Cover Page

EE 316-08
Electric Circuits & Electronics Design Lab

Lab 11 / 12: MOSFETS

By: Nolan Anderson

Lab Date: 04/20/2021

Lab Due: 04/20/2021

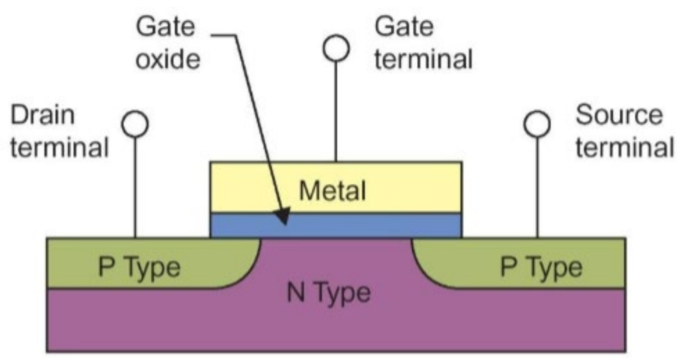
1. Introduction:

This lab will be a introduction and simulation of the MOSFET circuit. Lab 11 will analyze the depletion and enhancement modes of MOSFETS and lab 12 will analyze the gain. Section 2 will cover the theory for this lab, section 3 will show the simulations, section 5 will show the results, section 6 will answer the bonus question, and section 7 will be a short conclusion of the lab. This lab will consider both N-channel and P-channel MOSFETS.

2. Theoretical Analysis:

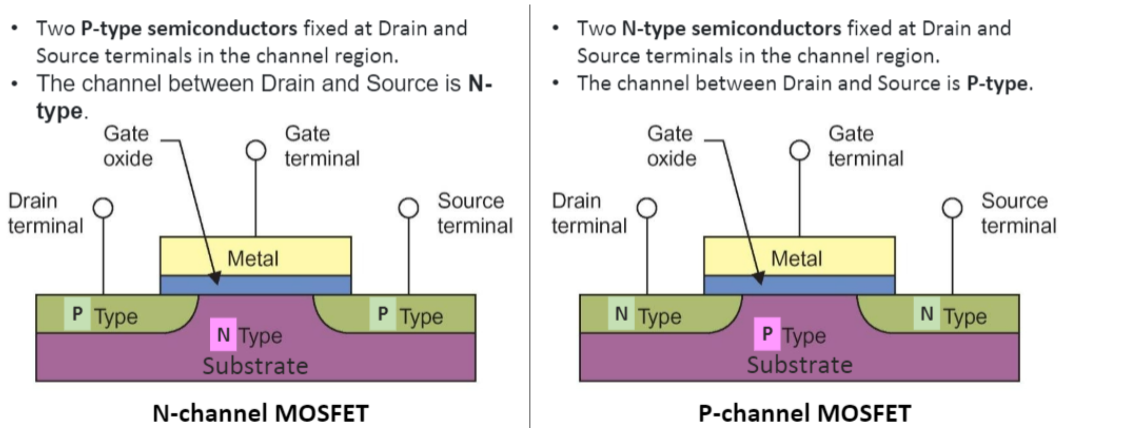
2.1 MOSFETS

Metal Oxide Semiconductor Field Effect transistors are the most common type of insulated gate FET. They are used to switch amplifying voltages in circuits. In simpler terms, they control the voltage of a field effect transitory. They have 3 devices, a gate, source, and drain. The current flowing through the drain and source is proportional to the input voltage. They consume small power and draw little current which makes them a very useful circuit component.



Structural diagram of N-channel MOSFET

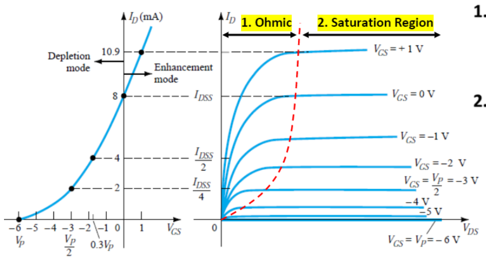
The metal oxide gate controller is insulated from the main semiconductor by a thin layer of material. When the gate is isolated from the main current, no current flows through the gate.



