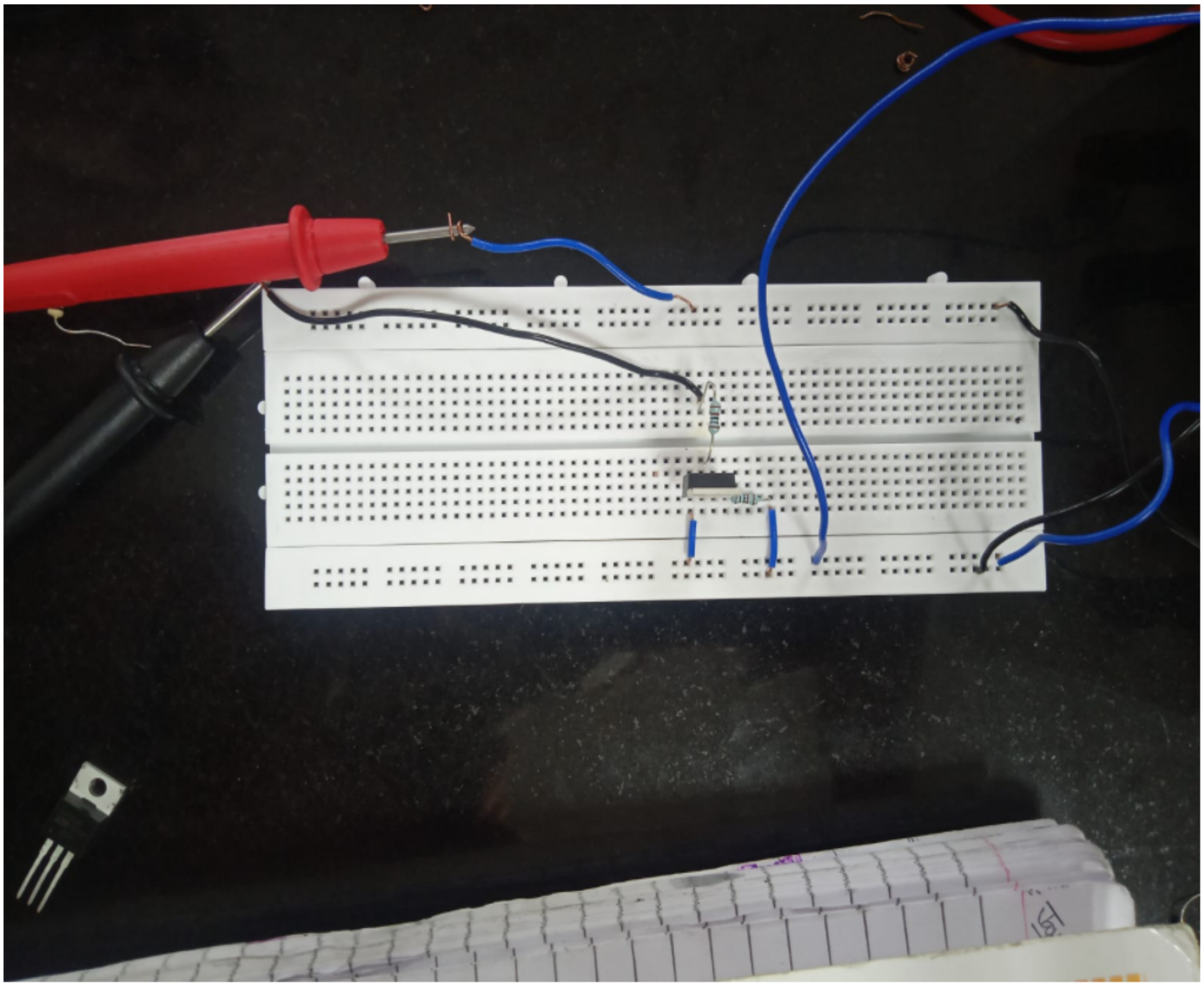
EECS Laboratory Experiment 8

Rita Abani 19244
Date : 27- 03 -2022

A few images of the experimental set-up



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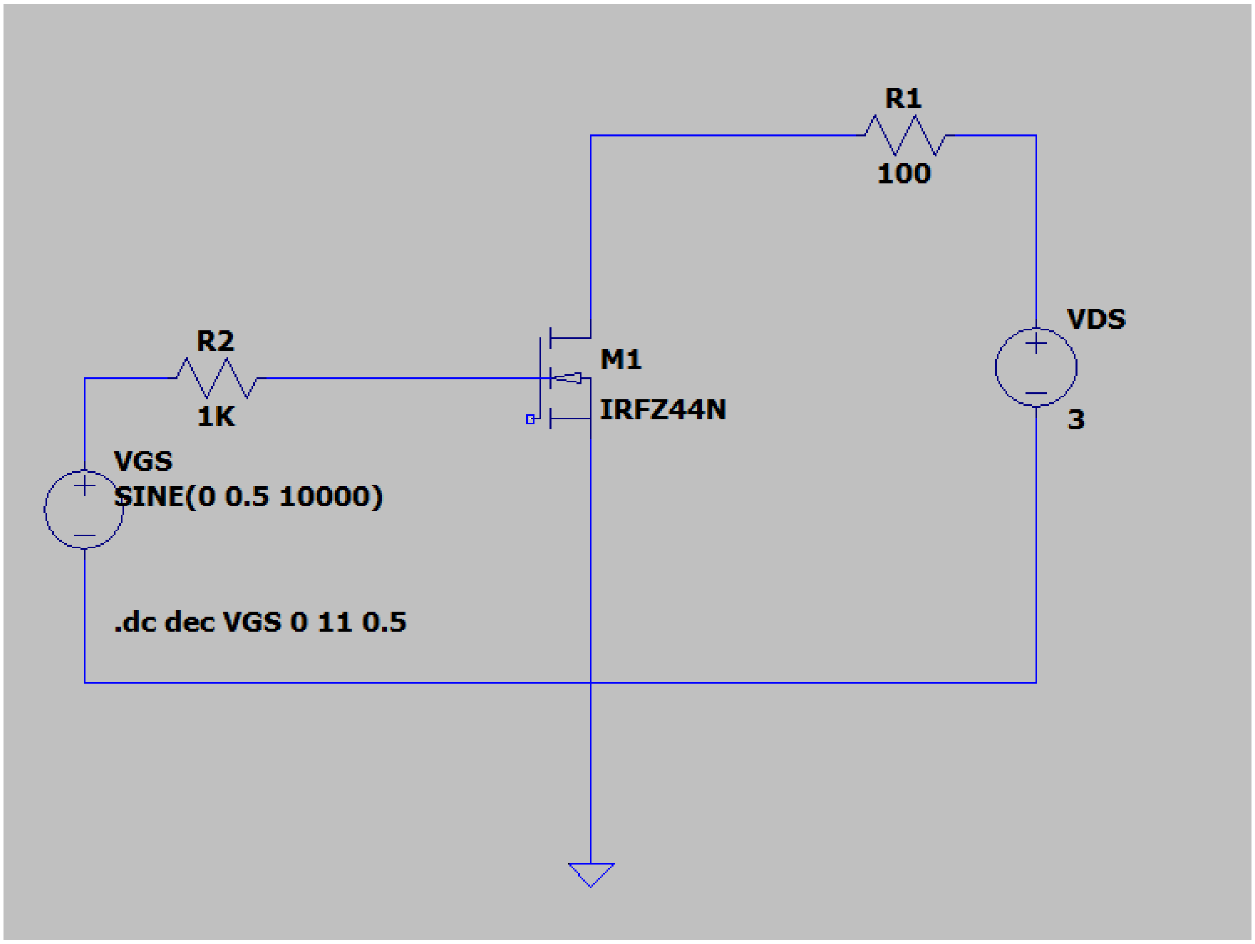
NMOS schematic in LTSpice



