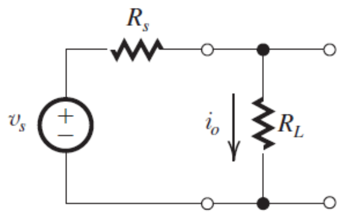
EMTR 1030 – Electronics

Assignment 1

Reference Solutions

Q1. Problem 1.26



$$\frac{i_O}{v_S} = \frac{1}{R_L + R_S}$$

$\Rightarrow v_S = i_O (R_L + R_S)$

Thus,

$v_S = 10^{-4} \times (10^5 + R_S) = 10 + 10^{-4} \times R_S \quad (1)$

and,

$v_S = 5 \times 10^{-4} (10^4 + R_S) = 5 + 5 \times 10^{-4} \times R_S (2)$

Subtracting equation (2) from equation (1) gives

$0 = 5 - 4 \times 10^{-4} \times R_S$

$\Rightarrow R_S = \frac{5}{4 \times 10^{-4}} = 12.5\ \text{k}\Omega$

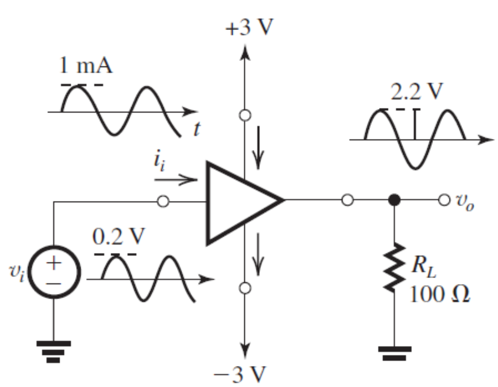
Substituting into equation (1),

$v_S = 10 + 10^{-4} \times 12.5 \times 10^3 = 11.25\ \text{V}$

Finally, the Norton equivalent source is found as follows,

$i_S = v_S / R_S = 900\ \mu\text{A}$

Q2. Problem 1.46



The voltage gain is

$$\frac{V_o}{V_i} = \frac{2.2}{0.2} = 11 \text{ V/V} = 20.8 \text{ dB}$$

The current gain is

$$\frac{I_o}{I_i} = \frac{2.2/0.1}{1.0} = 22 \text{ A/A} = 26.8 \text{ dB}$$

The power gain is

$$\frac{V_o I_o/2}{V_i I_i/2} = 11 \times 22 = 242 \text{ W/W} = 23.8 \text{ dB}$$

The supply power is

$$\frac{V_o^2}{2R_L} \times \frac{1}{\eta} = \frac{2.2^2}{2 \times 0.1 \times 0.1} = 242 \text{ mW}$$

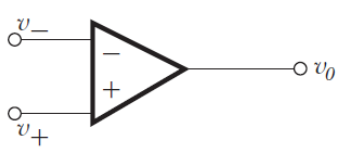
Since the power is drawn from ± 3 V supplies, the supply current must be

$$\frac{242}{3 - (-3)} = 40.3 \text{ mA}$$

The power dissipated in the amplifier is the total power drawn from the supply, less the power dissipated in the load.

$$242 - \frac{2.2^2}{2 \times 0.1} = 217.8 \text{ mW}$$

Q3. Problem 2.3



$$v_O = -3.500 \text{ V}$$

$$v_- = -1.000 \text{ V}$$

For ideal op amp,

$$v_+ = v_- = -1.000 \text{ V}$$

Measured voltage at positive input $= -1.002$ V

Amplifier gain $A = \dfrac{v_O}{v_+ - v_-}$

$$= \frac{-3.500}{-1.002 - (-1.000)}$$

$= 1750$ V/V

Q4. Problem 2.10

Closed-loop gain is

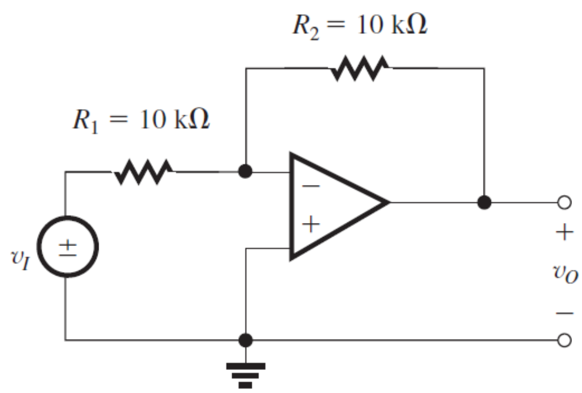
$$\frac{v_O}{v_I} = -\frac{R_2}{R_1} = -\frac{10\ \text{k}\Omega}{10\ \text{k}\Omega}$$

