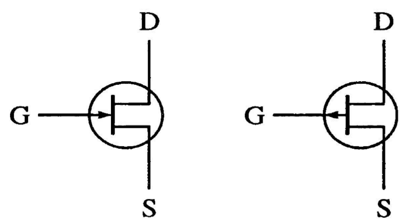
Solution Tutorial 2
BJTs, Transistor Bias Circuits, BJT Amplifiers, FETs and FETs Amplifiers

Part 2: FETs and FETs Amplifiers

1. Sketch the schematic diagrams for a p-channel and an n-channel JFET. Label the terminals.



n-channel p-channel

2. A certain p-channel JFET has a $V_{GS(off)}$ = 6 V. What is I_D when V_{GS} = 8 V?

Since $V_{GS} > V_{GS(off)}$, the JFET is off and I_D = **0 A**.

3. Using the curve in Figure 1, determine the value of R_S required for a 9.5 mA drain current.

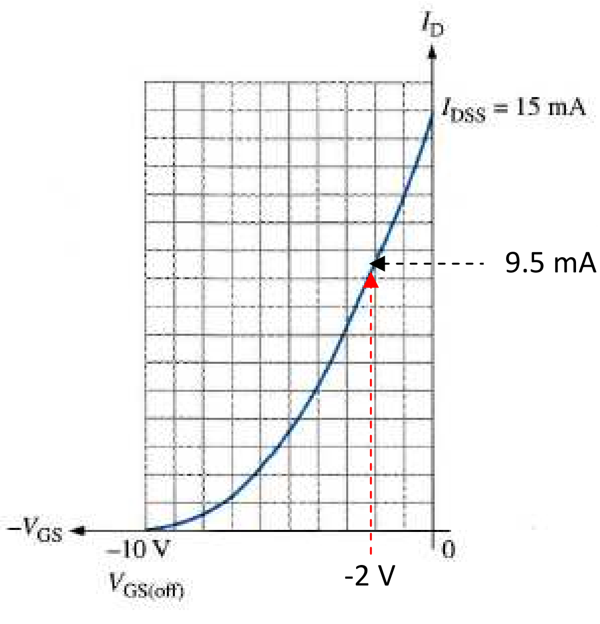


Figure 1

From the graph, $V_{GS} \cong -2$ V at I_D = 9.5 mA.

$$R_S = \left|\frac{V_{GS}}{I_D}\right| = \left|\frac{-2\text{ V}}{9.5\text{ mA}}\right| = \mathbf{211\ \Omega}$$

4. Graphically determine the Q-point for the circuit in Figure 2(a) using the transfer characteristic curve in Figure 2(b).

