

An Overview of Pericom's VCXO and Crystal Technology

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Introduction

The requirements of a stable and accurate signal source for many of today's applications requires the use of a voltage controlled crystal oscillator. Its applications can be found in set-top boxes, self-clocking source, RF, error recovery, and other applications where stable and accurate oscillation is required. Pericom Semiconductor offers the PI6CX100-27 and PI6CX100-35 along with an external crystal source, the PI6X027 and PI6X035, respectively. This application note will provide a general overview of VCXO and its characteristics. It will also provide a discussion on selecting the right crystal to provide the best performance for the PI6CX100-27 and PI6CX100-35.

VCXO

VCXO is a crystal oscillator that allows the output frequency to be adjusted in responses to the input voltage. Unlike VCXO modules, Pericom offers the PI6CX100-27 and PI6CX100-35 which do not integrate a crystal onto the chip to allow flexibility that is not made possible with VCXO modules. There are several things that are uniquely associated with VCXO that are required to have an understanding of its technology.

Deviation

Deviation is the amount of frequency change corresponding to the changes in control voltage. This is sometime known as the pull-range of the VCXO. Pull-range of the VCXO will very much depend on the pullability of the crystal. Crystal's pullability is explained below under "How to Choose the Right Crystal".

Linearity

Linearity is defined as the ratio between frequency error and total deviation. Expressed in percentage, it is the variation in output frequency versus control voltage from the best-fit straight line. For example, a 10% linearity for a 10KHz tuning range would allow a deviation of 1KHz away from the best straight line for an oscillator. An example of linearity is shown the Figure 1.

Slopes (Transfer Function)

It is defined as the direction in which the frequency will vary versus the control voltage. Standard slopes are usually positive as shown in Figure 1.

