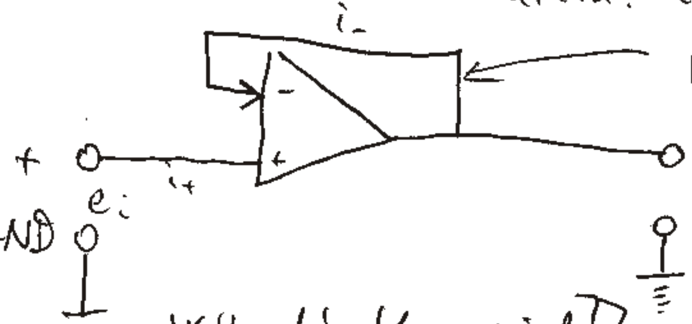
Op-Amp Applications.

NB: terminals not used are not shown.

Exclusion: power-supply inputs (always used, never shown)

Negative feedback loop: necessary because of likelihood of saturation. Circuits w/o feedback loop - almost never used.

$\boxed{\text{Example 1 (7.3)}}$ Voltage follower a.k.a. impedance transformer



feedback loop: holds $e_- \approx e_+$.

$e_o = e_- \approx e_+$

$\Downarrow$

$e_o = e_i \Rightarrow \boxed{G = 1}$

What's the point?!

$i_+ \sim 10^{-12} \div 10^{-9}$ A (Our input impedance is huge)

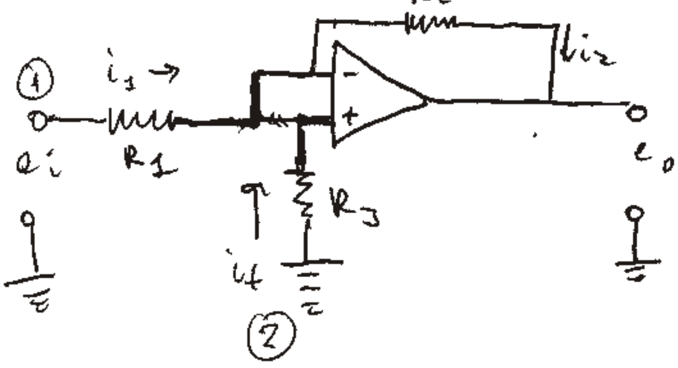
Output current ~ 25 mA (greatly amplified)

Input impedance ~ $10^{12}\,\Omega$

Output impedance < 1 Ω.

$\boxed{\text{Example 2 (7.4)}}$ Inverting amplifier

(useful not by itself, but as a part of a circuit).



R_2 - feedback resistor.

Resistance betw. ① and ② ~ $10^{12}\,\Omega$ (op. amp. input impedance).

$\Downarrow$

$i_+ \approx 0$.

Kirchoff rule for i_1, i_2, i_+ : $i_+ = 0 \Rightarrow i_1 = i_2$.

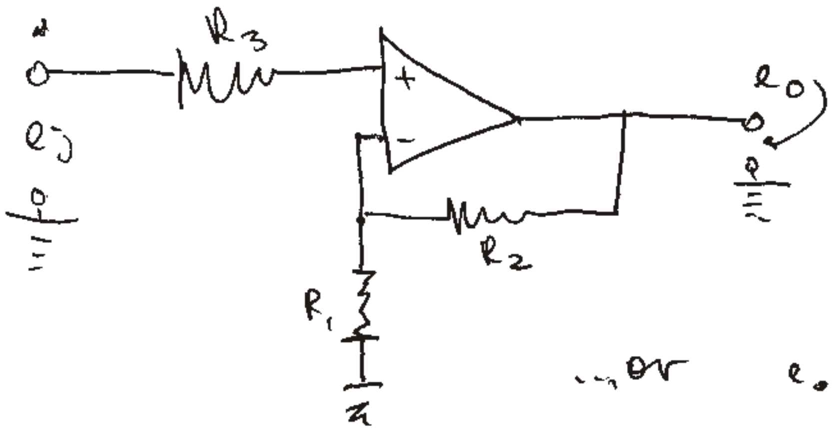
$\frac{e_i - 0}{R_1} = i_1$; $\frac{0 - e_0}{R_2} = i_2$. $\frac{e_i}{R_1} = -\frac{e_0}{R_2}$;

Phase inverted! $\boxed{e_0 = -\frac{R_2}{R_1} e_i}$ $G = -\frac{R_2}{R_1}$.

Usually R_3 is set @ $R_3 = \frac{R_1 R_2}{R_1 + R_2}$

to make input impedances @ ⊖ and ⊕ terminals of op amp equal.

