Anthony Sevarino
EET 2141
Fall '24

Experiment 10 Field Effect Transistors – FET Amplifier Circuits

Introduction:

The objective of this lab is to analyze junction field effect transistors, specifically, the interactions and behaviors of measurable data such as voltage and current across sources, gates, and drains within amplifier circuits. This study looks at two different common source amplifier circuits which use junction field effect transistors. The first of these circuits is simply contains four resistors, and a solid DC source. The second, both a DC and an AC source, as well as the addition of capacitors, which changes the behavior of the circuit noticeably. Note that the purpose of a JFET common source amplifier is to generate a voltage gain from a source which has a relatively high impedance along, which is useful when a high current gain is required from such an impedance input.

Bench Parts and Equipment List:

Components

- 1MΩ, 330kΩ, 4.7kΩ (x2), 10kΩ Resistors
- Numerous Connector Wires
- JFET Transistor (2N5458)
- 1uF (x2), 47uF Capacitors

Equipment

- Programmable DMM
- Windows Machine w/ Multisim
- Function Generator
- ELENCO Trainer Board
- Triple Power Supply
- Oscilloscope

Discussion:

Part 1 – The Simulation

The first step of this lab is to construct the given circuit in Multisim, of which there are two for this specific study. The following is the provided image for each given circuit purposed toward the study of this lab

(See below)

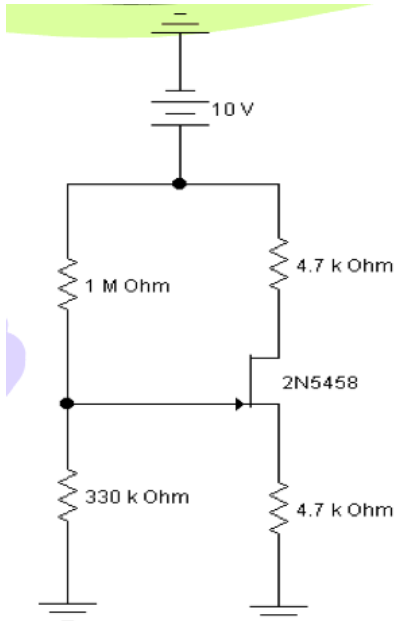


Figure 1 - Circuit 1 Diagram Provided by Lab Manual

The constructed Multisim circuit is as follows:

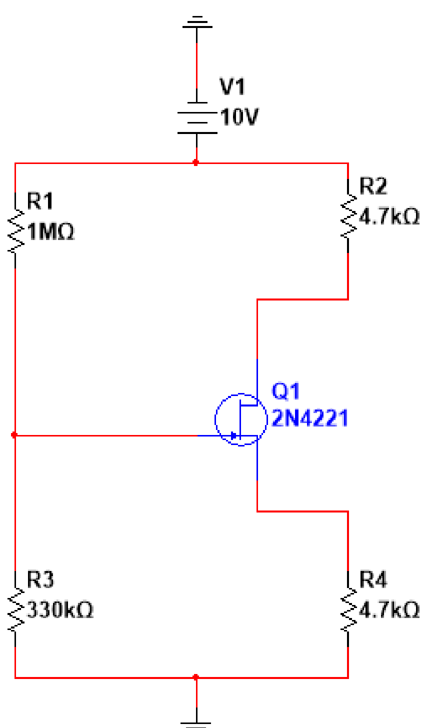


Figure 2 - Circuit 1 Constructed in Multisim

Note that attached are both digital multimeters, as well as Multisim analysis probes used for obtaining simulation measurements (notably the probes are used for current measurements as to eliminate the requirement for disconnecting the circuit, while digital multimeters are used for voltage measurements as they can simply be connected in parallel).

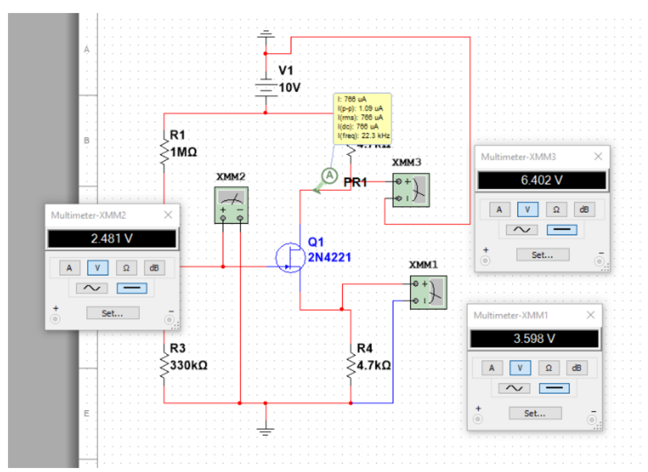


Figure 3 - Circuit 1 Constructed in Multisim with data probes

Viewing the resulting values of current and voltage throughout the circuit, it it is evident that the behavior of this circuit matches the original provided definition of a common source amplifier, which takes any signal and amplified the voltage through the drain.

