RF IC DESIGN AND MEMS
(VLSI 6132)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) If the line width of a spiral is doubled to reduce its resistance with D_{out}, S, and N remaining constant, the inductance
(a) reduces with reduction in mutual coupling
(b) reduces with decrease in diameter of the inner turns
(c) both (a) and (b)
(d) increases with increase in mutual coupling.

(ii) Shannon's theorem states that the achievable data rate of a communication channel is equal to
(a) 2B log2(1 + SNR) (b) B log2(1+SNR)
(c) (B/2) log2(1+SNR) (d) B log2(1+2SNR).

(iii) At high frequencies the current through a conductor prefers to flow at
(a) the surface
(b) at a depth inward from the surface
(c) a penetration depth as a function of frequency
(d) both (a) and (c).

(iv) In a basic heterodyne receiver, if $f_{L0j} = f_{RFj} - f_{IF}$, then it will require
(a) reconfigurable filter (b) frequency synthesizer
(c) image reject filter (d) none of the above.

(v) Packages for bioMEMS should be
(a) inert to body temperature (b) inert to mishandling by user
(c) inert to biological attack of human system (d) all of the above.

(vi) Crosstalk is
(a) the disturbance caused in the nearby channel or circuit due to transmitted signal
(b) adjacent frequency rejection
(c) generation of closely lying side bands
(d) none of these.

(vii) For high frequency (GHz) applications, if width of wire is increased it
(a) reduces inductance, series resistance, capacitance to substrate
(b) reduces inductance, series resistance but capacitance to substrate rises
(c) increases inductance, series resistance, capacitance to substrate
(d) increases inductance, series resistance, but reduces capacitance to substrate.

(viii) SOI stands for
(a) splitting of ions (b) silicon on insulator
(c) substrate on insulator (d) silicon orientation index.

(ix) Piezoelectric effect is the production of electricity by
(a) chemical effect (b) varying field
(c) temperature (d) pressure.

(x) The "double-Sideband (DSB)" noise figure (NF) in direct–conversion mixer is given by,
(a) 0 Db (b) -10 dB (c) -12 dB (d) -15 dB.

Fill in the blanks with the correct word

(xi) The fabrication process that grows Silicon dioxide layer on Silicon is called _____.

(xii) The fabrication process that removes unwanted material from a layer is _____.

(xiii) The inverse transducer of a microphone is _____.

(xiv) _____ inductors are typically realised as metal spirals.

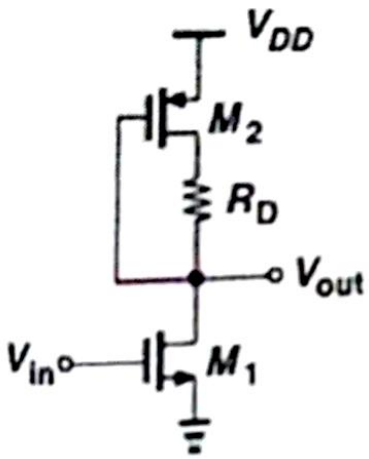
(xv) An application of Surface micromachining is _____.

Group - B

2. (a) Explain the concept of Noise Figure(NF) and express NF in terms of source impedance. *[(CO1)(Understand/LOCQ)]*

(b) Derive the expression of Friss Equation considering Noise Figure of cascaded stages. *[(CO1)(Apply/IOCQ)]*

(c) Determine the Noise Figure in the following circuit with respect to a source image R_s. Neglect channel-length modulation and Body effect.



[(CO1)(Evaluate/HOCQ)]

4 + 5 + 3 = 12

3. (a) Explain the principle of operation of varactors. *[(CO6)(Understand/LOCQ)]*

(b) An analog multiplier "mixes" its two inputs x1(t) = A1cos ω1t and x2(t) = A2cos ω2(t) and ideally produces y(t) = kx1(t)x2(t), where k is a constant. If the mixer is ideal, determine the output frequency components. If the input port sensing x2(t) suffers from third-order nonlinearity, determine the output frequency components. *[(CO1)(Apply/IOCQ)]*

(c) We wish to employ a capacitive coupling at the input of a stage (Fig.1) that as an input capacitance of Cin. Determine the additional input capacitance resulting from the coupling capacitor. Assume, Cp = 0.1Cc.

