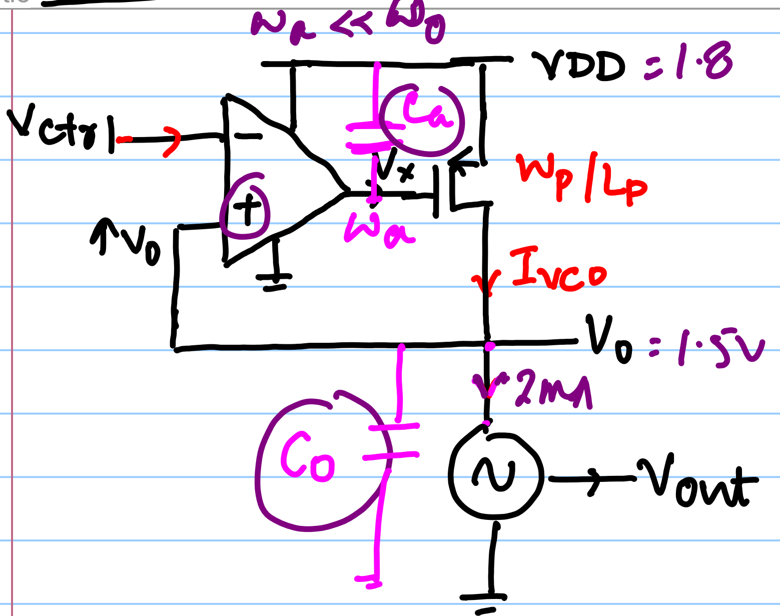
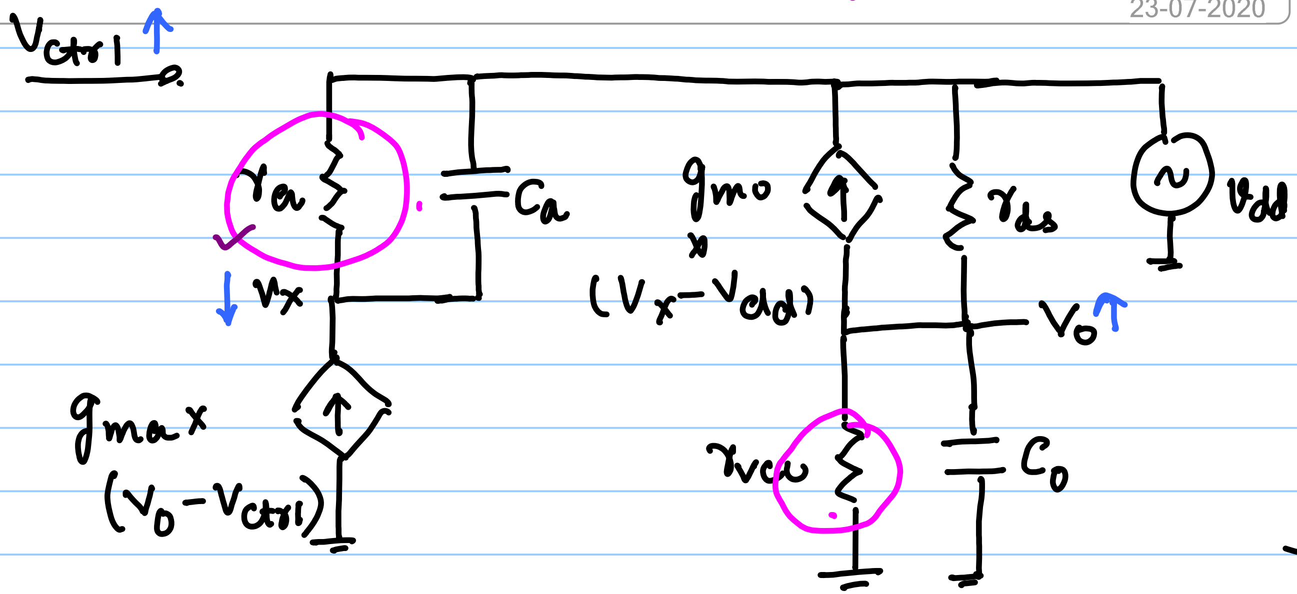
Lecture # 26

