Title of the experiment:

Design and Simulation of Asymmetric Astable Multivibrator using Op-Amps and Diodes

1. Introduction

An astable multivibrator, often known as a "free-running" oscillator, is an electrical circuit that alternates between two states constantly without the need for an external input signal. The asymmetric astable multivibrator produces a square wave with an asymmetric duty cycle, as the name implies, which means that there is a difference in the amount of time spent in the high and low states.

2. Theory

The Schmitt trigger circuit and diodes are commonly used in the construction of the asymmetric astable multivibrator. Resistors, capacitors, and diodes are essential parts that control the circuit's timing properties.

2.1. Basic Operation

1. **Schmitt Trigger Configuration:** By providing hysteresis, the Schmitt trigger configuration enables the circuit to have two separate threshold voltages: one for low-to-high switching and another for high-to-low switching. This arrangement makes sure that the circuit switches between its two states fast and aids in the production of stable oscillations.
2. **Capacitor Charging and Discharging**: Two resistors, two diodes, and a capacitor are linked in series. Through these resistors, the capacitor alternately charges and discharges, producing a ramp voltage. The resistor-capacitor (RC) time constants determine the charging and discharging times.
3. **Role of Diodes**: During the charging and discharging phases, current is directed by diodes. Different resistances regulate the charging and discharging processes because the charging and discharging routes are made asymmetric by connecting diodes in series with the resistors. An asymmetric square wave output is produced as a result of the high and low phases having distinct time constants.
4. **Output Waveform**: The diode configuration and the RC time constants determine the high and low durations (duty cycle) of the output waveform, which is a square wave. Applications for this waveform include timing circuits, pulse-width modulation (PWM), and clock production.

2.2. Working Mechanism

1. **Initial Condition:** Assume that the capacitor is initially devoid of charge. The capacitor will start to charge through a resistor and diode circuit connected to the Schmitt trigger output, which will initially be in a high state.
2. **Threshold Crossing:** As the capacitor charges, its voltage increases. When the output voltage exceeds the upper threshold voltage set by the Schmitt trigger, the output goes from high to low. This switching motion causes the capacitor to discharge across a separate resistor and diode channel.

3. **Asymmetry Introduction:** To ensure that the resistance along the charging and discharging routes vary, the circuit is equipped with diodes. The capacitor takes longer to charge than to discharge as a result of this disparity, which results in an uneven duty cycle in the output waveform.
4. **Repetition:** The capacitor then alternates between charging and discharging, causing the Schmitt trigger to alternate between states indefinitely after that. The outcome is a continuous square wave output with an uneven duty cycle.

