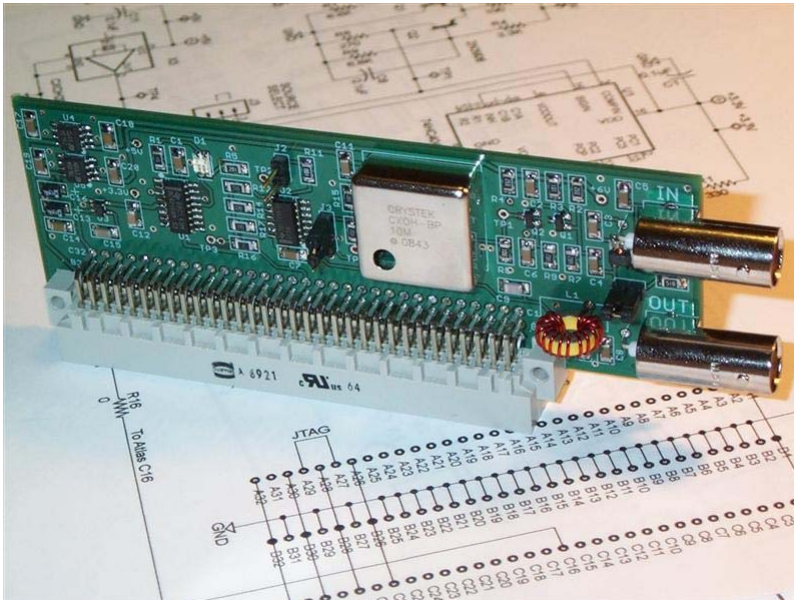




**High Performance Software Defined Radio**  
Open Source Hardware and Software Project  
Project Description: <http://openhpsdr.org>

## **Excalibur** **Assembly and Operation** **Instructions**



**Author: Graham Haddock, KE9H**

## Contents

<b><i>Introduction</i></b> .....	<b>3</b>
<b><i>Description</i></b> .....	<b>3</b>
<b><i>HPSDR SetUp</i></b> .....	<b>4</b>
<b><i>PowerSDR Settings</i></b> .....	<b>4</b>
<b><i>Excalibur Adjustment</i></b> .....	<b>4</b>
<b><i>Excalibur Configuration</i></b> .....	<b>5</b>
<b><i>Assembly Instructions</i></b> .....	<b>6</b>

***Appendix "A"*** Schematic and Board Top View, Silkscreen Errata.

***Appendix "B"*** Comments on hand assembly of SMT components.

***Appendix "C"*** Bill of materials.

***Appendix "D"*** Special sort of the bill of materials in recommended assembly order.

***Appendix "E"*** Instructions for winding the toroid.

***Appendix "F"*** Performance Measurements.

## Introduction

Excalibur is a small accessory card for the Atlas bus that enables the use of an external 10 MHz frequency reference for locking the frequency of an HPSDR radio to the same accuracy of the standard, or GPS disciplined oscillator.

It also provides an on-card TCXO frequency reference for the HPSDR, that is better than the on board 10 MHz oscillators, although not as good as an external reference standard or GPS-DO.

## Description

Excalibur can be configured in several ways, using the jumper clips, and also has an auxiliary output connector.

First, it can be configured to take an external 10MHz signal, such as a sine wave or square wave output from a reference standard or GPS disciplined oscillator, into a BNC input and process it into a square wave and put it on Atlas bus 10 MHz clock line C16.

Second, it is a way to have an on-bus "instant on" TCXO with more accuracy than the 10 MHz oscillators on either Penelope or Mercury. When the on-card TCXO is selected as the clock source, it will drive the Atlas bus via line C16.

No matter which source has been selected to drive the bus, the on board "beat" indicator will always compare the frequency of the TCXO to the frequency of whatever signal is coming in the "INPUT" BNC connector.

Excalibur also has an auxiliary output on two pin connector (J2), which can provide a square wave output for direct connection to the AUXCLK-(J8) input on Mercury, for special applications using that Mercury input.

