ECE-210 Circuits I

Electrical & Computer Engineering Department
Boise State University

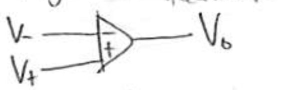
55/55

STUDENT (FIRST & LAST): Nicole Nagel

1 – Using an example show why we use the negative feedback of the amplifier to avoid saturation and to control the output voltage. The example can include an inverting amplifier with example resistors as inputs, a plot that shows the input output voltage relationship.

The output of an amplifier is given by $V_o = AV_d$, where "V_o" is the output, "A" is the gain of the amplifier, & "V_d" is the voltage differential across the inverting input (V_-) & the noninverting input (V_+).

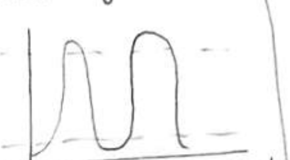
Fig1. Amplifier without feedback



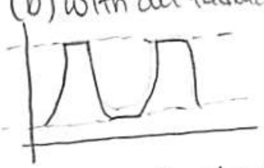
Since the gain is very high in op-amps, the output voltage can be very high as well. This can lead to very high outputs, shown by the equation: $V_o = AV_d$. The equation also shows the dependency of the output on the difference between the input voltages. Adding to the high output already indicated, the op-amp has an open-loop, causing for a wide variability in output. If one inputs a certain signal, such as the signal on the left (plot a), the output signal (with open loop gain & input voltage) could become like plot b, where the signal is cut off in some areas, resulting in plot c. This would give the signal noise, which is not a very applicable op-amp.

10/10

(a) original input



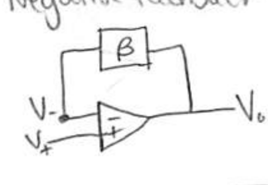
(b) theoretical output without feedback



(c) actual output without feedback

Therefore, when negative feedback is implemented, shown in Fig. 2, the voltage differential drops, according to the amount of the output fed back into the op-amp. "β" is a multiplier from 0-1, demonstrating a portion of the output fed back into the input.

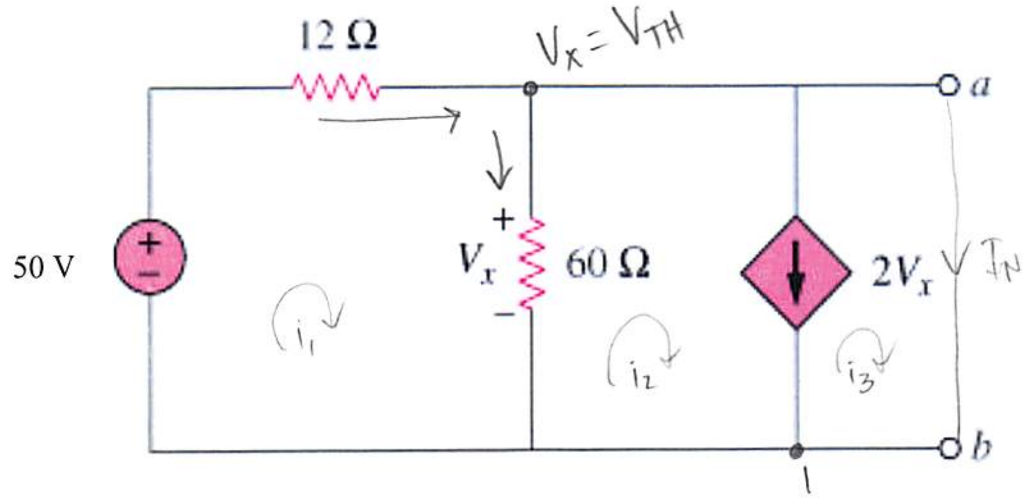
Fig.2. Op-amp with Negative feedback



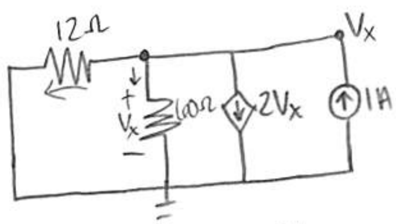
By showing the derivation of the output with the negative feedback (where $V_- = \beta V_o$), one can see that the output only relies on the input and "β" (not the gain), when the gain is large (which it is in pretty much all scenarios. This helps the stability of the output, decreasing distortion & avoiding saturation.

