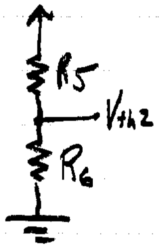
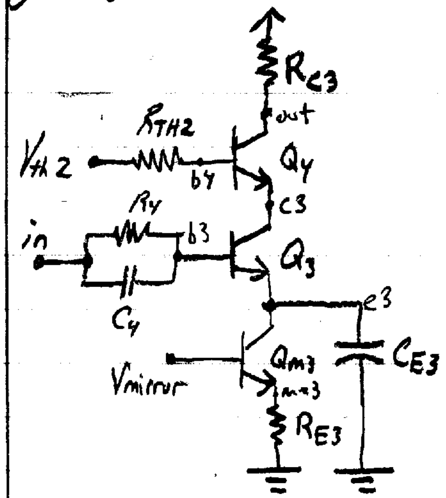
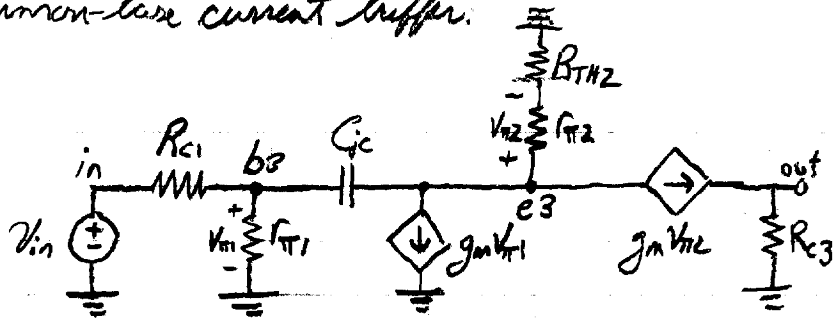
In Spice Simulation, the Miller capacitance was kicking in at about 1 MHz. To counter this, need to account for C_{jc} and add a common-base current buffer.







High Freq AC Model

KCL at b3:
$$\frac{V_B - V_{IN}}{R_{C1}} + \frac{V_B}{r_\pi} + \frac{V_B - V_E}{\frac{1}{j\omega C_{jc}}} = \emptyset$$

[1]
$$V_B\left[\frac{1}{R_{C1}} + \frac{1}{r_\pi} + j\omega C_{jc}\right] + V_E\left[-j\omega C_{jc}\right] = \frac{V_{IN}}{R_{C1}}$$

KCL at e3:
$$\frac{V_E - V_B}{\frac{1}{j\omega C_{jc}}} + g_m V_B + \frac{V_E}{r_{\pi 2} + R_{TH2}} + g_m V_E = \emptyset$$

[2]
$$V_B\left[g_m - j\omega C_{jc}\right] + V_E\left[g_m + \frac{1}{r_\pi + R_{TH2}} + j\omega C_{jc}\right] = \emptyset$$

Design R_{TH2} such that $r_\pi + R_{TH2} \approx r_\pi$

$$R_{TH2} = \frac{1}{10} r_\pi = \frac{V_T \beta}{10 I_{c3}} \qquad V_{TH2} = 3V_{BE} + 2V_{margin} \quad (\approx 3V)$$

$$\boxed{R_{C3} = \frac{1}{2} \cdot \frac{3V_{BE} + 2V_{margin}}{I_{c3}}} \qquad V_{b3} = 2V_{BE} + V_{margin}$$

$$R_5 = R_{TH} \frac{V_{cc}}{V_{TH}}$$

$$R_6 = R_{TH} \frac{V_{cc}}{V_{cc} - V_{TH}}$$

$$\boxed{\begin{aligned} R_5 &= \frac{V_T \beta}{10 I_{c3}}\left(\frac{V_{cc}}{3V_{BE} + 2V_{margin}}\right) \\ R_6 &= \frac{V_T \beta}{10 I_{c3}}\left(\frac{V_{cc}}{V_{cc} - 3V_{BE} - 2V_{margin}}\right) \end{aligned}}$$

