Assembly and Usage Notes for K8ZOA Crystal Test Fixture Revised for Version 1.2 PCB

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15 February 2009

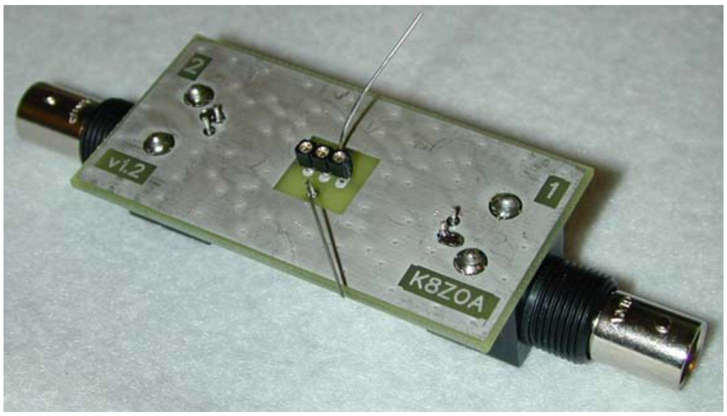
These notes summarize the assembly and usage of the 12.5 ohm crystal test fixture kit using printed circuit board version 1.2 and should be read in conjunction with the associated document CRYSTAL MOTIONAL PARAMETERS, available for download at http://www.cliftonlaboratories.com/Documents/Crystal%20Motional%20Parameters.pdf.

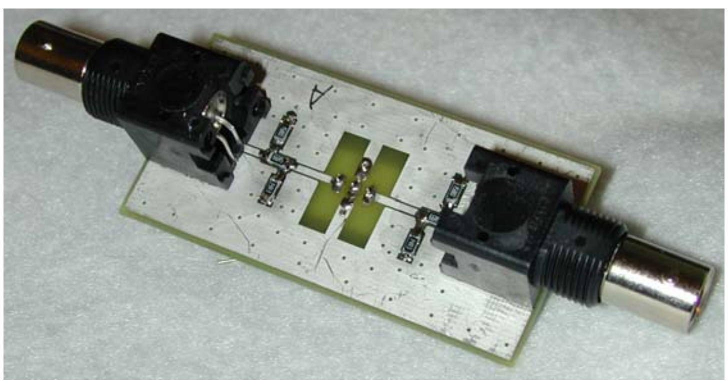
The purpose of the fixture is to aid in making accurate, repeatable measurements of the motional parameters of piezoelectric quartz crystals. In accordance with IEC recommendations, the fixture contains 15 dB (nominal) loss pads to match 50 ohm test equipment and present the crystal with a 12.5 ohm (nominal) source and load impedance. CRYSTAL MOTIONAL PARAMETERS describes several measurement approaches that may be used with the fixture to characterize motional parameters.

The fixture consists of a small printed circuit board, equipped with two BNC female connectors, the 1206 1% resistors comprising the two impedance matching pads and two socket options.

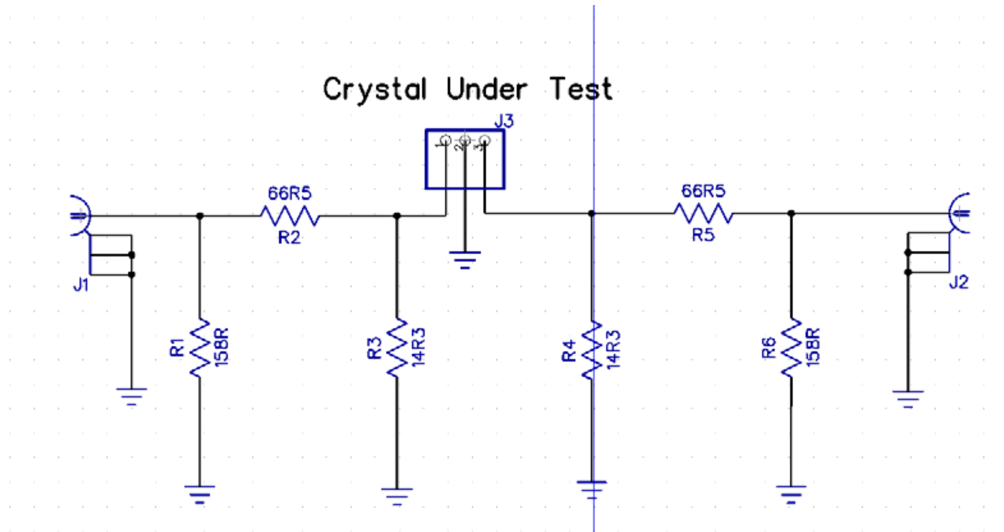
Accessories supplied include a 49.9 ohm 1% calibration comparison.

