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1946

BME 202 Electronics

Lecture 12: FET Amplifiers

Introduction

FETs provide:

- Excellent voltage gain
- High input impedance
- Low-power consumption
- Good frequency response

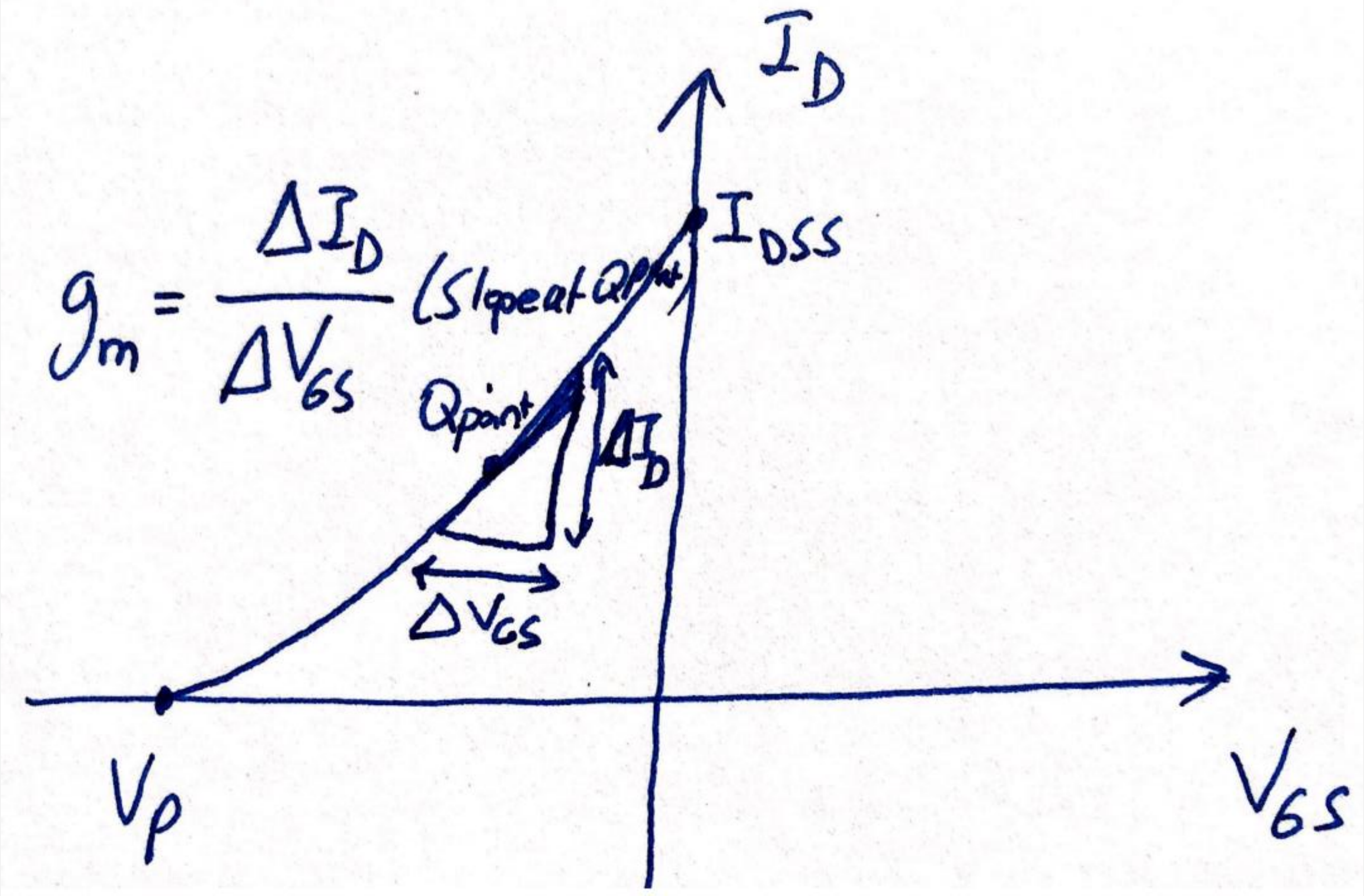
FET Small-Signal Model

Transconductance: The ratio of a change in I_D to the corresponding change in V_{GS}

Transconductance is denoted g_m and given by:

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$

Geographical Determination of gm



Mathematical Definitions of gm

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$g_m = \frac{2I_{DSS}}{|V_P|}\left[1 - \frac{V_{GS}}{V_P}\right]$$

For $V_{GS} = 0$ V

$$g_{m0} = \frac{2I_{DSS}}{|V_P|}$$

$$g_m = g_{m0}\left[1 - \frac{V_{GS}}{V_P}\right] = g_{m0}\sqrt{\frac{I_D}{I_{DSS}}}$$

FET Impedence

Input impedance:

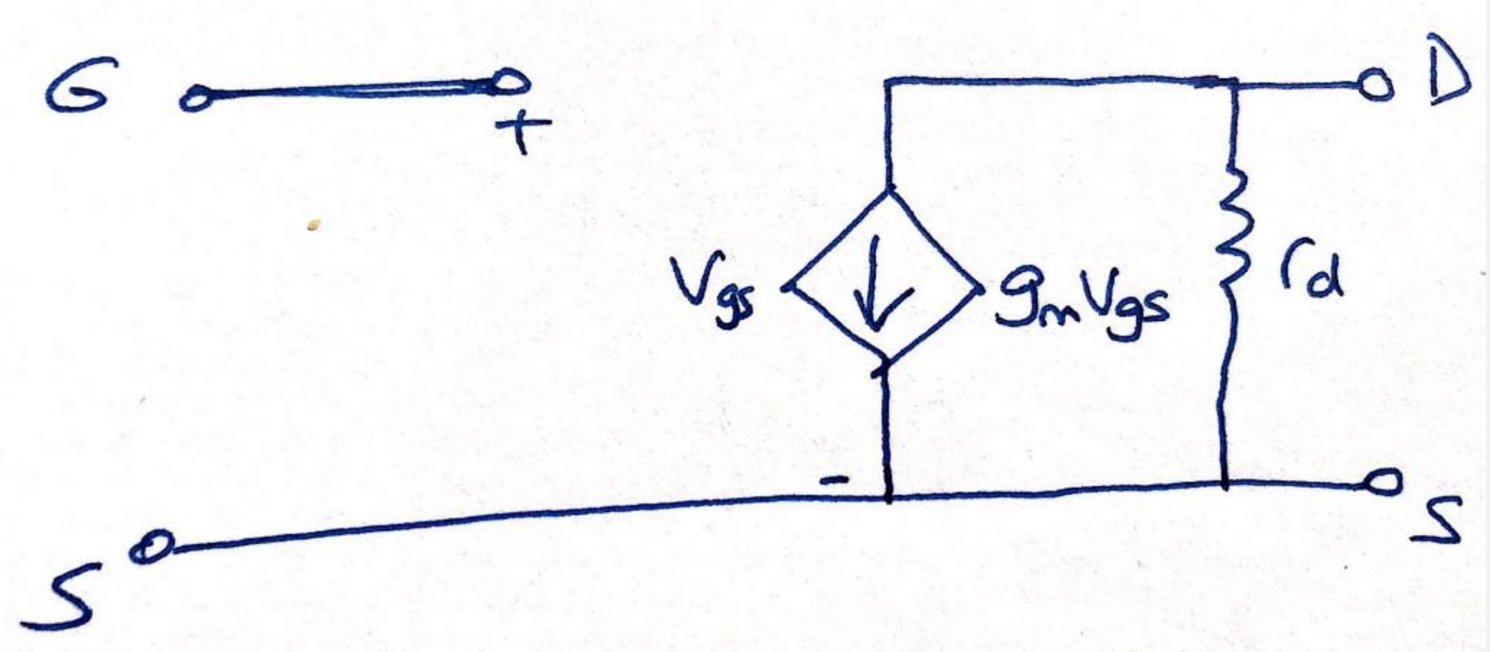
$$Z_i = \infty\,\Omega$$

Output Impedance:

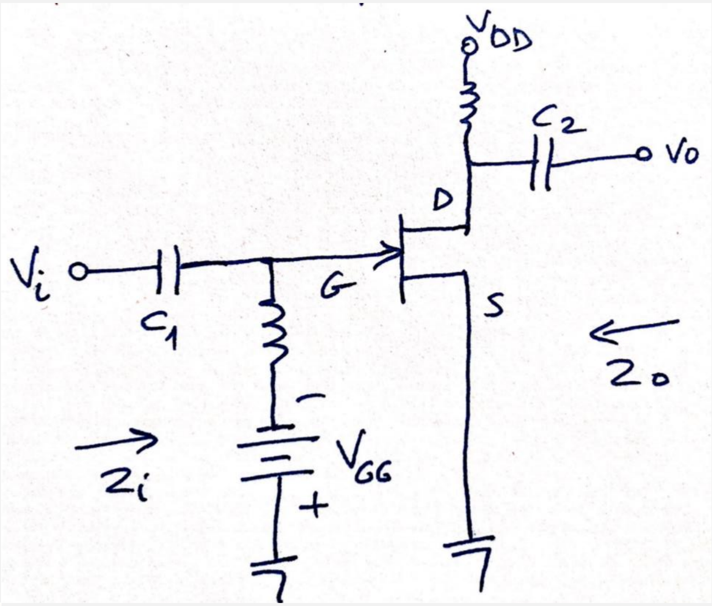
$$Z_o = r_d = \frac{1}{y_{os}} \qquad \text{where} \qquad r_d = \left.\frac{\Delta V_{DS}}{\Delta I_D}\right|_{V_{GS} = \text{constant}}$$

