# Multivibrators

# Multivibrators

- Multivibrator is an electronic circuit that generates square, rectangular, pulse waveforms.
- Also called as nonlinear oscillators or function generators.
- Multivibrator is basically a two amplifier circuits arranged with regenerative feedback.
- A multivibrator is used to implement simple **two-state systems** such as oscillators, timers and flip-flops.

# Three types of Multivibrators

- Astable Multivibrator
  - Circuit is not stable in either state—it continuously oscillates from one state to the other.
  - Application in Oscillators

- Monostable Multivibrator
  - One of the state is stable but the other is not.
  - Application in Timer

- Bistable Multivibrator
  - Circuit is stable in both the state and will remain in either state indefinitely. The circuit can be flipped from one state to the other by an external event or trigger.
  - Application in Flip flop

# Astable Multivibrator

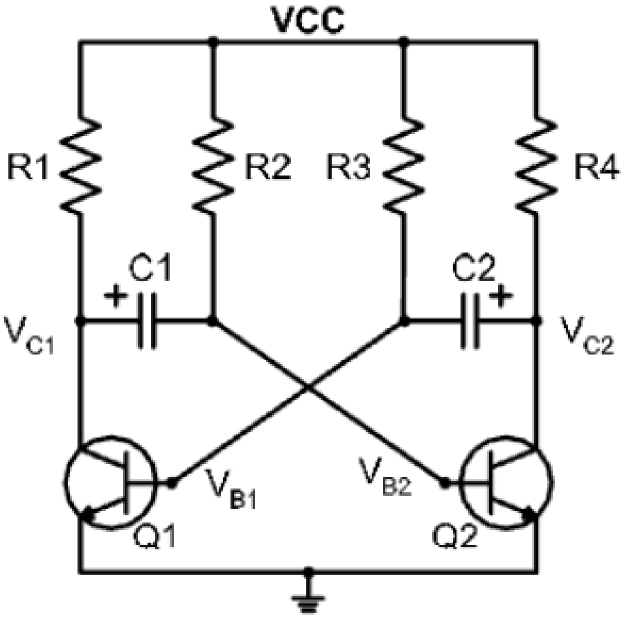
- The astable circuit has no stable state.

- With no external signal applied, the transistors alternately switch from cutoff to saturation at a frequency determined by the RC time constants of the coupling circuits.

- Astable multivibrator circuit consist of two cross coupled RC amplifiers.

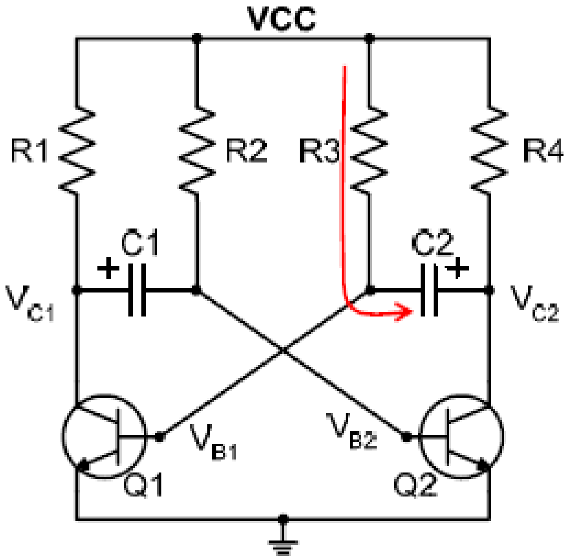
- Consists of two amplifying devices cross-coupled by resistors and capacitors.

