Astable Multivibrators

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***Abstract*—The LF411 chip contains an op amp that can be used within a circuit. In this lab, the op amp has been used as a square wave generator and a triangular wave generator. The resistor and capacitor values must be calculated to create a square wave generator. This circuit can generate square waves at the output with different frequencies, depending on the resistor and capacitor values. Attaching a resistor and capacitor to an op amp then connecting it to a noninverting bistable multivibrator can create a triangular wave generator. The value of the resistor and capacitor can determine the frequency of the triangular waves. PSPICE was used to help create a simulation for a square wave generator that generates 10 kHz waves and a triangular wave generator that generates 5 kHz waves. The circuits that were simulated were then created experimentally and the output voltages were recorded. The frequencies were calculated by finding the period and then compared.**

I.INTRODUCTION

The op amp within a LF411 chip was used in this lab to create a waveform generator. The pin out to this chip can be seen below in figure 1.

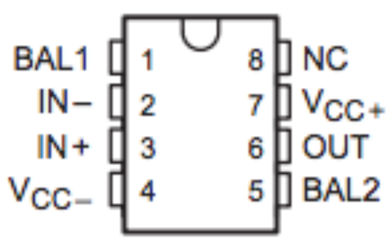

Fig. 1. LF411 pin out

The R_1, R_2, R, and C values were all calculated to give a square waveform output with a frequency of 10 kHz. The circuit used to create a square waveform generator can be seen in figure 3. Measuring the period and dividing one by the period can calculate the frequency. This is going to be done on both PSPICE and experimentally compare the voltage output.

A non-inverting bistable multivibrator was created as shown in figure 2. The input for the non-inverting bistable multivibrator was connected to the output of figure 5. The values for R and C were calculated to create a triangular waveform with a frequency of 5 kHz.

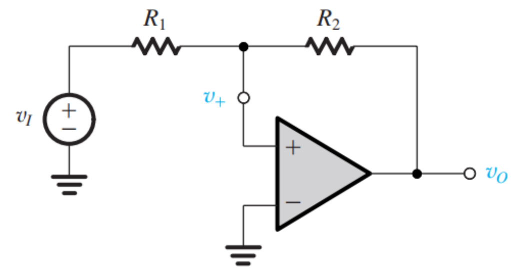

Fig. 2. A non-inverting bistable multivibrator.

This circuit was simulated using PSPICE and created experimentally. The frequencies were calculated and compared.

II. CIRCUIT THEORY

A square wave generator can be created using a bistable multivibrators switching between its two stable states periodically, and connecting it to a RC circuit as shown in figure 3.

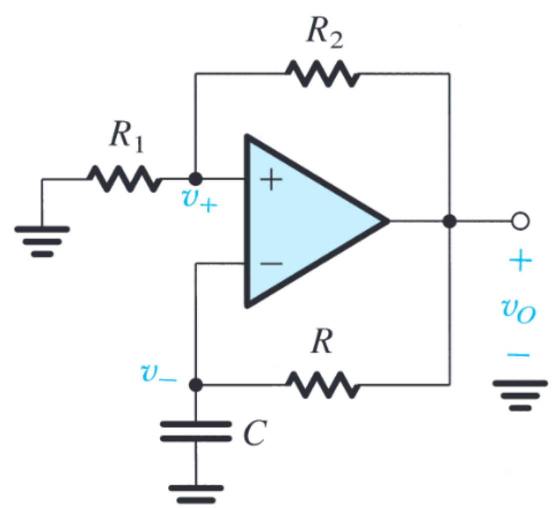

Fig. 3. An astable multivibrator made from a bistable mutlivibrator connected with a RC circuit at the negative terminal of the op amp.

This square wave generator is called the astable multivibrator because the output voltage continuously oscillates between L+ and L-, the supply voltage of the op amp, as seen in figure 4. The astable multivibrator has no input other than being powered on.

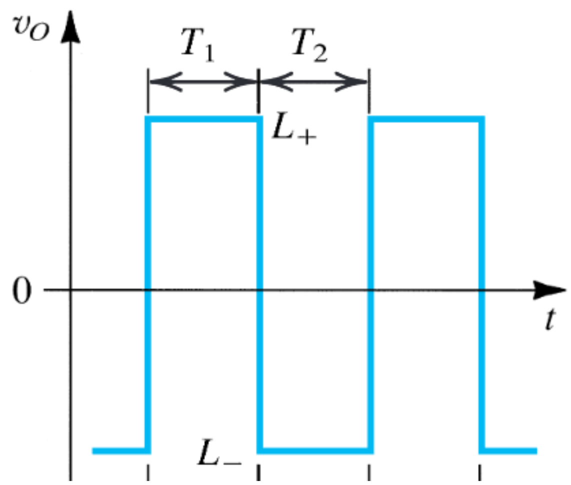

Fig. 4. The output square wave of the astable multivibrator.

