

# Circuit Analysis -II

## EE-226



## Complex Engineering Problem Project Report

Submitted By

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# Operating a Blinking Traffic Arrow

## 1.1 Abstract

The project is about design and implementation of a circuit that utilizes RC timing circuits to create a blinking arrow for traffic signaling. The circuit includes a full bridge rectifier to provide the dc power supply. An astable multivibrator is employed to generate a square wave with an 80% duty cycle, which serves as the driving signal for the blinking sequence. Multiple LEDs are connected in parallel to an RC circuit, resulting in a sequential blinking pattern from the tail to the head of the arrow.

The RC circuit determines the time constant, which governs the blinking rate of each LED. By using different values of resistors and capacitors in the RC circuit for each LED, a sequential blinking effect is achieved. This creates the illusion of a moving arrow, with the LEDs blinking one after another from the tail to the head.

The project aims to provide an affordable and efficient solution for creating a traffic blinking arrow using readily available components and basic electronic principles. The circuit can be easily replicated and implemented for traffic management systems or other applications requiring stunning visual indications.

## 1.2 Objectives

1. to gain familiarity with analog RC timing circuits
2. to simulate purposed designs in LTSpice

## 1.3 Introduction

RC circuits, consisting of a resistor (R) and a capacitor (C) connected in series or in parallel, are versatile components widely used in electronic circuits. One interesting application of RC circuits is in LED blinking circuits. By utilizing the charging and discharging time constant properties of RC circuits, it is possible to create blinking patterns and control the on-off duration of LEDs.

When an RC circuit is connected to a voltage source, the capacitor gradually charges or discharges through the resistor. The time it takes for the capacitor voltage to reach a certain level is determined by the RC time constant,  $\tau$ , which is the product of the resistance and capacitance values ( $\tau = R \times C$ ). During the charging process, the

voltage across the capacitor rises exponentially, while during discharging, it decreases exponentially.

LEDs can be integrated into an RC circuit in parallel or series with the capacitor. When the circuit is initially powered on, the capacitor begins charging or discharging, depending on its initial voltage and the circuit configuration. As the capacitor voltage changes, it affects the current flowing through the LED, causing it to turn on or off accordingly.

By adjusting the values of resistance and capacitance in the RC circuit, the charging and discharging times can be controlled. A smaller time constant ( $\tau$ ) results in faster charging and discharging, leading to rapid LED blinking. Conversely, a larger time constant results in slower blinking. This property allows for customization of blinking patterns, such as adjusting the frequency or duration of LED on and off states.

RC circuits provide a simple yet effective method for generating blinking effects in LED applications. This makes them a popular choice in applications ranging from decorative lighting to traffic signaling and beyond.

## 1.4 Problem Statement

Design a circuit to operate a blinking traffic arrow in which the lights turn on in sequence from the tail to the arrowhead with the following requirements:

- The circuit should use passive components only. It may use the op-amp.
- The circuit should be low cost.
- The circuit design should be based on analog circuit design technique.
- The circuit should be implementable in practically.

## 1.5 Purposed Solution

Based on the constraints and existing research, our proposed solution aims to address the problem by utilizing a square wave to charge and discharge multiple capacitors at varying rates, which are connected to individual LEDs. This circuit offers a cost-effective approach as it requires only two operational amplifiers. However, it should be noted that using this method may result in a less consistent time difference between the LED on times.

An alternative approach involves using a saw-tooth waveform to activate the LEDs at different times by gradually increasing the voltage and turning them off simultaneously. This alternative provides a uniform time difference for the LED on times but requires the use of five operational amplifiers, thus increasing the overall cost of the circuit.

