EG572EX: ELECTRONIC CIRCUITS I

555 TIMERS

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1) PIN DESCRIPTIONS

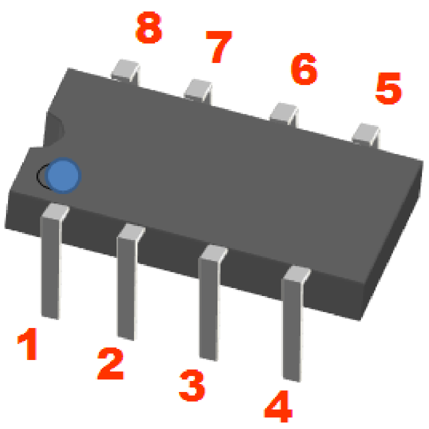

Fig.1 555 timer Pin Configurations

- **Pin 1 (Ground):-** All voltages are measured w.r.t. this terminal. This is the most negative supply potential of the device.
- **Pin 2 (Trigger Terminal)**:- This pin is an inverting input to a lower comparator. This is used to set the flip flop which causes the output to go high.
- **Pin 3 (Output Terminal)**:- There are 2 ways to connect load to the output terminal. If the output is connected between Pin 3 & Vcc, it's called a normally on load and if it's connected between Pin 3 & Ground, it's called a normally off load.
- **Pin 4 (Reset):-** To disable or reset the timer a negative pulse is applied to this pin. When this pin isn't used, it's connected to Vcc.
- **Pin 5 (Control Voltage)**:- The function of terminal is to control the threshold and trigger levels. The external voltage or a pot connected to this pin determines the pulse width of the output waveform. When not in use, it should be connected to ground through a 0.01uF capacitor to avoid any noise problem.
- **Pin 6 (Threshold):-** This is an input to the upper comparator. It's used to reset the flip-flop which drives the output low.
- **Pin 7 (Discharge)**:- When the npn transistor connected to it is turned "on," the pin is shorted to ground. The timing capacitor is usually between pin 7 and ground and is discharged when the transistor turns "on"
- **Pin 8 (Supply Voltage):-** A positive supply voltage is applied to this terminal

