**ES3350**

**THE UNIVERSITY OF WARWICK**

**Third Year Examinations: Summer 2008**

**COMMUNICATIONS SYSTEMS**

**SECTION A**

**SECTION B**

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**Candidates should answer FOUR QUESTIONS.**

**Time Allowed: 3 hours.**

**Only calculators that conform to the list of models approved by the School of Engineering may be used in this examination. The Engineering Databook will be provided.**

*Read carefully the instructions on the answer book and make sure that the particulars required are entered on each answer book.*

**PLEASE USE A SEPARATE ANSWER BOOK FOR EACH SECTION**

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## SECTION A

1. The general form of a carrier signal is given by:-

$$f(t) = A_0 \cos(\omega_0 t + \phi).$$

(a) Explain all the above terms, and show how the expression is modified for a double sideband, suppressed carrier (DSB/SC) amplitude-modulated (A.M.) signal, when the modulating function is $A_m \cos \omega_m t$. (6 marks)

(b) What is the practical limit to $A_m$ if distortion is to be avoided? Determine the amplitude of the sidebands when a 10 volts peak carrier signal is modulated by a signal of peak value 4 volts. (5 marks)

(c) For the values of carrier voltage and signal voltage above, determine the unnecessary wasted power in a 50 Ω load if double sideband with carrier (DSB) amplitude modulation is used instead of DSB/SC. Show the spectrum of the DSB/SC signal. On a separate diagram, show the spectrum of the DSB signal, with all amplitudes and frequencies indicated, if the carrier frequency is 10 MHz and the modulation frequency is 5 kHz. (10 marks)

(d) What modulation technique would you use to transmit a modulating signal if bandwidth was at a premium, that is, you had to use the smallest transmission bandwidth compatible with a modulating signal bandwidth of, say 3.5 kHz? Briefly explain how this kind of signal can be demodulated. (4 marks)

2. The circuit in Figure 1 below is that of a Clapp oscillator.

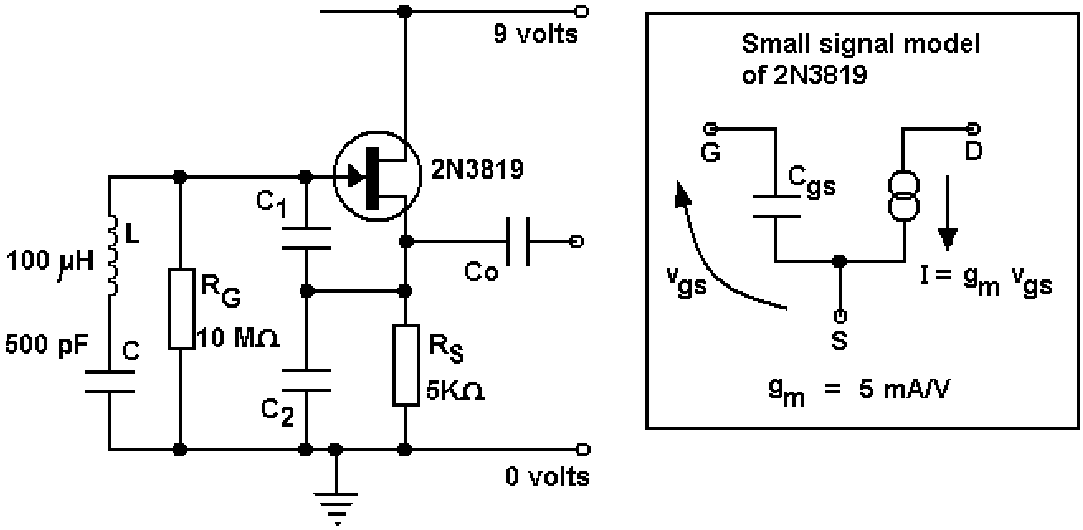


**Figure 1**

(a) Using the small signal model for the 2N3819 FET, determine the value of the negative resistance, **Rn**, created in the circuit due the presence of the FET at any frequency **f**, assuming the following conditions:-

(i) The majority of the small signal drain current, **I**, feeds into $\mathbf{C_1}$ and $\mathbf{C_2}$, and only a negligible amount goes into $\mathbf{R_s}$.

(ii) $\mathbf{C_1} = \mathbf{C_2}$ = 500 pF, and $\mathbf{C_{gs}}$ is negligible. (12 marks)

(b) Determine the frequency of oscillation, ***f***, assuming it can be approximated by:

$$f = 1 \Big/ \left( 2\pi \sqrt{LC_{eff}} \right),$$

where $\boldsymbol{C_{eff}}$ is the total effective capacitance across $L$. Hence, calculate the actual value of the negative resistance, **Rn** , at the oscillation frequency. (6 marks)

(c) What precautions have to be taken when connecting a load to the output? Suggest how you would improve the circuit to ensure that very little drain current actually flows into $\mathbf{R_s}$, and explain what effect this has if this current is not actually zero. (7 marks)

