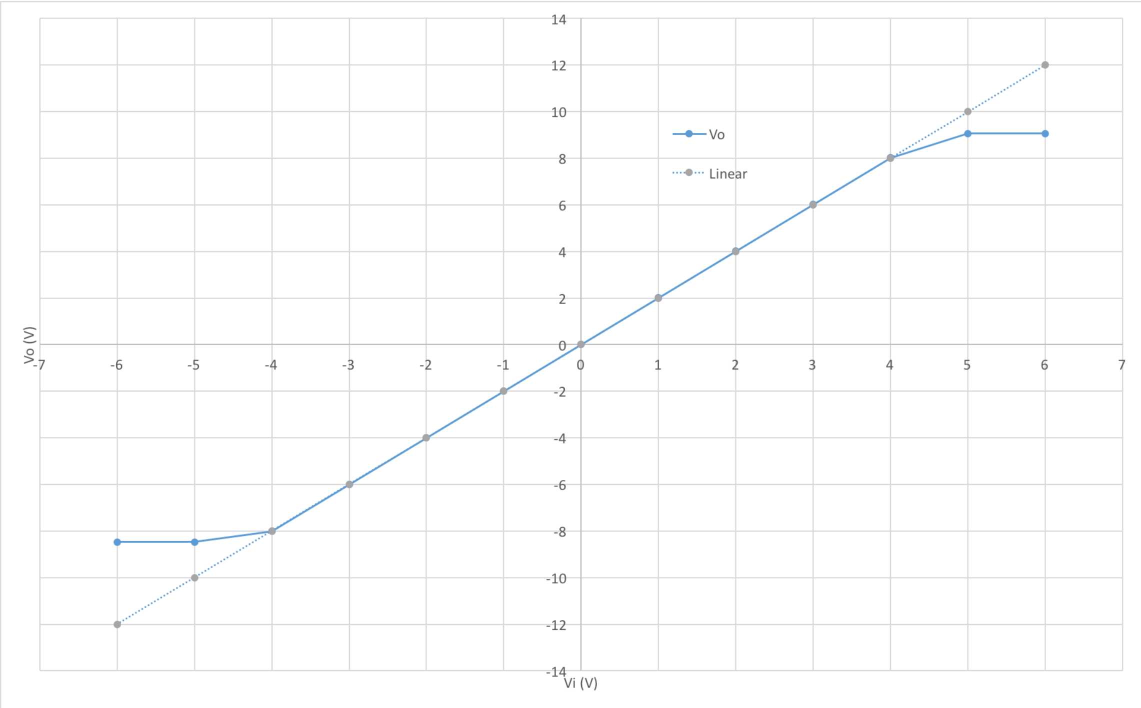



Figure 2: Response characteristic of VCVS with expected linear behavior

## 3.2 Voltage controlled current source (VCCS)

A VCCS was constructed following the schematic in Fig. 1(b). $\pm 10$ V was used as supply voltage for the op amp. The response of the output voltage to changes in input voltage is shown in Fig. 3 for $R_L = 1\,\mathrm{k\Omega}$.

