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California State University of Northridge
Department of Electrical & Computer Engineering

Experiment 12
Design of Common Drain Amplifiers

ECE 340L
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Introduction:

The purpose of this experiment was to design and implement a common source amplifier using the MOSFET 2n7000 and under the following specifications.

$A_v \geq |V_o/V_i| \geq .95$

$Z_i \geq 50\ k\Omega$

$Z_o = 150\ \Omega$ +/- 20%

V_o swing $\geq 2V_{p-p}$

$R_L = 5k\Omega$

Vcc $\leq$ 20V

This experiment will verify the theory behind MOSFETs discussed in lecture on Common drain amplifiers such as the gain calculations and input and output impedance.

Equipment:

Type	Model
Oscilloscope	Agilent Technologies DSO1002A
Digital Multimeter	Tektronix CDM250
Function Generator	Agilent 3322OA
Power supply	Hewlett Packard E363OA

Parts used:

QTY	Component	Value	Type
1	Resistor	10 Ω	Carbon +/- 5%
1	Resistor	100 Ω	Carbon +/- 5%
1	Resistor	150 Ω	Carbon +/- 5%
1	Resistor	1 kΩ	Carbon +/- 5%
1	Resistor	100 kΩ	Carbon +/- 5%
1	Resistor	150 kΩ	Carbon +/- 5%
1	Resistor	5.1 kΩ	Carbon +/- 5%
1	Resistor	10 kΩ	Carbon +/- 5%
2	Capacitor	10 µF	Polypropylene film +/- 5%
1	Transistor	2N7000	MOSFET

Software:

Pspice

Microsoft Word

Microsoft Excel

Procedure & Results:

Figure 1 was constructed with the following resistor values

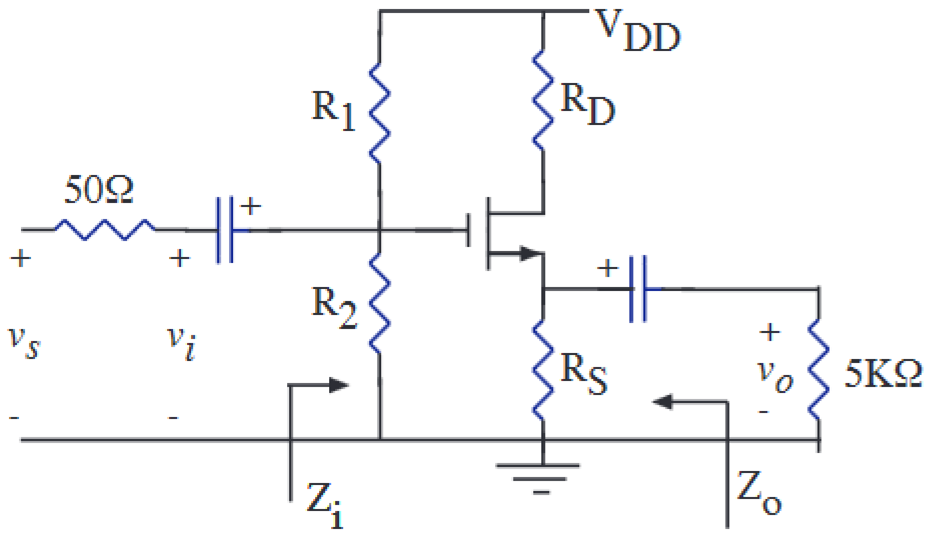
R_1 = 150 kΩ

R_2 = 100 kΩ

R_D = short circuit

R_S = 10 kΩ

Figure 1.



The circuit was then powered by a DC component only and its DC bias values were recorded in the Table 1.

Table 1.

	V_gs	V _ds	V_d	V_s	V_g	I_d
calc	2.19	13	18	5	7.2	0.5
measured	2.18	13.26	18.32	5.06	7.22	0.506
% error	0.46%	1.96%	1.75%	1.19%	0.28%	1.19%

Q Point.

The Q-point was calculated to be V_{DS} = 13 v with an I_D of 0.5 mA.

The measured Q - point was V_{DS} = 13.26 v and a current of 0.506 mA.

These values are significantly close to each other and shows that the circuit was operating correctly. The % error was on all our measured values are less than 2% which the theory behind these values.

