

## EX-380/385 Series

### 4 Pin Dip Evacuated Miniature Crystal Oscillator (EMXO)<sup>TM</sup>



#### Features

- Supply Voltage: **3.3 Vdc**, 5 Vdc or 12 Vdc available
- Aging:  $<1 \times 10^{-9}$  /day,  $<1 \times 10^{-7}$  /year,  $<1 \times 10^{-6}$  /10 years
- Temperature Stability: to  $\pm 7.5 \times 10^{-8}$  over  $-20^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$
- Acceleration Sensitivity:  $1 \times 10^{-9}$  /g, Total Gamma
- Uses SC Family 3<sup>rd</sup> Overtone Crystal
- Low Power Consumption:  $<0.35$  watts @  $+25^{\circ}\text{C}$
- Frequencies: 10 to 20 MHz (other frequencies in development)
- Fast Warm-up: 1 to 2 minutes
- Patented Technique\*

#### Applications

- SONET / SDH, DWDM, FDM, ATM, 3G
- Telecom Transmission and Switching Equipment
- Wireless Communication Equipment
- Military Airborne and Mobile systems

Notes: 1. We acknowledge the support of the U.S. Army for work on resonators associated with this product under contract #1X66001-97-C-8635.

\*U.S. Patent 5,917,272.

### Theory of Operation

OCXO's (Oven Controlled Crystal Oscillators) are used when frequency vs. temperature requirements are too stringent to be met by a basic XO (Crystal Oscillator) or TCXO (Temperature Compensated Crystal Oscillator). With an OCXO, the temperature of the crystal and critical circuits are kept constant as the temperature outside the oscillator varies. Controlling the temperature inside the oscillator with an oven maintains this constant temperature. In an OCXO, the changes in the ambient temperature are sensed and then fed back to an oven control that continually maintains a constant optimum temperature inside the oscillator enclosure. An OCXO can improve the crystal's inherent stability by more than 5000 times. The

oven control system is not perfect, the open loop gain is not infinite, there are internal temperature gradients inside the oven (oscillator) and, in a conventional oven, the circuitry outside the oven shell is subjected to ambient temperature changes that can "pull" the frequency.

The improved temperature stability performance of a conventional OCXO over an XO or TCXO comes at a steep price. OCXO power consumption, for instance, is greater by a factor of over 200. There is also a size consideration. In an ordinary OCXO, a crystal is enclosed in a metal case which is then placed inside an oven shell together with temperature sensitive circuitry, and then

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## Theory of Operation Continued.

surrounded by thermal insulation. All this, plus any additional circuitry are then placed in a metal housing making for a bulky package, which becomes very difficult to miniaturize.

To overcome these obstacles, the EX-380 Series EMXO (Evacuated Miniature Oven Controlled Crystal Oscillator) was specifically developed to achieve OCXO performance while significantly lowering power consumption and reducing package size. These characteristics go hand in hand since reducing package size makes it easier to improve power consumption. First, the volume of the package was made as small as possible to reduce the volume that the oven needs to heat. Secondly, the most effective insulation needed to be used. In the EX-380 Series, Vectron has done both. The package was designed to single DIP dimensions of 0.82" x 0.52" x 0.3", and the oscillator uses a vacuum as the insulation medium - a dramatic improvement over conventional polyfoam or fiber based insulation material. Another great contributor to Vectron's efforts to reduce size and still provide "oven oscillator" performance was to eliminate the use of large packaged crystals which, up until now, had to be used to achieve good aging. Instead, a way to use an open crystal blank was found and made practical. Vectron has succeeded in resolving outgassing and contamination issues which could degrade performance. To do this required manufacturing the oscillator with a high internal vacuum level, with low internal outgassing, to provide the needed thermal insulation. A high level of cleanliness was needed to prevent contamination of the open (un-encased) crystal blank and to ensure exceptional long term crystal aging.

