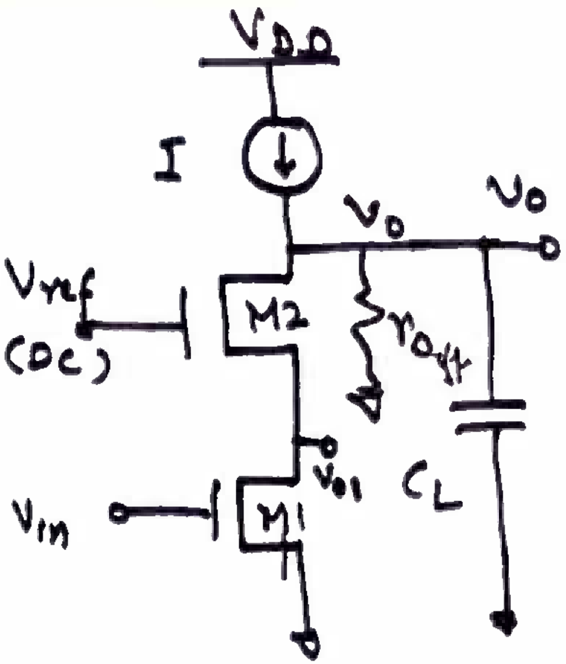
Cascode Amplifier



M1 & M2 are so biased with current source I, such that they remain in Saturation.

M2 is further applied a DC voltage Vref. However Gate of M_2 is at '0' volt for AC operation.

M1 is the Driver Transistor

C_L is capacitive Load.

The output resistance of Current Source is v. high $\rightarrow \infty$

We wish to find g_{meff} and g_{oeff}. of this this cascode stage.

Let g_{m1} and g_{o1} ($\frac{1}{r_{o1}}$) are the transconductance and output Conductance of Transistor M1 & Similarly g_{m2} & g_{o2} are for Transistor M2

By network theorems small signal current i (dI) is given by

$$i = g_{meff} \cdot v_{in} + g_{oeff} v_o \quad \text{— (1)}$$

Let v_{o1} be drain voltage of M1. However this voltage is also 'Source' voltage of M2.

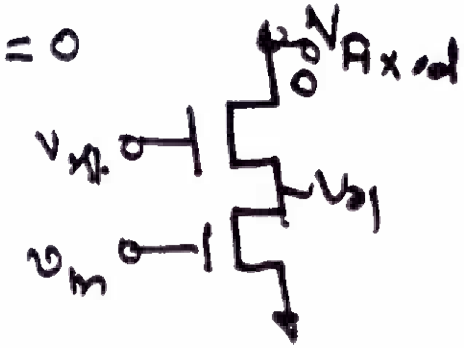
For AC signal, $V_{GS_2} = 0 - v_{01} = -v_{01}$

From current equation ①

$$g_{meff} = \frac{i}{v_{in}}\Big|_{v_o = 0} \quad \text{and} \quad g_{oeff} = \frac{i}{v_o}\Big|_{v_{in} = 0}$$

Assume we apply a fixed Voltage $\underline{V_{FIX}}$ at the Drain of M_2 (v_o terminal). Then for ac case, $v_o = 0$

$$\therefore \; (V_D - V_S)_{M2} = d(V_{DS_2}) = -v_{01}$$



Then

$$\therefore \; i = g_{m1} v_{in} + g_{o1}(+v_{01}) \quad \text{— ②}$$

&

$$i = g_{m_2}(-v_{01}) + g_{o2}(-v_{01}) \quad \text{— ③}$$

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From eq ③ $$v_{01} = \frac{-i}{g_{m2} + g_{02}}$$

substituting this in eq ② as

$$i = g_{m1} v_{in} + \frac{-g_{01}\, i}{g_{m2} + g_{02}}$$

$$\therefore\ i\left(1 + \frac{g_{01}}{g_{m2} + g_{02}}\right) = g_{m1} v_{in}$$

$$\therefore\ g_{meff} = \frac{i}{v_{in}} = \frac{g_{m1}}{\left(1 + \frac{g_{01}}{g_{m2} + g_{02}}\right)}$$

OR $$g_{meff} = \frac{g_{m1}(g_{m2}+g_{o2})}{g_{m2}+g_{o1}+g_{o2}}$$

If r_o of M1 & M2 are large, then g_{o1} & g_{o2} are very small.

$$\therefore g_{meff} \simeq \frac{g_{m1}\,g_{m2}}{g_{m2}} \simeq g_{m1}$$

Hence we observe that g_{meff} of the Cascode Stage is almost same as g_{m1}.

