- Charging RC circuit

$$V_C = V_{sup}\left(1 - e^{\frac{-t}{RC}}\right)$$

- Discharging RC circuit

$$V_C = V_{sup}e^{\frac{-t}{RC}}$$

- Charge up time or discharge time between $\frac{1}{3}V_{sup}$ and $\frac{2}{3}V_{sup}$ is

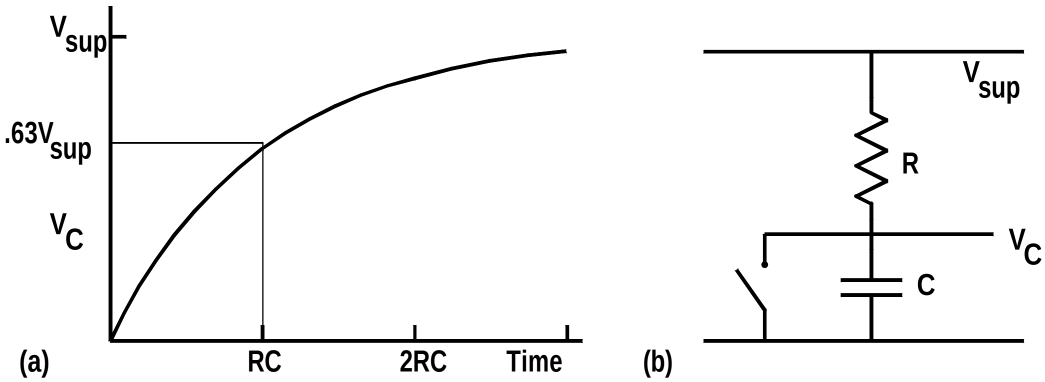
$$T = 0.7RC$$

- Time to charge from $0V$ to $\frac{2}{3}V_{sup}$ is

$$T = 1.1RC$$

- Time intervals for a 555 Timer IC are

$$T_1 = 0.7(R_A + R_B)C \quad \text{and} \quad T_2 = 0.7R_B$$



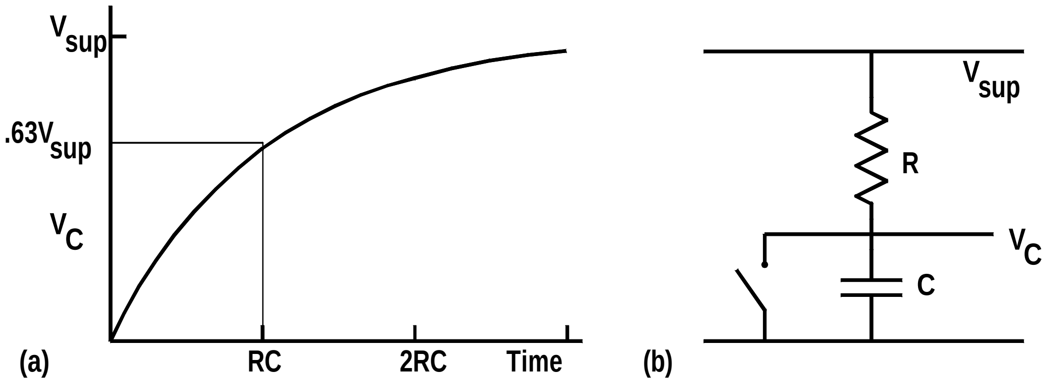
RC charging curve.
$V_{sup} - V_C$ across R.
Then $I = \frac{dQ}{dt} = \frac{V_{sup} - V_C}{R}$. Charge on capacitor is $Q = CV_C$
After differentiation becomes $\frac{dQ}{dt} = C\frac{dV_C}{dt}$. Equate these two expressions for the current to get

