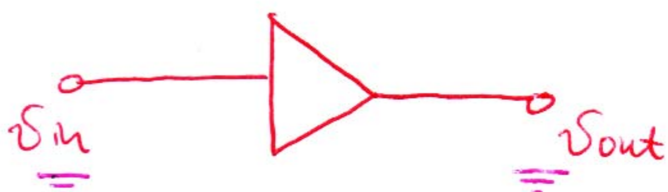
Lecture 4

Amplifiers

- another basic building block (anolog)
- inside quite complex (many transistors, etc.) but operationally simple; use like another element similar to R, L, C, etc.

- many applications
  - boost power in a signal
  - active filters with complex freq. response

Symbol



Characteristics

1. Gain

$G = \frac{v_{out}}{v_{in}}$ voltage gain ; other gain types e.g. current may be equally important

decibels $G_{dB} = 10 \log_{10} \frac{P_{out}}{P_{in}}$

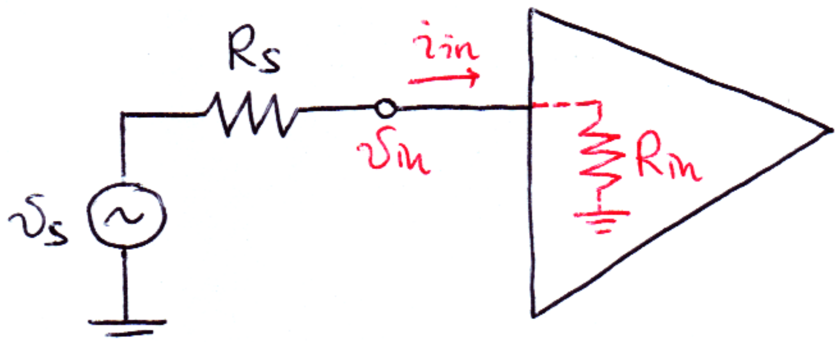
Since $P \propto V^2 \Rightarrow dB = 20 \log_{10} \frac{V_{out}}{V_{in}}$

$$G_{dB} = 20 \log_{10} \left(\frac{V_{out}}{V_{in}} \right) = 20 \log_{10} G$$

Q: why dB? A: add gain in dB for successive stages

$G = v_{out} / v_{in}$	G_{dB}
1	0 dB
$\sqrt{2}$	+3 dB
2	+6 dB
10	+20 dB
$\frac{1}{10}$	−20 dB

2 Input resistance (impedance)



$$R_{in} = \frac{v_{in}}{i_{in}} \; (= \text{const})$$

Q: what input impedance is ideal? A: depends.

If maximizing power transfer: $P_{in} = v_{in} \cdot i_{in}$

$$i_{in} = \frac{v_s}{R_s + R_{in}} \; ; \quad v_{in} = R_{in} \cdot i_{in} \Rightarrow P_{in} = v_s^2 \frac{R_{in}}{(R_s + R_{in})^2}$$

$P_{in} (R_{in} = 0) \rightarrow 0$

$P_{in} (R_{in} \rightarrow \infty) \rightarrow 0$

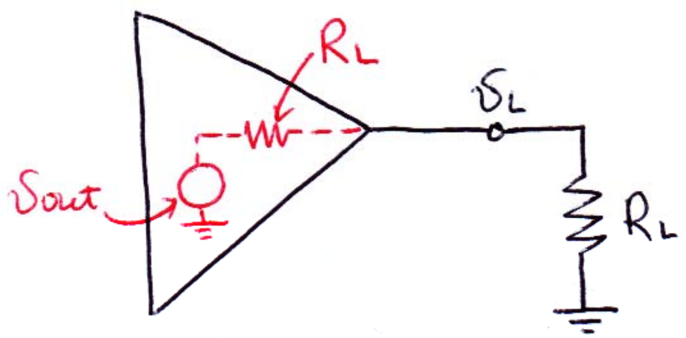
P_{in} is max when $\underline{R_{in} = R_s}$

If maximizing input current: $R_{in} = 0$ (P_s is max) ③

If maximizing input voltage: $R_{in} \to \infty$ ($P_s \sim 0$)

R_{in} = large is most common for amplifiers of small signals

③ Output impedance (resistance)



