國立成功大學
114學年度碩士班招生考試試題

編　號：119

系　所：生物醫學工程學系

科　目：電子學

日　期：0210

節　次：第 2 節

注　意：1.可使用計算機
2.請於答案卷(卡)作答，於試題上作答，不予計分。

Question 1: Semiconductor Fundamentals (5 points)

a. Explain what a semiconductor is and its basic properties. (2 points)

b. Describe the differences between p-type and n-type semiconductors. Include their doping processes and charge carriers. (3 points)

Question 2: Formation of a PN Junction (3 points)

Explain the process of creating a PN junction. Use diagrams to illustrate how p-type and n-type materials form a depletion region and the resulting electric field.

Question 3: Bipolar Junction Transistor (BJT) (5 points)

a. Describe the structure of a BJT. (2 points)

b. Explain the principle of operation for the BJT, focusing on the active mode. (3 points)

Question 4: Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) (7 points)

a. Explain the structure of a MOSFET, emphasizing the role of the gate, source, and drain. (3 points)

b. Discuss the different operating regions of a MOSFET (cut-off, linear/triode, and saturation regions) and their significance. (4 points)

Question 5: Common Base Amplifier (20 points)

a. Circuit Diagram: Draw the circuit diagram of a Common Base (CB) amplifier. Clearly label the input, output, and biasing components. (3 points)

b. Characteristics and Applications:
   - i. Explain the key characteristics of a CB amplifier, including input impedance, output impedance, and voltage gain. (3 points)
   - ii. ii. Discuss two practical applications of CB amplifiers. (2 points)

c. Analysis and Derivations:
   - i. Derive the voltage gain equation for a CB amplifier. (4 points)
   - ii. Derive the input resistance/output resistance of a CB amplifier, showing all steps. (4 points)

d. Frequency Response:
   - i. Explain the low-frequency, mid-frequency, and high-frequency behavior of a CB amplifier. (2 points)
   - ii. Discuss how the bypass capacitor (if present) impacts the frequency response. (2 points)

Question 6: Current-Mirror Loaded MOS Differential Amplifier (20 points)

a. **Circuit Diagram**:
   Draw the circuit diagram of a current-mirror loaded MOS differential amplifier. Clearly label all key components, including the differential pair, current mirror, input nodes, and output nodes. (5 points)

b. **Common-Mode Gain**:
   Derive the expression for the common-mode gain A_{CM} of the amplifier. Include all necessary steps and assumptions in your derivation. (7 points)

c. **Common-Mode Rejection Ratio (CMRR)**:
   - i. Define the common-mode rejection ratio (CMRR) and explain its significance in differential amplifiers. (3 points)
   - ii. ii. Derive the expression for the CMRR in terms of the differential gain A_{DM} and common-mode gain A_{CM}. Show all steps in the derivation. (5 points)

Question 7: Operational Amplifiers in Biomedical Signal Applications (20 points)

Operational amplifiers (OPAs) are widely used in biomedical signal processing due to their versatility and precision. Answer the following questions based on their applications:

a. **Characteristics and Requirements:**
Discuss the essential characteristics of an operational amplifier that make it suitable for biomedical applications. Consider parameters such as input impedance, output impedance, gain, and noise performance. (5 points)

b. **Applications in Biomedical Signals:**
   i. Explain how OPAs are used in amplifying weak biomedical signals, such as ECG or EEG signals. Include a discussion on the role of differential amplification in rejecting noise. (5 points)
   ii. Describe the role of an instrumentation amplifier (which uses OPAs) in biomedical circuits and why it is preferred for precise signal acquisition. (5 points)

c. **Practical Design Considerations:**
Discuss two challenges encountered when designing OPA-based circuits for biomedical applications and propose solutions to address them. (5 points)

Question 8: Please answer the following questions (20 points)

a. **DC bias design**
Perform a DC bias design for the amplifier in Figure 1. For this purpose, assume β is very high and $V_{BE} = 0.7\,\text{V}$, and neglect the Early effect. Design to obtain a DC base voltage of $V_{CC}/3$, a DC emitter current of 1 mA, and a DC voltage at the collector that allows for $\pm 1\,\text{V}$, signal swing at the collector with the minimum collector voltage no lower than V_B. Use a DC current in the base voltage divider is $I_E/10$. What values are required for R_{B1}, R_{B2}, R_E, and R_C? (4 points)

b. **Voltage and current calculation**
If the transistor has $\beta = 100$, find the actual values obtained for I_E, I_C, V_B, and V_C. (4 points)

c. **Small signal parameters**
What are the values of g_m, r_e, and r_π at the DC bias point? (2 points)

d. **Biasing resistor design**
Assuming very large coupling and bypass capacitors, find the values of R_{E1}, and R_{E2} that result in $R_{\text{in}} = 10\,\text{k}\Omega$. (4 points)

e. **Overall voltage gain**
Find the overall voltage gain $G_v = \frac{v_o}{v_{\text{sig}}}$. (6 points)

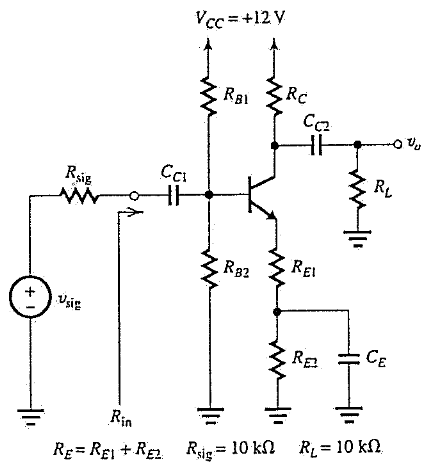

Figure 1.