WHITE PAPER

Rejustor™ Based Oscillator Stability Control

1 Introduction

Stable oscillators are the foundation of the trend towards high-speed serial networks like RapidIO, PCI-Express and 10G Ethernet. As these network elements become mainstream, the requirement to provide high-stability, inexpensive oscillators increases. Low-TCR *Rejustors* from Microbridge Technologies, provide the link between precision and flexibility for oscillator designers.

Oven Controlled Crystal Oscillators (OCXO) are characterized by their high stability profile. Using an oven to maintain constant temperature of a crystal can increase stability up to 5000[1] times!

The oscillating frequency of a typical crystal is dependant upon many parameters including its temperature. All crystals have a sweet spot. That is, a frequency that it is most stable for changes in temperature. Plotting a curve of delta-Freq vs. temperature shows a parabolic profile. The sweet spot is at the base of the parabola (with zero slope).

Oven-controlled crystal oscillators use an oven to stabilize the temperature of the crystal, thereby stabilizing the oscillating frequency. Obviously setting the nominal oven temperature to the temperature at which the slope of the delta-Freq vs. delta-temp is zero will provide the most stable oscillator.

The Rejustor-based oven temperature controller for OCXO's uses the Rejustor to set the operating temperature of the oven to the optimum temperature for the crystal.

2 OCXO Compensation Challenge

The basic OCXO uses a thermistor to sense temperature. The output of the thermistor turns the oven on or off depending on the set point (which is set with resistors). The set-point for each crystal is determined experimentally by changing the temperature of the oven and measuring the output frequency of the oscillator.

The change in oscillating frequency of the crystal as a function of temperature has a profile as shown in the graph below (Figure 1). The point at which the slope of the curve is zero represents the most stable operating temperature for the crystal. Since the slope is zero, small changes in temperature will have a minimum impact on the output frequency of the device, yielding a stable operating frequency.

™ *Rejustor* is a trademark of Microbridge Technologies

[1] Source Vectron International

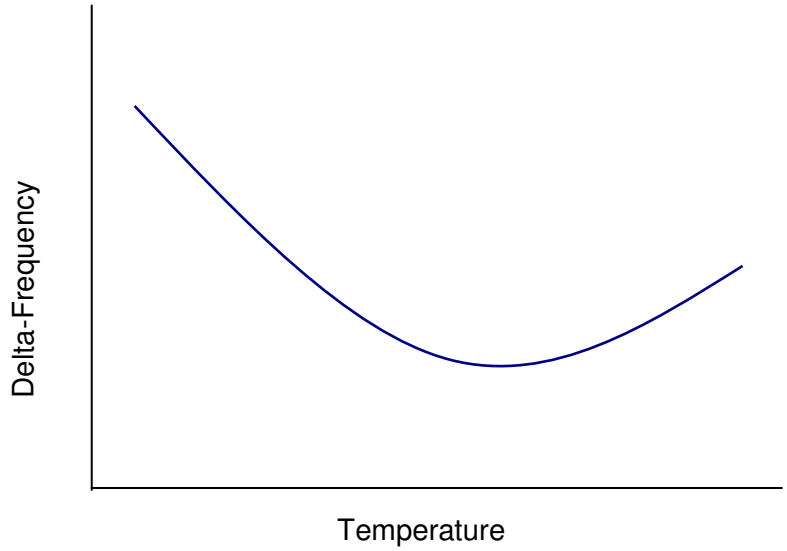

Figure 1: OXCO Frequency Response as a function of Temperature

One challenge for manufacturers of OCXO's is to trim the offset of the thermistor to the set-point of the oscillator. Currently the exact resistance is determined experimentally. Traditionally the circuit is assembled without the set-point resistors. A technician uses a decade box to sweep the frequency of the crystal to find the sweet-spot (zero slope). When the resistance is found, the board is sent back into manufacturing to have the correct fixed-resistor installed. Then the circuit goes back to the technician to be re-tested.

