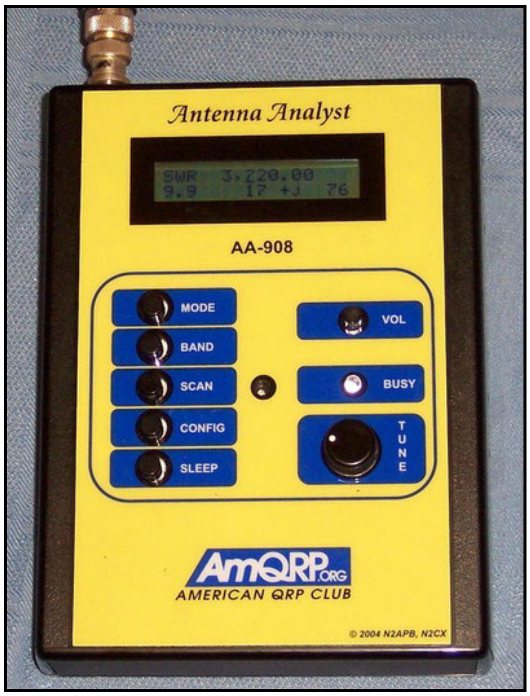
~ Technical Reference Manual ~

Micro908 Antenna Analyst

Revision 4.0

(Corresponds to AA908 software, version 4.0 and beyond)



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1.0 OVERVIEW

The Micro908 Antenna Analyst is a quality measurement instrument that determines antenna system performance across the amateur bands through use of automatically collected SWR and complex impedance readings. It was designed to be easily operated on the bench as well as in-hand while portable. The analyzer is comprised of a single printed circuit board containing all components, connectors, controls and a 2 row by 16 character liquid crystal display (LCD). The enclosure holds an 8-cell AA battery back enabling convenient field use.

The Antenna Analyst utilizes a powerful 8-bit microcontroller to instruct a Direct Digital Synthesis (DDS) integrated circuit to generate RF signals from 1.8 MHz to 30 MHz. The DDS generates extremely precise and accurate signals that give the Analyst the ability to also serve as a stable RF signal source for testing and basic network analysis. The low-current 68HC908AB32 microcontroller also handles the user interface of an LCD, pushbuttons and rotary encoder to allow full control of the instrument. The “field-programmable” feature allows the user to download new or updated software from the Micro908 website and load it into the Antenna Analyst.

The figure below shows the block diagram of the Antenna Analyst.

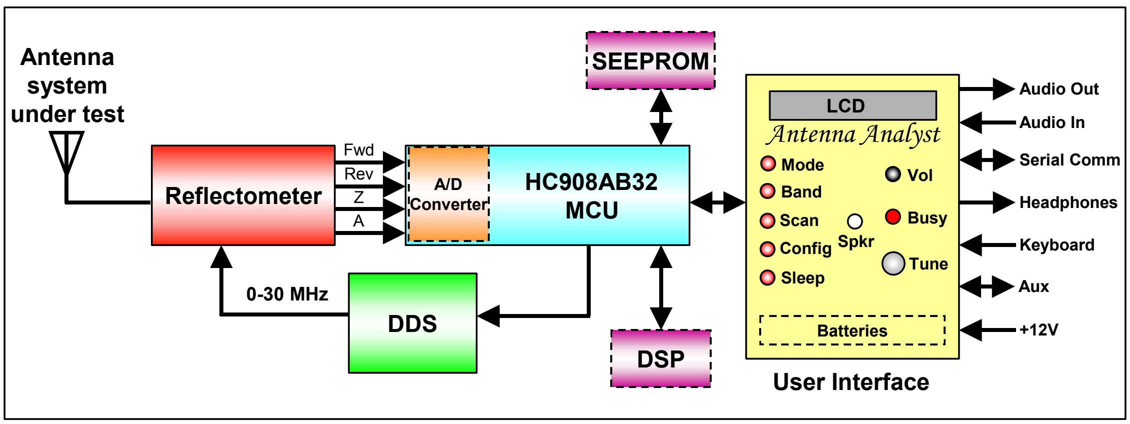


Figure 1 – Block Diagram of the Micro908 Antenna Analyst

A very low power transmitter is swept across selected frequencies by a microcontroller. The transmitter's signal is delivered to the antenna system through a reflectometer consisting of an absorptive SWR bridge using diode detectors and compensated buffer amplifiers. The data provided by the reflectometer are digitized and used by the microcontroller to compute SWR and impedance values. The microcontroller retains the frequency and corresponding results throughout the measurement period.

During this measurement period, the microcontroller rapidly displays the individual frequency and SWR values on an LCD. When all data are collected the microcontroller statically displays selected frequencies and the associated SWR readings.

Thus, with a press of a button the Antenna Analyst is able to automatically and quickly determine and display the frequency for which the antenna system is best matched, along with the associated complex impedance values at those frequencies.

Manual operation allows the user to control the band/frequency of operation while viewing the display of SWR results.

The Antenna Analyst also serves as a simple frequency source in manual mode. This signal may be used in troubleshooting RF equipment.