Example 3 (7.5) Noninverting amplifier



$e_+ = e_i$

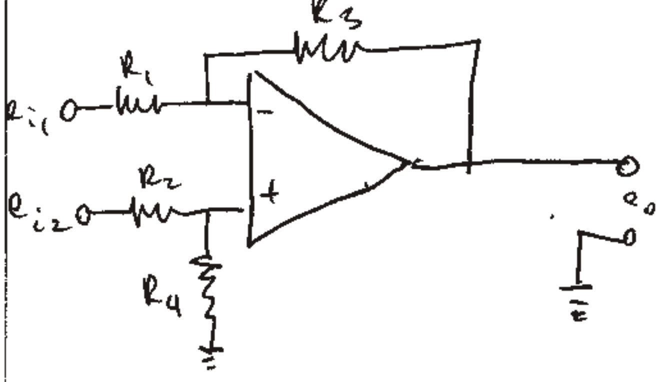
$e_- = e_+$ (negative feedback is present)

$e_- = \frac{R_1}{R_1 + R_2} e_0$

..., or $e_0 = \frac{R_1 + R_2}{R_1} e_i$

$G = \frac{R_1 + R_2}{R_1}$. R_3 - choose as in prev. example

Example 4 (7.6) Differential amplifier



Set $R_1 = R_2$

$R_3 = R_4$

Somewhat similar to inverting amp., but uses $e_{i1} - e_{i2}$ inst. of $e_i - 0$.

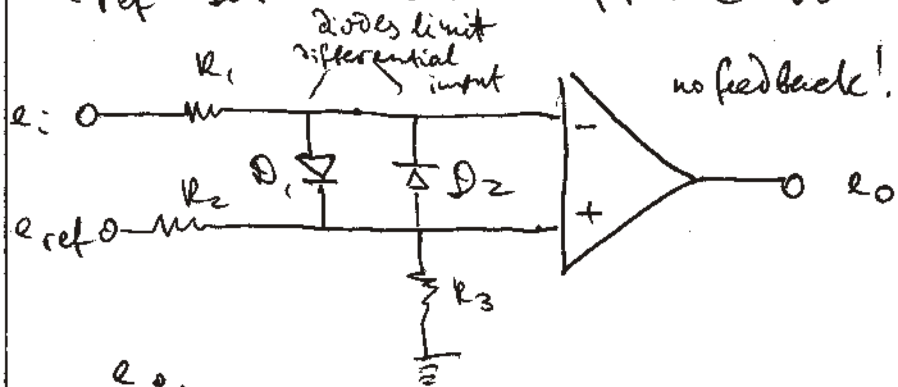
$e_o = \frac{R_3}{R_1}(e_{i1} - e_{i2})$.

Some caveats: need accurate resistor matching to get high CMRR

* can minimize offset w/o adjustment by making input resistances @ − and + equal.

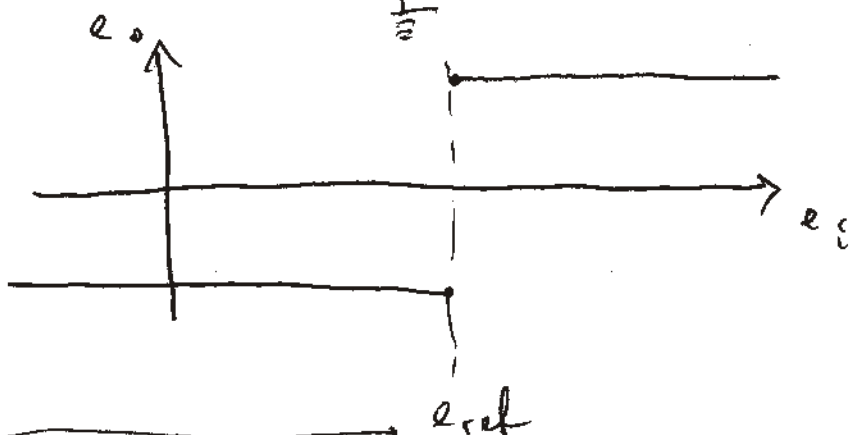
Voltage comparator $\boxed{\text{Example 5 (7.8)}}$

e_{ref} - set to desired reference voltage.



1) $e_i > e_{ref}$: output positively saturated

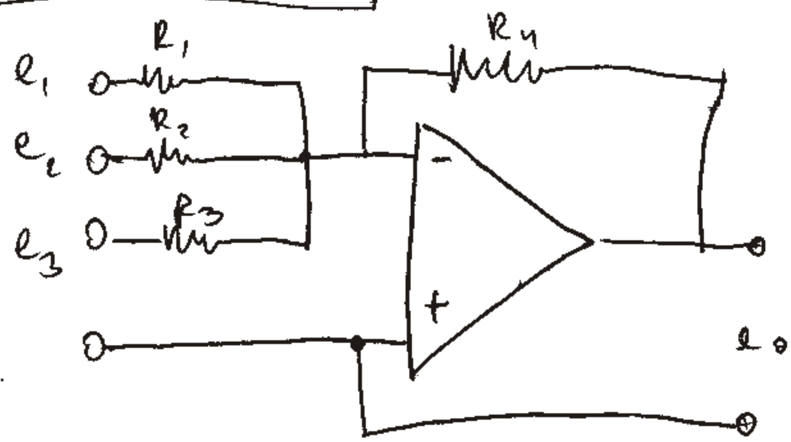
2) $e_i < e_{ref}$: output negatively saturated



$R_3 \approx \frac{R_2R_3}{R_2+R_3}$

(to equalize ⊕ and ⊖ impedances)

$\boxed{\text{Example 6 (7.9)}}$ Summing amplifier



$e_o = -\left(e_1\frac{R_4}{R_1} + e_2\frac{R_4}{R_2} + e_3\frac{R_4}{R_3}\right)$

$R_1 = R_2 = R_3 = R \Rightarrow$

$e_o = -\frac{R_4}{R}(e_1 + e_2 + e_3)$

spin-off of inverting amp.