EE 619

Radio Frequency Microelectronic Chip Design

Mid Semester Examination

27th Feb 2021, 1.00pm-4.00pm

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1. Consider a system: $y(t) = \alpha_0 + \alpha_1 x(t) + \alpha_2 x^2(t)$
   Where x(t) is the input and y(t) is the output
   Say $x(t) = A_{in}\cos(\omega t)$
   Suppose we plot the magnitude of the 2ω frequency component (in dB) at the output with respect to the magnitude of x(t) (in dB). What will be the slope of this line be? (Express it in the form x:y i.e., for every x horizontal distance, the plot has a y vertical distance) **(1 mark)**

2. In an LNA choose all that are true: **(1 mark)**

   a. The LNA decreases the signal noise as it passes through, thereby ensuring that SNR_{out} is slightly higher than SNR_{in}
   b. The LNA adds very little noise to the input signal, thereby ensuring SNR_{out} is not much less than SNR_{in}
   c. $Z_{s,opt}$ should be chosen close to 50Ω to ensure proper impedance matching.
   d. Z_{in} should be equal to 50Ω so that $NF = NF_{min}$

3. Choose all that are true. **(1 mark)**
   While calculating SFDR,

   a. $P_{in,min}$ is the value of P_{in} at which the SNR_{in} of the receiver is an acceptable value.
   b. $P_{in,max} = P_{IIP3}$
   c. $P_{in} = P_{in,max}$ when output intermodulation products are equal to the output noise floor.
   d. $P_{in,min}$ is the value of P_{in} at which the receiver produces an output with an acceptable SNR_{out}

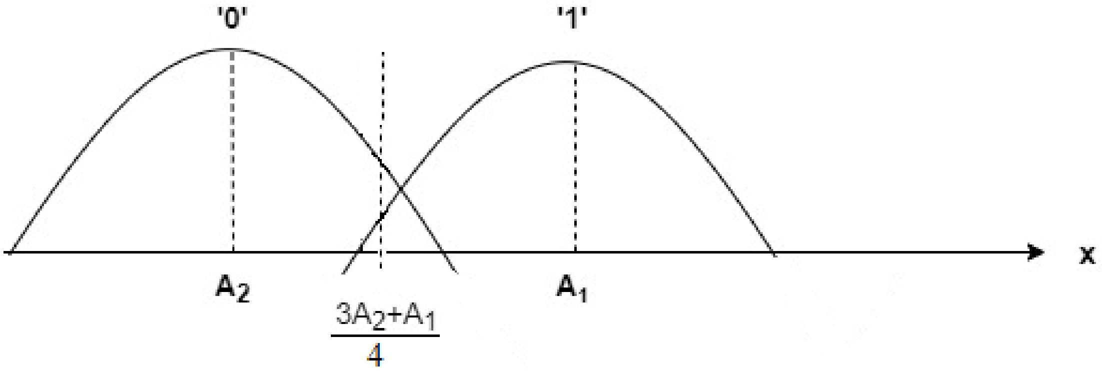
4. The number of frequency components of an FM modulated signal, when modulation index is 0 is **(0.5 mark)**

   a. 1
   b. 0
   c. 2
   d. 3

5. The bit energy (or power assuming T_b = 1s) for the bit '1' for ASK modulation is (write the answer) (assume A_c is the amplitude of the carrier) **(1 mark)**

   Ans: ____________________

6. The figure below shows the probability of detection of '0' and '1' .The probability for bit '0' and bit '1' are given below:



p(bit'0') = $\frac{1}{\sqrt{2\pi\sigma^2}}\ exp\left[-\ \frac{(x-A_2)^2}{2\sigma^2}\right]$ and p(bit'1') = $\frac{1}{\sqrt{2\pi\sigma^2}}\ exp\left[-\ \frac{(x-A_1)^2}{2\sigma^2}\right]$

Suppose instead of $\frac{A_1+A_2}{2}$ we choose the threshold to be $\frac{3A_2+A_1}{4}$

a. Find the probability of falsely detecting '0' **(2.5 mark)**
b. Find the probability of falsely detecting '1' **(2.5 mark)**