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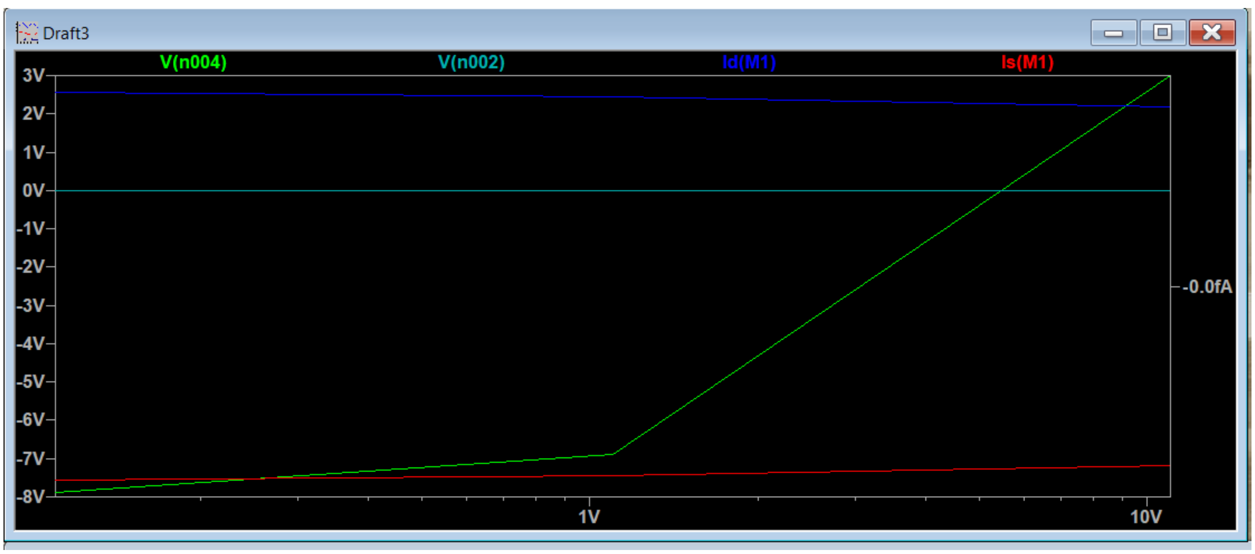
For V_{DS} = 3V

For V_{DS} = 8V



For V_{DS} = 11V

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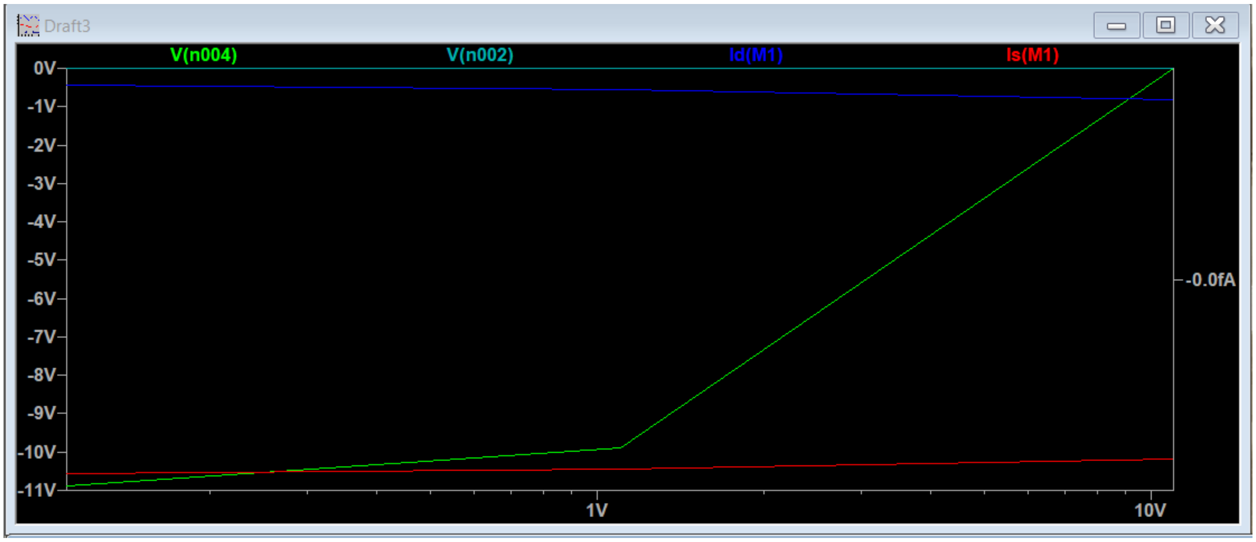
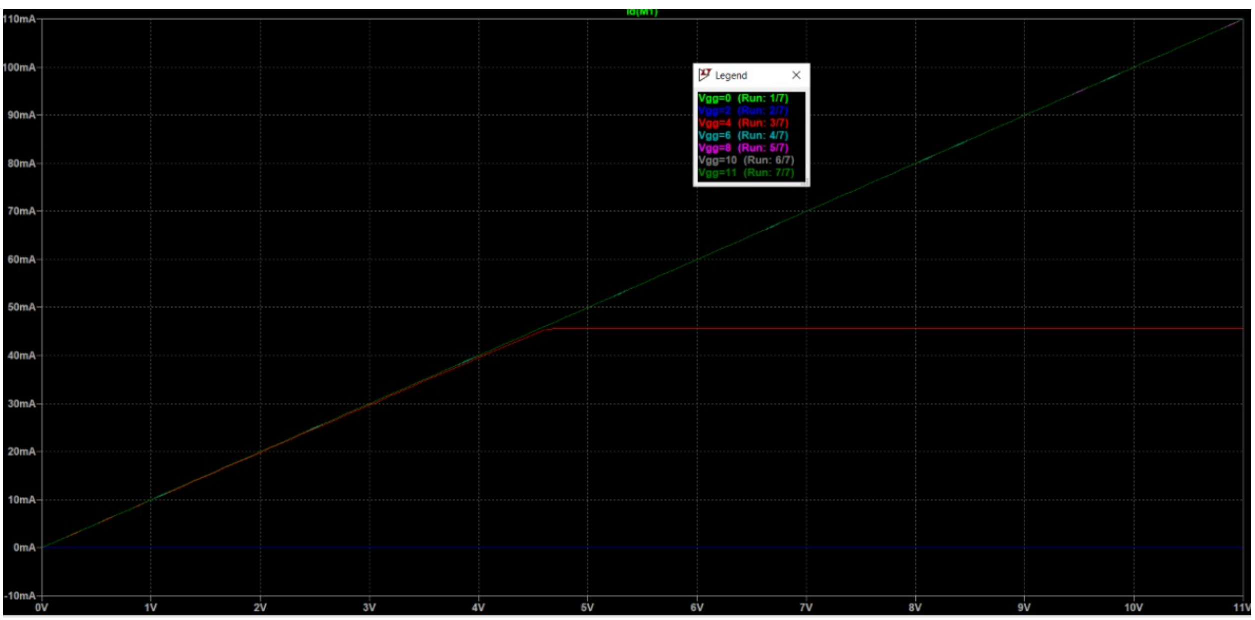


