Characteristics of MOSFET

(Circuits for Motor Control Appication)

Aim:

The objectives of this experiment are

1. To study the drain characteristics and transfer characteristics of enhancement type n-channel MOSFET.
2. To plot the characteristics curve I_D vs V_{DS} (drain characteristics) and I_D vs V_{GS} (transfer characteristics) of n-channel E-MOSFET using LTSpice software.

Software Used:

LTSpice

Theory:

FET's are similar in operation to that of BJT's but complementary in their working principle. BJTs are current-controlled devices whereas FETs are voltage controlled. It is a majority carrier device, where the conduction is due to either electron or due to holes. Hence FET forms a class of unipolar transistor/switch. The source terminal acts as an input terminal for the majority carriers, the drain terminal acts as the output terminal, and the gate as a control terminal that regulates the charge carrier flow through the substrate/channel in the device.

FETs are broadly classified into two major groups namely Junction Field Effect Transistor (JFET) and Metal Oxide Semiconductor Field Effect Transistor (MOSFET). The gate is conductively coupled to the substrate in JFET forming a *PN*-junction, whereas it is capacitively coupled in MOSFET. This is the most significant difference between both the groups of FETs. JFETs in turn are classified into n-channel and p-channel based on the conduction channel.

MOSFETs are classified into enhancement type and depletion type in addition to the type of channel.

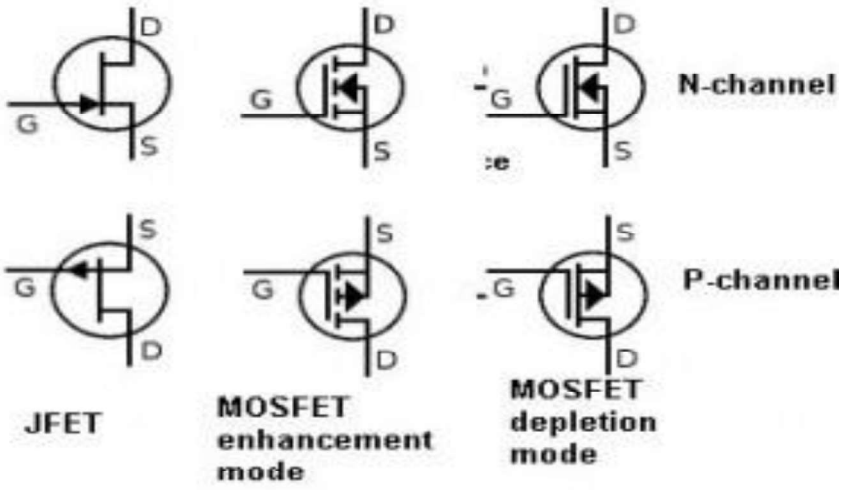


Figure 1 – Circuit symbols of JFET and MOSFET and its types

Experiment:

The circuit diagram to study the characteristics of enhancement type n-channel MOSFET is shown in figure 1. It requires two variable dc supplies to energize the drain-source and gate-source circuit. The power supply powering drain-source circuit is labeled as V_{DS} and the supply powering gate-source circuit is labeled as V_{GS}. For both the circuits, the source terminal is common and hence the configuration is referred to common source configuration.

In n-channel MOSFET, electrons are the majority carriers that flows from source to drain terminal within the device. To ensure this, the drain terminal is connected to +ve terminal of VDS with respect to source. To regulate the charge flow inside the device, a channel of negative ions to be induced on the substrate by powering the gate with positive voltage with respect to source. Hence the gate terminal is connected to +ve terminal of VGS with respect to source.

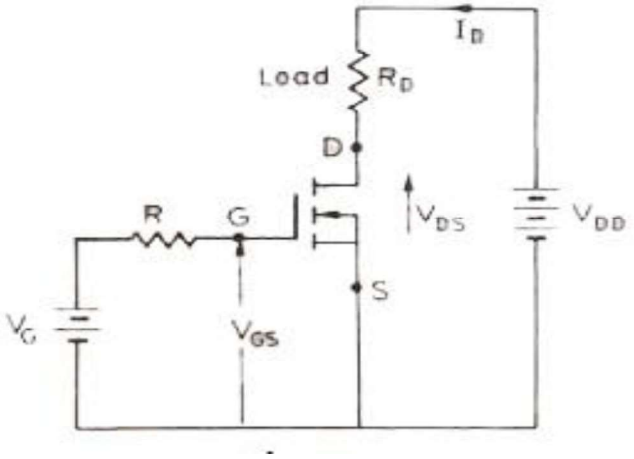


Figure 2 – Circuit to study characteristics of MOSFET

Transfer Characteristics:

It is the plot of drain current as a function of V_{GS} at constant drain-to-source voltage (V_{DS}). In this characteristic, the drain current is plotted as a function of gate-to-source voltage (V_{GS}). As long V_{GS} is equal to a threshold value V_{GST}, the drain current is zero, since no channel is established between source and drain for the charges to flow. At V_{GST}, a minimum channel is established between source and drain resulting in charge carrier flow from source to drain resulting in a small drain current. As V_{GS} increases, the width of the channel increases resulting in more charge flow from source to drain, decided by V_{DS} and drain-to-source resistance (R_{DS}). The transfer characteristics of enhancement MOSFET is shown in figure.

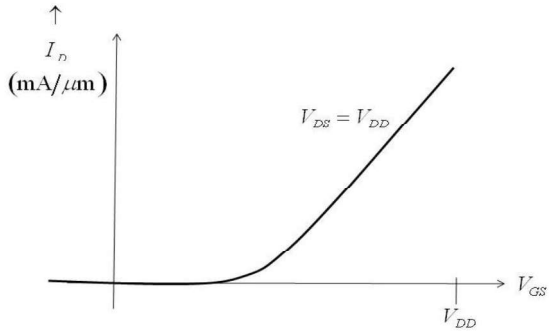


Figure 3 – Transfer characteristics of enhancement type MOSFET

Drain Characteristics:

It is the plot of drain current I_D as a function of V_{DS} with V_{GS} as constant. It is the set of characteristics plotted for various values of V_{GS}. It reveals the output characteristics of MOSFET. It has three significant operating regions namely cut-off region, saturation region and ohmic region.

Cut-off region is for which I_D is zero for any value of applied drain-to-source voltage V_{DS}. In this region, the MOSFET works as an "OPEN" switch. In saturation region, the drain current is limited by V_{GS} and is fairly constant for any value of V_{DS} applied. The MOSFET has the ability to work as amplifier in this region. Under ohmic region, the drain current I_D increases linearly even for a small change in V_{DS}. MOSFET works as "CLOSED" switch in this region.

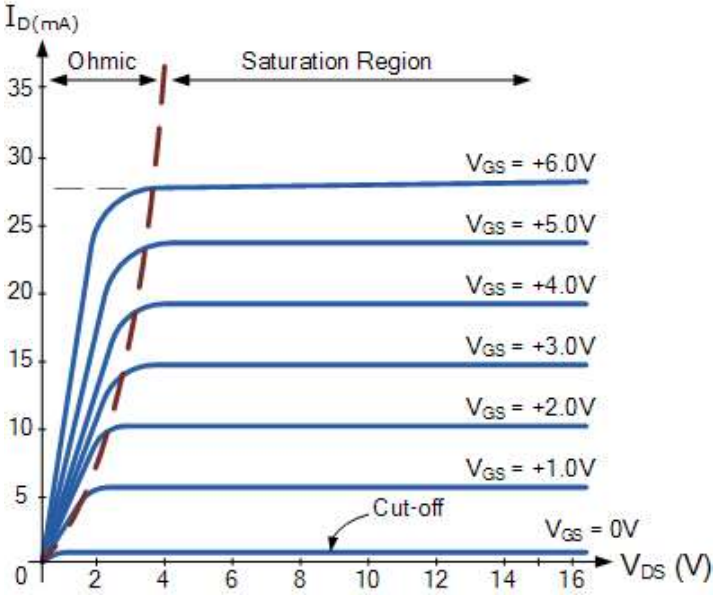
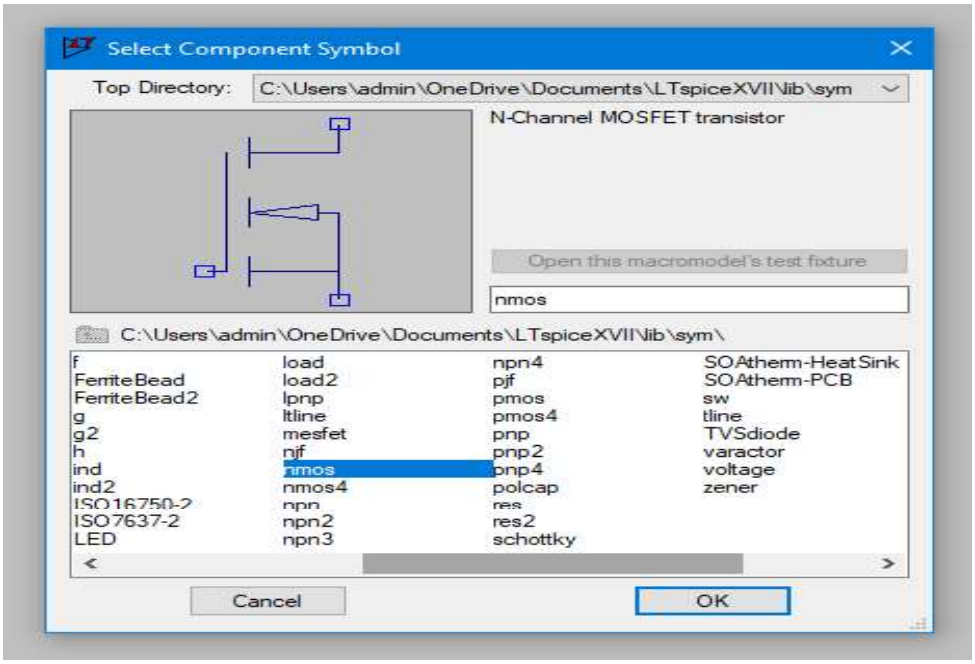


