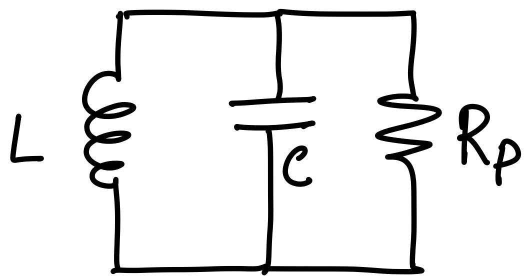
Cross Coupled Oscillator – Theory

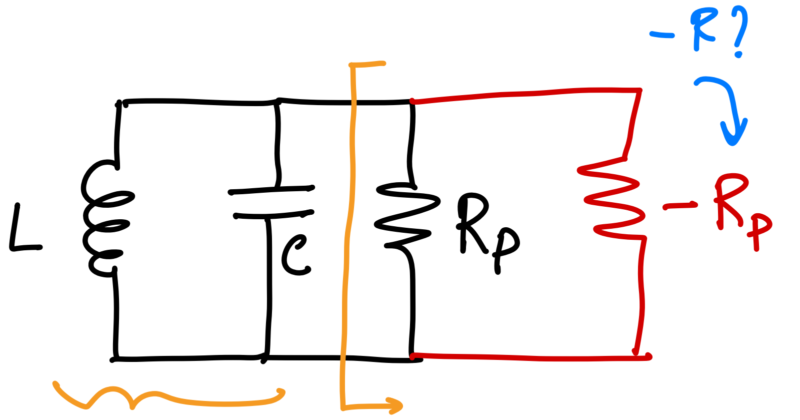
I Start-up condition

1) Barkhausen criteria. → Ring oscillators.

2) Negative resistance. → LC oscillators.

Note: Both of these criteria are mathematically wrong. (Why?) But they provide some intuition & we only use them to study the startup condition.

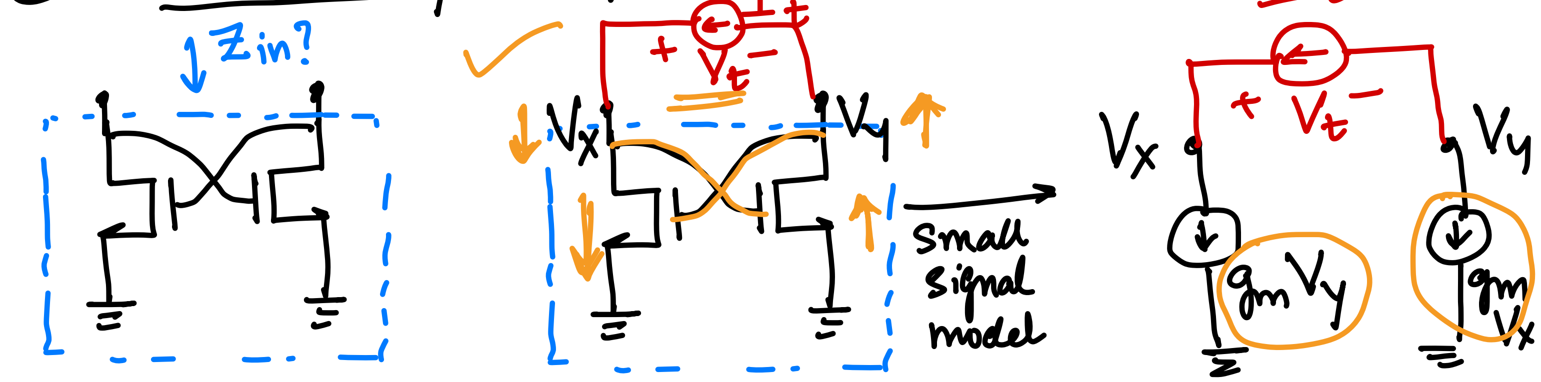




"oscillate"

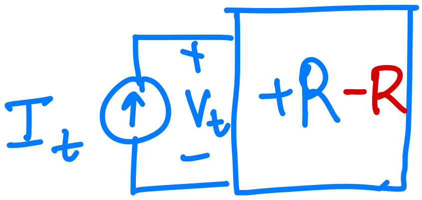
(Not accurate but intuitive)