2) SIMPLIFIED BLOCK DIAGRAM OF 555 TIMER

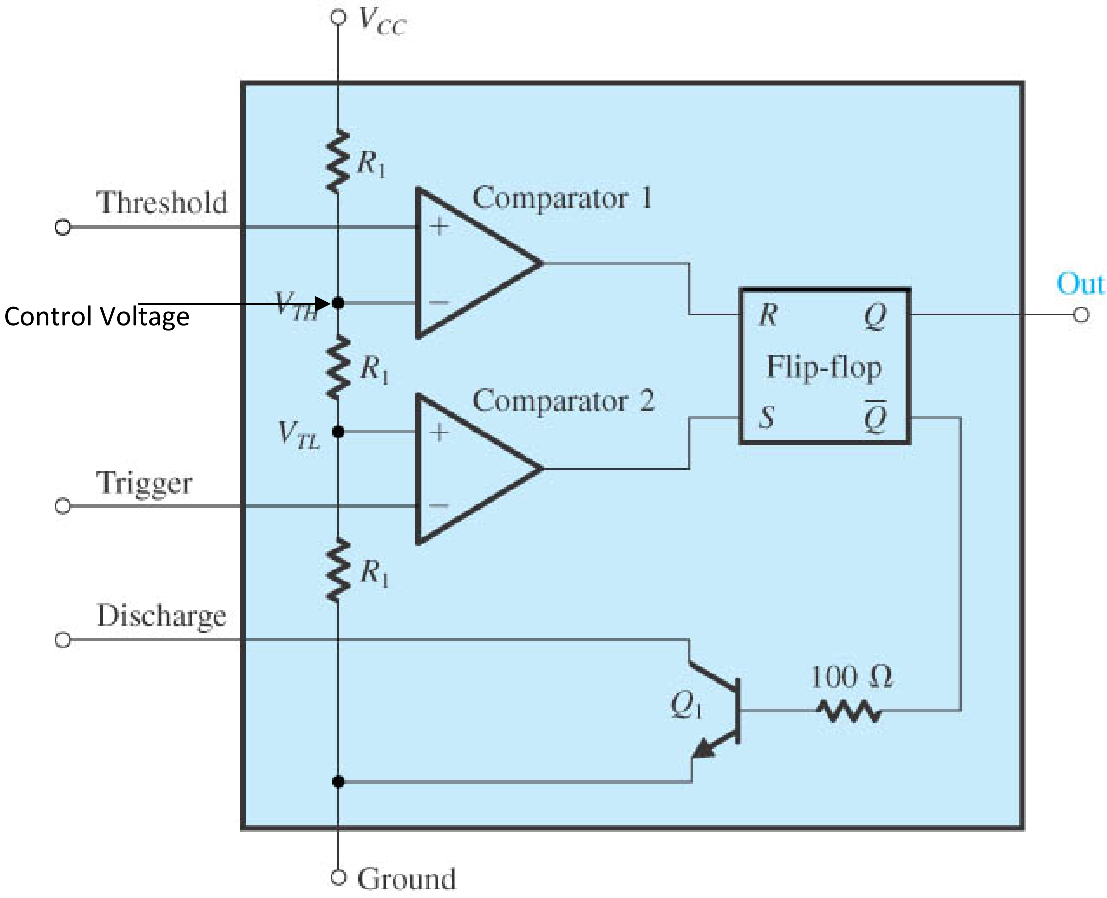

Fig. 2 Simplified Block Diagram of 555 Timer

3) 555 TIMER AS AN ASTABLE MULTIVIBRATOR:-

555 timers are widely used as astable multivibrators. The circuit diagram for using 555 timer as an astable multivibrator is given in fig. 3. The block diagram representation of 555 timer as an astable multivibrator is given in fig. 4.

