ECE ECE145B (undergrad) and ECE218B (graduate)

Mid-Term Exam. February 20, 2013

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.***

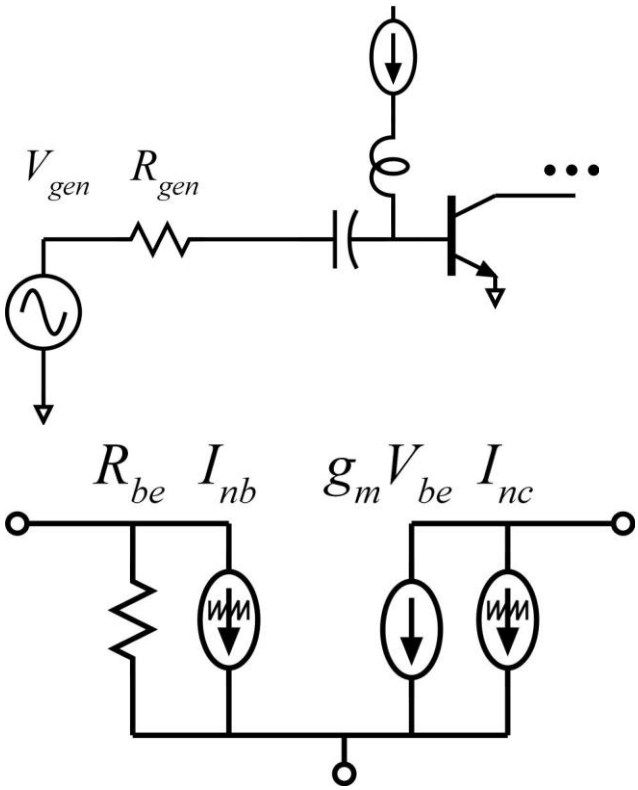
Problem	Points Received	Points Possible
1a		20
1b		10
2		20
3a		10
3b		10
3c		10
4a		10
4b		10
total (145b)		100

Name: _____

Problem 1, 30 points

Circuit Noise calculations

To the left is shown a representation of a bipolar transistor amplifier, and below it the BJT small signal noise model.



Note that the only transistor parasitic element is the finite current gain β and hence the presence of the small signal resistance R_{be}

The base is biased at current I_{bo}, producing DC collector current $I_{co} = \beta I_{bo}$. The inductor and capacitor are both very large (infinite inductive reactance, infinite capacitive susceptance).

Part a, 20 points

We will assume that the generator (V_{gen}, R_{gen}) has thermal noise at an associated temperature of 300 Kelvin. Device by source transposition the spectral density of the total input-referred noise voltage, including the contributions of the amplifier and of the generator. Please reduce your answer to an algebraic expression involving *only* the following terms: kT, q, I_{co}, β, R_{gen}.

expression for $S_{En,t}$ =

Part b, 10 points

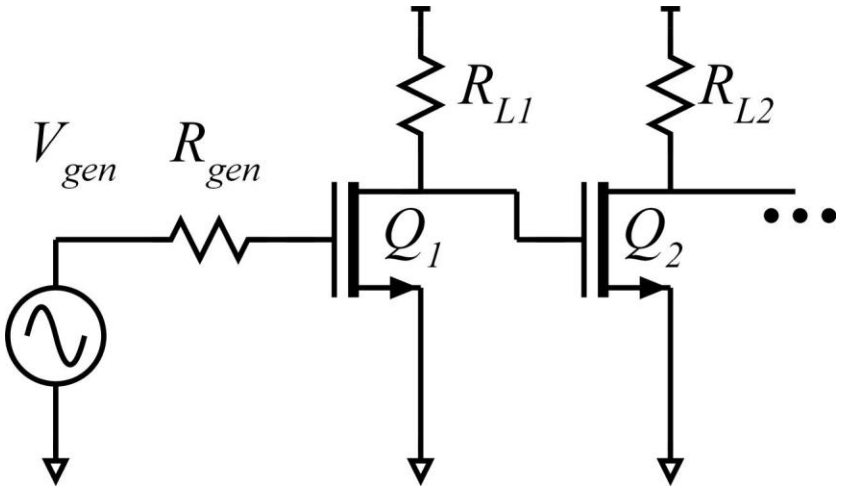
Adjusting the collector current (by adjusting the base bias current) will cause the total input-referred noise voltage to vary. What value of collector bias current gives the smallest input-referred noise ?