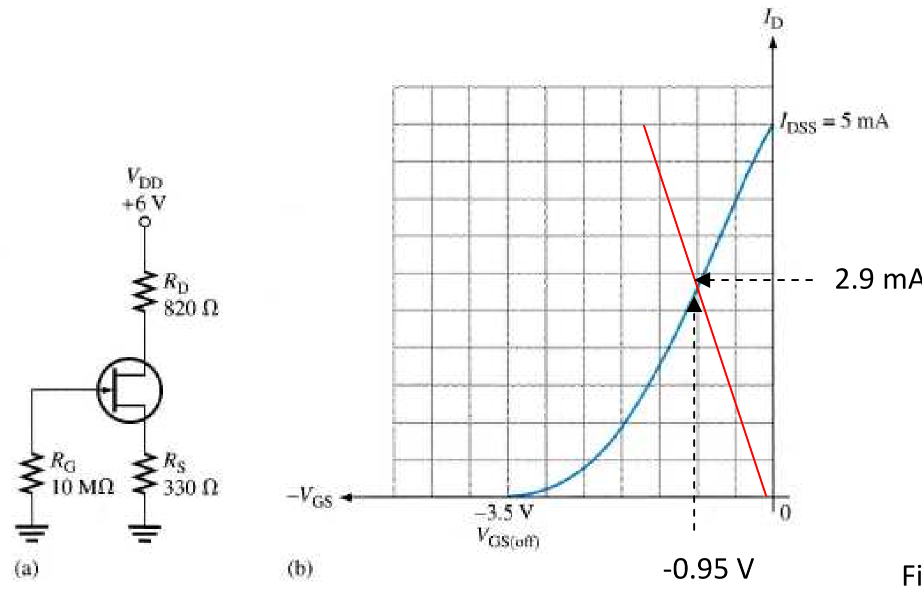


Figure 2

For $I_D = 0$

$V_{GS} = -I_D R_S = (0)(330\ \Omega) = 0\ \text{V}$

For $I_D = I_{DSS} = 5\ \text{mA}$

$V_{GS} = -I_D R_S = -(5\ \text{mA})(330\ \Omega) = -1.65\ \text{V}$

From the graph, the Q-point is

$V_{GS} \cong$ **-0.95 V** and $I_D \cong$ **2.9 mA**

5. Sketch the schematic symbols for p-channel and an n-channel D-MOSFETs and E-MOSFETs. Label the terminals.

n-channel D-MOSFET p-channel D-MOSFET n-channel E-MOSFET p-channel E-MOSFET

6. In what mode is an n-channel D-MOSFET with a positive V_{GS} operating?

An *n*-channel D-MOSFET with a positive V_{GS} is operating in the **enhancement mode.**

7. Determine I_{DSS}, given I_D = 3 mA, V_{GS} = -2 V and $V_{GS(off)}$ = -10 V.

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

$$I_{DSS} = \frac{I_D}{\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2} = \frac{3\ \text{mA}}{\left(1 - \frac{-2\ \text{V}}{-10\ \text{V}}\right)^2} = \mathbf{4.69\ mA}$$

8. Each E-MOSFET in Figure 3 has a $V_{GS(off)}$ of +5 V or -5 V, depending on a whether it is an n-channel or a p-channel device. Determine whether each MOSFET is on or off.

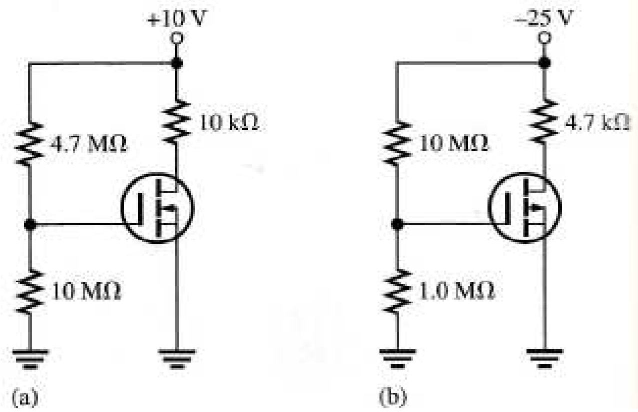


Figure 3

(a) $V_{GS} = \left(\frac{10\text{ M}\Omega}{14.7\text{ M}\Omega}\right)10\text{ V} = \mathbf{6.8\text{ V}}$ This MOSFET is **on**.

(b) $V_{GS} = \left(\frac{1.0\text{ M}\Omega}{11\text{ M}\Omega}\right)(-25\text{ V}) = \mathbf{-2.27\text{ V}}$ This MOSFET is **off**.

9. The gain of certain JFET amplifier with a source resistance of zero is 15.
Given g_m = 2300 µS, calculate the drain resistance.
$A_v = g_m R_d$
$R_d = A_v / g_m$ = 15 / 2300 µS = 15 / (2300 x 10^{-6} S) = 6.52 kΩ

