OSCILLATORS

Topic Outcomes

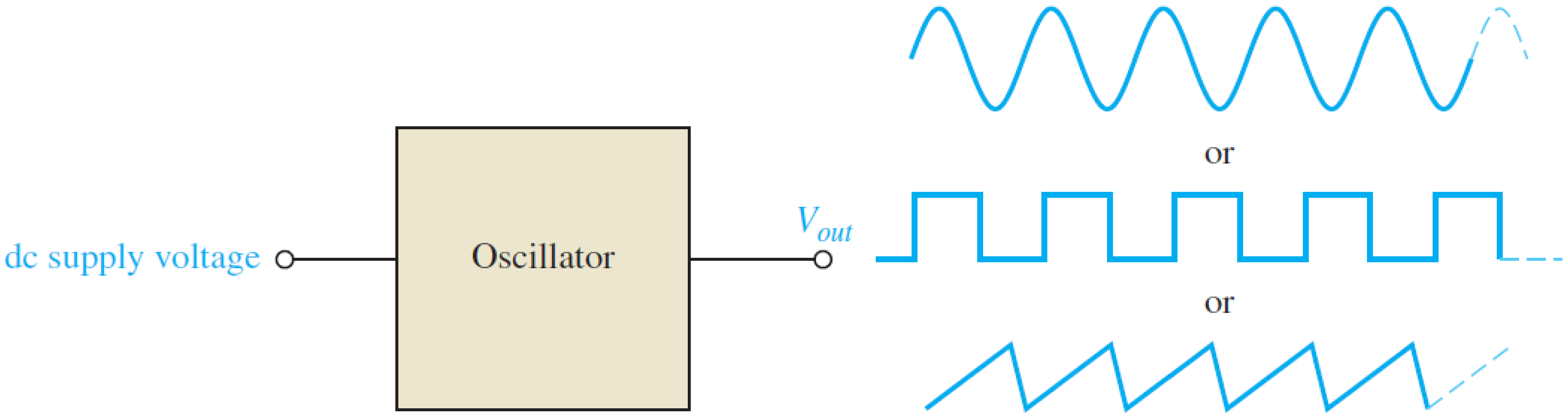
- Describe the operating principles of an oscillator
- Discuss the principle on which feedback oscillators are based
- Describe and analyze the operation of different types of oscillators

Oscillators

Oscillators

- An oscillator is a device or circuit that produces repetitive waveforms (oscillations)
- Oscillators are used in producing high frequency carriers, clocks, and timing circuits.
- Some oscillators are self sustaining while others are not.
  - A self-sustaining oscillator is called a free-running oscillator. They do not need external trigger signals.
  - Oscillators which are not self-sustaining require an input signal or trigger to produce a change in the output waveform. They are called triggered or one-shot oscillators.
- An oscillator converts a dc input signal to an ac output voltage.
- The output of an oscillator could be a sine wave, square wave, or any other waveform as long as it repeats at periodic intervals.

Oscillators



Oscillators

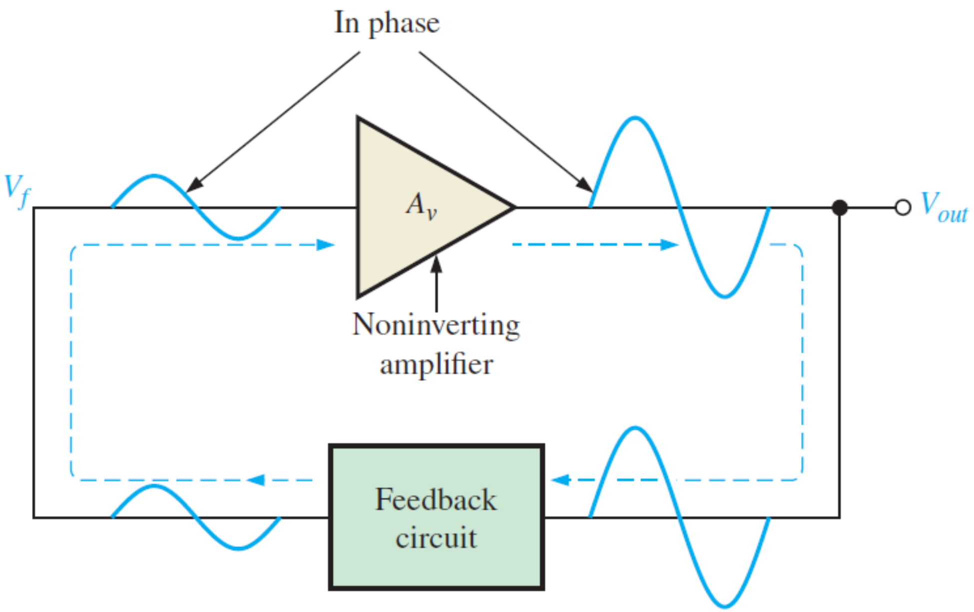
- Oscillators can be of 2 types:
  - Feedback Oscillators
  - Relaxation Oscillators

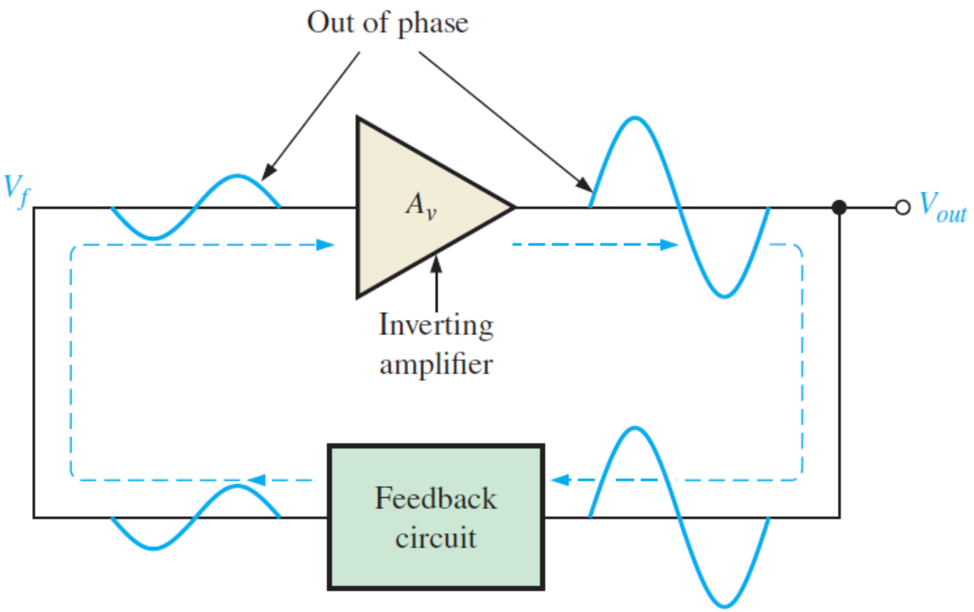
Feedback Oscillators

- A *feedback oscillator* is an amplifier with a feedback loop (that is a path for energy to propagate back from the output to the input).
- For a *feedback circuit* to sustain oscillations, the net voltage gain around the feedback loop must be unity or greater, and the net phase shift around the loop must be positive integer multiple of 360^0.
- Feedback oscillators are free running oscillators.
- The four requirements for a *feedback oscillator* are:
    1. Amplification – there must be at least one active device capable of voltage amplification.
    2. Positive feedback – The feedback signal must be regenerative. It must have the correct phase and amplitude necessary to sustain oscillation.
    3. Frequency determining components – such as capacitors, inductors, or crystals.
    4. Power source – such as a dc power supply.