y_{os}= admittance parameter listed on FET spec sheets

FET AC Equivalent Circuit

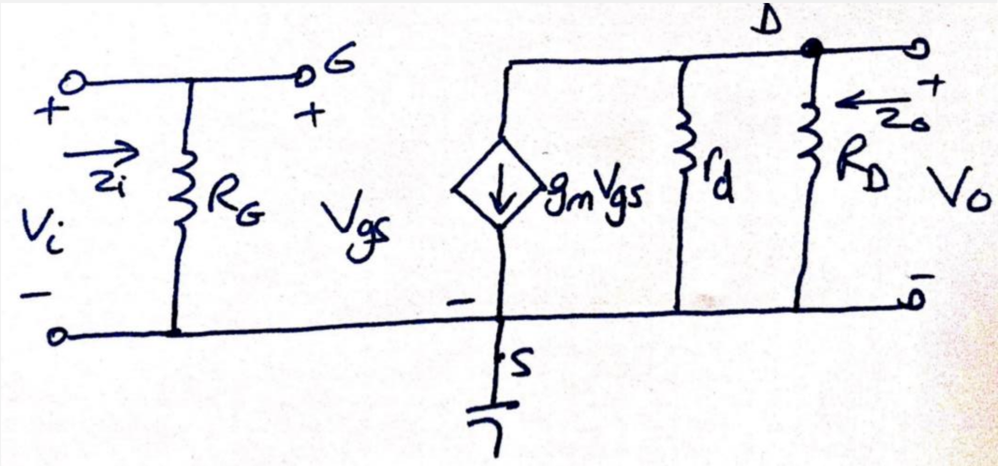


Common-Source (CS) Fixed-Bias



The input is applied to the gate and the output is taken from the drain

There is a 180° phase shift between the circuit input and output



Calculations

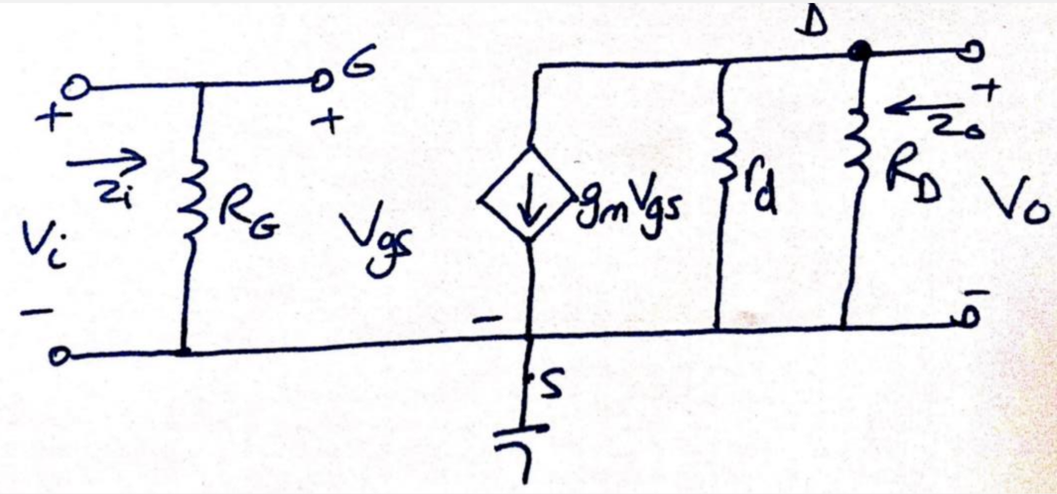
Input impedance:

$$Z_i = R_G$$

Output impedance:

$$Z_o = R_D || r_d$$

$$Z_o \cong R_D \Big|_{r_d \geq 10R_D}$$



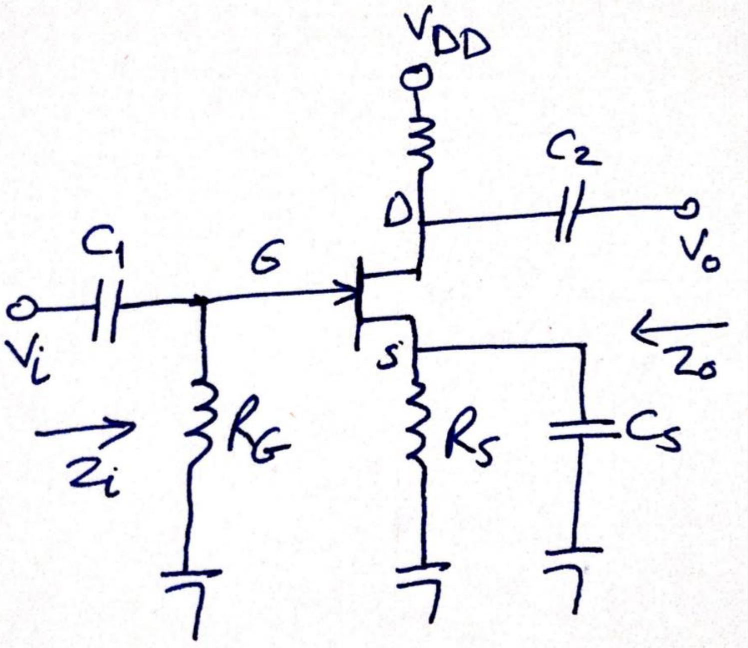
Voltage gain:

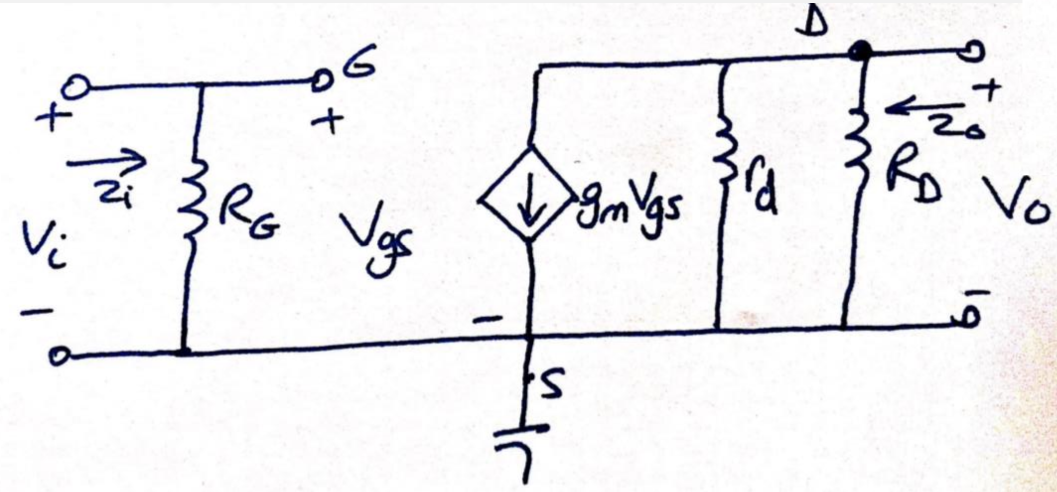
$$A_v = \frac{V_o}{V_i} = -g_m (r_d || R_D)$$