II Cross-coupled pair



$$V_t = V_x - V_y \; ; \; I_t = g_m V_y \; ; \; V_x = -V_y$$

$$\boxed{\frac{V_t}{I_t} = Z_{in} = -\frac{2}{g_m}} \rightarrow \text{Negative "small-signal" Resistance.}$$

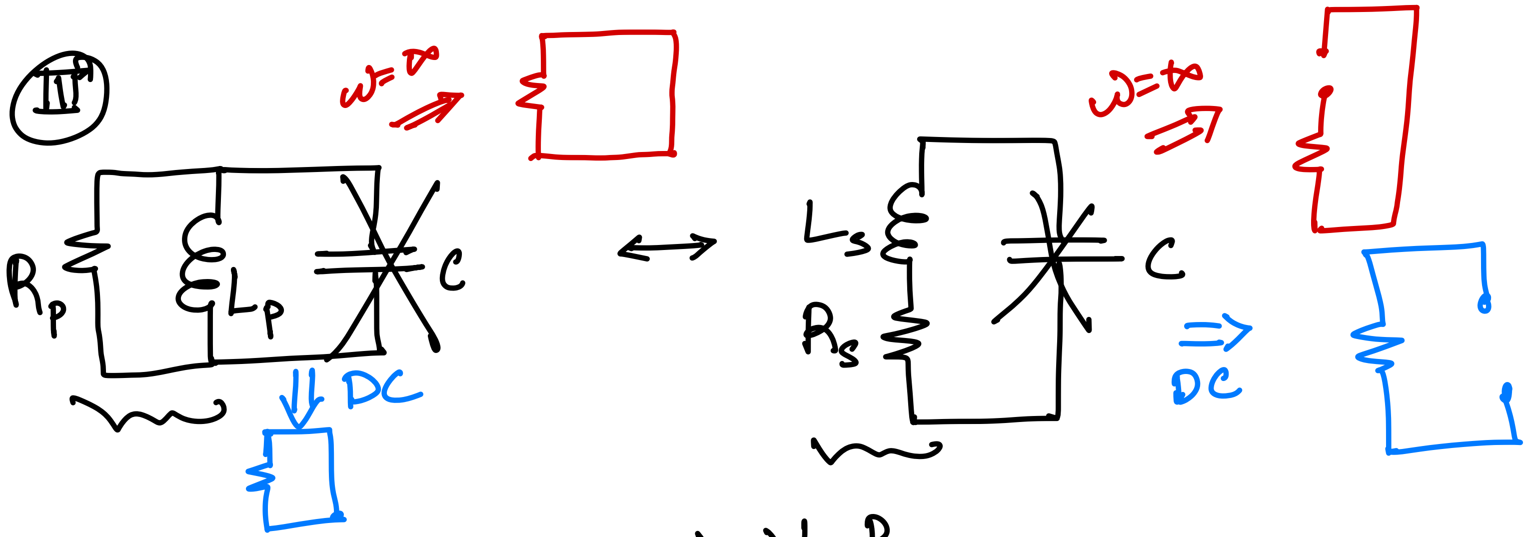


$I_t \uparrow \;\Rightarrow\; \partial I_t$ is +ve

$V_t \uparrow \;\Rightarrow\; \partial V_t$ is +ve.

$V_t \downarrow \;\Rightarrow\; \partial V_t$ is −ve.