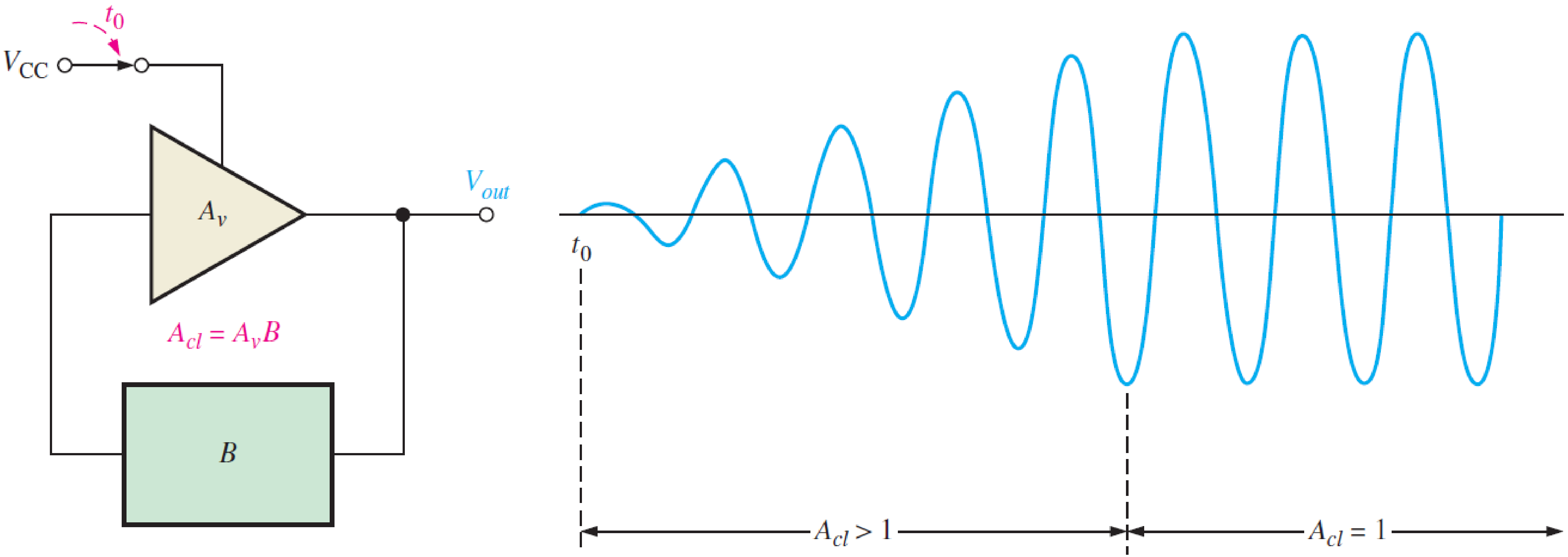
Positive Feedback

- Characterized by the condition wherein a portion of the output voltage is fed back to the input with no net phase shift around the loop, resulting in a reinforcement of the output signal.





Start-Up Conditions

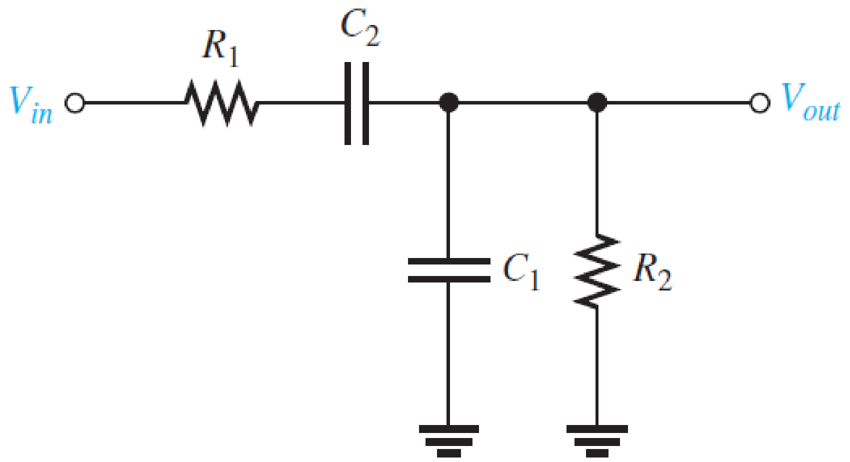


- When oscillation starts at t_0, the condition $A_{cl} > 1$ causes the sinusoidal output voltage amplitude to build up to a desired level. Then A_{cl} decreases to 1 and maintains the desired amplitude.

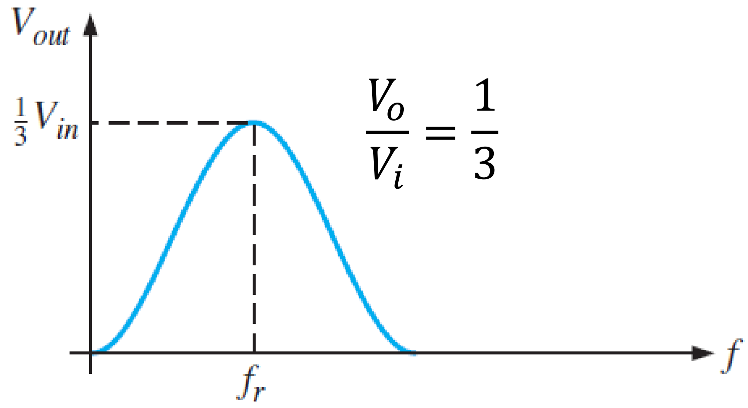
Feedback Oscillator Circuits

Wien-Bridge Oscillator

- An RC phase shift oscillator that uses both positive and negative feedback
- It is commonly used in frequencies between 5Hz and 1 MHz
- It uses a lead-lag network shown:



(a) Circuit



(b) Response curve

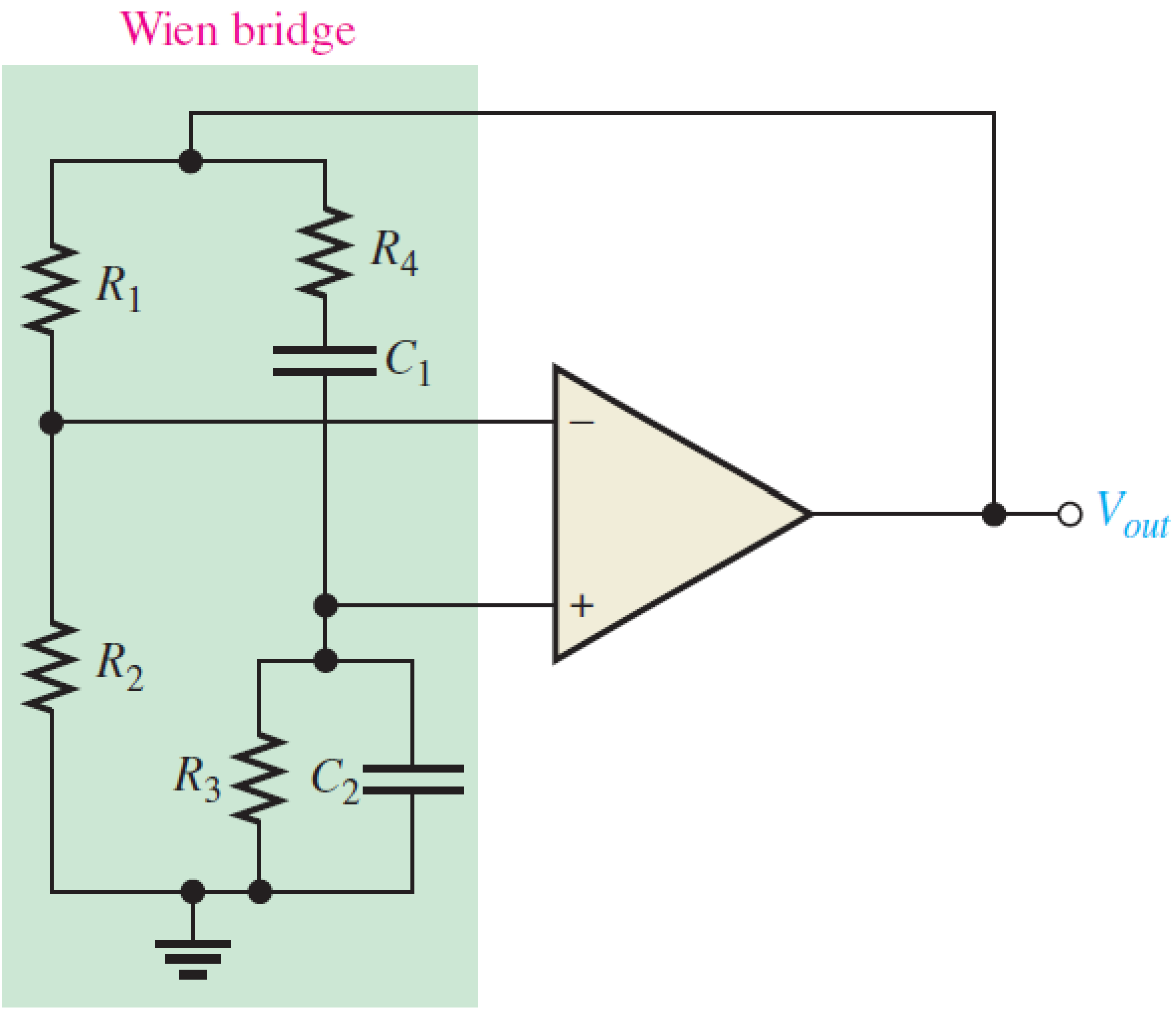
- At frequency of oscillation, f_0, $R=X_C$, the signal has -45° phase shift across R_1 and C_2 and +45° across R_2 and C_1. Total phase shift is 0° and output voltage is maximum
- At extremely low frequencies, C_2 looks like an open circuit and at extremely high frequencies C_1 appears like a short circuit thus preventing extremely low and high frequencies appearing at the output respectively.

