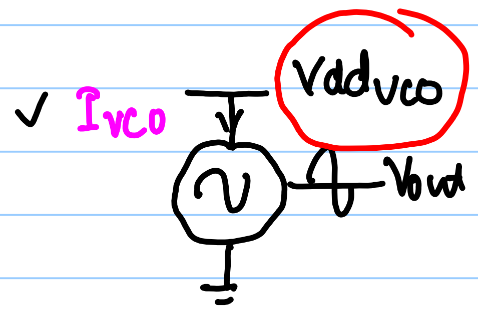
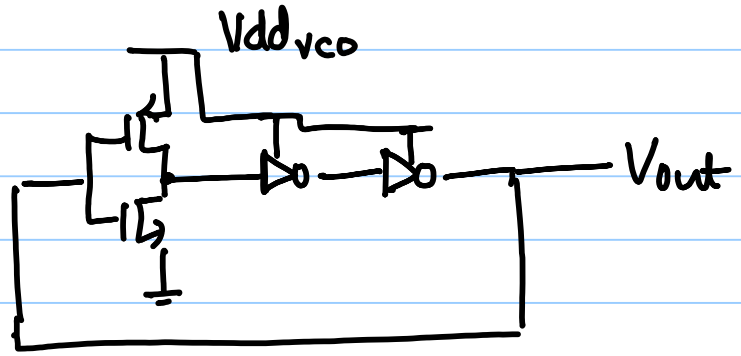
Note Title: Lecture # 25 — 21-07-2020

