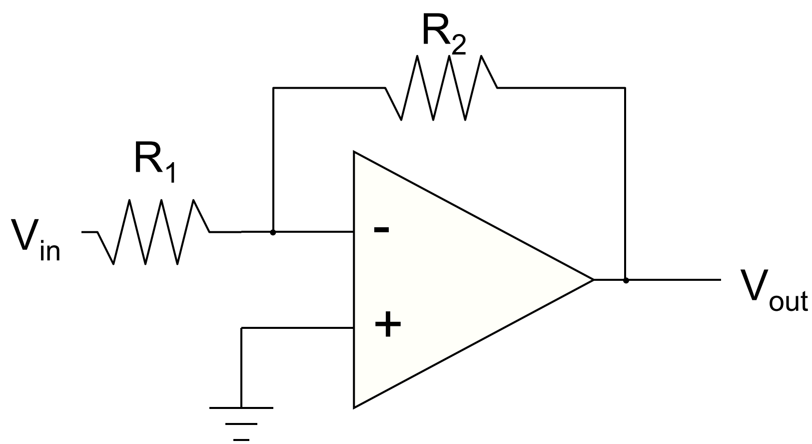
Esercizio n^o 2

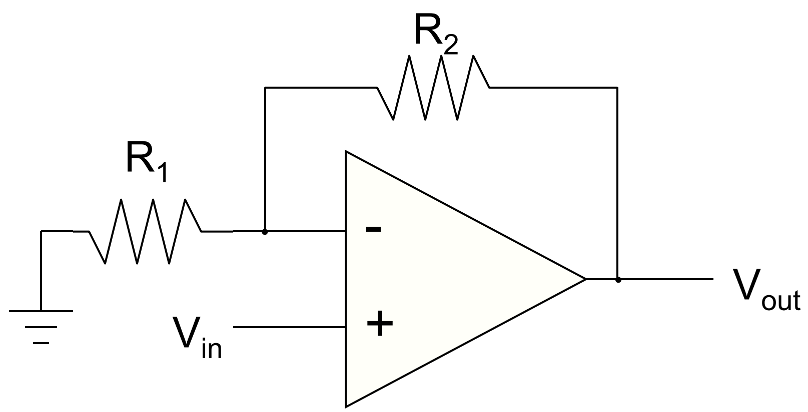
- Si realizzino i seguenti montaggi basati sull'amplificatore operazione 741 e se ne descriva il funzionamento:
  - amplificatore
  - amplificatore invertente
  - integratore o derivatore
- Si caratterizzino in modo quantitativo gli ampificatori al variare della frequenza del segnale in ingresso
- Si verifichi la banda passante di uno dei due amplificatori al variare del guadagno

Inverting amplifier example

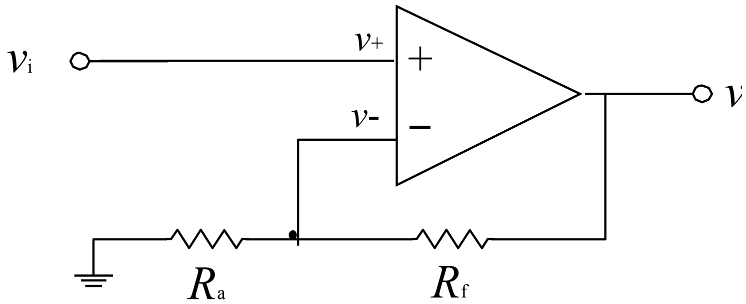


- Applying the rules: - terminal at "virtual ground"
  - so current through R_1 is $I_f = V_{in}/R_1$
- Current does not flow into op-amp (one of our rules)
  - so the current through R_1 must go through R_2
  - voltage drop across R_2 is then $I_f R_2 = V_{in}\times(R_2/R_1)$
- So $V_{out} = 0 - V_{in}\times(R_2/R_1) = -V_{in}\times(R_2/R_1)$
- Thus we amplify V_{in} by factor $-R_2/R_1$
  - negative sign earns title "inverting" amplifier
- Current is *drawn into* op-amp output terminal