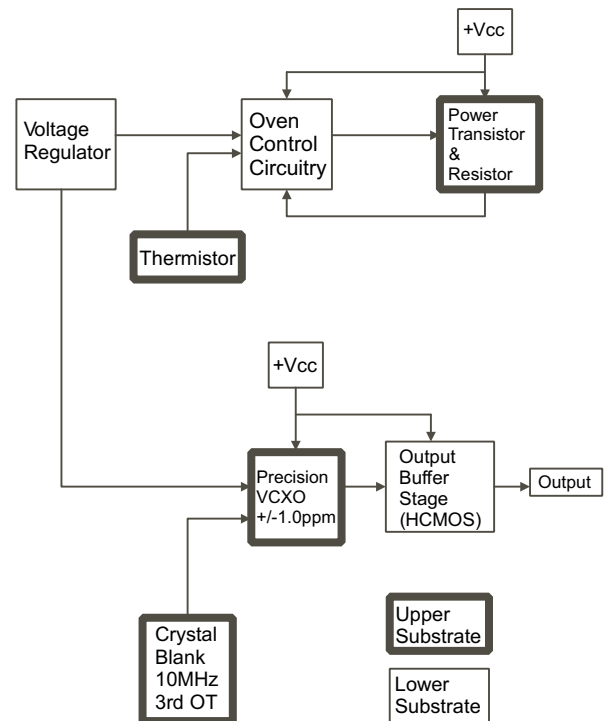


Figure 1. EX-380 Functional Block Diagram

The key design feature of this package utilized the concept of integrating the precision crystal in blank form in combination with hybrid microelectronics circuitry. In doing this, obtaining good aging performance was paramount. For this reason, a cold welded package was chosen rather than a more traditional resistance welded package. Cold weld sealing provided a true metallurgical bond between ductile metal surfaces without added heat from the sealing process. Under the high tonnage pressure introduced through the indentation of the welding die, a plasticity flow of material takes place on the mating surfaces. The end result is a hermetically sealed enclosure without contamination from weld splashes, dust and vapors. And, most important, cold weld sealed enclosures achieve a high level of vacuum integrity.

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## Theory of Operation Continued.

Mechanically, the hybrid circuit and crystal assembly are suspended directly over a highly insulating structure to minimize heat energy loss through conduction. In addition, the entire assembly is thermally insulated to the enclosure by vacuum at a pressure level of 10<sup>-6</sup> torr. Based on the steady state thermal conduction calculation, this package design resulted in a thermal resistance of >300 degrees C/watt.

The EMXO manufacturing process is interesting and a process flow diagram is shown below in figure 2.

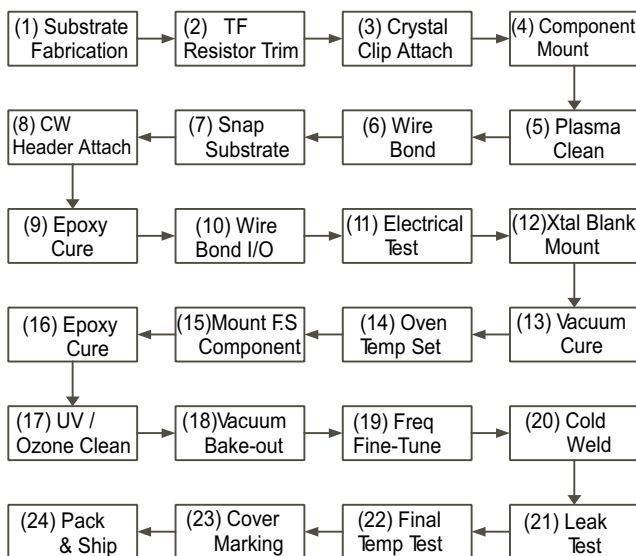


Figure 2. EMXO Process Flow Diagram

Substrates are fabricated with thick film screen printing techniques with each deposition layer subjected to three different process stages - print, dry and fire. Crystal clips are attached to the gold conductor trace on a substrate with high thermal conductivity. All active and passive components are mounted on the substrate using a conductive adhesive and then moved to a convection

oven for curing. After the cure process, the hybrid is cleaned to remove organic and non-organic contaminants. Wires are bonded on the hybrid circuit as interconnects. The hybrid circuits are then attached to the cold-weld package with adhesive. Finally, blank crystals are mounted onto the clips and tuned to the nominal frequency needed, by an evaporation process, to a typical accuracy of 1 ppm. The units are then cold weld sealed. The oven itself is heated by direct thermal conduction applied to a heat conductive substrate.

This "Open Blank" EMXO concept is shown and compared to conventional OCXO construction, in Figure 3 below.