The "Output" BNC provides a 10 MHz sine wave at + 8.5 dBm as a way to lock external equipment to which ever 10 MHz source is driving the bus.

There is a multi-colored LED, hooked to the output of a frequency-phase detector comparing the TCXO to whatever is coming in the "Input" connector. It gives both a HIGH/LOW frequency color indication and a visible beat indicator. It is useful for setting the TCXO to within a fraction of a Hertz.

The 10 MHz oscillators on the Mercury or Penelope cards have a rated stability of +/- 50 or 100 ppm over wide temperature, or +/- 500 Hz to 1 kHz at 10 MHz. Using the Calibrate function built into PowerSDR, you can set them to WWV or other reference, with an accuracy of about 10 to 30 Hz, but they could still move around +/- 50 to 100 Hz over normal room temperature variation.

The TCXO on Excalibur has a rated stability of +/- 1 ppM over wide temperature, or +/- 10 Hz at 10 MHz. Over normal room temperature variation, it stays within 1 Hz of the calibrated frequency, and will likely age at the rate of 1 Hz every several months. (See performance measurements, in Appendix “F”.)

A (high performance) external 10 MHz GPS disciplined oscillator will typically exceed +/- 0.0001 ppM or plus/minus one milli-Hz at 10 MHz for as long as the GPS system remains operating.

The card is the same width as Penelope or Mercury, but is only 4 cm. (1.6 inches) high, and takes one slot position on the Atlas bus.

Although the board contains no software, it is compatible with the JTAG chain, so that it will pass through JTAG programming from cards on either side of it.

## **HPSDR SetUp**

### **PowerSDR Settings**

It is important to configure PowerSDR so that there is just one source of 10 MHz driving Atlas bus. Both Mercury and Penelope should be configured so that neither are selected as a 10 MHz source while Excalibur is present on the bus. If “Excalibur Present” is selected on the Hardware Config Setup page, then this will happen automatically.

In PowerSDR >> Setup >> General >> Hardware Configuration  
Check Excalibur as present.

Then, under

PowerSDR >> Setup >> General >> HPSDR

Check that the 10 MHz Clock Source is selected as “Atlas.” This should have occurred automatically and further ability to select is “grayed out” if Excalibur Present was selected per the above.

### **Excalibur Adjustment**

The TCXO units come from the factory set to within 1 Hz of the specified 10 MHz frequency. If you don’t have a local 10 MHz reference standard to compare it to, just put the unit into service and start using it, since it is already closer to frequency than you will likely to be able to set it using WWV.

With no external input, the on card “beat indicator” LED will remain a solid bright green.

Using an external standard, connect the 10 MHz input to the “INPUT” (top) BNC connector. The beat indicator should now change colors and provide both frequency and phase information.

A predominately RED color means that the TCXO is lower in frequency than the reference input. A predominately GREEN color means that the TCXO is higher in frequency than the reference input.

When the TCXO and reference are within a few cycles per second, you will see a distinct beat as the LED alternates between red and green in time with the beat note. One Hertz is the color cycle from red to green back to red.

Adjust the frequency adjust control through the hole in the TCXO cover, so that the LED is cycling at one color cycle every two seconds or slower.

If the color cycle is taking one second to complete, your frequency error is 1 Hertz at 10 MHz. If the color cycle is taking four seconds to complete, then your frequency error is one fourth of a Hertz.

As a practical matter, it is not necessary to set the oscillator to an accuracy better than about one fourth of a Hertz, since the TCXO will move around about one Hertz over the course of a day due to room temperature variation.

The TCXO also has an aging specification, typical of all crystals, such that it will slowly drift at the rate of one Hertz every several months or so.

## Excalibur Configuration

There are two configurable jumper pin settings.

Jumper J1 should be present if you want to terminate the External Reference Input in 50 Ohms. Jumper J1 should NOT be present if you want to terminate in a high impedance.

Jumper J2 should be in the upper position (jumper center pin and upper pin) if you want the on board TCXO to drive the 10 MHz clock line on the Atlas bus. Jumper J2 should be in the lower position (jumper center pin and lower pin) if you want the External Reference Input to drive the 10 MHz line on the Atlas bus.

