## M.TECH/VLSI/3RD SEM/VLSI 6132/2021

# RF IC DESIGN AND MEMS
## (VLSI 6132)

**Time Allotted : 3 hrs** **Full Marks : 70**

***Figures out of the right margin indicate full marks.***

***Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.***

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

## Group – A
## (Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Integrated transmission lines used in RF design include
(a) Microstrip line (b) stripline
(c) Coplanar line (d) all of the above.

(ii) The *S*-parameter ($S_{12}$) characterizes
(a) Gain (b) reverse isolation
(c) Input matching (d) output matching

Of the two-port network

(iii) Desensitization occurs when receiver gain
(a) Reduced by large interferer & small desired signal
(b) Increased by large interferer & small desired signal
(c) Reduced by small interferer & small desired signal
(d) Increased by large interferer & large desired signal.

(iv) The stern stability factor for LNA is defined as
(a) $K = \frac{1+|\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2|S_{21}||S_{12}|}$ (b) $K = \frac{1+|\Delta|^2 + |S_{11}|^2 + |S_{22}|^2}{2|S_{21}||S_{12}|}$
(c) $K = \frac{1+|\Delta|^2 - |S_{21}|^2 - |S_{12}|^2}{2|S_{11}||S_{22}|}$ (d) $K = \frac{1+|\Delta|^2 + |S_{21}|^2 + |S_{12}|^2}{2|S_{11}||S_{22}|}$

(v) ____________ is commonly used as a mask for Si etching
(a) Silicon dioxide (b) Silicon nitride
(c) Silicone gel (d) Silicon sulphate.

(vi) The term LIGA refers to
(a) design (b) material
(c) microfabrication process (d) none of these.

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

(viii) One of the applications of Bulk micromachining is
(a) SAW sensor (b) Resonant sensor
(c) Temperature sensor (d) Pressure sensor.

(ix) Piezoelectric effect is the production of electricity by
(a) Chemical effect (b) Varying field
(c) Temperature (d) Pressure.

(x) The principle noise arising of a MOSFET is due to
(a) Drain current noise (b) Gate noise
(c) Shot noise (d) Flicker noise.

## Group – B

2. (a) Explain the concept of Third-Intercept point as a measure of intermodulation. Illustrate the method of its calculation graphically. [(CO1)( Understand/LOCQ)]
(b) A broadband circuit sensing an input $V_0 cos\omega_0 t$ produces a third harmonic $V_3 Cos(3\omega_0 t)$. Determine the *1-dB* compression point in terms of $V_0$ and $V_3$. [(CO1)(Apply/IOCQ)]
(c) A *LNA* senses *-80dBm* signal at *2.410GHz* and two *-20dBm* interferers at *2.420GHz* and *2.430GHz*. Evaluate the $IIP_3$ required if the intermodulation (*IM*) products must remain *20dB* below the signal. For simplicity, assume *50Ω* interfaces at the input and output. [(CO1)(Evaluate/HOCQ)]

**4 + 3 + 5 = 12**

3. (a) Explain the phenomenon of cross-modulation. Define *1-dB* compression point. [(CO1)(Understand/LOCQ)]
(b) Justify why the output noise of a circuit depends on the output impedance of the preceding stage. [(CO1)(Apply/IOCQ)]
(c) Prove that in Fig. 1 the noise power delivered by $R_1$ to $R_2$ is equal to that delivered by $R_2$ to $R_1$ if the resistors reside at the same temperature. Analyze what happens if they do not. [(CO6)(Evaluate/HOCQ)]

