Draw circuit of common source amp

Comment on poles already found

\[ W_{c_1} = \frac{1}{C_c (R_{\text{sig}} + R_0)} \]

\[ W_{c_0} = \frac{1}{\frac{1}{C_s} Z_s} \quad \text{also a pole at } \frac{1}{R_{\text{ss}} C_s} \]

Comes from

\[ \text{Id}_o = \frac{U_g}{\frac{1}{C_m} + Z_s} = \frac{U_g}{\frac{1}{C_m} + R_c \parallel R_{\text{ss}}} \]

\[ A_{\text{det}} \]

\[ g_m R_0 \]

\[ \frac{g_m R_c}{R_{\text{ss}}} \]

\[ W_{R_{\text{ss}}} \]
The FET acts like a current source. Therefore:

\[ V_{th} = -g_m V_{gs} R_0 \]

\[ R_{th} = R_{th} = \frac{1}{g_m C_{c2}} + R_0 \]

Equivalent circuit:

\[ V_o = \frac{-R_L g_m V_{gs} R_0}{R_0 + R_L + R_{th}} \]

\[ C_{c2} = \frac{1}{(R_0 + R_L) C_{c2}} \]
$$U_0 = i_L R_L = \frac{id}{Z_L + R_p}$$

Note: We could have done analysis using Norton equivalent

$$i_L = \left(\frac{R_0}{R_0 + Z_L}\right) id$$

Current divider

$$U_0 = id \frac{R_0 R_L}{R_L + \frac{1}{j \omega c_c} + R_0} = \frac{R_0 R_L}{\frac{1}{j \omega c_c} + (R_0 + R_L)}$$

Pole at

$$\frac{1}{j \omega c_c} = R_0 + R_L$$

So, we have found 3 poles, all high pass. If the capacitive effects do not interact, i.e., poles are well separated (factor of 4 in frequency) then we can draw the Bode plot.
Let's go back to the 1st pole and consider the midband gain.

For this amp,
\[ A_m = \frac{R_o}{R_o + R_{sig} + R_g} - g_m \left( \frac{R_o}{R_o + R_g} \right) \]

Look at the 1st pole. The input divider becomes
\[ \frac{R_o}{R_o + R_{sig} + R_{C1}} \]

Using \( u_{C1} = \frac{1}{C_1 \left( R_o + R_{sig} \right)} \), the divider becomes
\[ R_o \left( \frac{1}{u_{C1} \cdot C_1} + \frac{1}{S \cdot C_1} \right) = R_o \frac{S}{u_{C1} \cdot C_1} + \frac{1}{C_1} \]

\[ = R_o \cdot u_{C1} \cdot C_1 \cdot \frac{S}{S + u_{C1}} = \frac{R_o}{R_o + R_{sig}} \cdot \frac{S}{S + u_{C1}} \]

We can use this to write
\[ \mathbf{A}(s, u_{C1}) = \frac{S}{S + u_{C1}} \cdot A_m \]

A similar approach can be used to include the other 2 poles, to obtain
Note that the freq. dependent gain for a single pole high pass has the form

\[ A(s) = \frac{s}{s + \omega_b} \]

If we have multiple poles that are well separated

\[ A \approx A_0 \left( \frac{s}{s + \omega_1} \right) \left( \frac{s}{s + \omega_2} \right) \left( \frac{s}{s + \omega_3} \right) \cdots \]
In low freq. analysis, the capacitors were external components. In high freq. analysis the capacitors are generally internal and unavoidable.

For the FET these capacitors arise from:
- Gate to body
- Gate to source (source usually tied to body)
- Gate to drain

![Diagram showing capacitors and their relationships]

In saturation mode, \( C_{gs} \approx \frac{2W}{3L} \cdot \text{Cox} \)

If we assume the body is tied to the source and neglect \( C_{db} \), usually a good assumption, we obtain:

![High Frequency model for NMOS FET diagram]

High Frequency model for NMOS FET
Circuit for measuring unity gain

 Unity gain \equiv \text{frequency where the input current is equal to the short circuit output current}

\[ I_0 = \frac{U_0}{R_s} \] 

Rs selected as small as possible

Notice here that the assumption that \( I_0 = 0 \) no longer holds at high frequency.

\[ \nu = \frac{c}{\lambda} = \frac{300}{\text{MHz}} \]

**HF**: 3 - 30 MHz
100 - 10 m

**VHF**: 30 - 300 MHz
10 - 1 m

**UHF**: 300 - 3,000 MHz
1 - 0.1 m

**SHF**: 3 - 30 GHz
100 - 10 cm

**Visible light**: 400 - 790 THz
750 - 390 nm
Analysis of the common source amplifier

Realvaw for high freq. analysis

Midband gain = \frac{R_G}{R_{sig} + R_G} - g_m \left( \frac{R_D}{R_L} \right)

Realvaw using high freq. equivalent model

Analysis would be simple except for \text{Cgd} which creates a feed back loop
Technique for treatment of Cgd

1. Note that \( i_o = g_m \cdot U_{gs} - i_{gd} \)

2. Assume that, near \( f_b \), \( i_{gd} \ll g_m U_{gs} \)
   so that, \( U_o \approx -g_m U_{gs} R' \)

3. Then, we can write, for the current \( i_{gd} \):
   \[
   i_{gd} = \frac{U_o - U_{gs}}{R_c \cdot C_{gd}} \approx \frac{U_{gs} + U_{gs} \cdot g_m \cdot R_c}{R_c \cdot C_{gd}}
   \]
   \[
   i_{gd} = U_{gs} \cdot \frac{1 + g_m \cdot R_c}{R_c \cdot C_{gd}}
   \]
   \[
   \frac{1}{S \cdot C_{gd}} = U_{gs} \cdot \frac{1 + g_m \cdot R_c}{C_{gd} \cdot S}
   \]

   Since we are neglecting the contribution of \( i_{gd} \) compared with \( g_m U_{gs} \), the following circuit can be used for analysis:

Using this, we obtain

we recognize this as a single time constant network
To simplify, Thevenize the input

\[ V_{\text{sig}}' = \frac{R_{\text{sig}}}{R_{\text{sig}} + R_L} \]

\[ R_{\text{sig}}' = R_{\text{sig}} \parallel R_L \]

\[ V_{\text{sig}}' = \frac{1}{R_{\text{sig}}' + \frac{1}{C'}} \]

Use this to write

\[ V_p = \frac{1}{s + \frac{1}{\omega_b}} \]

\[ V_{ip} = \frac{V_p}{\omega_b} \]

\[ V_o = V_{\text{sig}} \frac{\omega_b}{s + \omega_b} - g_m \left( R_{\text{L}} \parallel R_L \right) \]

\[ A(s) = -\left( \frac{\omega_b}{s + \omega_b} \right) g_m \left( R_{\text{L}} \parallel R_L \right) \]