Steps for D.C Analysis of MOSFET Circuits

To analyze MOSFET circuit with D.C. sources, we **must** follow these **five steps**:

1. *ASSUME* an operating mode

2. *ENFORCE* the equality conditions of that mode.

3. *ANALYZE* the circuit with the enforced conditions.

4. *CHECK* the inequality conditions of the mode for consistency with original assumption. If consistent, the analysis is complete; if inconsistent, go to step 5.

5. *MODIFY* your original assumption and repeat all steps.

Let's specifically look at each step in **detail**.

1. *ASSUME*

Here we have **three** choices—cutoff, triode, or saturation. You can make an "**educated guess**" here, but remember, until you CHECK, it's just a guess!

2. ENFORCE

For all three operating regions, we must ENFORCE just **one equality**.

Cutoff

Since **no** channel is induced, we ENFORCE the equality:

$$I_D = 0$$

Triode

Since the conducting channel **is** induced but **not** in pinch-off, we ENFORCE the equality:

$$I_D = K\left[2\left(V_{GS} - V_t\right)V_{DS} - V_{DS}^2\right]$$

Saturation

Since the conducting channel **is** induced and **is** in pinch-off, we ENFORCE the equality:

$$I_D = K\left(V_{GS} - V_t\right)^2$$

Note for all cases the constant K is:

$$K \doteq \frac{1}{2} k' \left(\frac{W}{L} \right)$$

and V_t is the MOSFET **threshold voltage**.

3. ANALYZE

The task in D.C. analysis of a MOSFET circuit is to find **one current** and **two voltages**!

a) Since the gate current I_G is zero ($I_G = 0$) for all MOSFETS in all modes, we need **only** to find the **drain current** I_D--this current value must be **positive** (or zero).

b) We also need to find **two** of the three **voltages** associated with the MOSFET. Typically, these two voltages are V_{GS} and V_{DS}, but given any two voltages, we can find the third using KVL:

$$V_{DS} = V_{DG} + V_{GS}$$

Some hints for MOSFET DC analysis:

1) Gate current $I_G = 0$ **always** !!!

2) Equations sometimes have **two** solutions! Choose solution that is **consistent** with the original ASSUMPTION.

4. CHECK

You do not know if your D.C. analysis is correct unless you CHECK to see if it is consistent with your original assumption!

WARNING!-Failure to CHECK the original assumption will result in a SIGNIFICANT REDUCTION in credit on exams, regardless of the accuracy of the analysis !!!

Q: *What exactly do we CHECK?*

A: We ENFORCED the mode **equalities**, we CHECK the mode **inequalities.**

We must CHECK **two** separate inequalities after analyzing a MOSFET circuit. Essentially, we check if we have/have not induced a conducting channel, and then we check if we have/have not pinched-off the channel (if it is conducting).

Cutoff

We must only CHECK to see if the MOSFET has a **conducting channel**. If **not**, the MOSFET is indeed in **cutoff**. We therefore CHECK to see if:

$$V_{GS} < V_t \quad \text{(NMOS)}$$

$$V_{GS} > V_t \quad \text{(PMOS)}$$

Triode

Here we must first CHECK to see **if** a channel has been induced, i.e.:

$$V_{GS} > V_t \quad \text{(NMOS)}$$

$$V_{GS} < V_t \quad \text{(PMOS)}$$

Likewise, we must CHECK to see if the channel has reached **pinchoff**. If **not**, the MOSFET is indeed in the **triode** region. We therefore CHECK to see if:

$$V_{DS} < V_{GS} - V_t \quad \text{(NMOS)}$$

$$V_{DS} > V_{GS} - V_t \quad \text{(PMOS)}$$

Saturation

Here we must first CHECK to see **if** a channel has been induced, i.e.:

$$V_{GS} > V_t \quad \text{(NMOS)}$$

$$V_{GS} < V_t \quad \text{(PMOS)}$$

Likewise, we must CHECK to see if the channel has reached **pinchoff**. If it **has**, the MOSFET is indeed in the **saturation** region. We therefore CHECK to see if:

$$V_{DS} > V_{GS} - V_t \quad \text{(NMOS)}$$

$$V_{DS} < V_{GS} - V_t \quad \text{(PMOS)}$$

If the results of our analysis are consistent with **each** of these inequalities, then we have made the **correct** assumption! The **numeric** results of our analysis are then likewise **correct**. We can **stop** working!

However, if **even one** of the results of our analysis is **inconsistent** with our ASSUMPTION, then we have made the **wrong** assumption! → Time to move to step 5.

5. MODIFY

If **one or more** of the circuit MOSFETSs are **not** in their ASSUMED mode, we must change our assumptions and start **completely** over!

In general, **all** of the results of our previous analysis are incorrect, and thus must be **completely** scraped!