Coefficient Corrected Oscillator - CCXO

Introduction

The Coefficient Corrected Oscillator (CCXO) contains a high-stability ovenized crystal oscillator and an I^2C interface that communicates with temperature and current sensors, and an onboard EEPROM. The interface enables the customer to improve upon the already exceptional stability of the oscillator.

Definition

Advances in quartz resonators and single-oven control circuits have enabled the mass production of oven controlled crystal oscillators (OCXOs) that are capable of achieving ageing rates of 0.06 ppb/day and temperature stabilities of 0.4 ppb over a commercial temperature range. These stabilities can be further enhanced with the use of commercially available environmental sensors and microprocessors. Vectron's MX series oscillators embed the digital electronics inside the oscillator housing, and microprocessor corrected stabilities to 0.1 ppb have been achieved using this approach. The graph below shows an OCXO with 4 ppb temperature stability that has been corrected to less than 0.3 ppb using a microprocessor.

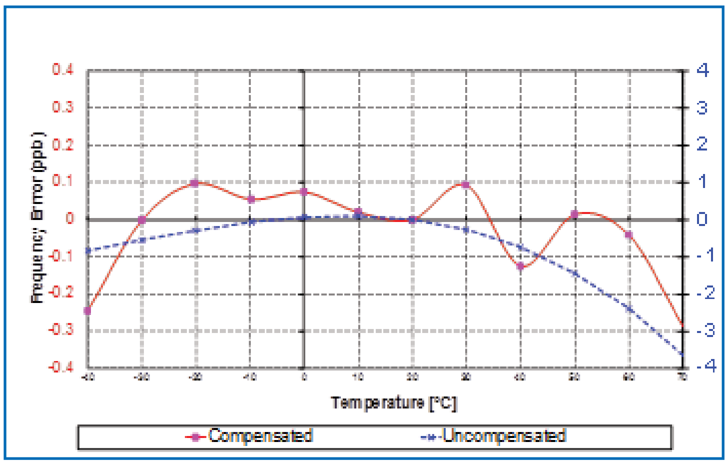

Figure 1 – Microprocessor corrected OCXO (red trace) with ~ 10 x improvement from the uncompensated results (blue trace).

For many applications the onboard microprocessor corrected approach is sufficient; however, in some applications customers achieve better results by performing the microprocessor corrections themselves. For these applications, Vectron provides our "Coefficient Corrected Oscillators" (CCXO) series. In addition, incorporating CCXO in a system may result in total lower bill of material costs if the customer already has a microprocessor in the end application.

A CCXO enables the customer to perform microprocessor correction through the use of an I2C interface. Through the interface, customers can access on board environmental sensors, digitally control the frequency, and access test information stored in the EEPROM. Each individual oscillator is characterized in a temperature chamber, and the values of the frequency error, temperature sensor, and the current sensor at each test temperature are stored in the EEPROM. The frequency error and temperature sensor results are used to generate the coefficients of the polynomial function

$$F(T) = A_4T^4 + A_3T^3 + A_2T^2 + A_1T + A_0$$

where F is the frequency error and T is the temperature sensor value. These coefficients are then stored in the EEPROM.

Chamber Temperature	Temperature Sensor Reading	Frequency Stability	Current Sensor Reading
-40	126	-0.432342	1098
-30	158	-0.2187234	1021
-20	190	-0.164123	944
-10	222	-0.1234545	867
0	254	-0.0976345	790
10	286	-0.0645658	713
20	318	-0.0478988	636
30	350	-0.0211176	559
40	382	0	482
50	414	-0.0155449	405
60	446	-0.034322	328
70	478	-0.0573457	251
80	510	-0.0855687	174

- A temperature test is performed on each unit.
- The value of the onboard temperature and current sensors, and frequency error of the oscillator at each test temperature is saved to the EEPROM.
- The coefficients of 4th order polynomial frequency vs. temperature are calculated and stored in EEPROM.
- The current and temperature sensors provide real time values via I^2C during operation.

Coefficient Value	
A0	-2.02214518
A1	0.022202701
A2	-9.63397E-05
a3	1.89217E-07
A4	1.39561E-10

$$F(T) = A_0T^0+A_1T^1+A_2T^2+A_3T^3+A_4T^4$$

Figure 2 – Example of data stored in EEPROM.

During use in an application, the customer steers the frequency of the oscillator with the I2C interface to address an onboard DAC. Alternatively the customer may use the F(T) information to steer a DDS and use a fixed frequency oscillator.

The block diagrams and table below illustrate the implementation and the differences between a corrected and a coefficient corrected oscillator.