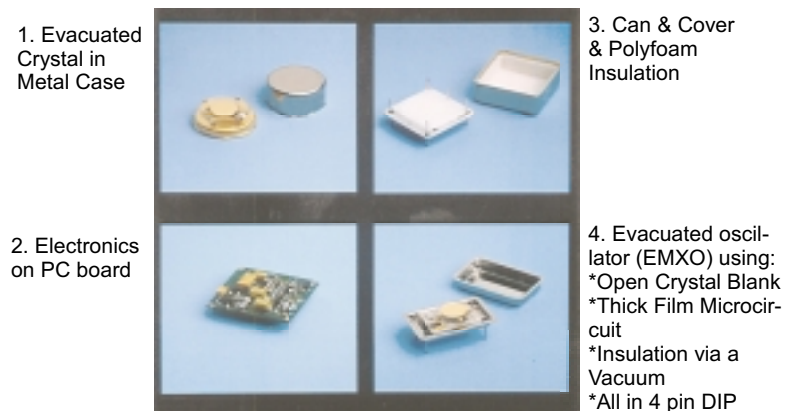


Figure 3, Open Blank EMXO concept

In figure 3 above, 1,2 and 3 reflect conventional OCXO construction while 4 is the EMXO. It shows the major elements of the SDIL EMXO. Only one substrate is used and all the elements are heated. The oscillator is essentially a CMOS gate type with an additional varactor diode and LC trap for overtone select. The resonator is a 3rd Overtone, AT or doubly rotated cut as required by the application, both of which offer superior aging performance when compared to a traditional fundamental resonator.

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## Theory of Operation Continued.

It is anticipated that the EX-380 Series will find applications where performance in severe mechanical environments is equally important to electrical performance. An additional focus for the EX-380 series, therefore, was to provide robust construction to withstand high shock and vibration and to yield good G-sensitivity performance. For example, when the physical orientation of an oscillator is changed, there is a small frequency change (typically not more than several parts in  $10^{-9}$  for a 90-degree rotation) due to change in stress on the crystal blank resulting from the gravitational effect upon the crystal supports. This characteristic is known as "tip-over" and is expressed in  $10^{-9}/g$  where one g represents one-half of a 180-degree orientation change. To minimize this change and also to enhance performance under shock and vibration, the crystal blank is mounted in a symmetrical mounting structure, instead of the more traditional 2 or 3 points. This helps to achieve a high shock and vibration endurance level, low g-sensitivity performance and symmetrical heat transfer. Also, when a crystal oscillator is operating and subjected to vibration, spurious frequencies are generated, offset from the frequency of oscillation by the

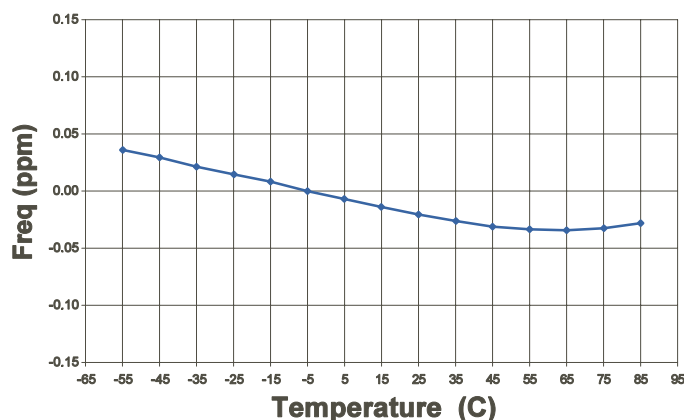
frequency of vibration. These are commonly referred to as "vibration induced side-bands" and these side-bands behave similarly to phase noise. The amplitude of these spurious outputs is related to the amplitude of vibration, the mechanical design of the crystal supports, and the mechanical design of the oscillator assembly, including the crystal mounting. Here also the symmetrical crystal mounting structure helps to reduce unwanted noise.

Both AT and doubly rotated crystals can be used in the EX-380 Series. Even though many types of doubly rotated crystals produce lower amplitude spuri under vibration than the AT, this characteristic is primarily determined by the mechanical design of the crystal and oscillator rather than the specific crystal cut. In many applications, Vectron uses doubly rotated resonators in the oscillator to provide lower close in phase noise, better aging rates and reduced acceleration sensitivity. In less critical applications, less expensive AT cut crystals are used.

The following figures represent the typical actual test data on qual samples for various characteristics.

**Figure 4**

Frequency vs Temperature  
Characteristics EX-380  
SERIES @ 10 MHz  
(Typical)

