Lec 16

\[ V_{DD}, M_1 = M_L \]

\[ \Rightarrow \text{Valid only if} \]

\[ I_{C0} \]

\[ \begin{align*}
    V_x &= \_ \_ \_ \_
    \\ 
    V_o &= \_ \_ \_ \\
\end{align*} \]

\[ \frac{V_x}{V_s} = \_ \_ \_ \_ \_
    \\ 
    \frac{V_o}{V_s} = \_ \_ \_ \_ \_
\]

**Incremental amp. ckt.**

\[ g_{m1}, v_{g1}, s_1 \]

\[ g_{m1} = g_m = g_m \quad (I_{D1} = I_{D2} = I_{ref}) \]
\[ \frac{U_x}{V_s} = \frac{R_b + \frac{1}{g_m}}{R_s + R_b + \frac{1}{g_m}} \]

\[ \frac{U_o}{V_s} = -\left(\frac{R_b + \frac{1}{g_m}}{R_s + R_b + \frac{1}{g_m}}\right) \cdot g_m \cdot (r_D || r_L) \]

* We usually choose \( R_b \gg R_s \) (as before)

\[ \Rightarrow \frac{R_b + \frac{1}{g_m}}{R_s + \frac{1}{g_m}} \gg R_s \]

\[ \Rightarrow \frac{U_o}{V_s} \approx -g_m \cdot (r_D || r_L) \]

* Swing limits = same as before because \( I_D = \text{same as before} \)

\[ V_D = 11 \]

* If \( V_{T1,2} \) changes \( \Rightarrow \) gain is constant
Can this be done without using an extra transistor? 

\[ \text{DC (bias) In domestic} \]

\[ \text{needs to be fixed} \]

\[ \text{gain} = \frac{r_{LL} \frac{1}{g_m}}{r_{LL} \frac{1}{g_m} + r_s} \quad \text{not what we want!} \]

\[ \text{we want to decouple DC & for inc. picture} \]
1)

\[
\begin{array}{c}
\text{here } I = 0 \\
\text{Impractical ( } L \text{ in } ICs \text{ are very large)}
\end{array}
\]

2)

\[
\begin{array}{c}
\text{Rx is very large} \\
\text{voltage drop across } Rx \text{ is zero}
\end{array}
\]
\[ V_x = V_s \]

\[ \frac{V_s - V_o}{R_x} = g_m V_s + \frac{V_o}{R_L} \]

\[ V_s (G_x - g_m) = V_o (G_x + g_L) \]

\[ \Rightarrow \frac{V_o}{V_s} = \frac{G_x - g_m}{G_x + g_L} \]

\[ \frac{V_o}{V_s} = -\frac{g_m}{g_L} \left[ 1 - \frac{G_x}{g_m} \right] \frac{1}{1 + G_x/g_L} \]

* \( g_m > g_L \) for large gain

* \( G_x \ll g_L \Rightarrow G_x \ll g_m \)

\[ \therefore R_x = \text{large} \Rightarrow R_x \gg R_L \Rightarrow \text{gain} \approx g_m \]

* Swing limits = lower

\[ \Rightarrow I_D = \text{same as before} \Rightarrow \text{cut-off limit is the same} \]

\[ \Rightarrow \text{voltage across } R_x = 0; \ V_D = V_a \]