BIRZEIT UNIVERSITY

Department of Electrical & Computer Engineering
ENEE2103 - Circuits and Electronics Laboratory

Experiment #8
Filed-Effect Transistor (FET)

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Abstract

This experiment demonstrates the difference between the Bipolar Junction Transistor (BJT) and the Junction Field-Effect Transistor (FET), the characteristics of the JFET, and how to use it as an amplifier. It also shows how to use the JFET as a common drain amplifier (SOURCE FOLLOWER).

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1 Theory

1.1 Junction Filed-Effect Transistor (JFET)

The field-effect transistor is eithar a Metal Oxide Semeiconductor Filed-Effect Transitor (MOSFET) or a Junction Field-Effect Transistor (JFET).

The JFET's are split into two, either n-channel or p-channel. The n-channel JFET has a n-type semiconductor between two p-type semiconductors, while the p-channel JFET has a p-type semiconductor between two n-type semiconductors.

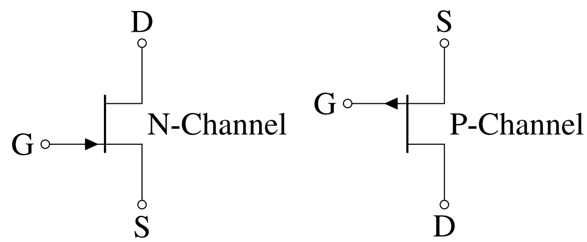

Figure 1: JFETs (n-channel and p-channel)

The main different between JFET's and BJT is that the JFET is a voltage controlled device, while the BJT is a current controlled device. The JFET is controlled by the voltage between the gate and the source, while the BJT is controlled by the current between the base and the emitter.

JFET's has higher input impedance than BJT's, however they have lower gain. JFET's are also more temperature stable than BJT's which makes them useful in integrated circuits. The main characteristics of the JFET is the pinch-off voltage V_p, the drain current I_D, and the transconductance g_m.

The pinch-off voltage is the voltage between the gate and the source at which the drain current is zero. The drain current is the current flowing from the drain to the source. The transconductance is the ratio between the change in the drain current and the change in the gate-source voltage.

1.2 Transconductance

The transconductance is the ratio between the change in the drain current and the change in the gate-source voltage. The transconductance is given by:

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}} \tag{1}$$

1.3 Common Source Amplifier

in this configuration the circuit acts as an amplifier, the voltage gain is higher in comparsion with the common drain amplifier, and the output voltage is out of phase with the input voltage (180°). The input impedance is high, while the output impedance is low. And the gain is given by:

$$A_v = -\frac{g_m \times R_D}{1 + g_m \times R_D} \tag{2}$$

Where g_m is the transconductance and R_D is the drain resistor.

1.4 Common Drain Amplifier (Source Follower)

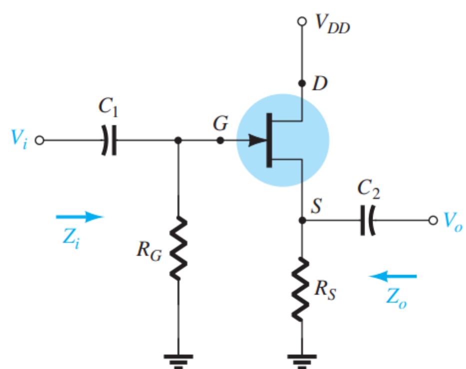

Figure 2: Common Drain Amplifier
[1]

in this configuration the circuit acts as a voltage follower, the output is connected to the source while the input is connected to the gate. The voltage gain is less than 1, and the output voltage is in phase with the input voltage. The input impedance is high, while the output impedance is low. And the gain is given by:

$$A_v = \frac{g_m \times R_S}{1 + g_m \times R_S} \tag{3}$$

Where g_m is the transconductance and R_S is the source resistor.

