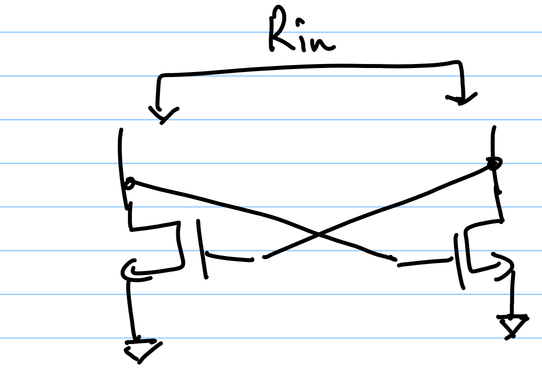
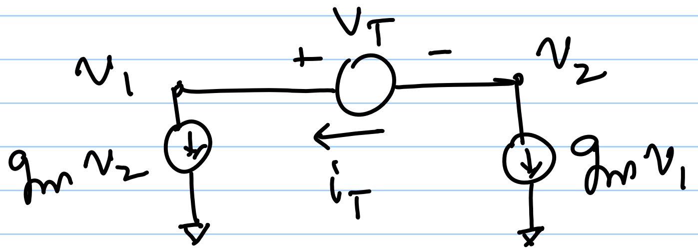
Lecture 28 : VCOs – II



$R_{in} = ?$



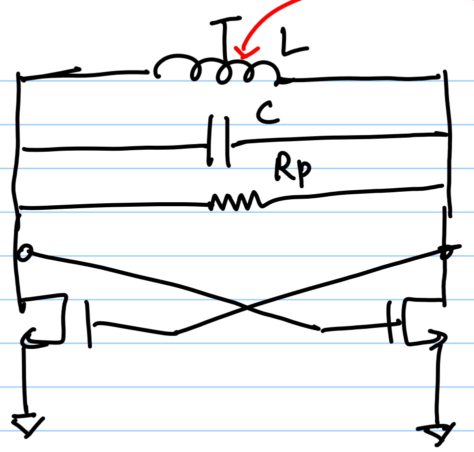
$$i_T = g_m v_2 = -g_m v_1$$

$$2 i_T = g_m (v_2 - v_1)$$

$$= -g_m v_T$$

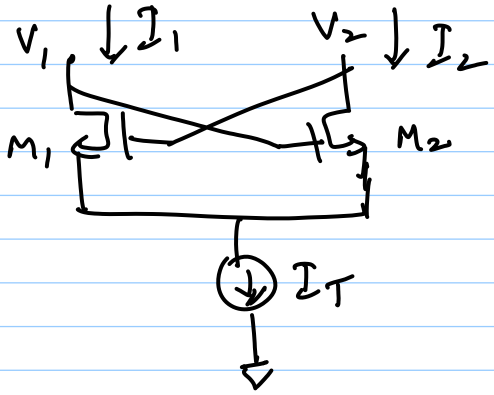
$$\Rightarrow \quad R_{in} = \frac{v_T}{i_T} = \frac{-2}{g_m}$$

centre-tap to V_{DD}



for oscillations,

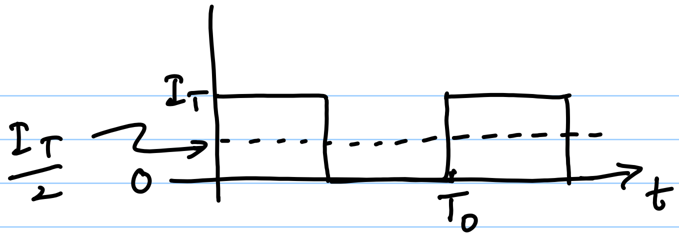
$$|R_p| = \left|\frac{-2}{g_m}\right| \Rightarrow \underline{\underline{g_m R_p = 2}}$$



positive feedback: assume

M1 & M2 switch quickly

$I_1 - I_2 = I_d$



$$I_1 = I_T\left[\frac{1}{2}+\frac{2}{\pi}\left\{\sin(\omega_0 t)+\frac{1}{3}\sin(3\omega_0 t)+\cdots\right\}\right]$$