The current process is labor intensive – since a technician is required to sweep the device. Every device needs re-work to install the fixed resistors. This means that the manufacturing environment must be setup to include rework and an inventory of fixed resistors are required at final assembly. Although a minor problem, after the fixed-resistors are installed, the crystal and oven assembly is potted and then packaged (typically in a metal can). There is the potential that the potting process can slightly shift the behavior of the crystal which could reduce the stability (since it can shift it past the zero-slope point).

3 Rejustor-based OCXO Compensation

Rejustors can be used in place of fixed resistors as shown in the schematic.

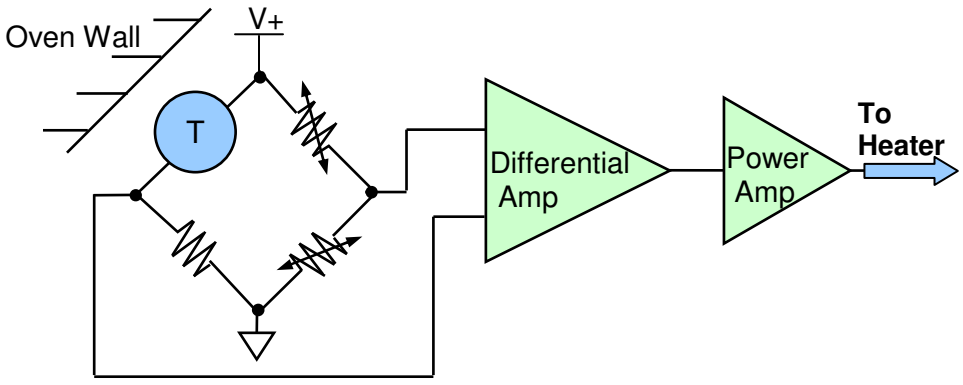

Figure 2: Rejustor-based OCXO Control - Schematic

Rejustors could be used in place of the fixed resistors for set-on-test adjustment of the set-point for the oven. Using Rejustors makes the assembly process more efficient because all OCXO's are assembled with identical components. The bill-of-materials is smaller. The inventory of fixed-resistors is eliminated. Devices don't need re-work as part of the normal production process.

Since Rejustors are adjusted electrically the OCXO can be encapsulated prior to adjustment. Test points need to be added to the OCXO (for example a tab or extension to the PCB that is broken off after adjustment) to apply the control signals to the Rejustor to change their resistance. After adjustment, the circuit is already in the final assemble so there are no further changes prior to final test. All parasitics are included when the adjustment is made. After adjustment the tab is snapped-off and OCXO is ready to ship.

A sample calibration setup is shown below.