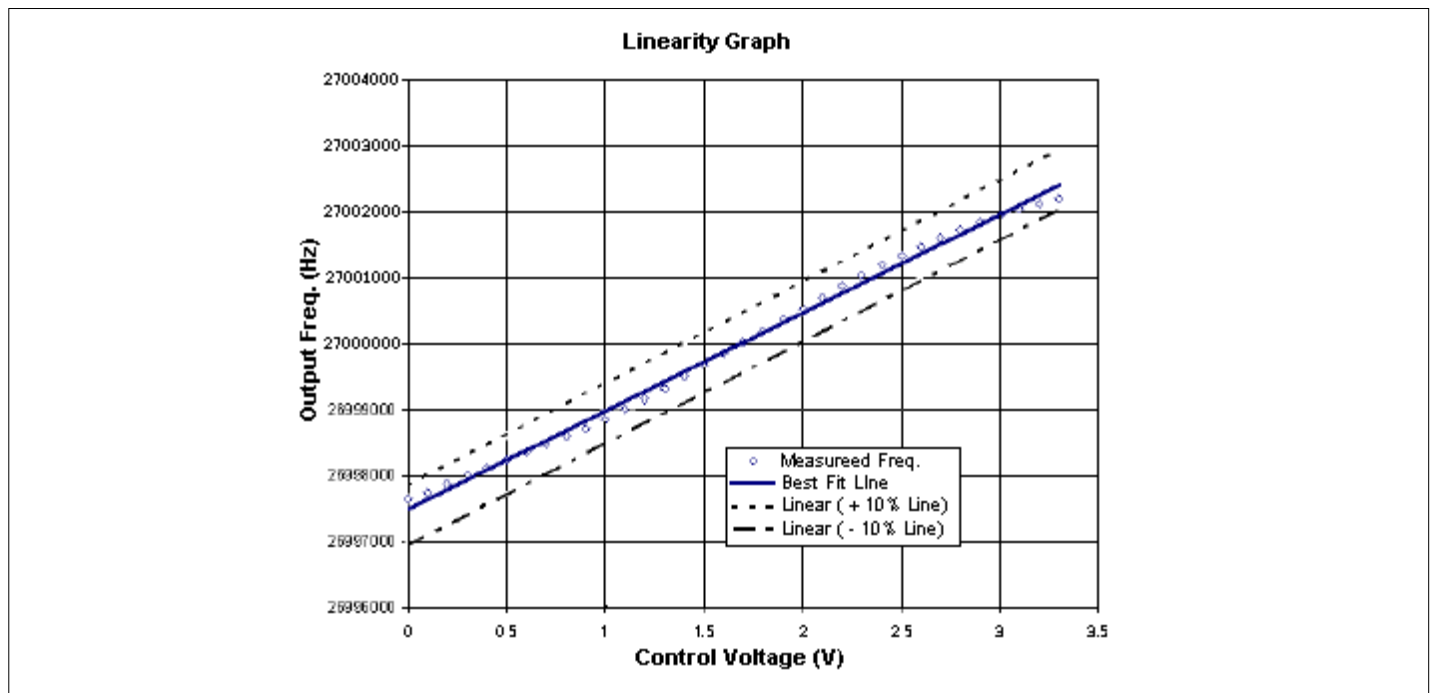


Figure 1. Example of Linearity

How to Choose the Right Crystal

One of the main advantages that Pericom’s PI6CX100-27 and PI6CX100-35 has over VCXO modules is that it allows designers the freedom of choosing their own crystal. Pericom does offer and highly recommends using the PI6CX100-27 and PI6CX100-35 with the PI6X027 and PI6X035 crystal, respectively. Although it is highly suggested that the PI6CX100-27/35 should be used with the Pericom’s crystals, it is not required. Designers may choose their own crystal based on their application and budget. It should be noted that the performance and accuracy of the oscillator greatly depends on the crystal’s characteristics. Therefore, selecting the right crystal can be the most critical step in designing VCXO applications. There are five main parameters that should be taken into consideration when selecting a crystal to use along with Pericom’s PI6CX100-27 and PI6CX100-35: frequency tolerance, temperature frequency stability, aging, load capacitance, and pullability.

Frequency Tolerance

Frequency tolerance specifies how much changes in frequency at room temperature (~25°C) to its specified frequency. Units associated with frequency tolerance is given in parts per million (ppm). For example, Pericom’s PI6X027 is a 27.000MHz crystal with a frequency tolerance of ±20ppm. Using the PI6X027 as an example, a ±20ppm frequency tolerance can deviate the frequency from the specified frequency as followed:

$$(\pm 20 \text{ parts}/1,000,000) \times (27,000,000.000) = \pm 540 \text{ Hz}$$

Therefore, the range in which the resonant frequency may be higher or lower than 27.000000MHz is:

$$27,000,540.000 \text{ Hz to } 26,999,460.000 \text{ MHz}$$

The accuracy impact over a one month period for a ±20ppm frequency tolerance is:

$$(\pm 20 \text{ parts}/1,000,000) \times (60 \text{ s}/\text{min}) \times (60 \text{ min}/\text{day}) \times (24 \text{ hrs}/\text{day}) \times (30 \text{ days}/\text{mon}) = 51.84 \text{ s}/\text{month}$$

When compared to a less tighter frequency tolerance such as ±50ppm, which is a typical value, the accuracy impact over a one month period can be as much as 2.60 min/month. Therefore, it is recommended that a frequency tolerance of ±30ppm or less should be used for the PI6CX100-27 and ±20ppm or less should be used for the PIC6X100-35.

Temperature Frequency Stability

Temperature frequency stability is the maximum allowable deviation from the frequency specified at room temperature over an operating temperature range. Similarly with frequency tolerance, it has units in parts per million (ppm). Typical stability is ± 100ppm

and tighter stability range from ± 50ppm to ±25ppm. But Pericom Semiconductor offers the PI6X027 and PI6X035 with extremely tight temperature frequency stability at ±20ppm. If choosing a crystal other than the PI6X027 and PI6X035, the recommended ppm level should be no more than ±50ppm (value includes aging).