LC tank filters out DC & harmonics of I

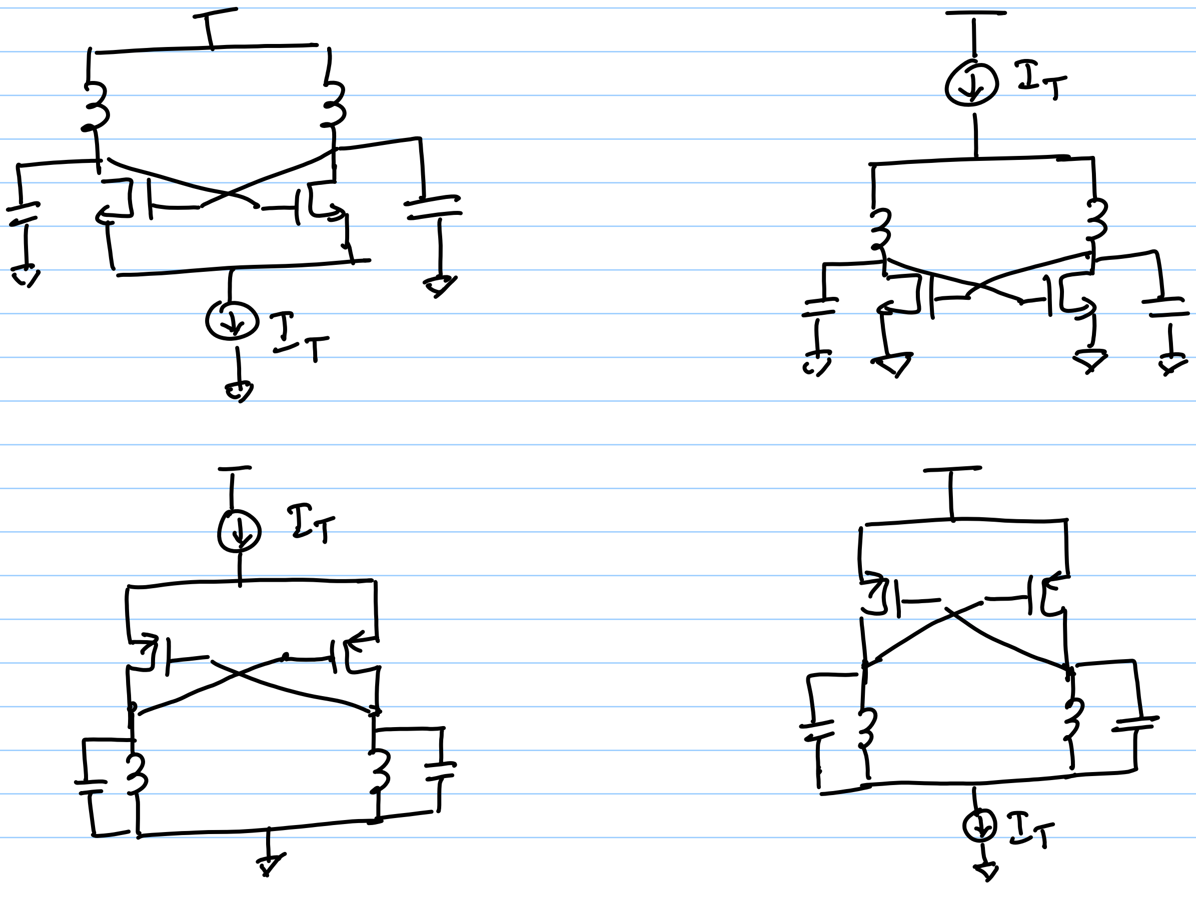
$$\Rightarrow V_1\{=-V_2\} = I_1(\omega_0)\cdot Z(j\omega_0) = \frac{2}{\pi}\cdot I_T\cdot\frac{R_p}{2}$$

$$= \frac{1}{\pi} I_T \sin(\omega_0 t)\cdot R_p$$

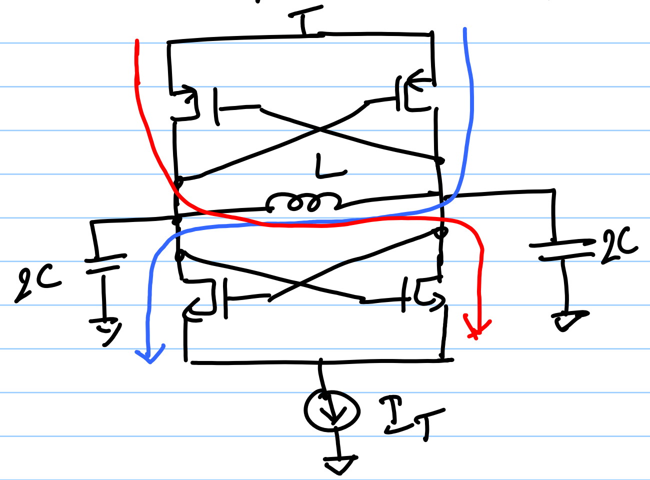
$$\boxed{|V_{od}| = \frac{2}{\pi} I_T R_p} \leftarrow \text{output amplitude}$$

* to a first order, oscillation ampl. is independent of device size!