Output characteristics :



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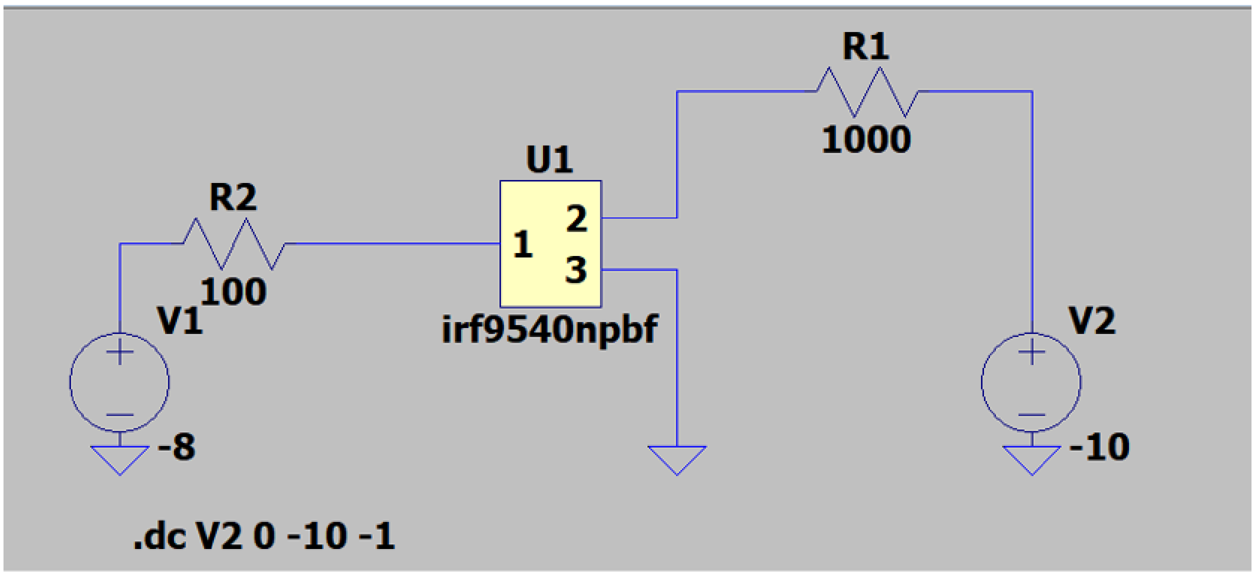
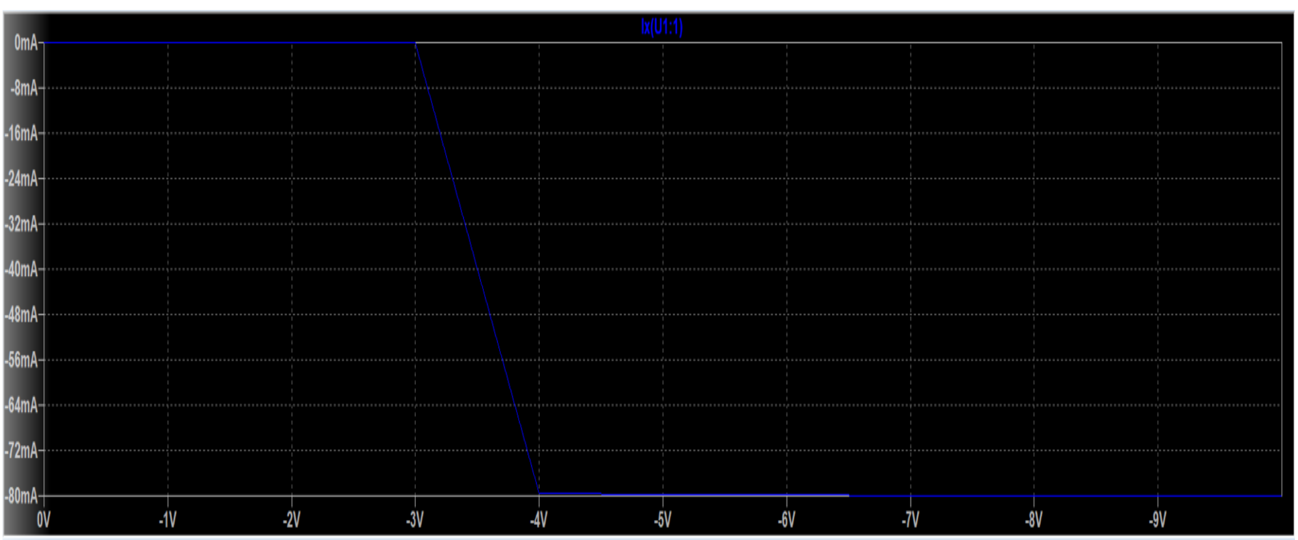
<u>LTSpice Schematic for PMOS circuit is as follows :</u>



Transfer characteristics for PMOS:



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Experimental results (performed in the lab)

For NMOS:

TRANSFER CHARACTERISTICS

V_{GS} (V)	$V_{DS} = 8\,V$	$V_{DS} = 11$ V	V_{GS} (V)	$V_{DS} = 8$ V	$V_{DS} = 11$ V
	I_D (mA)	I_D (mA)		I_D (mA)	I_D (mA)
0	0.01	0.01	6	71.8	106.1
0.5	0.01	0.01	6.5	71.8	106.2
1	0.01	0.05	7	72.3	106.2
1.5	0.01	0.01	7.5	72.4	106.3
2	0.01	0.01	8	72.6	106.4
2.5	0.20	0.61	8.5	72.8	106.0
3	13.55	18.61	9	72.7	106.3
3.5	63.6	90.9	9.5	73.1	105.6
4	70.9	104.5	10	73.3	104.6
4.5	71.9	106.1	10.5	72.9	104.9
5	71.3	106.2	11	72.7	104.5
5.5	71.1	106.1			

