MACHAKOS UNIVERSITY

University Examinations for 2023/2024 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR …….. SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION TECHNOLOGY)

EEE 519: RF CIRCUIT DESIGN

DATE: **TIME:**

INSTRUCTIONS

Answer question **ONE** and **ANY OTHER TWO** questions

QUESTION ONE (COMPULSORY) (30 MARKS)

(a) Describe the following classes of power amplifiers:
- i. Class B,
- ii. Class C;
- iii. Class D.

(6 marks)

(b) A circuit has an input that is made up of a 1-pF capacitor in parallel with a 200-Ω resistor. Use a transformer with a coupling factor of 0.8 to match it a source resistance of 50Ω. The matching circuit must have a bandwidth of 200 MHz and the circuit is to operate at 2 GHz.

(10 marks)

(c) A rectangular aluminum line has a width of 20 µm, a thickness of 3 µm, and a length of 100 µm. Compute the resistance of the line at dc and at 5 GHz assuming that all the current flows in an area one skin depth from the surface. Assume that aluminum has a resistivity of 3 µV?cm.

(8 marks)

(d) Draw the electric equivalent circuit of a high frequency inductor and describe each of its components.

(6 marks)

QUESTION TWO (20 MARKS)

(a) Derive the equation for equivalent noise power generated at the input of a receiver in terms of standard ambient temperature T_o and bandwidth.

(10 marks)

(b)

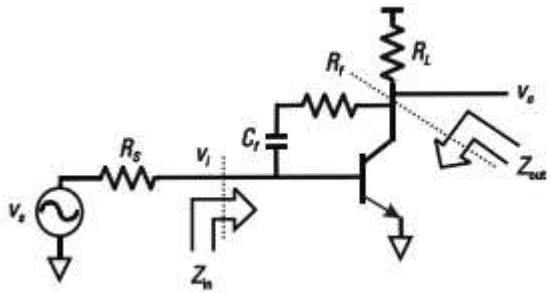
Design a Class C RF power amplifier to meet the following specifications: $V_I = 3.3\,\text{V}$, $P_O = 0.25\,\text{W}$, $V_{DSmin} = 0.2\,\text{V}$, $\theta = 60^\circ$, $BW = 240\,\text{MHz}$, and $f = 2.4\,\text{GHz}$.

(10 marks)

QUESTION THREE (20 MARKS)

(a)

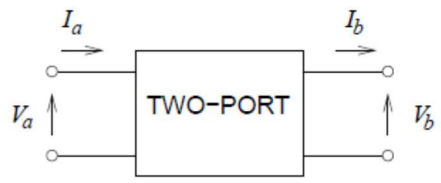
An amplifier similar to that shown in Figure 6.11 has a load resistor of $R_L = 100\Omega$, and a source resistance of $R_S = 50\Omega$. The transistors are in a 12-GHz f_T process with 15x transistors and 5 mA for a transconductance of $g_m = 200$ mA/V. With $\beta = 100$ and $r_\pi = 500\Omega$, parasitic capacitance was estimated at $C_\pi = 2.37$ pF. Assume C_μ can be ignored. (The Miller effect can be minimized by using a cascode structure.) At 900 MHz, compare gain and input and output impedance with feedback resistor at $R_f \to \infty$ and $R_f = 500\Omega$.



(12 marks)

(b) Use the ABCD parameters and the diagram shown below to show that

$A = z_{11}/z_{21}$
$B = \Delta_z/z_{21}$
$C = 1/z_{21}$
$D = z_{22}/z_{21}$,
where $\Delta_z = z_{11}z_{22} - z_{12}z_{21}$



FigQ3 (b)

(9 marks)

QUESTION FOUR (20 MARKS)

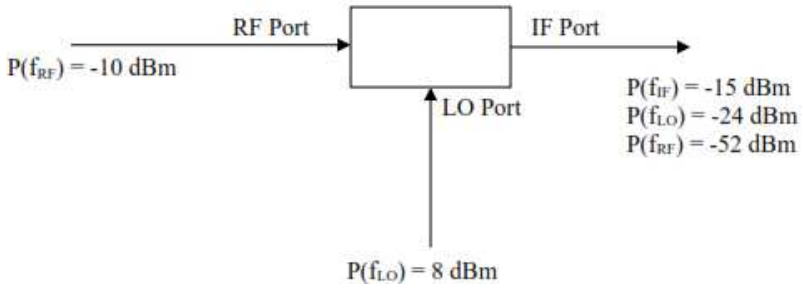
A mixer contains a diode with the following parameters: $C_j = 0.3$ pF, $R_s = 0.4\ \Omega$, $I_s = 90\ \mu$A, and $L_p = C_p = 0$. The mixer is designed to receive an RF input signal at a frequency of 2.4 GHz and down-convert it to an IF signal at 400 MHz. Use $\alpha = 1/(25$ mV).

(a) Compute the open-circuit voltage sensitivity at 2.4 GHz for $I_0 = 10$ mA (4 points).

(b)

If the local oscillator frequency is higher than the RF frequency, give the LO frequency and the image frequency (4 points).

For parts (c) and (d), assume that the following power levels are measured at the ports of a frequency-conversion system containing the mixer and necessary filtering:



(c) Calculate the conversion loss (4 points).

(d) Calculate the LO-to-IF isolation (4 points).

(e) Calculate the RF-to-IF isolation (4 points).

QUESTION FIVE (20 MARKS)

(a) With the aid of a diagram describe a reciprocal two port network.

(5 marks)

(b) Consider a loaded series resonant RLC circuit. The resonator consists of a 2 Ω resistor, a 15 nH inductor, and an 18 pF capacitor, all in series. The load is 50 Ω.

(i) What is the resonant frequency (in MHz) (5 points)?

(ii) What is the unloaded Q (5 points)?

(iii) What is the loaded Q (5 points)?