Aging Factor

Aging is the amount of frequency drift over a certain length of time. There are several factors that contribute to the gradual degradation of the crystal such as contamination and stress relief. Aging is specified in unit of ppm per year and is usually no more than ±10ppm per year. Aging specification for Pericom’s PI6X027 and PI6X035 is specified at ±3ppm per year. A method to reduce the aging factor is by keeping the amount of power dissipated by the crystal low (also known as the drive). This will reduce the level of vibration on the crystal.

Load Capacitance

Crystals may be modeled in the form of a circuit, comprising of an inductor, capacitor, and a resistor, all connected in series and parallel to the shunt capacitor as shown in Figure 2. The inductor (L1) and capacitor (C1) is the motional inductance and capacitance, respectively. The motional capacitance affects the ability of the crystal to change frequency with the changes in load capacitance. The shunt capacitance (C0) represents the capacitance of the crystal’s terminals. The resistor is the equivalent series resistor and only becomes a factor when working with series resonance type circuit. If the external load capacitance does not match the specified load capacitance of the crystal, it will cause a shift in the resonance frequency, which will result in unbalance pullability. Load capacitance includes the total capacitance, which includes the PC board’s capacitance and lead pin’s capacitance.

In most common applications, parallel-resonance mode is used, it is in this mode that the shunt and motional capacitance will affect the pullability of the crystal. Figure 3 illustrates the capacitance load in parallel-resonance mode type when the crystal is connected to a PC board. In Equation 1, it provides the calculations of the total capacitance load that will need to be matched with the crystal’s load capacitance specification. Series-resonance mode is less commonly used and makes the crystal look resistive. In series resonance mode the equivalent series resistor (ESR) is more critical than the load capacitance.

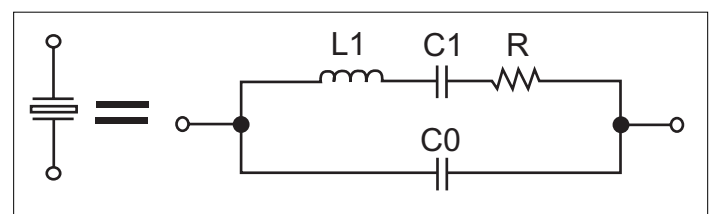


Figure 2. Crystal Equivalent Circuit

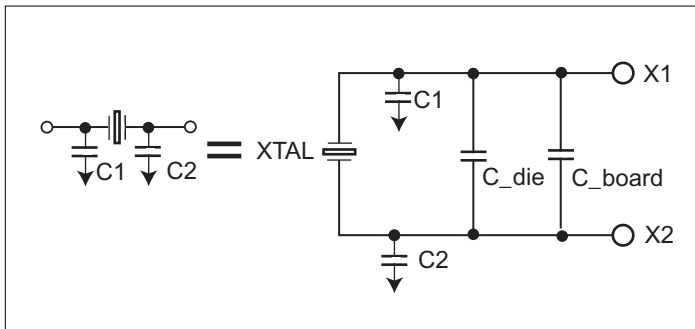


Figure 3. Crystal Circuit after Connecting to a PC Board

Calculation for the load capacitance (C_L) can be express as follows:

$$C_L = [(C1 \times C2)/(C1 + C2)] + C_{-die} + C_{-board} \quad \text{Eq. 1}$$

The recommended load capacitance specification for a crystal to be used with the PI6CX100-27 and PIC6X100-35 is 14pF and 17pF, respectively. The ratio for the shunt (C_0) and motional (C_1) capacitance should be no more than 240. The ESR should be 35 ohm maximum.

Pullability

Pullability is the amount of frequency change as a function of load capacitance (C_0 and C_1) as shown in Figure 4. As mentioned earlier, the pull-range of the VCXO will depend on the pullability of the crystal. By increasing the motional capacitance, the change in frequency will also increase. It should be noted that the pull range is limited by the crystal's structure.

