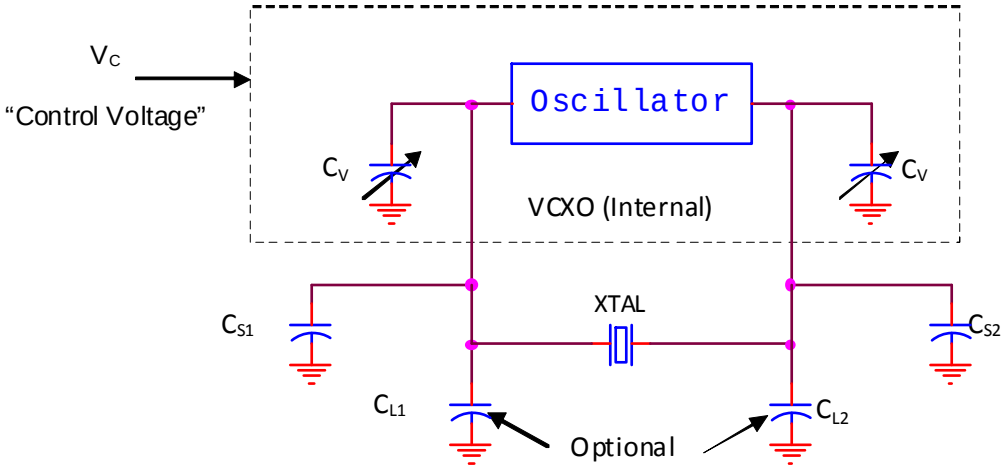
Introduction

Choosing a crystal with the correct characteristics is one of the most critical steps in using a Voltage Controlled Crystal Oscillator (VCXO).

VCXO Crystal Selection

The crystal parameters affect the tuning range and accuracy of a VCXO. Below are the key variables and an example of using the crystal parameters to calculate the tuning range of the VCXO.

Figure 1. VCXO Oscillator Circuit



where
Vc = Control voltage used to tune frequency
Cv = Varactor capacitance, varies due tot the change in votage control
CL1/CL2 = Load tuning capacitance used for fine tuning or centering nominal frequency
CS1/CS2 = Stray Capacitance caused by pads, vias, and other board parasitics

Crystal Parameters Example

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
	Mode of Oscillation			Fundamental		
f_N	Frequency			25		MHz
f_T	Frequency Tolerance				±20	ppm
f_S	Frequency Stability				±20	ppm
	Operating Temperature Range		-40		85	^{O}C
C_L	Load Capacitance			Note 1		pF
C_O	Shunt Capacitance			4		pF
C_O / C_1	Pullability Ratio			220	240	
F_{L_3OVT}	3rd Overtone F_L		200			ppm
$F_{L\_3OVT\_spurs}$	3rd Overtone F_L Spurs		200			ppm
ESR	Equivalent Series Resistance				20	Ω
	Drive Level				1	mW
	Aging @ 25 ^{0}C				±3 per year	ppm

Varactor Parameters

Symbol	Parameter	Typical	Unit
C_{VLOW}	Low Varactor Capacitance	15.4 (note 1)	pF
C_{VHIGH}	High Varactor Capacitance	29.6 (note 1	pF

Note 1: Refer to the device datasheet for recommended C_{VLOW} and C_{VHIGH}.

Formulas

$$C_{Low} = \frac{(C_{L1} + C_{S1} + C_{V\_Low}) \cdot (C_{L2} + C_{S2} + C_{V\_Low})}{(C_{L1} + C_{S1} + C_{V\_Low}) + (C_{L2} + C_{S2} + C_{V\_Low})} \qquad C_{High} = \frac{(C_{L1} + C_{S1} + C_{V\_High}) \cdot (C_{L2} + C_{S2} + C_{V\_High})}{(C_{L1} + C_{S1} + C_{V\_High}) + (C_{L2} + C_{S2} + C_{V\_High})}$$

- C_{Low} is the effective capacitance due to the low varactor capacitance, load capacitance and stray capacitance. C_{Low} determines the high frequency component on the TPR.
- C_{High} is the effective capacitance due to the high varactor capacitance, load capacitance and stray capacitance. C_{High} determines the low frequency component on the TPR.

$$Total\ \ Pull\ Range\ (TPR) = \left(\frac{1}{2 \cdot C_0/C_1 \cdot \left(1 + C_{Low}/C_0\right)} - \frac{1}{2 \cdot C_0/C_1 \cdot \left(1 + C_{High}/C_0\right)} \right) \cdot 10^6$$

$$AbsolutePullRange(APR) = TotalPullRange - (FrequencyTolerance + FrequencyStability + Aging)$$

Example Calculations

Using the tables and figures above, we can now calculate the TPR and APR of the VCXO using the example crystal parameters. For the numerical example below there were some assumptions made. First, the stray capacitance (C_{S1}, C_{S2}), which is all the excess capacitance due to board parasitic, is 4pF. Second, the expected lifetime of the project is 5 years; hence the inaccuracy due to aging is ±15ppm. Third, though many boards will not require load tuning capacitors (C_{L1}, C_{L2}), it is recommended for long-term consistent performance of the system that two tuning capacitor pads be placed into every design. Typical values for the load tuning capacitors will range from 0 to 4pF.

$$C_{Low} = \frac{(0 + 4pf + 15.4pf) \cdot (0 + 4pf + 15.4pf)}{(0 + 4pf + 15.4pf) + (0 + 4pf + 15.4pf)} = 9.7\,pf \qquad C_{High} = \frac{(0 + 4pf + 29.6pf) \cdot (0 + 4pf + 29.6pf)}{(0 + 4pf + 29.6pf) + (0 + 4pf + 29.6pf)} = 16.8\,pf$$

$$TPR = \left(\frac{1}{2 \cdot 220 \cdot \left(1 + 9.7pF/4pF\right)} - \frac{1}{2 \cdot 220 \cdot \left(1 + 16.8pF/4pF\right)} \right) \cdot 10^6 \cdot = 226.5\,ppm$$

$$TPR = \pm 113.25\,ppm$$

$$APR = 113.25\,ppm - (20\,ppm + 20\,ppm + 15\,ppm) = \pm 58.25\,ppm$$

The example above will ensure a total pull range of ±113.25 ppm with an APR of ±58.25ppm. Many times, board designers may select their own crystal based on their application. If the application requires a tighter APR, a crystal with better pull-ability (C_0/C_1 ratio) can be used. Also, with the equations above, one can vary the frequency tolerance, temperature stability, and aging or shunt capacitance to achieve the required pull-ability.

Recommended Vendors

Some of the Voltage controlled crystal oscillators devices from IDT require a pull-able crystal. There are VCXO's designed by IDT which do not require a pull-able crystal. The Crystal parameters for the VCXO's are in the datasheet. Most crystal manufactures, given the crystal specifications can manufacture a reliable crystal to work with IDT VCXO's. If there are any comments or concerns, please contact IDT.

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