Vidyavardhini's College of Engineering and Technology, Vasai (West)

First Year Engineering

Academic Year: 2024-2025

Problem Set 4: Solid state sensors

Subject: BSC2023/EP **Date: 10/03/2025**
Max Marks: 10 **Submission Deadline: 21-03-2025**

CO4: To describe the significance of solid-state sensors.

Q1: Explain the Hall effect and derive expressions for the Hall voltage, Hall coefficient, and determine the charge carrier concentration.

Solution The Hall effect occurs when a magnetic field is applied perpendicular to the current flowing in a conductor or semiconductor, generating a transverse voltage known as the Hall voltage. The Hall voltage is given by:

$$V_H = \frac{IB}{qnd} \tag{1}$$

where:

- V_H = Hall voltage
- I = Current flowing through the conductor
- B = Magnetic field strength
- q = Charge of the carrier
- n = Charge carrier concentration
- d = Thickness of the conductor

The Hall coefficient R_H is given by:

$$R_H = \frac{1}{qn} \tag{2}$$

By measuring the Hall voltage, we can determine the charge carrier concentration as:

$$n = \frac{IB}{qV_H d} \tag{3}$$

Q2: A sample carries a current of $I = 5\text{mA}$ in a magnetic field of $B = 0.2\text{T}$. If the sample thickness is $d = 1\text{mm}$ and the charge carrier concentration is $n = 8 \times 10^{22}\text{m}^{-3}$, find the Hall voltage assuming electron charge $q = 1.6 \times 10^{-19}\text{C}$.

Solution:

$$V_H = \frac{IB}{qnd} = \frac{(5 \times 10^{-3})(0.2)}{(1.6 \times 10^{-19})(8 \times 10^{22})(1 \times 10^{-3})} \tag{4}$$

$$V_H = 78.1 \times 10^{-6}\text{V} \tag{5}$$

Q3: A quartz crystal has a thickness of $t = 1\text{mm}$, Young's modulus $E = 7.9 \times 10^{10}\text{Pa}$, and density $\rho = 2.65 \times 10^{4}\text{kg/m}^3$. Calculate the fundamental and first harmonic frequency of ultrasonic vibrations.

Solution: Using the formula:

$$f = \frac{P}{2t}\sqrt{\frac{E}{\rho}} \tag{6}$$

For $P = 1$:

$$f = \frac{1}{2(1 \times 10^{-3})}\sqrt{\frac{7.9 \times 10^{10}}{2.65 \times 10^{4}}} \tag{7}$$

$$f \approx 8.7 \times 10^{5}\text{Hz} \tag{8}$$

For $P = 2$:

$$f \approx 1.74 \times 10^{6}\text{Hz} \tag{9}$$

Q4: A piezoelectric generator has an inductor of $L = 2\text{mH}$ and a capacitor of $C = 5\text{nF}$. Calculate the frequency of oscillation.

Solution: Using the formula:

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{10}$$

$$f = \frac{1}{2\pi\sqrt{(2 \times 10^{-3})(5 \times 10^{-9})}} \tag{11}$$

$$f \approx 50.33 \times 10^{3}\text{Hz} \tag{12}$$

Q5: An ultrasonic pulse is sent toward a wall and the echo is received after 0.02s. If the speed of sound is 343m/s, determine the distance of the wall.

Solution: Since the pulse travels to the wall and back:

$$d = \frac{vt}{2} = \frac{(343)(0.02)}{2} = 3.43\text{m} \tag{13}$$