Lecture 8 - Op Amps

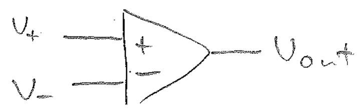
Finished now with individual components

Usually more convenient to work with integrated circuits

Example: operational amplifier

General purpose tool for analog circuits

Symbol:



Function: high gain differential amplifier

$$V_{out} = G(V_+ - V_-)$$

$$G \sim 10^5$$

- Z_{in} very high, 10 MΩ or more
- Z_{out} low, few Ω or less

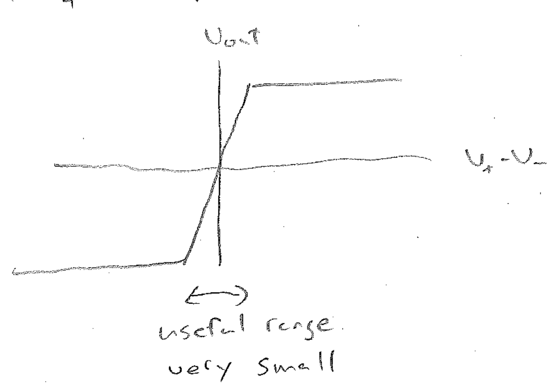
Constructed from transistors, resistors, capacitors, all integrated on single silicon wafer.

Fairly complicated design

Note that G is very large: too big for practical use:

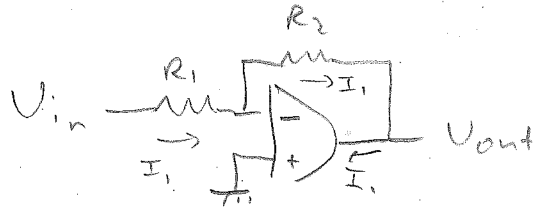
Output range limited by supply voltages, typically ± 15V

So if $|G(V_+ - V_-)| > 15V$, output is saturated,



Instead, always use external components to limit gain

Example:



Here $V_+ = 0 \Rightarrow V_{out} = -GV_-$

If $V_- > 0$, $V_{out} \ll 0$ ... pulls V_- down

If $V_- < 0$, $V_{out} \gg 0$ ... pulls V_- up

Only stable when $V_- \approx 0$

Not exactly, need some nonzero V_- to have $V_{out} \neq 0$. But $|V_-|$ very small.

Given $V_- \approx 0$, have current $I_1 = \frac{V_{in}}{R_1}$

But current doesn't flow into input: Z_{in} is very high.

Instead, flows through R_2

Then must have $V_{out} = V_- - I_1 R_2 = 0 - \frac{V_{in}}{R_1} R_2$

$$V_{out} = -\frac{R_2}{R_1} V_{in}$$

This is output value op amp requires in order to keep V_- close to zero

Note that current now flows in to output of op amp

Output terminal can sink or source current as needed.

Called inverting amplifier

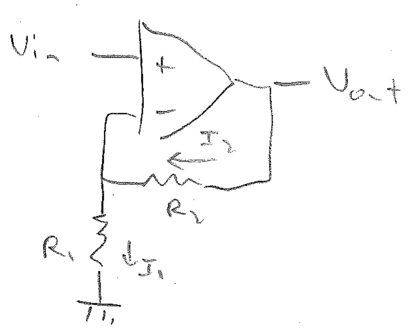
Get simple, linear gain. Value set by resistors as desired

Key to operation is negative feedback:
circuit path from output back to V_- terminal.

When operated with negative feedback, analyze circuits with "Golden Rules":

1) No current flows into inputs of op amp
2) Voltage at two inputs are equal

Another example:



Have $V_- = V_+ = V_{in}$ (rule 2)

$I_1 = I_2$ (rule 1)

Also have $V_- = V_{OUT} \cdot \frac{R_1}{R_1+R_2}$
(voltage divider)

So $V_{in} = V_{out} \frac{R_1}{R_1+R_2}$

$$V_{out} = V_{in} \frac{R_1+R_2}{R_1} = V_{in}\left(1+\frac{R_2}{R_1}\right)$$

Call this a non-inverting amplifier

<u>Many</u> other applications
See some in lab

In general, when faced with a problem in analog electronics,
look to op amp for solution

Here analog = continuously variable signals
vs digital: signals at discrete levels

Next four labs focus on analog electronics,
digital after that.