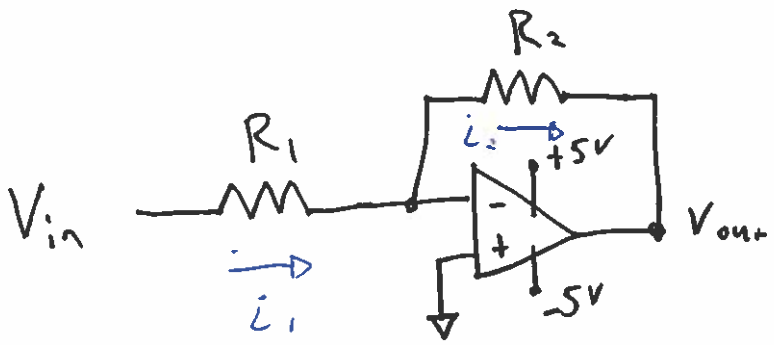
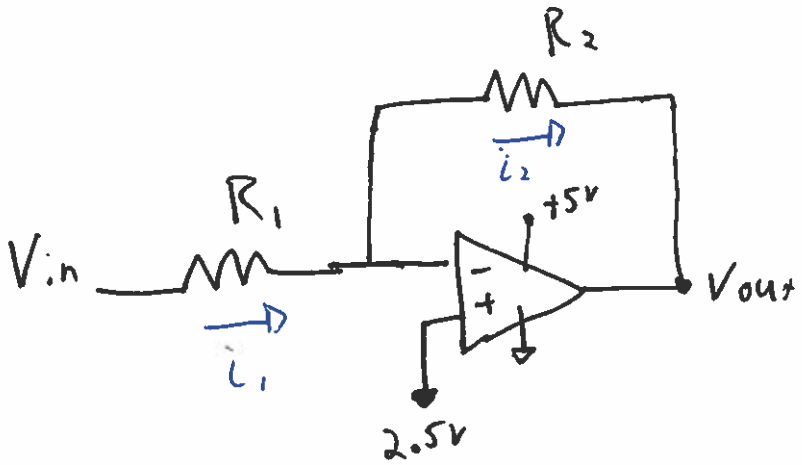
(1)



- $V_- = 0$, $i_1 = i_2$

$$\frac{V_{in}}{R_1} = i_1 = \frac{-V_o}{R_2} \Rightarrow \boxed{V_o = -\frac{R_2}{R_1} V_{in}}$$

(2)



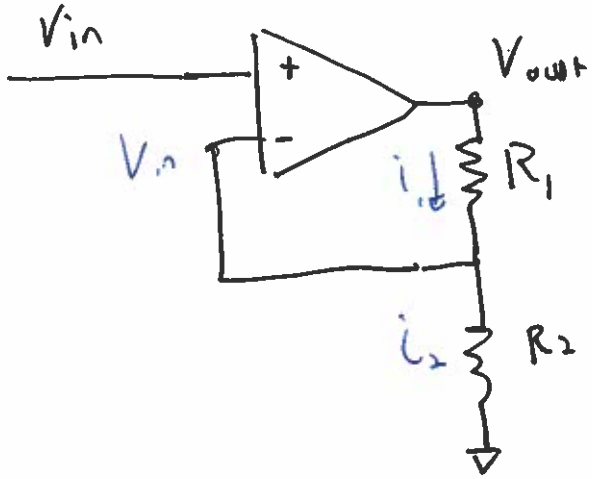
Same as above . .

- $V_+ = 2.5$
- $i_1 = i_2$

$$i_1 = \frac{V_{in} - 2.5}{R_1} = \frac{2.5 - V_{out}}{R_2}$$

$$(V_{out} - 2.5) = \frac{-R_2}{R_1}(V_{in} - 2.5)$$

(3)

