

Section	
Bench No.	

ECE110 Introduction to Electronics

Pre-Lab 7: Motor-Driven Circuit

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Pre-Lab 7: Motor-Driven Circuit

Learning Objectives

- Learn the basic function of MOSFET
- Build a motor - driven circuit for improved engineering design through Mosfet

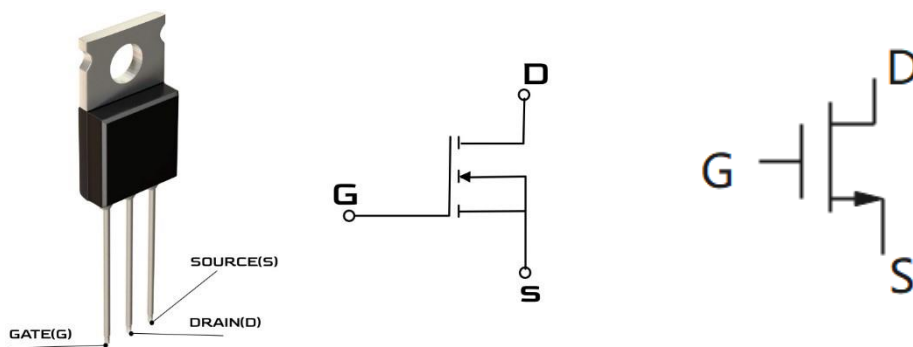
Background

Previously, we were controlling motor speed by using a current-limiting resistor network in series with each motor. One difficulty we recognized in this method was that the resistor network had to absorb significant power. In fact, the resistors were absorbing about as much power and dissipating it as heat (waste) as the wheels were dissipating (useful) resulting in low efficiency. Furthermore, the amount of power dissipated in the resistors necessitated the use of a resistor network to gain a higher effective power rating. The use of a MOSFET transistors will enable us to “buffer” low-power resistive control from the higher-powered motor circuitry. In this way, we will be able to reduce cost (lower-power-rated devices) and increase efficiency (less power waste).

Introduction to MOSFET

Metal Oxide Silicon Field Effect Transistors commonly known as MOSFETs are electronic devices used to switch in circuits. It is a voltage-controlled device and is constructed by three terminals. The terminals of MESFET are named as follows:

- Source
- Gate
- Drain



(a) Physical Diagram (b) Circuit Symbol (c) simplified circuit symbol

Figure 1: Profile and Symbol of MOSFET (the circuit symbol is for n-channel enhancement-type MOSFET)

MOSFET acts like a voltage-controlled resistor where the current flowing through the

main channel between the Drain and Source is proportional to the input voltage. There are two types of MOSFETs, P-channel (PMOS) and N-channel (NMOS). And there are two basic forms of each type of MOSFET: depletion type and enhancement type. The one we will be using in today's experiment is enhancement-mode N-channel MOSFET, for which a drain current (I_D) will only flow when a Gate-Source voltage (V_{GS}) is applied to the gate terminal greater than the threshold voltage (V_{TH}), and then switch the device "ON". N-channel MOSFETs are excellent electronic switches due to their low "ON" resistance and extremely high "OFF" resistance as well as their infinitely high input resistance due to their isolated gate.

The operation of the enhancement-mode MOSFET, can best be described using its I-V characteristics curves shown below. When the input voltage (V_{in}) to the gate of the transistor is zero, the MOSFET conducts virtually no current and the output voltage (V_{out}) is equal to the supply voltage V_{DD} . So, the MOSFET is "OFF" operating within its "cut-off" region.

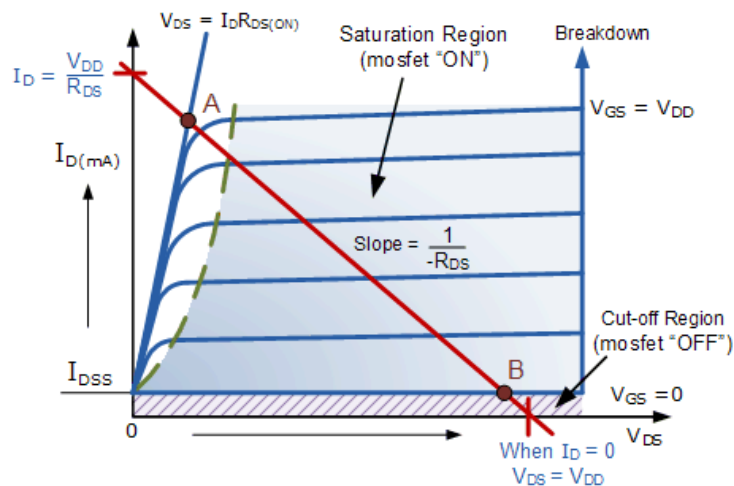
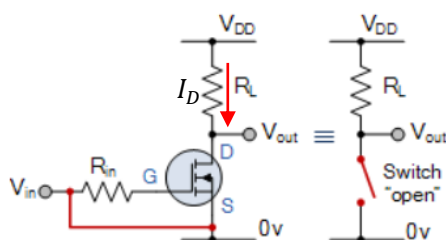


