

**EECE 310L**

**Electric Circuits Laboratory**

**Experiment 10**

**MOS Transistor**

**Name: Freddy Vartabedian**

**ID: 201203799**

**Email:** **fkv00@aub.edu.lb**

**Section: 5**

**Group: 8**

**December 26, 2012**

**Table of Contents Page**

I. Objectives 6

II. Lab Equipment Used 6

III. Lab Tools Used 6

IV. Lab Components Used 6

V. Experimental Procedure and Discussion 7

A. MOSFET Characteristics 7-10

1. Circuit Diagrams
2. Detailed Experimental Procedure
3. Measurements and Results
4. Discussion

B. MOSFET as a Voltage-Controlled Resistor 10-16

1. Circuit Diagrams
2. Detailed Experimental Procedure
3. Measurements and Results
4. Discussion

C. MOSFET as Logic Gate 16-19

1. Circuit Diagrams
2. Detailed Experimental Procedure
3. Measurements and Results
4. Discussion

D. MOSFET as Amplifier 20-24

1. Circuit Diagrams
2. Detailed Experimental Procedure
3. Measurements and Results
4. Discussion

E. MOSFET as a Current Source 25-28

1. Circuit Diagrams
2. Detailed Experimental Procedure
3. Measurements and Results
4. Discussion

VI. References 29

VII. Mistakes and Problems Faced in the Lab 30

**List of Figures, Graphs and Tables Page**

**Figures**

1. MOSFET Characteristics 7

2. MOSFET as a Voltage-Controlled Resistor 10

3. MOSFET as Logic Gate 16

4. MOSFET as Amplifier (without amplifier) 16

5. MOSFET as Amplifier 20

6. MOSFET as Amplifier (complete circuit) 20

7. MOSFET as a Current Source 25

8. MOSFET as a Current Source 25

**Graphs:**

1. ID Vs VDS for VGS – VT =2V 12

2. ID Vs VDS for VGS – VT =3V 13

3. ID Vs VDS for VGS – VT =4V 13

4. Vout Vs Vin 19

5. ID Vs RD 27

6. ID Vs VDS 28

**Tables**:

1. Resistors 6

2. VGS Measures 9

3. Calculated Values of k and VT 9

4. VGS Values 9

5. ID Values for VDS for VGS – VT =2V 11

6. ID Values for VDS for VGS – VT =3V 11

7. ID Values for VDS for VGS – VT =4V 12

8. RDS Values Using Slopes 14

9. Comparison of Calculated and Experimental Values of RD 15

10. Truth Table 17

11. MOSFET Operation Regions 18

12. DC Values 22

13. AC Values 22

14. Bandwidth 23

15. Values of RD, ID and VDS 26

**I. Objectives**

The purpose of this experiment is to investigate the characteristics of the Metal-Oxide-Semiconductor field-Effect transistor (MOSFET) and study its application as:

1. Voltage-controlled resistor
2. Logic gate
3. Amplifier
4. Current Source

**II. Lab Equipment Used**

* Breadboard
* Function generator
* DC power supply
* Oscilloscope
* Digital device multimeter (DDM)

**III. Lab Tools Used**

* Wire stripper/cutter

**IV. Lab Components Used**

* BS 170 MOSFET (N-channel enhancement type)
* Wires
* Capacitors of C=10μF
* Resistors of different values listed in the following table

|  |  |  |
| --- | --- | --- |
| **Resistor Theoretical (KOhms)** | **Resistor Measured (KOhms)** | **% Error** |
| 0.100 | 0.09821 | 1.79 |
| 0.470 | 0.4654 | 0.97 |
| 1 | 0.9993 | 0.07 |
| 3.3 | 3.347 | 1.42 |
| 4.7 | 4.585 | 2.45 |
| 10 | 9.863 | 1.37 |
| 15 | 14.74 | 1.73 |

**Table 1: Resistors**

**V. Experimental Procedure and Discussion**

1. **MOSFET Characteristics**

 **A1. Circuit Diagram**

****

Figure 1

**A2. Detailed Experimental Procedure**

a.Finding transconductance parameter k and threshold voltage VT:

We connect the circuit shown in Figure 1 on the breadboard and use it in order to determine the tansconductance k and the threshold voltage VT of the BS 170 Metal-Oxide- Semi-Conductor Field –Effect Transistor (MOSFET).