$$A_v = \frac{V_o}{V_i} = -g_m R_D \Big|_{r_d \geq 10R_D}$$

Common-Source (CS) Self-Bias

This is a common-source amplifier configuration, so the input is applied to the gate and the output is taken from the drain.





There is a 180° phase shift between input and output.

Calculations

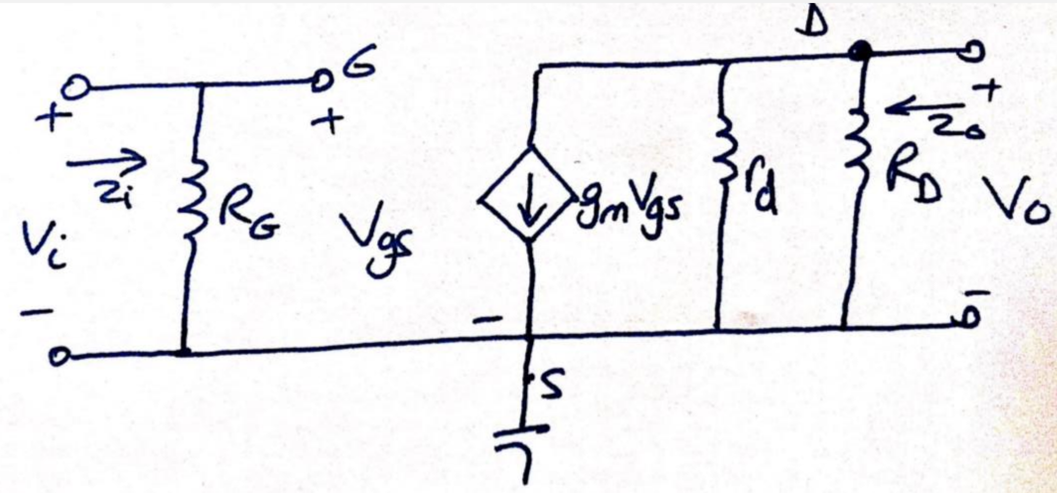
Input impedance:

$$Z_i = R_G$$

Output impedance:

$$Z_o = r_d || R_D$$

$$Z_o \cong R_D \Big|_{r_d \geq 10 R_D}$$



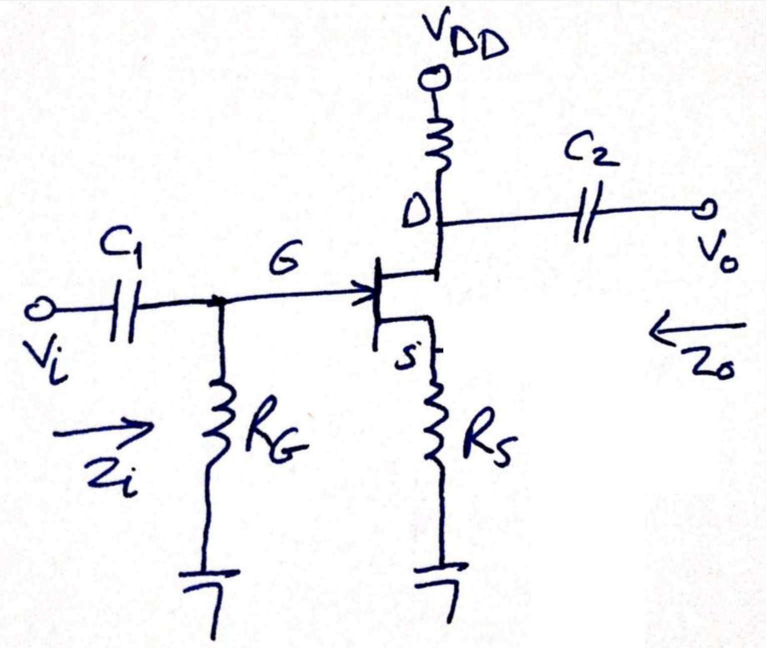
Voltage gain:

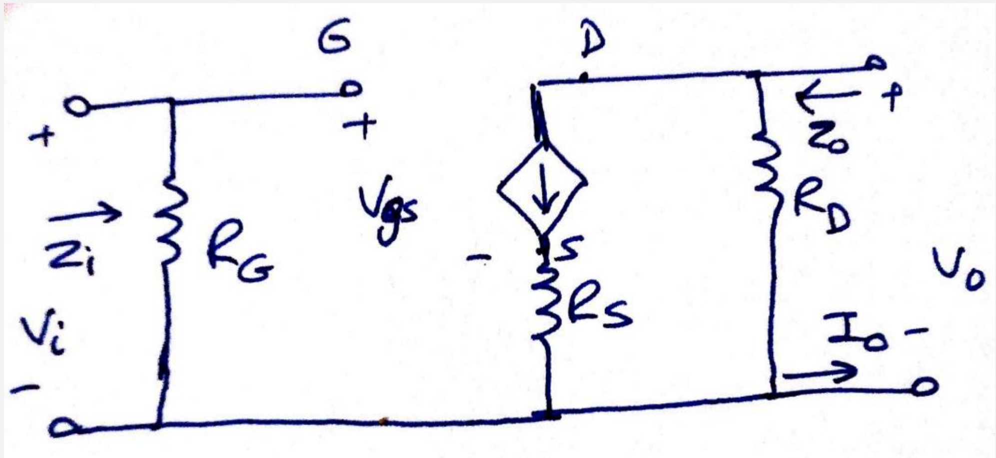
$$A_v = -g_m (r_d || R_D)$$

$$A_v = -g_m R_D \Big|_{r_d \geq 10 R_D}$$

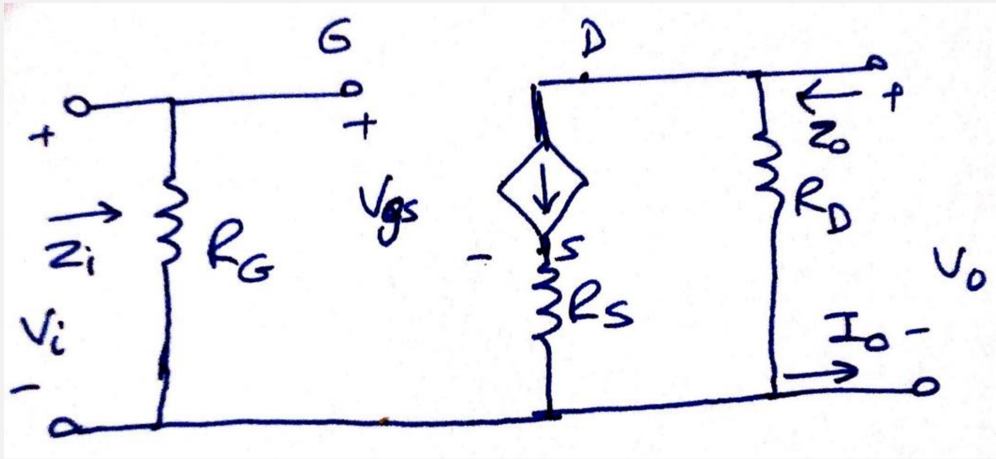
Common-Source (CS) Self-Bias

Removing C_s affects the gain of the circuit.





Calculations



Input impedance:

$$Z_i = R_G$$

Output impedance:

$$Z_o \cong R_D \Big|_{r_d \geq 10R_D}$$

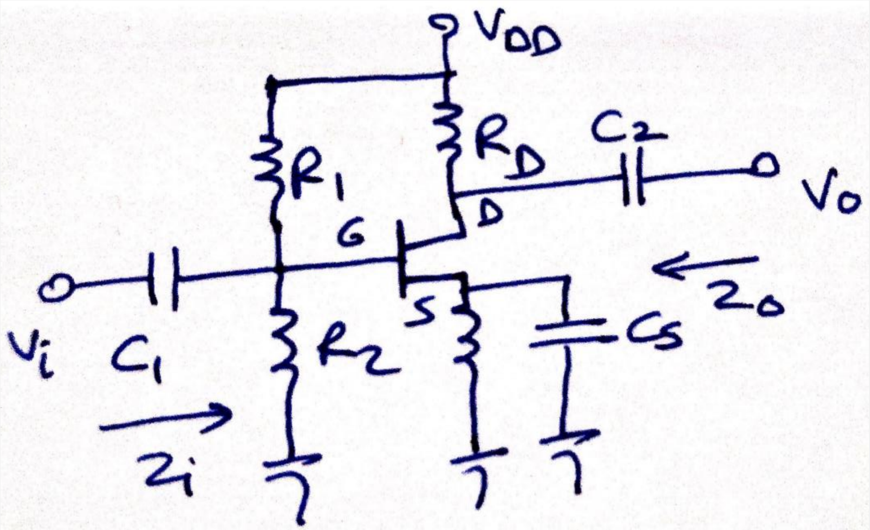
Voltage gain:

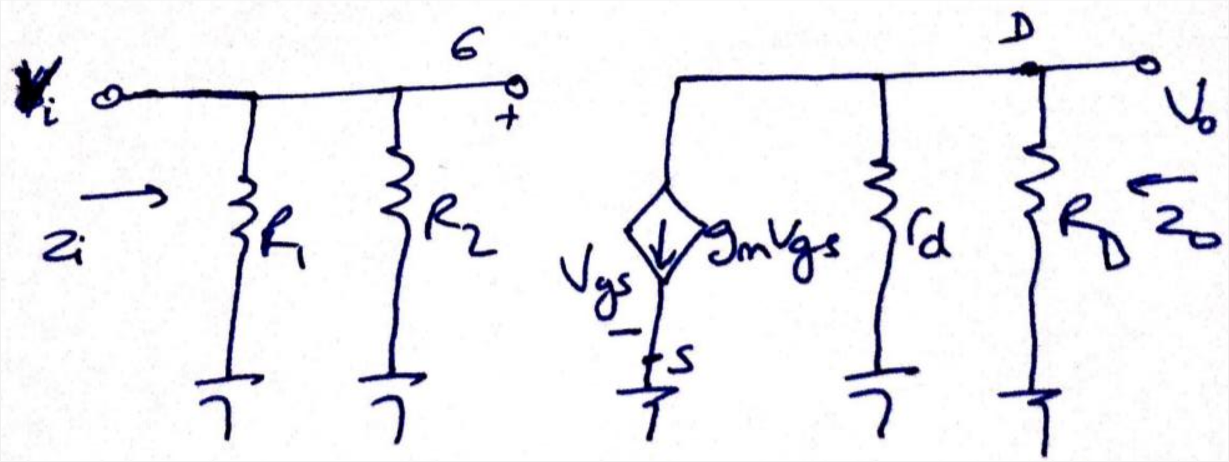
$$A_v = \frac{V_o}{V_i} = -\frac{g_m R_D}{1 + g_m R_S + \dfrac{R_D + R_S}{r_d}}$$

$$A_v = \frac{V_o}{V_i} = -\frac{g_m R_D}{1 + g_m R_S}\Bigg|_{r_d \geq 10(R_D + R_S)}$$

Common-Source (CS) Voltage-Divider Bias

This is a common-source amplifier configuration, so the input is applied to the gate and the output is taken from the drain.



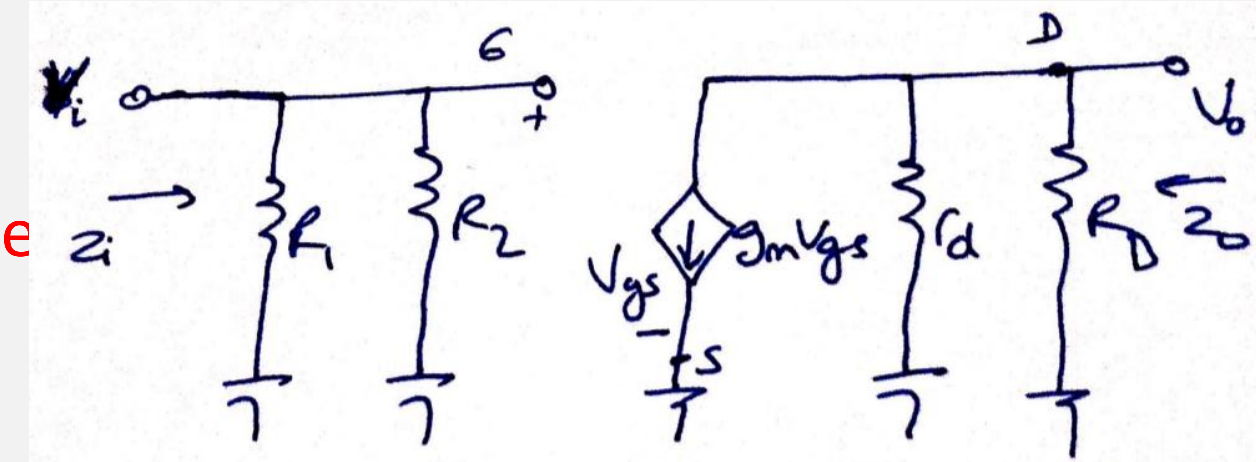


Impedances

Input impedance:

$$Z_i = R_1 || R_2$$

Output impedance



$$Z_o = r_d || R_D$$

$$Z_o \cong R_D \Big|_{r_d \geq 10 R_D}$$

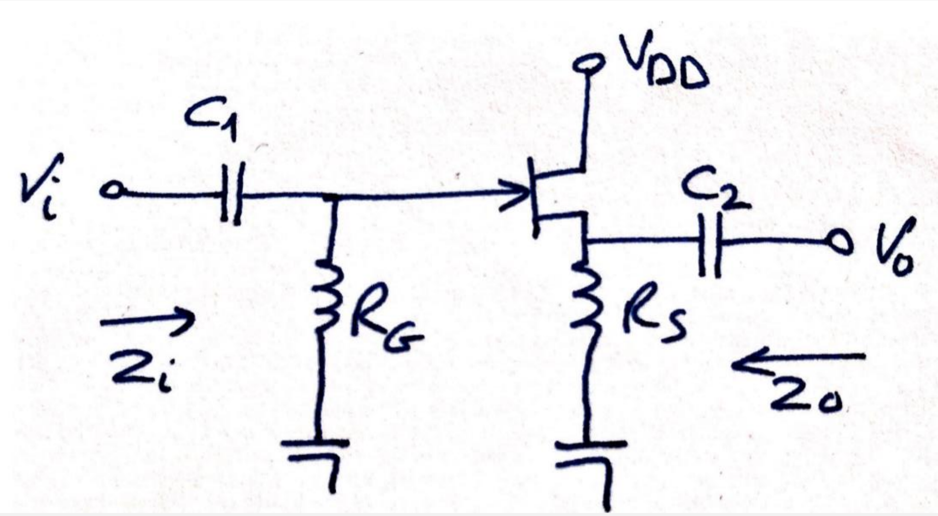
Voltage gain:

$$A_v = -g_m (r_d || R_D)$$

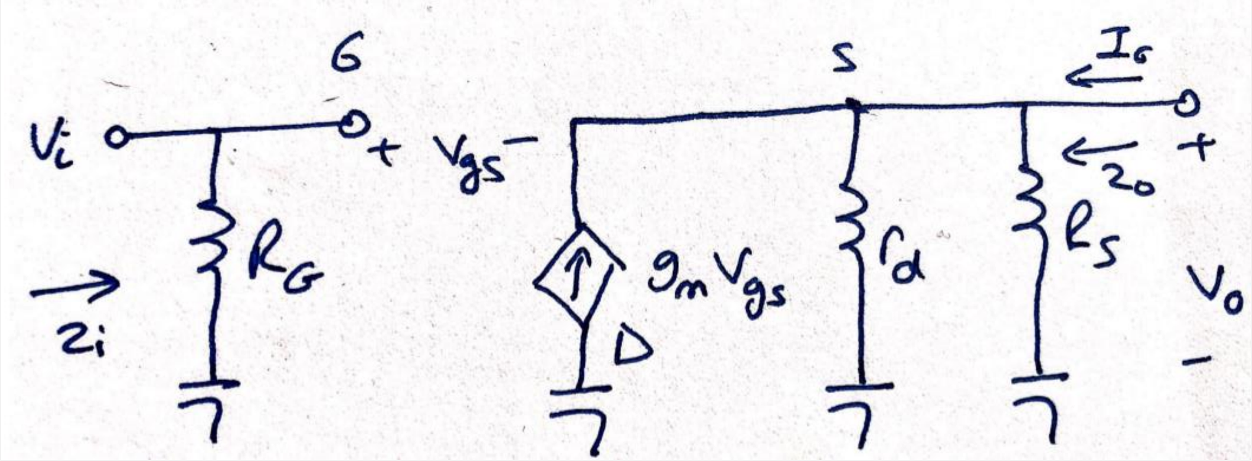
$$A_v = -g_m R_D \Big|_{r_d \geq 10 R_D}$$

Source Follower (Common-Drain)

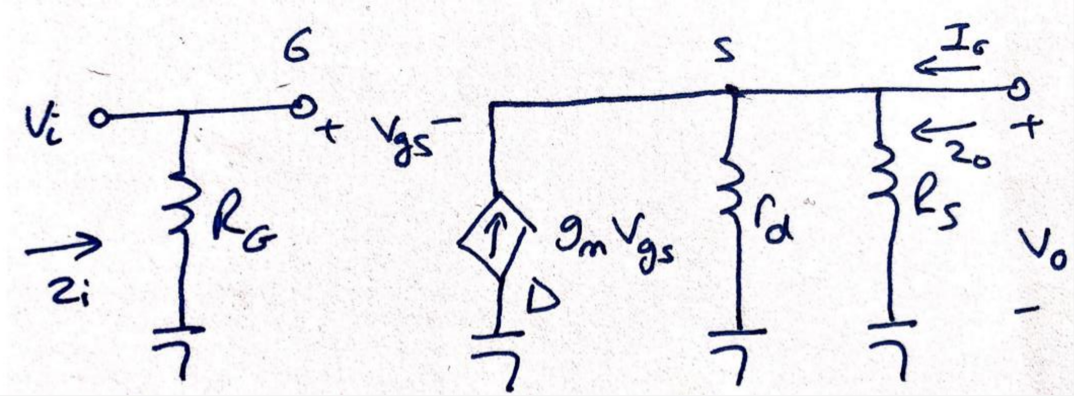
In a common-drain amplifier configuration, the input is applied to the gate, but the output is taken from the source.



There is no phase shift between input and output.



Impedances



Input impedance:

$$Z_i = R_G$$

Output impedance:

$$Z_o = r_d \,||\, R_S \,||\, \frac{1}{g_m}$$

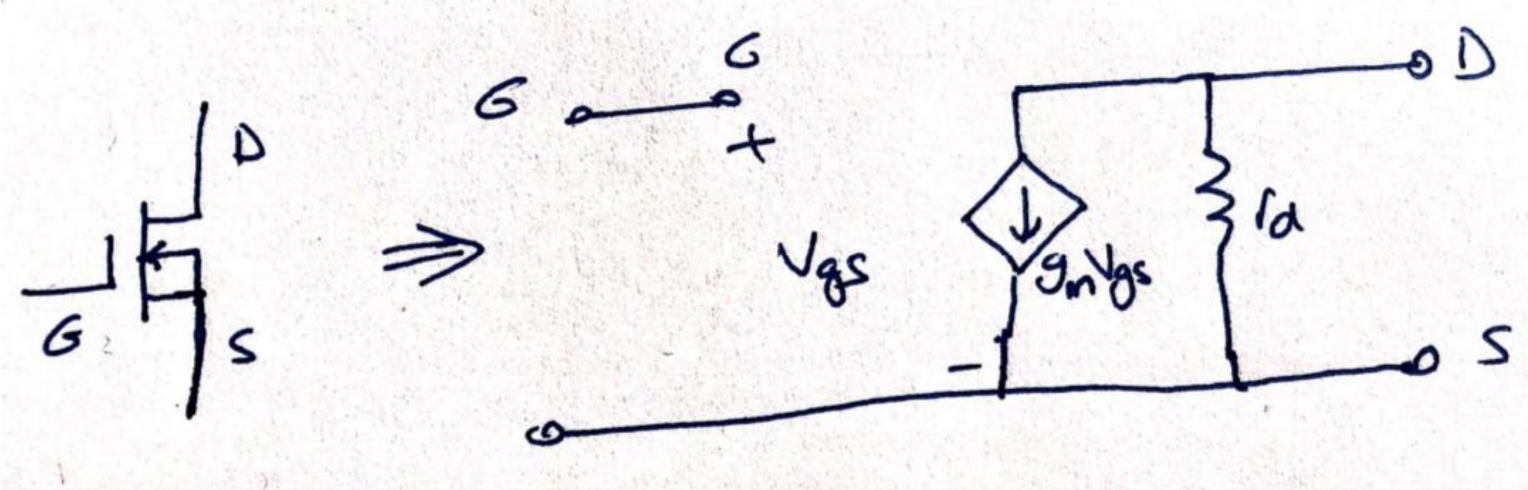
$$Z_o \cong R_S \,||\, \frac{1}{g_m}\bigg|_{r_d \geq 10R_S}$$

