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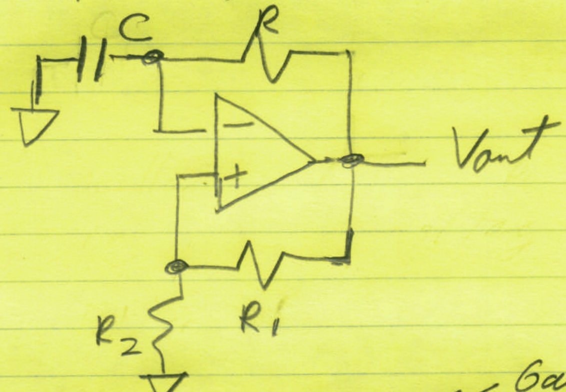
The basic oscillator circuit — Relaxation to a time varying target voltage

Consider the circuit:



We know at $V_{out} = A(V_+ - V_-)$ ← Gain, a big number

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

$$V_{out} = \begin{cases} +V_{supply} & V_+ > V_- \\ -V_{supply} & V_- < V_+ \end{cases}$$

The voltage divider assures that V_- is compared to $V_+ = \frac{R_2}{R_1+R_2} V_{out}$

V_- will evolve in time according to:

$$C\frac{dV_-}{dt} + \frac{V_- - V_{out}}{R} = 0 \qquad ; \ \tau \equiv RC$$

$$\therefore \underbrace{\frac{dV_-}{dt} + \frac{1}{\tau} V_-}_{} = \frac{1}{\tau} V_{out}$$

homogeneous eqn $\Phi(t) = e^{-t/\tau}$

$$V(t) = V(0)\, e^{-t/\tau} + \int_0^t \underbrace{\left(\frac{1}{\tau} V_{out}\right)}_{} e^{-(t-x)/\tau}\, dx$$

treat as constant since last transition

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$$V_-(t) = V_-(0)e^{-t/\tau} + \frac{1}{\tau}e^{-t/\tau}(\tau)(e^{t/\tau} - 1)$$

$$'' = V_-(0)\, e^{-t/\tau} + V_{out}(1 - e^{-t/\tau})$$

Lets start with $V_-(0) = 0$ and pick $V_{out} = +V_{supply}$.

Then $V_-(t) = +V_{supply}(1 - e^{-t/\tau})$

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

the value of V_{out} will change to $-V_{supply}$.

This occurs when

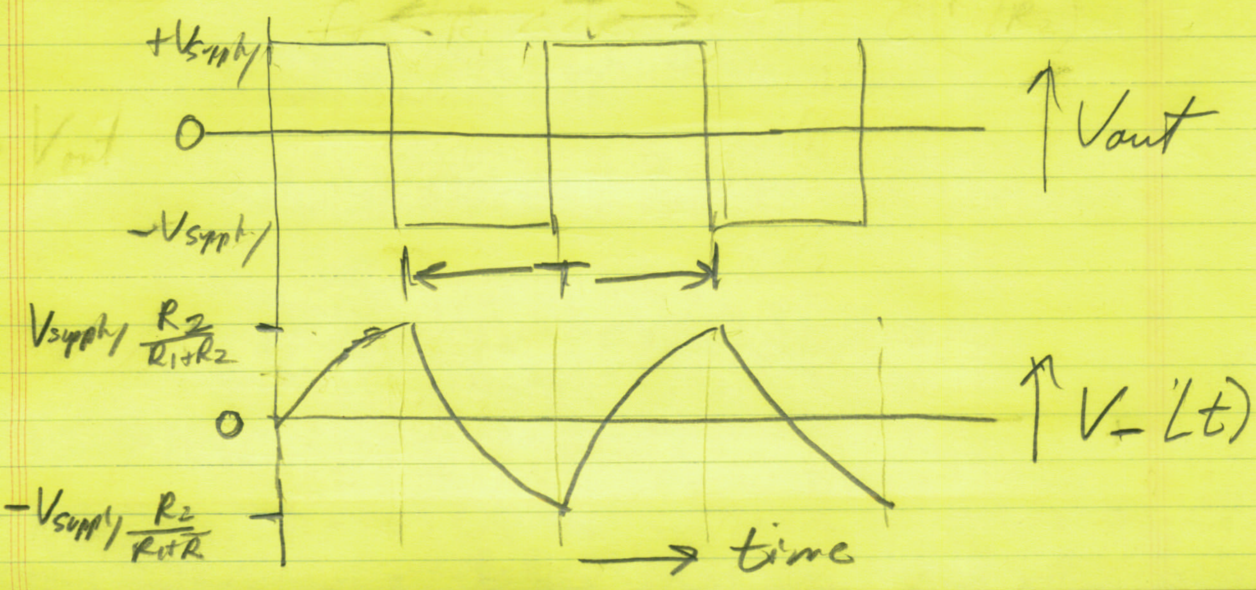
$$V_{supply}(1 - e^{-t/\tau}) = \frac{R_2}{R_1+R_2} V_{supply}$$

