EE 230: Analog Circuits Lab
Lab No. 8
MOSFET Characterics

Anupam Rawat, 22b3982

March 9, 2024

1 MOSFET Characterization

1.1 Aim of the experiment

Extract Kn and Vth of the NMOS using given excel file and then simulate the circuit and extract the simulation data.

1.2 Methods

To extract K_n and V_{th} from the data, we use the relation between I_D and V_{DS} and apply a polynomial fit on the data. Then we simulate the circuit and extract the corresponding data and compare it with the gien data.

1.3 Design

For a MOSFET operating in saturation mode,

$$I_D = \frac{k_n}{2}(V_{GS} - V_{Th})^2 \tag{1}$$

which can be re-written as:

$$\sqrt{\frac{2}{K_n}}\sqrt{I_D} + V_{Th} = V_{GS} \tag{2}$$

We'll apply a linear fit to $\sqrt{I_D}$ and V_{GS} data.

Then, the following circuit will be simulated:

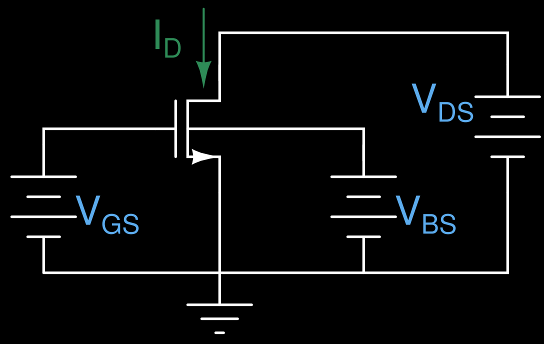
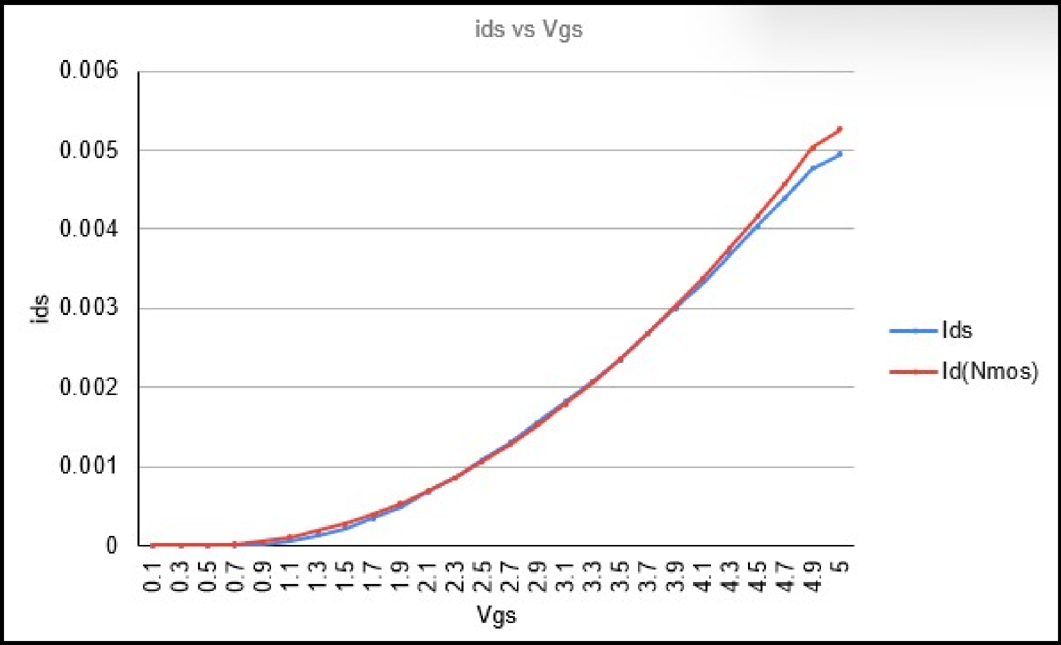


Figure 1: Testbench to extract MOSFET Parameters

1.4 Extraction of K_n and V_{Th}

On applying a linear fit to $\sqrt{I_D}$ and V_{GS} data, we get:
$K_n = 498.89\ \frac{\mu A}{V^2}$
$V_{Th} = 0.479028613\text{V}$



1.5 Simulation

1.5.1 Circuit component values

$V_{BS} = 0$V
$V_{DS} = 5$V
V_{GS} swept from 0 to 5V in steps of 0.1 V.