The Antenna Analyst is designed to be field-usable and operator friendly. The handheld form factor lends itself to convenient operation while away from the bench by means of pushbutton controls along the left top side of the unit. The operator is able to easily select the various modes and options with the left hand while making frequency with the right hand. The RF connector is located at the top of the instrument to provide convenient connection to the antenna system being measured. The external power jack and the power switch are located on the side of the instrument. The unit can be battery operated and the enclosure was selected to hold eight AA cells.

2.0 FEATURES

- Automated, microcontrolled antenna SWR analyzer
- A powerful 8-bit microcontroller (Motorola 68HC908AB32) controls all aspects of the operation
- A precision low power DDS signal generator (Analog Devices AD9850) is used as rock-solid signal source
- Precise and self-calibrating reflectometer design measures forward and reflected signals and impedance data
- Automatic scanning results displayed as frequencies of lowest SWR and complex impedance
- Configurable frequency scanning limits and step sizes
- Manual control option displays SWR and complex impedance at selected frequencies
- Audible tone indicates resonance – lower the tone, lower the SWR. (May be enabled/disabled.)
- Instrument Capabilities:
  - Measure antenna electrical parameters: SWR, impedance (resistance + reactance), capacitance, inductance
  - Measure feedpoint impedance
  - Measure ground loss
  - Adjust antenna tuners and determine loss
  - Measure inductors and capacitors:
  - Measure coax transmission line (SWR, length, velocity factor, approximate Q and loss, resonant frequency, and impedance)
  - Measure and determine optimum settings for tuning stubs: SWR, approximate Q, resonant frequency, bandwidth, impedance
  - Determine characteristic impedance of transmission line.
  - Determine length of ¼ and ½ wave phasing lines.
  - Coaxial Cable Loss
  - Determine antenna tuner loss
  - Measure balun loss.
  - Measure inductor Q
  - Estimate quartz crystal parameters
  - Measure magnetic loop resonance and SWR.
- Serial port connects to PC for field-upgradable software
- Serial port connects to PC for uploading and display of measurement data
- Battery-operated for convenient field use, or can use external 12V for bench operation

3.0 SPECIFICATIONS

- Frequency Generation & Control:
  - 1 - 30 MHz
  - Source Impedance: 50-Ohms
  - Stability: +/- 100 ppm
  - Spectral Purity: Harmonics down >-35 dB beyond 30 MHz
  - Step Size: User configurable increments of 100 Hz, 1 kHz, 10 kHz, and 100 kHz
- Usable Measurement Range:
  - SWR: 1.0 to 9.9
  - Impedance: approx. 5 to 600 ohms
- RF Output:
  - 2.0 Volt p-p (minimum)
- Power Supply:
  - External: 9-to-13.6 Volts DC
  - Internal: Eight AA-cells, alkaline or NiMH
  - Current Requirements: 220 ma (typical)
- Controls:
  - Pushbuttons (5): “Mode”, “Band”, “Scan”, “Config”, “Sleep”
  - Rotary Encoder: “Tuning”, 24-position/rotation
  - LED: “Busy”
  - Switch: “Power On”
- Connectors:
  - External Power: 2.1mm coaxial power plug (center pin positive)
  - RF Out: BNC
  - Serial Port: DB9F, RS232
- Environmental
  - Temperature: 0-70C
  - Humidity: 0-100% RH

4.0 SWR ANALYZER BASICS

The heart of the Analyzer is a simple reflectometer consisting of simple passive components. A simplified schematic diagram is shown below in Figure 2.

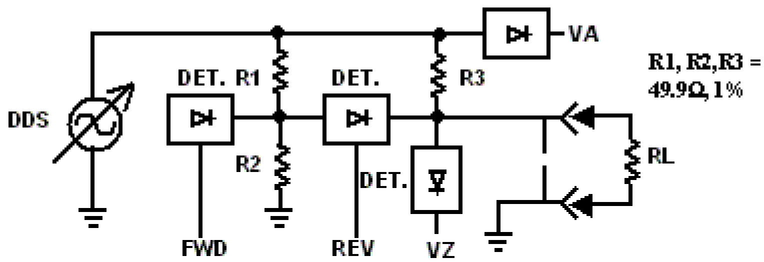


Figure 2: Conceptual analyzer bridge schematic

Resistors R1, R2 form the left-hand side of the bridge, and R3 and the load to be measured RL form the right-hand side. A clean sine wave at the test frequency is applied from the DDS and divides equally across R1 and R2. If RL is exactly 50 ohms (well actually 49.9 ohms) the input will also divide equally across R3 and RL. Thus the net voltage across the center of the bridge will be zero. This is known as a balanced bridge condition. If RL is larger than 50 ohms the voltage at the center of the right hand bridge leg will rise to a level of above half the input voltage while the value at the center of the left hand leg remains unchanged. The voltage difference across the bridge center is then non-zero. Similarly if RL is smaller than 50 ohms the difference voltage will again be non-zero.