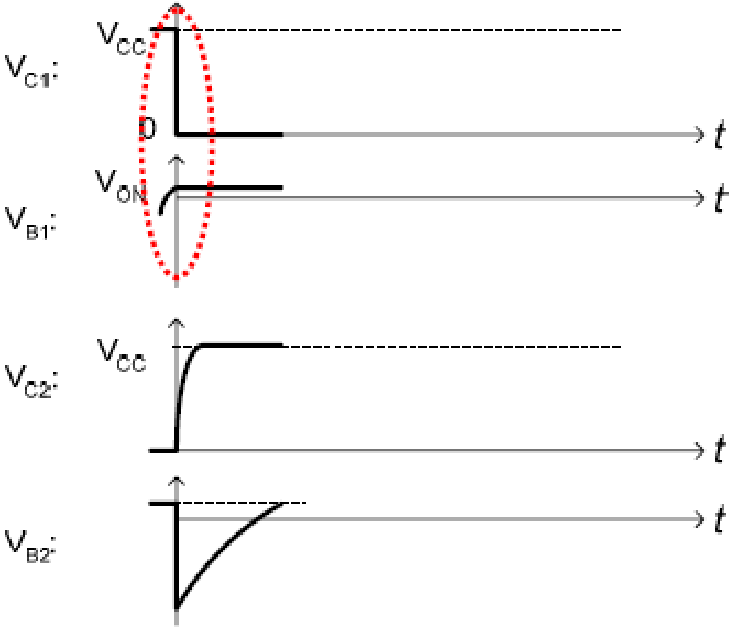
# Astable Multivibrator



- Typically, $R_2 = R_3$, $R_1 = R_4$, $C_1 = C_2$ and $R_2 >> R_1$.
- The circuit has two states
  - State 1: $V_{C1}$ LOW, $V_{C2}$ HIGH, Q1 ON (saturation) and Q2 OFF.
  - State 2: $V_{C1}$ HIGH, $V_{C2}$ LOW, Q1 OFF and Q2 ON (saturation).
- It continuously oscillates from one state to the other.

# Astable Multivibrator – mode of operation

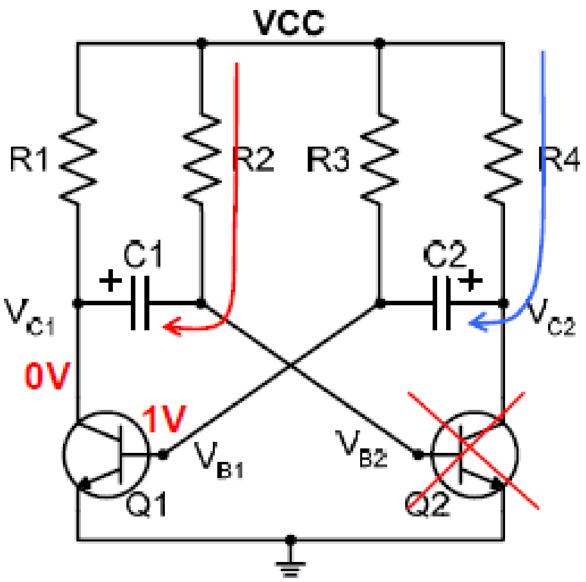


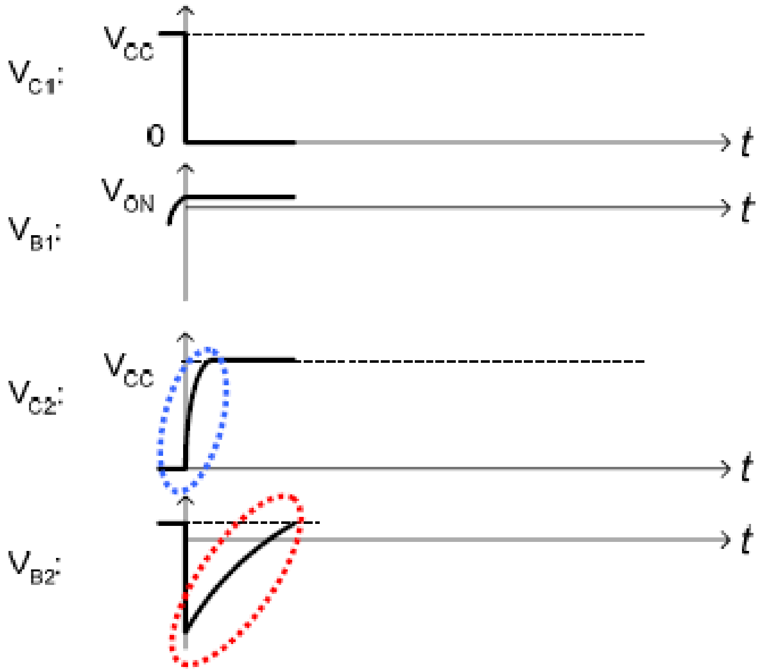


State 1:

- $V_{B1}$ charges up through $R_3$ from below ground towards $V_{CC}$.
- When $V_{B1}$ reaches $V_{ON}$ (of $V_{BE,}$ $\approx$1V), $Q_1$ turns on and pulls $V_{C1}$ from $V_{CC}$ to $V_{CESat} \approx 0V$.
- Due to forward-bias of the BE junction of $Q_1$, $V_{B1}$ remains at 1V.
- As $C_1$'s voltage cannot change instantaneously, $V_{B2}$ drops by $V_{CC}$.