$C_a > C_o$; $r_a > r_o$





- $\frac{V_o}{V_{ctrl}} =$
- $\frac{V_o}{V_{dd}} =$

$$V_x = g_{ma}(V_o - V_{ctrl}) \left(r_a \| \frac{1}{sC_a}\right)$$

$$= \frac{g_{ma} r_a}{(1 + sC_a r_a)} (V_o - V_{ctrl})$$

$$V_o = -g_{mo} V_x \left(r_{ds} \| r_{vco} \| \frac{1}{sC_o}\right)$$

$$= -g_{mo} V_x \left(r_o' \| \frac{1}{sC_o}\right)$$

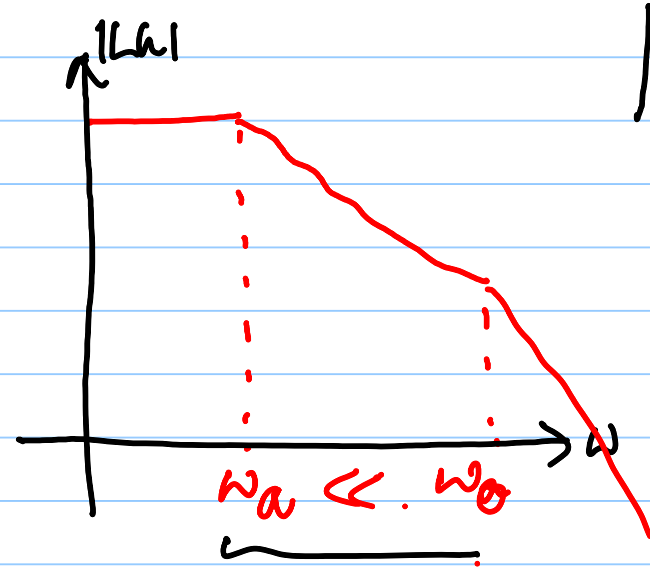
$$\frac{V_o}{V_{ctrl}} = \frac{1}{1 + \frac{(1+s/\omega_a)(1+s/\omega_o)}{A_a A_o}} = \frac{1}{H \frac{1}{L_G}}$$

$A_a = g_{ma} r_a$, $A_o = g_{mo} r_o'$, $\omega_a = \frac{1}{r_a C_a}$, $\omega_o = \frac{1}{r_o' C_o}$

$$\frac{V_o}{V_{ctrl}} = \frac{1}{1 + \frac{(1+s/\omega_a)(1+s/\omega_o)}{A_a A_o}}$$

$$= \frac{A_a A_o}{A_a A_o + 1 + s\left(\frac{1}{\omega_a} + \frac{1}{\omega_o}\right) + \frac{s^2}{\omega_a \omega_o}}$$