To understand how the circuit works the output voltage is considered first. If the output voltage is L_+, and the capacitor is completely discharged then current will flow across resistor R and charge the capacitor with time constant τ = RC. This relationship is shown in figure 5.

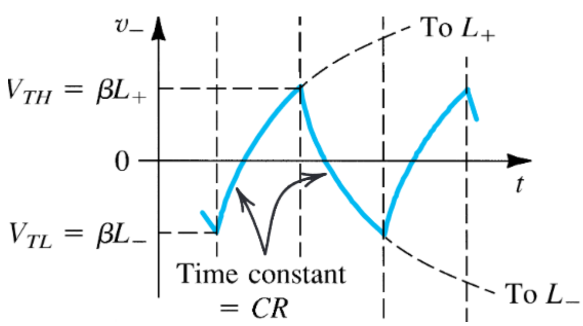

Fig. 5. The voltage across the capacitor charged by the voltage across the resistor R with time constant τ = RC.

The capacitor will continue to charge until the voltage at negative terminal V_-, passes the voltage at the positive terminal V_+. The circuit attached to the positive terminal is considered a voltage divider and so the voltage at V_+ will always be a fraction of the output voltage and also a square wave. Figure 6 shows the voltage at V_+. (1) shows the relationship between V+ and $V_o = L_+$.

$$V_{TH} = V_+ = \beta L_+ \text{ where } \beta = \left(\frac{R_1}{R_1+R_2}\right) \tag{1}$$

$$V_{TL} = V_+ = \beta L_- \text{ where } \beta = \left(\frac{R_1}{R_1+R_2}\right) \tag{2}$$

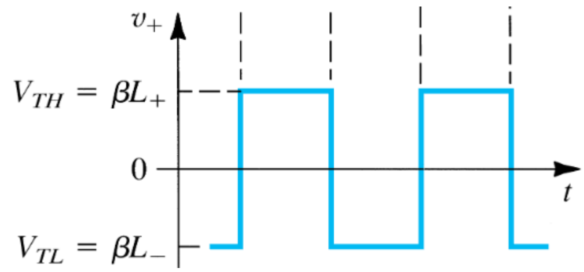

Fig. 6. The voltage input to V_+ of the op amp supplied by the output voltage.

As soon as V- passes V+, the output voltage switches from L+ to L- and V+ switches from βL+ to βL-. The capacitor will begin to discharge until V- becomes lower than βL-. (2) shows the threshold voltage for discharging the capacitor. This process will continue periodically and V- is modeled by (3).

$$V_- = L_+ - (L_+ - \beta L_-)e^{-t/\tau} \tag{3}$$

Using (3) to solve for t, the period T_1 when the capacitor is charging can be found. By substituting $V_- = \beta L_-$ and $t = T_1$, the following (4) is found.

$$T_1 = \tau \ln \left(\frac{1-\beta\left(\frac{L_-}{L_+}\right)}{1-\beta}\right) \tag{4}$$

Similarly, the period for discharging the capacitor can be found from (5). By substituting, $V_- = \beta L_+$ and $t = T_2$, (6) is found.

$$V_- = L_- - (L_- - \beta L_+)e^{-t/\tau} \tag{5}$$

$$T_2 = \tau \ln \left(\frac{1-\beta\left(\frac{L_+}{L_-}\right)}{1-\beta}\right) \tag{6}$$

The total period T is the sum. $T = T_1 + T_2$. Due to the symmetry of L+ and L-, the following (7) is true.

$$T_2 = 2\tau \ln \left(\frac{1+\beta}{1-\beta}\right) \tag{7}$$

A triangular wave form generator can be created by connecting a non-inverting bistable multivibrator as seen from experiment 3 and an op amp inverting integrator as seen in figure 7.

