Monostable Multivibrators

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***Abstract*—In this lab, two pulse generation circuits were designed. The resistor and capacitor values were selected to get a desired pulse width. One of the circuits built was the Op Amp Pulse Generator, which requires an op amp, diodes, resistors and capacitors. The other circuit was the 555 Timer-Based Pulse Generator, which includes a 555-timer integrated circuit, a resistor, and a capacitor. The Op Amp Pulse Generator needs to create a pulse with a 100 µs width. The 555 Timer-Based Pulse Generator needs to create a pulse with a width of 1 ms. A high valued resistor was added to the output of the circuit as well. Different formulas were used to help find the different component values for both circuits. The pulse width was found by subtracting two points from the result plot. PSPICE was used to simulate both circuits and the Op Amp Pulse Generator circuit was experimentally created on a breadboard.**

I. INTRODUCTION

The purpose of this lab is to use and understand the theory behind monostable multivibrator pulse generators. Occasionally, in the design of a circuit, a pulse of a certain amplitude and length is desired. The pulses provided by this circuit are controlled by choosing resistor values and capacitance values tied to the inverting input of the op amp. The monostable multivibrator used in this lab is an augmented circuit of the astable multivibrator used in the previous lab. In connection to the circuit, a few concepts must be understood, such as op amps, voltage dividers, RC circuits, and diodes. Additionally, the lab also introduces the use of 555 timers, one of the most popular IC's. The 555 timers can be used to implement a monostable multivibrator to produce pulses that may be desired in the design of any project. The 555 timer also includes the use of an internal RS flip flop and BJT.

II. CIRCUIT THEORY

Looking at figure 1, it can be seen that the monostable multivibrator is an augmented circuit of the astable multivibrator. A trigger circuit composed of capacitor C_2, diode D_2, and resistor R_4 was added to the non-inverting input and the diode D_1 was added to the inverting input. Unlike the astable multivibrator, the monostable multivibrator has a stable state in which it will stay in unless triggered.

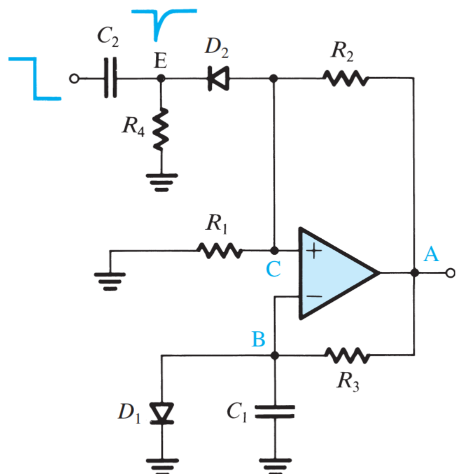


Fig. 1. The monostable multivibrator circuit.

The voltage V_A is saturated at L_+, the supply voltage of the op amp as seen in (1). This remains true until the circuit is triggered as seen in figure 2. The voltage V_C is determined by the voltage divider R_2 and R_1 shown in (2). Choosing R_4 to be largely greater than R_1 is important so that the current flowing through D_2 is small. V_E will always be at a difference of V_{D2} from V_C unless triggered and eventually C_2 is recharged as seen in figure 2 and (3). The voltage V_B is clamped by the diode in (4) and is discharged when the circuit is triggered as seen in figure 2. The following (1), (2), (3) and (4) show the node voltages prior to the trigger.

$$V_A = L_+ \tag{1}$$
$$V_c = \beta L_+ \tag{2}$$

$$V_E = \beta L_+ - V_{D2} \tag{3}$$
$$V_B = V_{D1} \tag{4}$$

Looking closely at figure 2, the resulting trigger from V_E also causes a dip in V_C. The difference between V_C and V_B forces V_A to drop to L_-. The negative voltage of V_A feeds back to C and sets $V_C = \beta L_-$. The negative voltage at A also causes the C_1 to discharge as current flows the opposite way and D_1 turns off. When $V_B = V_C = \beta L_-$ the difference between V_B and V_C is 0 and V_A returns to L_+.