3. Circuit Diagram

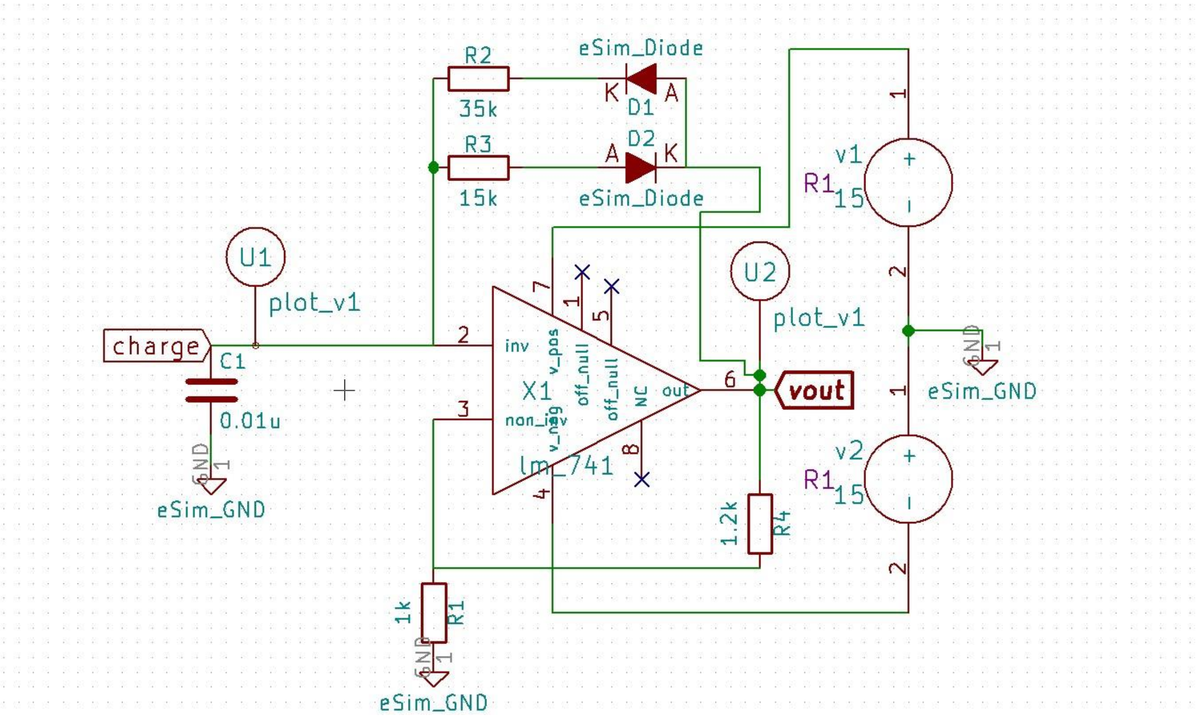

Figure 1: Schematic Diagram of Asymmetric Astable Multivibrator.

- Op-Amp (**U1**): Provides consistent switching with distinct high and low thresholds by functioning as a Schmitt trigger.
- Resistors **(R2, R3)**: Regulate the charge/discharge rates of the capacitor to modify the duty cycle and frequency.
- Capacitor **(C1)**: creates a sawtooth waveform by charging and discharging to set the time of oscillations.
- Diodes **(D1, D2)**: To create an asymmetric duty cycle, introduce asymmetry in the charge/discharge channels.

5. Design Steps:

Sl No.	Steps	Working
1.	Frequency of square wave required	f =
2.	Duty cycle of square wave required d=$\frac{T_{High}}{T_{HIGH}+T_{LOW}}$ d=$\frac{R_2}{R_2+R_3} \times 100$	d =
3.	Time period T =T_{HIGH} + T_{LOW} f=$\frac{1}{T}$ f=$\frac{1}{(R_2+R_{3)C}}$	T =
4.	Calculate T_{HIGH} and T_{LOW} T_{HIGH}=d $\times$ T T_{LOW}=T-T_{HIGH}	T_{HIGH}= T_{LOW}=
5.	Assume the value of Capacitor C	C =0.01uf
6.	Calculate $R_2$and R_3 R_2=$\frac{T_{HIGH}}{C}$ R_3=$\frac{T_{LOW}}{C}$	R_2= R_3=
7.	Calculate $R_1$and R_4 R_4=1.16R_1 Let R_1=1kΩ	R_1=1kΩ R_4=1.2kΩ

It is clear from the design stages that the values of resistors $R_2$and R_3 control the duty cycle, and by adjusting their values, the frequency may be changed.

6. Analysis

Nspice Plots:

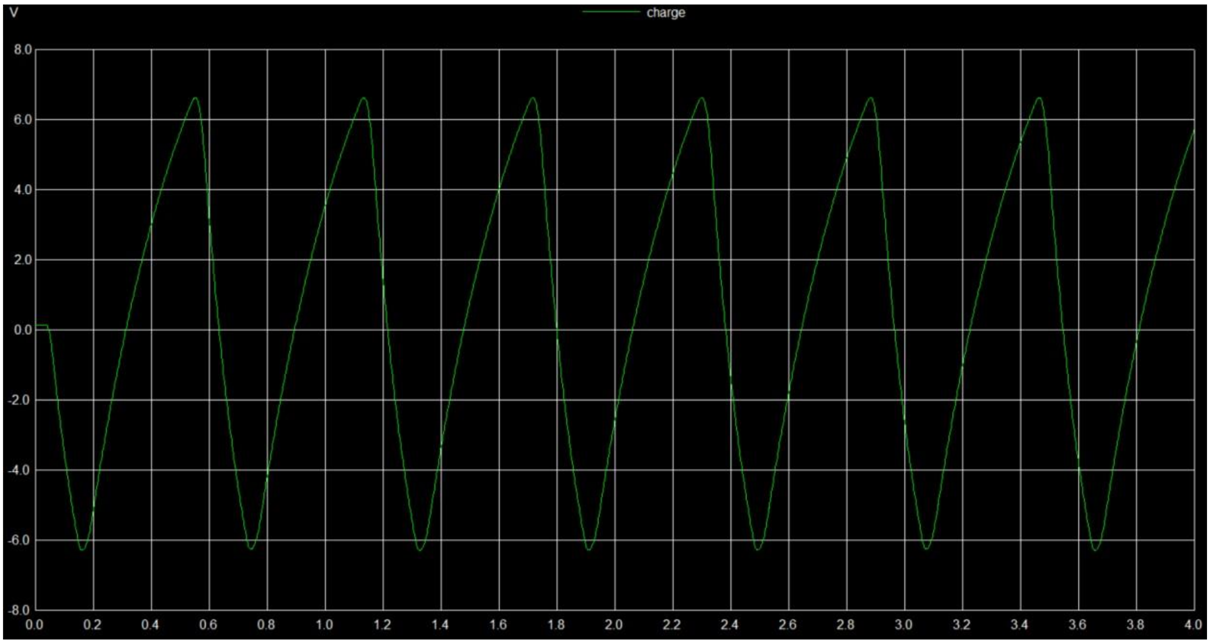

Figure 2: Ngspice Input capacitor charging discharging Plot.