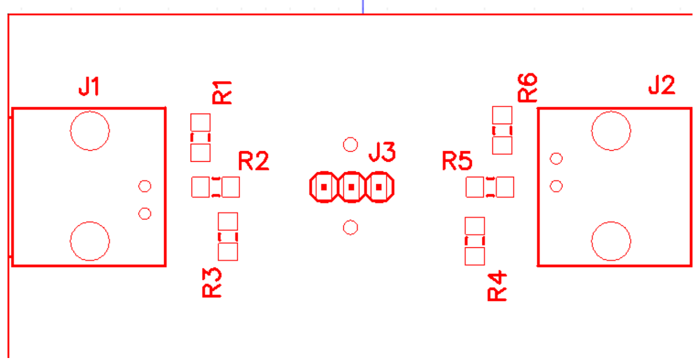
In use, the fixture is normally oriented so that the crystal socket faces upward, as illustrated in the photo below. The ends of the fixture are identified with numbers 1 and 2 etched into the PCB and may be used to identify the source and termination ports should the user desire to make consistent measurements. The fixture is symmetrical, and either port 1 or port 2 may be used for input or output, but for maximum repeatability, it is best to consistently use the same ports for input and output for all measurement series.

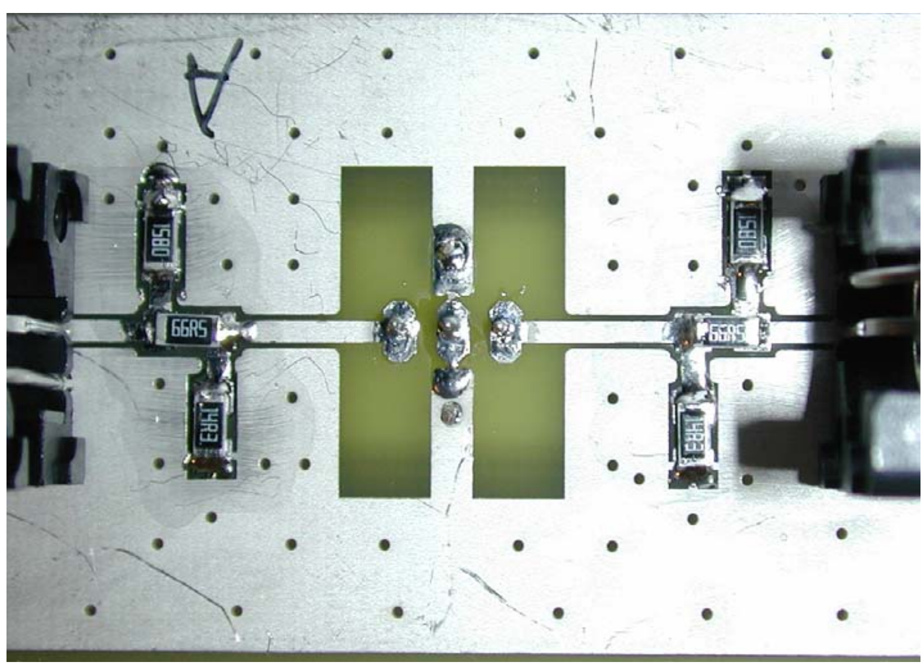




Assembly


Crystal Under Test
J3
66R5
R2
J1
R1
158R
R3
14R3
R4
14R3
66R5
R5
R6
158R
J2

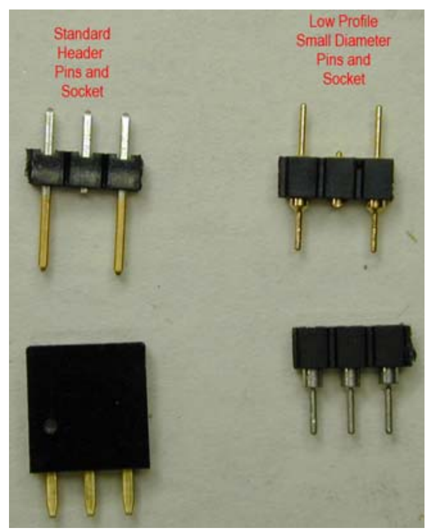

J1
R1
R2
J3
R3
R5
R6
R4
J2



The builder is assumed to be sufficiently skilled not to require Heathkit style instructions.

