GLASGOW COLLEGE UESTC

Exam paper

Communication Circuits Design (UESTC 3029)

Date: 17th June 2019
Time: 14:30-16:30pm

Attempt all PARTS. Total 100 marks

Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.

Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.

An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.

All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

DATA/FORMULAE SHEET IS PROVIDED AT THE END OF PAPER

Attempt all PARTS

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Q1 The circuit shown in Figure Q1 below includes an input band-pass filter and two amplification stages.

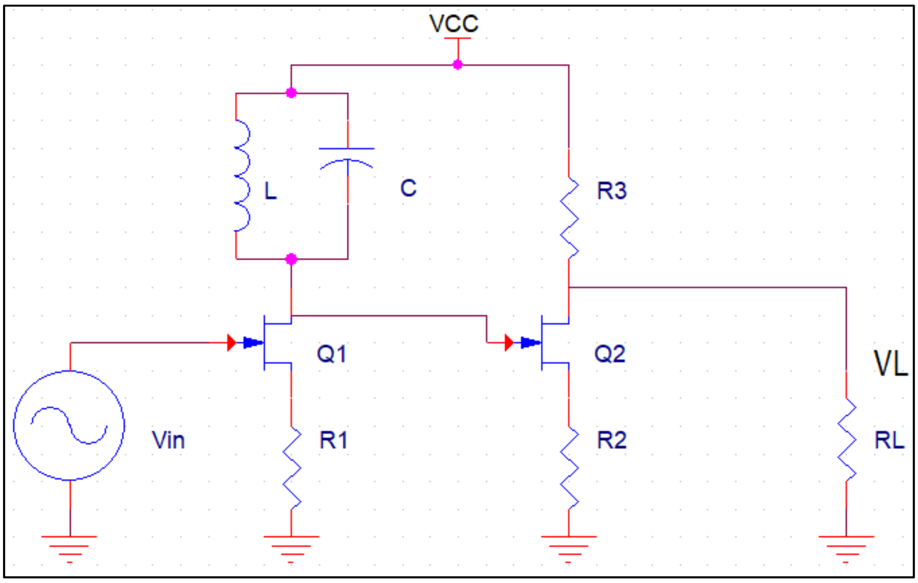

Figure Q1

(a) Calculate the input bandwidth of the circuit assuming that quality factor Q = 100, L = 8mH and C = 8nF. [4]

(b) Calculate the signal input power P_{IN} in dBm knowing that the amplification gain of the first amplifier is $G_1 = +10$ dB, the gain of the second stage is $G_2 = +20$ dB, and the output signal voltage on the load resistor (RL = 50 Ω) is 5V. [3]

(c) Calculate the noise output power P_{Nout} in dBm assuming that the system operates at room temperature (290 K), the noise factor of the first amplifier is F1 = 2 and the noise factor of the second amplifier is F2 = 5. [7]

(d) An additional amplifier stage needs to be added to the circuit above to increase the signal output power by an extra +15 dB. Recommend and justify the ideal position of this additional amplifier knowing that its noise factor F3 = 8. [4]

(e) Assume that the circuit shown above is integrated into a single chip block for generation of analogue base-band signals. Design a frequency up-conversion system to translate the base-band signals to a carrier frequency f_C which is 20 times higher than the base-band.
Evaluate the relative merits of direct up-conversion and super-heterodyne conversion, and provide a block diagram implementing the chosen approach, indicating suitable values of the local oscillators' frequencies. [7]

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Q2 (a) Oscillators are found in many communication systems to generate sinusoidal signals. Sketch the general block diagram of any oscillator and discuss the Barkhausen criteria for oscillation. [6]

(b) The circuit shown in Figure Q2 below is an example of a Clapp oscillator, where the biasing network of the BJT is omitted for simplicity.

i) Analyse the circuit indicating which components belong to the amplifier network; which ones form the feedback network; and describe the role of the RFC inductor and the two capacitors C respectively. [8]

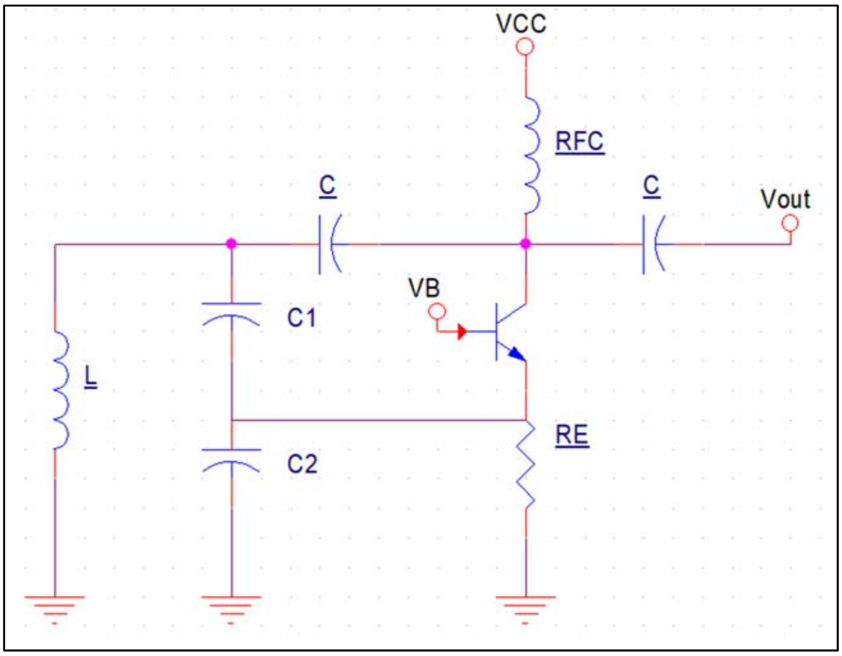

Figure Q2

ii) Calculate the oscillation frequency assuming that L = 21 mH, C1 = 50 nF, and C2 = 1.5 μF. [3]

iii) The oscillator is integrated into a heterodyne receiver for AM radio to be used as the LO. The requirement for this LO is to be tuned between approximately 4.5 and 5.5 kHz. Develop a modified version of the Clapp oscillator to address this additional tuning capability, evaluating the relative merits of at least two approaches to dealing with this problem and defending your recommended choice. [8]

