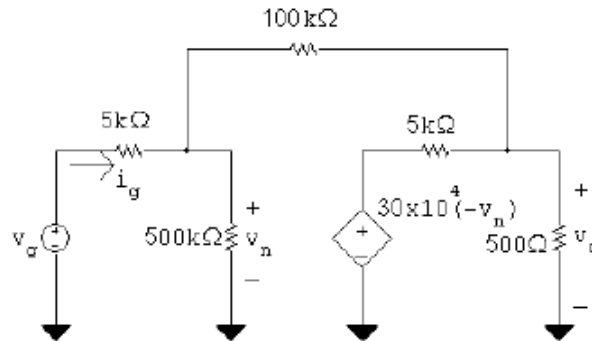


EENG 281 Homework #6 Solutions  
Fall 2013

P 5.43 [a] Replace the op amp with the model from Fig. 5.15:



Write two node voltage equations, one at the left node, the other at the right node:

$$\frac{v_n - v_g}{5000} + \frac{v_n - v_o}{100,000} + \frac{v_n}{500,000} = 0$$

$$\frac{v_o + 3 \times 10^5 v_n}{5000} + \frac{v_o - v_n}{100,000} + \frac{v_o}{500} = 0$$

Simplify and place in standard form:

$$106v_n - 5v_o = 100v_g$$

$$(6 \times 10^6 - 1)v_n + 221v_o = 0$$

Let  $v_g = 1$  V and solve the two simultaneous equations:

$$v_o = -19.9844 \text{ V}; \quad v_n = 736.1 \mu\text{V}$$

Thus the voltage gain is  $v_o/v_g = -19.9844$ .

[b] From the solution in part (a),  $v_n = 736.1 \mu\text{V}$ .

$$[c] \quad i_g = \frac{v_g - v_n}{5000} = \frac{v_g - 736.1 \times 10^{-6} v_g}{5000}$$

$$R_g = \frac{v_g}{i_g} = \frac{5000}{1 - 736.1 \times 10^{-6}} = 5003.68 \Omega$$

[d] For an ideal op amp, the voltage gain is the ratio between the feedback resistor and the input resistor:

$$\frac{v_o}{v_g} = -\frac{100,000}{5000} = -20$$

For an ideal op amp, the difference between the voltages at the input terminals is zero, and the input resistance of the op amp is infinite.

Therefore,

$$v_n = v_p = 0 \text{ V}; \quad R_g = 5000 \Omega$$

$$\text{P 5.45 [a]} \quad \frac{v_n}{16,000} + \frac{v_n - v_g}{800,000} + \frac{v_n - v_o}{200,000} = 0 \quad \text{or} \quad 55v_n - 4v_o = v_g \quad \text{Eq (1)}$$

$$\frac{v_o}{20,000} + \frac{v_o - v_n}{200,000} + \frac{v_o - 50,000(v_p - v_n)}{8000} = 0$$

$$36v_o - v_n - 125 \times 10^4(v_p - v_n) = 0$$

$$v_p = v_g + \frac{(v_n - v_g)(240)}{800} = (0.7)v_g + (0.3)v_n$$

$$36v_o - v_n - 125 \times 10^4[(0.7)v_g - (0.7)v_n] = 0$$

$$36v_o + 874,999v_n = 875,000v_g \quad \text{Eq (2)}$$

Let  $v_g = 1$  V and solve Eqs. (1) and (2) simultaneously:

$$v_n = 999.446 \text{ mV} \quad \text{and} \quad v_o = 13.49 \text{ V}$$

$$\therefore \quad \frac{v_o}{v_g} = 13.49$$

[b] From part (a),  $v_n = 999.446$  mV.

$$v_p = (0.7)(1000) + (0.3)(999.446) = 999.834 \text{ mV}$$

[c]  $v_p - v_n = 387.78 \mu\text{V}$

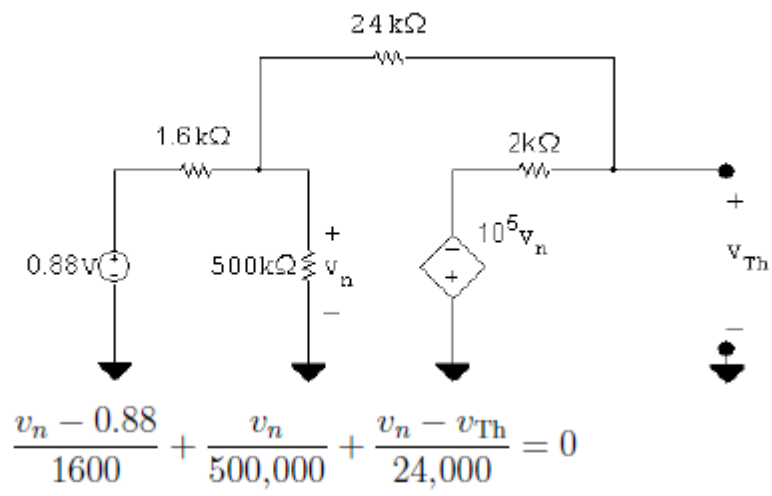
$$\text{[d]} \quad i_g = \frac{(1000 - 999.83)10^{-3}}{24 \times 10^3} = 692.47 \text{ pA}$$

$$\text{[e]} \quad \frac{v_g}{16,000} + \frac{v_g - v_o}{200,000} = 0, \quad \text{since } v_n = v_p = v_g$$

$$\therefore \quad v_o = 13.5v_g, \quad \frac{v_o}{v_g} = 13.5$$

$$v_n = v_p = 1 \text{ V}; \quad v_p - v_n = 0 \text{ V}; \quad i_g = 0 \text{ A}$$