J3 is an output connector. Do **NOT** put a jumper clip on J3. It is used for special applications to drive the AUX CLK input on Mercury.

# Assembly Instructions

## Recommended Hand Assembly Order

The general order is small to large, center to outside, surface mount first then thru hole last.

Specifically, this is the recommended order:

- 1.) Small common parts - bypass caps
- 2.) Other small surface mount capacitors, resistors, diode, transistors.
- 3.) Surface Mount ICs
- 4.) Connectors
- 5.) Toroid
- 6.) TCXO
- 7.) Install the two jumper clips according to desired configuration.

## Special assembly notes

- 1.) Tantalum capacitors C16 and C17 are polarity sensitive. The end with the “band” should go to the + mark on the PC board silkscreen.
- 2.) Diode D1 is polarity sensitive. The green band should be positioned “down” corresponding to the white band on the PCB silkscreen.
- 3.) The integrated circuits should be positioned with pin 1 corresponding to the white dot on the PCB. The integrated circuits may be marked with a dot at pin 1, or with a beveled edge corresponding to the side with pin 1, or with a white band at the end with pin 1. If marked with a beveled edge, this corresponds to the double line on the silkscreen. If a band or dot, that end corresponds to the dot on the silkscreen. U1, U4 and U5 are dot DOWN. U2 is dot UP. U3 has five leads, and can only be positioned one way.
- 4.) Pay particular attention to U4 and U5, which are identical in physical appearance. The part number is marked on the top of the IC. U4 is a 6 Volt regulator marked 78L06, and U5 is a 5 Volt regulator marked 78L05.
- 5.) There is an error in the silkscreen position for R08. The part position diagram in the Board Top View in Appendix “A” is correct, and the page following illustrates the error as printed on the silkscreen.

Appendix "D" is a special sort of the bill of materials in the recommended assembly order. You may print out a copy of Appendix "C", along with the "Board Top View" from Appendix "A" to use as a checklist and aid for assembly.

Refer to Appendix "B" for comments on hand assembly and soldering of SMT components, if you are not familiar with these techniques.

Appendix "A" contains the schematic and Board Top View, showing all part locations. This Board Top View should be used as the master reference for all part locations. Observe the silkscreen errata for Resistors R08 and R11.

Appendix "E" contains the instructions for winding the toroid.

### **Checkout prior to first power application.**

A convenient "Ground" connection is the shield of the LOWER (Output) BNC connector, or the lower pin of J3. (The shield of the upper BNC "floats.")

The unit draws power from both the Atlas +12 Volt and +5 Volt. So check for no shorts to ground on Atlas +5 Volts, the extreme left pins on the Atlas Connector, C32/B32/A32. Other than a brief capacitor charging, I show open with a digital Ohm meter.

Check for no shorts from Atlas +12 Volts to ground, the extreme right pins on the Atlas connector C1/B1/A1. Other than a brief capacitor charging, I show open on a digital Ohm meter.

There are three labeled test points for the internal voltages, towards the left center of the board. Without power applied, but measuring to ground with a digital Ohm meter...

For the +6V test point, I show 2.4 K to ground.

For the +5V test point, I show 4.1 K to ground.

For the +3.3V test point, I show 94K to ground.

