Op-amp based algebra.

Multiplication: non-inverting amp.

Addition: summing amp + inverting amp.

Subtraction: inverting amp (for one input) + summing amp.

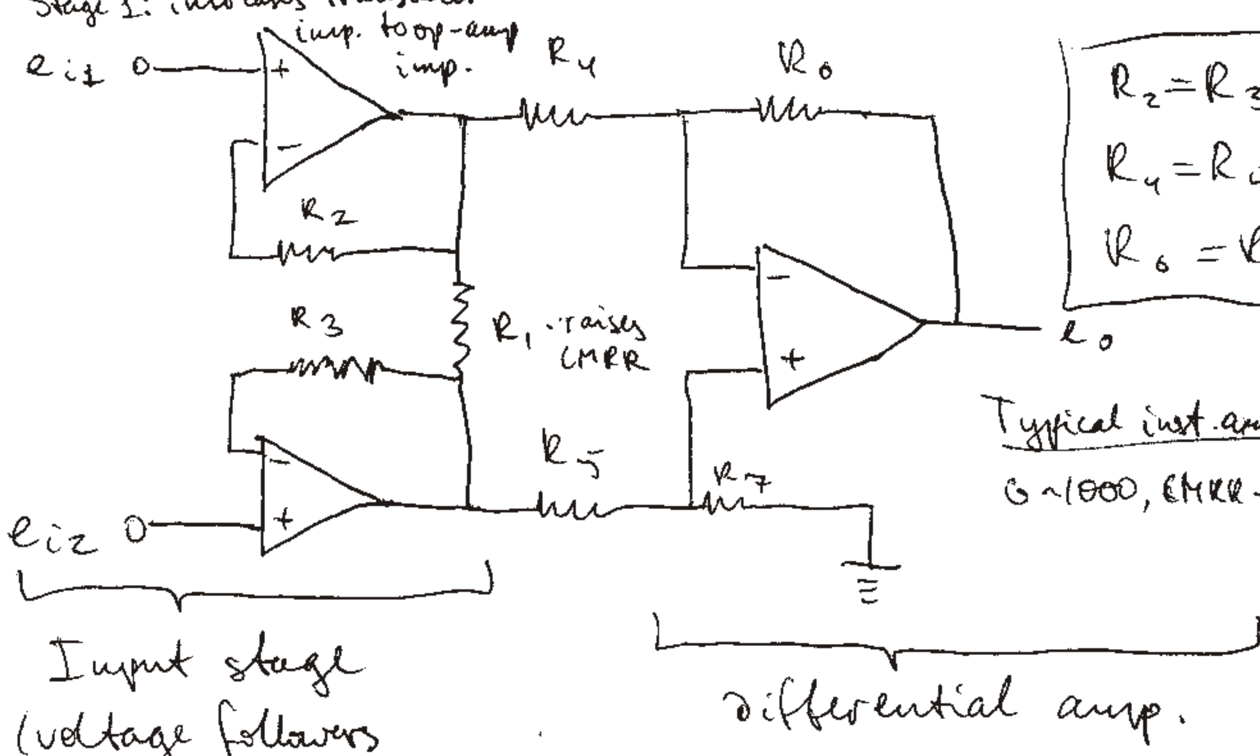
Can implement analog computing.

Special amplifier circuits (7.18)

Instrumentation amps. take care of:

* accurate amplification of small-voltage diffs. in presence of huge CM signal
* avoid loading the transducer by keeping current thru it small as possible

Stage 1: increases transducer imp. to op-amp imp.



$R_2 = R_3$
$R_4 = R_5$
$R_6 = R_7$

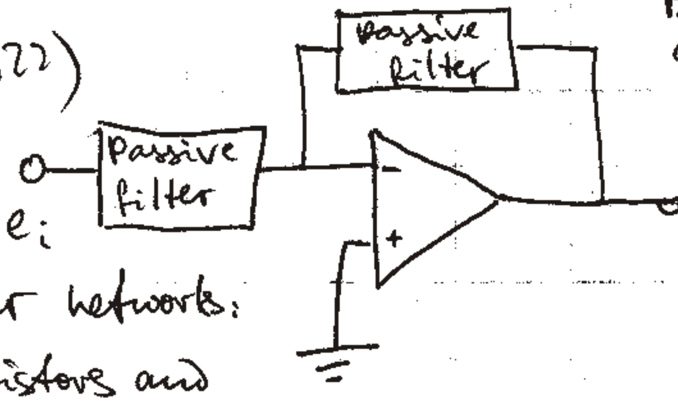
Typical inst. amp: $G \sim 1000$, CMRR ~ 130dB

$$G = \left(1 + \frac{2R_2}{R_1}\right)\frac{R_6}{R_4}$$

$$e_o = G\,(e_{i1} - e_{i2})$$

Additional uses of op amps (7.22, 7.23)

