RF Circuit Design

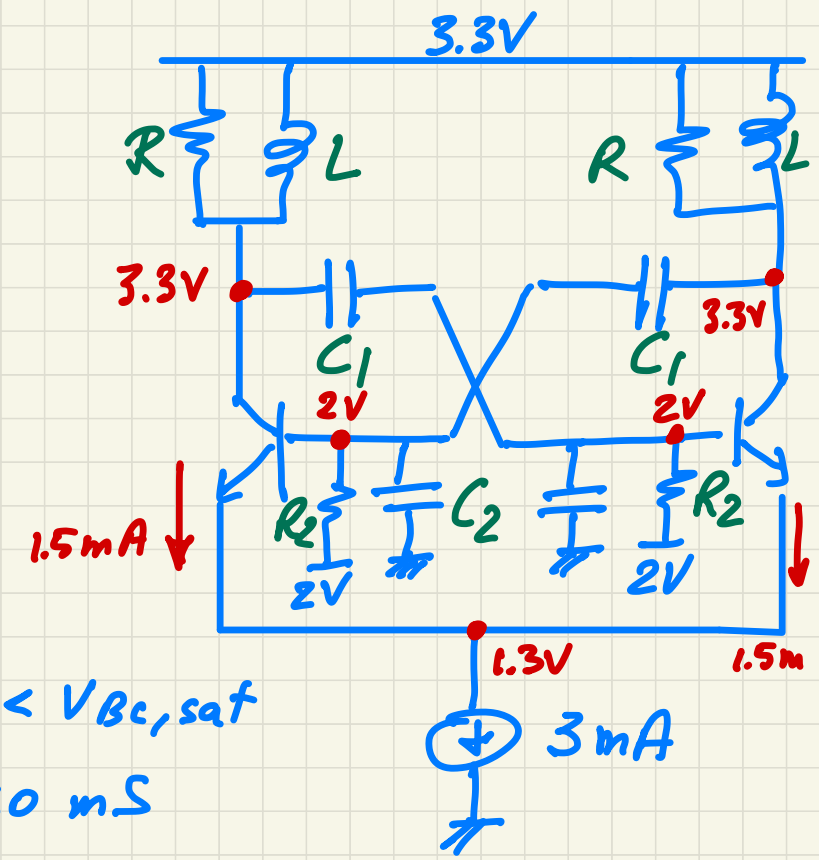
T8

T8.1

$$\begin{cases} V_{BE,on} = 0.7V \\ V_{BC,sat} = 0.5V \\ \beta \to \infty \end{cases}$$ BJT