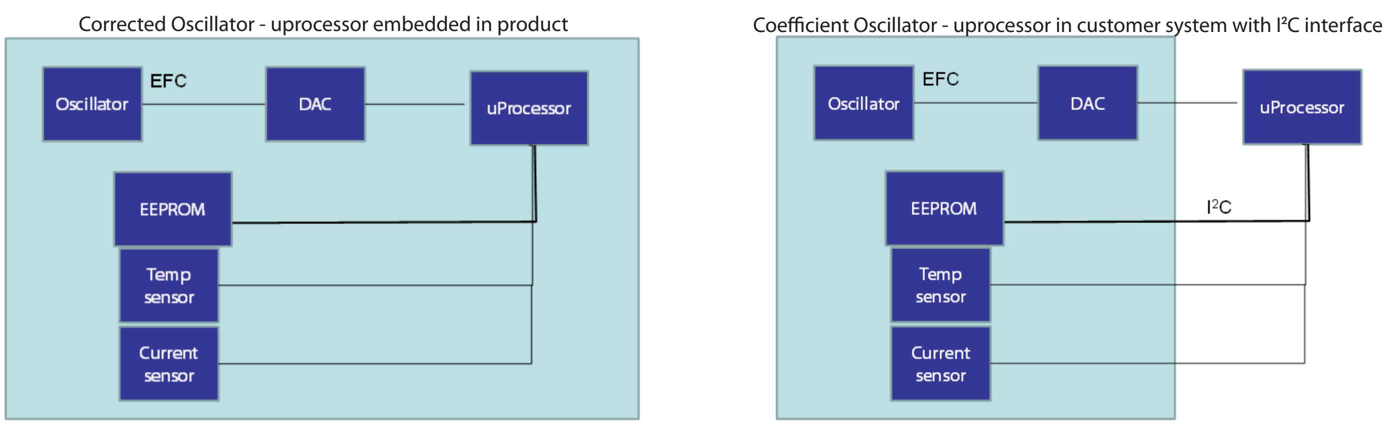

Figure 3 – Block diagrams of a coefficient and corrected oscillator. In a corrected oscillator the microprocessor is embedded in the OCXO.

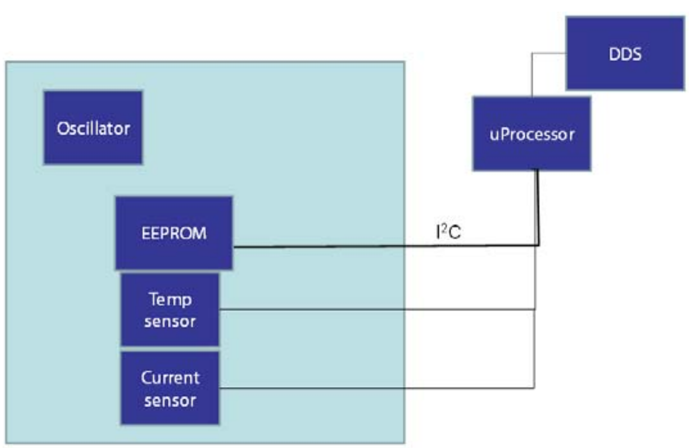

Figure 4 – Alternate configuration with DDS and fixed frequency oscillator for improved stability.

Corrected Oscillators (MX series products)	Coefficients for Correction (MD-xx3 series products)
Pros	
Minimal implementation effort by customers	Fever correlation issues
Best stability shipped from factory	allows customer additional sensing information into the oscscillator
	Temperature
	Current
	Anything that has an I^2C sensor available
	Customer can compensate for other effects
Cons	
Frequency vs Temperature curve is difficult for customer to model	Higher implementation effort at customer
Correlation issues	
Airflow may affect correlation	

The coefficient corrected oscillator approach requires more design effort at the customer to implement, but provides the customer with more control of the oscillator in the end application. In addition to the frequency versus-temperature benefits, the current sensor provides insight into the oscillator that can be used for several purposes. In an OCXO, an oven is used to keep the crystal at a constant temperature while the ambient environmental temperature is varied.

The current exhibits the following behavior:

- The steady-state oven current consumption varies inversely to the temperature.
- The current consumption at a fixed temperature increase as airflow is increased due to additional power required to stabilize the oven.
- Increased airflow may alter the measured frequency vs temperature performance.
- When the ambient temperature is varied, a transient current response occurs prior to reaching the new steady-state value.

The behavior can provide valuable insight into the oscillator allowing the customer to utilize the current sensor as an indicator for:

- Thermal stabilization
- Degradation of the F(T) equation if current is not similar to current stored in EEPROM for temperature

Ultimately this data can be used to create a new two independent variable relation F(I,T), where F is the frequency error, I is the current sensor value, and T is the temperature sensor value.

Conclusion

the CCXOs (MD-xx3 series) afford the customer the opportunity to gain valuable insight to the oscillator performance, and ultimately to enhance the performance in their end application at a reduced cost. The solution does require more upfront effort than an off-the-shelf corrected oscillator, but provides a path for improved performance.

For Additional Information, Please Contact

USA:
Vectron International
267 Lowell Road, Unit 102
Hudson, NH 03051
Tel: 1.888.328.7661
Fax: 1.888.329.8328

Europe:
Vectron International
Landstrasse, D-74924
Neckarbischofsheim, Germany
Tel: +49 (0) 7268.8010
Fax: +49 (0) 7268.801281

Asia:
Vectron International
68 Yin Cheng Road(C), 22nd Floor,
One LuJiaZui
Pudong, Shanghai 200120, China
Tel: +86 21 6194.6886
Fax: +86 21 6194.6699