3. Three signal processing stages are connected as shown in Figure 2 below.

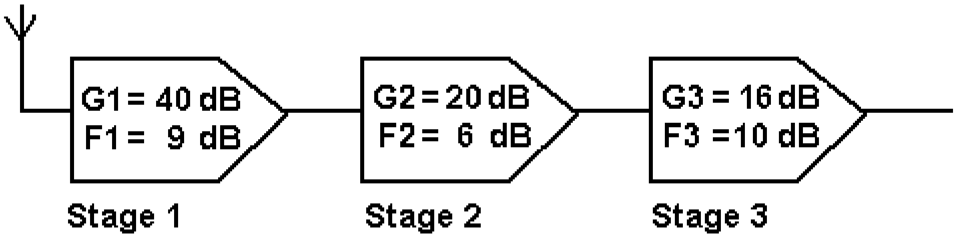


**Figure 2**

(a) If the stages have equal bandwidth, determine the noise figures of all the stages combined, that is, from the antenna at the first input to the output of Stage 3. Also, determine if there is at least one (if not more) better arrangement of stages in order to produce an overall lower noise figure. (9 marks)

(b) In the original configuration as shown above, a signal of power 0.01 μW is received at the antenna at the input such that the input signal to noise ratio is 10dB. Determine the ratio of signal power to noise power at the output of Stage 3, if all powers are with respect to 50 Ω. (8 marks)

(c) Determine the noise equivalent bandwidth of a system in which the power transfer response is given by:

$P(f) = 10$ for $f < 10$ MHz

$P(f) = 5$ for $10 \text{ MHz} \leq f < 20$ MHz

$P(f) = 0$ for $f \geq 20$ MHz (8 marks)

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## SECTION B

4. (a) Explain what is meant by the terms *quantisation* and *quantisation noise*.

(4 marks)

(b) Show that, assuming linear quantisation with step $\Delta$, the mean value of the quantisation noise is zero and its variance is $\Delta^2/12$.

(7 marks)

(c) Define the term signal to quantisation error ratio (sqer), and show that it is given by $N^2/2$ for a linear quantiser possessing N levels when its input is a signal with the probability density function (pdf) shown in Figure 3.

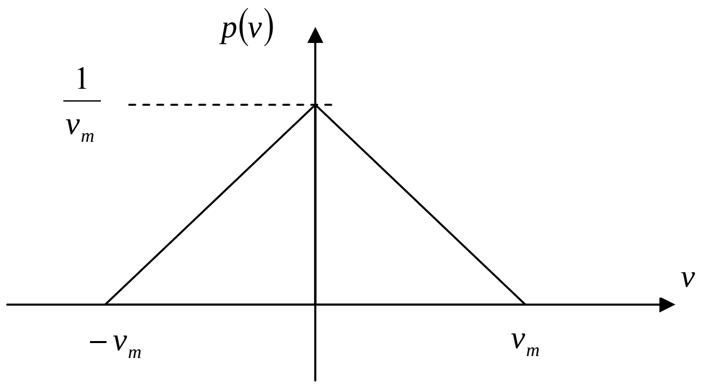


**Figure 3**

(10 marks)

(d) Determine the minimum bit rate of a pulse code modulation system that is to have an sqer of 50 dB when transmitting input signals of 10 kHz with the pdf given in part (c) above.

(4 marks)

5. (a) Outline the effect that a linear time invariant filter, with transfer function *H(f)*, has on Gaussian noise, with power spectral density (PSD) *S(f)*, that arrives at its input. (3 marks)

   (b) Sketch the output PSD of a low pass CR filter subjected to input white noise of PSD $10^{-8}$ $V^2Hz^{-1}$ given that C = 1 nF and R = 330 Ω. Show that the output noise power from the filter is 15.2 mW. (10 marks)

   (c) Calculate the Bit Error Rate for equiprobable 1s and 0s which would be obtained from a 2 $Mbits^{-1}$ digital communication system employing a receiver filter as in part (b). Assume that the noise PSD remains the same and that non-return to zero pulses of amplitude 1.5V are used. You may assume that the approximation $\mathrm{erfc}[u] \approx e^{-u^2} / u\sqrt{\pi}$ holds for the complementary error function (8 marks)

   (d) Show that the signal to noise ratio obtained with the arrangement in part (b) is within 1 dB of that which would result from utilisation of a matched filter, and comment on this result. (4 marks)

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6. (a) Explain what is meant by *additive, multiplicative*, and *affine* ciphers. (6 marks)

(b) Indicate the constraints (if any) placed on the choice of keys for the ciphers in part (a), illustrating your answer with reference to mod 10 ciphers. (6 marks)

(c) An additive cipher uses a mapping of each letter of the English alphabet to a number in the range 0 to 25 plus the symbol $\Phi$ mapped to 26. The extra symbol is used to represent a space between words plus the beginning and end of messages. Determine the plaintext of the message

**GWVVYGJVKLG**

produced by such the cipher given that $\Phi$ is the most common symbol because of its usage. (8 marks)

(d) Encode the first two letters of the plaintext message using the affine cipher $(2,11)$ and discuss the increase in security, if any, obtained using this affine cipher given the same knowledge as part (c). (5 marks)

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**END**