Example: A Small-Signal Analysis of a MOSFET Amplifier

Let’s again consider this simple NMOS Amplifier:

\[ i_d(t) = I_D + i_d(t) \]

\[ K = 0.25 \text{ mA/V}^2 \]

\[ V_T = 2.0 \text{ V} \]

We can perform a small-signal analysis to determine the small-signal open-circuit voltage gain \( A_o \):

\[ A_o = \frac{v_o(t)}{v_i(t)} \]
**Step 1: DC Analysis**

Turning **off** the small signal source leaves a **DC circuit** of:

We **ASSUME** saturation, so that we **ENFORCE**:

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

It is evident that:

\[ V_{GS} = 4.0 \text{ V} \]

Therefore the DC drain current is:

\[ I_D = K (V_{GS} - V_t)^2 = 0.25(4 - 2)^2 = 1.0 \text{ mA} \]

Thus, the DC voltage \( V_{DS} \) can be determined from **KVL** as:

\[ V_{DS} = 15.0 - I_D R_D \]
\[ = 15.0 - 1(5) \]
\[ = 10.0 \text{ V} \]

**We CHECK** our results and find:

\[ V_{GS} = 4.0 > V_t = 2.0 \]
Step 2: Determine the small-signal parameters

We find that the transconductance is:

\[ g_m = 2K(V_G - V_t) \]
\[ = 2(0.25)(4.0 - 2.0) \]
\[ = 1 \text{ mA/V} \]

Note that no value of \( \lambda \) was given, so we will assume \( \lambda = 0 \), and thus output resistance \( r_o = \infty \).

Steps 3 and 4: Determine the small-signal circuit

We now turn off the two DC voltage source, and replace the MOSFET with its small signal model. The result is our small-signal circuit:
**Step 5: Analyze the small-signal circuit**

The analysis of this small-signal circuit is fairly straightforward. First, we note that:

\[ V_{gs} = V_i \]

and that:

\[ i_d = g_m V_{gs} \]

\[ = 1.0 V_{gs} \]

\[ = V_{gs} \]

and that:

\[ V_o = -5 i_d \]

**Combining** these equations, we find that:

\[ V_o = -5 V_i \]

And thus the **small-signal** open-circuit voltage gain of this amplifier is:

\[ A_{vo} = \frac{V_o(t)}{V_i(t)} = -5.0 \]