

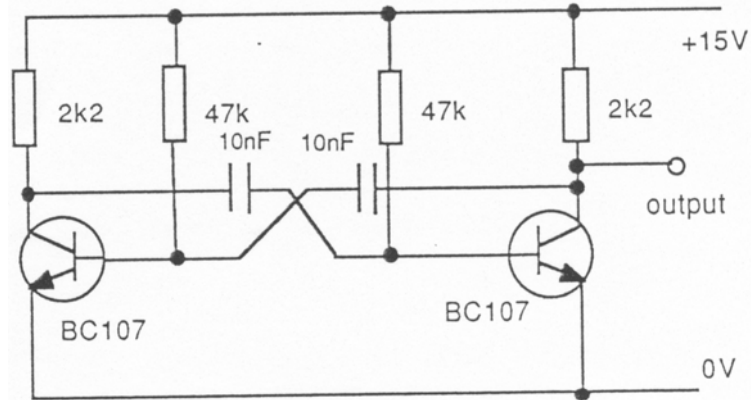
Multivibrators

- A multivibrator is used to implement simple **two-state systems** such as oscillators, timers and flip-flops.
- Three types:
 - **Astable** – neither state is stable.
Applications: oscillator, etc.
 - **Monostable** - one of the states is stable, but the other is not;
Applications: timer, etc.
 - **Bistable** – it remains in either state indefinitely.
Applications: flip-flop, etc.

Reference: <http://en.wikipedia.org/wiki/Multivibrator>

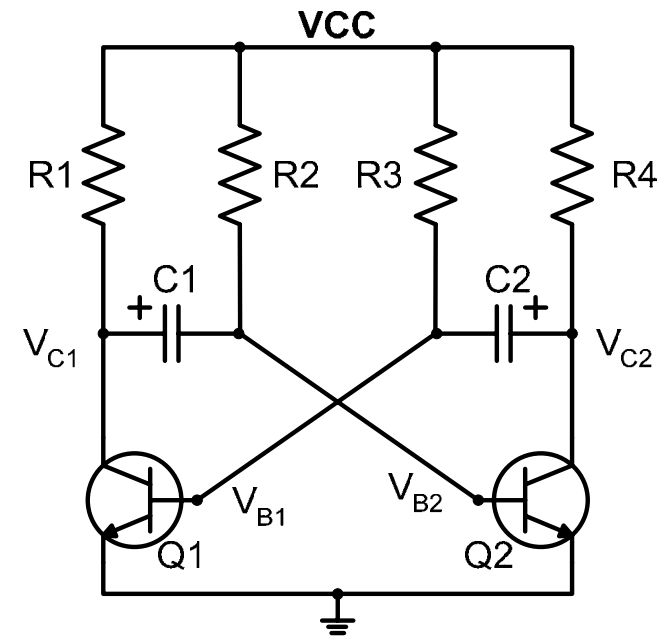


Astable Multivibrator



Circuit in Experiment A4

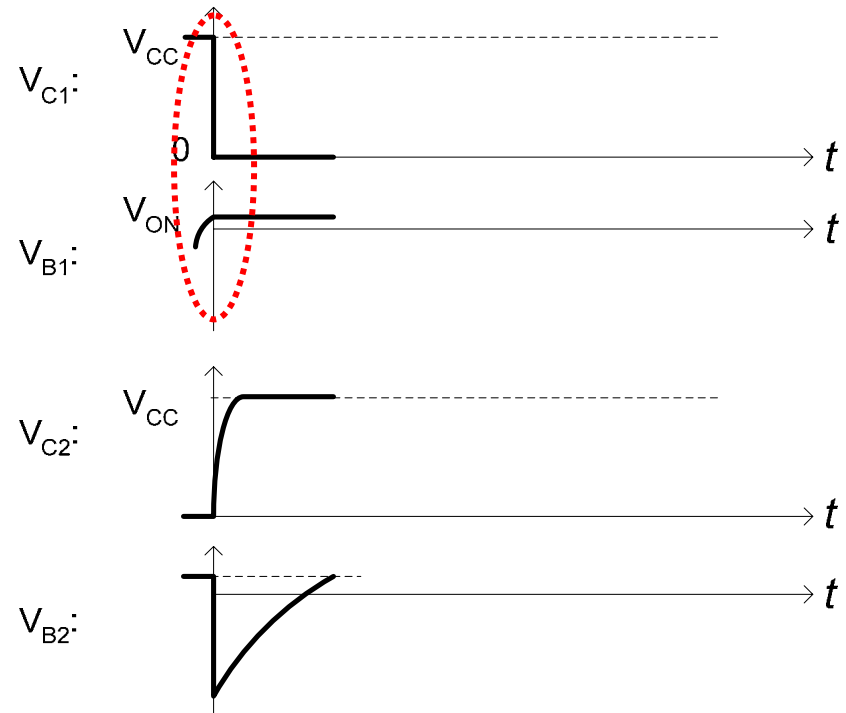
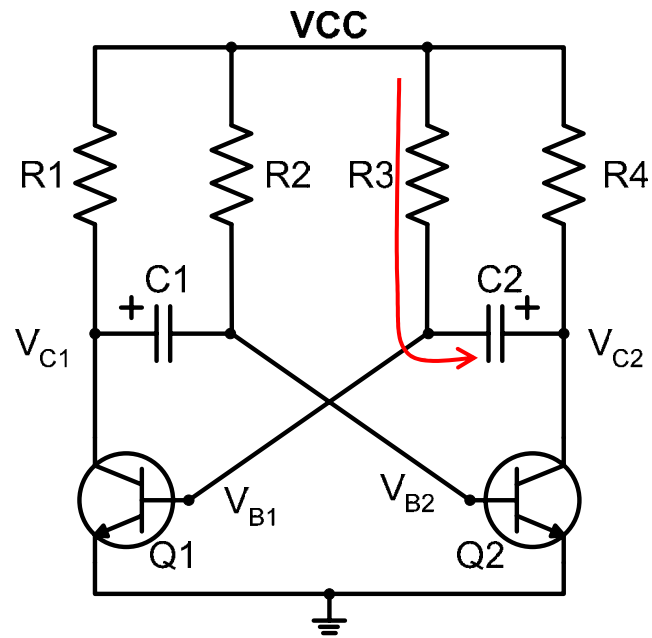
Redrawn