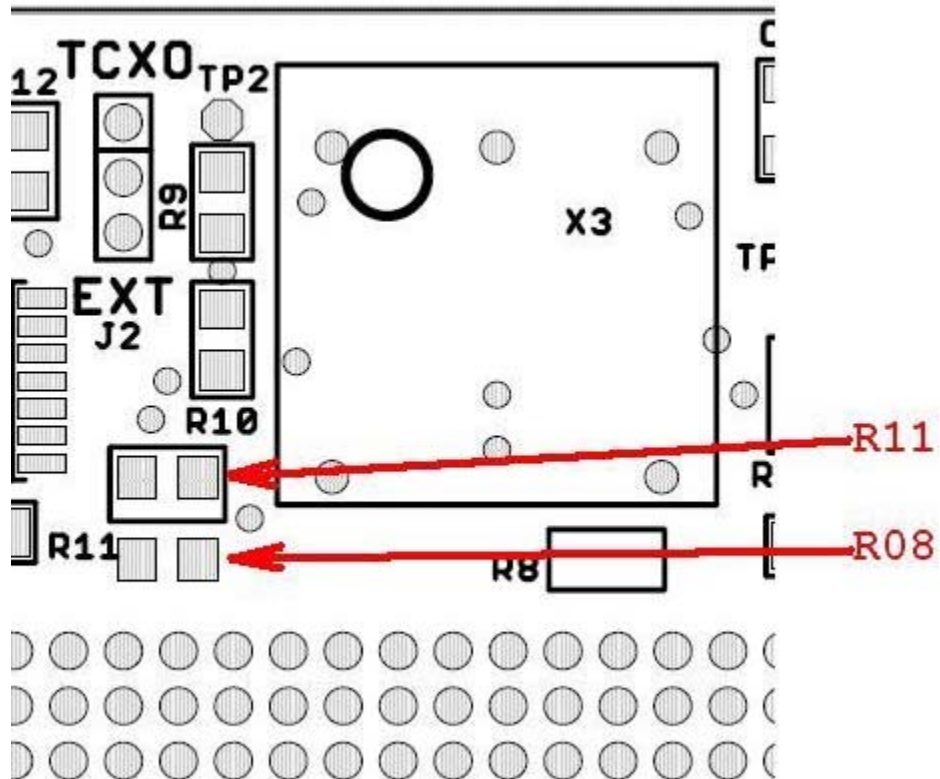
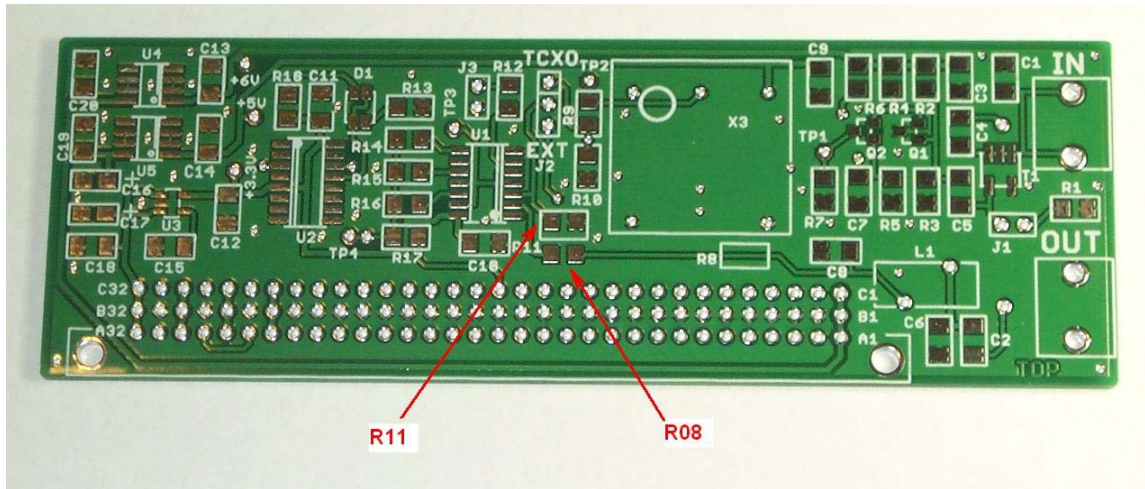
If you don't see any shorts and your readings are reasonable, plug your board into the Atlas bus and power it up.

With no external input, the on card "beat indicator" LED will show a solid bright green.

**Appendix "A"**  
**Schematic, Board Top View and**  
**PCB Silkscreen Errata**

## PCB Silkscreen Errata

There was a last minute change that didn't update the silkscreen properly. See below for the proper location of R11 and R08. The board layout on the previous page is correct.



