Austin QRP Club
Vector Impedance Analyzer
Operations Manual

By

Milt Cram (W8NUE)

&

Kees Talen (K5BCQ)

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Introduction:

Welcome and thank you for your interest in the **Vector Impedance Analyzer** (**VIA**). We sincerely hope that it has been an enjoyable and enlightening learning experience to build this kit. It's understood this is not a kit for the novice or intermediate kit builder. However, with research on Surface Mount Technology (SMT), a good set of tools, and with some practice, this tool will turn out to be an important tool for any electronic enthusiast. It's a very high quality tool with great flexibility in how it's completed to the builder's expectations. When this kit is finished, it will contain more functional capabilities than products costing much more which have less functionality. Plus, the Kit contains the capability of uploading new Firmware to stay up with new features and capabilities. Please understand this is a state of art technology tool using the latest in SMT devices. With parts that may not be the easiest to assemble by hand. However, the design of the **VIA** board layout has taken this into account. The part placement and solder joints have been spaced apart and extended slightly to help in the hand soldering of components. It's highly recommend that research is done on SMT soldering techniques before attempting the **VIA** assembly. Also having the right tools will make a big difference in the assembly; like magnification devices, good lighting, board holding devices, quality Soldering Iron with the capability to use very small tips, etc.

Check out all the other documentation on the web. Just enter **K5BCQ** in the search engine, then click on "**K5BCQ & K5JHF Kits - QSL.net**", and scroll down to Kit #25 and follow all the other documentation to help in assembling this quality **Vector Impedance Analyzer**.

Thank you again, and we hope you find many many uses for what we believe to be one of the finest tools with even greater possibilities in the future.

History:

This project was a collaborative development adventure of Milt Cram (W8NUE) and Kees Talen (K5BCQ). They decided to develop a project utilizing some very good products like the STM32F407-Discovery board which contains plenty of microcontroller capability and features with available "free" Development Tools and at a price being right for this type of project.

Milt drew on his SDR2GO firmware experience and code he used for the NUE-PSK Digital Modem, and also the more recent STM32-SDR code. He decided to base the design on audio baseband I/Q signals and process those for the required data. This is done by using TWO synchronously tuned RF signals F0 and F0+2 KHz.... one for the device under test and the other for the dual I/Q mixers. This has the unique advantage of being able to readily process negative complex numbers correctly, which is a problem with many of the mid-range commercial antenna analyzers in the market today.

After looking at several possibilities, including the little NOKIA touchscreen, it was decided to go for something far more usable and user friendly. Here we have it; The **AQRP Vector Impedance Analyzer kit #25**.

It's a standalone, battery powered, Vector Impedance Analyzer for portable operation. It can be used to check antennas, filter designs, etc., which we will go into later in the manual. This design will evolve over time as changes and improvements are made to function and visual presentation. The STM board firmware is easily updated by using STM-LINK software (free) and a USB cable. So future firmware updates will be easy to do.

DESIGN FEATURES:

- **Measures V (voltage) & I (Current)**
- **Calculates Z (Impedance....in complex numbers), Y (Admittance....in complex numbers), k (Reflection Coefficient), RL (Return Loss), VSWR (Voltage Standing Wave Ratio)**
- **Plots Z, Y, k, RL, VSWR, and Smith Chart (Reflection Coefficient Plot). Z and Y are complex number plots.**
- **Vertical line cursor on all linear plots, showing the frequency of the cursor**
- **The default HF mode Frequency Range of the data/plots is from 1 to 150 MHz .....an alternative LF mode Frequency Range is from 8KHz to 1MHZ....yes, 8KHz**
- **Auto Scan and Manual Scan modes**
- **Adjustable Start & Stop Frequencies, Frequency Step, and Dwell Time (in mS to allow the line to settle out)**
- **All parameters are saved on command for the next use**
- **Stores 500 data points with associated parameters for later PC Processing (TBD)**
- **Powered by six AA batteries and a 5V Switcher Power Supply. You may use another power source (LIPO) if you want and feed the 5V switcher with that. The DC-DC switcher will accept an input of up to 36V DC.**
- **Uses a TFT_320QVT display which is 320x240 pixels, color, and has a resistive touchscreen for parameter selection. These are readily available on eBay.**
- **Capable of Firmware download using USB cable from a computer.**
- **Capability of moving stored data from the VIA to a computer for further processing.**

Theory of Operation:

The **VIA** consists of an RF generator, a bridge circuit, and a vector voltmeter. The RF generator is two generators that produce two RF signals that differ in frequency by 2 kHz, regardless of the frequency of the first generator. A Si5351 chip from Silicon Labs is used for this dual generator. The bridge circuit produces two output voltages, one is proportional to the voltage applied to the load impedance and an additional resistor, and the other is proportional to the current flowing through the load impedance. The resistor in series with the load, limits the current in the load if it's a short circuit. Consequently, the ratio of the amplitudes of the two voltages, and the phase difference between them provide enough information to accurately determine the load impedance (plus the added series resistance).

From the calculated load impedance [**Impedance**], the complex reflection coefficient [**ReflCoeff**] and other parameters of interest may be determined. However, the "raw" measurements must be corrected for inaccuracies in the values used in the computations. This is accomplished in the calibration procedure.

Since the bridge produces two voltages with some phase difference between them, experience in using IQ signal processing to make the computations has been applied to the design. In particular, each of the voltage outputs is split into In-phase and Quadrature (IQ) components. This is done after each signal is mixed with a local oscillator (the RF signal that is offset by 2 KHz from the RF excitation of the bridge). The two audio signals thus generated, are then digitized with a 16 bit A/D converter and sent to the STM32 microcontroller. Each signal is filtered with a 2 KHz band pass filter. The filtered signals (now completely digital) are each mixed with complex mixers to produce the I and Q components of each of the two channels. Conventional DSP techniques are used to further filter the four signals that now exist and to calculate the ratio of the amplitudes of the two IQ pairs and the phase difference between them. At this point there is raw (uncalibrated) data. The ratio and phase signals are now corrected to provide calibrated data. The digital conversion of the two channels of 2 KHz analog signals and subsequent processing is what is referred to as a "Vector Impedance Analyzer".

All in all, this is a rather conventional approach to impedance measurement, but it has been chosen to capitalize on the design experience with microcontrollers and Software Defined Radio (SDR) to implement measurement, computation, plotting, and display into a compact portable unit for field use—all at a very reasonable cost.

Let's Get Started:

BEFORE POWER ON **---there are a few things that should be done before applying power to the VIA.**

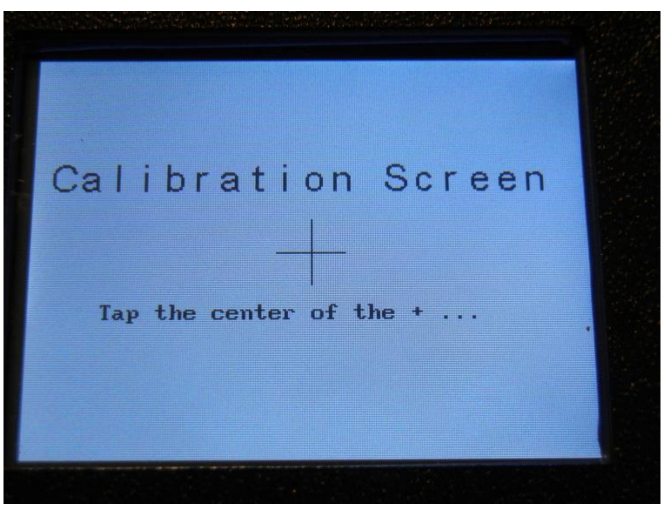
1) **Make sure that the switching power supply is set for 5VDC.**
2) **Before connecting the switching supply to the VIA, use the ohmmeter to check the resistance from the 5V line on the VIA to a convenient ground connection on the VIA board. This resistance check should be at least 100 ohms.**
3) **Make sure the two pin connector that supplies power to the VIA is oriented correctly. Mark one side of the board and connector, to insure proper orientation when connected.**

These checks are to minimize the risk of "**releasing the magic smoke**" when the **VIA** is first powered on.