Other flavours of CC VCO:

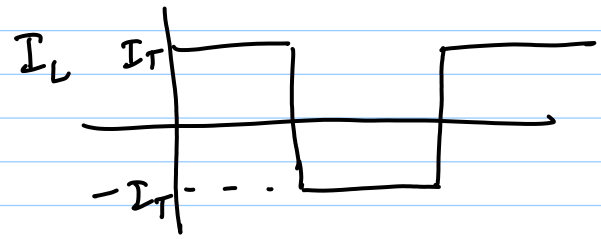


Another popular topology:



* current reuse

$$\Rightarrow R_{in} = \frac{-2}{g_{m_n} + g_{m_p}}$$

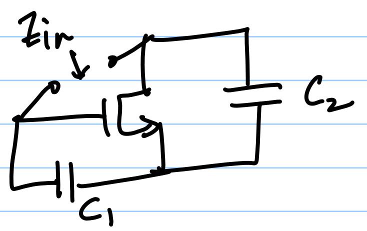


$$\Rightarrow I_L = \frac{4 I_T}{\pi}\left[\sin\omega_0 t + \frac{1}{3}\sin 3\omega_0 t + \cdots\right]$$

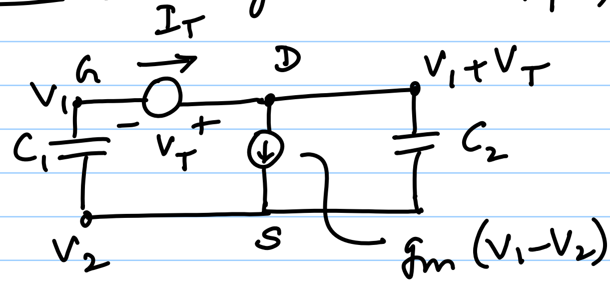
$$\Rightarrow \boxed{\text{Amplitude} = \frac{4}{\pi} I_T R_p}$$

← double the amplitude compared to nmos - c.c. VCO

Single-transistor oscillators (usually discrete apps)



$\equiv$



$$V_1 = V_2 - I_T \cdot \frac{1}{sC_1}$$

$$\Rightarrow (V_1 - V_2) = -\frac{I_T}{sC_1}$$

KCL @ D:

$$I_T = g_m(V_1 - V_2) + \{(V_1 - V_2) + V_T\} \cdot sC_2$$

$$= (g_m + sC_2)\cdot(V_1 - V_2) + V_T \cdot sC_2$$

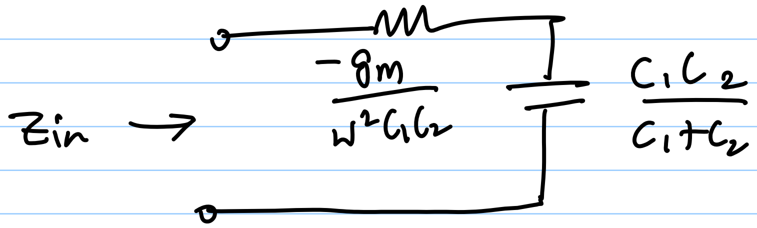
$$= -\frac{(g_m + sC_2)}{sC_1} \cdot I_T + V_T \cdot sC_2$$

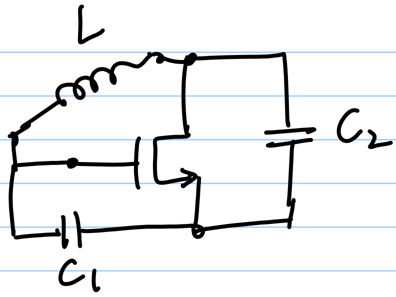
$$\Rightarrow Z_{in} = \frac{V_T}{I_T} = \frac{g_m + s(C_1+C_2)}{s^2 C_1 C_2}$$

$$= \frac{g_m}{s^2 C_1 C_2} + \frac{1}{s\,C_{eq}} \quad \text{where } C_{eq} = \frac{C_1 C_2}{C_1+C_2}$$