10. Determine the voltage gain of each common-source amplifier in Figure 4.

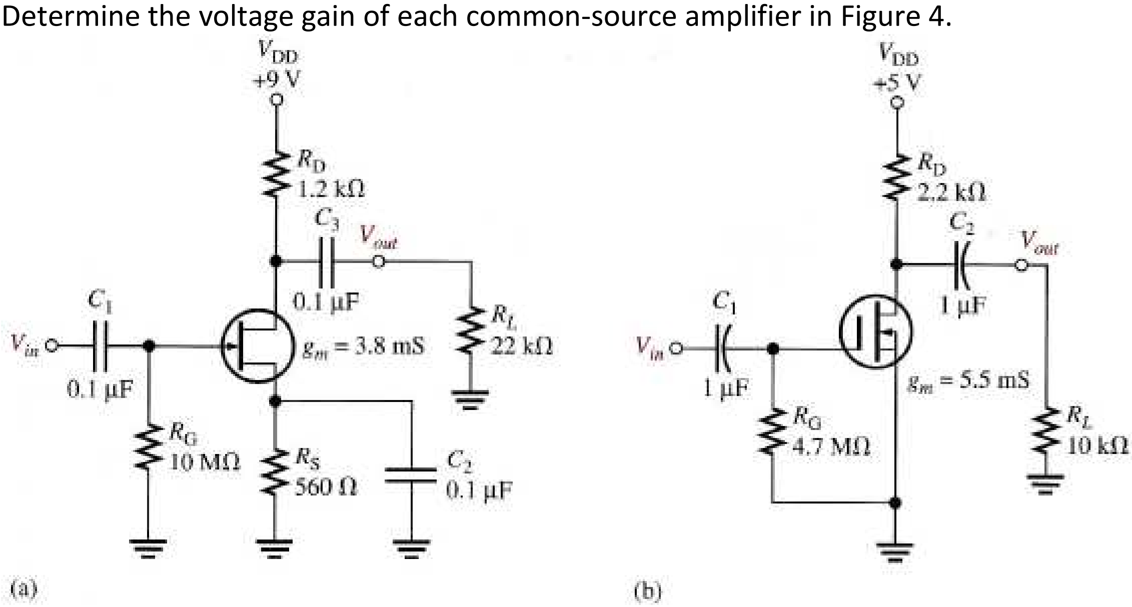


Figure 4

(a) $A_v = g_m R_d = g_m(R_D \parallel R_L) = 3.8\text{ mS}(1.2\text{ k}\Omega \parallel 22\text{ k}\Omega) = 3.8\text{ mS}(1138\ \Omega) = \mathbf{4.32}$

(b) $A_v = g_m R_d = g_m(R_D \parallel R_L) = 5.5\text{ mS}(2.2\text{ k}\Omega \parallel 10\text{ k}\Omega) = 5.5\text{ mS}(1.8\text{ k}\Omega) = \mathbf{9.92}$

11. For the common-source amplifier in Figure 5:
    (a) Calculate I_D, V_{GS}, and V_{DS} for a centered Q-point. I_{DSS} = 9 mA and $V_{GS(off)}$ = -3V.
    (b) If a 10 mV rms signal is applied to the input of the amplifier, calculate the rms value of the output signal.

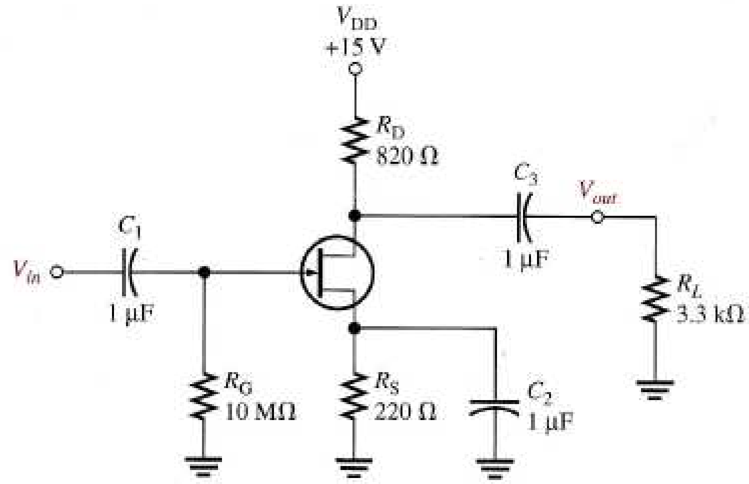


Figure 5

(a)