$$e^{-t/\tau} = 1 - \frac{R_2}{R_1+R_2} = \frac{R_1}{R_1+R_2}$$

$$t = \tau \log(1 + R_2/R_1) \qquad \left(\begin{array}{l}\text{check, } R_2 \to \infty \\ \text{gives } t \to \infty\end{array}\right)$$

The period is 4 times this, so.

$$T = \tau \log(1 + R_2/R_1)$$



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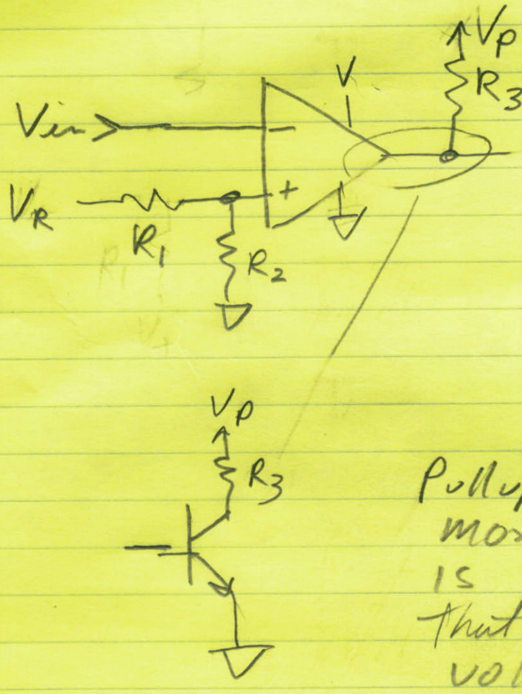
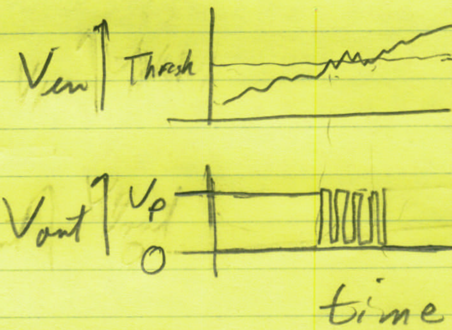
Schmidt Trigger Notes

This is a "trip" to minimize hysteresis with comparitor

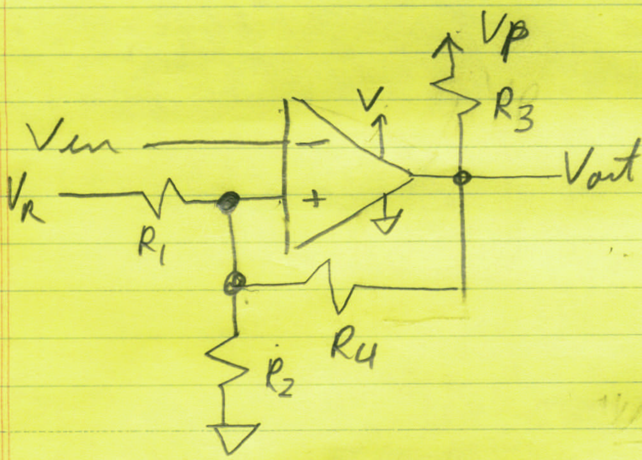




$V_+ = V_R \frac{R_2}{R_1+R_2}$

$V_- > V_+$ give V_{out} = "0"

Pullup 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 $V_R \frac{R_2}{R_1+R_2}$

