Name ______________________
Date ______________________
Instructor ______________________

EXPERIMENT

21

Multistage Amplifiers: *RC* Coupling

OBJECTIVE

To measure DC and AC voltages in a multistage FET amplifier. To obtain measured values of voltage amplification (A_v), input impedance (Z_i), and output impedance (Z_o).

EQUIPMENT REQUIRED

Instruments

Oscilloscope
DMM
Function generator
DC supply

Components

Resistors

(2) 510-Ω
(1) 1-kΩ
(2) 2.4-kΩ
(1) 10-kΩ
(3) 1-MΩ

Capacitors

(3) 15-μF
(2) 100-μF

Transistors

(2) 2N3823, or equivalent

EQUIPMENT ISSUED

Item	*Laboratory serial no.*
DC power supply	
Function generator	
Oscilloscope	
DMM	

RÉSUMÉ OF THEORY

The DC bias of a JFET is determined by the device transfer characteristic (V_P and I_{DSS}) and the external circuit connected to it. The AC voltage gain at this DC bias point is then dependent on the device parameters (g_m or g_{fs}) and circuit drain resistance.

AC Voltage Gain: The voltage gain of an amplifier stage as in Fig. 21.1 can be calculated from

$$A_v = \frac{V_o}{V_i} = -g_m R_D = -g_m(R_D \| R_L) \tag{21.1}$$

where

$$g_m = g_{m0}\left(1 - \frac{V_{GSQ}}{V_P}\right) \quad \text{with } g_{m0} = \frac{2I_{DSS}}{|V_p|} \tag{21.2}$$

AC Input Impedance: The AC input impedance is

$$Z_i = R_G \tag{21.3}$$

AC Output Impedance: The AC output impedance is

$$Z_o = R_D \tag{21.4}$$

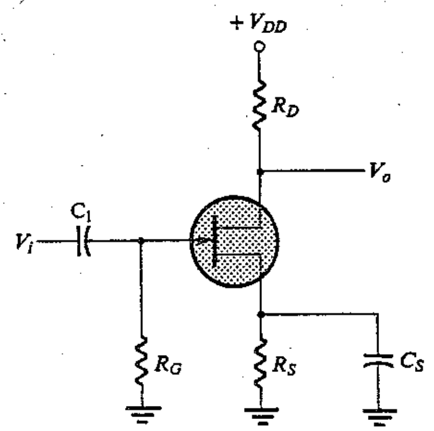

Figure 21-1

PROCEDURE

Part 1. Measurement of I_{DSS} and V_P

It is necessary to obtain values of I_{DSS} and V_P for both Q_1 and Q_2. Use a characteristic curve tracer, if available, to determine the values of I_{DSS} and V_P. Obtain readings at V_{DS} = +10 V.

For Q_1:

I_{DSS} = __________

V_P = __________

For Q_2:

I_{DSS} = __________

V_P = __________

Go on to Part 2.

Otherwise, use the following steps to obtain these values.

a. Construct the circuit of Fig. 21.2 with R_D = 510 Ω but with R_S = 0 Ω. Measure and record.

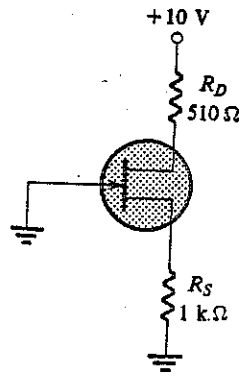

Figure 21-2

V_D (measured) = __________

Calculate the value of drain current, I_D

$$I_D = \frac{V_{DD} - V_D}{R_D}$$

I_D (calculated) = __________

since this is the drain current at $V_{GS} = 0$ V

$I_{DSS}(Q_1) = I_D =$ __________

(using the value of I_D just calculated).

Replace Q_1 and repeat measurement with Q_2.