$$V_o = A(V_+ - V_-)$$
$$V_o = A(V_+ - \beta V_o)$$
$$V_o = AV_+ - \beta A V_o$$
$$V_o + \beta A V_o = AV_+$$
$$V_o(1+\beta A) = AV_+$$
$$V_o = V_+\left(\frac{A}{1+\beta A}\right)$$
$$V_o = V_+\left(\frac{1}{\frac{1}{A}+\beta}\right)$$
$$V_o = V_+\left(\frac{1}{\beta}\right)$$

2 –Obtain the Thevenin and Norton equivalent of the circuit below



To find R_{TH}/R_N:



At V_0: $\left(1 = 2V_x + \frac{V_x}{60} + \frac{V_x}{12}\right)60$

$60 = 120V_x + V_x + 5V_x$

$126V_x = 60$

$V_x = \frac{60}{126} = \frac{30}{63} = \frac{10}{21}$

$R_{TH} = \frac{V_x}{1}$

$\boxed{R_{TH} = \frac{10}{21}\,\Omega}$

$V_{TH} = I_N R_{TH}$

$I_N = \frac{V_{TH}}{R_{TH}}$

$I_N = \left(\frac{\cancel{125}^{25}}{\cancel{63}_{3}}\right)\left(\frac{\cancel{21}^{1}}{\cancel{10}_{2}}\right) = \frac{25}{6}\text{ A}$

$\boxed{I_N = \frac{25}{6}\text{ A}}$

To find V_{TH} (using above diagram):

$\left(\frac{50 - V_x}{12} = \frac{V_x}{60} + 2V_x\right)60$

$250 - 5V_x = V_x + 120V_x$

$250 = 126V_x$

$V_x = \frac{250}{126} = \frac{125}{63}$

$\boxed{V_{TH} = \frac{125}{63}\text{ V}}$

10/10

To find I_N (using above diagram):

Loop 1: $-50 + 12i_1 + 60i_1 - 60i_2 = 0$

$72i_1 - 60i_2 = 50$

$36i_1 - 30i_2 = 25 \Rightarrow 36i_1 - 30i_1 = 25$

$6i_1 = 25$

$i_1 = \frac{25}{6}\text{ A} = i_2$

Loop 2 & 3: $60i_2 - 60i_1 = 0$

$i_1 = i_2$

$V_x = 60(i_1 - i_2)$

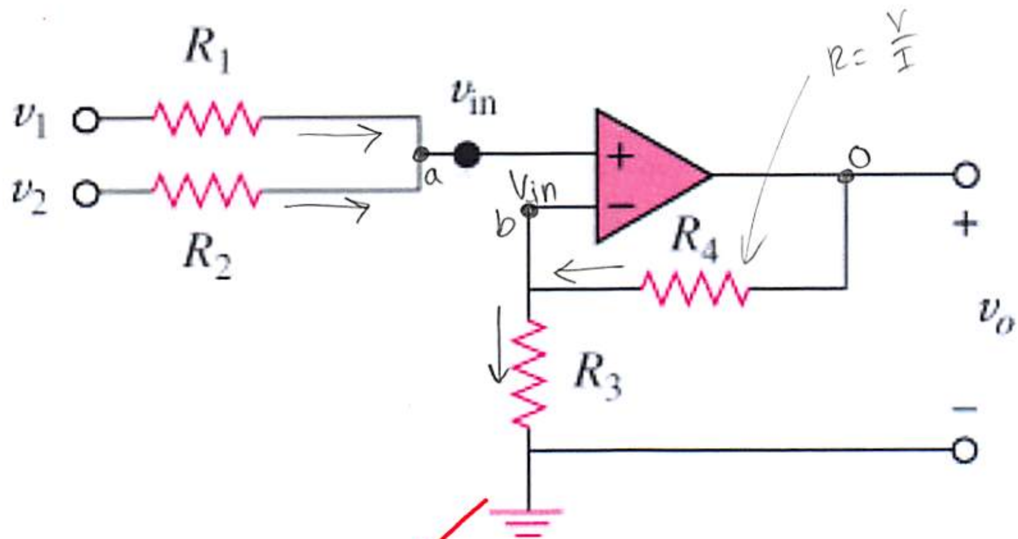
Node 1: $i_2 = i_3 + 2V_x$

$i_2 = i_3 + 120i_1 - 120i_2$

$i_3 = i_2$

$i_3 = \frac{25}{6}\text{ A}$

3. Given the op amp circuit shown, express v_o in terms of v_1 and v_2.



At node A:

$$\left(\frac{V_1 - V_{in}}{R_1} + \frac{V_2 - V_{in}}{R_2} = 0\right) R_1 R_2$$

$$V_1 R_2 - V_{in} R_2 + V_2 R_1 - V_{in} R_1 = 0$$

$$V_{in} R_2 + V_{in} R_1 = V_1 R_2 + V_2 R_1$$

$$V_{in}(R_1 + R_2) = V_1 R_2 + V_2 R_1$$

$$V_{in} = \frac{V_1 R_2 + V_2 R_1}{R_1 + R_2}$$

At node B:

$$\left(\frac{V_o - V_{in}}{R_4} = \frac{V_{in}}{R_3}\right) R_3 R_4$$

$$V_o R_3 - V_{in} R_3 = V_{in} R_4$$

$$V_o R_3 = V_{in}(R_3 + R_4)$$

$$V_o = V_{in}\left(\frac{R_3 + R_4}{R_3}\right)$$

	$V_1 R_2$	$+ V_2 R_1$
R_3	$V_1 R_2 R_3$	$V_2 R_1 R_3$
$+ R_4$	$V_1 R_2 R_4$	$V_2 R_1 R_4$

Plug in Vin from node A:

$$V_o = \left(\frac{V_1 R_2 + V_2 R_1}{R_1 + R_2}\right)\left(\frac{R_3 + R_4}{R_3}\right)$$

$$V_o = \frac{V_1 R_2 R_3 + V_1 R_2 R_4 + V_2 R_1 R_3 + V_2 R_1 R_4}{R_1 R_3 + R_2 R_3}$$

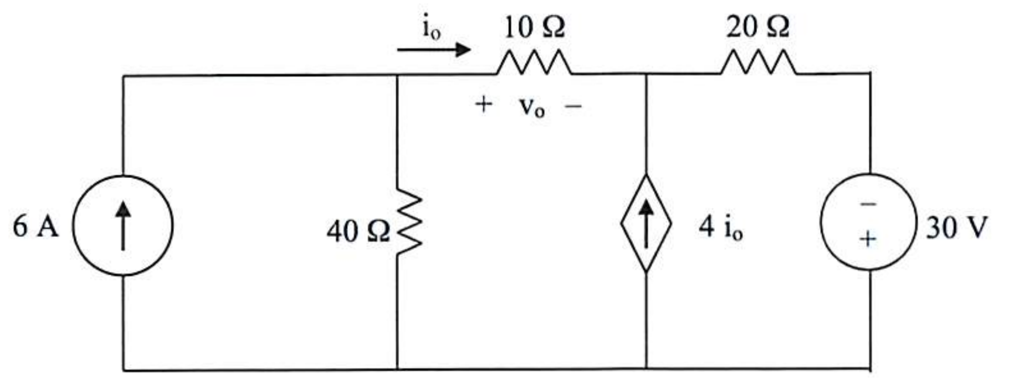
$$V_o = \frac{V_1(R_2 R_3 + R_2 R_4)}{R_1 R_3 + R_2 R_3} + \frac{V_2(R_1 R_3 + R_1 R_4)}{R_1 R_3 + R_2 R_3}$$

$$\boxed{V_o = V_1\left(\frac{R_2 R_3 + R_2 R_4}{R_1 R_3 + R_2 R_3}\right) + V_2\left(\frac{R_1 R_3 + R_1 R_4}{R_1 R_3 + R_2 R_3}\right)}$$