Wien-bridge Oscillator

$$f_o = \frac{1}{2\pi RC}$$
$$R = R_3 = R_4$$
$$C = C_1 = C_2$$

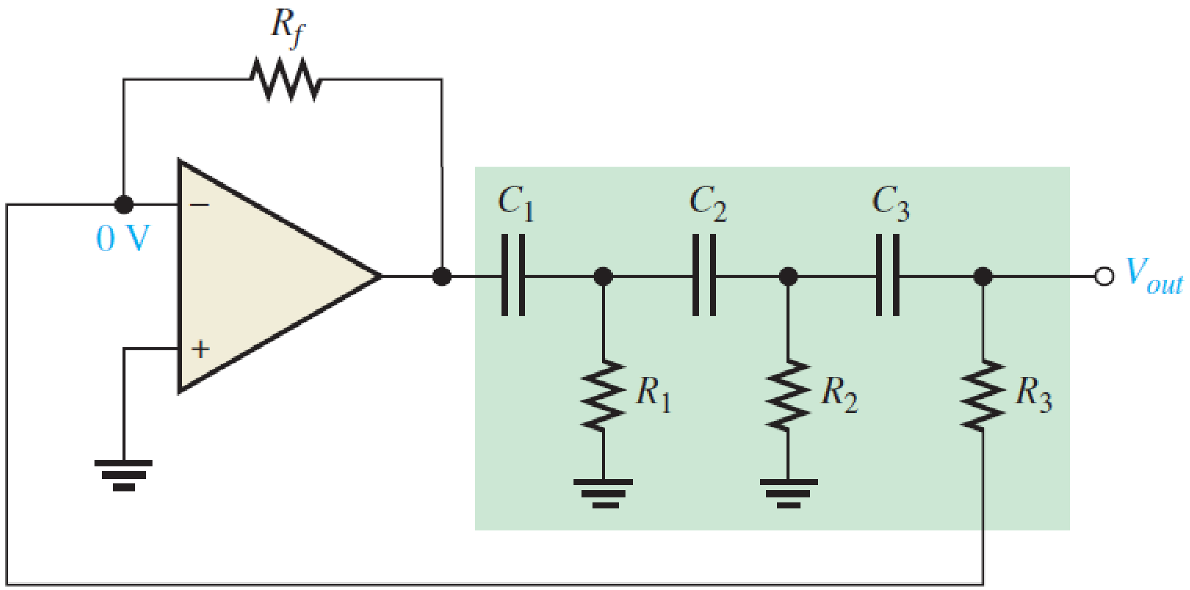
$A_{cl} = 3$ (to counter the attenuation of the lead lag network)

$$A_{cl} = \frac{R_1 + R_2}{R_2}$$



Phase Shift Oscillator

- Each RC circuit can provide a maximum phase shift approaching 60^0
- Oscillation occurs at the frequency where the total phase shift through the 3 RC circuits is 180^0
- The inversion of the op-amp provides additional 180^0 to meet the requirement for oscillation 360^0 (0^0)



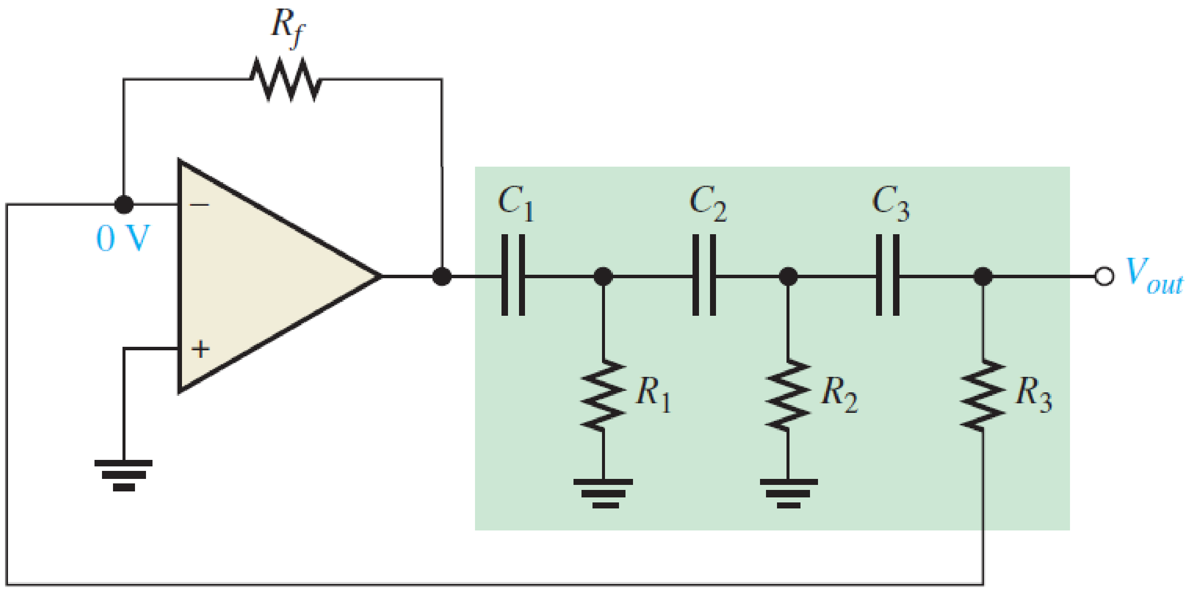
Phase Shift Oscillator

- The attenuation of the three-section feedback circuit is

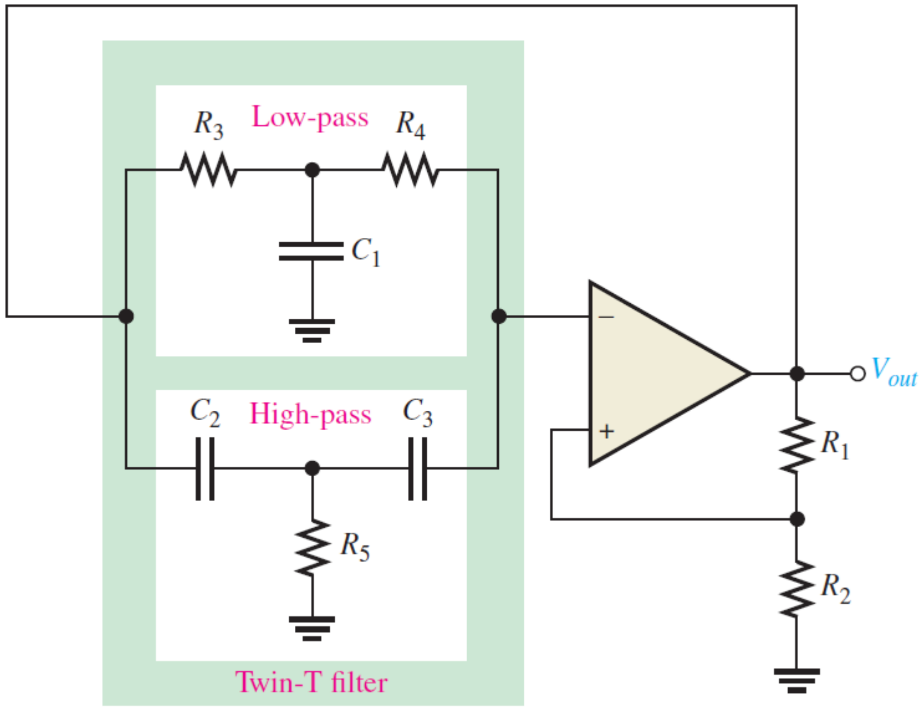
$$B = \frac{1}{29}, B = \frac{R_3}{R_f}$$

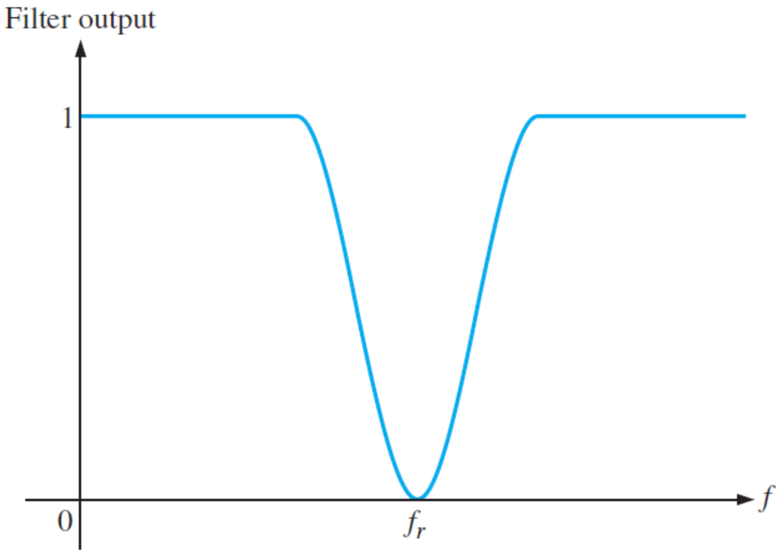
$$\therefore A_{Cl} = 29$$

$$f_r = \frac{1}{2\pi\sqrt{6}RC}$$



Twin-T Oscillator





- The combined parallel filters produce a band-stop or notch response with a center frequency equal to the desired frequency of oscillation, f_r
- At f_r, there is negligible negative feedback; thus, the positive feedback through the voltage divider R_1 and R_2 allows the circuit to oscillate.

