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

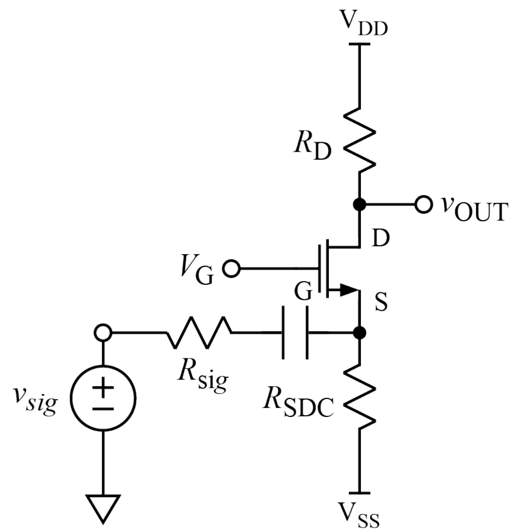

Fig. 1. CG amplifier with degeneration complete with bias and coupling capacitor.

For DC, the capacitor is an open circuit and we 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 FET data.

For AC, we treat the capacitor 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_{SDC}, and the capacitor. Fig. 2 shows the Thévenin equivalent.

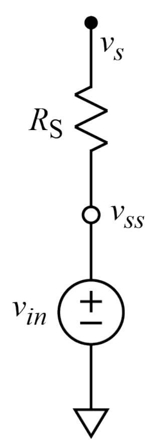

Fig. 2. Thévenin equivalent for AC signal at source of FET.

Fig. 3 shows the resulting AC model.

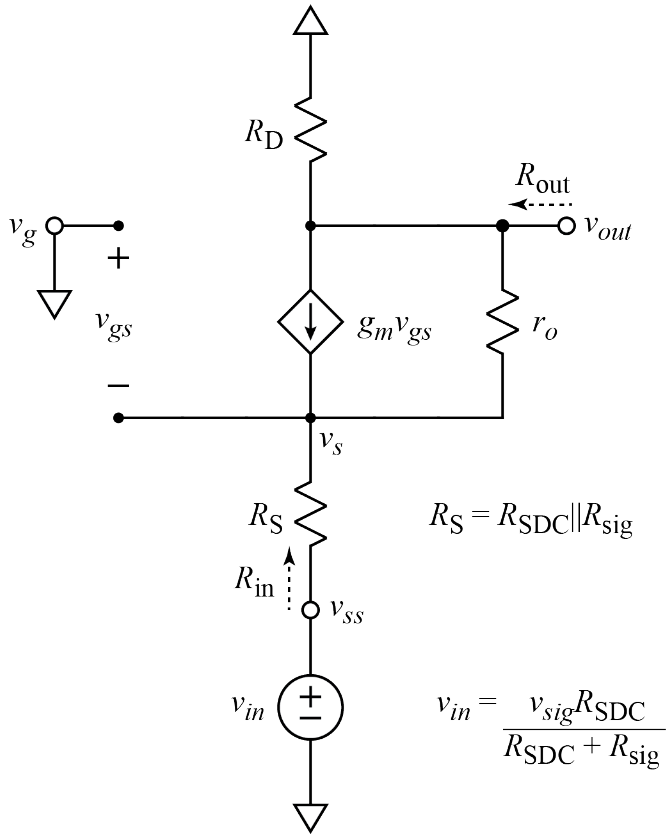

Fig. 3. AC model for CG amplifier circuit.

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.

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.