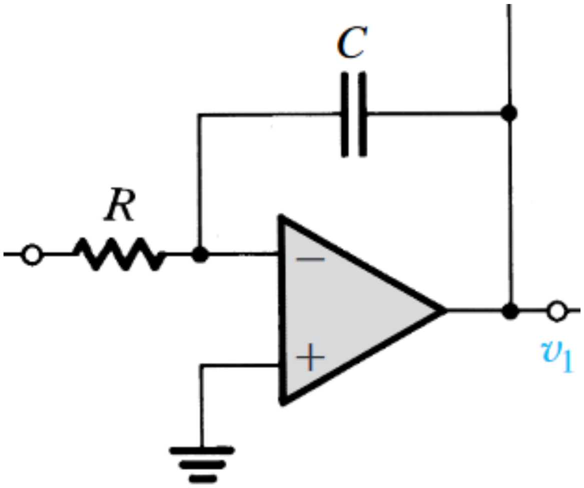

Fig. 7. The op amp inverted integrator to be connected to the non-inverting bistable multivibrator.

The output of the integrator is connected to the input of noninverting bistable multivibrator and the output of the noninverting bistable multivibrator is connected to the resistor R of the integrator as seen in figure 8.

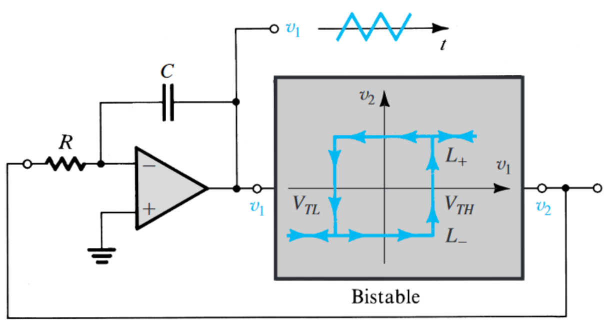

Fig. 8. General circuit of the triangular wave form generator.

To understand how this triangular wave form generator works, first the output voltage of $V_2 = L+$ is assumed. In this state, a current of L_+ / R flows through the capacitor and decreases the voltage at V_1 with a linear slope of $-L_+$ / RC. This continues until V_1 falls below V_{TL} of the noninverting multivibrator and the voltage V_2 switches to L-. The slope is expressed as the difference of V_{TH} to V_{TL} over the time period T_1 as seen in (8). Solving for T_1 results in (9).

$$\frac{V_{TH}-V_{TL}}{T_1} = \frac{L_+}{RC} \tag{8}$$

$$T_1 = RC\,\frac{V_{TH}-V_{TL}}{L_+} \tag{9}$$

When V_2 switches to L-, the current through R and C flows backwards and the voltage across the capacitor increases until V_1 reaches V_{TH}. The following (10) and (11) shows the period of this increase.

$$\frac{V_{TH}-V_{TL}}{T_2} = \frac{-L_-}{RC} \tag{10}$$

$$T_2 = RC\,\frac{V_{TH}-V_{TL}}{-L_-} \tag{11}$$

If -L- is equivalent to L+, then a symmetric triangular wave is created and the following (12) is true.

$$T = T_1 + T_2 = 2RC\,\frac{V_{TH}-V_{TL}}{L+} \tag{12}$$

III. SIMULATION AND EXPERIMENTAL RESULTS

The values were calculated to be R_1= 1 kΩ, R_r = 1kΩ, R = 4.3 kΩ, and C = 0.01 uF. These values are inputted for the square wave generator circuit shown in figure 9.

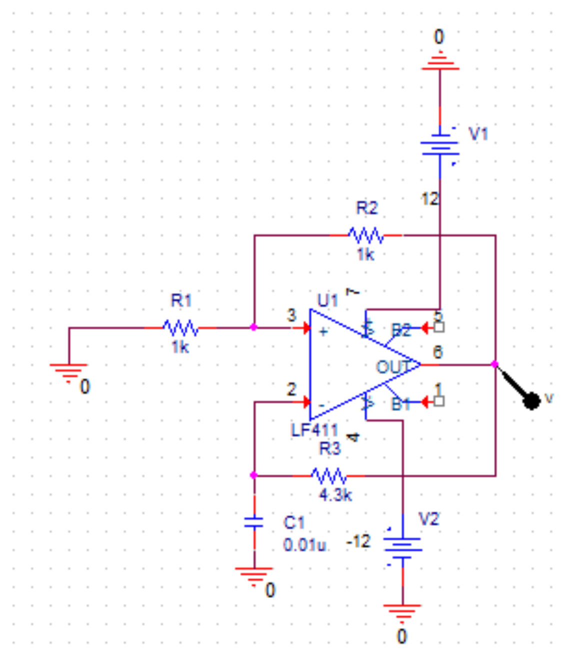

Fig. 9. A square wave generator circuit.