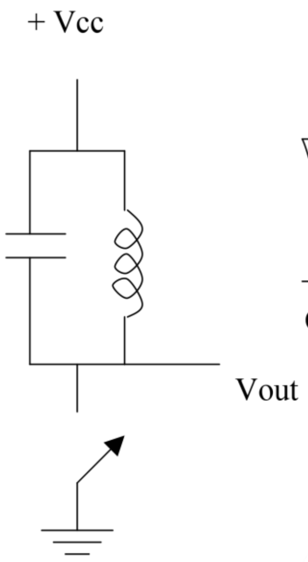
LC Oscillators

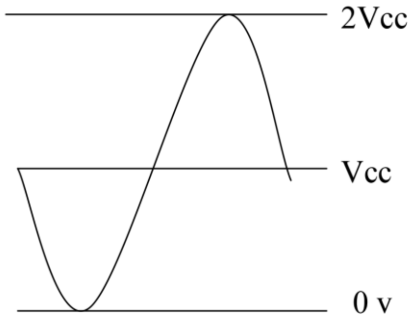
LC Oscillators

- LC oscillators are oscillators that use LC Tank circuits for the frequency determining components.
- Tank circuit operation involves an exchange of energy between kinetic and potential

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$BW = \frac{f_o}{Q}$$





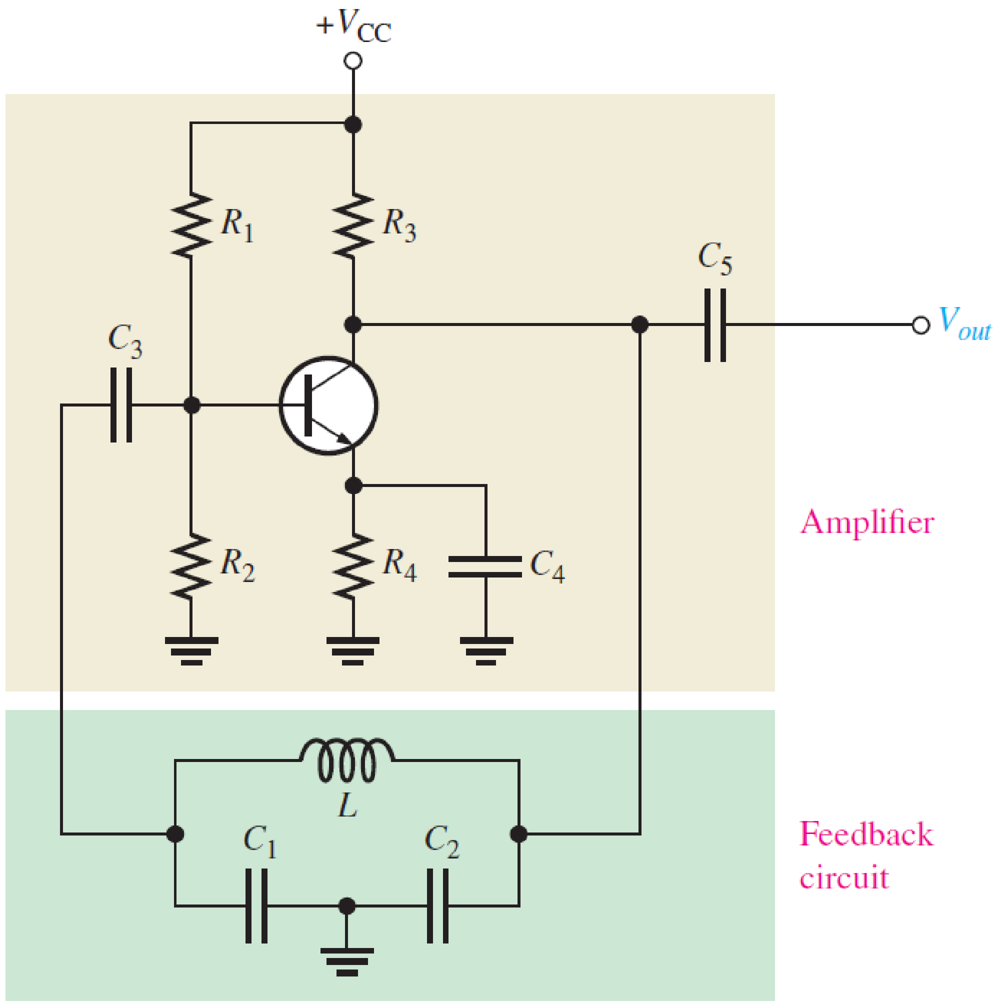
Output waveform (Vout)

- When the switch is turned on, current flows through C and L, thereby charging the capacitor to +Vcc, where the upper part of C becomes +.
- Energy is exchanged between L and C when the switch is turned off, producing a corresponding AC output voltage
- This is called the flywheel effect.

Colpitts Oscillator

$$f_o = \frac{1}{2\pi\sqrt{LC_T}}$$

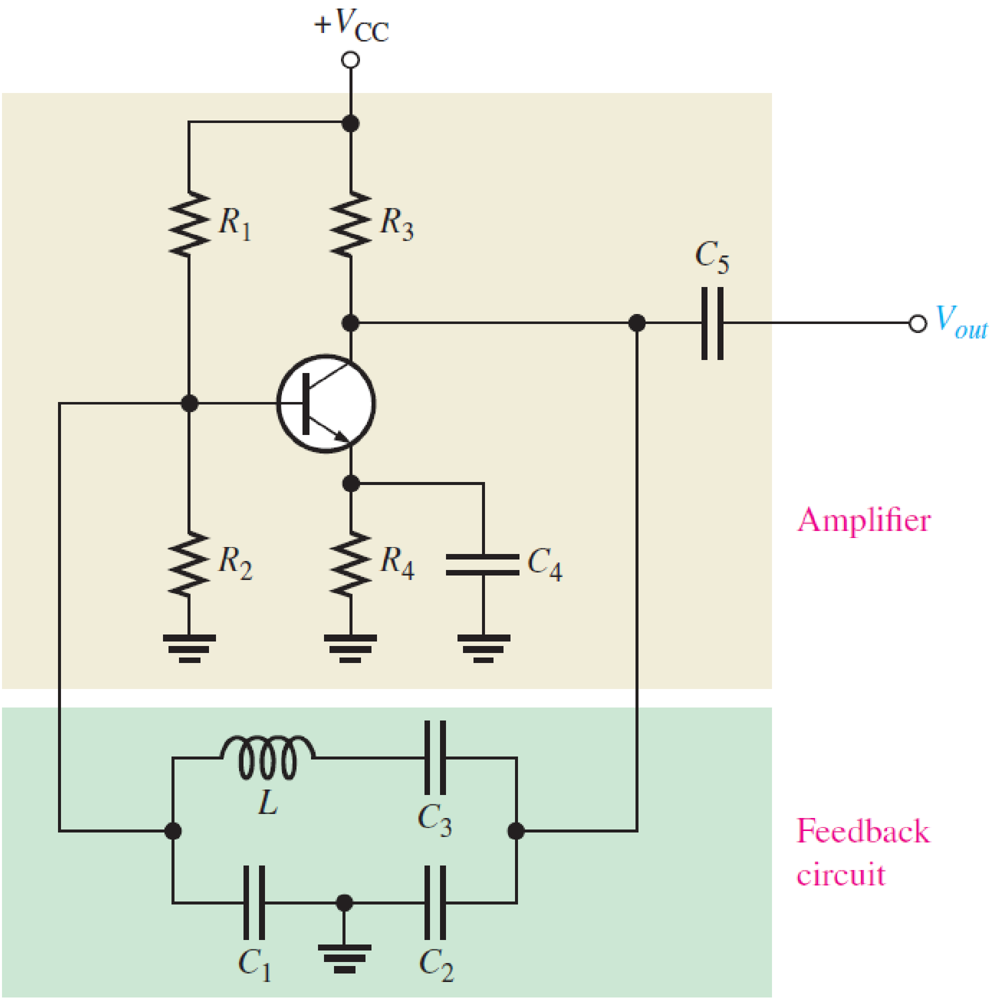
$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$