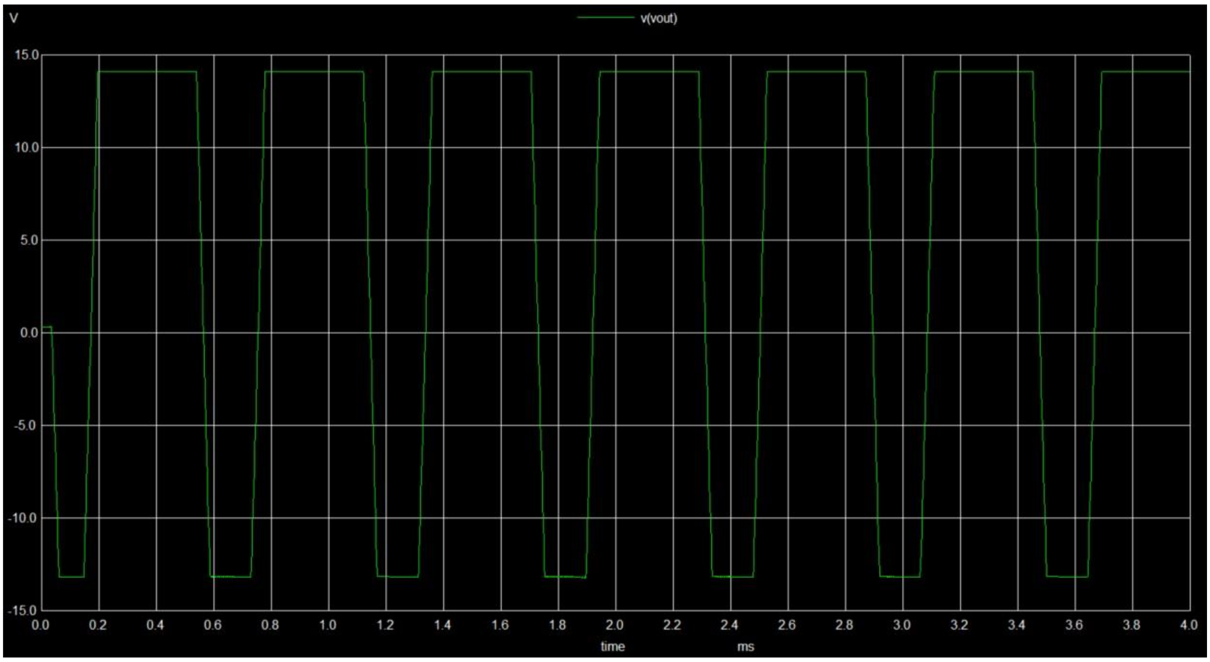

Figure 3: Ngspice Output Plot.

The output waveform of the asymmetric astable multivibrator can be analyzed by measuring the periods for the high and low states. The duty cycle, which is the ratio of the high time to the total period of the waveform, can be controlled by adjusting the resistors.

