EX: This example illustrates the application of the universal AC model for FETs to a Common Source (CS) amplifier to find the input resistance, R_{in}, the output resistance, R_{out}, and the AC gain, A_{v}. Fig. 1 shows the circuit.

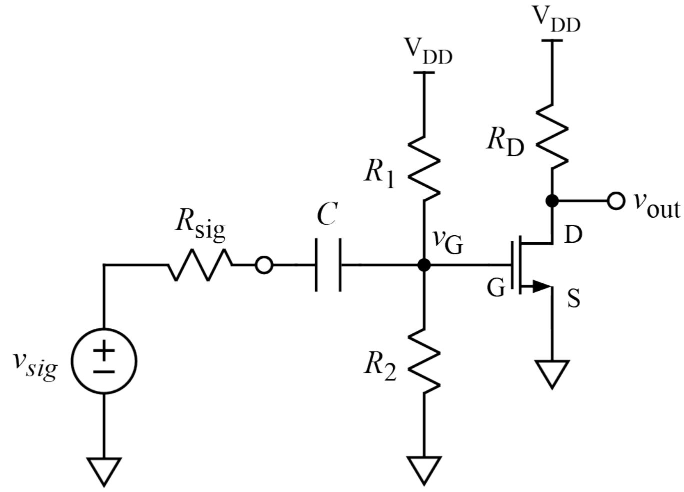

Fig. 1. CS amplifier complete with bias and coupling capacitor.

For DC, the C is an open circuit and we may solve for the DC drain current, I_{D}, from which we derive the transconductance, g_m, for the AC model. We also determine the channel modulation resistance, r_o, from I_{D} and the FET data sheet or characteristic curves.

For AC, we treat the C as a wire, turn off DC sources so they become reference, and we take the Thévenin equivalent of gate circuitry v_{sig}, R_{sig} R_1, R_2, and C. Fig. 2 shows the Thévenin equivalent. The values for the Thévenin equivalent are

$$v_{in} = v_{sig} \frac{R_1 || R_2}{R_{\text{sig}} + R_1 || R_2} \text{ and } R_{\text{g}} = R_{\text{sig}} || R_1 || R_2.$$

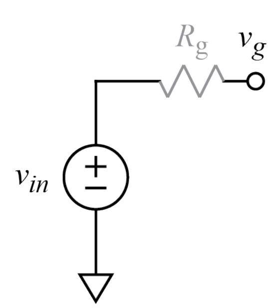

Fig. 2. Thévenin equivalent for AC signal at gate of FET.

Note: When the gain, A_v, is found below, it will be for v_{out}/v_{in}. To obtain the gain for v_{out}/v_{sig}, we must multiply by the voltage-divider factor in the Thévenin equivalent voltage source.

Since this Thévenin equivalent is connected to the gate and no current flows into the gate, the resistance, R_g, has no voltage drop (so it is shown in gray). Thus, we replace R_g with a wire and assume v_{in} is connected directly to the gate of the FET. Fig. 3 shows the resulting AC model.

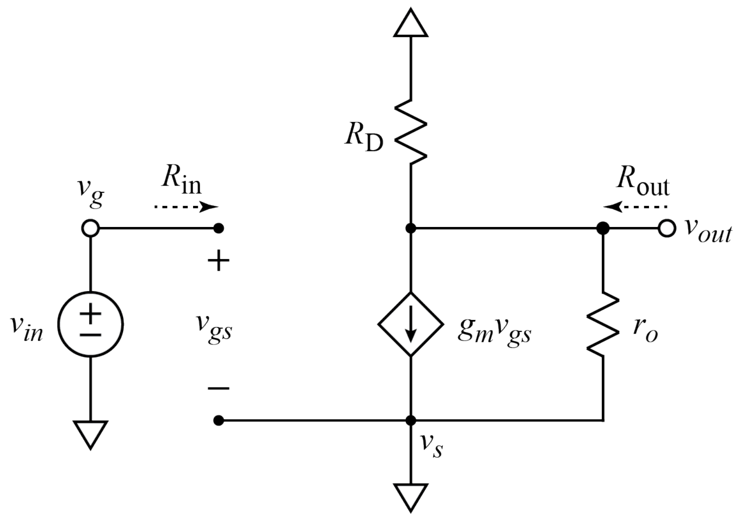

Fig. 3. AC model for CS amplifier circuit.

We apply the universal AC model shown in Fig. 4 to the circuit in Fig. 3 to find R_{in}, R_{out}, and A_v.

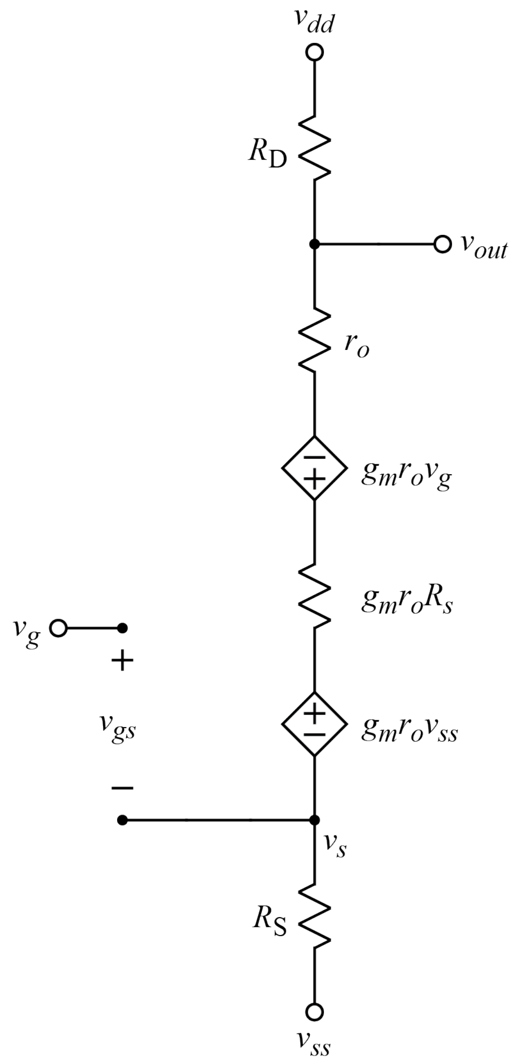

Fig. 4. Universal AC model for FET.

We have the following simplifications to the universal model in the case of our CS amplifier:

$R_S = 0\ \Omega$ $v_{ss} = 0$ V (no AC signal) $v_{dd} = 0$ V (no AC signal)

These simplifications eliminate one of the dependent sources and a resistor (shown grayed out going forward). Fig. 5 shows the resulting model for R_{in}.

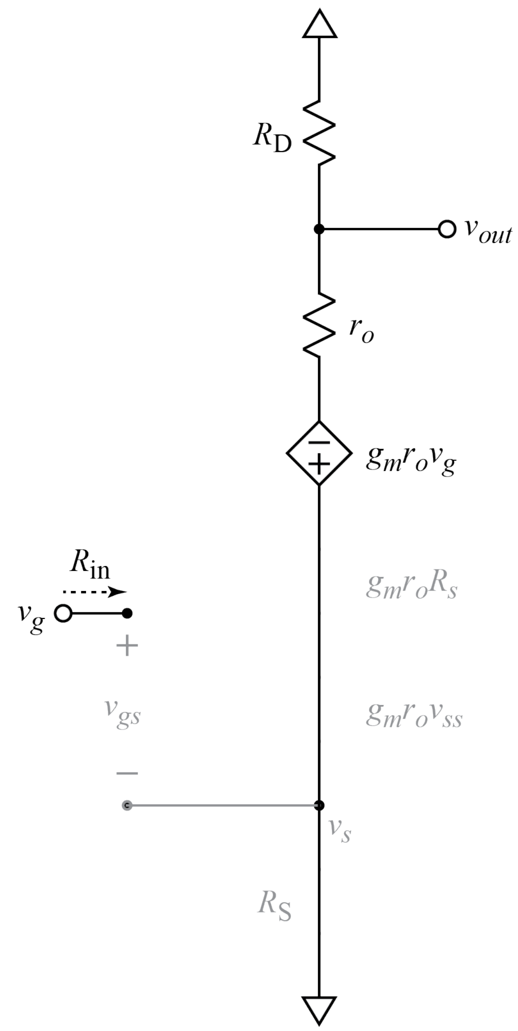

Fig. 5. Universal model applied to calculation of R_{in} for CS amplifier.

Since the gate is an open circuit, we can immediately write down the value of the input resistance.

$$R_{in} = \infty\ \Omega \text{ (open circuit)}$$

Fig. 6 shows the model for R_{out}. The input at the gate is set to zero when finding the output resistance. Setting the gate voltage to zero causes the second dependent source to disapper.