2.2 Depletion and Enhancement modes

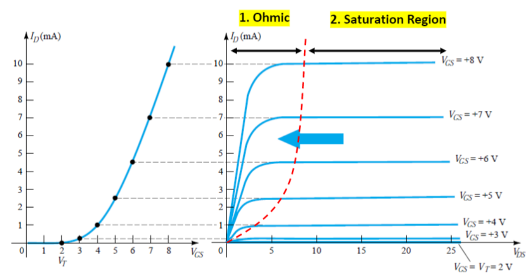
Mosfets can operate in two modes, enhancement and depletion. Depletion is where the transistor requires the Vgs to switch the device off. Essentially, this makes depletion mode a normally closed switch. Enhancement mode is just the opposite.

Depletion Mode N-Channel MOSFET

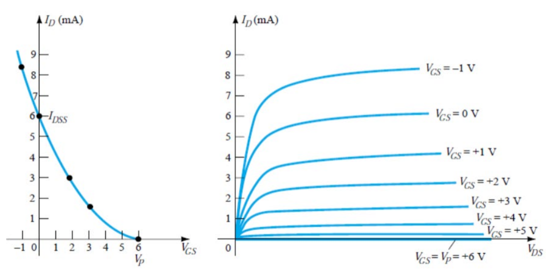


1. **Ohmic Region:** MOSFET acts like a variable resistor.
2. **Saturation Region or Linear Region:** MOSFET is strongly influenced by V_{GS}. MOSFET is ON.

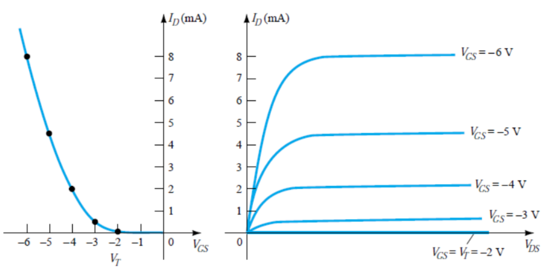
Enhancement Mode N-Channel MOSFET



Depletion Mode P-Channel MOSFET



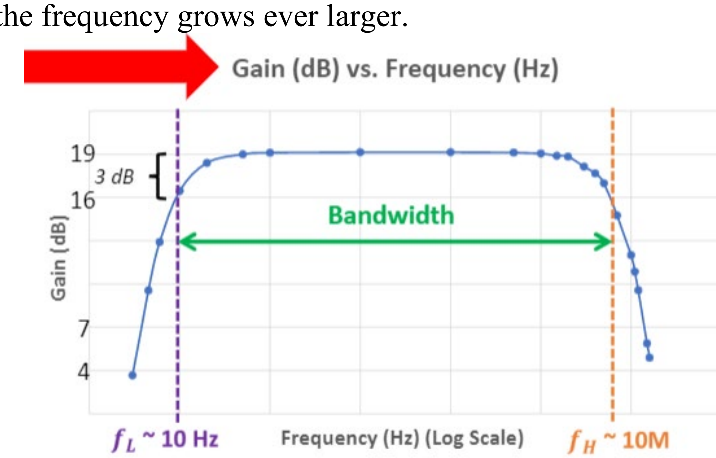
Enhancement Mode P-Channel MOSFET



As you can see, depletion mode takes longer to get to its saturated value.