$$RC\frac{dV_C}{dt} = V_{sup} - V_C$$

Solution is

$$V_C = V_{sup}\left(1 - e^{\frac{-t}{RC}}\right)$$

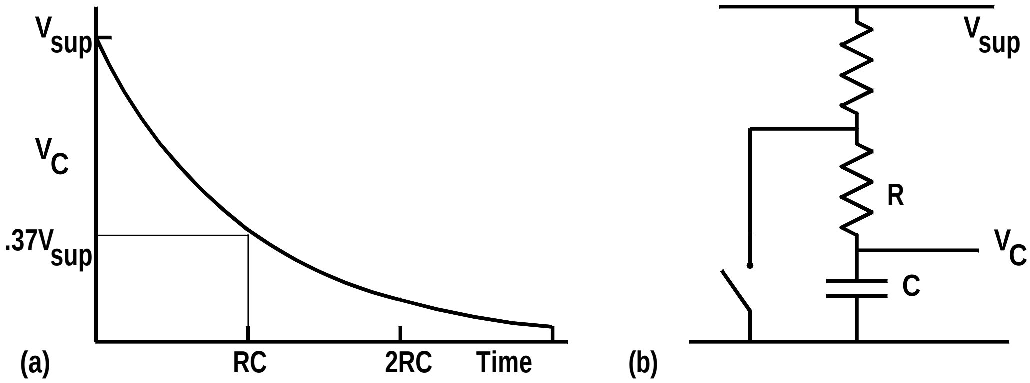
where RC is called the time constant.



RC charging curve.

At the time $T = RC$, the calculated value of the V_C is $0.63V_{sup}$.
The output has made 63% of its total change at time $T = RC$.

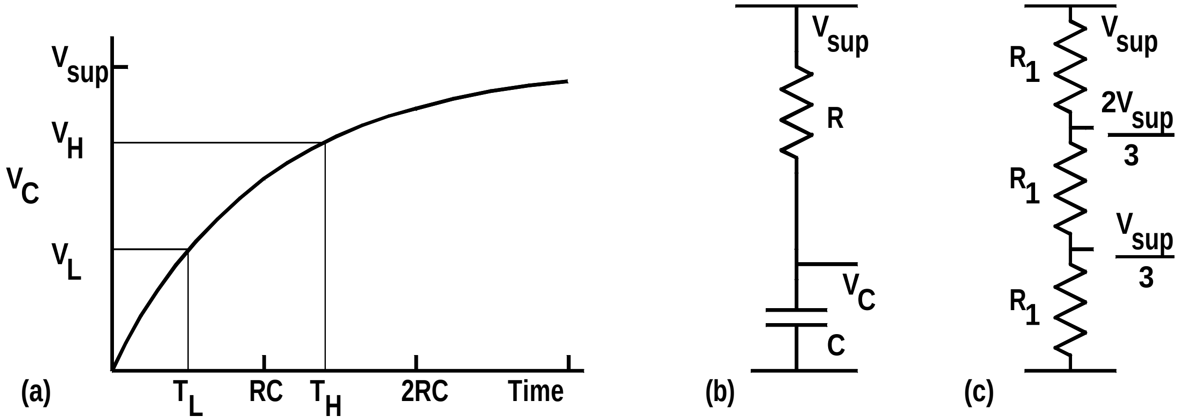
This 63% response is used in instrumentation.
Thermometer time constants.
Wait 3 time constants for valid reading.



RC discharging curve.
Close switch at $t = 0$
Set up differential equation

$$V_C = V_{sup} e^{\frac{-t}{RC}}$$

Define T_L is time for capacitor to charge from $0V$ to the lower voltage V_L.
Define T_H as time for capacitor to charge from $0V$ to the higher voltage V_H.



Time between voltages V_L and V_H.