The threshold voltage VT and the transconductance k allow us to calculate the drain current in MOSFET saturation according to the following formulas:

ID = k/2(VGS-VT)2  when VGS > VT and VDS > VGS-VT (conditions for saturation)

Moreover, in the circuit of Figure 1, VDS =VGS and since VT is positive for the BS 170 MOSFET, the transistor is in saturation whenever VGS > VT.

In order to find VT and k, we measure VGS for ID values of 10mA and 25mA.

Starting with VGG = 0.5V, we increase the value of VGG until the multimeter reading becomes 10mA and we record the corresponding value of VGS. We keep on increasing VGG until the drain current becomes exactly 25mA and we record the corresponding value of VGS.

We can now calculate k and VT using the following formulas:

ID = $\frac{1}{2}$k (VGS – VT)2  and

ID1/ID2 = (VGS1 – VT)2/ (VGS2 – VT)2

b.Verification of Values:

Using the same circuit (Figure 1), we increase VGG so that the multimeter records a current of 40mA and we measure the corresponding VGS.

We then compare the measured values of VGS with that obtained from the following equation:

VGS = VT + $\sqrt{\frac{2I\_{D}}{k}}$

**Assumptions:**

The following were ignored in the theoretical calculations:

* The 1.79% error of the resistor used.
* The resistance in the wires

**A3. Measurements and Results**

|  |  |
| --- | --- |
| **ID (mA)** | **VGS  (Volts)** |
| 10 | 1.83 |
| 25 | 2.04 |

 **Table 2: VGS Measures**

|  |  |
| --- | --- |
| **Calculate** | **Units** |
| **k** | 0.15316 | A/V2 |
| **VT** | 1.4686 | V |

 **Table 3: Calculated Values of k and VT**

|  |
| --- |
| **Calculated Versus Measured** |
| **VGS Calculated (Volts)** | 2.1913 |
| **VGS Measured (Volts)** | 2.2 |

 **Table 4: VGS Values**

**a.Calculation of k and VT:**

In MOSFET saturation region:

ID = $\frac{1}{2}$k (VGS – VT)2  and

ID1/ID2 = (VGS1 – VT)2/ (VGS2 – VT)2

Replacing with the obtained values and solving for VT:

10/25 = (1.83 – VT)2 / (2.04 – VT)2

VT = 1.4686V (The other solution was 1.9113V and we chose the lower value)

Replacing VT =1.4686 in ID = $\frac{1}{2}$k (VGS – VT)2  ,

10 x 10-3 = k/2 (1.83-1.4686)2

K =0.15316A/V2

**b.Calculation of VGS and verification of the obtained values of k and VT:**

VGS = VT + $\sqrt{\frac{2I\_{D}}{k}}$

VGS measured = 2.2V and ID =40mA

Replacing our values:

VGS = 1.4686 + $\sqrt{\frac{2×0.04}{0.15316}}$

VGS = 2.1913V

Error Percentage:

$\frac{(2.1913-2.2)}{2.1913}$ X100 = 0.397%

**A4.Discussion**

The percent error at 0.397% is small. We conclude that our obtained values of k and VT are accurate enough. The small error percentage can be due to experimental or measurement errors.

**B.MOSFET as a Voltage –Controlled Resistor**

**B1.Circuit Diagram**



Figure 2

**B2.Detailed Experimental Procedure:**

Connecting a circuit as in figure 2, ad using VT = 1.4686V from part A, we first set

VGG = VT + 2V.