## Appendix "B"

### Comments on Surface Mount assembly

This appendix is not intended as a tutorial on surface mount soldering, but to give a few highlights. You can find many tutorials on hand soldering SMT components on-line, particularly on YouTube.

This product has about 46 surface mount components, generally using the largest size available, that should make this a good choice for a first kit using surface mount assembly, by hand.

Although it is possible to oven reflow, hot air reflow or hot plate reflow a surface mount PCB, it is not necessary for building this board, and basic hand assembly and soldering will work fine.

Primary tools will be a desk mount lighted magnifying lens, a grounded fine point soldering iron, preferably temperature controlled, and a pair of curved point metal tweezers.

An antistatic work mat with wrist strap is appropriate.

A flux pen is helpful when soldering ICs, as is small diameter solder with a rosin core, and solderwick for picking up any excess solder.

Generally, the process for a capacitor or resistor is to put a small dot of solder on ONE of the pads the part is going to be soldered to. Then, holding the part in the tweezers, hold it in position, and touch the tip of the iron to the solder dot, allowing it to melt and wet the end of the part. Then, using the tip of the tweezer to lightly push down on the center of the part melt the solder again, and the part will "click" down flat against the board. If the part is in the final desired position, melt a tiny bit of solder and fresh flux on the other end of the part, allowing the solder to flow under the end of the part.

If you have a choice as to which end of the part to solder first, the end that is NOT grounded will be easier. Even though this board incorporates thermal reliefs (thermals) on all ground pads, the grounded end will still take more heat to solder than the other end.

For an IC, if you have a flux pen, put a little flux on all PCB pads. Then choose one pad, at a corner, to put a small dot of solder upon. Holding the IC in position with the tweezers, using the iron, melt and solder the one corner pin. If necessary, using the tweezers, and re-melting the solder on the one pin, re-position the IC until it is centered on all pads. Then go to the pin diagonally across the IC and solder it down. If necessary, press down lightly on the center of the IC while re-melting those first two pins, so that all pins are flat against their respective pads. Then work your way around the IC soldering

down all pins. If you have a solder short between adjacent pins, remove any excess solder with “solder wick.”

For final inspection, a "Jewelers eye loupe" of approximately 4x power is a great aid. Loupes manufactured in Asia are available on eBay or similar sources for a few dollars.

