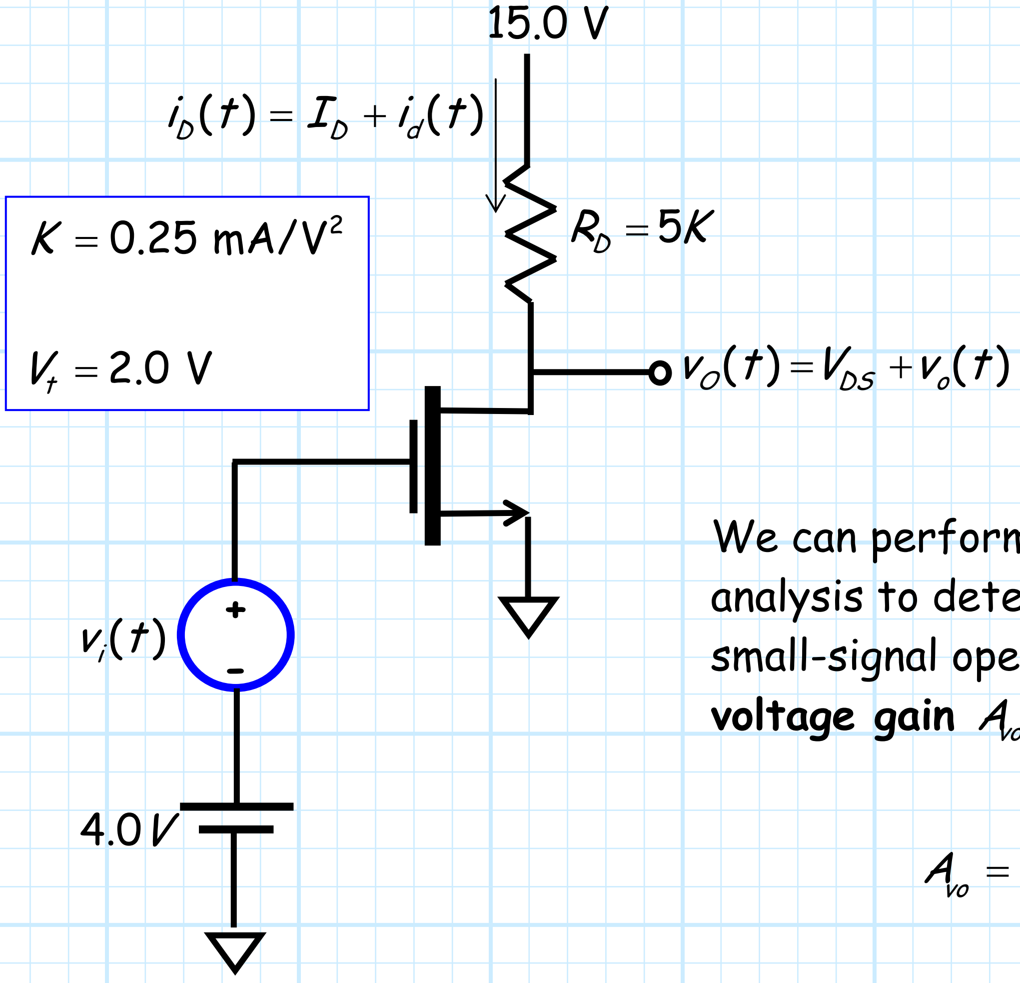
Example: A Small-Signal Analysis of a MOSFET Amplifier

Let's again consider this simple **NMOS Amplifier**:

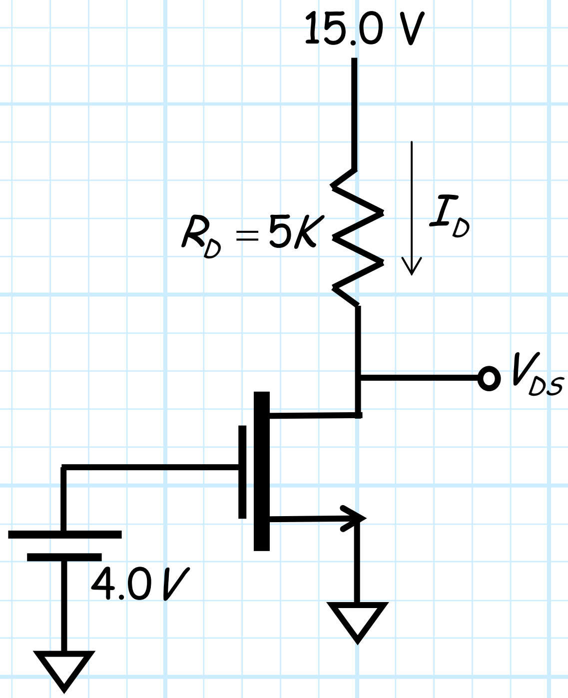


We can perform a small-signal analysis to determine the small-signal open-circuit **voltage gain** A_{vo}:

