Summary so far --

"small signal" "linear" applications of op amp.

We assumed it is ideal

Negative feedback

Virtual short-circuit applies.

Guru OA-D Sec. 11.18 only.

Today:

"Large signal" and "positive feedback" applications of op-amp.

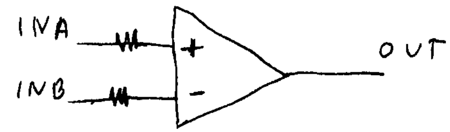
Not ideal.

Positive feedback

Can't use virtual-short-circuit (Nullor) model,

(but still, $I_{in}=0$)

Comparitor



OUT is positive when INA > INB

negative when INA < INB

unknown when INA ≈ INB

Uses: Analog to digital conversion
digital buffers
relay drivers.

Resistors limit current, I = 0 should still apply, but doesn't always

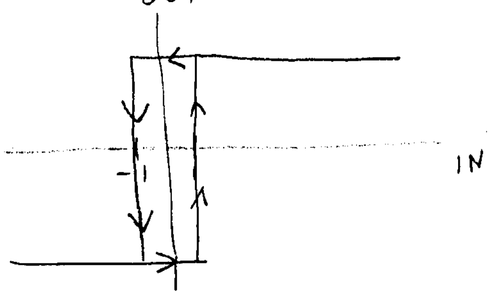
Typical value ≈ 10K — not critical.

Schmitt Trigger

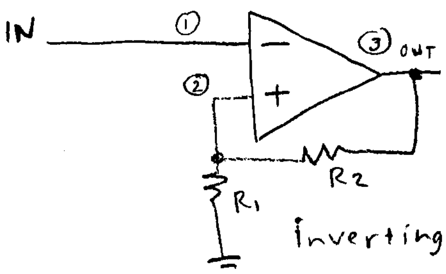
We want a window, where it doesn't change.
"hysteresis".

Example: IN > 1 volt → HIGH
IN < −1 volt → LOW

−1 < IN < 1 → maintain state.
initially unknown

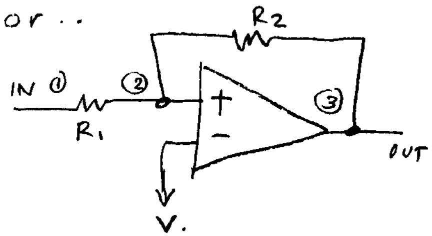


How? — Positive feedback



inverting

or . .



Non-inverting

Analysis of schmitt trigger

Inverting: $V_3 = \begin{cases} +14 & \text{in high state} \\ -14 & \text{in low state} \end{cases}$

↑ depends on power supply

Assume V_3 ...

then $V_2 = V_3 \dfrac{R_1}{R_1 + R_2}$

When output is high ...

when $V_1 < V_2$ — will remain high
$V_1 > V_2$ — will change state. (go low)

When output is low ...

when $V_1 > V_2$ — will remain low
$V_1 < V_2$ — will change state (go high)

— almost like comparator —
but V2 changes.

Example -- Suppose $R_1 = R_2 = 10K$

$V_{power} = \pm 15$

$$V_3 = \begin{cases} +14 & \text{in high state} \\ -14 & \text{in low state} \end{cases}$$

Must analyze in each state:

High state: $V_3 = 14 \Rightarrow V_2 = 7$

When $V_1 < 7$ — output remains high

$V_1 > 7$ — changes state (becomes low)

Low state: $V_3 = -14 \Rightarrow V_2 = -7$

When $V_1 > -7$ — output remains low

$V_1 < -7$ — changes state (becomes high).

so ---

IN	OUT
> 7	LOW
-7 to 7	hold state.
< -7	HIGH

Designing it —

we want threshold ± 1 V. →

IN	OUT
> 1	LOW
-1 to 1	hold.
< -1	HIGH

power = ± 12V

out = ± 11 V.

$$V_2 = V_3 \frac{R_1}{R_1+R_2}$$

$$1 = 11 \frac{R_1}{R_1+R_2}$$

$$\frac{R_1}{R_1+R_2} = \frac{1}{11} \rightarrow \frac{10K}{110K}$$

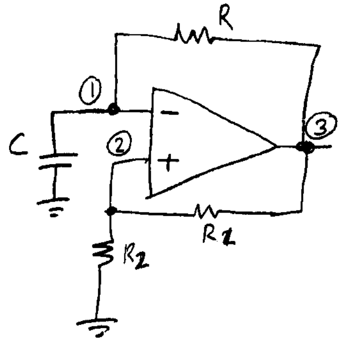
$R_1 = 10K$

$R_2 = 100K$

Waveform generation

By adding an R-C network to the Schmitt trigger, we can make an oscillator.

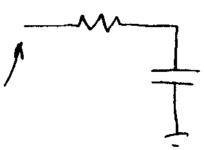
This one is called "relaxation oscillator"

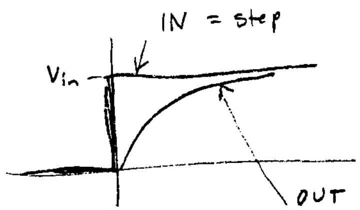


Positive feedback (③ to ②) makes it change state quickly, and hold it.

Negative feed back (③ to ①) determines timing.

Recall.... RC Network





$$\text{Out} = V_{in}\left(1 - e^{-\frac{t}{RC}}\right)$$

t	OUT (for $V_{in}=1$)
0	0
RC	.632
2RC	.864

$$T = 2RC \ln\left(1 + 2\frac{R_2}{R_1}\right)$$

Example: Let $R_2 = R_1$

then $\ln\left(1 + 2\frac{R_2}{R_1}\right) = \ln(3) = 1.1$

$T = 2.2\ RC$

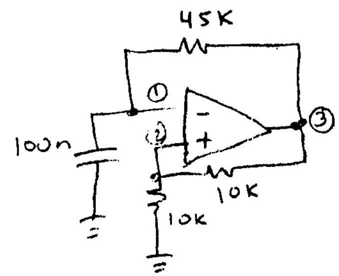
For 100 Hz, $T = .01$

Choose $C = 100\text{nf}$

Then $.01 = (2.2)(10^{-7})(R)$

$R = 4.5 \times 10^4$

$= 45\text{K}$



Waveforms: