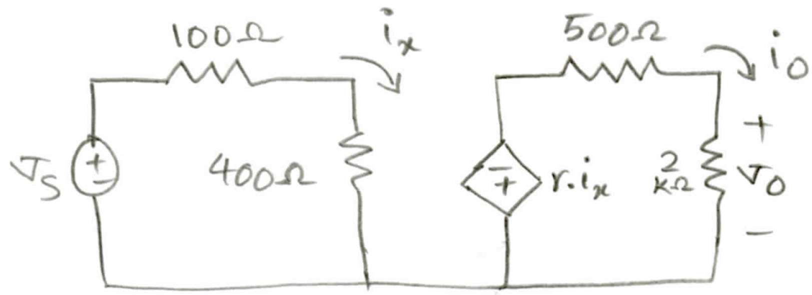
HW #5

MAE140

Fall 2013

4-1



$r = 5\,k\Omega$

KVL in left loop: $i_x = \dfrac{v_S}{0.1\times10^3 + 0.4\times10^3} = 2\,v_S \text{ mA}$

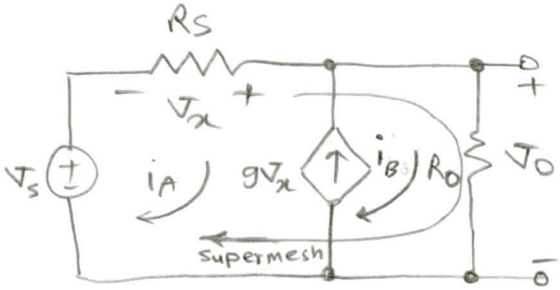
KVL in right loop: $i_0 = \dfrac{-r \cdot i_x}{0.5\times10^3 + 2\times10^3} = \dfrac{-5\times10^3\, i_x}{2.5\times10^3} = -2 i_x$

Voltage division:

$$v_0 = \frac{-2\times10^3\,(r \cdot i_x)}{0.5\times10^3 + 2\times10^3} = \frac{-2\times10^3\,(5\times10^3 \times i_x)}{2.5\times10^3} = -4 i_x \times 10^3 \text{ V}$$

$$\begin{cases} \dfrac{v_0}{v_S} = \dfrac{-4 i_x \times 10^3}{v_S} = \dfrac{-4(2 v_S \times 10^{-3})\times 10^3}{v_S} = -8 \\[2ex] \dfrac{i_0}{i_x} = \dfrac{-2 i_x}{i_x} = -2 \end{cases}$$

4-9



We can use a supermesh in the above circuit as;

$$-v_S + R_S i_A + R_O i_B = 0 \quad (\mathrm{I})$$

Also, we have; $\left.\begin{array}{l} i_B - i_A = g v_x \\ v_x = -R_S i_A \end{array}\right\} \Rightarrow i_A = \dfrac{i_B}{1-gR_S} \quad (\mathrm{II})$

$$(\mathrm{I}) \, \& \, (\mathrm{II}) \Longrightarrow -v_S + R_S \frac{i_B}{1-gR_S} + R_O i_B = 0$$

$$\Rightarrow i_B = \frac{v_S}{\dfrac{R_S}{1-gR_S} + R_O}$$

$$v_O = R_O i_B = \frac{R_O v_S}{\dfrac{R_S}{1-gR_S} + R_O}$$

$$\frac{v_O}{v_S} = \frac{R_O}{R_O + \dfrac{R_S}{1-gR_S}} = \frac{R_O(1-gR_S)}{R_O + R_S - gR_OR_S}$$

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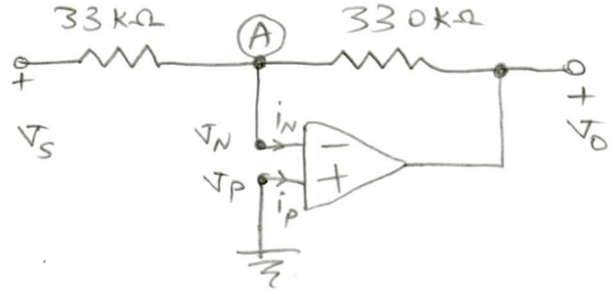
(a)



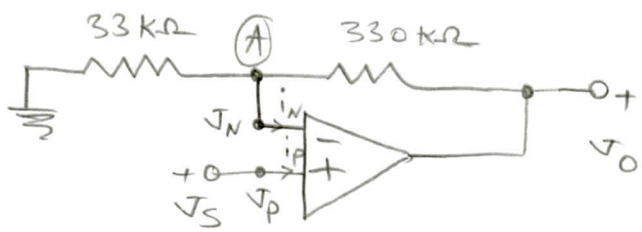
Based on the $i-v$ relationships of the ideal model of the Op Amp, we have;

$$\begin{cases} v_P = v_N \\ i_P = i_N = 0 \end{cases}$$

$\Rightarrow v_P = v_N = 0$

KCL at (A): $\dfrac{0 - v_S}{33 \times 10^3} + \dfrac{0 - v_O}{330 \times 10^3} = 0 \Rightarrow \dfrac{v_O}{v_S} = -10$

(b)

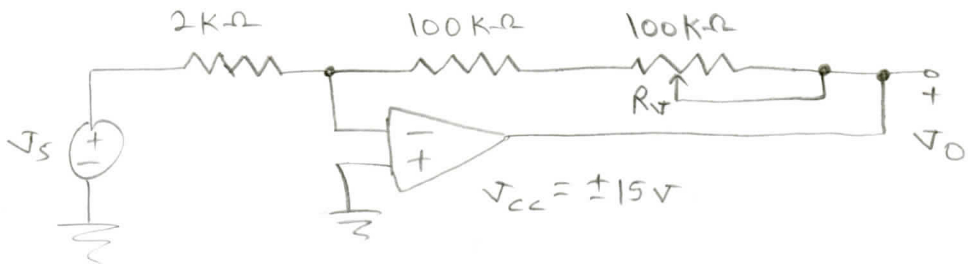


Again we have; $v_P = v_N \Longrightarrow v_N = v_P = v_S$

$i_P = i_N = 0$

KCL at (A): $\dfrac{v_S}{33 \times 10^3} + \dfrac{v_S - v_O}{330 \times 10^3} = 0 \Longrightarrow \dfrac{v_O}{v_S} = 11$

4-28



The variable resistor is denoted by R_v which is in the range of; $0 \leq R_v \leq 100\,k\Omega$

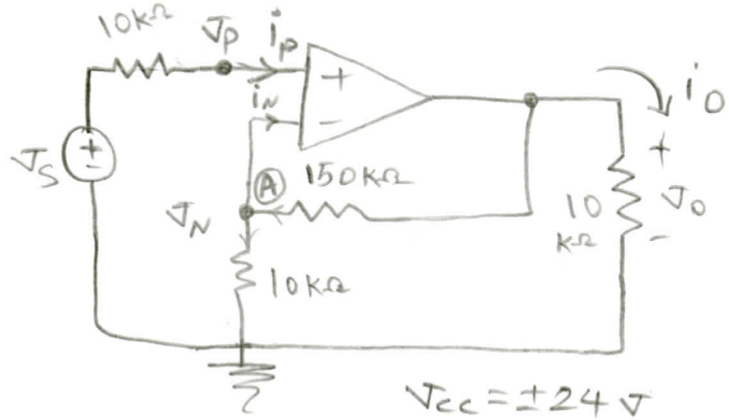
The above circuit is an inverting amplifier with a gain of;

$$K = \frac{v_o}{v_s} = -\frac{100\times 10^3 + R_v}{2\times 10^3}$$

$0 \leq R_v \leq 100\,k\Omega$, thus the gain is in the range of:

$$-100 \leq K = \frac{v_o}{v_s} \leq -50$$

4-30



(a) $i_p = i_N = 0 \Rightarrow v_p = v_s$

Also $v_p = v_N$ $\Longrightarrow v_N = v_s$

KCL at (A): $\dfrac{v_N}{10\times10^3} = \dfrac{v_o - v_N}{150\times10^3} \xrightarrow{v_N = v_s} \dfrac{v_o}{v_s} = 16$

(b) $v_s = 1\,V \Longrightarrow v_o = 16\times1 = 16\,V$

$v_s = 3\,V \Longrightarrow v_o = 16\times3 = 48\,V$

In this case, the Op Amp becomes saturated, thus

$v_o = +24\,V$ (coming from $V_{cc} = \pm24\,V$)

