ECE 320: Handout #23

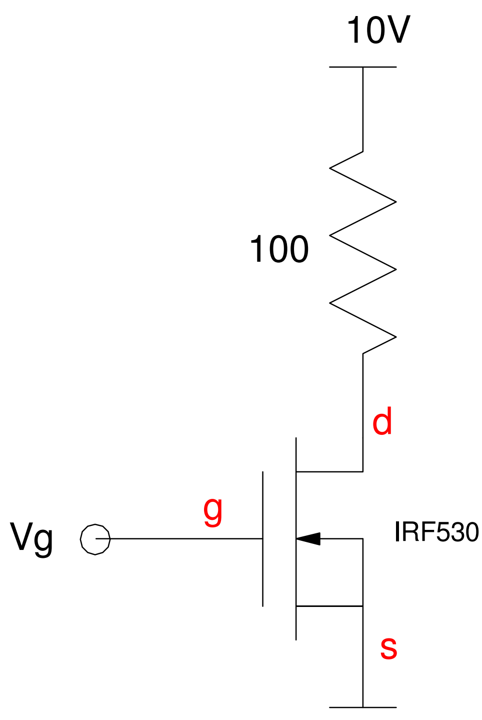
MOSFET Switch

The specifications for an IRF530 MOSFET (default MOSFET for CircuitLab) is

- max(Ic) = 14A continuous, 49A instantaneous
- max(Vds) = 100V
- 160mOhm @ Ids = 8.4A @ Vgs = 10V
- Vgs(th) = 4.0V (max)

Determine

- The transconductance gain, kn,
- The Q-point (Vds, Ids) when Vg = 5V, and
- The Q-point (Vds, Ids) when Vg = 5V and the 100 Ohm resistor is reduced to 10 Ohms

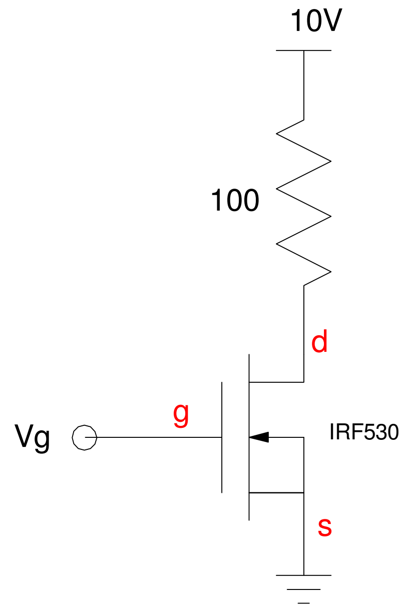


Solution:

The specifications for an IRF530 MOSFET (default MOSFET for CircuitLab) is

- max(Ic) = 14A continuous, 49A instantaneous
- max(Vds) = 100V
- **160mOhm @ Ids = 8.4A @ Vgs = 10V**
- Vgs(th) = 4.0V (max)

Determine the Q-point (Vds, Ids) when Vg = 10V



Problem 1: Determine kn

The spec is in the ohmic region

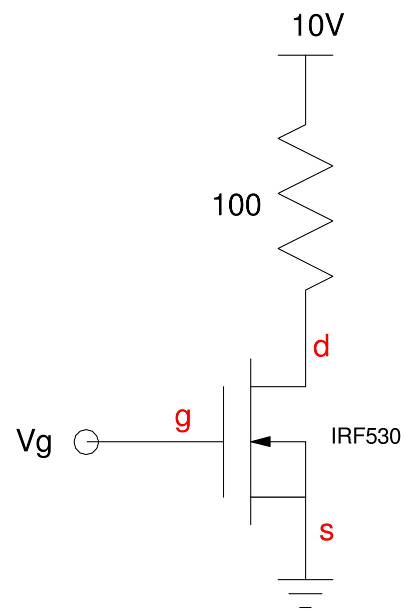
$$V_{ds} = (160m\Omega)(8.4A) = 1.344V$$

$$I_d = k_n\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

$$8.4A = k_n\left(10V - 4V - \frac{1.344V}{2}\right)1.344V$$

$$k_n = 1.173\,\frac{A}{V^2}$$

Problem 2: Determine (Vds, Ids) when Vg = 5V



Write 2 equations for 2 unknowns.