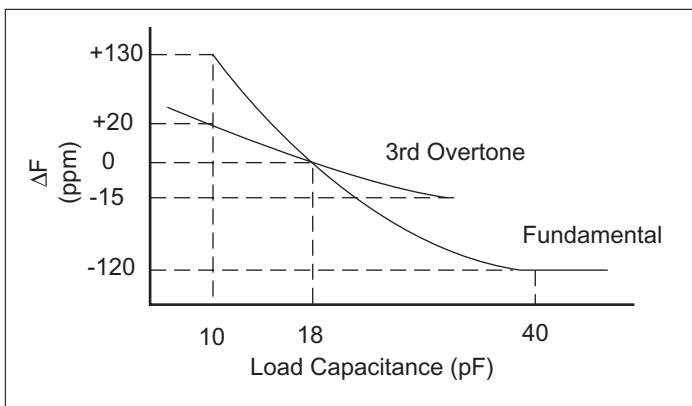


Figure 4: Pullability as a function of load capacitance

In order to assure the best performance for pullability and reliability for Pericom's PI6CX100-27 and PI6CX100-35, all recommended crystal parameters must be met as indicated in Table 1.

Pericom Semiconductor Recommended Crystal Specification

Description	Crystal for PI6CX100-27	Crystal for PI6CX100-35
Mode of Oscillation	Fundamental	Fundamental
Frequency Range	27.000MHz	35.328MHz
Frequency Tolerance	±30ppm	±20ppm
Temperature and Aging Stability (sum)	±50ppm	±50ppm
Operating Temperature	-20oC to +70oC	-20oC to +70oC
C0/C1	240(max)	240(max)
Load Capacitance (C_L)	18pF	17pF
Equivalent Series Resistance (ESR)	35Ω(max)	35Ω(max)

Design Notes

Working with the PI6CX100-27 and PI6CX100-35 as well as any other devices requires some basic layouts to obtain the best results. A 0.1μF along with a 0.47μF decoupling capacitors should be connected between VDD and GND to minimized the level of jitter caused by Vcc ripple and ground bounce. The decoupling capacitors should be placed as close as possible to the pin of the device. Proper termination is also required and should match the trace impedance. Usually trace impedance is 50 ohm.

The PI6CX100-27 and PI6CX100-35 use an external crystal. The crystal should also be placed as closed as possible to the device and the recommended crystal's parameters should be met to assure the best possible performance. Figure 5. shows simple setup for the PI6CX100-27 and PI6CX100-35.

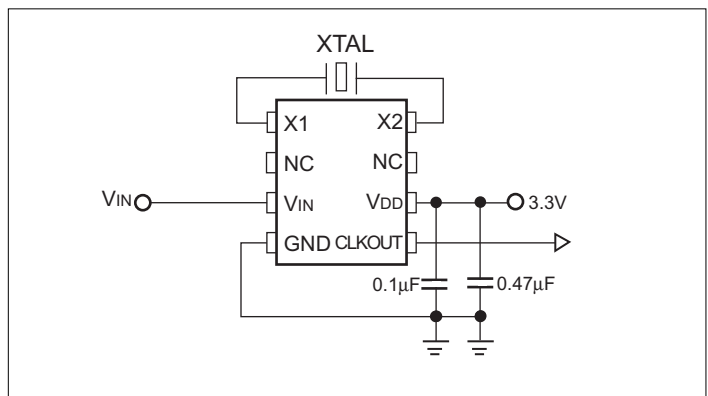


Figure 5. Circuit layout for the PI6X100-27 and PI6X100-35 with PI6XT027 and PI6XT035, respectively.

Application for PI6CX100-27 and PI6XT027

Pericom's VCXO technology can be found in many applications. A common application for the PI6CX100-27 and PI6X027 is in set-top boxes. The block diagram in Figure 6. shows how the PI6CX100-27 and PI6X027 can be applied.