- Consists of two amplifying devices cross-coupled by resistors and capacitors.
- Typically, $R_2 = R_3$, $R_1 = R_4$, $C_1 = C_2$ and $R_2 \gg R_1$.
- The circuit has two states
 - State 1: V_{C1} LOW, V_{C2} HIGH, Q_1 ON (saturation) and Q_2 OFF.
 - State 2: V_{C1} HIGH, V_{C2} LOW, Q_1 OFF and Q_2 ON (saturation).
- It continuously oscillates from one state to the other.



Basic Mode of Operation

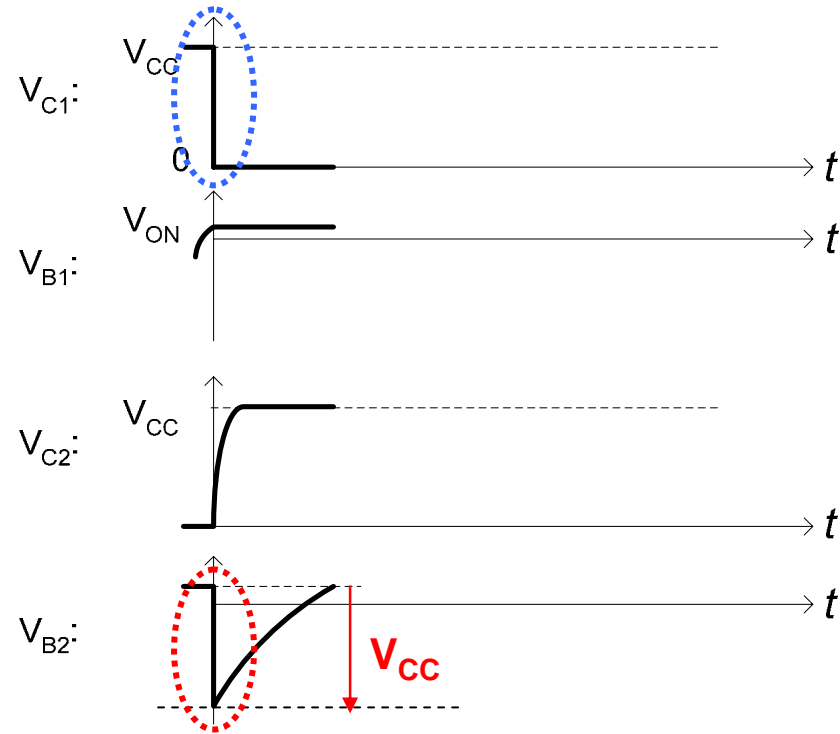
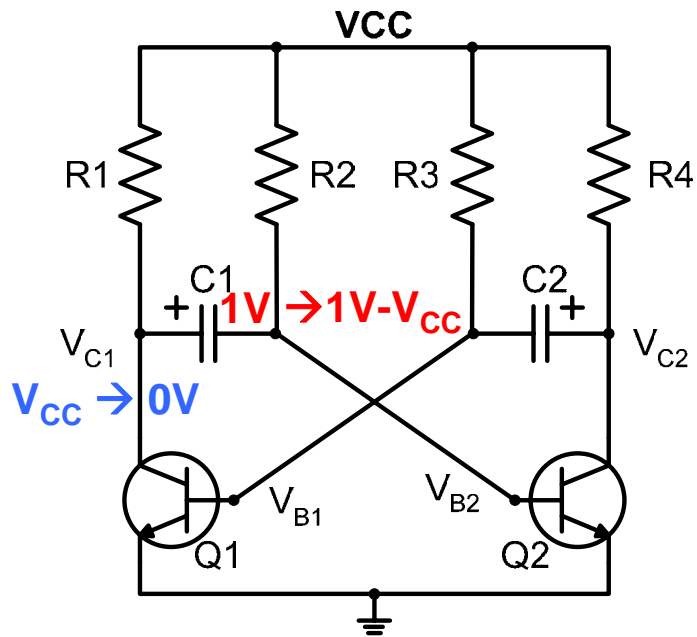


State 1:

- 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.