$$L_G = \frac{A_a A_o}{(1+s/\omega_a)(1+s/\omega_o)}$$



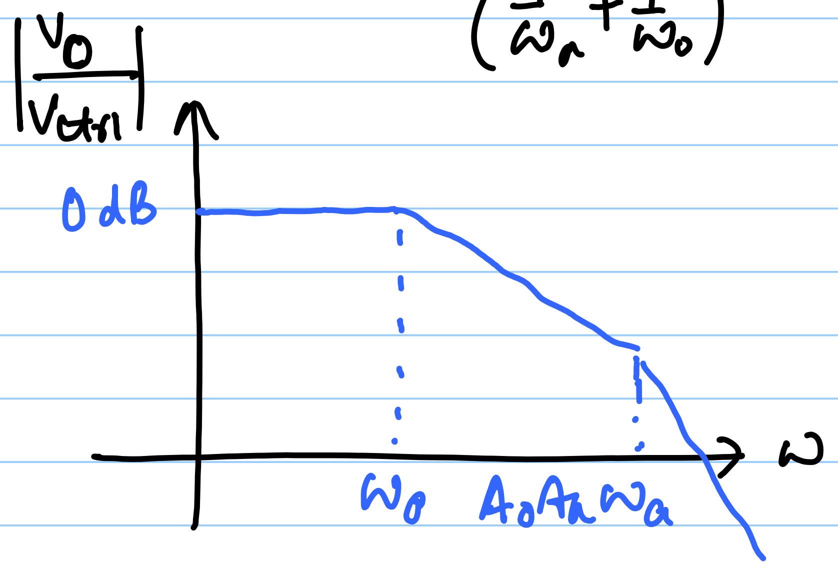
$$s_1 + s_2 = -\frac{\left(\frac{1}{\omega_a} + \frac{1}{\omega_o}\right)}{1/\omega_a \omega_o} = -(\omega_a + \omega_o)$$

$\omega_{pp} = s_2 \approx -\omega_o$

$ax^2 + bx + c = 0$

$x_1 + x_2 = -b/a$, $x_1 x_2 = c/a$

$$s_1 = -\frac{1+A_0A_a}{\left(\frac{1}{\omega_a}+\frac{1}{\omega_0}\right)} \approx A_aA_0\omega_a$$



$$x_1+x_2 \approx x_1 = -b/a.$$

$$x_1x_2 = -\frac{b}{a}x_2 = \frac{c}{a}$$

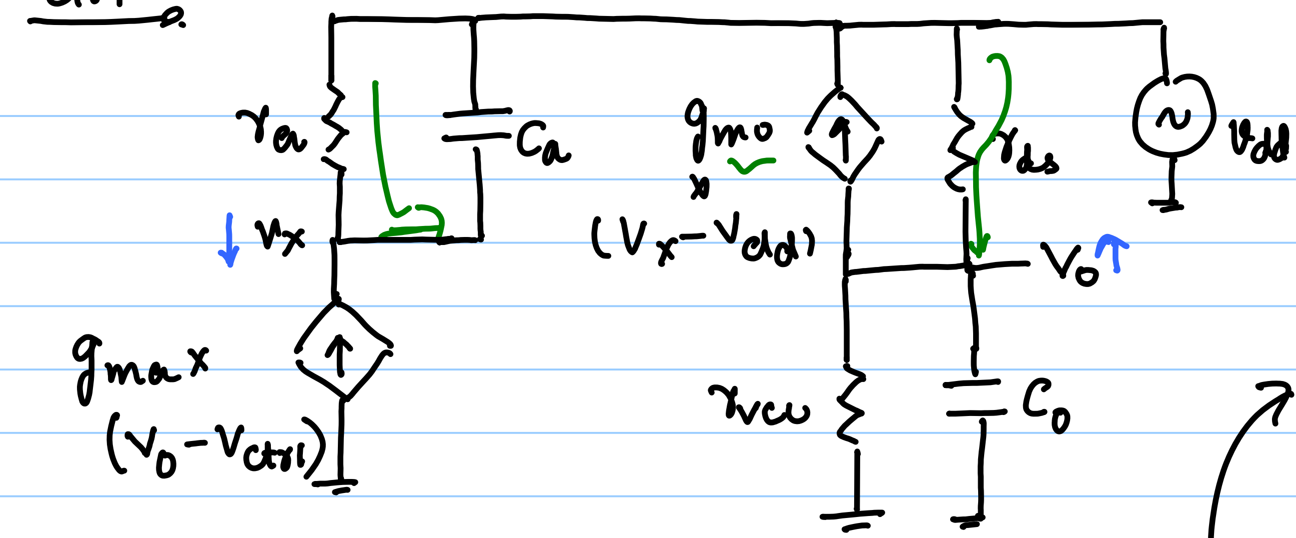
$$x_2 = -\frac{c}{b}$$

$$\frac{V_0}{V_{ctrl}} = \frac{A_0A_a/(1+A_0A_a)}{\left(1+\frac{s}{\omega_{p1}}\right)\left(1+\frac{s}{\omega_{p2}}\right)}$$ ✓