## 1.6 Design Calculations

### 1.6.1 Designing Asable Multivibrator

Referring to circuit 1.2

$$f = 500\text{Hz}$$

$$\text{Duty} = 80\%$$

$$C = 1, \mu\text{F}$$

By using following formulas:

$$t_{on} = RCl\ln(3) \quad (1.1)$$

$$t_{off} = (R|R')Cl\ln(3) \quad (1.2)$$

where

$$\ln(3) = \frac{1 + \beta}{1 - \beta} \quad (1.3)$$

$$\beta = \frac{R_1}{R_1 R_2} \quad (1.4)$$

take

$$R_1 = R_2 = 10k\Omega$$

using equations 1.1 and 1.2, we get :

$$\begin{aligned} R &= 1456 \approx 1.5k\Omega \\ R' &= 485.46 \approx 0.5k\Omega \end{aligned}$$

### 1.6.2 Designing Timing Circuit for LEDs

See figure 1.2 for shematic.

As we know for 500Hz 80% Duty Cycled Square Wave has 3.2ms on time. We set, say 1.8ms time for LED 2 to turn on fully after square wave has been applied to it. Since it takes 5 time constants to fully charge a capacitor, we have

$$5R_bC_b = 1.8\text{ms}$$

for

$$R_b = 200\Omega$$

$$C_b = 1.8\mu\text{F}$$

Similarly for LED 3, say it turns on after 3.5ms, we have

$$5R_cC_c = 3.5\text{ms}$$

for

$$R_c = 200\Omega$$

$$C_c = 3\mu F$$

we took  $4\mu F$  to make sure LED 3 turns on in end in simulations.

As far as LED 1 is concerned, we want to turn it without any delay, say in  $10\mu s$ .

$$5R_aC_a = 10\mu s$$

for

$$R_a = 200\Omega$$

$$C_a = 0.01\mu F$$

### 1.6.3 Designing Power Supply

In Pakistan, the operating voltages for domestic purposes are 220 volts in RMS at 60Hz frequency. Meanwhile, we need a 6 volts DC power supply in order to operate our flash circuit. See figure 1.1 for schematic.

Input Voltages at 60Hz:

$$V_{in(RMS)} = 220V$$

$$V_p = (0.7)(220) = 314V$$

Using turns ratio

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} \quad (1.5)$$

$$\frac{L_P}{L_s} = \left(\frac{N_P}{N_s}\right)^2 \quad (1.6)$$

Output of the Transformer:

$$V_s = 15V$$

Using eq 1.5 and eq 1.6 we get,

$$L_2 = 1mH$$

$$L_1 = 400mH$$

A bridge rectifier is used at the output of the transformer, we obtained negative and positive non-regulated DC voltages. As every diode has a voltage drop of 0.7 so, 13.3 volts are obtained as the output of the rectifier. Finally, a voltage regulator circuit is designed to finalize the power supply. As,