Circuit 1 is a JFET series-parallel circuit, with a single transistor and 4 value-varying resistors. There is one DC 10V power sources. As stated before, this circuit functions as a common source amplifier, who's purpose it is to increase the value of voltage. Applications such as those which obtain power from a high impedance source are examples of where a common source amplifier JFET would benefit. Note the orientation of the JFET (denoted by the arrow indicating the gate) is aligned with the bias of the current, which is known as *forward bias*.

The multimeter used to conduct testing was later changed to a multimeter following the capture of these images, in other words, the current probes appearing in the images was no longer used.

Now, here is the second provided circuit for the study

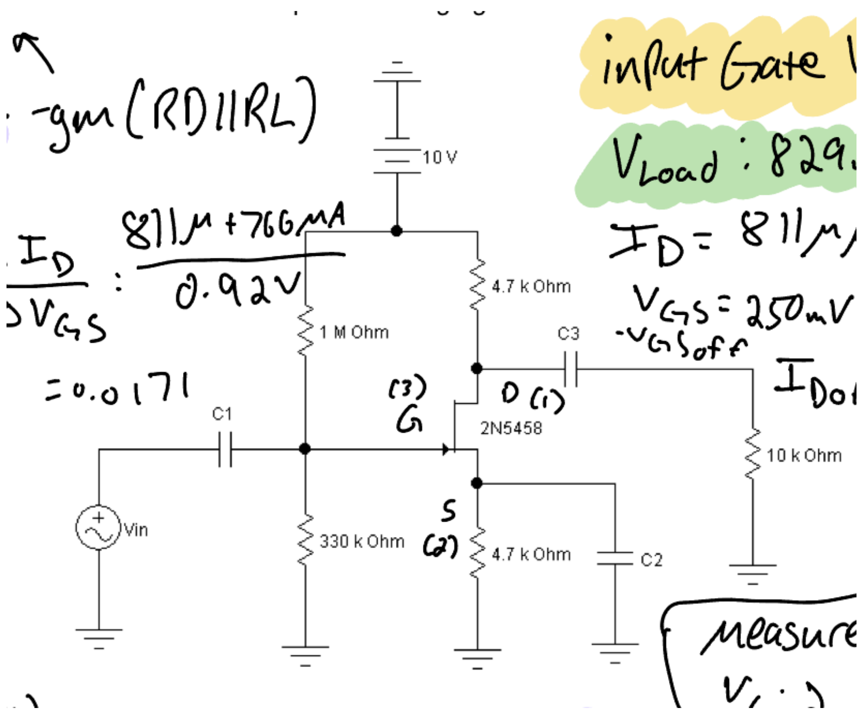


Figure 2 - Circuit 2 Diagram Provided by Lab Manual

The constructed Multisim circuit is as follows:

Note that attached are both digital multimeters, as well as Multisim analysis probes used for obtaining simulation measurements (notably the probes are used for current measurements as to eliminate the requirement for disconnecting the circuit, while digital multimeters are used for voltage measurements as they can simply be connected in parallel).

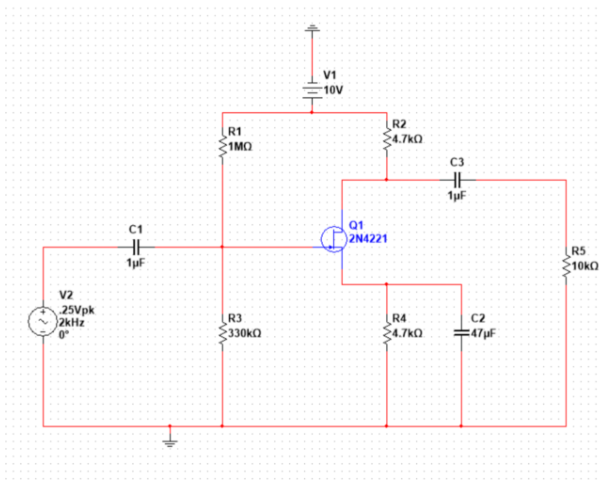


Figure 2 - Circuit 2 Constructed in Multisim

Viewing the resulting values of current and voltage throughout the circuit, it it is evident that the behavior of this circuit matches the original provided definition of a common source amplifier, which takes any signal and amplified the voltage through the drain.