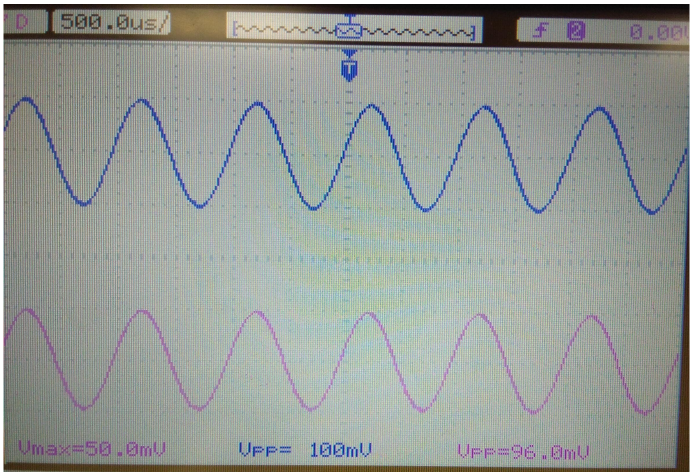
Gain measurements

The $100mV_{P\text{-}P}$ input wave was applied to the gate of the MOSFET. The input and the output across the load were measured and displayed in Oscilloscope 1. The gain was measured to be the following.

$A_V = \frac{input}{output} = \frac{96\ mV}{100\ mV} = 0.96$

These meets the design specification of $A_v \geq |V_o/V_i| \geq .95$

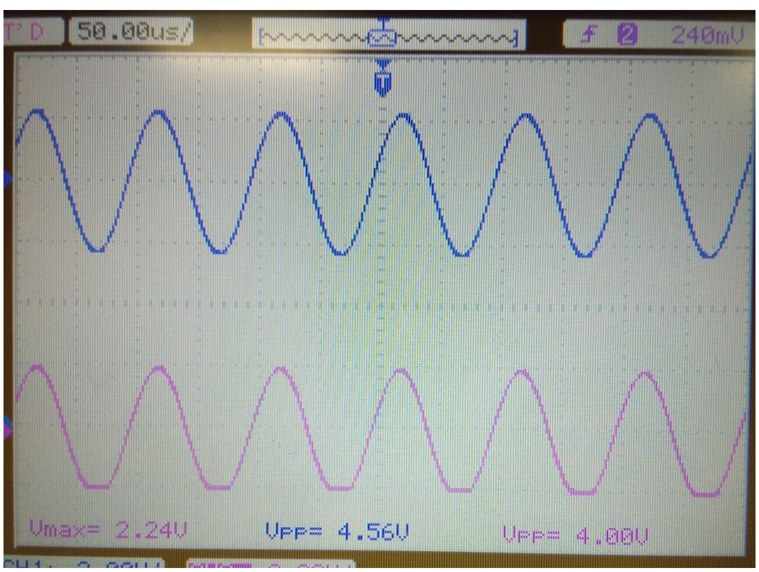
Oscilloscope 1.



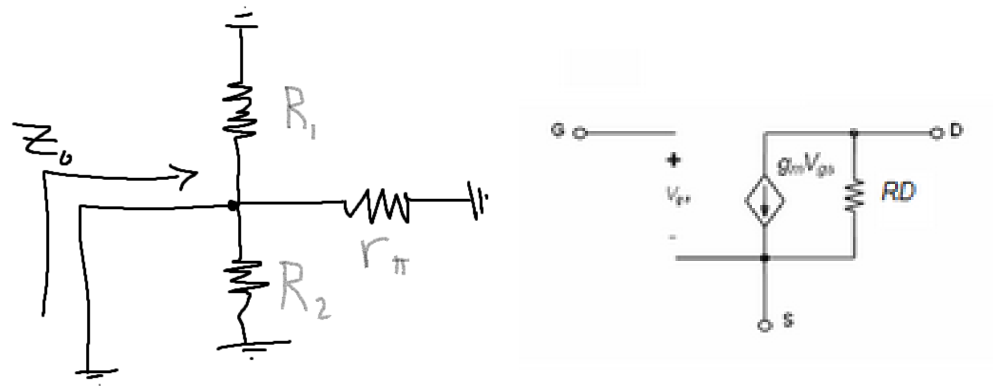
Hard clipping

The input signal was increased in amplitude until the Hard Clipping occured in the output signal. At least, a 2v swing was expected. Oscilloscope 2 shows the results where clipping occured at 2.24 $V_{P\text{-}P}$ and a swing of 2.32 v.

Oscilloscope 2.