Content of Kit		
Quantity	**Description**	**Marking if Any**
1	Printed circuit board	V 1.2
2	BNC connectors, PCB mounting style	
2	158 Ohm Resistor, 1% 1206 size	158R
2	66.5 Ohm Resistor, 1% 1206 size	66R5
2	14.3 Ohm Resistor, 1% 1206 size	14R3
1	49.9 Ohm Resistor, 1% 1206 size	49R9
1	3-pin socket for standard 0.025" rectangular header	
1 strip	Strip of 6 0.025" square header pins. User should cut into two 3-pin pieces	
1	3-pin socket for 0.015" diameter round pins. This socket is the low profile version	
1 strip	Strip of 6 0.015" diameter round header pins. User should cut into two 3-pin pieces.	

Socket/header options



The kit is supplied with two socket/header options. One is the standard header with square pins. The other has smaller diameter round pins.

If you intend to use the fixture only for crystal measurements, you will likely wish to use the small diameter socket and header. HC-49 crystal leads will fit snugly into the small diameter socket, but most other components, such as resistors and capacitors, will have lead diameters too large to fit.

The standard header socket will work with HC-49 crystal leads, but the connection will not be nearly as solid as with the smaller socket. ¼ watt resistor leads and many small capacitor leads will fit the standard socket, which extends the usefulness of the fixture.

Recommend order of assembly:

1. Install the six pad resistors.
2. Install the two BNC connectors

3. Install the crystal socket
4. Build the shorting plug
5. Build the calibration resistor assembly

A couple of points deserve amplification. The photographs identify the side that the crystal socket it mounted on. It is the opposite side from the pad resistors and the BNC connectors.

It is not necessary to install a shield across the crystal socket, although the builder is welcome to do so.

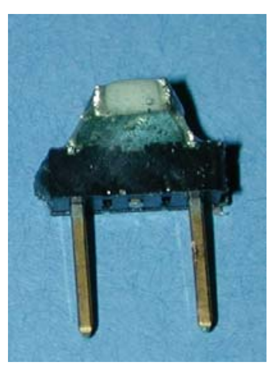
Make the shorting bar from one of the 3-pin headers. Remove the center pin. If you build the kit with the standard header, it is possible to pull the center header pin out by grasping it firmly with small pliers and pulling. The small round header has an internal barrel and is captive within the plastic header. Cut the center pin on both the upper and lower sides.

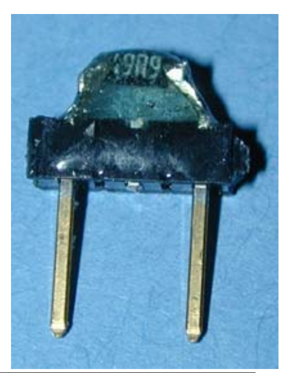
If you have not already done so, cut the appropriate 6 pin header strip into two three pin sections and remove the center pins.

Carefully bend the solder side of the pins to touch, or as come as close to touching as possible, as illustrated at the right. Note that the small diameter header has a turret on the plug side with the component side being of uniform diameter, as may be seen in the photo to the right. Solder the two pins together, using solder to bridge any gap between the two pins.

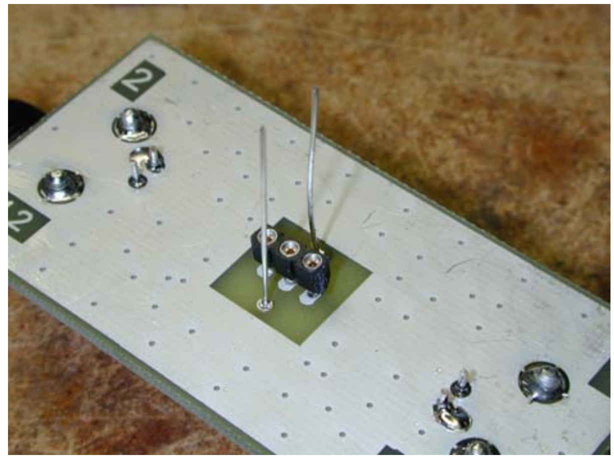
When working with the headers, the pins will sometime work loose if overheated, so you may find it helpful to hold the free ends with a heatsink clip, or a bit of wet tissue paper may be placed on them. Alternatively, you may be able to bend the solder-side of the pins until nearly touching and bridge the gap with solder. The header assemblies are fragile and I prefer to use the foil for mechanical reasons.

