Inverting and Non-Inverting Comparators

Ridge Tejuco, Oscar Tejeda

***Abstract*— The LF411 chip consists of one op amp, which will be used for this lab. This op amp can be used with resistors and some calculations to create an inverting or non-inverting comparator. Certain resistor values were chosen so that a certain voltage transition was obtained. Another voltage source can be added to create a shift in the voltage transition. The location in which the extra voltage source is located depend on whether the circuit is inverting or non-inverting. The amount of voltage being distributed by the extra source will determine the shift in the voltage transition. The voltage transition can be seen when the output voltage goes from high to low or low to high. If a sine wave is used as a power source, a square wave function comes out as the output. Zener diodes can also be added to the end of the circuit to limit the output voltages.**

I.INTRODUCTION

THE LF411 chip was used for this lab because the chip contains an op amp. Figure 1 shows the pin out for this chip.

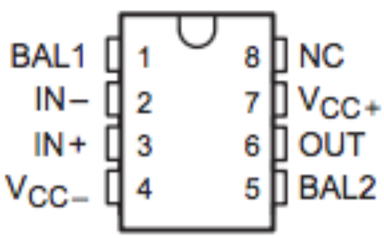

Fig. 1. L411 pin-out

A DC power source of +12 V and -12 V were used as the supply. The first circuit using the op amp needed the characteristics of VTL = -2.6 V, VTH = 2.6 V, and VR = 0 V. A plot of Vin versus Vout will be created and look similar to figure 2.

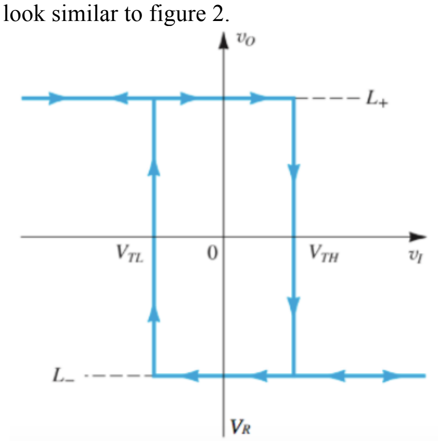

Fig. 2. Inverting comparator VTC

Another circuit is created with another DC voltage supply to shift the VTC on the plot. The new circuit should have the characteristics of VTL = -1.0 V, VTH = 3.0 V, and VR = 1.0 V. VR will cause VTL and VTH to shift by 1 V.

A non-inverting comparator is similar to an inverting comparator but with different voltage transfer characteristics. The first non-inverting comparator must have the characteristics of VTL = -1.2 V, VTH = 1.2 V, and VR = 0 V. The voltage transfer characteristic plot for a non-inverting comparator can be seen in figure 3.

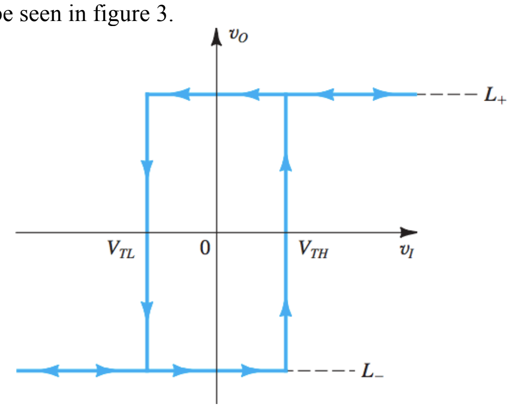

Fig 3. Non-inverting comparator VTC

A second circuit is created with a non-inverting comparator. The characteristics for this circuit are VTL = -3.4 V, VTH = 1.4 V, and VR = -1.0 V. VR creates a 1 V shift similar to the shift created in the inverting comparator. Zener diodes were added to the end of this circuit to manage the output voltage. This caused the minimum output voltage to be greater than -8.0 V and less than 8.0 V.

II. CIRCUIT THEORY, OPERATION, AND DESIGN METHODOLOGY

The Bistable Multivibrator consists of an operational amplifier connected in a feed back loop with a voltage divider seen in Figure 4. An input voltage applied to the negative terminal of the OP AMP can trigger a change between its two stable states.