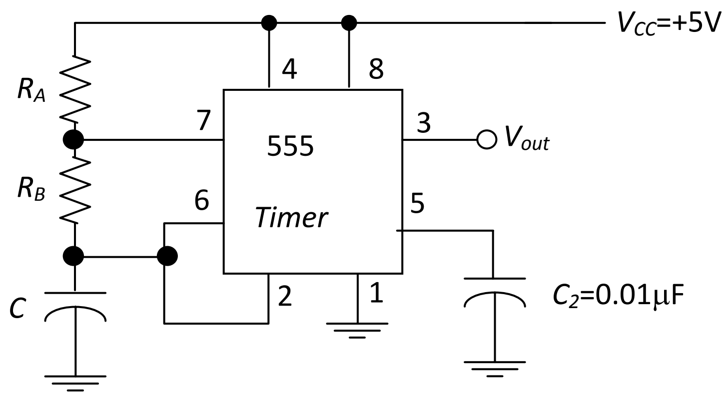

Fig. 3 Circuit Diagram of 555 Timer as an Astable Multivibrator

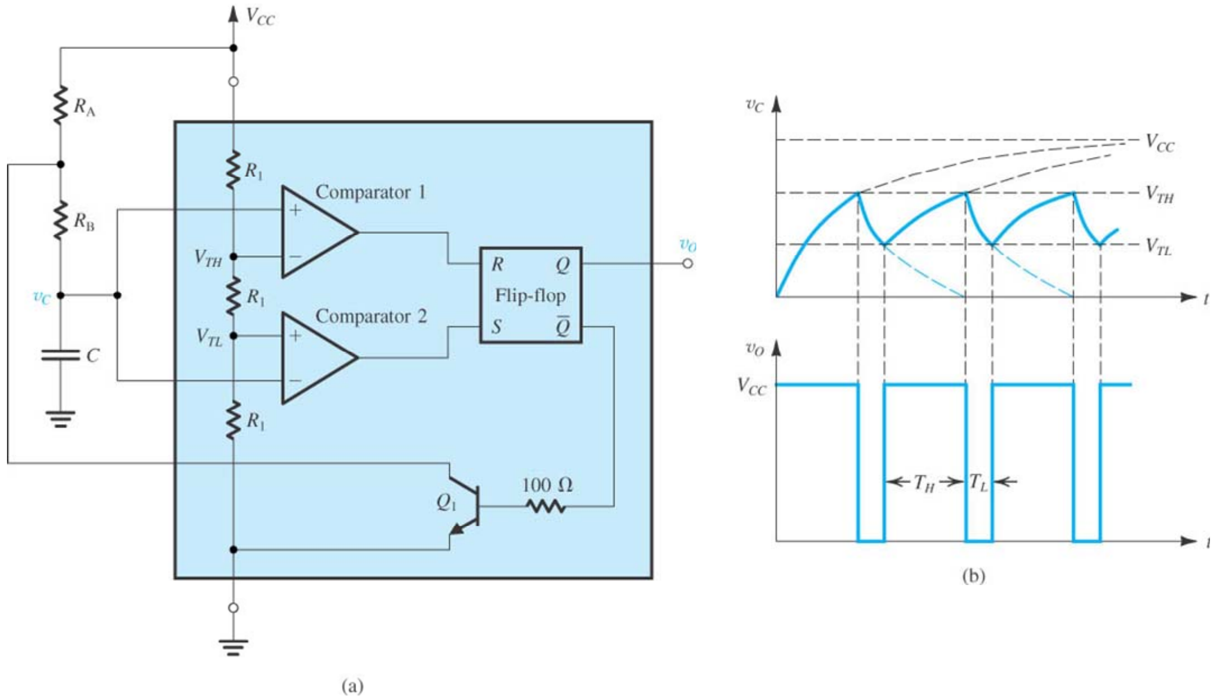

Fig. 4 (a) Block Diagram Representation of 555 timer as an astable multivibrator and (b) relevant waveforms

4) DESCRIPTION OF 555 TIMER AS AN ASTABLE MULTIVIBRATOR

Assume that the capacitor C is initially discharged and the flip flop is set. Since the flip flop is set, the output is high and $\overline{Q}$ is low. The low output from $\overline{Q}$ turns off transistor Q_1. Capacitor C will charge up through the series combination of R_A and R_B and the voltage across it, V_c will rise exponentially towards V_{cc}. A V_c crosses the level equal to VTL, the output of comparator 2 goes low. This, however has no effect on the circuit operation, and the flip-flop remains set. Indeed, this state continues until V_c reaches and begins to exceed the threshold of comparator 1, V_{TH}. At this instant of time, the output of comparator 1 goes high, and transistor Q_1 is turned on. The saturated transistor Q_1 causes a voltage of approximately zero volts to appear at the common node of R_A and R_B. Thus, C begins to discharge through R_B and collector of Q_1. The voltage V_C decreases exponentially with a time constant R_BC towards 0 V. When V_c reaches the threshold of comparator 2, V_{TL}, the output of comparator 2, goes high and sets the flip flop. The output V_o then goes high, and $\overline{Q}$ goes low, turning off Q1. Capacitor C begins to charge through the series equivalent of R_A and R_B and its voltage rises exponentially towards V_{cc} with a time constant C (R_A + R_B). This rise continues until V_c reaches V_{TH}, at which time the output of comparator 1 goes high, resetting the flip flop, and the cycle continues.

Thus, from the description above, it can be concluded that the circuit of fig. 4 (a) oscillates and generates a square waveform at the output. The frequency of oscillation can be determined as follows.

Fig. 4 (b) indicates that the output will be high during the interval T_H, in which V_c rises from V_{TL} to V_{TH}. The exponential rise of V_c is given as,

$$V_c = V_{applied} - (V_{applied} - V_{initial})\, e^{\frac{-t}{C\,(R_A+R_B)}}$$

