High frequency analysis of FET

Common source amplifier at high frequencies:

Let Y_L is admittance corresponds to load Resistor $R_{L,}$

Y_{DS} admittance corresponds to C_{DS}

g_d Conductance corresponds to r_d

Y_{GD} is admittance corresponds to load Resistor $C_{GD,}$

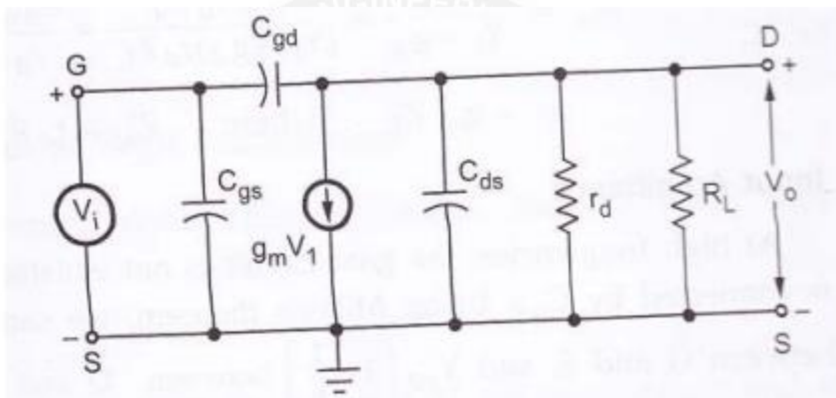

Figure 4.7.1 Small Signal Equivalent Circuit at high Frequencies

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$$Y = \frac{1}{Z} = Y_L + Y_{ds} + g_d + Y_{gd}$$

where

$$Y_L = \frac{1}{R_L}$$

$$Y_{ds} = j\omega C_{ds}$$

$$g_d = \frac{1}{r_d}$$

$$Y_{gd} = j\omega C_{gd}$$

$$I = -g_m V_i + V_i Y_{gd} = V_i(-g_m + Y_{gd})$$

Voltage gain:

The voltage gain for common source amplifier circuit with the load R_L is given by,

$$A_v = \frac{V_o}{V_i} = \frac{IZ}{V_i} = \frac{I}{V_i Y}$$

Substituting the values of I and Y from equations (2) and (3) we have,

$$A_v = \frac{-g_m + Y_{gd}}{Y_L + Y_{ds} + g_d + Y_{gd}}$$

At low frequencies, Y_{ds} and $Y_{gd} = 0$ and hence equation (4) reduces to

$$A_v = \frac{-g_m}{Y_L + g_d} = \frac{-g_m r_d Z_L}{(Y_L + g_d) r_d Z_L} = \frac{-g_m r_d Z_L}{r_d + Z_L}$$

$$= -g_m Z'_L \qquad \text{where} \qquad Z'_L = r_d \,||\, Z_L$$

Input Admittance:

$$Y_i = Y_{gs} + (1 - A_v) Y_{gd}$$

Input capacitance (Miller Effect):

$$A_v = -g_m R'_d \qquad \text{where} \qquad R'_d = r_d R_d$$

Substituting the value of A_v

$$\frac{Y_i}{j\omega} \equiv C_i = C_{gs} + (1 + g_m R'_d) C_{gd}$$

This increase in input capacitance C_i over the capacitance from gate to source is called Miller effect.

This input capacitance affects the gain at high frequencies in the operation of cascaded amplifiers. In cascaded amplifiers, the output from one stage is used as the input to a second amplifier. The input impedance of a second stage acts as a shunt across output of the first stage and R_d is shunted by the capacitance C_i.