You can think of RL as a load in a 50-ohm system. As it turns out, the bridge imbalance can be directly related to the load mismatch. Specifically the voltage at point A is proportional to forward power from the DDS and the difference voltage across the bridge is directly proportional to the reflected voltage. Check out recent editions of the ARRL Antenna Book for more detailed description of the circuit operation. It also helps to calculate the voltages at these points for several known conditions. Let's try RL of 100 ohms then 16.67 ohms.

With 2 volts input the voltage at A will always be 1 volt. VA for RL of 100 ohms is 2*100/(100+50) or 1.33V giving a voltage difference magnitude of 1.333 -1 = 0.333V across the bridge center. The ratio of these is 0.333/1 = 0.333. When this is plugged into the familiar SWR formula we get S = (1+.333)/(1-.333) = 2. Intuitively you can see that this is just the 2:1 SWR we would expect for a 100-ohm load in a 50 ohms system.

Doing the same thing for RL of 16.67 ohms gives us again 1 V at A but 0.5 V at B. The ratio is 0.5/1 = 0.5 for S = (1+ 0.5)/(1-0.5) = 3 confirming the 3:1 SWR from the 16.67 ohm resistor.

Try the same thing with loads of 25 and 150 ohms to convince yourself that it really works!

The RF voltages are converted to DC values by simple diode detectors. The voltage at A gives rise to a DC FWD voltage and the bridge difference voltage is produced at REV. Note that the REV detector measures the difference voltage directly by virtue of its connection across the bridge center. Thus it measures the difference voltage taking the relative phases of the two voltages into account.

For the resistive example above, the phase differences will be zero. However antenna loads are generally not pure resistance. The fact that the difference detector takes phase into account allows the bridge to accurately provide a reflected voltage sample regardless of whether or not the load is resistive or a complex impedance. Verification of this is left to the interested student.

There are two other detectors that we have not yet talked about. Both are on the right hand of the bridge, one across the top right hand resistor R3 and the other across the test connector so that it sees the voltage across the load RL. They measure the voltage magnitudes across their inputs. The detected sample across R3 is called VA and the sample of the output load resistance (actually impedance) is called VZ. The ratio of the magnitudes of these two voltages is equal to the ratio of the resistance of R3 and the impedance of the load across the test connector. Using the 100-ohm resistive load above and the input of 2V, we get 0.667 volts across R3 and 1.333 volts across RL. The impedance (in this case resistance) is then ZL = R3*VZ/VA = 50*1.333/0.667 = 100 ohms.

As with the SWR example we have resorted to pure resistors to show numerically how the calculations can be done. However the same process works with complex impedances where RL will actually be a load impedance ZL which mathematically is SQRT(R^2 = X^2) where R is the real part of the impedance and X is the reactive part. If you want to prove this to yourself please use a simulation tool like SPICE or the algebra will take the better part of a Saturday afternoon.

The basic equations used by the analyzer for these computations are:

SWR = (FWD+REV)/(FWD-REV)

Z = 50 * VZ/(VA)

And further, an estimate of the resistive and reactive parts of Z can be determined.

R = (2500+Z^2) * SWR/(50 * (SWR^2 + 1))
X = SQRT (Z^2 – R^2)

Note that in the above equations the only inputs are DC measurements so the computations are straightforward – no messy complex algebra or trigonometry involved!

More information can be obtained about the values already calculated. What we don't have is a determination of whether the X we just calculated is inductive or capacitive. We can tell this by moving the DDS frequency slightly and observing how Z changes. Since capacitive reactance decreases as frequency increases and inductive reactance goes the other way all we have to do is moved the DDS frequency slightly above and below the selected point and observe the results. This "diddling" technique generally works well except where the load being measured has a sharp resonance, so beware if you are measuring quartz crystals or magnetic loop antennas.

If the impedance is capacitive, the usual capacitance formula can be used to determine the effective capacitance C = 1/(2 * π * F * X). Similarly inductance is L = X / (2 * π * X). Note that is SWR is infinite that means that the impedance is all reactive so the load being measured is a pure inductor or capacitor.

Several additions are made to allow the equations to be accurately implemented in a program. The first is the use of a variable called "SCALE". In our examples above we assumed a DDS voltage of 2 volts. The analyzer's DDS will approximate this value but component variations, etc. may affect it slightly. In order to ensure arithmetic accuracy, we want to normalize the measured voltages to values where FWD is close to the maximum that can be represented the number scheme used. Initially the analyzer will use 8-bit arithmetic so FWD will be normalized to a value of 255. To do this the program first measures the FWD DC voltage and determines a value for SCALE that when multiplied by it will result in a new FWD value of 255. Further SCALE will be used to adjust REV and VZ accordingly.

Second, efforts were made to ensure that some error in measurement doesn't confuse the analyzer. Ideally REV and VZ should be in the ranges we expect and large enough to perform accurate calculations. However should they somehow get so large or small that accuracy would be drastically impacted, we incorporate LIMIT CHECK routines to be sure that they are in the expected range. Although not shown, the LIMIT CHECK fails the program will not proceed and will give an error indication to the operator. The elementary routines used to calculate L and C are not shown either.

5.0 THEORY OF OPERATION -- HARDWARE

Referring to the schematics at the end of the manual, a block-by-block description is next presented.

