Waveshapping Circuits and Data Converters

Lesson #18
Astable Multivibrators
Section 12.2

Astable Multivibrators

- A switching oscillator or Astable Multivibrator can be formed from a Schmitt trigger as follows:
- Assume that output levels are ±A and the thresholds are ±A/2 since the feedback voltage = ½ v_o.

$$v_i = v_t - v_{in}$$

when $v_i > 0; v_o = A;$ therefore,

$$v_i = v_t - v_{in} > 0$$

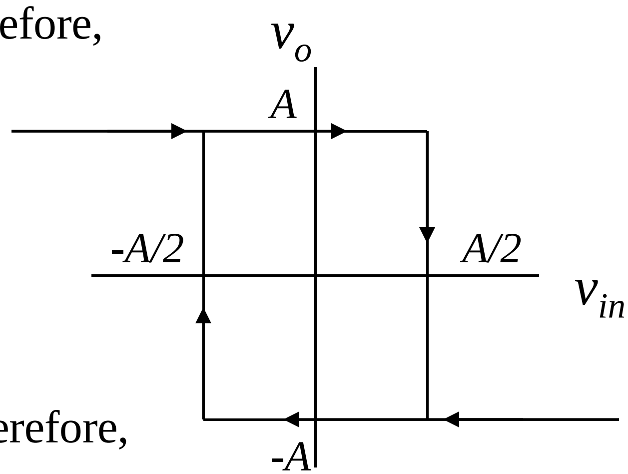
$$v_t > v_{in}; \text{ or } v_{in} < \frac{A}{2}$$