Basic Mode of Operation

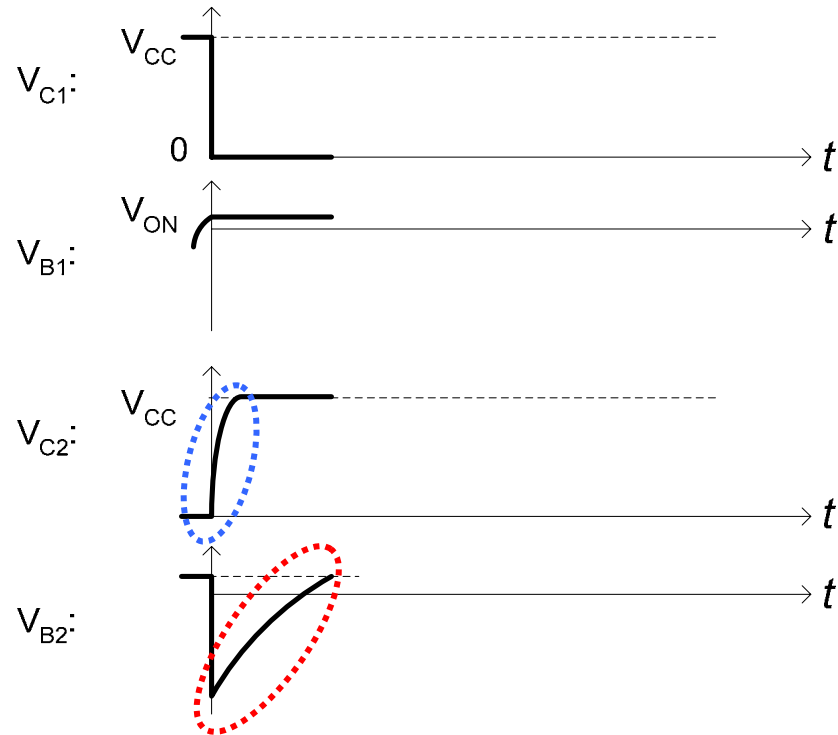
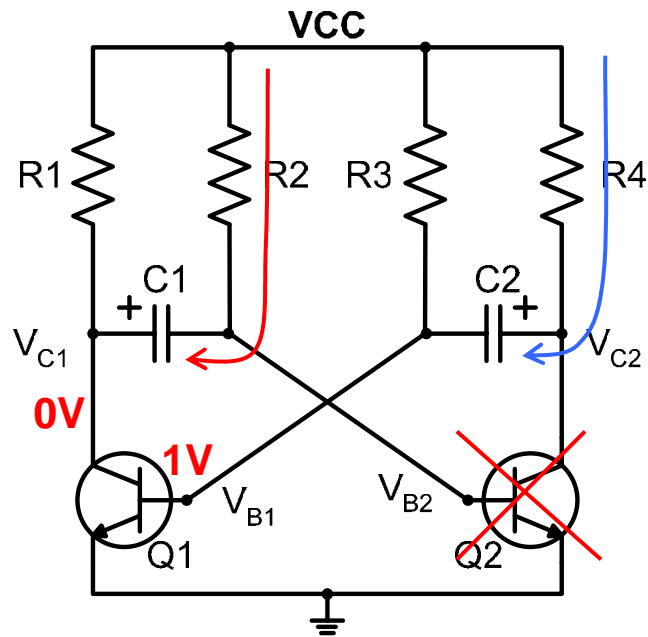


State 1 (cont'd):

- As C_1 's voltage cannot change instantaneously, V_{B2} drops by V_{CC} .



Basic Mode of Operation

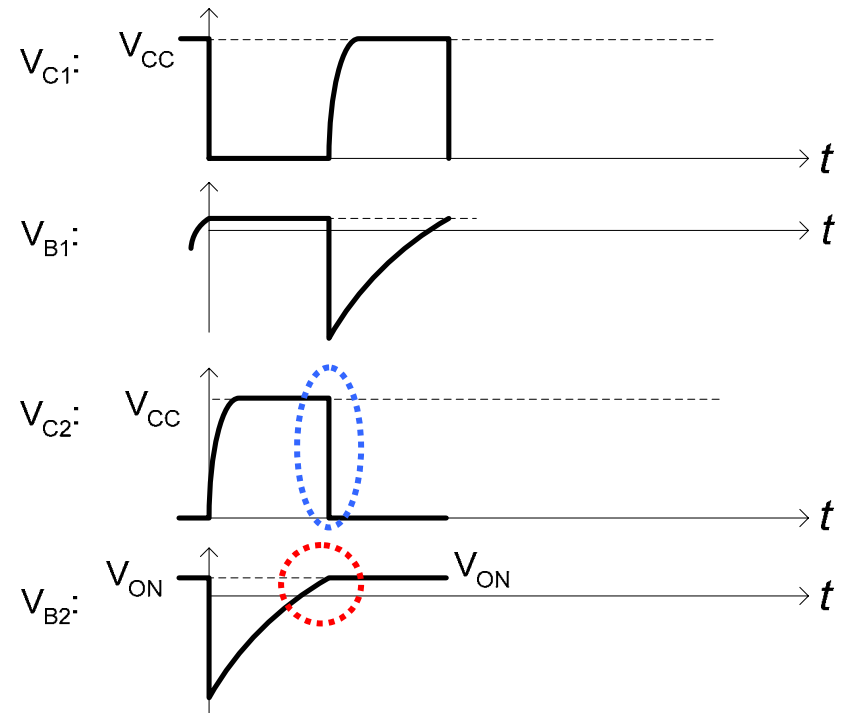
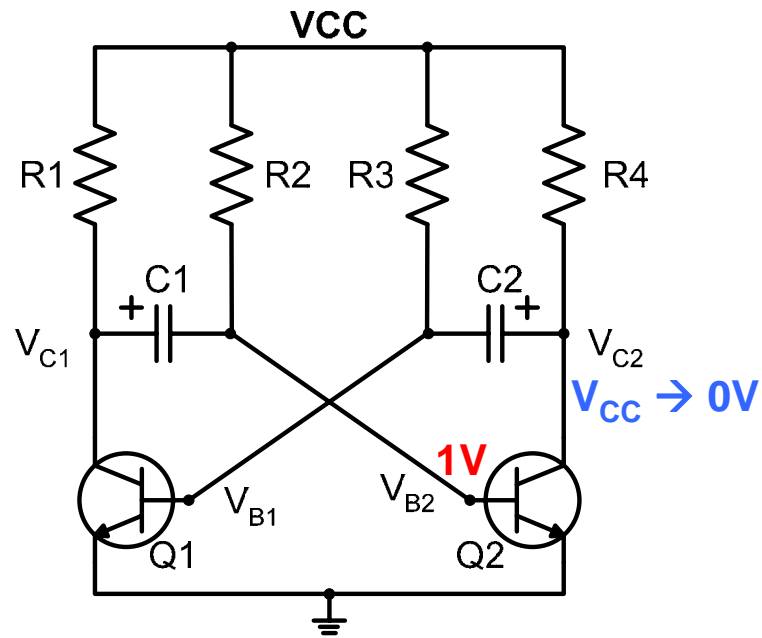


