Instructions, notes, and hints:

You may make reasonable assumptions and approximations in order to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

Assignment:

1. The circuit shown below uses an enhancement-mode MOSFET having $V_t = -1$ V and $k_p = 2 \text{ mA/V}^2$. For the power supply voltages shown, find the values of $R_S$ and $R_D$ that result in a DC bias current of 1 mA and a quiescent drain voltage that is 2 V away from the triode-saturation boundary. Assume that $\lambda = 0$ (i.e., no significant channel-length modulation).

   $V_{DD} = +5 \text{ V}$
   $I_D$
   $R_S$
   $V_{DS}$
   $R_D$
   $V_D$
   $V_{SS} = -5 \text{ V}$

2. The circuit below is a variation of the drain-to-gate feedback bias circuit of Fig. 5.54 of the textbook. Resistor $R_{G2}$ introduces an extra degree of freedom into the design. Assuming that the NMOS transistor has $V_t = 1$ V, $k_n = 6.25 \text{ mA/V}^2$ and $\lambda = 0$, find the values of the three resistors required to make $I_D = 2 \text{ mA}$ with the value of $V_D$ set to 2 V above the triode-saturation boundary. Use 2.2 M$\Omega$ as the largest resistor in the feedback network ($R_{G1}$ and $R_{G2}$). Specify all resistor values to two significant digits only.

   $V_{DD} = 5 \text{ V}$
   $I_D$
   $V_G$
   $R_{G1}$
   $R_{G2}$
   $V_{DS}$
   $R_D$
   $V_D$

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3. Shown below is an attenuator circuit that uses a single n-channel MOSFET as a voltage-controlled resistor. The MOSFET has parameters $k_n = 5 \text{ mA/V}^2$ and $V_t = 2.5 \text{ V}$. Source $v_g$ and resistor $R_g$ model an audio signal source like an iPod. The source voltage has a peak value no higher than $20 \text{ mV}$. Capacitors $C_1$ and $C_2$ act as shorts in the audio frequency range. The potentiometer $R_{pot}$ has a total end-to-end resistance of $100 \text{ k}\Omega$. Find the values of resistors $R_1$, $R_2$, and $R_3$ so that the control voltage $V_G$ varies from $2.5 \text{ V}$ to $10 \text{ V}$ as the potentiometer is varied over its full range. Multiple combinations of resistor values will work; there is not a unique answer. The op-amps cannot produce output voltages all the way to the power supply limits; the output voltages are limited to $\pm 10 \text{ V}$.

4. For the circuit shown in Prob. 3, find the attenuation $v_o/v_g$ for the cases when the potentiometer’s wiper is at the top ($R_{hi}$ end), middle, and bottom ($R_{lo}$ end) of its range. Hint: Use the superposition principle and consider the DC and AC cases separately.

5. Find an algebraic expression for the voltage gain $G_v = v_o/v_{sig}$ for the amplifier circuit shown below. Include the MOSFET’s output resistance $r_o$, and assume that all of the capacitors have negligible reactance at the signal frequency. The MOSFET’s parameters are $k_n = 100 \text{ mA/V}^2$, $V_t = 2 \text{ V}$, and $V_{ds} = 200 \text{ V}$.

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6. Find the numerical value of the voltage gain \( G_v = \frac{v_o}{v_{\text{sig}} \cdot r_o} \) for the circuit in Prob. 5. Include the effect of \( r_o \). 

7. Find an algebraic expression for the voltage gain \( G_v = \frac{v_o}{v_{\text{sig}}} \) for the amplifier circuit shown below. Verify that the expression reduces approximately to \( G_v = -g_m R_D \) for sufficiently large values of \( R_G \) (i.e., for \( R_G \gg R_D \) and \( R_G \gg 1/g_m \)). Assume that \( \lambda = 0 \) and that all of the capacitors have negligible reactance at the signal frequency.

![Amplifier Circuit Diagram]

8. The circuit shown below is used to measure the parameters \( k_n, V_t, \) and \( \lambda \) of an n-channel MOSFET. The data shown next to the figure were obtained as the drain resistor \( R_D \) was varied in value while \( v_{\text{GS}} \) was held at a value of 2.900 V. Find the value of \( \lambda \) from the given data. You do not have to find the values of \( k_n \) and \( V_t \), although you may if you wish. Hint #1: Equation (5.23) of the textbook appears to be applicable here, but it is an approximation. A more accurate form is

\[
i_D = \frac{1}{2} k_n v_{\text{OV}}^2 \left[ 1 + \lambda (v_{DS} - v_{\text{OV}}) \right],
\]

where \( v_{\text{OV}} = v_{\text{GS}} - V_t \) (\( v_{\text{OV}} \) is the “overvoltage”). Hint #2: The channel-length modulation parameter \( \lambda \) is equal to the reciprocal of the Early voltage \( V_A \). Figure 5.17 in the textbook should help you see the significance of this toward solving the problem.

![MOSFET Measurement Circuit Diagram]

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<th>( R_D ) (( \Omega ))</th>
<th>( v_D ) (V)</th>
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