# Astable Multivibrator – mode of operation

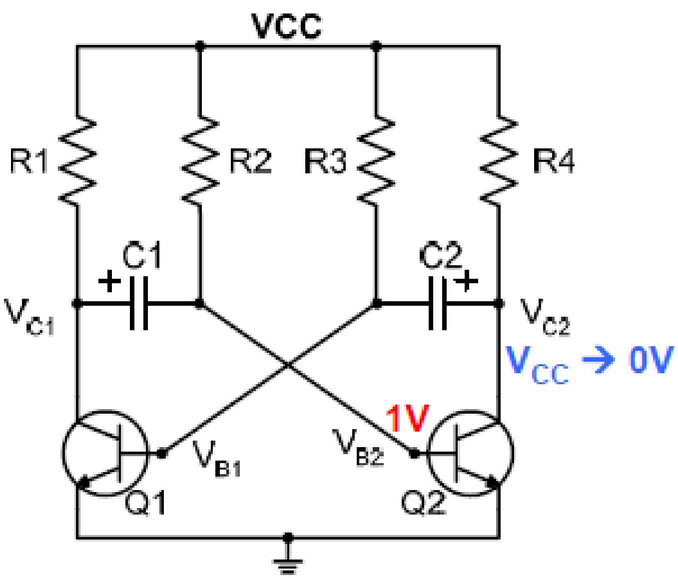


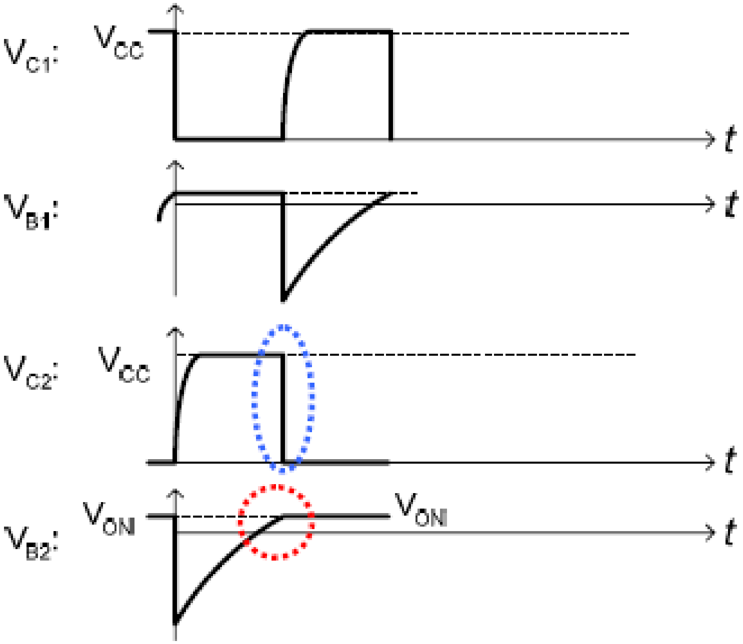


State 1 (cont'd):

- $Q_2$ turns off and $V_{C2}$ charges up through $R_4$ to $V_{CC}$ (speed set by the time constant $R_4C_2$).
- $V_{B2}$ charges up through $R_2$ towards $V_{CC}$ (speed set by $R_2C_1$, which is slower than the charging up speed of $V_{C2}$).