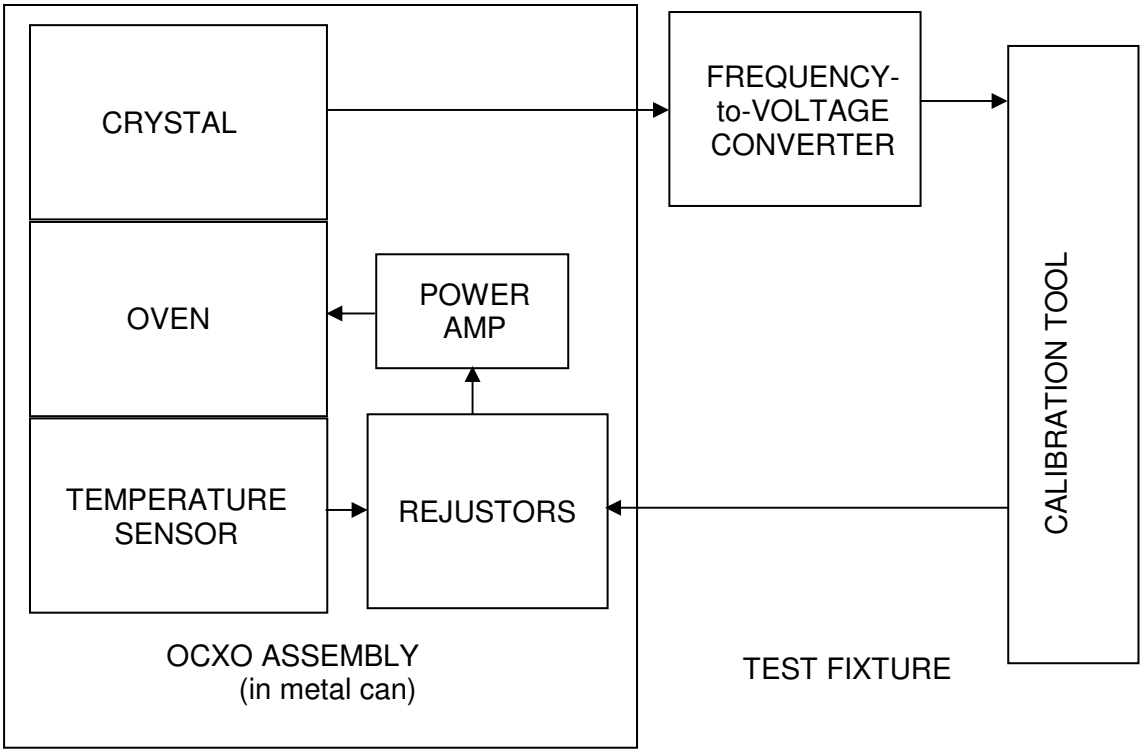

Figure 3: Calibration Fixture - Block Diagram

A frequency to voltage converter is required to provide an input signal to the MBK-408A Rejustor Calibration Tool. To get the most value from Rejustors, the calibration software is modified to sweep the delta-frequency vs. temperature curve to find the optimum temperature. Refer to Figure 1. Since the Rejustors control the temperature of the oven, the calibration tool can adjust the resistance of the Rejustors while measuring the output frequency. The resistance of the Rejustors can be set to the optimum value for each individual crystal. After they're set, the assembly can be re-tested to verify performance. This means no re-work and no re-testing afterwards.

4 Rejustor benefits

1) The resistance of Rejustors can be set at final assembly
   Traditionally the circuit is assembled without the set-point resistors. A technician uses a decade box to sweep the frequency of the crystal and find-out the sweet-spot. When the resistance is found, the board is sent back into manufacturing to have the correct fixed-resistor installed. Then the circuit goes back to the technician to be re-tested. With Rejustors the process is simplified:
   i. completely assemble the circuit
   ii. test it to find the optimum resistance value for the Rejustors
   iii. adjust the resistance of the Rejustors
   iv. verify the results
   The entire process can be automated so that a technician can supervise the final adjustment which eliminates the need for re-work and re-testing, which improves manufacturing efficiency
2) Rejustor tools can be automated to sweep the resistance range to discover the sweet-spot. This has the potential to decrease test time and it means lower-costs and increased efficiency.
3) Smaller bill-of-materials – all OCXO's are assembled with exactly the same parts instead of each assembly having a different set resistor. This lends itself well to mass production. It also reduces inventory cost associated with the range of fixed resistors.
4) Rejustors are adjusted electrically – this means that the crystal assembly can be fully-encapsulated prior to test and adjustment. During adjustment, the circuit is already in the can (or other encapsulation) so any changes (from parasitics for example) are already included when the adjustment is made.
5) Resistance of the Rejustors are stable across a wide temperature range making it possible to use the OCXO's in automotive and base-station applications

5 Summary

This is a typical application for ***Rejustors*** where an analog adjustment is required. The thermistor-based temperature sensor is a simple and flexible design. ***Rejustors*** can automate the calibration process with in-circuit adjustment[2] thereby improving efficiency without compromising precision.

As a passive device, the ***Rejustor*** is ideal for this type of application. Unlike digital solutions, ***Rejustors*** always maintain their resistance, reducing boot-up time.

Being able to perform simple analog electronic adjustment where digital solutions are excessive changes the game. Using in-circuit calibration to control offset and gain, ***Rejustors*** can replace the process of manually sorting or laser-trimming resistors. The ***Rejustor*** is more than just a resistor and Microbridge is a company committed to adjustment and compensation technologies.

We have focused on just a few of the many applications for small, precision adjustment using the ***Rejustor***. Adjust your design!

[2] Rejust-it in-circuit software required for target voltage adjustment