Solutions

EET-200/210 Problem set for Gain Calculations Name ______________________

1) Determine the voltage, current and power gain, as a ratio and in dBs, of an amplifier with the following input/output characteristics:

Vin = 25 mV	Vout = 4.4 V
Iin = 600 µA	Iout = 85 mA

2) An amplifier has a +30 dB voltage gain and an input voltage of 1 mV. Determine the output voltage (in volts).

3) A 5 Vp 400 MHz signal is input into 500 feet of cable (RG-6/U) which has an attenuation of -4 dB/100 feet. Determine the gain of the repeater (amplifier) needed at the end of this cable so that:

   a. The signal is restored to 5 Vp.

   b. The signal is increased to 10 Vp.

4) A student makes the following measurements on a differential amplifier using a 500 mVp input source:

$V_{out\ (DM)}$ = Differential Mode Output Voltage =10 Vp
$V_{out\ (CM)}$ = Common Mode Output Voltage = 75µ Vp

   a. Determine the Differential Mode Gain as a ratio & in dBs.

   b. Determine the Common Mode Gain as a ratio & in dBs.

   c. Determine the Common Mode Rejection Ratio (CMRR) as a ratio and in dBs.

5) A differential amplifier has an input consisting of 10 mVp of 250 Hz signal and 100mVp of 60 Hz noise. The amplifier has a differential gain of +40 dB with a C.M.R.R. of +71.5 dB. Determine the following:

   a. The input S/N ratio. (This is the signal to noise ratio, it is the ratio of the signal voltage to the noise voltage.) Express this as a ratio and in dB. (Hint: S/N = 0.1 as a ratio for the input.)

   b. The differential and common mode gains expressed in dB and ratio form. (Hint: A_{CM} = -31.5 dB)

   c. The signal and noise amplitudes at the output of the amplifier.

   d. The S/N ratio at the output of the amplifier expressed as a ratio and in dB. (Hint: S/N = +51.5 dB)

   e. Studying your answers for part a. and part d., How could the output S/N ratio (in dB's) be easily determined knowing the input S/N and the C.M.R.R?

6) An instrumentation amplifier (an improvement over the differential amplifier) has a C.M.R.R. of +120 dB. The input of this amplifier is a 50 µVp signal swamped with 1.5 Vp of noise (this corresponds to a -89.5 dB Signal-to-Noise ratio). If the differential gain of the instrumentation amplifier is +30 dB, determine:

   a. The common mode gain of the amplifier in dB.

   b. The peak voltages of the signal and noise at the output of the amplifier.

   c. The S/N ratio at the output in dBs.

EET-200/210 Solutions for Gain Calculations

1.) $V_{in} = 25mV$, $V_{out} = 4.4V$ $\Big\}$ $A_v = \frac{4.4V}{25\times10^{-3}V} = 176.0$ $\quad A_v(dB) = 20\log(176.0) = +44.9dB$

$I_{in} = 600\mu A$, $I_{out} = 85mA$ $\Big\}$ $A_I = \frac{I_{out}}{I_{in}} = \frac{85mA}{600\mu A} = 141.67$ $\quad A_I(dB) = 20\log(141.67) = +43.0dB$

$A_p = A_v \cdot A_I = (176.0)(141.67) = 24,933.9$ $\quad A_p(dB) = 10\log(24,933.9) = +43.9dB$

or

$A_p = \frac{P_{out}}{P_{in}}$ $\quad P_{in} = V_{in} \cdot I_{in} = (25mV)(600\mu A) = 15\mu W$

$P_{out} = V_{out} \cdot I_{out} = (4.4V)(85mA) = 0.374W$

$A_p = \frac{P_{out}}{P_{in}} = \frac{0.374W}{15\mu W} = \frac{0.374W}{15\times10^{-6}W} = 24,933$

$A_p(dB) = 10\log\left(\frac{P_{out}}{P_{in}}\right) = 10\log(24,933) = 10(4.396) = +43.9dB$

$A_v(dB) = +44.9dB$ $\quad A_I(dB) = +43.0dB$ $\quad A_p(dB) = +43.9dB$

2.) $A_v(dB) = 20\log\left(\frac{V_{out}}{V_{in}}\right)$ $\therefore$ $\frac{V_{out}}{V_{in}} = 10^{\left(\frac{A_v(dB)}{20}\right)} = 10^{\left(\frac{30dB}{20}\right)} = 10^{1.5}$

$\frac{V_{out}}{V_{in}} = 10^{(1.5)} = 31.6$ $\therefore$ $V_{out} = 31.6\,V_{in}$ $\quad$ Circuit has a gain of 31.6

$V_{out} = 31.6\,(1mV)$

$V_{out} = 31.6mV$

3.) The signal loses 4dB every 100 ft. Over a 500' run, the signal will be attenuated by $-20dB$. To restore the signal to 5V, the amplifier must have a gain of $+20dB$.

a.) $+20dB$ As ratio: $\frac{V_{out}}{V_{in}} = 10^{\left(\frac{+20dB}{20}\right)} = 10^{\left(\frac{20}{20}\right)} = 10^{(1)} = 10$; $A_v = +10$

b.) To get an output voltage of 10V, the signal must be amplified by twice the gain from step a, or 20.