Filtering (7.22)



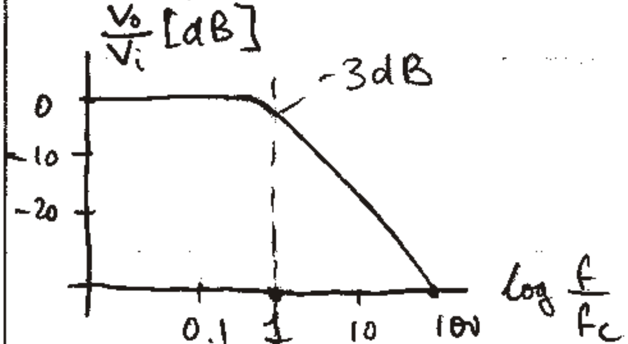
Basic active filter

Passive filter networks:

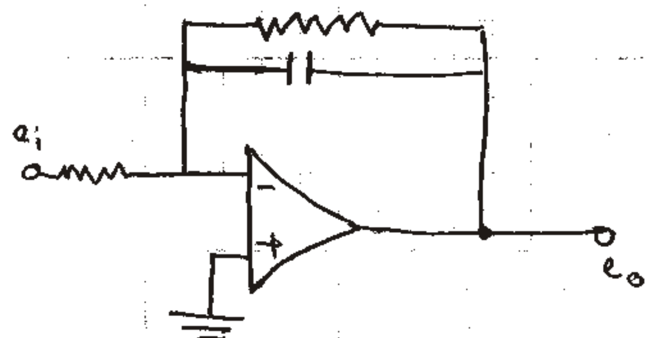
- built from resistors and capacitors
- do not have explicit inductive characteristics (unlike LC filters)

Examples of active filters

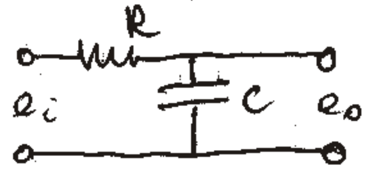
Low-pass filter: suppresses high-frequency components



f_c – cutoff frequency



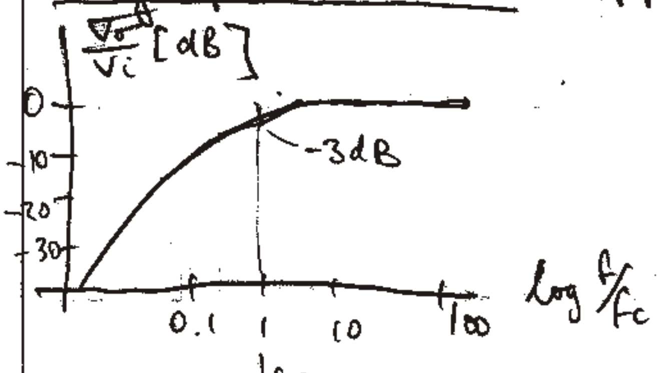
(compare with unpowered RC low-pass filter:

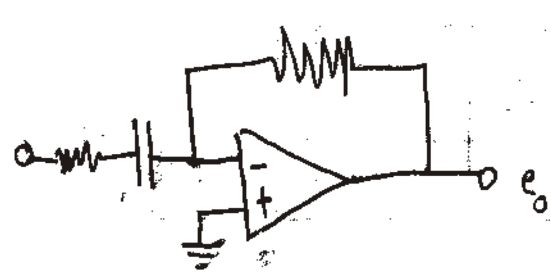


$f_c = \frac{1}{2\pi RC}$

frequency response $\frac{V_o}{V_i} = \frac{1}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}}$

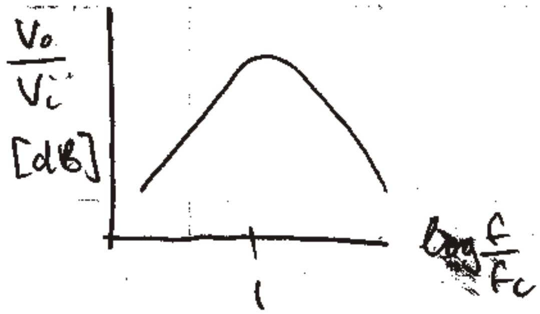
High-pass filter: suppresses low frequency.

