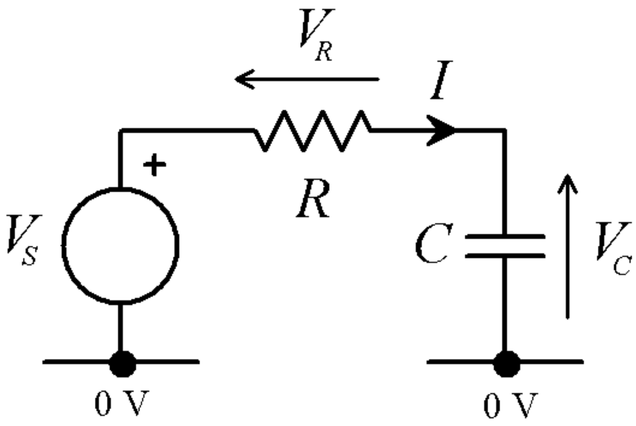
Unit-2
Lecture-8

Sinusoidal oscillators

Oscillators

- With the addition of a capacitor and resistor, the Schmitt trigger can be turned into a simple oscillator.
- Technically, it’s known as an *astable multivibrator*.
- Before looking at the circuit, it is worth reviewing the transient response of a first order RC network.

Transient Response



$$I = C\frac{\mathrm{d}V_C}{\mathrm{d}t} = C\frac{\mathrm{d}(V_S - V_R)}{\mathrm{d}t}$$

$$= C\frac{\mathrm{d}V_S}{\mathrm{d}t} - C\frac{\mathrm{d}V_R}{\mathrm{d}t} = -C\frac{\mathrm{d}V_R}{\mathrm{d}t}$$

and

$$I = \frac{V_R}{R}$$

$$\therefore \frac{\mathrm{d}V_R}{\mathrm{d}t} = -\frac{V_R}{CR}$$

$$\frac{\mathrm{d}V_R}{\mathrm{d}t} = -\frac{V_R}{CR}$$ is a separable first order differential equation.

These are the easiest kind to solve!

First, rearrange:

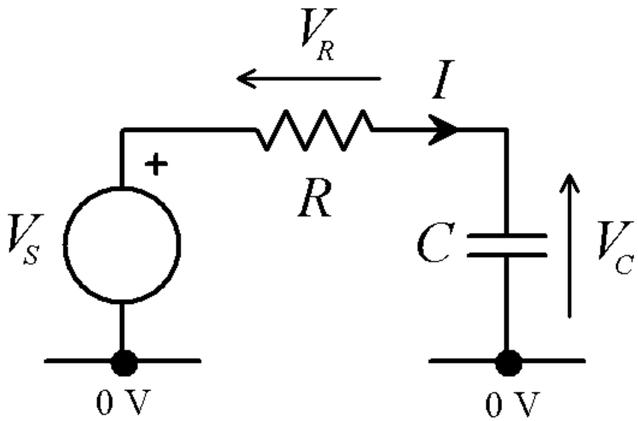
$$\frac{1}{V_R}\mathrm{d}V_R = -\frac{1}{CR}\mathrm{d}t$$

and integrate each side:

$$\ln(V_R) = -\frac{t}{CR} + k \Rightarrow V_R = \tilde{k}\exp\left[-\frac{t}{CR}\right]$$

The constant, $\tilde{k}$, is the value of V_R when time=0, so:

