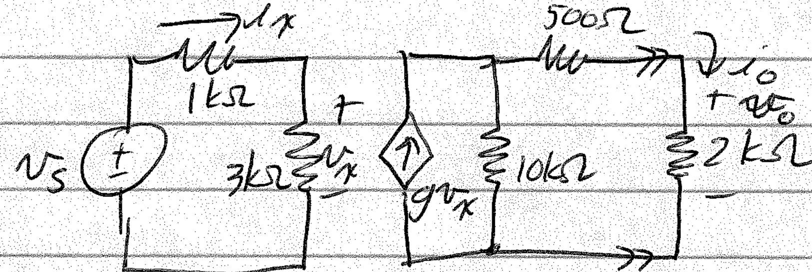
HW 5 - Solutions

4-3 Find voltage gain and current gain (i_o/i_x) for $g = 2\times10^{-3}$ S. For $v_s = 5$ V find the power supplied by the input source and the power delivered to the load.



$$v_x = \frac{3k\Omega}{3k\Omega + 1k\Omega} v_s = \frac{3}{4} v_s$$

$$i_x = \frac{v_s}{4k\Omega} = .25\times10^{-3} v_s$$

Current division

$$i_o = \frac{10k\Omega}{2k\Omega + 500\Omega + 10k\Omega} g v_x$$

$$= \frac{10k\Omega}{12.5k\Omega} g v_x$$

$$= \frac{1}{1.25} g v_x = \frac{4}{5} g v_x = 0.8 g v_x$$

$$i_o = (0.8)(2\times10^{-3}) v_x =$$

$$i_o = 1.6\times10^{-3} v_x = 1.6\times10^{-3}\left(\frac{3}{4}v_s\right) = 1.2\times10^{-3} v_s$$

$$v_o = 2k\Omega\, i_o = 3.2\, v_x = 3.2\left(\frac{3}{4}v_s\right) = 2.4 v_s$$

Voltage Gain $= \frac{2.4 v_s}{v_s} = 2.4$

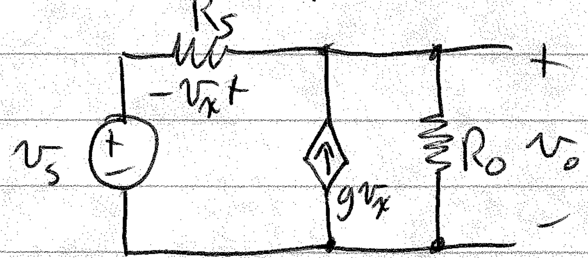
Current Gain $= \frac{1.2\times10^{-3} v_s}{.25\times10^{-3} v_s} = 4.8$

$$v_o = 2.4 v_s = 2.4(5V) = 12V$$

$$P_L = \frac{v_o^2}{R_L} = \frac{(12V)^2}{2k\Omega} = \frac{144}{2k} W = \underline{72 mW}$$

$$P_s = -i_x(5V) = -(.25 \times 10^{-3})(5V)(5V)$$
$$= -625 \times 10^{-5} W = \underline{-6.25 mW}$$

4-9 Find an expression for v_o/v_s:



Nodal Analysis: $\frac{v_o - v_s}{R_s} - g v_x + \frac{v_o}{R_o} = 0$

$$\left(\frac{1}{R_s} + \frac{1}{R_o}\right)v_o - \frac{1}{R_s}v_s - g(v_o - v_s) = 0$$

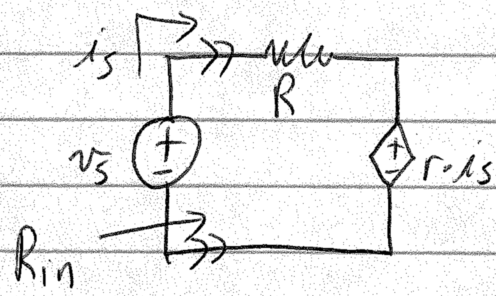
$$\left(\frac{1}{R_s} + \frac{1}{R_o} - g\right)v_o - \left(\frac{1}{R_s} - g\right)v_s = 0$$

$$\left(\frac{R_o + R_s - gR_oR_s}{R_oR_s}\right)v_o = \left(\frac{1 - gR_s}{R_s}\right)v_s$$

$$v_o = \left(\frac{R_o}{R_o + R_s - gR_oR_s}\right)(1 - gR_s)\, v_s$$

$$\boxed{\frac{v_o}{v_s} = \frac{R_o(1 - gR_s)}{(R_o + R_s - gR_oR_s)}}$$

4-15 Find R_{in}



$$R_{in} = \frac{v_s}{i_s}$$

$$i_s = \frac{v_s - r \cdot i_s}{R} = \frac{1}{R} v_s - \frac{r}{R} i_s$$

$$\left(1 + \frac{r}{R}\right) i_s = \frac{1}{R} v_s$$

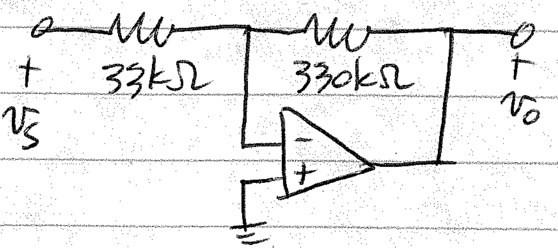
$$\frac{R+r}{R} i_s = \frac{1}{R} v_s$$

$$i_s = \frac{1}{R+r} v_s$$

$$R_{in} = \frac{v_s}{\frac{1}{R+r} v_s} = \underline{R+r}$$

4-23 Find the voltage gain of each:

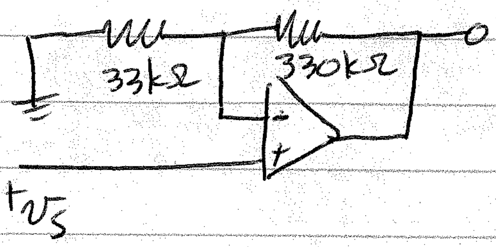
a.)



Inverting:

$G = -\frac{330k\Omega}{33k\Omega} = -10$

b.)



Noninverting

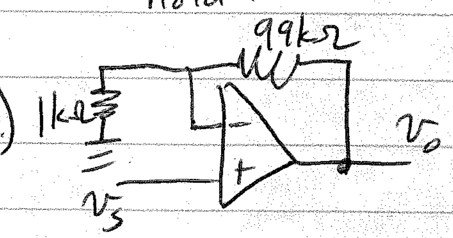
$G = 1 + \frac{330k}{33k} = 11$

4-25 Two Op amp ckts claim to have $|G| = 100$.

a.) Show that the claims are true.

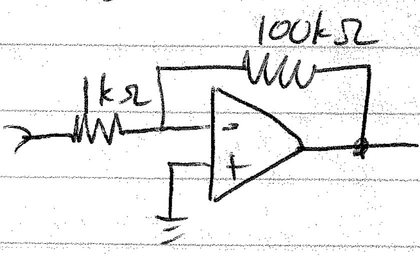
b.) A practical src ~~at~~ with 1 kΩ resistance is connected to input of each. Does the claim still hold?

a.)



Non inverting:

Gain $= \left(1 + \frac{99k}{1k}\right) = 100$ ✓



Inverting:

Gain $= -\frac{100k}{1k} = -100$ ✓

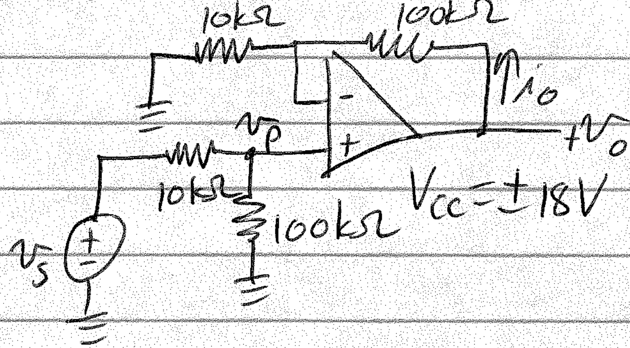
b.) Connecting to Non-Inverting, still holds. ✓

Connecting to Inverting we must include internal R in Gain: $G = -\frac{100k}{2k} = -50$

4-31 For ckt below,

a.) Find v_o in terms of v_s

b.) Find i_o for $v_s = 0.5V$. Repeat for $v_s = 2V$.



a.) Non Inverting: $v_o = \left(1 + \frac{100k}{10k}\right) v_p = 11 v_p$

Voltage Division: $v_p = \frac{100k}{100k + 10k} v_s = \frac{10}{11} v_s$

So $v_o = 11\left(\frac{10}{11}\right) v_s = \underline{10 v_s}$

b.) $i_o = \frac{v_o - v_p}{100k\Omega} = \frac{10 v_s - \frac{10}{11} v_s}{100k\Omega} = \frac{\frac{110-10}{11} v_s}{100k\Omega}$

$i_o = \frac{100}{11} v_s / 100k\Omega = \frac{1}{11} v_s \text{ (mA)}$

For $v_s = \frac{1}{2}V$, $\underline{i_o = \frac{1}{11}\left(\frac{1}{2}\right) mA} = \frac{1}{22} mA = 0.045 mA$

$\underline{v_o = 10\left(\frac{1}{2}\right) = 5V}$

For $v_s = 2V$, $\cancel{i_o = \frac{1}{11}(2V) mA = \frac{2}{11} mA}$

$v_o = 10(2V) = 20V$ which exceeds V_{cc},

so $v_o = 18V$ and $i_o = \frac{\left(18 - \frac{10}{11}(2)\right)V}{100k\Omega}$

$i_o = \frac{\frac{198-20}{11}}{100k} = \frac{\frac{178}{11}}{100k}$

$= 0.161 mA$