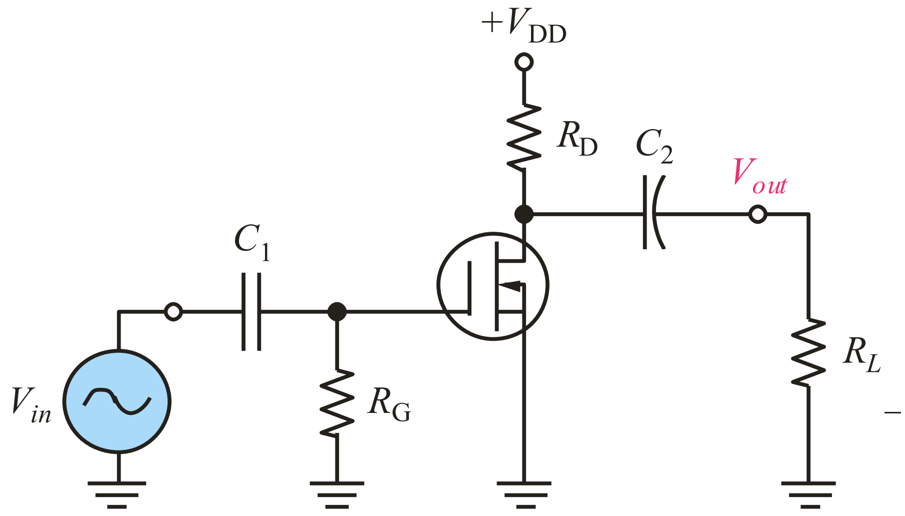
Lecture 13: Field Effect Transistors (FETs) (4)

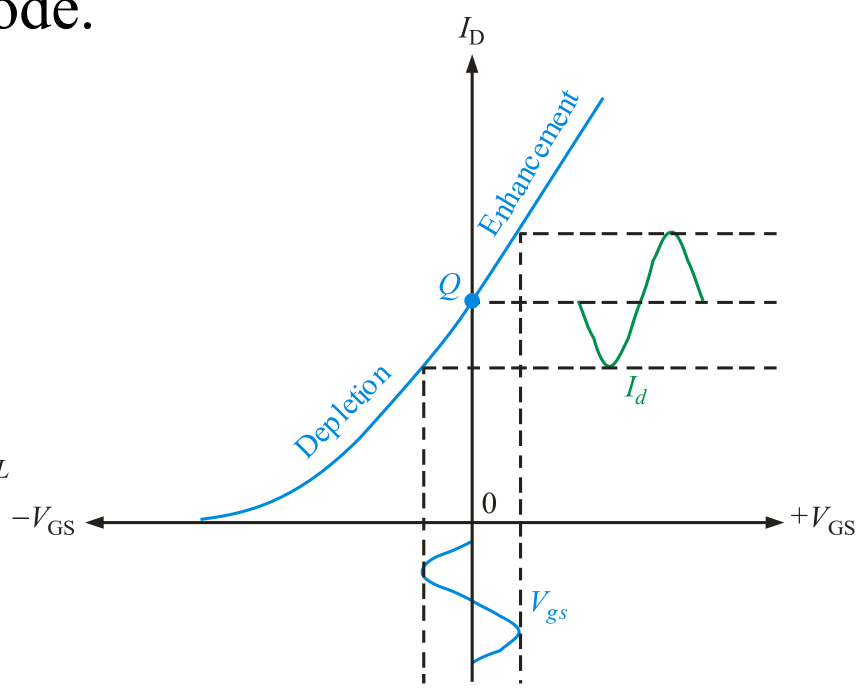
Chapter-9: Sections 9.2-9.3 (Floyd, 10Th Edition)

Common Drain Amplifiers, Common Gate Amplifiers, Cascode Amplifier, Examples

D-MOSFET

In operation, the D-MOSFET has the unique property in that it can be operated with zero bias, allowing the signal to swing above and below ground. This means that it can operate in either D-mode or E-mode.