Clapp Oscillator

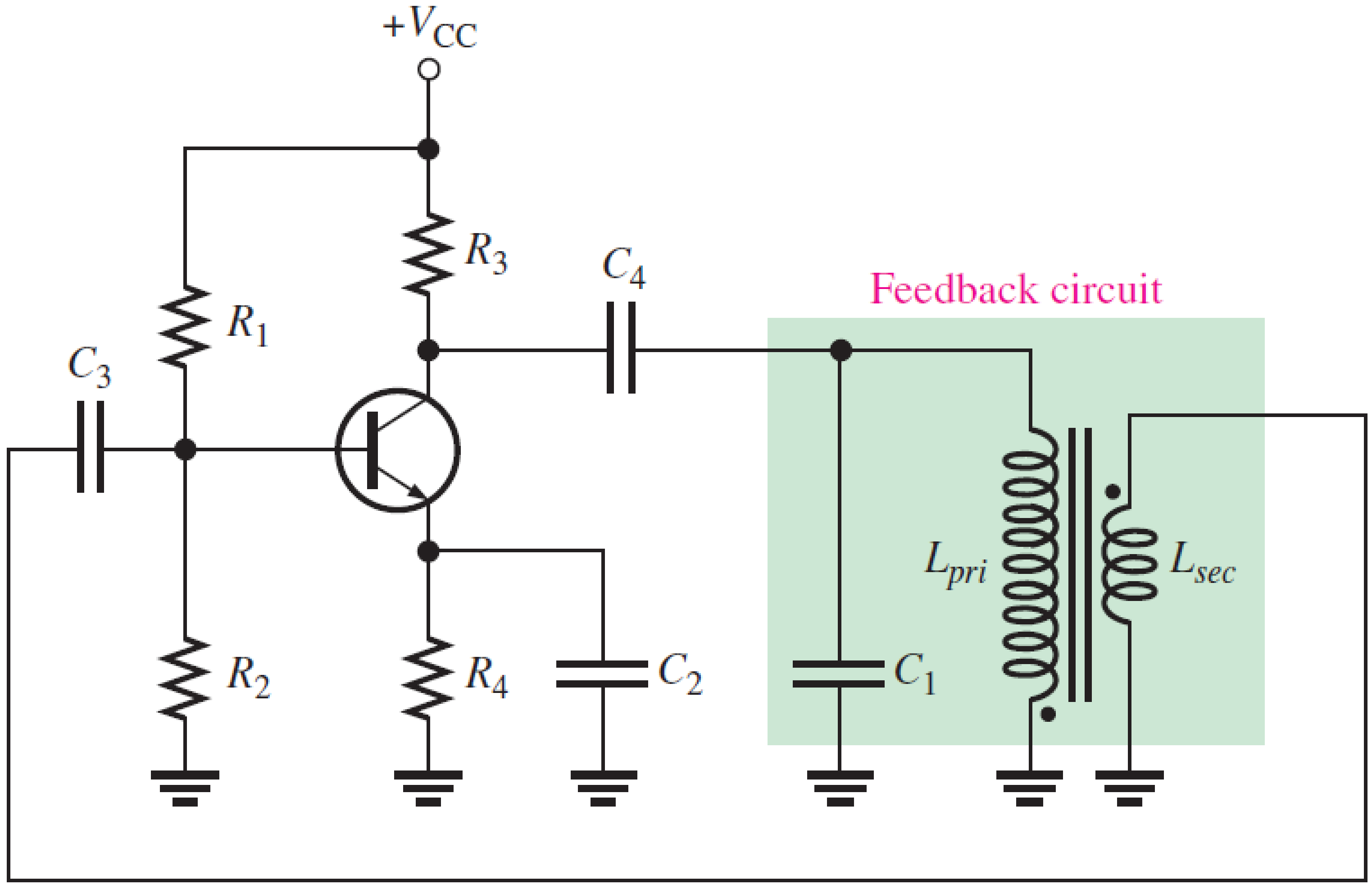
$$f_o = \frac{1}{2\pi\sqrt{LC_T}}$$

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$



Armstrong Oscillator

$$f_o = \frac{1}{2\pi\sqrt{L_{pri}C_1}}$$

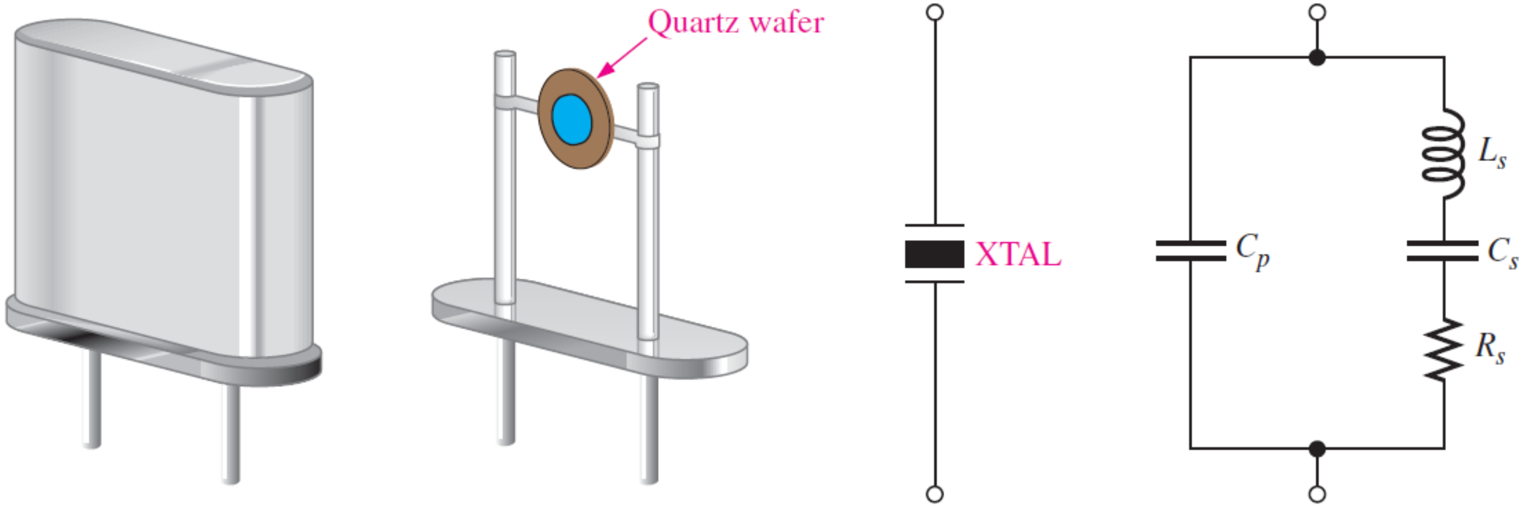


Crystal Oscillators

Crystal Oscillators

- These are feedback oscillator circuits in which the LC tank circuit is replaced with a crystal as the frequency determining component
- Crystals are sometimes called resonators and are capable of producing precise, stable frequencies
- The mechanical properties of crystal lattices allow them to exhibit piezoelectric effect.
    - Materials exhibiting piezoelectric effect generate electrical oscillations (vibrates) when a voltage is applied across the material, and it also produces a voltage across the material when it is subjected to oscillating mechanical stresses (squeezing, stretching, twisting or shearing)

