EE-226 Circuit Analysis-II

Complex Engineering Problem Report

Blinking Traffic Arrow Head LEDs.

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Abstract

This Complex Engineering Problem involves the design and implementation of a low-cost analog circuit to operate a blinking traffic arrow, utilizing only passive components and op-amps. The circuit includes a full wave bridge rectifier to provide the DC power supply. An astable multivibrator is employed to generate a 50% duty cycle square wave, which acts as the timing signal for the LED blinking sequence. The LEDs are arranged in a pattern and connected to individual RC circuits, which control the timing of each LED's illumination. By carefully selecting resistor and capacitor values, the LEDs blink in a sequential manner from the tail to the head of the arrow, creating a moving arrow effect. This project demonstrates a cost-effective and implementable solution in a laboratory setting for traffic management systems, highlighting the practical application of analog circuit design techniques.

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Chapter 1

Introduction

1.1 Purpose

The purpose of this complex engineering problem was to design blinking traffic arrow in such a way that lights turn on in a specific sequence using the passive components.

1.2 Background

In traffic management and signaling systems, the implementation of traffic light arrows serves as a crucial visual cue for directing vehicular movement. The integration of RC circuits in such applications has been a subject of study, offering a versatile platform for controlling and sequencing LED illumination. These arrows not only indicate turn signals but also provide directional guidance for motorists, enhancing road safety and efficiency. Leveraging the inherent properties of RC circuits, our project aims to employ different time constants to achieve a dynamic "going away" effect, delineating the arrow's movement in a specific direction. Through this application, we explore the practical utilization of RC circuits in traffic signaling, showcasing their adaptability and effectiveness in real-world scenarios.

1.2.1 RC Circuits

RC circuits, which consist of resistors (R) and capacitors (C) connected in series or parallel, are fundamental components in electronic design, known for their ability to create and control timing functions. The charging and discharging properties of capacitors within RC circuits are exploited in various applications, one of the most notable being LED blinking circuits. In these circuits, an RC network's time constant, denoted by , is the product of the resistance and capacitance values (= R $\times$ C). This time constant determines the rate at which the capacitor charges or discharges through the resistor when the circuit is connected to a voltage source. This characteristic allows for precise control over the on-off durations of LEDs, enabling the creation of complex blinking sequences. In this project, we delve into the use of RC circuits to design an analog traffic arrow that blinks in a sequential pattern from the tail to the head.

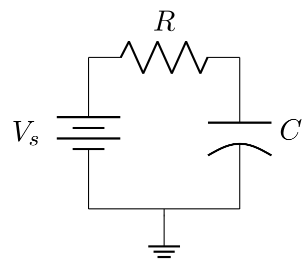

Figure 1.1: RC Circuit

1.2.2 Power Supply

To power the op-amp essential for the astable multivibrator design, a dedicated power supply circuit was indispensable. The power supply circuit provides clean and stable power for the op-amp. The design starts with a step-down transformer to reduce the incoming AC voltage to a manageable level. Next, a bridge rectifier converts the AC to pulsating DC. A filter circuit then smooths out these pulsations, resulting in a steadier DC output. Finally, a voltage regulator ensures a perfectly consistent DC voltage, crucial for the stable operation of the astable multivibrator.

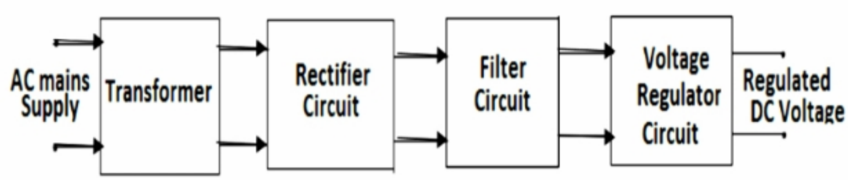

Figure 1.2: Block Diagram of Regulated DC Power Supply

1.2.3 Astable Multivibrator

Astable multivibrator, often referred to as a free-running multivibrator, is a fundamental electronic circuit widely used in various applications such as timing, signal generation, and pulse generation. Unlike its monostable and bistable counterparts, which have stable states, the astable multivibrator continuously oscillates between two unstable states without any external trigger or input signal. It consists of two active components, typically transistors or operational amplifiers, arranged in a feedback loop with capacitors and resistors. During operation, the circuit alternately charges and discharges capacitors, causing the output to continuously switch between high and low states. The frequency of oscillation and the duty cycle (the ratio of time spent in each state) can be adjusted by varying the values of capacitors and resistors in the circuit. Astable multivibrators find applications in various electronic devices such as timers, oscillators, LED flashers, and pulse generators, owing to their simplicity, versatility, and reliability.