$$Z_{in}(j\omega) = -\frac{g_m}{\omega^2 C_1 C_2} + \frac{1}{j\omega C_{eq}}.$$

i.e. equivalent ckt is



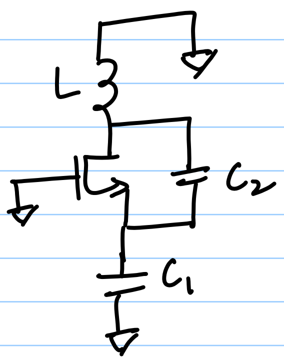


* For oscillations, we require

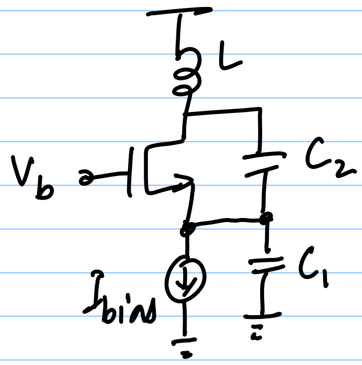
$$\frac{g_m}{\omega^2 C_1 C_2} \leq R_p$$

* Note that we can get 3 oscillator topologies by defining an AC ground

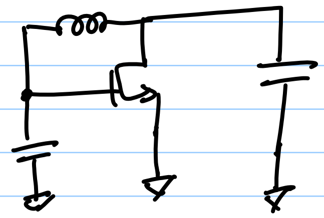
<u>Ground gate</u> $\Rightarrow$ Colpitts oscillator



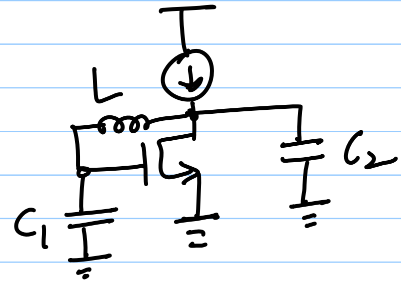
$\Rightarrow$ with biasing



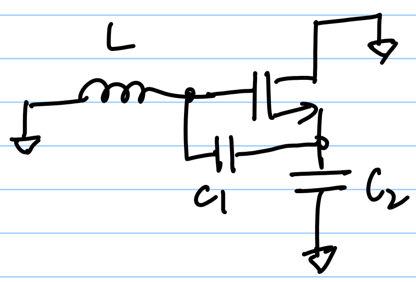
Ground source



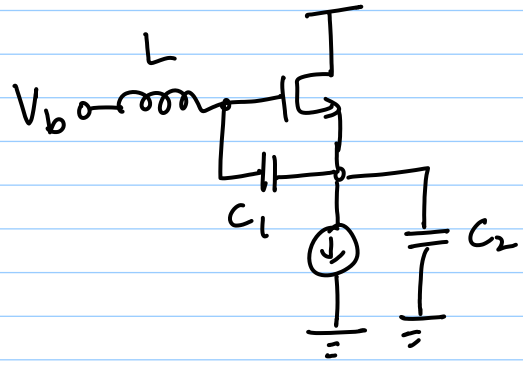
⇒ with biasing



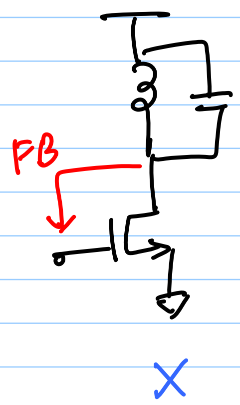
Ground drain

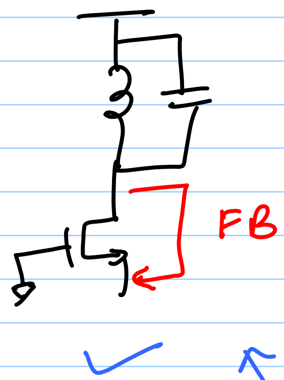


⇒ with biasing



* back to FB model :

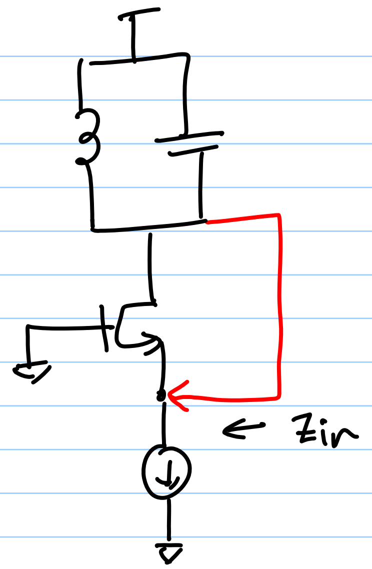




→ @ resonance, $Z(\text{tank}) = R_p$

⇒ V & I are in-phase

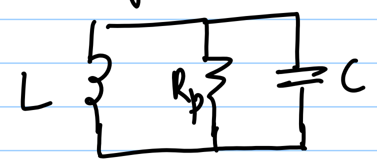
total phase = 0 ⇒ f.b. signal goes to emitter (without any additional phase in f.b.)