# Astable Multivibrator – mode of operation

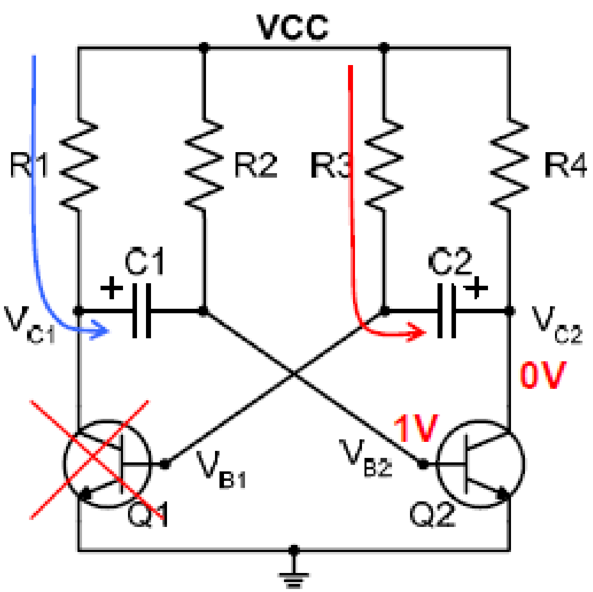


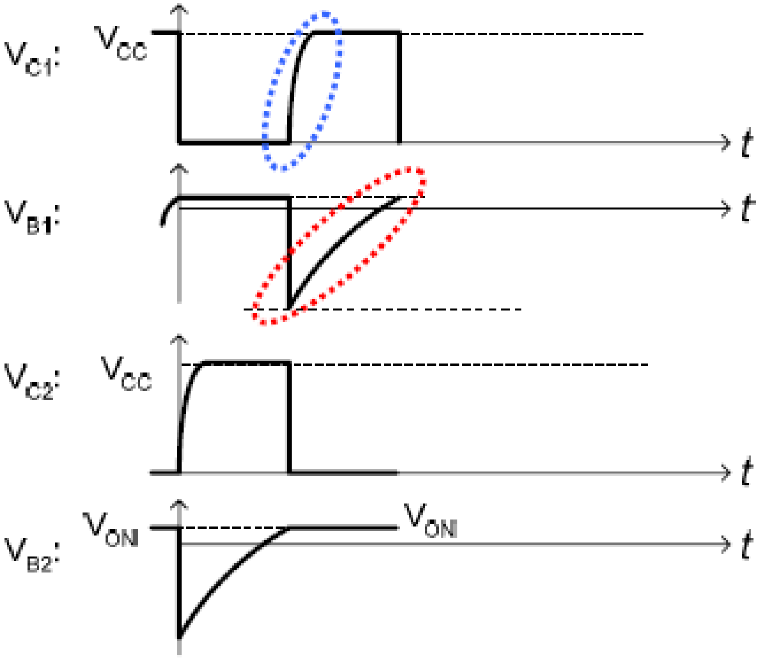


State 2:

- When $V_{B2}$ reaches $V_{ON}$, $Q_2$ turns on and pulls $V_{C2}$ from $V_{CC}$ to 0V.
- $V_{B2}$ remains at $V_{ON}$.
- As $C_2$'s voltage cannot change instantaneously, $V_{B1}$ drops by $V_{CC}$.