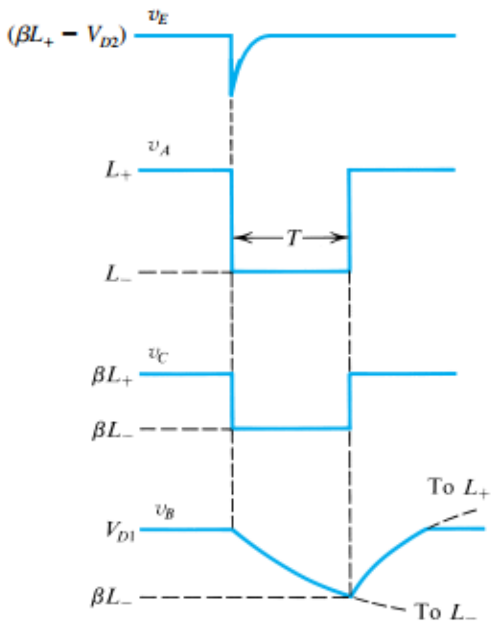


Fig. 2. Resulting node voltages of the monostable multivibrator from the trigger.

From figure 2, V_B shows that the period T of the pulse is determined by the RC time constant composed of C_1 and R_3. The equation for $V_B(t)$ is given by (5). Substituting t = T gives (6). Solving for period T results in (7). Choosing V_{D1} to be largely smaller than L_- the equation is simplified in (8).

$$V_B(t) = L_- - (L_- - V_{D1})\, e^{-\frac{t}{R_3 C_1}} \quad (5)$$

$$\beta L_- = L_- - (L_- - V_{D1})\, e^{-\frac{T}{R_3 C_1}} \quad (6)$$

$$T = C_1\, R_3 \ln\left(\frac{V_{D1} - L_-}{\beta L_- - L_-}\right) \quad (7)$$

$$T = C_1 R_3 \ln\left(\frac{1}{1-\beta}\right) \quad (8)$$

The 555 timer IC can also be used to generate pulses of a desired width and height. Figure 3 shows the internals and implementation of the monostable multivibrator. An RC circuit is attached to the comparator 1 non-inverting input and the Q_1 BJT collector.

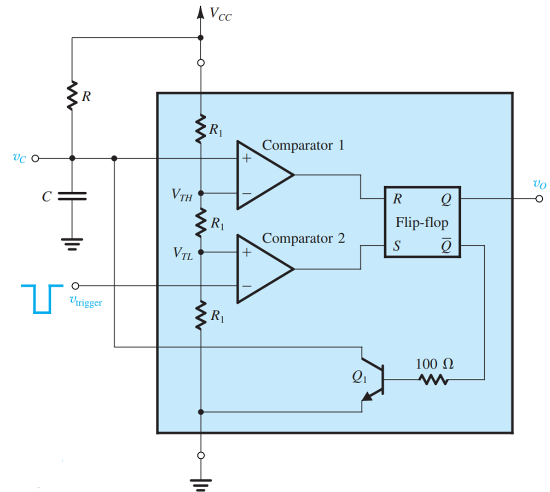


Fig. 3. The implementation of a monostable multivibrator using a 555 timer.

Initially, the 555 timer is in the steady state with the RS flip flop in its reset state. The Q' output is high and powering the Q_1 transistor. Since the current is saturated through Q_1, the voltage V_C will be constantly low because no current is charging the capacitor C. With a 0 input for comparator 1 and a high input for comparator 2, the 555 timer will remain in its steady state.

The 555 timer is triggered by inputting a signal lower than V_{TL}. Once triggered, comparator 2's output goes high and the RS flip flop is set. V_o is now output high. The Q' low output turns off Q_1 and the current can now start charging the capacitor C. Once capacitor C, reaches V_{TH}, comparator 1s output is set high and the RS flipflop is reset. V_o is back to output low and 555 timer is back in steady state. The process of this pulse is further illustrated in figure 4.

