MOSFET Small-Signal Analysis Steps

Complete **each** of these steps if you **choose** to correctly complete a MOSFET Amplifier **small-signal** analysis.

Step 1: Complete a **D.C. Analysis**

Turn **off** all **small-signal** sources, and then complete a circuit analysis with the remaining **D.C. sources** only.

* Complete this DC analysis exactly, precisely, the same way you performed the DC analysis in section 4.3. That is, you assume (the **saturation** mode), enforce, analyze, and **check (do not forget to check!)**.

* Note that you enforce and check exactly, precisely the same the same equalities and inequalities as discussed in section 4.3.

* Remember, if we "turn off" a **voltage** source (e.g.,$v_i(t) = 0$), it becomes a **short** circuit.

* However, if we "turn off" a **current** source (e.g., $i_i(t) = 0$), it becomes an **open** circuit!

* Small-signal amplifiers frequently employ large **capacitors**. Remember, the impedance of a capacitor at **DC** is infinity—a DC **open** circuit.

The goal of this DC analysis is to determine:

1) The DC voltage V_{GS} for **each** MOSFET.

2) The DC voltage V_{DS} for **each** MOSFET (you need this value for the CHECK).

You do not **necessarily** need to determine any other DC currents or voltages within the amplifier circuit!

Once you have found these values, you can **CHECK** your active assumption, and then move on to **step 2**.

Step 2: Calculate the **small-signal circuit parameters** for each MOSFET.

Recall that we now understand **2** MOSFET small-signal parameters:

$$g_m = 2K(V_{GS} - V_t) \qquad r_o = \frac{1}{\lambda K (V_{GS} - V_t)^2}$$

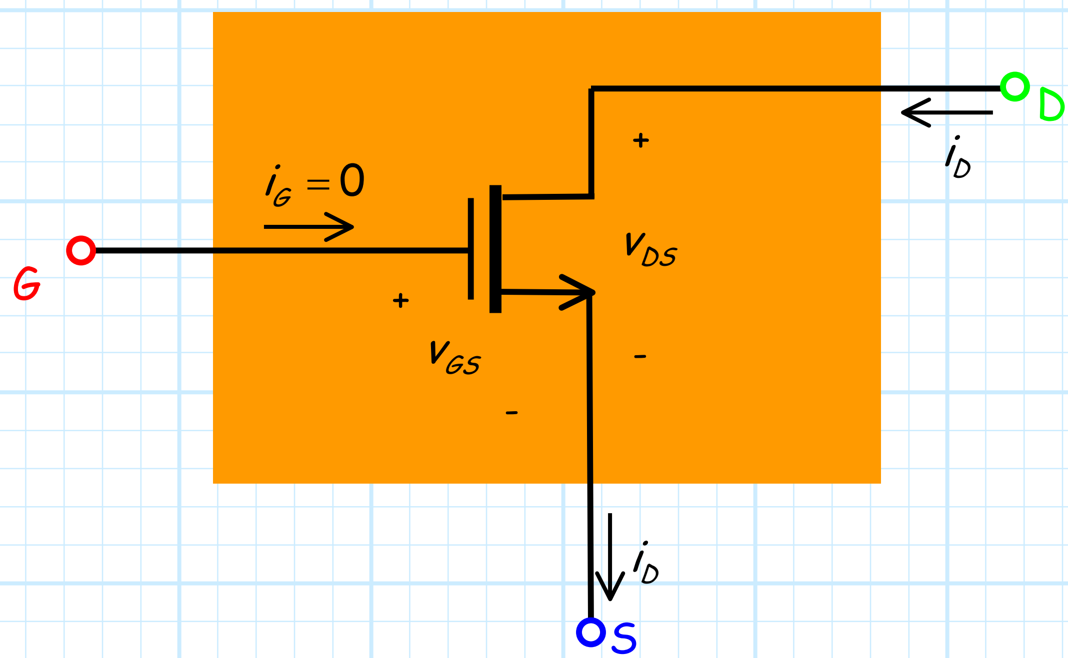
Step 3: Carefully replace all MOSFETs with their **small-signal circuit model.**

This step often gives students **fits**!

However, it is actually a **very simple** and straight-forward step. It does require four important things from the student—**patience**, **precision**, **persistence** and **professionalism**!

