# EE539: Analog Integrated Circuit Design; Lecture 1

Nagendra Krishnapura (nagendra@iitm.ac.in)

17 Mar. 2006

## 1 Single stage opamp

Single stage opamp is nothing but differential amplifier, and is shown in figure(1). In figure(1),

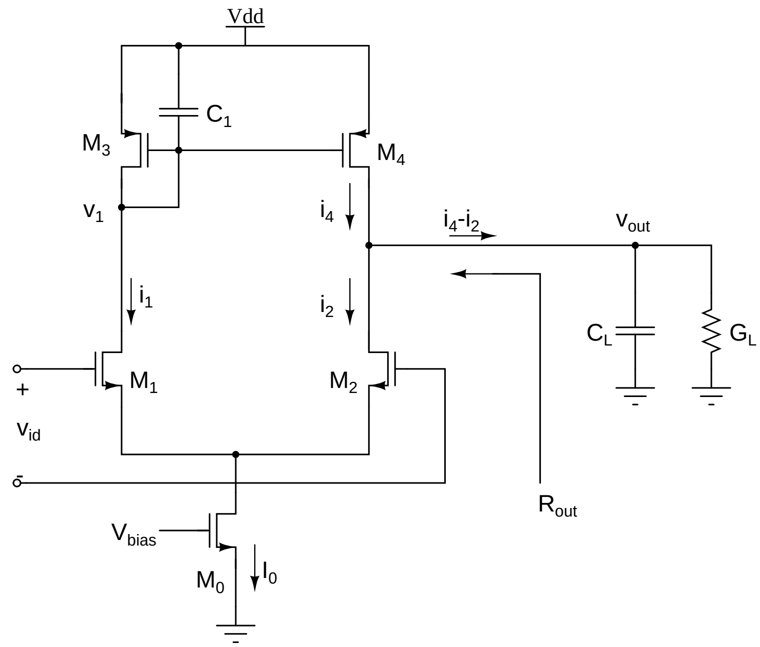


Figure 1: Single stage opamp

$$i_1 = g_{m1}\frac{v_i(s)}{2} = -i_2$$

$$v_1 = \frac{-g_{m1}\frac{v_i(s)}{2}}{g_{m3} + g_{ds3} + g_{ds1} + sC_1}$$

$$i_4 = -g_{m4}v_1$$

$$\Rightarrow i_4 = \frac{g_{m3}g_{m1}\frac{v_i(s)}{2}}{g_{m3} + g_{ds3} + g_{ds1} + sC_1}$$

$$i_{out} = i_4 - i_2$$

$$i_{out} = \frac{g_{m3} g_{m1} \frac{v_i(s)}{2}}{g_{m3} + g_{ds3} + g_{ds1} + sC_1} - (-g_{m1} \frac{v_i(s)}{2})$$

$$\Rightarrow i_{out} = g_{m1} v_i(s) \frac{g_{m3} + \frac{g_{ds3}}{2} + \frac{g_{ds1}}{2} + \frac{sC_1}{2}}{g_{m3} + g_{ds3} + g_{ds1} + sC_1}$$

Output voltage

$$v_{out} = i_{out} R_{out}$$

Transfer function

$$\Rightarrow \frac{v_{out}}{v_i} = \frac{g_{m1}}{g_{ds1} + g_{ds3} + G_L + sC_L} \frac{g_{m3} + \frac{g_{ds3}}{2} + \frac{g_{ds1}}{2} + \frac{sC_1}{2}}{g_{m3} + g_{ds3} + g_{ds1} + sC_1}$$

This Transfer function is second order .
DC gain ,

$$A_{dc} = \frac{g_{m1}}{g_{ds1} + g_{ds3} + G_L} \frac{g_{m3} + \frac{g_{ds3}}{2} + \frac{g_{ds1}}{2}}{g_{m3} + g_{ds3} + g_{ds1}}$$

$$P_1 = -\frac{g_{ds1} + g_{ds3} + G_L}{C_L}$$

$$P_2 = -\frac{g_{m3} + g_{ds3} + g_{ds1}}{C_1} \approx -\frac{g_{m3}}{C_1}$$

$$Z_1 = -\frac{g_{m3} + \frac{g_{ds3}}{2} + \frac{g_{ds1}}{2}}{C_L} \approx -2\frac{g_{m3}}{C_1}$$

$$w_u = \frac{g_{m1}}{C_L}$$

Frequency response of the single stage opamp is shown in the below figure.