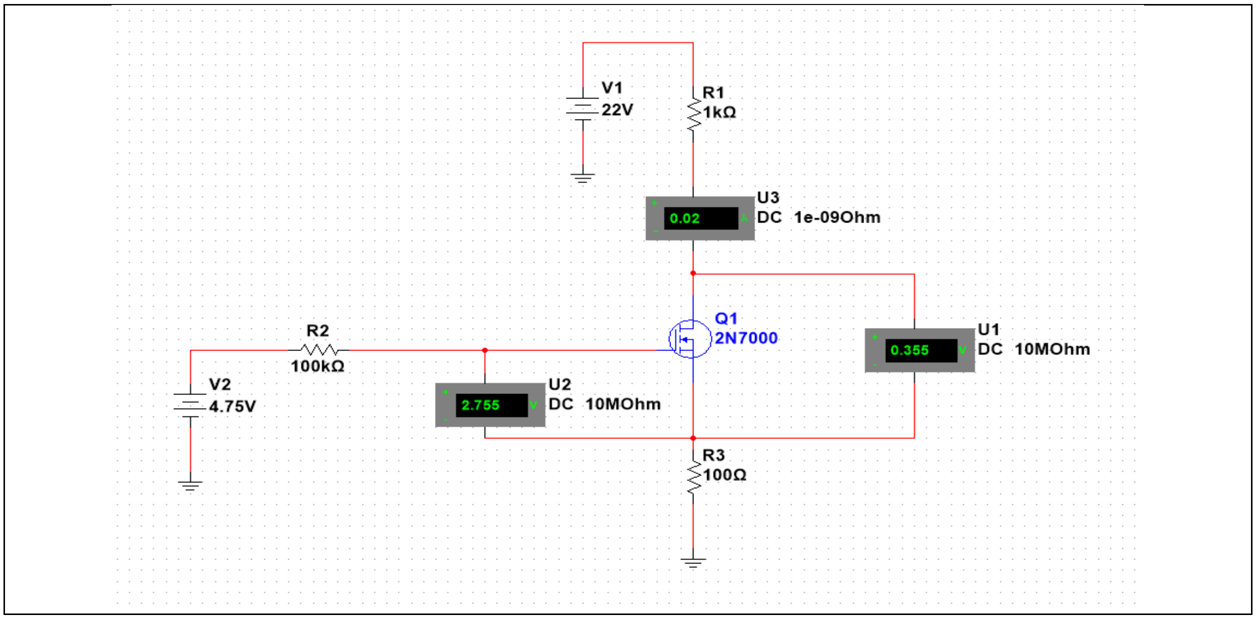
2.3 Bandwidth of a MOSFET

The bandwidth of a MOSFET should start low, go and remain high at the saturation, and then go low again as the frequency grows ever larger.