$$\tau = RC \quad (1.7)$$

Set,

$$\tau = 1s$$

$$R_3 = R_4 = 10k$$

Using eq 1.7 we get,

$$C_1 = C_2 = 100\mu F$$

## 1.7 Equipment

1. Capacitors
2. Diodes
3. Resistors
4. LM741 op-amps
5. Transformer
6. Digital Voltmeter
7. Oscilloscope

## 1.8 Schematics

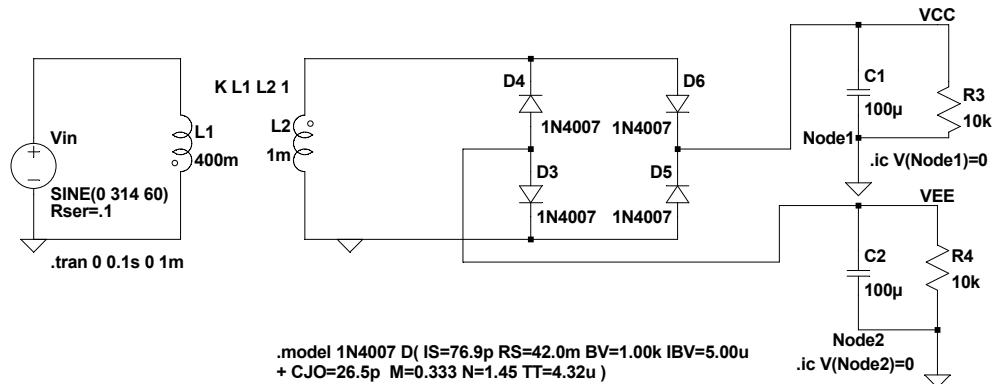


Figure 1.1: Power Supply

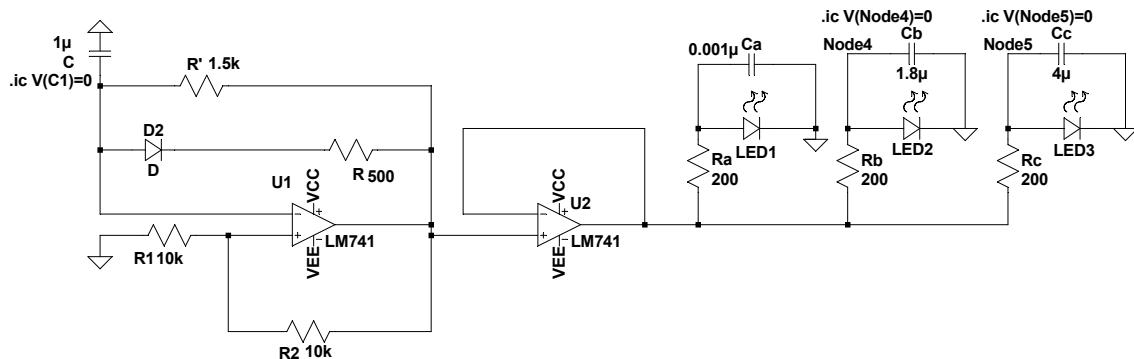


Figure 1.2: Flash Circuit

## 1.9 Graphical Analysis

### 1.9.1 Simulation Plots

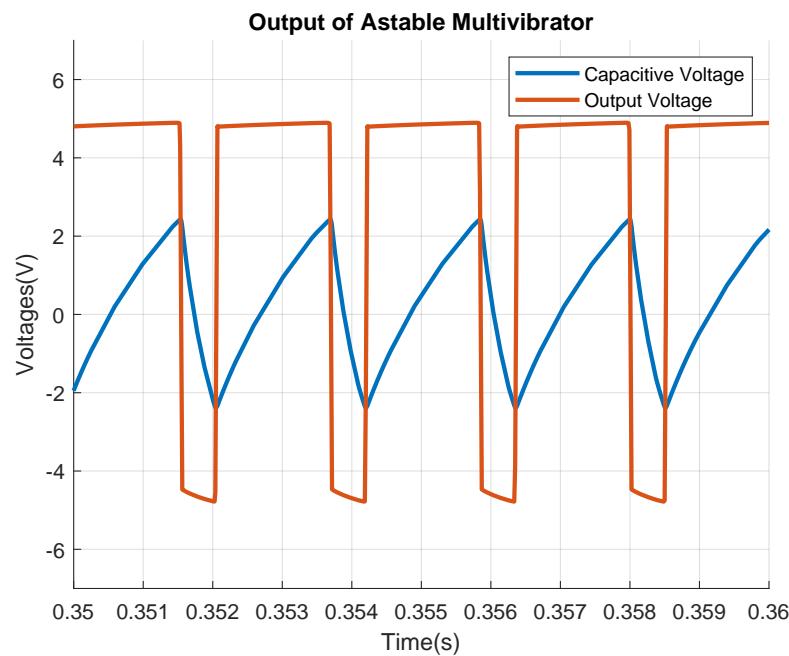


Figure 1.3: Astable Multivibrator Output

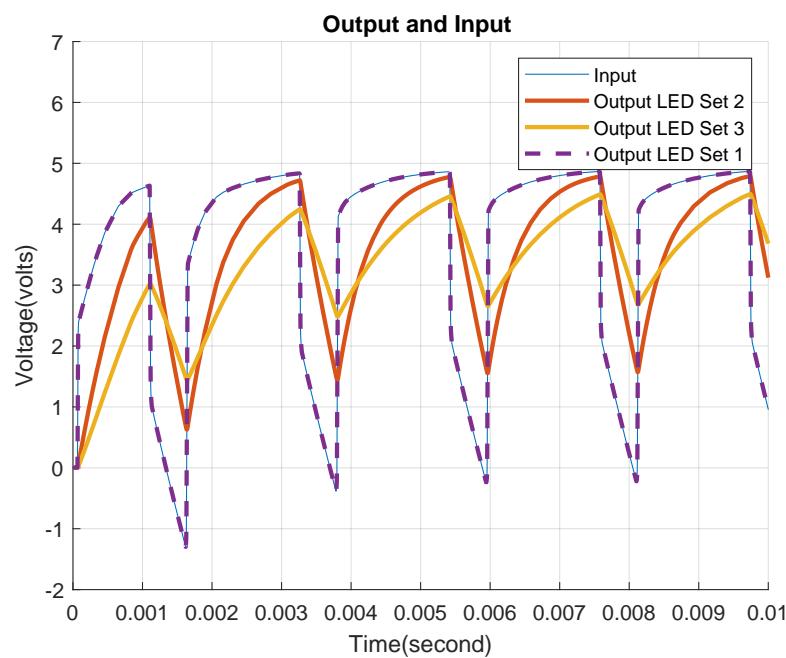


Figure 1.4: Flash Circuit Output

## 1.10 Discussion

The proposed circuit effectively addresses necessary constraints:

- (a) The circuit should use passive components only, with the possibility of incorporating operational amplifiers (op-amps).

To fulfill this requirement, we utilized a combination of passive components such as capacitors and resistors along with op-amps in the circuit design. The op-amps were used to control the charging and discharging of the capacitors, by generating a square wave.

- (b) The circuit should be low cost.

Our design approach successfully fulfills the requirement of a low-cost circuit. By utilizing only two operational amplifiers in the square wave-based solution, we were able to keep the overall cost of the circuit to a minimum.

- (c) The circuit design should be based on analog circuit design technique.

The proposed circuit design is predominantly based on analog circuit design techniques.

- (d) The circuit should be implementable in the laboratory.

The use of commonly available passive components and op-amps makes it feasible for practical implementation. The circuit design can be easily realized on a breadboard or a printed circuit board (PCB), enabling experimental validation and further refinement if required.