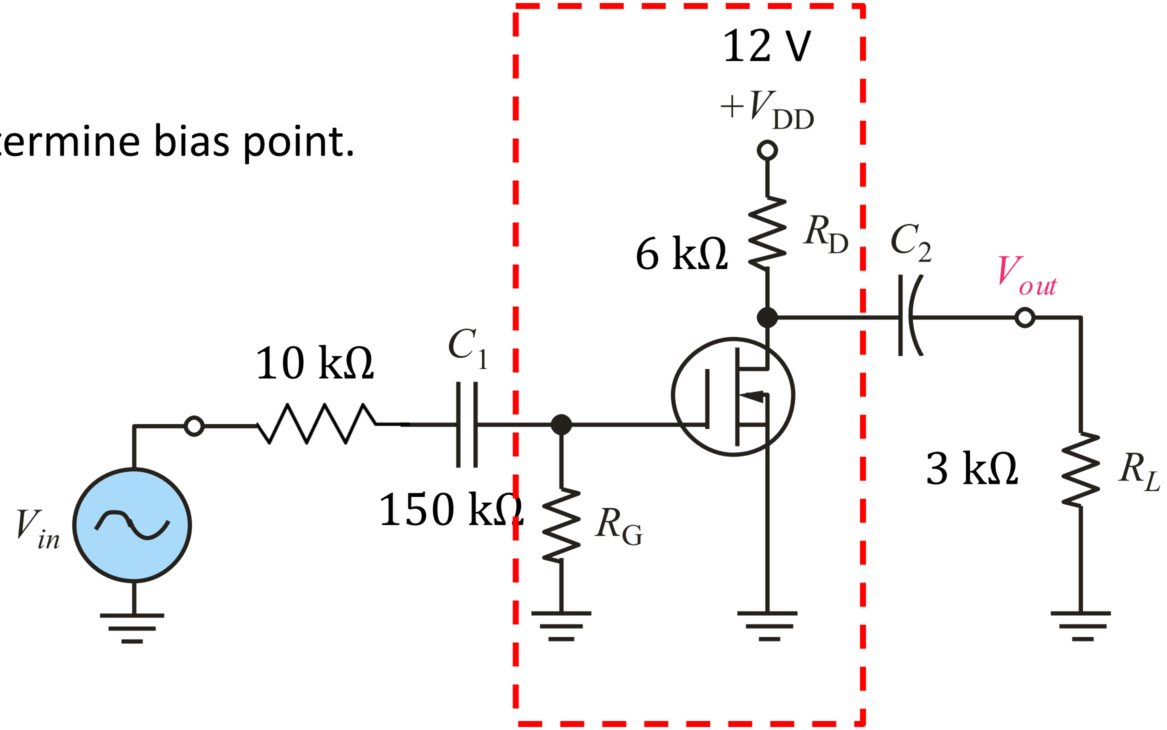


Example for D-MOSFET

Problem 1: Determine the gain of the following D-MOSFET amplifier. Given values are I_{DSS} = 1 mA and $V_{GS(off)}$= − 2 V.

Solution 1:

First, we perform DC analysis to determine bias point.



