ENGINEERING TRIPOS PART IIA

Tuesday 29 April 2003 2.30 to 4.00

Module 3B1

RADIO FREQUENCY ELECTRONICS

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

> You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

(TURN OVER

1. (a) Describe what is meant by the term 'image rejection' when applied to the design of an amplitude modulated (AM) superheterodyne (superhet) radio receiver. [20%]

An AM superhet radio has a local oscillator (LO) frequency of 1.6 MHz and an intermediate frequency (IF) of 455 kHz, what is the frequency of the tuned radio station? What is the image frequency? [10%]

(b) Explain, with the aid of a block diagram, the overall construction of an AM superhet radio receiver. Describe the functionality of each block. What are the advantages of the superhet system over the traditional tuned radio frequency (RF) type of receiver? [30%]

Describe the importance of LO and RF filter tracking in the superhet receiver and how it can be achieved. [10%]

(c) If the superhet radio was designed to be frequency modulated (FM) instead of AM, show how a phase locked loop (PLL) can be used to demodulate the intermediate frequency signal. [30%]

3B1 2003 examination answers

Q1 a) $f_{RF} = 1.145\text{MHz}$, $f_{IM} = 2.055\text{MHz}$

Q2 a) $z_0 = R_b // h_{ie} // (-2r_e)$, $r_e = 250\Omega$, $z_0 = -532\Omega$

b) $C = 50\text{pF}$ $L = 507\mu\text{H}$ c) $f_{3dB} = 1.27\text{MHz}$

Q3 b) HPF and LPF in parallel, 4 poles each, $f_{LPF} = 5.5\text{kHz}$, $f_{HPF} = 18\text{kHz}$, notch width = 12.5 kHz, R = 10k, LPF: $R_1 = 5.86\text{k}$ $C_1 = C_2 = 2.9\text{nF}$, $R_2 = 12.5\text{k}$, HPF: $R_3 = 5.86\text{k}$, $C_3 = C_4 = 0.88\text{nF}$, $R_4 = 12.5\text{k}$

Q4 b) $z_0 = \dfrac{d}{(w+2d)c_0\varepsilon_0\sqrt{\varepsilon_r}}$ c) $z_0 = 75\Omega$, w = 0.38mm, $C_s = 1.4\text{pF}$, l = 165mm, for dc path $L_s = 18\text{nH}$, l = 12mm

2 (a) Using the small signal model (neglecting C, h_{oe} and h_{re}) of the circuit in Fig 1, show that it has an equivalent negative resistance to ground when measured at the input X. State any assumptions made. [50%]

Given that $V_{ss} = -5$ V, $V_{be} = 0.75$ V, $R_b = 10$ kΩ, $h_{fe} = 200$ and $R_e = 22$ kΩ, estimate the value of the resistance at the input X. [10%]

(b) Describe how the circuit in Fig. 1 can be converted into an oscillator. Estimate component values to give a 1 MHz oscillation frequency. [20%]

(c) If the transistors in the circuit in Fig. 1 have an f_T of 250 MHz, estimate the 3 dB frequency roll off which will lead to the loss of the negative resistance. [20%]

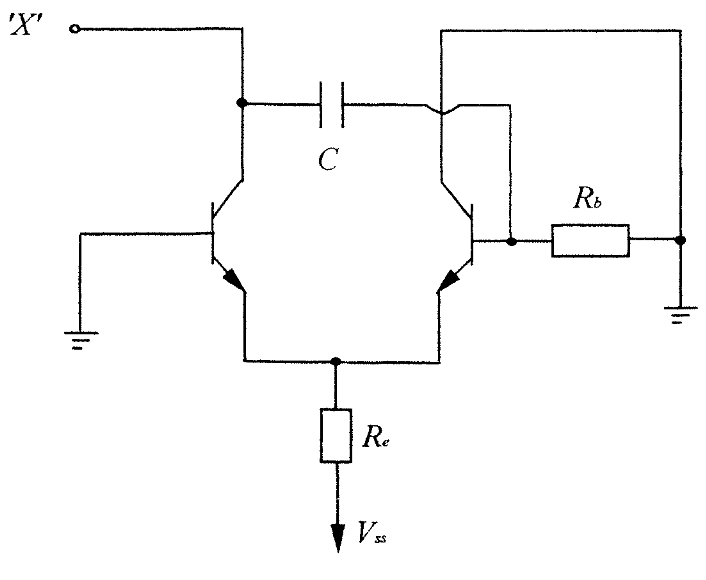

Fig. 1

3 (a) Explain with the aid of simple sketches the differences between the three main types of filter characteristics; Bessel, Butterworth and Chebyshev. Give examples of applications where each type might be best suited. [30%]

(b) A submarine sonar system is designed to receive signals in the range of 100 Hz to 100 kHz, however the main low frequency submarine communications signal is sent on a carrier frequency of 10 kHz. A pair of high and low pass voltage controlled voltage source (VCVS) filters are required as part of the sonar system to create a bandstop filter to attenuate crosstalk noise from the communications signal by at least a factor of 100. A total of 5 operational amplifiers are available for the filter and it has been decided that a Butterworth characteristic would be best suited.

Design a suitable VCVS filter and calculate the 3 dB width of the stop band created. [50%]

(c) Explain why the attenuation at 10 kHz will in fact be considerably higher than the actor of 100 designed for. [20%]

n	Bessel		Butterworth		Chebyshev	(0.5dB)
	f_n	A	f_n	A	f_n	A
2	1.274	1.268	1	1.586	1.231	1.842
4	1.432	1.084	1	1.152	0.597	1.582
	1.606	1.759	1	2.235	1.031	2.660
6	1.607	1.040	1	1.068	0.396	1.537
	1.692	1.364	1	1.586	0.768	2.448
	1.908	2.023	1	2.483	1.011	2.846

4 (a) Briefly describe two ways in which a Smith chart can be used to calculate the length of a transmission line required to match two impedances at radio frequencies. [20%]

(b) Derive an expression for the characteristic impedance for the microstrip line shown in Fig. 2. State any approximations made. [30%]

$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} and $c_0 = 3 \times 10^8$ m s^{-1}

(c) A short length of microstrip transmission line is to be used to match a 75 Ω source to a 300 Ω patch antenna operating at a frequency of 1 GHz. Use a Smith chart to calculate the required piece of microstrip and series capacitance using a 0.5 mm thick printed circuit board with dielectric constant $\varepsilon_r = 3.3$. [40%]

How would the design change if the microstrip was also designed to supply dc power to the antenna? [10%]

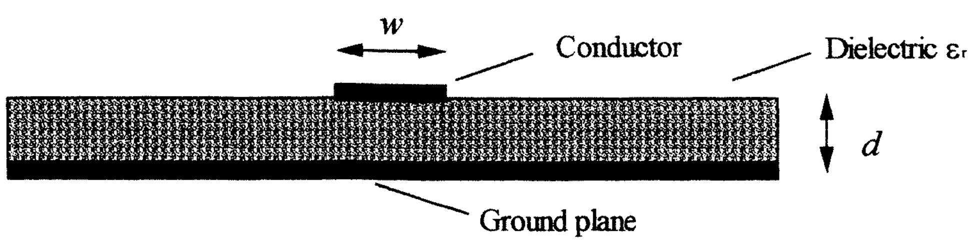

Fig 2.

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