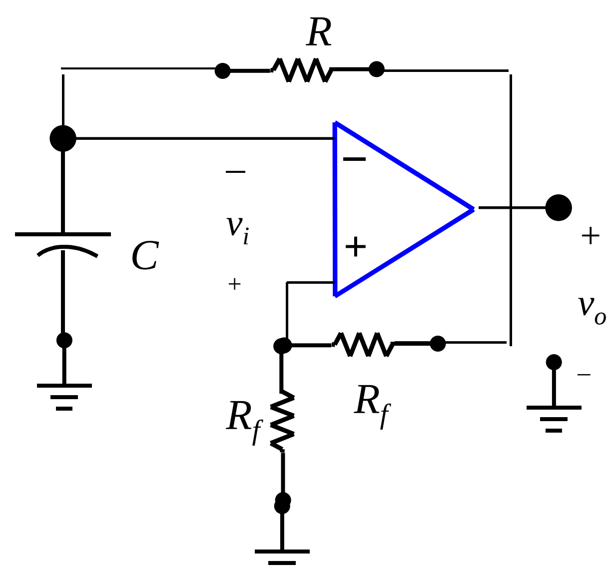
$$v_i = v_t - v_{in}$$

when $v_i < 0; v_o = -A;$ therefore,

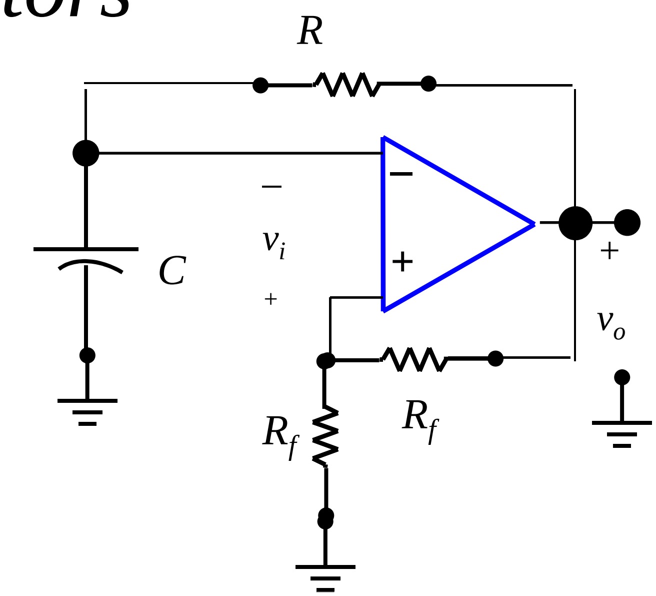
$$v_i = v_t - v_{in} < 0$$

$$v_t < v_{in}; \text{ or } v_{in} > -\frac{A}{2}$$

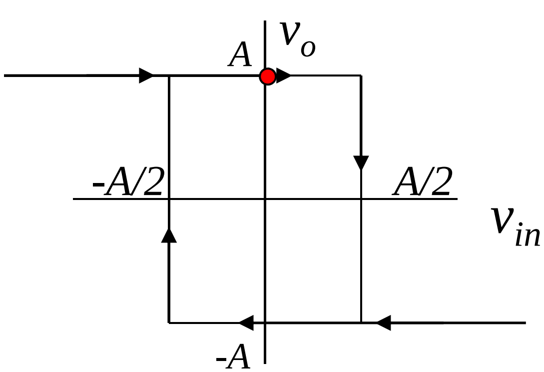


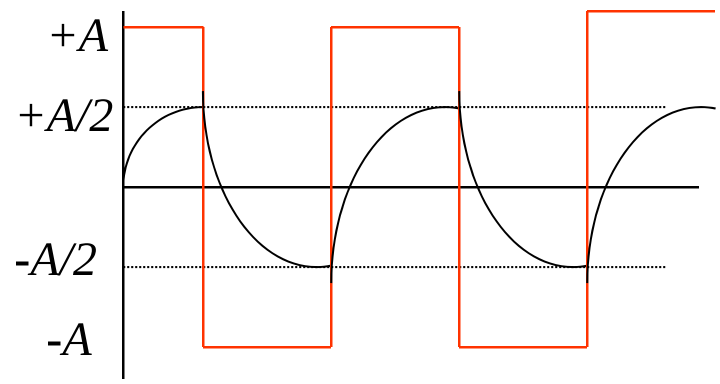


Astable Multivibrators

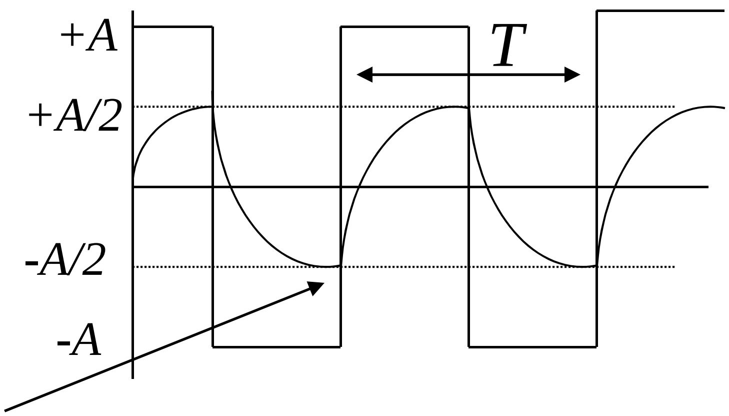


- Assume that the output starts off at +A.
- The capacitor starts to charge to +A
- However, when it reaches +A/2, v_i = 0 and the output switches to –A.
- The capacitor then charges to –A.
- However, when it reaches –A/2, v_i =*0* and the output switches to +A
- And the capacitor charges to +A
- This process continues.





Timing Calculation



Start the timing calculation here

$v_c(t) = K_1 + K_2 e^{-t/RC}$

Initial Condition :

$v_c(0) = -\frac{A}{2} = K_1 + K_2 e^{-0/RC} = K_1 + K_2 \text{ (eqn.1)}$

Final Condition :

$v_c(\infty) = +A = K_1 + K_2 e^{-\infty/RC} = K_1 \text{ (eqn. 2)}$

From eqns (1) and (2)