As $I_G = 0\ A,\ V_G = 0\ V$

$$V_{GS} = V_G - V_s = 0 - 0 = 0\ \text{V}$$

Assuming saturation,

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

Example for D-MOSFET

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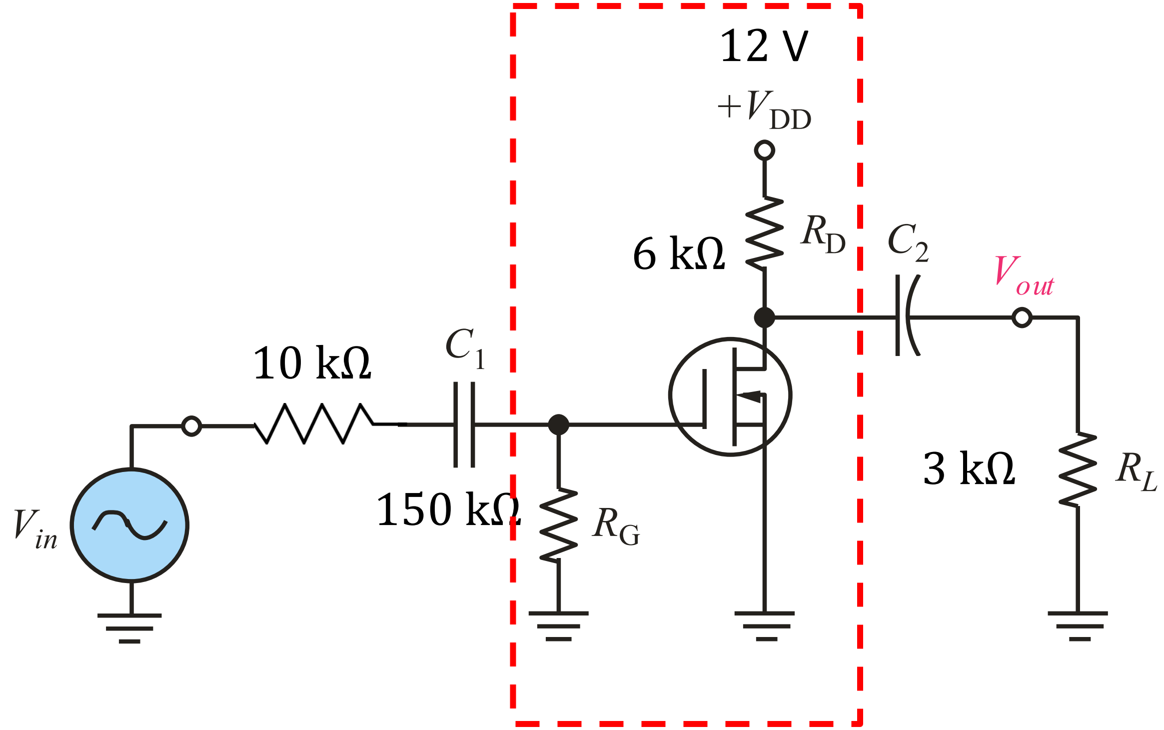
Solution 1:



$$g_m = \frac{\Delta I_{DS}}{\Delta V_{GS}}$$

$$g_m = \frac{-2I_{DSS}}{V_{GS(off)}}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$$

$$V_{GS} = 0 \text{ V}$$

$$I_{DS} = I_{DSS} = 1\,mA$$

$$g_m = \frac{-2\times 1mA}{-2} = 1\,mA/V$$

Example for D-MOSFET

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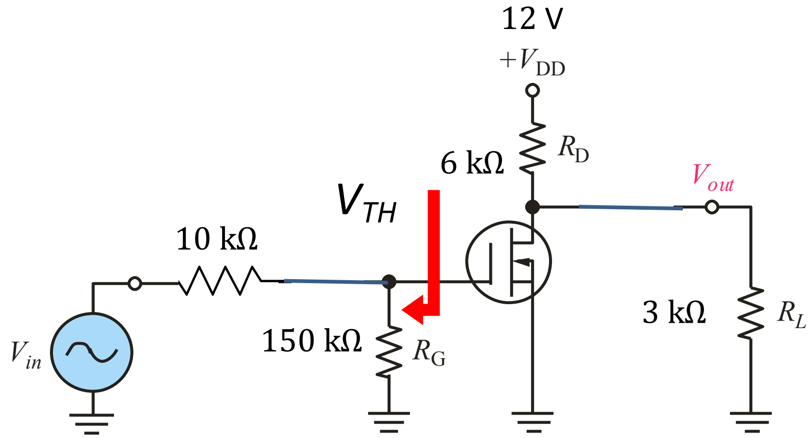
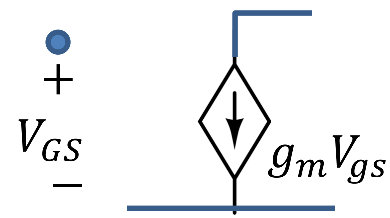


Solution 1:

$$V_{TH} = 0.937V_{in} \qquad R_{TH} = 9.375\ k\Omega$$

$$R_T = R_L||R_D = 6k||3k = 2k\Omega$$

- Now we perform the small signal analysis.