1.5.2 Plot

1.6 Conclusion and Inference

We conclude that the given data fits very closely using the I_D vs V_{GS} relation. And the experiment also verifies the relation between I_D and V_{GS} as seen in the simulation.

1.7 Experiment completion status

This experiment was completed entirely in the lab.

2 Common Source (CS) Amplifier with Resistive Load

2.1 Aim of the experiment

Simulating a common source amplifier circuit with a resistive load, amplifying the small signal AC component of the input Voltage.

2.2 Methods

An input voltage consisting of a DC component and a small signal AC component is applied. The DC component is used to bias the MOSFET in saturation.

2.3 Design

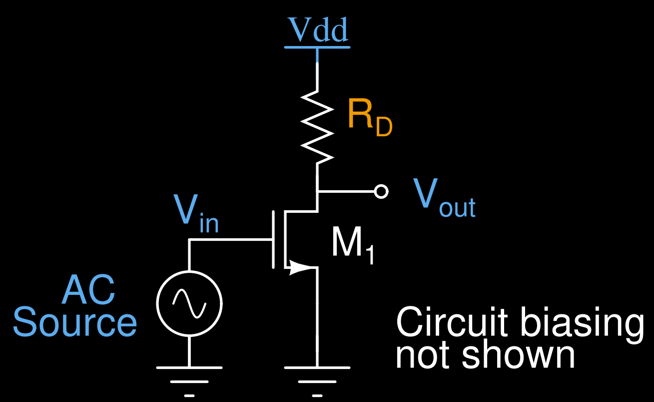


Figure 2: CS amplifier with resistive load

for the above circuit:

1. V_{bias} = DC component of V_{in}, is given by:

$$V_{bias} = \frac{V_{DD} - V_m}{1 + \frac{A_v}{2}} + V_{Th} \tag{3}$$

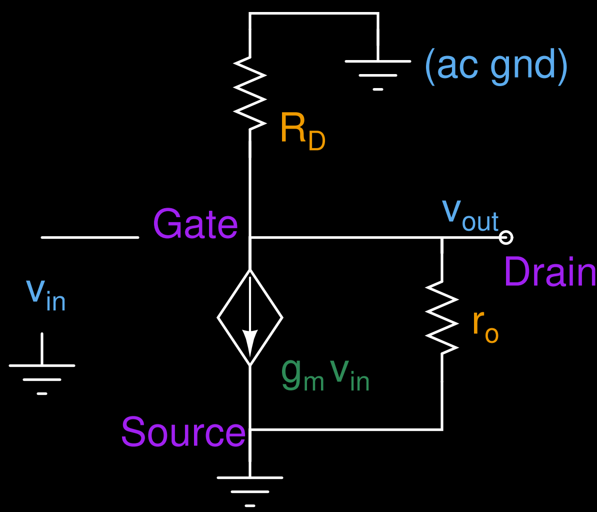


Figure 3: Small signal model of CS amplifier with resistive load

where V_m is the margin volatge, which has been chosen to be 0.5V.
2.