$$L_{G,PLL} = \frac{I_p}{2\pi}\frac{(1+sRC_1)}{\left(1+\frac{sRC_1C_2}{C_1+C_2}\right)}\frac{2\pi K_{VCO}}{s^2C_1N}$$ ✓

$$\times\frac{V_0}{V_{ctrl}}$$ ✓

$\underline{V_{ctrl}=0}$



$$V_x = \frac{g_{ma} r_a}{1 + sC_a r_a} V_0 + V_{dd}$$

$$g_{ma} V_0 = (V_x - V_{dd}) \left(\frac{1}{r_a} + sC_a \right) \quad \text{—(1)}$$

$$g_{mo}(V_x - V_{dd}) + \frac{(V_0 - V_{dd})}{r_{ds}} = -\frac{V_0}{r_{vco}} - V_0 s C_0 \quad \text{—(2)}$$

$$g_{mo} V_x = -V_0 \left(\frac{1}{r_{vco}} + \frac{1}{r_{ds}} + sC_0 \right) + V_{dd} \left(\frac{1}{r_{ds}} + g_{mo} \right)$$

$$\frac{g_{mo} g_{ma} r_a}{1 + sC_a r_a} V_0 + g_{mo} V_{dd} = -V_0 \left(\frac{1}{r_0'} + sC_0 \right) + V_{dd} \left(\frac{1}{r_{ds}} + g_{mo} \right)$$

$$V_o \frac{g_{mo} r_o' \, g_{ma} r_a}{1+sC_a r_a} + V_o (1+sC_o r_o') = V_{dd} \cdot r_o' / r_{ds}$$

$$r_o' = \frac{r_{ds} \cdot r_{vco}}{r_{ds}+r_{vco}}$$

$$\frac{V_o}{V_{dd}} = \frac{r_o'}{r_{ds}} \frac{(1+sC_a r_a)}{A_o A_a + (1+sC_o r_o')(1+sC_a r_a)}$$

$$= \frac{r_{vco}}{r_{vco}+r_{ds}} \frac{(1+sC_a r_a)}{A_o A_a + (1+sC_a r_o')(1+sC_a r_a)}$$

$$= \frac{r_{vco}}{r_{vco}+r_{ds}} \frac{1}{A_a A_o} \frac{(1+s/\omega_a)}{1+\frac{(1+s/\omega_o)(1+s/\omega_a)}{A_o A_a}}$$

$$= \frac{r_{vco}}{r_{vco}+r_{ds}} \frac{1}{A_a A_o} (1+s/\omega_a) \left(\frac{V_o}{V_{ctrl}} \right)$$

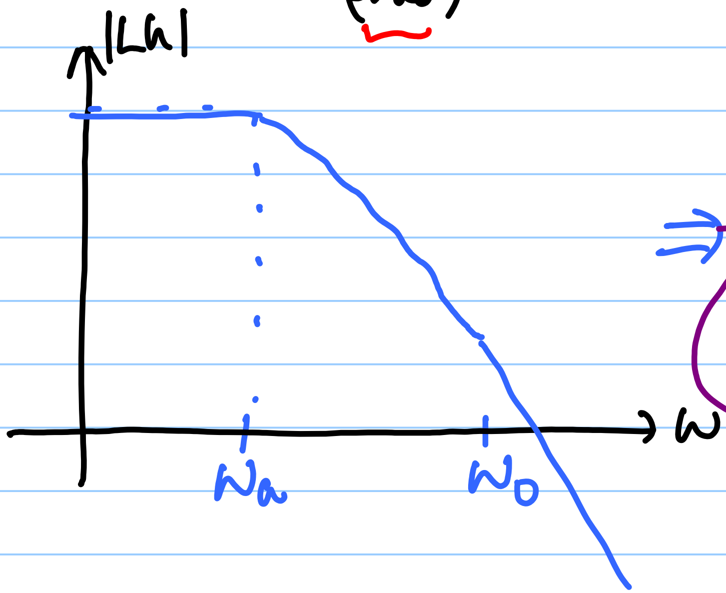
$$\frac{V_o}{V_{ctrl}} = \frac{1}{1 + \dfrac{(1+s/\omega_o)(1+s/\omega_a)}{A_o A_a}}$$

