M.E. ELECTRICAL ENGINEERING FIRST YEAR SECOND SEMESTER EXAMINATION, 2024

TRANSDUCER TECHNOLOGY (MS)

Full Marks 100

Time: Three hours

(50 marks for each part)

Use a separate Answer-Script for each part

PART I

Answer any *TWO* questions

1.   Answer the following with relevant explanations/ derivations

(a) "In *variable air-gap* capacitive displacement transducers with composite dielectric, increase in sensitivity is achieved at the cost of linearity". Justify or correct the statement.   5

(b) Why should the piezoelectric sensor used in an accelerometer be prestressed?   5

(c) What is the working principle of a transistor based 'Complementary To Absolute Temperature' (CTAT) sensor?   5

(d) "The Rogowski coil current transducer is immune to the effect of any current path outside the aperture of the core." Justify or correct the statement.   5

(e) Why does an open-loop Hall-effect current transducer require a field-enhancing ferromagnetic toroid ? What other advantage and disadvantage do the use of this toroid have?   5

2. (a) Consider a capacitive liquid level gauge consisting of two coaxial cylindrical electrodes, each having a height of 80 cm. The liquid level rises in a direction parallel to the axis of the electrodes. The separation between the electrodes is one-tenth the radius of the inner electrode. Determine the sensitivity of the gauge in V/m, when used for a liquid with relative permittivity of 6. Consider the permittivity of free space as 8.842 pF/m. The above sensor is used as the timing capacitor in an astable multivibrator circuit employing a 555 timer. The timing resistances are each 1.5 MΩ. Determine the nominal frequency of the output. Calculate the % deviation of the   15

frequency from its nominal value, when the liquid level is 20 cm up from the bottom of the electrodes. Derive the expressions used.

(b) With reference to any appropriate signal conditioning circuit for capacitive transducers, bring out clearly the functioning of diode based asynchronous demodulation arrangement. Give suitable illustrations and explanations for both static and dynamic measurements.   **10**

OR

2. (a) A piezoelectric transducer consists of a rectangular slab held between two metal electrodes placed on the opposite surfaces. The charge sensitivity of the sensor material is 8 pC/N. The capacitance and the leakage resistance of the sensor are 25 pF and 2×10^{10} Ω respectively. Connections from the transducer are taken to a voltage measuring device preceded by a unity gain buffer amplifier through a coaxial cable having a shunt capacitance of 10 pF. The input resistance and the capacitance of the buffer amplifier are 1000 MΩ and 1 pF respectively. Calculate the sinusoidal steady state gain of the system in mV/N at 2000 Hz. Derive the expression used for calculating the gain.   **15**
How is the low frequency limit of such a system defined? Determine the value of this low frequency limit.

(b) What betterment in the performance can be attained by replacing the unity-gain buffer amplifier with a charge amplifier? Explain with relevant equivalent circuit and mathematical analysis.   **10**

3. (a) Examine the possibility of achieving a proportional to absolute temperature (PTAT) sensor, using a single transistor and two constant current sources with switching arrangement.   **10**

(a)   **OR**
Indicate clearly the advantages of Rogowski coil (with integrator) over conventional CTs with ferromagnetic core.   **10**

(b) Explain with sketches the necessity of electrostatic shielding of Rogowski coil current transducer. How is it implemented?   **8**

(c) Under what condition can a Rogowski coil current transducer be operated in the current transformer mode? Elucidate.   **7**

4.   Write notes on <u>any two</u> of the following.

(a)   Transformer double ratio bridge.   **12 ½**
                                                                                          +
(b)   Capacitive humidity sensor.   **12 ½**

(c)   Closed-loop Hall effect current transducer.

(d)   Synchronous demodulation arrangement for capacitive sensor signal conditioning.

------   -------

M.E. Electrical Engineering First Year Second Semester Examination, 2024

Transducer Technology

Time: Three Hours   Full Marks: 100

(50 Marks for each part)

Use a separate Answer Script for each Part

PART-II

Answer _Any Two_ Questions

Q1a) What are the key factors for selecting magnetic particles in magnetic NDT? What method of applying magnetic particles is considered to be the most sensitive? Explain with reasons. How the orientation of defects does affect magnetic particle testing?

3+3+3

Q1b) Explain the principle of operation of eddy current eddy current testing (ECT). What are the main variables that affects eddy current signals in test piece? What type of frequencies should be used to detect surface and subsurface flaws and why?   4+4+3

Q.1c) Briefly discuss the characteristics of penetrant materials used in liquid inspection testing.

5

Q.2a) Define acoustic impedance. Why it is important for ultrasonic testing? Briefly describe how the excess penetrants can be removed from the surface of the part in LPI.   What frequencies should be used to detect surface and subsurface flaws in eddy current testing and why?

2+2+3+2

Q.2b) Why longitudinal waves are rarely used for angle beam ultrasonic inspection? In ultrasonic testing; why a liquid coupling medium is necessary between the crystal surface and the part surface? In ultrasonic contact testing, defects near the entry surface cannot be always detected because of i) far-field effect, ii) attenuation, iii) dead-zone, iv) refraction –choose the correct answer and justify. Why the velocity of the ultrasonic waves changes when travel from steel to aluminum but its frequency remain same.

2+2+2+2

Q.2c) Why continuous magnetization technique is advantageous over residual magnetization technique?

What is meant by acoustic emission technique? Explain AE linear source location technique and also advantages of AE testing method. 3+(2+3)

Q.3a) Explain the dry oxidation and wet oxidation processes for growing oxide on silicon and give the relative merits and demerits of each process. 2+2+2+2

Q.3b) Why Development and Hard Bake process steps are necessary after transferring pattern on to the substrate. What do you mean by resist stripping? 3+3

Q.3c) Why Etching is necessary in microfabrication for creating MEMS device? How Silicon can be etched out by using this process?

Briefly describe the PECVD process for thin film deposition of material. In what ways it is different from LPCVD process? 2+3+4+2

Q.4a) Name the different micromachining processes and also the differences between them related to fabrication process. 4+4

Q.4b) Briefly mention the process steps involves in creating cantilever beam through surface micromachining and mention it's differences from bulk micromachining process. 12

Q.4c) Why silicon is best suited material for MEMS? 5