Electronic Hardware

Onboarding: 555 Timer Explanation

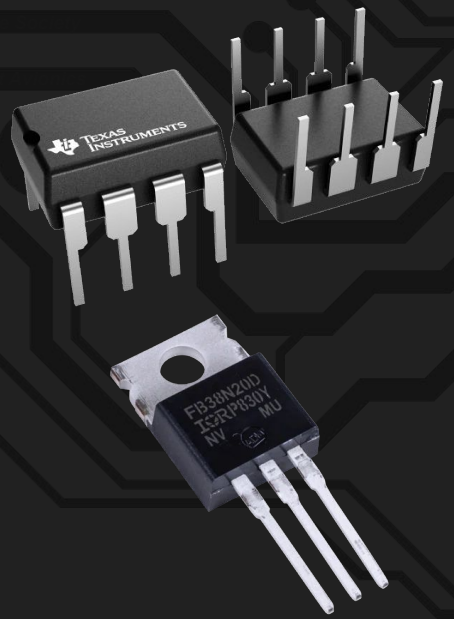
#002

2023

Introduction

Agenda:

1. Intro to LM555
2. Intro to N-Channel MOSFET
3. Putting Everything Together



Goal:

Understand the expected behavior of the 555 Timer Circuit

Intro to LM555

What is it?

- A square-wave generator controlled by using different resistors and capacitors

How to Use It?

- Two modes: **Astable** (our application) and Monostable
  - Astable Operation: Its state is Astable (not stable), and it will generate a consistent square wave
- Application:
  - Follow the diagram shown on the right
  - Use the formula given to calculate the frequency and duty cycle based on resistance and capacitance (**note that the duty cycle formula gives us % time output is low**)
- But How Does It Work?:
  - A great explanation video by Ben Eater: Astable 555 Timer - 8-bit computer clock - part 1

7.4.2 Astable Operation

If the circuit is connected as shown in Figure 14 (pins 2 and 6 connected) it will trigger itself and free run as a multivibrator. The external capacitor charges through $R_A + R_B$ and discharges through R_B. Thus the duty cycle may be precisely set by the ratio of these two resistors.

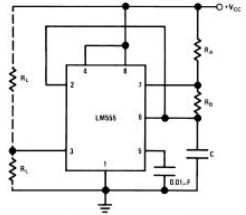


Figure 14. Astable

In this mode of operation, the capacitor charges and discharges between 1/3 V_{CC} and 2/3 V_{CC}. As in the triggered mode, the charge and discharge times, and therefore the frequency are independent of the supply voltage.

Figure 15 shows the waveforms generated in this mode of operation.

The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C \quad (1)$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C \quad (2)$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C \quad (3)$$

The frequency of oscillation is:

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)\ C} \quad (4)$$

Figure 16 may be used for quick determination of these RC values.

The duty cycle is:

$$D = \frac{R_B}{R_A + 2R_B} \quad (5)$$

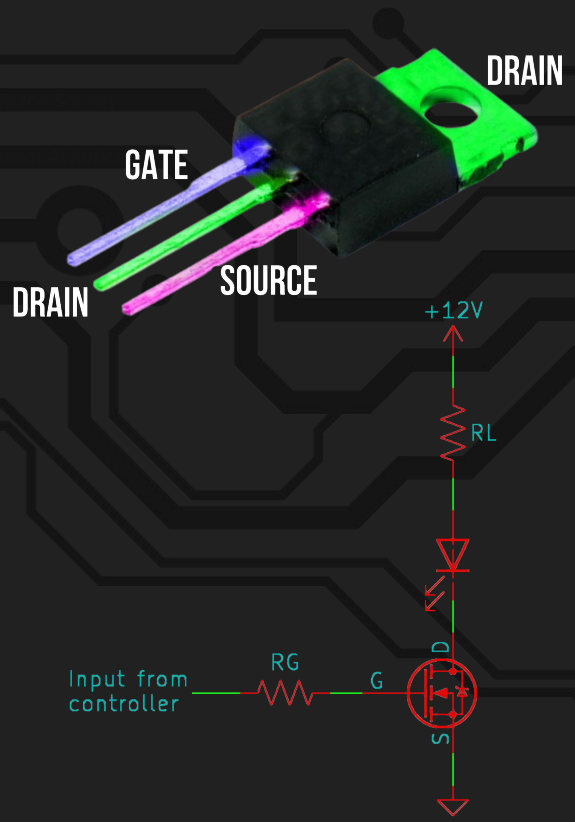
Intro to N-Channel MOSFET

What is it?