# Astable Multivibrator – mode of operation

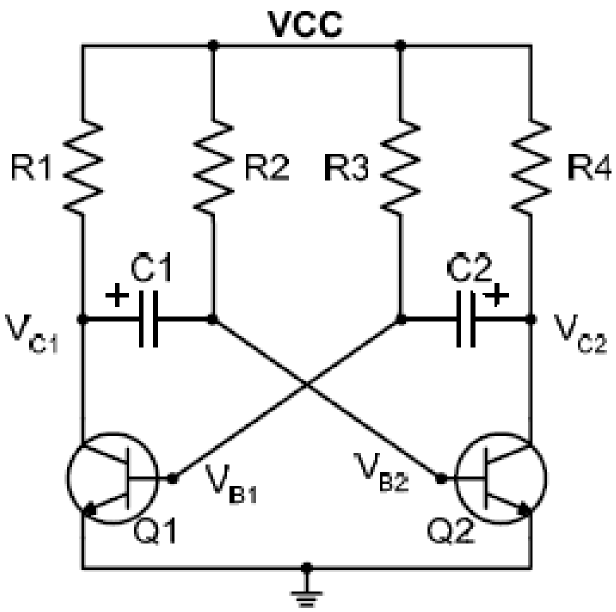


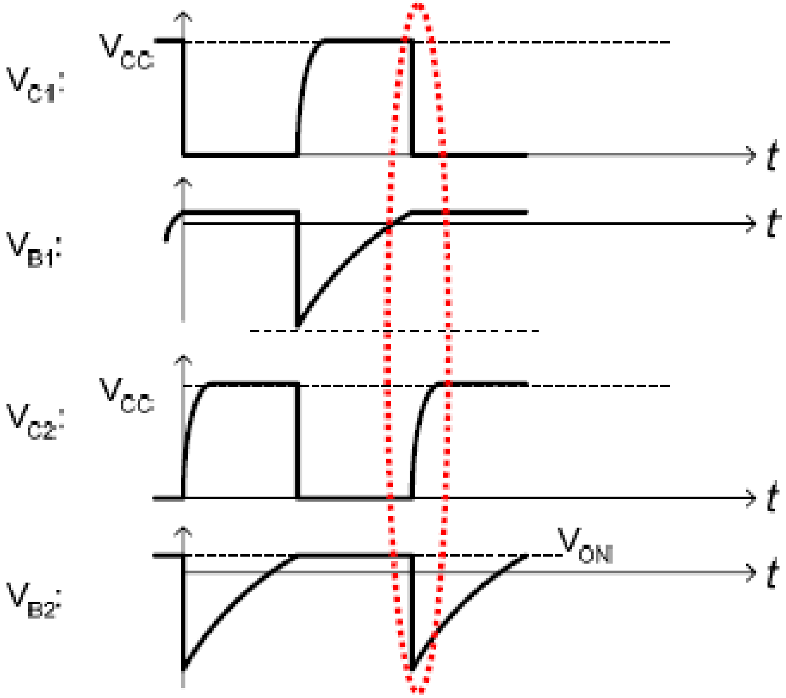


State 2 (cont'd):

- $Q_1$ turns off and $V_{C1}$ charges up through $R_1$ to $V_{CC}$, at a rate set by $R_1C_1$.
- $V_{B2}$ charges up through $R_3$ towards $V_{CC}$, at a rate set by $R_3C_2$, which is slower.

# Astable Multivibrator – mode of operation





Back to state 1:

- When $V_{B1}$ reaches Von, the circuit enters state 1 again, and the process repeats.

# Astable Multivibrator – Time period

Time period of wave depends only upon the discharge of capacitors $C_1$ and $C_2$.

Consider $V_{B2}$ during discharge of $C_2$: $V_{B2} = V_{CC} - i_{C1}R_2$

Since the capacitor $C_1$ charged up to $V_{CC}$, the initial discharge current will be

$$i_{C1} = \frac{V_{CC} + V_{CC}}{R_2}$$

Current decays exponentially with a time constant of $R_2C_1$

$$V_{B2} = V_{CC} - 2V_{CC}(e^{-t/R_2C_1})$$

**Transistor will switch when $V_{B2}$ = 0V (actually 0.7V for Si which is small compare to $V_{CC}$)**

$$\boxed{0 = V_{CC} - 2V_{CC}(e^{-t/R_2C_1})} \qquad \boxed{2e^{-t/R_2C_1} = 1} \qquad \boxed{t = T_2 = R_2C_1 \ln(2)}$$

where T2 is the off time for transistor $Q_2$

# Astable Multivibrator – Time period

Similarly off time for transistor $Q_1$ can be obtained.

$$\boxed{t = T_1 = R_3 C_2 \ln(2)}$$

Total time period T:

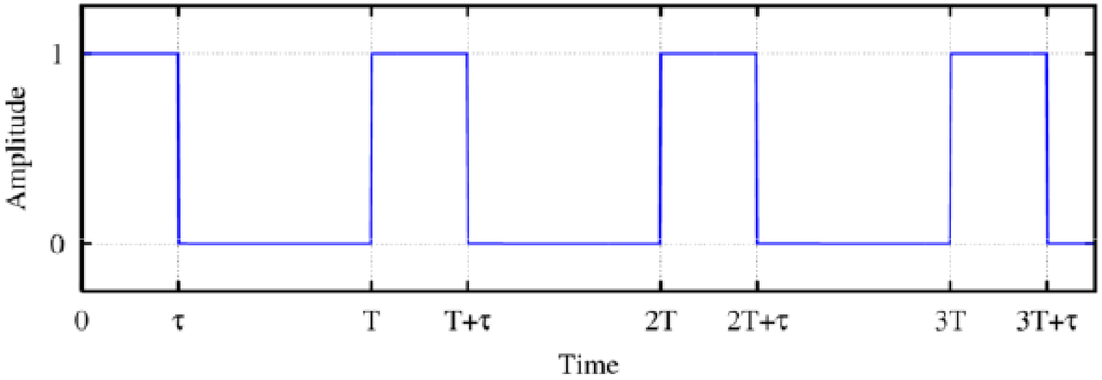
$$\boxed{T = T_1 + T_2 = [R_3 C_2 + R_2 C_1] \ln(2) = 0.694 (R_3 C_2 + R_2 C_1)}$$