Since, $V_{initial}$ is equal to V_{TL} when the capacitor rises from the voltage level of V_{TL} to V_{TH}, the above expression can be written as,

$$V_c = V_{CC} - (V_{CC} - V_{TL})\, e^{\frac{-t}{C\,(R_A+R_B)}}$$

Substituting, $V_c = V_{TH} = \frac{2}{3}$ of Vcc at $t = T_H$ and $V_{TL} = \frac{1}{3}$ Vcc results in

$$T_H = C\,(R_A + R_B) \ln 2 \approx 0.69\, C\,(R_A + R_B)$$

Thus, V_o will be low during the interval T_L, in which V_c falls from V_{TH} to V_{TL}. The exponential fall of Vc can be described by

$$V_c = V_{TH}\, e^{\frac{-t}{C\,R_B}}$$

Substituting, $V_c = V_{TL} = \frac{1}{3}$ of Vcc at $t = T_L$ and $V_{TH} = \frac{2}{3}$ Vcc results in

$$T_L = C\,R_B \ln 2 \approx 0.69\, C\,R_B$$

The total time period fo the output square wave is given as,

$$\mathbf{T = T_H + T_L = 0.69\, C\,(R_A + 2R_B)}$$

and, the frequency of oscillation is given as,

$$\mathbf{f = \frac{1}{T} = 1/\,[0.69\, C\,(R_A + R_B)]}$$

5) 555 TIMER AS A MONOSTABLE MULTIVIBRATOR:-

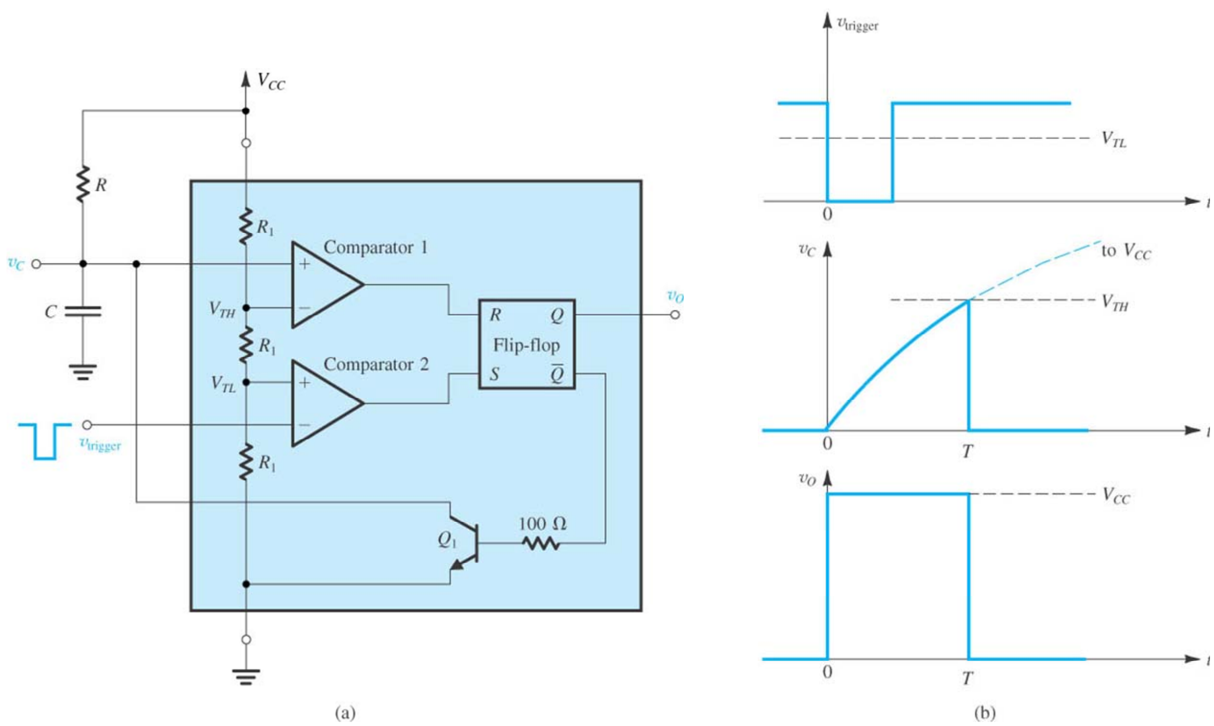

Fig. 5 (a) Block Diagram Representation of 555 timer as an astable multivibrator and (b) relevant waveforms