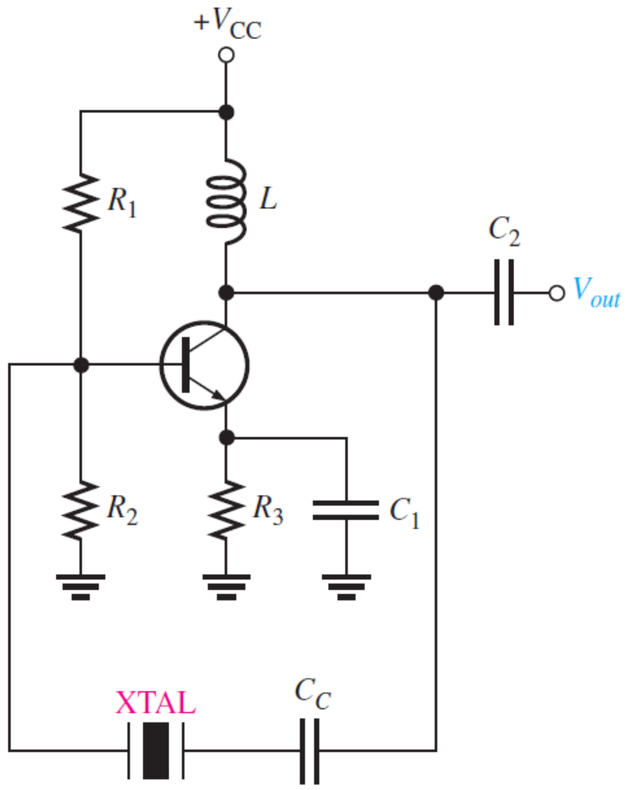
Crystal Oscillators

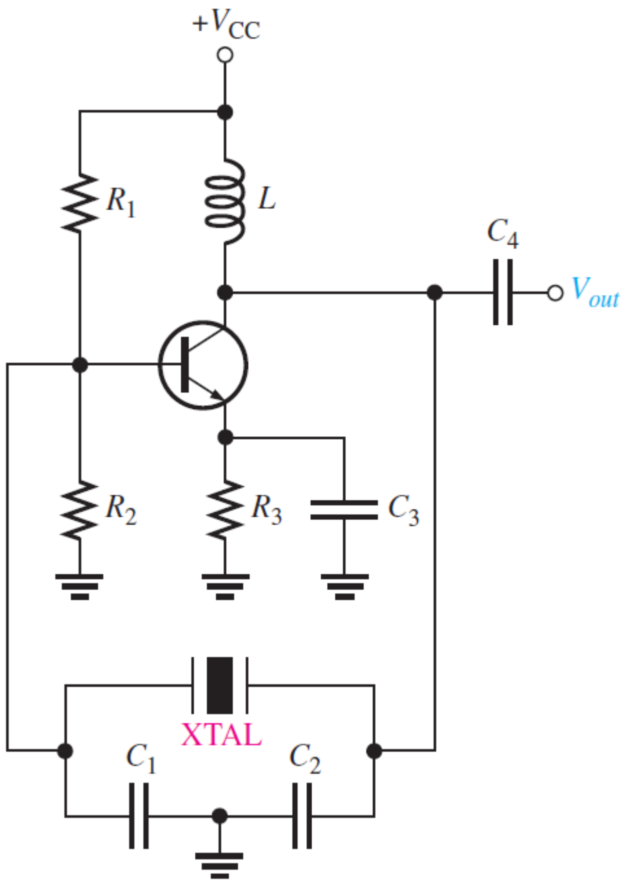


(a) Typical packaged crystal (b) Basic construction (without case) (c) Symbol (d) Electrical equivalent

- The crystal's equivalent circuit is a series-parallel RLC circuit and can operate in either series resonance or parallel resonance.
- At series resonance, the inductive reactance is cancelled by the reactance of C_s, R_s determines the impedance of the crystal. N
- Parallel resonance occurs when the inductive reactance and the reactance of the parallel capacitance, C_p are equal
- The parallel resonant frequency is usually at least 1kHz higher than the series resonant frequency.

Modified Colpitts Oscillator using Crystal



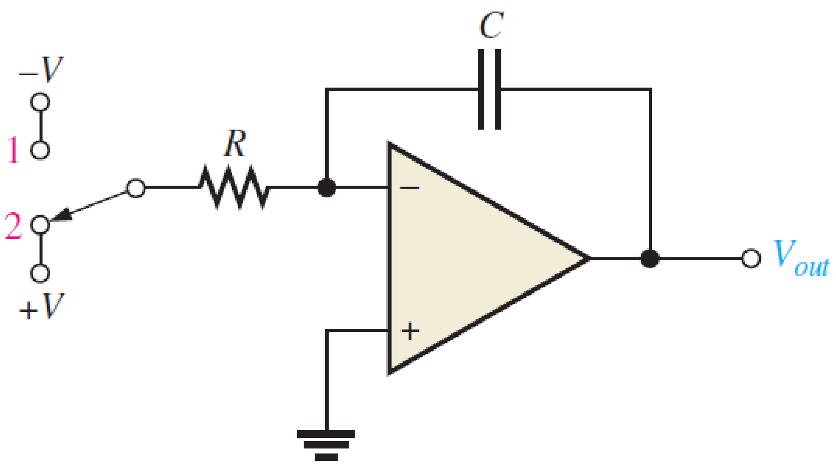


Relaxation Oscillators

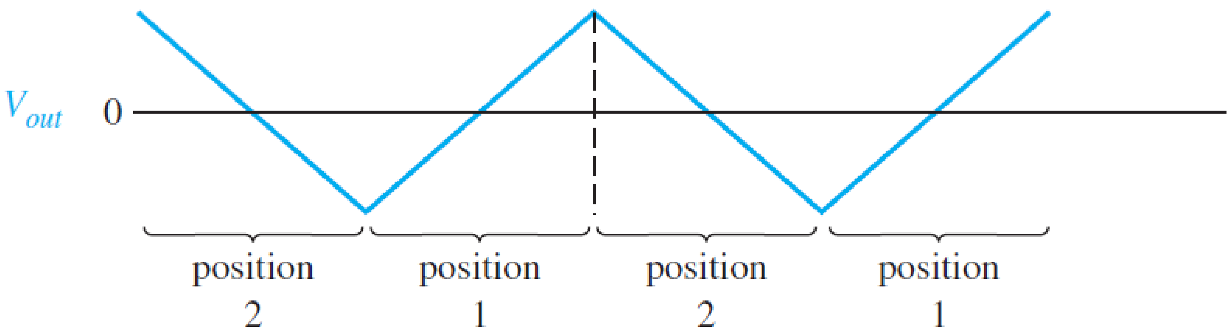
Relaxation Oscillators

- Instead of feedback, a relaxation oscillator uses an RC timing circuit that generates a waveform that is generally a square wave or other non-sinusoidal waveform
- Typically a relaxation oscillator uses a Schmitt trigger or other device that changes states to alternately charge and discharge a capacitor through a resistor.

Triangular-Wave Oscillator



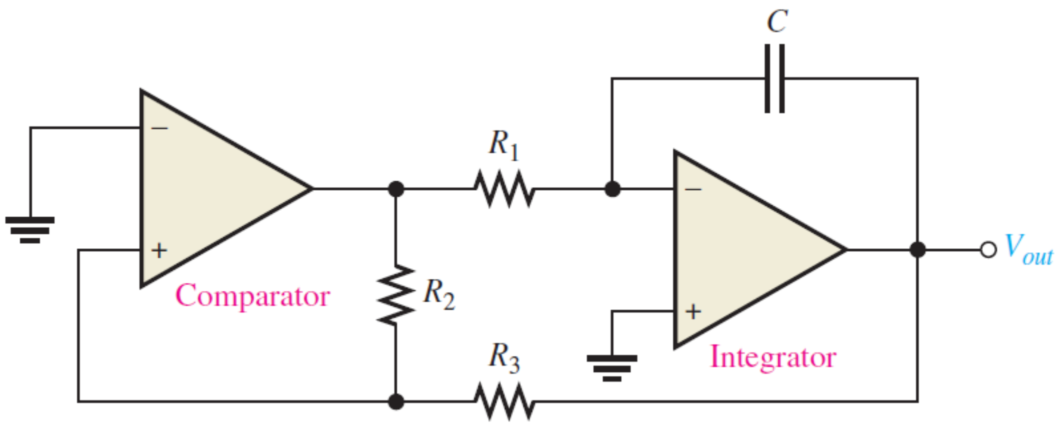
(a)