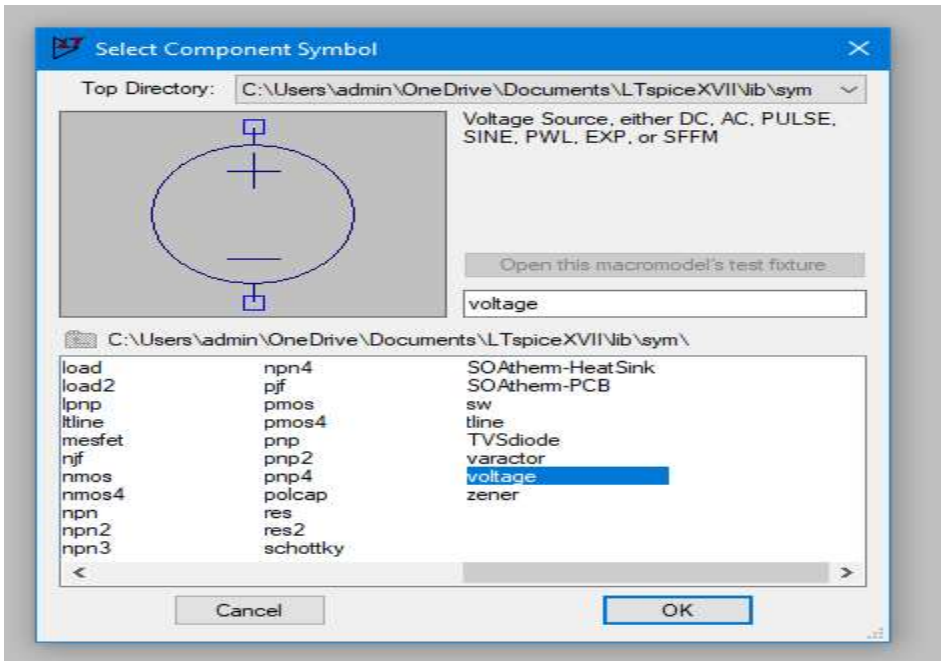
Figure 4 – Drain characteristics of enhancement type MOSFET

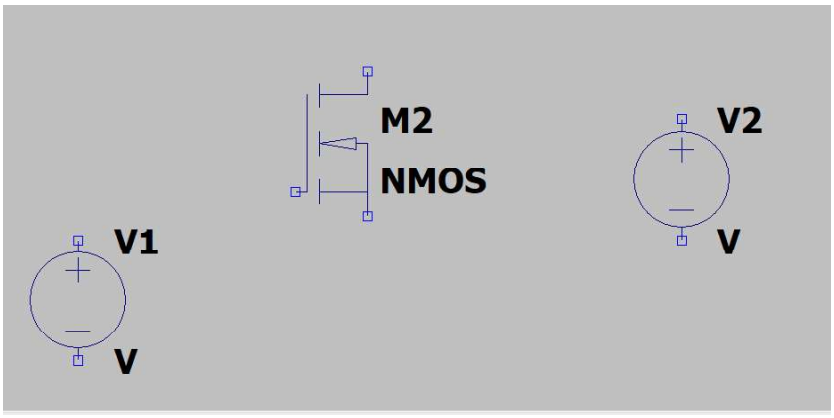
Procedure:

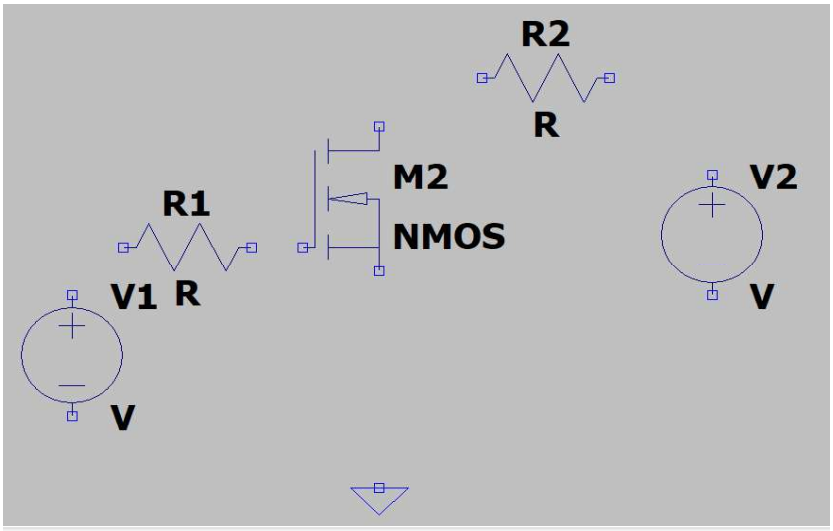
1. Open LTSpice software and create a new file.
2. Click on “ADD COMPONENTS” icon and search for ‘nmos’ in the component search dialog box.