68HC908AB32 MPU

The Motorola 68HC908AB32 is the most popular 8-bit microcontroller in the world, with a tremendous amount of support libraries, tools and applications available for reference. This HC08-class device MPU has lots of memory and I/O, and peripherals like counter/timers, asynchronous serial ports, and A/D converters making it a powerful and flexible controller of the Antenna Analyzer.

The control software supplied in the Analyzer allows for easy software updates to be made by the user. Software updates may be easily downloaded from the Micro908 website for loading into the instrument. No need to return the unit to the factory for bug fixes or for adding new features when they become available!

A MAX-232 RS-232 line driver chip is used for serial communications with the PC, used in delivering software updates to the instrument.

A small surface mount LED serves as a “heartbeat” indicator under program control during normal operation of the board. The Antenna Analyzer application blinks this LED at a regular rate to indicate that the board and software are operating properly. The board is in “monitor mode” when running the Boot Loader program and the LED is turned on all the time.

This microcontroller serves as the heart of the Antenna Analyzer. It was helpful to select such a CISC (complex instruction set controller) instead of a low-end RISC (reduced instruction set controller) like those in the Microchip PIC family. The software designed to control the many peripheral chips and I/O functions would be present great programming challenges in a RISC device because of inherent program memory and register memory addressing restrictions. The 68HC908 is the Motorola equivalent of the popular 8051-class of processors from Intel, SST, and others, offering plentiful I/O capabilities, unrestricted addressing space and high clock speeds.

Another deciding factor in the selection process was the massive amount of I/O pins available for controlling various hardware peripherals typically used in instruments like the Antenna Analyzer – LCD displays, DDS chips, pushbuttons, LEDs, serial port, et al. Eight separate I/O ports provide up to 51 general purpose input and output pins. Many of these pins are software configurable to serve as analog interfaces, contain integrated pull-up resistors, and couplings to the interrupt structure of the processor.

Working in conjunction with the physical I/O pins, the 68HC908AB32 has some internal macro functions that greatly ease the programmer’s job. The MPU has built-in modules for asynchronous communications providing an RS-232 serial port, timer modules for frequency counting and timing, programmable interrupt timing for precise interval control, an 8-bit/8-channel A-to-D converter, a keyboard interrupt module, and a watchdog timer. This microcontroller is really quite amazing and is perfect for use on the Antenna Analyzer.

Plentiful memory is a must for a CISC microcontroller being used in a large application such as with the Antenna Analyzer. The MPU has 32 kilobytes of flash memory that will hold the software program. There is 1 kilobyte of RAM space available for data variables and other time-changing data. The controller also has 512 bytes of EEPROM (electrically erasable programmable read only memory) that is used to store user-set configuration, calibration and custom string data that is used every time the Analyzer is turned on.

From a software perspective, the MPU supports the enhanced Motorola HC08 programming model. It has 16 addressing modes (direct, indirect, indexed, etc.), a 16-bit index register and stack pointer, and extensive loop controls (e.g., BRCLR n). It supports memory-to-memory data transfers and can perform fast 8x8 bit multiplication and 16/8 division. These last two capabilities will prove quite valuable when it comes to scaling input values and calculating SWR, power, and filter coefficients. Finally, the microcontroller’s hardware and software architecture is optimized for controller applications and for C-language support with the free MetroWerks “Code Warrior” package.

Boot Loader Program

A boot loader program was developed to support field updates of the software program running in the Antenna Analyzer. The operator interfaces a PC to the instrument by means of a serial cable, and a terminal program running on the PC presents a “Software Update” function to allow re-programming of the Analyzer while in the field.

An important goal in designing the Antenna Analyzer was to be able to have the user easily update the software running on the after the unit was manufactured and deployed to the field. The MPU has ample onboard flash memory, making for a non-volatile project. That is, the microcontroller retains its program memory even when power is removed.

The 68HC908AB32 MPU has the ability to be in-circuit programmed, which means that a conventional +5V power supply and proper timing is all that's required in order to burn a new program into its flash memory. A special boot loader program was developed that allows the customer to download the binary image of a new program over the built-in RS232 serial data port connected to a PC. In order to install an updated version of the Antenna Analyzer software, all the user needs to do is download the updated program from the Micro908 website to the local PC, then connect the Analyzer to the serial port of the PC and invoke the Update Software command.

Most "dumb terminals" may be used to communicate with the Analyzer’s boot loader. A useful public domain (freeware) terminal program called "Tera Term" is available to run on Microsoft Windows platforms. Tera Term has a convenient scripting ability that can be invoked to send an S-record file (like a new software program) to the Analyzer for flash programming by the Boot Loader.

DDS Signal Generation

An Analog Devices AD9850 DDS chip is programmed by the 68HC908AB32 microcontroller to generate signals ranging from 0.0001 Hertz to 30 MHz. The stability of the 100MHz clock oscillator module X1 determines the ultimate stability of the generated RF signal. The 5^{th}-order elliptic filter limits the high-end sampling artifacts, and the MAR-4SM RF amplifier U2 boosts the raw 200 mV p-p DDS signal to a more usable 3-volt level.

