

Analysis of VCO Q

This sheet is used to find the Q of three types of oscillator configuration, Colpitts, Clapp and Seiler. It can be seen from this analysis that the Clapp and Seiler will result in a high Q oscillator. The reference used here is 'Introduction to radio frequency design' by W Hayward, chapter 7.2. A high Q oscillator has a fast phase change with frequency.

Chris Haji-Michael

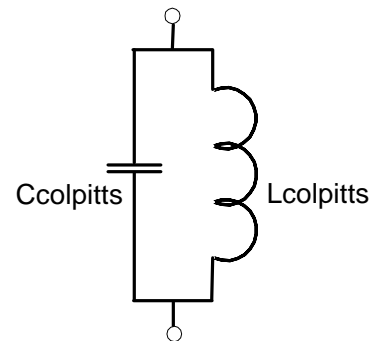
<http://www.sunshadow.co.uk/chris.htm>

$$fF := 10^{-15} \cdot \text{farad} \quad \text{mW} := 10^{-3} \cdot \text{watt} \quad \text{nH} := 10^{-9} \cdot \text{henry} \quad \text{k}\Omega := 10^3 \cdot \Omega$$

Design parameters $f_o := 1 \cdot 10^9 \cdot \text{Hz}$ $Q_C := 200$ $L_{\text{colpitts}} := 8 \cdot \text{nH}$ $Q_L := 10$

Q of a Parallel Tuned Circuit for Colpitts Oscillator

First calculate the required capacitance, and then the equivalent parallel resistance
 $Q_t = Q$ of Oscillator tank
 V_{tank} = peak voltage swing in LC
 P_s = power in loop (assumed to be output power)



$$C_{\text{colpitts}} := \frac{1}{(2 \cdot \pi \cdot f_o)^2 \cdot L_{\text{colpitts}}}$$

$$R_C := \frac{Q_C}{2 \cdot \pi \cdot f_o \cdot C_{\text{colpitts}}}$$

$$R_L := Q_L \cdot L_{\text{colpitts}} \cdot 2 \cdot \pi \cdot f_o$$

$$R_{\text{pcolpitts}} := \frac{1}{\frac{1}{R_L} + \frac{1}{R_C}}$$

$$Q_{\text{Colpitts}} := R_{\text{pcolpitts}} \cdot \sqrt{\frac{C_{\text{colpitts}}}{L_{\text{colpitts}}}}$$

$C_{\text{colpitts}} = 3 \times 10^3 \text{ fF}$

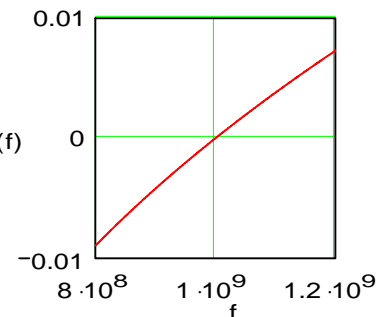
$R_{\text{pcolpitts}} = 479 \Omega$

$Q_{\text{Colpitts}} = 9.5$

$$Z_{\text{im_colpitts}}(f) := \left(2 \cdot \pi \cdot f \cdot \text{Hz} \cdot C_{\text{colpitts}} - \frac{1}{2 \cdot \pi \cdot f \cdot \text{Hz} \cdot L_{\text{colpitts}}} \right)$$

This graph plots the imaginary impedance of the Colpitts tuned circuit

$Z_{\text{im_colpitts}}(f)$



Q of Tuned Circuit for Clapp Oscillator

The Clapp VCO requires the Colpitts Capacitor to remain unchanged. The inductor is increased by the Clapp-Ratio, with a new series capacitor added to bring the oscillation frequency back. The Clapp-ratio is greater than 1

Clappratio := 10

$$L_{Clapp} := L_{Colpitts} \cdot Clappratio$$

$$C_{Clapp} := \frac{1}{(2 \cdot \pi \cdot f_o)^2 \cdot L_{Clapp} \cdot (Clappratio - 1)}$$

