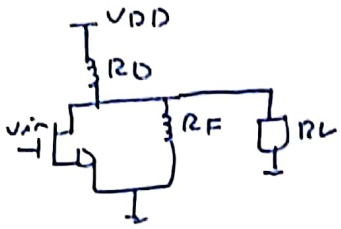
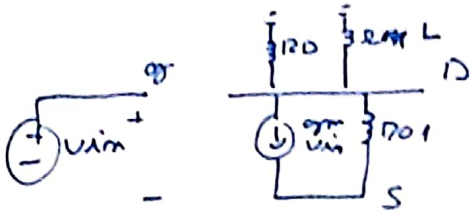
amplifier 1





$$\Delta V = \frac{v_{out}}{v_{in}} = \frac{-g_{m1}}{\frac{1}{r_{o1}} + \frac{1}{R_D} + \frac{1}{R_F} + \frac{1}{R_L}}$$

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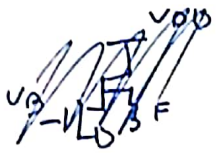
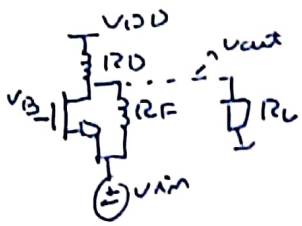
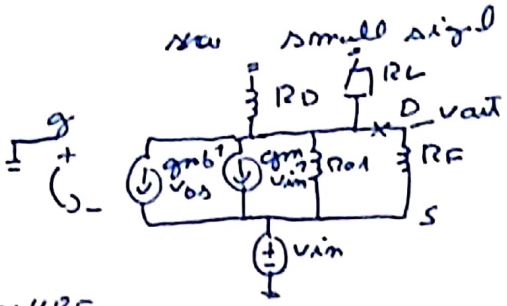
amplifier 2







$R_{eq_1} = R_D \,//\, R_L \qquad R_{eq_2} = R_{o1} \,//\, R_F$

$v_{gs} = -v_{in}$

$v_{bs} = -v_{in}$

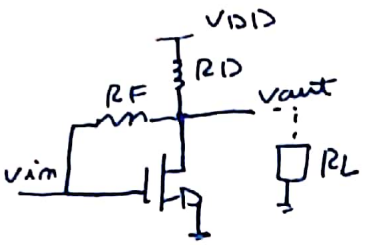
$$-\frac{v_{out}}{R_{eq_1}} - \frac{v_{out} - v_{in}}{R_{eq_2}} - g_{m_1}(v_{gs}) - g_{mb_1}(v_{bs}) = 0$$ -> sum of all of currents In node v_{out}

$$-\frac{v_{out}}{R_{eq_1}} - \frac{v_{out}}{R_{eq_2}} + v_{in}\left(\frac{1}{R_{eq_2}} + g_{m_1} + g_{mb_1}\right) = 0$$

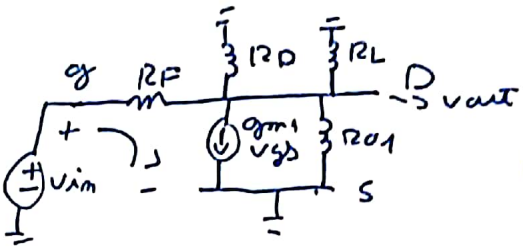
$$\frac{v_{out}}{v_{in}} = \frac{\left(\frac{1}{R_{eq_2}} + g_{m1} + g_{mb1}\right)}{\frac{1}{R_{eq_1}} + \frac{1}{R_{eq_2}}}$$

$$\Delta V = \frac{\frac{1}{R_{o1}} + \frac{1}{R_F} + g_{m1} + g_{mb1}}{\frac{1}{R_{o1}} + \frac{1}{R_F} + \frac{1}{R_D} + \frac{1}{R_L}}$$

amplifier 3



Small signal model



$V_{gs} = +V_{in}$

$R_{eq} = R_D // R_L // r_{o1}$

currents In Vout

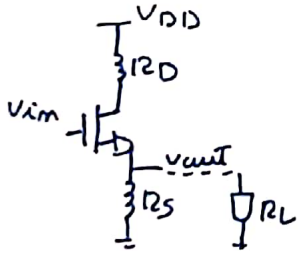
$$-\frac{V_{out}}{R_{eq}} - \frac{V_{out} - V_{in}}{R_F} = g_{m1} V_{gs}$$

$$-V_{out}\left(\frac{1}{R_{eq}} + \frac{1}{R_F}\right) + V_{in}\left(-g_{m1} + \frac{1}{R_F}\right) = 0$$

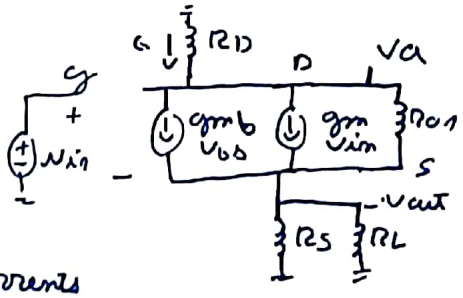
gain Initially is Positive changes Then ~~skips~~ To negative

$$\frac{V_{out}}{V_{in}} = \frac{\frac{1}{R_F} - g_{m1}}{\frac{1}{R_D} + \frac{1}{R_L} + \frac{1}{r_{o1}} + \frac{1}{R_F}}$$

amplifier 4



seen as a small model



$V_{gs} = V_{in} - V_{out}$

$V_{bs} = -V_{out}$

$R_{eq} = R_S // R_L$

$$\frac{V_{out}}{R_{eq}} = -\frac{V_a}{R_D}$$

$$V_a = -\frac{V_{out} R_D}{R_{eq}}$$

Sum off all currents In Vout

$$-\frac{V_{out}}{R_{eq}} + g_{mb} V_{bs} + g_m V_{gs} - \frac{(V_{out} - V_a)}{r_{o1}} = 0$$

$$-\frac{V_{out}}{R_{eq}} - g_{mb} V_{out} - g_m (V_{out}) + g_m V_{in} - \frac{V_{out}}{r_{o1}} - \frac{V_{out} R_D}{r_{o1} R_{eq}} = 0$$

$$\frac{V_{out}}{V_{in}} = \frac{g_m}{\frac{1}{R_S} + \frac{1}{R_L} + g_{mb} + g_m + \frac{1}{r_{o1}} + \frac{R_D}{r_{o1}\left(\frac{R_S R_L}{R_S + R_L}\right)}}$$

gain always smaller Than 1

serves as a buffer stage