The AD9850 contains a 32-bit phase accumulator, a 14-bit lookup table and a 10-bit D/A converter. It can be clocked at 125 MHz to produce a 41 MHz sine wave output, although a 100 MHz module is used to generate a maximum usable frequency of 30 MHz, which extends up to the top of the common HF spectrum of interest to hams.

A 40-bit control word is serially loaded into pin 25 using pin 7 as the data write clock. By toggling pin 8 the input register is shifted to the DDS core. The 40-bit control word contains a 32-bit frequency, 3 control bits and 5 phase modulation bits. These bits determine the generated frequency and some software calculation guidelines provided in the AD9850 data sheets.

The output of the AD9850 is supplied as a differential current signal on pins 20 and 21. A resistor placed from pin 12 to ground determines the full-scale output current for the D/A converter. Setting the resistor to 3.92K-ohms yields a D/A converter current of about 10.2 mA and a voltage swing of about 250-mVpp into a 50-ohm load.

The output of the DDS is a digitized sine wave. Such a wave shape has strong frequency components at the reference clock frequency plus or minus the output frequency. Filtering out these components produces a clean sine wave. Using a clock frequency of 100 MHz, and thus a maximum output frequency of 30 MHz, the low pass filter must cut off frequencies above 70 MHz while passing frequencies below 30 MHz. A fifth-order elliptic low pass filter used in this circuit has a 55 dB or greater attenuation at the higher frequencies.

Once the 40-bit control word is serially loaded into the DDS, the raw waveform is generated and presented to an elliptic filter that removes unwanted high-end frequency components, resulting in signal of sufficient quality to serve as a local oscillator for a transceiver. Refer to the AD9850 data sheets for signal purity specifications. This peak-to-peak signal is typically only about 200 millivolts, so we use a 13 dB MAR-4SM amplifier to boost that signal to about 2.5-V p-p, which is quite usable in a variety of applications. The amplified signal is then presented to the Reflectometer module.

REFLECTOMETER

The reflectometer module is a basic absorptive SWR bridge driven by the computer-controlled DDS frequency source, whose output in turn drives an antenna system. The analog outputs of the SWR bridge are digitized by the built-in A/D converter on the 68HC908AB32 microcontroller. The antenna analyzer function is performed by sweeping the DDS frequency across a given ham band and computing the SWR of the antenna system at various points along the way. **Figure 2** illustrates this system.

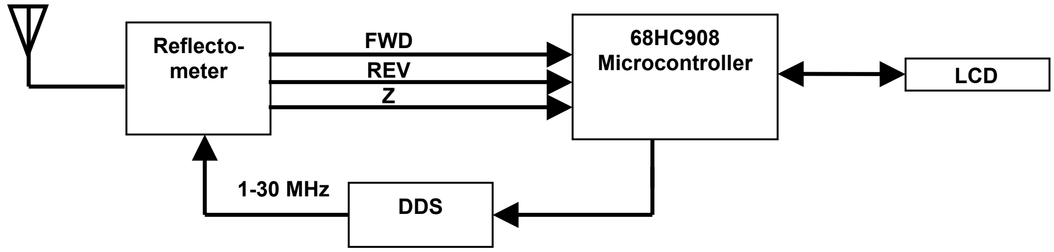


Figure 2: Block diagram of the SWR measurement system

SWR Bridge & Diode Detector -- Referring to **Figure 3**, a Wheatstone bridge is composed of 50-ohm resistors with the antenna as the "unknown" leg of bridge. When the antenna is at resonance, presenting a minimum impedance with a pure 50-ohm resistive "real" component, the bridge is balanced and the AC voltages on each side of the bridge are identical. No AC current flows between the legs.

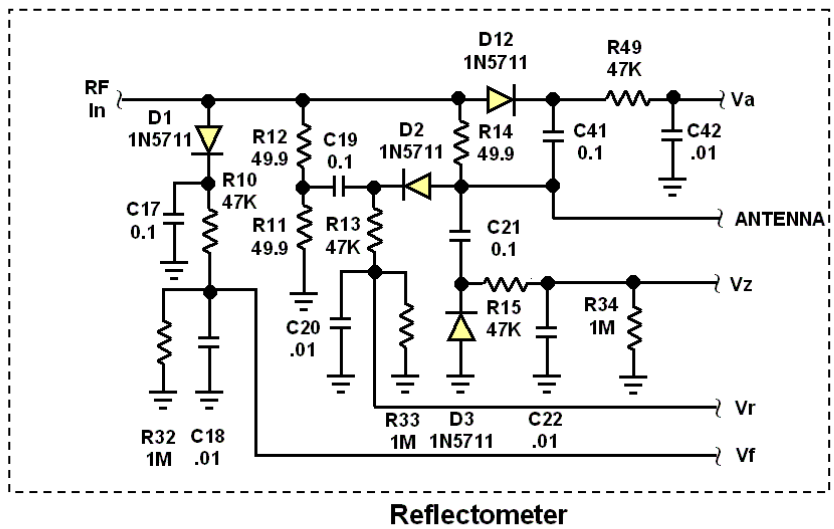


Figure 3: Schematic of the SWR bridge and diode detectors

However when the antenna system is not resonant, the complex impedance of the antenna is not 50-ohms but something greater, which creates a bridge imbalance. The 1N34 diode samples that AC signal imbalance, rectifies it, and after filtering, the DC signal is directly analogous to "reflected" sample of more familiar SWR bridges. We then sample the "forward" power using another diode detector on the original incoming signal.These forward and reflected DC signals are presented to the next stage for compensation, buffering and amplification.