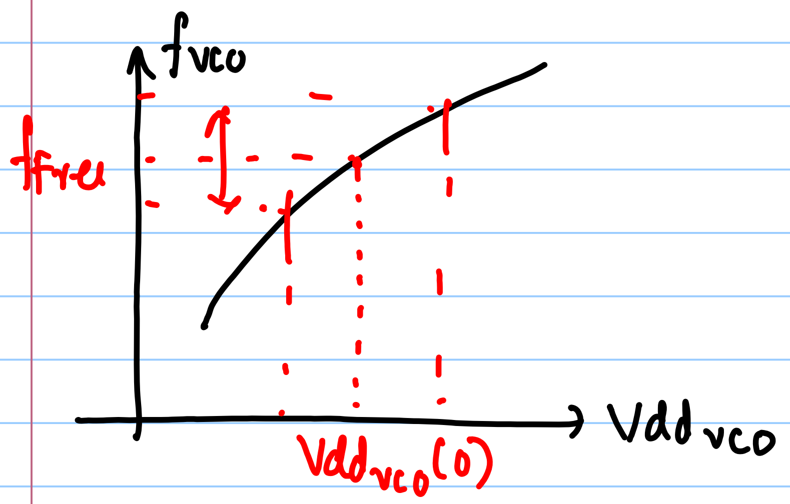
Ring-Oscillator

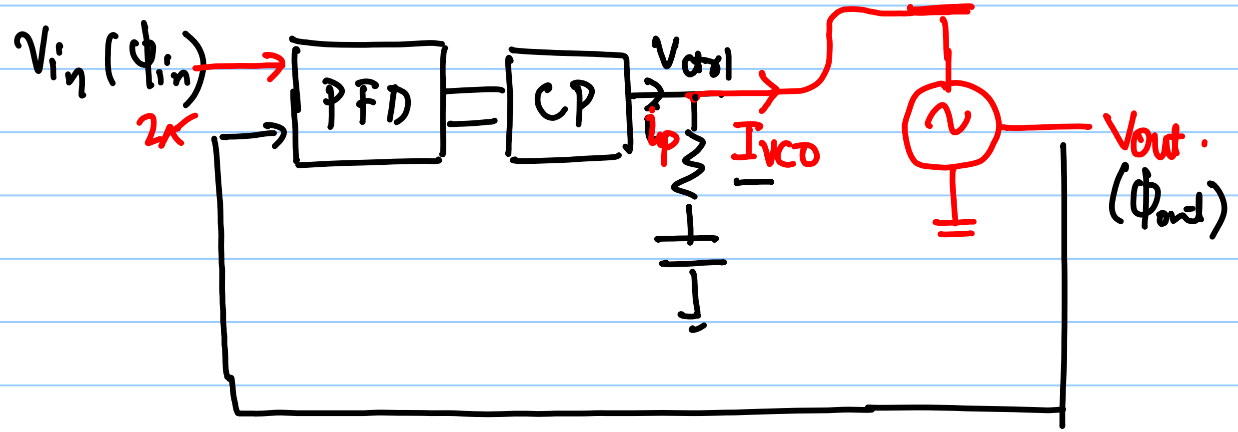


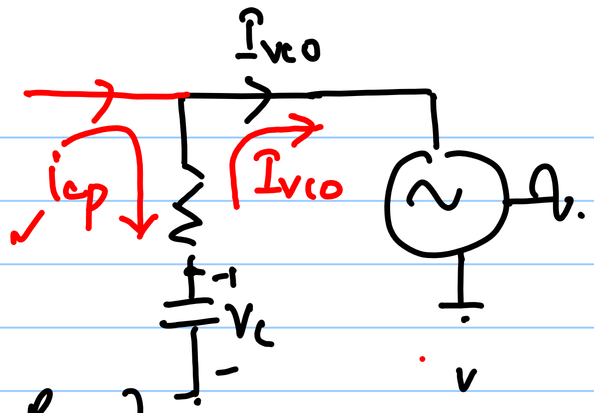


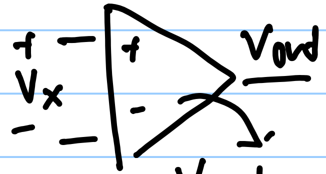
$$f_{out} = f(Vdd_{vco}) = f_{free} + K_{vco} \times (Vdd_{vco} - Vdd_{vco}(0))$$