Chapter 2

Equipment and Procedure

2.1 Equipment

The experimental arrangement consists of the following items:

1. Capacitors;
2. Diodes;
3. Resistorss;
4. LM741 op-amp;
5. LEDs;
6. DMM;
7. Oscilloscope.

2.2 Procedure

The following procedure was followed to actualize this cirucit:

1. First, we calculated the turns ratio of the transformer to ensure a secondary voltage of 15V AC
2. Then, we designed and implemented a bridge rectifier to convert the 15V AC from the transformer to DC voltage, and measured the output DC voltage after rectification.
3. After that, we designed a filter circuit using a capacitor and resistor to smooth the rectified DC voltage, calculating the appropriate values for the capacitor and resistor to achieve the desired level of ripple reduction.
4. Next, we added a voltage regulator to stabilize the smoothed DC voltage at the required level for subsequent circuits.
5. Following the power supply design, we designed an astable multivibrator circuit to generate a square wave with a 50% duty cycle, set the operating frequency of the multivibrator to 1 Hz, and calculated the required resistor and capacitor values to achieve the desired frequency and duty cycle.

6. Measure the period T.
7. We performed detailed hand calculations for all components and circuit parameters to verify the theoretical design.
8. Subsequently, we simulated the entire circuit in LTspice to validate the design, recording and analyzing the waveforms to ensure the LEDs blink in the correct sequence and timing.
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Chapter 3

Calculations

In this chapter, we take a detailed look at the calculations required for the appropriate design of the circuitry required for the Blinking Traffic Arrow-Head LEDs.
For the Astable Multivibrator,
Let,

$$\begin{aligned} T &= 1s \\ C &= 22\mu F \end{aligned} \tag{3.1}$$

We assume that,

$$\begin{aligned} R1 &= R2 \\ R &= 10k\Omega \\ \beta &= R/2R \end{aligned} \tag{3.2}$$

$$\begin{aligned} T = 2 * R * C * ln(\frac{1+\beta}{1-\beta}) \\ T = 2.2 * R * C \\ 1 = 2.2 * R * 22\mu F \\ R = \frac{1}{2.2 * 22\mu F} \\ R = 20.61k\Omega \end{aligned} \tag{3.3}$$

For the RC circuit followed by the Astable Multivibrator,

$$\begin{aligned} T_c &= 5\tau \\ \tau &= R * C \end{aligned} \tag{3.4}$$

For the first RC circuit,

$$\begin{aligned} T &= 50ms \\ \tau &= \frac{50}{5}ms \\ \tau &= 10ms \end{aligned} \tag{3.5}$$

Assuming $C_1 = 22\mu F$

$$\mathrm{R}_1 = 625\Omega$$

For the second RC Circuit

$$\begin{aligned} T &= 300ms \\ \tau &= \frac{300}{5}ms \\ \tau &= 60ms \end{aligned} \tag{3.6}$$

Assuming $\mathrm{C}_2 = 0.33\mu F$

$$\mathrm{R}_2 = 18.18k\Omega$$

For the third RC Circuit

$$\begin{aligned} T &= 600ms \\ \tau &= \frac{600}{5}ms \\ \tau &= 120ms \end{aligned} \tag{3.7}$$

Assuming $\mathrm{C}_3 = 10\mu F$

$$\mathrm{R}_3 = 12k\Omega$$

For the fourth RC Circuit

$$\begin{aligned} T &= 850ms \\ \tau &= \frac{850}{5}ms \\ \tau &= 170ms \end{aligned} \tag{3.8}$$

Assuming $\mathrm{C}_4 = 10\mu F$

$$\mathrm{R}_4 = 17k\Omega$$

For Power Supply,

$$\begin{aligned} V_{in(rms)} &= 220V \\ V_p &= 220/0.7 \\ V_p &= 314V \\ V_s &= 15V \\ \frac{N_p}{N_s} &= \frac{314}{15} \\ (\frac{N_p}{N_s})^2 &= (\frac{314}{15})^2 \\ L_1 &= 400mH \\ L_2 &= 1mH \end{aligned} \tag{3.9}$$

Chapter 4

Results and Discussion

4.1 Results

The DC Power Supply circuit shown in Fig **??** is useful for providing a constant DC voltage from a sinuisodal input. The inclusion of a DC power Supply in our design makes it more practically applicable. The output of the DC Power Supply is shown in Fig **??**.