$$Z_{in} = \frac{1}{g_m + g_{mb}} + \underbrace{\frac{R_p}{(g_m+g_{mb})\,r_o}}_{\text{neglect this}}$$

$$= \text{low impedance}$$

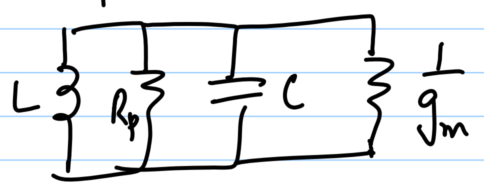
original tank



$\left\{\begin{matrix}\text{unloaded} \\ Q\end{matrix}\right\}$

$$Q_0 = \frac{R_p}{\omega_0 L}$$

after f.b.



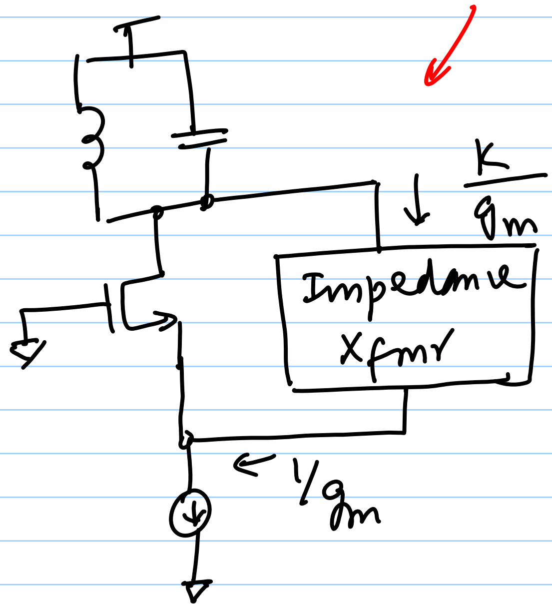
$\left\{\begin{matrix}\text{loaded} \\ Q\end{matrix}\right\}$

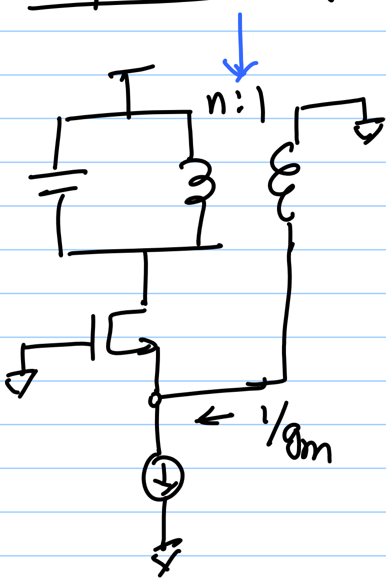
$$Q_1 = \frac{R_p \parallel 1/g_m}{\omega_0 L} \ll Q_0$$

$\Rightarrow$ LG can become < 1 $\Rightarrow$ no oscillations

$\rightarrow$ Use an Impedance Xfmr

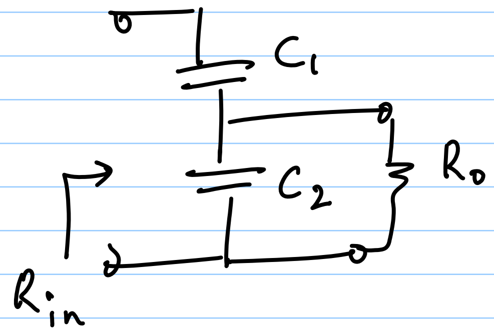
Explicit Xfmr





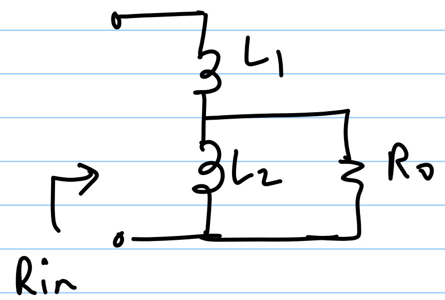
$\frac{n^2}{g_m}$ is seen by tank

Remember from impedance matching :



$$R_{in} = \underbrace{\left(1+\frac{C_2}{C_1}\right)}_{n}^{2} R_0$$

$$= n^2 R_0$$



$$R_{in} = \underbrace{\left(1+\frac{L_1}{L_2}\right)}_{n}^{2} R_0$$

$$= n^2 R_0$$