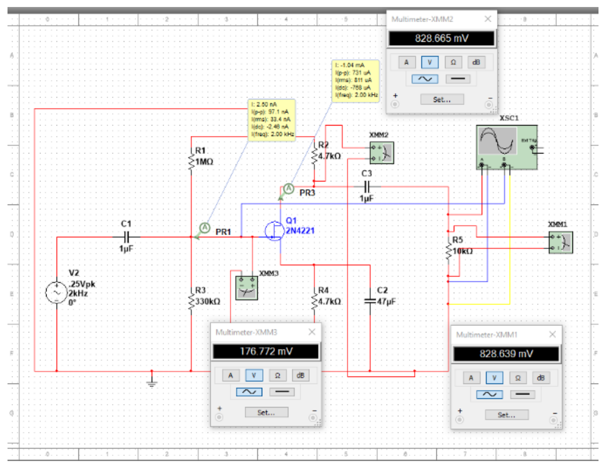


Figure 3 - Circuit 2 Constructed in Multisim with data probes

Circuit 2 is a JFET series-parallel circuit, with a single transistor and 5 value-varying resistors. There is one DC 10V power source, and one 0.5vpp sinusoidal AC source. As stated before, this circuit functions as a common source amplifier, who's purpose it is to increase the value of voltage. Applications such as those which obtain power from a high impedance source are examples of where a common source amplifier JFET would benefit. Note the orientation of the JFET (denoted by the arrow indicating the gate) is aligned with the bias of the current, which is known as *forward bias*.

The multimeter used to conduct testing was later changed to a multimeter following the capture of these images, in other words, the current probes appearing in the images was no longer used.

Below is the recorded waveform for both the load resistor voltage drop (blue) and the voltage at the gate (red).

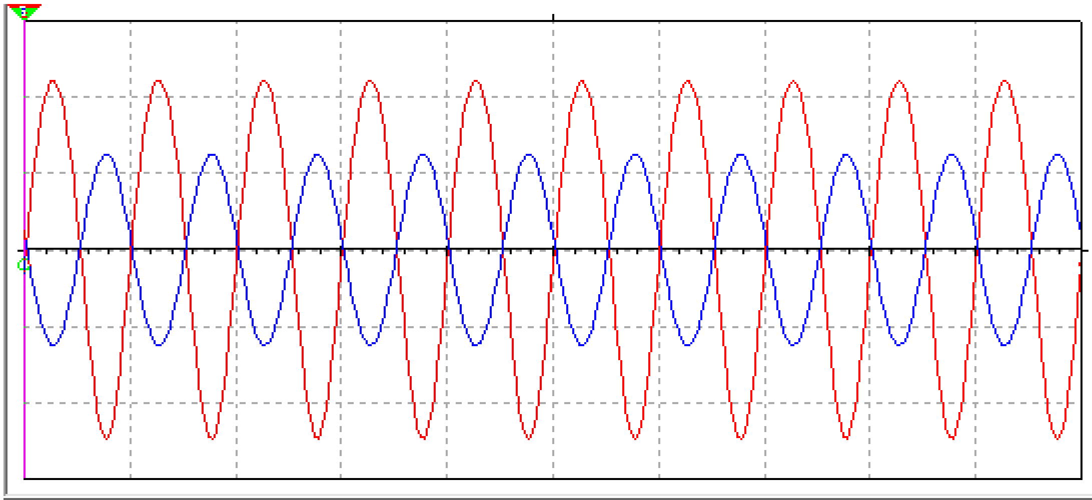


Figure 5 – Waveform of Simulation Data

Part 2 – The Bench

The circuit is now constructed on the bench, below are captures of each circuit constructed:

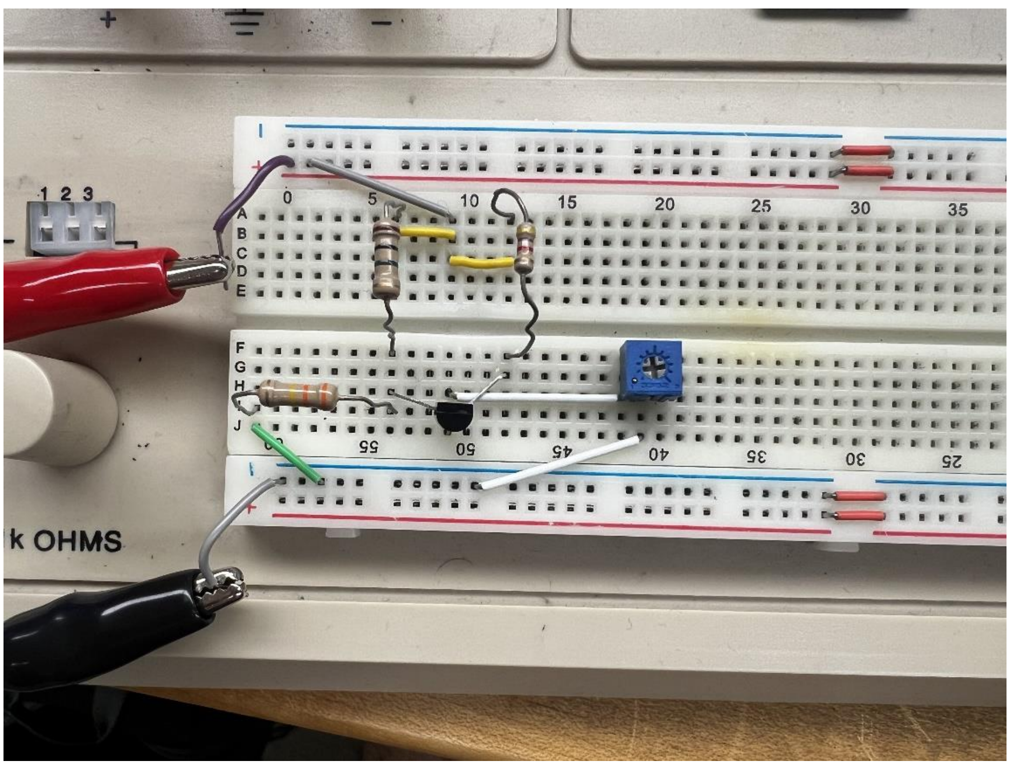


Figure 6 – Circuit 1 Constructed on the Bench

Note that above a potentiometer was used to simulate the value of a 4.7kΩ resistor, as supplies were short in the lab. The function generator is not yet needed in this circuit, and thus the only source of power is found on the left positive and negative buses, connected to a 10V DC source from the triple power supply.

The second circuit constructed on the bench:

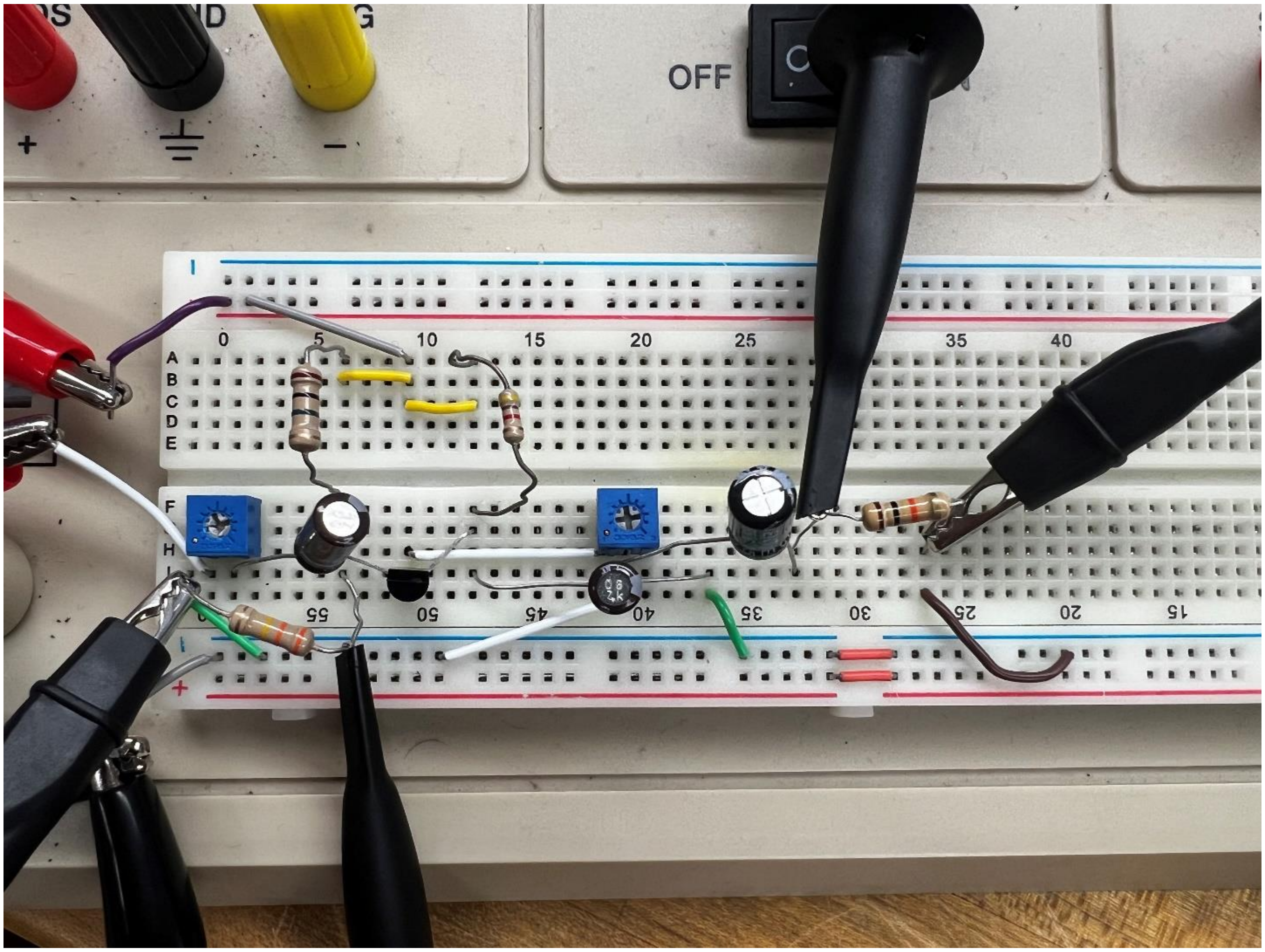


Figure 3 - Circuit 2 constructed on the bench

Below is an analysis of the data obtained on the bench, compared to the found simulation data:

Table 1 – Resistor Nominal and Measured Values

Resistor	Nominal	Measured
R1	1MΩ	1.014kΩ
R2	330kΩ	337.48kΩ
R3	4.7kΩ (1)	4.668kΩ
R4	4.7kΩ (2)	4.681kΩ

Table 1 – Bench vs Simulation Data (Circuit 1)

	Simulation	**Bench**
VG	2.48V	2.509V
VS	3.60V	2.698V
VD	6.40V	7.367V
Q Point	-1.12,766E-6	-1.34, 577E-6

The Q point was calculated using the following formula:

$$Q = (V_{GS}, I_D)$$

Where

$$V_{GS} = V_G - V_S$$

Table 2 – Bench vs Simulation Data (Circuit 2)

	Simulation	**Bench**
VG	2.49V	2.450V
$\mathbf{V_{Load}}$	829.0mV	338.92mV
Voltage Gain	54.67dB	38.22dB

The voltage gain was calculated using the following formula:

$$Av = -gm(RD||RL)$$

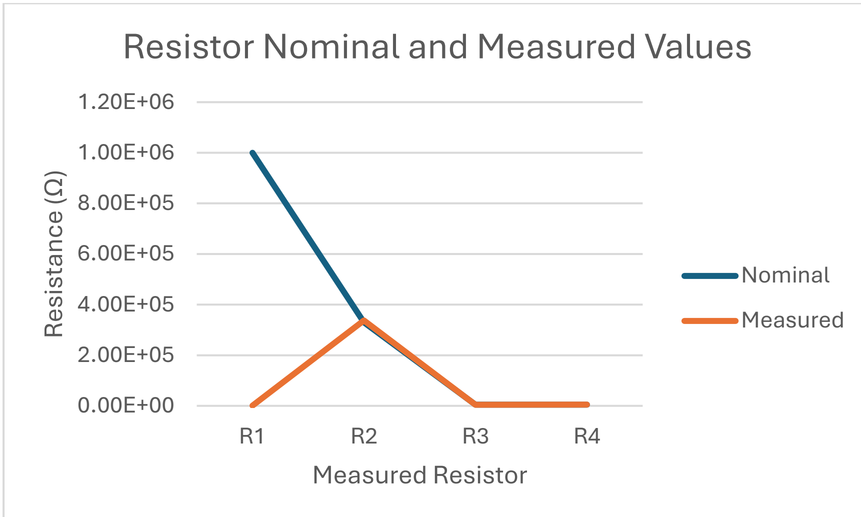
Where gm is the transconductance of the JFET, which is calculated as follows:

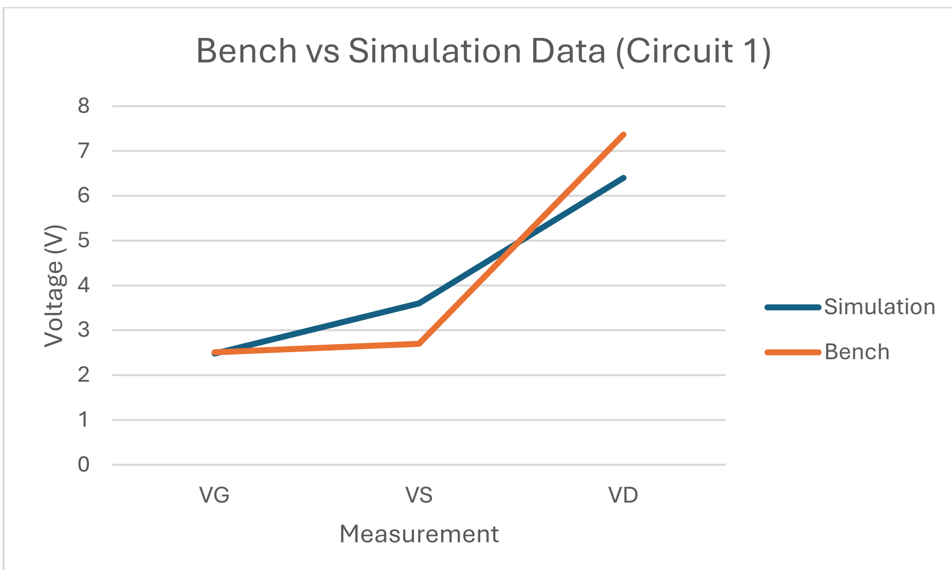
$$gm = \frac{\Delta I_D}{\Delta V_{GS}}$$

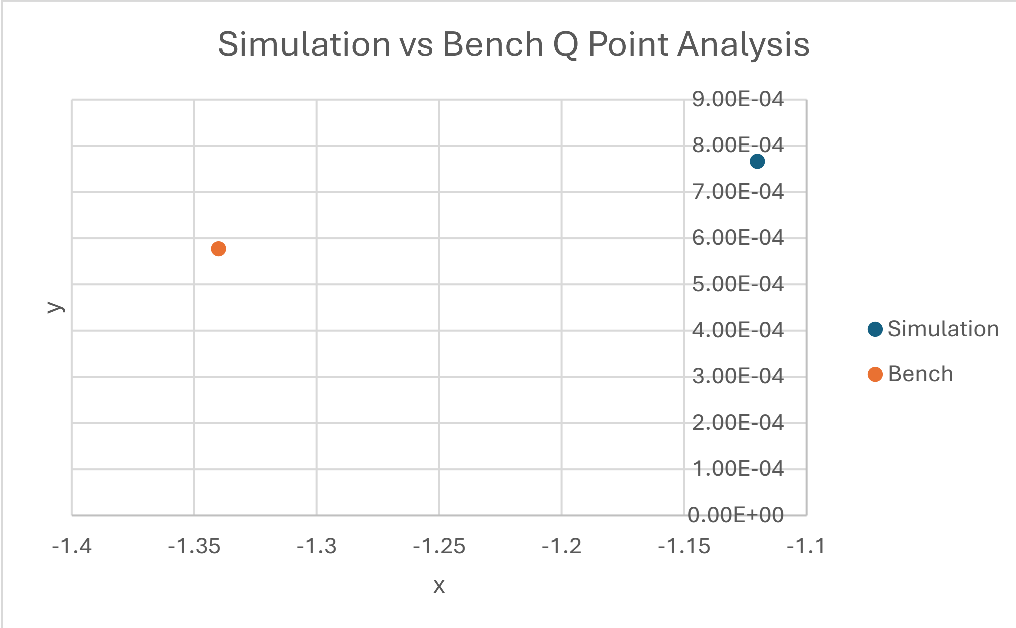
And RD represents the drain resistance, while the RL represents the load resistance

