Calculating currents:

\[ V_{\text{out}} + V_{\text{out}} = V_{\text{in}} + V_{\text{in}} \quad \nu_i = 0 \]
\[ V_{\text{out}} + V_{\text{in}} + V_{\text{in}} = V_{\text{in}} + V_{\text{in}} + V_{\text{in}} + V_{\text{in}} \]

Let All

\[ \left( \frac{W}{L} \right)_i = \left( \frac{W}{L} \right)_i = \left( \frac{W}{L} \right)_i \]
\[ \left( \frac{2 \cdot I_s}{W} \right)_i \cdot k_i + \left( \frac{2 \cdot I_s}{W} \right)_i \cdot k_i = \left( \frac{2 \cdot I_s}{W} \right)_i \cdot k_i + \left( \frac{2 \cdot I_s}{W} \right)_i \cdot k_i \]

\[ I_i = I_s \]

Transistor \( M_2 \) has \( M_7 \) as its source resistance.

If \( g_m' \)'s are all equal = \( g_m \)

\[ \frac{g_m'}{2} \cdot \Delta V_i = \frac{g_m'}{2} \cdot \Delta V_i \]
Class AB Input Stage Cross Coupled Differential Pair (Cont.)

As $\Delta v_i$ increase $i_{out}$ continues to increase.

If $\Delta v_i$ decreases M2 & M7 cutoff.

But then current comes from M3 & M6.

So for Small Signals

$$GM = \frac{i_{ds}}{\nu_{in}} + \frac{i_{ds}}{\nu_{in}} = g_m$$

$$R_{out} = g_m \cdot r'_d || g_m \cdot r'_d = \frac{g_m \cdot r'_d}{2}$$

$$A_v = \frac{g_m \cdot r'_d}{2}$$

Class AB Input Stage Cross Coupled Differential Pair (Cont.)

For Large Signals either M2, M9 or M3, M6 cutoff so the $g_m$ drops, but since the current is increasing it increases again.

Slew Rates can be very high since they are independent of the Bias Current ⇒ Bigger Signal gives more current to drive the next stage.

Another Class AB
Another Class AB (Cont.)

Small Signals M5 & M6 are degenerated by $R_i$ & $R_s$.

But for Large Signals the INPUT appears across $R_i$ + $R_s$.

\[ I_{\text{out}} = \frac{V_{\text{in}}' - V_\text{in}}{R_i + R_s} \]

Feedback Zero Compensation

Shunt - Series Feedback

Feedback Zero Compensation (Cont.)

\[ |T(\omega)| \]

\[ \theta = 0 \quad \omega = \omega_{\text{off}} \]

\[ -90^\circ \]

\[ -180^\circ \]

\[ 20^\circ = \theta_m \]

\[ \theta(\omega) \]

But we want 45° of $\theta_m$ so we add $C_f$.

\[ f = \frac{R_i}{R_i + R_s} \left( \frac{1 + R_s \cdot j \cdot \omega \cdot C_f}{1 + (R_i \parallel R_s) \cdot j \cdot \omega \cdot C_f} \right) \]

If $R_s \ll R_i$

\[ f = \frac{R_i \cdot j \cdot \omega \cdot R_s \cdot C_f}{R_s \cdot j \cdot \omega \cdot R_i \cdot C_f} \]

\[ \omega_z = \frac{1}{R_s \cdot C_f} \quad \omega_r = \frac{1}{R_i \cdot C_f} \]

Since $R_s \ll R_i \quad \omega_z \ll \omega_r$

\[ T = a(\omega) \cdot f(\omega) \]
Feedback Zero Compensation (Cont.)

We can add positive phase shift from the zero at $\omega_{\text{unity}}$ and as long as the contribution is $< 45^\circ$. There is no change in the magnitude of $f(\omega)$ and thus $T(\omega)$

$$\tan(\omega_{\text{unity}}(R_f \cdot C_f)) = 25^\circ$$

or,

$$C_f = \frac{1}{R_f \omega_{\text{unity}} \cdot \arctan(25^\circ)}$$