Non-inverting Amplifier

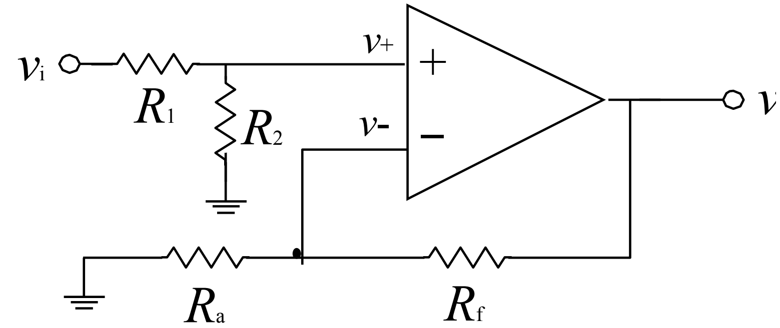


- Now neg. terminal held at V_{in}
  - so current through R_1 is $I_f = V_{in}/R_1$ (to left, into ground)
- This current cannot come from op-amp input
  - so comes through R_2 (delivered from op-amp output)
  - voltage drop across R_2 is $I_f R_2 = V_{in}\times(R_2/R_1)$
  - so that output is higher than neg. input terminal by $V_{in}\times(R_2/R_1)$
  - $V_{out} = V_{in} + V_{in}\times(R_2/R_1) = V_{in}\times(1 + R_2/R_1)$
  - thus gain is $(1 + R_2/R_1)$, and is positive
- Current is sourced from op-amp output in this example



