ECSE-2050

Introduction to Electronics
Summer 2020 **Name** Saqif Ahmed

Homework 10

Reading: 5.1-5.7

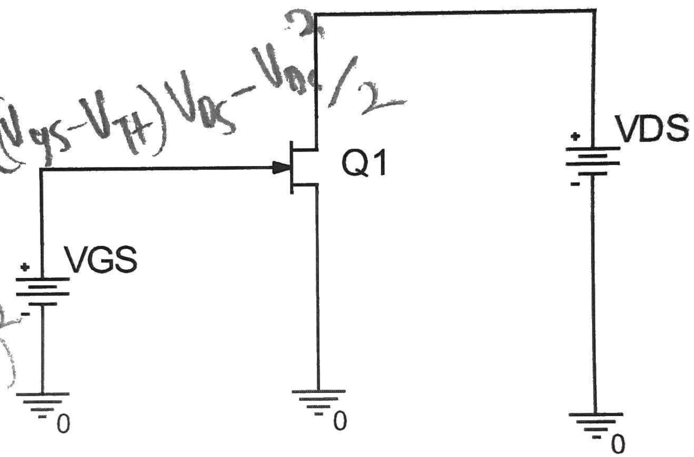
Problem1) I-V characteristics, simple biasing

$V_{gs} < V_{TH}$. $I_D = 0$

$V_{DS} < V_{gs} - V_{TH}$ $I_D = .1\left((V_{gs} - V_{TH})V_{DS} - V_{DS}^2/2\right)$

$V_{DS} > V_{gs} - V_{TH}$

$I_d = \frac{1}{2} .1 (V_{gs} - V_{TH})^2$

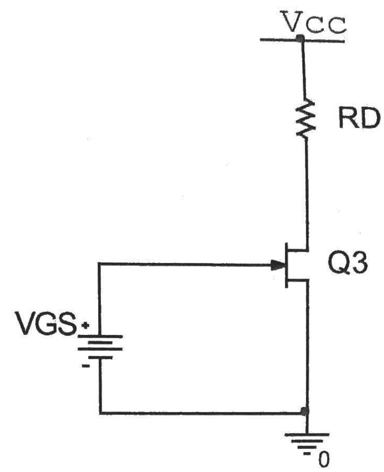


The above NMOSFET has a threshold voltage of VTN = 2.5V and Kn = 100mA/V^2

a) Use a program (Matlab, Excel, or any other tool) to plot ID-VGS for 0 < VGS < 6V when VDS = {1V, 2.5,2V} (three plots). The plots should be on the same set of axis. For each plot clearly indicate the regions where the FET is off, in Triode and in saturation. On each plot, identify VGS voltage when at the off-saturation and saturation-triode transitions for the FET. (Note, this plot should be comparable to pre-lab 3.1.)

b) Use a program (Matlab, Excel, or any other tool) to plot ID-VDS for 0 < VDS < 6V when VGS = {2.75V,3.0V,2.25V} (three plots). The plots should be on the same set of axis. For each plot clearly indicate the regions where the FET is in Triode and in saturation. On each plot indicate the VDS voltage when the FET transitions from Triode to saturation.

Problem 2) Basic biasing



For the above circuit, VTN = 2.5V and Kn = 100mA/V^2

a) When VGS = 3V and Vcc = 15V, determine the range of resistor values, RD, such that the transistor is in saturation.
b) When VGS = 3V and RD = 500Ω, determine the range of values for Vcc such that the transistor is in saturation.
c) When Vcc = 10V and RD = 500Ω, determine the range of values of VGS for each of the three regions of operation (off, Triode, saturation).