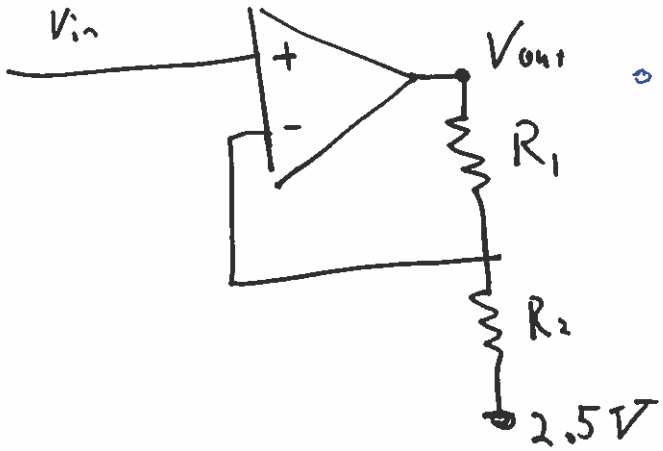


- $V_- = V_{in}$; $i_1 = i_2$

$$i_1 = \frac{V_{out} - V_n}{R_1} = \frac{V_{in}}{R_2}$$

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

(4)



Same...

- $V_- = V_{in}$; $i_1 = i_2$

$$i = \frac{V_{out} - V_{in}}{R_1} = \frac{V_{in} - 2.5}{R_2}$$

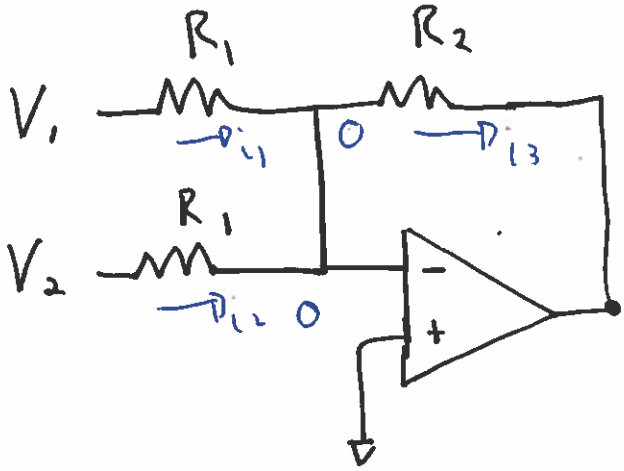
$$V_{out} = V_{in}\left(1 + \frac{R_1}{R_2}\right) - \frac{R_1}{R_2} 2.5$$

- or -

$$V_{out} - 2.5 = V_{in}\left(1 + \frac{R_1}{R_2}\right) - 2.5\left(1 + \frac{R_1}{R_2}\right)$$

$$\left(V_{out} - 2.5\right) = \left(V_{in} - 2.5\right)\left(1 + \frac{R_1}{R_2}\right)$$

(5)

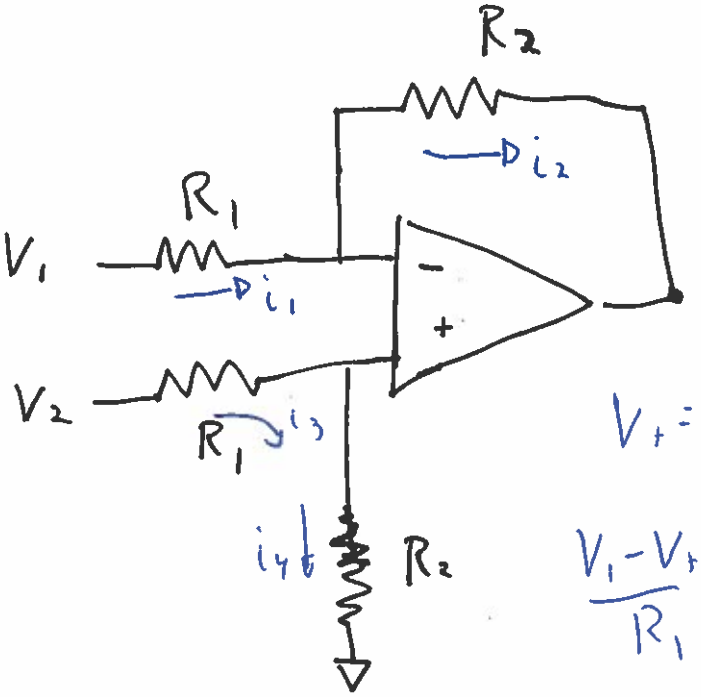


- $V_- = 0$
- $i_1 + i_2 = i_3$

$$V_{out}\quad \frac{V_1 - 0}{R_1} + \frac{V_2 - 0}{R_1} = \frac{0 - V_{out}}{R_2}$$

$$V_{out} = -\frac{R_2}{R_1}(V_1 + V_2)$$

(6)