With the R_{TH} design, equation [2] simplifies to

$$V_B\left[g_m - j\omega C_{jc}\right] + V_E\left[g_m + \frac{1}{r_\pi} + j\omega C_{jc}\right] = \emptyset$$

$$V_B\left[\frac{I_{c3}}{V_T} - j\omega C_{jc}\right] + V_E\left[\frac{I_{c3}}{V_T}\left(1+\frac{1}{\beta}\right) + j\omega C_{jc}\right] = \emptyset$$

[2'] $$V_B\left[\frac{I_{c3}}{V_T} - j\omega C_{jc}\right] + V_E\left[\frac{I_{c3}}{V_T} + j\omega C_{jc}\right] = \emptyset$$

Adding [2'] to [1]

$$V_B\left[\frac{1}{R_{c1}} + \frac{I_c}{V_T\beta} + \frac{I_c}{V_T}\right] + V_E\left[\frac{I_{c3}}{V_T}\right] = \frac{V_{IN}}{R_{c1}}$$

[1'] $$V_B\left[\frac{1}{R_{c1}} + \frac{I_{c3}}{V_T}\right] + V_E\left[\frac{I_{c3}}{V_T}\right] = \frac{V_{IN}}{R_{c1}}$$

Need to scale 1' in preparation for combination with 2'.

$$\frac{I_{c3}}{V_T} + \frac{1}{R_{c1}} \longmapsto \frac{-I_{c3}}{V_T} + j\omega C_{jc}$$

$$\frac{V_T + R_{c1}I_{c3}}{V_T R_{c1}} \longmapsto \frac{-I_{c3}}{V_T}\left(1 + j\omega\frac{C_{jc}V_T}{I_{c3}}\right) = \frac{-I_{c3}}{V_T}\sqrt{1+\left(\frac{\omega}{\omega_s}\right)^2}\, e^{-j\tan^{-1}\frac{\omega}{\omega_s}}$$

$$V_B\left[j\omega C_{jc} - \frac{I_{c3}}{V_T}\right] + V_E\left[\frac{I_{c3}}{V_T}\right]\left[\frac{-I_{c3}}{V_T}\sqrt{1+\left(\frac{\omega}{\omega_s}\right)^2}\, e^{-j\tan^{-1}\left(\frac{\omega}{\omega_s}\right)}\right]\left[\frac{V_T R_{c1}}{V_T + R_{c1}I_{c3}}\right]$$

$$= V_{IN}\left[\frac{1}{R_{c1}}\right]\left[\frac{-I_{c3}}{V_T}\sqrt{1+\left(\frac{\omega}{\omega_s}\right)^2}\, e^{-j\tan^{-1}(\omega/\omega_s)}\right]\left[\frac{V_T R_{c1}}{V_T + R_{c1}I_{c3}}\right]$$

$$V_B\left[j\omega C_{jc} - \frac{I_{c3}}{V_T}\right] + V_E\left[\frac{R_{c1}I_{c3}}{V_T + R_{c1}I_{c3}}\right]\left[\frac{-I_c}{V_T}\right]\sqrt{1+\left(\frac{\omega}{\omega_s}\right)^2}\, e^{-j\tan^{-1}\left(\frac{\omega}{\omega_s}\right)}$$

$$= V_{IN}\left[\frac{-I_{c3}}{V_T + R_{c1}I_{c3}}\sqrt{1+\left(\frac{\omega}{\omega_s}\right)^2}\, e^{-j\tan^{-1}(\omega/\omega_s)}\right]$$

Adding 1' (scaled) to [2']:

$$V_E\left[\frac{I_{c3}}{V_T} + j\omega C_{jc} + \frac{-R_{c1}I_{c3}^2\sqrt{1+(\omega/\omega_s)^2}}{V_T(V_T + R_{c1}I_{c3})}\, e^{-j\tan^{-1}\left(\frac{\omega}{\omega_s}\right)}\right] = V_{IN}\left[\frac{-I_{c3}}{V_T + R_{c1}I_{c3}}\, e^{-j\tan^{-1}\left(\frac{\omega}{\omega_s}\right)}\right]$$

$$V_E\left[\left(\frac{I_{c3}}{V_T} + j\omega C_{jc}\right)\left(\frac{V_T + R_{c1}I_{c3}}{-I_{c3}}\right) + \left(\frac{-R_{c1}I_{c3}^2(V_T + R_{c1}I_{c3})}{V_T(R_{c1}I_{c3} + V_T)(-I_{c3})}\right)e^{-j\tan\left(\frac{\omega}{\omega_s}\right)}\right]e^{j\tan\left(\frac{\omega}{\omega_s}\right)} = V_{IN}$$