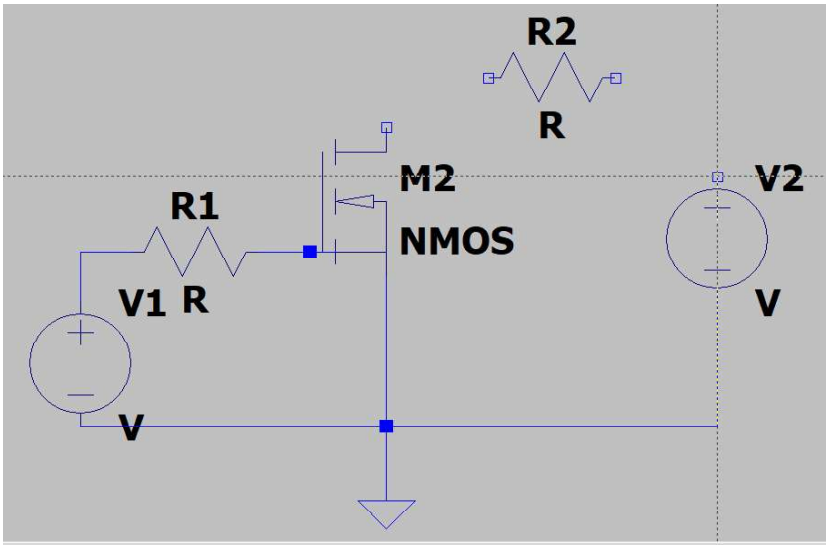


3. Add required components based on the circuits to the new file.

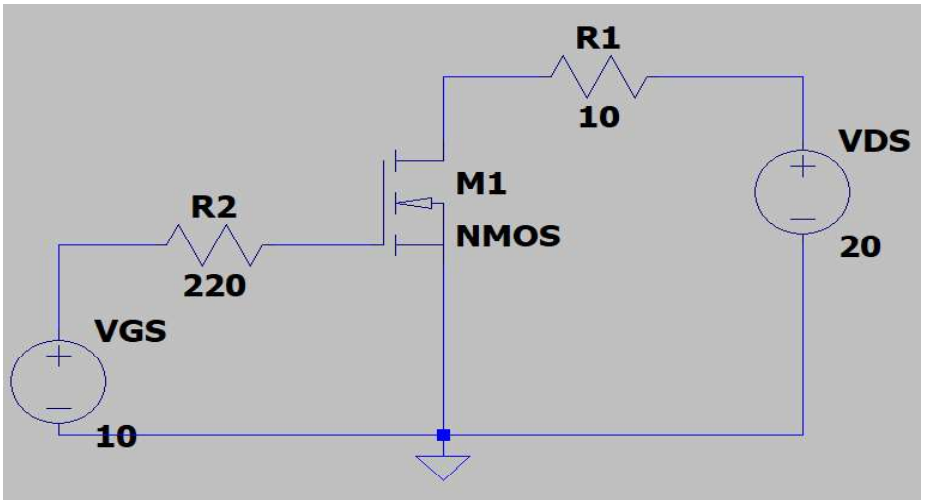



M2
NMOS
V2
V
V1
V

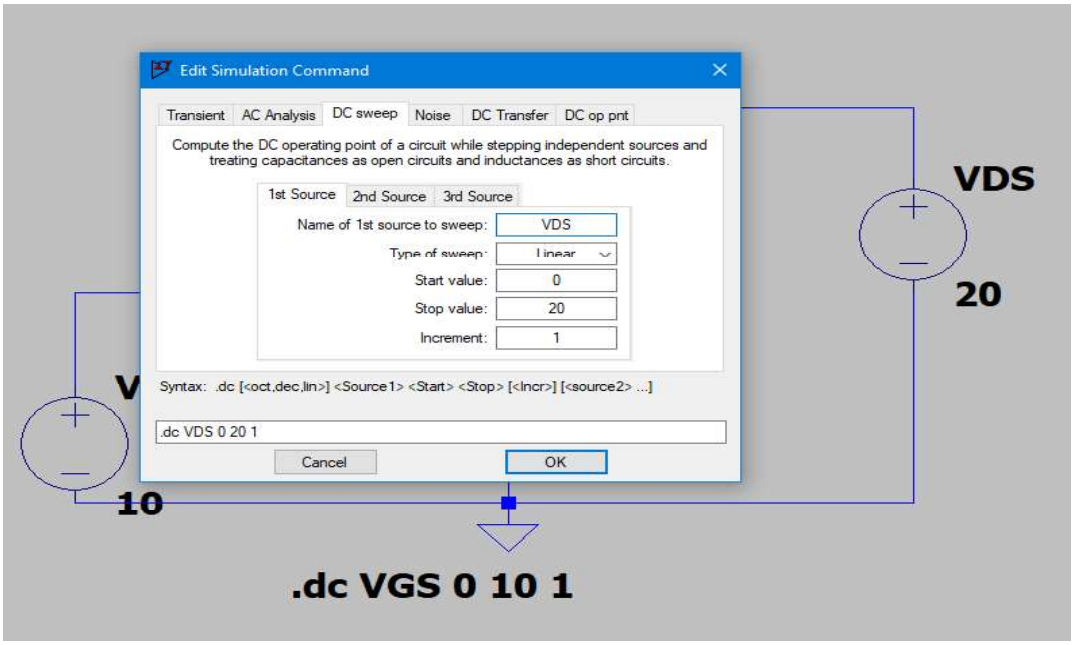

R2
R