After the items above have been verified and the unit has been assembled, turn on the power. The "**Splash Screen**" should come up within two to three seconds after the power has been applied. It will display the date and time of the latest version firmware. See below.

Screen Calibration:

When the unit is turned on for the first time, the unit will immediately go from the "**Splash**" screen to the "**Calibration**" screen. See below. Follow the instructions on the screen, and when instructed, tap the screen three times in quick succession, to save the touch screen calibration.



Now turn the power off and back on. Like mentioned before, the "**Splash**" screen should show up after about two to three seconds, and after the "**Splash**" screen is displayed for a few seconds, the **VIA Setup** screen should be displayed. All is good! YEA! ☺

Okay, here's where the fun starts and where the rubber meets the road! ☺ But it depends on the mannerism of the person who spent all this time building the **VIA** and if the unit doesn't startup as stated.

If the unit takes longer than two to three seconds to display the "**Splash**" screen, there is something wrong in the assembly of the **VIA** board. It usually means that the components are not talking to each other and there's either a bad component or solder joint issue. Please remove the VIA and check the solder joints. You may just find one that looked like it was well soldered but did not make a good connection.

If the unit has no display at all see the "**No display when power is applied**" in the **Trouble Shooting** section of this manual.

After visually checking **ALL** the parts and touching up **ALL** the solder joints, re-assemble the unit and apply power. The sequence as mentioned earlier should occur. If not, then there is still something else to discover. See the "**Splash Screen turn on timing issue**" in the **Trouble Shooting section** of this manual for further assistance**.**

If the Screen Calibration was not made because of initial issues and the unit is now working, it's easy to go back and do the **Calibration Screen**. Just push down both **Control** knobs at the same time until they click and turn on the power. Hold the **Controls** down until the **Calibration Screen** is visible. Then release the **Controls**. At this time go through the screen calibration, and when instructed, tap the screen three times in quick succession to save the touch screen calibration. If all parts are communicating, the three tap screens should change quickly. Then the screen will revert to the **VIA Setup** screen.

Frequency Setup:

Okay, now that the screens are doing what they should, let's go setup the frequencies.

Prior to setting the "**Cal**" function, it is necessary to enter some values into the different field on the **VIA Setup** screen.

On the left side of the **VIA Setup** screen there are four buttons which will be programmed now for a 40 meter test example later. These are used to set the **VIA** parameters for measurements, and which to some may seem intuitive, however we'll explain their usage anyway.

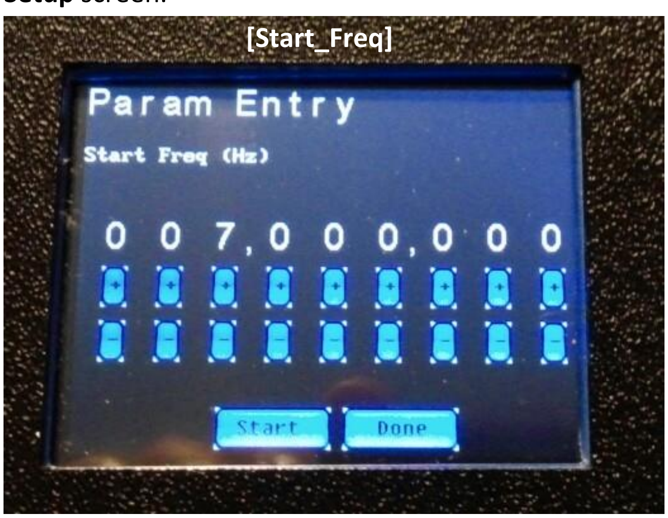
[Start_Freq] button is used to set the **Starting Frequency** of what is to be tested.
[Stop_Freq] button is used to set the **Stop Frequency** of what is to be tested.
[Freq_step] button is used to set the **Frequency Steps** at which the chart will be drawn.
[Dwell_Time] button is used to set the speed at which the chart is to be drawn.

Screen buttons may be activated by tapping the buttons with the **index finger**, or by using a **retracted** ball point pen as the pointing device to activate the button.

For the 40 meter test example, tap the [**START_FREQ]** button. In the next screen, set the frequency to 7 MHz on the display. Tapping the "**Start**" button for the first time will display a frequency of "001,000,000". The display contains a "**Plus**" and "M**inus**" button under each number. Just tap the "**Plus**" button to increase the number or tap the "**Minus**" button to decrease the number.

So let's set the start frequency to **007,000,000**, than tap the "**Done**" button. This will set the start frequency for the test and take the screen back to the **VIA Setup** screen.

Next, tap the [**Stop_Freq]** button and set it to "**007,300,000**" and tap the "**Done**" button to go back to the **VIA Setup** screen.



Next, tap the [**Freq_Step]** button to set the steps to "**000,001,000**", and tap the "**Done**" button.

Now tap the [**Dwell_Time]** button to set the Dwell timing to "**000,000,010**", than tap the "**Done**" button. If you wish, you may tap the "**Store**" button on the **VIA Setup** screen to save this information so the next time the tool is turned on these parameters will be set automatically.

"**VIA Cal**" **setup:**

For this setup, a 50 Ohm resistor and a zero Ohm resistor are required. Solder one side of the 50 Ohm resistor to the center pin of a BNC connector and the other to the ground or shield side of the connector. This will work for the "**50 ohm" load**, and a shorted BNC connector will work for the **"0 Ohm load"**.

Now, tap the "**Cal**" button on the **VIA Setup** screen and the screen should change to show the "**VIA Cal**" screen. See below.

This screen view is an example of the V1.03 Firmware.

Please note the instruction on the top of the screen.

1 – Connect the "**50 Ohm load**" to the antenna connection at the top of the unit. Now tap the "**Cal 50**" button. A value should be displayed to the left of the "**< 1.05**" figure on the screen. If the Screen shows "**nan**" please refer to the "**"nan" in the "Cal" setting"** in the **trouble shooting** section of this manual. If the screen shows "**inf**", please check "**"INF" in the "Cal" setting**" in the **trouble shooting** section.

2 – The display at the top of the screen will change and ask to "**Connect 0 Ohm Load**". Remove the 50 Ohm load and install the shorted BNC connector. Tap the "**Cal 0**" button and another number should show up to the left of the "**< .62**" on the screen. Again notice the instruction at the top of the screen asking to remove the "**0 Ohm Load**" after the number has been displayed.

3 – After removing the load, tap the "**C0-Comp**" button, and a capacitance value should show up below the other values.

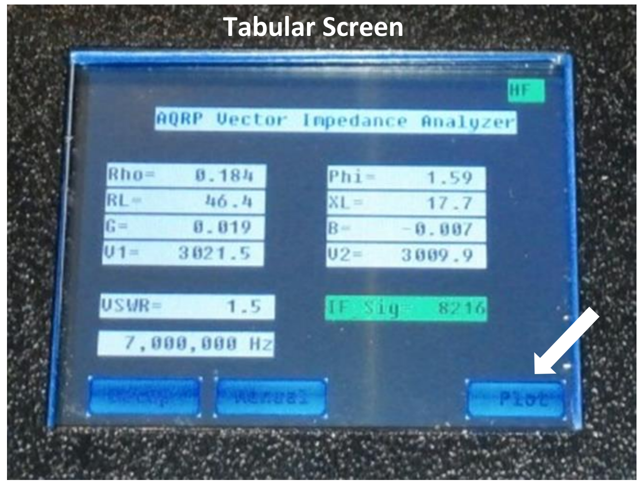
Values should be something like what is shown on the view to the right.