**Appendix "C"**  
**Bill of Materials**

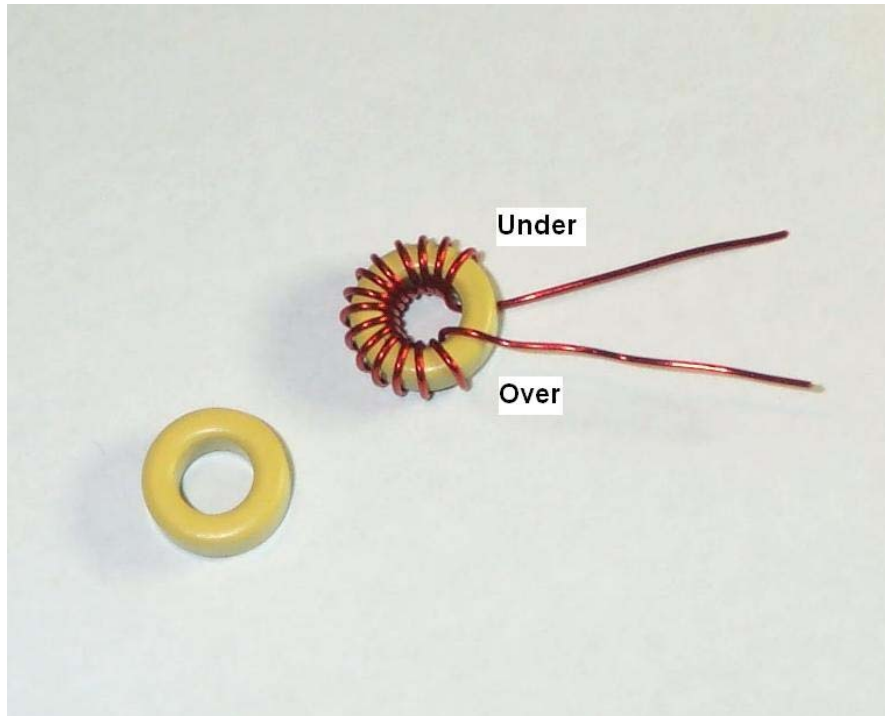
## **Appendix "D"**

### **BOM Special Sort - Recommended Assembly Order**

## Appendix "E"

### Instructions for Winding the Toroid

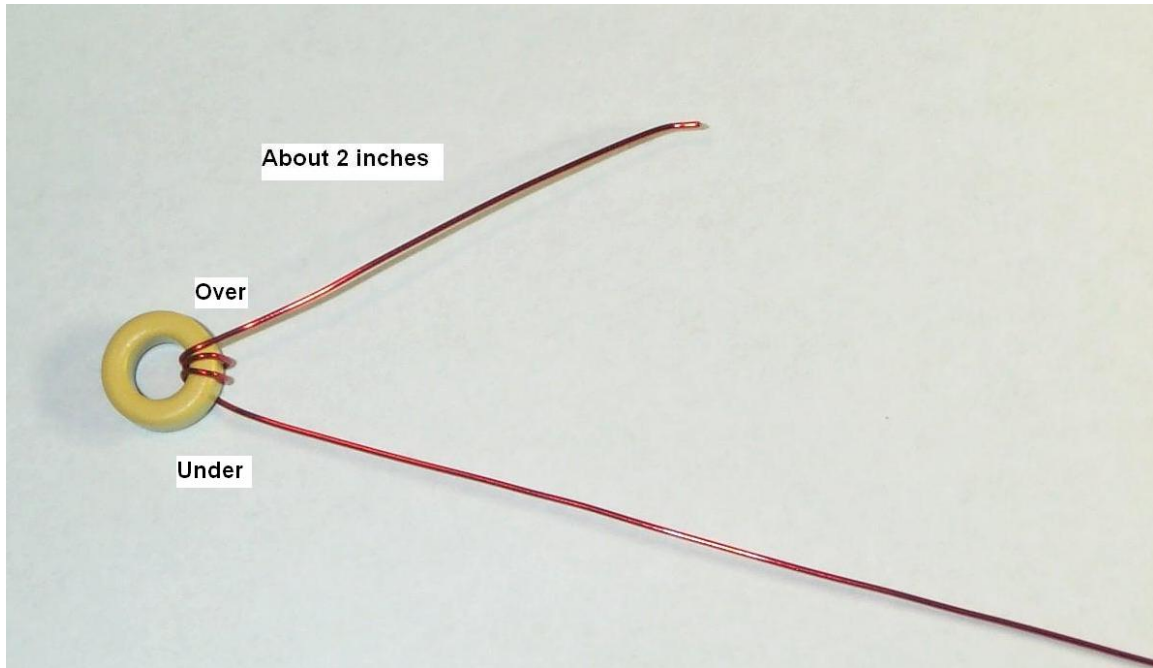
**Note :** When counting turns of wire on a toroid, the definition of a turn is a pass through the center of the toroid. So, a two turn toroid, would have the wire passing through the center hole two times.



FINISHED TOROID

**L1** is constructed using an Amidon/MicroMetals T37-6 toroid core, wound with 15 turns of number 24 wire.

The direction of the winding is important, so that the leads, when they exit the toroid, match the hole pattern in the PC board.



### STARTING THE WINDING

Start the winding with the wire positioned as shown. Proceed winding until there are fifteen turns of wire on the toroid.

The completed, the toroid should look as shown at the front of this section. Check that the top and bottom wire exit as shown. The turns should be equally spaced around the perimeter of the toroid.

Cut the leads to about one half inch long (1.3 cm). Strip and tin the wire from the edge of the toroid to the end of the lead.

The insulation on the wire provided with this kit will break down and allow solder to tin the wire, with a soldering iron temperature of 825 degrees F (440 degrees C). You can speed up the process by exposing the copper towards the tip of the wire, to allow faster heat transfer into the copper, since the coating is a thermal insulator.