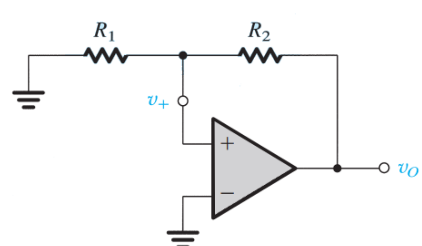

Fig. 4. A bistable multivibrator with a v_+ voltage set to ground.

In order to better understand Bistable Multivibrators, a setup where V_+ is close to ground in value is considered in Figure 4. This circuit cannot hold V_+ at ground for an indefinite amount of time because electrical noise will eventually provide a voltage difference between the positive and negative terminals of the OP AMP. A voltage difference due to electric noise in the circuit will provide an initial difference for the large gain of the OP AMP, which will result in larger signal that appears at V_o. The voltage divider provides feedback and the following (1) shows the portion of the output voltage fed back to V_+.

$$\beta = \frac{R_1}{R_1+R_2} \qquad (1)$$

This feedback will in turn provide another voltage difference gain for the OP AMP and this process will continue until V_o is saturated at L_+, which is the positive voltage used to power the OP AMP. (2) and (3) show the positive stable state of the OP AMP.

$$V_o = L_+ \qquad (2)$$

$$V_+ = L_+\left(\frac{R_1}{R_1+R_2}\right) \qquad (3)$$

Likewise, if the electric noise provided a small decrement to V_+. Then the feedback would have set the circuit into its negative stable state. (4) and (5) shows the negative stable state.

$$V_o = L_- \qquad (4)$$

$$V_+ = L_-\left(\frac{R_1}{R_1+R_2}\right) \qquad (5)$$

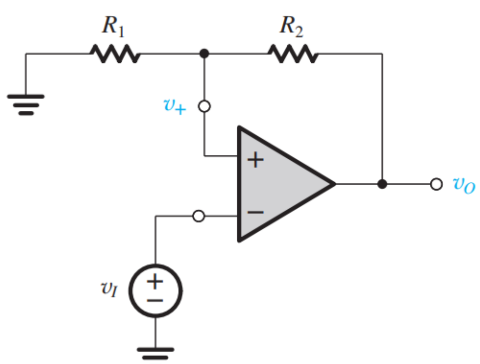

Fig. 5. A Bistable circuit with an input applied to the negative terminal of the OP AMP.

In order to switch between both states an input is applied to the negative terminal of the OP AMP as seen in Figure 5. In order to switch from the positive to negative stable state, the input voltage must pass the value of the saturated V_+. (6) shows this relationship, where V_{TH} is the high threshold voltage. Figure 6 shows the transfer characteristic of the input for V_{TH}.

$$V_i = V_{TH} = L_+\left(\frac{R_1}{R_1+R_2}\right) \qquad (6)$$

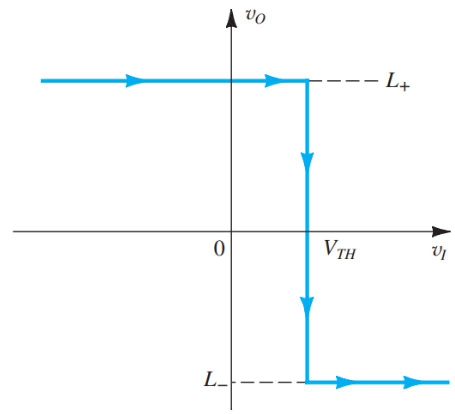

Fig. 6. The transfer characteristic of the bistable multivibrator for input V_i passing V_{TH}.

Similarly, for switching between the negative stable state to the positive stable state. The input voltage must be lower than the value of V_+. (7) and Figure 7 shows the effect the input voltage dropping below V_{TL}. Figure 8 combines the low and high threshold voltage transfer characteristics.

$$V_i = V_{TL} = L_-\left(\frac{R_1}{R_1+R_2}\right) \qquad (7)$$

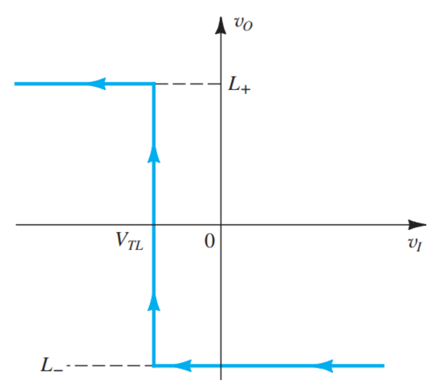

Fig. 7. The transfer characteristic of the bistable multivibrator for an input voltage dropping lower than V_{TL}.