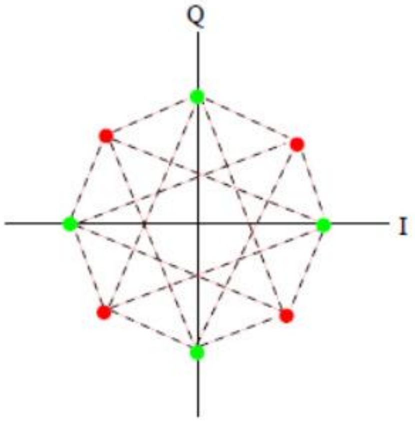
Express the answers in terms of the function Q( ), $A_1 - A_2$ and σ

7. The expression for $BER = Q\left(\frac{E_d}{2\sigma}\right)$ is applicable for all 3 ASK, PSK &FSK when threshold is $\frac{A_1+A_2}{2}$

   - True or False? **(0.5 mark)**

8. In the figure shown OQPSk constellation is represented by the green dots or red dots?

(0.5 mark)



9. Power efficient modulation refers to (Choose all that are true) **(1 mark)**

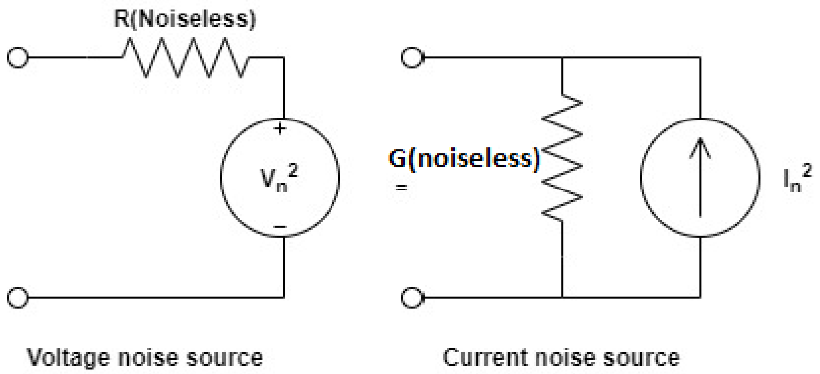
a. A modulation scheme where resistive power loss in transmitter is less
b. When spreading of spectrum due to non-linearities is less
c. When the envelope of the modulated signal is constant
d. When the inter-modulation distortion experienced by the transmitted signal is less

10. Which of the following modulation schemes can be detected non-coherently? **(0.5 mark)**

a. OQPSK
b. PSK
c. FM
d. DPSK

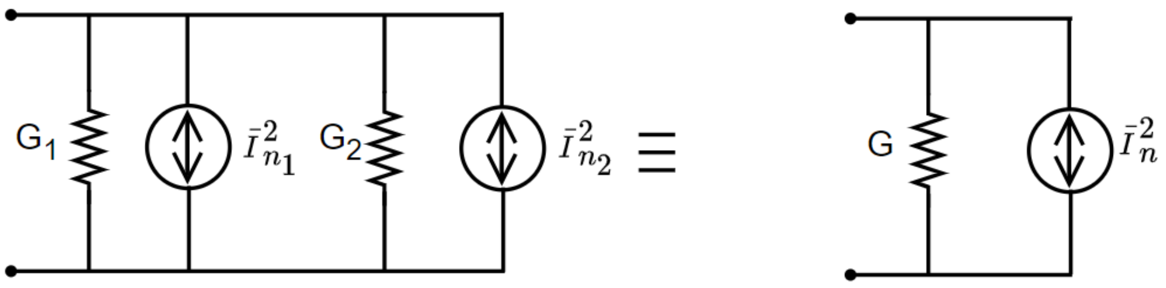
Choose all that are true.

11. Suppose the circuits shown in the figures below are equivalent **(1 mark)**



a. Express I_n^2 in terms of V_n^2 & R
b. Express G in terms of R

12. Consider the following 2 equivalent circuits: **(1 mark)**



$\bar{I}_{n1}^2$ and $\bar{I}_{n2}^2$ are the current noise sources of G_1 and G_2. They are uncorrelated.

$\bar{I}_n^2$ is the current noise source of G.

G_1, G_2 are noiseless conductances. G is a noiseless conductance.