State 1 (cont'd):

- 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}).



Basic Mode of Operation

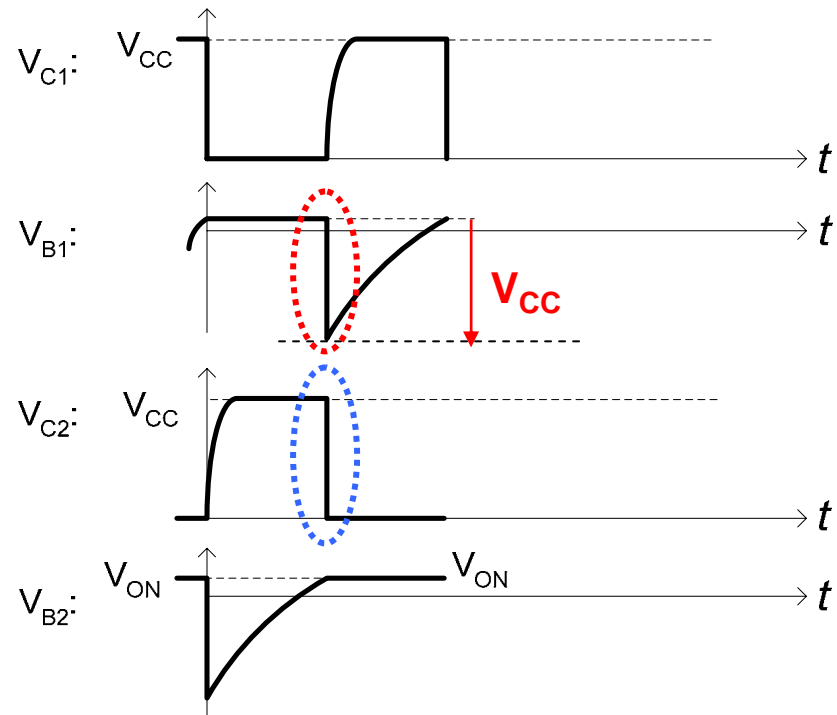
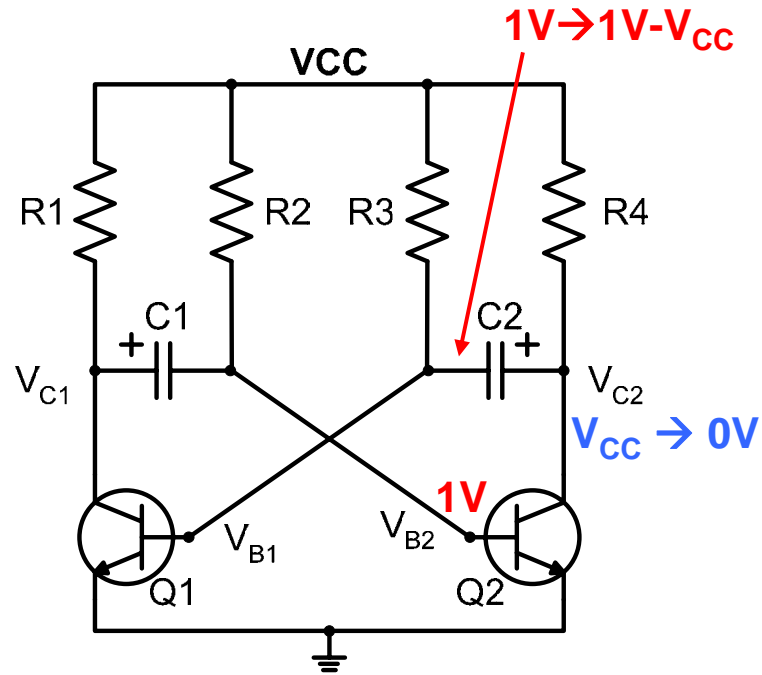


State 2:

- When V_{B2} reaches V_{ON}, Q₂ turns on and pulls V_{C2} from V_{CC} to 0V.
- V_{B2} remains at V_{ON}.