The gate current in the MOSFET being zero, VGS – VT = 2V.

After connecting the DDM as in Figure 2, we regulate VDD in order to get VDS = 0.1V and we record the corresponding ID. We repeat the regulation for the different values of VDS provided and record the corresponding values of ID. We use the oscilloscope to measure VGS and VDS while the ammeter is connected.

We repeat the same measurement procedure for VGS = VT + 3V and for VGS = VT + 4V.

The MOSFET in this experiment will be operating in triode region.

Conditions for triode region operation: VGS > VT and VDS < VGS – VT.

**Assumptions:**

The 0.07% error of the resistor and wire and ammeter resistances were ignored.

**B3. Measurements and Results**

**Part 1:** VGS = VT + 2 = 1.4686 + 2 = 3.4686V

|  |
| --- |
| VGS – VT = 2 Volts |
| VDS (Volts) | ID (mA) |
| 0.1 | 44 |
| 0.15 | 59.5 |
| 0.2 | 77.5 |
| 0.25 | 94.6 |
| 0.3 | 107.5 |

**Table 5: ID values for VGS – VT = 2 Volts**

**Part 2:** VGS = VT + 3

|  |
| --- |
| VGS – VT = 3 Volts |
| VDS (Volts) | ID (mA) |
| 0.1 | 77.5 |
| 0.15 | 94.53 |
| 0.2 | 136 |
| 0.25 | 164 |
| 0.3 | 197 |

 **Table 6:**  **ID values for VGS – VT = 3 Volts**

**Part 3:** VGS = VT + 4.

|  |
| --- |
| VGS – VT = 4 Volts |
| VDS (Volts) | ID (mA) |
| 0.1 | 81 |
| 0.15 | 103 |
| 0.2 | 156 |
| 0.25 | 174 |
| 0.3 | 226 |

**Table 7:**  **ID values for VGS – VT = 4 Volts**

**B4.Discussion**

The following are the graphs of ID versus VDS for the results of the 3 parts using Microsoft Excel.

**Plot1**: ID versus VDS for VGS – VT = 2 Volts

**Plot 2**: ID versus VDS for VGS – VT = 3 Volts

**Plot 3**: ID versus VDS for VGS – VT = 4 Volts

The graph for VGS – VT = 2 Volts is linear to a great extent.

The graph for VGS – VT = 3 Volts can also be considered linear, but with some errors.

The graph for VGS – VT = 4 Volts exhibits linear behavior, but with increased fluctuations which might be due to measurement errors.

The linear behavior of the plots is due to the fact that the MOSFET in this part is acting as a linear resistor between the drain and the source and ID = VDS/RDS.

* Slope Calculations:

Slope for plot 1: (107.5 $-$ 44) / (0.3 – 0.1) = 317.5mA/V = 0.3175A/V

Slope for plot 2: (197 $–$ 77.5) / (0.3 $–$ 0.1) = 0.5975A/V

Slope for plot 3: (226$ –$ 81) / (0.3 $–$ 0.1) = 0.725A/V

* RDS Calculation :

RDS = 1/slope

Sample calculation: R1 = 1/slope of plot 1 = 1/0.3175 = 3.15Ω.

|  |  |
| --- | --- |
| VGS – VT (Volts) | RDS (Ω) |
| 2 | 3.15 |
| 3 | 1.67 |
| 4 | 1.38 |

**Table 8: RDS Values Using the Slopes**

-The MOSFET in all 3 parts is biased in the triode region, since in all 3 cases plotted above the conditions for operation in triode region, VGS > VT and VDS < VGS – VT, are satisfied.

-The triode region is also called ohmic or linear because, in this region ID = VDS/RDS and this relation is linear. Moreover, the value of the resistance in this region is not constant, but depends on VGS – VT. Therefore the MOSFET in the triode region behaves as a resistor whose value changes with voltage; hence it acts as a voltage-controlled resistor and satisfies Ohm’s law.