$$= f_{free} + K_{vco} \times \Delta Vdd_{vco}$$

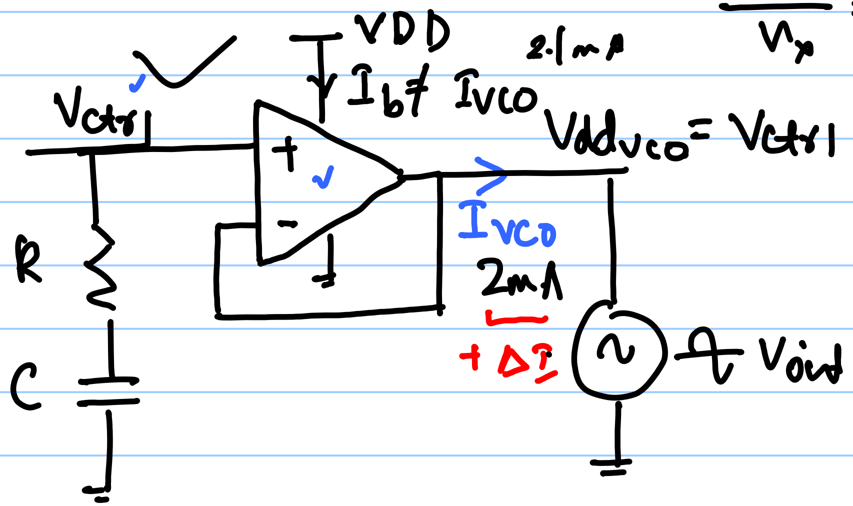




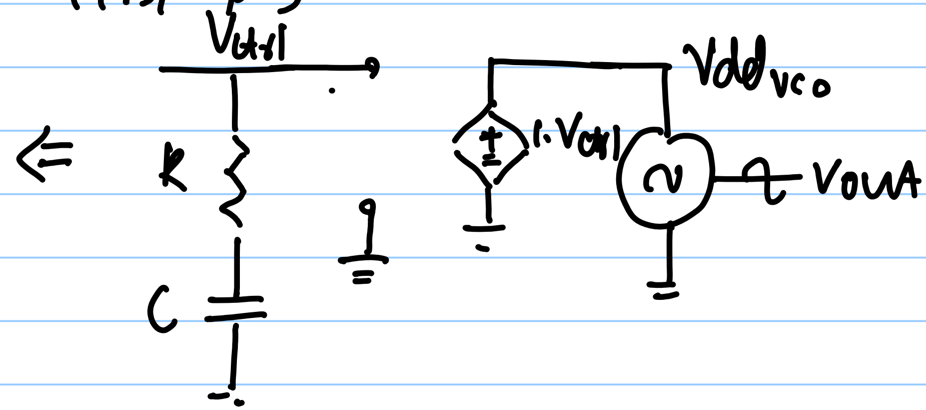




$$\frac{V_{out}}{V_x} = \frac{g_m R_L}{1 + s/\omega_p}$$



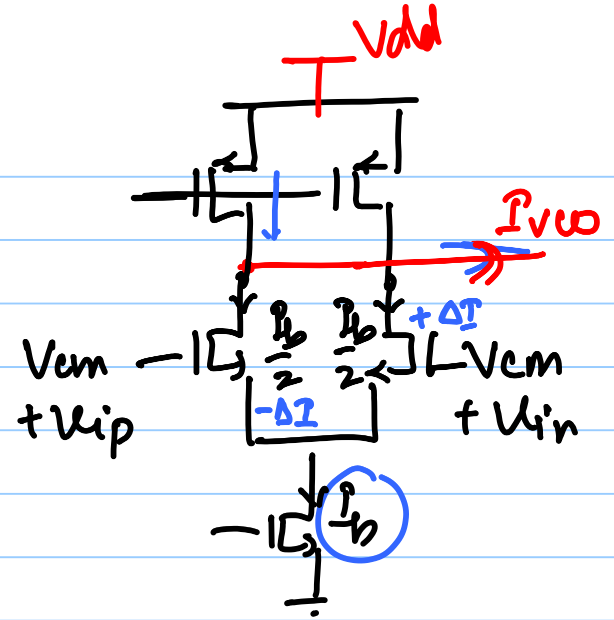
$\Leftarrow$



$I_b > I_{VCO}$

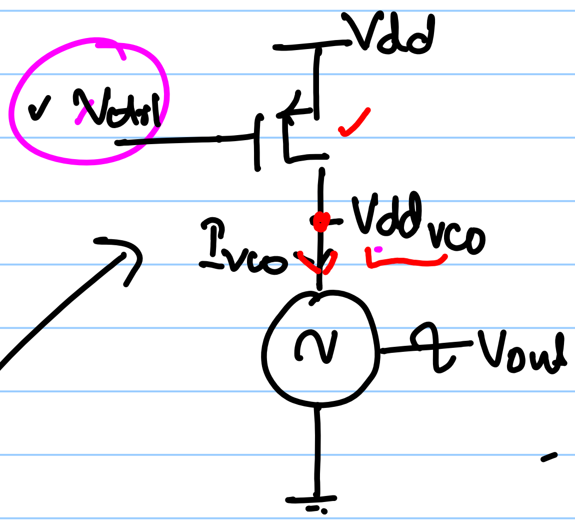
$$LG = \frac{1}{2\pi} I_{cp} \times \left(R + \frac{1}{sC}\right) \frac{2\pi K_{vco}}{s} \times \frac{1}{N} \times \frac{1}{1 + s/\omega_{p4}}$$

$$\frac{Vdd_{vco}}{V_{ctrl}} = H(s) = \frac{1}{1 + s/\omega_{p4}}$$



$$i_{out} = g_m v_{diff}$$

$$v_{ip} = -v_{in} = \frac{v_{diff}}{2}$$

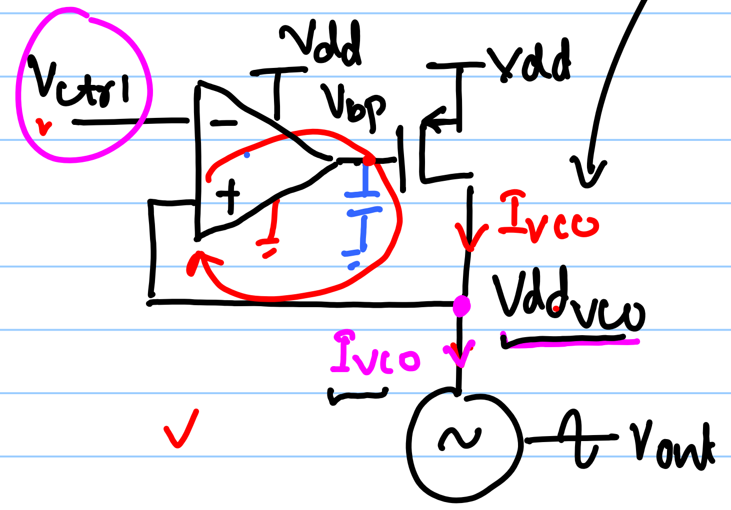


f_{vco}

$\Delta V_{ctrl} \rightarrow g_m \Delta V_{ctrl} = \Delta I_{vco}$

$\Delta f_{out} = K_{cco} \times \Delta I_{vco}$ [Hz/A]

