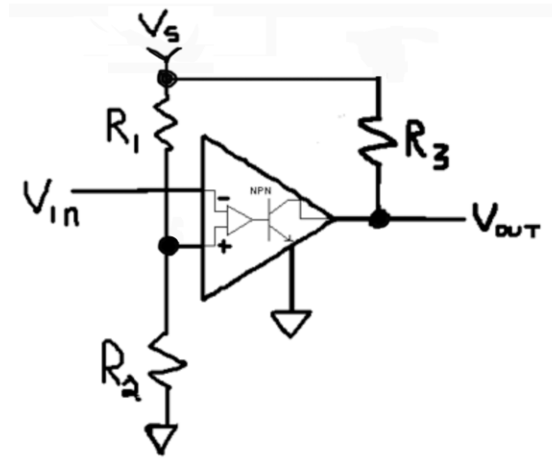
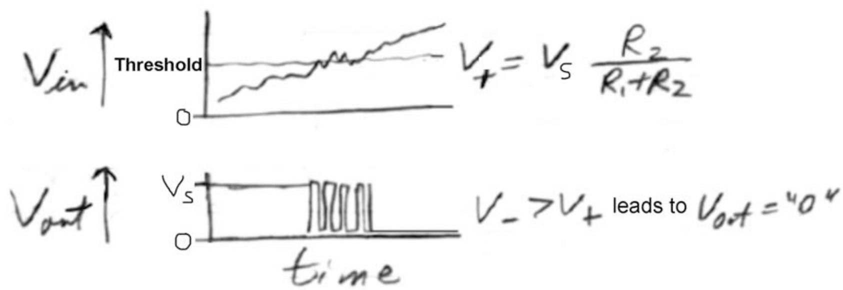
Notes on Schmidt Trigger

Physics 120, David Kleinfeld, Spring 2017

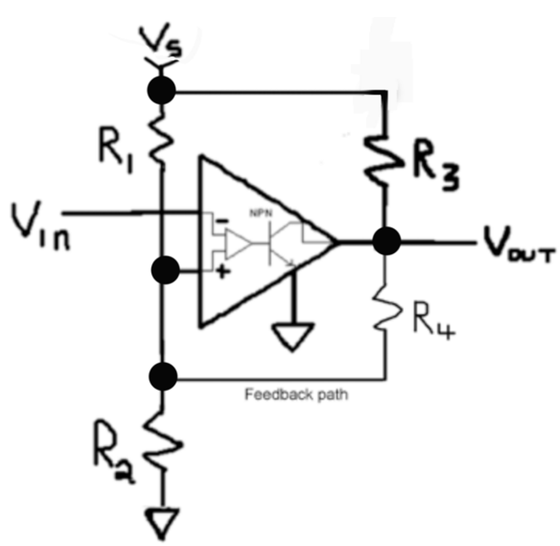
This circuit uses feedback to minimize the effect of noise on a threshold transition. It involves hysteresis (shown below), in terms of a higher level for the up than down transition, with the output from the comparator. First, the case without feedback:



where the threshold is $V_+ \approx \frac{R_2}{R_1+R_2} V_s$.



Let's now add a feedback resistor, R_4, so that the threshold will depends on the value of the output, V_{out}.



K V L gives $\frac{V_+ - V_R}{R_1} + \frac{V_+}{R_2} + \frac{V_+ - V_{out}}{R_4} = 0$

Case of $V_{out} = 0$

The NPN output transistor acts as a short, so K V L gives

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

so

$$V_+ = \frac{R_4 R_2}{R_2 R_1 + R_4 R_1 + R_4 R_2} V_s$$

Usually R_4 is chosen to be large (the fed back current is small) so that, to order $(1/R_4)$,

$$V_+ \approx \frac{R_2}{R_1 + R_2}\left[1 - \frac{R_1}{R_4}\frac{R_2}{R_1 + R_2}\right] V_s$$

and we see that the feedback lowers the lower threshold relative to the case without feedback.

Case of $V_{out} \neq 0$

The NPN output transistor acts as an open circuit, so K V L gives

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

and

$$\frac{V_{out} - V_S}{R_3} + \frac{V_{out} - V_+}{R_4} = 0$$

This leads to a morass of algebra

$$V_+ = \left(\frac{R_2 R_4 (2R_1 + R_4)}{(R_4 R_2 + R_1 R_4 + R_1 R_2)(R_1 + R_4) - R_1 R_2 R_3}\right) V_S$$

that simplifies when R_4 is large and becomes:

$$V_+ \approx \frac{R_2}{R_1 + R_2}\left[1 + \frac{R_1}{R_4}\right] V_S$$

and we see that the feedback raises the upper threshold relative to the case without feedback.

- When the value of the input heads from high to low, the "0" to "V_s" transition causes an increase in threshold that adds hysteresis and prevents jitter.

- When the value of the input heads from low to high, the "V_P" to "0" transition causes a decrease in threshold that adds hysteresis and prevents jitter.

Example

A simple but useful case is $R_1 = R_2;\ R_4 = 10R_1$

$\therefore$ the threshold voltages are:

$$V_+ = \begin{cases} \frac{V_S}{2}\left(1 - \frac{1}{10}\right) \approx\ 0.45\,V_S;\ \ V_{out}(t = 0^-) = 0 \\ \frac{V_S}{2}\left(1 + \frac{1}{10}\right) \approx\ \ 0.55\,V_S\,;\ V_{out}(t = 0^-) \approx 1.05\,V_S \end{cases}$$