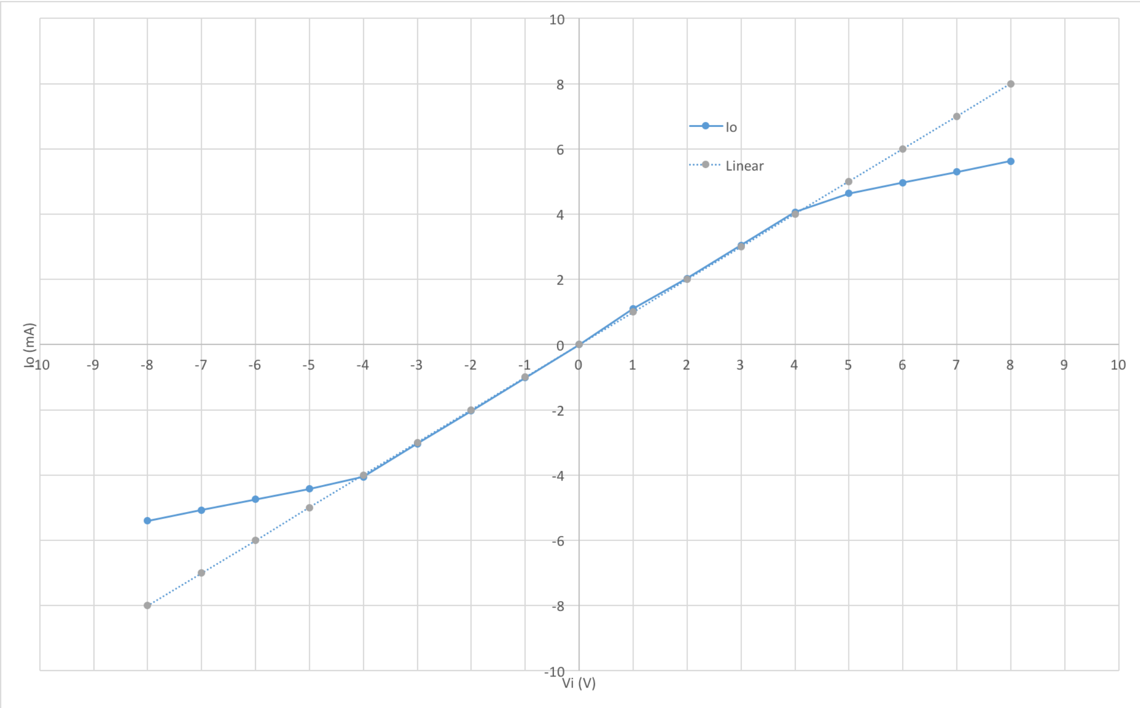



Figure 3: Response characteristic of VCCS with expected linear behavior

# 4 Discussion

## 4.1 VCVS

The predicted gain of $K = 2$ in the voltage-controlled voltage source is reflected in the slope in Fig. 2 for $-4.2\text{V} < V_i < 4.5\text{V}$. The op-amp experiences saturation at the lower limit sooner when compared to the upper limit. This is due to the internal circuitry of the op-amp; caused by inbalanced losses such as resistances and the voltage drop that occurs in transistors.

When we attempted to estimate the internal resistance using a 150Ω load ($R_L$ in Fig. 1(a)), we were only receiving a drop in voltage of approximately 6µV (peak-to-peak), which implied an internal resistance of approximately 500µΩ: this was considered to be incorrect. Replacing the 150Ω load with a 47Ω load, we experienced a more plausible result. With a load of 47Ω, the voltage across the load was measured to be 788.5mV, which means the source has an estimated internal resistance of approximately 39.1Ω (see (3)).

$$I_o = \frac{V_o}{R_L} = \frac{0.7885\text{V}}{47\Omega} = 16\text{mA}$$

$$V_{internal} = V_i - V_L = 1.4135\text{V} - 0.7885\text{V} = 625\text{mV}$$

$$R_{internal} = \frac{V_{internal}}{I_o} = \frac{625\text{mV}}{16\text{mA}} = 39.1\Omega \quad (3)$$

### 4.2 VCCS

Evaluating (2) gives $-5\text{V}V_i < 5\text{V}$, whereas we observed a linear region between approximately $-4.0\text{V} < V_i < 4.2\text{V}$. When the edge of the linear region was reached, rather than hard limiting the current experience soft limiting where $G$ dropped to $328 \times 10^{-6}$. The op-amp experiences saturation at the lower limit sooner when compared to the upper limit, again due to the internal circuitry of the op-amp. $47\,\Omega$ was used to compensate for $R_{internal}$, which differs from the expected value in (3).

When shorting the output carrying 1mA when measured under a 1kΩ load, the measured current dropped to 0.951mA. As the op-amp doesn't draw infinite current, there must be a non-zero internal resistance of the VCCS. When the op-amp drawing 1mA across a 1kΩ load (with a subsequent 1.1828V across the load), is shorted, the resulting current is 0.951milliA. Refering to (4), the internal resistance of the source must be 1240Ω.

$$V_{internal} = \frac{V_o}{I_o} = \frac{1.1828\text{V}}{0.951\text{mA}} = 1240\Omega \quad (4)$$

Measuring the voltage between the inverting and non-inverting gives a reading of 0.97mV. In comparison to other voltages within the circuit and considering the immense input impedance, the current into each pin is indeed nearly non-existent and certainly negligible.

## 5 Conclusion

Building and analyzing the two op-amp based dependent sources showed the assumptions made regarding op-amps are largely valid. Assuming rail-to-rail output voltage swing showed while the meausured voltage swing was lower, it was only lower by 16% on the lower bound, and 10% lower on the upper bound, in the case of the VCVS source. While the internl resistance of the sources, especially the current source, are not zero, in comparison to the resistances on the input and the load resistance for typical use of an op-amp (which is not a high-power circuit), this assumption is valid. The assumption of 0V potential between the input pins was shown to be valid, with a measured potential of 0.97mV: significantly lower than the voltages elsewhere in the circuit, and within the error caused by input biases.

## References

[1] P. So and A. Zielinski, *Laboratory manual for elec 300 - linear circuits ii*, University of Victoria.