4 – Tap the "**Done**" button and the data will be automatically saved. The top of the screen will indicate the function of the data being saved, and the screen will revert back to the **VIA Setup** screen.

Using the VIA to make measurements:

VSWR Measurement using the Auto Plot mode:

To create the chart of the 40 meter antenna example, tap the "**Auto**" button in the **VIA Setup** screen and it will change to the "**Tabular**" screen showing some figures in each of the different fields, like the ones shown below.



Please note, there should be numbers showing up in all the fields in the "**Tabular**" screen, and especially in "**V1**", "**V2**", and "**IF_Sig**" fields. Oh and yes, there must be a load connected to the **VIA** for it to read correctly. Please connect the antenna to the **VIA**. ☺ If the fields do not show any varying numbers, please refer to the ""**Tabular**" **Screen Issues"** in the **Trouble Shooting** section for more help.

If everything is reading sort of like in the example on the right above, and the fields are White and Green, tap the "**Plot**" button. This will move to a screen to select which test is to be made on the device connected to the **VIA**.

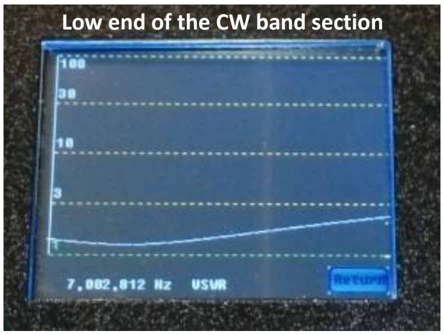
If some of the fields are shown in the color **RED**, there is likely some parameter which has not been set. Please check the above procedure again and check "**Typical values for V1, V2 and IF_Sig"** in the "**Other Functions**" section of the manual.

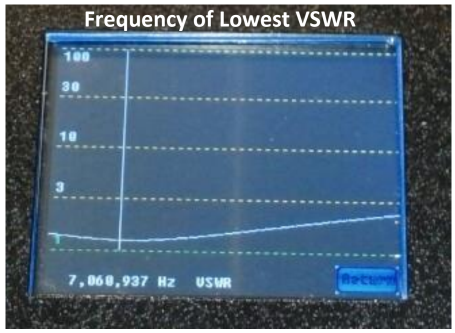
Test performed by the VIA:

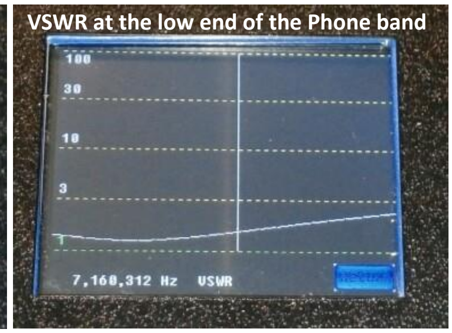
[SmithChart] = **Smith Chart**
[Impedance] = **Impedance**
[Admittance] = **Admittance**
[ReturnLoss] = **Return Loss**
[ReflCoeff] = **Reflection coefficient**
[VSWR] = **Voltage Standing Wave Ratio**

The **VSWR** test for the 40 meter antenna is the next step. So tap the "**VSWR**" button and watch the show as the chart is drawn on the screen as we speak.

If the antenna's in range, it should look something like the views below. The antenna in the views below is set to the CW end of the Band and at the low end of the phone band as indicated by the line using the "**Cursor Control**". The location of the defined function knobs may vary based on the individuals positioning of the controls. The "**Cursor Control**" is used to move the vertical line on the screen to identify the frequency at the lowest indication on the curve, or lowest VSWR in this example.







VSWR Measurement using the Manual Plot Mode:

In the **VIA Setup** screen there is also a "**Manual**" button. When this button is selected, it requires the use of the "**Manual Control**" knob to plot the chart manually instead of automatically.

The processes are the same as the "**AUTO**" mode, but this time tap the "**Manual**" button from the **VIA Setup** screen, than tap the "**Plot**" button, and tap the "**VSWR**" button. After the screen changes to the "**Chart**" screen, rotate the "**Manual Control**" knob in a clock wise direction to plot the curve. Continue turning the knob until the frequency displayed stops changing. This should equal or be very close to the **[Stop_Freq]** setting (7,300,000 Hz). This completes the **Manual** creation of the plot for the device under test.

To avoid cluttering the display during plots, the Frequency cursor is parked just off the left edge of the display, and as in the **AUTO** mode, rotating the "**Cursor Control**" will move the vertical line across the screen displaying the frequency.

By the way, if **both Control** knobs do not increase their function to the right on the screen when turned in the clock wise direction; please see "**Control Reverse wiring Function**" in the **Trouble Shooting** sections of this manual.

To return to the **VIA Setup** screen, tap the "**Return**" button from the **Chart** screen, then tap the "**Setup**" button from the **Tabular** screen. This completes the VSWR test of a 40 meter dipole.

The same process is used to test any other antenna by setting the Start and Stop Frequencies and connecting the antenna to the **VIA** and running the test. Multiple band antennas may also be tested by just entering the lowest frequency for the start frequency and the highest frequency of the highest band for the stop frequency.

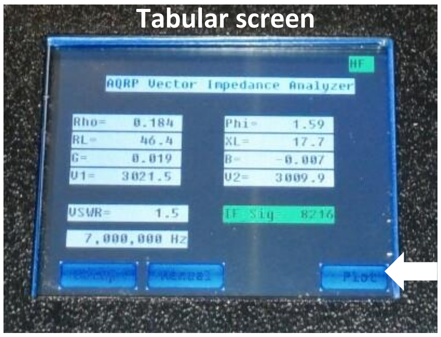
How to do Tests:

With the start and Stop Frequency parameters set, different tests may be made with the **VIA** by just selecting the type of test. ([SmithChart], [Impedance], [Adimittance], [ReturnLoss], [ReflCoeff], and [VSWR]).

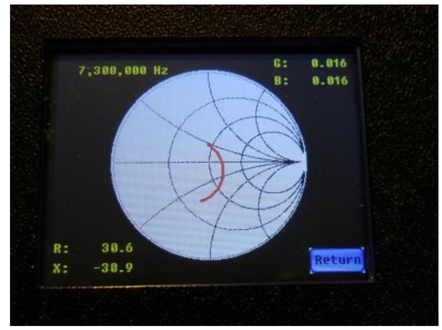
[**SmithChart**]:

Creating a Smith Chart of an antenna may be accomplished by simply **1** - tapping the "**Return**" button from the previous **chart** screen. **2** - Tap the "**Plot**" button from the **Tabular** screen. The next screen will display which test to select. **3** - Just tap the [**SmithChart**] button and watch the magic. That's if it's still in the Auto Plot mode. ☺

Each type of chart may be created by these same steps, just select the type of profile as the last step.

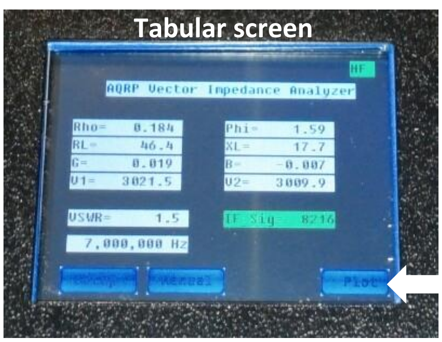


Tabular screen

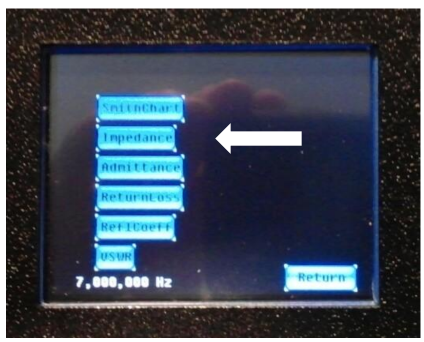


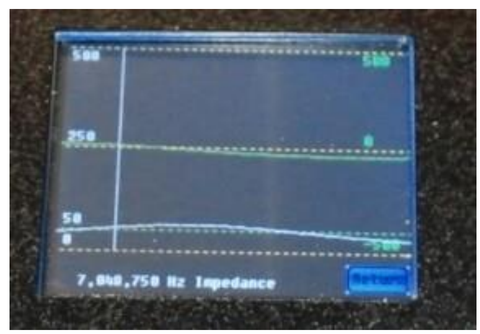
[Impedance]:

To create an Impedance profile select **[Impedance]** as the last step.

