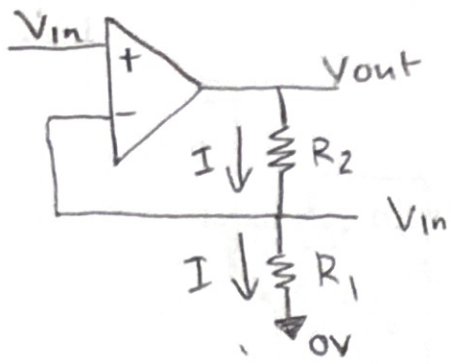
① 

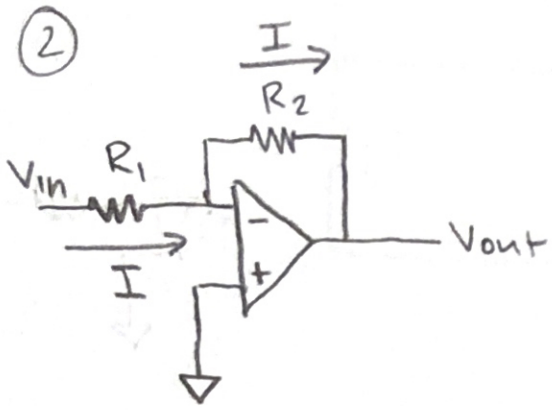

$V_{in}^{+} = V_{in}^{-}$

$V = IR$

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

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

amplifier

② 

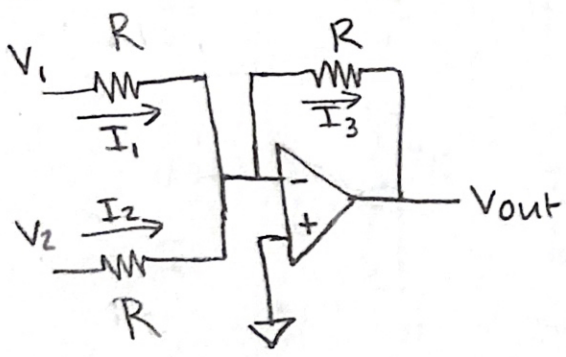

$V_{in}^{+} = V_{in}^{-} = 0$

$I_{in} = 0$

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

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

inverting amplifier

③ 

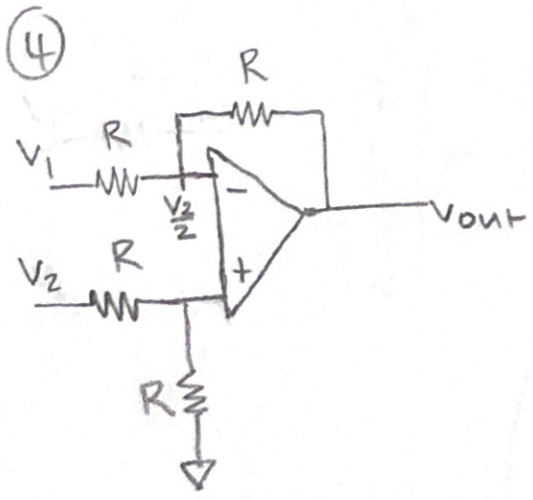

$V_{in}^{+} = V_{in}^{-}$

$I_1 + I_2 = I_3$

$$\frac{V_1}{R} + \frac{V_2}{R} = -\frac{V_{out}}{R}$$

$$V_{out} = -(V_1 + V_2)$$

inverting voltage adder

④ 


$I_{in} = 0$

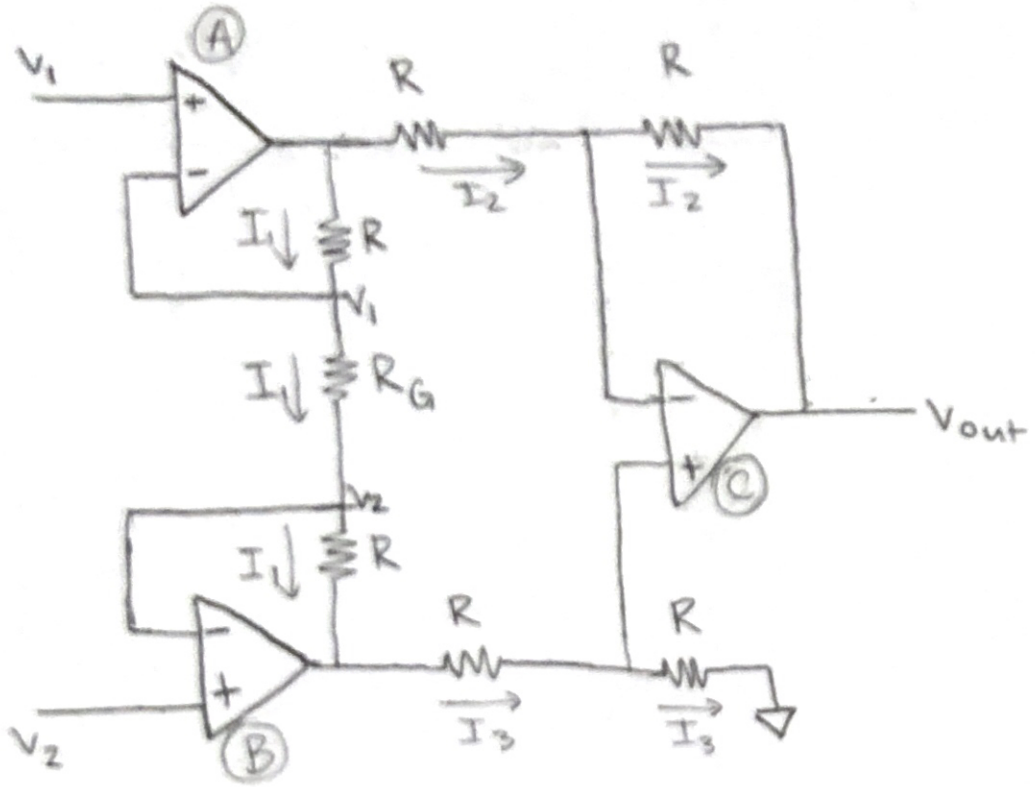
$$V_{in} = V_2 \cdot \frac{R}{2R} = V_2/2$$

$$\frac{V_1 - \frac{V_2}{2}}{R} = \frac{\frac{V_2}{2} - V_{out}}{R}$$

$$V_{out} = V_2 - V_1$$

voltage subtractor

(5)




$\Sigma$ current @ node = 0

$\Sigma$ voltage in = $V_{out}$ @ node