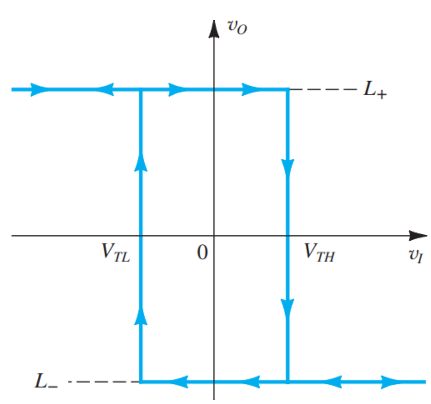

Fig. 8. The complete transfer characteristic of the bistable multivibrator.

The bistable multivibrator can also be used to provide a noninverting transfer characteristic. The noninverting configuration is shown in Figure 9, which shows the input voltage applied to the resistor R_1.

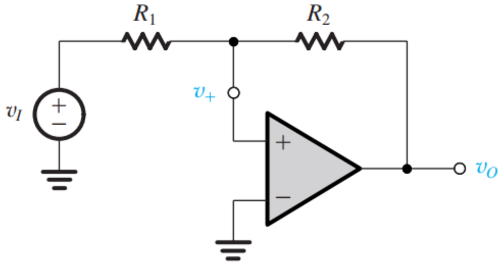

Fig. 9. The noninverting bistable multivibrator.

Through the superposition principle, the voltage at V_+ is expressed in (8). (9) and (10) show the corresponding V_{TH} and V_{TL} respectively. Looking closely at Figure 10, the transfer characteristic indicates that a positive increase in the input voltage results in a switch from low to high output voltage. Similarly, a decrease in the input voltage results in the switch from high to low output voltage.

$$V_+ = V_i\left(\frac{R_2}{R_1+R_2}\right) + V_o\left(\frac{R_1}{R_1+R_2}\right) \tag{8}$$

$$V_{TH} = -L_-(\frac{R_1}{R_2}) \tag{9}$$

$$V_{TL} = -L_+(\frac{R_1}{R_2}) \tag{10}$$

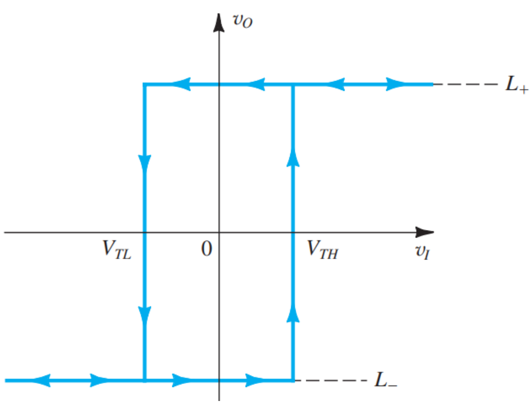

Fig. 10. The noninverting transfer characteristic of the multivibrator

The output voltage of the bistable multivibrator can be more precise by applying a limiter circuit to the output. The value of R is chosen to limit current supplied to the Zener diodes based on their specifications. The Zener diodes limit the saturation voltage for the output and the feedback provided to the V_+ terminal. (11) and (12) show these relationships.

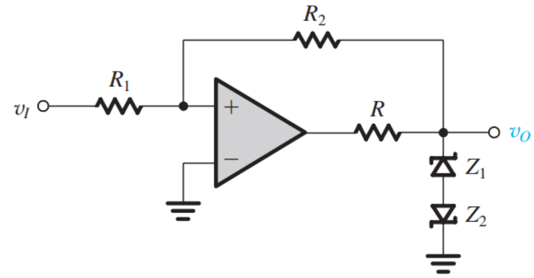

Fig 11. The limited noninverting circuit using two Zener diodes upon V_o.

$$L_+ = Vz_1 + V_D \tag{11}$$

$$L_- = -(Vz_2 + V_D) \tag{12}$$

III. SIMULATION AND EXPERIMENTAL RESULTS

An inverting comparator was built as shown in figure 12 and the output is shown in figure 13. VTL = -2.6 V, and VTH = 2.6 V.

