Waveshaping 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 $\pm A$ and the thresholds are $\pm A/2$ since the feedback voltage = $1/2 v_o$.

\[ v_i = v_i - v_{in} \]
when $v_i > 0; v_o = A$; therefore,
\[ v_i = v_i - v_{in} > 0 \]

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

\[ v_i = v_i - v_{in} \]
when $v_i < 0; v_o = -A$; therefore,
\[ v_i = v_i - v_{in} < 0 \]

\[ v_t < v_{in}; \text{ or } v_{in} > -\frac{A}{2} \]
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.

BME 373 Electronics II – J.Schesser
**Timing Calculation**

\[ v_c(t) = K_1 + K_2 e^{-t/RC} \]

Initial Condition:

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

Final Condition:

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

From eqns (1) and (2)

\[ K_1 = A \]

\[ K_2 = -\frac{A}{2} - K_1 = -\frac{3}{2} A \]

\[ v_c(t) = A \left(1 - \frac{3}{2} e^{-t/RC}\right) \]

But

\[ v_c\left(\frac{T}{2}\right) = \frac{A}{2} = A \left(1 - \frac{3}{2} e^{-T/2RC}\right) \]

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

\[ T = 2RC \ln(3) \]
An Example

• Assume output levels are ± A

1. What are the thresholds?
   \[ \beta = \frac{2R_f}{(2R_f+R_f)} \Rightarrow \pm \frac{2}{3}A \]

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:

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

Final Condition:

$v_c(\infty) = +A = K_1 + K_2 e^{-\infty/RC} = K_1$ (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 $v_o$
  3. Frequency of Oscillation

\[
v_t = \frac{R_f \parallel R_f}{R_f + R_f \parallel R_f} A + \frac{R_f \parallel R_f}{R_f + R_f \parallel R_f} v_o
\]
\[
v_t = \frac{R_f/2}{R_f + R_f/2} A + \frac{R_f/2}{R_f + R_f/2} v_o
\]
\[
v_t = \frac{1}{3} A + \frac{1}{3} v_o
\]
\[
v_{t\text{,}v_o=0} = \frac{1}{3} A
\]
\[
v_{t\text{,}v_o=A} = \frac{2}{3} A
\]
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

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

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

$T = 2RC \ln(2)$

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

• Astable Multivibrators
  – Problems: 12.14