M2
NMOS
V2
V
R1
V1
R
V

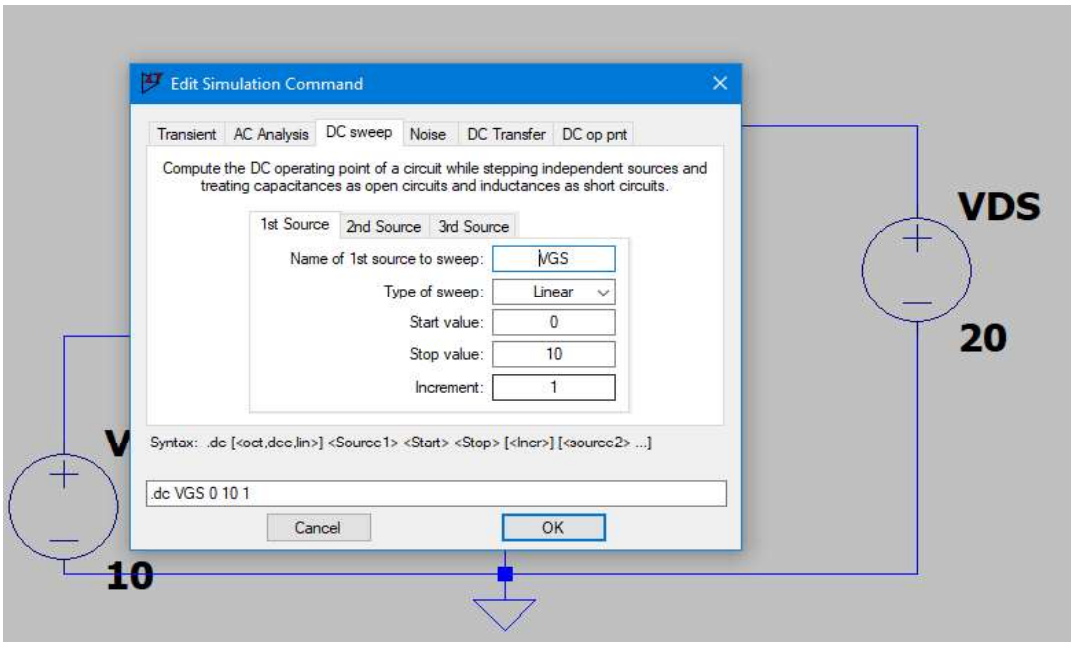

R2
R
M2
NMOS
V2
V
R1
V1
R
V

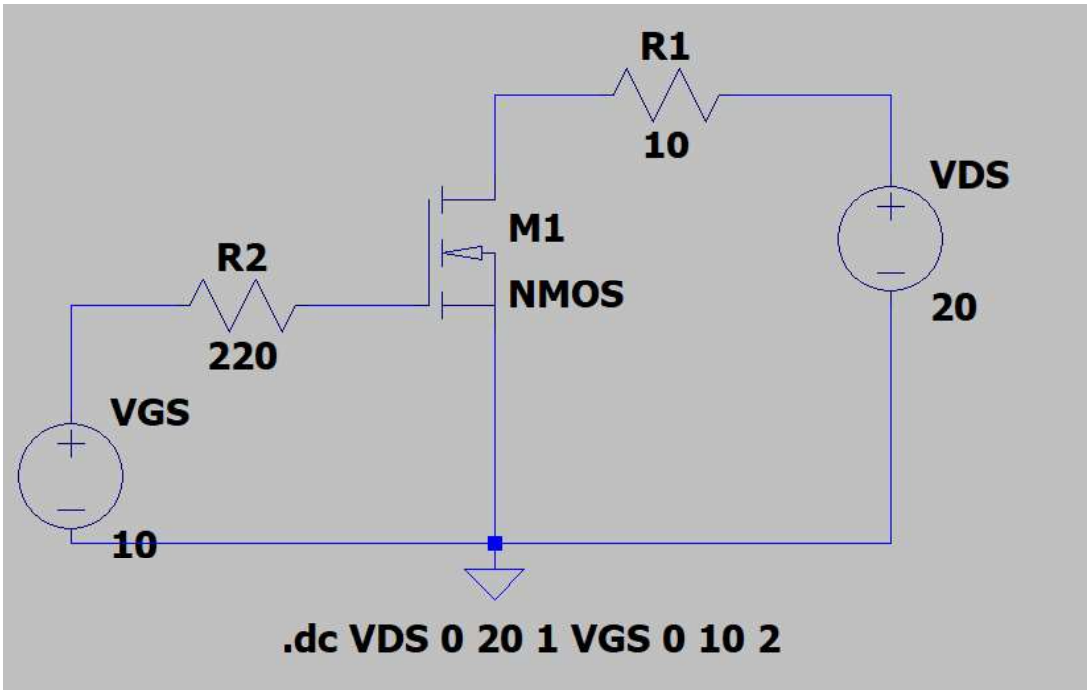
4. Configure the power sources and components following the guidelines in video.