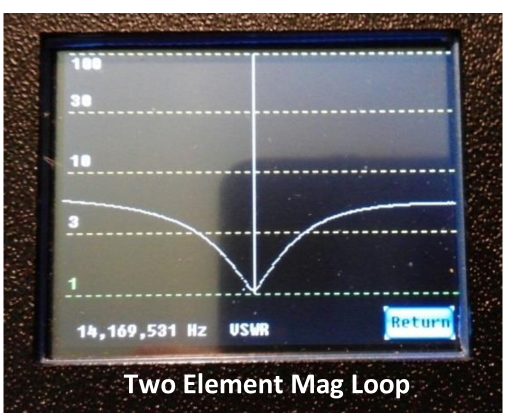


Tabular screen





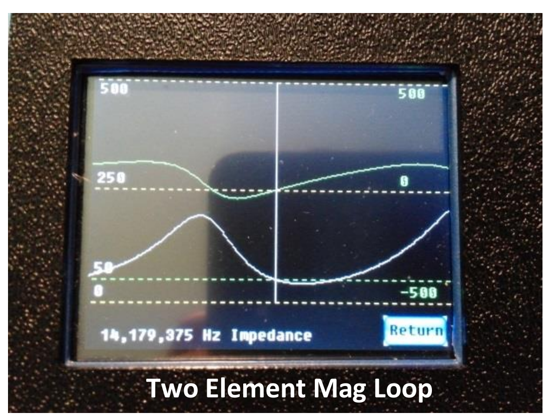
Please note when conducting an Impedance test there are two lines and scales, the White line corresponds to the scale on the left side of the screen which is for the **Resistive Part of the Load Impedance**, and the Green line corresponds to the scale on the right side and is for the **Reactive part of the load impedance**. Use the "**Cursor Control**" to find where the white line intersects the 50 Ohm line on the left scale, and the Green line intersects the Zero line on the right scale. This will result in the optimum frequency of the device being tested which should also approximately correspond to the lowest VSWR frequency measurement. However, this may not always be true, e.g. if the **VIA** is being used to check a very narrow band antenna such as a high Q magnetic loop.



Two Element Mag Loop

Left example is a "**VSWR**" graph. Note the sharp tuning.

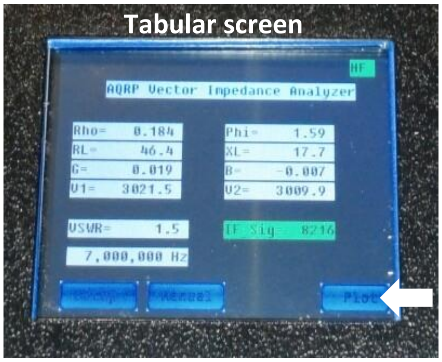
Right example is an "**Impedance**" graph. Note where the two plot lines cross their "**0**" line.

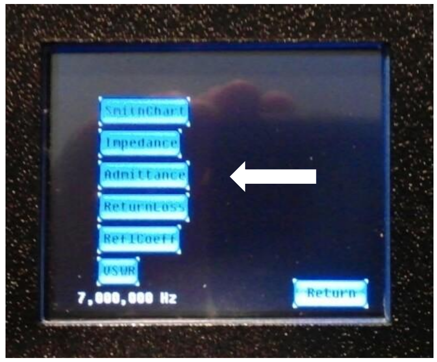


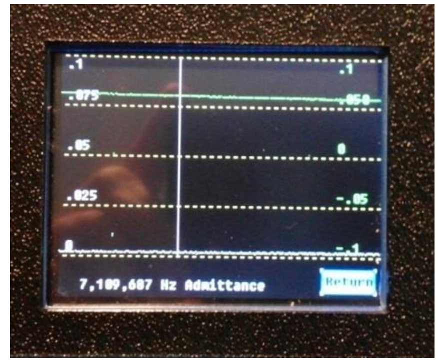
Two Element Mag Loop

[Admittance]:

To create an Admittance profile select **[Admittance]** as the last step.



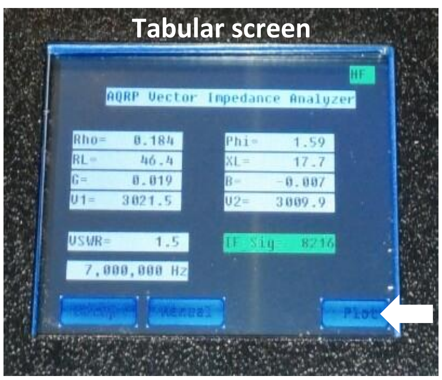




Again we have two scales to compare, however in this case no matter at what frequency the "**Cursor Control**" is at really doesn't matter, because both the White and Green line are pretty flat. See the definition for Admittance for more details on this graph.

[ReturnLoss]

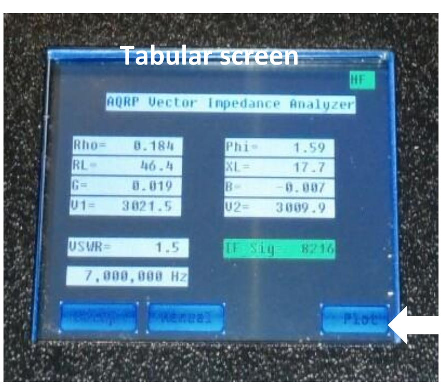
To create a Return Loss profile select **[ReturnLoss]** as the last step.



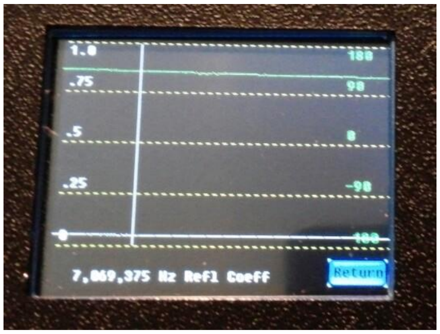
In this test there is only one scale, and rotating the "**Cursor Control**" to the lowest location on the graph will identify the frequency of the lowest reading on the plot. Again this should be close to the lowest VSWR measurement frequency. See the definition for **Return Loss** for more details on this graph.

[ReflCoeff] Coax Testing

To create a Reflection Coefficient profile select **[ReflCoeff]** as the last step.



50 Ohm Terminated 25 Ft RG-8X



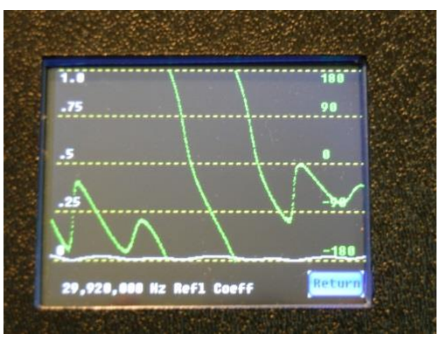
Open ended 25 Ft RG-8X

Shored end of a 25 Ft of RG-8X

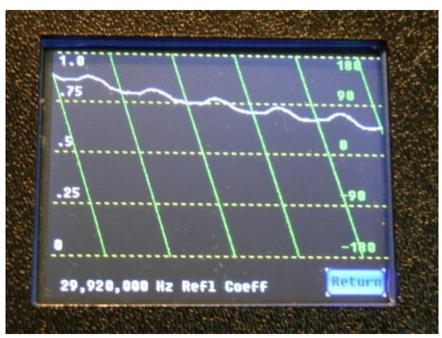
This is the test to check the condition of a length of coax with the end of the coax terminated with 50 Ohms, Open Ended coax, and with a short at the end of the coax. For more details on the explanation of the **Reflection Coefficient**, please see the **Technical Definition** section. Also the photos used in this example were made with a relatively narrow frequency range. Generally, coax testing is done over a wide range of frequencies where the length may be one or more quarter wavelengths and the plots will show much greater variation.