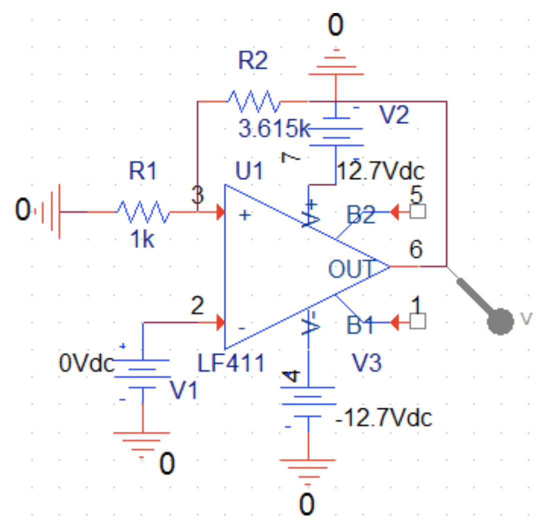

Fig. 12. Inverting comparator

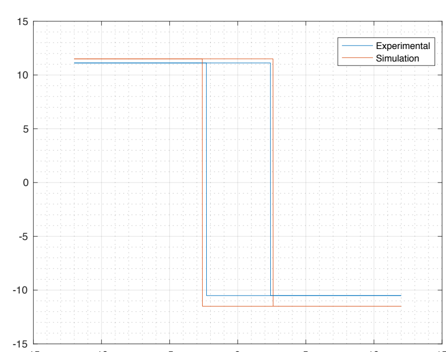

Fig. 13. Inverting comparator voltage output

An inverting comparator was built to have the characteristics VTL = -1.0 V,

V_{TH} = 3.0 V, and V_R = 1.0 V in figure 14. The voltage output is shown in figure 15.

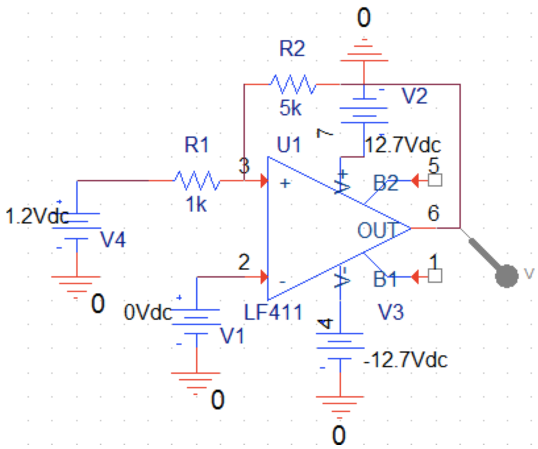

Fig. 14. Inverting comparator with shift

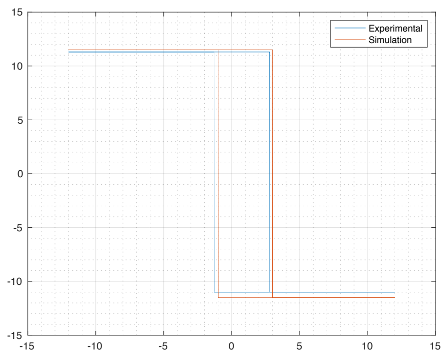

Fig. 15. Inverting comparator with shift voltage output

The same circuit from figure 14 was kept and a sine wave with amplitude of 5 V and frequency of 1 kHz was added. This can be seen in figure 16 and the voltage output can be seen in figure 17.