Basic Mode of Operation

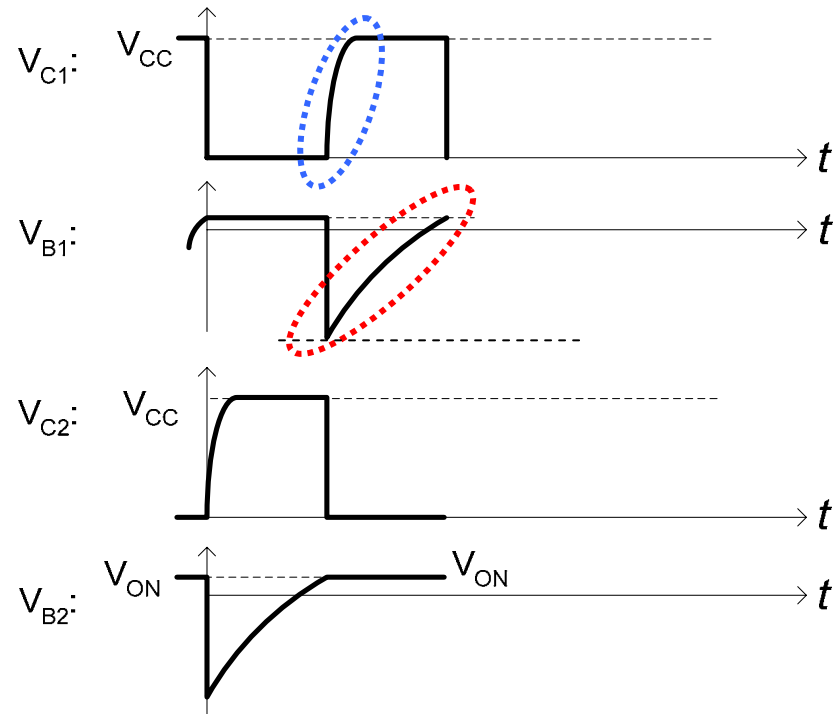
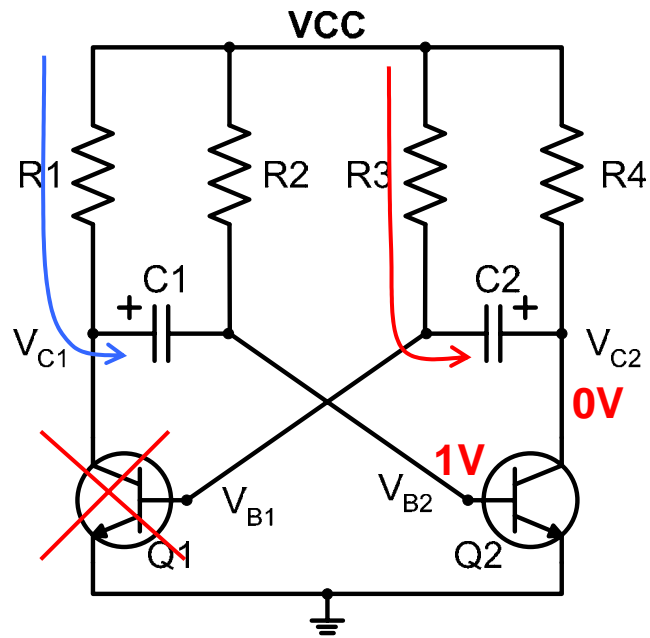


State 2 (cont'd):

- As C₂'s voltage cannot change instantaneously, V_{B1} drops by V_{CC}.



Basic Mode of Operation

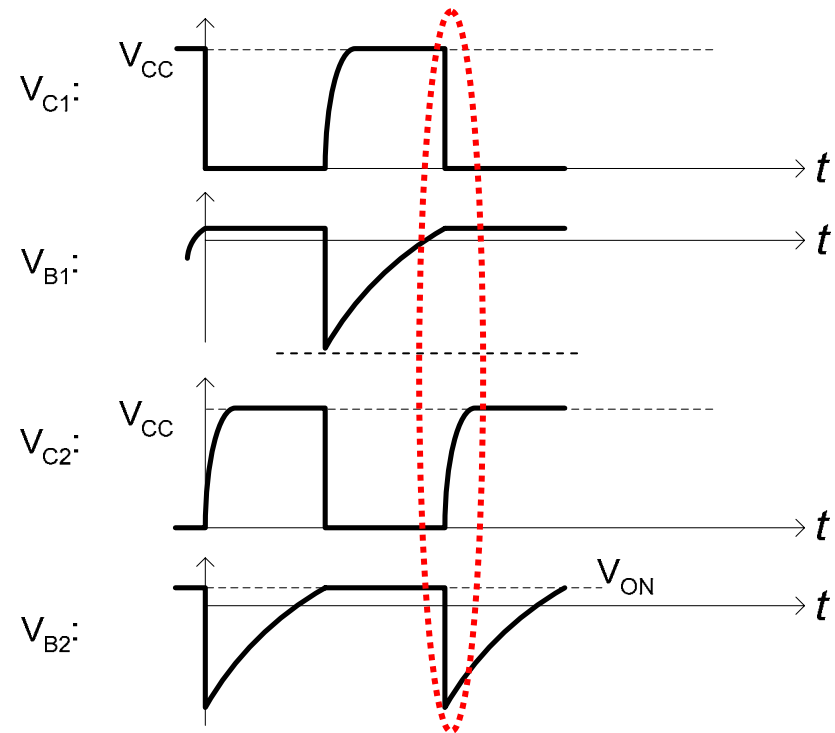
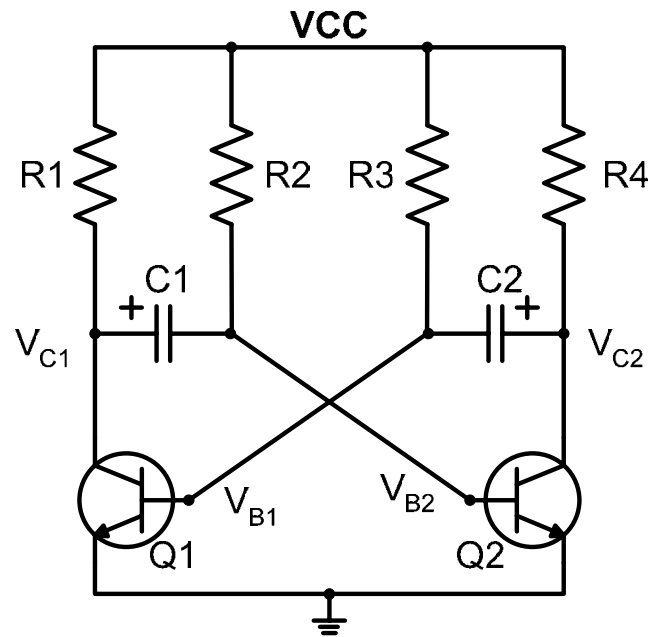