If R2 = R3 = R, C1 = C2 = C then $\boxed{T = 1.4RC}$

Frequency of oscillation is given by

$$\boxed{f = \frac{1}{T} = \frac{0.7}{RC}}$$

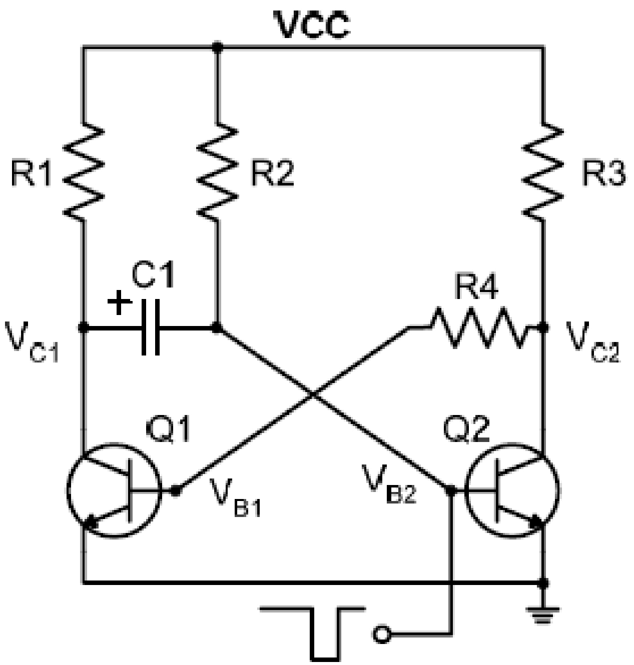
# Duty cycle



- ***Duty Cycle*** duty cycle is defined as the ratio of pulse duration to pulse period.

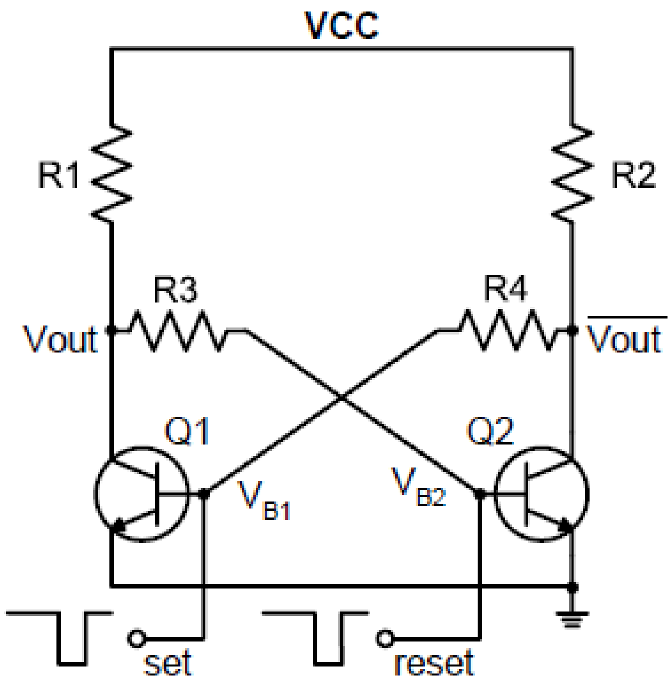
- The pulse duration is the duration for which the pulse remains high.
- The pulse period T is the duration of one complete cycle, and is just the inverse of the frequency in Hz ($f = 1/T$).