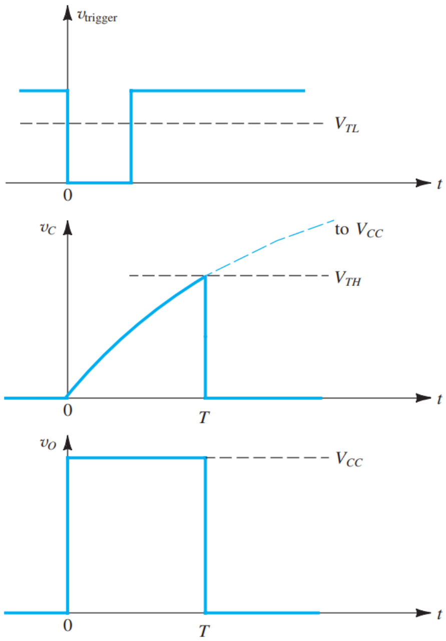


Fig. 4 Resulting voltages from the trigger of the 555 timer.

Looking closely at figure 4, the period T is determined by the RC time constant. $V_C(t)$ is given by (9). By substituting t = T and $V_C(T)$ = (2/3) V_{CC} and then solving for T, the period is determined by (10).

$$V_C(t) = V_{CC}\,(1 - e^{-t/RC}) \tag{9}$$

$$\mathrm{T} = \mathrm{RC}\ln(3) \tag{10}$$

III. SIMULATION AND EXPERIMENTAL RESULTS

The values were calculated to be R_1=R_2= 1 kΩ, R_3= 1.2 kΩ, R_4= 10 kΩ, C_1= 0.1 uF, C_2= 0.005uF. The values were selected for the Op Amp Pulse Generator shown in Fig. 5.

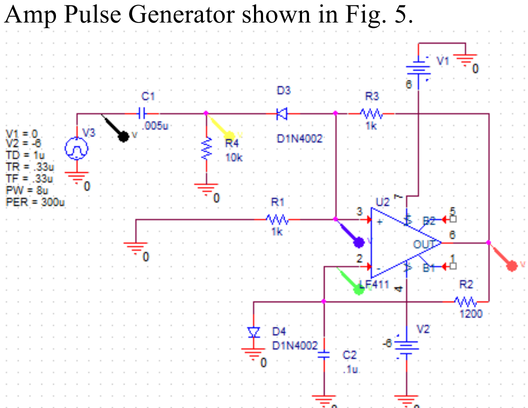
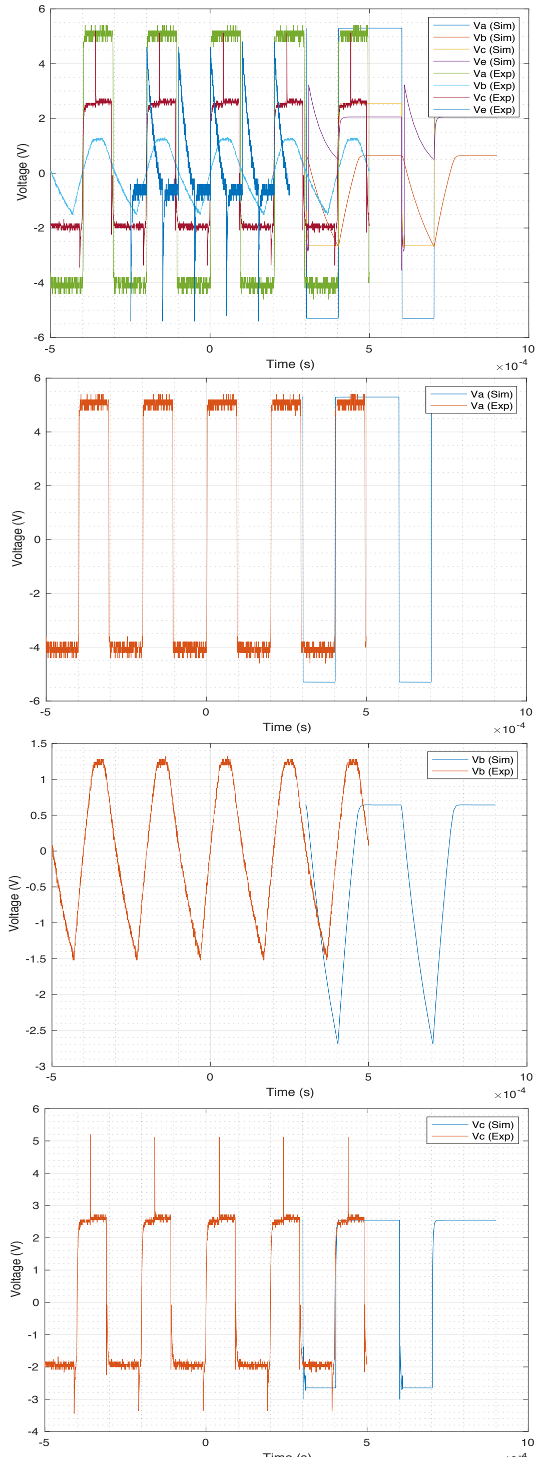


Fig. 5. An Op Amp Pulse Generator circuit.