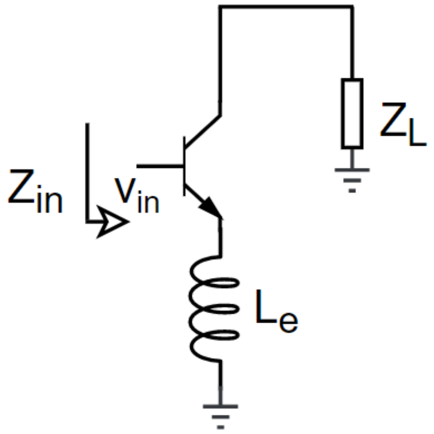
a. Express G in terms of G_1 and G_2.
b. Express $\bar{I}_n^2$ in terms of $\bar{I}_{n1}^2$ and $\bar{I}_{n2}^2$

13. While expressing Noise Figure (NF) in dB, which of the following is the correct formula:

(0.5 mark)

a. $20\log_{10}(NF)$
b. $10\log_{10}(NF)$

14. Consider an Emitter degenerated CE amplifier as shown below:



The BJT small signal model parameters for the active region are as follows –

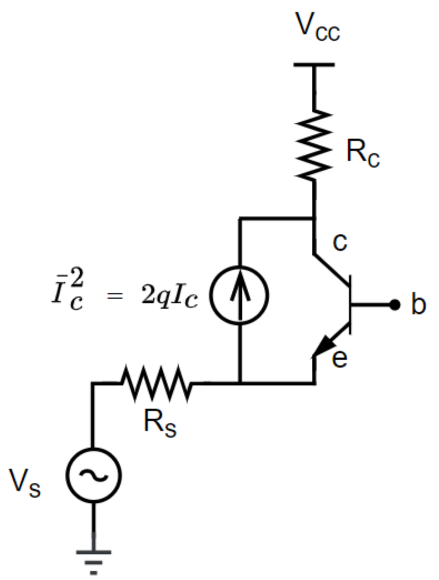
g_m = 40 mA/V

r_b = 100 Ω
C_π = 1 fF
L_e = 6.33 µH
Frequency, f = 2 GHz

a. Obtain an expression for $G_m = \frac{I_c}{V_{in}}$, ignoring r_b. Show that for sufficiently high values of L_e, G_m is independent of BJT parameters. **(2.5 mark)**

b. Show that even if we include r_b, values of G_m will only be dependent on L_e (approximately) for the values given above. **(2.5 mark)**

15. Consider a BJT in CB configuration:

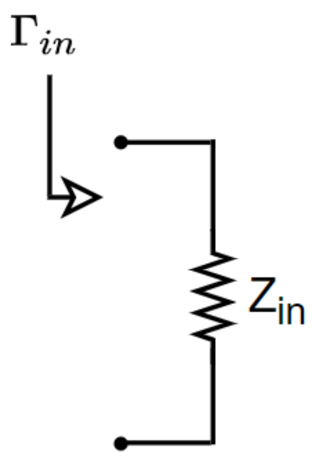


Ignore all other sources of noise other than $\bar{I}_c^2$ and R_s:

a. Find the expression for Noise Figure (NF) of this circuit. **(4 marks)**

b. Show that when g_m = Gs = 1/Rs, NF = 3/2 **(1 mark)**

16. Consider the following circuit:

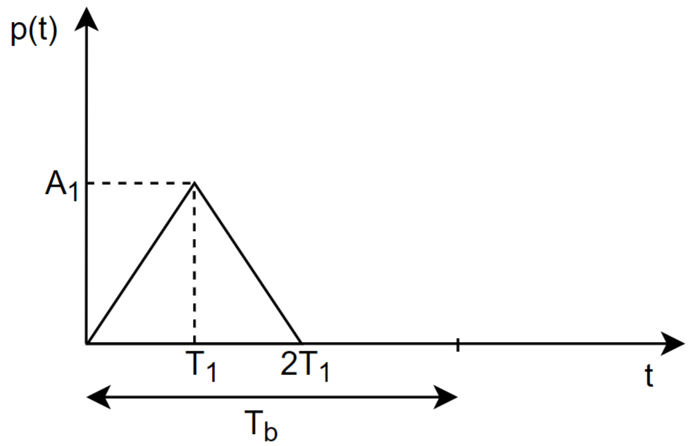


Γ_{in} is the reflection coefficient when characteristic impedance is Zo.

a. What is the value of Zin in terms of Γ_{in} and Zo? **(2 marks)**

b. What will the reflection coefficient be when the characteristic impedance is Zo’ (in terms of Γ_{in}, Zo and Zo’) **(2 marks)**

17. Given:



Draw the waveform for p (T_b – t) **(1.5 mark)**

[NOTE: Correctly label all amplitudes and points on‘t’ axis]