A: $V_{cc} - V_{R_D} > 0.5V$

$I_D = (.5)(.1)(.5)^2 = 0.0125$

$R_D \cdot I_D < 14.5V$

$R_D < 1160$

$R_D < 1160\ \Omega$

B: $-(R_D \cdot I_D) > 0.5V - V_{cc}$

$-6.25 > 0.5V - V_{cc}$

$V_{cc} > 6.75V$

C: off: $V_{gs} < 2.5V$

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saturation: $I_D = 0.5 \cdot .1(V_{gs}-2.5)^2$ $V_{cc} - R_D \cdot I_D > V_{gs} - 2.5$

$10 - 500(.5 \cdot .1(V_{gs}-2.5)^2) - V_{gs} + 2.5 > 0$

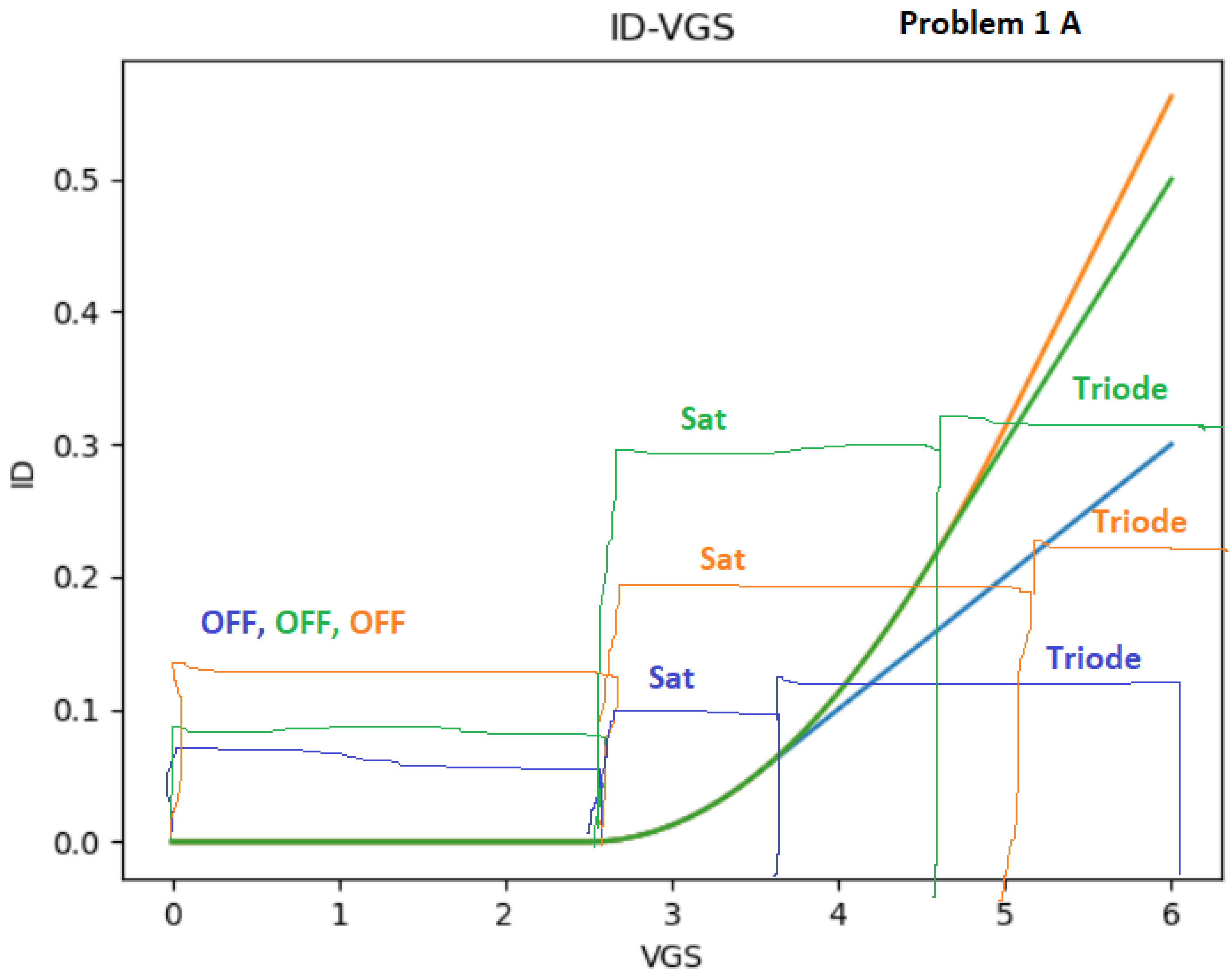
$12.5 - 25(V_{gs}-2.5)^2 - V_{gs} > 0$

$12.5 - 25V_{gs}^2 + 124V_{gs} - 156.25 > 0$

$(V_{gs} - 3.113)\cancel{(V_{gs} - 1.847)} > 0$

$2.5V < V_{gs} < 3.113V$

Triode: $V_{gs} > sat \rightarrow V_{gs} > 3.113V$



Blue : VDS = 1V

Orange: VDS = 2.5V

Green: VDS = 2V

Blue Plot:

Off -> Sat = 2.5V

Sat -> Tri = 3.5V

Orange Plot:

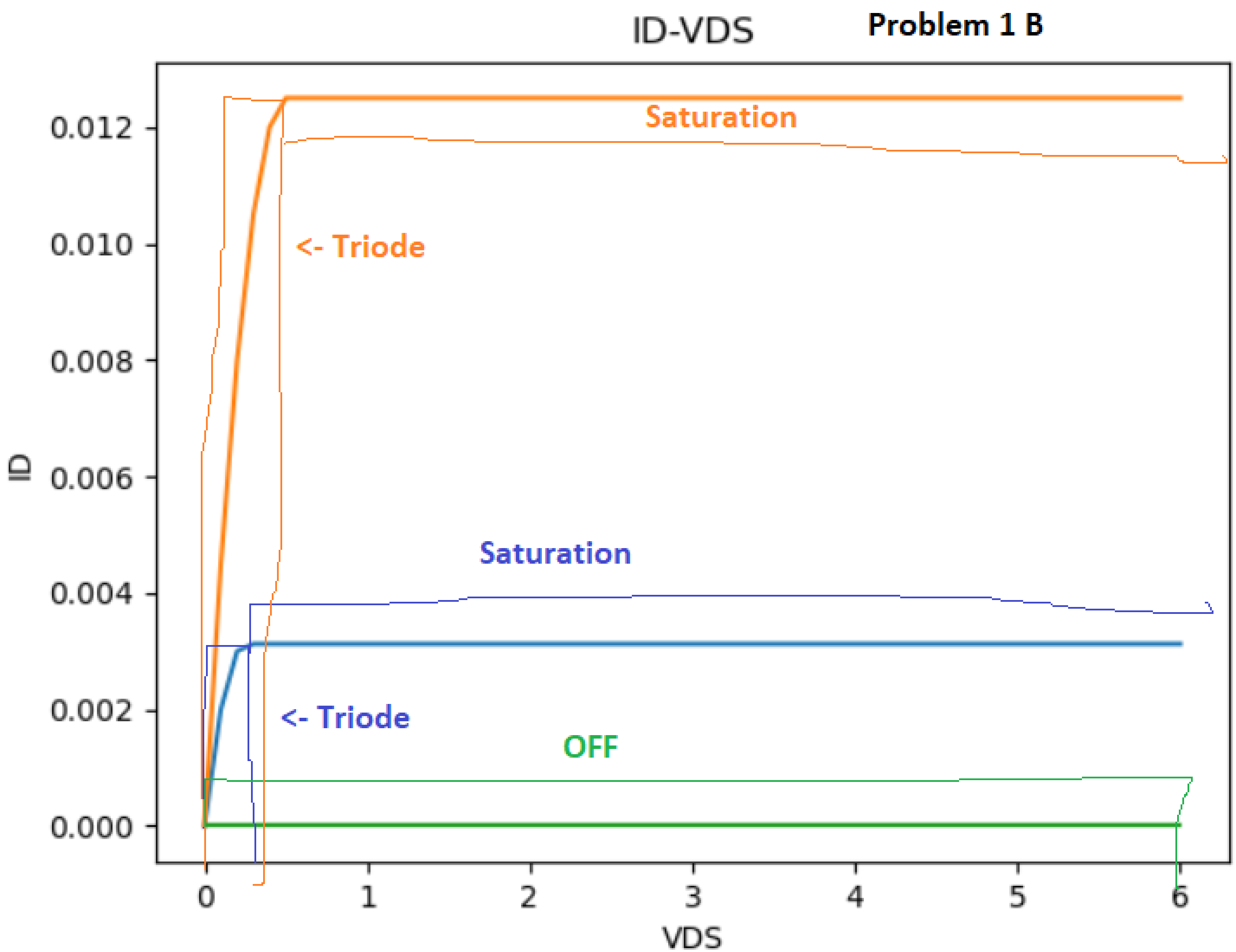
Off -> Sat = 2.5V

Sat -> Tri = 5V

Green Plot:

Off -> Sat = 2.5V

Sat -> Tri = 4.5V



Blue: VGS = 2.75V
Orange: VGS = 3V
Green: VGS = 2.25V

Blue Plot:
Triode -> Sat = 0.25V

Orange Plot:
Triode -> Sat = 0.5V

Green Plot:
Triode -> Sat : Never

```
#IE HW 10 Prob 1 A

from matplotlib import pyplot as plt
import numpy as np

vgs = np.arange(0, 6.1, 0.1)

vg = 0
vds = 1
id = []
id2 = []
id3 = []
vtn = 2.5
kn = 0.1
while vg < 6:
    if vg< vtn:
        id.append(0)
    else:
        if vds < (vg- vtn):
            print("vgs triode", vg)
            current = kn * ((vg - vtn) * vds - vds ** 2 / 2);
            id.append( current)

        else:
            print("vgs saturation", vg)
            current = kn * (vg - vtn) ** (2) / 2
            id.append(current)
    vg+= 0.1

print("next set of values vd = 2.5")
vg = 0
vds = 2.5
while vg < 6:
    if vg< vtn:
        id2.append(0)
    else:
        if vds < (vg- vtn):
            print("vgs triode", vg)
            current = kn * ((vg - vtn) * vds - vds ** 2 / 2);
            id2.append( current)

        else:
            print("vgs saturation", vg)
            current = kn * (vg - vtn) ** (2) / 2
            id2.append(current)
    vg+= 0.1

print("next set of values vd = 2")
vg = 0
vds = 2
while vg < 6:
    if vg< vtn:
        id3.append(0)
    else:
        if vds < (vg- vtn):
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```
            print("vgs triode", vg)
            current = kn * ((vg - vtn) * vds - vds ** 2 / 2);
            id3.append( current)

        else:
            print("vgs saturation", vg)
            current = kn * (vg - vtn) ** (2) / 2
            id3.append(current)
    vg+= 0.1

plt.plot(vgs,id)
plt.plot(vgs, id2)
plt.plot(vgs, id3)
plt.xlabel("VGS")
plt.ylabel("ID")
plt.title('ID-VGS')
plt.show()
```

```python
#IE HW 10 Prob 1 B

from matplotlib import pyplot as plt
import numpy as np

vds = np.arange(0, 6.1, 0.1)

vd = 0
vgs = 2.75
id = []
id2 = []
id3 = []
vtn = 2.5
kn = 0.1
while vd < 6:
    if vgs< vtn:
        id.append(0)
    else:
        if vd < (vgs- vtn):
            print("vds triode", vd)
            current = kn * ((vgs - vtn) * vd - vd ** 2 / 2);
            id.append( current)

        else:
            print("vds saturation", vd)
            current = kn * (vgs - vtn) ** (2) / 2
            id.append(current)
    vd+= 0.1

print("next set of values vgs = 3.0")

vd = 0
vgs = 3

while vd < 6:
    if vgs< vtn:
        id2.append(0)
    else:
        if vd < (vgs- vtn):
            print("vds triode", vd)
            current = kn * ((vgs - vtn) * vd - vd ** 2 / 2);
            id2.append( current)

        else:
            print("vds saturation", vd)
            current = kn * (vgs - vtn) ** (2) / 2
            id2.append(current)
    vd+= 0.1

print("next set of values vgs = 2.25")

vd = 0
vgs = 2.25
while vd < 6:
    if vgs< vtn:
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```
        id3.append(0)
    else:
        if vd < (vgs- vtn):
            print("vds triode", vd)
            current = kn * ((vgs - vtn) * vd - vd ** 2 / 2);
            id3.append( current)

        else:
            print("vds saturation", vd)
            current = kn * (vgs - vtn) ** (2) / 2
            id3.append(current)
    vd+= 0.1

plt.plot(vds,id)
plt.plot(vds, id2)
plt.plot(vds, id3)
plt.xlabel("VDS")
plt.ylabel("ID")
plt.title('ID-VDS')
plt.show()
```