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FACULTY OF COMPUTER SCIENCE AND ENGINEERING

Electrical Electronic Circuits

Lab Report

Lab 5

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1 Introduction

Operational Amplifiers, also known as Op-amps, are basically a voltage amplifying device designed to be used with components like capacitors and resistors, between its in/out terminals. They are essentially a core part of analog devices. Feedback components like these are used to determine the operation of the amplifier. The amplifier can perform many different operations, giving it the name Operational Amplifier.

One key to the usefulness of these little circuits is in the engineering principle of feedback, particularly negative feedback, which constitutes the foundation of almost all automatic control processes. The principles presented in this section, extend well beyond the immediate scope of electronics. It is well worth the electronics student's time to learn these principles and learn them well.

Operational amplifiers can have either a closed-loop operation or an open-loop operation. The operation (closed-loop or open-loop) is determined by whether or not feedback is used. Without feedback the operational amplifier has an open-loop operation. This open-loop operation is practical only when the operational amplifier is used as a cooperator (a circuit which compares two input signals or compares an input signal to some fixed level of voltage). As an amplifier, the open-loop operation is not practical because the very high gain of the operational amplifier creates poor stability. (Noise and other unwanted signals are amplified so much in open-loop operation that the operational amplifier is usually not used in this way.) Therefore, most operational amplifiers are used with feedback (closed-loop operation).

2 Closed Loop Operation

Operational amplifiers are used with degenerative (or negative) feedback which reduces the gain of the operational amplifier but greatly increases the stability of the circuit. In the closed-loop configuration, the output signal is applied back to one of the input terminals.

This feedback is always degenerative (negative). In other words, the feedback signal always opposes the effects of the original input signal. One result of degenerative feedback is that the inverting and non-inverting inputs to the operational amplifier will be kept at the same potential.

Closed-loop circuits can be of the inverting configuration or non-inverting configuration.

2.1 Non inverting configuration

The typical circuit for this configuration is shown in the figure bellow:

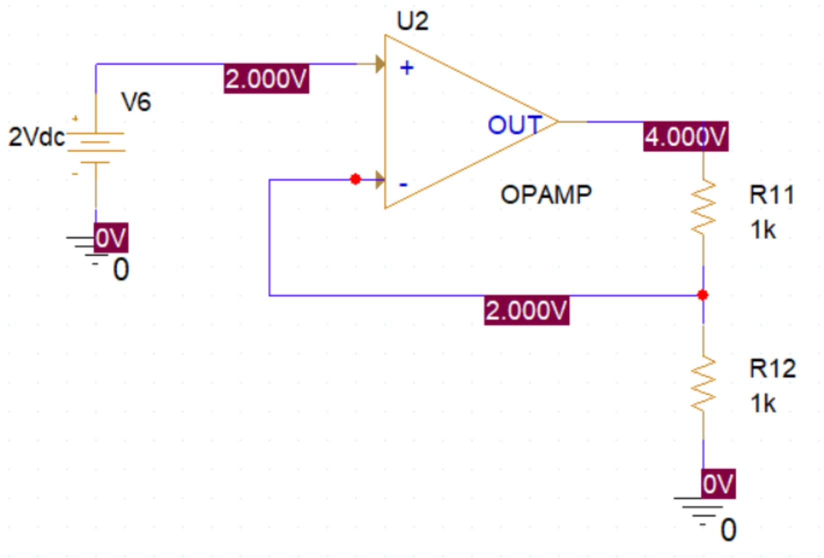

Figure 2.1: Non inverting configuration

The new component, named also OPAMP (Operational Amplifier) is easily found in the favorite list of the PSPICE.

In order to explain the 4V at the ouput, it is obviously that $V(+) = V(-) = 2V$ in a closed loop configuration. Therefore, from a resistor bridge at the output, $V_{out} = 4V$.