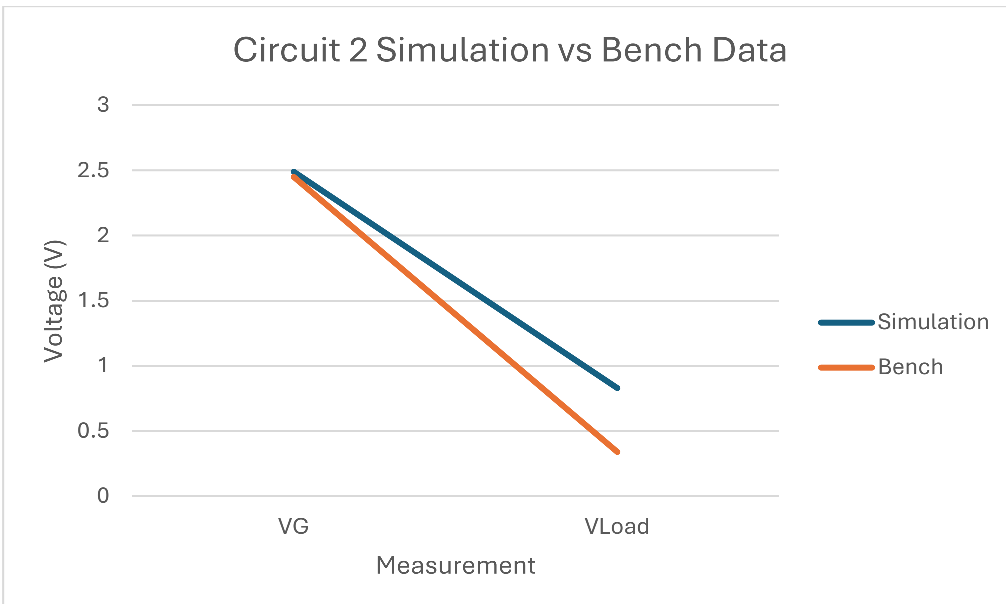
Part 3 – The Comparison

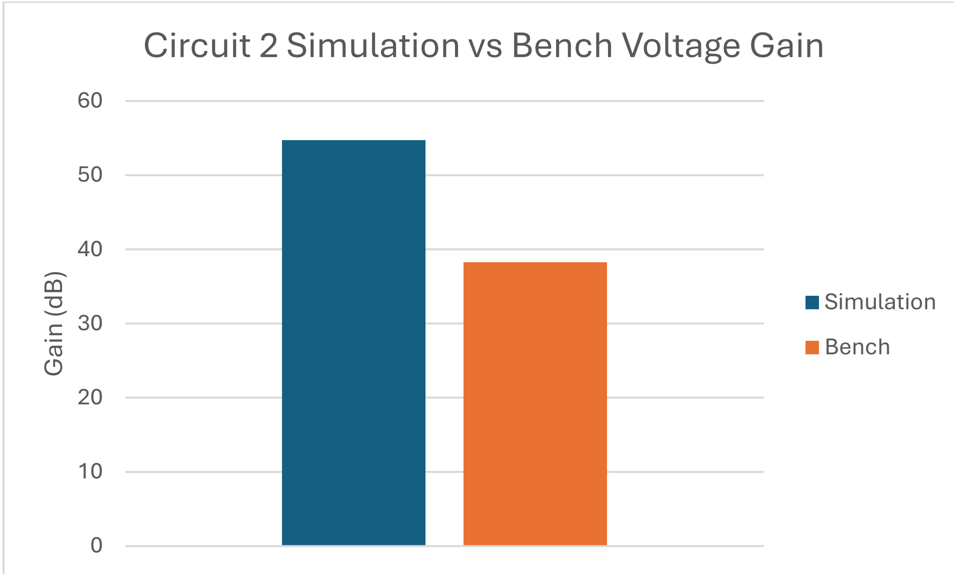
Thus, it would appear that the bench measurements and simulation data both follow the same trend, and are relatively close in terms of values. Below is a graphical comparison of the two datasets:






Simulation vs Bench Q Point Analysis
9.00E-04
8.00E-04
7.00E-04
6.00E-04
5.00E-04
4.00E-04
3.00E-04
2.00E-04
1.00E-04
0.00E+00
-1.4
-1.35
-1.3
-1.25
-1.2
-1.15
-1.1
x
y
Simulation
Bench


Circuit 2 Simulation vs Bench Data
3
2.5
2
1.5
1
0.5
0
Voltage (V)
VG
VLoad
Measurement
Simulation
Bench



Finally, for certification purposes, below the instructor sign-off can be found. As a reminder, this signature is obtained by either the course instructor or a certified lab assistant to ensure proper results are being obtained.

Experiment 10
Field Effect Transistors
FET Amplifier Circuits

Junction Field Effect Transistor, is commonly used in amplifier circuit design because of its much higher input resistance with respect to bipolar junction transistor. In this experiment the student will investigate the characteristics and operation of an n-channel JFET and JFET amplifier circuit. The biasing scheme for this experiment is voltage divider bias circuit because of its stable quiescent point (Q point).

Objective: To investigate the operation of a JFET common source amplifier circuit.

Materials
- Power Supply
- JFET Transistor (2N5458) [Multisim Equivalent: 2N4221]
- Resistors & Capacitors
- Input: Function Generator
- Output: Oscilloscope, Voltmeter

Rvals:

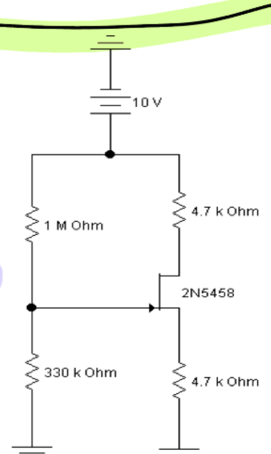
	E	M
	4.7k	4.681k
	330k	337.48k
	1M	1.014M
	4.7k (1)	4.668k

Procedure:

1- Build the amplifier circuit shown in Figure 1.
2- Measure and record the resistance values.
3- Measure and record the DC gate, source, and drain voltage.
4- Calculate the DC Q point for the bias circuit.