Figure 2: MOSFET Characteristics Curves (show in website [Electronic Tutorials](http://www.electronicstutorials.com/))

When the input voltage is zero, Drain current I_D and output voltage V_{DS} are both zero, the device is switched "OFF".



- The input and Gate are grounded (0V)
- Gate-source voltage less than threshold voltage $V_{GS} < V_{TH}$
- MOSFET is "OFF" (Cut-off region)
- No Drain current flows ($I_D = 0$ Amps)
- $V_{OUT} = V_{DS} = V_{DD} = "1"$
- MOSFET operates as an "open switch"

Figure 3: Off-state of MOSFET

When a positive voltage is applied to Gate terminal, the conductive channel is open and

drain current flows through the MOSFET switch, the device is switched “ON”.

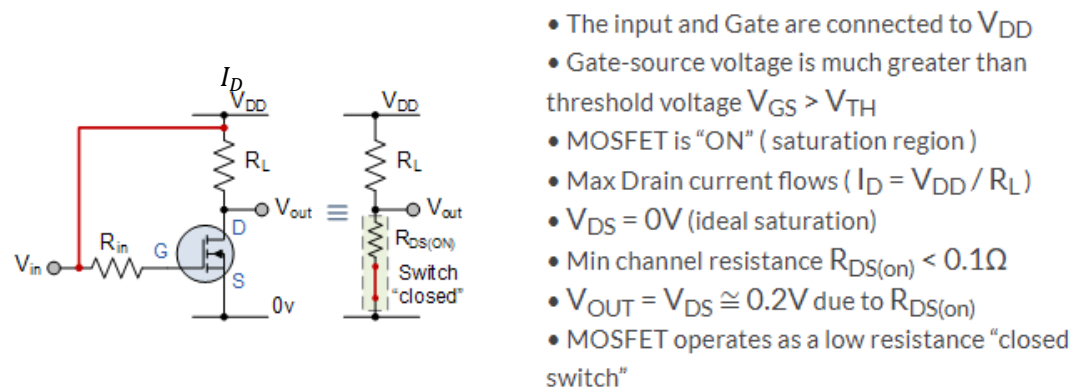


Figure 4: On-state of MOSFET

Then we can define the saturation region or “ON mode” when using an enhancement-mode MOSFET as a switch as gate-source voltage $V_{GS} > V_{TH}$ thus $I_D = \text{Maximum}$.

When using MOSFET as a switch, we can drive the MOSFET to turn “ON” faster or slower or pass high or low currents. This ability to turn the power MOSFET “ON” and “OFF” allows the device to be used as a very efficient switch with switching speeds much faster than standard transistors.

Find the 30N06 n-channel MOSFETs from your kit. There is an image of it below but be sure to check the label on the device as others may look similar. The datasheet may be found at:

<https://datasheet.ciiva.com/4439/fqp30n06-112142-4439293.pdf?src-supplier=Mouser>.

Question1: Use the datasheet to determine the drain (D), and source (S), and gate (G) pins of the 30N06 MOSFET. Label the pins on the image below correctly with D, S, and G (placing them in the correct order, of course).

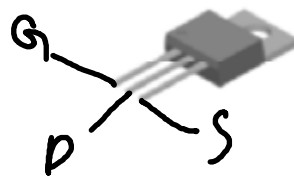


Figure 5: Pinout of the MOSFET(you label it!)

