# The 4 States QRP Group
# HF Test Set Construction Manual


## Containing several key pieces of simple Test Equipment that are used to either test or troubleshoot radio circuitry

**By Wayne McFee, NB6M**
**Revision 0.2**
**October 21, 2007**

# The HF Test Set

## Introduction

Thank you for buying the HF Test Set.  This project combines several key pieces of test equipment onto one PC Board, providing an easy way to test and troubleshoot radio circuitry.

As part of a talk and demonstration of troubleshooting procedures at Salmoncon, 2006, the first annual group QRP radio outing of the PNW (Pacific NorthWest) QRP Group, the following items were used in actually troubleshooting a faulty transceiver.

A Frequency Counter

An RF Probe

A 50 Ohm Dummy Load

A Crystal Controlled Oscillator

An Audio Oscillator

Clip leads, a digital multi-meter, and DC blocking capacitors of appropriate values for passing either RF or Audio were used, as appropriate, in taking voltage readings or injecting signals into the transceiver.

During a group discussion after that event, much interest was expressed in building the individual pieces of test equipment, and it became obvious that if they were all combined onto one PC Board, as a test set with several functions, this project would be useful to many radio amateurs.  Thus, the HF Test Set was born.

This kit, when completed, contains the following individual pieces of test equipment:

Frequency Counter

Crystal Oscillator

Wideband Noise Generator

Audio Oscillator

50 Ohm Dummy Load

RF Probe

Time Domain Reflectometer

As designed, the LCD display mounts right on the board, two-pin SIP Headers and Jumpers are used to apply power to the individual test equipment circuits, and one header is used to connect the RF Probe directly to the Dummy Load when desired, making it easy to determine output levels of transmitters and other 50 Ohm output amplifiers.

However, ribbon cable or other wiring can be used between the board and display, so that it can be mounted into the front of a case. The two-pin headers and the Test Point Loops would then be left off. SPST switches could be wired to the board so as to turn on the various functions.

These would be mounted on the case front, along with BNC connectors that would be wired, with coax where appropriate, to the various inputs and outputs of the individual circuits.

In other words, the finished look of the HF Test Set is up to the individual builder.

The Frequency counter uses the familiar PIC 16F84 circuit, and employs the .hex code developed by Francesco, IK3OIL. Thank you, Francesco, for permission to use your work in this project.

The Crystal Oscillator is a version of the oscillator shown on page 3.19 of EMRFD[i], which can be used for testing crystals, determining crystal parameters for use in filter design, matching crystals for use in filters, or as an RF source for testing and troubleshooting receiver and transmitter circuitry.

The Wideband Noise Generator puts out a signal that covers the HF and lower VHF spectrum, from about 1 MHz all the way up through at least the 6 Meter band. It is used as an RF source for testing receiver circuitry, or can be used, along with a Spectrum Analyzer, for determining the passband characteristics of filters.

The Audio Oscillator is used as a signal source for testing earphones or audio amplifiers. It is equipped with a volume control, so that the output can be adjusted to the appropriate level for the circuit being tested.

The Dummy Load is a proper 50 Ohm, resistive load, using ten, paralleled, 510 Ohm, two Watt resistors, and is capable of handling at least 20 Watts of power.

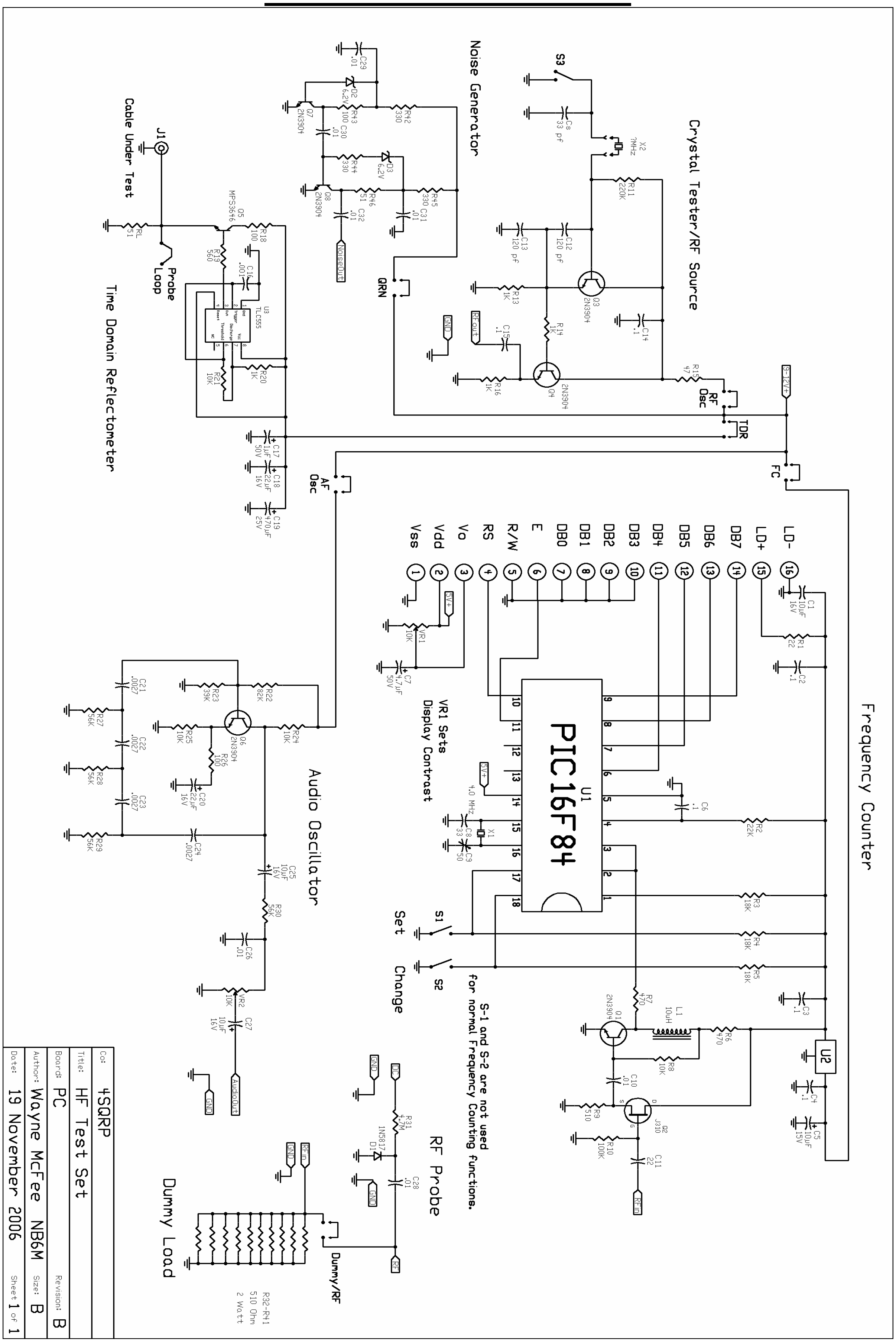
The RF Probe, used with a Digital Multimeter that has either a 10 or 11 Megohm input impedance, provides a readout in RF Volts, RMS.

The Time Domain Reflectometer is used with an Oscilloscope to test Coax Cable runs for opens, shorts, or impedance bumps that might be caused by crimps in the cable.

