ECE ECE145B (undergrad) and ECE218B (graduate)

Mid-Term Exam. February 15, 2012

Do not open exam until instructed to.

Open notes, open books, etc

You have 1 hr and 15 minutes.

Use any and all reasonable approximations (5% accuracy is fine.) , ***AFTER STATING THEM.***

Problem	Points Received	Points Possible
1a		7
1b		7
1c		8
1d		8
2a		10
2b		10
3a		15
3b		25
total (145b)		100

ECE 218b students ONLY will be working problem 4

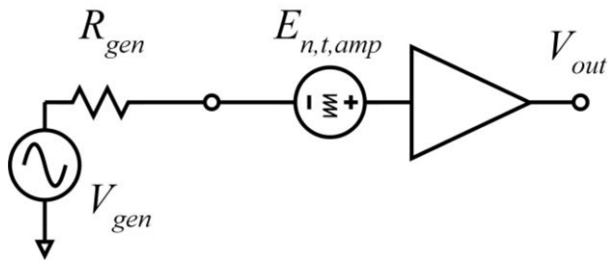
4		40
total (218b)		140

Name: _________________________

Problem 1, 30 points

Signal/noise ratios and noise figure

$R_{gen} = 50\ \Omega$. The amplifier has a total input-referred noise volgate $E_{n,t,amp}$ whose spectral density is $3.31 \cdot 10^{-18}\ \text{V}^2/\text{Hz}$.



The generator is at 300 Kelvin, i.e. the thermal voltage noise of R_{gen} has a spectral density of $4kTR_{gen}$.

Part a, 7 points

Find the spectral density, in V^2/Hz ,of the ***total*** input-referred noise.

$E_{n,t}$ =____

Part b, 7 points

Find amplifier noise figure. Please state in linear and in dB units.

Noise figure ________________________(linear) ____________________(dB)

Part c, 8 points

If we filter V_{out} with a 1 Hz bandwidth*, what RMS value of V_{gen} would result in a 0 dB signal/noise ratio ?

*One can relate integation time or averaging time in an experiment with an equivalent filter bandwidth. 1 Hz filter bandwidth is roughly equivalent to observing a signal for 1 second. So the analysis is, in effect, determining the minimum observable signal in a one-second observation time.

RMS value of V_{gen} ______________________________________

Part d, 8 points

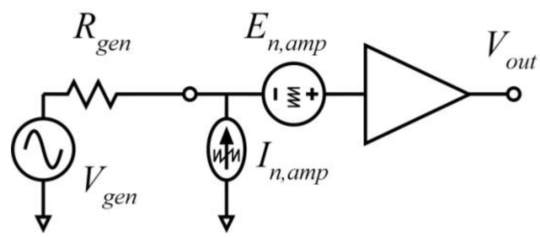
If we filter V_{out} with a 10 kHz bandwidth, about that required for an AM radio, what RMS value of V_{gen} would result in a 20 dB signal/noise ratio ? What is the available generator signal power in this case ?

RMS value of V_{gen} ______________________________________

available generator signal power_____________________________________

Problem 2, 20 points

2-port noise descriptions and signal/noise ratios. .



$R_{gen} = 100\ \Omega$.

$E_{n,amp}$ has a spectral density is $1.0 \cdot 10^{-18}\ \text{V}^2/\text{Hz}$.

$I_{n,amp}$ has a spectral density is $1.0 \cdot 10^{-22}\ \text{A}^2/\text{Hz}$.

The cross spectral density of $E_{n,amp}$ and $I_{n,amp}$ is $5.0 \cdot 10^{-21}\ \text{V} \cdot \text{A/Hz}$, and is purely real.

The generator is at 300 Kelvin, i.e. the thermal voltage noise of R_{gen} has a spectral density of $4kTR_{gen}$.

Part a, 10 points

Find the spectral density, in V^2/Hz ,of the ***total*** input-referred noise.

$E_{n,t}$ =_____________________________________

Part b, 10 points

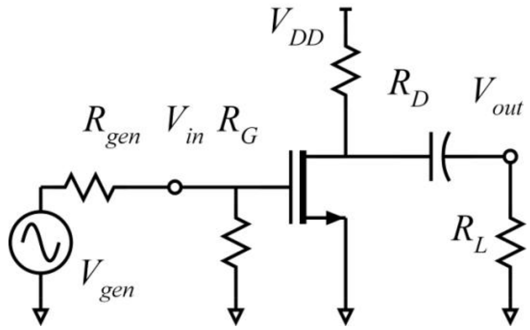
Find amplifier noise figure. Please state in linear and in dB units.