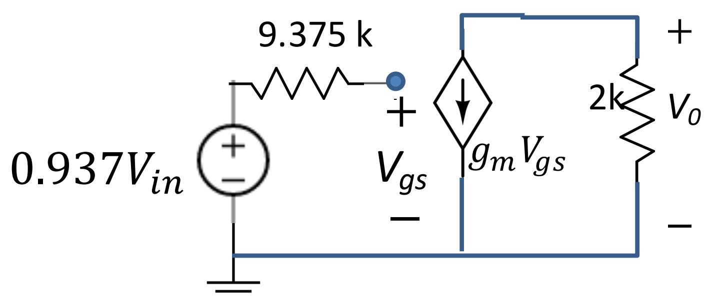


$$V_0 = -g_m \times R_T \times V_{gs}$$

$$V_0 = -1mA \times 0.937V_{in} \times 2k\Omega$$

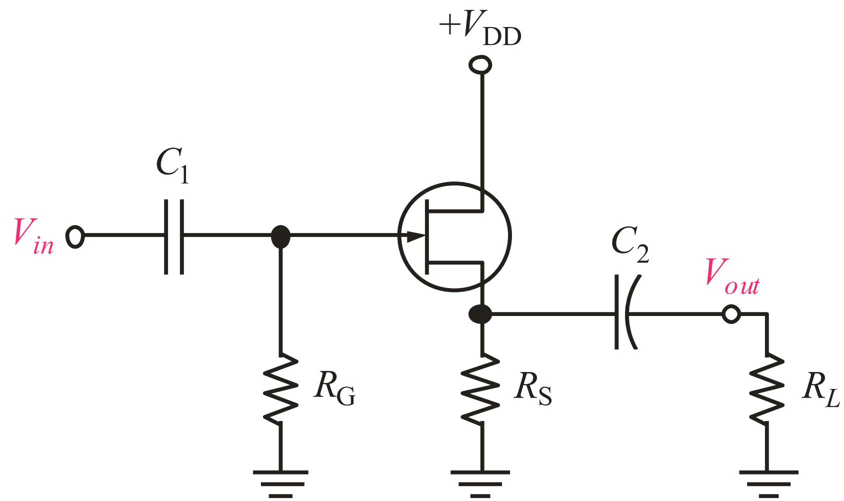
$$V_0 = -1.875V_{in}$$

$$\frac{V_0}{V_{in}} = -1.875$$



Common Drain Amplifier

In a CD amplifier, the input signal is applied to the gate and the output signal is taken from the source. There is no drain resistor, because it is *common* to the input and output signals.



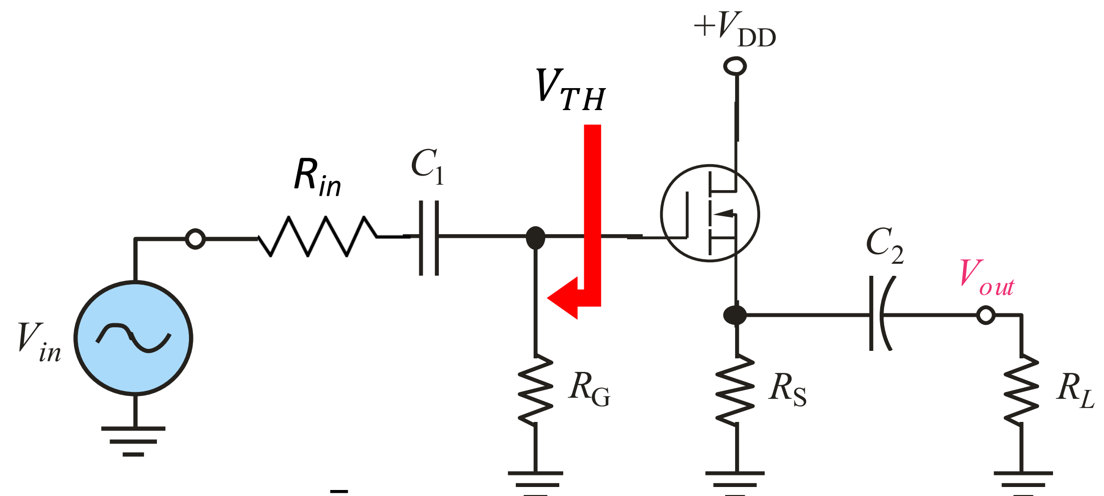
The voltage gain is given by the equation $A_v = \dfrac{g_m R_s'}{1 + g_m R_s'}$.