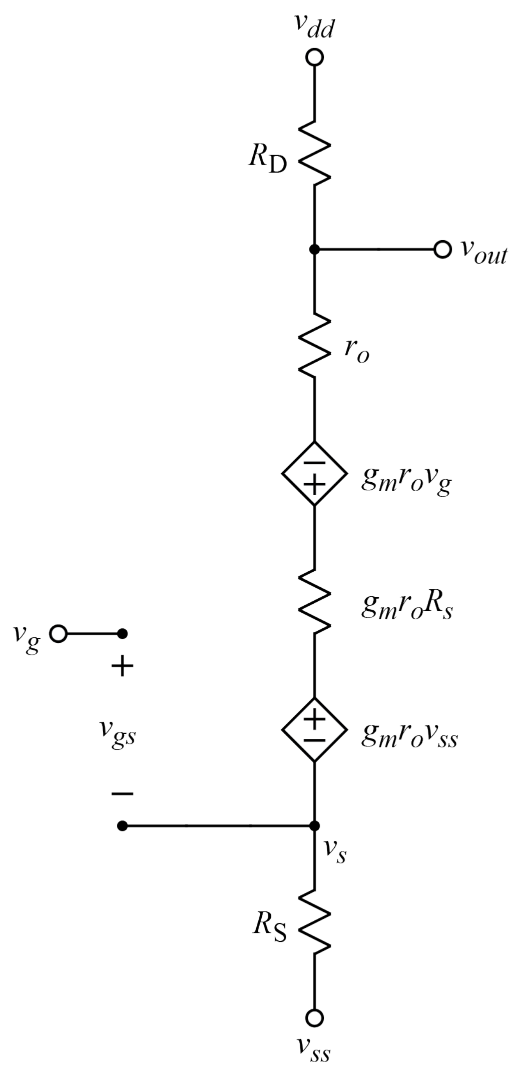

Fig. 4. Universal AC model for FET.

We have the following simplifications to the universal model in the case of our CG amplifier with degeneration:

$v_g = 0$ V (no AC signal) $v_{dd} = 0$ V (no AC signal)

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

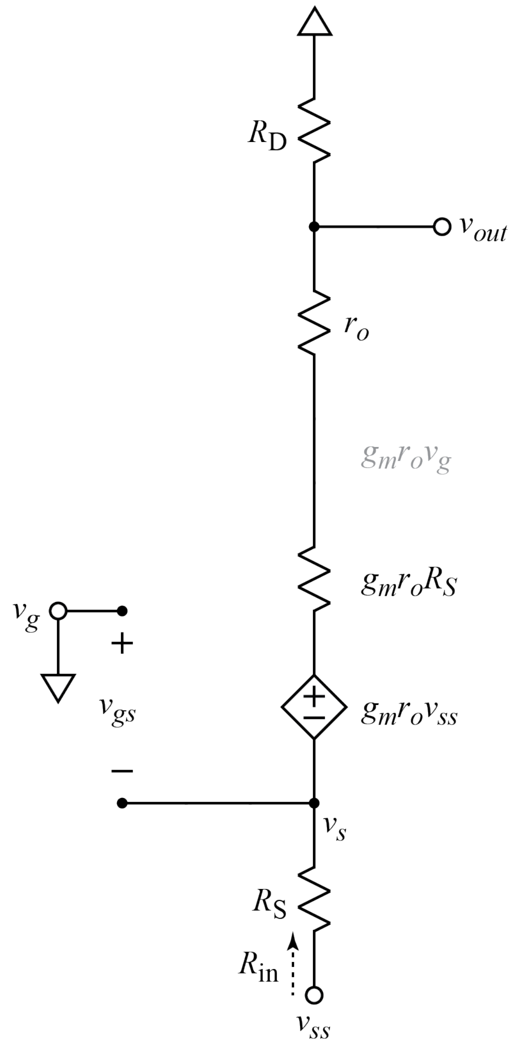

Fig. 5. Universal model applied to calculation of R_{in} for CG amplifier.

The input resistance is the applied voltage, v_{ss}, divided by the current flowing into the circuit at the vss terminal. When calculating the current, we treat v_{ss} as a voltage source, and we add the $g_m r_o v_{ss}$ voltage to it. Then we divide by the total resistance.

$$R_{in} = \frac{v}{i} = \frac{v_{ss}}{\dfrac{v_{ss} + g_m r_o v_{ss}}{R_S + g_m r_o R_S + r_o + R_D}} = \frac{R_S + g_m r_o R_S + r_o + R_D}{1 + g_m r_o}$$