$L = 2\,nH$ $\quad C_1 = 1\,pF$

$R = 630\,\Omega$ $\quad C_2 = 2\,pF$

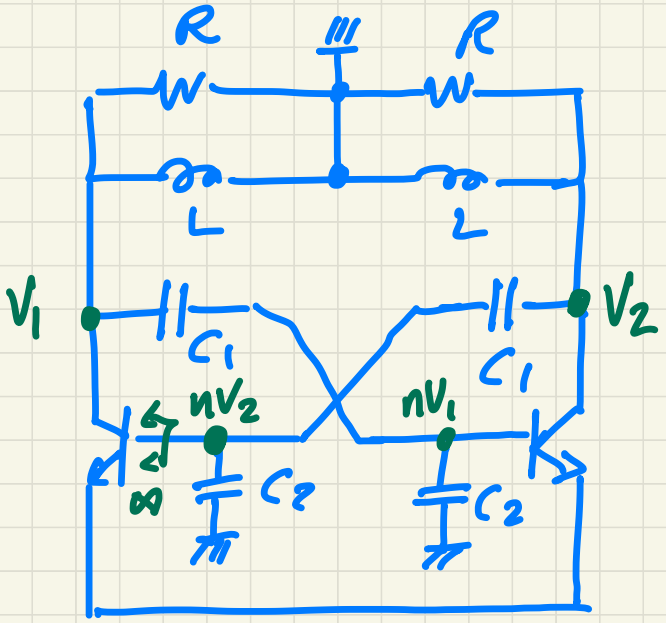


a) bias point

$$V_{BC} = 2V - 3.3V = -1.3V < V_{BC,sat}$$

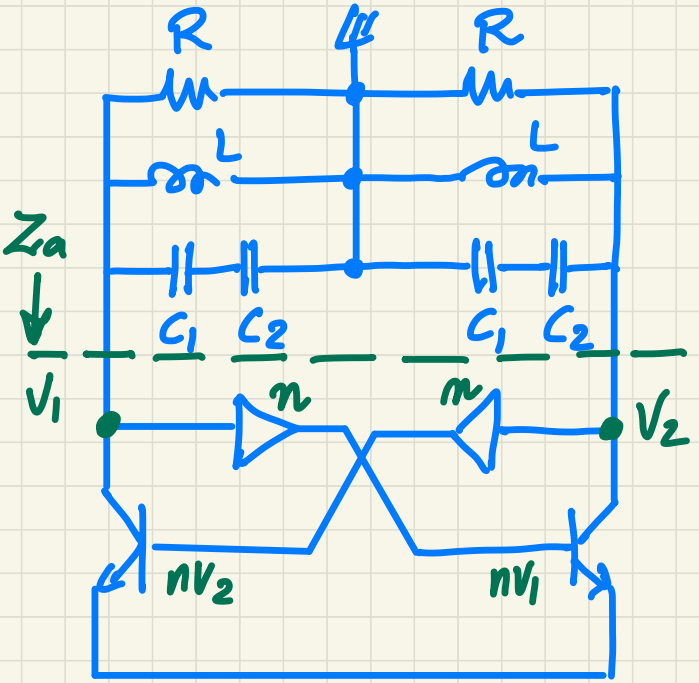
$$g_m = \frac{I_C}{V_t} = \frac{1.5\,mA}{25\,mV} = 60\,mS$$

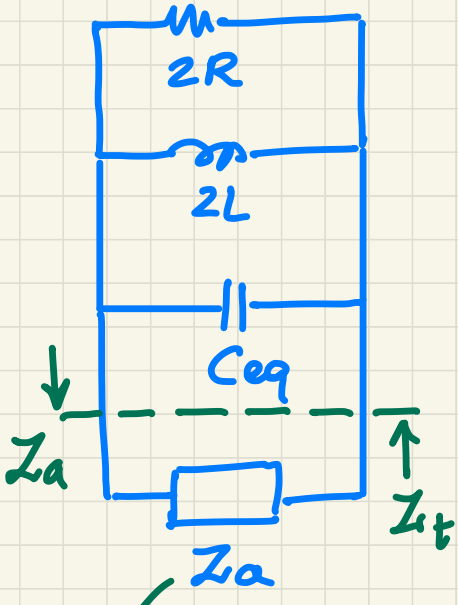
b) $R_2 \to \infty$ $\quad r_\pi \to \infty$ oscillation condition



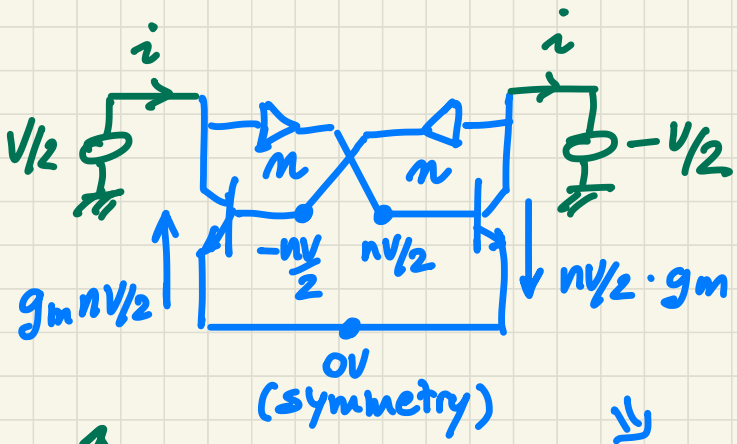
$$n = \frac{C_1}{C_1 + C_2} = \frac{1p}{1p + 2p} = \frac{1}{3}$$

$\Leftrightarrow$





$$C_{eq} = \frac{1}{2}\,\frac{C_1 C_2}{C_1 + C_2} = \frac{1}{2}\cdot\frac{1p\cdot 3p}{3p} = \frac{1}{3}\,pF$$