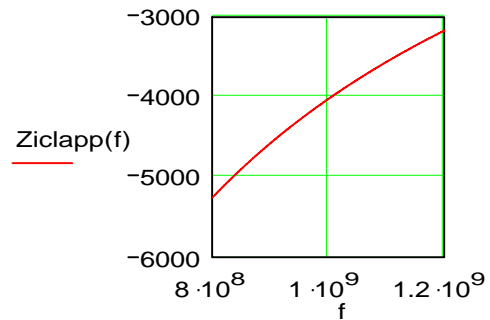
$$R_{LClapp} := Q_L \cdot L_{Clapp} \cdot 2 \cdot \pi \cdot f_o$$

$$R_{C_{Clapp}} := \frac{Q_C}{2 \cdot \pi \cdot f_o \cdot C_{Clapp}} \quad R_{pClapp} := \frac{1}{\frac{1}{R_C} + \frac{1}{R_{LClapp} + R_{C_{Clapp}}}}$$

$$Q_{Clapp} := R_{pClapp} \cdot \sqrt{\frac{C_{Colpitts}}{L_{Colpitts}}}$$

$$Z_{iClapp}(f) := \left(2 \cdot \pi \cdot f \cdot \text{Hz} \cdot L_{Clapp} - \frac{1}{2 \cdot \pi \cdot f \cdot \text{Hz} \cdot C_{Clapp}} \right)$$

This graph plots the imaginary impedance of the Clapp tuned circuit, which is assumed to be dominated by L_{Clapp} & C_{Clapp}



$$C_{Clapp} = 35.2 \text{ fF}$$

$$L_{Clapp} = 80.0 \text{ nH}$$

$$R_{pClapp} = 9.9 \text{ k}\Omega$$

$$Q_{Clapp} = 197.8$$

Q of Tuned Circuit for Seiler Oscillator

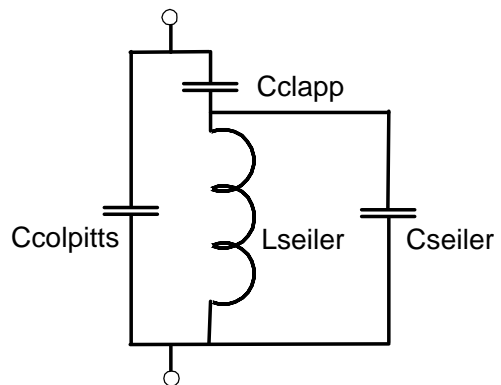
Note: the Seiler-ratio is less than 1 and in this case $1/\text{clappratio}$

The Seiler circuit does not add to the Q, but brings the inductor value back down again. Very useful

$$\text{Seilerratio} := \frac{1}{Clappratio}$$

$$L_{Seiler} := L_{Colpitts} \cdot Clappratio \cdot \text{Seilerratio}$$

$$C_{Seiler} := \frac{1 - \text{Seilerratio}}{(2 \cdot \pi \cdot f_o)^2 \cdot L_{Clapp} \cdot Clappratio \cdot \text{Seilerratio}}$$



$$R_{C_{Seiler}} := \frac{Q_C}{2 \cdot \pi \cdot f_o \cdot C_{Seiler}}$$

$$R_{p\text{seiler}} := \frac{1}{\frac{1}{R_C} + \frac{1}{R_{C\text{clapp}} + \frac{1}{\frac{1}{R_{L\text{seiler}}} + \frac{1}{R_{C\text{seiler}}}}}}$$

$$Q_{\text{seiler}} := R_{p\text{seiler}} \cdot \sqrt{\frac{C_{\text{colpitts}}}{L_{\text{colpitts}}}}$$

$$R_{L\text{seiler}} := Q_L \cdot L_{\text{seiler}} \cdot 2 \cdot \pi \cdot f_0$$

$$C_{\text{colpitts}} = 3.2 \times 10^3 \text{ fF}$$

$$C_{\text{clapp}} = 35.2 \text{ fF}$$

$$L_{\text{seiler}} = 8.000 \text{ nH}$$

$$C_{\text{seiler}} = 285.0 \text{ fF}$$

$$R_{p\text{seiler}} = 9.943 \text{ k}\Omega$$

$$Q_{\text{seiler}} = 197.8$$