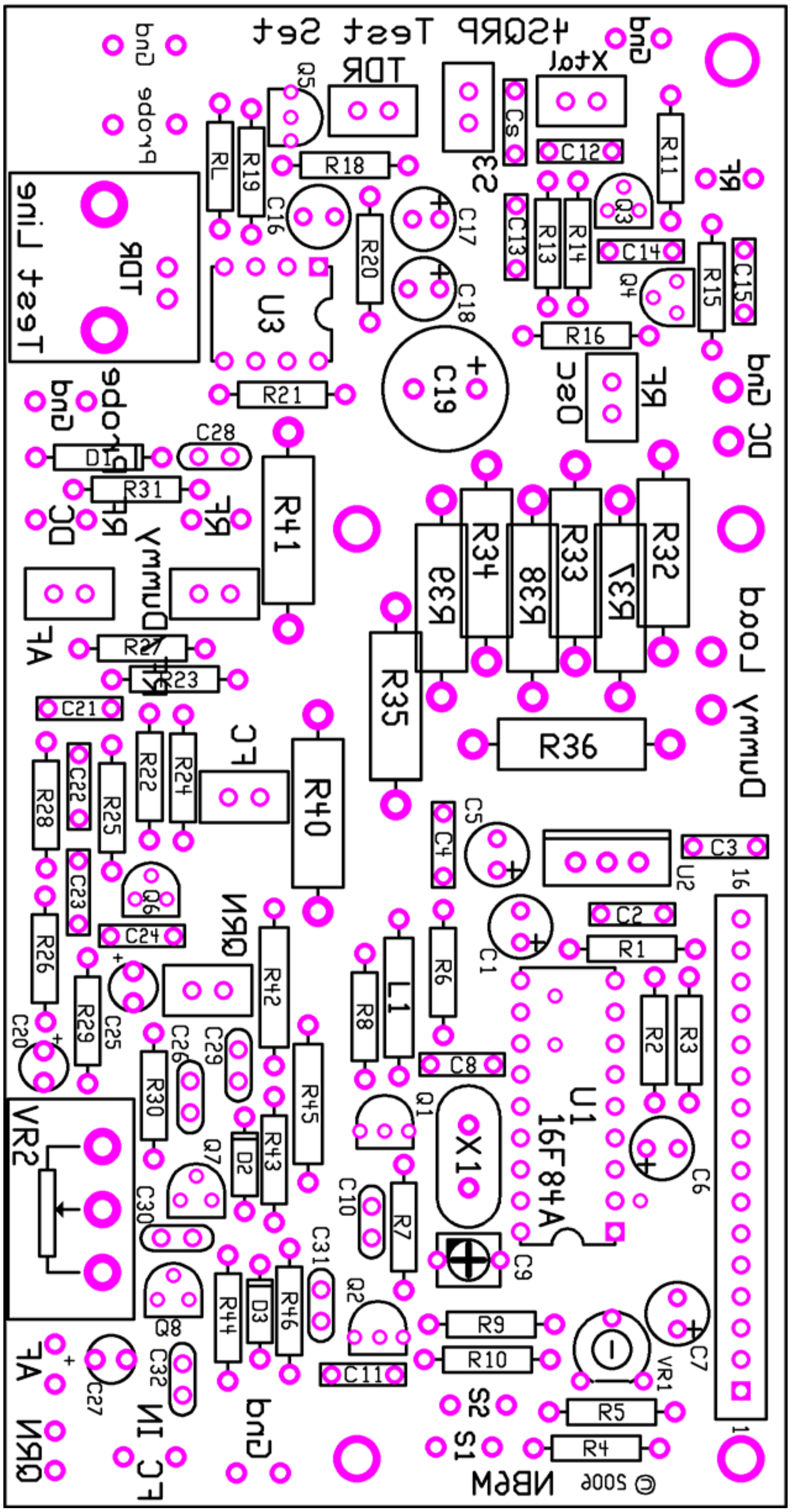
With the use of these individual pieces of test gear, along with a digital multi-meter, it should be possible to test or troubleshoot most radio equipment.

The following three pages show the Schematic, PC Board Layout, and Parts List for the HF Test Set.

# HF Test Set Schematic



# Board Layout




**NOTE:  C6 is shown as an electrolytic.  Originally, that was correct.  However, C6 has been changed to a .1 uF bypass Capacitor.**

# Parts List

| TYPE/VALUE | IDENTIFIER | QUANTITY | COMPONENT NUMBER |
|---|---|---|---|
| 1 uF | 1 uF Electrolytic | 1_____ | C17 |
| 4.7 uF | 4.7 uF Electrolytic | 1_____ | C7 |
| 10 uF | 10 uF Electrolytic | 4_____ | C1, C5, C25, C27 |
| 22 uF | 22 uF Electrolytic | 2_____ | C18, C20 |
| 470 uF | 470 uF Electrolytic | 1_____ | C19 |
| | | | |
| .001 uF | 1000J Polystyrene | 1_____ | C16 |
| .0027 uF | 272 NP0 Monolithic | 4_____ | C21, C22, C23, C24 |
| .01 uF | 103 | 7_____ | C10, C26, C28, C29, C30, C31, C32 |
| .1 uF | 104 | 6_____ | C2, C3, C4, C6, C14, C15 |
| 22 pF | 22 NP0 | 1_____ | C11 |
| 33 pF | 33 NP0 | 2_____ | C8, Cs |
| 120 pF | 121 NP0 Monolithic | 2_____ | C12, C13 |
| | | | |
| 50 pF Trimcap | Orange small trimcap | 1_____ | C9 |
| | | | |
| 10 uH | Brown, Black, Black | 1_____ | L1 (Green or Brown Molded Choke) |
| | | | |
| 1N34A | 1N34A | 1_____ | D1 |
| 1N5231B | 1N5231B | 2_____ | D2, D3 |
| 2N3904 | 2N3904 | 6_____ | Q1, Q3, Q4, Q6, Q7, Q8 |
| J310 | J310 | 1_____ | Q2 |
| PN3646 | PN3646 | 1_____ | Q5 |
| 555 Timer IC | TS555IN | 1_____ | U3 |
| 7805 Regulator | L7805 | 1_____ | U2 |
| 16F84 PIC | 16F84 (programmed) | 1_____ | U1 |
| | | | |
| 22 Ohm | Red, Red, Black | 1_____ | R1 |
| 47 Ohm | Yellow, Violet, Black | 1_____ | R15 |
| 51 Ohm | Green, Brown, Black | 2_____ | RL, R46 |
| 100 Ohm | Brown, Black, Brown | 3_____ | R18, R26, R43 |
| 330 Ohm, ½ Watt | Orange, Orange, Brown | 2_____ | R42, R45 |
| 470 Ohm | Yellow, Violet, Brown | 2_____ | R6, R7 |
| 510 Ohm | Green, Brown, Brown | 2_____ | R9, R44 |
| 560 Ohm | Green, Blue, Brown | 1_____ | R19 |
| 1K Ohm | Brown, Black, Red | 4_____ | R13, R14, R16, R20 |
| 10K Ohm | Brown, Black, Orange | 4_____ | R8, R21, R24, R25 |
| 18K Ohm | Brown, Gray, Orange | 3_____ | R3, R4, R5 |
| 22K Ohm | Red, Red, Orange | 1_____ | R2 |
| 39K Ohm | Orange, White, Orange | 1_____ | R23 |
| 56K Ohm | Green, Blue, Orange | 4_____ | R27, R28, R29, R30 |
| 82K Ohm | Gray, Red, Orange | 1_____ | R22 |
| 100K Ohm | Brown, Black, Yellow | 1_____ | R10 |
| 220K Ohm | Red, Red, Yellow | 1_____ | R11 |
| 4.7M Ohm | Yellow, Violet, Green | 1_____ | R31 |
| 510 Ohm, 2 Watt | Green, Brown, Brown | 10____ | R32 through R41 |
| 10K Trimpot | 6mm Trimpot, 103 | 1_____ | VR1 |

| | | | |
|---|---|---|---|
| 10K Pot | Potentiometer | 1_____ | VR2 |
| 4.000 MHz Crystal | 4.00ECSH | 1_____ | X1 |
| LCD Display | LCM-S01601DTR | 1_____ | |
| Board Mount BNC | Board Mount BNC | 1_____ | J1 |
| Lockwasher | For Board Mount BNC | 1_____ | |
| Nut | For Board Mount BNC | 1_____ | |
| Low Profile 16 pin SIP Socket | | 1_____ | For LCD Display |
| Low Profile 16 pin SIP Header | | 1_____ | For LCD Display |
| 14 pin SIP Header | | 1_____ | Break into seven, two pin headers |
| 2 pin SIP Jumper | | 4_____ | |
| 2 pin SIP Socket | | 1_____ | Crystal Socket for Crystal Oscillator |
| 8 pin DIP Socket | For U3 | 1_____ | |
| 18 pin DIP Socket | For U1 | 1_____ | |
| 3/16" diameter, ¼" long Nylon Spacer | | 4_____ | For mounting LCD display |
| ½" long, 3-48 Screws | | 4_____ | For mounting LCD display |
| 3-48 Nuts | | 4_____ | For mounting LCD display |

Add to these parts the DC Power connector of your choice, and a case, which could consist of a variety of types, such as a tin box with either a hinged or removable lid, so as to provide easy access to the headers and test points on the Test Set, or could be a simple, three sided case, with just bottom, front and back panels, made from printed circuit board material and soldered together.