Differential-mode impedance

$$\Downarrow$$

$$i = -n g_m V/2$$

$$\Downarrow$$

$$Z_a = \frac{V}{i} = -\frac{2}{g_m \cdot n}$$

Oscillation condition: $Z_a(j\omega_0) + Z_t(j\omega_0) = 0$

$$\Downarrow$$

$$\begin{cases} (1)\ \ \mathrm{Re}\{Z_a\} + \mathrm{Re}\{Z_t\} = 0 \\ (2)\ \ \mathrm{Im}\{Z_a\} + \mathrm{Im}\{Z_t\} = 0 \end{cases}$$

$$(2) \Rightarrow \quad \omega_0 = \frac{1}{\sqrt{2L \cdot C_{eq}}} = \frac{1}{\sqrt{4n \cdot \frac{1}{3}P}} =$$

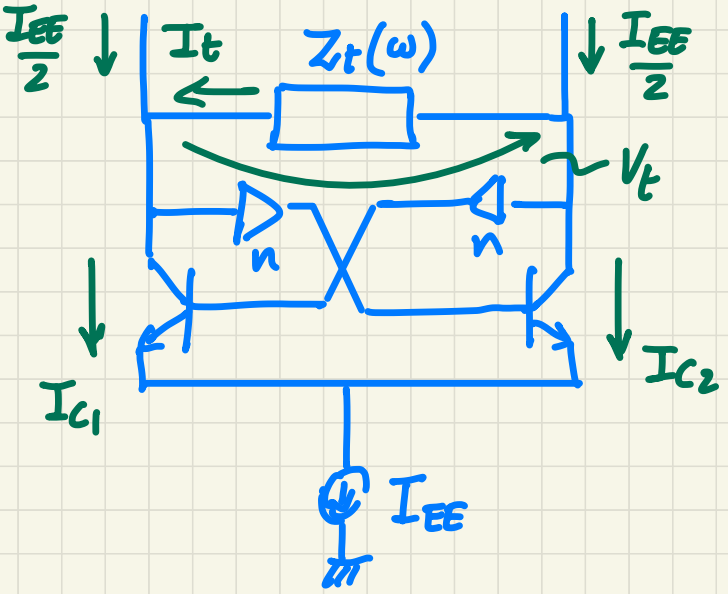
$$= 2\pi \cdot 4.36\ \text{Grad/s} \qquad \underline{f_0 = 4.36\ \text{GHz}}$$

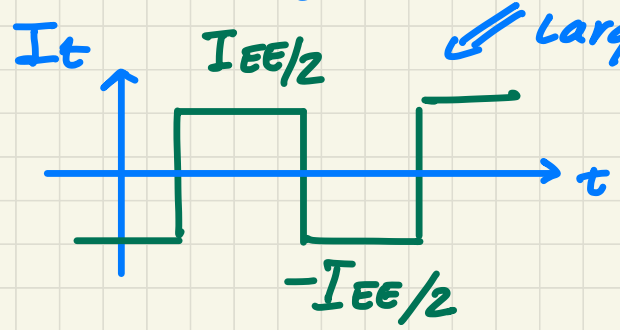
$$(1) \Rightarrow \quad 2R - \frac{2}{g_m \cdot n} = 0 \ ; \qquad n g_m \cdot R = 1$$

$$\underline{EG} = Z_t/Z_a = g_m R \cdot n = 60\,m \cdot 630 \cdot \frac{1}{3} = \underline{12.6}$$

c) Oscillation amplitude ($V_B(t)$, $V_C(t)$) (full switching)