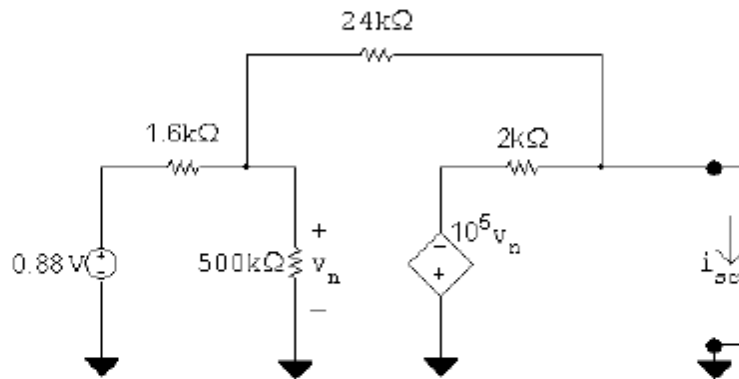
P 5.46 [a]



$$\frac{v_{Th} + 10^5 v_n}{2000} + \frac{v_{Th} - v_n}{24,000} = 0$$

Solving,  $v_{Th} = -13.198 \text{ V}$

Short-circuit current calculation:

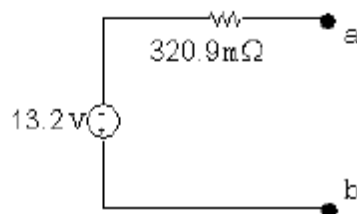


$$\frac{v_n}{500,000} + \frac{v_n - 0.88}{1600} + \frac{v_n - 0}{24,000} = 0$$

$$\therefore v_n = 0.8225 \text{ V}$$

$$i_{sc} = \frac{v_n}{24,000} - \frac{10^5}{2000} v_n = -41.13 \text{ A}$$

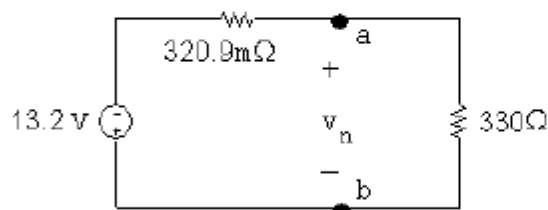
$$R_{Th} = \frac{v_{Th}}{i_{sc}} = 320.9 \text{ m}\Omega$$



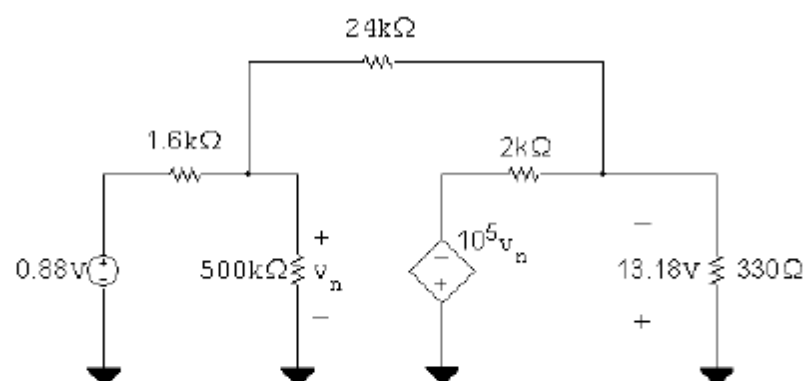
[b] The output resistance of the inverting amplifier is the same as the Thévenin resistance, i.e.,

$$R_o = R_{Th} = 320.9 \text{ m}\Omega$$

[c]



$$v_o = \left( \frac{330}{330.3209} \right) (-13.2) = -13.18 \text{ V}$$



$$\frac{v_n - 0.88}{1600} + \frac{v_n}{500,000} + \frac{v_n + 13.18}{24,000} = 0$$

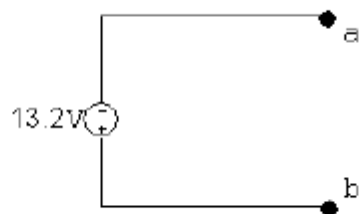
$$\therefore v_n = 942 \mu\text{V}$$

$$i_g = \frac{0.88 - 942 \times 10^{-6}}{1600} = 549.41 \mu\text{A}$$

$$R_g = \frac{0.88}{i_g} = 1601.71 \Omega$$

P 5.47 [a]  $v_{Th} = -\frac{24,000}{1600}(0.88) = -13.2 \text{ V}$

$R_{Th} = 0$ , since op-amp is ideal



[b]  $R_o = R_{Th} = 0 \Omega$

[c]  $R_g = 1.6 \text{ k}\Omega$  since  $v_n = 0$