University of Washington

BEE331 Lab 2.1

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Characterising MOSFET; I-V Curve

Design Objective

In this lab, we introduce ourselves to the MOSFET, we characterise its function V_{DS} and I_D curve; related to Triode, Threshold, and Saturation.

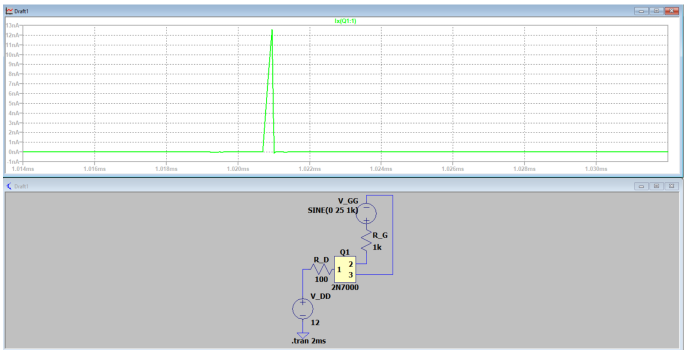
Circuit Design Outline

With an NMOS (2N7000) Transistor in series from Voltage Input $V_{DD} = 12V$ to a resistor ($R_D = 100\Omega$), the voltage drop in $V_{DS} = V_D - V_S$, to ground. In the Gate V_G over the capacitor of the MOSFET; in series with a resistor ($R_G = 1k\Omega$), being supplied with it's own voltage source; V_{GG}.

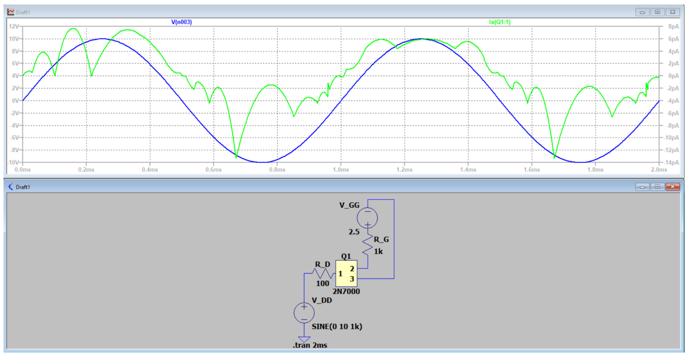
The demonstrated circuits below use a sinusoidal sweep with V_{DD} and V_{GG} respectively to demonstrate the I_D relation over a voltage-change.