Hint: please simplify the calculus by assuming that R_{be} ***is much larger than*** R_{gen}.

expression for $I_{c,opt}$=

Problem 2, 20 points

More circuit noise calculations.
A two-stage FET amplifier is shown at the right.



Ignore DC bias considerations; you don't need these.

The FETs have
-zero parasitic capacitances,
-zero parasitic gate, source, and drain resistances.

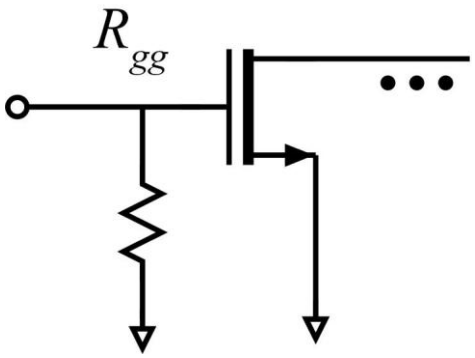
Both FETs have 10 mS transconductance and a channel noise parameter $\Gamma = 1.5$. $R_{L1} = R_{L2} = 1\text{k}\Omega$, $R_{gen} = 100$ Ohms. Find the spectral density of the total (amplifier plus generator) input-referred noise voltage.

$S_{En,t}$ =_____ (give units)

Problem 3, 30 points

En-In models of circuits, noise figure

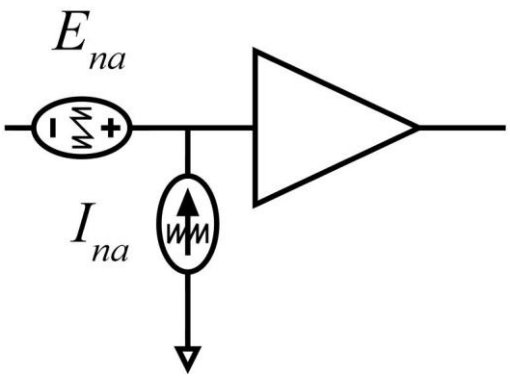
A FET is biased with an input resistor R_{gg} as shown.



The FET has
-zero parasitic capacitances,
-zero parasitic gate, source, and drain resistances.
- a channel noise parameter of Γ

Part a, 10 points

Calculate from the above the spectral density of E_{na} and of I_{na}, and their cross-spectral density



expression for $S_{En,a}$ =

expression for $S_{In,a}$ =

expression for $S_{E_{n,a}I_{n,a}}$ =

Part b, 10 points

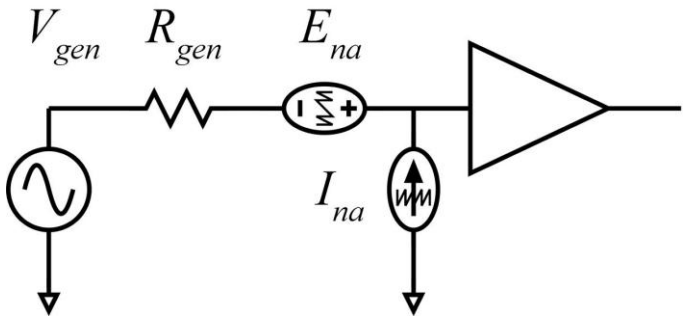
We now have a ***different circuit*** with

$S_{E_{na}} = 10^{-18} V^2 / Hz$,

$S_{I_{na}} = 10^{-22} A^2 / Hz$,

and $S_{E_{n,a}I_{n,a}} = 10^{-21} W / Hz$.