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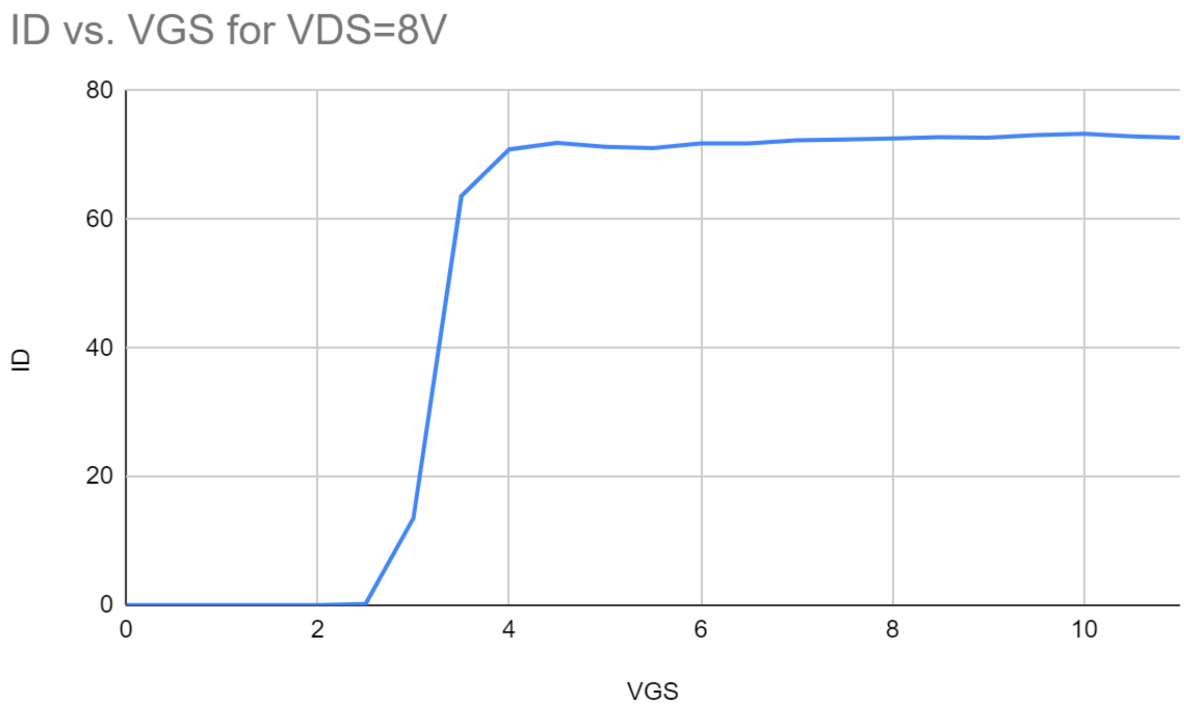

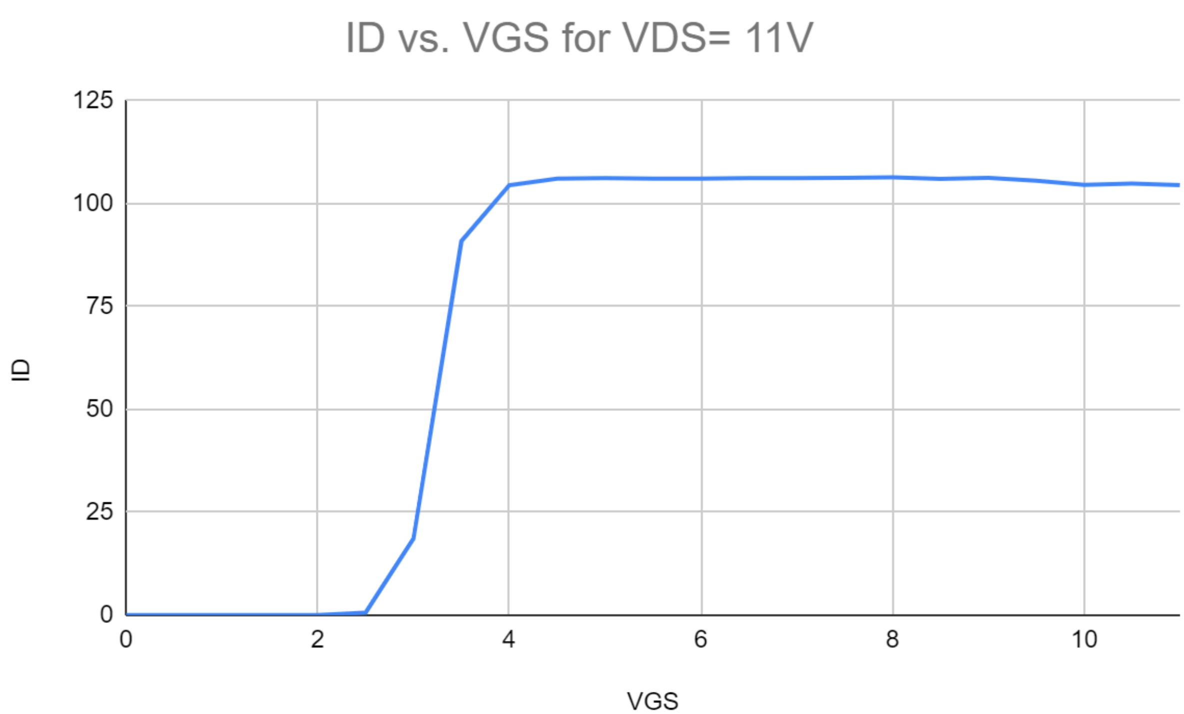

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OUTPUT CHARACTERSTICS

V_{DS} (V)	$V_{GS} = 2.5\ V$	$V_{GS} = 3\ V$	$V_{GS} = 3.5\ V$
	I_D (mA)	I_D (mA)	I_D (mA)
1	**0.23**	**1.04**	**0.99**
2	**0.23**	**1.97**	**1.91**
3	**0.23**	**2.98**	**2.84**
4	**0.23**	**3.98**	**3.86**
5	**0.23**	**4.89**	**4.79**
6	**0.24**	**5.87**	**5.70**
7	**0.24**	**6.92**	**6.63**
8	**0.24**	**7.79**	**7.59**
9	**0.24**	**8.85**	**8.91**
10	**0.24**	**9.87**	**9.82**
11	**0.24**	**10.87**	**10.9**
12	**0.25**	**11.68**	**11.83**
13	**0.24**	**12.30**	**12.90**
14	**0.24**	**12.59**	**13.84**
15	**0.26**	**12.86**	**14.88**
16	**0.26**	**13.13**	**15.83**
17	**0.26**	**13.26**	**15.80**

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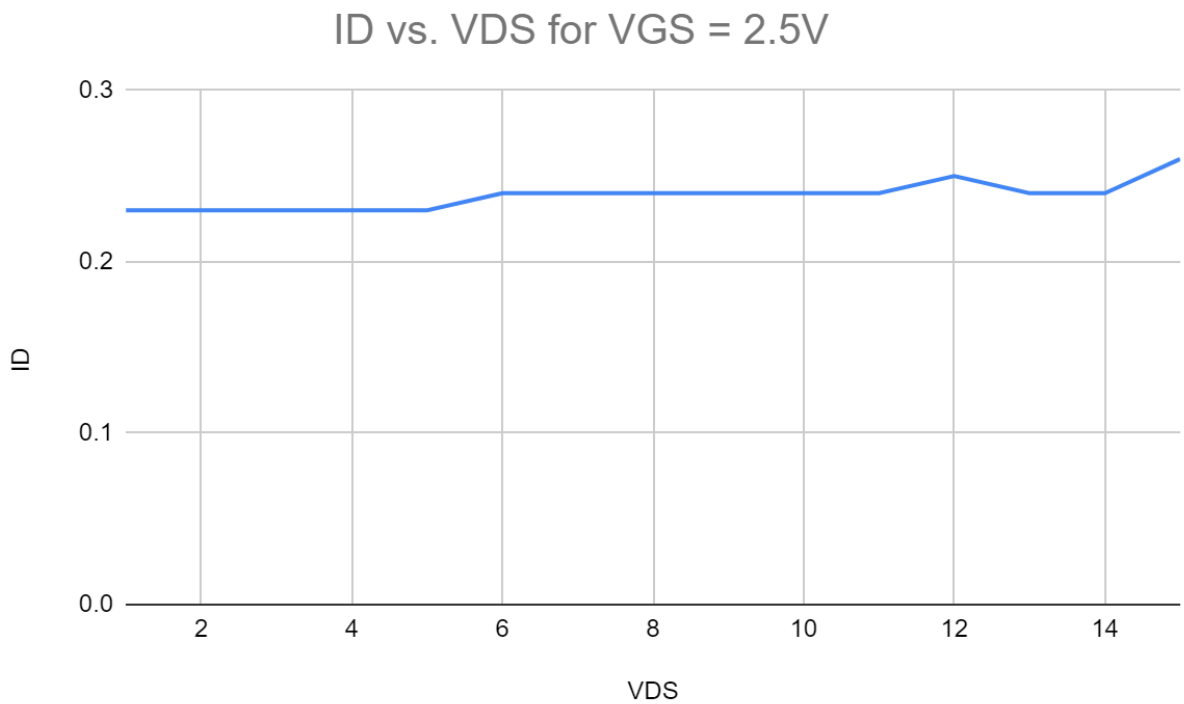