Should parts be missing, contact

Joe Porter, W0MQY
306 East Hudson
Pittsburg, KS
66762

Email Address: W0MQY@sbcglobal.net

# Tools and Equipment Needed

The types of tools commonly associated with building electronics projects are used in assembling the HF Test Set.  The following will be needed:

A fine-tipped soldering iron with variable heat, or two soldering irons of different heat, such as irons with a 15 Watt element and a 30 Watt element.  The higher heat iron may be necessary for soldering ground connections on the board.

Silver content solder – this is better, health wise, than lead solder, and also forms a stronger, cleaner solder joint.

Small Diagonal Cutters

Long Nosed or Needle Nosed Pliers

#1 Phillips Screwdriver

The following items will also be helpful:

De-soldering Braid or a Solder Sucker for removing solder

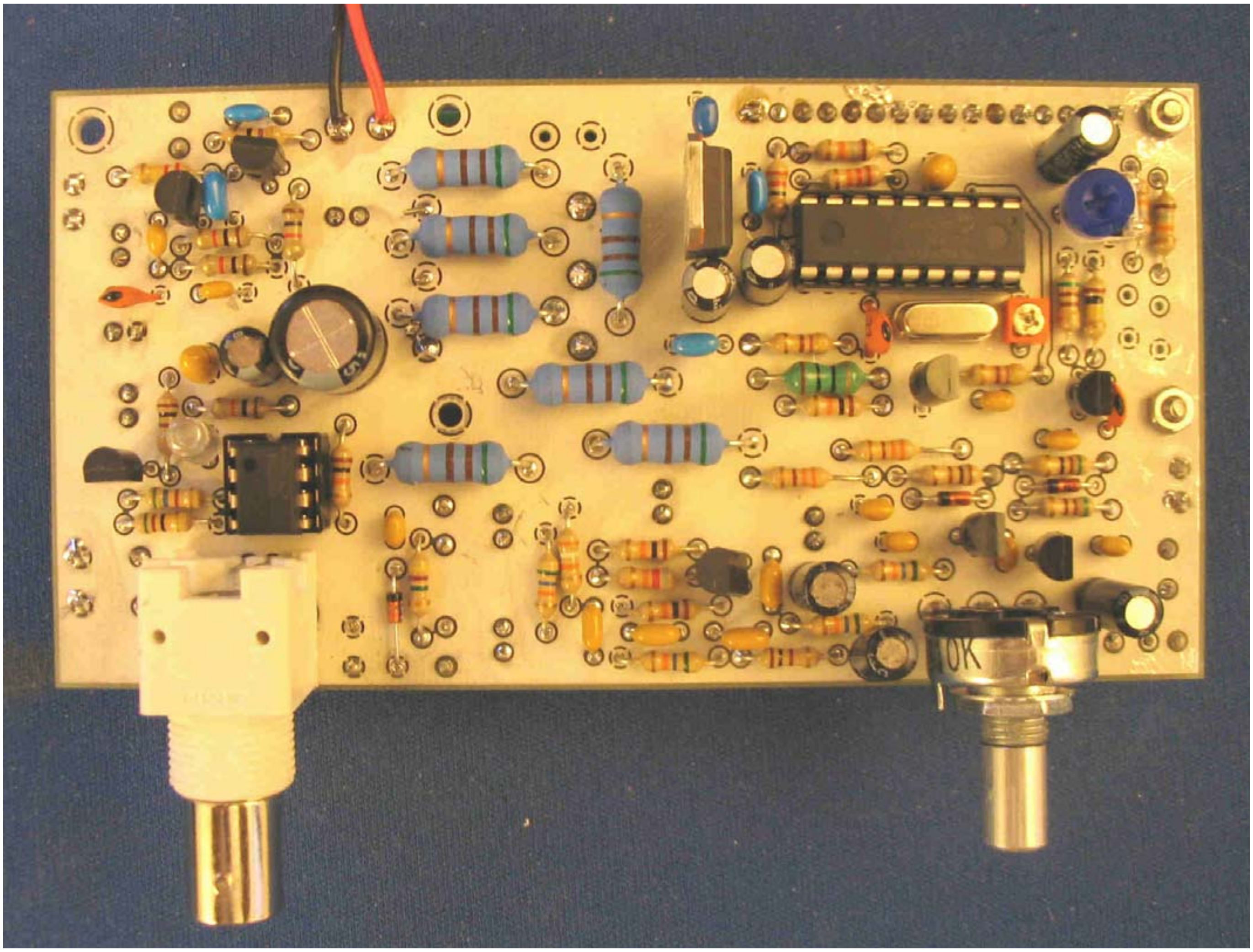
Hemostats or other clamping type pliers

A Magnifier and Strong Light

# PC Board, Parts Side

Refer to the previously shown parts layout in order to place parts in their correct locations on the board. It is helpful to print out that page, as well as the Parts List, to make them easy to refer to.

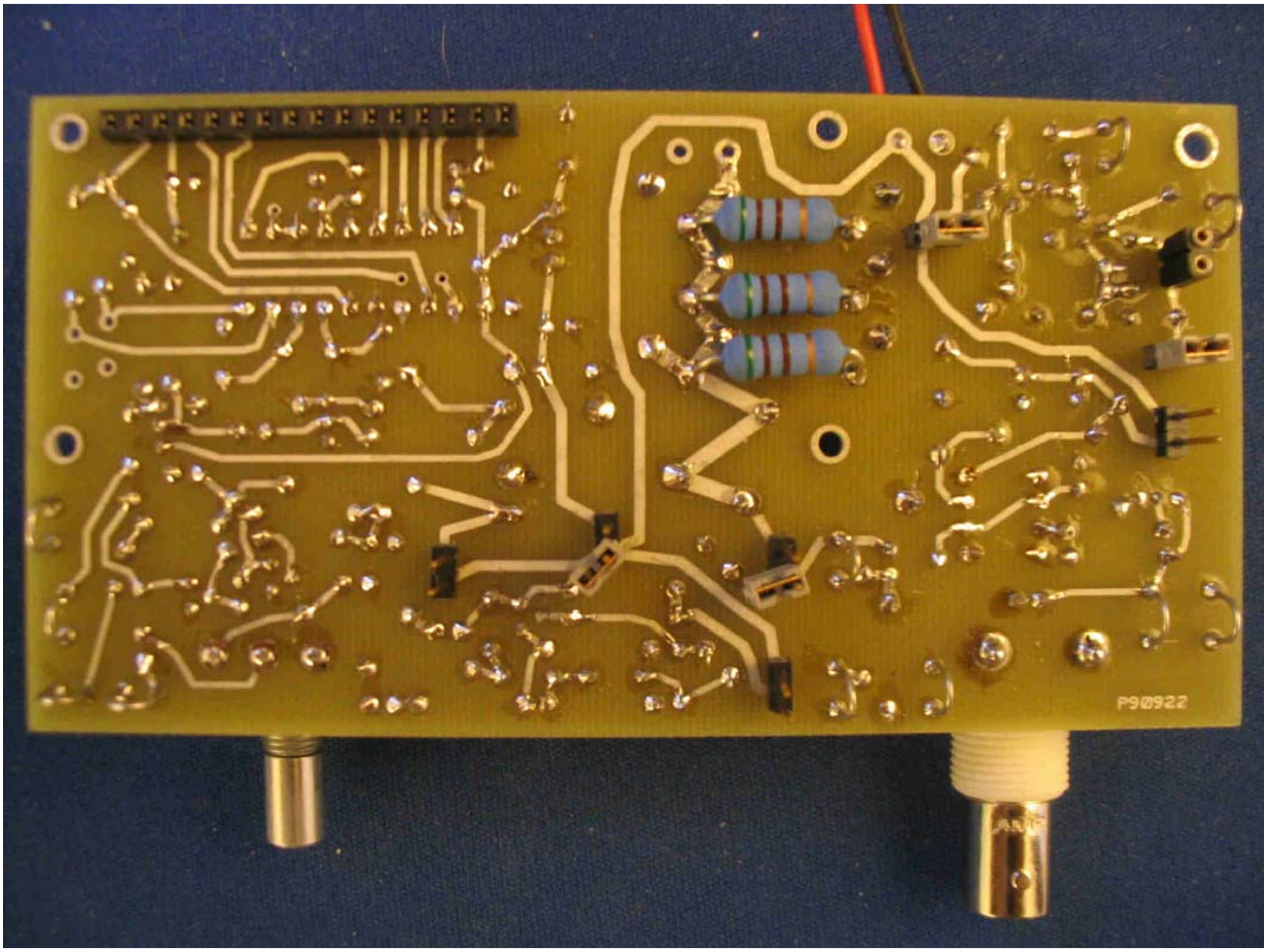
The picture below shows the parts side of the PC Board.