-In the triode region the current iD is given by the following equation:

ID = k/2 [2(VGS – VT)VDS – VDS2]

The values of VDS being very small, the term VDS2 can be neglected and the equation becomes:

ID = k (VGS – VT) VDS and hence, RDS = 1/ k (VGS – VT).

It follows that since k and VT are constant in value, the value of RDS depends only on the value of VGS. Therefore, the MOSFET in the triode region acts as a voltage- controlled resistor.

-Since ID = k/2 [2(VGS – VT)VDS – VDS2] and after neglecting the term VDS2, we get:

ID approximated = k (VGS – VT) VDS

Error = │ID - ID approximated│/ ID < 0.05

│ {k/2 [2(VGS – VT)VDS – VDS2] - k (VGS – VT) VDS} │/│ k/2 [2(VGS – VT)VDS – VDS2] │< 0.05

Eliminating k in the numerator and the denominator and simplifying gives:

│- VDS2/2│/│ [(VGS – VT)VD - VDS2/2] │< 0.05

Simplifying further we get:

│-VDS/2│ /│ [(VGS – VT) - VDS/2] │< 0.05

And the final answer: VDS < 2/21(VGS – VT) for errors in current less than 5%

-Values of RDS from the Equation:

RDS = 1/ k (VGS – VT)

Sample Calculation:

RDS for VGS – VT = 2 Volts: RDS = 1/ 0.15316x2= 3.26Ω

|  |  |  |  |
| --- | --- | --- | --- |
| VGS – VT (Volts) | RDS Calculated (Ohms) | RDS Experimental from plots (Ohms) | % Error |
| 2 | 3.26 | 3.15 | 3.37 |
| 3 | 2.18 | 1.67 | 23.4 |
| 4 | 1.63 | 1.38 | 15.32 |

**Table 9: Comparison of Calculated and Experimental Values of RDS**

The calculated and experimental values of RDS are close for VGS – VT = 2V. This is expected because the plot is almost linear; hence the slope and the corresponding value of RDS are more accurate. Whereas, in the other cases, the calculated slopes and the corresponding values of RDS are not accurate, because of the fluctuations of the plots. Hence the increased observed % errors are expected and are the result of our slope approximations.

-Applications on MOSFET in the linear region:

The MOSFET in the linear region has applications when variable gain control is desired such as in a voltage controlled attenuator which can be seen in cell phones to avoid saturation. It is also seen in noise attenuation associated with electronic devices, so as to get less amplified noise at the output.

It can be used as a buffer amplifier to isolate a preceding stage from a following stage.

The MOSFET in the linear operation region (triode) can act as an electronic switch. For example, in a cordless telephone in which a single antenna is used for both transmission and reception, the electronic switch serves to connect either receiver or transmitter to the antenna.

It also has useful applications in digital circuit design. It is used in digital devices such as logic gates, flip flops, digital memory and CPU logic.

**C.MOSFET as Logic Gate**

**C1.Circuit Diagrams**

**Figure: 3**

**C2.Detailed Experimental Procedure**

**Part 1:**

In this part, we use the 2 MOSFET circuit in figure 3 and measure VIN1, VIN2 and Vout using the DDM.

The circuit in Figure 3 implements a logic gate and it will be used to determine the logic function of the gate and it characteristics. There are 2 inputs, IN1 and IN2 and 1 output. In order to operate as a logic gate each MOSFET has to operate either in triode or cut-off regions which is equivalent to a 2-input gate.

In order to build the truth table for this gate, we apply all combinations of inputs and observe the output.

We start by connecting the input nodes to the ground to get logic 1, where IN1=logic 0 and IN2=logic 0. We then apply the other logic inputs: IN1=0 and IN2=1, IN1=1 and IN2=0, IN1=1 and IN2=1. For logic 0, we connect the desired terminal to ground and for logic 1 we connect it to VDD.