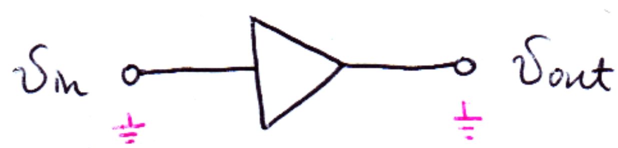
$$v_L = v_{out} \frac{R_L}{R_L + R_{out}}$$

if $R_{out} \ll R_L$, $\Rightarrow v_L \approx v_{out}$

Need R_{out} = small when driving large power loads

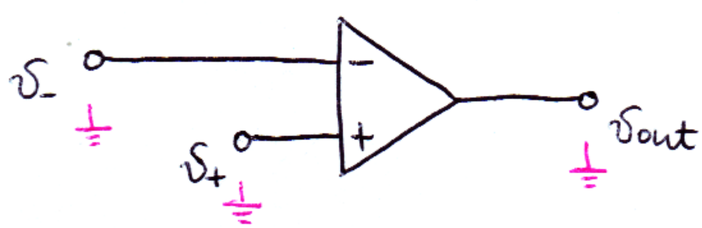
Input types

a) single input



$$v_{out} = G \cdot v_{in}$$

b) differential



$$v_{out} = G(v_+ - v_-) + G_{cm} \frac{v_+ + v_-}{2}$$

G = differential gain

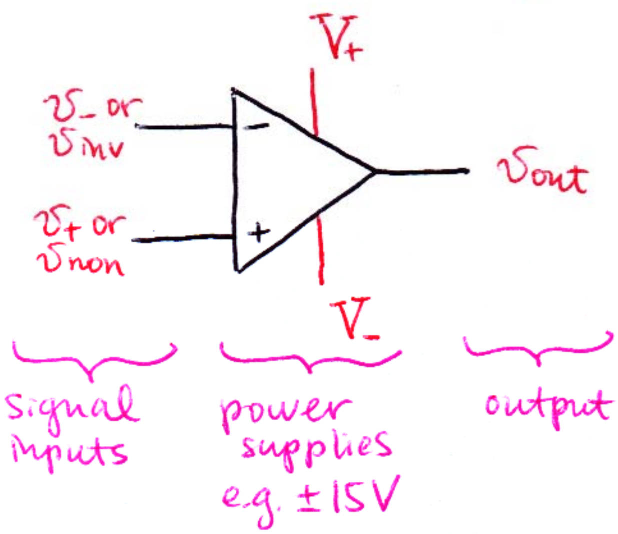
Common mode gain: for $v_+ = v_- = v_{cm}$, $G_{cm} = \frac{v_{out}}{v_{cm}}$

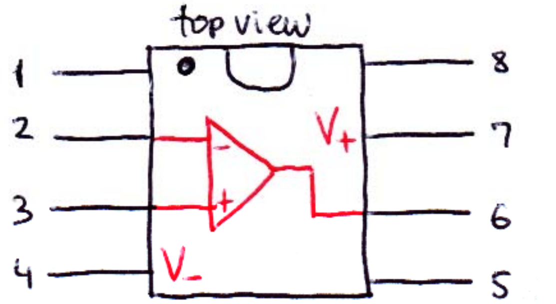
CMRR $= \frac{G}{G_{cm}} \gg 1$ for a good diff. amp.

(usually in dB)

Operational amplifier (op-amp)

- standard IC diff. amplifier, widely used in analog
- "operational" b/c it was used in analog computers (i.e. volt. is a math variable, can perform operations such as integration, different., sum, log, exp, etc.)





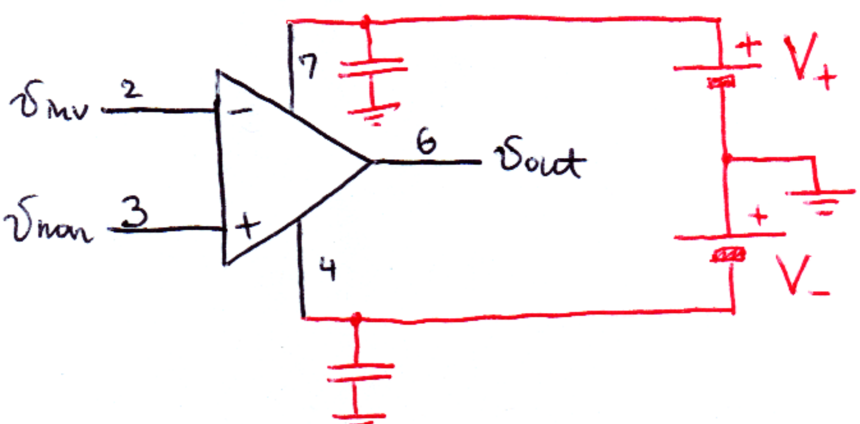
DIP package, CCW pin #

741 and $\underbrace{3140}_{\text{legacy, can use NTE 7144 instead}}$ op-amps used in the lab

Manufacturer spec sheets

- everything you need to know about an IC
- see PDF's on the course web-site / books in the lab

Powering op-amp



- need 2 power supplies
- 2 bypass caps (0.01–0.1 μF)
- long wires can act as antennas, bypass caps block hi-freq. noise
- usually don't draw all that