EXAMPLES OF FEEDBACK

Today we will

- Look at an example of negative feedback: a single transistor circuit with source resistance
- Look at an example of positive feedback: Schmitt trigger

NEGATIVE AND POSITIVE FEEDBACK

A circuit exhibits **feedback** when the circuit input is affected by the value of the circuit output.

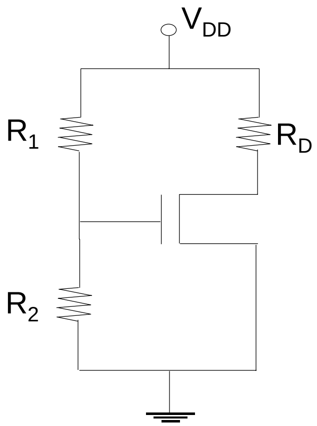
Suppose some disturbance occurs in a circuit, changing the value of the output.

If the circuit has **negative feedback**, the change in output adjusts the value of the input so as to bring the circuit back closer to its original state.

If the circuit has **positive feedback**, the change in output adjusts the value of the input so as to make an even bigger change in the output. This continues until the circuit reaches a new stable state.

EXAMPLE OF NEGATIVE FEEDBACK

Consider our usual transistor circuit, being used as a constant current source supplying the resistor R_D.



Problem: The transistor curves are greatly affected by changes in temperature.

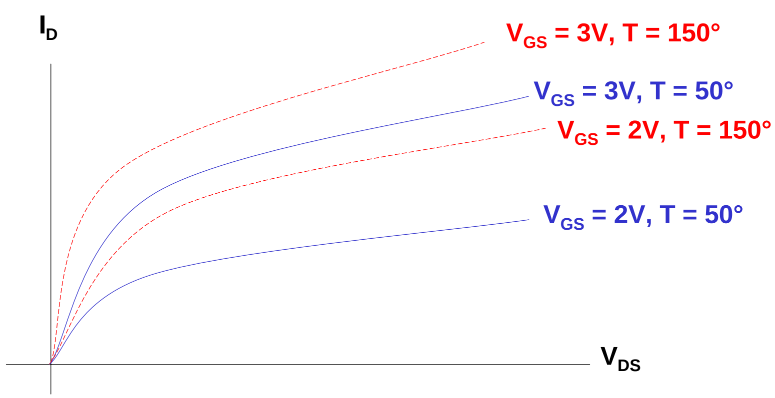
The relatively constant I_{DSAT} supplied to R_D increases as the circuit operates and heats up.

This makes the current supplied by this constant current source unpredictable. Increased I_{DSAT} could put the transistor in triode mode.

EXAMPLE OF NEGATIVE FEEDBACK

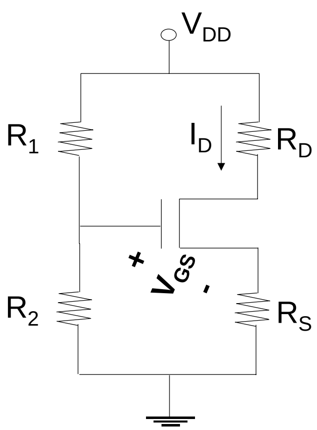
When temperature rises, electron mobility μ increases (generally).

So, the I_D vs. V_{DS} curves get higher with heat.



EXAMPLE OF NEGATIVE FEEDBACK

Solution: Add a feedback resistor R_S.



$$V_{GS} = V_{DD}\frac{R_2}{R_1 + R_2} - I_D R_S$$

If I_D increases (e. g. due to heat), V_{GS} decreases.

This brings I_D back down a little.

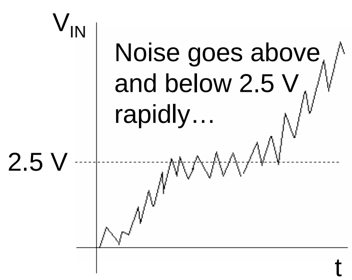
Small adjustments continue until an equilibrium is reached.

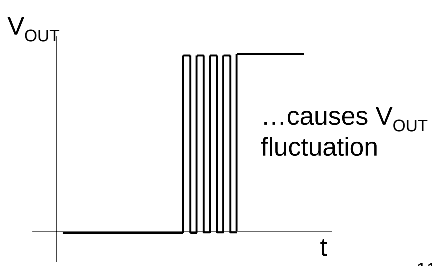
The final value of I_D will be closer to the original "cold" value than it would be without feedback.

POSITIVE FEEDBACK: SCHMITT TRIGGER

We used a comparator to "sharpen" a signal; to convert input voltages to either logic 1 (high rail) or logic 0 (low rail) depending on whether input is higher or lower than threshold.

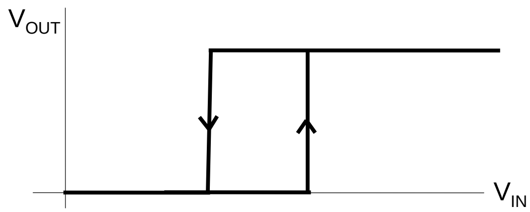
What if the signal had a high-frequency noise component?