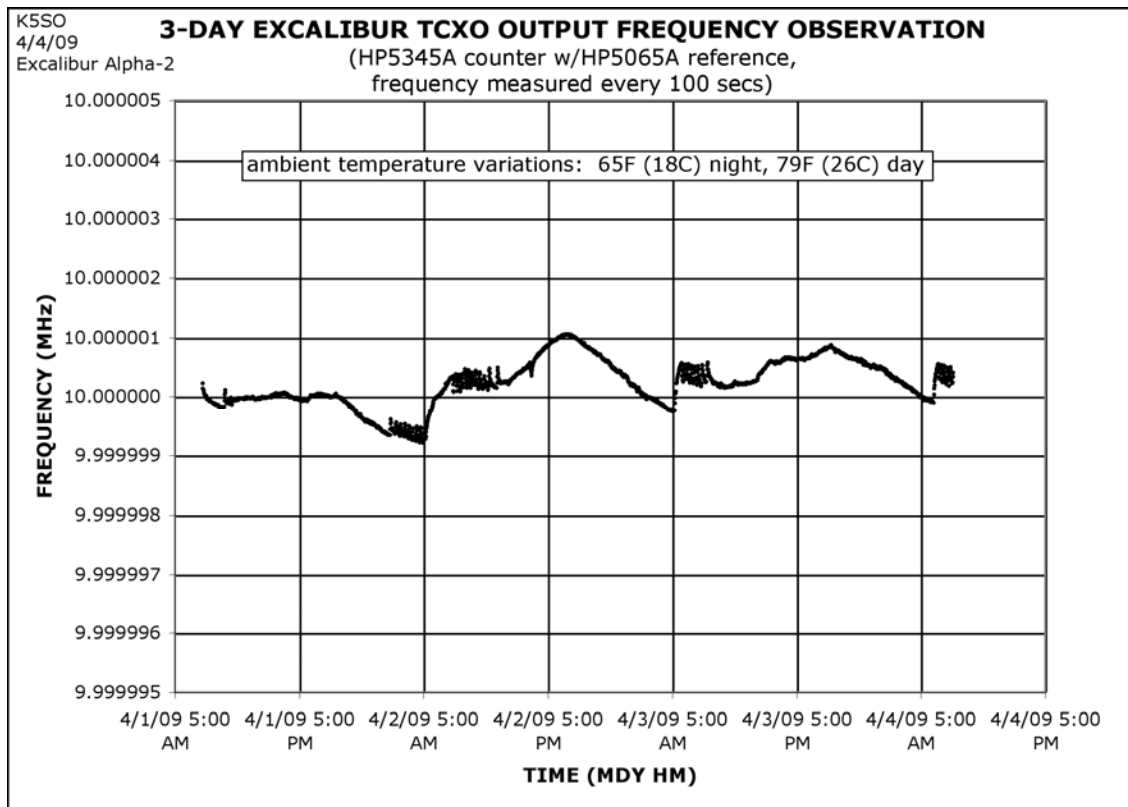
Just be sure not to nick the wire close to where it will pass through the PC board.

**Appendix "F"**  
**Performance Measurements**

From Joe, K5SO ---

Here is a JPEG image of my measurement results of Excalibur's TCXO output frequency over a 3-day period. Measurements were taken every 100 seconds with a precision of 1 milli-Hz using the equipment indicated in the image file. The Excalibur board was open (in an Antec NSK2480 enclosure with the top off) to the shack environment. Daily ambient shack temperature variations were over the range 65F to 79F; I did not record the precise time-temperature profile of the shack during these measurements. As you can see from the plot, the Excalibur TCXO stayed at 10 MHz within about +/- 1 Hz during the entire measurement period.

73, Joe K5SO



**John Ackermann, N8UR** did some very detailed testing of stability and phase noise performance. Refer to his website at <http://www.febo.com/pages/excalibur> for a lot more detail of his testing methodology, results, and comments on the TCXO performance.