$V_t = A_0 \cos\omega_0 t$ ← large signal





$$G_{MH} = \frac{I_t^{(1)}}{V_t^{(1)}} = \frac{\frac{2}{\pi} I_{EE}}{A_0}$$

Small-signal loop gain

$$LG = \underbrace{\frac{n \cdot g_m}{2}}_{G_m} \cdot 2R$$

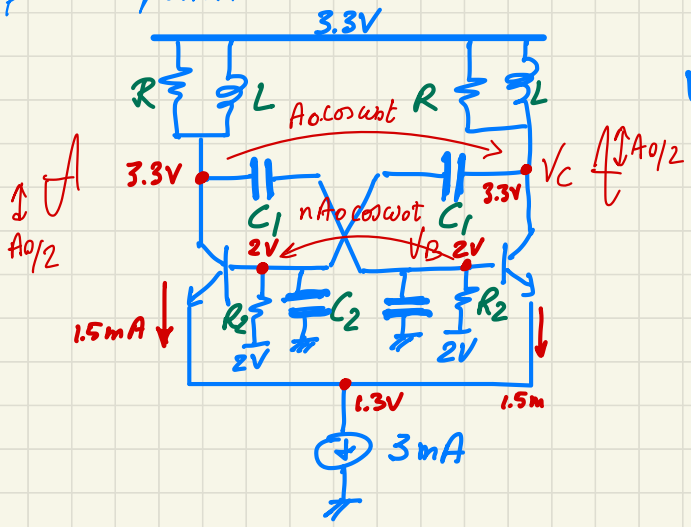
Large signal oscillation condition

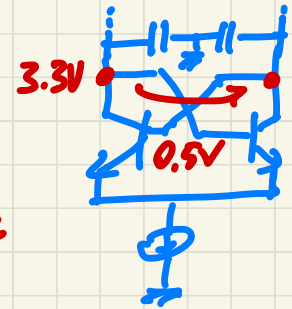
$$G_{MH} \cdot 2R = 1$$

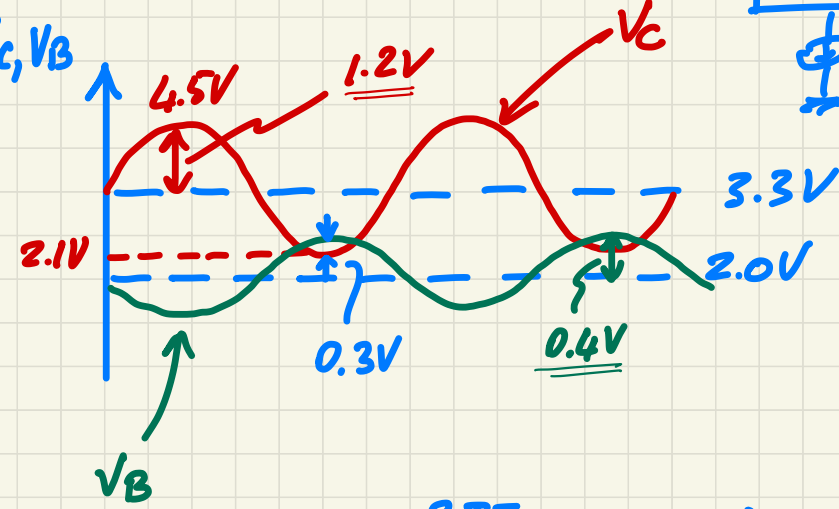
$$\frac{2}{\pi} I_{EE} \cdot 2R = A_0$$

$$A_0 = \frac{2}{\pi} \cdot 3m \cdot 2 \cdot 630 = 2.41\ V$$

Differential peak amplitude





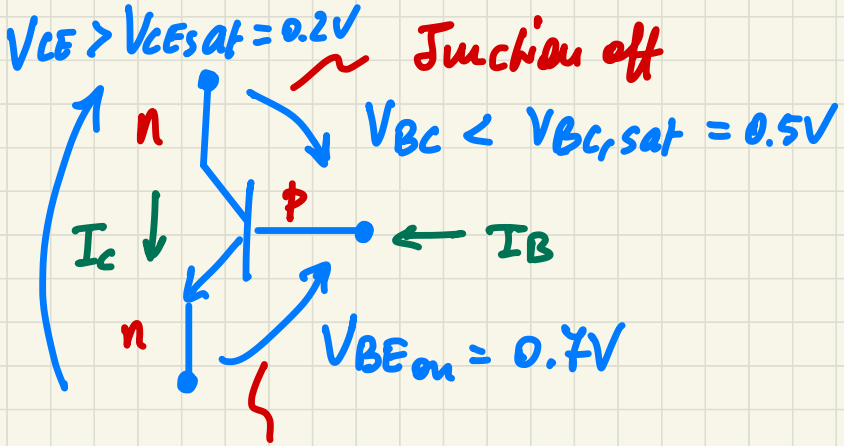


$$nA_0 = \frac{2.41}{3} \simeq 0.8V$$

BJTs never in saturation region

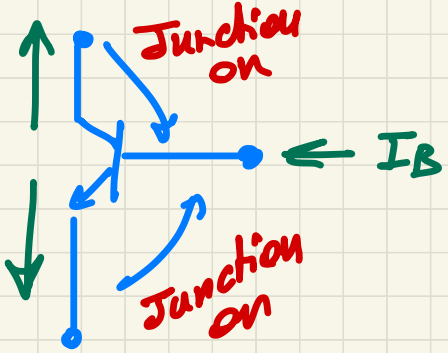
Forward region: $V_{BC} < 0.5V$: $V_{BC} = 2V + 0.4V - (3.3V - 1.2V) =$