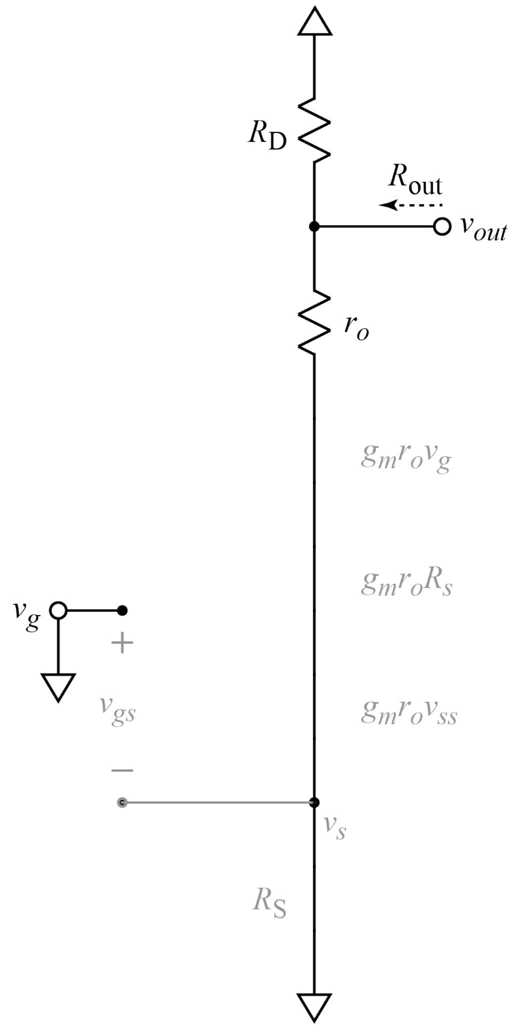

Fig. 6. Universal model applied to calculation of R_{out} for CS amplifier.

It is readily apparent that the output resistance is the drain and channel modulation resistances in parallel.

$$R_{out} = R_D \parallel r_o$$

Fig. 7 shows the model for gain A_v. The dependent source that depends on v_g is written as being dependent on v_{in} since v_g equals v_{in}.

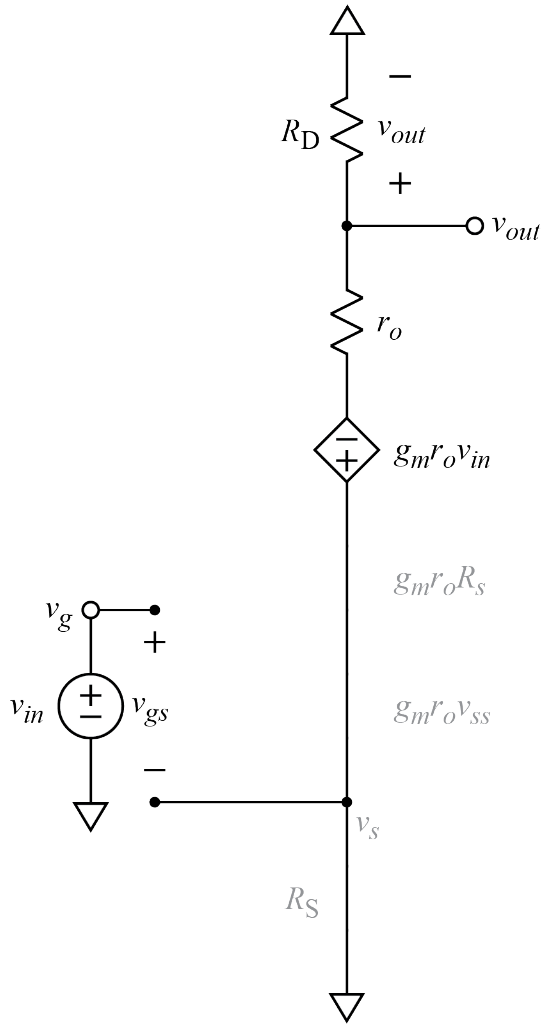

Fig. 7. Universal model applied to calculation of A_V for CS amplifier.

The gain is

$$A_v = \frac{v_{out}}{v_{in}}.$$

Since the dependent voltage-source value cannot alter the value of the dependent variable, v_{in}, we may treat the dependent source as an independent source and calculate v_{out} using a simple voltage divider.

$$v_{out} = -g_m r_o v_{in} \frac{R_D}{R_D + r_o} \quad \Rightarrow \quad A_v = -\frac{g_m r_o R_D}{R_D + r_o} = -g_m \cdot R_D || r_o$$

If we let r_o approach infinity, we get $A_V = -g_m R_D$, as expected.

REF: Behzad Razavi, *Fundamentals of Microelectronics with Robotics and Bioengineering Applications, 3rd Ed., Enhanced eText,* New York, NY: Wiley, 2021. ISBN: 9781119694397