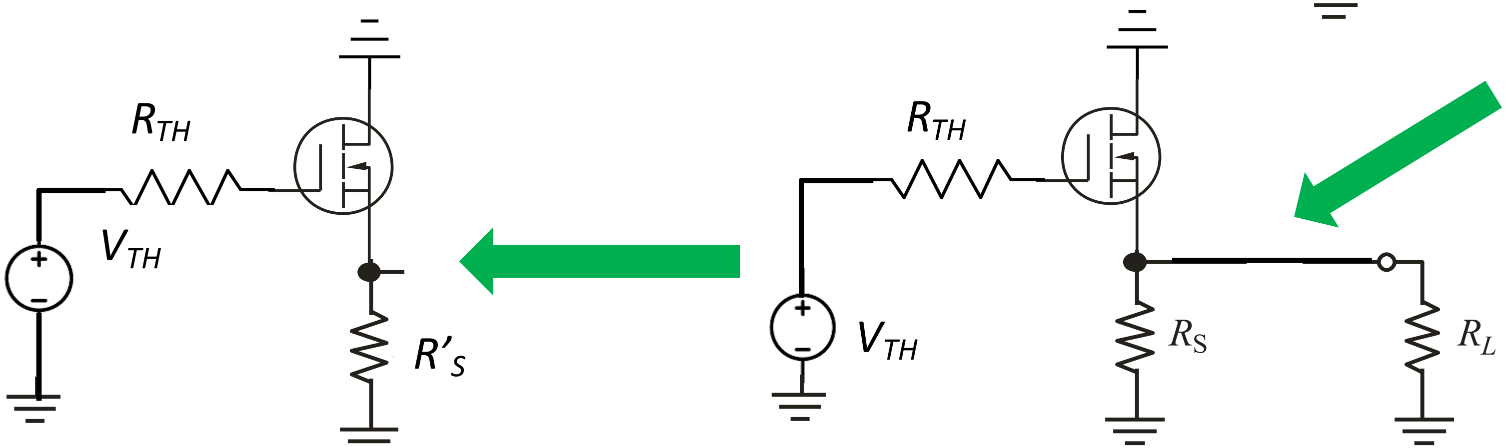
The voltage gain is always < 1, but the power gain is not.

Example for Common Drain Amplifier

Problem 2: Derive the expression for the gain and input resistance for the common drain amplifier.

Solution 2:

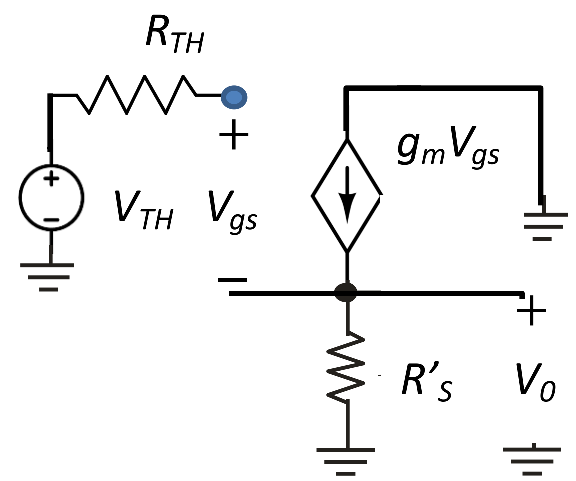




Example for Common Drain Amplifier

Problem 2: Derive the expression for the gain and input resistance for the common drain amplifier.