2 Procedure and Data Analysis

2.1 Characteristics of N-Channel JFET

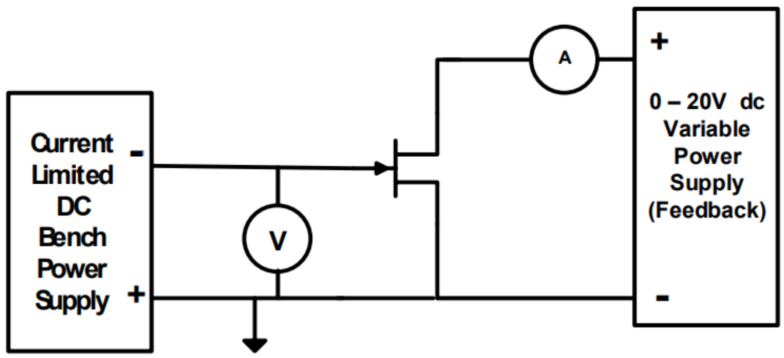

Figure 3: N-Channel JFET Characteristics Circuit

The circuit above was connected, and the following values were measured by reading different values for I_D at values for V_{DS} ranging from 0 to 15V for V_{GS} ranging from 0 to -2.5V. The results are shown in Table 1 and Figure 4.

	I_D(mA) for V_{DS}						
V_{GS}	0	0.5	1	2	5	10	15
0	0.0339	1.2	2.8	4.7	5.8	6	6
-0.5	0.0347	1.1	2.4	3.6	4.5	4.7	4.7
-1	0.0333	0.91	1.35	2.45	3.29	3.75	3.63
-1.5	0.0331	0.7	1.22	1.57	1.76	1.82	1.85
-2	0.0285	0.52	0.75	0.89	0.97	1.01	1.03
-2.5	0.0225	0.24	0.25	0.31	0.34	0.36	0.37

Table 1: N-Channel JFET Characteristics

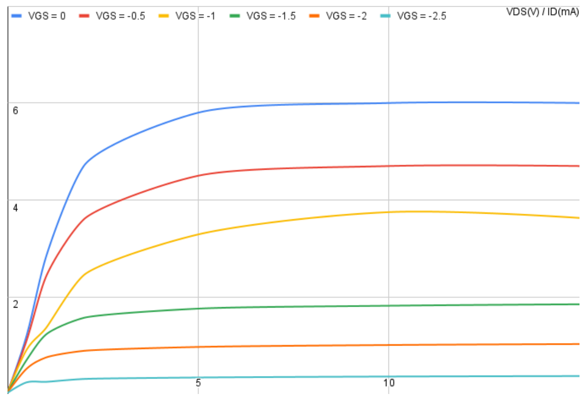

Figure 4: N-Channel JFET Characteristics Curves

According to the results in Table 1 and Figure 4, the pinch-off voltage is $|V_p| \approx 10V$, since at $V_{GS} = 0V$ the drain current is constant after $V_{DS} = 10V$. Furthermore at the pinch-off voltage and $V_{GS} = -1.0V$ the I_G is very small since at the pinch-off voltage the drain current is taking using most of the current.

The transconductance is:

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}} = \frac{I_{D2} - I_{D1}}{V_{GS2} - V_{GS1}} = \frac{3.75 - 1.01}{-1 - (-2)} = 2.74 \frac{mA}{V} \tag{4}$$

