

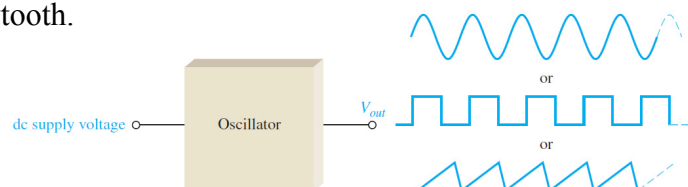
Chapter 16: Oscillators

16.1: The Oscillator

■ **Oscillators** are widely used in most communications systems as well as in digital systems, including computers, to generate required frequencies and timing signals. Also, oscillators are found in many types of test instruments like those used in the laboratory.

■ An **oscillator** is a circuit that produces a periodic waveform on its output with the necessity of an input signal. Only the dc supply voltage is used as an input.

■ Essentially, an oscillator converts electrical energy from the dc power supply to periodic waveforms at the output like sine wave, square wave, and sawtooth.

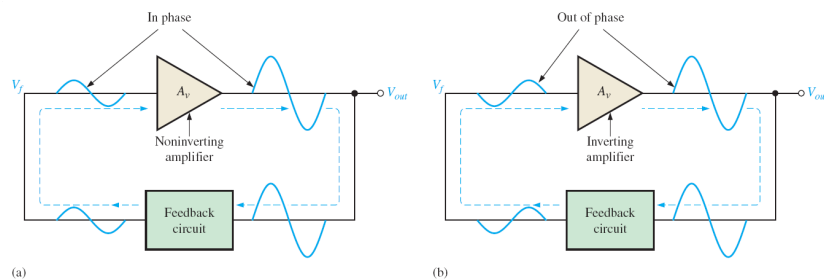
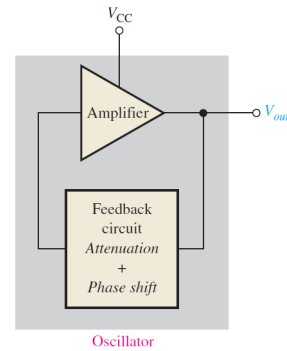


■ Many oscillator circuits exist like feedback oscillators, relaxation oscillators, integrated circuit oscillators,

16.2 Feedback Oscillators

■ A **feedback oscillator** consists of an amplifier for gain (either a discrete transistor or an op-amp) and a positive feedback circuit that produces phase shift and provides attenuation.

■ feedback oscillator returns a fraction of the output signal to the input with no net phase shift (**positive feedback**), resulting in a reinforcement of the output signal. After oscillations are started, the loop gain is maintained at 1 to maintain oscillations



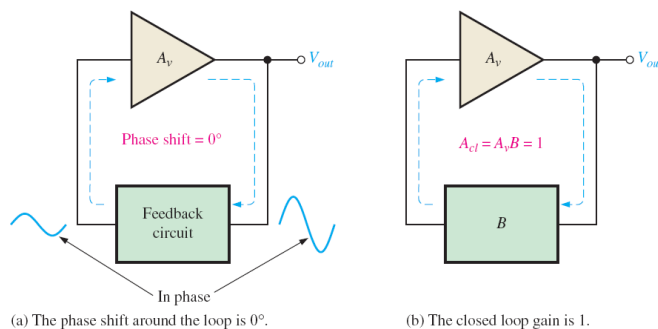
Noninverting and inverting amplifier with no net phase difference (positive feedback)

16.2 Feedback Oscillators

Conditions for Oscillation

1. The phase shift around the feedback loop must be effectively 0°
2. The voltage gain, A_{cl} , around the closed feedback loop (loop gain) must equal 1 (unity) $\rightarrow$ The closed loop gain A_v of the amplifier times the attenuation B must equal to 1

$$\rightarrow A_{cl} = A_v B = 1$$



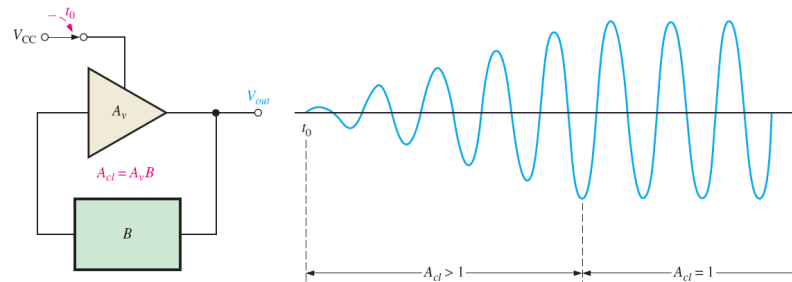
(a) The phase shift around the loop is 0° .