State 2 (cont'd):

- 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.



Basic Mode of Operation



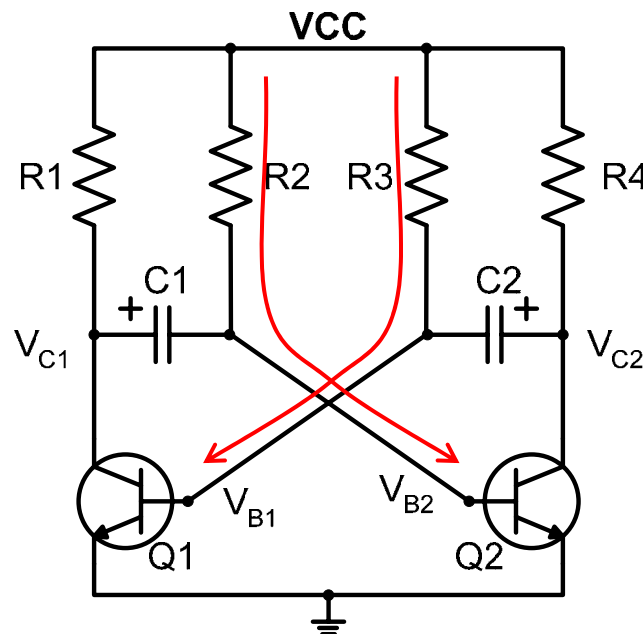
Back to state 1:

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

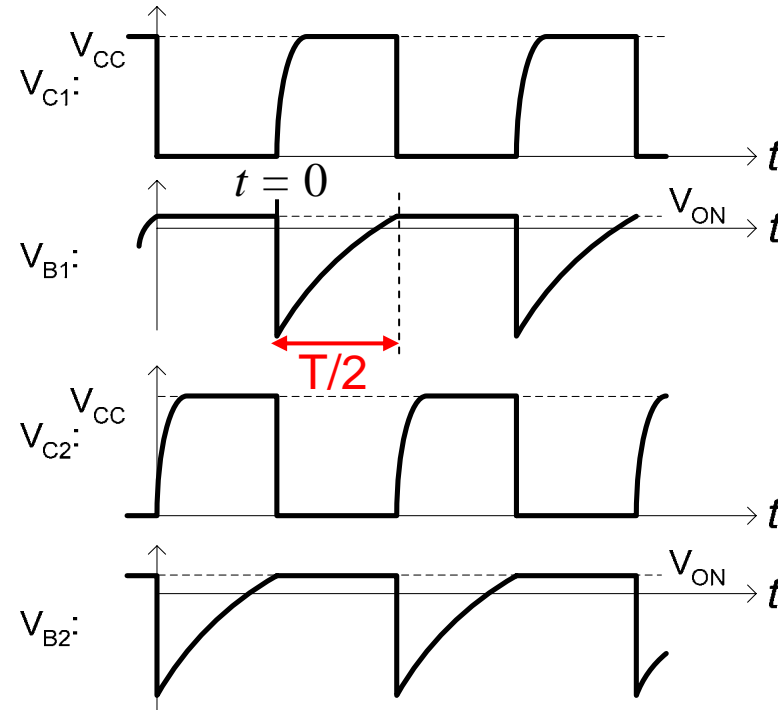
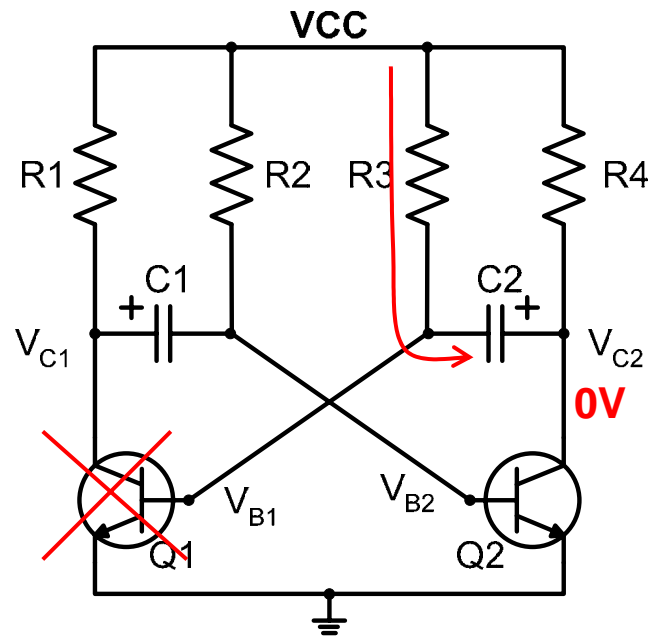