The square wave generator output can be seen in figure 10. The frequencies for the simulated and experimental circuits are 10.06 kHz and 11.1 kHz.

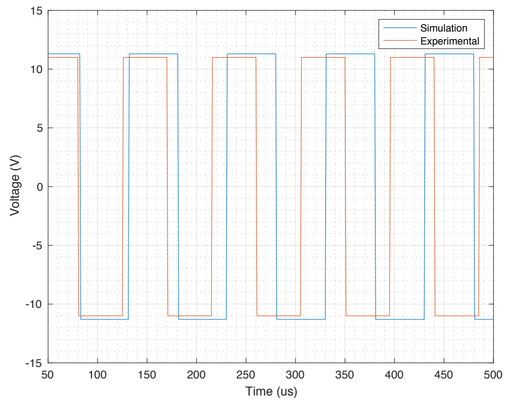

Fig. 10. Square wave generator output

The values for the triangular wave generator were calculated to be R= 47 kΩ, and C= 0.01 uF. These values can be seen with the circuit in figure 11.

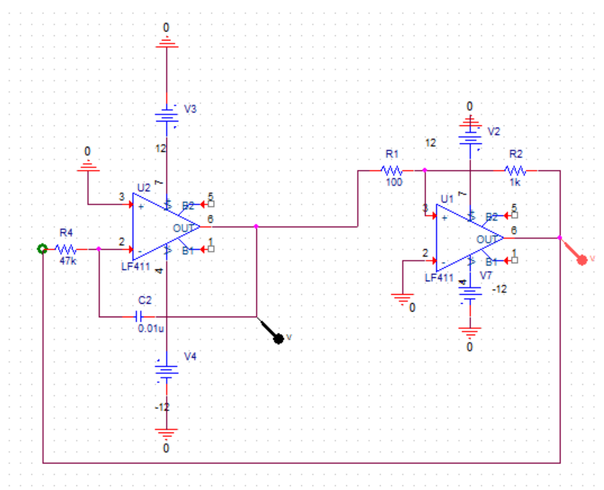

Fig. 11. A triangular wave generator circuit.

The outputs for the triangular wave generator can be seen in figure 12. The frequencies for the simulation and experimental circuits are 5.05 kHz and 4.99 kHz.

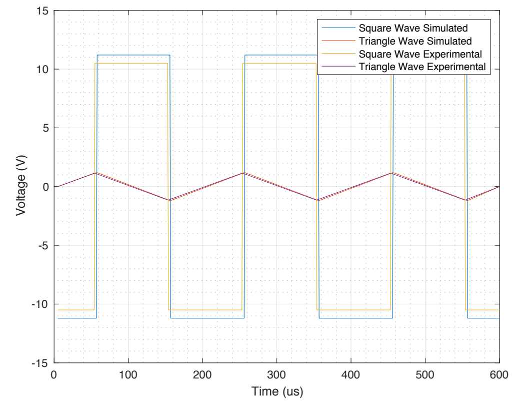

Fig. 12. Triangular wave generator outputs

IV. DISCUSSION AND CONCLUSION

An op amp was used to create a square wave generator and a triangular wave generator. The resistor and capacitor values were calculated to get the desired frequency. A frequency of 10 kHz was desired for the square wave generator. Frequencies of 10.06 kHz and 11.1 kHz was obtained from the PSPICE simulation and the experimental. A frequency of 5 kHz was desired for the triangular wave generator. Frequencies of 5.05 kHz and 4.99 kHz was obtained from the PSPICE simulation and the experimental. The voltage values were also different as we got a peak voltage of 11.3 V and 11 V for the square wave generator. The voltage values for the triangular wave generator were 1.1 V and 1.0 V.

The frequency difference can be due to the fact that the resistor values are not exactly the values that they say they are. This error can cause the frequency to change. The voltage differences can be due to the fact that more voltage is lost throughout the circuit. This can be because some voltage is consumed by the chip or the voltage drop for some resistors are different due to the resistors not being the exact value.

ACKNOWLEDGEMENT

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

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

REFERENCES

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