$$\frac{V_o}{V_{dd}} = \frac{\gamma_{vco}}{\gamma_{vco} + \gamma_{ds}} \times \frac{1}{A_o A_a} \times \frac{(1+s/\omega_a)}{1 + (\quad)} \sim$$

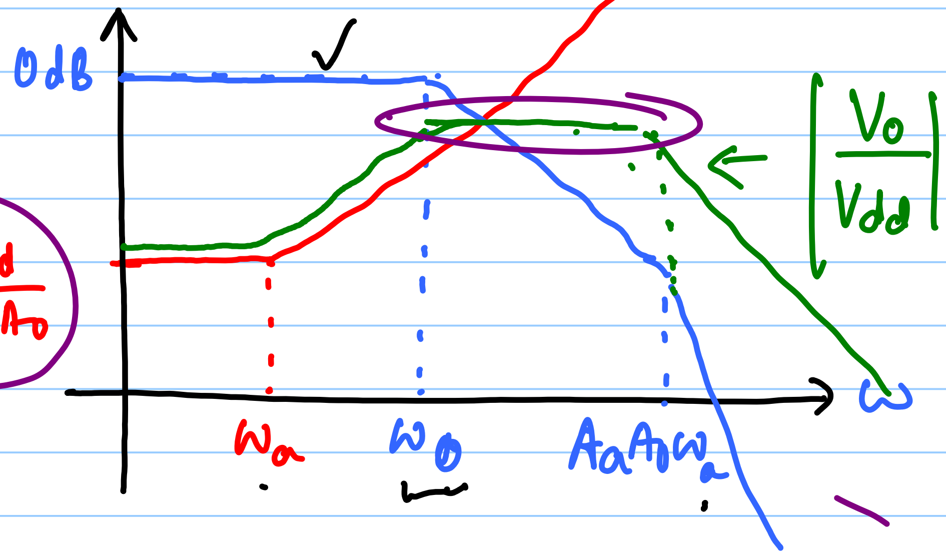
(S_{vdd})

$$\approx \frac{S_{vdd}}{A_a A_o} \cdot \frac{\omega_o/\omega_a}{\dfrac{\omega_o^2}{\omega_o \cdot \omega_a} \cdot \dfrac{1}{A_o A_a}}$$