Another example:
Below are graphs of a piece of RG-8A coax, 66 feet long and made for a 40 meter ¼ wave length feed line to feed a 40 meter coaxial antenna. The coax was rolled up into a about a 15 inch diameter loop when the measurement was taken.

Note: the waveforms for an **Open Output** and **Shorted Output** should be the same when measured directly at the VIA coax connector.



¼ Wave on 40 W/50 Ohm load



¼ Wave on 40 Open Ended

¼ Wave on 40 W/Shorted End

Other Functions:

Encoder Knob functions:

Anytime the unit is turned on without **Encoder** action, the default **HF** frequency will be set.

HF Frequency = 1 MHz to 150 MHz
LF Frequency = 8 KHz to 1 MHz

When the **Cursor Control** knob (top knob) is pushed down to engage the switch while applying power, the unit will set the frequency range from 8 KHZ to 1 MHZ. When applying this function, the **Control** must be held down until the **VIA Setup** screen is visible.

When the **Manuel Control** knob is pushed down to engage the switch while applying power, the unit will reset the Start and Stop Frequencies to their initial default values of 1MHZ and 30MHz respectively. Remember to hold the **Control** down until the **VIA Setup** screen is visible.

Typical values for V1, V2 and IF_Sig:

The following table shows values that are typical when the ***start frequency** is set for **3 MHz*** and with various loads: This is good information to better understand the readings in the "**Plot**" screen prior to creating a chart.

Load	V1	V2	IF_Sig
OPEN	3900	60	16000
50 Ohm	3200	3200	9200
0 Ohm	2800	4700	7000

Component variations may change these values, but their relative magnitudes should be consistent for the various load conditions. Note particularly that **V1** will be much larger than **V2** with an open load. V1 and V2 will be nearly equal with a 50 ohm load. With a 0 Ohm load (SHORT), **V2** will be larger than **V1**. In addition, IF-Sig will be largest with an open circuit load and will drop as the load resistance approaches 0 ohms.

Section 3: Technical Definitions:

[SmithChart]

The **Smith chart**, invented by Phillip H. Smith (1905–1987),[1][2] is a graphical aid or nomogram designed for electrical and electronics engineers specializing in radio frequency (RF) engineering to assist in solving problems with transmission lines and matching circuits.[3] Use of the Smith chart utility has grown steadily over the years and it is still widely used today, not only as a problem solving aid, but as a graphical demonstrator of how many RF parameters behave at one or more frequencies, an alternative to using tabular information. The Smith chart can be used to simultaneously display multiple parameters including impedances, admittances, reflection coefficients, S_{nn} scattering parameters, noise figure circles, constant gain contours and regions for unconditional stability, including mechanical vibrations analysis.[4][5] The Smith chart is most frequently used at or within the unity radius region. However, the remainder is still mathematically relevant, being used, for example, in oscillator design and stability analysis.

[Impedance]

Impedance is the complex-valued generalization of resistance. It may refer to:

- Acoustic impedance, a constant related to the propagation of sound waves in an acoustic medium
- Electrical impedance, the ratio of the voltage phasor to the electric current phasor, a measure of the opposition to time-varying electric current in an electric circuit
  - Characteristic impedance of a transmission line
  - Impedance (accelerator physics), a characterization of the self interaction of a charged particle beam
  - Nominal impedance, approximate designed impedance
- Mechanical impedance, a measure of opposition to motion of a structure subjected to a force
- Wave impedance, a constant related to electromagnetic wave propagation in a medium
  - Impedance of free space, a universal constant and the simplest case of a wave impedance

[Admittance]

In electrical engineering, **admittance** is a measure of how easily a circuit or device will allow a current to flow. It is defined as the inverse of impedance. The SI unit of admittance is the Siemens (symbol S). Oliver Heaviside coined the term *admittance* in December 1887.[1]

Admittance is defined as

$$Y \equiv \frac{1}{Z}$$

where

Y is the admittance, measured in siemens

Z is the impedance, measured in ohms

The synonymous unit mho, and the symbol ℧ (an upside-down uppercase omega Ω), are also in common use.

Resistance is a measure of the opposition of a circuit to the flow of a steady current, while impedance takes into account not only the resistance but also dynamic effects (known as reactance). Likewise, admittance is not only a measure of the ease with which a steady current can flow, but also the dynamic effects of the material's susceptance to polarization:

$$Y = G + jB$$

where

- Y is the admittance, measured in Siemens.
- G is the conductance, measured in Siemens.
- B is the susceptance, measured in Siemens.

- $j^2 = -1$

[ReturnLoss]

In telecommunications, **return loss** is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in decibels (dB);

$$RL(\mathrm{dB}) = 10\log_{10}\frac{P_\mathrm{i}}{P_\mathrm{r}}$$

where RL(dB) is the return loss in dB, P_i is the incident power and P_r is the reflected power.

Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss.

Return loss is used in modern practice in preference to SWR because it has better resolution for small values of reflected wave

Electrical:

In metallic conductor systems, reflections of a signal traveling down a conductor can occur at a discontinuity or impedance mismatch. The ratio of the amplitude of the reflected wave V_r to the amplitude of the incident wave V_i is known as the reflection coefficient Γ.

$$\mathit{\Gamma} = \frac{V_\mathrm{r}}{V_\mathrm{i}}$$

When the source and load impedances are known values, the reflection coefficient is given by

$$\mathit{\Gamma} = \frac{Z_\mathrm{L} - Z_\mathrm{S}}{Z_\mathrm{L} + Z_\mathrm{S}}$$

where Z_S is the impedance toward the source and Z_L is the impedance toward the load.

Return loss is the negative of the magnitude of the reflection coefficient in dBs'. Since power is proportional to the square of the voltage, return loss is given by,

$$RL(\mathrm{dB}) = -20\log_{10}|\mathit{\Gamma}|$$

where the vertical bars indicate magnitude. Thus, a large positive return loss indicates the reflected power is small relative to the incident power, which indicates good impedance match from source to load.

When the actual transmitted (incident) power and the reflected power are known (i.e., through measurements and/or calculations), then the return loss in dB can be calculated as the difference between the incident power P_i (in dBm) and the reflected power P_r (in dBm),

$$RL(\mathrm{dB}) = P_\mathrm{i}(\mathrm{dBm}) - P_\mathrm{r}(\mathrm{dBm})$$

[ReflCoeff] - Reflection Coefficient

In physics and electrical engineering the **reflection coefficient** is a parameter that describes how much of an electromagnetic wave is reflected by an impedance discontinuity in the transmission medium. It is equal to the ratio of the amplitude of the reflected wave to the incident wave, with each expressed as phasors. For example, it is used in optics to calculate the amount of light that is reflected from a surface with a different index of refraction, such as a glass surface, or in an electrical transmission line to calculate how much of the electromagnetic wave is reflected by an impedance. The reflection coefficient is closely related to the *transmission coefficient*. The reflectance of a system is also sometimes called a "reflection coefficient".

A wave experiences partial transmittance and partial reflectance when the medium through which it travels suddenly changes. The reflection coefficient determines the ratio of the reflected wave amplitude to the incident wave amplitude.

A signal travelling along an electrical transmission line will be partly, or wholly, reflected back in the opposite direction when the travelling signal encounters a discontinuity in the characteristic impedance of the line, or if the far end of the line is not terminated in its characteristic impedance. This can happen, for instance, if two lengths of dissimilar transmission lines are joined together.