$$V_R(t) = V_R(0)\exp\left[-\frac{t}{CR}\right]$$

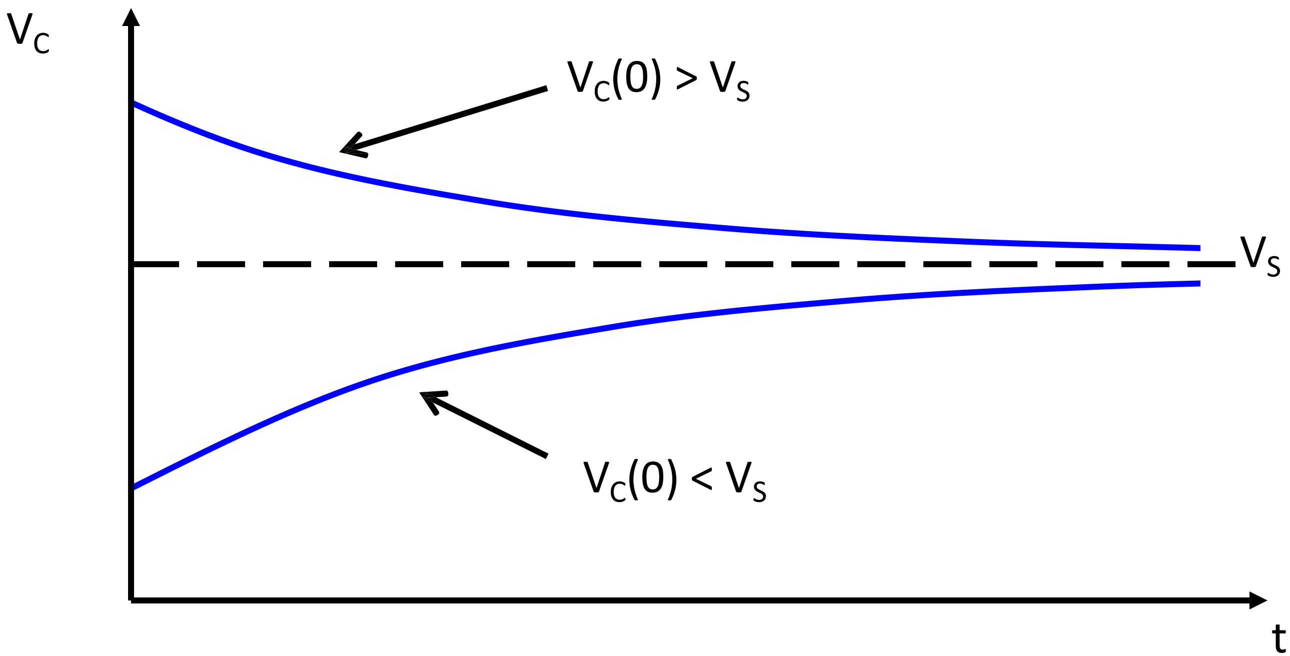


$$V_R(t) = V_R(0)\exp\left[-\frac{t}{CR}\right]$$

$$V_C = V_S - V_R$$

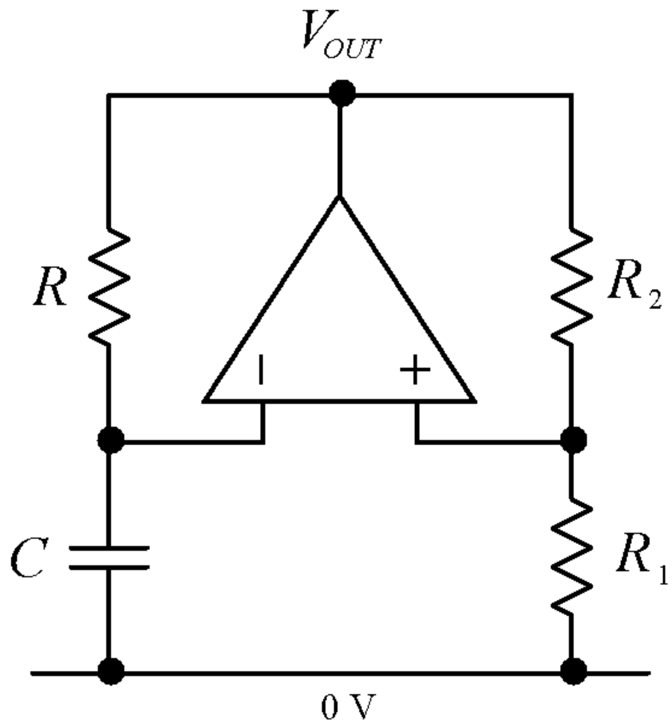
$$V_C(t) = V_S - V_R(0)\exp\left[-\frac{t}{CR}\right]$$

$$= V_S - \left[V_S - V_C(0)\right]\exp\left[-\frac{t}{CR}\right]$$



NB. In either case, $V_C \rightarrow V_S$ as $t \rightarrow \infty$. $V_C(\infty)$ is known as the *aiming potential*.