Noise figure ________________________(linear) ____________________(dB)

Problem 3, 50 points

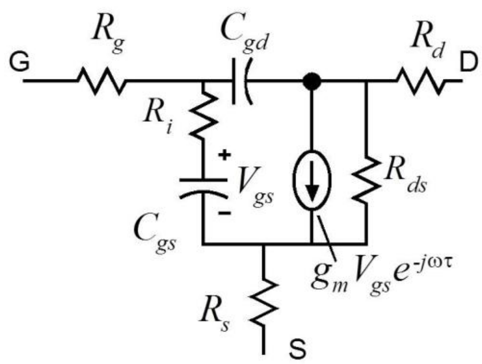
Low-Frequency Circuit Noise Analysis.

We are analyzing the FET amplifer to the right, with the FET small-signal model shown below. $R_D = 1\ \text{k}\Omega$ $R_L = 2\ \text{k}\Omega$, $R_G = 10\ \text{M}\Omega$ (please take this as infinity to simplify the math), $R_{gen} = 1\ \text{k}\Omega$.



The FET has $g_m = 100$ mS, $R_g = 100\ \Omega$, $R_D = R_S = R_i = 0\ \Omega$, $C_{gs} = C_{gd} = 0$ fF, $G_{ds} = 0$ S, $\Gamma = 2/3$.

The generator is at 300 Kelvin, i.e. the thermal voltage noise of R_{gen} has a spectral density of $4kTR_{gen}$.



Part a, 15 points

Draw an equivalent circuit diagram with all random voltage and current generators indicated. Assign a name/symbol to each. Give (1) algebraic expressions and (2) numerical values in A^2/Hz or V^2/Hz for the spectral desnity of each noise generator.

Part b, 25 points

Compute the total input-referred noise voltage spectral density of the circuit, including the noise contributions of the generator, of the amplifier, and of the load resistor.

Give both an algebraic expression and a numerical value in $\mathrm{V^2/Hz}$.

Hint: You might either use the source transposition method, or might choose to compute the output noise and subsequently divide by the circuit gain.

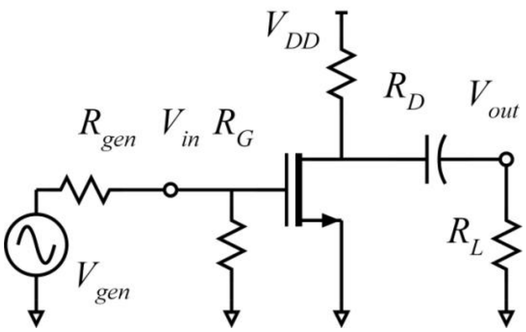
expression for $S_{En,t} =$	
$S_{En,t} =$	$(\mathrm{V^2/Hz})$

Problem 4, 40 points

ECE 218B students only

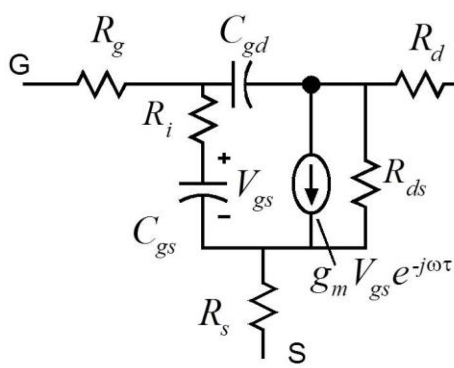
High-Frequency Circuit Noise Analysis.

We are analyzing the FET amplifer to the right, with the FET small-signal model shown below. R_D = 1 kΩ R_L =2 kΩ , R_G =10 MΩ (please take this as infinity to simplify the math), ** R_{gen} =50 Ω. **



The FET has g_m =100 mS, ** R_g =10 Ω** , $R_D = R_S = R_i$ = 0 Ω , C_{gd} = 0 fF, G_{ds} =0 S, Γ =2/3.

The generator is at 300 Kelvin, i.e. the thermal voltage noise of R_{gen} has a spectral density of $4kTR_{gen}$.



We now set * C_{gs} =100 fF* This gives f_τ =100 GHz.

Compute the noise figure at 10 GHz.