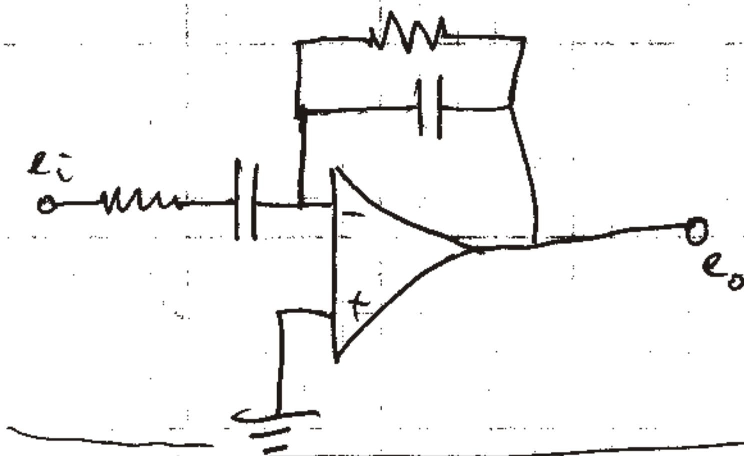




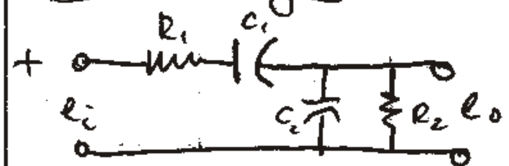
Corresponding RC filter would be...

<u>Band-pass filter</u> (chops out low <u>and</u> high freq.)

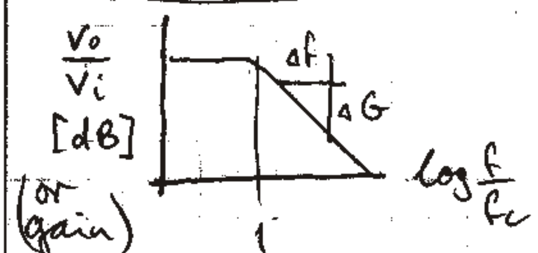




<u>RC analog</u>



What's good about <u>active</u> filters compared w/ <u>RC</u> or <u>LC</u>?



<u>Roll-off</u>: $\frac{\Delta G}{\Delta f}$ in terms of

$\frac{dB}{octave}$ or $\frac{dB}{decade}$

Decade = frequency change by a factor of 10

Octave = " " " " " " 2

Roll-off for RC filters: $\sim 6\ \frac{dB}{octave}$.

active filters: $\sim 80\ \frac{dB}{octave}$.

<u>Differentiators & Integrators</u> (7.23)

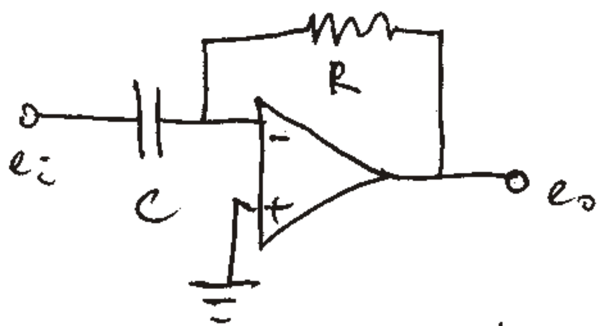
Addition to "op amp algebra".

Respond to: — rate of change of input

or

— time history of input

Op. amp. differentiator



Currents through R and C are equal (impedance of op amp is HUGE).

$e_- = e_+ = 0$.

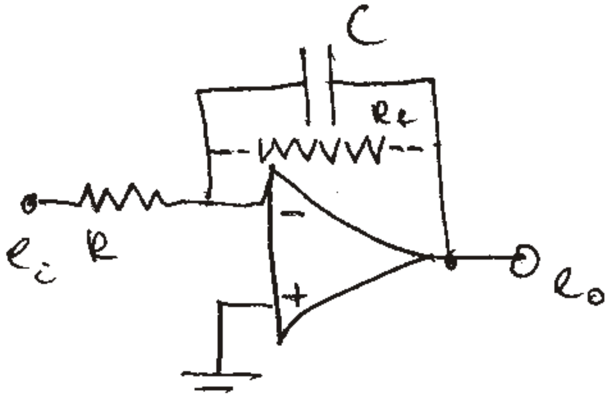
$$C\frac{d}{dt}(e_i - 0) = \frac{0 - e_o}{R}.$$

$$\Downarrow$$

$$\boxed{e_o = -RC\frac{d}{dt}e_i}$$

Output = time derivative of input * const

Op. amp. integrator



From resistor and capacitor current equality (again),

$$\frac{e_i}{R} = -C\frac{d}{dt}e_o.$$

Integrate:

$$e_o = -\frac{1}{RC}\int e_i\,dt + \text{const}.$$

R_f - may be placed in parallel w/ C.
huge resistor.

* Prevents drift in capacitor charge over long-time intervals
* Restricts signal frequencies to $f \gg 2\pi R_f C$.