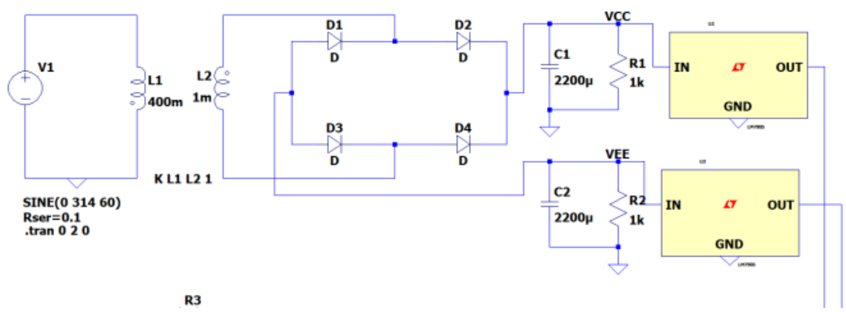

Figure 4.1: Circuit Diagram of the DC Power Supply

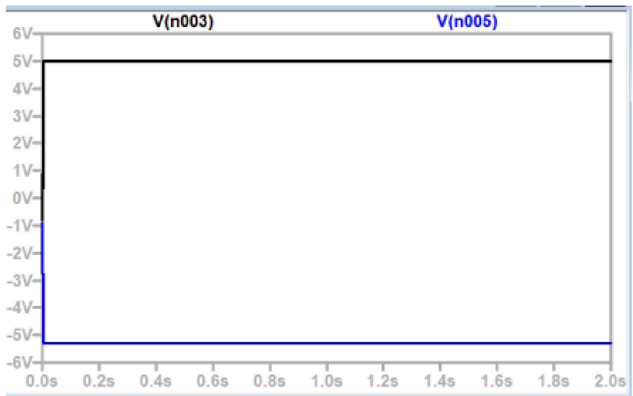

Figure 4.2: Output of the Dc Power Supply

To generate a square wave, we employed an Astable Multivibrator. The Astable Multivibrator was designed for a duty cycle of 50% and a time period of 1s. The circuit diagram of the Astable Multivibrator is shown in Fig 4.3. The output of the Astable Multivibrator is shown in Fig 4.4.

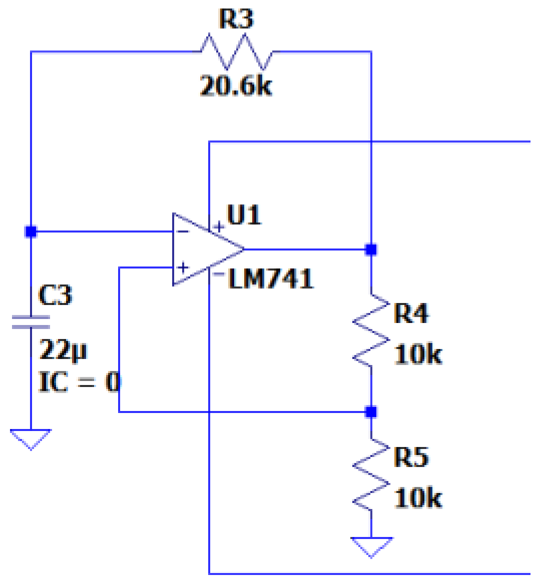

Figure 4.3: Circuit Diagram of the Astable Multivibrator

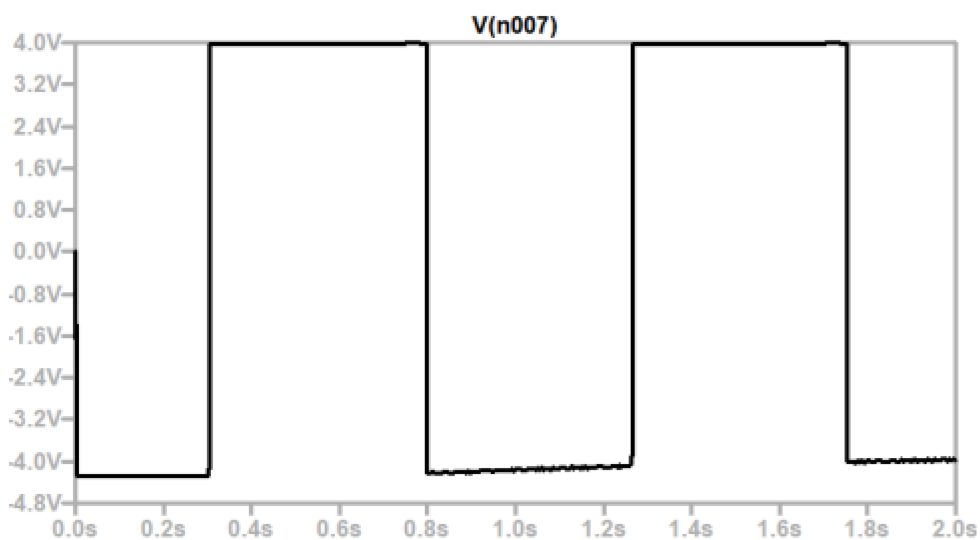

Figure 4.4: Output of the Astable Multivibrator

To add a delay in the leds, we implemented and RC network and set the time constants τ in such a manner that the leds turned on in succession. The cirucit diagram of the RC network is shown in the Fig 4.5. The output of the RC network is shown in the Fig 4.6.