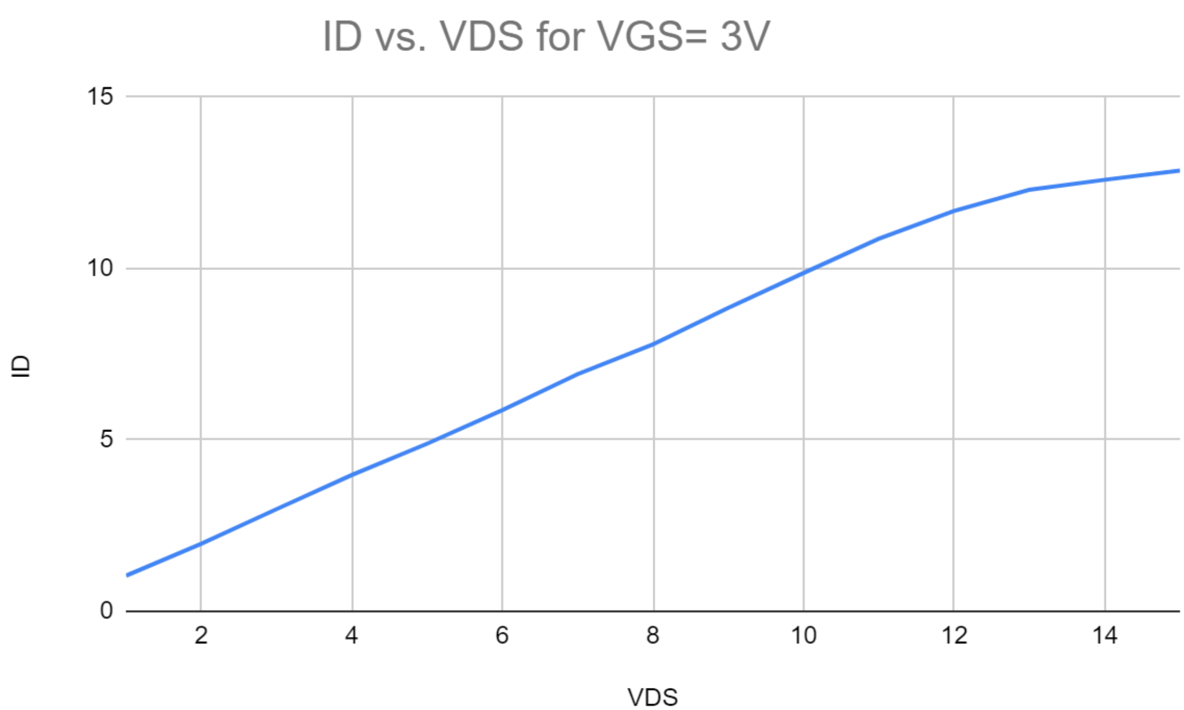

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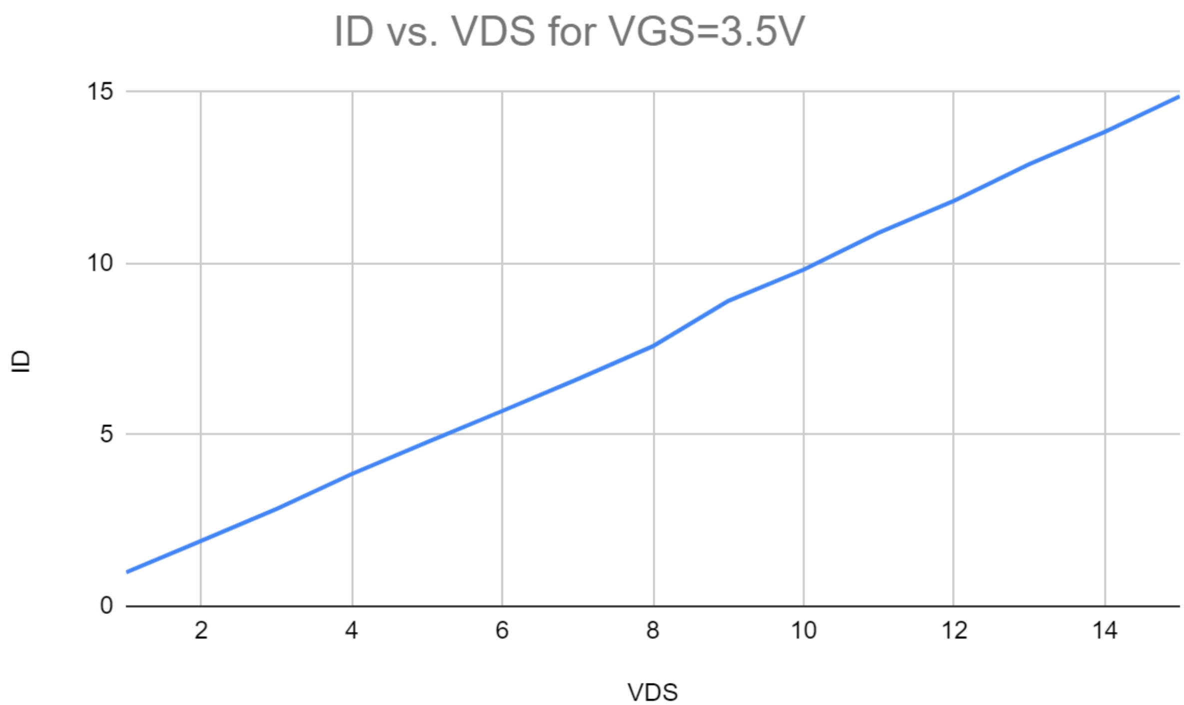

1. **Threshold voltage V_T:** Gate to source voltage at which, drain current starts flowing
2. **Transconductance g_m:** Ratio of small change in drain current (ΔI_D) to the corresponding change in gate to source voltage (ΔV_{GS}) for a constant V_{DS}.

$$g_m = \Delta I_D / \Delta V_{GS} \text{ when constant is } V_{DS}$$

3. **Output drain resistance:** It is given by the relation of small change in drain to source voltage (ΔV_{DS}) to the corresponding change in Drain Current (ΔI_D) for a constant V_{GS}.

$$r_d \text{ or } r_o = \Delta V_{DS} / \Delta I_D \text{ at a constant } V_{GS}$$

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RESULTS:

1. V_T: 0.5 V

2. g_m: approximately 1.75 mA/V (calculated graphically) for V_{DS} = 8V

   1.925 mA/V (calculated graphically) for V_{DS} = 11V

   Average g_m = 1.8375 mA/V

3. r_o: **45.5 k ohms for V_{GS} = 2.5 V**
   0.8 k ohms for V_{GS} = 3 V
   0.75 k ohms for V_{GS} = 3.5 V

   Average r_0 = 47.05 k ohms

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For PMOS:

TRANSFER CHARACTERISTICS

V_{GS} (V)	$V_{DS} = 8\,V$	$V_{DS} = 11$ V
	I_D (mA)	I_D (mA)
0	0	0
0.5	0	0
1	0	0
1.5	0	0
2	0	0
2.5	0	0
3	-0.02	-0.02
3.5	-4.58	-3.78
4	-7.69	-10.30
4.5	-7.70	-10.36
5	-7.71	-10.37
5.5	-7.71	-10.38
6	-7.71	-10.36
6.5	-7.70	-10.36
7	-7.72	-10.36

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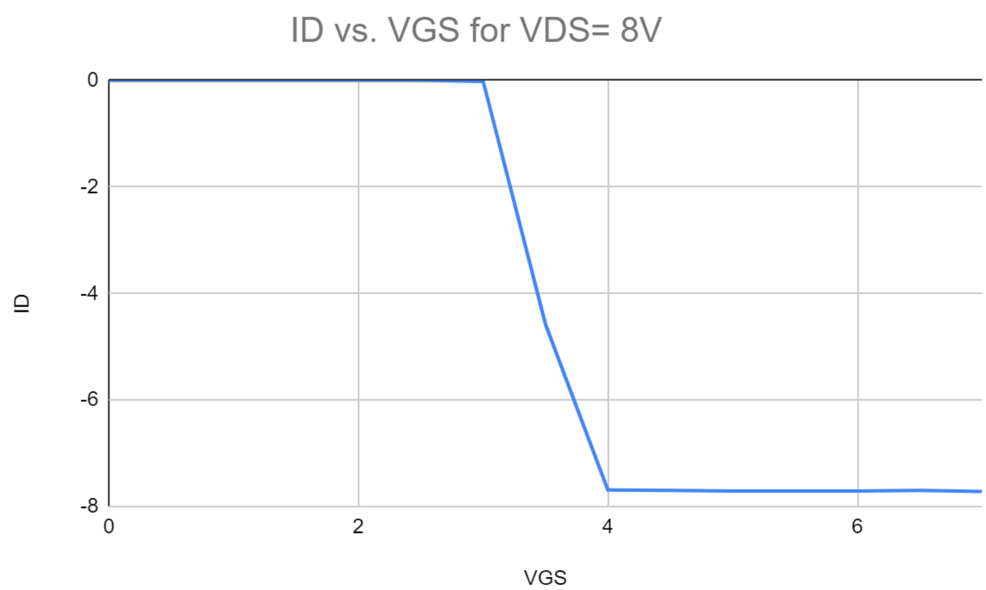

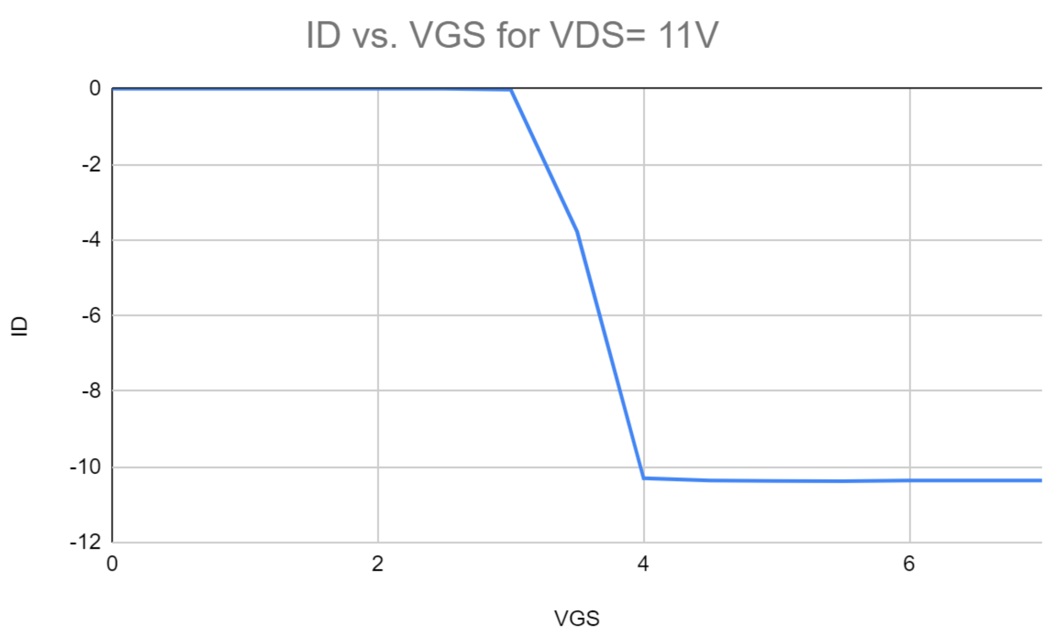

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OUTPUT CHARACTERISTICS

V_{DS} (V)	$V_{GS} = 3\ V$	$V_{GS} = 3.5\ V$	$V_{GS} = 4\ V$
	I_D (mA)	I_D (mA)	I_D (mA)
1	-0.04	-0.94	-1
2	-0.04	-1.95	-1.81
3	-0.04	-2.92	-2.73
4	-0.04	-3.82	-3.22
5	-0.04	-4.73	-3.24
6	-0.03	-5.74	-3.24
7	-0.04	-6.61	-3.22
8	-0.04	-7.67	-3.22
9	-0.05	-8.61	-3.22
10	-0.04	-9.57	-3.22
11	-0.06	-10.40	-3.22
12	-0.06	-11.28	-3.22
13	-0.05	-12.24	-3.22
14	-0.05	-13.28	-3.24
15	-0.05	-14.23	-3.24
16	-0.05	-14.24	-3.24
17	-0.05	-14.24	-3.24