$$\frac{\Delta f_{out}}{\Delta V_{ctrl}} = g_m K_{cco}$$



$$\frac{Vdd_{vco}}{V_{ctrl}} = \frac{g_m r_o}{1 + s/\omega_p}$$

$Vdd_{vco} = V_{ctrl}$

$f_{vco} = f_{free} + K_{vco} \cdot (V_{ctrl} - V_{ctrl}(0))$

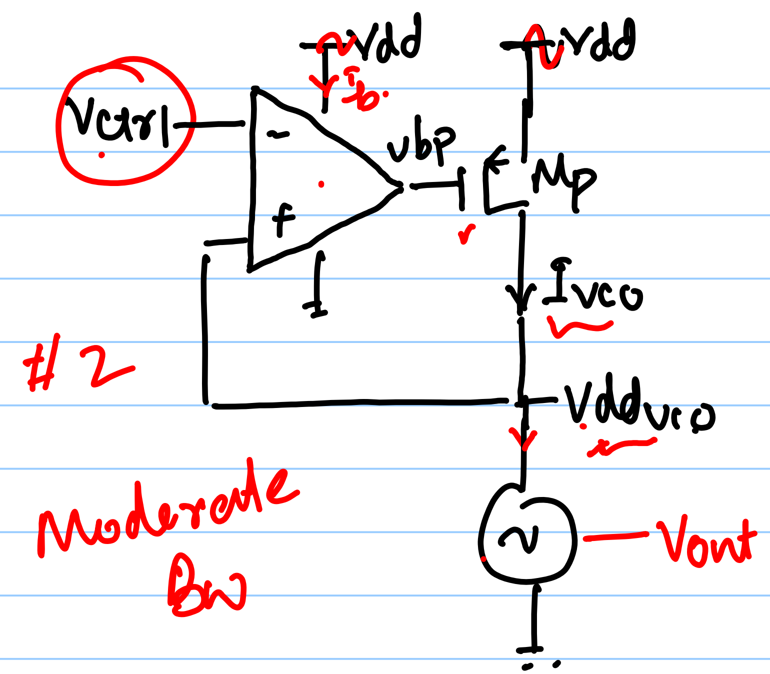
$I_{vco} = f(f_{vco})$

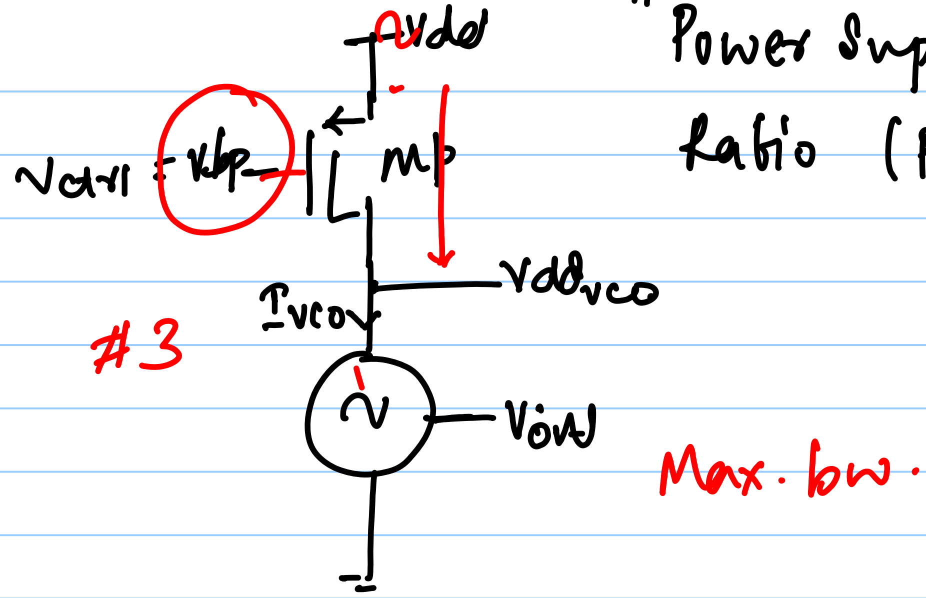
$f_{vco} = f(I_{vco}, Vdd_{vco})$

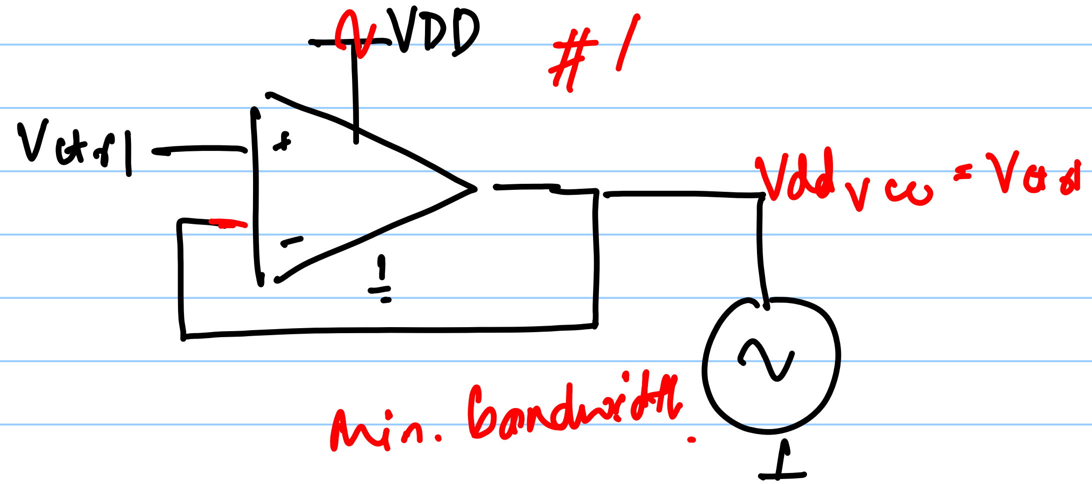
$$K_{vco} = \frac{\Delta f_{out}}{\Delta V_{ctrl}}$$