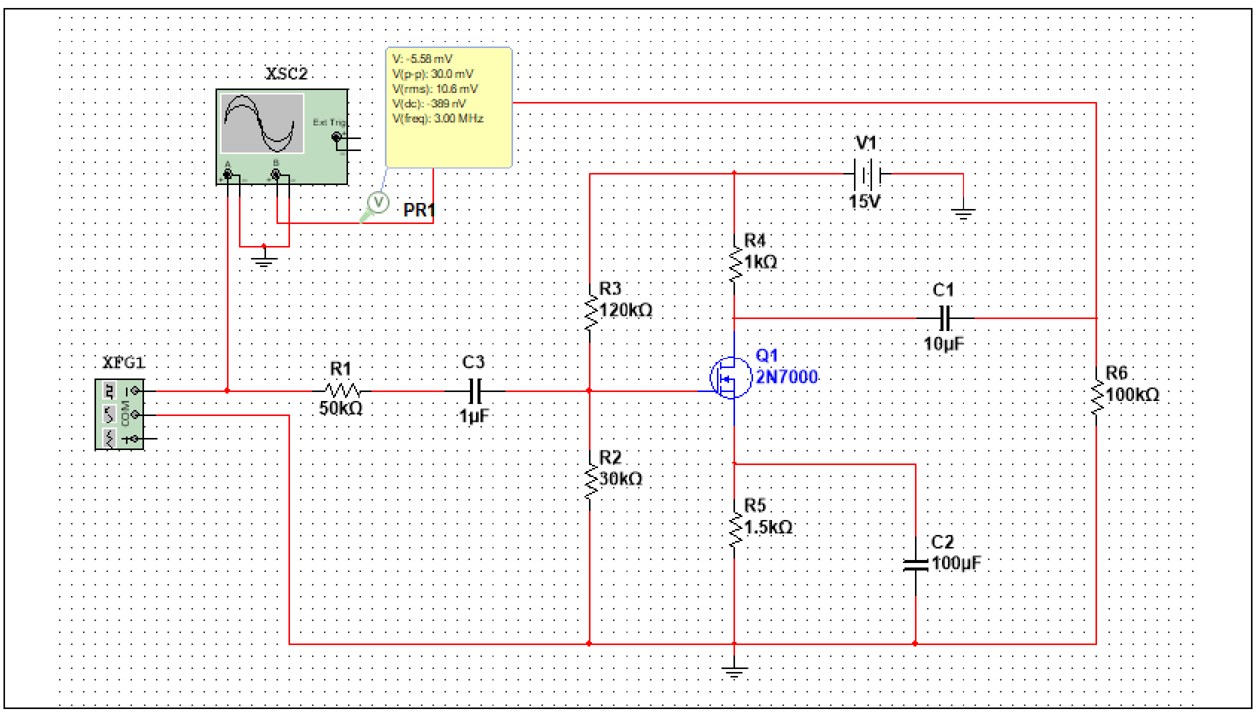


3. Simulations:

3.1 Lab 11



3.2 Lab 12



~~4. Experimental:~~

We were not instructed to provide experimental results for this lab, see the following screenshot.

Summary

- Lab 11 and 12 Report is due Tuesday 20th April 2021 by midnight.
- Final Exam will be available from Tuesday 20th April 2021 to Tuesday 27th April 2021.

- Fill out Table 11.1, 11.2 and 12.1 with results from…
  - Simulation
  - ~~Experimental results~~

5. Results and Discussion:

5.1 Lab 11 Results

V_2 = 2.5 V	V_2 = 2.5 V	V_2 = 2.5 V	V_2 = 3 V	V_2 = 3 V	V_2 = 3 V	V_2 = 3.5 V	V_2 = 3.5 V	V_2 = 3.5 V	V_2 = 4 V	V_2 = 4 V	V_2 = 4 V
V_{ds} (mV)	V_{gs} (V)	I_d (mA)	V_{ds} (mV)	V_{gs} (V)	I_d (mA)	V_{ds} (mV)	V_{gs} (V)	I_d (mA)	V_{ds} (mV)	V_{gs} (V)	I_d (mA)
0.000487	2.475	-0.000022	-0.00031	2.97	-0.000027	-0.00025	3.465	-0.000031	-0.00022	3.96	-0.000036
11	2.431	0.445	11	2.881	0.889	16	3.287	1.803	19	3.692	2.71
24	2.387	0.887	25	2.793	1.795	37	3.109	3.603	45	3.424	5.414
42	2.344	1.325	42	2.704	2.689	66	2.931	5.395	82	3.158	8.108
67	2.301	1.757	65	2.616	3.577	110	2.755	7.173	142	2.893	11
107	2.26	2.176	97	2.529	4.457	190	2.582	8.918	173	2.806	12
215	2.25	2.532	148	2.444	5.32	732	2.451	10	216	2.72	13
712	2.24	2.534	266	2.364	6.121	2731	2.451	10	280	2.635	13
1212	2.224	2.534	632	2.352	6.243	4731	2.451	10	405	2.557	14