From the results we can determine the value of high corresponding to logic 1 and the value of low corresponding to logic 0.

**Part 2:**

In this part we set VIN2 to zero and we vary VIN1 from 0volts to 5 volts in increments of 0.4 volts and measure the corresponding Vout. We then determine the MOSFET region of operation and the logic value at the output.

**Assumptions:**

The 0.97% resistor error and the wire resistances were ignored in our calculations.

**C3.Measurements and Results**

**Part 1:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **IN1(logic)** | **IN2(Logic)** | **Out(Logic)** | **VIN1(V)** | **VIN2(V)** | **Vout(mV)** |
| 0 | 0 | 1 | 0.0 | 0.0 | 5000 |
| 0 | 1 | 0 | 0.0 | 5.00 | 40 |
| 1 | 0 | 0 | 5.00 | 0.0 | 40 |
| 1 | 1 | 0 | 5.00 | 5.00 | 20 |

**Table 10: Truth Table**

The truth table above indicates that the logic function of this circuit is a **NOR** gate.

**Part 2:**

|  |  |  |  |
| --- | --- | --- | --- |
| **VIN1(V)** | **Vout(mV)** | **MOSFET Region** | **Logic Value at output** |
| 0 | 5000 | Cut-off | 1 |
| 0.4 | 5000 | Cut-off | 1 |
| 0.8 | 5000 | Cut-off | 1 |
| 1.2 | 5000 | Cut-off | 1 |
| 1.6 | 4800 | Saturation | no |
| 2.0 | 3000 | Saturation | no |
| 2.4 | 1000 | Saturation | no |
| 2.8 | 79 | Triode | 0 |
| 3.2 | 57 | Triode | 0 |
| 3.6 | 50 | Triode | 0 |
| 4.4 | 40 | Triode | 0 |
| 4.8 | 38 | Triode | 0 |

**Table 11: MOSFET Operation Regions**

**C4.Discussion**

1-The value of high corresponding to logic 1 is 5V.

The Value of low corresponding to logic 0 is 0.04V.

2-The results show that when one or both MOSFETs are in triode region, the output logic would be 0, since as Vin increases, the resistance in the MOSFET as it acts as a voltage controlled resistor increases and the output decreases.

-If one MOSFET is in the triode region and its resistance is RDS, then if we apply voltage divider:

Vout / VDD = RDS / RDS + RD

And Vout = VDD . RDS / RDS + RD

Consequently, if we increase RD, Vout will decrease.

-If the two MOSFETS are in triode region and have resistances RDS1 and RDS2, with the same argument,

Vout = VDD . RDS1 ││RDS2 / (RDS1 ││RDS2) + RD

Again we notice that increasing RD will decrease Vout.

-When both MOSFETS are in cut-off region, RD has no effect on the output.

-Conclusion: When at least one MOSFET is in triode operation region, increasing RD will decrease the low, or the low voltage corresponding to logic 0.

3- **Plot 4**: Vout versus Vin

From the plot, we notice:

From Vin =0V to Vin = 1.2V, the MOSFET is in cut-off.

After Vin =1.2V, that is from around Vin =1.6 until around Vin =2.4 the MOSFET is in saturation.

The MOSFET switches into triode operation at Vin = 2.8V and stays in triode operation until Vin = 4.8V (logic output 0).

**D.MOSFET as an Amplifier**

**D1.Circuit Diagrams**

****

 **Figure 4**

****

 **Figure 5**

****

 **Figure 6**

**D2.Detailed Experimental Procedure**

In this experiment, we start by connecting a circuit as in Figure 4. The voltage source is a 100mV peak to peak and 10 KHz sine signal.

The voltage gain Vo / Vs <1.

If we increase the amplitude of the input signal, the voltage gain does not change. Similarly, if we change the frequency of the signal, the gain doesn’t change.

We next connect the circuit as in Figure 6, first as in the dotted part and later we connect the source voltage and the load. In this circuit, the MOSFET acts as an amplifier.