- $V_+ = V_-$
- $i_1 = i_2$ • $i_3 = i_4$

$$V_+ = V_2 \frac{R_2}{R_1 + R_2}$$

$$\frac{V_1 - V_+}{R_1} = \frac{V_+ - V_{out}}{R_2}$$

$$V_{out} = \frac{R_2}{R_1}(V_+ - V_1) + V_+$$

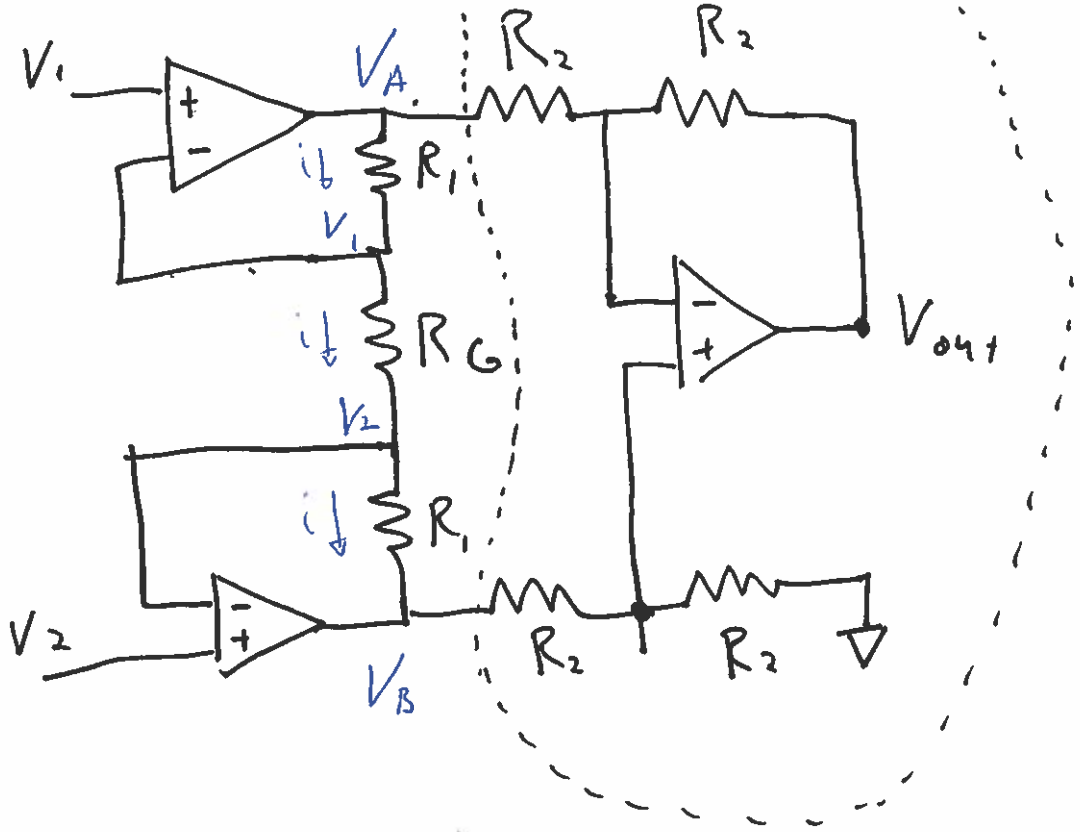
$$V_{out} = \frac{R_2}{R_1}\left(V_2 \frac{R_2}{R_1 + R_2} - V_1\right) + V_2 \frac{R_2}{R_1 + R_2}$$

$$= \left(\frac{R_2}{R_1} + 1\right)\left(\frac{R_2}{R_1 + R_2}\right) V_2 - \frac{R_2}{R_1} V_1 = \left(\frac{R_2 + R_1}{R_1}\right)\left(\frac{R_2}{R_1 + R_2}\right) V_2 - \frac{R_2}{R_1} V_1$$

$$\boxed{V_{out} = \frac{R_2}{R_1}(V_2 - V_1)}$$

(7)

