Summary of results for common base configuration

\[ V_o \over V_s = \frac{R_c}{R_s} \frac{1}{(1 + j\omega R_c C_{\mu})(1 + j\omega C_{C_2} s_1)} \]

Notice that the impact of the feedback capacitor is small (i.e., the Miller capacitance is small, \( g_m \) is sufficiently large.)
Summary of results for low frequency

\[
\frac{V_o}{V_s} = \left( \frac{g_m}{G_c + G_L} \right) \left( \frac{G_s}{G_s + G_E + g_m + g_n} \right) \left( \frac{G_B + j\omega C_B}{j\omega C_B + G_B + \frac{1}{G_s + G_E + g_m + g_n}} \right)
\]

\[
\frac{V_o}{V_s} = \left( \frac{g_m}{G_c + G_L} \right) \left( \frac{G_s}{G_s + G_E + g_m + g_n} \right) \left( \frac{1}{1 - j\omega C_2} \right)
\]
\[ V_o \frac{1}{V_s} = \left( \frac{g_m}{G_c + G_L} \right) \frac{G_s}{G_s + G_E + g_m + g_n} \left( \frac{1}{1 - j\omega C_1 \left( \frac{G_s (G_E + g_m + g_n)}{G_s + G_E + g_m + g_n} \right)} \right) \]
The CE configuration is limited in its frequency response due to Miller Capacitance. The CB configuration has good high frequency potential but its input impedance is very low (not easy to use). A better configuration for high frequency combines the CE configuration (with low voltage gain) with the CB configuration (with low current gain) to achieve a better combination of input impedance and high frequency response.

\[\text{Cascode stage}\]

Combination of CE stage (1st stage) and CB stage (2nd stage).
Cascode amplifier

High frequency small signal model

Node 2: \( g_m V_{\pi 1} - g_m V_{\pi 2} - g_m V_{\pi 2} - j\omega C_{m1} (V_{\pi 1} + V_{\pi 2}) - j\omega C_{m2} V_{\pi 2} \)

\[ V_{\pi 2} (g_m + g_{m2} + j\omega C_{m1} + j\omega C_{m2}) = V_{\pi 1} (g_m - j\omega C_{m1}) \]

\[ -\frac{V_{\pi 2}}{V_{\pi 1}} = \frac{g_m - j\omega C_{m1}}{g_m + g_{m2} + j\omega (C_{m1} + C_{m2})} \]

\[ = \frac{A_2 (1 - j\omega \omega_3)}{(1 + j\omega \omega_2)} \]
Notice that \( \frac{g_{m1}}{g_{m2} + j\omega C_{x2}} = \frac{g_{m1}r_{P2}}{g_{m2}r_{P2} + 1} \).

Since \( g_{m1} \approx g_{m2} \) and \( g_{m2}r_{P2} = \beta \approx 1 \),

then \( A_2 \approx 1 \).

Node 1:

\[ V_{\pi 1} = (V_{\pi 1} - V_s) G_s + V_{\pi 1}g_{\pi 1} + V_{\pi 1}G_0 + j\omega C_{\pi 1} V_{\pi 1} + j\omega C_{x1}(V_{\pi 1} + V_0) \]

\[ V_{\pi 1}(G_s + g_{\pi 1} + G_0 + j\omega C_{\pi 1} + j\omega C_{x1}) = -V_{\pi 2} j\omega C_{\pi 1} + G_s V_s \]

But, given \( \omega_1 \ll \omega_2, \omega_3 \) we notice that \( V_{\pi 2} \approx -V_{\pi 1} \), and so

\[ \frac{V_{\pi 1}}{V_s} = \frac{G_s}{G_s + G_0 + g_{\pi 1} + j\omega(C_{\pi 1} + 2C_{x1})} = \frac{A_1}{1 + \frac{\omega}{\omega_1}} \]

\[ = \frac{G_s}{G_s + G_0 + g_{\pi 1}} \frac{1}{1 + j\omega \left( \frac{C_{\pi 1} + 2C_{x1}}{G_s + G_0 + g_{\pi 1}} \right)} \]

\[ = \frac{R_s}{R_s + R_i} \frac{A_1}{1 + j\omega \left( \frac{C_{\pi 1}R_i}{R_s + R_i} \right)} \]

