EE539: Analog Integrated Circuit Design

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4/4/06

TWO STAGE OPAMP.

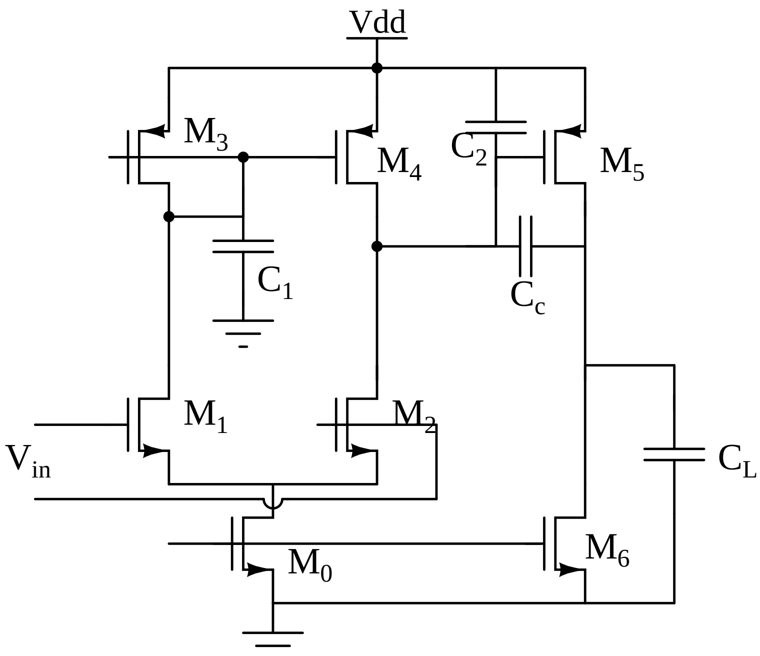

Figure 1: TWO STAGE

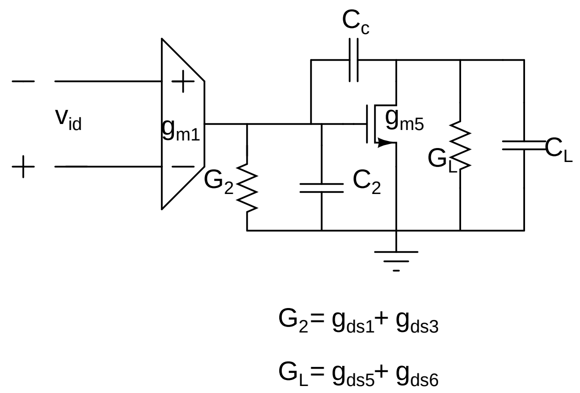

Figure 2: TWO STAGE

This circuit can be redrawn as
DC gain of stage 1=$\frac{g_{m1}}{G_2}$
DC gain of stage 2=$\frac{g_{m5}}{G_L}$
Overall DC gain=$\frac{g_{m1}}{G_2}\frac{g_{m5}}{G_L}$
Frequency response
No: of poles=2

$$\frac{V_o}{V_{in}} = \frac{g_{m1}(-sC_c + g_{m5})}{s^2(C_2C_c + C_2C_L + C_cC_L) + s(C_c(g_{m5} + G_L + G_2) + C_2G_L + C_LG_2) + G_2G_L} \tag{1}$$

If $C_c = 0$ then

$$\frac{V_o}{V_{in}} = \frac{g_{m1}g_{m5}}{s^2C_2C_L + s(C_2G_L + C_LG_2) + G_2G_L} \tag{2}$$

This is just a cascade of two transfer functions but when we introduce C_c , the two gets coupled.
To find the poles of the transfer function, we assume that the two poles are far apart,then

$$ax^2 + bx + c = 0 \tag{3}$$

$$P_1 = \frac{-c}{b} \tag{4}$$

$$P_1 = \frac{-G_2G_L}{C_c(g_{m5} + G_L + G_2) + C_2G_L + C_LG_2} \tag{5}$$

$$P_1 = \frac{-G_2}{C_c(\frac{g_{m5}}{G_L} + 1 + \frac{G_2}{G_L}) + C_2 + C_L\frac{G_2}{G_L}} \tag{6}$$

The term $C_c(\frac{g_{m5}}{G_L} + 1 + \frac{G_2}{G_L})$ shows the MILLER EFFECT , but it is not exact since this is not an ideal voltage amplifier.

$$P_2 = \frac{-b}{a} \tag{7}$$

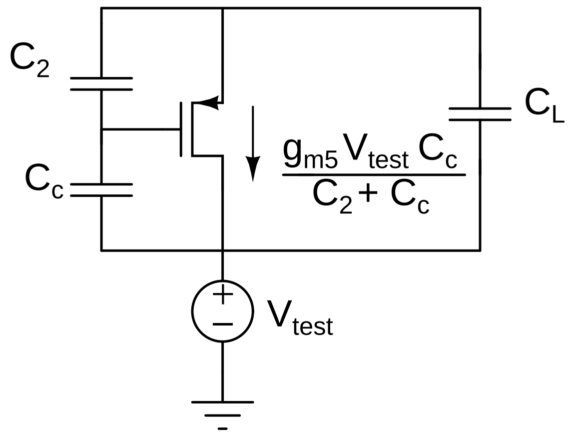

Figure 3: THE POLE

$$P_2 = -\frac{C_c(g_{m5} + G_L + G_2) + C_2 G_L + C_L G_2}{C_2 C_c + C_2 C_L + C_c C_L} \quad (8)$$

$$P_2 = -\frac{g_{m5} + G_2 + G_L + \frac{C_2}{C_c} G_L + \frac{C_L}{C_c} G_2}{C_2 + C_L + C_L \frac{C_2}{C_c}} \quad (9)$$

Since g_{m5} is large, P_2 becomes the non dominant term.It has increased to high frequency due to pole splitting.
If $g_{m5} >> G_L, G_2$ and $C_c >> C_2, C_L$, then $P_2 = \frac{-g_{m5}}{C_2 + C_L}$.
This is true since at high frequency when C_c is shorted C_2 and C_L is parallel.But since C_c is introduced for compensation so the assumption $C_c >> C_2, C_L$ is not valid,So taking only that

$$g_{m5} >> G_L, G_2$$

then

$$P_2 = \frac{-g_{m5}}{C_2 C_c + C_2 C_L + C_c C_L}$$

i.e

$$P_2 = \frac{-g_{m5} \frac{C_c}{C_c + C_2}}{C_L + \frac{C_2 C_c}{C_c + C_2}}$$

This is correct since applying a V_{test} at the drain of M_5,

$$I = \frac{g_{m5} V_{test} C_c}{C_2 + C_c}$$

So the effective conductance is $\frac{g_{m5} C_c}{C_2 + C_c}$ and the effective capacitance is $C_L + \frac{C_c C_2}{C_c + C_2}$