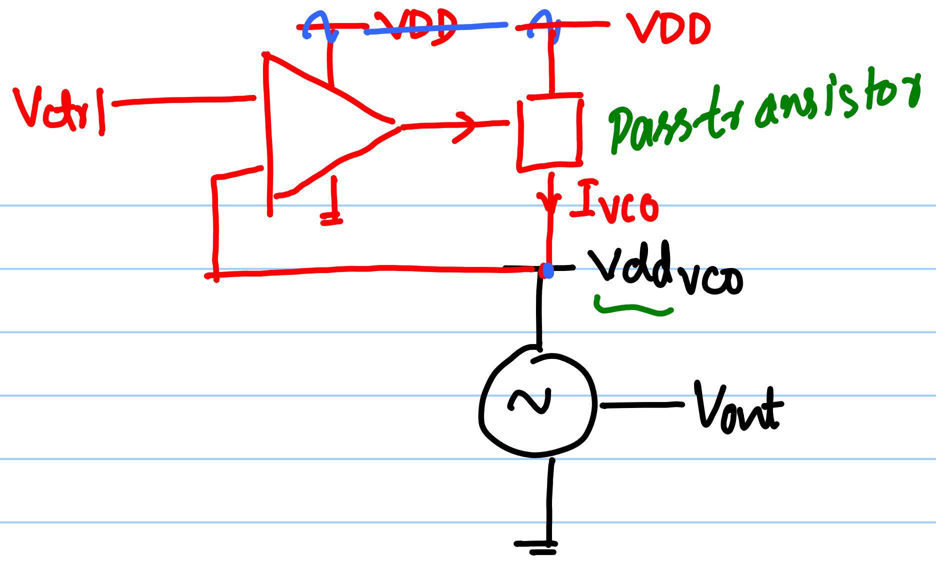
$\Delta V_{ctrl} \longrightarrow K_{vco} \cdot \Delta Vdd_{vco} = K_{vco} \cdot \Delta V_{ctrl}$

"Power Supply Rejection Ratio (PSRR)"









$$\Delta f_{out} = K_{vco} \cdot \Delta V_{ddvco}$$

$$\Delta \phi_{out} = 2\pi \frac{\Delta f_{out}}{s}$$

$$\frac{\Delta \phi_{out}}{\Delta V_{ddvco}} = \frac{2\pi K_{vco}}{s}$$

$$\frac{\Delta V_{ddvco}}{\Delta V_{DD}} =$$

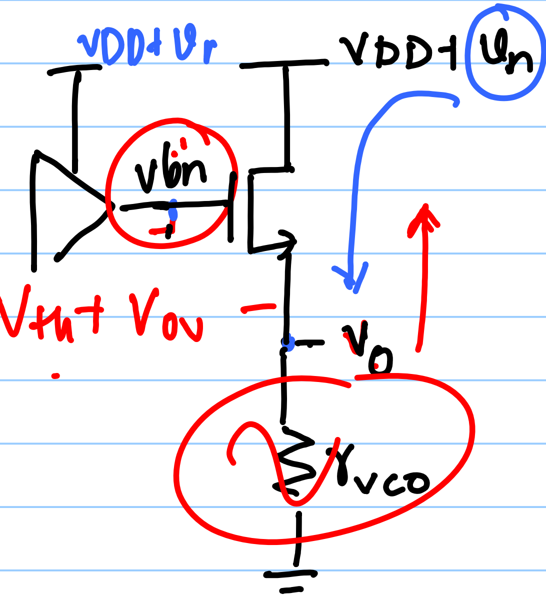
$$\frac{\Delta \phi_{out}}{\Delta V_{DD}} = \frac{\Delta \phi_{out}}{\Delta V_{ddvco}} \cdot \left(\frac{\Delta V_{ddvco}}{\Delta V_{DD}} \right)$$