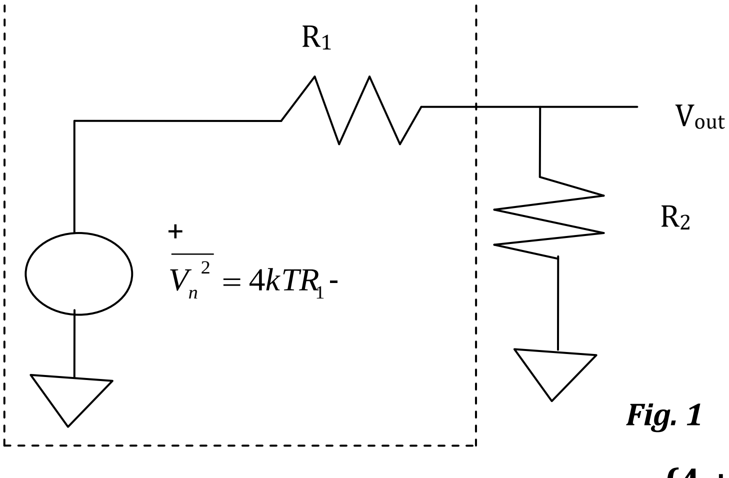


*Fig. 1*

**(4 + 1) + 3 + 4 = 12**

## Group – C

4. (a) Explain the basic principle of oscillation. What do you understand by phase noise? [(CO3)(Understand/LOCQ)]

(b) Consider a receiver architecture (Fig. 2) wherein $\omega_0 = (\omega_{RF}/2)$ so that the RF channel is translated to *IF* of $\omega_{RF} - \omega_{LO} = \omega_{LO}$ and subsequently to zero. Study the effect of port-to-port feedthrough in this architecture. [(CO3)(Analyze/IOCQ)]

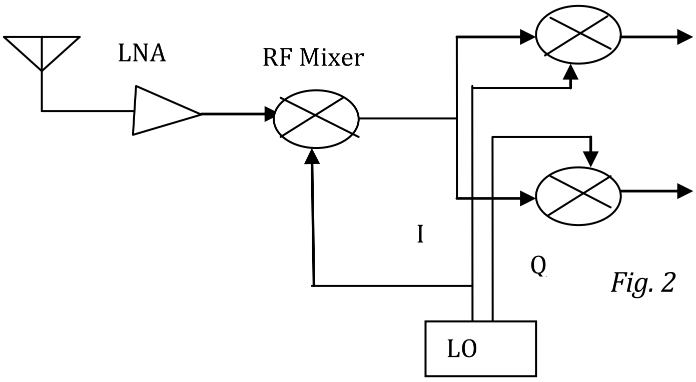


*Fig. 2*

(c) Prove that the voltage conversion gain of a single-balanced return-to-zero mixer is equal to $(2 / \pi)$ even for upconversion. [(CO3)(Evaluate/HOCQ)]

**(4 + 1) + 3 + 4 = 12**

5. (a) Derive the expression of *NF* of common-gate stage *LNA*. [(CO3)(Analyze/IOCQ)]

(b) Consider a *2.4GHz* dual-downconversion receiver (Fig. 3) where the first *LO* frequency is chosen so as to place the (primary) image in the GPS band for some of the channels. Determine a few mixing spurs. [(CO2)(Analyze/IOCQ)]

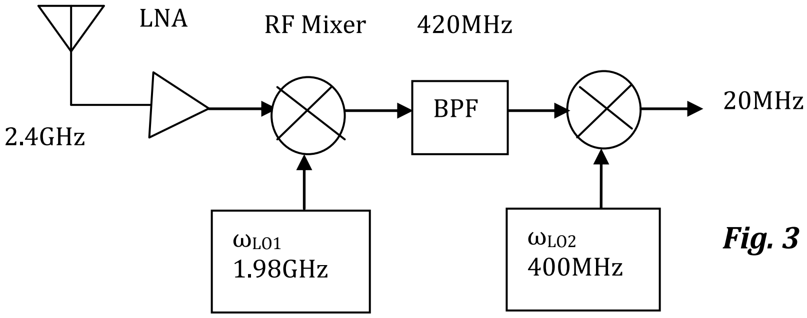


***Fig. 3***

(c) A designer wishes to provide bias current of the common-gate stage by a current-source (Fig. 4(a)) or a resistor (Fig.4(b)). Evaluate the additional noise in these two cases. [(CO6)(Evaluate/HOCQ)]