Question 2: According to the datasheet, find the **Gate Threshold Voltage** V_{TH} (you just provide a range of the voltage).

$$V_{TH} = 2 - 4 V.$$

Question 3 : According to the datasheet, we find the on-state characteristics of MOSFET as show in

Figure 6, and according to this figure, what relationship can you find between I_D vs V_{DS} with same V_{GS} , also I_D vs V_{GS} with same V_{DS} ? (Just a qualitative description is enough.)

With a given V_{GS} , $I_D \propto V_{DS}$ when V_{DS} is small
 $I_D \propto V_{GS}^2$ when V_{DS} is big

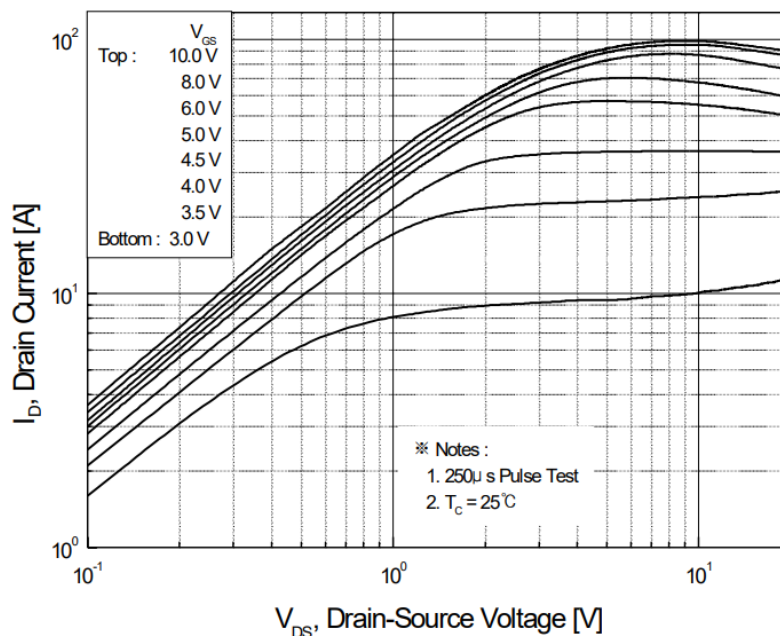


Figure 6: On-state characteristics of MOSFET

Simulation for MOSFET (I_D vs V_{DS})

In this section we will perform LTspice simulation to obtain the I_D - V_{DS} characteristics of a MOSFET.

The setup for obtaining I_D and V_{DS} is shown in Figure 7. we use a single NMOS

and two variable voltage to observe the drain current I_D . Please follow the step below to do the simulation.

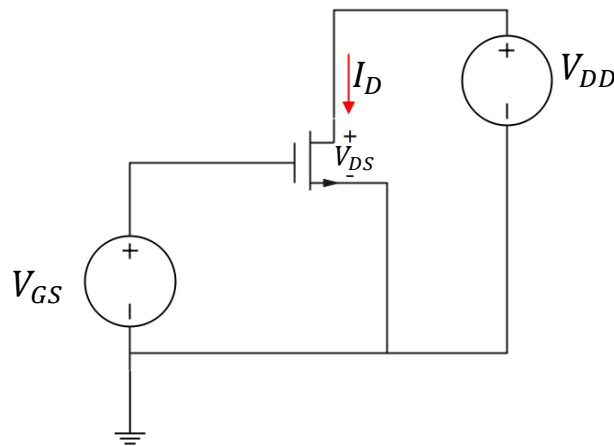



Figure 7: n-channel MOSFET I_D vs V_{DS} characterization setup.

1. Open the software LTSpice, and create a new schematic
2. Click , in the *Select Component Symbol* page, input **nmos**, choose a MOSFET symbol, as show in Figure 8.