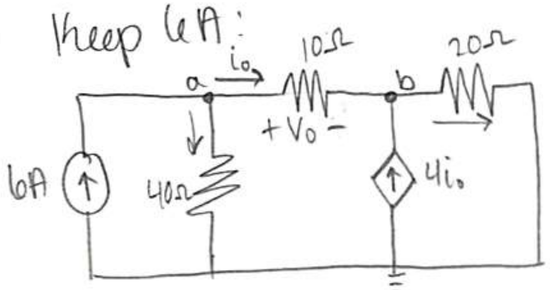
10/10

$$V_o = V_1\left(\frac{R_2 R_3}{R_1 R_3 + R_2 R_3} + \frac{R_2 R_4}{R_1 R_3 + R_2 R_3}\right) + V_2\left(\frac{R_1 R_3}{R_1 R_3 + R_2 R_3} + \frac{R_1 R_4}{R_1 R_3 + R_2 R_3}\right)$$

4 – Use the superposition principle to find i_o and v_o in the circuit below



Keep 6A:



Node A: $\left(6 = \frac{V_a}{40} + \frac{V_a - V_b}{10}\right)40$

$240 = V_a + 4V_a - 4V_b$

$5V_a - 4V_b = 240$

Node B: $\frac{V_a - V_b}{10} + 4i_o = \frac{V_b}{20}$

$i_o = \frac{V_a - V_b}{10}$

$\Rightarrow \left[\frac{V_a - V_b}{10} + 4\left(\frac{V_a - V_b}{10}\right) = \frac{V_b}{20}\right]20$

$2V_a - 2V_b + 8V_a - 8V_b = V_b$

$10V_a = 11V_b$

$10V_a - 11V_b = 0$

$$\begin{bmatrix} 5 & -4 \\ 10 & -11 \end{bmatrix}\begin{bmatrix} V_a \\ V_b \end{bmatrix} = \begin{bmatrix} 240 \\ 0 \end{bmatrix}$$

$|A| = -55 + 40 = -15$

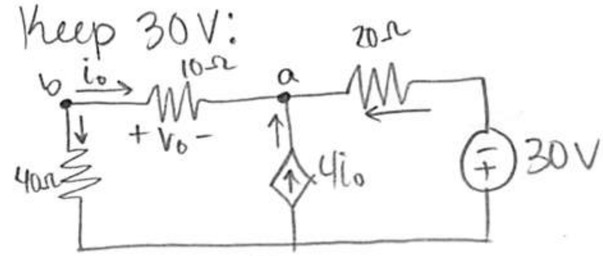
$|A_{Va}| = \begin{vmatrix} 240 & -4 \\ 0 & -11 \end{vmatrix} = -2640 - 0 = -2640$

$|A_{Vb}| = \begin{vmatrix} 5 & 240 \\ 10 & 0 \end{vmatrix} = 0 - 2400 = -2400$

$V_a = \frac{2640}{15} = \frac{528}{3}V$ & $V_b = \frac{2400}{15} = \frac{480}{3}$ $\Rightarrow V_o = V_a - V_b = \frac{528 - 480}{3} = \frac{48}{3} = 16$ & $i_o = \frac{V_o}{10} = 1.6A$

$V_o = 16V$

Keep 30V:



Node A: $\frac{-30 - V_a}{20} + 4i_o + \frac{V_b - V_a}{10} = 0$

$i_o = \frac{V_b - V_a}{10}$

$\left(\frac{-30 - V_a}{20} + 4\left(\frac{V_b - V_a}{10}\right) + \frac{V_b - V_a}{10} = 0\right)20$

$-30 - V_a + 8V_b - 8V_a + 2V_b - 2V_a = 0$

$-11V_a + 10V_b = 30$

10/10

Node B: $\left(\frac{V_b - V_a}{10} + \frac{V_b}{40} = 0\right)40$

$4V_b - 4V_a + V_b = 0$

$-4V_a + 5V_b = 0$

$$\begin{bmatrix} -11 & 10 \\ -4 & 5 \end{bmatrix}\begin{bmatrix} V_a \\ V_b \end{bmatrix} = \begin{bmatrix} 30 \\ 0 \end{bmatrix}$$