$$A_{vo} = \frac{v_o(t)}{v_i(t)}$$

Step 1: DC Analysis

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



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

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

It is evident that:

$$V_{GS} = 4.0 \text{ V}$$

Therefore the DC drain current is:

$$\begin{aligned} I_D &= K\left(V_{GS} - V_t\right)^2 \\ &= 0.25(4-2)^2 \\ &= 1.0 \text{ mA} \end{aligned}$$

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

$$\begin{aligned} V_{DS} &= 15.0 - I_D R_D \\ &= 15.0 - 1(5) \\ &= 10.0 \text{ V} \end{aligned}$$

We **CHECK** our results and find:

$$V_{GS} = 4.0 > V_t = 2.0$$

and:

$$V_{DS} = 10.0 > V_{GS} - V_t = 2.0$$

Step 2: Determine the small-signal parameters

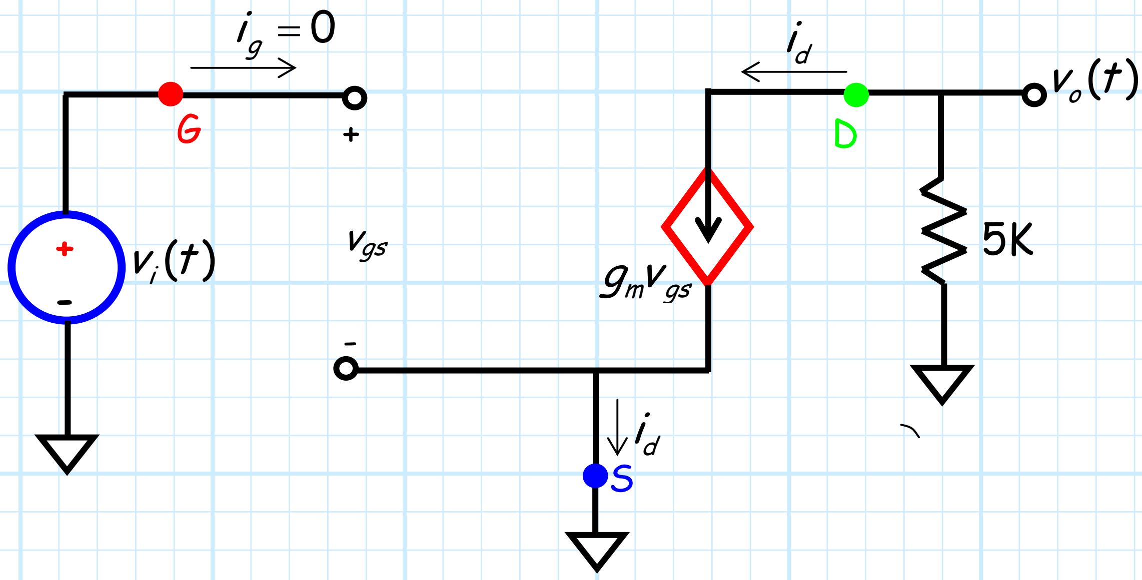
We find that the **transconductance** is:

$$\begin{aligned} g_m &= 2K\left(V_{GS} - V_t\right) \\ &= 2(0.25)(4.0 - 2.0) \\ &= 1 \ \text{mA}/\text{V} \end{aligned}$$

Note that **no** value of λ 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 from KVL that:

$$v_{gs} = v_i$$

and that:

$$\begin{aligned} i_d &= g_m v_{gs} \\ &= 1.0 v_{gs} \\ &= v_{gs} \end{aligned}$$

and that from Ohm's Law:

$$v_o = -5 i_d$$

Combining these equations, we find that:

$$v_o = -5 v_i$$

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

$$A_{vo} = \frac{v_o(t)}{v_i(t)} = -5.0$$