The output for the Op Amp Pulse Generator circuit can be seen in Fig. 6.



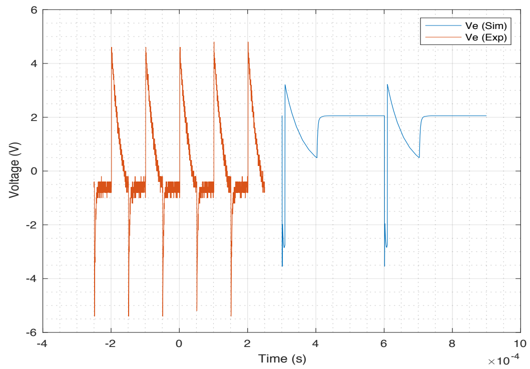


Fig. 6. Different outputs for the Op Amp Pulse Generator

The pulse width can be seen to be about 100 µs for both simulation and experimental. The values for the 555-Timer Based Pulse Generator were R= 9.1 kΩ and C= 0.1 uF. The circuit can be seen in Fig. 7.

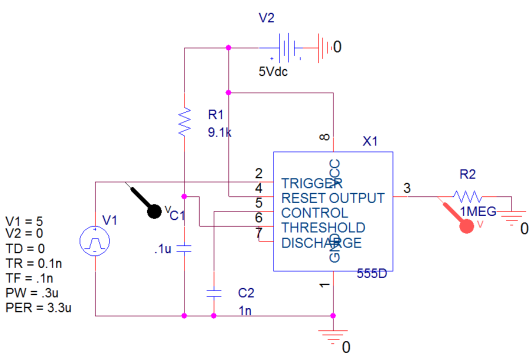


Fig. 7. 555-Timer Based Pulse Generator circuit

The output for the 555-Timer Based Pulse Generator can be seen in Fig. 8.

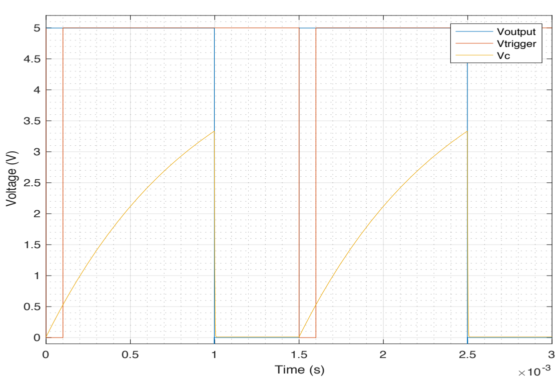


Fig. 8. 555-Timer Based Pulse Generator outputs

The pulse width measured for the output is about 1 ms.

IV. DISCUSSION AND CONCLUSION

An op amp and diodes were used to create an Op Amp Pulse Generator. The resistors and capacitors were chosen to receive a pulse width of 100 µs. The simulation output was 100 µs while the experimental was about 98 µs. A 555-Timer Based Pulse Generator was also created and the desired pulse width was 1 ms. The pulse width received was about 0.7 ms. There was no experimental value for the 555-Timer Based Pulse Generator due to campus being closed.

The experimental and simulation values were different for the Op Amp Pulse Generator due to error. One error was that the circuit was measured during different time intervals. This wasn't allowed get fixed due to the campus closure. Another error can be due to our measuring probes quality. This can account for the spikes in some of our experimental data. The voltage values aren't the same because some voltage could've been lost in the circuit.

ACKNOWLEDGMENT

Ridge- 50% Lab, Introduction and Circuit Theory

Oscar- 50% Lab, Abstract, Simulation Results and Conclusion

REFERENCES

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