Buffer Amp -- There are two reasons for employing the op amp circuits in **Figure 4**. The first amplifier in each path (FWD and REV) compensates for the nonlinearities in the diode detectors when the bridge is operated at very low power levels. These first stage op amps employ 1N5711 diodes in their feedback paths to counteract these nonlinearities in the bridge diodes. This action essentially moves the natural knee of the curves closer to zero, thus improving the accuracy of the readings FWD and REF readings ultimately presented to the A/D input on the microcontroller.

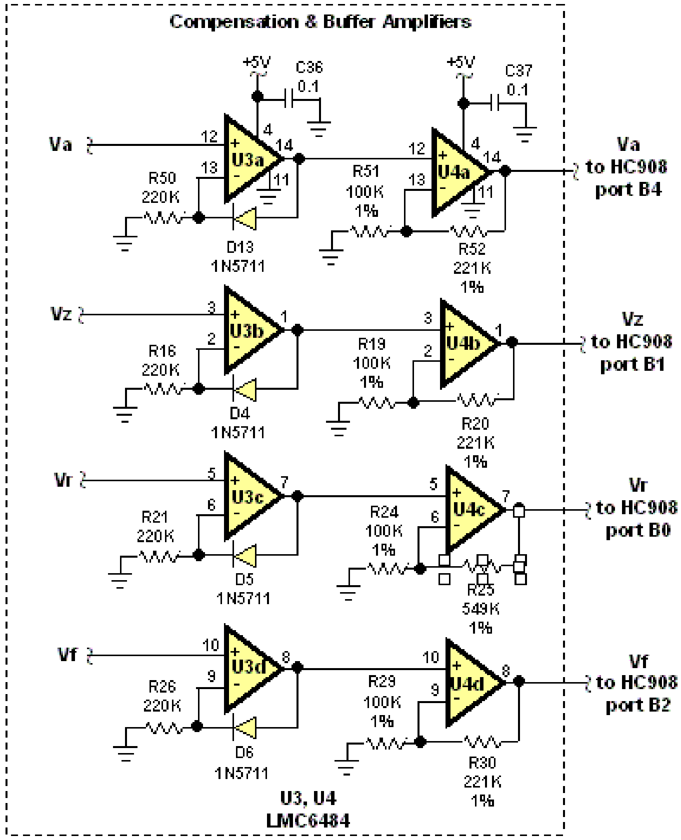


Figure 4: Schematic of the LMC6485 buffer amp.

The second purpose for the op amps is to amplify. The DC signal levels coming from the bridge, and through the unity gain of the first compensation stage, are fairly low. In order to make the most use of the 8-bit A/D, we need to amplify the detector voltage up to the 5V range of the A/D. Further, the output of the op amp circuits is quite low which provides a better condition when presenting signals to the 10K input impedance of the A/D. (The output impedance of the diode detectors themselves is approximately 100K-ohm. If those signals were directly input to the A/D, they would be greatly affected by the lower impedance of the A/D.)

Liquid Crystal Display

The design uses an inexpensive 2-line by 16-character/line device to display status and measurement information to the user. The software driver for this display assumes that a common HD44780 controller-based LCD is used, so one could actually use larger or smaller LCDs fairly easily instead of the specified one.

Rotary Encoder

A rotary encoder provides ultimate flexibility to the operator as a continuous rotation menu selector, numeric dial setting, frequency tuning, and so on.

Power Supply

Finally, room is provided within the Antenna Analyst enclosure for an eight-AA cell pack, thus providing portable power for the field use of the unit.

6.0 THEORY OF OPERATION – SOFTWARE

The real heart of any given project running on the Micro908 hardware platform is the software controlling it. The system components are controlled and operated in unison to create a fine-tuned measurement system. Let's walk through the program logic a bit to see how things are accomplished.

The main operation of the Antenna Analyst is achieved as a sequence of six basic operations that repeatedly occur within in the main program loop …

- Set the DDS frequency
- Display the frequency on the LCD
- Read the analog signals from the reflectometer
- Compute the SWR and impedance
- Display the values for SWR, R & X
- Store the results in list for post-processing

When the scan is complete, the program analyzes the list of scan data to determine antenna resonance, or the frequency of the minimum data point.

Setting the DDS Frequency

The DDS frequency, phase and control bits are serially delivered to the device via three I/O lines coming from the 68HC908: data, clock and load. Per the details provided in the AD9850 data sheet, the 68HC908 delivers these 40 bits of programming information by repeatedly setting the data line to the desired value, and toggling the clock line in order to move the data bit into the DDS chip. After 40 such bit clocks, the load line is toggled which instructs the DDS chip to put that 40-bit programming word into effect. At that point, the output of the DDS changes and the new frequency is present on its output.