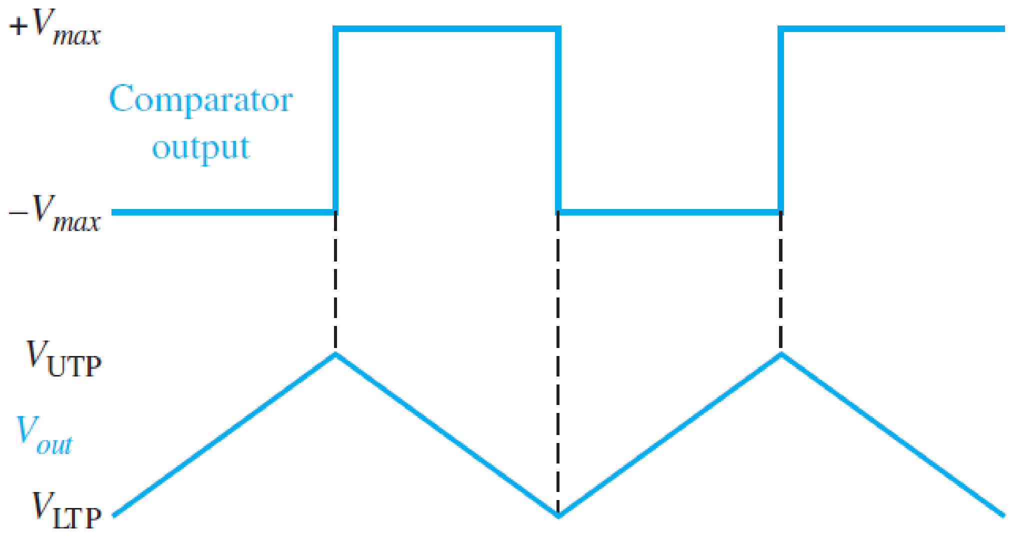


(b) Output voltage as the switch is thrown back and forth at regular intervals

Basic Triangular Wave Oscillator

Triangular-Wave Oscillator



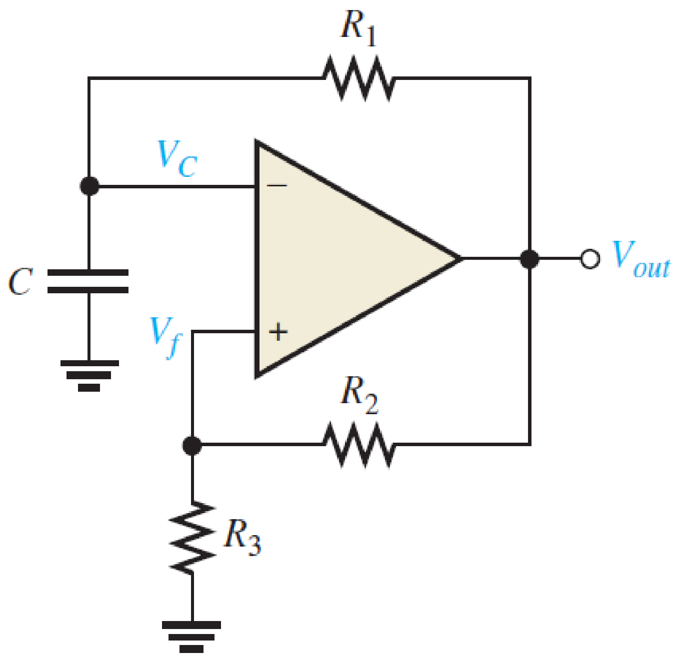


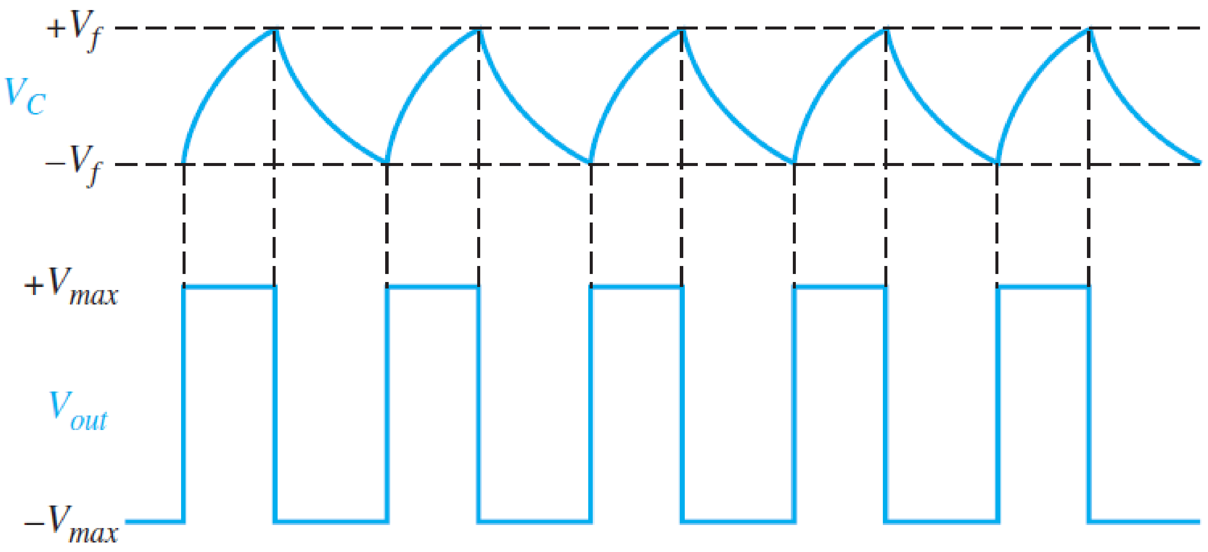
$$V_{UTP} = +V_{max}\left(\frac{R_3}{R_2}\right)$$

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

$$f_r = \frac{1}{4R_1C}\left(\frac{R_2}{R_3}\right)$$

Square Wave Oscillator

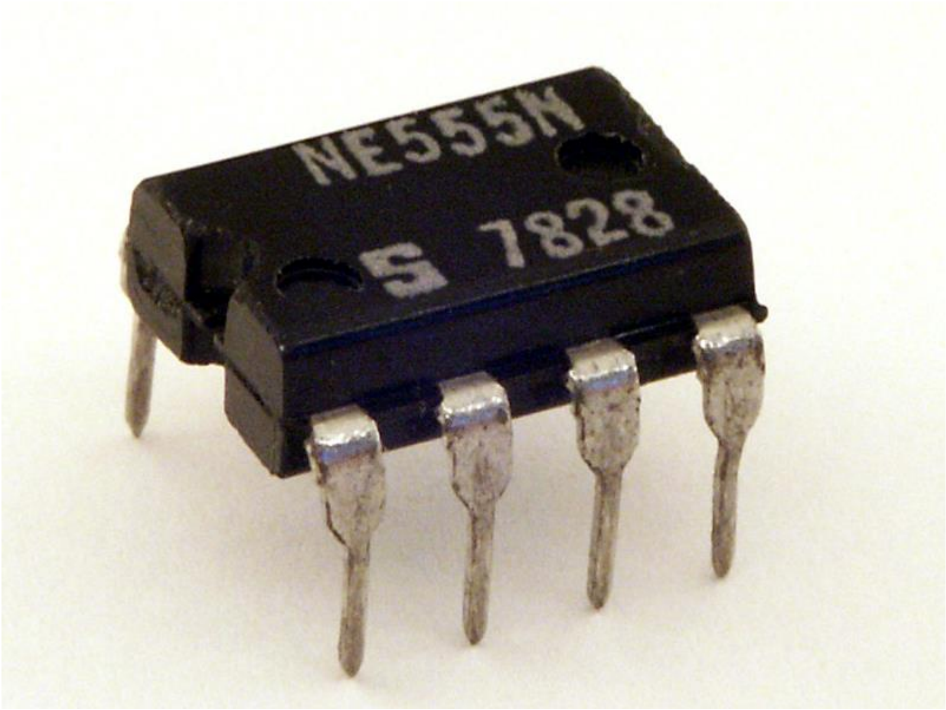




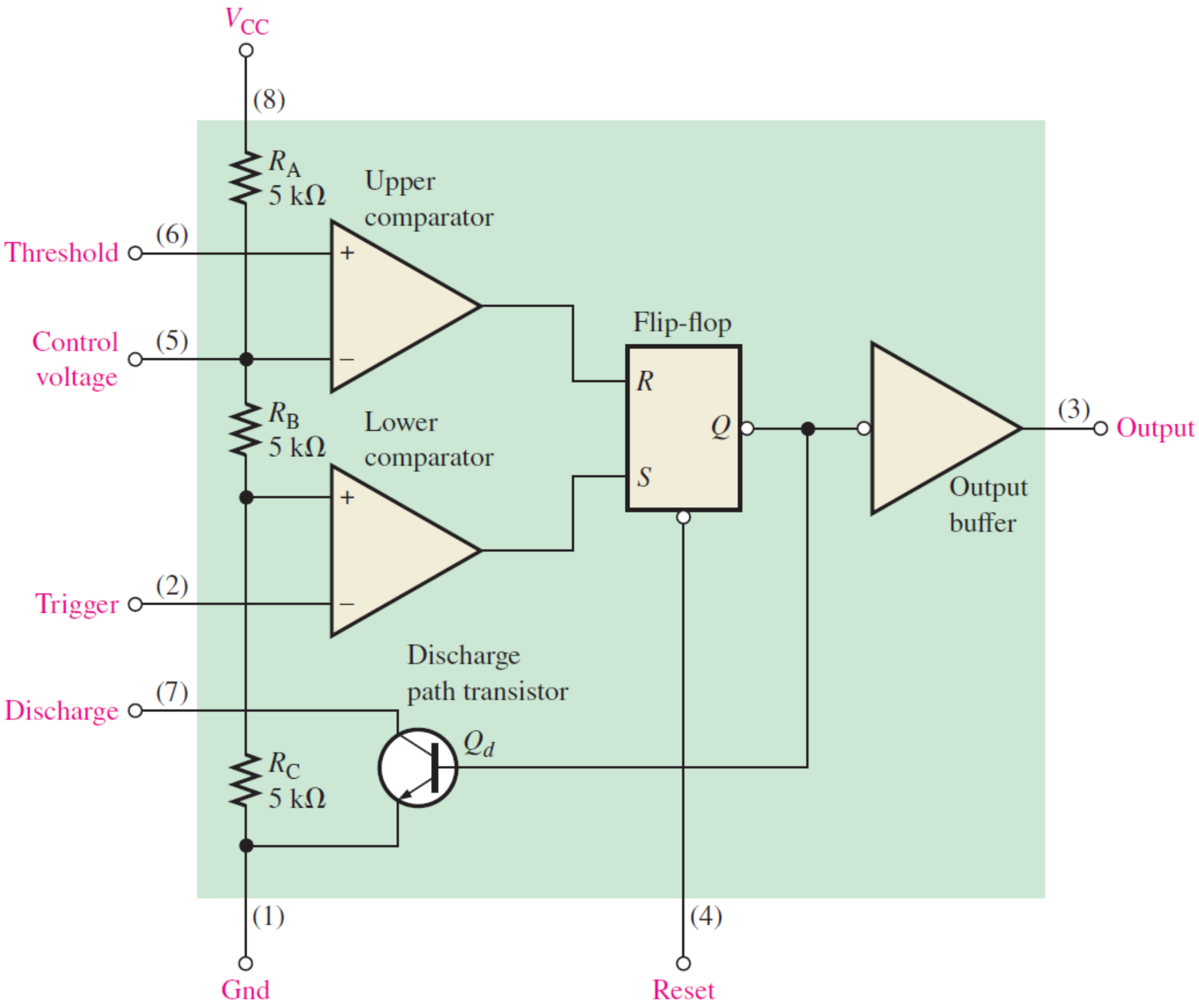
555 IC Timer

555 IC Timer

- The 555 IC Timer can be used in many applications such as monostable multivibrator, astable multivibrator and ramp generators
- It consists of the following:
  - Potential dividing network
  - Two voltage comparators
  - Set-reset flip flop
  - Inverting buffer output stage
  - Two transistors
- Supply voltage can range from 4.5V to 18V