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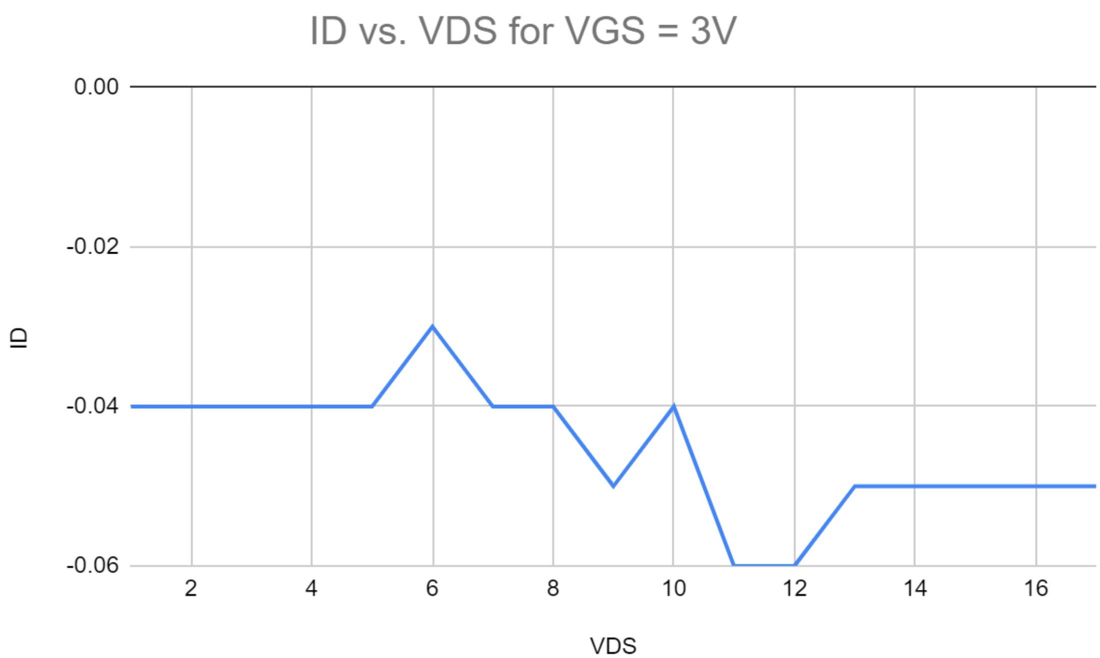

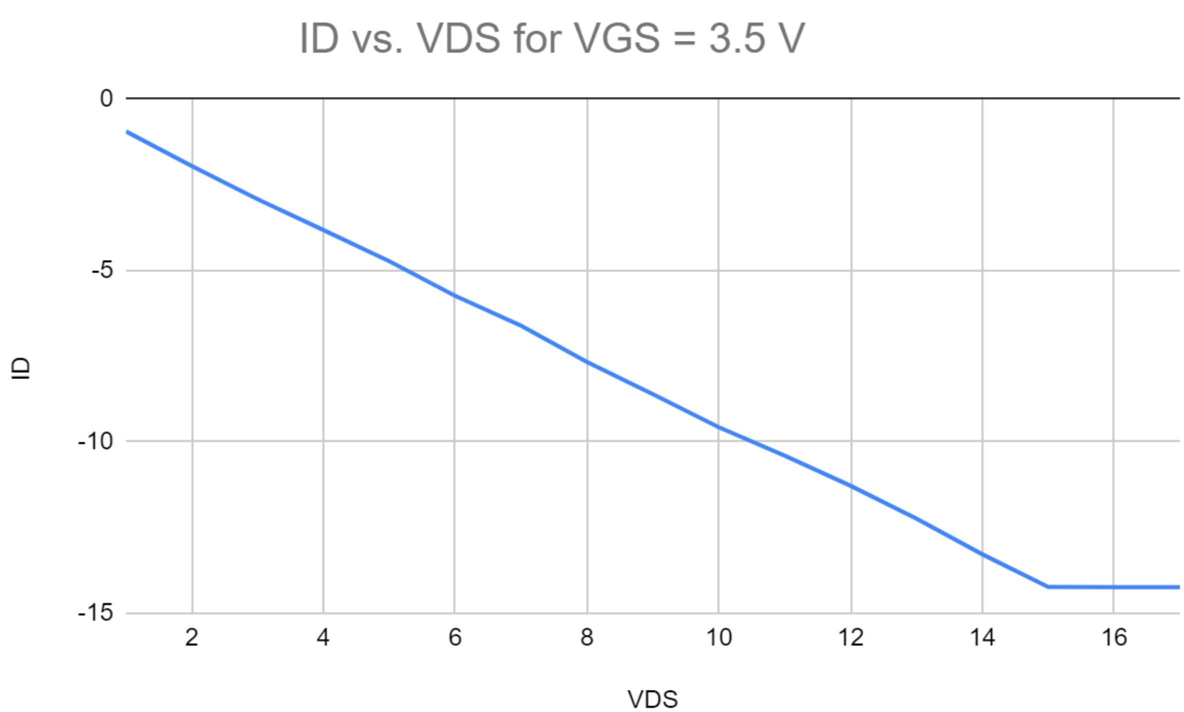

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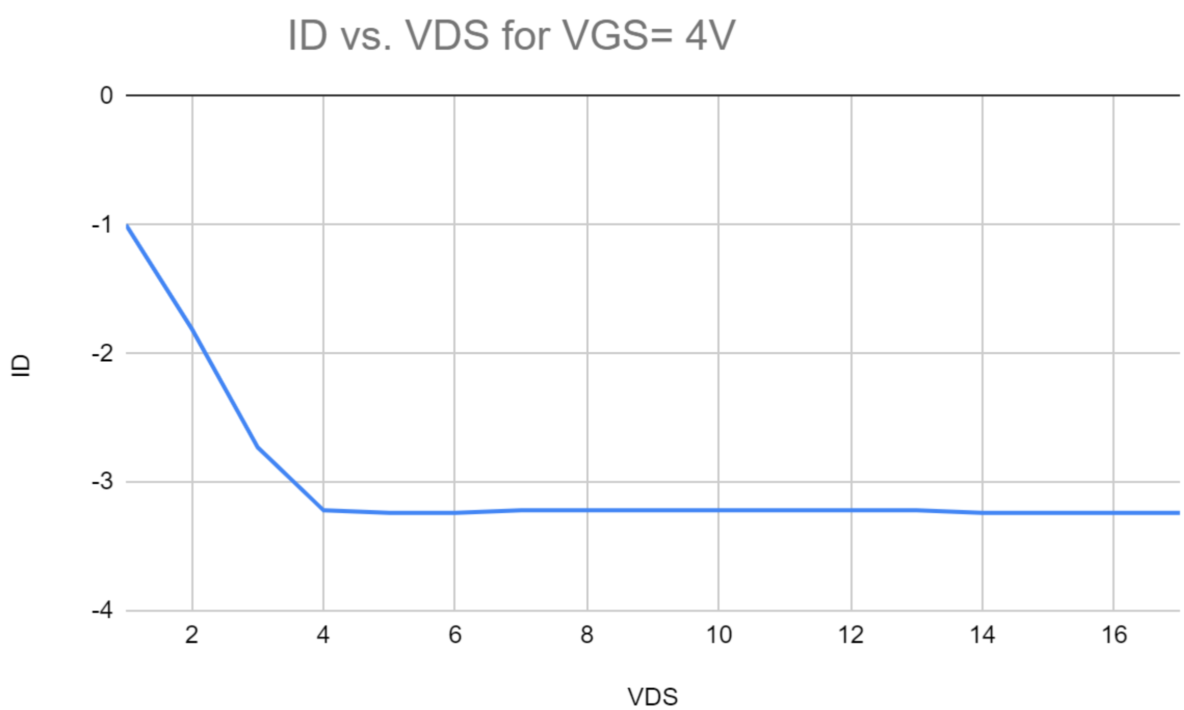

1. **Threshold voltage V_T:** Gate to source voltage at which, drain current starts flowing
2. **Transconductance g_m:** Ratio of small change in drain current (Δ I_D) to the corresponding change in gate to source voltage (ΔV_{GS}) for a constant V_{DS}.

$$g_m = \Delta I_D / \Delta V_{GS} \text{ when constant is } V_{DS}$$

3. **Output drain resistance:** It is given by the relation of small change in drain to source voltage (Δ V_{DS}) to the corresponding change in Drain Current (Δ I_D) for a constant V_{GS}.