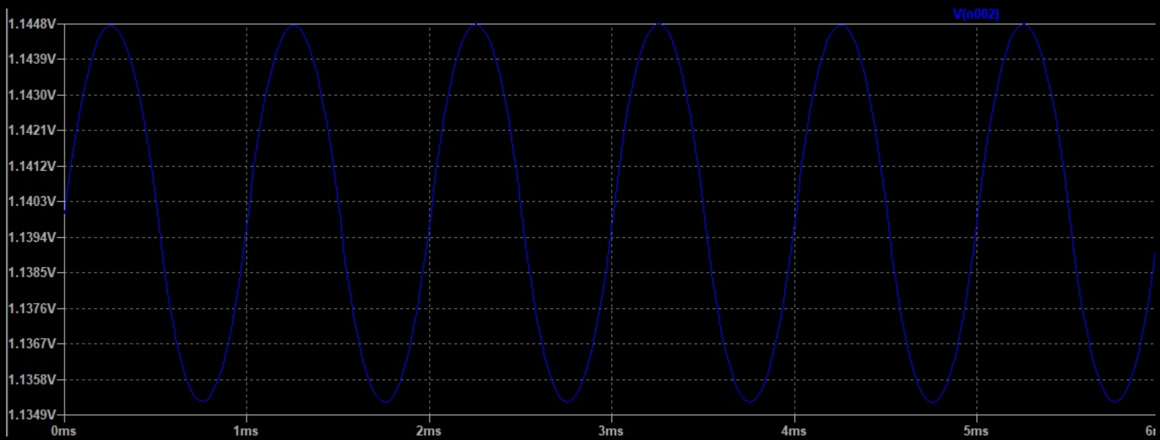
$$A_v = -g_m R_D = -k_n(V_{bias} - V_{Th})R_D \tag{4}$$

2.4 Experiment Results

The calculations yielded the following values:
Assuming A_v = 20dB, which is 10,
taking $V_{in} = V_{bias} + V_{SS}$, with V_{SS} = 5sin(wt) mV,
R_D = 30.324kΩ

	Simulation Result
$V_{gs}(=V_{in})$	1.14
$V_{ds}(=V_{out})$	1.638
A_v	9.5
$I_D(\mu$ A)	110.864446
g_m	492.029

2.5 Simulation Plots



2.6 Conclusion and Inference

This experiment demonstrated the method to bias a MOSFET in the correct region to use it for the intended task, and also demonstrated a common source small signal amplifier.

2.7 Experiment completion status

This experiment was completed entirely in the lab.

3 Common Source (CS) Amplifier with Diode Connected Load

3.1 Aim of the experiment

Simulating a common source amplifier circuit with a Diode Connected Load, amplifying the small signal AC component of the input Voltage.

3.2 Methods

An input voltage consisting of a DC component and a small signal AC component is applied. The DC component is used to bias the MOSFET in saturation.

3.3 Design

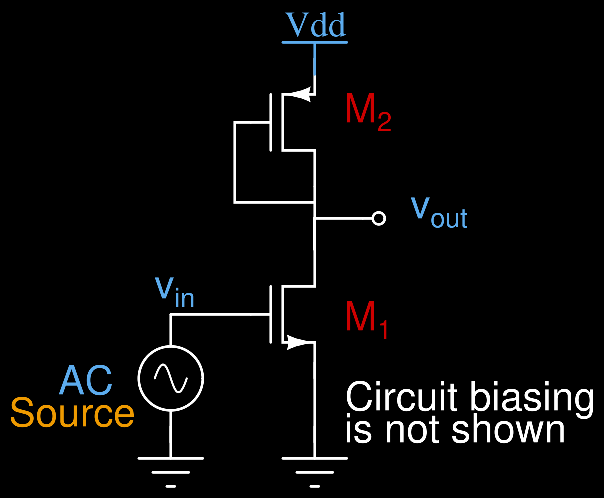


Figure 4: CS amplifier with diode connected load

for the above circuit:

1. V_{bias} = DC component of V_{in}, is given by:

$$V_{bias} = \sqrt{\frac{k_{p2}}{k_{n1}}}(V_{DD} - V_{out} - V_{th2}) + V_{th1} \tag{5}$$