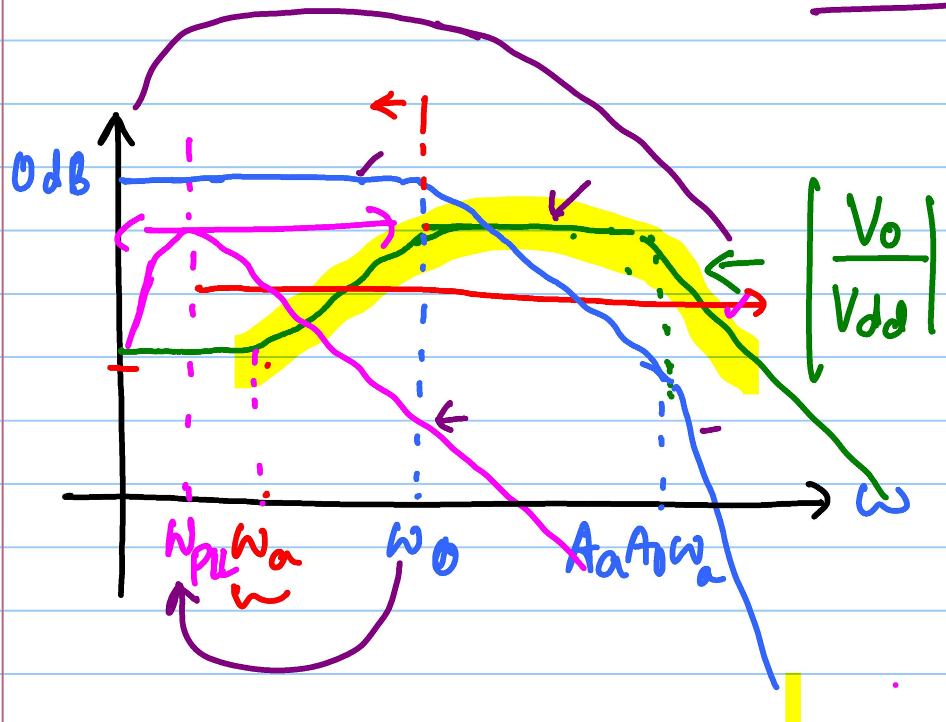
$$= S_{vdd}$$



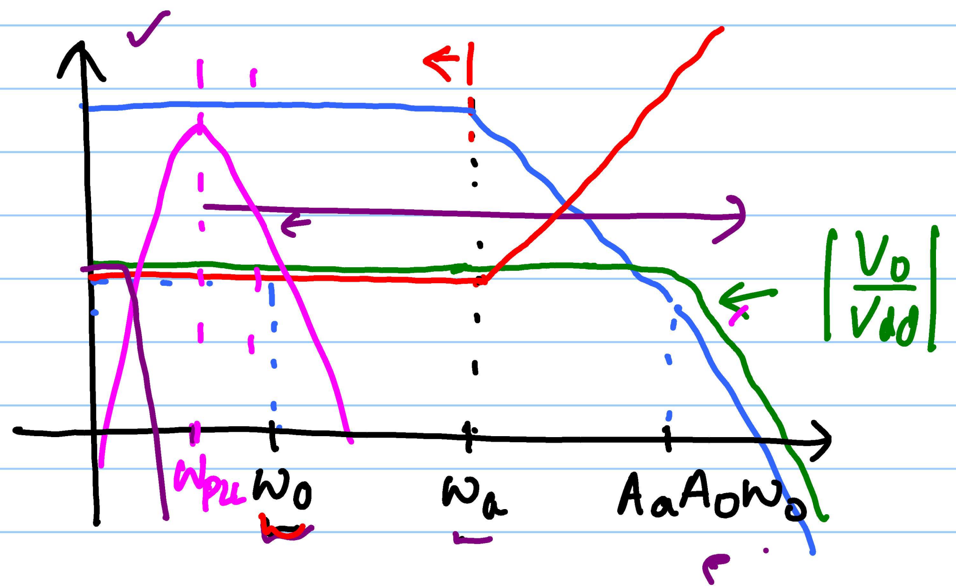
$$\frac{S_{vdd}}{A_a A_o}$$



#1



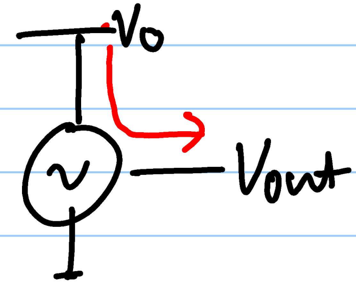
#2



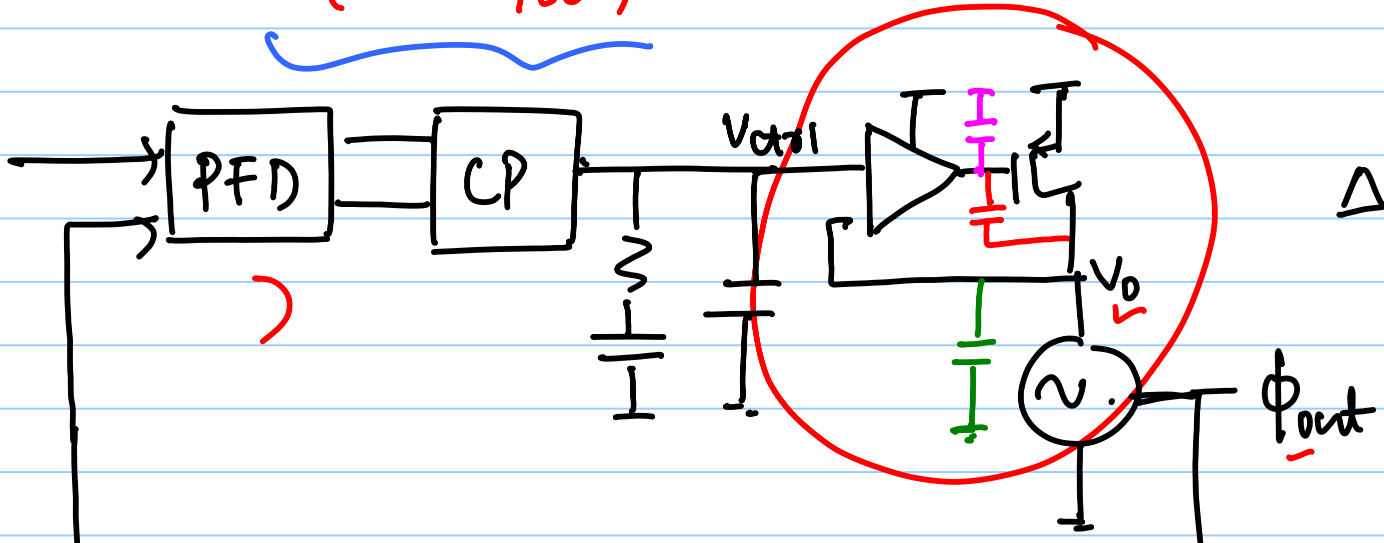
$$LG_{PLL} = \frac{I_{cp}}{2\pi} \cdot \frac{(1+sRC_1)}{\left(1+sR\frac{C_1C_2}{C_1+C_2}\right)} \frac{2\pi K_{VCO}}{s^2(C_1+C_2)} \frac{1}{N} \times \left(\frac{V_0}{V_{ctrl}}\right) \approx \frac{A_{DC}(1+s/\omega_z)}{\left(1+\frac{s}{\omega_{p3}}\right)s^2}$$