The graphical analysis provides a good insight of how LEDs turn on and off at different time. One thing is clear that the LED that turns on first, turns off first too, producing an effect of a arrow glowing and moving from tail to head. However, it is important to note that the proposed circuit design does have limitations. One limitation is that the square wave gets distorted due to loading effect in capacitors in LED circuit as can be see in figure 1.3 (original wave) and 1.4 (distored). It's on LEDs blinking is almost negligible for LED 2 and LED 3 but LED1 turns on late as a result of distored input square wave.

## 1.11 Conclusion

In conclusion, the proposed circuit design offers a cost-effective solution to the problem at hand. By utilizing passive components and a minimal number of operational amplifiers, the circuit achieves its functionality while maintaining a low-cost design. This affordability makes it an attractive option, especially in situations where budget constraints are a primary concern.

However, it is worth noting that there exist alternative circuits that may provide better precision and performance. For instance, incorporating digital electronics, such as 555 timer ICs or other digital components like decoders and counters, could potentially offer more precise control and synchronization of LED on times. Considering the cost-effectiveness of the proposed circuit, our solution may be recommended as a market solution in scenarios where precision requirements are not critical and the primary focus is on keeping the costs low. However, for applications where precise

timing synchronization is crucial, alternative circuits leveraging digital electronics may be more suitable, despite the higher associated costs.

From a learning perspective, the development and implementation of this circuit have provided valuable insights into the underlying principles of analog electronics. Through this project, we gained a deeper understanding of passive component characteristics, operational amplifier behavior, and the importance of analog circuit design techniques. Furthermore, it served as a motivation to explore and further study digital components like 555 timer ICs, decoders, and counters, understanding their advantages and potential applications in various projects.