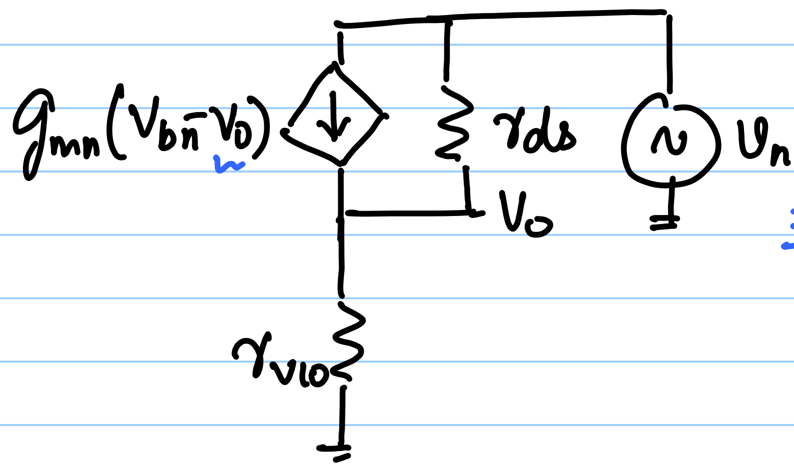
$$= \frac{2\pi K_{vco}}{s} \cdot \downarrow$$

$$\frac{\Delta V_{ddvco}}{\Delta V_{ctrl}} = \frac{1}{1 + s/\omega_p}$$

$$\omega_p \gg \omega_{ugb,pll}$$

Pass-transistor





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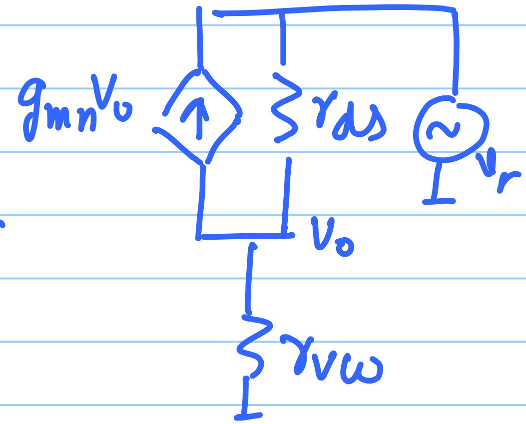


#1, $v_{bn} = 0$ ✓

$$-\frac{v_o}{r_{vco}} = \frac{v_o - v_n}{r_{ds}} + g_{mn} v_o$$

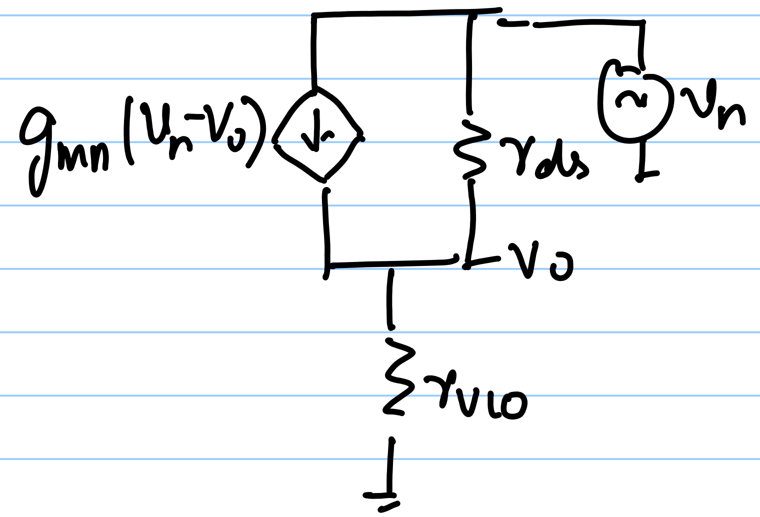
$$\frac{v_o}{v_n} = \frac{1/r_{ds}}{\frac{1}{r_{vco}} + \frac{1}{r_{ds}} + g_{mn}} = \frac{1}{1 + g_{mn} r_{ds} + \frac{r_{ds}}{r_{vco}}}$$

$\gg 1$ ✓

$V_{bn} - V_o - V_{th} = V_{ov}$

$\uparrow V_{bn} = V_{ov} + V_o^{\uparrow} + V_{th}$.