V_D (measured) = __________

Calculate the value of drain current, I_D

$$I_D = \frac{V_{DD} - V_D}{R_D}$$

I_D (calculated) = __________

since this is the drain current at $V_{GS} = 0$ V

$I_{DSS}(Q_2) = I_D =$ __________

(using the value of I_D just calculated).

b. Now connect $R_S = 1\ \text{k}\Omega$. Measure and record the values of

V_{GS} (measured) = ________

V_D (measured) = ________

Using the measured values just obtained, calculate V_P as follows.

$$I_D = \frac{V_{DD} - V_D}{R_D}$$

I_D (calculated) = ________

$$V_P = \frac{V_{GS}}{1 - \sqrt{\frac{I_D}{I_{DSS}}}}$$

$V_P(Q_2)$ (calculated) = ________

Replace transistor Q_2 and repeat step 1(**b**) measurements.

V_{GS} (measured) = ________

V_D (measured) = ________

Using the measured values just obtained, calculate V_P as follows.

$$I_D = \frac{V_{DD} - V_D}{R_D}$$

I_D (calculated) = ________

$$V_P = \frac{V_{GS}}{1 - \sqrt{\frac{I_D}{I_{DSS}}}}$$

$V_P(Q_1)$ (calculated) = ________

Part 2. DC Bias of Common-Source Circuit

a. Calculate the DC bias expected in the circuit of Fig. 21.3, using I_{DSS} and V_P obtained in Part 1 for each transistor.

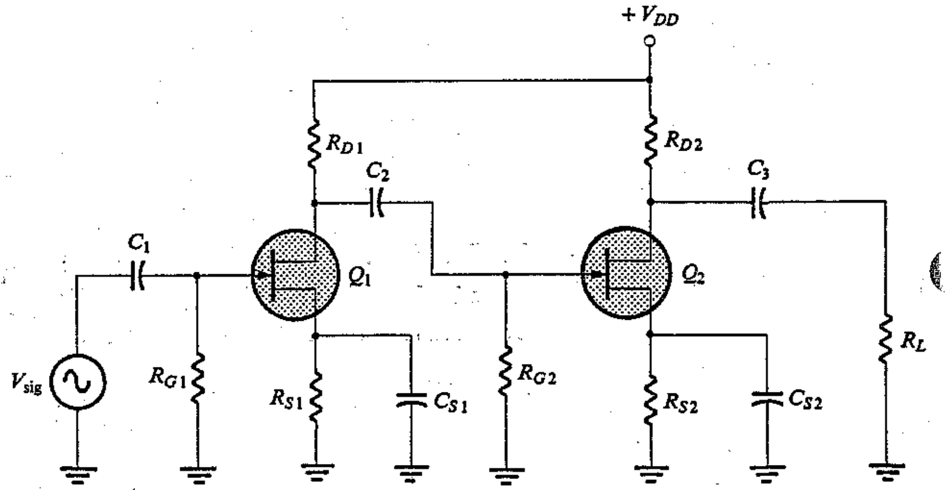

Figure 21-3

Draw graphs of the equations

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 \text{ and } V_{GS} = -I_D R_S$$

to obtain the equations intersection.
Or use a computer or programmable calculator to solve the simultaneous equations.
The calculated DC bias values are:

V_{GS1} (calculated) = ________

I_{D_1} (calculated) = ________

using

$$V_{D1} = V_{DD} - I_{D_1}R_{D_1}$$

V_{D_1} (calculated) = ________

The calculated DC bias values are:

V_{GS_2} (calculated) = ________

I_{D_2} (calculated) = ________

using

$$V_{D_2} = V_{DD} - I_{D_2}R_{D_2}$$

V_{D_2} (calculated) = ________

b. Build the circuit of Fig. 21.3 using $R_{G_1} = R_{G_2} = 1\ \text{M}\Omega$, $R_{S_1} = R_{S_2} = 510\ \Omega$, and $R_{D_1} = R_{D_2} = 2.4\ \text{k}\Omega$. Set $V_{DD} = +20$ V.

c. Measure the DC bias voltages.