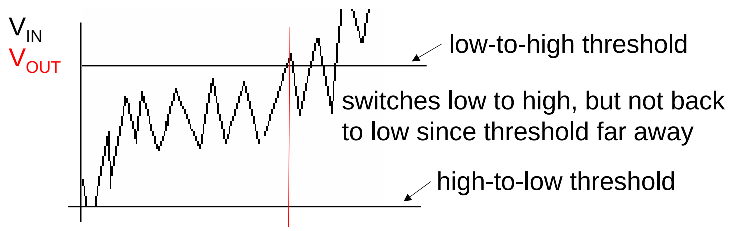


POSITIVE FEEDBACK: SCHMITT TRIGGER

A Schmitt trigger has a higher low-to-high threshold than high-to-low:

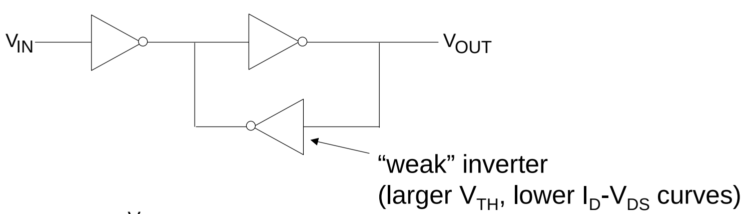


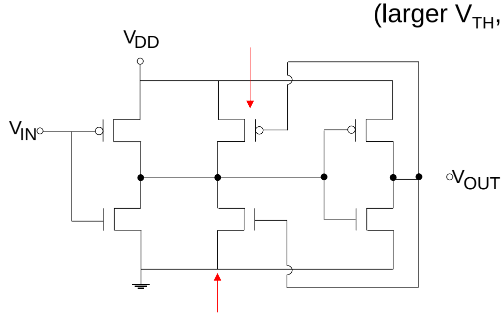
Now consider that noisy signal, sharpened with Schmitt trigger:



Reduces fluctuations.

SCHMITT TRIGGER CIRCUIT

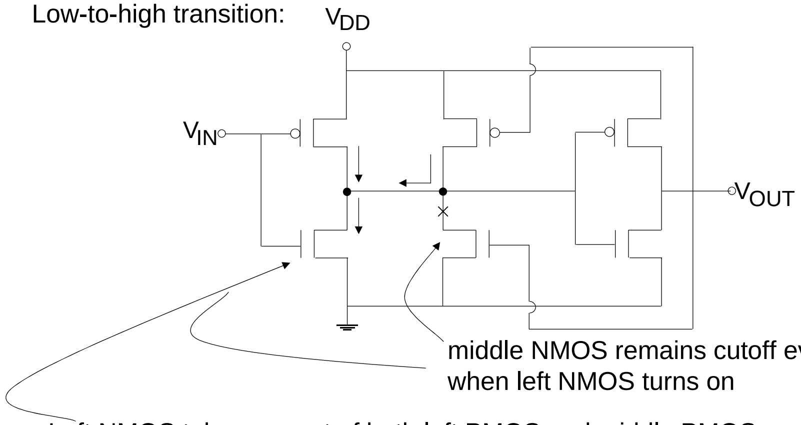




middle transistors have higher threshold magnitude, shallower I_D vs V_{DS} curves

SCHMITT TRIGGER CIRCUIT

Low-to-high transition:



middle NMOS remains cutoff even when left NMOS turns on

Left NMOS takes current of both left PMOS and middle PMOS

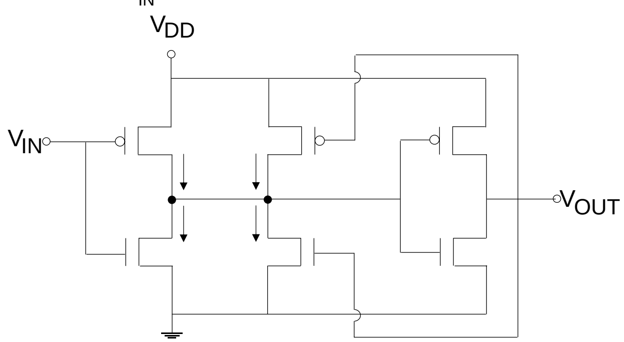
Left NMOS I_D is higher than in normal unloaded inverter (for given V_{IN})

Left NMOS V_{DS} is higher than in normal unloaded inverter (for given V_{IN})

V_{DS} remains higher longer $\Rightarrow$ **transitions later**

SCHMITT TRIGGER CIRCUIT

Now we reach the V_{IN} value that turns on the middle NMOS…



Now middle NMOS can accept current; less current remains for left NMOS.
I_D in left NMOS decreases. V_{DS} on left NMOS decreases.
V_{OUT}, the inverse of V_{DS}, increases. V_{GS} on middle NMOS increases.
I_D in middle NMOS increases. I_D in left NMOS decreases.

Chain reaction causes rapid transition. The transition region is **unstable**.
When we start up, we are pushed up all the way by positive feedback!