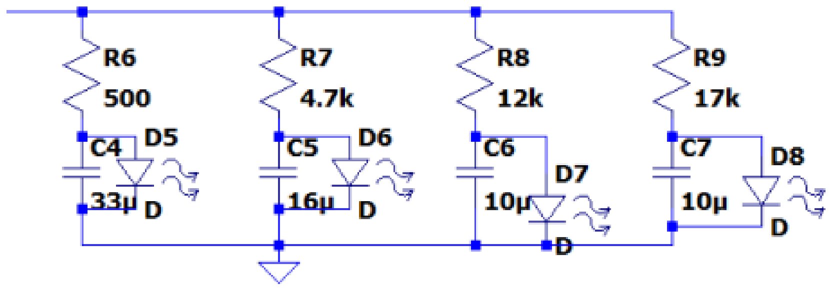

Figure 4.5: Circuit Diagram of the Astable Multivibrator

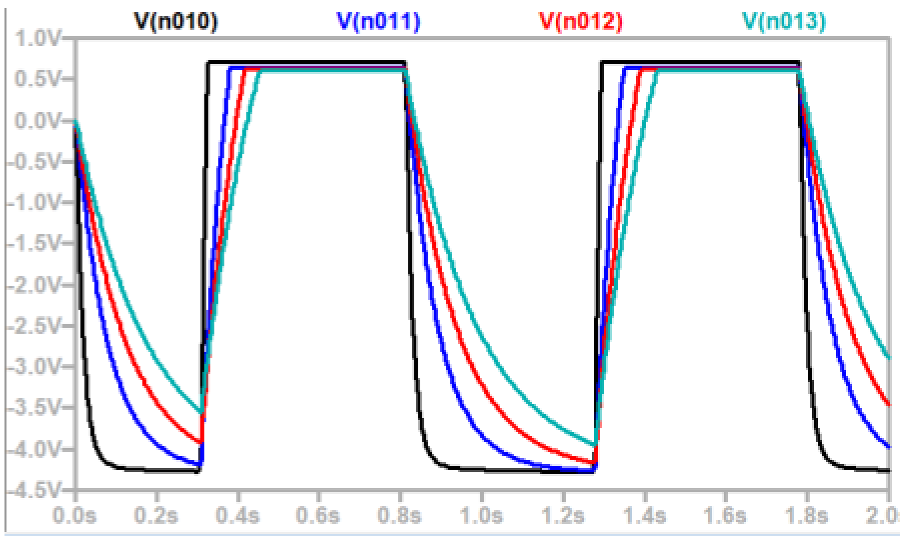

Figure 4.6: Output waveform

The final step involved the practical implementation of the designed circuit. Below is an image showcasing the hardware setup of the blinking traffic arrow circuit, demonstrating the successful realization of our design.