Table 11.1: VDs, VGs, Id of Figure 11.1

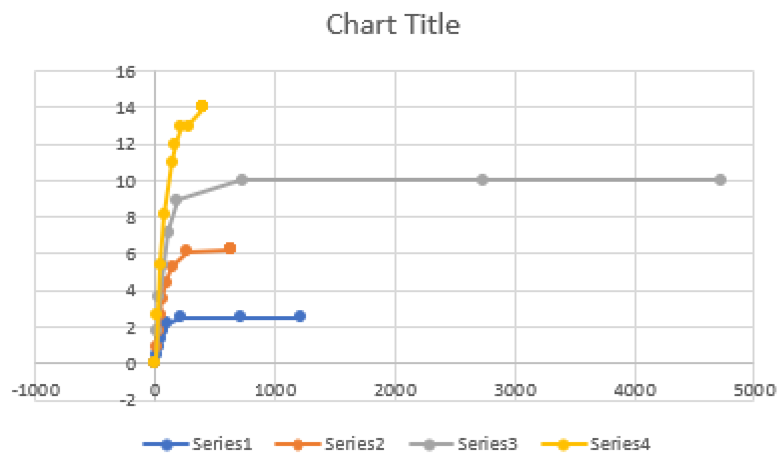


Figure 11.1: Table 11.1 graphed

V_2 (V)	V_{gs} (V)	I_d (mA)
0	-0.217	0
2	1.98	0
2.25	2.136	0.927
2.5	2.224	2.533
2.75	2.293	4.334
3	2.352	6.242
3.25	2.404	8.219
3.5	2.451	10
3.75	2.494	12
4	2.535	14
4.25	2.573	17
4.5	2.609	19
4.75	2.755	20

Table 11.2: Vgs vs Id

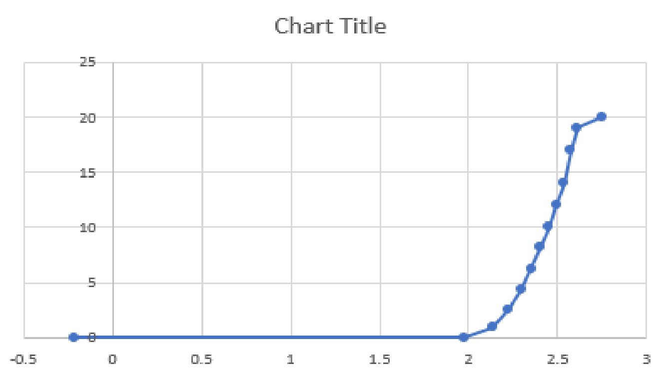


Figure 11.2: Table 11.2 graphed

5.2 Lab 12 Results

Frequency	Vout (mV)	Voltage Gain	Gain (ratio)	Calculated Vout
10	328	4.296876961	1.64	164
30	589	9.381705982	2.945	294.5
60	657	10.33070748	3.285	328.5
100	677	10.59117346	3.385	338.5
200	685	10.69321152	3.425	342.5
500	688	10.73116885	3.44	344
1 KHz	687	10.71853483	3.435	343.5
2 KHz	688	10.73116885	3.44	344
5 KHz	688	10.73116885	3.44	344
10 KHz	684	10.68052212	3.42	342
15 KHz	683	10.66781416	3.415	341.5
20 KHz	678	10.60399396	3.39	339
50 KHz	639	10.08941725	3.195	319.5
75 KHz	595	9.469739401	2.975	297.5
100 KHz	546	8.723252941	2.73	273
150 KHz	453	7.101364127	2.265	226.5
200 KHz	378	5.529236083	1.89	189
500 KHz	175	-1.15983894	0.875	87.5
750 KHz	119	-4.509660685	0.595	59.5
1 MHz	89.6	-6.97443972	0.448	44.8
2.0 MHz	45.1	-12.93706908	0.2255	22.55
3.0 MHz	30	-16.47817482	0.15	15