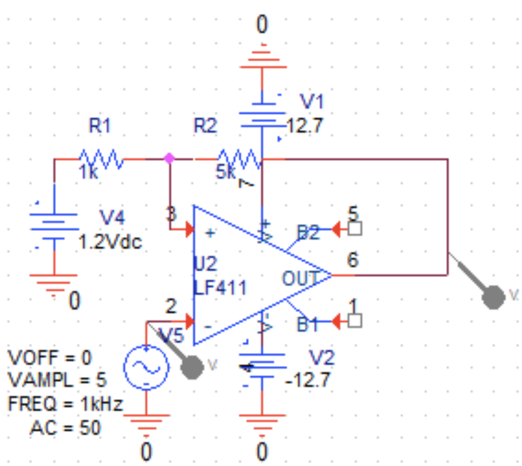

Fig. 16. Inverting comparator with shift and sine wave source.

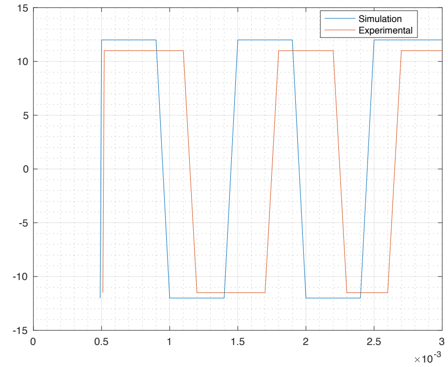

Fig. 17. Inverting comparator with shift and sine wave source voltage output.

A non-inverting comparator was built as shown in figure 18. The resistors were chosen to give the characteristics V_{TL} = -1.2 V, V_{TH} = 1.2 V, and V_R = 0 V. This can be confirmed in figure 19 which shows the voltage output.

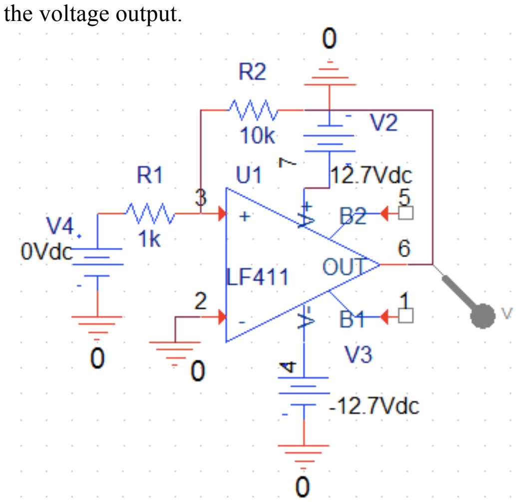

Fig. 18. Non-inverting comparator

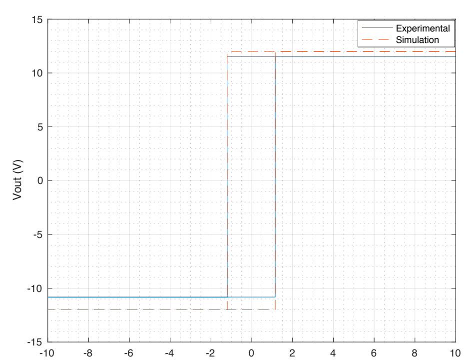

Fig. 19. Non-inverting comparator voltage output

A non-invert comparator was build to meet the characteristics of V_{TL} = -3.4 V, V_{TH} = 1.4 V, and V_R = -1.0 V. The output voltage can be seen in figure 20 to confirm these characteristics.

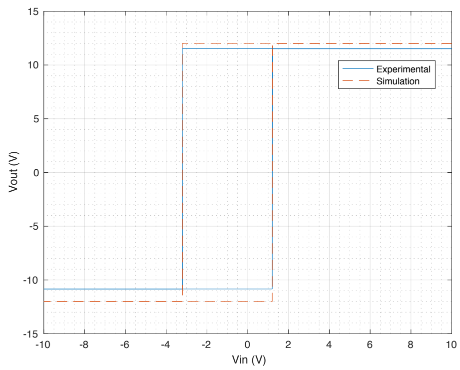

Fig. 20. Non-inverting comparator with shift voltage output

Zener diodes are added to the circuit with a shift voltage to control the output voltage. The output voltage remained greater than -8 V and less then 8 V as seen in figure 22.