$$I_D = \frac{I_{DSS}}{2} = \frac{9\text{ mA}}{2} = \mathbf{4.5\ mA}$$
$$V_{GS} = -I_D R_S = -(4.5\text{ mA})(330\ \Omega) = \mathbf{-1.49\ V}$$
$$V_{DS} = V_{DD} - I_D(R_D + R_S) = 9\text{ V} - (4.5\text{ mA})(1.33\text{ k}\Omega) = \mathbf{3\ V}$$

(b)

$$A_v = g_m R_d = g_m\left(R_D \parallel R_L\right) = 3700\ \mu\text{S}\left(1.0\text{ k}\Omega \parallel 10\text{ k}\Omega\right) = 3700\ \mu\text{S}(909\ \Omega) = 3.36$$
$$V_{out} = A_v V_{in} = (3.36)(10\text{ mV}) = \mathbf{33.6\ mV\ rms}$$

12. For the unloaded amplifier in Figure 6, calculate I_D, V_{GS}, and V_{DS}, and the rms output voltage V_{ds}. Given = 8 mA at V_{GS} = 12 V, $V_{GS(th)}$ = 4V and g_m = 4500 μS.

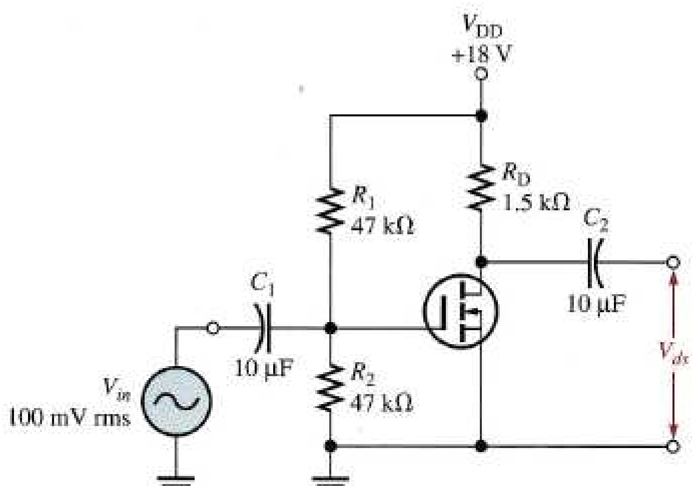


Figure 6

$$V_{GS} = \left(\frac{R_2}{R_1 + R_2}\right)V_{DD} = \left(\frac{47\ \text{k}\Omega}{94\ \text{k}\Omega}\right)18\ \text{V} = \mathbf{9\ V}$$

$$K = \frac{I_{D(on)}}{(V_{GS} - V_{GS(th)})^2} = \frac{8\ \text{mA}}{(12\ \text{V} - 4\ \text{V})^2} = 0.125\ \text{mA/V}^2$$

$I_{D(on)} = K(V_{GS} - V_{GS(th)})^2 = 0.125\ \text{mA/V}^2(9\ \text{V} - 4\ \text{V})^2 = \mathbf{3.13\ mA}$

$V_{DS} = V_{DD} - I_D R_D = 18\ \text{V} - (3.125\ \text{mA})(1.5\ \text{k}\Omega) = \mathbf{13.3\ V}$

$A_v = g_m R_D = 4500\ \mu\text{S}(1.5\ \text{k}\Omega) = 6.75$

$V_{ds} = A_v V_{in} = 6.75(100\ \text{mV}) = \mathbf{675\ mV\ rms}$

13. For the source-follower (common-drain amplifier) in Figure 7, calculate the voltage gain and input resistance. I_{GSS} = 50 pA at V_{GS} = -15 V and g_m = 5500 µS.