Display Frequency on LCD

The frequency is displayed to the LCD by placing the binary coded decimal (BCD) value of each digit into seven sequential locations LCD_dat+0 through LCD_dat+6. These digits represent the 10 MHz position through the 10 KHz position in the frequency display. The LCD driver routines take these BCD numbers and display them to specific locations in the LCD memory, thus making them appear on the display itself.

The numbers contained at these locations represent the start of increment/decrement functions (used in scanning), and in subsequent calculation of the DDS programming 40-bit word (used in setting the DDS frequency.)

Read Analog Signals

The forward voltage FWD, reverse voltage REV, impedance voltages VZ and VA are read as 0-5V analog signals by the A/D converters built into port D of the HC908. These 8-bit converters quantize the analog signal to one of 256 values, based on the analog signal presented on the respective port B input pin. Thus a granularity of 19.531 mV is achieved. This level of precision is entirely adequate for determining even the low-end knee of the diode detectors primarily because of the compensation diode placed in the second op amp circuit for each signal path.

Compute the SWR, Z, R & X

Using measured values to calculate SWR means that instrument is self-calibrating. This is a good thing in test equipment! The following simple equations are coded in the software, using the FWD, REV, VZ and VA signals read by the A/D.

SWR = (FWD + REV) / (FWD – REV)

$Z = 50 * VZ/(VA)$

$R = (2500+Z^2) * SWR/(50 * (SWR^2 + 1))$

$X = SQRT (Z^2 – R^2)$

Store the data in list

Each frequency sample's computed SWR and impedance value is stored in a list in Serial EEPROM memory for processing at the conclusion of the scan.

7.0 OPERATION

1) Power On -- Upon applying power, the unit will show the following Home Display:

Ant Analyst v1.3
Select Function

- The heartbeat LED, as seen through the small hole on the rear of the instrument, will continuously blink, indicating that the program is running properly.

2) User Interface

The user interface consists of five pushbuttons, one for each instrument "function" as described in the next section, and a rotary "dial" that is used to select various options presented in a menu-like manner. You use the function pushbuttons and the dial in a similar manner to operate the Antenna Analyst: by pressing a function button and rotating the dial you are able to see the options for that function sequentially displayed on the LCD. Once you see the desired option or operation on the LCD, you may select it by pressing the dial pushbutton.

3) Function Selection

You have the choice of doing four things, listed in the order of normal usage.

a) Band -- Pressing BAND pushbutton will present four band options: 1-10 MHz, 10-20 MHz, 20-30 MHz, and "Custom Band". Once you have dialed in the range that you wish to automatically scan, press the dial pushbutton to select it. You will then exit back to the Home Display. (The Custom Band is a user-specified start/stop frequency pair, set under the Configuration function, that allows the user to specify a custom frequency range for scanning.)

b) Scan -- Pressing the SCAN pushbutton will automatically sweep the Antenna Analyst test signal across the Band range previously selected, incrementing from the lower limit to the upper limit, in steps of either 100 Hz, 1 kHz, 10 kHz, or 100 kHz, as set in the Config menu. The red BUSY LED is turned on and the following message is displayed during the Scan:

~~Scanning~~
(please wait)

The four reflectometer signals (Vf, Vr, Vz and Va) are sampled after each step change and are used to calculate the SWR and impedance at each frequency step. Each SWR value is compared to previous values in order to determine if a minima, or a "dip", has occurred at this point in the scan. If so, that data point is stored for later display. The Scan takes approximately 6 seconds at the 1 kHz step rate. At the end of the Scan, the collected the points of minimum SWR are displayed in the following manner:

c) Mode -- Pressing the MODE pushbutton will present two modes of possible operation: "MANUAL", and "REMOTE". Pressing the dial pushbutton will select the desired mode.

- **Manual --** This is the fun mode! You can selecting this mode by pressing the dial pushbutton and you will see the following display:

  10,345.00
  2.1 0049 +j 023

  - The top line indicates the frequency at which the SWR minimum is found.
  - The left value is the SWR. In this case it is 2.1:1.
  - The middle value is Resistance, the real part of Impedance. In this case it is 49-ohms.
  - The rightmost value is the Reactance, or the reactive part of Impedance. In this case it is 23-ohms inductive. (Capacitive reactance would be indicated as a negative number.)

In the Manual mode, you have the ability to manual adjust the Frequency and see the SWR, Resistance and Reactance values at whatever frequency is dialed up.

Frequency is changed by adjusting a single digit indicated at the point in the display where the cursor (_) is. Upon initial entry, the 10 kHz digit is the adjustment point, as shown by the digit with the cursor in the display above.

To move the cursor to a different digit to be adjusted, press the dial pushbutton simultaneously while turning the dial. The cursor will move to any of the seven available digits, allowing subsequent up/down adjustment of that digit with the dial pushbutton is released.

Rotating the dial clockwise will increase the digit value and, correspondingly, the signal generated by the unit. Counter-clockwise rotation will decrease the digit and the generated signal.

When the digit is incremented past 9, or when it is decremented past 0, the digits above the selected adjustment point are rolled up or down, respectively.