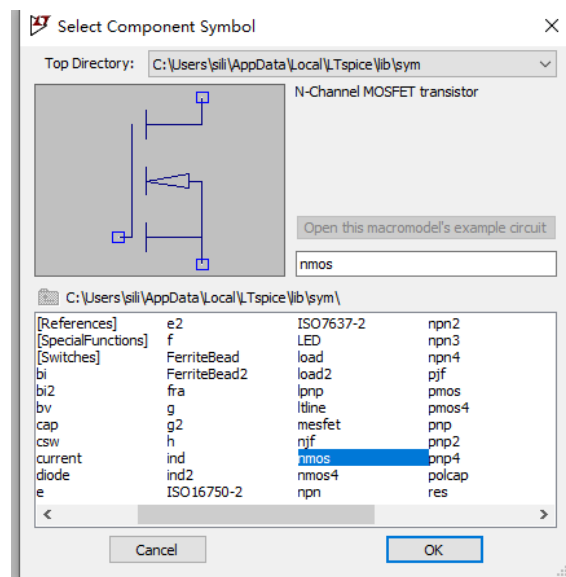


Figure 8: choose nmos symbol

3. Add voltage source V_{GS} and V_{DD} to the circuit, also with the GND, and you will get a circuit like in Figure 9.

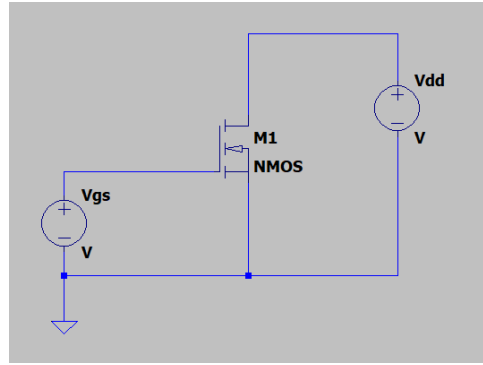


Figure 9: The circuit in LTSpice

- Then we choose a MOSFET mode to do the simulation. Right click on the MOSFET Symbol, it will show the preference page of MOSFET, then click *Pick New MOSFET*.

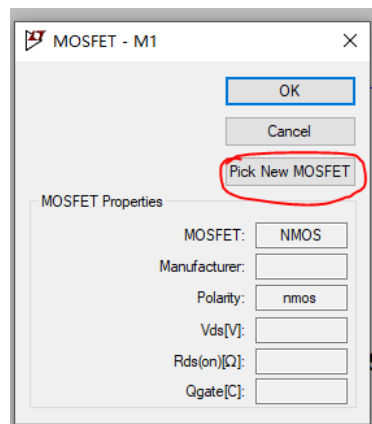



Figure 10: Pick a MOSFET model

- From the list, we choose **RSR030N06**, this one is similar to the one we use.