7. Graphical Analysis of Asymmetric Astable Multivibrator Output

7.1. Python Plots:

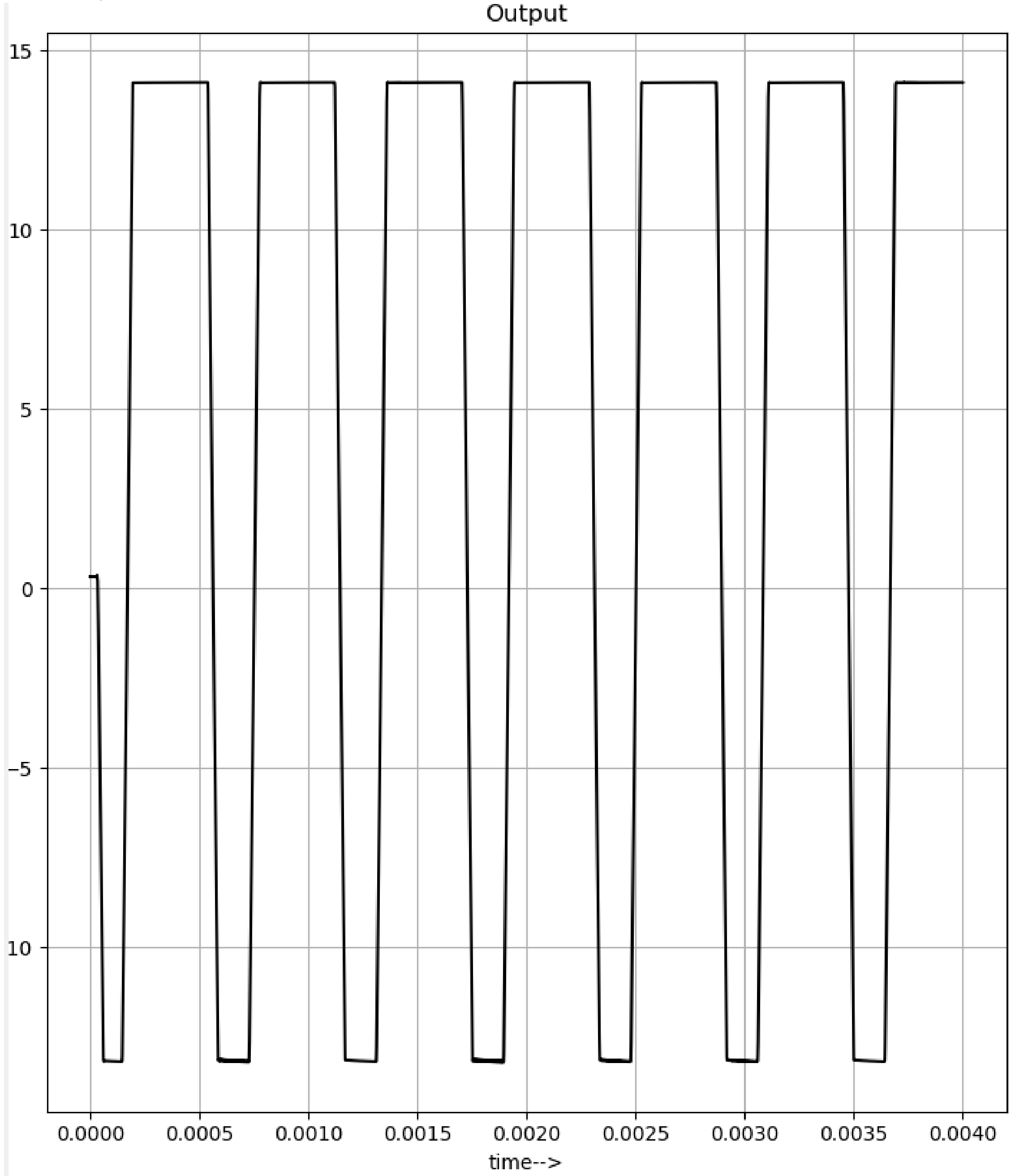

Figure 4: Output Plot.