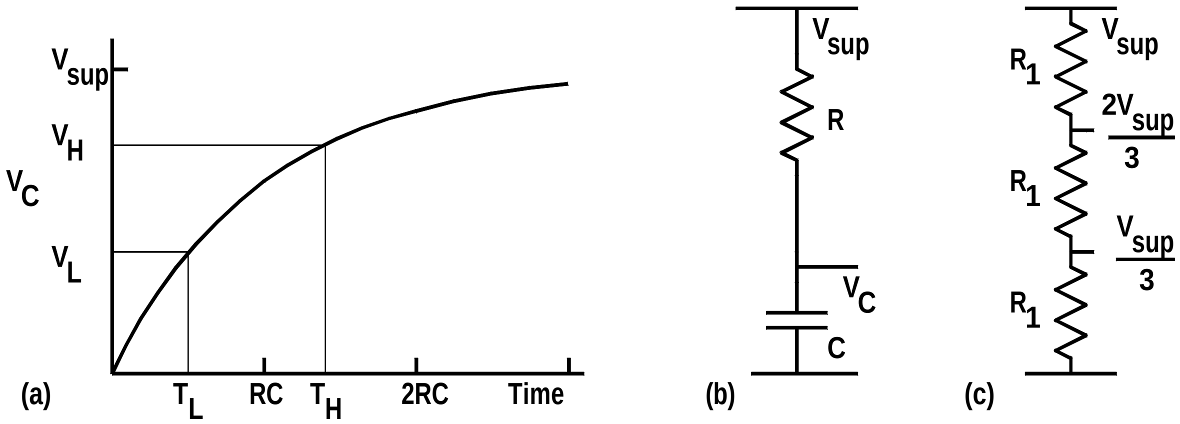
$$V_L = V_{sup}\left(1 - e^{\frac{-T_L}{RC}}\right)$$

$$\text{and} \quad V_H = V_{sup}\left(1 - e^{\frac{-T_H}{RC}}\right)$$

Rearrange and take natural logs

$$-T_L = RC \ln\left(\frac{V_{sup} - V_L}{V_{sup}}\right)$$

$$\text{and} \quad -T_H = RC \ln\left(\frac{V_{sup} - V_H}{V_{sup}}\right)$$



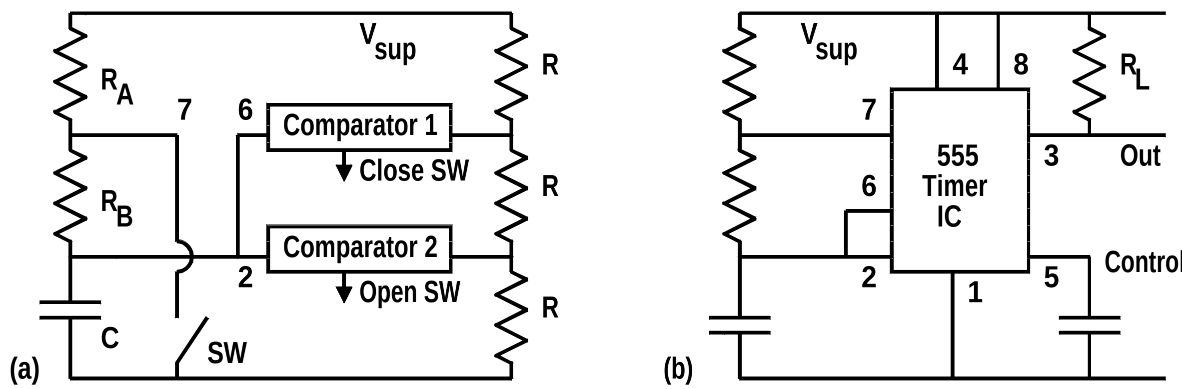
Subtract

$$T_H - T_L = RC\left(\ln\left(\frac{V_{sup} - V_L}{V_{sup}}\right) - \ln\left(\frac{V_{sup} - V_H}{V_{sup}}\right)\right)$$