$= 3.6 - 3.3 = 0.3V < 0.5V$



Forward active region

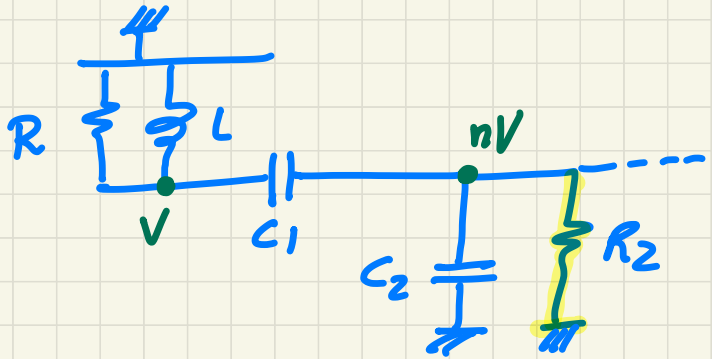
$$I_B = \frac{I_C}{\beta}$$

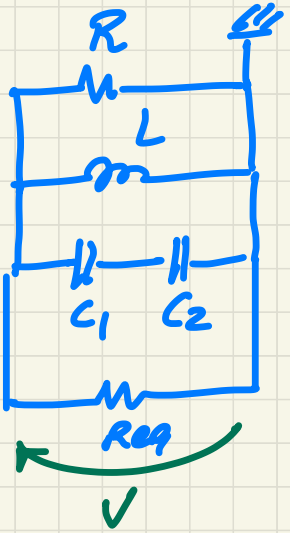


Saturation Region

- I_B very large
- long time to get back to forward region

d)