Reflections cause several undesirable effects, including modifying frequency responses, causing overload power in transmitters and overvoltage's on power lines. However, the reflection phenomenon can also be made use of in such devices as stubs and impedance transformers. The special cases of open circuit and short circuit lines are of particular relevance to stubs.
Reflections cause standing waves to be set up on the line. Conversely, standing waves are an indication that reflections are present. There is a relationship between the measures of reflection coefficient and standing wave ratio.

In discussing transmission lines the **source** value is replaced with Z0, the characteristic impedance of the transmission line. Consequently,

Gamma = (ZL-Z0)/(ZL+Z0)

Note that Gamma approaches -1 when ZL goes to zero. In addition, Gamma approaches +1 when ZL becomes very large.

[VSWR]

VSWR (*Voltage Standing Wave Ratio*), is a measure of how efficiently radio-frequency power is transmitted from a power source, through a transmission line, into a load (for example, from a power amplifier through a transmission line, to an antenna).

In an ideal system, 100% of the energy is transmitted. This requires an exact match between the source impedance, the characteristic impedance of the transmission line and all its connectors, and the load's impedance. The signal's AC voltage will be the same from end to end since it runs through without interference.

In real systems, mismatched impedances cause some of the power to be reflected back toward the source (like an echo). Reflections cause destructive interference, leading to peaks and valleys in the voltage at various times and distances along the line.

VSWR measures these voltage variances. It is the ratio of the highest voltage anywhere along the transmission line to the lowest. Since the voltage doesn't vary in an ideal system, its VSWR is 1.0 (or, as commonly expressed, 1:1). When reflections occur, the voltages vary and VSWR is higher -- 1.2 (or 1.2:1), for instance

Section 4: Trouble Shooting

Before starting on trouble shooting, please be aware that it has been proven time and time again that 95%+ of the problems are due to solder problems, opens, shorts, and miss registration of parts.

Splash Screen turn on timing issue:

If the Splash screen takes about 20 seconds to show up, there is an issue in the **VIA** board that says the parts are not talking to each other. The correct function of the tool is for the Splash screen to come up within two to three seconds after power is applied.

So, what do we do? Take the **VIA** board out of assembly and closely check every SMT part for a good solder joint. It may be worthwhile to re-solder every contact of all the parts to their respective pads and make sure all devices are installed properly. Double check pin 1 orientation. This can be checked by also using a DVM in the lowest Ohm setting and touching one lead to the pad and the other lead to the part that is to be soldered to that pad. I know it sound crazy, but………… However this type of test will not work on the parts with their leads on the bottom of the part, like U4, X1, and U1. If a connection is made between each pad and its respective component side, then reassemble the unit and turn it on. Pay close attention to the time it takes for the Splash Screen to start up. If the Splash Screen comes up within two to three seconds, that means all the parts are talking to each other and that's goodness. We can stop trouble shooting and start using the unit.

However, ☹ if the Splash Screen is still taking ~ 20 seconds or so, there is something else wrong.

Again remove the **VIA** and this time check for signals on the **VIA**. This will require the use of a Scope to detect the signals. Or even a radio that has the capability of tuning to 12MHz.

To start, let's see if we have a 12 MHz signal present on the **VIA**.

1 – 12 MHz Oscillator U4 Check:

Solder one end of an 8 inch piece of 30 gauge wire to the side of R7 that goes to pin 1 of U1 (TLV320AIC3204).

Put the **VIA** back together and turn on the power.

If a radio is to be used to detect the 12 MHz signal; set the radio to 12 MHz and set the unit close to the radio. If the oscillator is working, its signal will be heard in the speaker. Make sure you have the volume up.

If you don't have a radio and have a scope, turn on the scope and connect the probes ground lead to the chassis and the probe to wire coming off of R7, and adjust the scope to find the 12 MHz signal.

If the signal is present on the radio or displayed in the Scope, this section of the circuit is working properly.

If there is no signal present at this point remove the VIA from the assembly and double check the solder joints again. Retouch all solder joints on U4 and make sure there are no shorts between pads.

Put the VIA back together and turn it on. Try it again and if still no signal, a new part may be required.

Repeat all the steps above after installing the new Oscillator U4 (DSC1001).

After the part has been replaced and the 12 MHZ signal is present, but the screen still takes a long time to come up. We now have to check other areas on the board.

If the screens come up quickly, Jump up and down and have fun using the tool.

2 – Fo and Fo+2KHz Signal from U6 Check:

Now that the 12 MHz Oscillator is working, let's check U6 for its **Fo** and **Fo+2KHz** signal. Using the same small 8 inch wire:

1 – Solder one end of the wire to the side of R6 that connects to R5. (**Fo+ 2KHz** signal).
2 – Add another 8 inch wire and solder it to the side of R3 that connects to R2. (**Fo** signal)
3 – Add another 8 inch wire to the side of C1 where it attaches to L1.
4 – Mark the end of each wire for their respective test points.

Put the VIA back together and turn it on.

Using a DVM put the Negative lead to chassis ground, and the Plus lead on the wire from C1. The meter should read a steady level 3.3 Volts. Using a Scope, connect the ground side of the probe to chassis ground and touch the probe end to the wire coming from R6. Adjust the scope to detect the signal. Once the signal is detected connect the probe to the wire coming from R3. There should be very little change to adjust the signal. If both of these signals are detected, U6 is working. We can move on to the next test in the sequence.

If there is 3.3 Volts on C1 and if there is no signal on R6 and R3, remove the **VIA**, double and triple check the solder joints of U6 (Si5351) and actually apply heat to each lead to allow the solder to reflow. This one is tricky because of the small lead spacing and will be the second hardest parts to install and solder properly.

Put the **VIA** back together, turn it on, and recheck for voltage and signals. If no signal, remove the part and replace it with a new one.

Repeat all the steps above after installing the new U6 (Si5351).

If the screens come up quickly, Jump up and down and have fun using the tool.

3 – Signal processing through U2 and U3

Now that we have signals emanating from U6, we need to check the signal coming from U6 to U2 and U3. There is a **Resistive attenuator/leveling network** circuits between the output of U6 and input of U2 and U3 that needs to be checked.

Checking U2 functionality:

However, we'll take a giant step and go right to the inputs of U2 and U1 first. This will tell us if we have an issue somewhere in the leveling circuit of U2 and if U2 is having issues.

Remove the wires connected to U6 and connect as follows:

1 - Solder a wire to the side of C16 that goes to Pin 16 of U1.
2 - Solder a wire to the side of C21 that goes to Pin 1 of U2.
3 - Solder a wire to the side of C23 that goes to Pin 2 of U2.
4 – Solder another 8 inch length of small wire to the side of C19 that goes to Pin 6 of U2.
5 – Solder another 8 inch length of small wire to the side of C26 that goes to Pin 8 of U2.
6 – Don't forget to mark the wires so you know who is who.

The accomplishment of this test is to find out if there is a signal going from U6 to the inputs of U2 and from the output of U2 to U1. It also checks if there is power getting to U2.

Reassemble the unit and apply power. Before checking for signals, connect a DVM between chassis ground and the wire coming from C26. This wire should read ~5.0 Volts. If it does remove the DVM and connect the scope probe to the small wire connected to C21 and adjust the scope for a signal. If a signal is detected move the scope probe to the small wire connected to C23. If a signal is detected move the scope probe to the wire from C19 and adjust the scope to detect a signal. Than move the scope probe to the lead connected to C16. If a signal is detected on C21, C23, and C19, it means the attenuator/leveling circuit is working. However, if there is no signals C21 or C23 or C19 that means there is a bad solder joint in one or more of the attenuator /leveling components. Remove the **VIA** and re-solder C19, C21, R11, R14, and C23, and make sure there is a connection between C23 and Pin 2, and C21 and Pin 1 of U2. This can be checked by using a DVM.