6) DESCRIPTION OF 555 TIMER AS A MONOSTABLE MULTIVIBRATOR:-

Fig. 5 (a) shows a monostable multivibrator implemented using 555 timer together with an external resistor R and an external capacitor C. In the stable state the flip flop will be in the reset state, and thus its $\bar{Q}$ output will be high, turning on transistor Q1. Transistor Q1 will be saturated, and thus V_c will be close to 0 V, resulting in a low level at the output of comparator 1. The voltage at the trigger input terminal, labeled $V_{trigger}$, is kept high (greater than V_{TL}), and thus the output of comparator 2 also will be low. Finally, note that since the flip flop is in the reset state, Q will be low and thus V0 will be close to 0 V.

To trigger the monostable multivibrator, a negative input pulse is applied to the trigger input terminal. As $V_{trigger}$ goes below V_{TL}, the output of comparator 2 goes to the high level, thus setting the flip-flop. Output Q of the flip-flop goes high, and thus V_0 goes high, and output $\bar{Q}$ goes low, turning off transistor Q1. Capacitor C now begins to charge up through resistor R, and its voltage V_c rises exponentially towards Vcc, as shown in fig. 5 (b). The monostable multivibrator is now in its quasi-stable state. This state prevails until V_c reaches, and begins to exceed the threshold of comparator 1, V_{TH}, at which the output of comparator 1 goes high, resetting the flip-flop. Output $\bar{Q}$ of the flip flop now goes high and turns on transistor Q1. In turn, transistor Q1 rapidly discharges capacitor C, causing V_c to go to 0 V. Also, when the flip flop is reset its Q output goes low, and thus V_0 goes back to 0 V. The monostable multivibrator is now back in its stable state and is ready to receive a new triggering pulse.

From the description above we see that the monostable multivibrator produces an output pulse V_0 as indicated in fig. 5 (b). The width of the pulse, T, is the time interval that the monostable multivibrator spends in the quasi- stable state; it can be determined by reference to the waveforms in fig. 5 (b) as follows: Denoting the instant at which the trigger pulse is applied at t=0, the exponential waveform of Vc can be expressed as,

$$V_c = V_{applied} - (V_{applied} - V_{initial})\, e^{\frac{-t}{CR}}$$

$$V_c = V_{cc} - (V_{cc} - 0)\, e^{\frac{-t}{CR}}$$ [we have assumed to be discharged initially]

$$V_c = V_{cc}\left(1 - e^{\frac{-t}{CR}}\right)$$

Substituting $V_c = V_{TH} = \frac{2}{3}Vcc$ at t= T gives,

T = RC ln 3 ≈ 1.1 RC

Design Problems

1) Design an astable multivibrator using 555 timer which produces an output frequency (f) equal to your roll number KHZ and check your design using Multisim Version 10.0.

2) Design a monostable multivibrator using 555 timer which produces an output pulse (T) equal to your roll number milliseconds and check your design using Multisim Version 10.0.

VOLTAGE CONTROLLED OSCILLATOR

In all the preceding RC Oscillators, the frequency is determined by the RC time constant. However, there are applications such as frequency modulation (FM), tone generators, and frequency shift keying (FSK), where the frequency needs to be controlled by means of an input voltage called control voltage. This function is achieved in voltage controlled oscillator (VCO). VCO is also known as voltage to frequency converter. ***A voltage controlled oscillator (VCO) is thus defined as a circuit that provides an oscillating output signal (typically of square wave for triangular waveform) whose frequency can be adjusted over a range by a dc voltage.***

VCO USING 555 TIMER

Fig. 6 illustrates the circuit diagram of voltage controlled Oscillator using 555 timer. The frequency of oscillation is controlled by the potential at pin 5 (i.e. the control voltage terminal). Recall that pin 5 is connected to the inverting input of the upper comparator (comparator 1) which is at a potential of 2/3 of V_{cc}. When 555 timer is operated as an astable multivibrator, pin 5 is bypassed to ground through a capacitor, so that V_{TH} = 2/3 of V_{cc} and is undisturbed from noise. However, when 555 timer is used as a VCO, the voltage from the potentiometer R overrides the internal 2/3 of VCC voltage, producing another voltage V_{con} determined by the position of the potentiometer. By adjusting the potentiometer, V_{con} can be changed from V_{CC} to 0 V.