**NOTE: Most of the parts go on the ground plane side of the board, and their leads are soldered on the trace side of the board. However, the low-profile 16 pin SIP socket for the LCD display, some of the Dummy Load resistors, and the two-pin SIP headers are all installed on the trace side, and their leads are soldered on the ground plane side.**

**Care will be needed so as not to form solder bridges between the pads for the LCD display, and ground, as they are soldered on the parts side of the board.**

# PC Board, Trace Side




The picture above shows the trace side of the board.

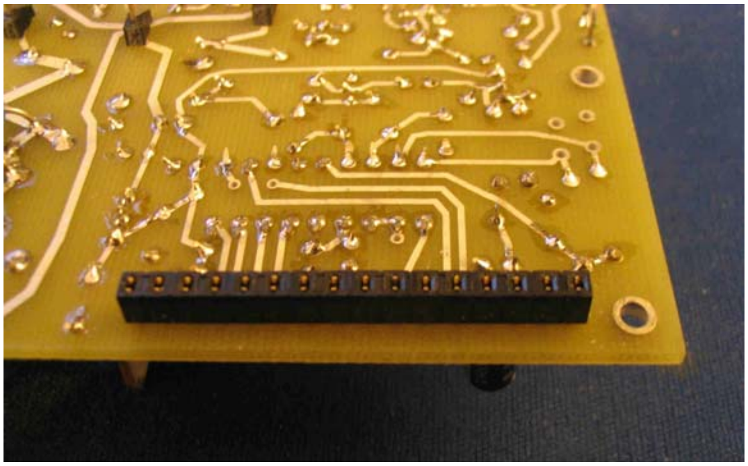
**Note that the low-profile socket for the LCD display goes on this side of the board and its pins are soldered on the parts side. The seven, two-pin SIP headers used to select the various functions are also installed on this side, as are all of the test point loops, which are made from cut-off part leads.**

**Note also that R37, R38, and R39, three of the Dummy Load resistors, are installed on this side of the board. Their leads may be soldered on this side, as well.**

# Starting the build

☐ Install the low-profile 16 pin SIP Socket on the board first. As stated above, the socket goes on the Trace side of the board, and its pins are soldered on the Parts side. Take care not to form solder bridges, by using a fine point soldering iron and small-diameter, silver content solder, such as Radio Shack 64-035E. The socket should sit at a 90 degree angle to the board, when viewed lengthwise.

The picture below shows detail of the socket installation.

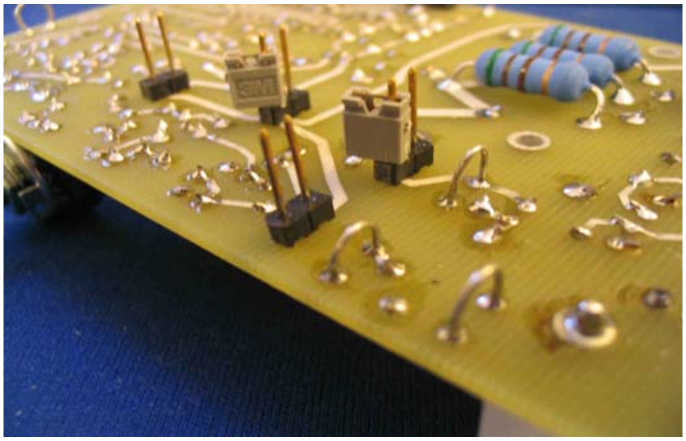


☐ Next, referring to the photo of the complete Trace side of the board, install the seven, two-pin headers, soldering their short pins on the Parts side of the board.

☐ When the two-pin headers have been soldered in place, install the two-pin SIP socket in its location in the Crystal Oscillator section of the board.

Note that the test point loops, which will be made from cut-off part leads, can be easily installed after all the remaining parts are put on the board. Although the loops are meant to be accessible on the trace side of the board, they can all be soldered much more easily from the trace side of the board.

The picture below shows detail of Header and Test Point Loop installation.



The various sections of the Test Set can be installed and tested before proceeding to the next section. In which case, the various test point loops associated with each section will be installed as that section is completed.

In any case, the LCD display should be mounted on the board as the last step of board assembly.

## Assembling and Testing the Individual Sections

If you like, make a check mark next to each component or step when it is completed, so as to keep track of your build.

# Building the RF Probe

Install the following:

☐ R31 4.7M Ohm

☐ D1 (its cathode stripe goes towards the hole furthest away from the edge of the board)

☐ C28 .01 uF

☐ Form three Test Point Loops from cut-off part leads and install them in the locations for the RF (input), DC (output) and Gnd (Ground) connections of the RF Probe. Remember that the loops formed should be on the Trace side of the board.

# Building the Dummy Load

Install the following:

☐ R32 through R41, a total of ten, two-watt resistors, all 510 Ohms

R37, R38, and R39 are installed on the Trace side of the board. The other seven are installed on the Parts side.

☐ Connect a short length of small-diameter coax and the temporarily attached panel-mount BNC jack to the Dummy Load connections on the board. Take note of the polarity.

# Testing the RF Probe and Dummy Load

When the RF Probe and Dummy Load have been installed, before proceeding to a test of the RF Probe, take an Ohm-Meter reading across the contacts of the Dummy Load's BNC Jack. You should get a reading of, or very near, 51 Ohms.

Then, use a SIP Jumper to connect the RF Probe to the Dummy Load, by means of the conveniently provided header.

Next, a low power transmitter's output is connected to the Dummy Load's BNC connector, and a Voltmeter's leads are connected to the DC and Ground loops for the RF Probe, so that an RMS voltage reading can be taken.

RF Power in this case is calculated by the formula:

Volts RMS, squared, divided by 50 (ohms)

For example:

7 Volts RMS, squared, is 49, divided by 50 (ohms) equals almost exactly One Watt.

Note that this RF Probe is not a laboratory instrument, and will have a small error. For most of our measurements, this small error can be disregarded, as we are looking for an approximate.

# Building the Crystal Oscillator

Install the following:

- ☐ Q3 2N3904
- ☐ Q4 2N3904
- ☐ Cs 33 pF NP0 disk ceramic
- ☐ R11 220K Ohm
- ☐ C12 120 pF NP0 Monolithic Bend its leads slightly, so that they will easily fit into the holes on the board.
- ☐ C13 120 pF NP0 Monolithic Bend its leads also.
- ☐ R13 1K Ohm
- ☐ R14 1K Ohm
- ☐ R15 47 Ohm

☐ R16 1K Ohm

☐ C14 .1 uF

☐ C15 .1 uF

☐ Form two test loops from cut-off part leads. Install one in the RF Out Test Point for the Crystal Oscillator, and install the other in the Ground Test Point for the oscillator. Remember that the loops formed should be on the Trace side of the board.

## Supplying DC Power

☐ Connect a DC Power jack of your choice to the DC input pads on the board. Again, note polarity, both on the board, and on the jack itself, when you make the connections. Just to double check, take an Ohm-Meter reading from the positive contact of the DC Power Jack to Ground. The reading should be infinite.

