EE 321 Analog Electronics, Fall 2011
Homework #2 solution

SS 2.22. The circuit in Fig. P2.22 is frequently used to provide an output voltage v_o proportional to an input signal current i_i. Derive expressions for the transresistance $R_m \equiv v_o/i_i$ and the input resistance $R_i \equiv v_i/i_i$ for the following cases:

(a) A is infinite.

(b) A is finite.

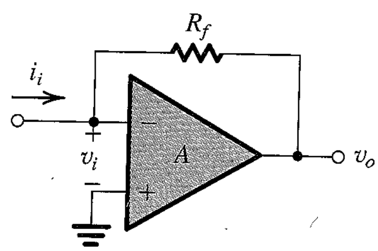

FIGURE P2.22

(a) We have

$$v_o = v_i - i_i R_f = -i_i R_f$$

and thus the transresistance is

$$R_m = \frac{v_o}{i_i} = -R_f$$

For the input resistance we have $v_i = 0$ for all values of i_i, and thus

$$R_i = \frac{v_i}{i_i} = \frac{0}{i_i} = 0$$

(b) We have the same expression

$$v_o = v_i - i_i R_f$$

But in this case we also have $v_o = -Av_i$ (negative because the polarity of v_i is opposite the polarity on the inputs of the op-amp), and thus

$$v_o = -\frac{v_o}{A} - i_i R_f$$

$$v_o\left(1 + \frac{1}{A}\right) = -i_i R_f \tag{1}$$

and

$$R_m = \frac{v_o}{i_i} = -\frac{R_f}{1 + \frac{1}{A}}$$

For the input resistance we have

$$R_i = \frac{v_i}{i_i} = -\frac{v_o}{A i_i}$$

From equation 1 we can find v_o and insert it

$$R_i = \frac{i_i R_f \frac{1}{1+\frac{1}{A}}}{A i_i} = R_f \frac{1}{A+1}$$

(notice that both expressions go to the expressions found in (a) as we let $A \to \infty$).

SS 2.82. Measurements made on the internally compensated amplifiers listed below provide the DC gain and the frequency at which the gain has dropped by 20 dB. For each, what are the 3 dB and unity-gain frequencies?

(a) 3×10^5 and 6×10^2 Hz.

(b) 50×10^5 and 10 Hz

(c) 1500 and 0.1 MHz

(d) 100 and 0.1 GHz

(e) 25 V/mV and 25 kHz

The 3 dB frequency, f_c, is a tenth of the 20 dB frequency. The unity gain frequency, f_1, is the 3 dB frequency multiplied by the DC gain.

(a) $f_c = 60\,\text{Hz}$, $f_1 = 60 \times 3 \times 10^5 = 18\,\text{MHz}$

(b) $f_c = 1\,\text{Hz}$, $f_1 = 1 \times 50 \times 10^5 = 50 \times 10^5 = 5\,\text{MHz}$

(c) $f_c = 10\,\text{kHz}$, $f_1 = 10 \times 10^3 \times 1500 = 15\,\text{MHz}$

(d) $f_c = 10\,\text{MHz}$, $f_1 = 1\,\text{GHz}$

(e) $f_c = 2.5\,\text{kHz}$, $f_1 = 2.5 \times 10^3 \times 25 \times 10^3 = 62.5\,\text{MHz}$

SS 2.102. A noninverting amplifier with a closed-loop gain of 1000 is designed using an op amp having an input offset voltage of 3 mV and output saturation levels of ±13 V. What is the maximum amplitude of the sine wave that can be applied at the input without the output clipping? If the ampliifier is capacitively coupled in the manner indicated in Fig. 2.36, what would the maximum possible amplitude be?

If the maximum output is 13 V, the the maximum input is 13 mV. Of that 3 mV is the offset, leaving a maximum signal amplitude of 10 mV.

If the amplifier is capcitively coupled on the input we can use superposition for the analysis, adding the DC offset voltage source and the AC input source. Since for the DC source the gain path has a open circuit there will be no current flowing in it, and the output voltage from the offset is equal to the offset voltage, 3 mV. The result is that the AC source can supply up to 13 V − 3 mV, effectively 13 V on the output, which corresponds to 13 mV on the input. This works when the input source is an AC signal only.

SS 2.110. An op amp is connected in a closed loop with gain of +100 utilizing a feedback resistor of 1 MΩ.

(a) If the input bias current is 100 nA, what output voltage results with the input grounded?

(b) If the input offset voltage is ±1 mV and the inptut bias current as in (a), what is the largest possible output that can be observed with the input grounded?

(c) If the bias-current compensation is used, what is the value of the required resistor? If the offset current is no more than one-tenth the bias current, what is the resulting output offset voltage (due to offset current alone)?

(d) With the bias-current compensation as in (c) in place what is the largest DC voltage at the output due to the combined effect of offset voltage and offset current?

This is a non-inverting op-amp. Since the feedback resistor is $R_2 = 1\,\text{M}\Omega$, the resistor to ground must be $R_1 = 1\,\text{M}\Omega/99 = 10.1\,\text{k}\Omega$.

(a) If the input is grounded then the inverting input is also at ground and thus all the bias current flows through the feedback resistor, resulting in a positive output voltage

$$v_o = I_B R_2 = 100 \times 10^{-9} \times 1 \times 10^6 = 0.1\,\text{V}$$

(b) With an input offset voltage of ±1 V we expect an output $v_o = 100 \times (\pm 1\,\text{mV}) = \pm 0.1\,\text{V}$. Thus the maximum output is 0.2 V.

(c) The bias compensating resistor, R_B, should be equal to the ground resistor, R_1, thus $R_B = 10.1\,\text{k}\Omega$. This gives rise to a voltage drop which causes exactly the bias current to flow through R_1, no current through R_2, and zero output voltage. If the offset current is one tenth of the bias current, then the resulting output voltage is one tenth of the output voltage when considering only bias current without compensation, except that it can be either positive or negative,

$$v_o = \pm 0.01\,\text{V}$$

(d) The value of the output due to offset voltage is 0.1 V with either sign. The value of output due to offset current is 0.01 V with either sign. The largest value of the combined output is 0.11 V, either positive or negative.