The MOSFET in this circuit is biased to operate in the saturation region, so that it can be used as an amplifier. The conditions for MOSFET saturation are: VGS >VT and VDS>VGS – VT.

The capacitors C1 and C2 are added to act as coupling capacitors in order to eliminate DC offset. The capacitor Cs is used as a bypass capacitor and at high frequencies it shortcuts Rs2.

After connecting the components of the circuit as in the dotted region of figure 6, we perform a DC measurement of each of ID, VGS and VDS and record the values.

We then connect the circuit to the voltage source and the load. We apply a 100mV peak to peak, 10KHz sine signal at the input source and measure Vo, VI(input voltage of amplifier) and the phase shift (VI, Vo).

Next, we decrease the frequency to below 100Hz and observe the output changes. We repeat the same with increasing the frequency to values above 10MHz. In this way we can find the cut-off frequencies. These frequencies correspond to a value of Vo = 0.7071 x Vo mid-frequency.

Finally, we increase the amplitude of the input signal to more than 400mV (to 800mV) and observe the shape and distortion of the output signal.

**Assumptions:**

We took for granted that the MOSFET was in saturation region.

We ignored all errors associated with the resistors used in the circuit, as well as the internal resistance of wires.

**D3. Measurements and Results**

**Part 1:** Measurement of DC values

|  |  |
| --- | --- |
|  | Value |
| ID (DC) mA | 2.55 |
| VGS (DC) Volts | 2.31 |
| VDS (DC) Volts | 6.99 |

**Table 12: DC Values**

**Part 2:** Measurements of AC Values

|  |  |
| --- | --- |
|  | Value |
| Vs pk-pk (mV) | 114 |
| VI pk-pk (mV) | 63.2 |
| Vo pk-pk (mV) | 912 |
| Phase Shift (VI, Vo) degrees | 180 |

**Table 13: AC Values**

**Part 3:** Bandwidth Measurement

|  |
| --- |
| Bandwidth Measurements |
| F low (Hz) | 400 |
| F High (KHz) | 220 |

**Table 14: Bandwidth**

- DC and small signal gain analysis and gain calculation:

**Theoretically:**

VG/ VDD = RG2/(RG2 + RG1)

VG = 12. (10K / (10K +15K)

VG = 4.8V

When MOSFET is operating in saturation area:

iD = 1/2. K (VGS – VT)2

KVL: VGS = VG – RS2ID

iD = ½ x 0.15316 (4.8 – 103iD – 1.4686)2

iD = 3.13 x 10-3 A

VGS = 4.8 – 103x3.13x10-3 = 1.67V >VT (condition for saturation: VGS >VT and VDS>VGS – VT)

VDS = 12 – (1+1) x103x3.13x10-3 =5.74V

gm = 2xID / Vov = 2x3.13x10-3 / (1.67 – 1.4686) =0.0311A/V

Av $≅$ $-$ gm (RD ││ RL)

Av = $-$0.031x767.4 = $-$23.8V/V

**Experimentally:**

Gain = -g.RD and Gain = -Vo/Vi (The negative sign indicates the phase shift of 180°)

From our measurements:

Voltage Gain= -Vo/Vi= - 912 / 63.2 = - 14.43V/V

Io = Vo / RL and Ii = Vi / RS1 ││ RG1

Current Gain: Io / I1 = - (Vo / RL) / (Vi / RS1 ││ RG1 ) = - 15.65A/A

Power Gain = Voltage Gain x Current Gain = 225.9W/W

The comparison of our results shows the following percent errors:

ID: 18.53%, VGS: 38.3%, VDS: 21.78% and Gain: 39.4%

- Bandwidth:

Bandwidth = f2 – f1 = 220x103 – 400 = 21.96 KHz

**D4. Discussion**

-The presence of the capacitors limits the MOSFET. At low frequencies, the capacitor acts as an open circuit since X = 1 / ωC and the signal source as such will be disconnected. Consequently, the output voltage will drop and the amplification Vo / VI will drop.