Table 12.1: Vout, gain, and frequency

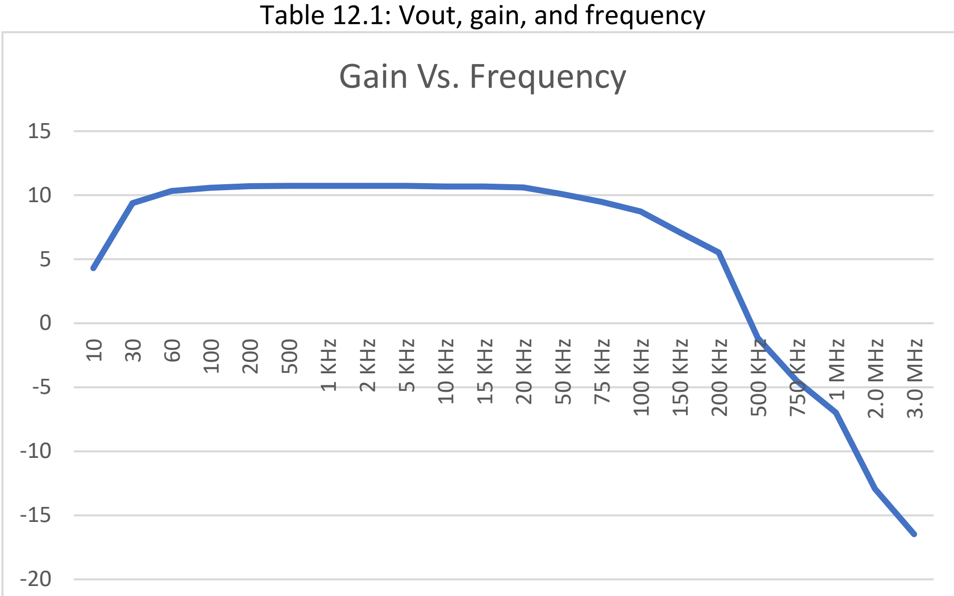


Figure 12.2: Gain vs Frequency

5.3 Discussion

When looking at the results from Lab 11 and 12, we can see that it lines closely with the theoretical portion of the assignment. Figure 11.1 eventually saturates to a value after a certain amount of time, and changes with varying input. Figure 11.2 also has a similar trend to the theory sections. Lastly, lab 12 has a very similar graph to the theory portion. After some time, the circuit saturates and then begins to drop above 20khz. Overall, the results from my simulations lie closely with the theory portion of this lab.

6. Bonus Questions:

6.1 Lab 11 Bonus

Bonus Points(up to 100): Compare your MOSFET, JEFT (lab 9), and BJT (lab 7)results and identify the reasons these devices behave differently. What are the MOSFET vs. JFET vs. BJT pros and cons?

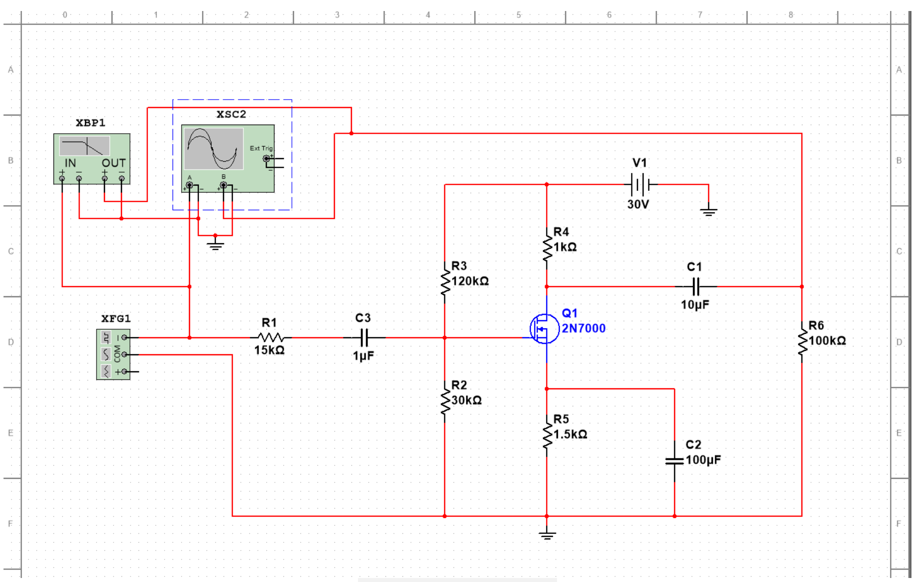
MOSFET Vs JFET: Like a MOSFET, a JFET also has a drain, source, and gate and two configurations P-Channel and N-Channel. The differences are plentiful, however. JFETs can only operate in depletion mode while MOSFETS can additionally operate in enhancement. MOSFETs also have a higher input impedance but are slightly more expensive and complicated to produce. MOSFETs are also more prone to electrostatic discharge than JFETs but are more widely used than JFETs.