$$= RC \ln\left(\frac{V_{sup} - V_L}{V_{sup} - V_H}\right)$$

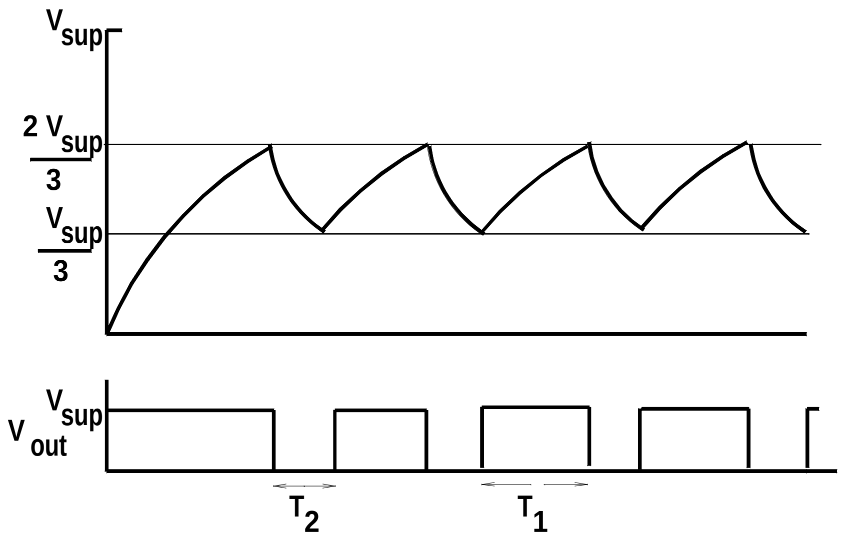
Set $V_L = \frac{1}{3}V_{sup}$ and $V_H = \frac{2}{3}V_{sup}$. Put into expression for $T_H - T_L$

$$T = RC \ln\left(\frac{V_{sup} - \frac{1}{3}V_{sup}}{V_{sup} - \frac{2}{3}V_{sup}}\right) = RC \ln 2 = .693RC \approx 0.7RC$$



Internal circuit blocks of the 555 Timer.

Three resistors in series give reference voltages of $\frac{1}{3}V_{sup}$ and $\frac{2}{3}V_{sup}$.
Comparators toggle a switch SW



Capacitor and output voltage waveforms for the 555 Timer.

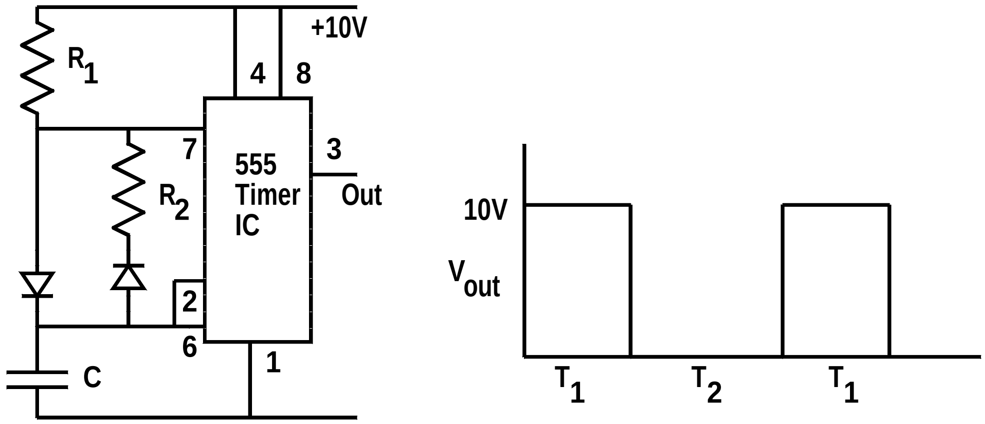
Pin 3 gives an output signal which is a indicator of the state of the IC comparators.