$$\frac{\phi_{out}}{V_{dd}} = \frac{\phi_{out}}{V_0} \times \frac{V_0}{V_{dd}}$$

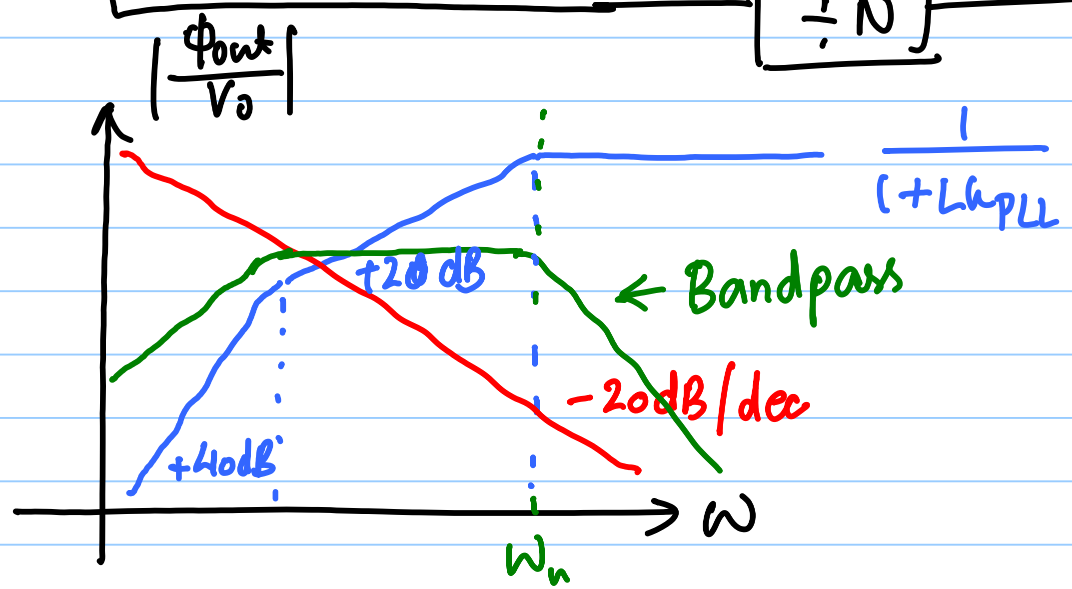
$$= \frac{2\pi K_{VCO}/s}{1+LG_{PLL}}$$



$$= \frac{2\pi K_{VCO}}{s\,(1+LG_{PLL})} \times \frac{V_o}{V_{ctrl}}$$



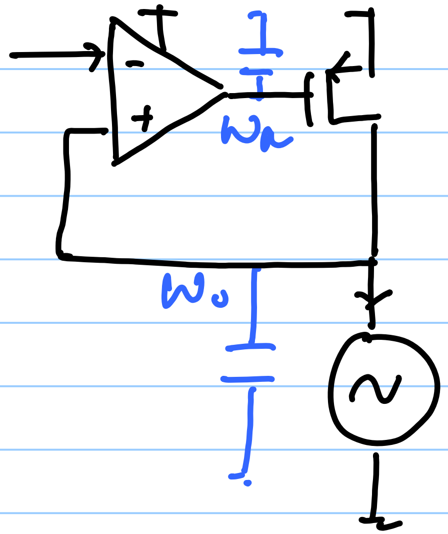
$$\Delta f_{VCO} = K_{VCO} \cdot \Delta V_o$$

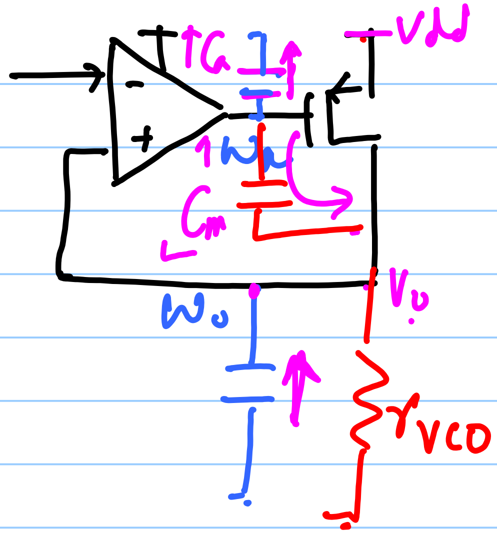


$$\frac{1}{1+LG_{PLL}}$$

$$= \frac{1}{1+\dfrac{A_{dc}\,(1+s/\omega_z)}{s^2\,(1+s/\omega_{p3})}}$$

$$= \frac{s^2\,(1+s/\omega_{p3})}{s^2(1+s/\omega_{p3}) + A_{dc}\,(1+s/\omega_z)}$$


ωp
ωo


Vdd
Cm
ωo
Vo
rVCO