Initial Power-Up

- When the circuit is first powered up, neither transistor is ON.
- Parasitic capacitors between B and E of Q_1 and Q_2 are charged up towards V_{CC} through R_2 and R_3 . Both V_{B1} and V_{B2} rise.
- Inevitable slight asymmetries will mean that one of the transistors is first to switch on. This will quickly put the circuit into one of the above states, and oscillation will ensue.



Multivibrator Frequency



$$v_{B1} = (V_{ON} - V_{CC}) + (2V_{CC} - V_{ON})(1 - e^{-t/R_3C_2})$$

$$\approx -V_{CC} + 2V_{CC}(1 - e^{-t/R_3C_2}) \quad \text{for } V_{ON} \ll V_{CC}$$

$$\text{At } t = T/2, v_{B1} = V_{ON}: \quad V_{ON} = -V_{CC} + 2V_{CC}(1 - e^{-T/2R_3C_2})$$



Multivibrator Frequency

$$V_{ON} = -V_{CC} + 2V_{CC}(1 - e^{-T/2R_3C_2})$$

$$\therefore V_{CC} \approx 2V_{CC}(1 - e^{-T/2R_3C_2}) \quad \text{for } V_{ON} \ll V_{CC}$$

$$\therefore 1 = 2(1 - e^{-T/2R_3C_2})$$

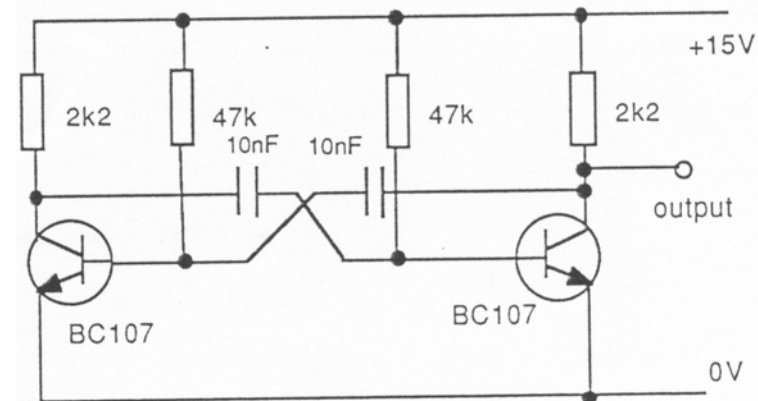
$$\therefore e^{-T/2R_3C_2} = 0.5$$

$$\therefore -\frac{T}{2R_3C_2} = -\ln 2$$

$$\therefore T = 2(\ln 2)R_3C_2$$

or

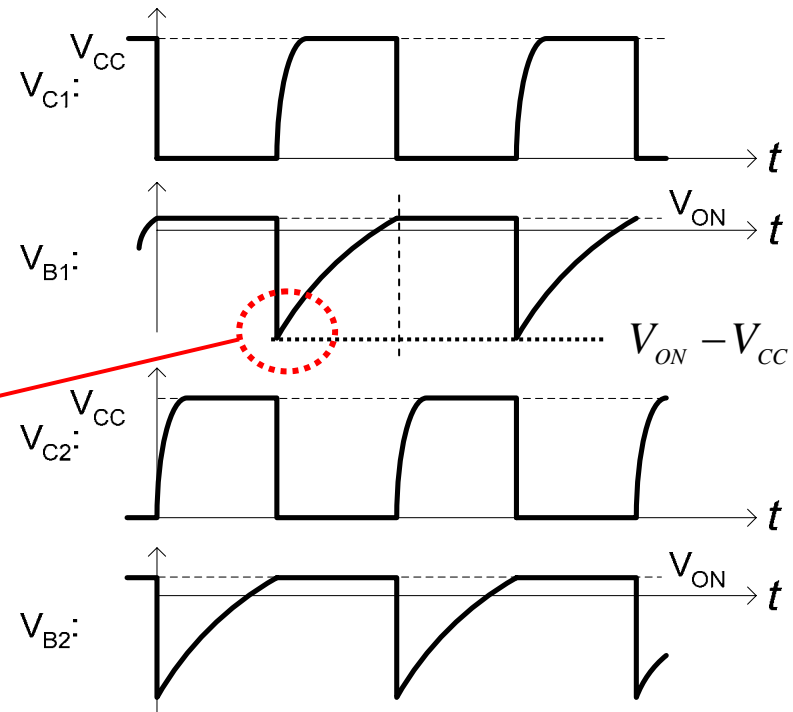
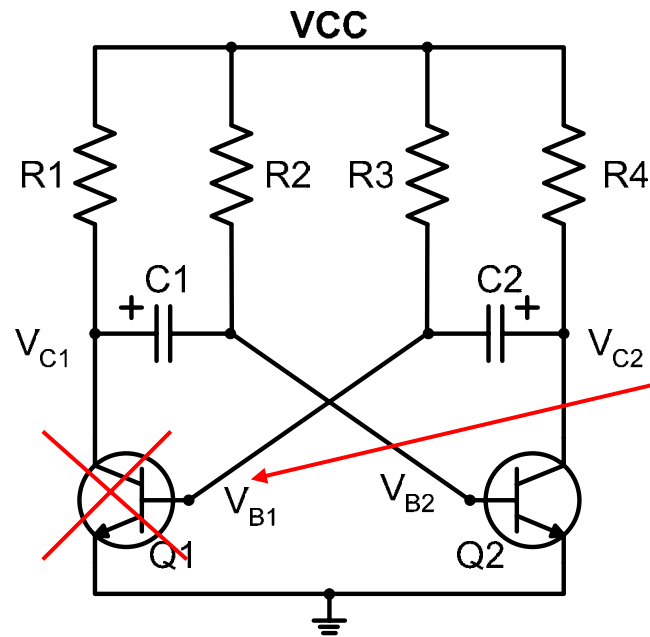
$$f = \frac{1}{2(\ln 2)R_3C_2}$$