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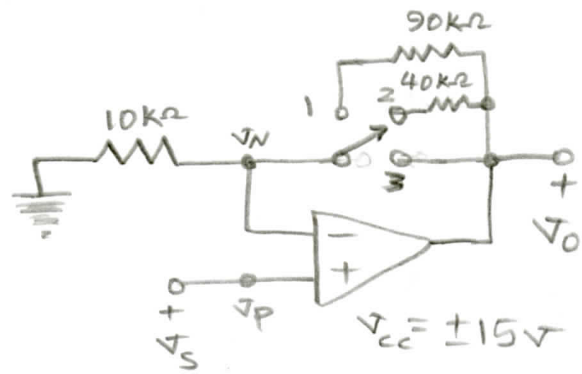

$v_s = 2V$

Amplification by a factor of 1 ⇒ connect switch "3"

because $v_p = v_N$

$v_p = v_s \Rightarrow v_o = v_s = 2V$

$v_N = v_o$

Amplification by a factor of 5 ⇒ connect switch "2"

because in this case, the circuit acts like a noninverting amplifier with a gain of $K = \frac{v_o}{v_s} = \frac{40\times10^3 + 10\times10^3}{10\times10^3} = 5$

$\Rightarrow v_o = 5 \times v_s = 10V$

Amplification by a factor of 10 ⇒ connect switch "1"

because again in this case, the circuit acts like a noninverting amplifier with a gain of;

$$K = \frac{v_o}{v_s} = \frac{90\times10^3 + 10\times10^3}{10\times10^3} = 10$$

$\Rightarrow v_o = 10 \times v_s = 20V$

Due to $V_{cc} = \pm 15V$, the Op Amp becomes saturated and thus v_o can be have a maximum value of $v_o = 15V$. therefore, another recommendation to fix the circuit for this case is to increase $V_c = \pm 15V$ to $V_c = \pm 20V$.

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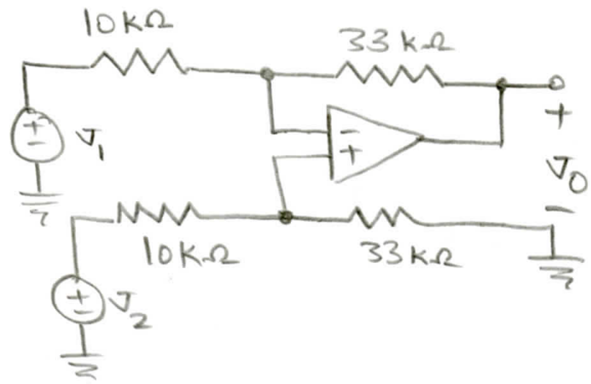
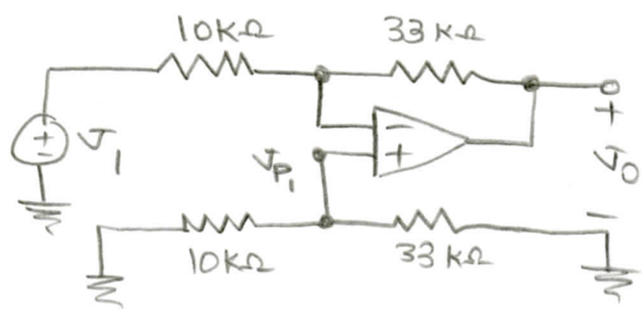


using superposition to find v_O:

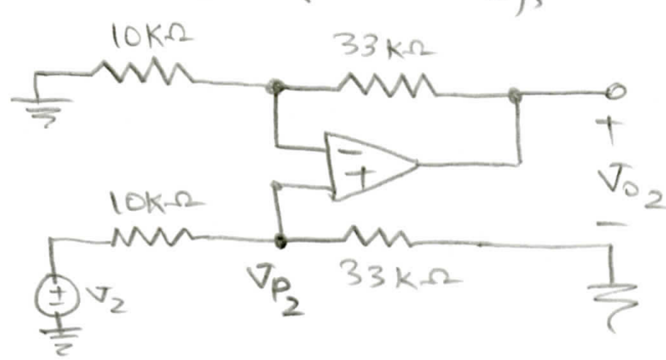
(I) First set $v_2 = 0$ (turn off v_2);



In above circuit, $v_{P_1} = 0$. Therefore the circuit acts like an inverting amplifier with the result that

$$v_{O1} = -\frac{33 \times 10^3}{10 \times 10^3} v_1$$

(II) Second set $v_1 = 0$ (turn off v_1);



The circuit looks like a noninverting amplifier with a voltage divider connected at its input.