#2 $v_{bn} = v_n$ ✓

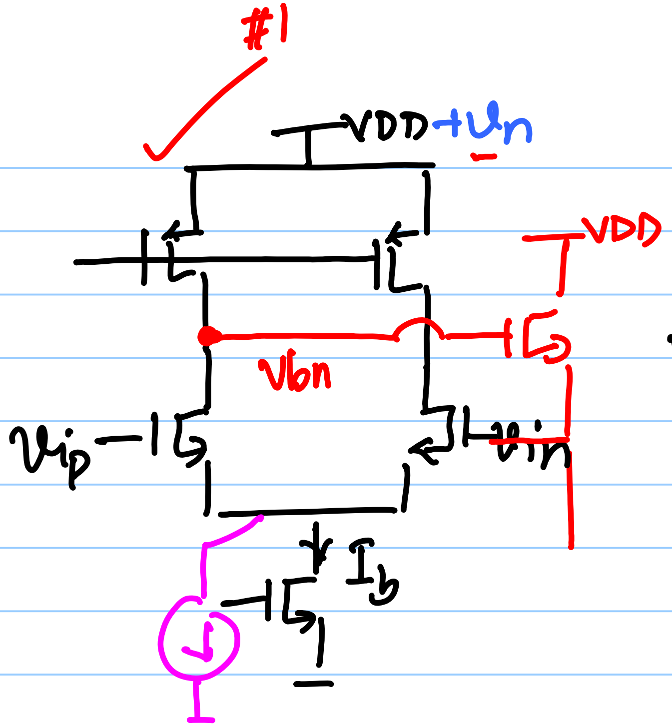


$$g_{mn}(v_n - v_o) + \frac{v_n - v_o}{r_{ds}} = \frac{v_o}{r_{vlo}}$$

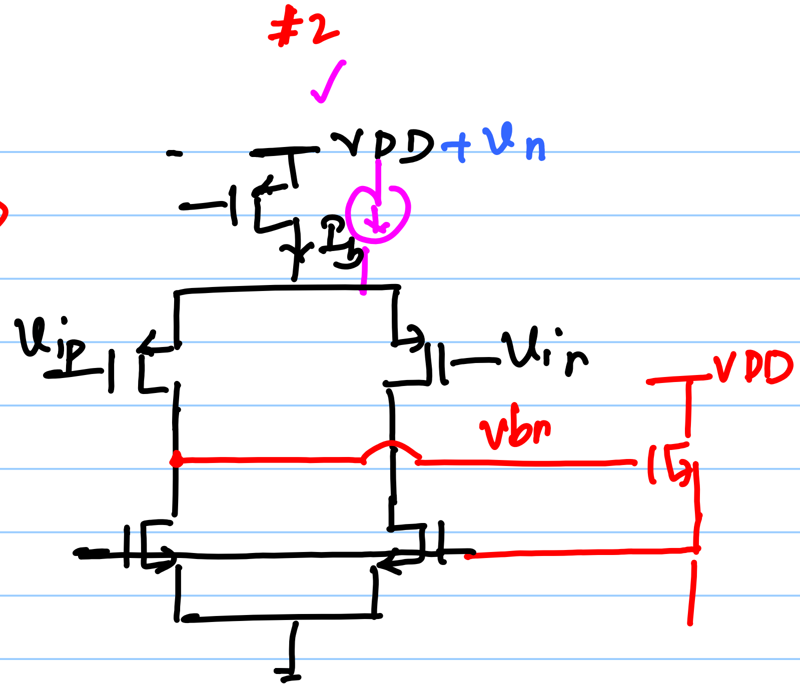
$$v_n\left(g_{mn} + \frac{1}{r_{ds}}\right) = v_o\left(\frac{1}{r_{vlo}} + \frac{1}{r_{ds}} + g_{mn}\right)$$

$$\frac{v_o}{v_n} = \frac{1 + g_{mn} r_{ds}}{1 + g_{mn} r_{ds} + \frac{r_{ds}}{r_{vlo}}} \approx 1$$