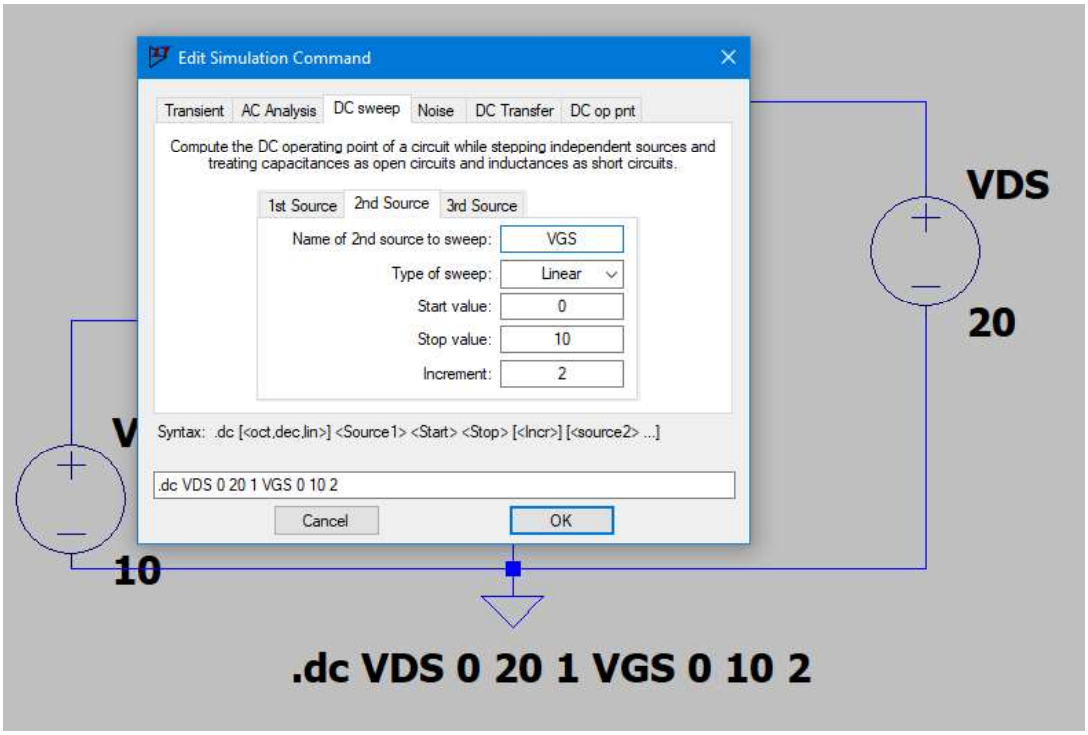
5. Configure the simulation command for transient response characteristics.
   a) For Drain characteristics


Edit Simulation Command
Transient
AC Analysis
DC sweep
Noise
DC Transfer
DC op pnt
Compute the DC operating point of a circuit while stepping independent sources and treating capacitances as open circuits and inductances as short circuits.
1st Source
2nd Source
3rd Source
Name of 1st source to sweep:
VDS
Type of sweep:
Linear
Start value:
0
Stop value:
20
Increment:
1
Syntax: .dc [<oct,dec,lin>] <Source1> <Start> <Stop> [<Incr>] [<source2> ...]
.dc VDS 0 20 1
Cancel
OK
VDS
20
10
.dc VGS 0 10 1


Edit Simulation Command
Transient
AC Analysis
DC sweep
Noise
DC Transfer
DC op pnt
Compute the DC operating point of a circuit while stepping independent sources and treating capacitances as open circuits and inductances as short circuits.
1st Source
2nd Source
3rd Source
Name of 1st source to sweep:
VGS
Type of sweep:
Linear
Start value:
0
Stop value:
10
Increment:
1
Syntax: .dc [<oct,dec,lin>] <Source1> <Start> <Stop> [<Incr>] [<source2> ...]
.dc VGS 0 10 1
Cancel
OK
VDS
20
10

