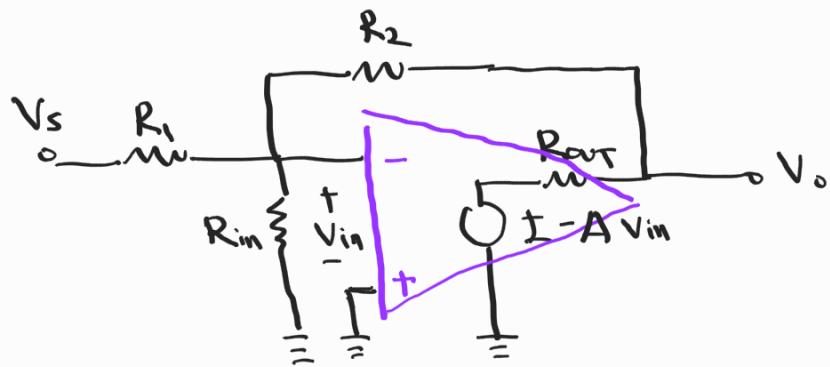
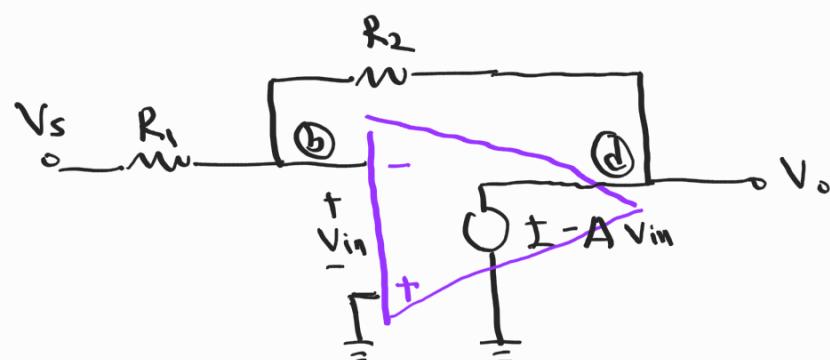


1.

i)

 $\Leftrightarrow$ 

$$\therefore R_{in} = \infty \\ R_{out} = 0$$

ii) two equations

$$\left\{ \begin{array}{l} \frac{V_s - V_{in}}{R_1} = \frac{V_{in} - V_o}{R_2} \quad (\text{KCL at } b) \dots 2 \text{ points} \\ -AV_{in} = V_o \quad (\text{KVL at } d) \dots 2 \text{ points} \end{array} \right.$$

iii) gain ( $= \frac{V_o}{V_s}$ )

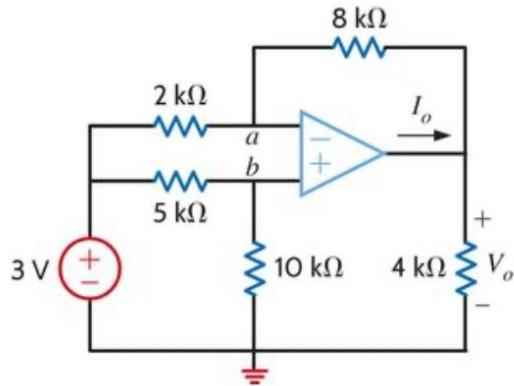
$$\frac{V_s + \frac{V_o}{A}}{R_1} = \frac{-\frac{V_o}{A} - V_o}{R_2}$$

$$\Rightarrow \frac{R_2}{R_1} \left( V_s + \frac{V_o}{A} \right) = V_o \left( \frac{1}{A} - 1 \right)$$

$$\Rightarrow V_o \left( \frac{R_2}{R_1} \frac{1}{A} + \frac{1}{A} - 1 \right) = -\frac{R_2}{R_1} V_s$$

$$\Rightarrow \frac{V_o}{V_s} = -\frac{R_2}{R_1} \frac{1}{1 + \frac{1}{A} \left( 1 + \frac{R_2}{R_1} \right)} \quad \dots 2 \text{ points}$$

2. (6 Points) Find  $V_o$  and  $I_o$  in the circuit shown below.