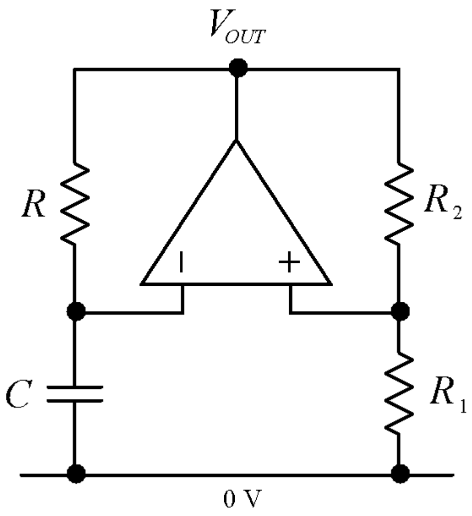
Oscillator Circuit

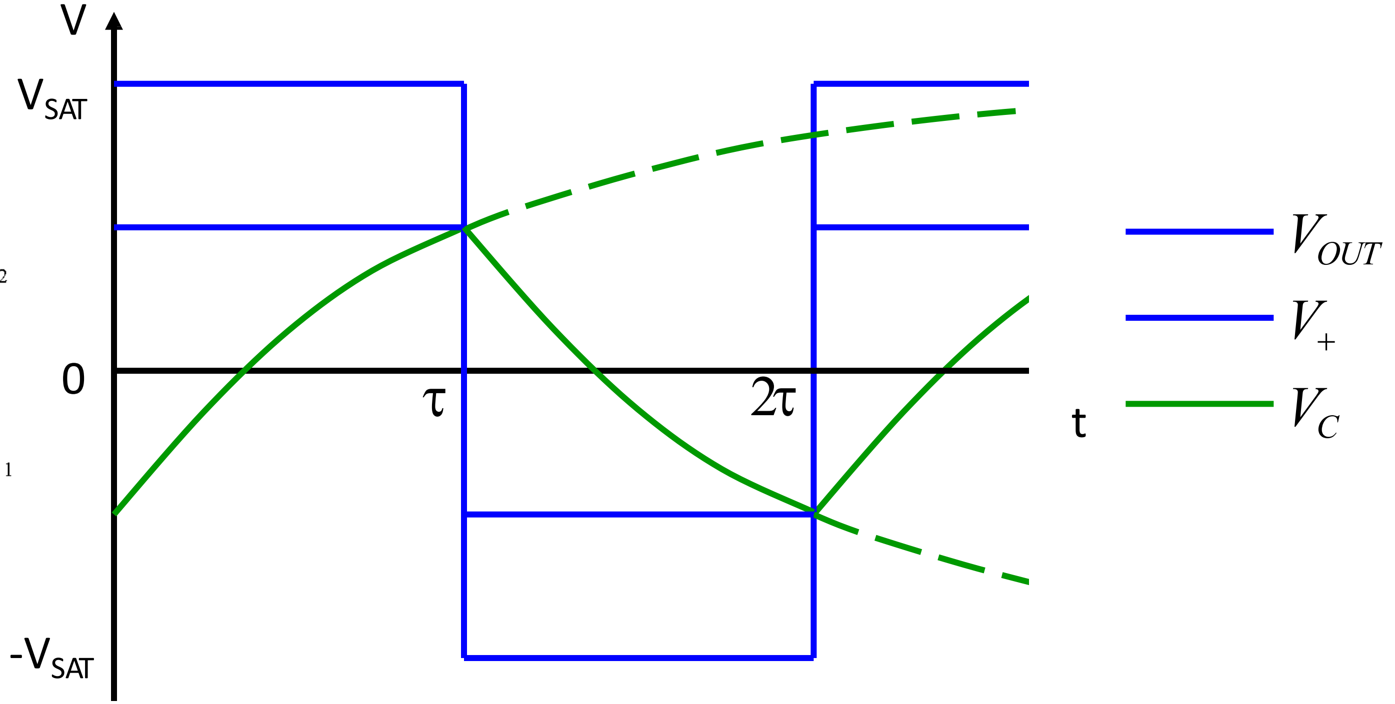


$R_1 = R_2$

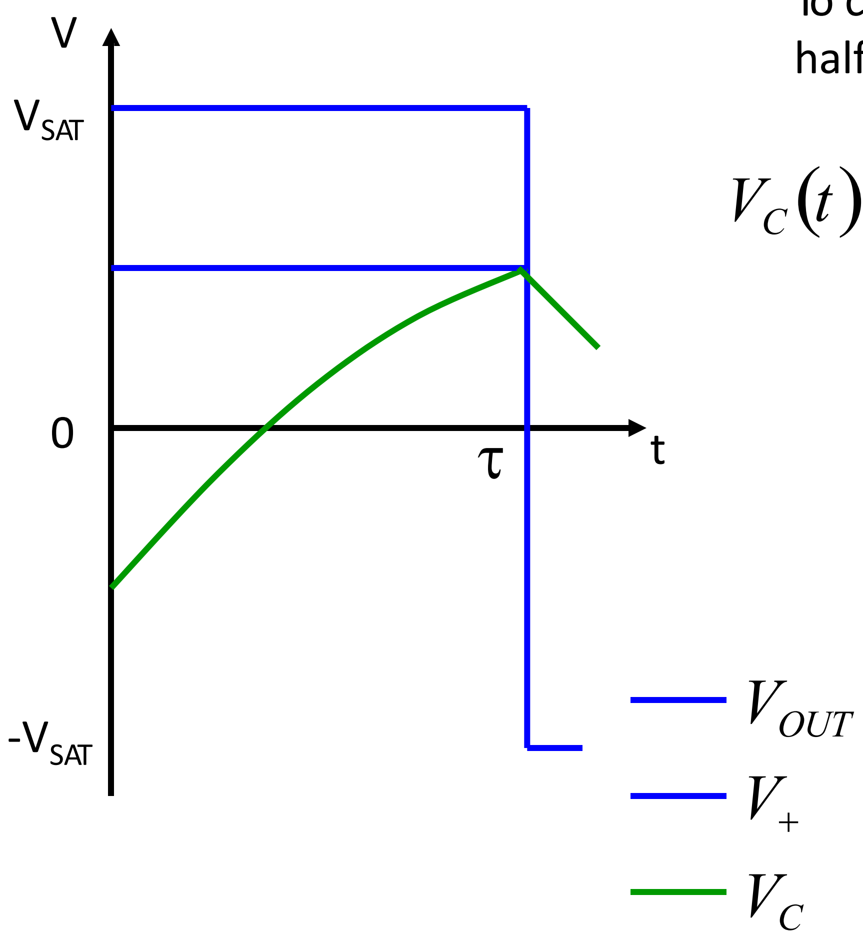
- The op-amp, R_1 and R_2 form an inverting Schmitt trigger
- As $R_1 = R_2$, threshold levels are $\pm V_{SAT}/2$
- The output is fed-back to the inverting input via an RC network
- The aiming potential of the capacitor voltage will be either $+V_{SAT}$ or $-V_{SAT}$