Solution 2:



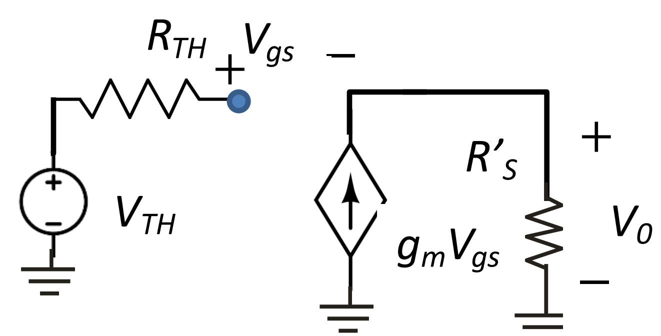
$$V_{TH} = V_{gs} + g_m V_{gs} R'_s$$

$$V_{gs} = \frac{V_{TH}}{(1 + g_m R'_s)}$$

$$V_0 = g_m V_{gs} R'_s$$

$$\frac{V_0}{V_{TH}} = \frac{g_m R'_s}{1 + g_m R'_s} \cong 1$$

Near unity gain amplifier



$$R_{in} = R_{in(gate)} || R_G \qquad R_{in(gate)} = \frac{V_{GS}}{I_{GSS}}$$

Example for Common Drain Amplifier

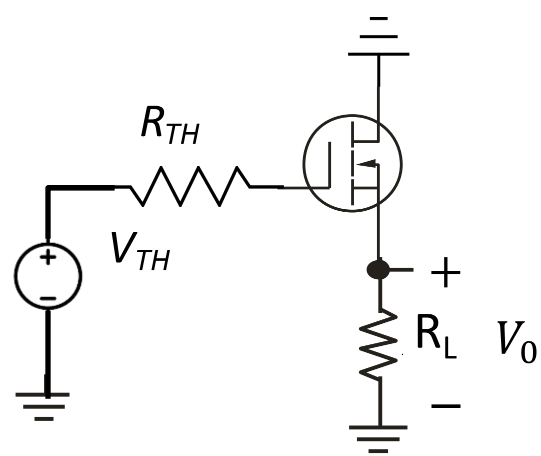
Problem 3: Considering the derived small signal model, find the voltage gain if V_{TH}=0.99 V_{in}, g_m=0.50 mA/V and R_L=10.7 kΩ.

Solution 3:

$$Gain1 = \frac{V_0}{V_{TH}} = \frac{g_m R_L}{1 + g_m R_L}$$

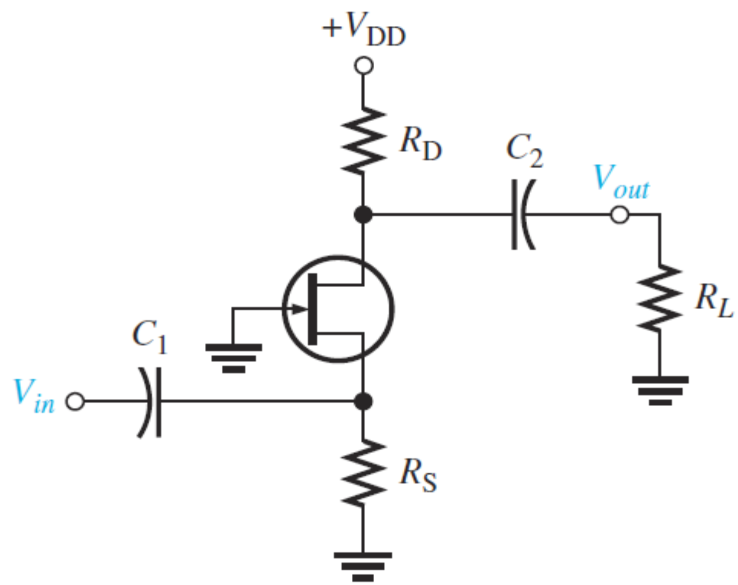
$$Gain1 = \frac{0.5\times10^{-3}\times10.7\times10^3}{1 + 0.5\times10^{-3}\times10.7\times10^3} = 0.84$$

$$Gain = \frac{V_0}{V_{in}} = \frac{V_0}{V_{TH}}\times\frac{V_{TH}}{V_{in}} = 0.84\times0.99 = 0.83$$



Common Gate Amplifier

The input is applied to the Source and the output is collected from the Drain. The Gate is grounded and is common to both the input and the output.