## Testing the Crystal Oscillator

Before actually supplying power to the board, take an Ohmmeter reading from the pin of the Crystal Oscillator's DC Power header that is closest to the crystal socket, and ground.

You should see a reading of a very high resistance.

Next, remove the jumper from the header that connects the RF Probe to the Dummy Load.

Connect the positive and negative leads of your Voltmeter back to the DC and Gnd test point loops of the RF Probe.

Connect a short clip lead between the RF output loop of the Crystal Oscillator and the RF input loop of the RF Probe.

Note that for this test, the jumper for S3, in the Crystal Oscillator circuit, should be connected to both pins of its header, and then left in that position for later testing of the Frequency Counter.

S3 is used to help determine the motional parameters of individual crystals, and its use will be explained later.

Plug a crystal for any frequency in the HF range into the crystal socket of the crystal oscillator, and then slide the jumper for DC Power to the oscillator over both pins of its header, which acts as a switch supplying power to that section of the test set.

You should then see a reading on your voltmeter, of from .7 to 3 Volts, indicating that the crystal oscillator is in fact oscillating and producing an output. This particular oscillator will have more output at the lower frequencies than at the higher output.

Once the Frequency Counter is built, you will be able to check the frequency of the oscillator's output, and use those two sections of the Test Set to do such tasks as matching crystals for use in filters.

At the moment, connecting the output of the Crystal Oscillator to the RF Probe, and getting a reading on the voltmeter, confirms the operation of that section of the circuit.

A second, independent test, would be to tune a receiver up and down across the crystal frequency, and listen to the oscillator's output.

If the signal seems weak, simply touch a finger to the crystal case, and, with your body acting as an antenna, the signal will be much stronger in the receiver. Alternatively, attaching a clip lead to the RF output loop of the Crystal Oscillator and let it serve as the radiating antenna for the signal. By the use of either of those methods, the signal should be quite strong in your receiver.

An Oscilloscope can be used to observe the waveform and measure the output, as well. Do not be surprised if the waveshapes are not pure sine waves, however. This is mostly due to the fact that we are using one set value of feedback capacitance in this oscillator (C12 and C13 at 120 pF) with crystals that cover most of the entire HF spectrum.

## Building the Audio Oscillator

To build the Audio Oscillator, install the following:

- ☐ R22 82K
- ☐ R23 39K
- ☐ R24 10K
- ☐ R25 10K
- ☐ R26 100 Ohm
- ☐ R27 56K
- ☐ R28 56K
- ☐ R29 56K
- ☐ R30 56K
- ☐ Q6 2N3904 Oriented to match the case shape printed on the PC Board.
- ☐ C21 .0027 uF (272 NP0)
- ☐ C22 .0027 uF (272 NP0)

☐ C23 .0027 uF (272 NP0)

☐ C24 .0027 uF (272 NP0)

☐ C26 .01 (103)

☐ C20 22 uF

Note its polarity, the positive (long) lead goes in the hole closest to Q6.

☐ C25 10 uF

Note its polarity, the positive (long) lead goes in the hole closest to Q6.

☐ C27 10 uF

Note its polarity, the positive (long) lead goes in the hole closest to the edge of the board.

☐ VR2 10K Pot

☐ Form two Test Point Loops from cut-off part leads, and install them, one in the AF (output) location on the board, and the other in the Gnd (Ground) location, at the edge of the board, close to the mounting hole for the LCD Display.

# Testing the Audio Oscillator

Before applying power to the Audio Oscillator, take an Ohmmeter reading from the pin of its DC Power header that is closest to the edge of the board, and ground.

You should get a reading that changes, starting out somewhere around 50 or 60 K Ohms, and going up. What you are watching, if you continue to hold the Ohmmeter leads in contact with those two points, is the effect of the electrolytic capacitors in the Audio Oscillator being charged by the DC current from the Ohmmeter. If you held the leads there long enough, the reading should rise to a point approaching infinity.

If the Ohmmeter reading checks out, apply power to the board, and use a jumper across the two-pin header labeled “AF” to turn the Audio Oscillator on.

Use clip leads to connect the AF output test loop and Gnd test loop to the connections on the plug of a set of earphones. With the audio level pot turned all the way up (clockwise), the oscillator’s tone should be heard in one or both of the earphones.

The oscillator’s output can be injected into an audio amplifier, as well, to check its performance. Turn the audio level pot all the way down (counter-clockwise) first, before doing so, and then turn the level up slowly when the oscillator is connected to the amplifier.

An oscilloscope can also be used to observe the waveshape on the audio oscillator’s output.

# Building the Wideband Noise Generator

Install the following:

☐ Q7 and ☐ Q8 (2N3904)

Use the case shapes on the board as installation guides.

☐ D2 and ☐ D3 (1N5231B)

Their cathode stripes go to the left, when the board is oriented so that their printed parts designations are right side up.

☐ R42 and ☐ R45 (330 Ohm, ½ Watt)

☐ R43 (100 Ohm)

☐ R44 (330 Ohm)

☐ R46 (51 Ohm)

☐ 29, ☐ C30, ☐ C31, and ☐ C32 (.01 uF)

☐ Form a Test Point Loop from a cut-off part lead, and install it in the location marked “QRN”, next to the Audio Oscillator’s output loop.

# Testing the Wideband Noise Generator

Before supplying DC Power to the board, take an Ohmmeter reading from the “QRN” header pin that is furthest from the edge of the board, to ground. The reading should be a high value that increases to infinity.

If the Ohmmeter reading is good, supply DC power to the board and use a jumper on both of the “QRN” header pins to turn the Wideband Noise Generator on.

Connect a clip lead to the Wideband Noise Generator’s output loop, and touch it to the center contact of a coax cable attached to the antenna jack of any HF Receiver. Doing so should result in a noise signal being heard distinctly in the receiver’s audio output.

Since the noise generator has output over the continuous range of from about 1 MHz up through 50 MHz or higher, the noise signal should be heard on any frequency an HF Receiver can tune to.

Alternatively, an oscilloscope can be used to observe the noise signal on the output of the Wideband Noise Generator, appearing as “grass” on the scope trace.

# Building the Time Domain Reflectometer

Install the following:

- ☐ An 8 pin DIP Socket for U3.

  Ensure that the notch in the end of the socked faces toward R20's location on the board.

- ☐ Q5 (PN3646)

  Use the printed case shape on the board as an installation guide.

- ☐ R18 (100 Ohm)
- ☐ R19 (560 Ohm)
- ☐ RL (51 Ohm)
- ☐ R20 (1K Ohm)
- ☐ R21 (10K Ohm)
- ☐ C16 (.001 Polystyrene)
- ☐ C17 (1 UF Electrolytic)
- ☐ C18 (22 uF Electrolytic)
- ☐ C19 (470 uF Electrolytic)
- ☐ J1 (Board mount BNC connector)
- ☐ U3 (TS555IN)
- ☐ Form two Test Point Loops from cut-off part leads, and install them in the "TDR" and "GND" locations next to J1.

# Testing the TDR

Testing the Time Domain Reflectometer properly requires the use of an oscilloscope. If short runs of coax cable are to be tested, then at least a 50 MHz scope should be used. For longer runs, a 20 MHz scope will suffice.

If no oscilloscope is on hand, two simple tests can still be performed. First, take an Ohmmeter reading between the TDR header pin closest to J1 and ground. This should result in a high reading, perhaps 1.5 Meg Ohms, varying as the electrolytic capacitors in the DC path charge.

A receiver can be used to verify the pulse activity of the TDR. Clip one end of a long clip lead to the "Probe" loop of the TDR, to act as an antenna.

The TDR's signal, basically a square wave, can be heard on an HF receiver on multiples of 3.545 MHz, roughly.

Tune your receiver up and down across that frequency, or around 7.090 MHz, and the TDR's signal should be heard. When a steady carrier is heard, unclipping and re-clipping the lead will verify that the signal heard is from the TDR.

If an oscilloscope is on hand, a X10 scope probe is connected between the Probe loop and ground, and the waveform from the TDR observed.