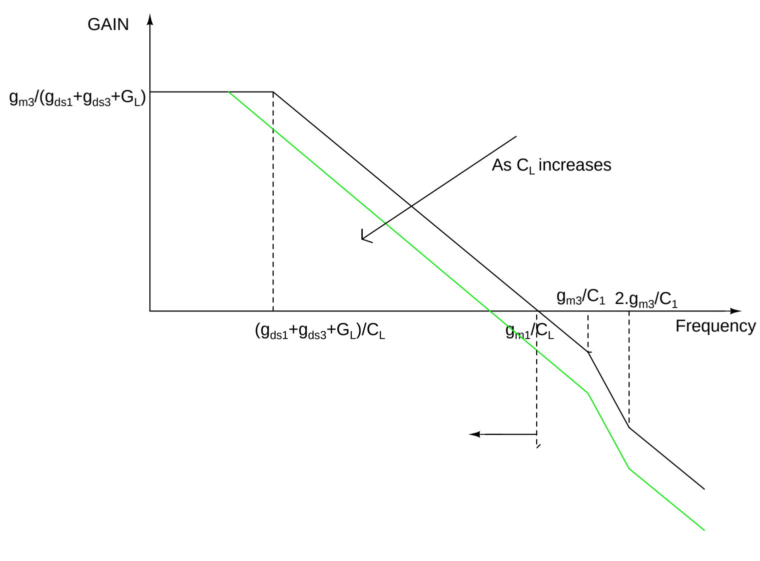


Figure 2: Frequency response of Single stage opamp

## 1.1 Disadvantages of single stage opamp

Range of values of output voltage for the single stage opamp is

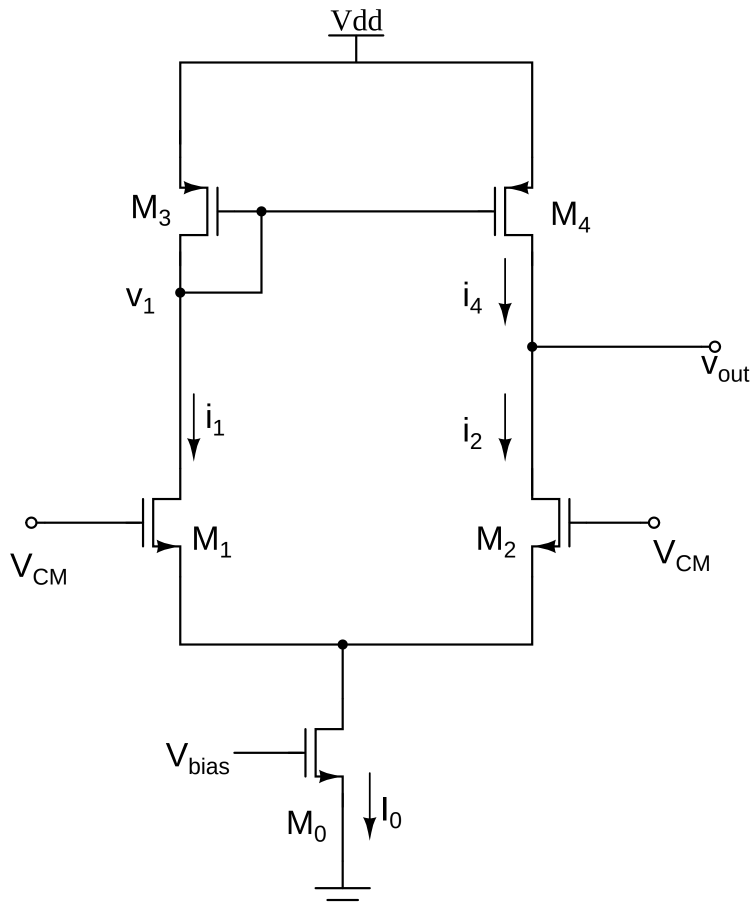


Figure 3: Single stage opamp

$$V_{CM} - V_{T2} < V_{out} < V_{dd} - V_{dsat4}$$

or

$$V_{dsat0} + V_{dsat1} < V_{out} < V_{dd} - V_{dsat4}$$

If we use this opamp as unity gain buffer then

$$V_{dsat0} + V_{dsat1} + V_{T2} < V_{out} < V_{dd} - V_{dsat4}$$

That implies the allowable voltage swing reduced.

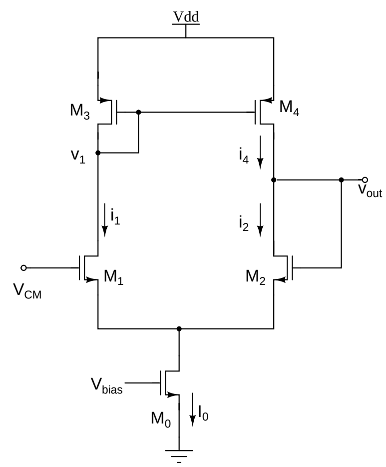


Figure 4: Single stage opamp as unity gain buffer

## 2 Slewrate

Let the unity gain buffer shown in the below figure(5).

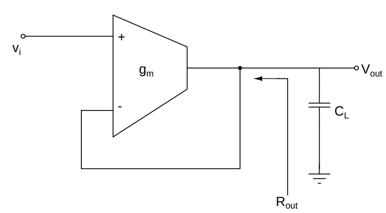


Figure 5: unity gain buffer

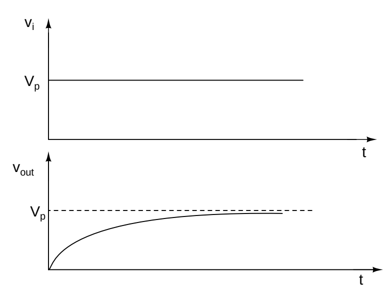


Figure 6: Step response of unity gain buffer

$$R_{out} = \frac{1}{g_m}$$

Time constant

$$= \frac{C_L}{g_m}$$

$$w_u = \frac{g_m}{C_L}$$

$$v_{out} = V_P(1 - e^{-tw_u})$$

$$\frac{dv_{out}}{dt}|_{t=0} = V_P w_u = V_P \frac{g_m}{C_L}$$

For Single stage opamp

Slewrate,

$$\frac{dv_{out}}{dt}|_{max} = \frac{I_0}{C_L}$$

Maximum input voltage we can apply at the input without slewing is,

$$V_{P,max} = \frac{I_0}{g_m}$$