To make the calibration check module, remove the center pin from one of the 3-pin header strips and carefully bend the solder side of the pins together until the 49.9 ohm 1% resistor will fit. Solder the resistor in place as illustrated in the photos.





The result will be fragile; the resistor's ceramic substrate is easily broken. I use a small bit of 5-minute epoxy to encapsulate the resistor and mount to reduce the risk of breakage.



In making crystal parameter measurements, it's generally good practice to ground the crystal case. I've added pads to solder two ground wires to that may be used to ground the crystal holder.

Install two solid wires, approximately 1 inch (25 mm) extending above the PCB surface as illustrated.

In use, the ground wires may be held against the crystal case with a clip. I use a wooden spring clothespin as illustrated at the right. I'm sure there's a more elegant way of accomplishing this task.

Checkout

After assembly, with the crystal socket open, the resistance from either BNC center pin to ground should be 53.46 ohms ±1.5 ohms. Readings significantly departing from this value should be investigated, with the most likely fault being inadvertently shorting the one of the resistor pads to ground.

Typical Performance

If assembled in accordance with the instructions, your fixture should have performance characteristics similar to those illustrated below.

This section may also be used as an advanced performance verification test of the fixture.

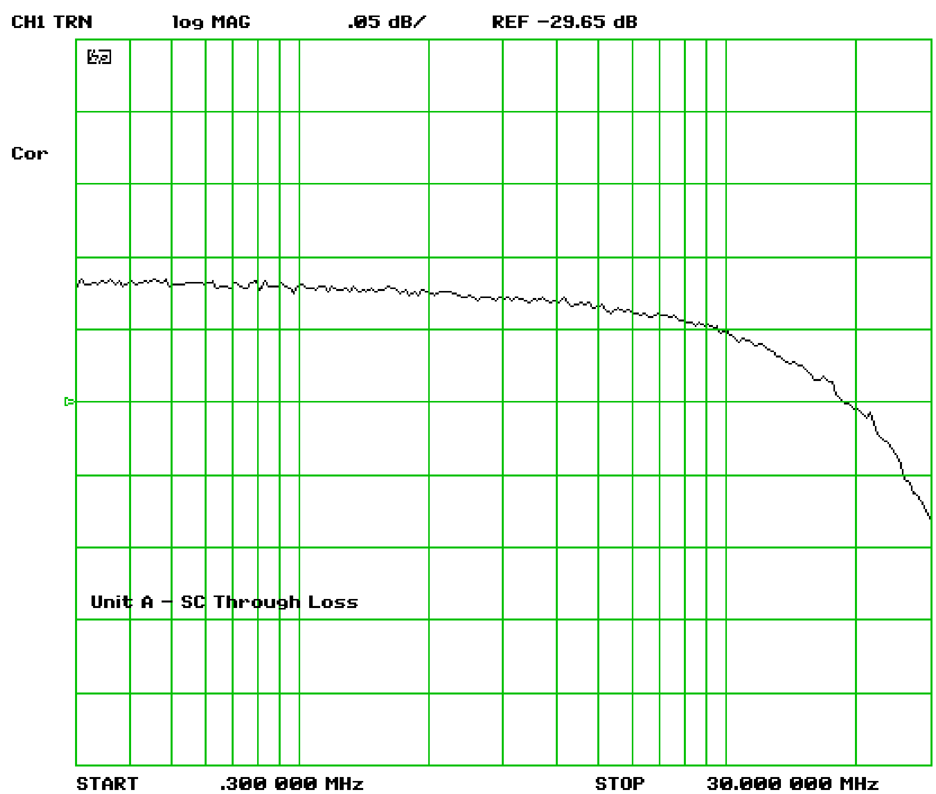
Note that some measurements are at the -120 dB level and small variations in assembly can cause departures from the sample readings. These are likely to be inconsequential when the fixture is used for its normal purposes.

The data presented is taken with an HP 8752B vector network analyzer, sweep 300 KHz – 30 MHz, log horizontal axis.