**Solution)**

At node b, using voltage divider

$$v_b = \frac{10k}{10k + 5k} \cdot 3V = 2V$$

You can also resolve  $v_b$  using KCL at node b. (same result)

$$\text{KCL : } \frac{3V - v_b}{5k} = \frac{v_b - 0V}{10k} \rightarrow 6V - 2v_b = v_b \rightarrow v_b = 2V \quad (\text{a}) \text{ 2pts}$$

At node a, using nodal analysis (KCL)

$$\frac{3V - v_a}{2k} = \frac{v_a - v_o}{8k}$$

$$12V - 4v_a = v_a - v_o \rightarrow 12V = 5v_a - v_o$$

$$v_a = v_b = 2V$$

So,

$$12V = 10V - v_o$$

$$v_o = -2V \quad (\text{b}) \text{ 2pts}$$

At node  $+v_o$  using KCL

$$i_o = \frac{v_o - v_a}{8k} + \frac{v_o - 0V}{4k} = \frac{-2 - 2}{8k} + \frac{-2}{4k} = -1mA$$

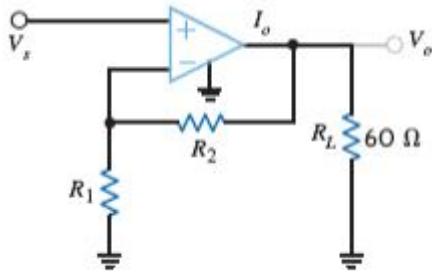
$$i_o = -1mA \quad (\text{c}) \text{ 2pts}$$

-1pts for incorrect sign

### Quiz 3 Problem 3

The op-amp in the amplifier in Fig. P4.14 operates with  $\pm 15V$  supplies and can output no more than  $200mA$ . What is the maximum gain allowable for the amplifier if the maximum value of  $V_s$  is  $1V$ ? (6pts)

$$R_1 + R_2 = 60k\Omega$$



<Solution>

$$A_v = \frac{V_o}{V_s} = 1 + \frac{R_2}{R_1} = \frac{R_1 + R_2}{R_1} = \frac{6 \times 10^4}{R_1}, \quad |V_o| = |V_s| \left( \frac{6 \times 10^4}{R_1} \right) \leq 15 \quad \dots 1pts(a)$$

$$(1) \text{ For } V_{s,\max} = 1V \text{ case, } V_o = \frac{6 \times 10^4}{R_1} \quad \dots 1pts(b)$$

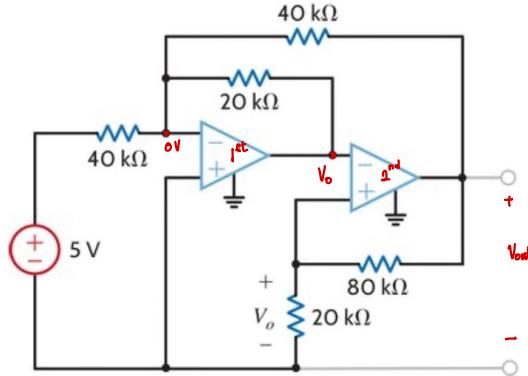
$$(2) \text{ For } I_{o,\max} = 200mA \text{ case,}$$

$$I_o = \frac{V_o}{R_1 + R_2} + \frac{V_o}{R_L} = \frac{6 \times 10^4}{R_1 \times 60 \times 10^3} + \frac{6 \times 10^4}{R_1 \times 60} = \frac{1001}{R_1} \leq 200mA \quad \dots 2pts(c)$$

$$\text{Therefore, } R_1 \geq 5005\Omega, R_2 \leq 54995\Omega \Rightarrow A_{v,\max} = 1 + \frac{R_{2,\max}}{R_{1,\min}} = 11.988 \quad \dots 2pts(d)$$

저항값을 통해 gain을 구하는 것이 아닌 단순히  $V_o \leq 11.988V$ 이라는 이유를 답의 근거로 제시할 시  $V_s \geq 1V$ 가 아닌  $V_s \leq 1V$ 이므로  $\text{Gain} = V_o / V_s \leq 11.988$ 라는 부등식이 성립하지 않아 답으로 인정안함 (e)

4. (6 Points) Find  $V_o$  in the circuit shown below.