Output Admittance:

From above figure, the output impedance is obtained by looking into the drain with the input voltage set equal to zero. If $V_i = 0$ in figure, r_d ,C_{ds} and C_{gd} in parallel. Hence the output admittance with R_L considered external to the amplifier is given by

$$Y_o = g_d + Y_{ds} + Y_{gd}$$

Common Drain Amplifier at High Frequencies:

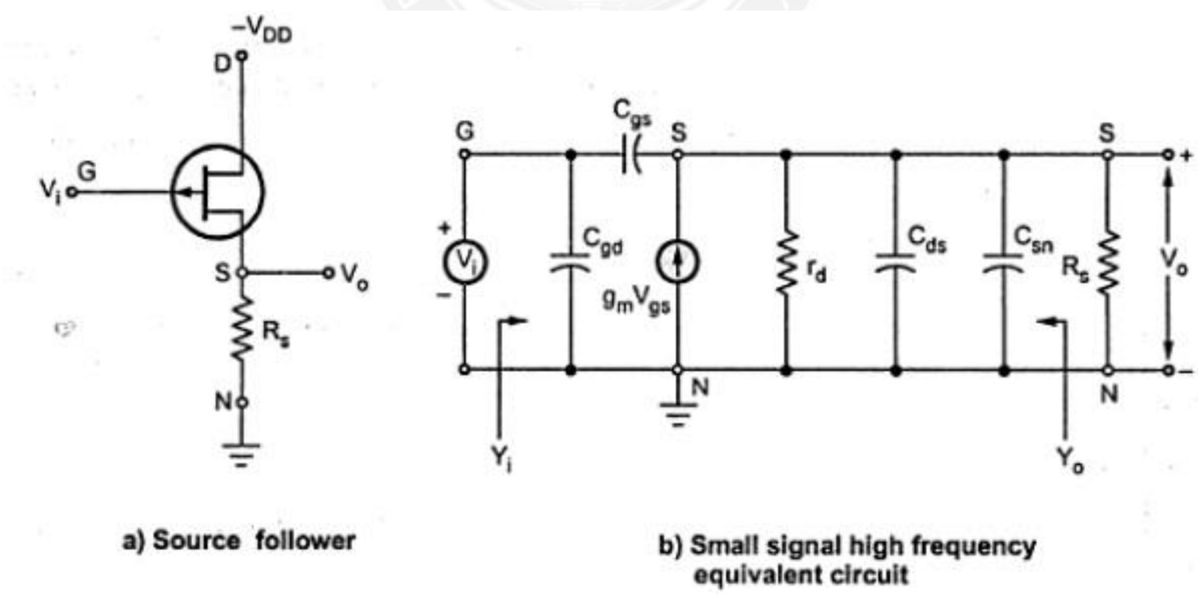

Figure 4.7.2 a Common Drain Amplifier Circuit (Source Follower) & 4.7.2 b, Small signal equivalent circuit at high frequencies

Diagram Source Brain Kart

Figure 4.7.2 a Common Drain Amplifier Circuit (Source Follower) & 4.7.2 b, Small signal equivalent circuit at high frequencies.

Voltage gain:

The output voltage V_o can be found from the product of the short circuit and the impedance between terminals S and N. Voltage gain is given by,

$$\frac{V_o}{V_i} = \frac{g_m + j\omega C_{gs}}{R_s + (g_m + g_d + j\omega C_T)}$$

where $C_T = C_{gs} + C_{ds} + C_{sn}$

$$A_v = \frac{(g_m + j\omega C_{gs})R_s}{1 + (g_m + g_d + j\omega C_T)R_s}$$

At low frequencies the gain reduces to

$$A_v = \frac{g_m R_s}{1 + (g_m + g_d)R_s}$$

Input Admittance:

Input Admittance Y_i can be obtained by applying Miller's theorem to C_{gs}. It is given by,

$$Y_i = j\omega C_{gd} + j\omega C_{gs}(1 - A_v) \approx j\omega C_{gd}$$

because $A_v \approx 1.$

Output Admittance:

Output Admittance Y_o with R_s considered external to the amplifier, it is given by

$$Y_o = g_m + g_d + j\omega C_T$$

At low frequencies, output resistance R_o is given by,

$$R_0 = \frac{1}{g_m + g_d} \approx \frac{1}{g_m} \qquad \text{since } g_m >> g_d.$$

Frequency Response of Common Source Amplifier:

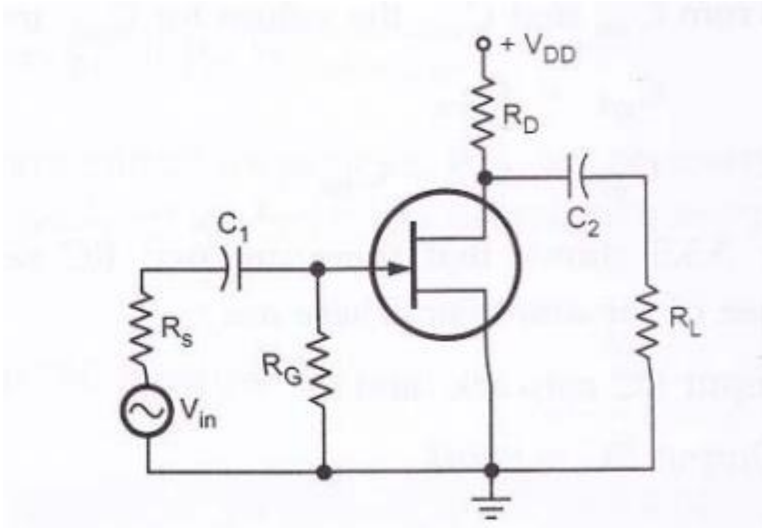

Figure 4.7.3 A typical RC Coupled common source amplifier

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Let us consider a typical common source amplifier as shown in the above figure 4.7.3.

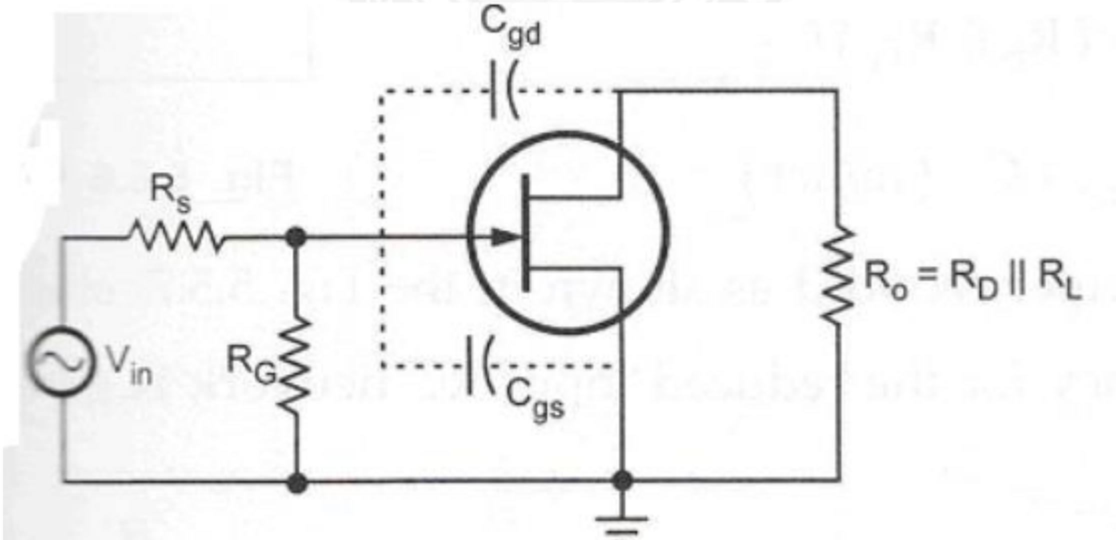

Figure 4.7.4 High Frequency Equivalent Circuit

Diagram Source Brain Kart

From above figure 4.7.4, it shows the high frequency equivalent circuit for the given amplifier circuit. It shows that at high frequencies coupling and bypass capacitors act as short circuits and do not affect the amplifier high frequency response. The equivalent circuit shows internal capacitances which affect the high frequency response.

Using Miller theorem, this high frequency equivalent circuit can be further simplified as follows:

The internal capacitance C_{gd} can be splitted into $C_{in(miller)}$ and $C_{out(miller)}$ as shown in the following figure.

Simplified high frequency equivalent circuit

$$C_{in\,(miller)} = C_{gd}\,(A_v + 1)$$

$$C_{out\,(miller)} = C_{gd}\,\frac{(A_v + 1)}{(A_v)}$$

Where

$$C_{gd} = C_{rss}$$

$$C_{gs} = C_{iss} - C_{rss}$$

From simplified high frequency equivalent circuit, it has two RC networks which affect the high frequency response of the amplifier. These are Input RC network and Output RC network