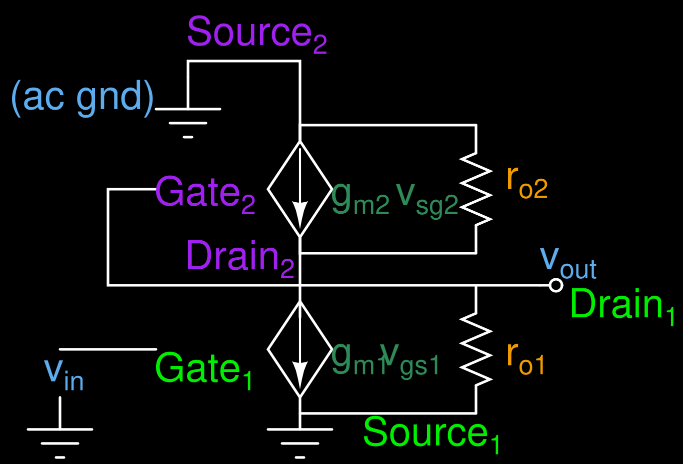


Figure 5: Small signal model of CS amplifier with diode connected load

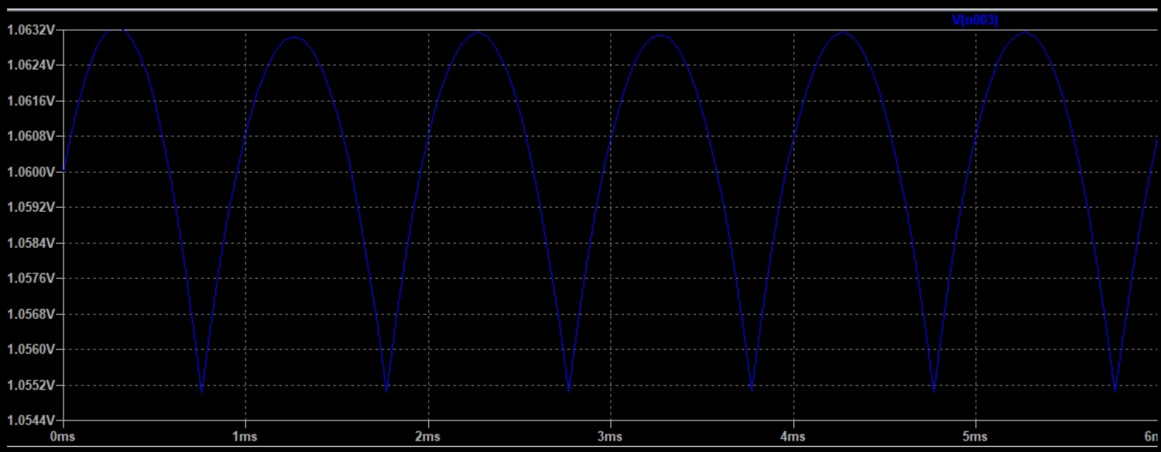
where V_m is the margin volatge, which has been chosen to be 0.5V.
2.

$$A_v = -\sqrt{\frac{k_{n1}}{k_{p2}}} \tag{6}$$

3.4 Experiment Results

For $V_{DD} = 5$V, the calculations yielded the following values:
taking $V_{in} = V_{bias} + V_{SS}$, with $V_{SS} = 5\sin(wt)$ mV,
we get $V_{bias} = 1.835$V, in the simulation, $V_{out,DC} = 2.356$V
$V_{out,AC,magnitude} = 0.0.0086$V and $A_v = 1.547$

3.5 Simulation Plots



3.6 Conclusion and Inference

This experiment demonstrated the method to bias a MOSFET in the correct region to use it for the intended task, and also demonstrated a common source small signal amplifier. The PMOS was used as a diode load in this experiment.

3.7 Experiment completion status

This experiment was completed entirely in the lab.

4 Current Mirror Design

4.1 Aim of the experiment

Simulating a current mirror circuit to reflect the current in a branch of the circuit to another branch.

4.2 Methods

A DC input voltage is applied to the circuit and the resistance is adjusted to match the given current value, then the drain voltage of the other MOSFET is varied using DC sweep so as to bring the other MOSFET in saturation mode as well.