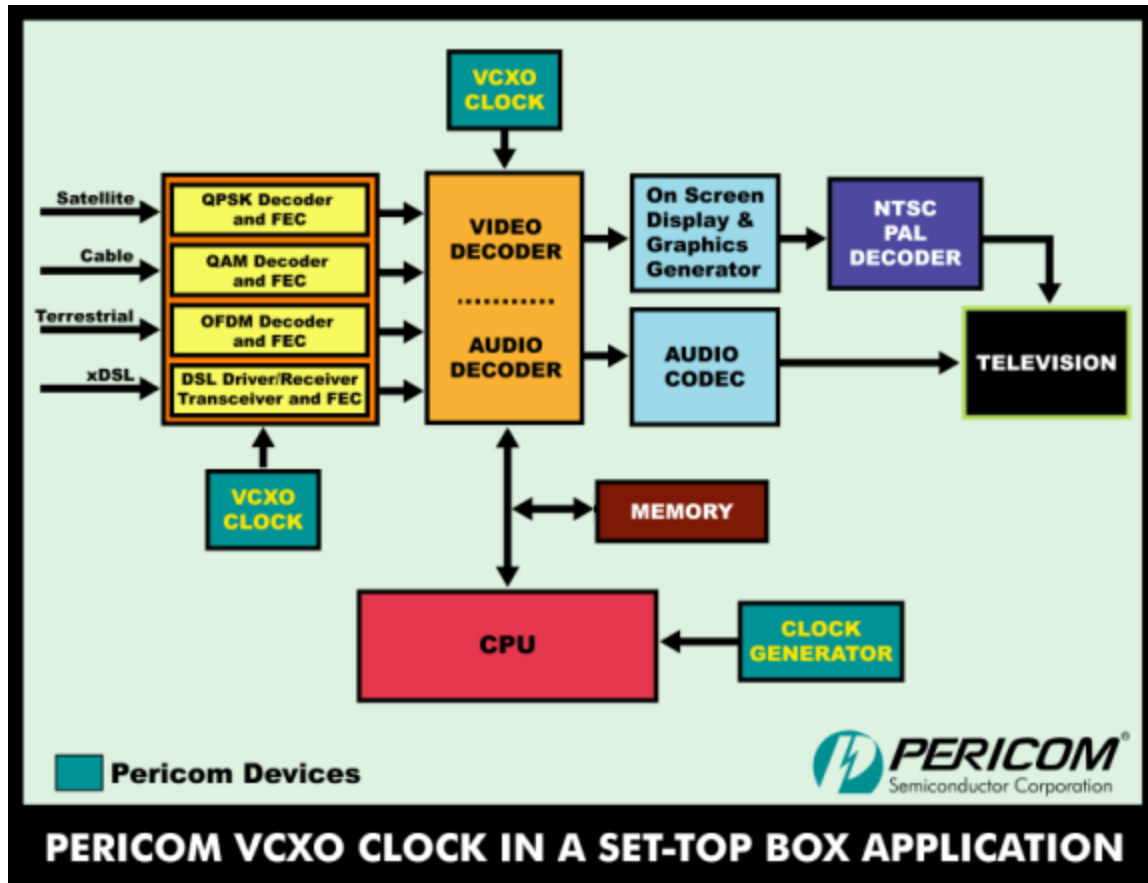


Figure 6. Applications for the PI6CX100-27 and PI6X027

Conclusion

Pericom Semiconductor offers the PI6CX100-27 and PI6XC100-35 along with the PI6X027 and PI6X035 crystal, respectively, for VCXO application. With the increase in demands for high accuracy clock source, Pericom Semiconductor will continue to provide the right solution.

References:

1. Norman Bujanos, "Choosing the Right Crystal for Your Oscillator"
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2. James Northcutt, "Specifying Crystal For Use in VCXO' and TCXOs for Wireless Designs"
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