# Monostable Multivibrator



- Capacitive path between $V_{C2}$ and $V_{B1}$ removed.
- Stable for one state (state 2 here)
  - $Q_1$ OFF and $Q_2$ ON
  - $V_{C1}$ High, $V_{C2}$ Low
- When $V_{B2}$ is momentarily pulled to ground by an external signal
  - $V_{C2}$ rises to $V_{CC}$
  - $Q_1$ turns on
  - $V_{C1}$ pulled down to 0V
  - Enter state 1 temporarily
- When the external signal goes high
  - $V_{B2}$ charges up to $V_{CC}$ through $R_2$
  - After a certain time T, $V_{B2}$=$V_{ON}$, $Q_2$ turns on
  - $V_{C2}$ pulled to 0V, $Q_1$ turns off
  - Enters state 2 and remains there
- Can be used as a timer

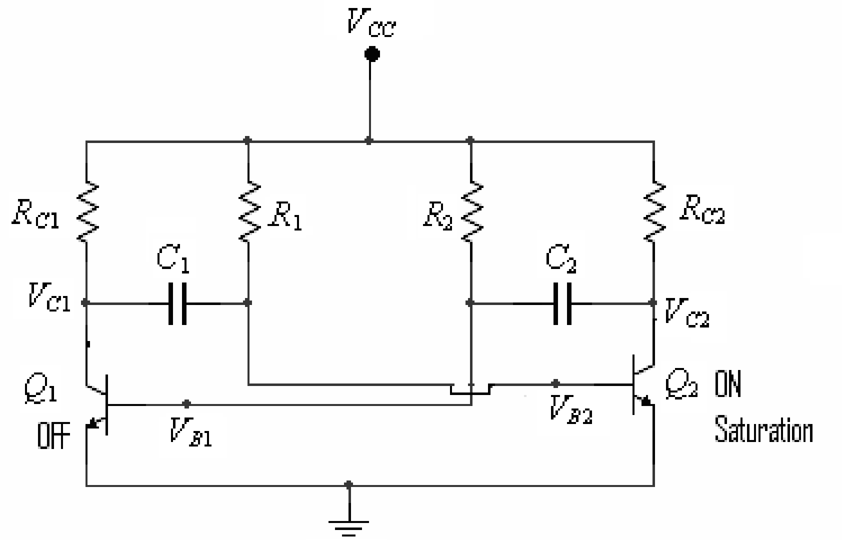
# Bistable Multivibrator



- Both capacitors removed
- Stable for either state 1 or 2
- Can be forced to either state by Set or Reset signals
- If Set is low,
  - $Q_1$ turns off
  - $V_{C1}$ ($V_{out}$) and $V_{B2}$ rises towards $V_{CC}$
  - $Q_2$ turns on
  - $V_{C2}$ (/$V_{out}$) pulled to 0V
  - $V_{B1}$ is latched to 0V
  - Circuit remains in state 2 until Reset is low
- If Reset is low
  - Similar operation
  - Circuit remains in state 1 until Set is low
- Behave as an RS flip-flop

# Problem #1

For the multivibrator in figure, $R_1 = R_2 = R = 47\ \text{k}\Omega$, $C_1 = C_2 = C = 0.01\ \mu\text{F}$. Find the time period and frequency.



Solution:

Given $R_1 = R_2 = R = 47\ \text{k}\Omega$, $C_1 = C_2 = 0.01\ \mu\text{F}$.

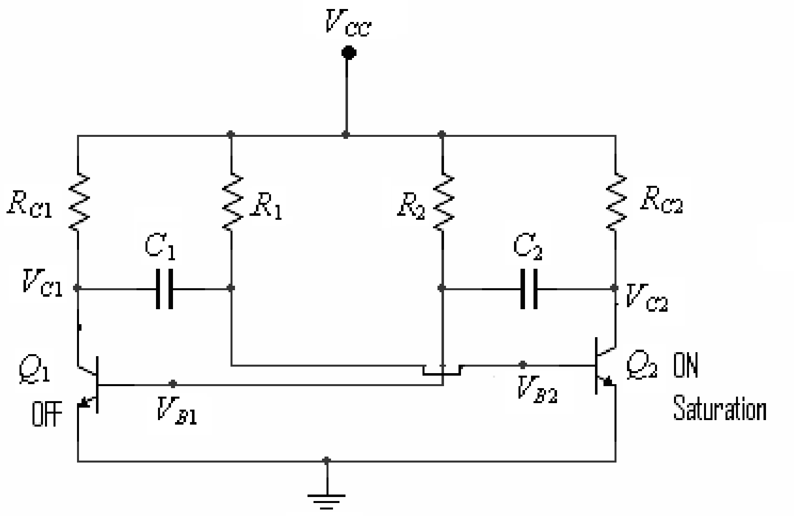
This is a symmetric astable multivibrator.