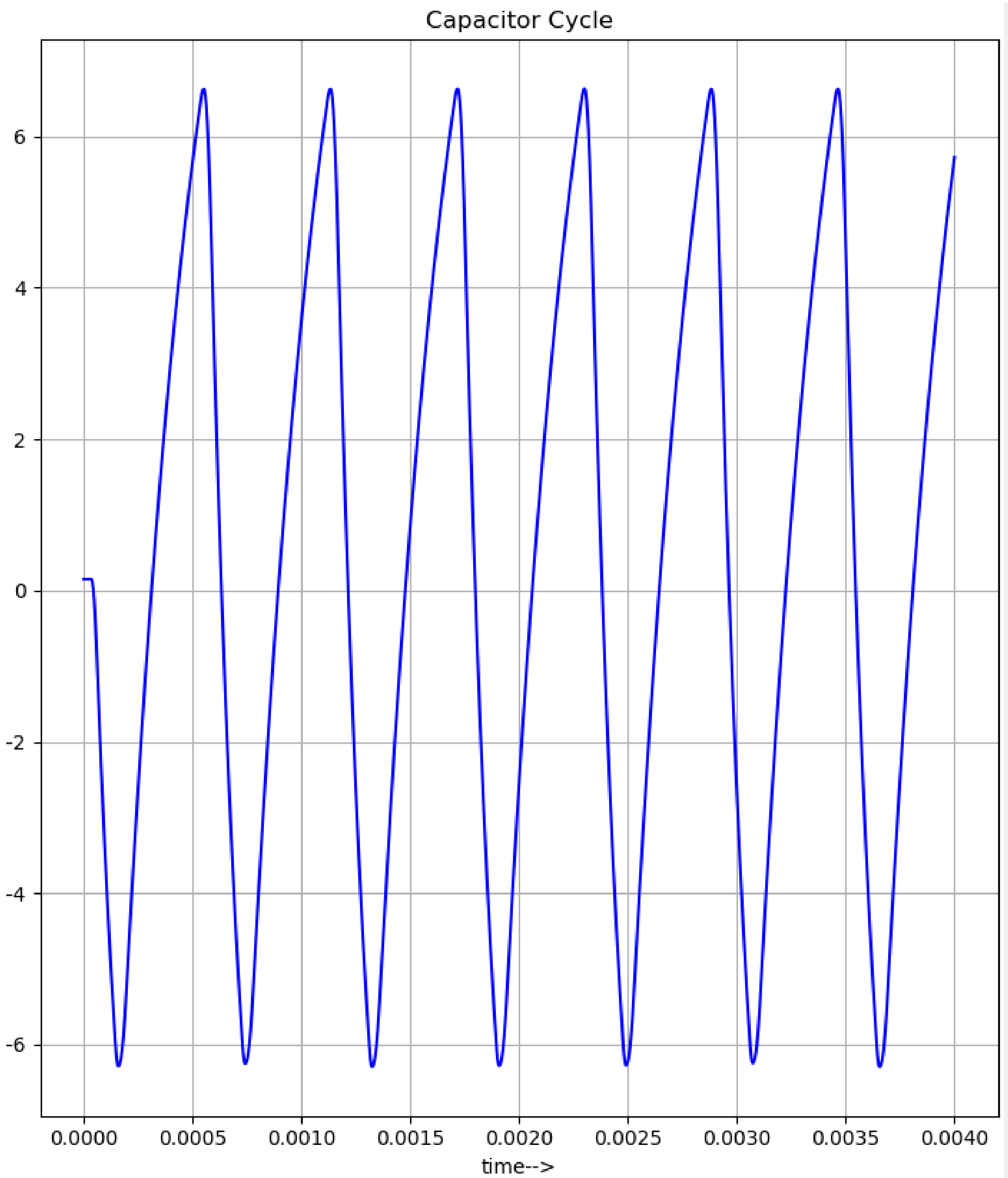

Figure 5: Input capacitor charging discharging Plot.

The characteristics of an asymmetric astable multivibrator circuit are depicted in the following graph. Two waveforms can be seen on the graph:

1. **Capacitor Voltage:** The voltage across the timing capacitor is shown by the blue curve. Sawtooth patterns, which are common in astable multivibrator circuits, are visible in this waveform. The output switches from high to low or low to high when the capacitor discharges after charging exponentially towards a particular voltage level. When the capacitor voltage approaches the Schmitt trigger-established threshold values, the square wave output abruptly transitions.

2. **Square Wave Output:** The output voltage waveform of the asymmetric astable multivibrator is represented by the black curve. This is the typical square wave produced by the circuit, which has an asymmetric duty cycle because of the difference in the amount of time spent in the high and low states. The circuit's resistors and capacitors determine the varying charging and discharging time constants, which are the cause of this imbalance.

7.2. Key Observations

- **Asymmetry:** The square wave is asymmetric, which means that the high state's duration is different from the low state's. One important aspect of the circuit is its asymmetry, which can be changed by adjusting the values of the resistor and capacitor in the charging and discharging routes.
- **Charging and Discharging Cycles**: The capacitor's charging and discharging activity is shown by the sawtooth waveform (blue). The time periods in which the square wave output stays high or low are represented by the voltage's linear rise and fall during these cycles.
- **Frequency and Duty Cycle**: The duty cycle is controlled by the relative lengths of the high and low phases, but the frequency of the output waveform is determined by the overall time period of one complete cycle (high + low). The parts of the circuit allow for exact control of these parameters.

8. Practical Applications

Because it can regulate the output waveform's frequency and duty cycle, the asymmetric astable multivibrator is a useful instrument for applications like:

- **Pulse Width Modulation (PWM):** Used in digital communication, motor control, and signal modulation.
- **Clock Signal Generation:** By using this circuit, clock signals with particular temporal properties can be produced.
- **Timing Circuits**: A necessary component of circuit design for devices like timers and delay generators that demand exact timing intervals.

9. Conclusion

The Schmitt trigger and diodes-based asymmetric astable multivibrator is a flexible circuit that can be applied to a number of situations where a square wave with a duty cycle of less than 50% is required. This circuit is a crucial tool for timing and waveform creation activities because it uses a Schmitt trigger and diode to precisely regulate the timing parameters.
Using eSim, the asymmetric astable multivibrator with an op-amp was simulated, and the necessary waveforms were produced.

10. References:

- https://www.electronics-tutorials.ws/opamp/op-amp-multivibrator.html
- https://www.multisim.com/content/H2ZwqdvwNBj7Us8vYTXwH5/asymmetricastable-multivibrator-using-op-amp/