V_{G_1} (measured) = ________

V_{S_1} (measured) = ________

V_{D_1} (measured) = ________

V_{GS_1} (measured) = ________

Calculate the value of I_D under DC bias conditions (using nominal resistor values)

$$I_{D_1} = \frac{V_{S_2}}{R_{S_2}}$$

I_{D_1} = ________

V_{G_2} (measured) = ________

V_{S_2} (measured) = ________

V_{D_2} (measured) = ________

V_{GS_2} (measured) = ________

Calculate the value of I_{D_2} under DC bias conditions

$$I_{D_2} = \frac{V_{S1}}{R_{S1}}$$

I_{D_2} = ________

Compare the DC bias values calculated in step 2(**a**) with those measured in step 2(**c**).

Part 3. AC Voltage Gain of Amplifier

a. Calculate the voltage gain of the common-source amplifier of Fig. 21.3.

For stage 2:

$$A_{v_2} = -g_m(R_{D2} \| R_L)$$

$$\text{with } g_m(Q_2) = \frac{2I_{DSS}(Q_2)}{|V_p(Q_2)|}\left(1 - \frac{V_{GS_2}}{V_p(Q_2)}\right)$$

Using $V_P(Q_2)$, $I_{DSS}(Q_2)$ from Part 1, and V_{GS_2} calculated in Part 2

A_{V2} (calculated) = ________

For stage 1:

$$A_{v_1} = -g_{m_1}(R_{D1} \| Z_{i_2})$$

$$\text{with } g_m(Q_1) = \frac{2I_{DSS}(Q_1)}{|V_p(Q_1)|}\left(1 - \frac{V_{GS_1}}{V_p(Q_1)}\right)$$

Using $V_P(Q_1)$, $I_{DSS}(Q_1)$ from Part 1, and V_{GS_1} calculated in Part 2

A_{V_1} (calculated) = ________

Calculate the overall amplifier gain:

$$A_v = A_{v_1} \times A_{v_2}$$

A_v (calculated) = ________

b. Connect input of V_{sig} = 10 mV, rms at f = 1 kHz. Use the oscilloscope to obtain an undistorted output voltage, adjusting V_{sig} if necessary. Measure and record:

V_{sig} (measured) = ________
V_L (measured) = ________

Calculate the voltage gain of the overall amplifier

$$A_v = \frac{V_L}{V_{sig}}$$

A_v = ________

Measure and record:

V_{o_1} (measured) = ________

Calculate the gain of each stage:

$$A_{v_1} = \frac{V_{o_1}}{V_{sig}}$$

A_{v_1} (calculated) = ________

$$A_{v_2} = \frac{V_L}{V_{o1}}$$

A_{v_2} (calculated) = ________

Part 4. Input and Output Impedance Measurements

a. The input impedance is

$$Z_i = R_{G_1}$$

Z_i = ________

b. The output impedance is

$$Z_o = R_{D_2}$$

Z_o = ________

c. Connect a 1-MΩ resistor, R_x in series with the input signal, V_{sig} = 10 mV, rms at f = 100 Hz. Measure V_{i_1}.

V_{i_1} (measured) = ________

Calculate the input impedance using

$$Z_i = \frac{V_{i_1}}{V_{sig} - V_{i_1}} R_x$$

Z_i = ________

Remove measurement resistor, R_x.

d. Measure V_L

V_L (measured) = __________

Disconnect load $R_L = 10\ k\Omega$. Measure output voltage, V_o.

V_o (measured) = __________

Calculate the AC output impedance using

$$Z_o = \frac{V_o - V_{i_1}}{V_L} R_L$$

Z_o = __________

Compare the input impedance calculated in step 4(**a**) with that determined from measurements in step 4(**c**).

Compare the output impedance calculated in step 4(**b**) with that determined from measurements in step 4(**d**).