Voltage division: $v_{P_2} = \dfrac{33\times10^3}{10\times10^3+33\times10^3} v_2$

Noninverting amplifier: $v_{o_2} = \dfrac{33\times10^3+10\times10^3}{10\times10^3} v_{P_2}$

$\Rightarrow v_{o_2} = \dfrac{33}{10} v_2$

$$v_o = v_{o_1} + v_{o_2} = \frac{-33}{10} v_1 + \frac{33}{10} v_2$$

$$\Rightarrow v_o = \frac{33}{10}(v_2 - v_1)$$

As we can see, the output voltage is proportional to the difference between the two inputs. Thus, such a circuit is called differential amplifier or subtractor.

In page 195 of book, we can see the general equation for gain of a subtractor circuit.

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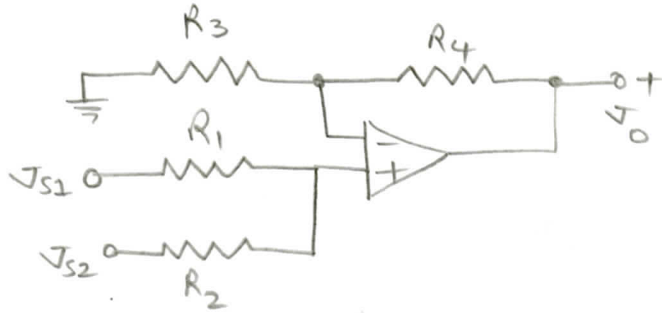
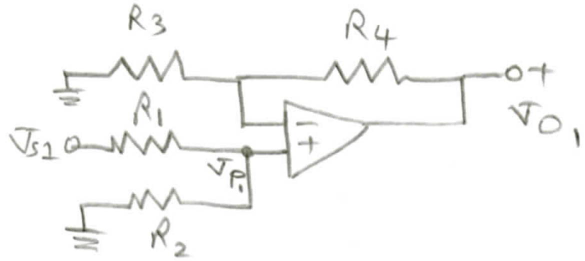


using superposition to find V_o;

(I) First Set $V_{S2} = 0$;

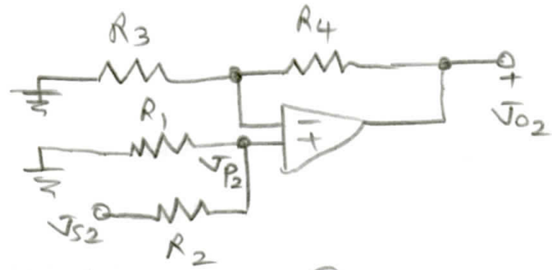


Circuit looks like a noninverting amplifier with a voltage divider connected at its input.

Voltage division: $V_{P_1} = \frac{R_2 V_{S1}}{R_1 + R_2}$

Noninverting amplifier: $V_{O_1} = \frac{R_3 + R_4}{R_3} V_{P_1} = \frac{R_3 + R_4}{R_3} \cdot \frac{R_2 V_{S1}}{R_1 + R_2}$

(II) Second Set $V_{S1} = 0$;



The same as case (I);

$V_{P_2} = \frac{R_1 V_{S2}}{R_1 + R_2}$, $V_{O_2} = \frac{R_3 + R_4}{R_3} V_{P_2}$

$\Rightarrow V_{O_2} = \frac{R_3 + R_4}{R_3} \cdot \frac{R_1 V_{S2}}{R_1 + R_2}$

$V_O = V_{O1} + V_{O_2} = \left(\frac{R_3 + R_4}{R_3}\right)\left(\frac{1}{R_1 + R_2}\right)\left(R_2 V_{S1} + R_1 V_{S2}\right)$