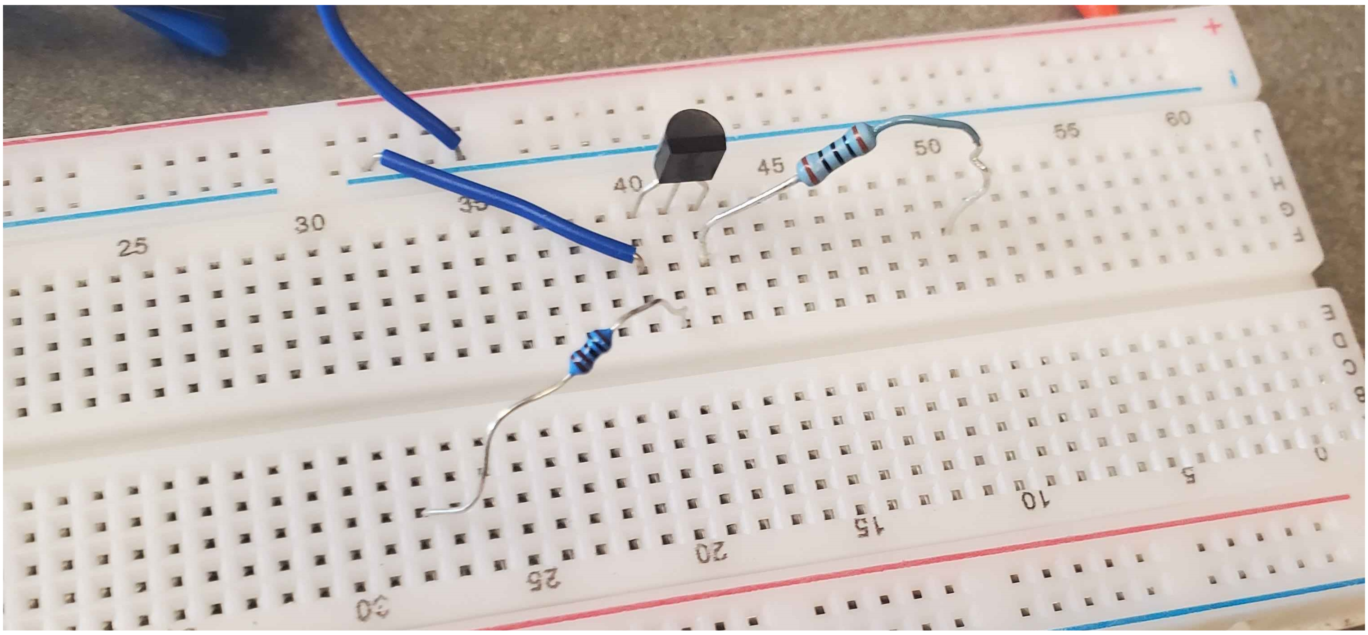
Figure 1: 2N7000 NMOS

(a) LTSpice + Rudimentary Schematic I_D vs V_{GS} Sweep



(b) LTSpice + Rudimentary Schematic I_D vs V_{DS} Sweep





(c) 2N7000 NMOS Transistor MOSFET Circuit

Descriptions of Measurements & Calculations

Analysis

- **i. Use your plot (or data) to find the value of V_{GS} which just starts to produce a non-zero drain current. This is the threshold voltage V_t of the MOSFET under test.**

  See below for tables and graphs of [I_D vs V_{GS}], and [I_D vs V_{GS}].

- **ii. How close are the measured and calculated values of V_{DS} at the boundary of triode and saturation regions of the MOSFET?**

  V_{GS} *vs* I_D: From when the current has a measurable rating ($1.8V$), saturates at a $0.6V$ difference ($2.4V$).

  V_{DS} *vs* I_D: From when the current plateaus at its greatest amount ($1V$ to $1.5V$), saturates at a $.5V$ difference ($@1.5V$). Then proceeds to break the component's specifications by breaching current at around $5V$

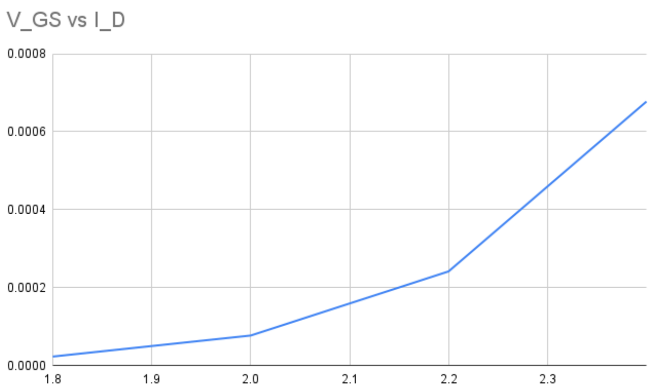
- **What model parameters of the MOSFET would you adjust (and how) to match the experimental results?**

  To simulate the I_D change over a voltage change for [Saturation] and [To $10V$] respectively, we AC-swept over a region. Aside from the simulation-method, here is the Github link to the .lib model we used to simulate the 2N7000 component.

- **Do the values of k_n obtained from measurements agree with k_n obtained from the model?**

  Simply, yes; given $k_n = (\frac{I_D*2}{V_{RD}-1.6})^2$

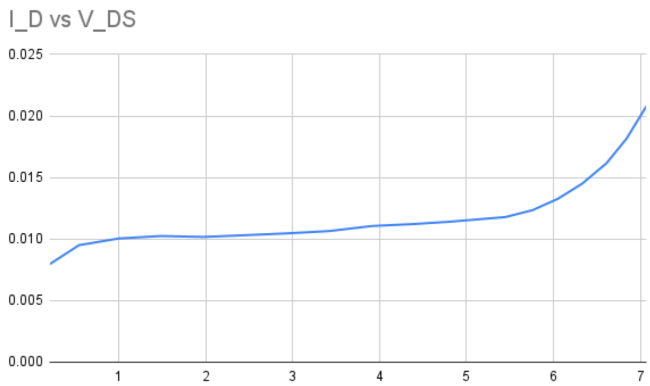
Figure 1: NMOS Circuits



(a) V_{GS} vs I_D Graph

VGS	V(RD)	ID	kn
0.2	0		
0.4	0		
0.6	0		
0.8	0		
1	0		
1.2	0		
1.4	0		
1.6	0.0002	0.000002	#DIV/0!
1.8	0.00228	0.0000228	0.00114
2	0.00768	0.0000768	0.00096
2.2	0.024139	0.00024139	0.001341055556
2.4	0.06775	0.0006775	0.0021171875