MOSFET vs BJT: BJTs and MOSFETs differ much more than JFETs vs MOSFETs. For starts, a BJT is current controlled while the other two are voltage controlled. BJT’s operate in PNP and NPN. BJT’s are cheaper, have low input resistance, frequency response is slow, input impedance is low, and are typically used for a low current application. Essentially, if your circuit has high tolerances (or quickly switching speeds), use a MOSFET or JFET, and if you want to save some money and hassle go with a BJT. While MOSFETs and JFETs are like each other, BJTs are very different. Small circuits: use a BJT. Something like a power supply, go with a MOSFET.

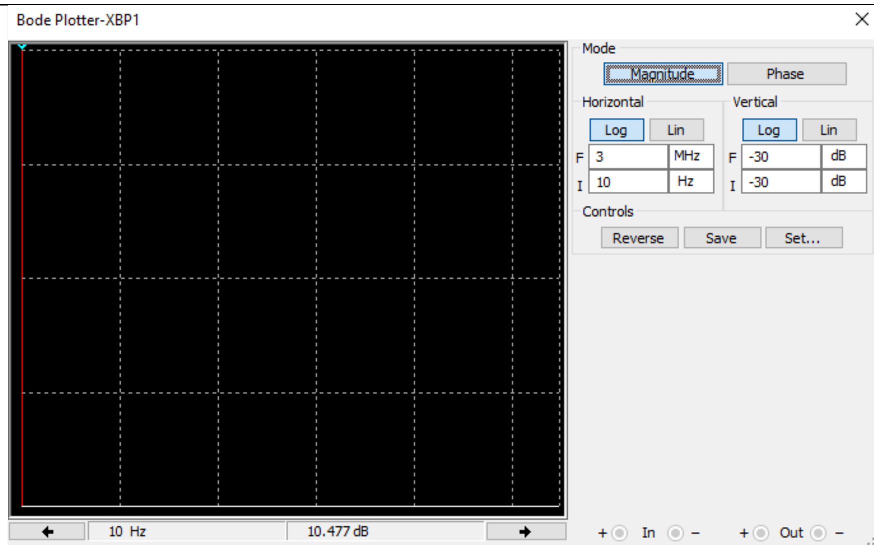
This is my graph from lab 7. As you can see, the BJT takes a lot longer to respond than the MOSFET in this lab.

6.2 Lab 12 Bonus

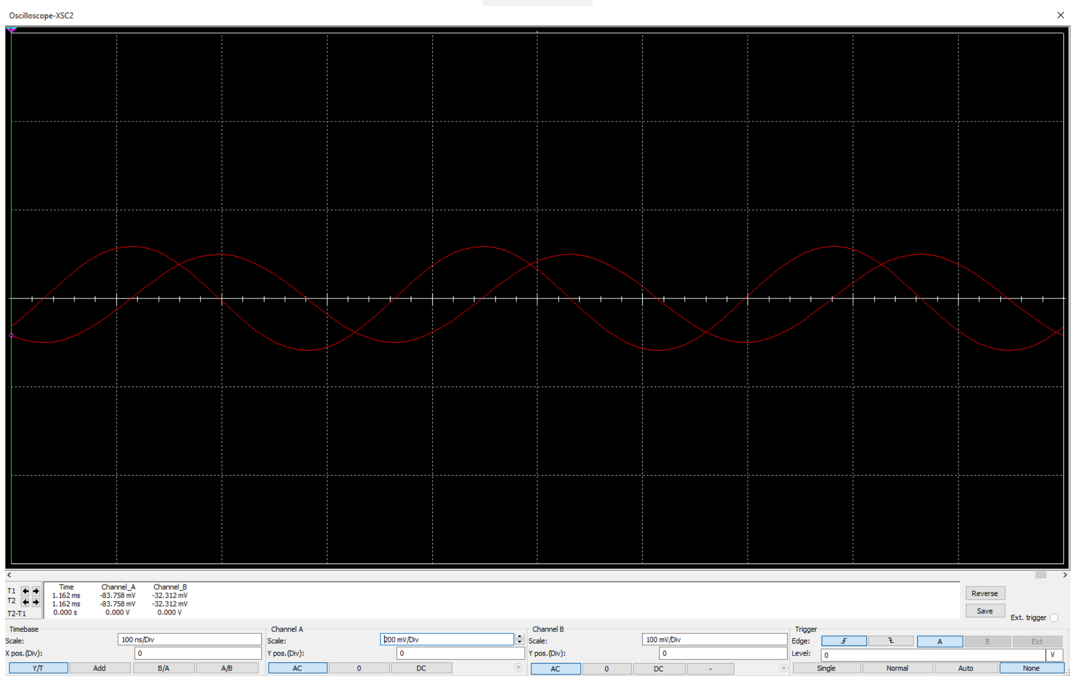
Bonus(up to 50 points, simulation only): [….] No credit will be given if you do not submit your modified circuit diagram.