For the above component values,
 $f = 1.53\text{kHz}$.



Supply Voltage Limit

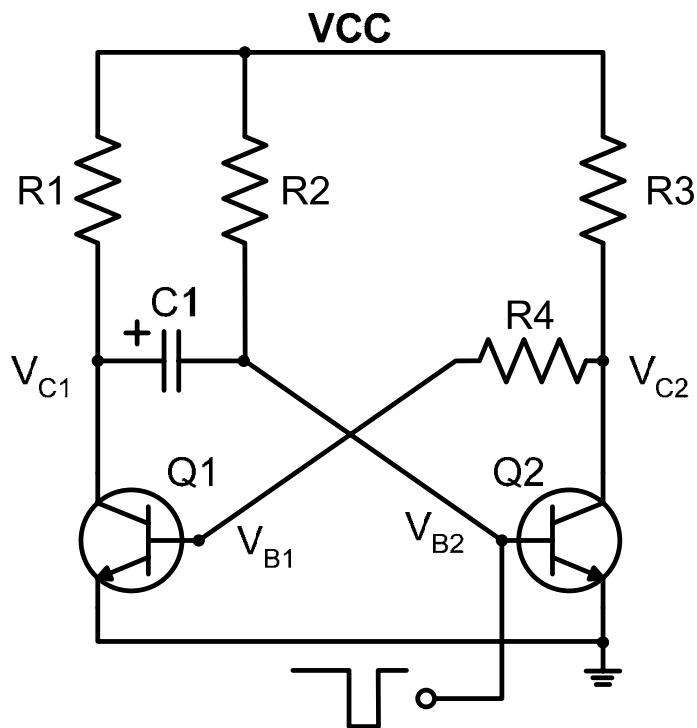


- When V_{B1} is negative, BE junction of Q_1 is reverse-biased.
- Suppose the breakdown voltage of this junction is V_{break} (positive). then to avoid breakdown,

$$V_{ON} - V_{CC} > -V_{Break} \Rightarrow V_{CC} < V_{ON} + V_{Break}$$



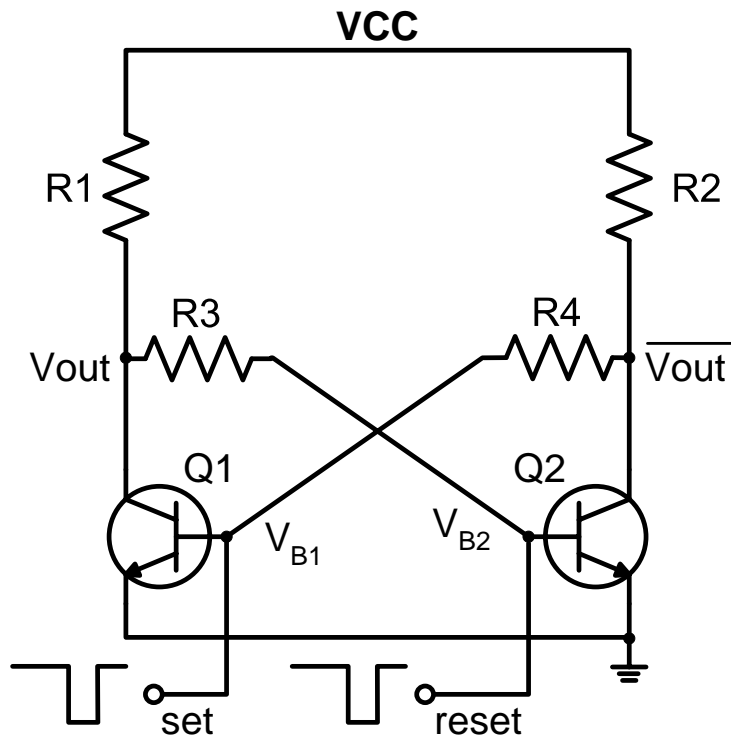
Mono-stable Multivibrator



- 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



Bi-stable 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} ($\overline{V_{out}}$) 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