On the scope, the TDR's signal will appear as a square wave of about 4.5 Volts, peak to peak, of amplitude.

Use of the TDR to locate faults in coaxial cable runs will be described later in this document.

# Building the Frequency Counter

The 16 pin, Low Profile SIP Socket for the LCD display has already been installed on the board.

☐ Install the 16 pin, Low Profile header on the display itself. The shorter side of the pins goes through the holes in the display.

The picture below shows detail of the header installation.

Install the following:

- ☐ An 18 pin DIP Socket for U1.

  The notch in the end of the socket should face the VR1 end of the board.

- ☐ Q1 (2N3904)

  Use the printed case shape on the board as an installation guide.

- ☐ Q2 (J310)

  Use the printed case shape on the board as an installation guide.

- ☐ C9 (50 pF, Orange trimcap)

  Note that the plastic surrounding the actual screw-driver slotted metal top of the trimmer is round except for in one corner, where it is square, leaving a triangular opening. The trimmer's leads will need to be straightened with long-nose pliers, and then the trimmer is installed so that the triangular opening is on the side facing AWAY from the IC socket.

  This is done so that the trimmer's metal top is grounded, helping to eliminate any added capacitance effects when an alignment tool is used to adjust it.

- ☐ X1 (4.00 MHz Crystal)

  Leave just a little space between the bottom of the crystal's case and the PC board, so that there is no chance of the case shorting against the pads for its leads.

- ☐ C8 (33 pF NP0)
- ☐ R1 (22 Ohm)
- ☐ R2 (22K Ohm)
- ☐ R3 (18K Ohm)
- ☐ R4 (18K Ohm)
- ☐ R5 (18K Ohm)
- ☐ R6 (470 Ohm)

- [ ] R7 (470 Ohm)
- [ ] R8 (10K Ohm)
- [ ] R9 (510 Ohm)
- [ ] R10 (100K Ohm)
- [ ] C11 (22 pF NP0)
- [ ] C2 (.1 uF)
- [ ] C3 (.1 uF)
- [ ] C4 (.1 uF)
- [ ] C6 (.1 uF)
- [ ] C10 (.01 uF)
- [ ] C1 (10 uF Electrolytic)

    Note its polarity, the positive (long) lead goes in the hole closest to U1.

- [ ] C5 (10 uF Electrolytic)

    Note its polarity, the positive (long) lead goes in the hole closest to U1.

- [ ] C7 (4.7 uF Electrolytic)

    Note its polarity, the positive (long) lead goes in the hole closest to R5.

- [ ] L1 (10 uH Molded Inductor)
- [ ] VR1 (10K Ohm trimpot)
- [ ] U2 (L7805 three-terminal voltage regulator)

    Note that its metal tab goes on the side facing away from U1.

- [ ] Form a Test Point Loop from a cut-off part lead and install it in the ”FC” location on the board, between the “QRN” output loop and the “Gnd” loop near the corner of the display.

☐ Install U1 (16F84 PIC, programmed)

Ensure that the notch in the end of U1 is on the end facing VR1, matching the notch in the end of its socket.

☐ Plug the LCD display into its socket on the board. Complete its installation by fastening it, using the four ¼" long nylon spacers and the four ½" long 3-48 screws and nuts.

The screw heads should be on the top of the display's PCB, and the nuts should be on the parts side of the Test Set PCB.

Do not over-tighten the screws, as torqueing the display's PC board can cause intermittent operation or failure of the display.

Use a dab of fingernail polish or epoxy glue on the ends of the screws, where they protrude from the nuts on the parts side of the board, to lock the nuts in place and prevent their coming loose and falling off, which could cause an electrical short.

# Testing the Frequency Counter

An Ohmmeter reading, taken between the FC header pin closest to the LCD display, and ground, should show a high resistance, slowing increasing in value as the electrolytic capacitors in the DC supply line charge.

If the Ohmmeter reading is correct, apply DC power to the board, and use a jumper on the two pins of the FC header to turn the Frequency Counter on.

Do not be alarmed if, once power has been applied, you do not see anything on the display. This is frequently the case until VR1 has been adjusted so as to set the contrast properly on the display.

Adjust VR1 so that the letters of the abbreviation "Freq.:" are clearly visible and the rectangular backgrounds of the individual characters are not visible.

Once this is done, the counter can be tested.

In order to do this, plug a crystal into the socket on the Crystal Oscillator, and use a jumper on the two pins of the RF Osc header to turn the oscillator on.

Connect a short clip lead between the RF output loop of the Crystal Oscillator and the FC input loop. The LCD display should now show the frequency of oscillation, which should be close to the designed frequency of the crystal. If there is no reading yet, adjust C9, the trimcap next to X1, so as to get a reading.

# Putting the HF Test Set into a Case

The HF test set, built as shown in the photos accompanying this text, should be put into a case or box that has either a removable or hinged lid, so as to provide easy access to the various headers and test point loops.

The board is mounted by means of the Audio Level pot and Test Line BNC in front, and a nylon spacer, 4-40 screw and nut by means of the mounting hole in the right rear of the PC board.

The DC Power jack of choice and the BNC jack for the Dummy Load are mounted on the rear panel of the case.

As can be seen in the cover photo of the assembled test set, a quite serviceable case can be fashioned from three pieces of PC board material.

Alternatively, switches can be used in place of the two-pin headers, BNC jacks can be used instead of test point loops, and the LCD display can be mounted separately from the PC board.

The choice is up to you.

Now that you have built the HF Test Set, and have it in the case of your choice, how do you best make use of it, in either testing or troubleshooting radio circuitry?

# Using the RF Probe

The RF Probe in this test set performs two functions. It converts RF signals to DC Voltages, and when used in conjunction with a 10 or 11 Meg Ohm impedance Voltmeter, it provides a readout in Volts, RMS.

It will be important to use as short a pair of clip leads as possible to connect between the RF Probe's input and ground loops and the circuit in question, especially at the higher frequencies.

One simply clips one lead from the ground loop for the RF Probe to ground on the circuit to be tested, and connects another short lead from the RF input loop to the point in the circuit where RF is to measure.

Curious to see how low an RF voltage could be measured, a reading of 27.5 milliVolts, RMS, was obtained at the input to the Post Filter Amplifier in the Nuts and Bolts 40 Transceiver. While I do not expect the reading to be accurate at that low level, it is certainly useful as an indicator of the presence of that low level signal on transmit.

If I didn't make a mistake with my math, that works out to one and a half one-hundredths of a milliWatt, to a 50 Ohm load.

# Using the Dummy Load

The Dummy Load built into the test set is a resistive 50 Ohm load consisting of ten, 510 Ohm, two Watt resistors in parallel. This should safely dissipate at least 20 Watts of RF Power.

A convenient two-pin SIP header is provided for connecting the Dummy Load directly to the RF Probe, making it easy to read the RMS RF voltages present, and calculate the RF power level applied.

The formula is: Volts RMS, Squared, divided by 50 (Ohms).

The Dummy Load and RF Probe can be used to determine the output levels of any 50 Ohm output RF Amplifier or Transmitter, up to 20 Watts or more.

# Using the Frequency Counter

The Frequency Counter is very simple to use. For absolute accuracy, it requires calibration, through the adjustment of C9, correcting the readout so as to match the frequency standard used in calibration.

If a frequency standard is not available, the uncalibrated counter is still quite useful, as the amount of error is usually no more than the standard variation of the crystal, which us about one part per million, or one Hz per MHz.

Short clip lead length will help keep readings accurate. One lead goes from ground on the test set to ground on the circuit being tested. The other lead goes from the FC input loop of the counter to the output of the oscillator or amplifier being tested.

Be advised that even though the input of the Frequency Counter is high impedance, taking a frequency reading from the tank circuit or other frequency determining elements of an oscillator will pull the oscillator off frequency somewhat, perhaps several KHz.

Taking a reading further along in the circuit, say from the output of a buffer amplifier, should cause less, or no pulling at all, of the frequency.