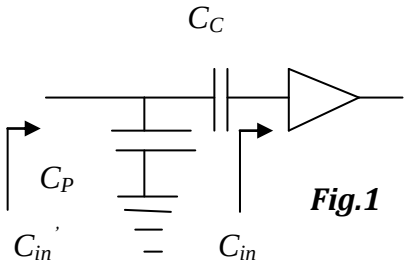


Fig.1

[(CO6)(Evaluate/HOCQ)]]

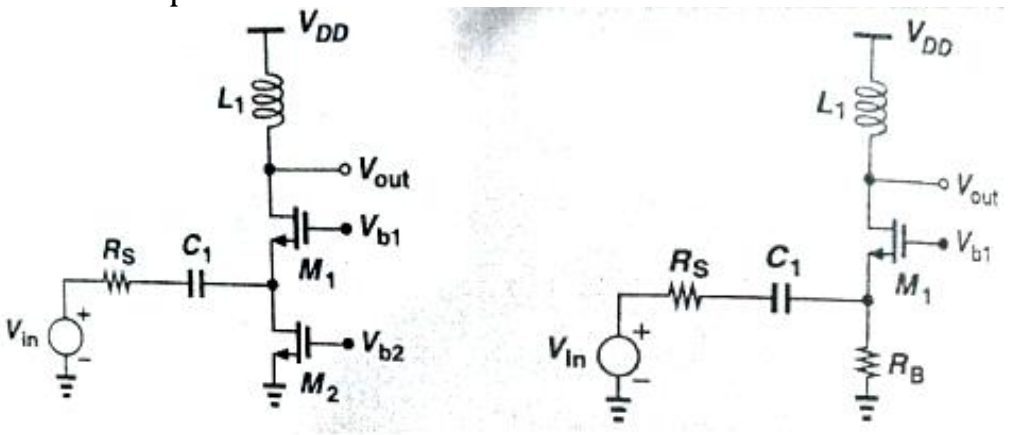
4 + 5 + 3 = 12

Group - C

4. (a) Briefly discuss the gain and linearity considerations of a Low –Noise Amplifier (LNA). *[(CO3)(Understand/LOCQ)]*

(b) Derive the expression of the Noise Figure (NF) of the Common-Gate (CG) stage topology for the LNA design. *[(CO3)(Apply/IOCQ)]*

(c) We wish to provide the bias current of the CG stage by a current source or a resistor. Compare the additional noise in these two cases.



[(CO6)(Evaluate/HOCQ)]

4 + 5 + 3 = 12

5. (a) Explain the principle of operation of basic heterodyne receiver. What do you understand by "image" frequency? *[(CO2)(Understand/LOCQ)]*

(b) Formulate the down-conversion in such receiver if the desired signal and the image are expressed by $A_{in}(t)\cos[\omega_{in}t + \Phi_{in}(t)]$ and $A_{im}(t)\cos[\omega_{im}t + \Phi_{im}(t)]$. *[(CO2)(Apply/IOCQ)]*

(c) Explain how a band-pass filter following LNA can alleviate the Tx-Rx leakage in a CDMA system. *[(CO6)(Apply/IOCQ)]*

(4 + 2) + 3 + 3 = 12

Group - D

6. (a) Discuss the steps of Bulk Micromachining with proper diagrammatic illustrations. *[(CO4)(Understand/LOCQ)]*
   (b) Discuss in detail how the CVD process can be utilized during the fabrication of Microsystems. *[(CO5)(Understand/LOCQ)]*

6 + 6 = 12

7. (a) Discuss the process of screen printing and hot embossing with suitable diagramatic illustrations. *[(CO4)(Apply/IOCQ)]*
   (b) Illustrate on: (i) Anisotropic etching (ii) MEMS pressure sensor. *[(CO4)(Apply/IOCQ)]*
   (c) Classify the different processes of actuation. *[(CO4)(Analyse/IOCQ)]*

3 + 5 + 4 = 12

Group - E

8. (a) Write the fabrication steps of a square fluid nozzle. Draw a suitable diagram. *[(CO6)(Analyze/IOCQ)]*
   (b) Explain micromechanical resonators. Review the alterations that can be made in the MEMS resonator to increase its resonant frequency. *[(CO4) (Analyze/IOCQ)]*

6 + (3 + 3) = 12

9. (a) Explain working principle of MEMS gas sensor. *[(CO5)(Remember/LOCQ)]*
   (b) Draw a neat diagram of a surface micro-machined variable capacitor. Explain its working principle. *[(CO6)(Apply/IOCQ)]*
   (c) What are the desirable properties in an rf micromechanical switch? *[(CO6)(Analyze/IOCQ)]*

4 + (3 + 3) + 2 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	35.41	55.2	9.37

Course Outcome (CO):

After the completion of the course students will be able to

1. Specify noise and interference performance metrics like noise figure, IIP3 and different matching criteria.
2. Comprehend different multiple access techniques, wireless standards and various transceiver architectures.
3. Design various constituents' blocks of RF receiver front end.
4. Describe MEMS fabrication technologies.
5. Critically analyze micro-systems technology for technical feasibility as well as practicality.
6. Comprehend the working of various systems and design electronic circuits for various applications

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*