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Q3 (a) The following questions are related to Amplitude Modulation (AM).

i) When does overmodulation occur, and what impact does overmodulation have on the output signal? [3]

ii) A transmitter with a 10 kW carrier transmits 11.2 kW when modulated with a single sine wave. Calculate the modulation index (or % of modulation). [2]

iii) If the carrier of part ii) is simultaneously modulated with another sinewave at 50 percent modulation, calculate the effective modulation index and the total transmitted power. [3]

(b) What are advantages and disadvantages of Single Side Band (SSB) compared to AM transmission? [4]

(c) An FM signal, $2000\ \sin(2\pi \times 10^8 t + 2\ \sin \pi \times 10^4 t)$, is applied to a 50 Ω antenna. Determine the carrier frequency, the transmitted power and intelligence frequency. [4]

(d) Determine the worst-case output S/N for a narrowband FM receiver with $\delta_{max} = 10\ kHz$ and a maximum intelligence frequency of 3 kHz. The S/N input is 3:1. [3]

(e) Draw the block diagram of Phase Locked Loop (PLL) and briefly explain its operation. [6]

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Q4 (a) What is a transceiver and what is it used for? [3]

(b) What is the name given to simultaneous two-way communication? Give two examples of industrially relevant systems that use simultaneous two-way communication. [3]

(c) Using the complete diode model with $r'_d = 20\ \Omega$, determine the forward voltage and forward current of the silicon diode in Figure Q4(c). [8]

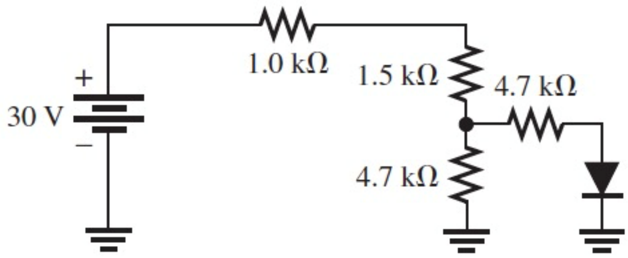

Figure Q4(c)

(d) Find the values of V_{BE}, V_{CE}, and V_{CB} in the circuit of Figure Q4(d). [11]

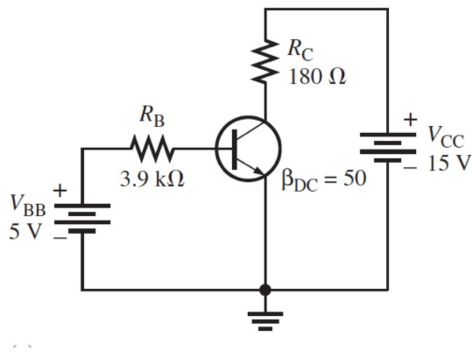

Figure Q4(d)

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FORMULAE SHEET

$$|A_r| = \frac{|V_0|}{V_0(\omega_0)} = \frac{1}{\sqrt{1+(\delta Q)^2}} \qquad \delta = \frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}$$

$$RL = -20\log_{10}\left|\frac{Vref}{Vinc}\right|;\ VSWR = \frac{1+10^{-\frac{RL}{20}}}{1-10^{-\frac{RL}{20}}}$$

$$Q_L = \frac{reactance}{resistance} = \frac{\omega L}{R};\ Q_C = \frac{susceptance}{conductance} = \frac{\omega C}{G} = \omega CR;\ Q = \frac{f_0}{BW}$$

$$R_P = R_S(1+Q^2);\ X_P = X_S(1+\frac{1}{Q^2})$$

$$C_D = C_{Varactor} \approx \frac{C_0}{\sqrt{1+\frac{|V_D|}{0.5}}} \quad C_{Miller} = C(A_v+1)$$

	Input R_I		**Output R_o**		**Gain Av**
	Large R_L	Small R_L	Large R_S	Small R_S	
CB	$R_E + R_B$	R_E	$R_c + R_b$	$R_c \frac{R_e + R_b(1-\alpha)}{R_e + R_b}$	$\frac{R_L}{R_S + R_i}$
CE	$r_i = r_b + r_e \approx r_b$	$r_b + \beta r_e$	$r_e + \frac{r_c}{\beta}$	$r_c \frac{r_e + \frac{r_b}{\beta}}{r_b + r_e} \approx r_c$	$\frac{R_c}{R_b + R_e}$
CC	$r_i = r_b + r_c \approx r_c$	$r_b + \frac{r_e}{1-\alpha} = r_b + \beta r_e$	$r_e + r_c(1-\alpha) \approx \frac{r_c}{\beta}$	$r_e + \frac{r_b}{\beta} \approx r_e \approx \frac{1}{g_m}$	$\frac{R_L}{R_L + R_S/\beta}$

$$B_{-1dB} = \sqrt{0.145\left|\frac{a_1}{a_3}\right|}\ ;\ B_{IIP3} = \sqrt{4/3\left|\frac{a_1}{a_3}\right|};\ B_{-1dB} = IIP3 - 9.6dB$$

$$DR = 1dB_{point} - S_n;\ S_n = P_n + SNR;\ P_{n,input} = 10log_{10}(kT\Delta f_{eff})$$

$$k = 1.38 \times 10^{-23}$$

End of question paper