III



$$j\omega L_s + R_s = \frac{j\omega L_p R_p}{j\omega L_p + R_p}$$

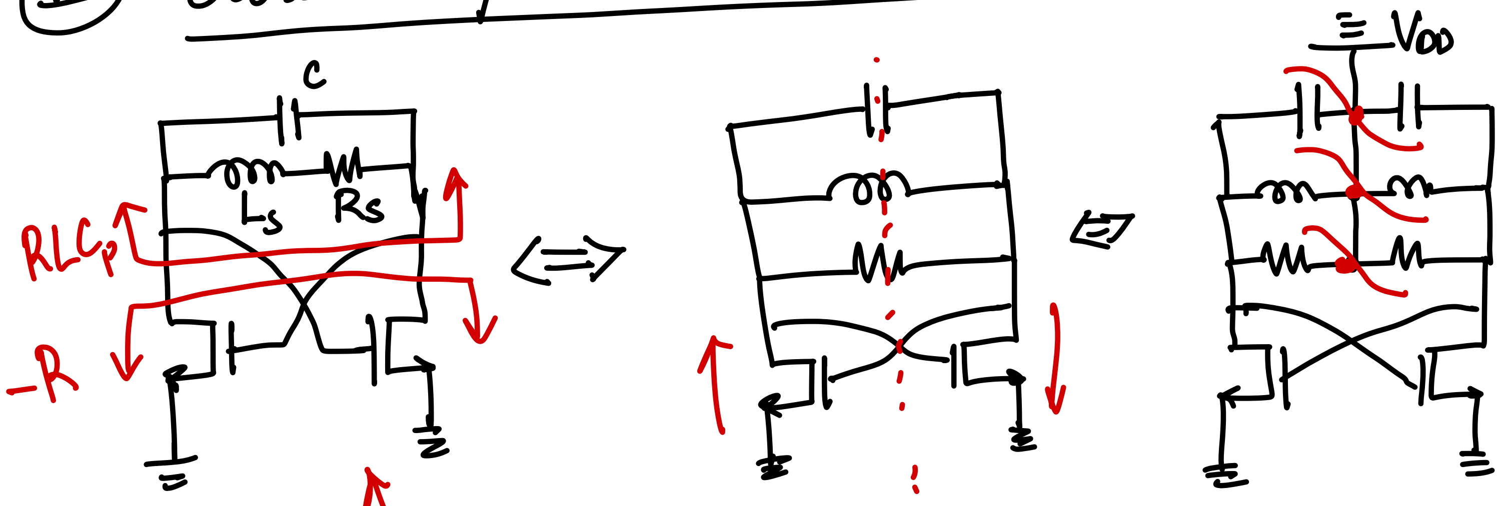
$$L_p = \frac{R_s^2}{L_s \omega^2} + L_s \qquad Q_L = \frac{L_s \omega}{R_s}$$