[2''] $$V_E\left[\left(\frac{I_{c3}}{V_T} + j\omega C_{jc}\right)\left(\frac{V_T + R_{c1}I_{c3}}{-I_{c3}}\right)e^{j\tan^{-1}\left(\frac{\omega}{\omega_s}\right)} + \frac{R_{c1}I_{c3}}{V_T}\right] = V_{IN}$$

Next, we need the 3rd equation from the output node:

[3] $$V_{OUT} = R_{C3} g_m V_E = \frac{R_{C3} I_{C3}}{V_T} \cdot V_E \quad \text{or} \quad V_E = V_{OUT} \frac{V_T}{R_{C3} I_{C3}}$$

Substituting this into eq [2''] gives

$$V_{OUT}\left[\frac{V_T}{R_{C3} I_{C3}}\right]\left[\frac{R_{C1} I_{C3}}{V_T} - \left(\frac{I_{C3}}{V_T} + j\omega C_{jc}\right)\left(\frac{V_T + R_{C1} I_{C3}}{I_{C3}}\right) e^{j\tan^{-1}\left(\frac{\omega}{\omega_5}\right)}\right] = V_{IN}$$

$$G^{-1} = \frac{1}{R_{C3}}\left[R_{C1} - \frac{V_T}{I_{C3}}\left(\frac{I_{C3}}{V_T} + j\omega C_{jc}\right)\left(\frac{V_T + R_{C1} I_{C3}}{I_{C3}}\right) e^{j\tan^{-1}\left(\frac{\omega}{\omega_5}\right)}\right]$$

$$G^{-1} = \frac{1}{R_{C3}}\left[R_{C1} - \left(1 + j\frac{\omega}{\omega_5}\right)\left(\frac{V_T + R_{C1} I_{C3}}{I_{C3}}\right) e^{j\tan^{-1}\frac{\omega}{\omega_5}}\right]$$

$$G^{-1} = \frac{R_{C1}}{R_{C3}}\left[1 - \left(1 + j\frac{\omega}{\omega_5}\right)\left(\frac{V_T}{R_{C1} I_{C3}} + 1\right) e^{j\tan^{-1}\frac{\omega}{\omega_5}}\right]$$

[2'''] $$G^{-1} = \frac{R_{C1}}{R_{C3}}\left[1 - \left(1 + \frac{V_T}{R_C I_{C3}}\right)\sqrt{1 + \left(\frac{\omega}{\omega_5}\right)^2}\, e^{j2\tan^{-1}\frac{\omega}{\omega_5}}\right]$$

So finally, the inverse of gain of the 2nd stage is

[4] $$G^{-1} = \frac{R_{C1}}{R_{C3}}\left[1 - \left(1 + \frac{V_T}{R_C I_{C3}}\right)\sqrt{1 + \left(\frac{\omega}{\omega_5}\right)^2}\, e^{j2\tan^{-1}\left(\frac{\omega}{\omega_5}\right)}\right]$$

where

$$\omega_5 = \frac{I_{C3}}{V_T C_{jc}} \qquad \omega_5 = \frac{I_{C3}}{V_T C_{jc}} \geq 10(2\pi f_{op})$$

and the size of R_{C3} is limited by

$$R_{C3} = \frac{3V_{BE} + 2V_{margin}}{2I_{C3}}$$

To extend the bandwidth past the high frequency pole, the quiescent current should be

$$I_{C3} \geq 20\pi V_T C_{jc} f_{op} \leftarrow 10\,MHz\text{, this will set pole at } 100\,MHz$$