$K_1 = A$

$K_2 = -\frac{A}{2} - K_1 = -\frac{3}{2}A$

$v_c(t) = A(1 - \frac{3}{2}e^{-t/RC})$

But

$v_c(\frac{T}{2}) = \frac{A}{2} = A(1 - \frac{3}{2}e^{-T/2RC})$

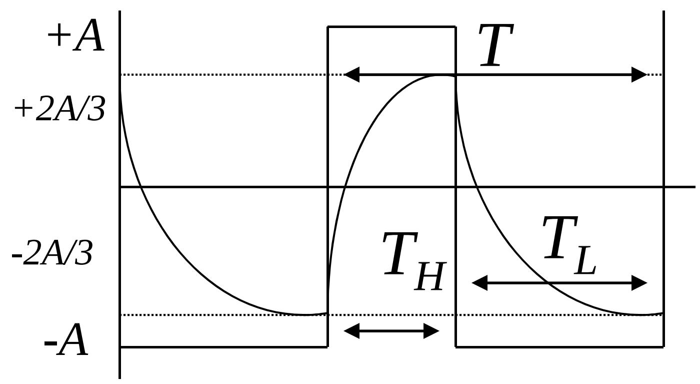
$\therefore e^{-T/2RC} = \frac{1}{3}$

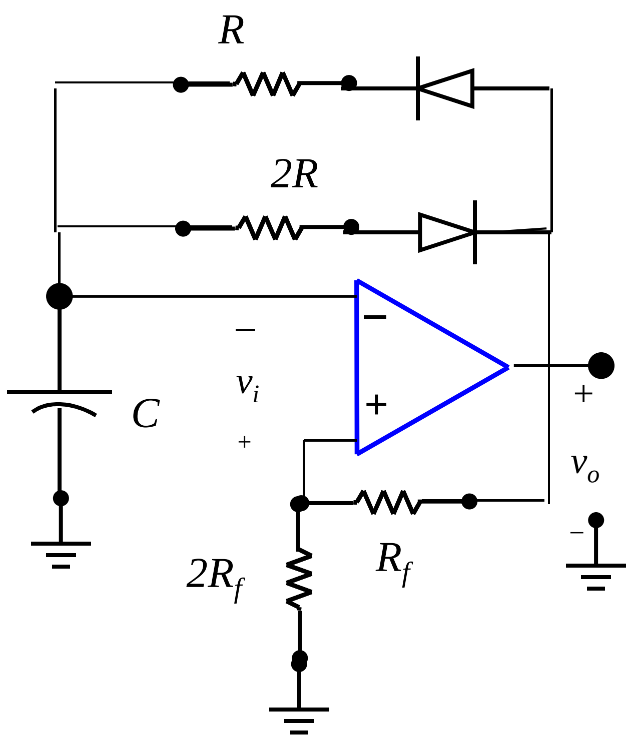
$T = 2RC\ln(3)$

An Example

- Assume output levels are ± A
  1. What are the thresholds?

     $\beta = 2R_f / (2R_f + R_f) \Rightarrow \pm 2/3A$
  2. Sketch v_c and v_o





  3. Duty Cycle of the Pulse $T_L = 2T_H$
  4. Frequency of Oscillation

Frequency of Oscillation

For Charging to + A

$$v_c(t) = K_1 + K_2 e^{-t/RC}$$

Initial Condition :

$$v_c(0) = -\frac{2A}{3} = K_1 + K_2 e^{-0/RC} = K_1 + K_2 \text{ (eqn.1)}$$

Final Condition :

$$v_c(\infty) = +A = K_1 + K_2 e^{-\infty/RC} = K_1 \text{ (eqn. 2)}$$

From eqns (1) and (2)

$$K_1 = A$$

$$K_2 = -\frac{2A}{3} - K_1 = -\frac{5}{3}A$$

$$v_c(t) = A(1 - \frac{5}{3}e^{-t/RC})$$

But

$$v_c(T_H) = \frac{2A}{3} = A(1 - \frac{5}{3}e^{-T_H/RC})$$

$$\therefore e^{-T_H/RC} = \frac{1}{5}$$

$$T_H = RC\ln(5)$$

For Charging to – A

$$v_c(t) = K_1 + K_2 e^{-t/2RC}$$

Initial Condition :

$$v_c(0) = \frac{2A}{3} = K_1 + K_2$$

Final Condition :

$$v_c(\infty) = -A = K_1$$

$$K_2 = \frac{2A}{3} - K_1 = \frac{5}{3}A$$

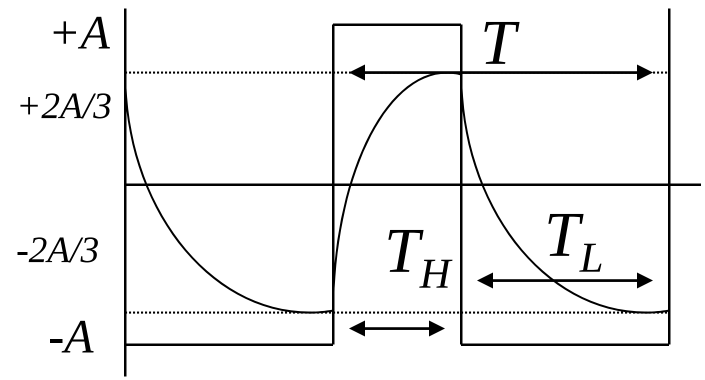
$$v_c(t) = A(\frac{5}{3}e^{-t/2RC} - 1)$$