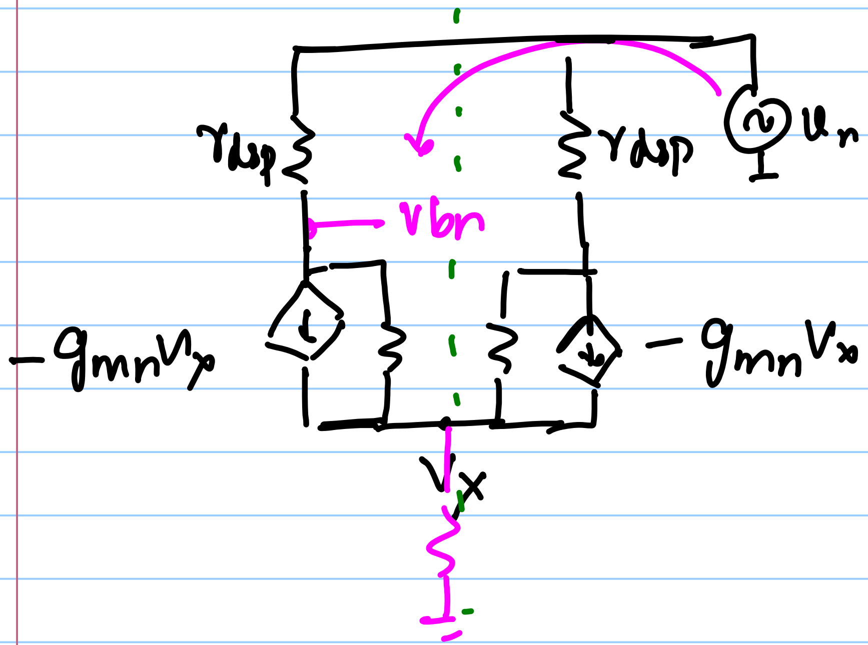
$g_{mn} r_{ds} \gg 1$



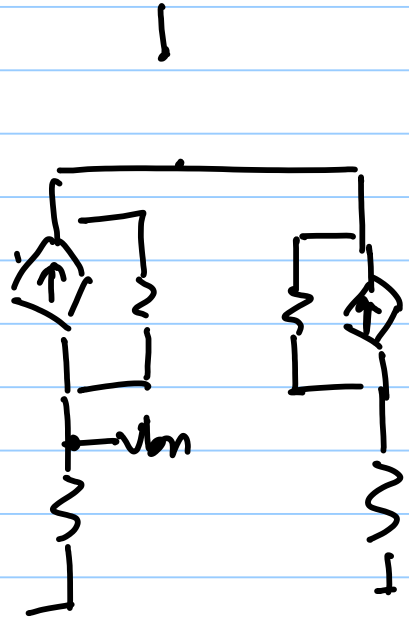
#1
VDD+vn
VDD
vbn
vip
vin
Ib



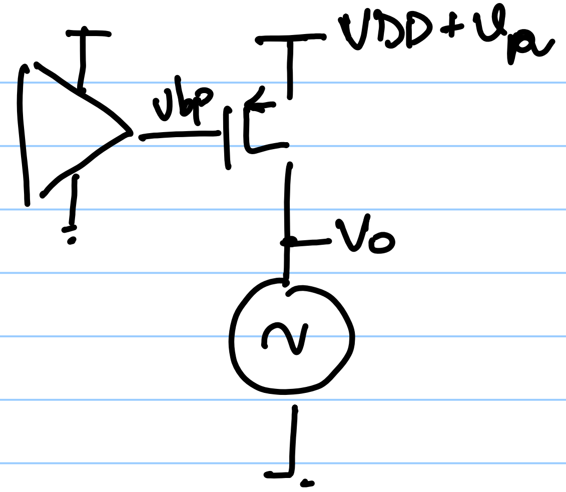
#2
VDD+vn
Ib
vip
vin
vbn
VDD

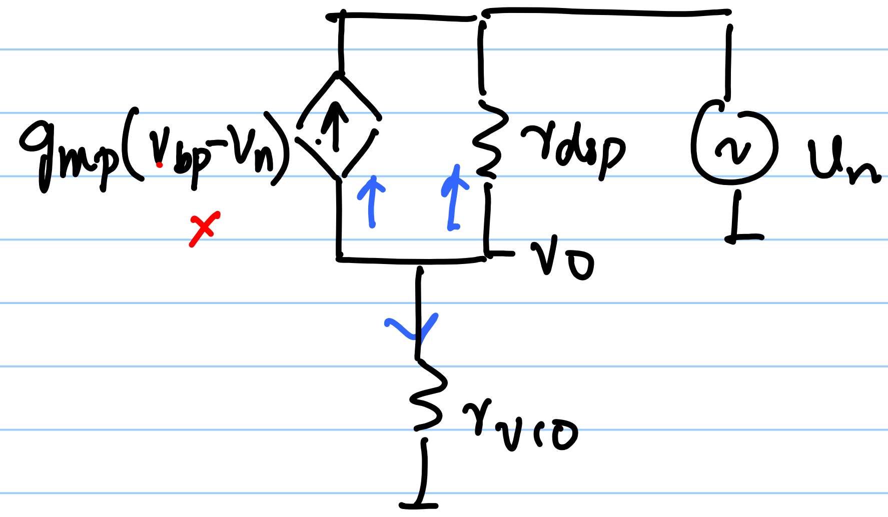


rdsp
rdsp
vn
vbn
−gmnVx
−gmnVx
Vx



vbn





#1 $v_{bp} = v_n$ (NMOS i/p amp.)

$$\frac{V_o}{V_n} = \frac{r_{VCO}}{r_{dsp}+r_{VCO}} = \frac{1}{1+\frac{r_{dsp}}{r_{VCO}}}$$ ✓

#1 $v_{bp} = 0$

$$\frac{V_o}{r_{VCO}} + g_{mp}(-v_n) + \frac{V_o - V_n}{r_{dsp}} = 0$$

$$\frac{V_o}{v_n} = \frac{g_{mp}+\frac{1}{r_{dsp}}}{\frac{1}{r_{dsp}}+\frac{1}{r_{VCO}}} = \frac{1+g_{mp}r_{dsp}}{\frac{r_{dsp}}{r_{VCO}}+1}$$

✓ NMOS i/p amp. + PMOS as pass-transistor for VCO ✓

PMOS i/p amp. + NMOS as pass-transistor for VCO ✓