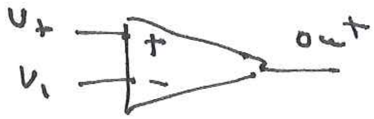
Digital meets Analog: Comparator (311)

Digital: 0 & 1

Analog: voltages that are any real number.

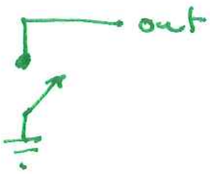


if $V_+ > V_-$ then out = High

if $V_+ < V_-$ then out = Low

Note: like all the chips we've been using comparator requires power connects (which we often don't bother to show in our diagrams) — often ±15 V

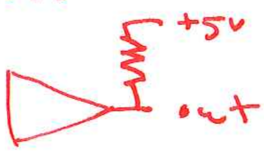
Note: the 311 (and many comparators) is an open collector device — meaning its "output" is effectively either a connection to ground or a disconnect



"High" above means a disconnect

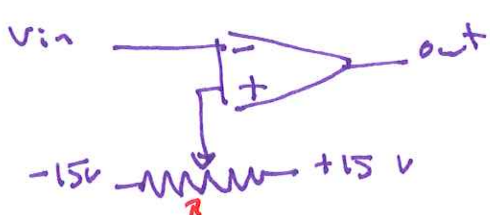
"Low" means a closed switch to ground

In typical usage we would need a "pull up" resistor connected to the output

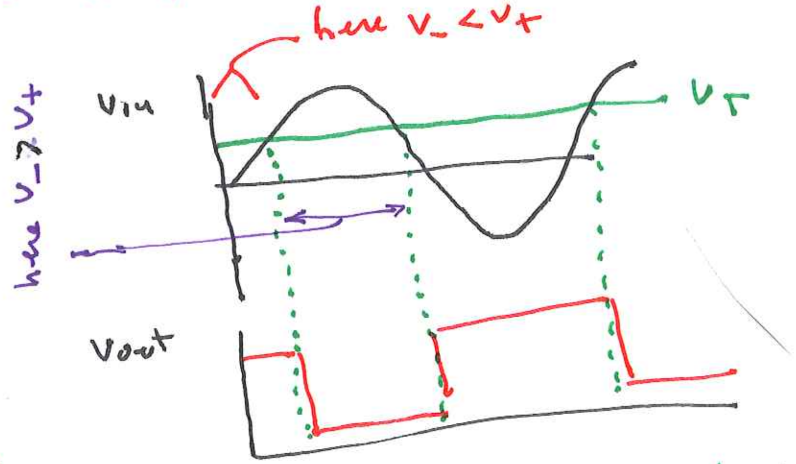


Often I will ignore this also in diagrams and pretend 311 output is +5V or 0 V

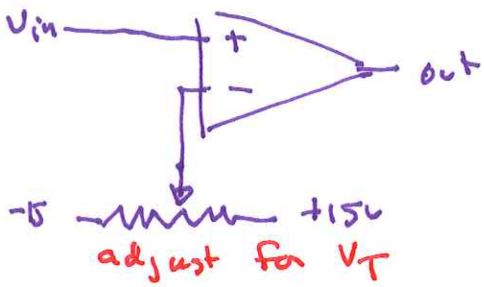
Basic Circuits

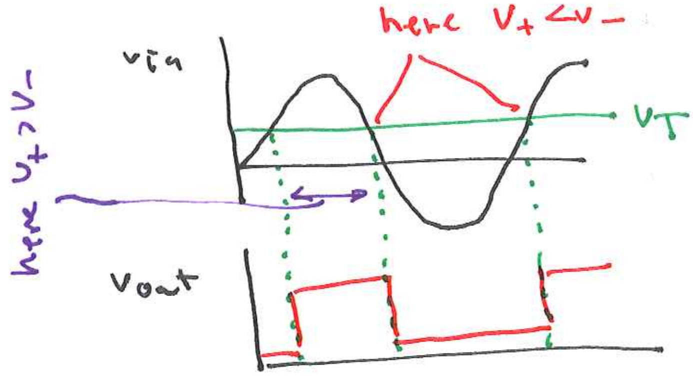


adjust pot for desired transition voltage = V_+

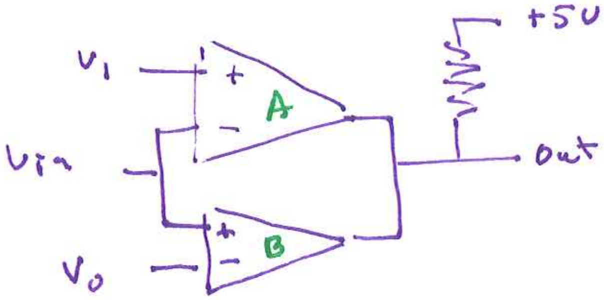


note: inversion: Vout high where Vin below V_T





"window" circuit: if $V_0 < V_{in} < V_1$ then out = High
otherwise out = Low



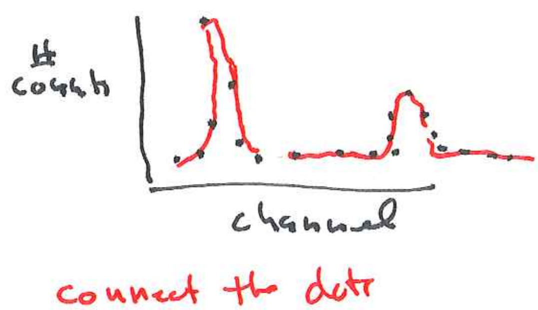
if $V_{in} > V_1$ then A output to GND

if $V_{in} < V_0$ then B output to GND

Note: if either output connected to ground output IS GND

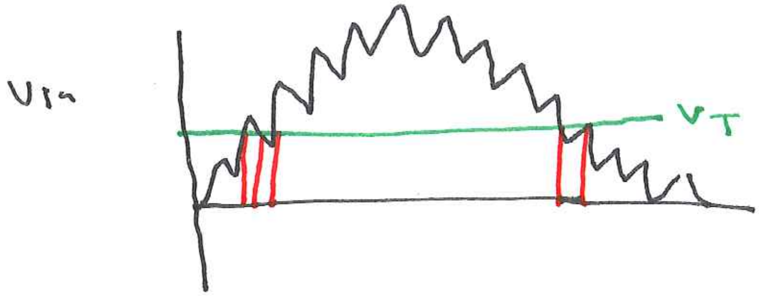
if $V_0 < V_{in} < V_1$ then A output unconnected, B output unconnect } result High

Note: "Multi Channel Analyzer" MCA: a stack of such window circuits such that exactly one window will be satisfied by any signal with outputs connected to counters — count the # pulses in each window display result as graph:



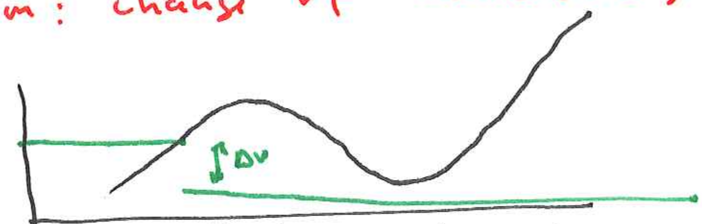
often channel # relates to some physical quantity (like photon energy) and the result is called a spectrum.