Circuit Design



>10 dB



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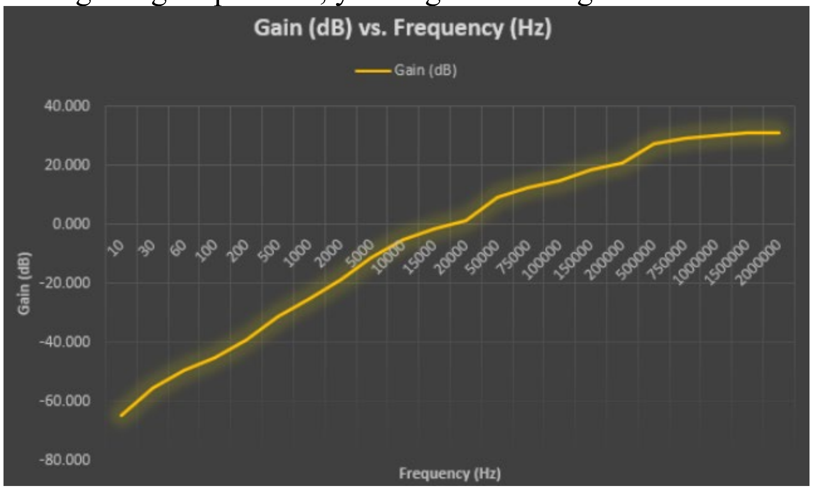
Bonus(up to 100 points): Compare MOSFET signal amplification to JFET (Lab # 10) and BJT (Lab # 08). What are the pros and cons of using MOSFETs, JFETs, and BJTs?

When comparing the gain graphs from lab 08, we can see that MOSFETs act very differently from a BJT: As you can see in the graph from my Lab 7 & 8 report, the gain is ever increasing, whereas in this lab it saturates around 11db and then falls off again around 20Khz. Essentially, if you are operating within a known range of values and want a specific gain, you might want to go with a MOSFET. However, if you do not know what your frequency will be and want the highest gain possible, you might want to go with a BJT.



When looking at the JFET in lab 10, we can see that the gain stays the same basically the whole time. So overall, if you know your frequency range and want a specific gain, use a MOSFET. If you want the highest gain possible, use a BJT. If you want your gain to be the same the whole time, use a JFET.

7. Conclusion

With the bonus questions, this lab was a great introduction into new MOSFET ideas and practices that I was not aware of. Going back and comparing with previous labs was very helpful in seeing how each circuit component differs and when to use each of them. This lab also increased my understanding and technical ability with multisim. Overall, this was a fantastic lab and I learned probably the most from this lab when compared to the other ones.

8. Hand Calculations

$$V_{out} = 10 \cdot \frac{Gain(DB)}{20} \cdot V_{in}$$

$$Gain = 10 \frac{Gain(dB)}{20} = 10^{\frac{4.32}{20}} = 1.6443$$

$$V_{out} = Gain \times V_{in} = 164.43\,mV\ peak$$