Pad Loss and Socket Stray Capacitance

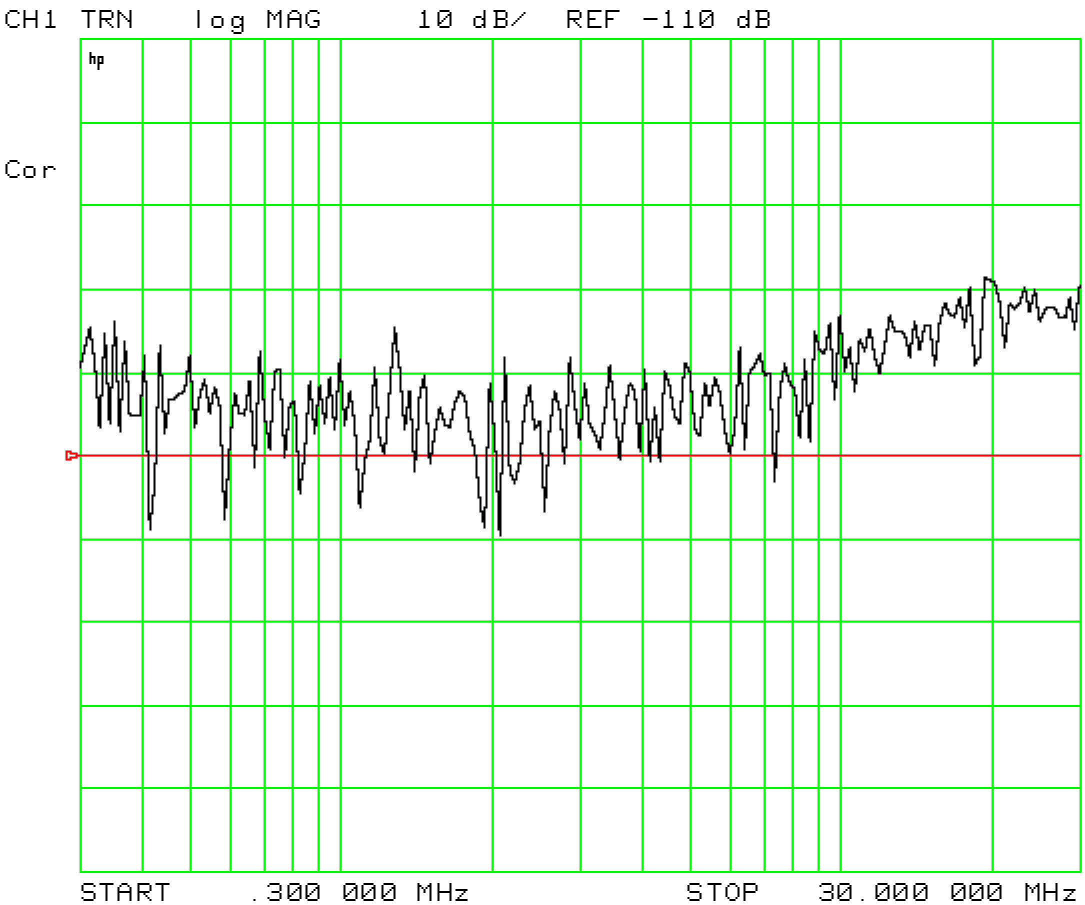
With the VNA calibrated for a through measurement, with a BNC-BNC FF as the 0 dB reference point, install the shorting bar in the socket.

The result should be similar to the plot below. The theoretical attenuation of the fixture in this configuration is 29.5 dB. Component tolerance and other variations will result is slight departure from the theoretical value.



With the same test setup, remove the shorting bar. This measures the pad loss and the stray capacitance between the crystal socket pins.

With my 8752B, the fixture measures as below the instrument's dynamic range until about 10 MHz, where some decreased loss due to stray capacitance across the socket can be seen. At 30 MHz, the attenuation is approximately 92 dB, or 62 dB above the shorting bar case. (Additional significant figures are not justified given the noise in the data.)



Since the impedance of the stray capacitance is high compared with the driving and terminating impedance, we can neglect vectors and use a simplified technique to determine the capacitance.

$$|Z| \approx 2R\left(10^{\frac{\alpha}{20}} - 1\right)$$

Where R is the driving and terminating impedance (assumed equal; hence the factor of 2), 12.5 ohms in this case.
α is the attenuation in dB over the shorting bar case, 62 dB here.

Plugging in measured values, we determine that |Z| is 31.45 Kohms.