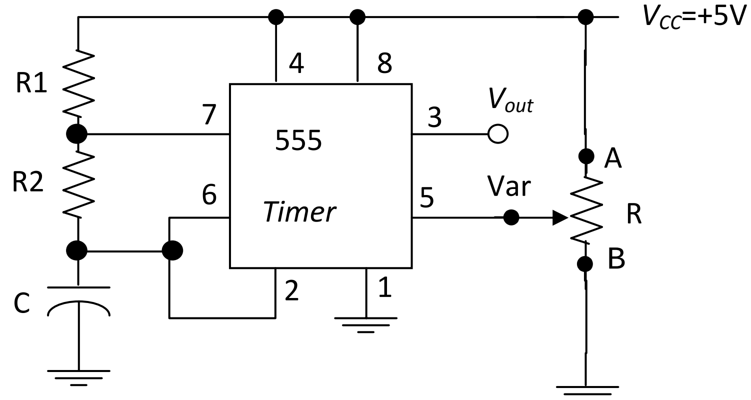

Fig. 6 VCO using 555 timer

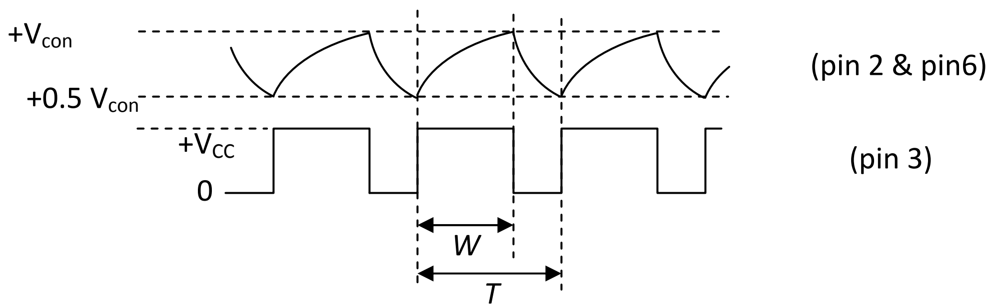

Fig.7 Related waveforms of VCO

The control voltage V_{con} is obtained from the center tap portion of the potentiometer 'R'. The voltage waveform across the timing capacitor can charge and discharge between 0.5 V_{con} and V_{con}. From fig. 7 it's obvious that if the magnitude of V_{con} is increased, it takes the capacitor longer time to charge as well as discharge. Hence, frequency decreases when V_{con} increases. Therefore, the frequency of oscillation of the square wave output at pin 3 varies inversely with the magnitude of V_{con} at pin 5.

RELATED EQUATIONS (DERIVATION NOT REQUIRED)

1. Charging time of capacitor $(t_1) = (R1 + R2)\, C \ln\left(\frac{Vcc - 0.5\, Vcon}{Vcc - Vcon}\right)$

2. Discharging time of capacitor $(t_2) = R_2\, C \ln 2$

3. Total time period $(T) = t_1 + t_2 = (R1 + R2)\, C \ln\left(\frac{Vcc - 0.5\, Vcon}{Vcc - Vcon}\right) + R_2\, C \ln 2$

4. Frequency of square wave output (f) = 1/T

5. Duty Cycle $= \frac{t_1}{T}$

Numerical Problem

If the circuit as shown in fig. 6 is used to construct a voltage controlled oscillator and the values of the R1 = 75K, R2=30K, C= 47nF and Vcc=12V. Determine the frequency and duty cycle when Vcon =11V and Vcon =1V.

REFERENCES AND FURTHER READING

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4. Thomas L. Floyd, *Electronic Devices*, Pearson Education