in dB: $A_v(dB) = 20\log(20) = 20(1.3) = +26dB$

4.) $V_{in} = 500\,mV_p$

$V_{out_{DM}} = 10V_p$

$V_{out_{CM}} = 75\mu V_p$

Ratio

a.) A_{DM} $\quad A_{DM} = \frac{V_{out_{DM}}}{V_{in}} = \frac{10V_p}{500mV_p} = \underline{20}$

dB

$A_{DM}(dB) = 20\log(20)$

$\underline{A_{DM}(dB) = +26dB}$

b.) $A_{cm} = \frac{V_{out_{cm}}}{V_{in}} = \frac{75\mu V_p}{500mV_p} = \underline{0.00015}$

$A_{cm}(dB) = 20\log(0.00015)$

$\underline{A_{cm}(dB) = -76.48dB}$

c.) $CMRR = \frac{A_{DM}}{A_{cm}} = \frac{20}{0.00015} = \underline{133{,}333.\bar{3}}$

$CMRR(dB) = 20\log(133{,}333.\bar{3})$

$\underline{+102.5dB}$

OR

$CMRR(dB) = A_{DM}(dB) - A_{cm}(dB)$

$= +26dB - (-76.48dB)$

$CMRR(dB) = +102.48dB$

5.) $V_{in} = 10mV_p$ @ 250 Hz

$V_{in_{noise}} = 100mV_p$ @ 60Hz

$A_{DM} = +40dB$

$CMRR = +71.5dB$

a.) $S.N.R._{input} = \frac{V_{in_{signal}}}{V_{in_{noise}}} = \frac{10mV_p}{100mV_p} = 0.1$

$SNR_{input} = 0.1$ or $SNR(dB) = 20\log(0.1) = -20dB$

These SNR figures tell us the noise is 10 times stronger than the signal or the signal is -20dB lower than the noise.

b.) $\underline{A_{DM} = +40dB}$ (given) $\quad A_{DM}\text{ ratio} = 10^{\left(\frac{A_{DM}(dB)}{20}\right)} = 10^{\left(\frac{+40}{20}\right)} = 10^{2} = 100$

$\underline{A_{DM} = 100}$ as ratio.

$A_{cm}(dB) = A_{DM}(dB) - CMRR(dB) = +40dB - (71.5dB) = \underline{-31.5dB}$, $\quad A_{cm}\text{ ratio} = 10^{\left(\frac{A_{cm}(dB)}{20}\right)} = 10^{\left(\frac{-31.5}{20}\right)} = 10^{-1.575}$

$\underline{A_{cm} = 0.0266}$ as a ratio

c.) $V_{out_{signal}} = V_{in_{signal}} \times A_{DM} = (10mV_p)(100) = 1V_p$ $\quad V_{out_{noise}} = V_{in_{noise}} \times A_{cm} = (100mV_p)(0.0266)$

$\underline{V_{out_{signal}} = 1V_p \text{ signal}}$ $\quad \underline{V_{out_{ratio}} = 2.66mV \text{ noise}}$

d.) $SNR_{output} = \frac{V_{out_{signal}}}{V_{out_{noise}}} = \frac{1V_p}{0.00266V_p} = \underline{375.9 \text{ ratio}}$ $\quad SNR_{output}(dB) = 20\log(375.9) = \underline{+51.5dB}$

e.) $SNR_{input} = -20dB$; $CMRR = +71.5dB$; $SNR_{output} = +51.5dB$ $\therefore SNR_{output}(dB) = SNR_{input}(dB) + CMRR(dB)$

6.) $CMRR = +120\,dB$ given

$V_{in\,signal} = 50\mu V_p$

$V_{in\,noise} = 1.5\,V_p$ noise

$\Big\}\ SNR = -89.5\,dB.$ In otherwards, there is 30,000 times more noise than signal at the input.

$A_{Dm} = +30\,dB$ given

a.) $A_{cm}(dB) = A_{Dm}(dB) - CMRR(dB) = +30\,dB - (120\,dB) = -90\,dB$

$A_{cm}(dB) = -90\,dB$

b.) $A_{Dm}(dB) = +30\,dB \quad A_{Dm} = 10^{\left(\frac{+30\,dB}{20}\right)} = 10^{1.5} = 31.6$ ratio

$V_{out\,signal} = V_{in\,signal} \cdot A_{Dm} = (50\mu V_p)(31.6) = 1{,}580\,\mu V_p = 1.58\,mV_p$

$$\underline{V_{out\,signal} = 1.58\,mV_p}$$

$A_{cm} = -90\,dB \quad A_{cm} = 10^{\left(\frac{-90\,dB}{20}\right)} = 10^{-4.6} = 0.00002512$

$V_{out\,noise} = V_{in\,noise} \cdot A_{cm}$

$V_{out\,noise} = (1.5\,V_p)(0.00002512) = 0.0000377\,V_p$

$V_{out\,noise} = 37.7\,\mu V_p$

c.) $SNR_{output} = \dfrac{V_{out\,signal}}{V_{out\,noise}} = \dfrac{1.58\,mV_p}{37.7\,\mu V_p} = \dfrac{1.58 \times 10^{-3}}{37.7 \times 10^{-6}} = 41.9$

SNR(dB) output = 20*log(41.9) = 20*(1.622) = +32.4 dB

Summing up, the input had 30,000 times more noise than signal. The output had 42 times more signal than noise! This is without filtering or using any additional noise suppression techniques which might be availble.