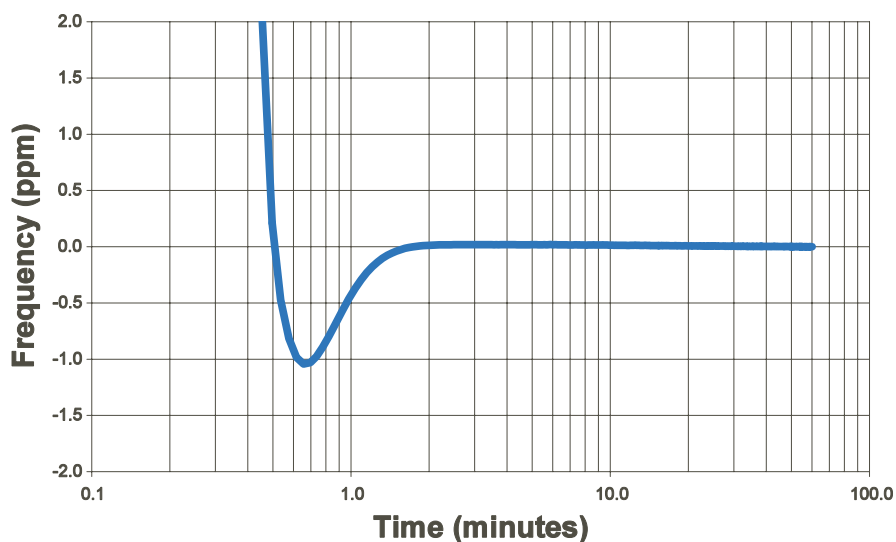


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## Theory of Operation Continued.

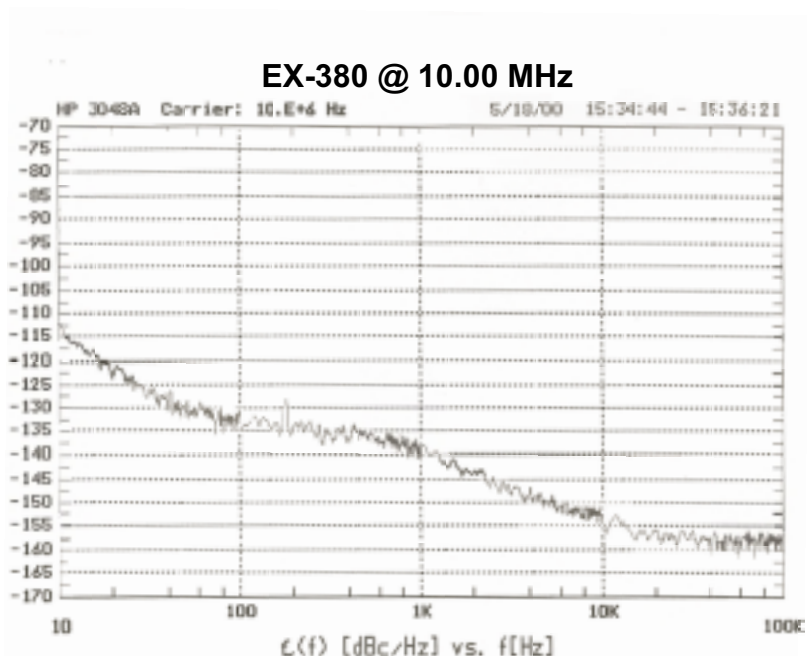
**Figure 5**

Warm-up (Restabilization)  
Characteristic at +25°C



**Figure 6**

This is a typical phase noise plot for the EX-380 series at 10 MHz. Significant phase noise improvement, both close in and at the noise floor, can be obtained on special order.

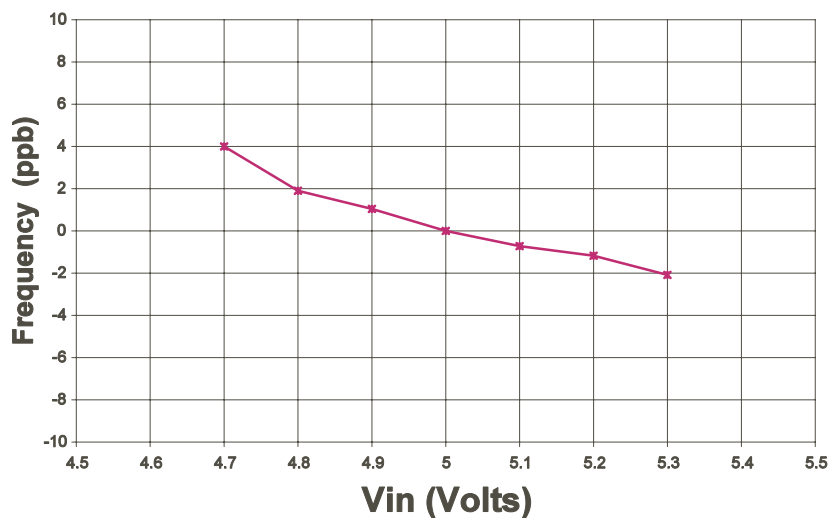


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## Theory of Operation Continued.