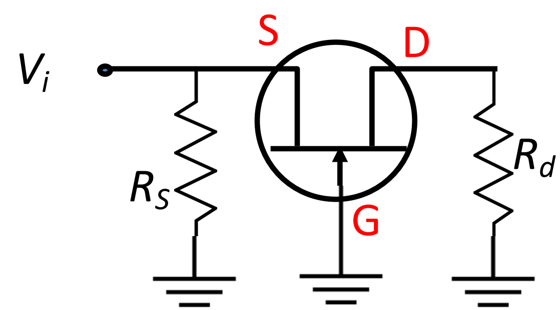
Voltage gain $A_v = g_m\ (R_D // R_L)$

Low input resistance $R_{in} = 1/g_m$

Example for Common-Gate Amplifier

Problem 4: Find the gain expression for the JFET common gate. amplifier.

Solution 4:



At the signal input node (**S**),

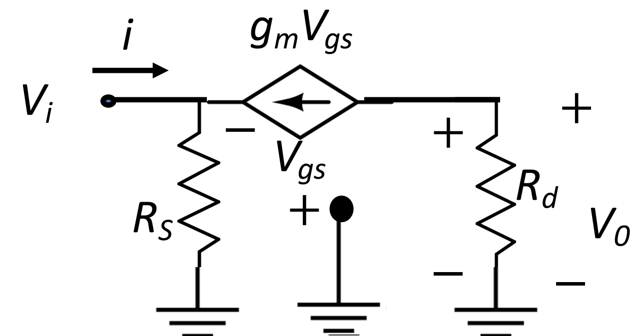
$$V_i = -V_{gs}$$

$$V_0 = -g_m V_{gs} R_d$$

$$R_d = R_D || R_L$$

$$V_0 = g_m R_d V_i$$

$$Gain = \frac{V_0}{V_i} = g_m R_d$$



$$i = -g_m V_{gs} - \frac{V_{gs}}{R_s}$$

$$Input\ resistance = \frac{\boldsymbol{V_i}}{\boldsymbol{i}} \cong \frac{\mathbf{1}}{\boldsymbol{g_m}}$$

Example for Common-Gate Amplifier

Problem 5: Find the gain of the common gate E-MOSFET amplifier if V_{TH}=0.99 V_{in}, g_m=0.5 mS, R_{TH}=50 Ω, and R_L=100 kΩ.

Solution 5:

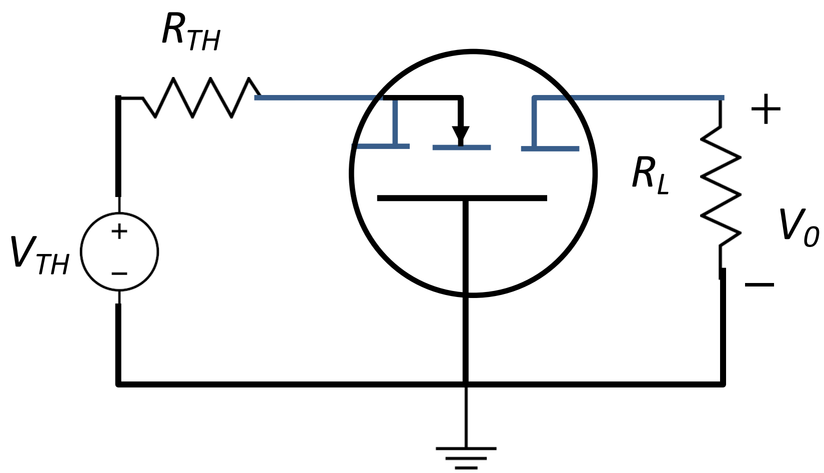
$$gain = g_m R = 0.5 \times 10^{-3} \times 10^{5} = 50$$

$$gain = \frac{V_0}{V_{TH}} = 50$$

If $V_{TH} = 0.99 V_{in}$

$$gain = \frac{V_0}{V_{in}} = 50 \times 0.99$$

$$gain = 49.5$$



Cascode Amplifier

The Cascode connection is a combination of CS and CG amplifiers. This forms a good high-frequency amplifier.