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

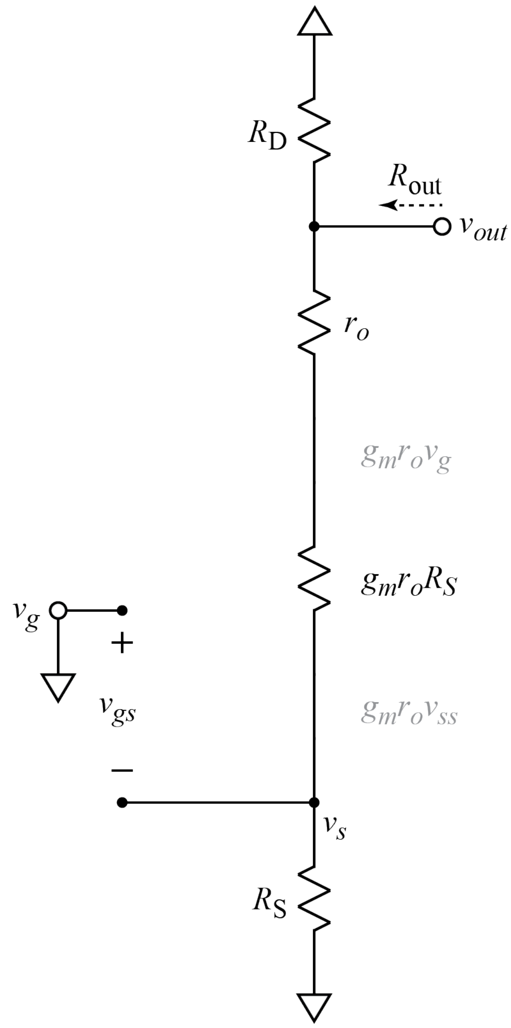

Fig. 6. Universal model applied to calculation of R_{out} for CG amplifier.

The output resistance is resistances in parallel to reference.

$$R_{out} = R_D \parallel (r_o + g_m r_o R_S + R_S)$$

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

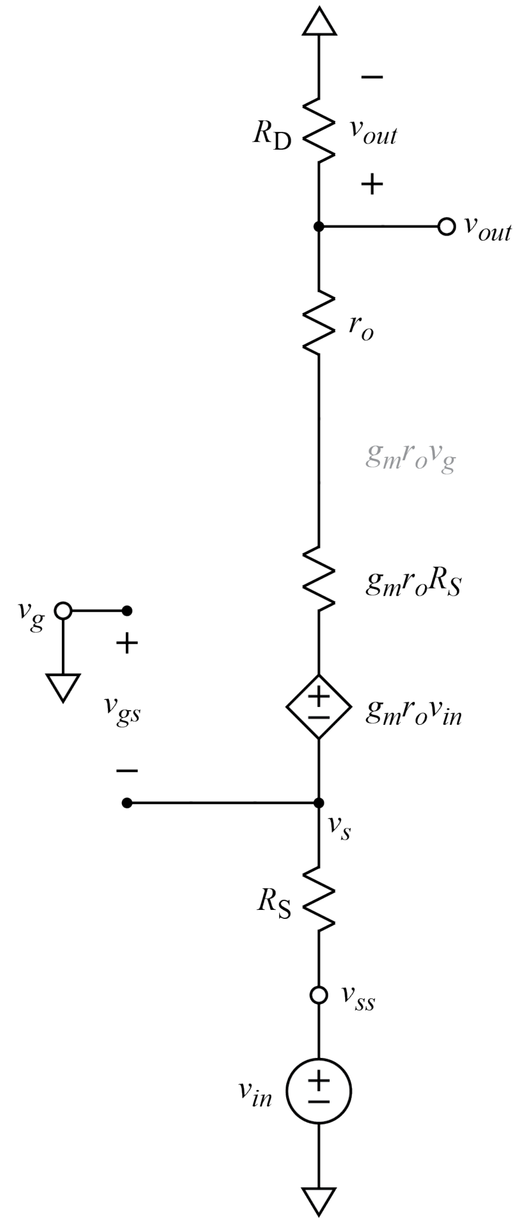

Fig. 7. Universal model applied to calculation of A_v for CG amplifier.

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 voltage divider.

$$v_{out} = (1 + g_m r_o) v_{in} \frac{R_\mathrm{D}}{R_\mathrm{D} + r_o + g_m r_o R_\mathrm{S} + R_S} \quad \Rightarrow \quad A_\mathrm{v} = \frac{(1 + g_m r_o) R_\mathrm{D}}{R_\mathrm{D} + r_o + g_m r_o R_\mathrm{S} + R_S}$$

If we let r_o approach infinity, we get $A_\mathrm{v} = g_m R_\mathrm{D}/(1 + g_m R_\mathrm{S})$.

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