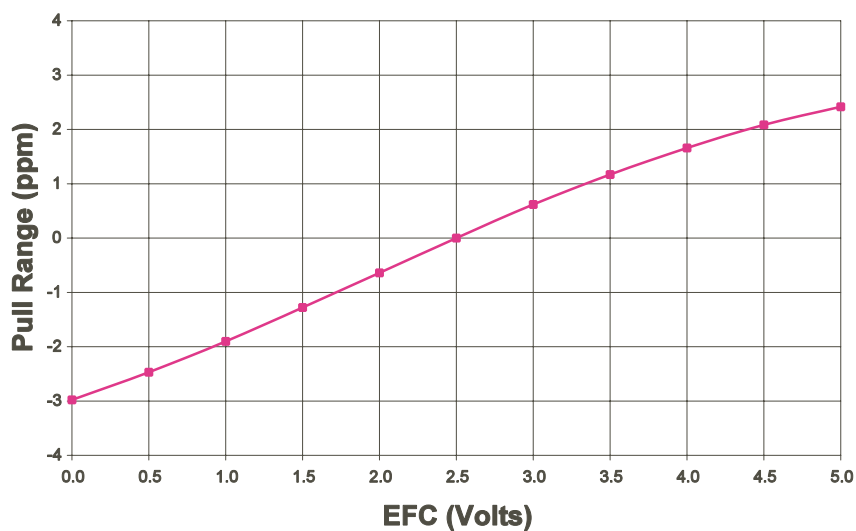
**Figure 7**

Frequency vs Supply  
Voltage (Typical)



**Figure 8**

Pullability Characteristic.  
Frequency Change vs  
Control Voltage Input

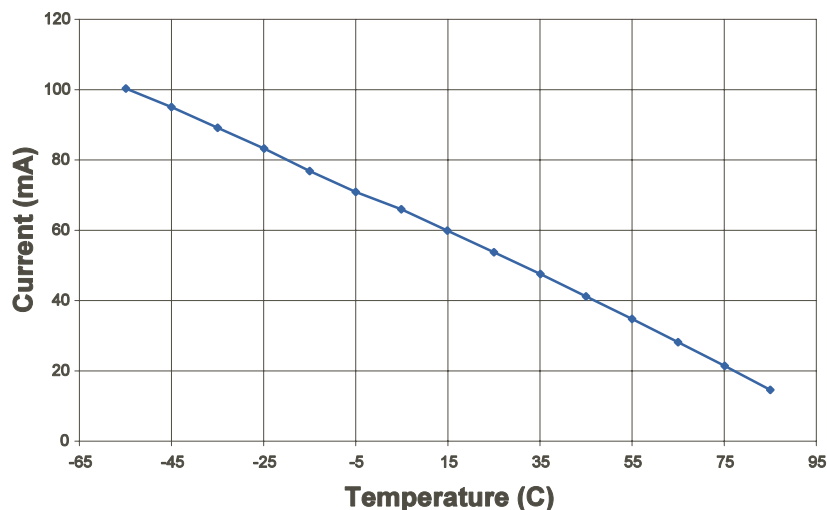


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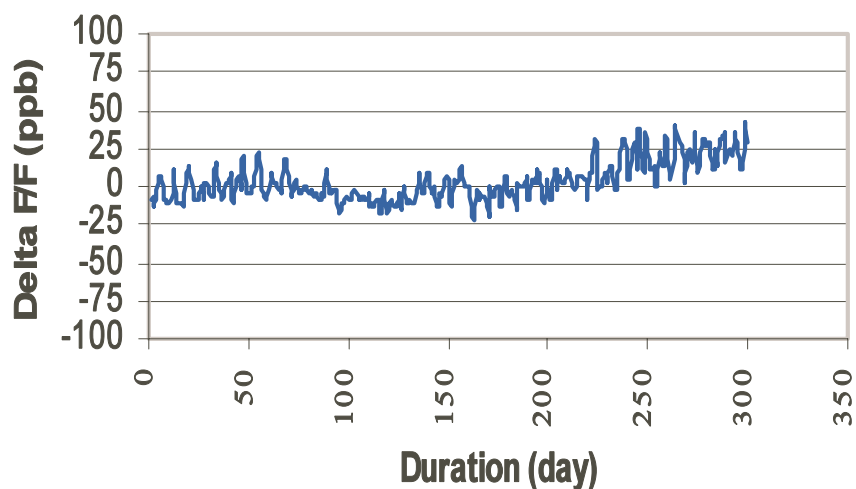
**Figure 9**

Steady State Current vs  
Ambient Temperature at  
10 MHz (Typical)



**Figure 10**

Frequency vs Time.  
aging plot @ 10 MHz  
(Typical)



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