國立成功大學
115學年度碩士班招生考試試題

編　號：113

系　所：生物醫學工程學系

科　目：電子學

日　期：0203

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: Terminologies (20%)

Please explain the following terminologies. You may use diagrams or equations to support your explanation.

(a) Thermal Noise (Johnson Noise): Explain its physical origin and write down the power spectral density equation for a resistor R. (4%)
(b) Crossover Distortion: Explain why this phenomenon occurs in Class-B output stages and how to eliminate it. (4%)
(c) Input Offset Voltage (V_{OS}): Define V_{OS} in a differential amplifier and list two major causes of it in MOS fabrication. (4%)
(d) CMRR (Common Mode Rejection Ratio): Define CMRR and explain why a high CMRR is critical for biomedical signal acquisition (e.g., ECG). (4%)
(e) Slew Rate: Explain the definition of slew rate in an operational amplifier and how it differs from the small-signal bandwidth limit. (4%)

Question 2: Cascode Amplifier with Active Load (20%)

Please draw the circuit diagram of a MOS Cascode Amplifier utilizing a Cascode Current-Source Load (i.e., a telescopic cascode topology consisting of an NMOS cascode driver stage and a PMOS cascode load stage), and derive the complete expression for its Small-Signal Voltage Gain (A_v). In your derivation, you must explicitly derive and express the Output Resistance (R_{out}) looking into the output node and the Short-Circuit Transconductance (G_m) of the amplifier. (Assume all transistors are biased in the saturation region and neglect the body effect for simplicity).

Question 3: Biomedical Filter Design (20%)

In ECG measurement, power line interference (60 Hz) is a significant noise source that can saturate the amplifier or corrupt the signal.

(a) You are asked to design an Active Notch Filter (Band-stop filter) to remove 60 Hz noise. Draw the circuit diagram of a Twin-T Notch Filter combined with an Op-Amp. (8%)
(b) Explain the function of the Op-Amp in your design (e.g., "Bootstrapping" or buffering) and how it affects the Q-factor of the filter. Why is a high Q-factor desirable for this specific application? (7%)

If the capacitors in the Twin-T network have a value of $C = 0.1\ \mu F$, calculate the required resistor value R to set the center frequency at exactly 60 Hz. (5%)

Question 4: Non-ideal MOS Differential Amplifier (20%)

Consider a MOS differential pair with resistive loads as shown in Figure 1 (Basic NMOS diff-pair with drain resistors R_D). Assume the circuit is symmetric ideally, but in reality, there are mismatches.

(a) If the two transistors have a threshold voltage mismatch of ΔV_{th} (i.e., $V_{th1} = V_{th}$, $V_{th2} = V_{th} + \Delta V_{th}$), please derive the expression for the resulting Input Offset Voltage (V_{OS}). Assume g_m is the transconductance of the transistors. (10%)

(b) Based on your derivation in (a), explain the design trade-off between the Overdrive Voltage ($V_{OV} = V_{GS} - V_{th}$) and the input offset voltage. Should we bias the transistors with a large or small V_{OV} to minimize the offset contributed by ΔV_{th}? (5%)

(c) If we use a current source (I) with a finite output resistance R_{SS} to replace the ideal tail current source, please derive the Common Mode Gain (A_{cm}) of this amplifier. (5%)

Question 5: Frequency Response - Time Constant Method (20%)

Figure 2 shows a Common-Source amplifier. There are three external capacitors: Input coupling capacitor C_{C1}, Output coupling capacitor C_{C2}, and Source bypass capacitor C_S.

(a) Among these three capacitors (C_{C1}, C_{C2}, C_S) and the internal parasitic capacitors (C_{gs}, C_{gd}), which group determines the Low-Frequency (f_L) response and which group determines the High-Frequency (f_H) response? (5%)

(b) Please use the Short-Circuit Time Constant (SCTC) method to derive the approximate lower 3-dB frequency (ω_L). You need to express the time constants τ_1, τ_2, τ_3 associated with each capacitor in terms of the circuit resistances ($R_{sig}, R_G, R_D, R_L, 1/g_m$). (15%) **(Note: Assume $\lambda = 0$ and ignore r_o for simplicity.** $R_G = R_{G1} || R_{G2}$)

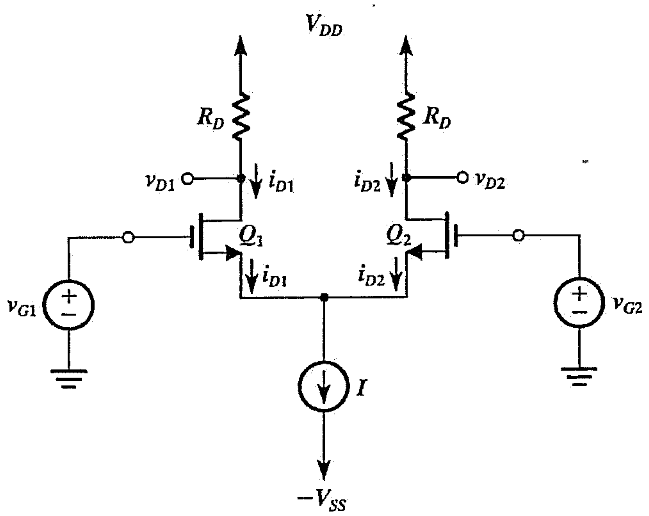

Figure 1

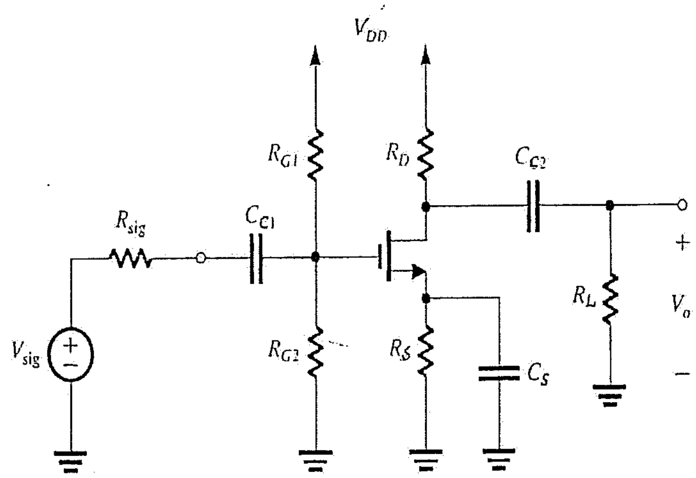

Figure 2