Voltage gain:

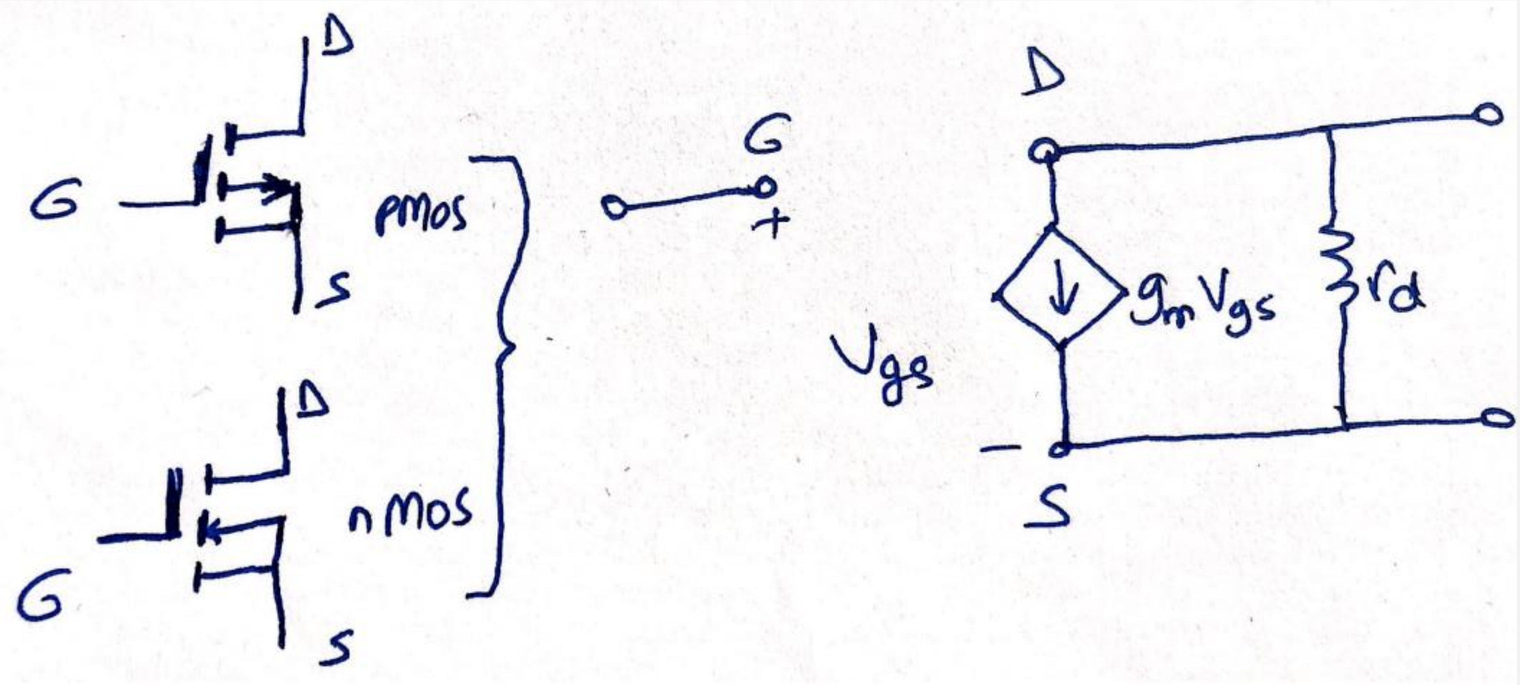
$$A_v = \frac{V_o}{V_i} = \frac{g_m(r_d \,||\, R_S)}{1+g_m(r_d \,||\, R_S)}$$

$$A_v = \frac{V_o}{V_i} = \frac{g_m R_S}{1+g_m R_S}\bigg|_{r_d \geq 10}$$

D-Type MOSFET AC Equivalent



E-Type MOSFET AC Equivalent



g_m and r_d can be found in the specification sheet for the FET.

Troubleshooting

Check the DC bias voltages:

If not correct check power supply, resistors, FET. Also check to ensure that the coupling capacitor between amplifier stages is OK.

Check the AC voltages:

If not correct check FET, capacitors and the loading effect of the next stage

Practical Applications

- Three-Channel Audio Mixer
- Silent Switching
- Phase Shift Networks
- Motion Detection System