$$T = 1.38RC = 1.38 \times 47 \times 10^3 \times 0.01 \times 10^{-6} = 0.648\ \text{ms}$$

$$f = \frac{1}{T} = \frac{1}{0.648 \times 10^{-3}} = 1.54\ \text{kHz}.$$

# Problem #2

For the multivibrator in figure, $R_1 = 20\ \text{k}\Omega$ $R_2 = 30\ \text{k}\Omega$, $C_1 = C_2 = C = 0.01\ \mu\text{F}$. Find the time period, duty cycle and the frequency.



Solution:

This is an un-symmetric astable multivibrator.

$$T_2 = 0.69 R_1 C_1 = 0.69 \times 20 \times 10^3 \times 0.01 \times 10^{-6} = 0.2\ \text{ms}$$

$$T_1 = 0.69 R_2 C_2 = 0.69 \times 30 \times 10^3 \times 0.01 \times 10^{-6} = 0.138\ \text{ms}$$

$$T = T_1 + T_2 = 0.138 + 0.2 = 0.338\ \text{ms}$$

$$\text{per cent } D = \frac{T_1}{T} \times 100 \text{ per cent } = \frac{0.138}{0338} \times 100 \text{ per cent} = 59.17 \text{ per cent}$$

$$f = \frac{1}{T} = \frac{1}{0.338 \times 10^{-3}} = 2.95\ \text{kHz.}$$

# Problem #3

Design a symmetric collector-coupled astable multivibrator to generate a square wave of 10 kHz having peak-to-peak amplitude of 10 V where $h_{FEmin} = 30$, $V_{CE(sat)} = 0.2$ V, $I_{C(sat)} = 2$ mA.

Solution:

Given $V_{CE(\text{sat})} = 0.2\text{ V}$, $V_{BE(\text{sat})} = V_\sigma = 0.7\text{ V}$, $I_{C(\text{sat})} = 2\text{ mA}$, $f = 2\text{ kHz}$, $h_{FE\min} = 30$.

As the output amplitude is specified as 12 V, choose $V_{CC} = 12$ V.

As $f = 2$ kHz,

$$\therefore T = \frac{1}{f} = \frac{1}{10 \times 10^3} = 0.1\text{ ms}$$

The astable is symmetric, hence

$R_1 = R_2 = R$ and $C_1 = C_2 = C$

$$T_1 = T_2 = \frac{T}{2} = \frac{0.1}{2} = 0.05\text{ ms}$$

To calculate $R_{C2}$:

$$R_{C2} = \frac{V_{CC} - V_{CE(\text{sat})}}{I_{C(\text{sat})}} = \frac{10 - 0.2}{2 \times 10^{-3}} = 4.9\text{ k}\Omega$$

$R_{C1} = R_{C2} = 4.9\text{ k}\Omega.$

To calculate $R_2$:

$$R_2 = \frac{V_{CC} - V_\sigma}{I_{B2(\text{sat})}}$$

$$I_{B2\min} = \frac{I_{C(\text{sat})}}{h_{FE\min}} = \frac{2\text{ mA}}{30} = 0.066\text{ mA}$$

# Problem #3

If $Q_2$ is in saturation

$$I_{B2(\text{sat})} = 1.5 I_{B2(\text{min})}$$

$$= 1.5 \times 0.066 = 0.099 \text{ mA}$$

$$R_2 = \frac{10 - 0.7}{0.099 \times 10^{-3}} = 93.9 \text{ k}\Omega$$

$$R_1 = R_2 = 93.9 \text{ k}\Omega$$

As $C_1 = C_2$

$$T_1 = 0.69 R_2 C_2$$

$$C_2 = \frac{0.05 \times 10^{-3}}{0.69 \times 93.9 \times 10^3} = 771.7 \text{ pF}$$

$$C_1 = C_2 = 771.7 \text{ pF}$$