$= -1$ V/V

For $v_I = +1.00$ V,

$v_O = -1 \times 1.00$

$= -\ 1.00$ V



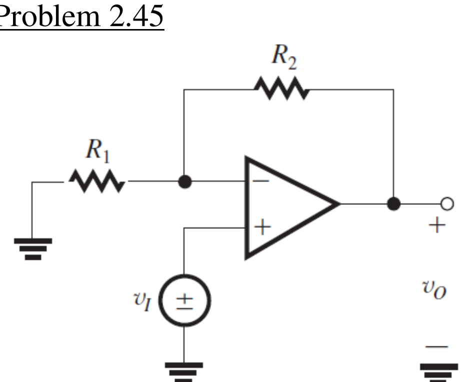
The two resistors are 1% resistors

$$\left|\frac{v_O}{v_I}\right|_{\min} = \frac{10(1-0.01)}{10(1+0.01)} = 0.98\ \text{V/V}$$

$$\left|\frac{v_O}{v_I}\right|_{max} = \frac{10(1+0.01)}{10(1-0.01)} = 1.02\ \text{V/V}$$

Thus the measured output voltage will range from -0.98 V to -1.02 V.

Q5. Problem 2.45



$$\frac{v_O}{v_I} = 1 + \frac{R_2}{R_1}$$

(a) $\frac{v_O}{v_I} = 5 = 1 + \frac{R_2}{R_1}$

$\frac{R_2}{R_1} = 4$; set $R_1 = 10\ \text{k}\Omega$, $R_2 = 40\ \text{k}\Omega$

(b) $\frac{v_O}{v_I} = 10 = 1 + \frac{R_2}{R_1}$

$\frac{R_2}{R_1} = 9$; set $R_1 = 10\ \text{k}\Omega$, $R_2 = 90\ \text{k}\Omega$

(c) $\frac{v_O}{v_I} = 21 = 1 + \frac{R_2}{R_1}$

$\frac{R_2}{R_1} = 20$; set $R_1 = 10\ \text{k}\Omega$, $R_2 = 200\ \text{k}\Omega$

(d) $\frac{v_O}{v_I} = 100 = 1 + \frac{R_2}{R_1}$

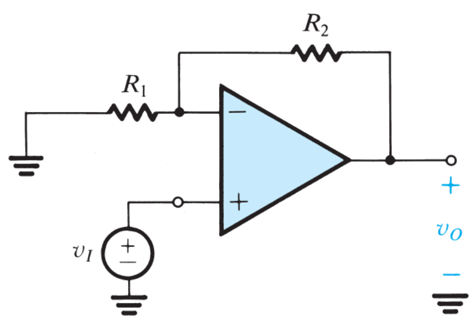
$\frac{R_2}{R_1} = 99$; set $R_1 = 10\ \text{k}\Omega$, $R_2 = 990\ \text{k}\Omega$

Q6:

Consider the noninverting amplifier as shown in the following graph, with $R_1 = 2\ \text{k}\Omega$ and $R_2 = 10\ \text{k}\Omega$, ~~and an ideal closed-loop gain of 100~~.

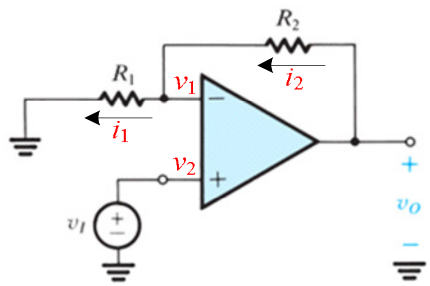
(a) Find the closed-loop gain if $A = 10^5$. Determine the percentage error in the magnitude of G relative to the ideal value of $1+R_2/R_1$. Also determine the voltage v_1 that appears at the noninverting input terminal when $v_I = 0.2$ V.

(b) If the open-loop gain A changes from 10^5 to 10^4, what is the corresponding percentage change in the magnitude of the closed-loop gain G?



Reference Solution

(a) There are two typos: the ideal gain of a non-inverting Op-amp should be $1+\frac{R_2}{R_1}$, instead of $\frac{R_2}{R_1}$. Given $R_1 =$ 2 kΩ and $R_2 =$ 10 kΩ, the ideal gain should be 6, instead of 100.



The ideal gain: $G=\frac{v_o}{v_I}=1+\frac{R_2}{R_1}=1+\frac{10}{2}=6$

If $A = 10^5$, the real gain will be

$$G'=\frac{v_o}{v_I}=\frac{1+R_2/R_1}{1+(1+R_2/R_1)/A}=5.9996$$

Percentage gain change: $\frac{G'-G}{G}=\frac{5.9996-6}{6}=-6.67\times10^{-5}=-0.00667\%$

$v_I = v_2,\ v_1 = v_2 = 0.2V$

(b) If the gain $A = 10^4$, the real gain will be

$$G'=\frac{v_o}{v_I}=\frac{1+R_2/R_1}{1+(1+R_2/R_1)/A}=5.9964.$$

In comparison with the real gain of 5.9996 when the gain $A = 10^5$, the change is:

$$\frac{5.9996-5.9964}{5.9996}=5.334\times10^{-4}=0.005334\%$$

Or even though A has a 10 times change, the real close-loop gain change is negligible!