Part No.	Manufacturer	Polarity	Vds[V]	Ron[mΩ]	Gate Chg[nC]	SPICE Model
RUI002N06	Rohm	N-chan	60.0	1600.0	1	model RUI002N06 VDMOS(Pg=110 Vto=1.201 Rd=778m Rb=500m Rb=173.58m Kp=962.2m Lambda=50m Cgdmin=3p Cgdm=
2N7002	Fairchild	N-chan	60.0	2000.0	2	model 2N7002 VDMOS(Pg=3 Vto=1.6 Rd=0 Rb=75 Rb=14 Kp=17 mtride=1.25 Cgdmin=90p Cgdm=12p Cgr=50p Qp=50t
RK7002BM	Rohm	N-chan	60.0	1700.0	2	model RK7002BM VDMOS(Pg=380 Vto=1.92 Rd=1.47 Rb=30m Rb=250m Kp=601.15m Lambda=50m Cgdmin=1.5p Cgdm=1
RSF015N06	Rohm	N-chan	60.0	210.0	2	model RSF015N06 VDMOS(Pg=36 Vto=2.037 Rd=146m Rb=50m Rb=25m Kp=9.057 Lambda=40m Cgdmin=5p Cgdm=80p /
RSQ015N06	Rohm	N-chan	60.0	210.0	2	model RSQ015N06 VDMOS(Pg=35 Vto=2.08 Rd=137.4m Rb=40m Rb=25m Kp=10 Lambda=40m Cgdmin=5p Cgdm=80p /
RH002N06	Rohm	N-chan	60.0	1700.0	2	model RH002N06 VDMOS(Pg=160 Vto=2.08 Rd=220m Rb=1.2 Rb=199.07m Kp=456.6m Lambda=50m Cgdmin=2.7p Cgdm=
RSR020N06	Rohm	N-chan	60.0	120.0	3	model RSR020N06 VDMOS(Pg=28 Vto=1.8772 Rd=50m Rb=60m Rb=25m Kp=12.5 Lambda=0.05 Cgdmin=10p Cgdm=120p
RH003N06	Rohm	N-chan	60.0	700.0	3	model RH003N06 VDMOS(Pg=50 Vto=2.064 Rd=180m Rb=400m Rb=172.09m Kp=1.077 Lambda=50m Cgdmin=4p Cgdm=
RK7002A	Rohm	N-chan	60.0	700.0	3	model RK7002A VDMOS(Pg=50 Vto=2.064 Rd=180m Rb=400m Rb=172.09m Kp=1.077 Lambda=50m Cgdmin=4p Cgdm=80
SP9K31	Rohm	N-chan	60.0	85.0	4	model SP9K31 VDMOS(Pg=21 Vto=2.02 Rd=68.7m Rb=10m Rb=20m Kp=19.81 Lambda=50m Cgdmin=15p Cgdm=220p A=
RSR030N06	Rohm	N-chan	60.0	60.0	5	model RSR030N06 VDMOS(Pg=16.5 Vto=1.3 Rd=41.1m Rb=14m Rb=20m Kp=25.4 Lambda=0.03 Cgdmin=20p Cgdm=2
RUP020N06	Rohm	N-chan	60.0	165.0	5	model RUP020N06 VDMOS(Pg=25 Vto=1.208 Rd=80.9m Rb=60m Rb=40m Kp=12.85 Lambda=50m Cgdmin=12p Cgdm=50t
BUK9S260E	NXP	N-chan	60.0	55.0	6	model BUK9S260E VDMOS(Pg=8.48 Vto=2.00 Rd=27m Rb=100u Rb=4.1m Kp=25.7 Lambda=0 Cgdmin=39.3p Cgdm=50t
BUK9S560E	NXP	N-chan	60.0	59.0	6	model BUK9S560E VDMOS(Pg=5.73 Vto=2.16 Rd=40m Rb=100u Rb=5.4m Kp=35.7 Lambda=0 Cgdmin=37.4p Cgdm=550
AOV6266E	Alpha & Omega	N-chan	60.0	14.0	6	model AOV6266E VDMOS(Pb=3.5m Rd=3.3m Rg=1.3 Vto=1.66 Kp=20.0 lambda=55.2m mtride=2.42 kaubthree=1.1e=998 N=
RSQ035N06	Rohm	N-chan	60.0	50.0	6	model RSQ035N06 VDMOS(Pg=19 Vto=2.424 Rd=17.3m Rb=30m Rb=15m Kp=46.75 Lambda=40m Cgdmin=28p Cgdm=33
AOV6264E	AOS	N-chan	60.0	7.7	7	model AOV6264E VDMOS(Vto=2.3 Kp=92 Lambda=52m mtride=1.6 BV=72 IBV=250u Rd=0.1m Rb=6.7m Rg=1.2 Rb=4.5m C=

Figure 11: Choose RSR030N06 MOSFET

6. Set $V_{gs} = 5V$. Click  to set up the parameter, perform a DC sweep simulation by changing the V_{dd} from 0-15V with increments of 100mV. Then Plot the curve for I_D vs V_{DS} , first you will see nothing on the figure, then right click on the black area, choose **Add Traces**, then choose Id(YOUR MOSFET NAME), click OK, the curve will show on the screen, as Figure 14.