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

and KVL gives

$$\frac{V_+ - V_R}{R_1} + \frac{V_+}{R_2} + \frac{V_+ - V_{out}}{R_4} = 0$$

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Case of $V_{out} = 0$

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

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

$$V_+ = V_R \frac{R_2}{R_1+R_2}\left[\frac{1}{\underbrace{1 + \frac{R_1 R_2}{R_1+R_2}(1/R_4)}_{\text{denominator} > 1,\ \text{so } [\ ] < 1}}\right] V_R$$

$$\therefore V_+ < \frac{R_2}{R_1+R_2} V_R$$ reduced Threshold when output is "0"

Case of $V_{out} = V_P$ (assume to be V_P!)

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

$$V_+ = \frac{R_1 R_2}{R_1+R_2}\underbrace{\left[\frac{1}{1 + \frac{R_1 R_2}{R_1+R_2}\frac{1}{R_4}}\right]}_{<1}\left(\frac{V_R}{R_1} + \frac{V_P}{R_4}\right)$$

$$V_+ = V_R \frac{R_2}{R_1+R_2}\underbrace{\left[\frac{1}{1 + \frac{R_1 R_2}{R_1+R_2}\frac{1}{R_4}}\right]}_{<1}\underbrace{\left[1 + \frac{R_1}{R_4}\frac{V_P}{V_R}\right]}_{>1}$$

$\therefore$ We can have

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

Simple case is $R_1 = R_2$; $R_4 = 10 R_1$, $V_R = 2 V_P$.

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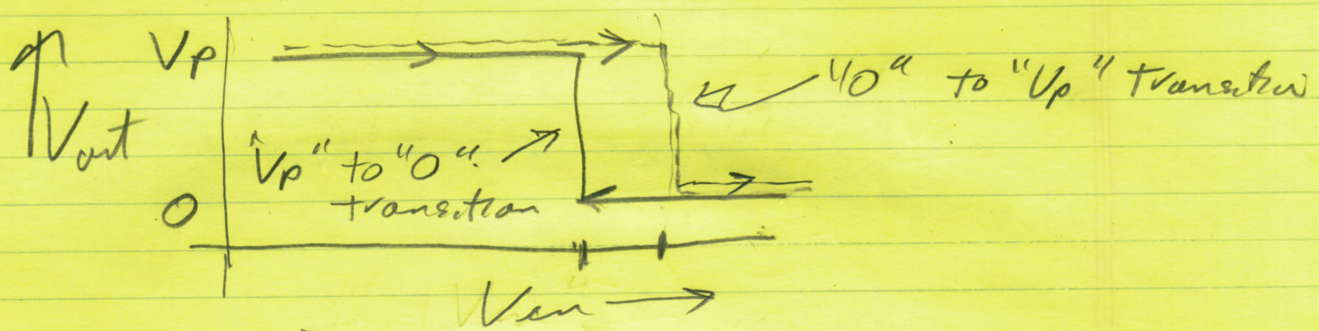
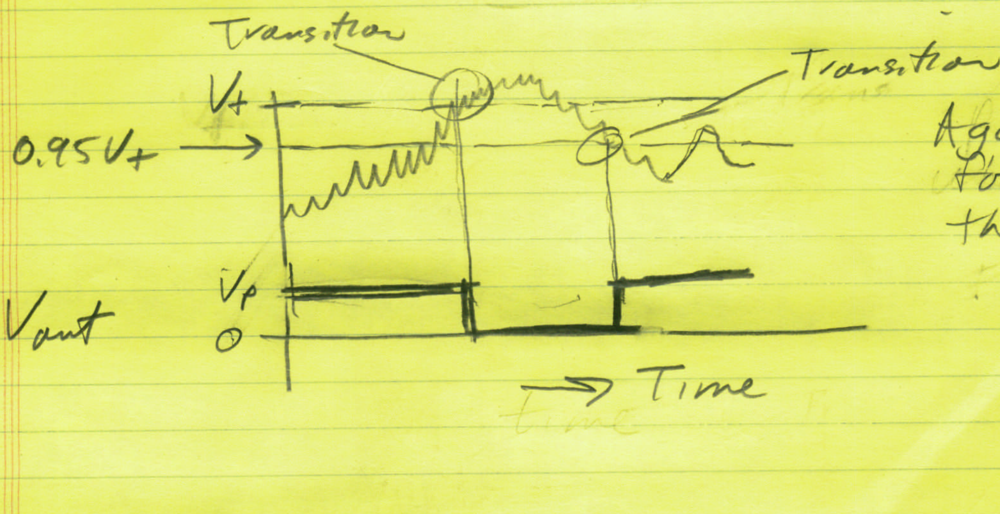
$$\left[\frac{1}{1+\frac{R_1R_2}{R_1+R_2}\,{}^{1}/_{R_4}}\right] = \cdots = \frac{1}{1.05}$$

$$\left[1+\frac{R_1}{R_4}\,\frac{V_p}{V_R}\right] = \cdots = 1.05$$

∴ The threshold voltage is

$$V_+ = \begin{cases} \frac{V_p}{2}\cdot\frac{1}{1.05} = \frac{V_p}{2}(0.95); & V_{out}(t=0^-)=0 \\ \frac{V_p}{2}\,\frac{1}{1.05}\times 1.05 = \frac{V_p}{2}; & V_{out}(t=0^-)=V_p \end{cases}$$

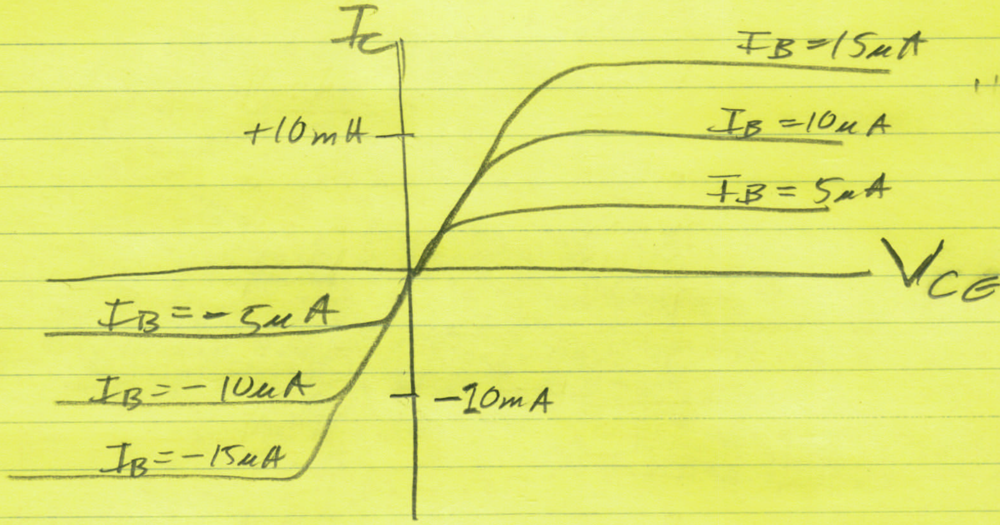


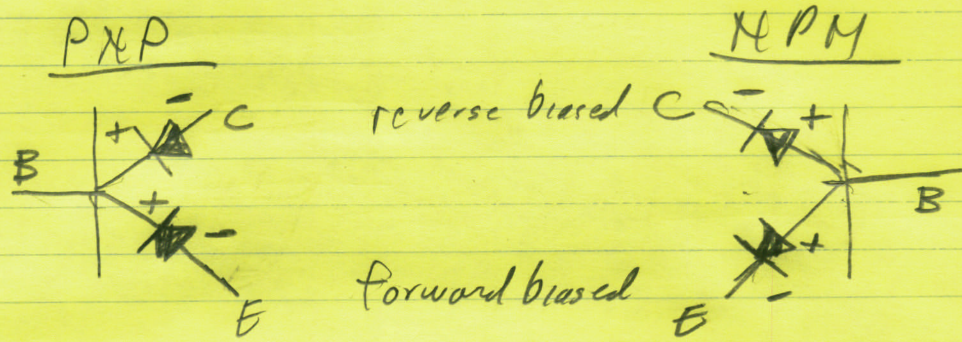


Again, recall that for $V_- = V_{in} > V_+$ the output is "0"

Notes on "push-pull" circuit. (8.8)

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 $I_B < 0$.





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