- N-Channel Metal-Oxide-Semiconductor Field-Effect Transistor
- We are using it as a voltage-controlled switch

How to Use it?

- Off when no voltage applied to Gate pin
  - Very large resistance between Drain and Source
  - Only a few **Micro Amp** can go through
- When a voltage is applied to Gate pin
  - When the voltage difference between Gate and Source ($\mathbf{V_{GS}}$, which is $\mathbf{V_{Gate}}$ - $\mathbf{V_{Source}}$) is larger than the Threshold Voltage ($\mathbf{V_{TH}}$, ~2.5V in our case), it turns on
  - The resistance between Drain and Source reduce based on the difference between $\mathbf{V_{GS}}$ and $\mathbf{V_{TH}}$
- Source pin usually connected to GND when using N-Channel



Putting Everything Together

Our Application

- 555 Timer generates 9V square waves to drive the MOSFET
- MOSFET turns on and off to blink the LEDs

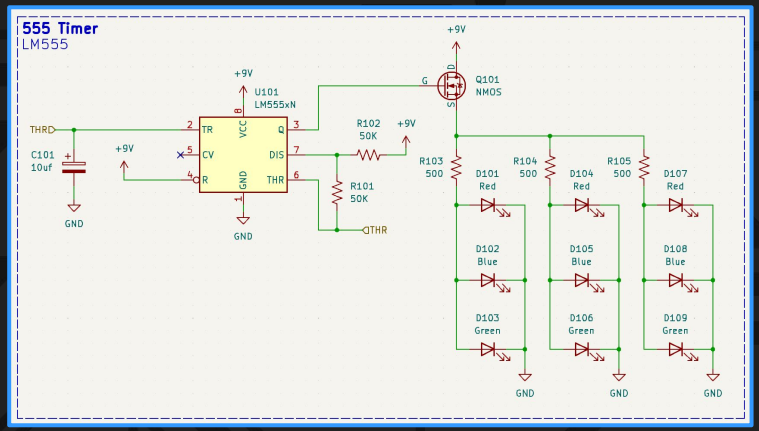
Calculations

- MOSFET:
  - Because $\mathbf{V_{GS}}$ has to be larger than $\mathbf{V_{TH}}$ (~2.5V) and we know $\mathbf{V_{Gate}}$ is 9V, so $\mathbf{V_{Source}}$ will be ~6.5V
- 555 Timer:
  - $R_A = R_B = 50K\ Ohm$, $C = 10\ uF$

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2R_B)C} = \frac{1.44}{(50*10^3\text{Ohm} + 2*50*10^3\text{Ohm})10*10^{-6}\ \text{F}} = 0.96\ \text{s}$$

$$D = \frac{R_B}{R_A + 2R_B} = \frac{50*10^3\text{Ohm}}{50*10^3\text{Ohm} + 2*50*10^3\text{Ohm}} = 0.33$$

  - Remember that duty cycle gives % time output is low (0V)
  - So % time output is high (9V) = 1 - 0.33 = 0.67



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The duty cycle is:

$D = \frac{R_B}{R_A + 2R_B}$ (5)

Further Reading

Works Cited:

Ben Eater. “Astable 555 timer - 8-bit computer clock - part 1.” *YouTube*, Mar. 2016, https://www.youtube.com/watch?v=kRISFm519Bo.

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Image Source:

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https://www.ti.com/product/LM555/part-details/LM555CN/NOPB

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