$|A| = -55 + 40 = -15$

$|A_{Va}| = \begin{vmatrix} 30 & 10 \\ 0 & 5 \end{vmatrix} = 600$

$|A_{Vb}| = \begin{vmatrix} -11 & 30 \\ -4 & 0 \end{vmatrix} = 120$

$V_a = \frac{-600}{15} = \frac{-120}{3} = -40$

$V_b = \frac{-120}{15} = \frac{-24}{3} = -8$

$V_o = V_b - V_a$

$V_o = -8 + 40$

$V_o = 32V$

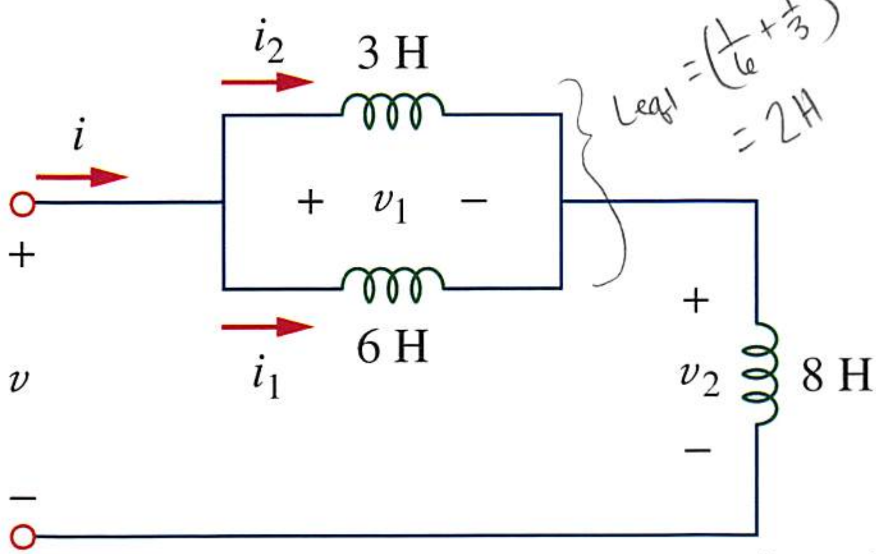
$i_o = \frac{V_b - V_a}{10}$

$i_o = \frac{32}{10} = 3.2A$

$$\boxed{\begin{aligned} V_o &= 16 + 32 = 48V \\ i_o &= 3.2 + 1.6 = 4.8A \end{aligned}}$$

5. In the circuit below, $i_1(t)$ $0.6e^{2t}$ A. If $i(0)$ 1.4 A, find: (a) $i_2(0)$; (b) $i_2(t)$ and $i(t)$; (c) $v_1(t)$, $v_2(t)$, and $v(t)$.

$\hookrightarrow \frac{di_1}{dt} = 1.2e^{2t}$



$L_{eq} = \left(\frac{1}{6} + \frac{1}{3}\right)^{-1} = 2H$

a) $i_2(0)$

$i_1(0) = 0.6e^0 = 0.6$ A

$i(0) = 1.4$ A

$i = i_1 + i_2 \Rightarrow i_2 = i - i_1$

$i_2 = 1.4 - 0.6$

$\boxed{i_2 = 0.8 A}$

b) $i_2(t)$ & $i(t)$

$i_2 = 2 * i_1 - 0.4$

$i_2 = 2(0.6e^{2t}) - 0.4$

$\boxed{i_2 = (1.2e^{2t} - 0.4) A} \rightarrow \frac{di_2}{dt} = 2.4e^{2t}$

$i = i_1 + i_2$

$i = 0.6e^{2t} + 1.2e^{2t} - 0.4$

$\boxed{i = (1.8e^{2t} - 0.4) A} \rightarrow \frac{di}{dt} = 3.6e^{2t}$

c) $\overbrace{V_1(t)}^{2H}$, $\overbrace{V_2(t)}^{8H}$, & $\overbrace{V(t)}^{10H}$

$V = L\frac{di}{dt}$

$2.4 \times 3 = 7.2$ $\quad$ $3.6 \times 8 = 28.8$

V_1 (using 3H) $= 3(2.4e^{2t}) = 7.2e^{2t}$

$\boxed{V_1 = 7.2e^{2t} V}$

V_1 (using 6H) $= 6(1.2e^{2t}) = 7.2e^{2t}$

$V_2 = 8(3.6e^{2t}) = 28.8e^{2t}$

$\boxed{V_2 = 28.8e^{2t} V}$

$V = 10(3.6e^{2t}) = 36e^{2t}$

$\boxed{V = 36e^{2t} V}$

15/15