① $I_1 = \frac{V_{out\,A} - V_1}{R} = \frac{V_1 - V_2}{R_G} = \frac{V_2 - V_{out\,B}}{R}$

② $I_2 = \frac{V_{out\,A} - V_{out\,C}}{2R} = \frac{V_{out\,A} - V_{in\,C}}{R} = \frac{V_{in\,C} - V_{out\,C}}{R}$

③ $I_3 = \frac{V_{out\,B}}{2R} = \frac{V_{out\,B} - V_{in\,C}}{R}$

④ $V_1 + V_2 = V_{out\,A} + V_{out\,B}$

⑤ $V_{out\,C} = -V_{out\,A} + 2V_{in\,C}$

⑥ $V_{in\,C} = \frac{V_{out\,B}}{2}$

⑦ $V_{out\,C} = -V_{out\,A} + 2\left(\frac{V_{out\,B}}{2}\right) = -V_{out\,A} + V_{out\,B}$

$= -V_{out\,A} + (V_1 + V_2 - V_{out\,A})$

$= -2V_{out\,A} + V_1 + V_2$

⑧ $V_{out\,A} = \frac{R}{R_G}(V_1 - V_2) + V_1$

⑨ $V_{out\,C} = -2 \cdot \left(\frac{R}{R_G} \cdot (V_1 - V_2) + V_1\right) + V_1 + V_2$

$= \frac{2R}{R_G}(V_2 - V_1) - 2V_1 + V_1 + V_2$

$= \frac{2R}{R_G}(V_2 - V_1) + (V_2 - V_1)$

$= \boxed{(V_2 - V_1)\left(1 + \frac{2R}{R_G}\right)}$

instrumentation amplification

⑩ $V_{out\,A} - \frac{V_{out\,B}}{2} = \frac{V_{out\,B}}{2} - V_{out\,C}$

⑪ $V_{out\,C} = V_{out\,B} - V_{out\,A}$