$$r_d \text{ or } r_o = \Delta V_{DS} / \Delta I_D \text{ at a constant } V_{GS}$$

RESULTS:

1. V_T: 3V
2. g_m: approximately 0.625 mA/V (calculated graphically) for V_{DS} = 8V

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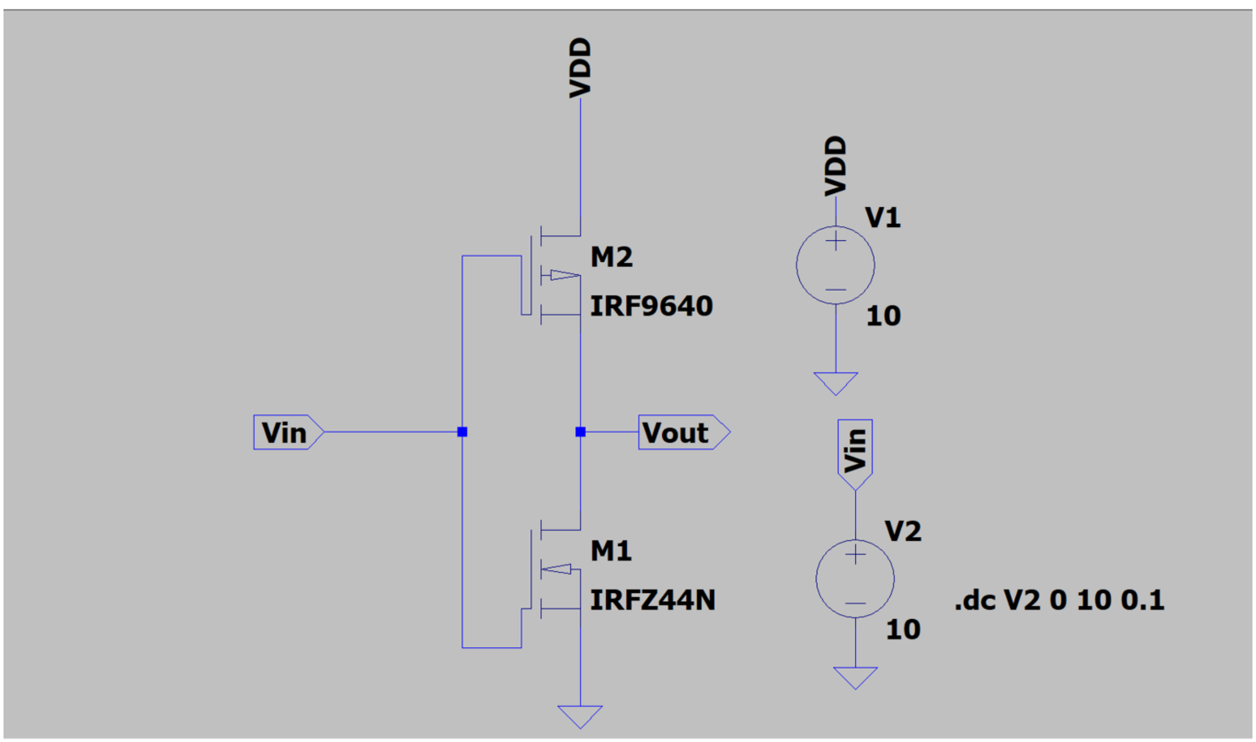
7.52 mA/V (calculated graphically) for V_{DS} = 11V

Average g_m = 4.0725 mA/V

3. $\boldsymbol{r_o}$: 95.6 k ohms for V_{GS} = 3 V
   1.2 k ohms for V_{GS} = 3.5 V
   1.66 k ohms for V_{GS} =4 V

   Average r_0 = 32.82 k ohms

CMOS inverter :



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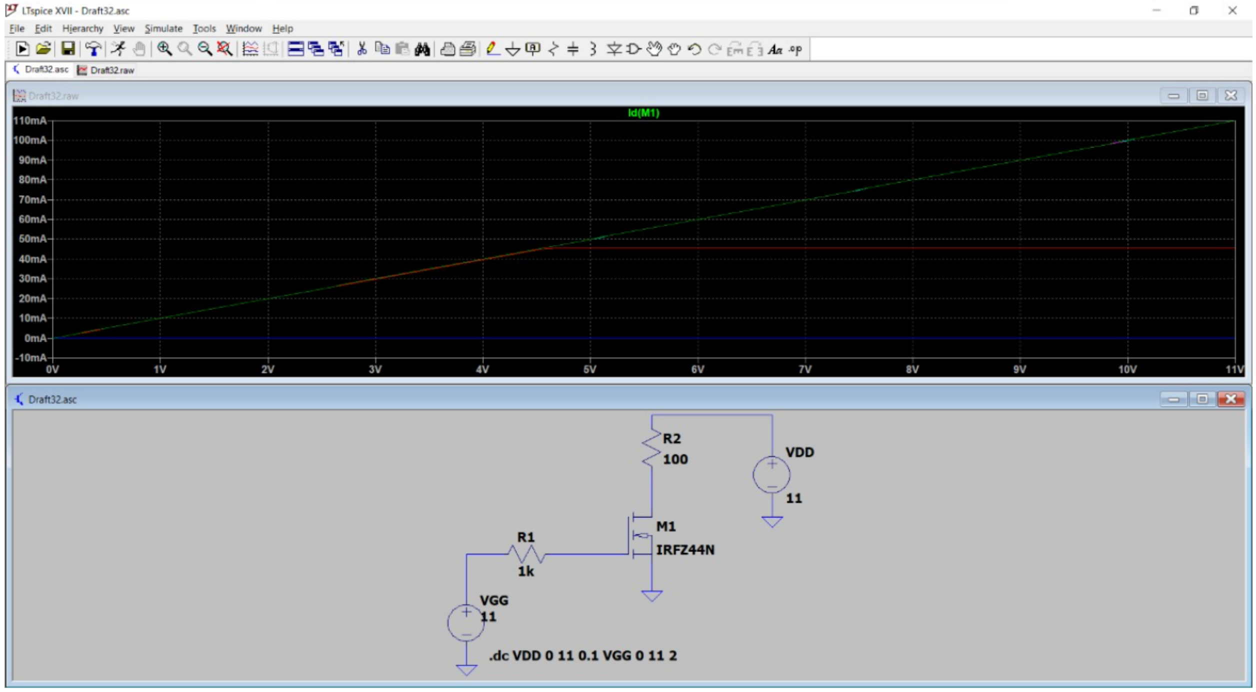

Vinput	Voutput
0	5.06
0.5	5.06
1	5.06
1.5	5.06
1.6	5.06
1.7	4.40
1.8	0.45
1.9	0.0062
2	0.0006
2.1	0.0002
2.2	0.0004
2.3	0.0002
2.4	0.0004
2.5	0.0003
2.6	0.0003
2.7	0.0003
2.8	0.0004
2.9	0.0004
3	0.0005
3.1	0.0006

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3.2	0.0007
3.3	0.0007
3.4	0.0009
3.5	0.001
3.6	0.0012
3.7	0.0014
3.8	0.0017
3.9	0.0019
4	0.0021
4.5	0.0057
5	0.009
5.5	0.0134
6	0.0194

The voltage transfer characteristics are as follows :