(b) The closed loop gain is 1.

16.2 Feedback Oscillators

Start-Up Conditions

■ with dc input, normally there is no output. To start oscillations, feedback oscillators require a small disturbance such as that generated by thermal noise from other components or from power supply turn-on transient. This initial voltage starts the feedback process and oscillations.



■ The feedback circuit permits only a voltage with a frequency equal to the selected oscillation frequency to appear in phase on the amplifier's input. This initial feedback voltage is amplified and continually reinforced, resulting in a buildup of the output voltage with gain of unity.

16.3 Relaxation Oscillators

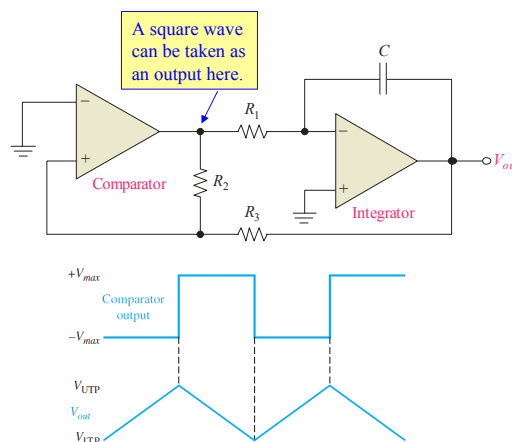
■ **Relaxation oscillators** are characterized by an RC timing circuit and a device that periodically changes state.

■ The triangular wave oscillator is an example. For this circuit, the device that changes states is a comparator with hysteresis (Schmitt trigger). The RC timing device is an integrator. The comparator output can be used as a square wave output.

■ The trigger points for the integrator op-amp set the output triangle's peak-to-peak voltage:

$$V_{UTP} = +V_{max} \left(\frac{R_3}{R_2} \right)$$

$$V_{LTP} = -V_{min} \left(\frac{R_3}{R_2} \right)$$



16.6 the 555 timer as an Oscillator

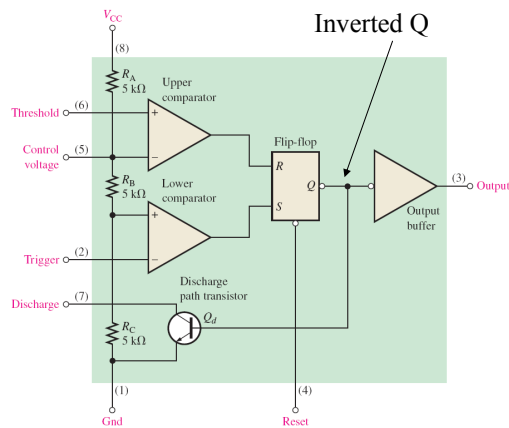
The 555 timer consists basically of two comparators, a flip-flop, a discharge transistor, and a resistive voltage divider, as shown

- The flip-flop is a digital two-state device whose output Q can be at either a high voltage level (set, S) or a low voltage level (reset, R). The state of the output can be changed with proper input signals.

- The resistive voltage divider is used to set the voltage comparator levels.

- When the trigger voltage goes below $1/3 V_{CC}$, the flip-flop sets and the output jumps to its high level.

- When the threshold voltage goes above $2/3 V_{CC}$, the flip-flop sets and the output to its low level.



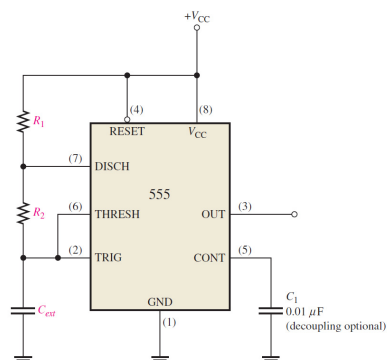
- When the device output is low, the discharge transistor (Q_d) is turned on and provides a path for rapid discharge of the external timing capacitor.