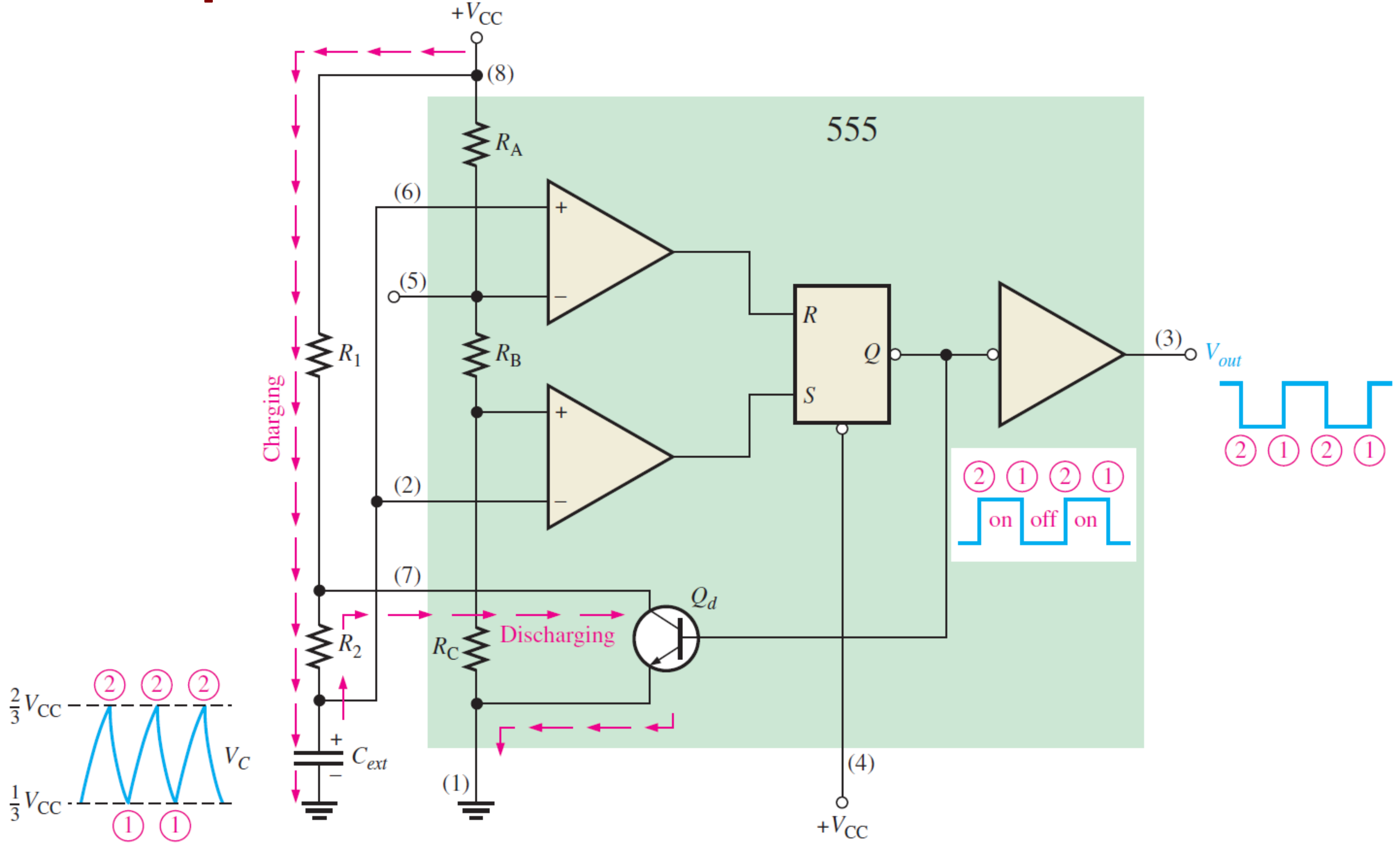


555 IC Timer



V_{CC}
(8)
R_A
5 kΩ
Upper
comparator
Threshold
(6)
+
Control
voltage
(5)
−
Flip-flop
R
Q
S
(3)
Output
R_B
5 kΩ
Lower
comparator
+
Output
buffer
Trigger
(2)
−
Discharge
path transistor
Discharge
(7)
Q_d
R_C
5 kΩ
(1)
(4)
Gnd
Reset

Astable Operation

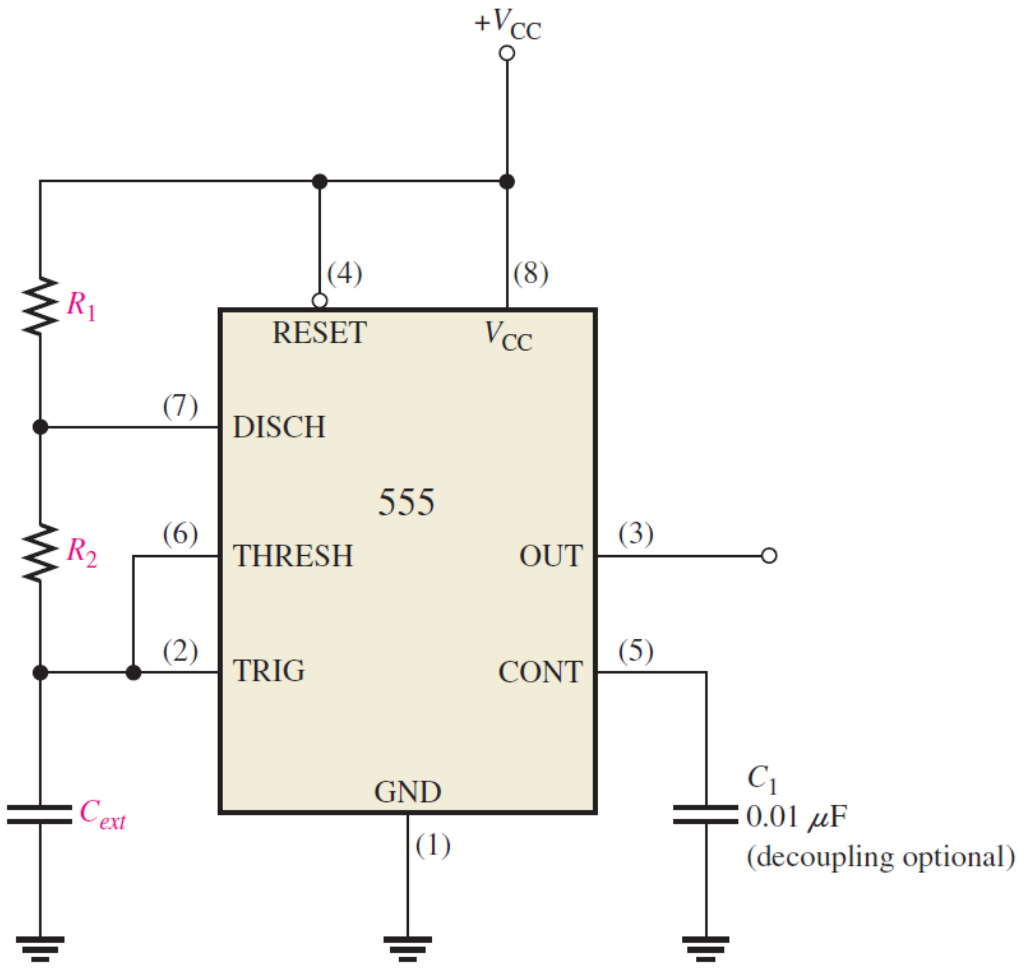


Astable Operation

$$f_r = \frac{1.44}{(R_1 + 2R_2)C_{ext}}$$
$$t_H = 0.694\,(R_1 + R_2)C_{ext}$$

t_H – the time it takes C_{ext} to charge from $\frac{1}{3}V_{CC}$ to $\frac{2}{3}V_{cc}$

$$Duty\ cycle = \frac{t_H}{t_H + t_L} \times 100\%$$
$$= \frac{t_H}{1/f_r} \times 100\%$$
$$= \frac{R_1 + R_2}{R_1 + 2R_2} \times 100\%$$



End