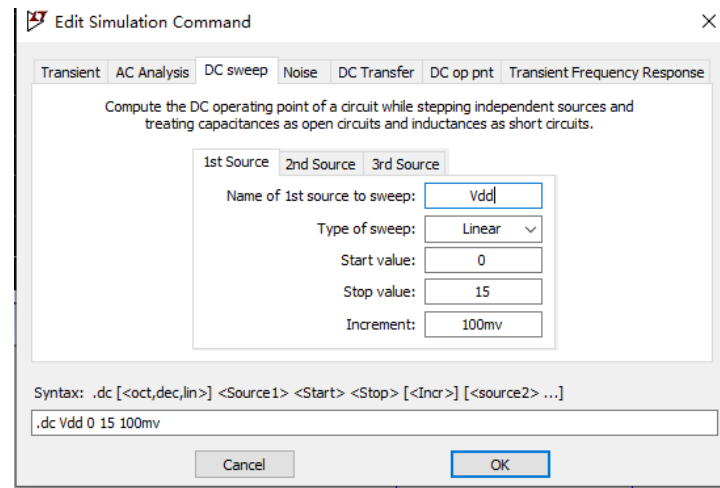


Figure 12: DC sweep configuration for V_{dd}

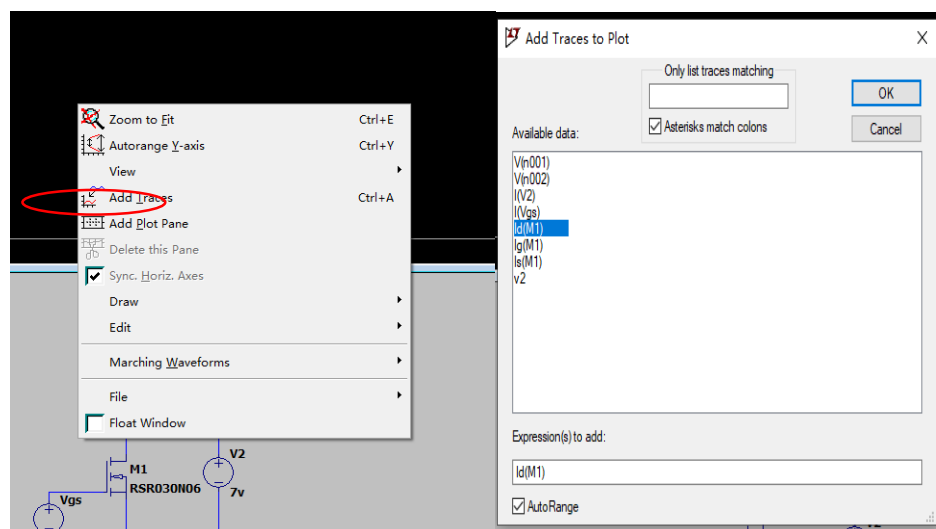


Figure 13: Add trace for simulation

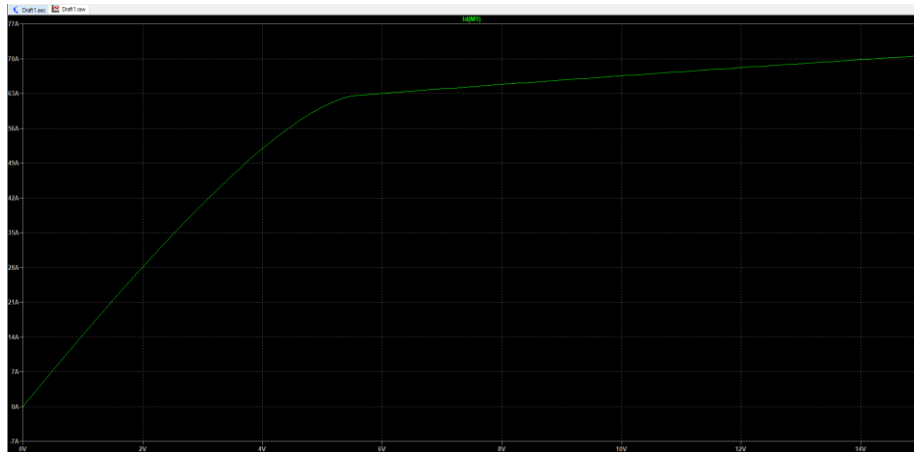


Figure 14: I_D vs V_{DS} ($V_{GS} = 5V$)

Question 4: What is the value of V_{DS} , when the increase in I_D starts to slow down?

5.54V

7. We add a DC sweep to V_{GS} at the same time, to see the relationship between V_{DS} and I_D . Still in the DC sweep configuration, select 2nd source, configure it as show in Figure 15.

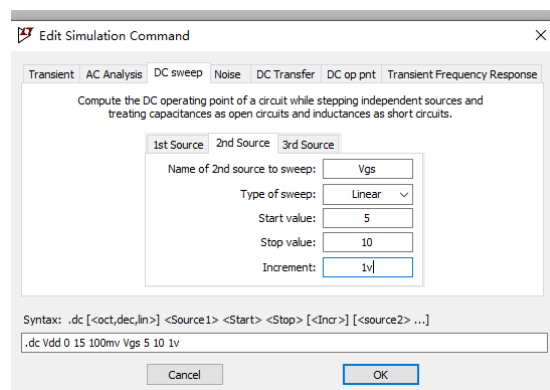


Figure 15: Configuration for V_{GS}

Question5: Run the simulation, and there will be 6 curves show on the same graph. Take a screenshot of this graph and attach it on the last page of your prelab. Compare it with Figure 6, are they similar to each other or totally different?



similar in shape,