# Using the Crystal Oscillator

The crystal oscillator in this test set has several functions these are:

Crystal Testing

Frequency Matching of individual crystals

Motional Parameter determination of individual crystals

RF Source for testing and troubleshooting of receiver or transmitter circuitry.

To use the Crystal Oscillator to test crystals, simply connect the RF output loop of the oscillator to the Frequency Counter's input loop with a short clip lead, supply power to the board, and turn on both the Crystal Oscillator and the Frequency Counter by means of jumpers on their DC power headers.

Then, when a functional crystal is plugged into the crystal jack on the oscillator, a stable frequency readout will indicate that the crystal is working and you will also have, displayed, the frequency of the crystal down to 10 Hz resolution.

The same setup is used either to match crystal frequencies for their use in filters, or for determining the motional parameters of individual crystals so as to design a crystal filter.

The header, S1, in the Crystal Oscillator provides a way to either place a small amount of capacitance, Cs, in series with the crystal being tested, or bypass that capacitance. The difference in frequency between having the Cs in series and having it bypassed is used to calculate the motional parameters of the crystal, which are, in turn, used in designing a crystal filter with a specified bandwidth.

This procedure is detailed in the ARRL publication, EMRFD[ii]. The formulas used are as follows:

Cm (Motional Capacitance) = 2 X Cs (33pF) X [△F (amount of Frequency Change) divided by F (Frequency)]

And,

Lm (Motional Inductance) = 1 divided by [(2πF, squared) X Cm]

Cm will have the same units as Cs (pF to pF, for example)

The example given in EMRFD, page 3.19, for a 10 MHz crystal:

$F = 1 \times 10^7$ $\Delta F = 1609$ Hz $Cs = 33$ pF

to yield Lm = .0239H and Cm = 10.6fF (1000 fF = 1 pF)

See EMRFD, or other treatises on crystal filter design for details. A search on the ARRL website should produce several excellent articles on filter design.

The crystal oscillator can also be used as an RF Signal source for testing receiver or transmitter circuitry.

A crystal for the HF band in question is plugged in to the Crystal Oscillator. Simply setting the operating oscillator on a nearby bench will suffice. When a functioning receiver with an antenna connected to it is tuned to the oscillator frequency, the signal will be clearly heard. Touching a finger to the crystal case will cause a dramatic increase in the received signal.

With crystals of appropriate frequencies, the oscillator's signal can be injected stage by stage through the RF, and IF sections of the receiver. When testing the RF section of the receiver, no more signal should be needed than that provided by simply having the operating oscillator sitting nearby.

When testing the IF strip, connect one clip lead to the RF output loop of the oscillator, in order to radiate the signal, and use another clip lead as a receiving antenna.

One end of the receiving clip lead is left dangling free, and the other end is carefully touched to consecutive input and output points in the circuit.

For testing transmitter circuitry, the output of the Crystal oscillator, given a crystal of an appropriate frequency, can be injected directly into an amplifier stage such as a buffer amp, and or driver amplifier. The .1 uF capacitor in line with its output will prevent conduction of any DC current present in the circuit.

## Using the Audio Oscillator

Measured on an oscilloscope, the Audio Oscillator has between a 600 and 700 mV, Peak to Peak, output.

When applied to the jack of the typical stereo headset used with modern receivers, this is just enough to provide a discernable tone.

An output level control is provided, so that the output can be reduced to zero before the signal is injected into the input of an audio amplifier chain, and then can be increased slowly, so as not to produce ear-injuring level sounds when testing this type of circuit.

The audio output from this oscillator is injected, using a clip lead, into the inputs of the individual audio amplifier stages in a receiver, working backwards through the circuit, where a louder tone is expected as each stage of amplification is added.

As with the Crystal Oscillator, a capacitor in the output line prevents DC current from being drawn from the circuit under test.

## Using the Wideband Noise Generator

The Wideband Noise Generator produces a noise signal that covers the entire HF Spectrum and beyond, providing useful signals from about 1 MHz up through 50 MHz.

Eliminating the need for crystals of appropriate frequencies, or a tunable RF source, this signal can be used to test all types of receiver circuitry, by injecting the signal, through the use of a clip lead attached to its output loop, into each successive stage of RF and IF amplification.

The .01 uF capacitor in its output path will prevent conduction of any DC current from the circuit under test. This wideband signal can also be used, along with a Spectrum Analyzer, for determining the bandwidth of several types of filters.

# Using the Time Domain Reflectometer

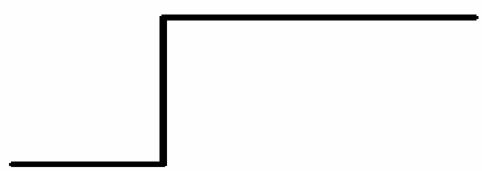
The TDR is a very useful piece of test equipment, which allows one to determine faults in coaxial cable runs.

Problems such as open circuits, shorts, and even impedance bumps can be seen, through the use of an Oscilloscope, and their distance from the end of the cable connected to the TDR can be quickly calculated, using the time base of the oscilloscope.

In order to get an idea of what to look for on the scope, first hook a X10 scope probe to the probe loop of the TDR, and connect the probe's ground lead to the nearby ground loop on the Test Set.

Connect a 50 Ohm resistor from the center contact of J1 to ground.

Once the TDR is turned on, you should be able to see a square wave on the scope that is about 4.5 Volts, Peak to Peak. Adjust the time base on the scope until you are seeing just the left hand portion of one square wave, where finishes its lowest voltage point, rises rapidly to its highest, and then tracks off directly to the right.



**50 Ohm Waveshape**

The drawing above shows approximately what a 50 Ohm Waveshape looks like on the portion of the wave you want to observe, and this is what the impedance on the output of the TDR will be with nothing connected to it.

Now connect a 50 Ohm load to one end of a coaxial cable, and connect the other end to the TDR. The shape should remain roughly the same, with perhaps a little slope to the top edge of the shape, as shown in the photo below.

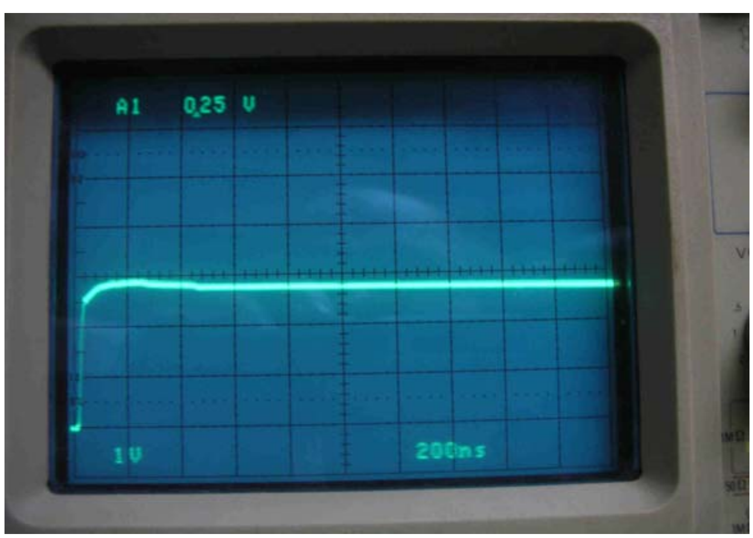
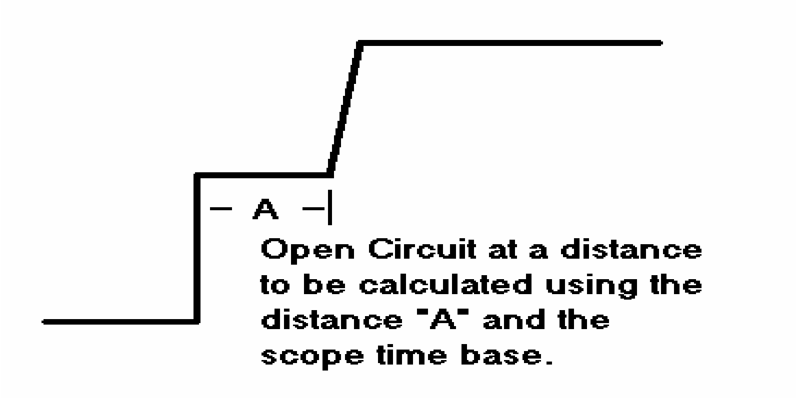



Photo courtesy of K7RXV

Notice in the scope trace shown above, a slight bump and reduction in trace height about one major division to the right of the initial vertical rise of the left end of the square wave.