$$\text{KCL at } v^- \text{ input of 1st op-amp: } \frac{5}{40k} + \frac{V_o}{20k} + \frac{V_{out}}{40k} = 0 \quad (+2)$$

$$5 + 2V_o + V_{out} = 0 \quad - \textcircled{1}$$

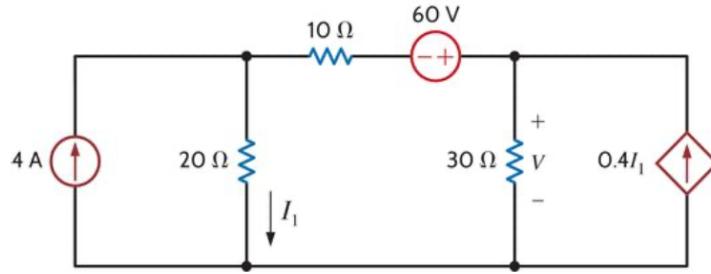
$$\text{KCL at } v^+ \text{ input of 2nd op-amp: } \frac{V_o}{20k} + \frac{V_o - V_{out}}{80k} = 0 \quad (+2)$$

$$V_{out} = V_o \left(1 + \frac{80k}{20k}\right) = 5V_o \quad - \textcircled{2}$$

Substituting equation  $\textcircled{2}$  in equation  $\textcircled{1}$ ,

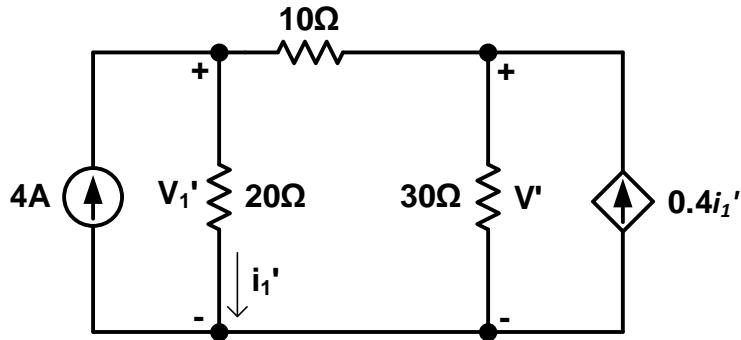
$$5 + 2V_o + 5V_o = 0 \Rightarrow V_o = -\frac{5}{7} = -0.714V \quad (+2)$$

5. (6 points) Use superposition to find the voltage  $V$  in the circuit shown below.



Without using 'superposition': 0pts

### Step 1. – Short voltage source (60V)



$$4 = \frac{V'_1}{20} + \frac{V'_1 - V'}{10}$$

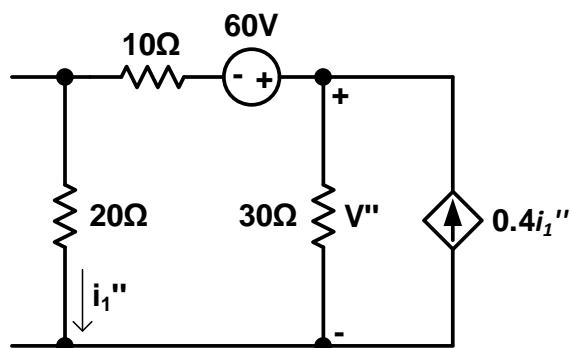
$$0.4i' = \frac{V'}{30} + \frac{V' - V'_1}{10}, \quad i'_1 = \frac{V'_1}{20}$$

$$3V'_1 - 2V' = 80, \quad 7.2V'_1 = 8V'$$

$$V' = 60V \quad [+1]$$

Equation : [+1.5]

### Step 2. – Open current source (4A)



$$60 = -30i''_1 - 30(i''_1 - 0.4i''_1)$$

$$60 = -48i''_1, \quad i''_1 = -1.25A$$

$$V'' = -30 \times (i''_1 - 0.4i''_1)$$

$$V'' = -18i''_1, \quad V'' = 22.5V \quad [+1]$$

Equation : [+1.5]

Answer :  $V = V' + V'' = 60 + 22.5 = 82.5V \quad [+1]$

Wrong units (or no unit) : [-1]