Finally,

Node 3:

\[ V_s \left[ G_c + C_c + j\omega(C_{x2} + C_{x1}) \right] + g_{m2} V_{\pi 2} = 0 \]

\[ \Rightarrow \frac{V_s}{-V_{\pi 2}} = \frac{g_{m2} - \frac{2m_{x2} G_c}{G_c + G_c + j\omega(C_{x2} + C_{x1})}}{G_c + G_c + j\omega(C_{x2} + C_{x1})} = \frac{A_3}{1 + \frac{j\omega}{\omega_2}} \]

\[ = \frac{g_{m2}}{G_c + G_c + \frac{G_{x2}C_{x2}}{1 + j\omega(C_{x2} + C_{x1})}} \frac{A_3}{1 + j\omega \left( \frac{C_{x2} + C_{x1}}{G_c + G_c} \right)(R_c + R_i)} \]
Hence, the combined response is

\[ A_{vs} = \frac{V_o}{-V_{T2}} \times \frac{V_{T3}}{V_{S}} \times \frac{-V_{M2}}{V_{T1}} = \frac{V_o}{V_s} \]

\[ A_1 A_2 A_3 \left( 1 - \frac{j \omega}{\omega_3} \right) \]

\[ \frac{1}{1 + \frac{j \omega}{\omega_1}} \left( 1 + \frac{j \omega}{\omega_2} \right) \left( 1 + \frac{j \omega}{\omega_4} \right) \]

\[ = -g_m (R_{11} R_3) \left[ \frac{R_i}{R_i + R_3} \right] \left( 1 - \frac{j \omega}{\omega_3} \right) \]

\[ \left( 1 + \frac{j \omega}{\omega_1} \right) \left( 1 + \frac{j \omega}{\omega_2} \right) \left( 1 + \frac{j \omega}{\omega_4} \right) \]

Consider the example of drill 9.9 pg. 926.

Find \( A_{vs} \) and

- \( R_s = 1 k\Omega \)
- \( R_c = 3.3 k\Omega \)
- \( R_1 = 4.7 k\Omega \)
- \( R_B = 10 k\Omega \)
- \( I_c = 1 mA \)
- \( \beta_e = 100 \)
- \( C_m = 1 \mu F \)
- \( C_{\pi} = 2 \mu F \)
- \( C_w = 2 \mu F \)

\( \omega_1 = \frac{1}{(R_{11} R_3) (C_{\pi} + 2C_w)} = \frac{1}{(1k \Omega \times 0.064 \times 0.001 \mu F)} = 371 \times 10^6 \text{ rad/sec} \)

\( \omega_2 = \frac{g_m + \beta_e \pi}{C_{\pi} + C_w} = \frac{0.03846}{3 \times 10^{-12}} = 12.9 \times 10^9 \text{ rad/sec} \)

\( \omega_3 = \frac{g_m}{C_{m1}} = \frac{0.03846}{\mu F} = 38.46 \times 10^9 \text{ rad/sec} \)

Hence, \( \omega_2, \omega_3 \gg \omega_1 \)

\( \omega_4 = \frac{1}{(R_{11} R_3) (C_{w} + C_w)} = \frac{1}{(1.959 k \Omega \times 3 \times 10^{-3})} = 171.9 \times 10^6 \text{ rad/sec} \)
Another circuit configuration that is a cascode (to improve frequency response) is the BiCMOS cascode.

This circuit has the following advantages over the simple 2-BJT cascode:
- lower dc power consumption
- higher voltage gain

The major disadvantage is poor bandwidth.
Frequency-dependent small-signal FET model

There are two effective junctions in the basic JFET structure:

1) the reverse-bias junction between the drain-source channel and gate
2) the reverse-bias junction between the gate and substrate (if present)

The first \( \frac{1}{2} \) component, i.e., capacitance between the gate and drain region, and capacitance between the gate and source region.

\[
C_{gd} = \frac{C_{gd0}}{\left(1 + \frac{V_{gs}}{V_0}\right)^{\frac{1}{2}}} \quad \text{Typically a graded junction}
\]

\[
C_{gs} = \frac{C_{gso}}{\left(1 + \frac{V_{gs}}{V_0}\right)^{\frac{1}{2}}}
\]

Second (gate to substrate)

\[
C_{gss} = \frac{C_{gss0}}{\left(1 + \frac{V_{gss}}{V_0}\right)^{\frac{1}{2}}} \quad \text{Approximately an abrupt junction}
\]
Including all of the parasitic parameters shown we obtain

In effect \( r_2, r_3, r_5, r_b, r_{bd} \) have negligible so we don't include them. Further, \( r_{ds} \) is labeled \( r_b \) in the simplified circuit.

This is the model we use in analysis.