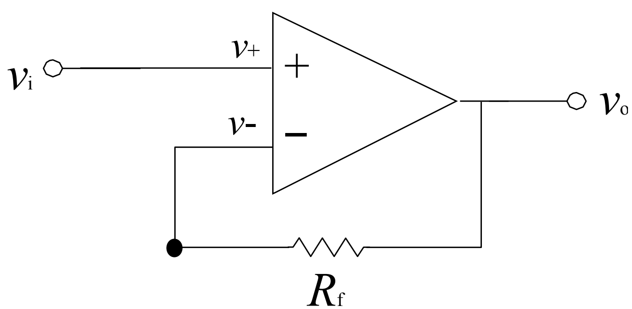
Noninverting amplifier

$$v_o = (1 + \frac{R_f}{R_a}) v_i$$



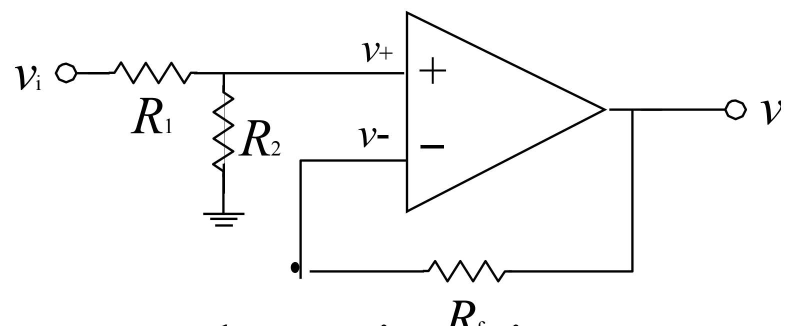
Noninverting input with voltage divider

$$v_o = (1 + \frac{R_f}{R_a})(\frac{R_2}{R_1 + R_2}) v_i$$



Voltage follower

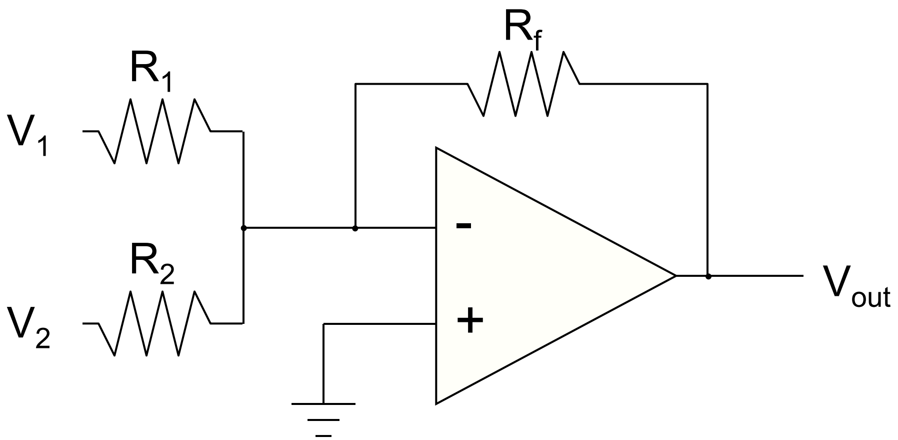
$$v_o = v_i$$



Less than unity gain

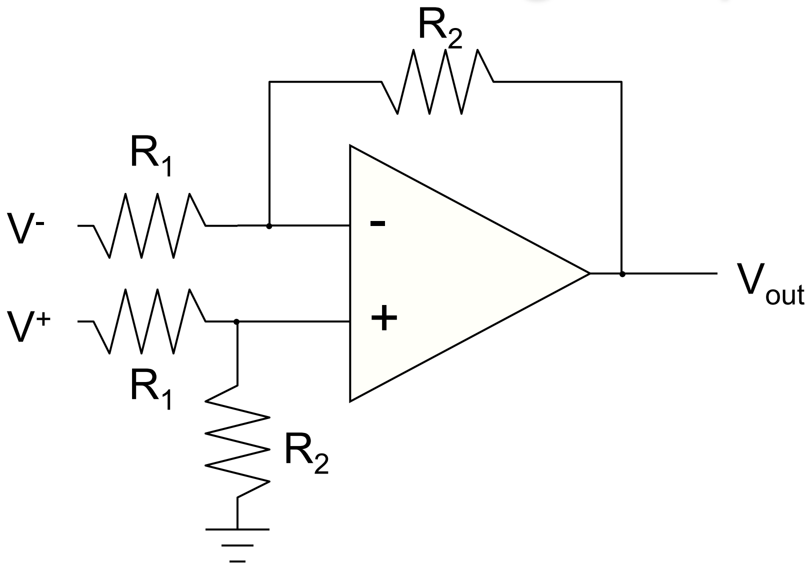
$$v_o = \frac{R_2}{R_1 + R_2} v_i$$

Summing Amplifier



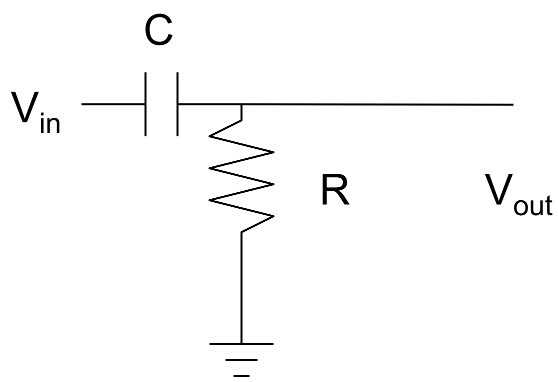
- Much like the inverting amplifier, but with two input voltages
  - inverting input still held at virtual ground
  - I_1 and I_2 are added together to run through R_f
  - so we get the (inverted) sum: $V_{out} = -R_f \times (V_1/R_1 + V_2/R_2)$
    - if $R_2 = R_1$, we get a sum proportional to $(V_1 + V_2)$
- Can have any number of summing inputs
  - we'll make our D/A converter this way