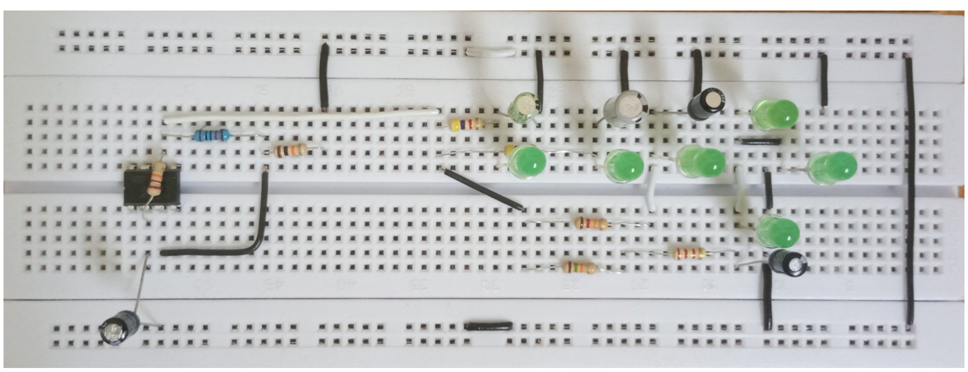

Figure 4.7: Hardware Implementation

4.2 Discussion

In this Complex Engineering Problem, we designed Blinking Traffic Arrow-Head LEDs with the help of an Astable Multivibrator and a network of RC circuits. This discussion dives into the design choices, challenges, and solutions encountered while building a blinking LED arrow circuit. In order to provide a dedicated and a stable power supply for the cirucit. We designed a DC Power Supply which would convert the $220V_{rms}$ to a DC voltage of 5V. This 5V is used to drive the Op-Amp used in the Astable Multivibrator. We opted to design and build our own power supply unit to provide a consistent voltage, often denoted as V_{CC}, to the operational amplifier (op-amp) and other components. This approach offered several advantages compared to using a pre-made option. Firstly, it allowed us to tailor the power supply specifically to the requirements of our circuit. By carefully selecting components like transformers, rectifiers, and voltage regulators, we could ensure the power supply delivered the exact voltage and current needed for optimal performance. For instance, if the LEDs require a specific voltage to shine brightly, we could design the power supply to deliver that precise voltage.

Secondly, designing the power supply ourselves provided valuable learning experience. We gained a deeper understanding of how power supplies function and the various factors that influence their output characteristics.

The astable multivibrator constitutes the fundamental building block of the blinking LED arrow circuit. This electronic circuit operates in a self-oscillating manner, continuously flipping between two stable states. This oscillation results in the generation of a square wave output, perfectly suited for driving LEDs and creating a blinking effect. Unlike circuits requiring external triggers for initiation, the astable multivibrator offers a self-contained solution, simplifying the design and enhancing overall reliability. We designed an Astable Multivibrator with a duty cycle of 50% and a gain of $\beta = 1/2$.

In addition to the Astable Multivibrator, the RC network acts as the timing source of our blinking LED arrow. The RC network is a combination of a resistor (R) and a capacitor (C). By carefully selecting the values of these components, we can control the time constant of the circuit. This time constant dictates the rate at which the capacitor charges and discharges. In essence, the RC network acts like a timer that tells the circuit how long to keep an LED on before switching it off and moving on to the next LED in the sequence, creating the illusion of a blinking arrow. The astable multivibrator generates a square wave output, characterized by alternating high and low voltage levels. The RC network interacts with this square wave, influencing the timing of LED activation within the blinking sequence. During the high portion of the square wave, the capacitor in the RC network charges towards the voltage level of the astable multivibrator's output. Conversely, during the low portion of the square wave, the capacitor discharges through the resistor.

4.2.1 Challenges

Even with careful planning, hurdles arose during the design and build process. One major challenge was fine-tuning the timing parameters of the RC network to achieve the desired LED sequence. The time constant of the RC network is influenced by the values of both the resistor and capacitor. We needed to find the perfect balance between these two components to create the desired on and off times for the LEDs. This involved spending time simulating the circuit behavior using LTSpice. This software allowed us to virtually adjust the values of the resistor and capacitor and see how it affected the timing of the square wave output.

Chapter 5

Summary and Conclusion

5.1 Summary

This report details the design and construction of a blinking LED arrow circuit. The core of the circuit utilizes a self-oscillating astable multivibrator to generate a square wave output, which drives the rhythmic blinking of LEDs arranged in an arrow formation. A precisely controlled RC network dictates the timing sequence, creating the illusion of a smoothly blinking arrow animation. A custom power supply unit ensures consistent voltage delivery throughout the circuit. This project successfully demonstrates the design principles behind a blinking LED arrow circuit. By carefully considering the challenges and implementing appropriate solutions, we achieved the desired functionality and visual effect.

5.2 Conclusion

In conclusion, this experiment provided valuable hands-on experience in measuring phase differences between voltage waveforms using oscilloscope-based techniques. Through the time difference and Lissajous curve methods, we gained insights into phase analysis and its application in circuit characterization.

The results demonstrated good agreement between experimental measurements and theoretical expectations, validating the accuracy of the employed techniques. We observed consistent trends in phase difference for both passive low pass and high pass filters, reflecting their frequency-dependent phase angles. Overall, this experiment strengthened our understanding of phase analysis techniques and their significance in signal processing and circuit design. The acquired knowledge and skills are valuable assets for further studies in electrical engineering and related fields.

References

[1] Ghulam Mustafa. *EE-226 Circuit Analysis-II Laboratory Manual*. PIEAS, Islamabad, 2024.

[2] James W. Nilsson and Susan A. Riedel. *Electric circuits*. Pearson Education, 10th edition, 2015.