2.2 Inverting configuration

In this configuration, the output is connected directly to a pin of the opamp as follow:

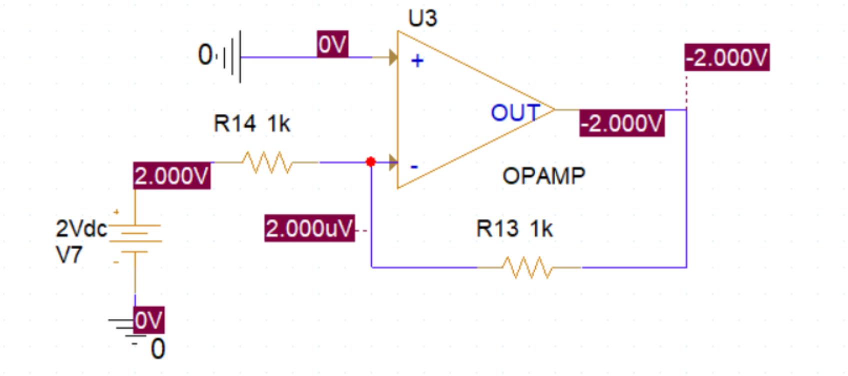

Figure 2.2: Inverting configuration

As the output voltage is negative, which is inverted to the input, the name of this circuit is the invert connection. Students are proposed to perform calculations to confirm the output, which is -2V .

Calculation:

Since the circuit have negative feedback, we have $V(+) = V(-) = 0V$.

Therefore, the current flowing through R_{14} is:

$$I = \frac{V_{in} - V(-)}{R_{14}} = \frac{2 - 0}{1k} = 2\ mA$$

As no current flows into the opamp pin, the same current flows through R_{13}, so the output voltage is:

$$V_{out} = V(-) - I \cdot R_{13} = 0 - 2\ mV \cdot 1k = -2V$$

3 Exercise and Report

3.1 Voltage Follower

Voltage follower is one of the simplest uses of an operational amplifier, where the output voltage is exactly same as the input voltage applied to the circuit. In other words, the gain of a voltage follower circuit is unity. The connections are proposed as follows:

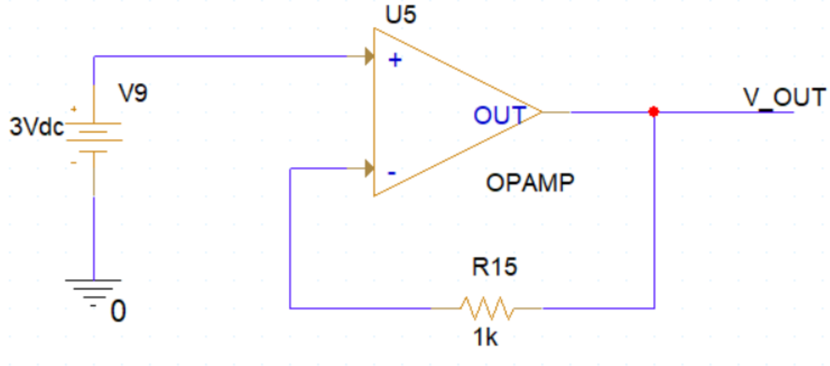

Figure 3.1: Opamp follower circuit

A voltage follower has low output impedance and extremely high input impedance, and this makes it a simple and effective solution to problematic impedance relationships. If a high-output-impedance sub-circuit must transfer a signal to a low-input-impedance sub-circuit, a voltage follower placed between these two sub-circuits will ensure that the full voltage is delivered to the load.

Students are propose to run the simulation with bias mode to confirm that $V_{OUT} = V(+)$. **The feedback resistance is also required to change.**

Simulation results:

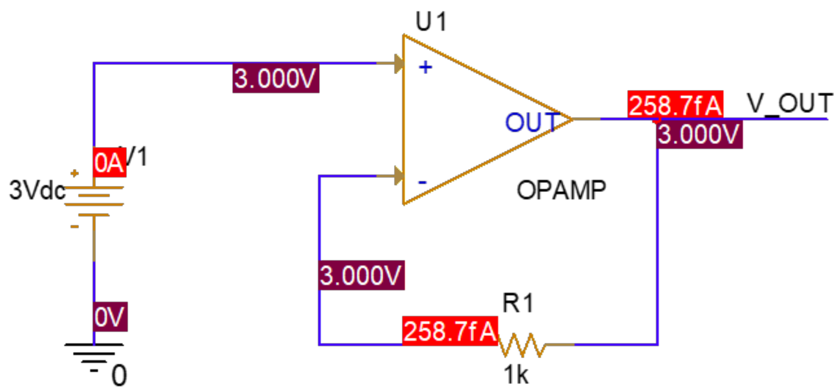

Figure 3.2: Simulation result with R = 1kΩ

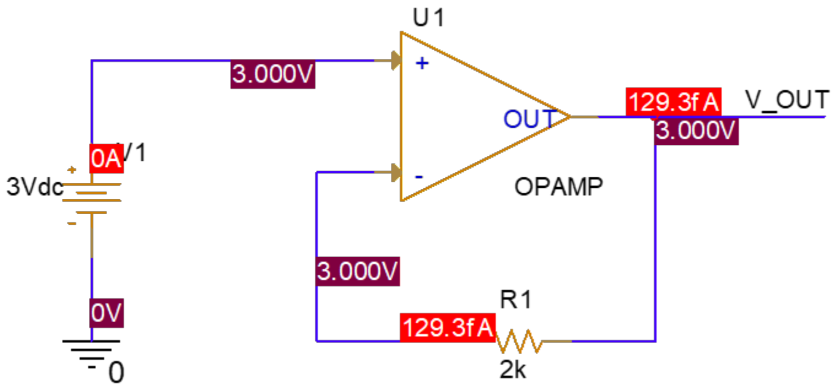

Figure 3.3: Simulation result with R = 2kΩ

Your calculations are presented here to prove $V_{OUT} = V(+)$ with any value of R15.

Solution:

The general voltage gain of a non-inverting operational amplifier is given by:

$$A_v = 1 + \frac{R_f}{R_{in}}$$

For the voltage follower configuration:

- $R_f = 0$ (short-circuited feedback)
- $R_g \to \infty$ (no resistor connected to ground)

Substituting these values into the gain formula:

$$A_v = 1 + \frac{0}{\infty} = 1 + 0 = 1$$

Therefore, we confirm that:

$$V_{OUT} = A_v \cdot V_{IN} = 1 \cdot V_{IN} = V_{IN}$$

3.2 Voltage Follower with Gain

This basic circuit is not limited to the unity-gain configuration. As with a non-buffered op-amp, you can insert resistors into the feedback path to create overall gain from the input to the load voltage. Here is the non-unity-gain version of the circuit:

Students are proposed to implement this circuit on PSPICE with input is 2V and the gain is 3. The voltage supply for the load side is 12VDC. Value of R_{LOAD} is 1K.

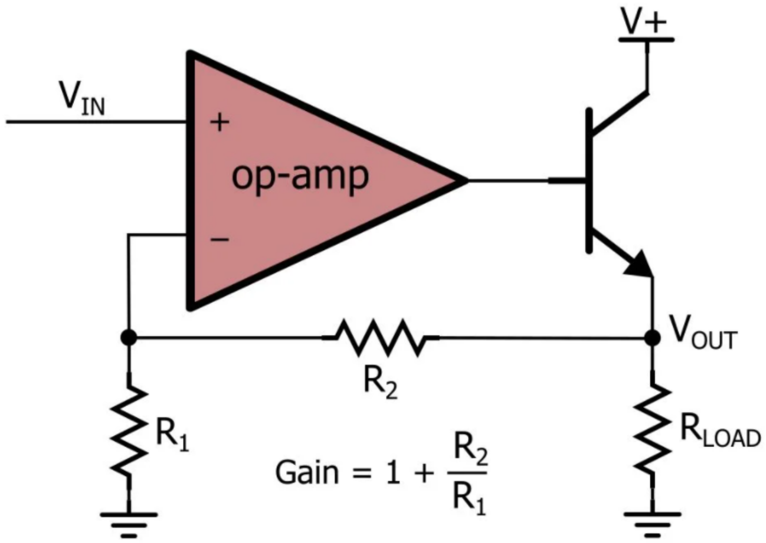

Figure 3.4: Opamp follower with gain for the output

The simulation results in PSPICE (bias configuration) are presented here. Moreover, a short explanations are required in this report to explain the gain of the output follower voltage.