At high frequencies, the capacitor will become a short circuit and the MOSFET will no longer stay in saturation region. Consequently, it won’t operate properly as an amplifier at such high frequency and the output signal will be distorted accompanied with a drop in the gain.

-When the block is connected and we increase the amplitude of the input signal, the MOSFET biasing will be affected and it will go from saturation to triode or the linear region. Hence it won’t work as an amplifier at high frequency and the output signal will be distorted. When the block is not connected, we don’t have the problem of the MOSFET changing operation region, so we won’t have any distortions.

**E. MOSFET as a Current Source**

**E1. Circuit Diagrams**

** **

**Figure7**  **Figure 8**

**E2. Detailed Experimental Procedure**

In this part, the MOSFET acts as a current source. Therefore, it must be biased to operate in saturation region.

This part of the experiment was not done in the lab and in what follows, the provided data are used.

**Assumptions:**

Resistor and internal resistances in wires were not taken into consideration in our calculations.

**E3.Measurements and Results**

**Part1:** Calculation of R2

For saturation region: ID = 1/2. K (VGS – VT)2 and VGS = V R2 – Rs ID

Therefore: ID= 1/2. K (V R2 – Rs ID – VT)2

K=0.15316A/V2

VT=1.4686V

ID=10mA

Replacing and solving:

10x10-3 = 0.5x0.15316 (V R2-100x10-2 – 1.4686)2

V R2 = 2.6V

Using voltage divider:

V R2 / VDD = R2 / (R2 + 10K)

2.6 / 10 = R2 / (R2 +10K)

R2 = 3.5135KΩ

|  |  |  |
| --- | --- | --- |
| RD (Ohms) | ID (mA) | VDS (Volts) |
| 0 | 9.85 | 9.9 |
| 100 | 9.83 | 7.9 |
| 220 | 9.81 | 6.8 |
| 330 | 9.8 | 5.7 |
| 470 | 9.78 | 4.4 |
| 560 | 9.76 | 3.56 |
| 680 | 9.7 | 2.54 |
| 820 | 9.67 | 1.17 |
| 1000 | 9.63 | 0.25 |

**Table 15: Values of RD, ID and VDS**

**E4.Discussion**

**Plot 5: ID as a function of RD**

-The region of the curve with the lowest slope includes the values of RD from 0Ω to 330Ω. So, we can say that the current is constant for these values of RD and the transistor behaves as a current source.

-The value of Is is around 9.82mA.

**Plot 6: ID versus VDS**

-ID is nearly constant for the values of VDS from 4.4V or more so from 5.7V to 9.9V.

This range corresponds to the saturation region of the MOSFET and in this region ID is independent of VDS.

-We can get the value of ro, the output resistance in saturation, from the slope of the region of the curve corresponding to the region of saturation.

ro = 1 / slope

Slope = (9.85 – 9.8) / (9.9 – 5.7)

ro = 84KΩ

**VI.References:**

FET Applications, Available: <http://www.circuitstoday.com/fet-applications>

Fundamentals of Microelectronics, Chapter 6 Physics of MOS Transistors, Available: <http://www.utdallas.edu/~torlak/courses/ee3311/lectures/ch06updated.pdf>

Sedra /Smith, Microelectronic Circuits, Oxford University Press, 6th Edition

The MOSFET as an Amp and Switch, Available: <http://www.ittc.ku.edu/~jstiles/312/handouts/The%20MOSFET%20as%20an%20Amp%20and%20Switch.pdf>

The MOSFET as a Switch, Availabe: <http://www.electronics-tutorials.ws/transistor/tran_7.html>

**VII.Mistakes and Problems Faced in the Lab**

The main problem faced in the lab was the malfunctioning or burned MOSFETS, but the instructors solved it by changing them. We also needed help in assembling the MOSFET as an amplifier.

****