2.2 JFET as an Amplifier

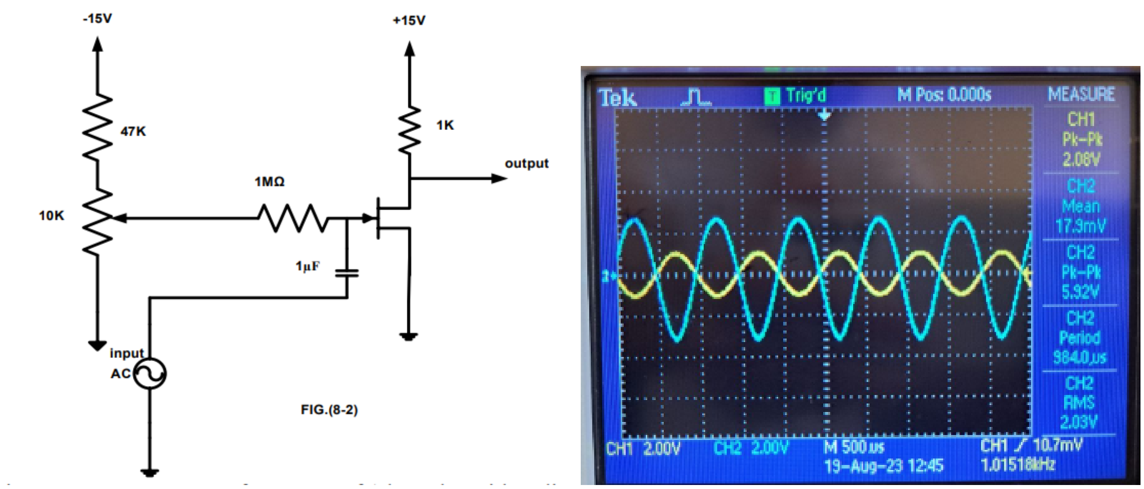

Figure 5: JFET Amplifier Circuit

The circuit above was connected to a function generator and an oscilloscope. The function generator was set to produce a 1kHz sine wave with 2V peak-to-peak. The potentomiter was set to give a value of $V_{DS} = 10V$, The oscilloscope was connected to the input and output of the circuit and the following results were obtained. The gain is:

$$A_v = \frac{V_{out}}{V_{in}} = \frac{5.92}{2.08} = 2.85 \tag{5}$$

The input impedance is:

$$Z_{in} = \frac{V_{in}}{I_{in}} = \frac{0.707}{38.4\mu} = 18.4k\Omega \tag{6}$$

We noticed that the ampilfer gain is low in comparsion with the bjt amplifier, this is because the JFET has a lower transconductance than the BJT. The input impedance is higher than the BJT amplifier, this is because the JFET has a higher input impedance than the BJT.

2.3 Common Drain Amplifier

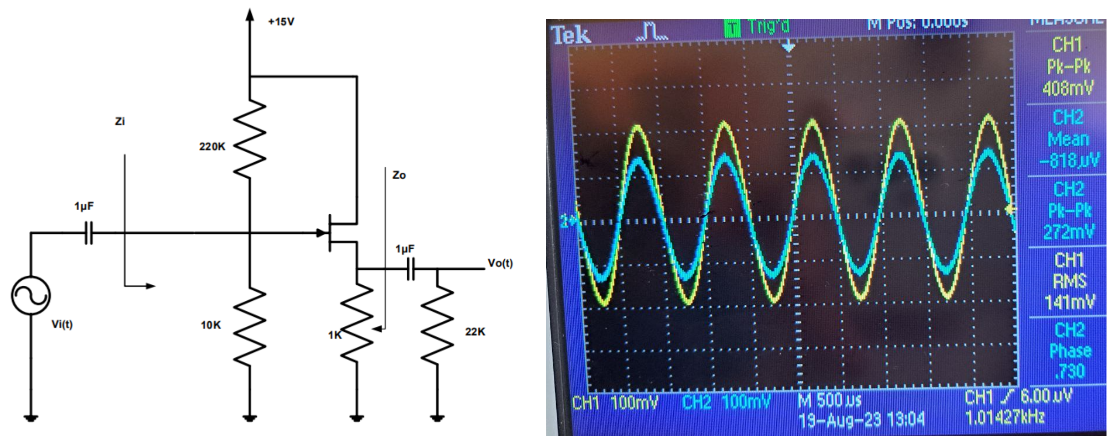

Figure 6: Common Drain Amplifier

The circuit above was initialy connected without the AC source, and the following values were measured V_G = 0.645 and V_S = 2V. The AC source was connected and the function generator was set to produce a 1kHz sine wave with 2V peak-to-peak. The oscilloscope was connected to the input and output of the circuit and the following results were obtained. The gain is:

$$A_v = \frac{V_{out}}{V_{in}} = \frac{272mV}{408mV} = 0.667 \tag{7}$$

The phase shift is 0.730° ≈ 0 and the input and output impedances:

$$Z_{in} = \frac{V_{in}}{I_{in}} = \frac{140m}{39\mu} = 3.58k\Omega \tag{8}$$

$$Z_{out} = \frac{V_{out}}{I_{out}} = \frac{39.43}{37.77\mu} = 1.04k\Omega \tag{9}$$

The theoritical gain is:

$$A_v = \frac{g_m \times R_S}{1 + g_m \times R_S} = \frac{0.00274 \times 1k}{1 + 0.00274 \times 1k} = 0.733 \tag{10}$$

the theoritical gain is close to the measured gain and it doesn't excced 1 because the common drain amplifier is a voltage follower.

3 Conclusion

In conclusion, we learned the characteristics of the JFET, and how to use it as an amplifier. We also learned how to use the JFET as a common drain amplifier (SOURCE FOLLOWER), Finally we learned the difference between the Bipolar Junction Transistor (BJT) and the Junction Field-Effect Transistor (JFET).