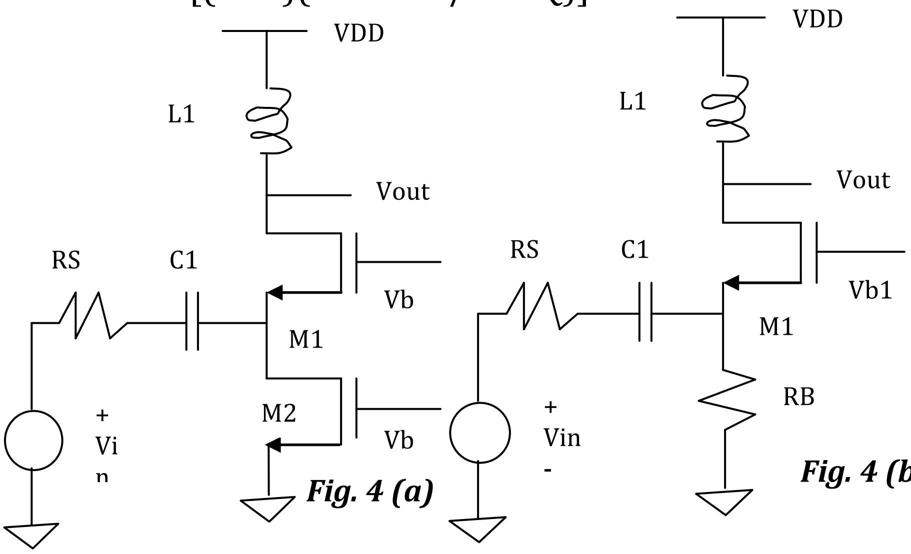


***Fig. 4 (a)*** ***Fig. 4 (b)***

**4 + 3 + 5 = 12**

## Group – D

6. (a) Illustrate the various processes of oxidation of Silicon, clearly stating the possible advantages and disadvantages of each process. [(CO4)(Understand/LOCQ)]
   (b) Illustrate the process of bulk micromaching in steps with the help of sketching a proper diagram. Name a MEMS device which can be made by this technique. [(CO5)(Understand/LOCQ)]

**6 + 6 = 12**

7. (a) Highlight the process and importance of (i) Chemical Vapour Deposition (ii) Isotropic Etching. [(CO4)(Understand/LOCQ)]
   (b) Choose any 3 physical effects. Illustrate them and relate how those effects are utilized in designing and determining the working principles of sensors. [(CO4)(Apply/IOCQ)]

**6 + 6 = 12**

## Group – E

8. (a) Illustrate the operation of a surface micromachined variable capacitor. [(CO5)(Understand/LOCQ)]
   (b) Explain the steps of realizing cantilever structure by surface micromachining process. [(CO4)(Analyze/IOCQ)]
   (c) Define the working principle of an accelerometer sensor with the help of a simple illustrative diagram. [(CO5)(Understand/LOCQ)]

**4 + 5 + 3 = 12**

9. (a) Illustrate the alterations that can be made in the MEMS resonator to increase its resonant frequency. [(CO6)(Analyze/IOCQ)]
   (b) Sketch a membrane switch distinctly during on state and off state. Outline the desired properties and applications of a MEMS RF switch. [(CO6)(Apply/IOCQ)]
   (c) Briefly structure a Lab-On-Chip application of MEMS. [(CO6)(Analyze/IOCQ)]

**3 + (4 + 2) + 3 = 12**

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| Cognition Level | LOCQ | IOCQ | HOCQ |
|---|---|---|---|
| Percentage distribution | 40.63% | 40.63% | 18.74% |

**Course Outcome (CO):**

After the completion of the course students will be able to

CO1 : Specify noise and interference performance metrics like noise figure, IIP3 and different matching criteria.
CO2 : Comprehend different multiple access techniques, wireless standards and various transceiver architectures.
CO3 : Design various constituents' blocks of RF receiver front end.
CO4 : Describe MEMS fabrication technologies.
CO5 : Critically analyze micro-systems technology for technical feasibility as well as practicality.

CO6 : Comprehend the working of various systems and design electronic circuits for various applications.

| **Department & Section** | **Submission link:** |
|---|---|
| VLSI | https://classroom.google.com/w/NDE4NjIzMDIxMjU3/tc/NDY0MTg4MDUxODI2 |