Reassemble the unit and apply power, and repeat the measurements as stated previously. If a signal is detected on C21, C23, and C19, it means the filter circuit is now working. However, if there is no signal on C16, it means U2 may still have issues.

Remove the **VIA** and double check the solder joints on all the pins of U2, and especially on Pin 4 of U2. Re-solder both sides of C15 to make sure it is making a good connection.

Before the unit is reassembled check that there is a short between Pin 4 of U2, and one side of C16. Just checking for a broken trace between the two points before the unit is reassembled. Again use the DVM to ensure the signal path between the parts is good. This check is making sure there is a path for the signal to get from U2 to pin 16 of U1.

Put the **VIA** back together and turn it on.

Now check for signals at all test leads. If there is a signal at C19, C21, and C23, but still no signal at C16, and all the solder joints are okay on U2, this means U2 is bad and needs to be replaced.

After replacing U2, and reattaching the five test leads, put the **VIA** back together and turn it on.

Pay close attention to the screen timing. If the screen comes up quickly then you're finished trouble shooting, and can now start enjoying the use of this great tool.

Remove the five test leads and enjoy. ☺

However, ☹ if the screen still comes up slowly, check for a signal at C19, C21, C23, and C16. If all four leads show a signal than U2 is working.

Remove all the test leads.

Checking U3 functionality:
Repeat the same test on U3 and its associated components.

1 – Solder one test lead to the side of C20 that goes to pin 6 of U3.
2 – Solder another lead to the side of C24 that goes to pin 1 of U3.
3 – Solder another lead to the side of C22 that goes to pin 2 of U3.
4 – Solder the forth test leads to the side of C15 that goes to pin 15 of U1.
5 – Solder another 8 inch length of small wire to the side of C25 that goes to Pin 8 of U3.
6 - Don't forget to mark the wires so you know who is who.

Before the unit is reassembled check the solder joints on all the pins on U3, and especially on Pin 4 of U3. You should now have 5 wires coming out of the unit for testing. Check that there is a short between U3 Pin 4 and one side of C15. Again checking for a broken trace between the two points before the unit is reassembled.

Put the **VIA** back together and turn it on.

Before checking for signals, connect a DVM between chassis ground and the wire coming from C25. This wire should read ~5.0 Volts. If it does remove the DVM and check for signals at the other test leads. If there is a signal at C20, C22, and C24, but no signal at C15, and all the solder joints are okay on U3, this means the attenuator/leveling circuit is good to U3. However if there is no signals on either of C20, C22, or C24, that means there is a bad solder joint in one or more of the attenuator/leveling components.

Remove the **VIA** and re-solder C20, C22, R12, R15, and C24, and make sure there is a connection between C24 and Pin 1of U3, and C22 and Pin 2 of U3. Again this can be checked using a DVM.

Reassemble the unit and apply power, and repeat the measurements as stated previously. If a signal is detected on C20, C22, and C24, it means the attenuator circuit is now working. However, if there is no signal on C15, it means U3 may still have issues.

Remove the **VIA** and double check the solder joints on all the pins of U3, and especially on Pin 4 of U3. Re-solder C16 just to make sure it has a good connection.

Before the unit is reassembled check that there is a short between Pin 4 on U3, and one side of C15. Again just checking for a broken trace between the two points before the unit is reassembled. Again use the DVM to ensure the signal path between the parts is good.

Put the **VIA** back together and turn it on.

Now check for signals at all test leads. If there is a signal at C20, C22, and C24, but still no signal at C15, and all the solder joints are okay on U3, this means U3 is bad and needs to be replaced.

After replacing U3, and reattaching the five test leads, put the **VIA** back together and turn it on.

Pay close attention to the screen timing. If the screen comes up quickly then you’re finished trouble shooting, and can now start enjoying the use of this great tool.

Remove the four test leads and enjoy. ☺

However ☹ if the screen still comes up slowly, check for a signal at C20, C22, C24, and C15. If all four leads show a signal than U3 is working.

Remove the test leads.

3 – Signal process through the Codec (U1)

Prior to removing the **VIA** to check components, power up the **VIA** and move to the **Tabular** screen (tap the **Auto** or **Manual** button on the **VIA Setup** screen) and check the values in **V1**, **V2**, and **IF-Sig** fields. If there are values in these fields the codec is most likely working, if not follow the process below.

Remove the VIA and recheck all the solder joints to U1 which is the hardest part to solder, and most likely the one that is not soldered properly, and will be the major problem and the hardest to fix. So closely inspect all the solder joints to this part and make sure there is a good solder joint on all the pins and verify pin 1 placement on the board.

Check and re-solder R7, R8, R9, R10, C6, C7, C8, C9, C10, C11, C12, C17, and C18.

Verify the solder connections at pins 4 and 5 of the U1. These are the very important I2C control lines.

Verify pin 4 of U6 (CODEC SCL) is connected to pin 6 of U5, and to the end of R9 that's connected to pin 9 of U1.

Verify pin 5 of U6 (CODEC SDA) is connected to pin 5 of U5, and to the end of R10 that's connected to pin 10 of U1.

Verify there is a good connection between the other side of R9 and R10 to Pin 6 of U1.

Reassemble the boards and while turning on the power, watch the screen. If everything above was verified the screen should update quickly. Remove the leads and you are ready to go.

No display when power is applied:

A short on the 3.3 Volt line in the **VIA** will cause the screen to not display.

3.3 Volt check:

The 3.3 Volt is supplied from the **Discovery** board and needs to be checked for a **steady level voltage**. This can be accomplished by attaching the ground lead from a DVM to the chassis and checking the voltage on pin 5 & 6 on P2 on the **Discovery** board, or by using a scope to see the 3.3V line for fluctuations. Look for the Voltage markings on the **Discovery** board.

Any fluctuation of the voltage means there is a short somewhere on the **VIA** board. This will require a thorough check of the **VIA** board and its 3.3V line connections.

Turn off the power, remove the power connection from the **VIA** board and remove the **Discovery** and **VIA** boards from the stack, and don't forget to unsolder the leads to the BNC connector.

While checking components, it's advisable to use high magnification and good lighting to inspect between leads for shorts!

Areas to check:

U6:	**U5:**	**U1:**
Pins 7 to pin 8	Pins 7 to pin 8	Pins 6 to pin 7
Across C1	across C4	across C6
		Pins 26 to pin 28
		across C9 and C10

Do a detailed visual inspection of all the areas mentioned above, and re-solder any suspicious area.
Use an ohmmeter on the lowest resistance setting to check the points mentioned above.

If the reading indicates a short, re-solder the leads or component to remove the excess solder and inspect the part very closely.

Re-solder ALL the pins of U1 and again check for a short on the 3.3V line, by connecting the negative lead of the ohmmeter to ground and touching the positive lead to Pin 5 & 6 of J2 on the **VIA** board.

If a short is still indicated, there is most likely a glob of solder under U1 creating the problem. Remove U1 and remove the excess solder to any pins of U1. Re-install U1 and re-check for the short test on the pins of J2.

If no short is indicated, re-install the boards to the stack, connect the power connector the **VIA** board and apply power to the unit. Re-check the 3.3V line on P2 for any variations. Also check to see if the **Splash** and

Calibration screens came up. If screens are now working, continue with the instructions on page 6, and go through the initial setup. Don't forget to reconnect the wires to the BNC connector.

However, if nothing happened, it might just be U1 got fried and needs to be replaced.

After replacing U1 re-check for the short test on the pins of J2 for a short in the 3.3V line. If good re-assemble and have fun.

Start, Stop, Step, Dwell not being saved:

When trying to enter new parameters, tapping **START**, results in strange values on the display. This can be because this is the first time the EEPROM (U5) has been used and has no previously stored data.