References

[1] Robert L Boylestad and Louis Nashelsky. *Electronic devices and circuit theory*. Pearson, Upper Saddle River, NJ, 11 edition, April 2012.

Appendix

Experiment #8 ENEE2103

The Field-Effect Transistor

Objectives:

1. To understand the difference between the bipolar and the field effect transistor.
2. To examine the characteristics of N-channel JFET when using as a common source and common drain.

Pre-lab Work:

1. Simulate the circuits in the procedure section and determine the required values (set the parameters that must be assigned by the instructor in the procedure to proper values).
2. Verify if Simulation Results match the expected results

Procedure:

I. CHARACTERESTICS OF AN N-CHANNEL JFET.

1. Connect the circuit of Fig.(8-1) taking into account the polarities.

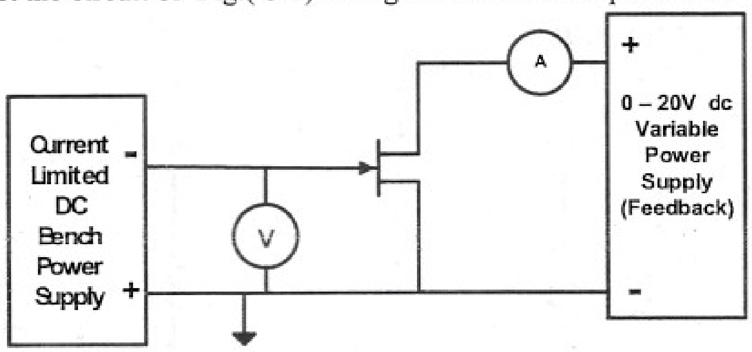

Fig. (8.1)

2. Set the current limit on the bench power supply to its minimum value .
3. Set the voltage to zero , then switch on the power supply.
4. Set the V_{DS} to the first value in table 8.1 , and then read I_D for each value of V_{GS}.
5. Repeat for all the values of V_{DS} in the table, recording the corresponding I_D values.
6. Plot the results from your table onto your graph, drawing one curve of I_D against V_{DS} for each value of V_{GS}.

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Table 8.1

V_{GS}(V)		I_D(mA) for V_{DS}=(V)						
Desired	**Actual**	**0**	**0.5**	**1**	**2**	**5**	**10**	**15**
0	0	33.9μA	1.2mA	2.8mA	4.7mA	5.8mA	6 mA	6 mA
-0.5	-0.5	34.7μA	1.1mA	2.4mA	3.6mA	4.5mA	4.7mA	4.7mA
-1.0	-1	33.3μA	.91mA	1.54mA	2.45mA	3.29mA	3.75mA	3.63mA
-1.5	-1.5	34. μA	0.7mA	1.22mA	1.59mA	1.76mA	1.82mA	1.85mA
-2.0	-2	28.5μA	0.52mA	0.75mA	0.89mA	0.97mA	1.01mA	1.03mA
-2.5	-2.5	22.5μA	0.24mA	0.25mA	0.31mA	0.34mA	0.36mA	0.37mA

7. Now go back to your circuit and set V_{DS} to 10 V and V_{GS} to -1.0 V ,then try to measure I_G. O

Note: When preparing the prelab in Pspice use dc and parametric sweep to get the curves measured in Table 8.1

Questions:

- From your graph above which values of V_{DS} is I_D almost unaffected by V_{DS} when V_{GS}=0?
- For a given value of V_{DS} , (say 10 V),do equal changes of V_{GS} cause equal changes of I_D?
- Can you measure I_G or is it too small?
- From your graph, estimate the change in I_D for 0.5 change in V_{GS} when V_{DS} =10 V , and V_{GS} -1.0 V ,then find the trans conductance of the transistor(g_m).

Note: trans-conductance g_m =(change in I_D)/(change in V_{GS}).