<u>Input impedance</u>
Since the input was applied to the Gate of the MOSFET. The input impedance was calculated by finding the terminal resistance of the gate. This was done by using Thevenin's theorem.
<u>Figure 2 Thevenin of input impedance.</u>

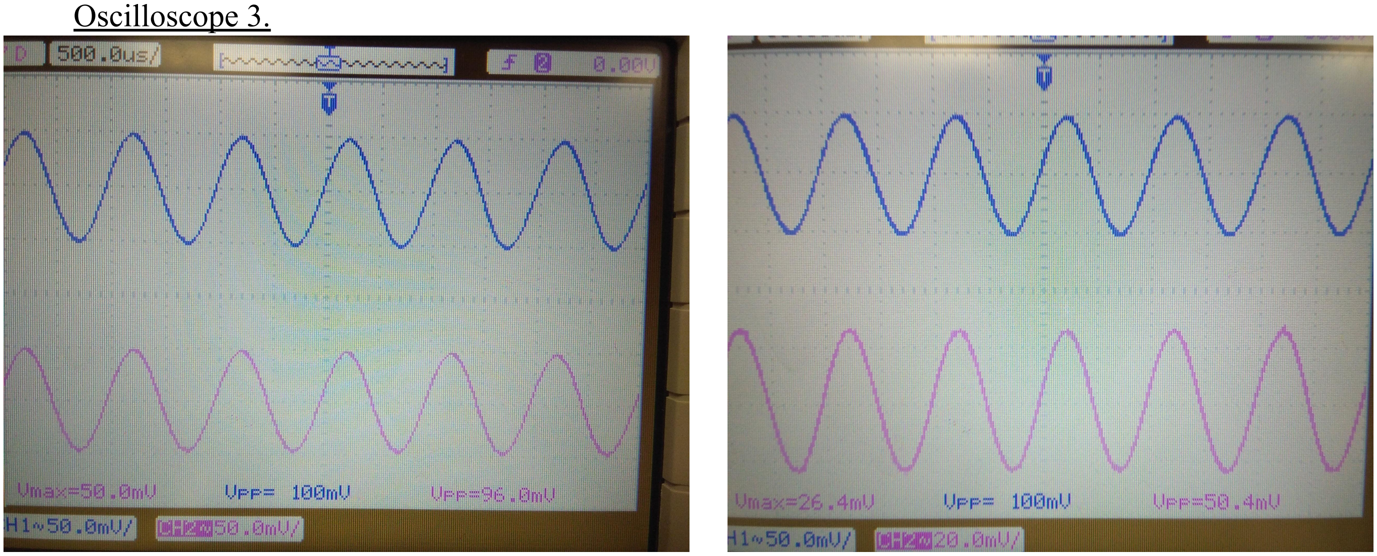


$$Z_i = R_1 \,||\, R_2 \,||\, r_{\pi}$$

In a MOSFET, r_π is considered to be infinite and is modeled by an open circuit. Given $r_{\pi} = \infty$, Input impedance is the following.

$$Z_i = R_1 \,||\, R_2 = \frac{R_1 * R_2}{R_1 + R_2} = \frac{150\ k\Omega * 100\ k\Omega}{150\ k\Omega + 100\ k\Omega} = 60\ \mathrm{k\Omega}$$

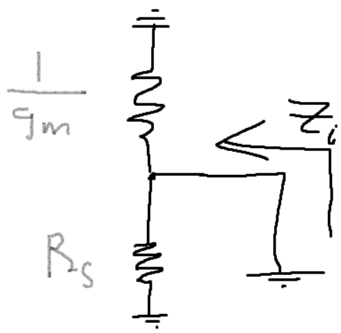
The input impedance of our circuit was measured by adding a value R_S in series at the input of the circuit until the output voltage was decreased by half.
The V_1 was measured to be 96 $mV_{P\text{-}P}$.
V2 was found to be 48 mV at an R_S value of 62 kΩ.
Oscilloscope 3 displays these results.
<u>Oscilloscope 3.</u>



Output impedance

The output was tied to the Source of the MOSFET. The thevenin equivalent is displayed in Figure 3.