See prob #6



We know from #6 $V_o = (V_B - V_A)$

$$i = \frac{V_A - V_1}{R_1} = \frac{V_1 - V_2}{R_G} = \frac{V_2 - V_B}{R_1}$$

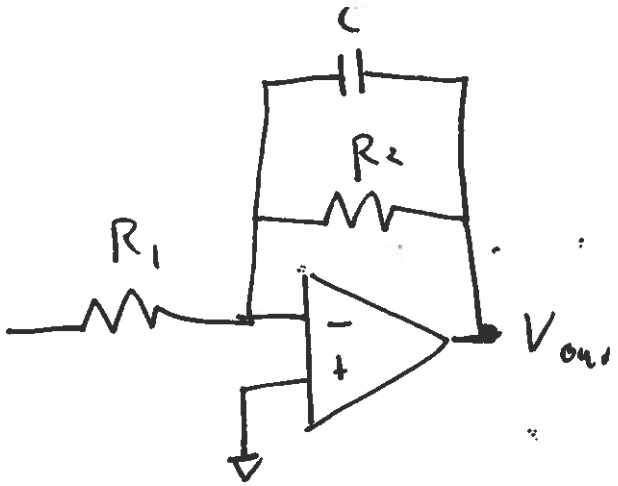
$$V_A = (1 + R_1/R_G)V_1 - V_2 \quad ; \quad V_B = (R_1/R_G + 1)V_2 - V_1$$

$$V_{out} = \left(V_2(1 + R_1/R_G) - V_1 - (1 + R_1/R_G)V_1 + V_2\right)$$

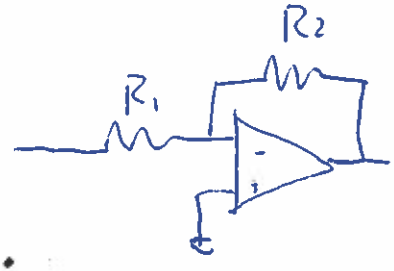
$$V_{out} = (2 + R_1/R_G)(V_2 - V_1)$$

Instrumentation Amplifier

(8)



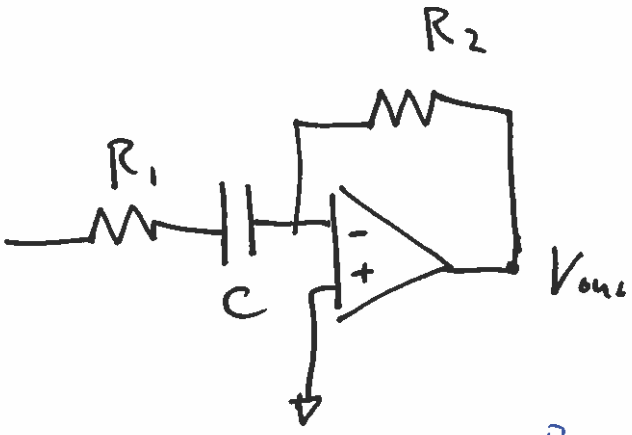
at low freq Circuit ≈



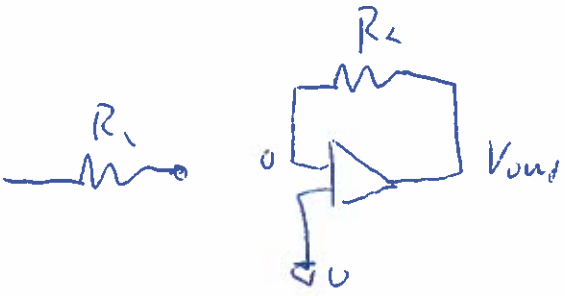
So acts like amplifier w/ gain of $-\frac{R_2}{R_1}$

Low pass filter w/ gain of $-R_2/R_1$ at low freq.

(9)



at low freq.



$V_{out} = 0$

So high pass filter w/ gain of $-\frac{R_2}{R_1}$ at high freq.