This could also be due to problems communicating with the EEPROM (U5). Check the solder connections to all of the pins on U5 and C4.

If the **Discovery** board has not been updated with firmware V1.03, maybe updating the **Discovery** board with the latest firmware may help because it takes care of pre-loading information into the EEPROM (U5) when power is applied to the system. See **Firmware Updates** on page 26.

"nan" in the "Cal" setting:

This situation is not too bad. It just means that before the "**Cal**" adjustment is made, a set of frequencies need to be entered into the unit. So start the unit and when it goes to the **VIA Setup** screen go and add a start and stop frequency. See **Frequency Setup** on page 8 for setting the parameters.

This is a situation which may occur with older firmware version 1.02 and below. This has been corrected in version 1.03 and above, which preprograms a set of parameters into the tool on the initial startup.

"inf" in the "Cal" setting:

"inf" indicates that the **VIA** is not able to read the **Load**, and there's something wrong in the resistor network. Using an ohmmeter, check the resistance from the center pin of the BNC connector to ground. The meter should read 107 ohms plus or minus the meter calibration and resistor values in the circuit. If the reading is close to this value, the resistors values are correct and solder joints are good. The problem may be in the Load resistor or solder joint at the BNC. Or resistors may need to be checked for their value and proper solder joints. Please check the schematic for detail values. Here are some hints for different resistance readings:

Measurement	Component
Inf =	R14 and/or R16 open
115 ohms =	R1 and/or R2 open
146 ohms =	R3 open
123 ohms =	R12 and/or R13 open

"Tabular" Screen issues:

This is a situation where the Parameters have not been programmed into the Start and Stop Frequencies. See "**Frequency Setup**" on page 8 for setting the parameters. If the system is not up to V1.03 firmware see the "**Firmware Updates**" section. This update pre-programs information in the EEPROM so the first time a "P**lot**" screen is brought up, the data is read from the EEPROM to help set up the different fields.

If there's still an issue with the correct readings for **V1**, **V2**, and **IF_Sig**, then try the following:

Very low readings for V1, V2, and IF_Sig

This is usually due to a low, or no, signal being passed to the codec (U1). The problem may be due to a non-functioning U6, or a problem in the signal path from the U6 to the codec U1. Chances are there is a solder problem. In addition, if the connections are all good, there could be a problem with the setup of the U6 due to a failure to set the start and stop frequencies.

The following paragraphs describe how to check signals through the PCB to the U1 codec.

If an oscilloscope is available, check for a square wave signal at the junction of R1 and R2. Also check for a square wave signal at the junction of R4 and R5. These are the two outputs of the U6. Each should have an amplitude level of about 1.5 volts peak-peak (pk-pk). If either signal is not present, check the connections to U6 again, as well as the connections to C2 and C3. If both outputs are missing, make sure that crystal X1 is properly soldered.

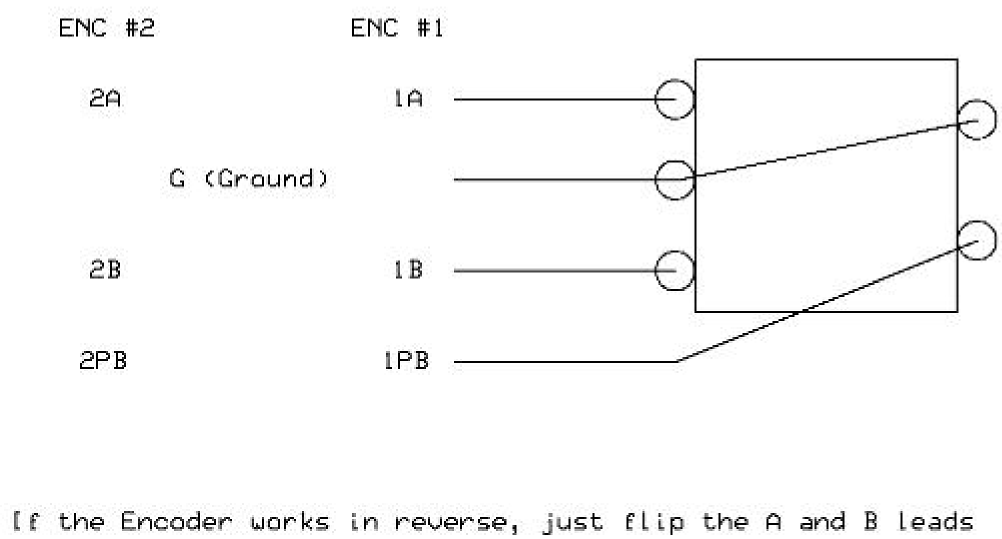
If these checks are OK, check the outputs of the two attenuators. The signal at the junction of R2 and R3 should be about 300 millivolts pk-pk. The signal at the junction of R5 and R6 should be about 100 millivolts pk-pk. Check the solder connections again if either signal is missing. (If the levels are incorrect, check the resistor values R1 to R6).

Now check the signals at the junction of R11, R12, R14, and R15. This should be the same as at the junction of R2 and R3. Next check the signal at the junction of C19 and C20. This signal should be the same as the junction of R5 and R6. The same signal should be present at pin 6 of each of the SA612s (U2 and U3). This completes verification of the "local oscillator" going into the mixers and the excitation to the bridge.
Finally check continuity from pin 4 of U2 to the end of C16 that is opposite the end that is connected to pin 16 of U1. Also check continuity from pin 4 of U3 to the end of C15 that is opposite the end that is connected to pin 15 of U1.

If all else check OK, make sure that U4 is properly soldered. If the available oscilloscope is capable of displaying a 25 MHz signal, check for this signal at both ends of R7.

At this point, assuming that there are no damaged components, V1, V2 and IF-Sig should be close to the values shown in the note below.

Encoder Reverse wiring Function:



Section 5: Firmware updates

STM32 Utility link:
Download the STSW-LINK004 STM32 ST-LINK utility. Click on the link, or enter this link into the search a computer search program: http://www.st.com/web/en/catalog/tools/PF258168

After clicking on the link a web page will open for the **STSW-LINK004 SSTM32 ST-LINK utility**. Scroll down the page to where it show the **Download** button. 

Click on the **Download** button and follow the installation instructions.

Once the file is installed it will put a short cut Icon on the Desk Top. Click on the Icon to open the file (**STM32 ST-link Utility)**. This sets up the utility to update the latest firmware on the **VIA**.

Connect a USB cable to the VIA and then connect the other end of the cable to the computer. The unit will be powered and turn on from the connection in the computer.

VIA Firmware Updates:
Next get the latest Firmware upgrade and copy it to a folder. Go to http://www.qsl.net/k5bcq/Kits/Kits.html site and scroll down the kit page until the section called:

PROGRAMMING/RE-PROGRAMMING
Download the desired AQRP VIA HEX file.

Right click on the latest Firmware and click on "**Save Target as….**", from the dropdown window. The computer will ask what to do with the file. Select a folder or create a new **VIA Firmware folder** and save the file into that folder. When the computer comes up with the window at the bottom of the screen, click on "**Open folder**".

Go back to the **STM32 ST-Link Utility** and click on "**File**". From the dropdown window click on "**Open File…**". From the next window find where the firmware was saved, select that folder, click on the latest firmware file to highlight it, and click on the "**Open**" button at the bottom of the screen. This will open the file and set it ready to down load to the unit.

On the Utility program Tool Bar, click on "**Target**". From the dropdown window, click on "**Program & Verify…**" This will open a window to down load the firmware to the **VIA**. Click on the "**OK**" button and watch the process window. It will take about 20 second to down load and verify. After the program is loaded see the information in the bottom of the window which defines what has been completed.

Close the Utility program and disconnect the VIA from the USB cable. Turn on the **VIA** and notice in the Splash Screen for the new firmware update.

That's it, now go and enjoy this great tool with its new firmware functionality.