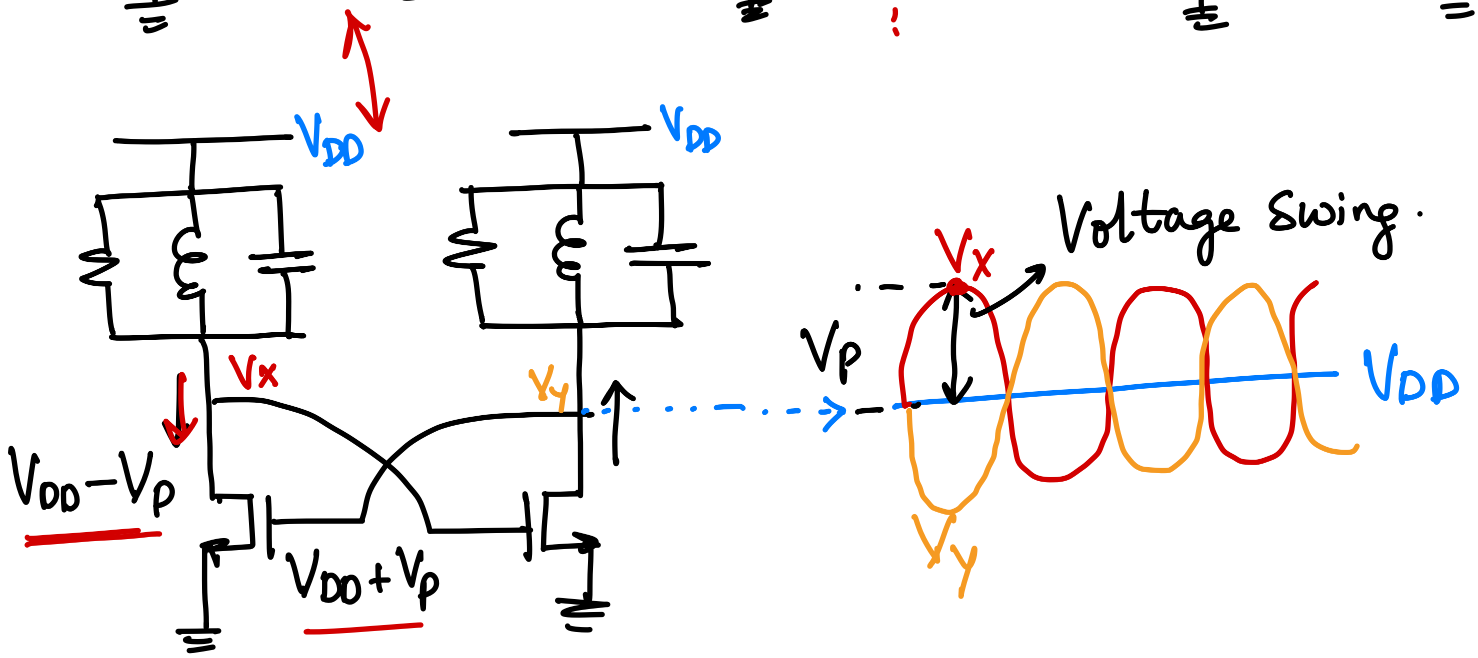
$\ll 1$

$$\Rightarrow L_p = L_s \;; \qquad \boxed{R_p \cong \frac{L_s^2 \omega^2}{R_s \uparrow}}$$

<u>Note</u>: This equivalence is narrow band.

(IV) Cross Coupled Oscillator





$$\left.V_{DS} > V_{GS} - V_{TH}\right\} \quad V_{DS} = V_{GS} - V_{TH}$$

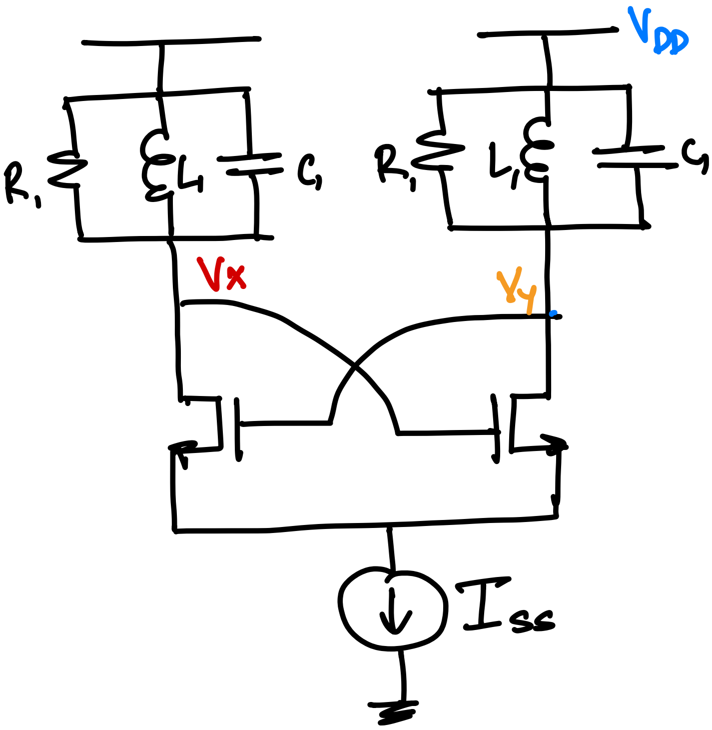
$$V_D - V_G = -V_{TH}$$

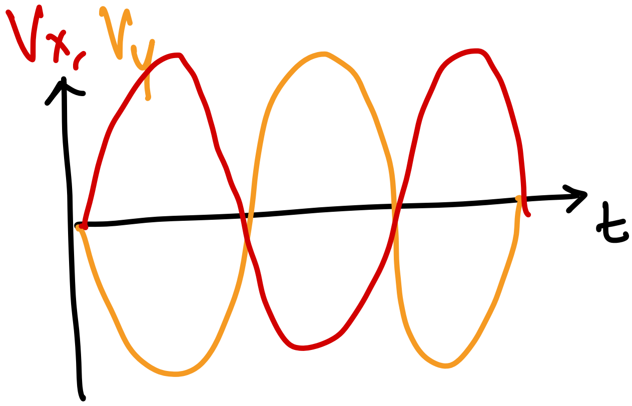
$$(V_{DD} - V_p) - (V_{DD} + V_p) = -V_{TH}$$