Simulation results:

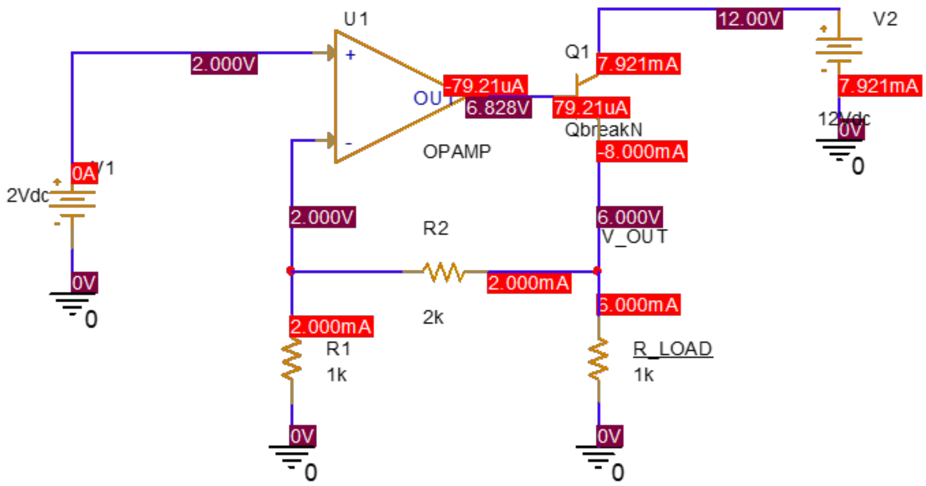

Figure 3.5: Simulation results with $R_1 = 1K\Omega$ and $R_2 = 2K\Omega$

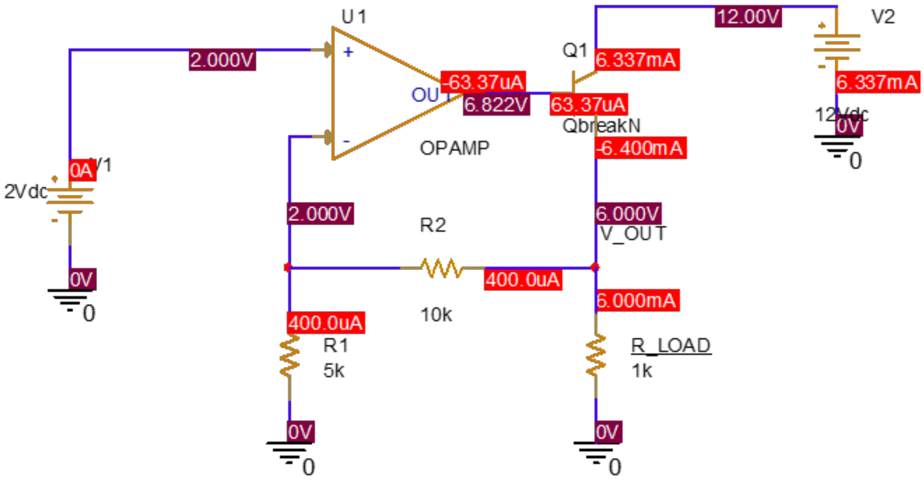

Figure 3.6: Simulation results with $R_1 = 5K\Omega$ and $R_2 = 10K\Omega$

Explanation:

Both simulations use the same input voltage $V_{in} = 2\,V$ and the same resistor ratio $\dfrac{R_2}{R_1} = 2$. Therefore, the voltage gain is:

$$A_v = 1 + \frac{R_2}{R_1} = 1 + 2 = 3$$

So the output voltage is:

$$V_{out} = A_v \cdot V_{in} = 3 \cdot 2\,V = 6\,V$$

This result is confirmed by both simulations in fig. 3.5 and fig. 3.6.