Important Problem (and its solution) — analog signals usually come with "noise" — random variations



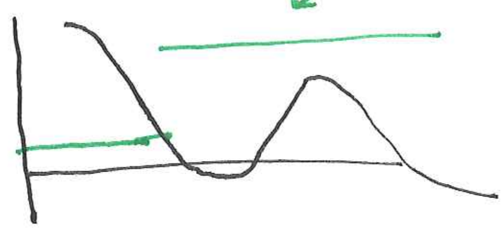
Noise results in multiple transitions whereas "real" signal has just one.

Solution: change V_T immediately following a transition



magnified view of noise (change of "sec/div")

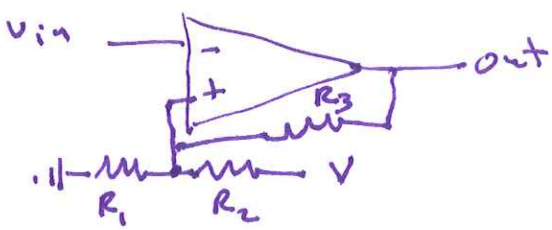
transition voltage level changes and changes back



Circuit analysis based on basic voltage divider eq:

$$V_{out} = \frac{R_1}{R_1 + R_2} V$$

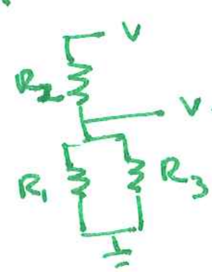
Note: this very important equation assumes V_{out} draws a small fraction of the current flowing thru R_1 & R_2 — ie we assume R_1 & R_2 face exactly the same current



Notation: $R_x \| R_y$ refers to parallel combo of R_x & R_y ie

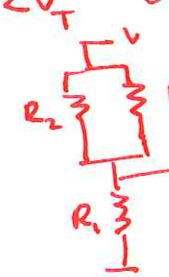
$$R_x \| R_y = \frac{R_x R_y}{R_x + R_y}$$

if $V_{in} > V_T$ out is Low & circuit is:



$$V_T = \frac{R_1 \| R_3}{R_2 + R_1 \| R_3}$$

if $V_{in} < V_T$ out is High & circuit is



$$V_T = \frac{R_1}{R_1 + R_2 \| R_3}$$

Some algebra:

$$V_T = \frac{R_1 \| R_3}{R_2 + R_1 \| R_3} = \frac{\frac{R_1 R_3}{R_1 + R_3}}{R_2 + \frac{R_1 R_3}{R_1 + R_2}} = \frac{R_1 R_3}{R_2 R_1 + R_2 R_3 + R_1 R_3}$$

$$V_+ = \frac{R_1}{R_1 + R_2 \| R_3} = \frac{R_1}{R_1 + \frac{R_2 R_3}{R_2 + R_3}} = \frac{R_1 (R_2 + R_3)}{R_1 R_2 + R_1 R_3 + R_2 R_3}$$

(−)

$$\Delta V = V_+ - V_T = \frac{R_1 R_2}{R_1 R_2 + R_1 R_3 + R_2 R_3} = \frac{R_1 R_2 / R_1 + R_2}{\frac{R_1 R_2}{R_1 + R_3} + R_3}$$

$$= \frac{R_1 \| R_2}{R_1 \| R_2 + R_3}$$

Remark: the current value of V_T depends on the history of the circuit "hysteresis"

graph of V_T vs V_{in}:

symbol for hysteresis input

Design: the basic V_T is set by voltage divider

$$\frac{R_1}{R_2 + R_1} V = \frac{R_1 \| R_2}{R_2} V, \quad \text{so} \quad R_2 + V_T \rightarrow R_1 \| R_2$$

ΔV & $R_1 \| R_2 \rightarrow R_3$

R_2 & $R_1 \| R_2 \rightarrow R_1$