Multivibrators

Monostable multivibrator - provides a one-off pulse of predetermined pulse width $T_w$ when triggered by an input pulse with width $T_p \ll T_w$.

- provides a gaining pulse after a fixed delay.

Schmitt triggers and flip-flops have two stable states. If one state is suppressed, the circuit becomes a monostable multivibrator, with one stable state and one quasi-stable state (for time $T_w$ only). A single trigger signal is used as input to switch from the stable to the quasi-stable state. These are regenerative circuits - switching transitions are fast.

**Schmitt trigger monostable multivibrator**

Assume circuit is in stable state

$v_o = +V_m \quad v_+ = \frac{R_2}{R_1+R_2} V_m \quad v_- \approx 0.7 \, V$

Choose $R_1$, $R_2$ to ensure $\frac{R_2}{R_1+R_2} V_m > 0.7 \, V$

Now apply a pulse $v_p$ of |voltage| $> \frac{R_2}{R_1+R_2} V_m - 0.7$

Comparator switches to $-V_m$

Capacitor charges towards $-V_m$ (no current flows through $D_1$), until it reaches $v_+ = -\frac{R_2}{R_1+R_2} V_m$. At this point, the comparator switches back to $v_o = +V_m$, but $C$ only charges to $0.7 \, V$ because $D_1$ is now forward-biased.
During charging of \( C \) towards \( -V_m \),

\[
\begin{align*}
V_c &= -V_m - (V_m - 0.7) \exp\left(-\frac{t}{RC}\right) \\
-\frac{R_2}{R_1 + R_2} V_m &= -V_m + (V_m + 0.7) \exp\left(-\frac{t}{RC}\right) \\
\frac{R_1}{R_1 + R_2} V_m &= (V_m + 0.7) \exp\left(-\frac{t}{RC}\right) \\
-\frac{t}{RC} &= \ln\left(\frac{R_1 + R_2}{R_1} \cdot \frac{V_m + 0.7}{V_m}\right) \\
T &= RC \ln\left(\frac{R_1 + R_2}{R_1} \cdot \frac{V_m + 0.7}{V_m}\right)
\end{align*}
\]

\( T_p \) must be much smaller than \( T_w \). \( D_2 \) prevents spurious triggering in the case of any positive spikers in the trigger signal.

\( V_o \) can be used to gate other circuits, or generate a fast transition at a delay \( T_w \) after the trigger.

Note that once the circuit returns to its stable state, it requires a recovery time of \( T_p \), so that re-triggering can only occur after \( T + T_r \).

Can reduce \( T_r \) if \( R \) is replaced by:

\[ (R' < R) \]
Retriggerable monostable

\[ V_{cc} \]

\[ V_p = V_{cc} - \frac{R_2}{R_1 + R_2} V_{cc} \]

\[ V_o = -V_{cc} \]

Start by assuming JFET \( T_1 \) is off

\[ V_c = V_{cc} = V_p \]

\[ V_+ = \frac{R_1}{R_1 + R_2} V_{cc} \]

At \( t = 0 \) a positive pulse \( V_p \) turns on \( T_1 \), and discharges \( C \) (almost linearly)

Assuming \( T_p \ll T_w \), when \( V_c \) falls below \( \frac{R_2}{R_1 + R_2} V_{cc} \), \( V_o \) switches to \( +V_{cc} \)

\( V_c \) charges towards \( V_{cc} \) again, until it reaches \( \frac{R_2}{R_1 + R_2} V_{cc} \), \( V_o \) switches back to \( -V_{cc} \)

For \( T_p \ll T_w \),

\[ T_w = RC \ln \left( \frac{R_1 + R_2}{R_1} \right) + T_p \]

\[ V_c(t) \approx V_{cc} - \left( V_{cc} - 0 \right) \exp \left( -\frac{t}{RC} \right) \]

\[ V_c(T_w) \approx \frac{R_1}{R_1 + R_2} V_{cc} = V_{cc} - V_{cc} \exp \left( -\frac{T_w}{RC} \right) \]

\[ T_w \approx RC \ln \left( \frac{R_1 + R_2}{R_1} \right) + T_p \]

\( T_p \) needs to be long enough to allow \( C \) to discharge to 0; in practice this can still be much less than \( T_w \)

If a new trigger pulse appears at any time (less than or greater than \( T_w \)), \( C \) discharges to 0 and the output reverts to (or stays at \( +V_{cc} \)) → can be retrigged at any time.

If a new pulse appears at \( t' < T_w \), then the pulse width will be \( t' + T_w \).
Monostable based on logic gates

At $t=0$, $v_2$ is high ($V_{DD}$), $v_0$ is low (0 V), $v_p$ is low, so $v_1$ is high.

At $t>0$, $v_p$ goes high, so NOR output $v_1$ goes low. Since the voltage across $C$ cannot change instantaneously, $v_2$ starts low i.e. $v_0$ goes high.

As $C$ charges up, $v_0 = V_{DD} \left(1 - \exp\left(-\frac{t}{RC}\right)\right)$ and $v_2$ rises. When $v_2$ reaches the inverter threshold (typically $\frac{1}{2}V_{DD}$), the output $v_0$ switches back to low again. So $T_w = RC \ln\left(\frac{V_{DD}}{V_{DD} - V_{th}}\right)$, where $V_{th}$ is the inverter threshold.

$v_0 \rightarrow$ low causes $v_1$ to go high ($v_p$ is zero again, since $T_p \ll T$). Since $v_2$ is still at $V_{th}$, it overshoots to $V_{th} + V_{DD}$ before decaying back to $V_{DD}$.

Re-triggerable after $T_w$. 

![Diagram](image-url)