Sim

DC Q Point:
(V_{GS}, I_D)
$\Rightarrow (-1.12, 766E\text{-}6)$



DC Gate: 2.48V
Source: 3.60V
Drain: 6.40V
I_D: 766µA
$V_{GS} = 2.48 - 3.60$
$= -1.12\ V$

Figure 1

Measured: V_G: 2.509V V_D: 7.367V
V_S: 2.698V I_D: 575.52µA

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V

5- Connect the common source amplifier circuit in Figure 2 with C1=1μF, C2=47μF, and C3=1μF.

6- Apply an input ac signal with 0.5 volt peak-to-peak with a frequency of 2 KHz.

7- Measure and record the input ac signal amplitude (V_{RMS}) at the gate and the output voltage across the load resistance.

8- Follow the steps for "Measuring Rin of the Amplifier with a Potentiometer" listed in the Appendix and record the potentiometer value as the amplifier's input resistance.

9- Calculate the amplifier's voltage gain.

transconductance

Voltage gain (Av) : $-g_m(R_D \| R_L)$

input Gate V: 2.49v

V_{Load}: 829mV

$I_D = 811\mu A$

$V_{GS} = 250mV - (\frac{2.34v}{2}) = .92V$

$-V_{GS\,off}$

$I_{D\,off}$: $-766\mu A$

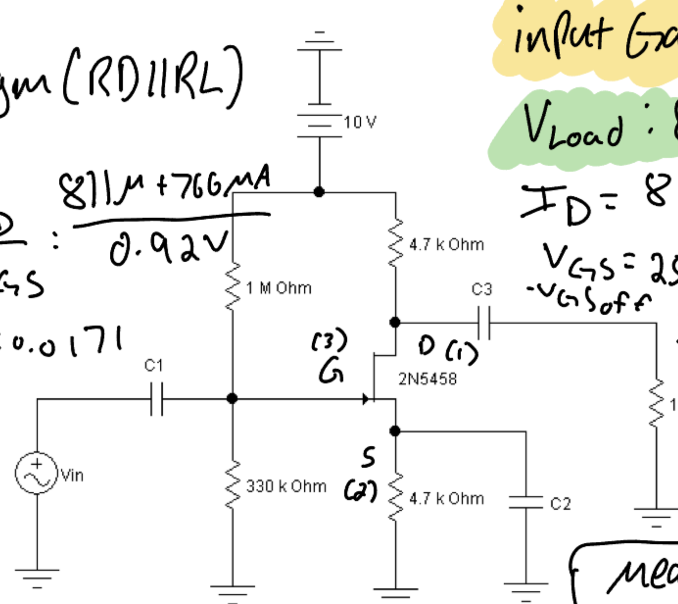
$g_m = \frac{\Delta I_D}{\Delta V_{GS}} = \frac{811\mu + 766\mu A}{0.92V}$

$= 0.0171$

(3) G

D (1)

S (2)



RD ll RL

$(4.7k \| 10k)$

$= 3197.28$

$\Rightarrow -0.0171(3197.28) \approx \boxed{54.67V}$

Figure 2

measured:

V_G: 2.450V

V_L: 338.92mV

I_D: 33.31μA

V_S: 2.69v

$V_{G\,off}$: 18.11mV

$V_{S,off}$: 0v

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Conclusion:

The objective of this lab is to obtain an understanding and visualization of the behavior and purposes of JFETs in common source amplifier circuits. The particular behavior of this circuit is to increase the AC signal (which may have a high impedance) and amplify the voltage a moderate amount, alongside the current as well. Thus, the primary measurements being taken throughout the circuit will be voltage and current, however it is pertinent to test the resistance values of all resistors and components, as well as determining the input resistance of the AC source signal. While only two circuits are analyzed, and they are both common source amplifier circuits, there are variations which allow for a broader education and understanding of the circuit type. If this experiment were to be conducted again, it would be beneficial to observe other types of JFET based amplifier circuits, such as drain and gate amplifier circuits. That being said, the lab was conducted successfully based on the comparison of the data between simulation and bench measurements and subsequent data findings between simulation and bench experimentation, as they not only follow the same trends, but match data values closely.