First, note that a **MOSFET** is:

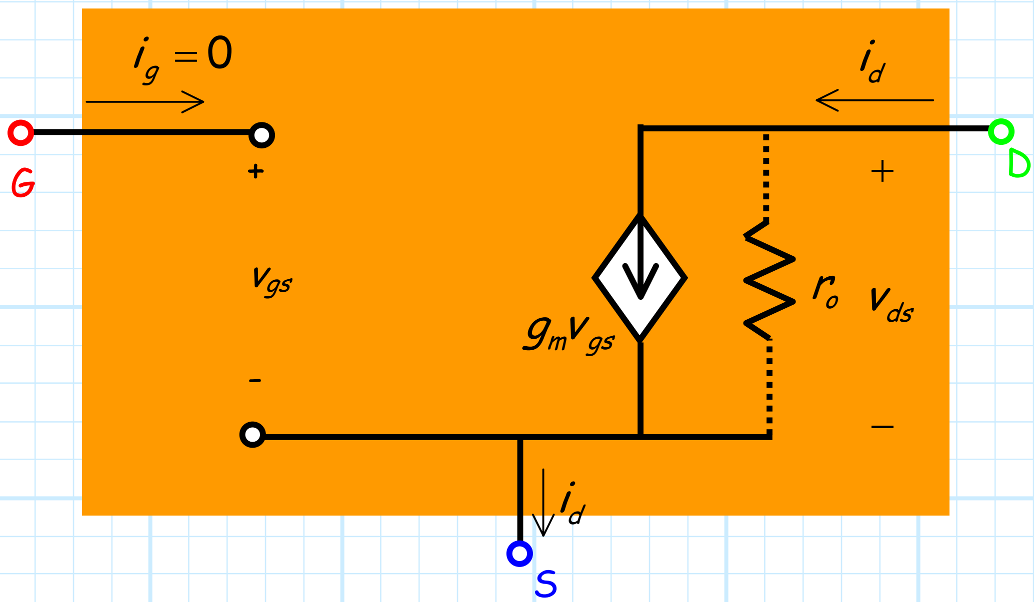
> A device with **three** terminals, called the gate, drain, and source. Its behavior is described in terms of current i_D and voltages v_{GS}, v_{DS}.



Now, **contrast** the MOSFET with its small-signal circuit model. A MOSFET small-signal circuit model is:

A device with **three** terminals, called the gate, drain, and source. Its behavior is described in terms of current i_d and voltages v_{gs}, v_{ds}.

Exactly the **same**—what a coincidence!



Therefore, replacing a MOSFET with its small-signal circuit model is very simple—you simply change the stuff **within** the orange box!

Note the parts of the circuit **external** to the orange box do not change! In other words:

1) every device attached to the MOSFET **terminals** (i.e, gate, drain, source) is attached in **precisely** the same way to the terminals of the **circuit model**.

2) **every** external voltage or current (e.g., v_i, v_o, i_R) is defined in **precisely** the same way both before and after the MOSFET is replaced with its circuit model is (e.g., if the output voltage is the drain voltage in the MOSFET circuit, then the output voltage is **still** the drain voltage in the small-signal circuit!).

Step 4: Set all **D.C. sources** to zero.

Remember:

A zero voltage DC source is a **short**.

A zero current DC source is an **open**.

The schematic in now in front of you is called the **small-signal circuit**. Note that it is **missing** two things—**DC sources** and MOSFET **transistors**!

* Note that steps three and four are **reversible**. You could turn off the DC sources **first**, and then replace all MOSFETs with their small-signal models—the resulting small-signal circuit will be the **same**!

* You will find that the small-signal circuit schematic can often be greatly **simplified**. Once the DC voltage sources are turned **off**, you will find that the terminals of many devices are connected to **ground**.

* Remember, all terminals connected to ground are **also** connected to each other! For **example**, if the source terminal is connected to ground, and one terminal of a resistor is connected to ground, then that resistor terminal is connected to the source!

* As a result, you often find that resistors in different parts of the circuit are actually connected in **parallel**, and thus can be **combined** to simplify the circuit schematic!

* Finally, note that the AC impedance of a **very large capacitor** (i.e., $|Z_C| = 1/\omega C$) is small for all but the lowest frequencies ω. If this impedance is smaller than the other circuit elements (e.g., < 10Ω), we can view the impedance as **approximately zero**, and thus replace the **large** capacitor with a (AC) **short**!

Organizing and **simplifying** the small-signal circuit will pay **big** rewards in the next step, when we **analyze** the small-signal circuit.

Step 5: Analyze **small-signal circuit**.

We now can **analyze** the small-signal **circuit** to find all small-signal **voltages** and **currents**.

* For small-signal **amplifiers**, we typically attempt to find the small-signal output voltage v_o in terms of the small-signal input voltage v_i. From this result, we can find the **voltage gain** of the amplifier.

* Note that this analysis requires **only** the knowledge you acquired in **EECS 211**! The small-signal circuit will consist **entirely** of resistors and (small-signal) voltage/current sources. These are **precisely** the same resistors and sources that you learned about in EECS 211. You analyze them in **precisely** the same way.

* Do **not** attempt to insert any MOSFET knowledge into your small-signal circuit analysis—there are **no** MOSFETs in a small-signal circuit!!!!!

* Remember, the MOSFET circuit model contains **all** of our MOSFET small-signal knowledge, we **do** not—indeed **must** not—add any more information to the analysis.

You must **trust** completely the MOSFET small-signal circuit model. It **will** give you the correct answer!