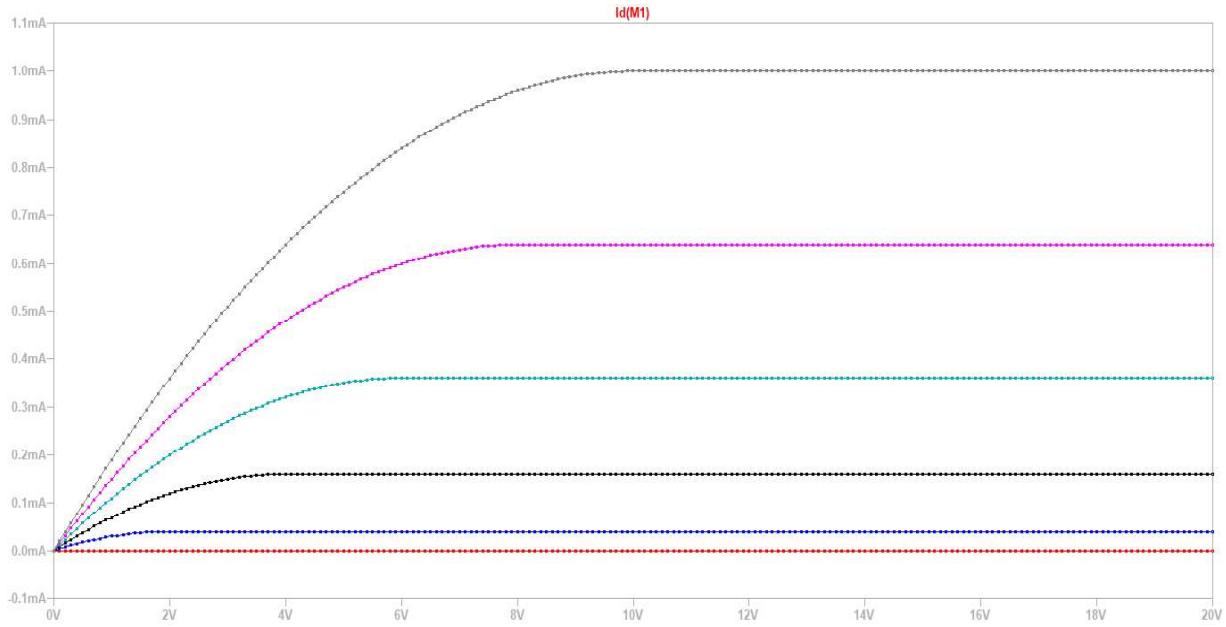


b) Transfer Characteristics:

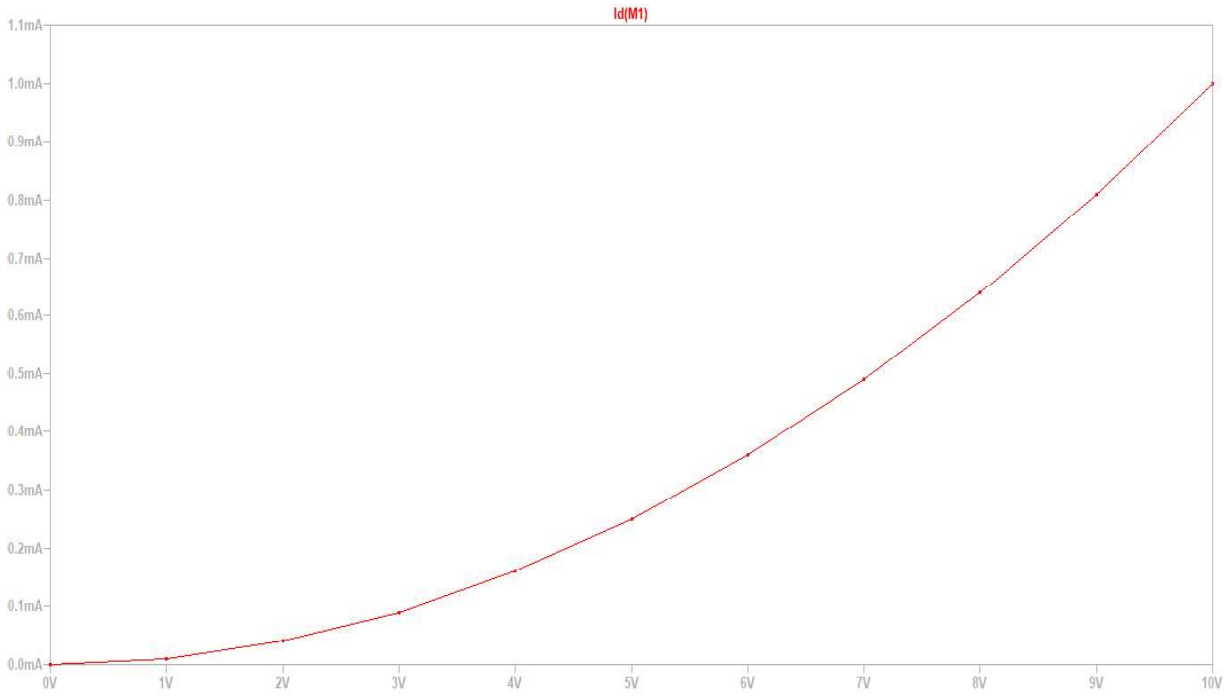


6. Simulate by clicking the “RUN” icon.

a) Drain Characteristics:



b) Transfer Characteristics:



Results and Inferences:

In this experiment, the characteristics of enhancement type n-channel MOSFET is studied theoretically and using LTSpice software. The transfer and drain characteristics of MOSFET were plotted using LTSpice.

Practical Applications:

MOSFETS are majorly used in switching applications from milliwatts to Megawatt power levels.

It is used in switched-mode power supplies, dc-dc converters, microinverters etc.

Course Outcome:

CO5. Analyze the characteristics of semiconductor devices and comprehend the various modulation techniques in communication engineering

Student Learning Outcomes (SLO):

SLO2. Having a clear understanding of the subject related concepts and of contemporary issues

Video Link:

Characteristics of MOSFET using LTSpice:

https://youtu.be/ErpKbG7HCG0