But

$$v_c(T_L) = -\frac{2A}{3} = A(\frac{5}{3}e^{-T_L/2RC} - 1)$$

$$\therefore e^{-T_L/2RC} = \frac{1}{5}$$

$$T_L = 2RC\ln(5)$$

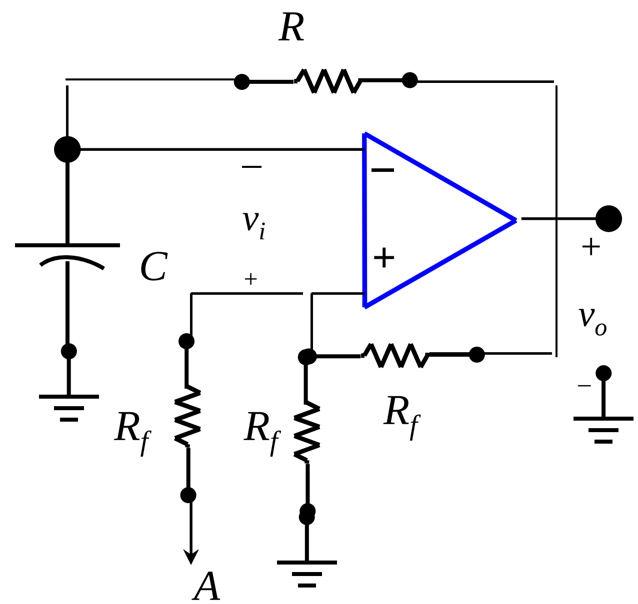


$$T = T_H + T_L = 3RC\ln(5)$$

$$f = \frac{1}{3RC\ln(5)}$$

Another Example

- Assume output levels are 0 and A
  1. What are the Thresholds
  2. Sketch v_c and vo
  3. Frequency of Oscillation



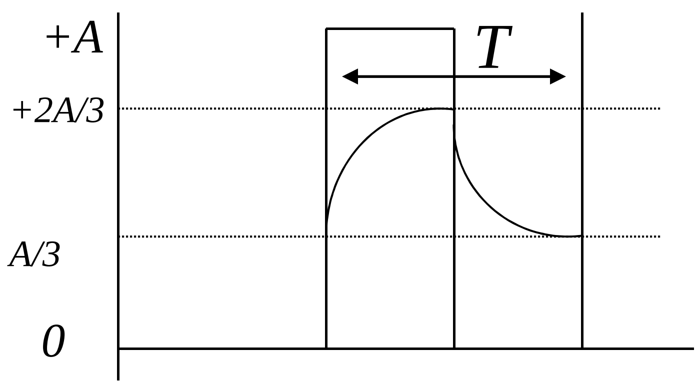
$$v_t = \frac{R_f \parallel R_f}{R_f + R_f \parallel R_f} A + \frac{R_f \parallel R_f}{R_f + R_f \parallel R_f} v_o$$

$$v_t = \frac{R_f/2}{R_f + R_f/2} A + \frac{R_f/2}{R_f + R_f/2} v_o$$

$$v_t = \frac{1}{3} A + \frac{1}{3} v_o$$

$$v_{t\,v_o=0} = \frac{1}{3} A$$

$$v_{t\,v_o=A} = \frac{2}{3} A$$



Frequency of Oscillation

For Charging to + A

$v_c(t) = K_1 + K_2 e^{-t/RC}$

Initial Condition :

$v_c(0) = \frac{A}{3} = K_1 + K_2$

Final Condition :

$v_c(\infty) = +A = K_1$

$K_2 = \frac{A}{3} - K_1 = -\frac{2}{3}A$

$v_c(t) = A(1 - \frac{2}{3}e^{-t/RC})$

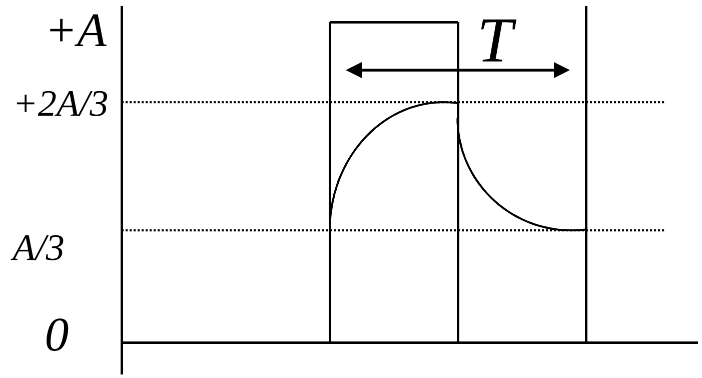
But

$v_c(\frac{T}{2}) = \frac{2A}{3} = A(1 - \frac{2}{3}e^{-T/2RC})$

$\therefore e^{-T/2RC} = \frac{1}{2}$

$T = 2RC\ln(2)$

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



Homework

- Astable Multivibrators
  - Problems: 12.14