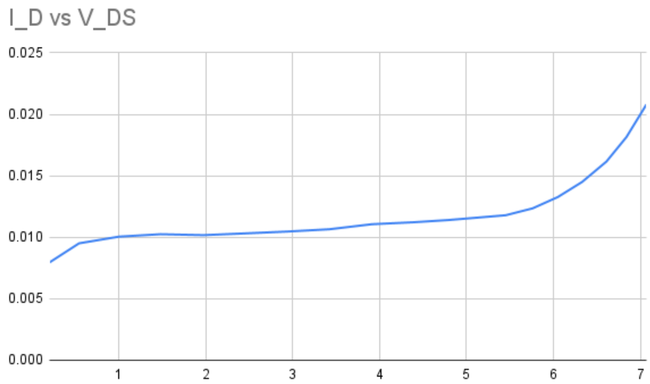
(b) Lab 2 2-2A-I Table



(c) I_D vs V_DS

VDD	V(RD)	ID	VDS
1	0.7955	0.007955	0.2
1.5	0.9507	0.009507	0.54
2	1.005	0.01005	1
2.5	1.0248	0.010248	1.48
3	1.0172	0.010172	1.97
3.5	1.0314	0.010314	2.45
4	1.0465	0.010465	2.94
4.5	1.065	0.01065	3.42
5	1.106	0.01106	3.91
5.5	1.122	0.01122	4.39
6	1.14	0.0114	4.79
6.5	1.16	0.0116	5.13
7	1.179	0.01179	5.45
7.5	1.235	0.01235	5.76
8	1.327	0.01327	6.05
8.5	1.45	0.0145	6.33
9	1.616	0.01616	6.61
9.5	1.815	0.01815	6.84
10	2.08	0.0208	7.07

(d) Lab 2 2-2A-I Table



(e) I_D vs V_DS @$V_{GS} = 2.5V$

VDD	V(RD)	ID	VDS
1	0.7955	0.007955	0.2
1.5	0.9507	0.009507	0.54
2	1.005	0.01005	1
2.5	1.0248	0.010248	1.48
3	1.0172	0.010172	1.97
3.5	1.0314	0.010314	2.45
4	1.0465	0.010465	2.94
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7	1.179	0.01179	5.45
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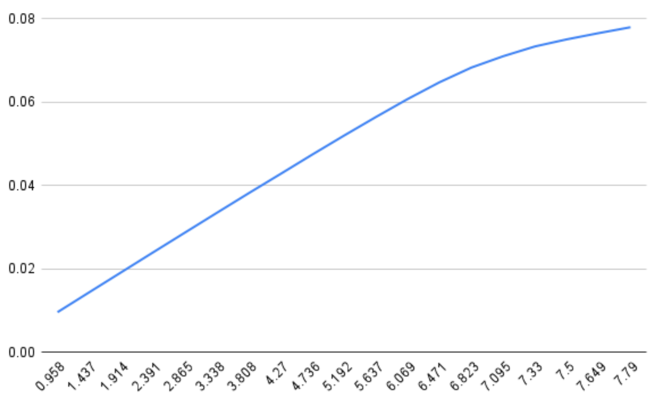
8.5	1.45	0.0145	6.33
9	1.616	0.01616	6.61
9.5	1.815	0.01815	6.84
10	2.08	0.0208	7.07

(f) Lab 2 2-2A-I Table @$V_{GS} = 2.5V$

VDD	V(RD)	ID	VDS
1	0.958	0.00958	0.03
1.5	1.437	0.01437	0.06
2	1.914	0.01914	0.08
2.5	2.391	0.02391	0.1
3	2.865	0.02865	0.13
3.5	3.338	0.03338	0.16
4	3.808	0.03808	0.19
4.5	4.27	0.0427	0.23
5	4.736	0.04736	0.27
5.5	5.192	0.05192	0.32
6	5.637	0.05637	0.38
6.5	6.069	0.06069	0.46
7	6.471	0.06471	0.59
7.5	6.823	0.06823	0.81
8	7.095	0.07095	1.12
8.5	7.33	0.0733	1.47
9	7.5	0.075	1.84
9.5	7.649	0.07649	2.22
10	7.79	0.0779	2.6

(g) I_D vs V_DS @$V_{GS} = 3V$



(h) Lab 2 2-2A-I Table @$V_{GS} = 3V$

Addendum Pages

Figure -1: Jason Truong Addendum

(a) Lab Design Calculations

$$I_D = I_S(e^{qV_D / NkT} - 1)$$

Where,

I_D = Diode current in amps

I_S = Saturation current in amps (typically 1×10^{-12} amps)

e = Euler's constant (~ 2.718281828)

q = charge of election (1.6×10^{-19} coulombs)