Differencing Amplifier



- The non-inverting input is a simple voltage divider:
  - $V_{node} = V^+R_2/(R_1 + R_2)$
- So $I_f = (V^- - V_{node})/R_1$
  - $V_{out} = V_{node} - I_fR_2 = V^+(1 + R_2/R_1)(R_2/(R_1 + R_2)) - V^-(R_2/R_1)$
  - so $V_{out} = (R_2/R_1)(V^+ - V^-)$

Differentiator (high-pass)



$$Q = CV$$

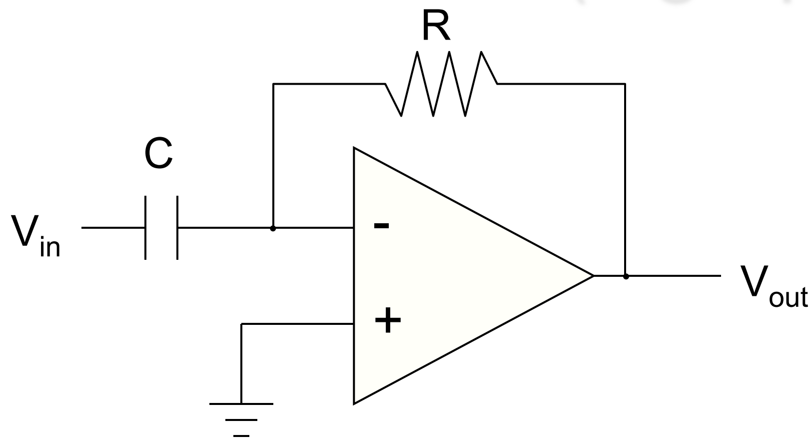
$$I = \frac{dQ}{dt} = C\frac{dV}{dt}$$

$$I = C\frac{d}{dt}(V_{in} - V_{out}) = \frac{V_{out}}{R}$$

$$\frac{dV_{out}}{dt} \ll \frac{dV_{in}}{dt} \qquad C\frac{dV_{in}}{dt} = \frac{V_{out}}{R}$$

$$V_{out} = RC\frac{dV_{in}}{dt}$$

Differentiator (high-pass)



- For a capacitor

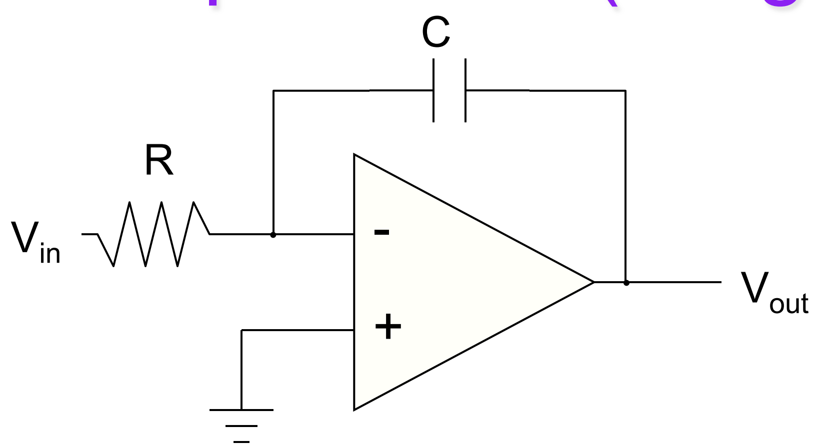
$$Q = CV$$

$$I = \frac{dQ}{dt} = C\frac{dV}{dt}$$

$$V_{out} = -I_{cap}R = -RC\frac{dV}{dt}$$

- So we have a differentiator, or high-pass filter

Low-pass filter (integrator)



$$Q = CV$$

$$I = \frac{dQ}{dt} = C\frac{dV}{dt}$$

- $I_f = V_{in}/R$, so $C \cdot dV_{cap}/dt = V_{in}/R$
  - and since left side of capacitor is at virtual ground:

$$-\frac{dV_{out}}{dt} = \frac{V_{in}}{RC}$$

$$V_{out} = -\frac{1}{RC}\int V_{in} dt$$

  - and therefore we have an integrator (low pass)