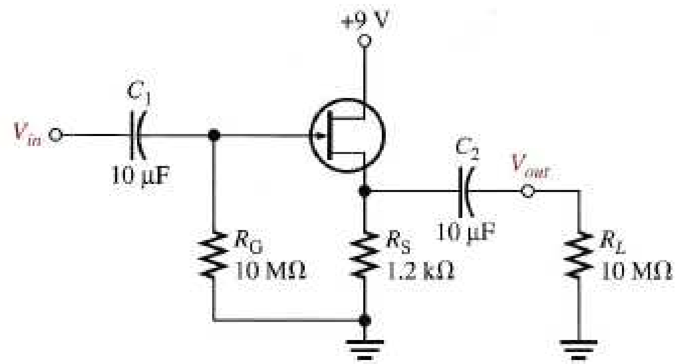


Figure 7

$R_s = 1.2\ \text{k}\Omega \parallel 10\ \text{M}\Omega \cong 1.2\ \text{k}\Omega$

$$A_v = \frac{g_m R_s}{1 + g_m R_s} = \frac{(5500\ \mu\text{S})(1.2\ \text{k}\Omega)}{1 + (5500\ \mu\text{S})(1.2\ \text{k}\Omega)} = \mathbf{0.868}$$

$$R_{IN} = \left|\frac{V_{GS}}{I_{GSS}}\right| = \left|\frac{-15\ \text{V}}{50\ \text{pA}}\right| = 3 \times 10^{11}\ \Omega$$

$R_{in} = 10\ \text{M}\Omega \parallel 3\times10^{11}\ \Omega \cong \mathbf{10\ M\Omega}$

14. Calculate the gain if a common-gate amplifier has a g_m = 4000 µS and R_d = 1.5 kΩ.

$A_v = g_m R_d = 4000\mu\text{S}(1.5\ \text{k}\Omega) = \mathbf{6.0}$

15. Consider the common-gate amplifier circuit in Figure 8:
(a) Calculate voltage gain and input resistance of the amplifier.
(b) For the unloaded amplifier in Figure 8, calculate its voltage gain and input resistance

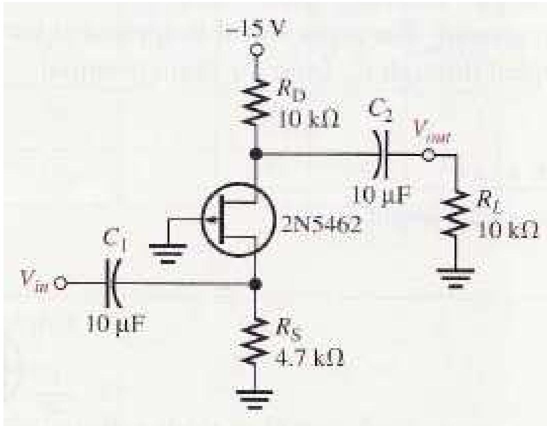


Figure 8

(a) Voltage gain and input resistance of the amplifier:

From data sheet 2N5460 p-channel JFET, g_m = 2000 µS minimum.
This common-gate amplifier has a load resistor, so the effective drain resistance is $R_D||R_L$ and the minimum voltage gain, A_v :

$A_v = g_m(R_D||R_L)$
$= (2000\ \mu S)(10\ k\Omega||10\ k\Omega) = \mathbf{10}$

The input resistance at the source terminal is
$R_{in(source)} = 1/g_m = 1/2000\ \mu S = 500\ \Omega$

The signal source actually sees R_S in parallel with $R_{in(source)}$, so the total input resistance is

$R_{in} = R_{in(source)}||R_S$
$= 500\ \Omega\ ||4.7\ k\Omega = \mathbf{452\ \Omega}$

(b) For the unloaded amplifier

$A_v = g_m Rd$
$= (2000\ \mu S)(10\ k\Omega) = \mathbf{20}$

$R_{in} = R_{in(source)}||R_S$
$= 500\ \Omega\ ||4.7\ k\Omega = \mathbf{452\ \Omega}$