Time T_1 to charge from $\frac{1}{3}V_{sup}$ to $\frac{2}{3}V_{sup}$ is

$$T_1 = 0.7(R_A + R_B)C$$

Time to discharge from $\frac{2}{3}V_{sup}$ to $\frac{1}{3}V_{sup}$ is

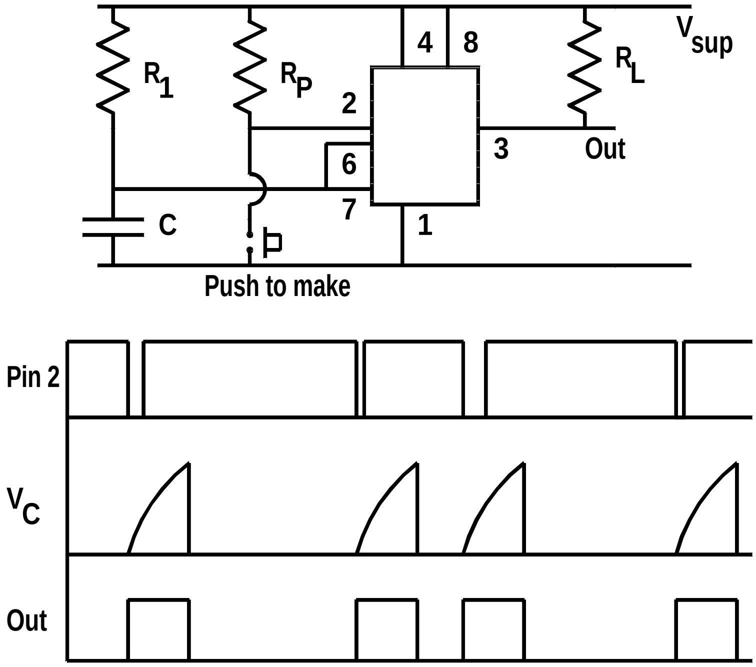
$$T_2 = 0.7R_BC$$



Circuit for generation of arbitrary Mark Space ratio.

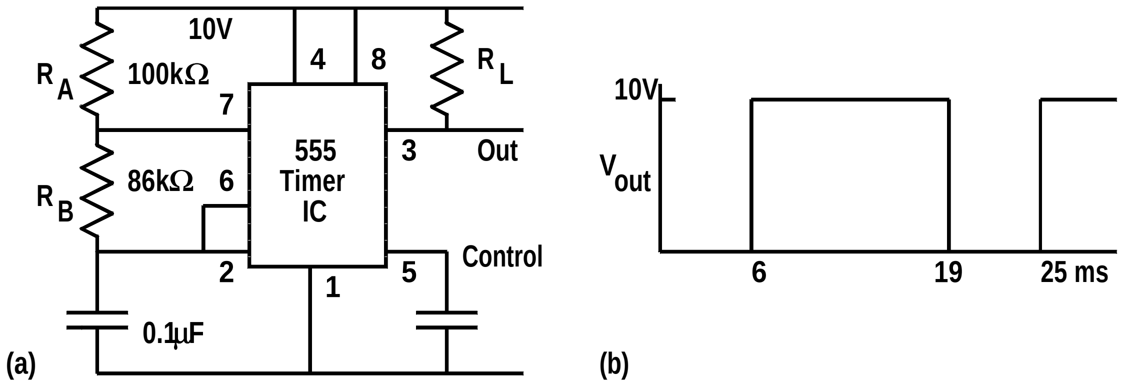
Capacitor charges through R_1 and the diode with a time constant of $T_1 = 0.7R_1C$.

The discharge path is through R_2 and the diode in series with R_2 to give a time constant $T_2 = 0.7R_2C$.



Triggered operation of the 555 Timer.

Monostable operation instead of astable operation.



555 Timer circuit to give $0V$ for $6ms$ followed by $10V$ for $13ms$.

Choose $C = 0.1\mu F$.

$$T_2 = 6 \times 10^{-3} = 0.7 \times .1 \times 10^{-6} \times R_B$$

and therefore $R_B = \frac{6 \times 10^{-3}}{.7 \times .1 \times 10^{-6}} = 86k\Omega$

$T_1 = 13 \times 10^{-3} = .7 \times .1 \times 10^{-6}(86k\Omega + R_A)$ and therefore $86k\Omega + R_A = 186k\Omega$ which gives

$$R_A = 100k\Omega$$