II. A JFET AMPLIFIER.

1. Connect the circuit as shown in Fig. (8-2).

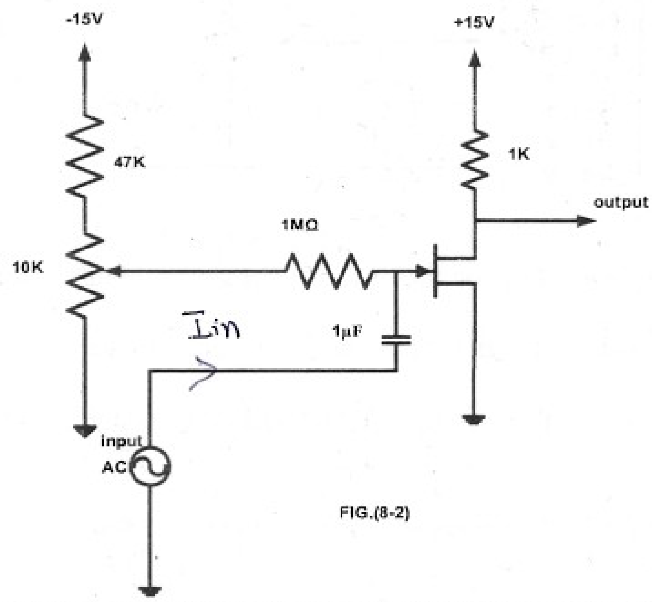

FIG.(8-2)

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2. Set the sine wave generator to a frequency of 1 kHz ,but either disconnect its output ,or turn its output amplitude to zero, so there is no signal input to the circuit. 10.08
3. Set the potentiometer to give a value of +10 V for V_{DS}.
4. Now apply an input of 2volts peak-to-peak from the generator and observe the output on the oscilloscope.
5. Measure the peak-to-peak output voltage and calculate the voltage gain.

$V_{ac} = 0.7V$

~~$V_{dc} = 0.44V$~~

6. Measure the ac input current and voltage using DMM and calculate the input impedance Zin seen by the source.

$I_{ac} =$ ~~0.075mA~~ 38.44uA

III. COMMON DRAIN AMPLIFIER.

1. Connect the circuit as shown in fig. (8-3).

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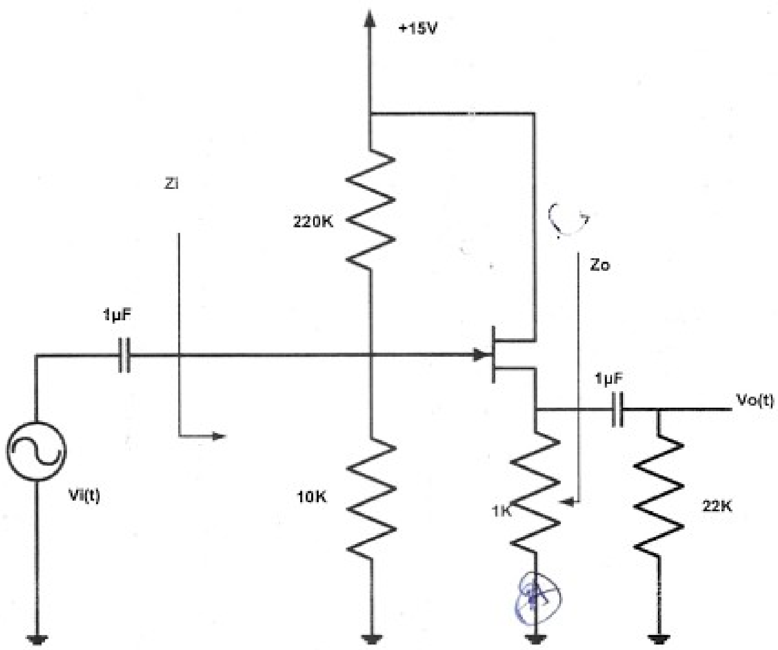

Fig.(8-3)

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0.4

2. Set the sine wave generator to a frequency of 1 kHz ,but either disconnect its output ,or turn its output amplitude to zero, so there is no signal input to the circuit.

0,6953 408mV

2.1V

3. Measure the DC voltages of V_G, and V_S.
4. Now apply an input of 0.4 volts peak-to-peak from the generator and observe the output on the oscilloscope. 0.732
5. Calculate the voltage gain and the phase shift between the input and output voltage. 2

$V_{in} = 140mV$

6. Measure the values of Z_{in} and Z_{out} using the appropriate voltages and currents at the places shown in the previous figure. $I_{in} = 39\mu A$

AV = .272/408

Question:

- Compare the voltage gain of step 5 with the theoretical gain value.

$V_{out} = 93.43mV$

$I_{out} = 37.78\mu A$