That bump and slight reduction in trace height is the end of the coax, with a 50 Ohm load connected. The second small bump, and again, slight reduction of the trace height is the second harmonic, so to speak, of the reflection of the coax length. This will all become quite clear after viewing the next photo.

Now remove the 50 Ohm load from the end of the coax, and you should see a shape like this one below.




Below is a photo of an actual scope trace, showing the effects of an open circuit at the end of a length of coax.

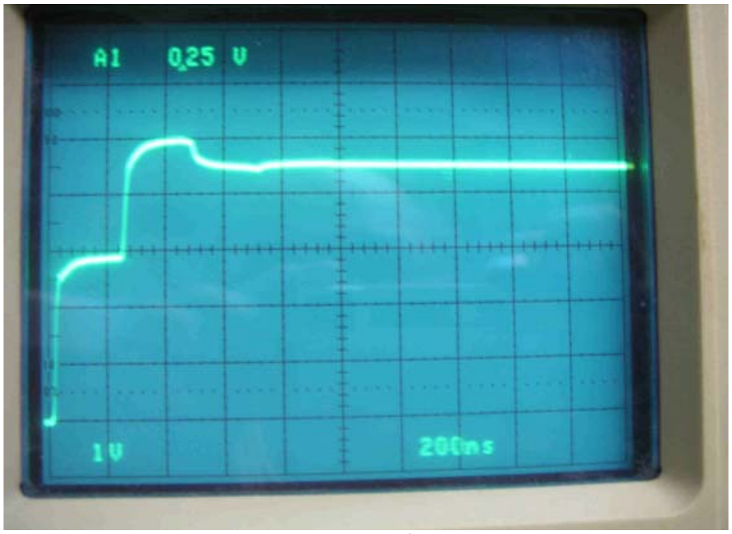



Photo courtesy of K7RXV

The physical length of the coax, preceding the open circuit, is represented by the initial level line, in left center of the scope trace, between the top of the initial rise of the TDR's square wave and the point at which it breaks sharply upwards once again.

Where it breaks almost straight up, just to the right of the first major division line on the scope, is the location of the open circuit, and this distance on the scope is just over one major division wide. For purposes of calculating the distance between the TDR and the open circuit, we use the 200 ns (NanoSeconds) per division time base of the scope, and will approximate the reflection time of the length of coax from the TDR to the open circuit at about 215 ns, or .215 us.

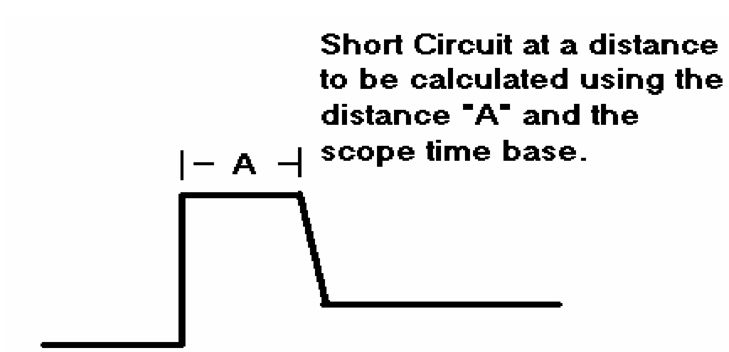
That reflection time of .215 us (MicroSeconds) is multiplied by the number 983.6, representing the speed of the radio wave, which travels at the speed of light, and the velocity factor of the coax being tested (.80), and then divided by 2, in order to arrive at the approximate distance in feet from the TDR to the open circuit.

In this case, Length = $\frac{983.6 \text{ X } .80 \text{ X } .215}{2}$ = 84.6 Feet

The fact that the actual velocity factor of a piece of coax can vary by as much as 10% from the manufacturer's published figures is why we said we would arrive at the approximate distance from the TDR to the open circuit.

The actual length of the coax under test was 85 feet, 4 inches.  So our calculated distance was some nine inches away from the actual length.  However, that is less than a 1% error, and certainly would get us quite close to any problem in our coax.

Now use a short piece of wire, like a cut-off part lead, to short the center contact of the free end of the coax to the shield.  You should see a waveshape like this one below.




Here is a photo of an actual scope trace with a short at the length of the coax being tested.

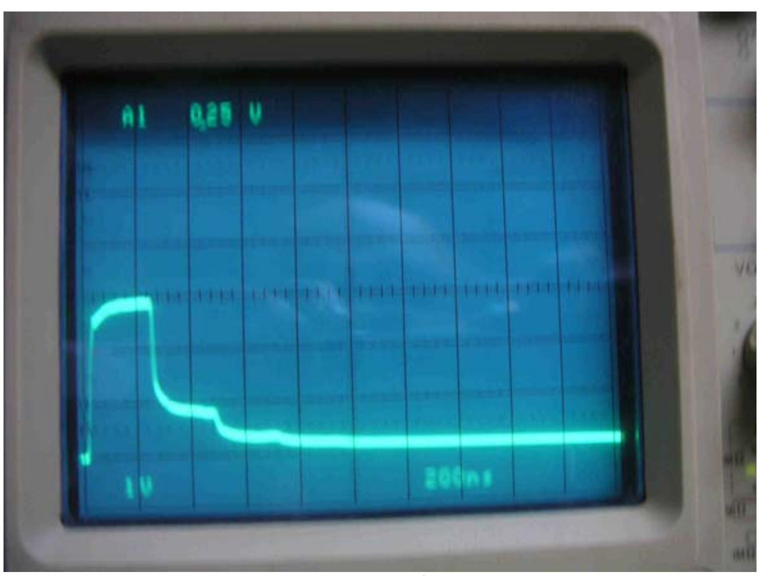



Photo courtesy of K7RXV

The physical length of the coax from the TDR to the short circuit is represented by the length of the trace between the top of the initial rise of the waveshape and the point where it dips sharply downwards.

After having looked at the waveshapes produced by 50 Ohm loads, open circuits, and short circuits, and calculating the distance from the end of the coax that is connected to the TDR, using the distance "A" and the time base of the scope, you will begin to get a real handle on what a good run of coax looks like.

An impedance bump will show up as a smaller version of one or the other errant waveshapes.

Remember that a 50 MHz or higher bandwidth oscilloscope will give much better resolution for testing short coax lengths.  A 20 MHz scope is sufficient for longer runs.

## In Summary

Now that you have a pretty good idea of how to go about using the various sections of the HF Test set, I would like to suggest that you take the time to make RF voltage readings in various parts of at least one of your QRP rigs, as well as learning what to expect when RF from the Crystal Oscillator or the Wideband Noise Generator is injected into the various stages.  And, also learning what to expect in the audio amplifier section when you inject the signal from the Audio Oscillator.

Take Frequency readings from the tank circuits of a VFO, note the frequency, and then remove the Frequency Counter leads from the circuit and tune a general coverage receiver in the vicinity of the frequency recorded, so as to see for your self how much the stray inductance and capacitance of the test leads pull the oscillator.

The combination of the individual pieces of test equipment in the HF Test set should give you the necessary tools both to test and troubleshoot radio circuitry and to learn more about how the various sections of a rig work together, by seeing for yourself what the various signal levels throughout the rig really are.

I would like to take the time here to thank Roger Steyaert, K7RXV, and Song Kang, WA6AYQ, for being beta builders and evaluators of the HF Test Set.  And, once again I would like to thank Wes Hayward, W7ZOI, Rick Campbell, KK7B, and Bob Larkin, W7PUA, for that goldmine of technical information, Experimental Methods in RF Design.

Enjoy,

Wayne  NB6M

[i] Experimental Methods In RF Design, Hayward, Campbell and Larkin, ARRL, 2003, Page3.19
[ii] Experimental Methods In RF Design, Hayward, Campbell and Larkin, ARL, 2003, Page 3.18-3.19