Figure 3. Thevenin of output resistance.



$$Z_i = R_S \parallel (1/g_m)$$

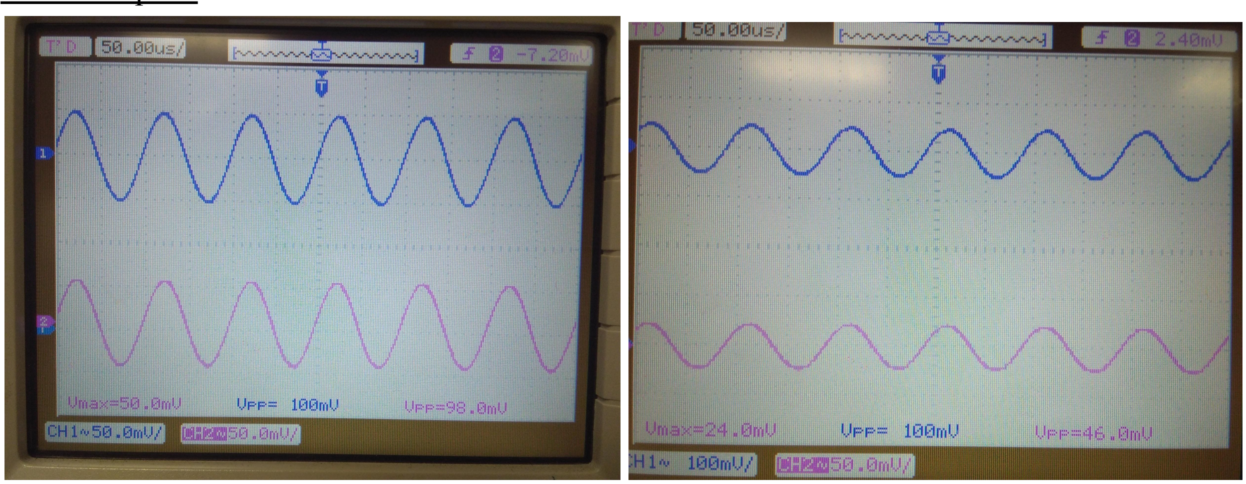
Given that $R_S >> (1/g_m)$ the following approximation is true.

$$Z_i = (1/g_m)$$

The load was removed and V_1 was recorded to be 98 mV.

A load resistance was added until the output voltage was recorded to be 49 mV. This value was found at a R_L of 150 Ω.

Oscilloscope 4.



Current and Power gain

The current gain was calculated using ohm's law of the input voltage and the input impedance.

$I_{in} = V_{in} / Z_i = 100$ mV/ 60kΩ $= 1.612$ µA

$I_{OUT} = V_{out}/ Z_o = 96$ mV/ 150 Ω = 64 mA

$A_I = 64$ mA/ 1.62 mA = 39680 ≅∞

$P_{IN} = V_{in} * I_{in} = 100$mV * 1.62 µA

$P_{OUT} = V_{out} * I_{out} = 96$ mV * 64 mA

$A_P = 41333 \cong \infty$

Power vs Load resistance

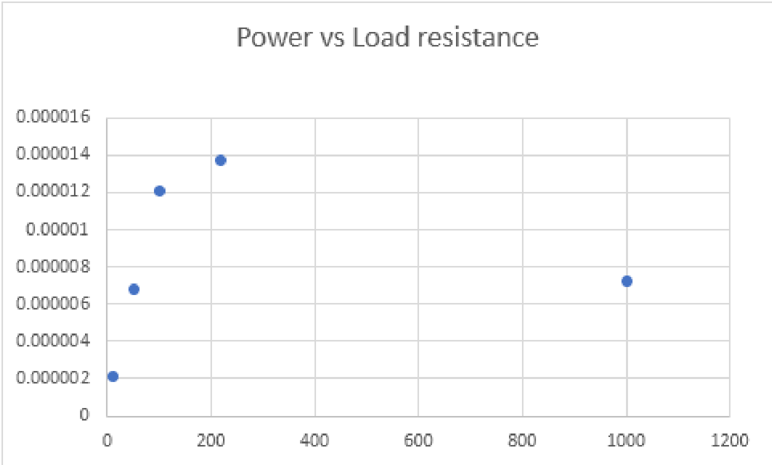
The 5.1 k resistor was removed once again and replaced with values of R_L= 10, 50, 100, 220, 1000 Ω. The output voltage across the loads were recorded in Table 2. The power was calculated by the following.

P = V^2/ R.

Table 2. Power vs Load

V_o(mV)	R_L	P_o
4.6	10	0.000002116
18.6	51	6.78353E-06
34.8	100	1.21104E-05
55	220	0.00001375
85	1000	0.000007225

Graph 1.



Maximum power occurs at 220 Ω. If 150 Ω was tested it most likely would have been the largest power.

The Maximum power theorem states that when the load is equivalent to the resistance of the circuit the power dissipated across the load is at its peak.