$$\frac{n^2V^2}{R_2} = \frac{V^2}{R_{eq}} \Rightarrow R_{eq} = \frac{R_2}{n^2}$$

$n = 1/3$

$$R_T = R \,//\, \frac{R_2}{n^2} = 0.9 \cdot R \;;$$

$$\frac{1}{R} + \frac{9}{R_2} = \frac{1}{0.9 \cdot R} \;;$$

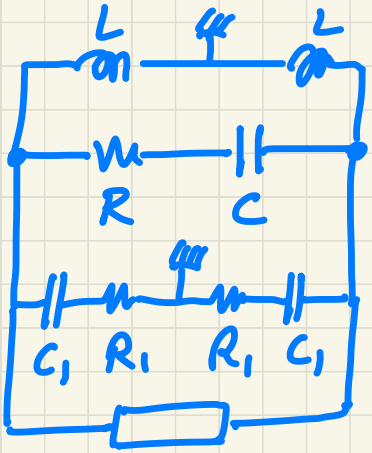
$$R_2 = R = 630\,\Omega$$

T8.2

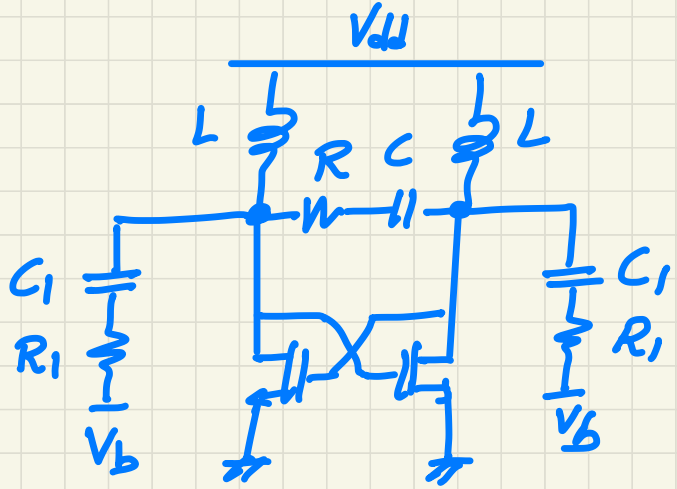
$L = 1\,nH$

$\begin{cases} R = 10\,\Omega \\ C = 250\,\Omega \end{cases}$

$\begin{cases} C_1 = 1\,pF \\ R_1 = 1\,K\Omega \end{cases}$



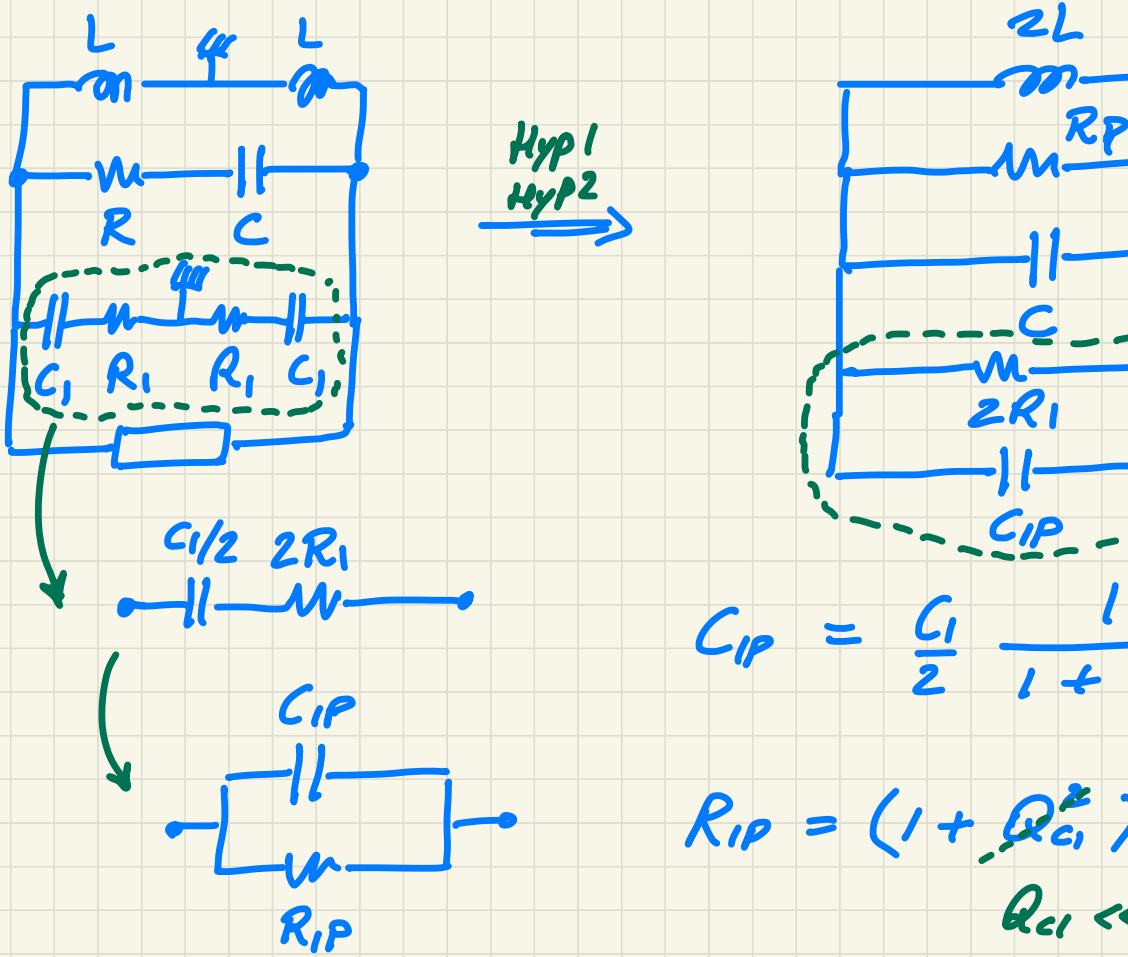
$$\frac{1}{j2\pi fC} = \frac{1}{j2\pi \cdot 1G \cdot 1p} = \frac{10^3}{j2\pi}$$



$$\text{Hyp 1}: Q_C = \frac{1}{\omega_0 RC} \gg 1$$

$$\text{Hyp 2}: Q_{C_1} = \frac{1}{\omega_0 R_1 C_1} \ll 1$$

$$\frac{1}{\omega_0 C_1} \ll R_1$$



$$R_P \cong Q_C^2 \cdot R$$

$$C_{1P} = \frac{C_1}{2} \frac{1}{1 + 1/Q_{C1}^2} \approx \frac{C_1}{2} \cdot Q_{C1}^2$$

$$R_{1P} = (1 + Q_{C1}^2) \cdot 2R_1 \approx 2R_1$$

$$Q_{C1} \ll 1$$