The basic oscillator circuit — Relaxation to a time varying target voltage

Consider the circuit,

\[ V_{out} = A (V_4 - V_2) \]

Since \( V_{out} \) is bounded by \( V_{supply} \), this means that

\[ V_{out} = \begin{cases} V_2 + V_{supply} & V_4 > V_2 \\ V_2 - V_{supply} & V_2 < V_4 \end{cases} \]

The voltage divider assumes that \( V_2 \) is composed to \( V_4 = \frac{R_2}{R_1 + R_2} V_{out} \)

\( V_2 \) will evolve in time according to:

\[ C \frac{dV_2}{dt} + \frac{V_2 - V_{out}}{R} = 0 \quad \therefore \quad C = RC \]

\[ \therefore \frac{dV_2}{dt} + \frac{1}{C} V_2 = \frac{1}{C} V_{out} \]

homogeneous solution \( \phi(t) = e^{-t/C} \)

\[ V(t) = V(0) e^{-t/C} + \int_0^t \left( \frac{1}{C} V_{out} \right) e^{-\frac{t-t'}{C}} dt' \]

treat \( V_{out} \) constant sine last transition
\[ V_c(t) = V(0) e^{-t/2} + \frac{1}{2} e^{-t/2} (e^{+t/2} - 1) \]

\[ V_\text{out} = V(0) e^{-t/2} + V_\text{supply} (1 - e^{-t/2}) \]

Let's start with \( V(0) = 0 \) and pick \( V_\text{out} = +V_\text{supply} \).

Then \( V(t) = +V_\text{supply} (1 - e^{-t/2}) \)

But when \( V_-(t) > V_+ = \frac{R_2}{R_1 + R_2} V_\text{supply} \)

the value of \( V_\text{out} \) will change to \( -V_\text{supply} \).

This occurs when

\[ V_\text{supply} (1 - e^{-t/2}) = \frac{R_2}{R_1 + R_2} V_\text{supply} \]

\[ e^{-t/2} = 1 - \frac{R_2}{R_1 + R_2} = \frac{R_1}{R_1 + R_2} \]

\[ t = \tau \log \left(1 + \frac{R_2}{R_1}\right) \] (\( \text{gives } t = \infty \))

The period is 4 times this, so

\[ T = \tau \log \left(1 + \frac{R_2}{R_1}\right) \]
Schmidt Trigger Notes

This is a "trip" to minimize hysteresis with comparators.

\[ V_{out} = \begin{cases} 0 & V_{in} > V_+ \\ V_p & V_{in} < V_+ \end{cases} \]

and KVL gives

\[ \frac{V_+-V_k}{R_1} + \frac{V_+}{R_2} + \frac{V_+ - V_{out}}{R_4} = 0 \]

Pull-up resistor \( R_3 \) is used in most comparators as output is an "open collector," so that user can define output voltage.

Pick \( V_p \) to equal \( V_R \frac{R_2}{R_1+R_2} \)
Case if $V_{out} = 0$

$$V_+ \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_4} \right) = \frac{VR}{R_1}$$

$$V_+ \left( \frac{R_1 + R_2}{R_1 R_2} \right) \left[ 1 + \frac{R_1 R_2}{R_1 + R_2} \frac{1}{R_4} \right] = \frac{VR}{K_1}$$

$$V_+ = VR \frac{R_2}{R_1 + R_2} \left[ \frac{1}{1 + \frac{R_1 R_2}{R_1 + R_2} \frac{1}{R_4}} \right] \frac{Vr}{K_1}$$

Denominator > 1, so $\left[ \right] < 1$

$V_+ < \frac{R_2}{R_1 + R_2} VR$ reduced threshold when output is "0"

Case if $V_{out} = V_p$

$$V_+ \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_4} \right) = \frac{VR + Vp}{R_1 + R_4}$$

$$V_+ = \frac{R_1 R_2}{R_1 + R_2} \left[ \frac{1}{1 + \frac{R_1 R_2}{R_1 + R_2} \frac{1}{R_4}} \right] \left( \frac{VR + Vp}{R_1 + R_4} \right)$$

$\leq 1$

$$V_+ = VR \frac{R_2}{R_1 + R_2} \left[ \frac{1}{1 + \frac{R_1 R_2}{R_1 + R_2} \frac{1}{R_4}} \right] \left[ 1 + \frac{R_1}{R_4} \frac{Vp}{VR} \right]$$

$\leq 1$

$\geq 1$

$\therefore$ We can have

$$V_+ \geq \frac{R_2}{R_1 + R_2} VR$$

Simple case as $R_1 = R_2, \quad R_4 = 10R_1, \quad VR = 2Vp$. 

$\frac{C_{input}}{C_{output}} = \frac{R_2}{R_1 + R_2}$
\[
\left[ 1 + \frac{R_1 R_2}{R_1 + R_2} V_K V_H \right] = \cdots = \frac{1}{1.05}
\]

\[
\left[ 1 + \frac{R_4}{R_4 + V_P} \right] = 0.00 = \frac{1}{1.05}
\]

The threshold voltage is:

\[
V_T^+ = \begin{cases} 
\frac{V_P}{2} \left( \frac{1}{1.05} \right) = \frac{V_P}{2} (0.95) & V_{out} (t=0^+) = 0 \\
\frac{V_P}{2} \left( \frac{1}{1.05} \times 1.05 \right) = \frac{V_P}{2} & V_{out} (t=0^-) = V_P
\end{cases}
\]

Diagram:

- Transition from 0 to \(V_P\) to \(0\) to \(V_P\) transition.
- Transition from \(0.95V_T^+\) to \(V_T^+\) transition.

Again, recall that for \(V_2 = V_{in} > V_T^+\) the output is "0."
Notes on "push-pull" circuit (B8)

This is a circuit with two emitter followers, one that uses a NPN transistor for \( I_B > 0 \) and one that uses a PNP transistor for \( I_B < 0 \).

\[ \begin{align*}
I_C & \quad I_E = 15 \mu A \\
I_E & = 10 \mu A \\
I_E & = 5 \mu A \\
I_E & = -5 \mu A \\
I_E & = -10 \mu A \\
I_E & = -15 \mu A \\
\end{align*} \]

\( V_{CE} \)

PNP

reverse biased

forward biased

NPN

The "push-pull" circuit allows you to source a large current to the load.