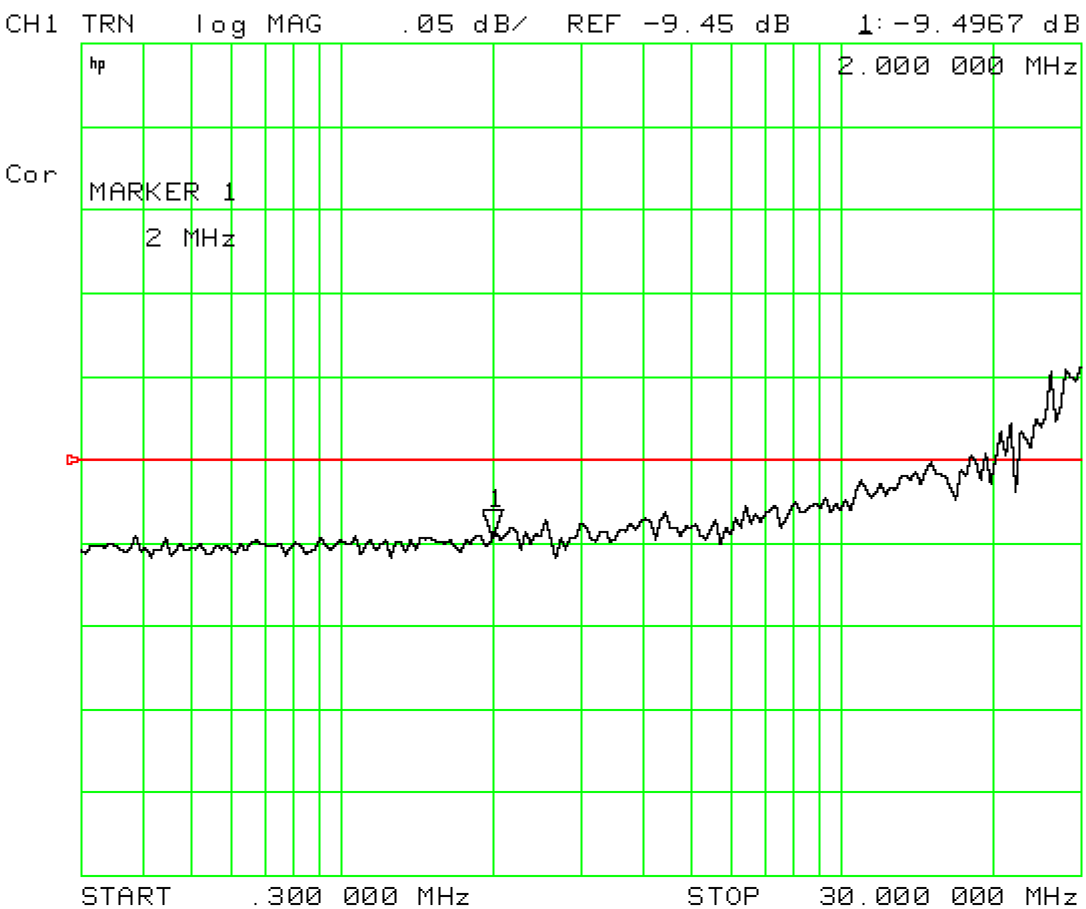
Since |Z| is, for all practical purposes, purely capacitive reactance, and since $X_C = \frac{1}{\omega C}$ where ω = 2πf, and our measurement frequency is 30 MHz, we calculate C = 0.17 pF.

This is more of an estimate than a hard number, given the noise in the measurement.

Measurement of 49.9 Ohm Test Resistor

Calibrate the VNA using the test fixture and shorting bar as the "through" or 0 dB case.

Remove the shorting bar and insert the 49.9 ohm test resistor. The result should be similar to that shown below.



Using the same formula presented for the open socket case, using the measured attenuation of 9.4967 dB at 2 MHz, we calculate the resistance of the 49.9 ohm test resistor as 49.63 ohms. A measurement at 1 KHz with a General Radio 1658 precision RLC bridge shows 49.77 ohms.

Actual Source and Load Resistance

The earlier calculations assumed the impedance presented to the crystal socket (source and load both) was 12.5 ohms, the nominal design value.

The actual impedance, assuming all resistors are perfect, is 12.578 ohms. If you wish to measure your assembled unit, place a high quality 50 ohm termination on one port and, with a 4-wire digital ohmmeter, measure the resistance from the corresponding crystal socket to ground. Move the 50 ohm load to the other side and repeat for the other crystal socket.

If you wish to measure the impedance using your VNA to get a frequency specific value, you can build a two-pin shorting assembly and measure the reflected value of either end.

Or, you can use the through loss and calculate the resistance as outlined before and assume the loss is equally divided between the two fixture ports.

Revision Notes

15 Feb 2009. Corrected text reference at page 10 to read: "attenuation of 9.4967 dB at 2 MHz."