EE 521 Instrumentation and Measurements
Fall 2007
Solutions for homework assignment #3

2.9
A)

$$I_1 + I_F = 0 \qquad I_F = \frac{V_o}{R_F}$$

$$G = \frac{V_o}{I_1} = -R_F$$

B)
This is not a negative feedback circuit. When $V_1 > 0$, V_o goes to maximum negative voltage. When $V_1 < 0$, V_o goes to maximum positive voltage.
C)

$$I_1 + I_F = 0 \qquad I_F = V_0 sC$$

$$G = \frac{V_o}{I_1} = -\frac{1}{sC}$$

D)

$$I_1 + I_2 = 0 \qquad I_1 = \frac{V_1}{\frac{1}{sC_1} + R_1} \qquad I_2 = V_o sC_2 + \frac{V_o}{R_2} = V_o\left(sC_2 + \frac{1}{R_2}\right)$$

$$G = \frac{V_o}{V_1} = -\frac{\frac{1}{sC_1} + R_1}{sC_2 + \frac{1}{R_2}}$$

E)

$$I_1 + I_2 = 0 \qquad I_1 = \frac{V_1}{R_1} \qquad I_2 = \frac{V_o}{R_2 + \frac{1}{sC_2}}$$

$$G = \frac{V_o}{V_1} = -\frac{R_2 + \frac{1}{sC_2}}{R_1}$$

F)

$$I_1 + I_2 + I_3 = 0 \qquad I_1 = \frac{V_1}{R_1} \qquad I_2 = V_1 sC_1 \qquad I_3 = V_o sC_2$$

$$G = \frac{V_o}{V_1} = -\frac{\frac{1}{R_1} + sC_1}{sC_2}$$

G)

$$I_1 + I_2 = 0 \qquad I_1 = \frac{V_1}{R_1 + \frac{1}{sC_1}} \qquad I_2 = \frac{V_o}{R_2}$$

$$G = \frac{V_o}{V_1} = -\frac{R_2}{R_1 + \frac{1}{sC_1}}$$

2.10

Node equation for point V_2

$$\frac{V_B}{R_3} + \frac{V_1}{R + \Delta R} = 0$$

Node equation for V_3

$$\frac{V_B}{R_3} + \frac{V_1}{R} + \frac{V_o}{R_2} = 0$$

We want to eliminate V_1

$$-V_B \frac{R + \Delta R}{R_3} = V_1 = -V_B \frac{R}{R_3} - V_o \frac{R}{R_2}$$

$$V_o \frac{R}{R_2} = V_B \frac{R + \Delta R}{R_3} - V_B \frac{R}{R_3} = V_B \frac{\Delta R}{R_3}$$

$$\frac{V_o}{V_B} = \frac{R_2}{R_3} \frac{\Delta R}{R}$$

2.11

A DA has $V_o = A_D V_{1d} + A_C V_{1c}$, and $\frac{A_D}{A_C} = 120\,\mathrm{dB}$, where $V_{1d} = \frac{V_+ - V_-}{2}$, and $V_{1c} = \frac{V_+ + V_-}{2}$. We are given that

$$V_+ = A \sin \omega t \qquad V_- = 0$$

and that

$$\langle V_o^2 \rangle = 1.0\,\mathrm{V}$$

We are to determine A_D and A_C.

$$V_{1d} = \frac{A}{2} \sin \omega t \qquad V_{1c} = \frac{A}{2} \sin \omega t$$

$$V_o = \left(\frac{AA_D}{2} + \frac{AA_C}{2} \right) \sin \omega t$$

so that

$$\langle V_o^2 \rangle = \frac{1}{2} \left(\frac{AA_D}{2} + \frac{AA_C}{2} \right)^2 = \frac{A^2}{8} \left(A_D + A_C \right)^2 = \frac{A^2}{8} \left(10^6 + 1 \right)^2 A_C^2$$

$$A_C = \sqrt{\frac{8\langle V_o^2 \rangle}{A^2 \left(10^6+1\right)^2}} = \sqrt{\frac{1}{0.004^2 10^{12}}} = 7.07 \times 10^{-4}$$

Then

$$A_D = 10^6 A_C = 707$$

2.12

We have a DA described by $V_o = A_D V_{1d} + A_C V_{1c}$, where $V_1(t) = A_1 \sin(\omega_1 t)$, and $V_1'(t) = -A_1 \sin(\omega_1 t) + A_2 \sin(\omega_2 t)$, $A_D = 10^3$, and $A_C = 10^{-2}$.

(a) The CMRR of the amplifier is

$$\text{CMRR} = \frac{A_D}{A_C} = \frac{10^3}{10^{-2}} = 10^5 = 100\,\text{dB}$$

(b) To find $V_o(t)$ we first write down V_{1d} and V_{1c},

$$V_{1d}(t) = \frac{V_1(t) - V_1'(t)}{2} = A_1 \sin(\omega_1 t) - \frac{A_2}{2} \sin(\omega_2 t)$$

$$V_{1c}(t) = \frac{V_1(t) + V_1'(t)}{2} = \frac{A_2}{2} \sin(\omega_2 t)$$

$$\begin{aligned} V_o(t) =& A_D V_{1d}(t) + A_C V_{1c}(t) = A_D A_1 \sin(\omega_1 t) - \frac{A_D A_2}{2} \sin(\omega_2 t) + \frac{A_C A_2}{2} \sin(\omega_2 t) \\ =& A_D A_1 \sin(\omega_1 t) - (A_D - A_C) \frac{A_2}{2} \sin(\omega_2 t) \end{aligned}$$

Inserting numbers we get

$$V_o(t) = 2 \sin(2\pi 400 t) - 1000 \sin(377 t)$$