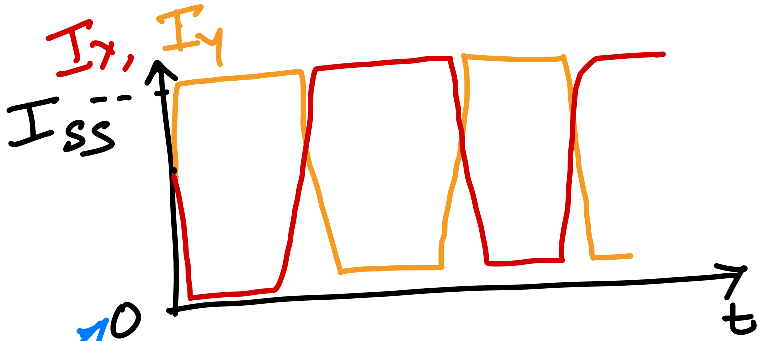
$$\Rightarrow \quad V_p = \frac{V_{TH}}{2}$$

To avoid Triode

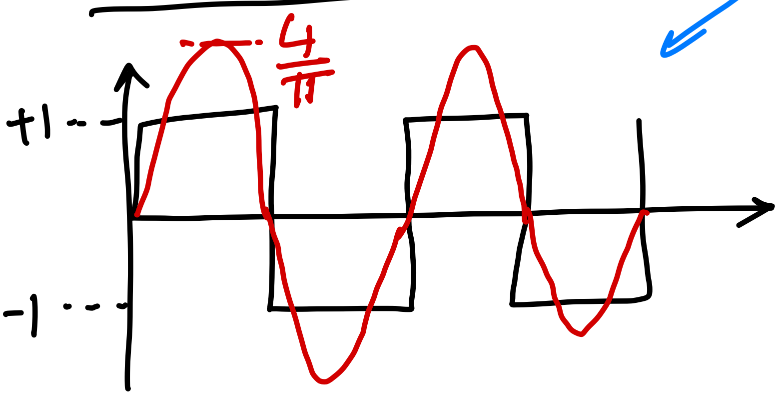
$$\boxed{V_{pp} = V_{TH}}$$

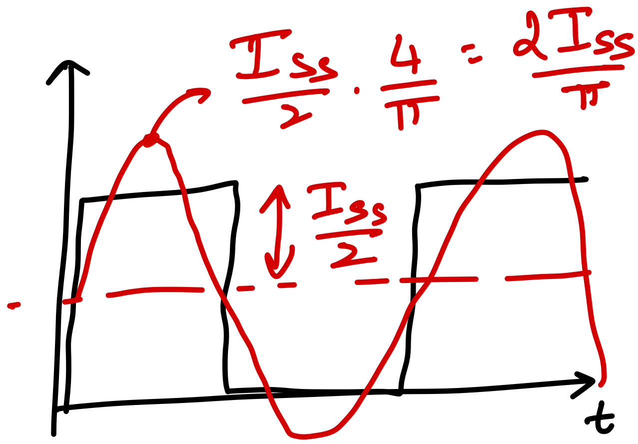






What is V_p?





$$\Rightarrow \boxed{V_p = \frac{2 I_{ss}}{\pi} R_p}$$

$$\boxed{V_{pp}^{diff} = \frac{8 I_{ss} R_p}{\pi}}$$

→ Assuming I is a square wave.

$(g_m R_p \gg 2)$ → Rule of Thumb.

Design Procedure (Algorithmic approach)

(Specified P_{DC} & low phase noise constraint).

1) Set P_{DC} & $V_p = \frac{V_{TH}}{2}$

2) $\boxed{I_{SS} = \frac{P_{DC}}{V_{DD}}}$

$V_{pp} = V_{TH} = \frac{4 I_{SS} R_p}{\pi}$

$\Rightarrow \boxed{R_p = \frac{\pi V_{DD} V_{TH}}{4 P_{DC}}}$

3) $Q_L = \frac{R_p}{L_1 \omega_0} \Rightarrow \boxed{L_1 = \frac{R_p}{Q_L \omega_0}}$

Predetermined by process & ω_0. (8 − 10)

$\boxed{C_1 = \frac{1}{\omega_0^2 L_1}}$

Also includes parasitic caps.

4) Choose $\frac{W}{L}$ to get full current steering, i.e. square wave current steering; $V_{pp} = \frac{4}{\pi} I_{SS} R_p$

(Also look at $J_D = \frac{I_{DS}}{W}$)

5) Simulate & tune C_1 to get ω_0. Look at the PN performance $\Rightarrow$ Increase power budget if needed.

(Taken from Behzad Razavi's PLL book).