Waveforms





Analysis



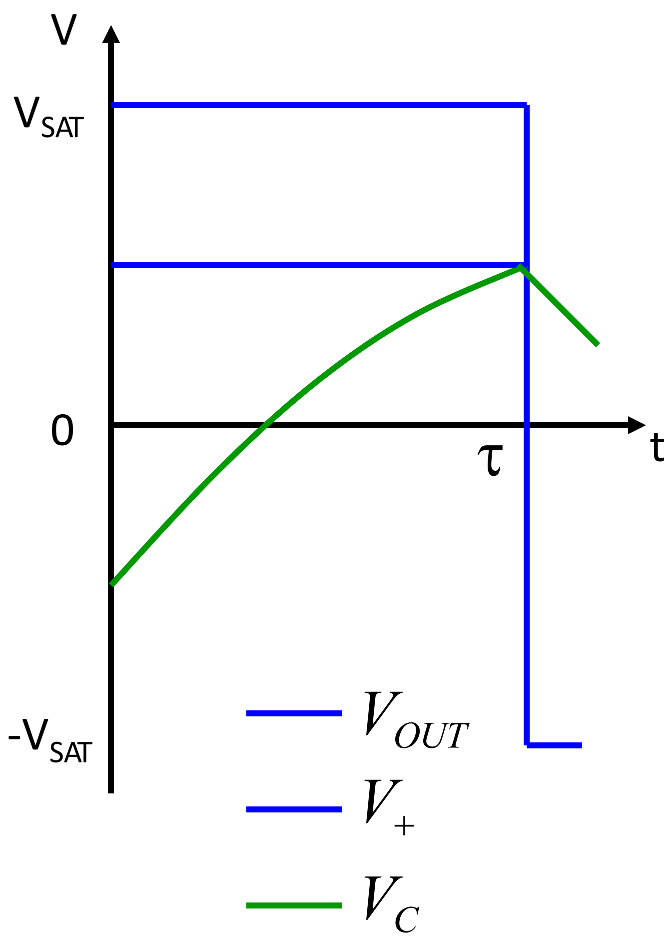
To calculate the time-period, consider just one half-cycle of the oscillation.

$$V_C(t) = V_{SAT} - [V_{SAT} - V_C(0)]\exp\left[-\frac{t}{CR}\right]$$

$$= V_{SAT} - [V_{SAT} - (-V_{SAT}/2)]\exp\left[-\frac{t}{CR}\right]$$

$$= V_{SAT}\left(1 - \frac{3}{2}\exp\left[-\frac{t}{CR}\right]\right)$$

Analysis (cont)



Half-cycle ends when V_C reaches $V_{SAT}/2$

$$V_C(\tau) = \frac{V_{SAT}}{2} = V_{SAT}\left(1 - \frac{3}{2}\exp\left[-\frac{\tau}{CR}\right]\right)$$

$$\therefore \frac{1}{2} = 1 - \frac{3}{2}\exp\left[-\frac{\tau}{CR}\right]$$

$$\Rightarrow \exp\left[-\frac{\tau}{CR}\right] = \frac{1}{3}$$

$$\Rightarrow \tau = -CR\ln(1/3) = CR\ln(3)$$

Full period of oscillation is 2 half cycles,

$$T = 2\tau = 2CR\ln(3) \approx 2.2CR$$

Oscillator Summary

- Using only a couple of extra components, the Schmitt trigger can be converted into a simple oscillator
- R & C set the period of oscillation independently of V_{SAT}
- Many square wave oscillators work using the same basic principles