If the generator resistance is 100 Ohms, find the spectral density of the total input-referred noise voltage (including that of the generator).



$S_{En,t}$ =_____ (give units)

Part c, 10 points

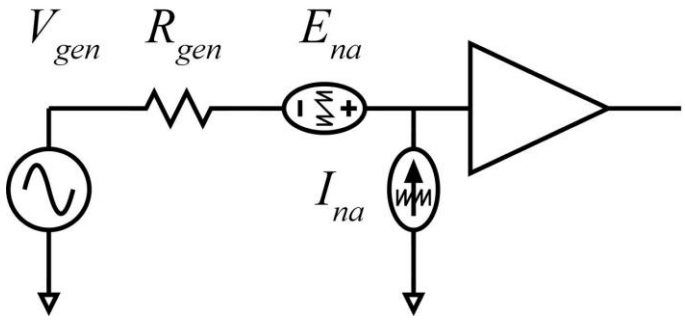
Continuing with the same circuit, i.e.

$S_{E_{na}} = 10^{-18} V^2 / Hz$,

$S_{I_{na}} = 10^{-22} A^2 / Hz$,

and $S_{E_{n,a}I_{n,a}} = 10^{-21} W / Hz$.

If the generator resistance is 100 Ohms, find the noise figure.



noise figure =_____

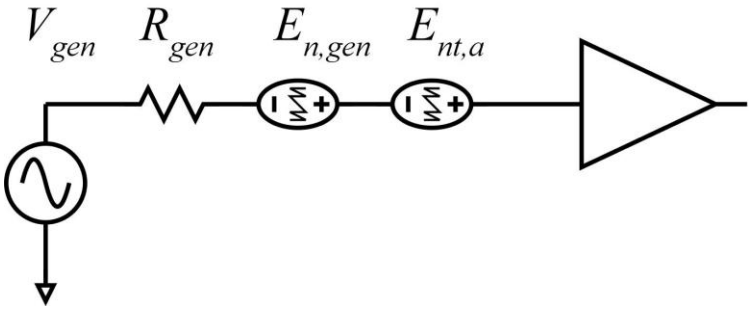
(specify whether the answer is in linear units or dB)

Problem 4, 20 points

Signal/noise calculations

Part a, 10 points

We are now analyzing a generator whose noise voltage is $E_{n,gen}$, connected to an amplifier whose total noise voltage is $E_{nt,a}$



We are working in a music recording studio, for which R_{gen} is standardized at 600 Ohms for microphones. The generator noise is thermal at 300K. $E_{nt,a}$ has a spectral density whose ***square root*** is 5 nV/Hz$^{1/2}$. Working with a standard audio system bandwidth of 20Hz-20kHz, what RMS voltage is required from V_{gen} to obtain a 30 dB signal/noise ratio ? What available signal power does that correspond to ?

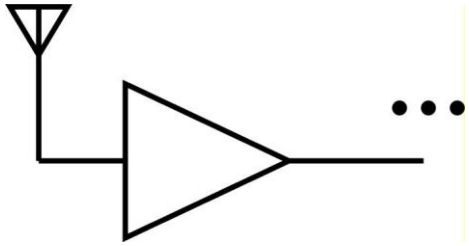
RMS value of V_{gen} =_____(give units)

Available signal power from the generator=_____
(give units)

Part b, 10 points

We are now analyzing a radio receiver.

The antenna radiation resistance is at 300K. The antenna has negligible conductor resistance. The amplifier has 3 dB noise figure.



The receiver is receiving QPSK data at 100 megabits/second data rate.

If we use ideal raised-cosine filters with zero excess bandwidth (β =0), what receiver bandwidth do we need ?

receiver bandwidth= _____ Hz

If no error-correcting code is used, we need a signal/noise ratio of 36:1 to obtain 10^{-9} bit error rate. What is the corresponding received signal power ?

Signal power =_____ (give units)