→ Hence if we have normal amplifier without M2, then Transconduct. $g_m = g_{m1}$

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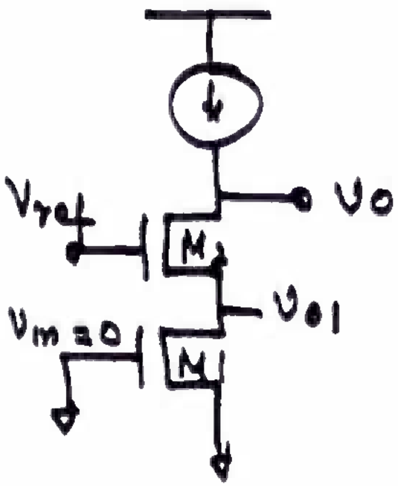
Next we evaluate g_{oeff}.

To get g_{oeff}, from equ. (1) we have

$$g_{oeff} = \frac{i}{v_0}\Big|_{v_{in}=0}$$

∴ Circuit looks like as shown in Fig. We do ac analysis and get



$$i = -g_{m2}v_{o1} + g_{o2}(v_{o2} - v_{o1}) \quad — (4) \qquad v_o = v_{o2}$$

& $$i = g_{m1}\cdot 0 + g_{o1}v_{o1} \quad — (5)$$

$$\therefore v_{o1} = \frac{i}{g_{o1}}$$

Substituting this in eq (4)

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$$\therefore \quad i = -\frac{g_{m2}\, i}{g_{01}} + g_{02} v_0 + g_{02}\left(-\frac{i}{g_{01}}\right)$$

$$\text{or} \quad i\left(1 + \frac{g_{02}}{g_{01}}\right) + \left(\frac{g_{m2}}{g_{01}}\right) i = g_{02} v_0$$

$$\therefore \quad g_{oeff} = \frac{i}{v_0} = \frac{g_{02}}{1 + \frac{g_{02}}{g_{01}} + \frac{g_{m2}}{g_{01}}}$$

$$= \frac{g_{01}\, g_{02}}{g_{01} + g_{02} + g_{m2}}$$

$$\therefore \quad r_{oeff} = \frac{g_{01} + g_{02} + g_{m2}}{g_{01}\, g_{02}}$$

$$= \frac{1}{g_{02}} + \frac{1}{g_{01}} + \frac{g_{m2}}{g_{01}\, g_{02}}$$

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$$\therefore r_{oeff} = r_{o1} + r_{o2} + r_{o1}\left(\frac{g_{m2}}{g_{o2}}\right)$$

$$= r_{o1} + r_{o2} + A_{v_2} r_{o1}$$

$$r_{oeff} = r_{o2} + (1 + A_{v_2}) r_{o1}$$

Voltage Gain A_v of the Cascode Stage Amplifier is

$$A_{v_{eff}} = -\frac{g_{meff}}{g_{oeff}} = -g_{m1}\left[r_{o2} + (1 + A_{v_2}) r_{o1}\right]$$

$$= + A_{v2} + A_{v1} + A_{v1} A_{v2}$$

$$\simeq A_{v1} \cdot A_{v2}$$

If $A_{v1} = A_{v2}$

then $A_{veff} = A_{v1}^2$

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Gain Bandwidth Product GBW of Cascode

$$= \frac{g_{m\,eff}}{C_{in}} \cong \frac{g_{m1}}{C_{in}} \rightarrow \underline{\text{NO CHANGE}}$$

If M1 & M2 are identical, then $g_m = g_{m1} = g_{m2}$

$r_o = r_{o1} = r_{o2}$

Then $\text{Gain}_{cascode} \cong (\text{Gain}_{single\ stage})^2$

For Cascode, Gain Enhances (Boosted) but Bandwidth remains same.

Thus Technology Constraint of Transistor is as if BROKEN.