4.3 Design

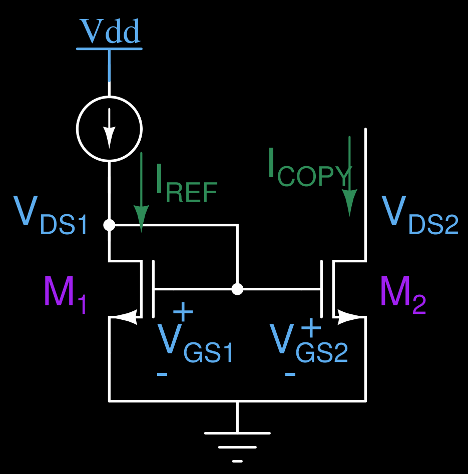


Figure 6: Basic NMOS current mirror circuit

for the above circuit:

$$\frac{I_{COPY}}{\frac{W_2}{L_2}} = \frac{I_{REF}}{\frac{W_1}{L_1}} \tag{7}$$

since the two NMOS' are identical, $I_{COPY} = I_{REF}$
But we have to ensure that both the MOSFETs are in saturation mode.

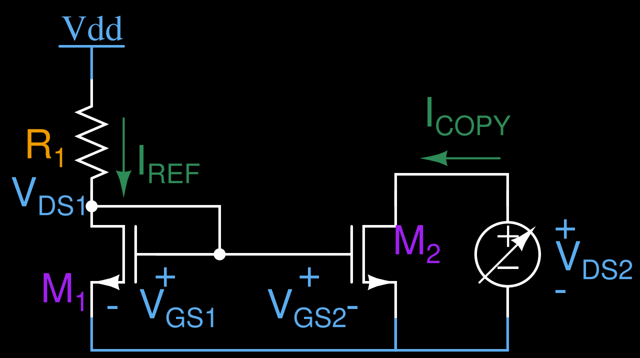
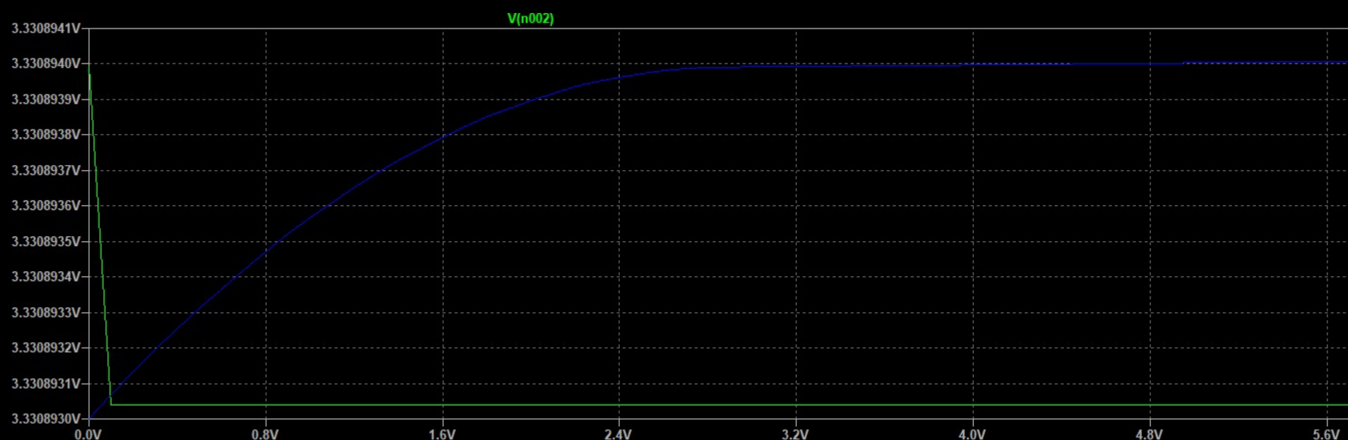


Figure 7: NMOS current mirror circuit setup for simulation

4.4 Experiment Results

for $V_{DD} = 8$V,
The calculations yielded the following values:
R1 = 2.3855kΩ, $V_{GS1} = 3.229$V
$V_{DS1} = 3.229$V

4.5 Simulation Plots



4.6 Conclusion and Inference

This experiment demostarted the working of a current mirror and the method to adjust the drain voltages to get the MOSFETS operating in saturation mode.

4.7 Experiment completion status

This experiment was partially entirely in the lab, due to lack of time.