Assume Ohmic

$$I_d = k_n\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

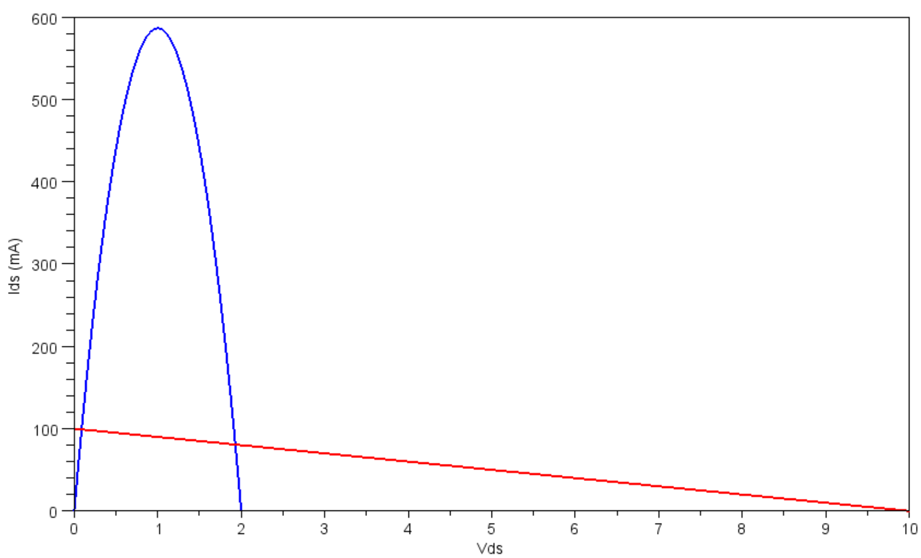
$$I_d = 1.173\left(5V - 4V - \frac{V_{ds}}{2}\right)V_{ds}$$

The load line is

$$100 I_d + V_{ds} = 10$$

Turns are two solutions. In Matlab, you can see these

```
-->Vds = [0:0.01:10]';

-->I1 = 1.173*(5 - 4 - Vds/2).*Vds;
-->I2 = (10 - Vds) / 100;

-->plot(Vds,I1*1000,Vds,I2*1000);
-->xlabel('Vds');
-->ylabel('Ids (mA)')
```

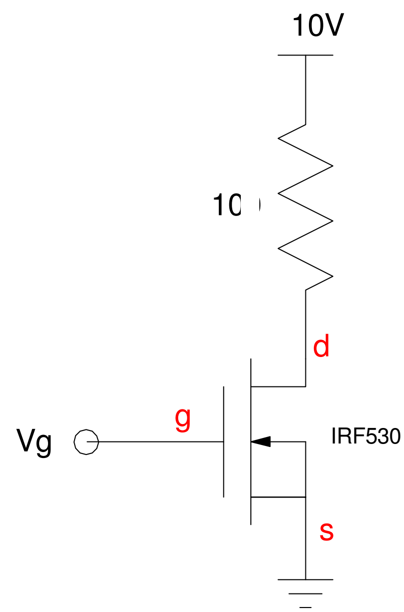


The solution on the left is

- Vds = 88.33mV
- Ids = 99.1mA

Problem 3: Determine (Vds, Ids) when Vg = 5V and Rd = 10 Ohms

Assume Ohmic again. The MOSFET equation is (no change)



$$I_d = 1.173\left(5V - 4V - \frac{V_{ds}}{2}\right)V_{ds}$$

The load line becomes.