V_D = Voltage applied across diode in volts

N = "Nonideality" or "Emission" coefficient (typically between 1 and 2)

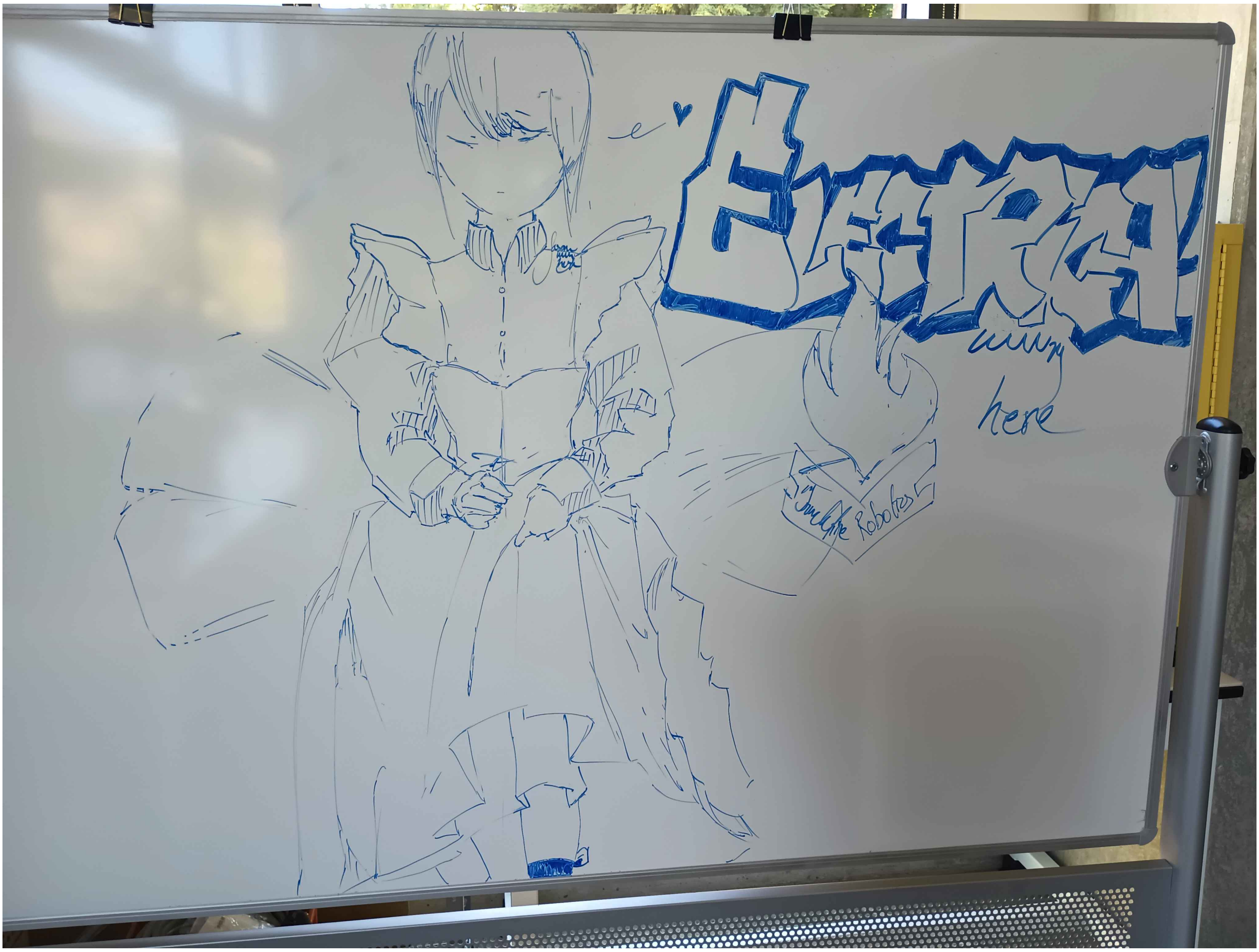
k = Boltzmann's constant (1.38×10^{-23})

T = Junction Temperature in Kelvins

Bibliography

Cited:

- Lab 1 Manual
- Sedra, Adel, and Kenneth Smith. Microelectronic Circuits. S.L., Oxford Univ Press Us, 2019.



(a) Keep believing in yourself.