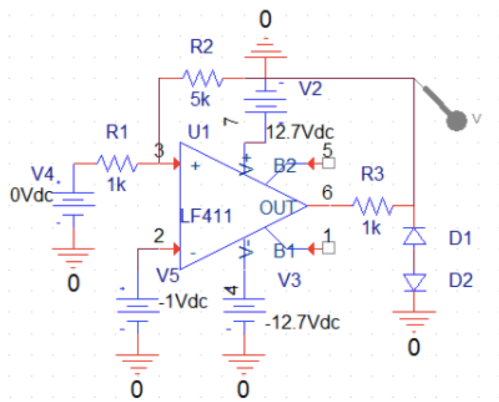

Fig. 21. Non-inverting comparator with shift and zener diodes

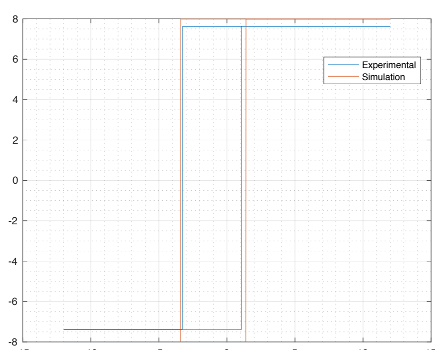

Fig. 22. Non-inverting comparator with shift and zener diodes voltage output

A sine wave was added to the non-inverting comparator circuit as shown in figure 23. The output voltage can be seen in figure 24 which happen to be square waves.

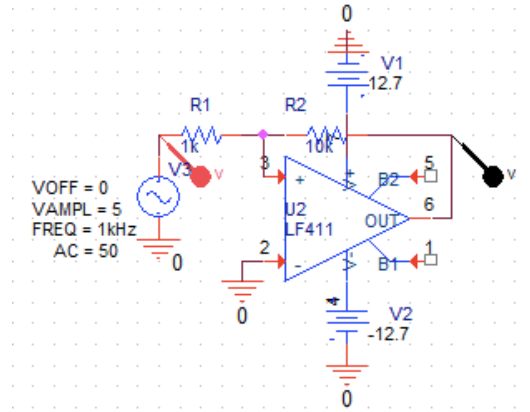

Fig. 23. Non-inverting comparator with sine wave source

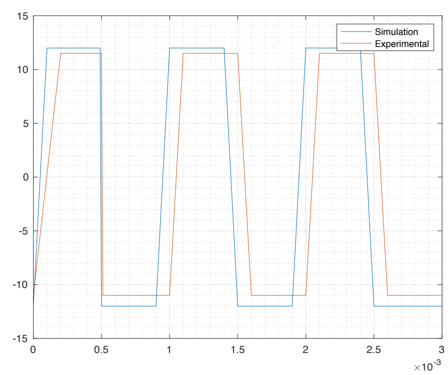

Fig. 24. Non-inverting comparator with sine wave source voltage output

IV. DISCUSSION AND CONCLUSION

The op amp of a LF411 chip was used to create an inverting comparator and a non-inverting comparator. Different resistors were used to meet the certain characteristics. This was done by using a PSPICE simulation and on a breadboard. The same resistor values were used but received slightly different outcomes. One noticeably difference is the maximum voltages. The PSPICE simulation was closer to 12 V than the experimental outcome. This can happen due to the resistors not being the exact value that was needed. The LF411 chip looks to be keeping some voltage inside of it, preventing the 12 V maximum output. The values of VTL and VTH are off by around 0.1 V as well. This can happen because of the value of beta. The resistor values can be a little off which can cause the value of beta to be different from the calculated value.

ACKNOWLEDGEMENT

Ridge- 50%, Circuit Theory and part of Simulation Results

Oscar- 50%, Abstract, Introduction, part of Simulation Results, Conclusion

REFERENCES

[1] Jackson, Bradley. “Bistable Multivibrators” 13 Feb. 2020, Northridge

[2] Poole, Ian. “Op Amp Inverting Amplifier: Circuit; Design; Equations, Basics, Tutorial..” *Electronics Notes,* Electronics Notes, www.electroniccs-notes.com/articles/analogue_circuits/operational-amplifier-op-amp/inverting-amplifier.php.
[3] ECE 443 Lab Manual