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 equalities and inequalities as discussed in section 4.3.

* Remember, if we “turn off” a voltage source (e.g., \(v(t) = 0\)), it becomes a short circuit.

* However, if we “turn off” a current source (e.g., \(i(t) = 0\)), 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:

$$g_m = 2K(V_{gs} - V_t) \quad r_o = \frac{1}{\lambda K(V_{gs} - V_t)^2}$$
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!

![Diagram of MOSFET small-signal model](image)

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 $\omega$. If this impedance is smaller than the other circuit elements (e.g., $< 10\Omega$), 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!