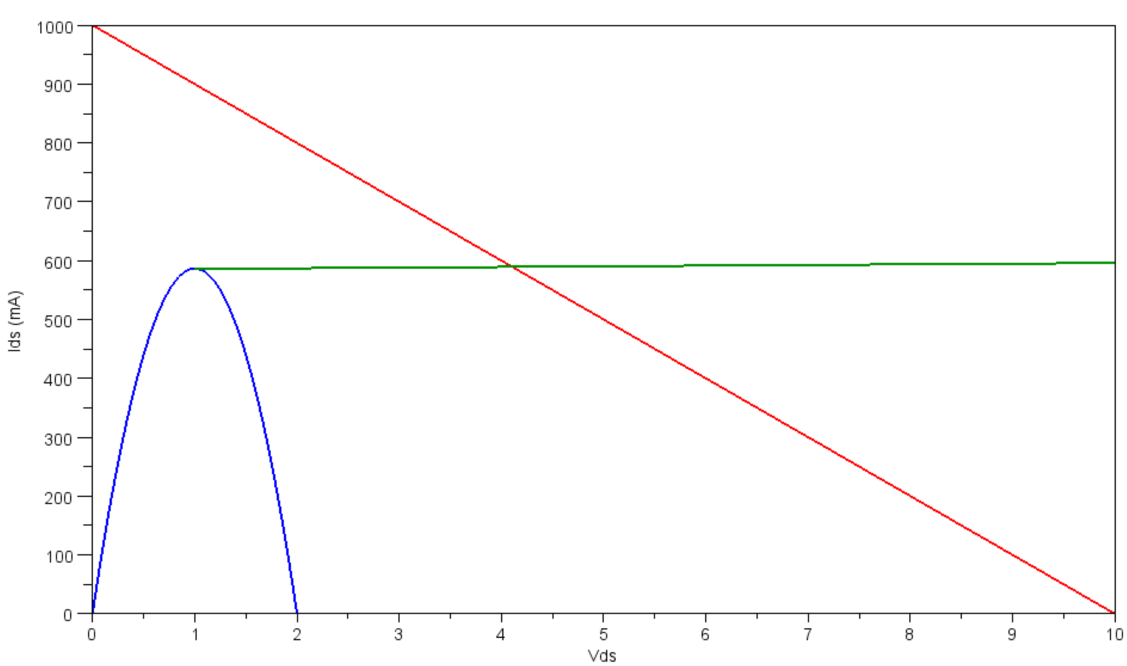
$$10I_d + V_{ds} = 10$$

Now there is no solution. This tells you

- The load line does not intersect the Ohmic region equation
- The MOSFET is actually saturated

In Matlab

```
-->Vds = [0:0.01:10]';

-->I1 = 1.173*(5 - 4 - Vds/2).*Vds;
-->I2 = (10 - Vds) / 10;

-->plot(Vds,I1*1000,Vds,I2*1000);

-->max(I1)*1000

    586.5

-->plot([1,10],[586,596],'m')
-->xlabel('Vds');
-->ylabel('Ids (mA)')788
```



Load Line (red), Ohmic VI curve (blue), Saturated VI curve (green)

Since we're actually operating in the saturated region, the two equations you need to solve are

$$I_d = \frac{k_n}{2}(V_{gs} - V_{th})^2$$

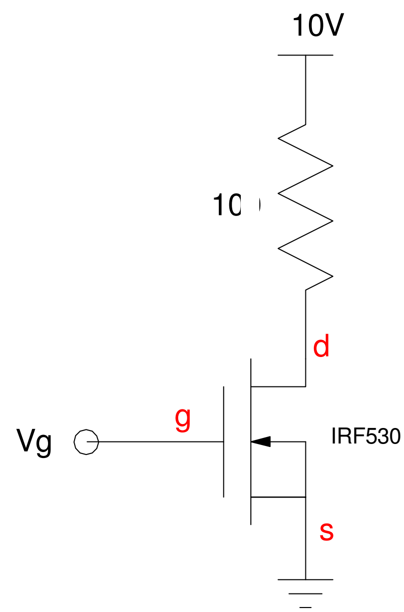
$$I_d = \frac{1.173}{2}(5V - 4V)^2$$

$$I_d = 586.5mA$$

and the load line

$$10I_d + V_{ds} = 10$$

$$V_{ds} = 4.135V$$



Problem 2: Determine (Vds, Ids) when Vg = 10V

Assume saturated state

$$I_d = \left(\frac{k_n}{2}\right)(V_{gs} - V_{th})^2$$

$$I_d = \left(\frac{1.173}{2}\right)(10 - 4)^2 = 21.149A$$

This is more than is possible (10V / 100Ohms = 100mA)

Assume Ohmic. Write 2 equations for 2 unknowns (Id, Vds)

$$I_d = k_n\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

$$I_d = 1.173\left(10 - 4 - \frac{V_{ds}}{2}\right)V_{ds}$$

$$V_{ds} + 100I_d = 10$$

Solving

Vds = 14.18mV, Ids = 99.7mA

Rds = (Vds / Ids) = 142mOhms