16.6 the 555 timer as an Oscillator

Astable Operation

- A 555 timer connected to operate in the **astable** mode as a free-running relaxation oscillator (astable multivibrator) is shown in Figure

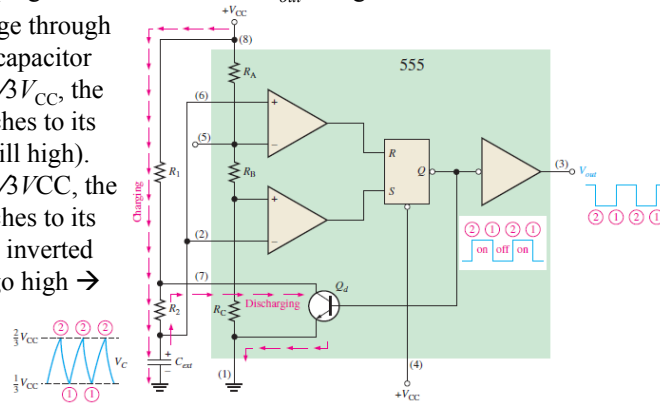
- the threshold input (THRESH) is now connected to the trigger input (TRIG). The external components R_1 and R_2 and C_{ext} (timing circuit) sets the frequency of oscillation. The capacitor connected to the control (CONT) input is strictly for decoupling and has no effect on the operation.



16.6 the 555 timer as an Oscillator :Astable Operation

■ when the power is turned on, the capacitor is uncharged and thus the trigger voltage (pin 2) is at 0 V. This causes the output of the lower comparator to be high ($0 < V_{CC}$) forcing the inverted output of the flip-flop to be low, and thus the base of Q_d low and keeping the transistor off $\rightarrow V_{out}$ is high.

■ $\rightarrow C_{ext}$ begins to charge through R_1 and $R_2 \rightarrow$ When the capacitor voltage (V_{cap}) reaches $\frac{1}{3}V_{CC}$, the lower comparator switches to its low output state (V_{out} still high). when the V_{cap} reaches $\frac{2}{3}V_{CC}$, the upper comparator switches to its high output state $\rightarrow$ the inverted output of the flip-flop go high $\rightarrow V_{out}$ goes to low.



■ The high state at Q_d (the transistor) base turns on the transistor and capacitor begins to discharge through R_2 (V_{out} still low) until V_{cap} reaches slightly $\frac{1}{3}V_{CC}$ again $\rightarrow V_{out}$ will be high again $\rightarrow$ repeating $\rightarrow$ square wave oscillation output with high states (when capacitor charging) and low states (when capacitor discharging)

16.6 the 555 timer as an Oscillator :Astable Operation

■ The frequency of oscillation is given by

$$f_r = \frac{1.44}{(R_1 + 2R_2)C_{ext}}$$

By selecting R_1 and R_2 the frequency and duty cycle of the output can be adjusted

■ Duty cycle can be calculated as follows

The time that the output t_H is high is $t_H = 0.694(R_1 + R_2)C_{ext}$

The time that the output t_L is low is $t_L = 0.694R_2C_{ext}$

The period, T , of the output waveform is

$$T = t_H + t_L = 0.694(R_1 + 2R_2)C_{ext}$$

$\rightarrow$ Finally, the percent duty cycle is

$$\text{Duty cycle} = \left(\frac{t_H}{T}\right)100\% = \left(\frac{t_H}{t_H + t_L}\right)100\%$$

$$\text{Duty cycle} = \left(\frac{R_1 + R_2}{R_1 + 2R_2}\right)100\%$$

16.6 the 555 timer as an Oscillator :Astable Operation: Example

A 555 timer configured to run in the astable mode (oscillator) is shown in Figure. Determine the frequency of the output and the duty cycle.

$$f_r = \frac{1.44}{(R_1 + 2R_2)C_{ext}}$$

$$= \frac{1.44}{(2.2 \text{ k}\Omega + 9.4 \text{ k}\Omega)0.022 \text{ }\mu\text{F}}$$

$$= \mathbf{5.64 \text{ kHz}}$$

$$\text{Duty cycle} = \left(\frac{R_1 + R_2}{R_1 + 2R_2} \right) 100\%$$

$$= \left(\frac{2.2 \text{ k}\Omega + 4.7 \text{ k}\Omega}{2.2 \text{ k}\Omega + 9.4 \text{ k}\Omega} \right) 100\%$$

$$= \mathbf{59.5\%}$$