Using this frequency adjustment scheme, the user can conveniently pick an "increment" digit and manually scan frequencies with the desired granularity. Rough scans can manually be done by positioning the cursor under the 100 kHz digit or the 1 MHz digit, giving a wide and course scan of the frequencies with a quick twist of the ENCODER dial. The signal frequency can then be set to the area of interest and the cursor set to a lower granular digit (e.g., 10 kHz or 1 kHz) in order to manually perform a detailed scan while watching displayed results for SWR, Impedance and Reactance.

An audio tone is generated when turning the dial in Manual Mode. When you approach a resonance (i.e., an SWR "dip"), the tone lowers according to the SWR. Thus the operator will have an audible indication of when minimum SWR is found. The tones may be enabled or disabled in the Config menu, and the setting is saved in nonvolatile EEPROM so the selection stays in the unit when power is turned off.

To exit the Manual mode and return to the Home Display, press the Mode pushbutton.

NOTE: Although the Antenna Analyst may be adjusted to produce signals as low as 10 Hertz, the practical lower limit of the unit is about 1 MHz due to the coupling capacitors used in the internal circuitry. The upper limit of the unit is restricted to 30 MHz, as this is the highest pure frequency safely obtainable from a DDS clocked at 100 MHz.

- **Remote –** This mode allows the PC to remotely control the Antenna Analyst, record each data measurement, and display the data in graphical manners. *[This section needs further description.]*

d) Configuration-- Pressing the CONFIG pushbutton presents sub-displays to allow setting of configurable settings for the Analyst. Press the dial pushbutton when the given operation is displayed in order to select the desired mode.

- **Set Scan Step Size** – This function allows the user to select the step size to be used for the Scan operation. Available step sizes are 100 kHz, 10 kHz, 1 kHz (default), and 100 Hz.
- **Set Custom Band Scan Limits** – This function allows the user to set custom limits for the Scan operation, thus providing a scan of targeted frequencies.
- **Enable Piezo Annunciator** – This function provides an audible tone whose pitch corresponds to the SWR being measured. This is useful in low-light conditions or by visually-impaired users. Additional tones and clicks are provided to signify control changes made on the Analyst.
- **Software Update** – This function provides for field upgrading the Analyst software. Whenever newer improved-capability software is available, the customer may download the binary file from the AmQRP website to his local PC. Then, with the Analyst connected to the serial port of the PC, this function will erase the current (old) program on the Analyst and burn the newly-downloaded program into the unit.
- **Diagnostics** – This function provides rudimentary operation of the system components to help the user assess operational status of the Antenna Analyst. The functions listed below are entered by means of

rotating the ENCODER dial until the desired function is displayed and then pressing the ENCODER pushbutton to select it.

- **Set DDS** – Commands the DDS to generate a 1 MHz signal. Exit this function by pressing the SCAN pushbutton.
- **Display Test** – Displays known data to both lines of the LCD. Exit this function by pressing the SCAN pushbutton.
- **Pushbutton Test** – Displays the state of each of the four pushbuttons as a '1' (pushed) or '0' (not pushed). The position of the 1/0 indication is relative to the position of the pushbutton itself. That is, in left-to-right order of display: Config, Mode, Band and Scan. Exit this function by pressing BAND and SCAN pushbuttons simultaneously.
- **Encoder Test** – Displays a two-digit number on the LCD ranging from 00 to 99 corresponding to the rotation of the ENCODER dial. Exit this function by pressing the SCAN pushbutton while turning the ENCODER dial.
- **Piezo-LED Beep Test** – The Piezo is beeped and the red BUSY LED is blinked at approximately 1 Hz rate. Exit this function by pressing the SCAN pushbutton.
- **Timing Test** – This development function puts the internal microcontroller into a very tight loop that is useful for timing measurement purposes. The only way to exit this function is to power cycle the Analyst.
- **Write EEPROM Test** – This function writes a known data string of 15 characters to EEPROM memory (i.e., non-volatile memory used for storing settings and saving collected data.). The known string is displayed on the LCD. Exit this function by pressing the SCAN pushbutton.
- **Read EEPROM Test** – This function reads and displays the first 15 locations of EEPROM memory. Use this function after using the Write EEPROM function and subsequent power cycling of the unit to verify the non-volatile nature of this memory. Exit this function by pressing the SCAN pushbutton.
- **Erase EEPROM Test** – This function clears all 512 locations of EEPROM data. Use the Read EEPROM function after this one to determine that the non-volatile memory has been cleared. Exit this function by pressing the SCAN pushbutton.
- **Debug Monitor** – This function is useful for development purposes and may be hidden in future versions of software. The Debug Monitor communicates with a dumb terminal connected to the RS-232 serial port on the Analyst to allow low-level software debugging with breakpoints, register inspection and modification, etc.
- **Exit Diags** – This function is used to exit the Diagnostic functions and return control back to the Home Display of the Analyst.

e) Sleep – This function is not yet available.

8.0 BASIC USES

The Micro908 Antenna Analyzer is an extremely useful instrument to have around any ham shack or homebrewer's workbench. The Analyzer is suitable to serve in the following ways:

Antenna measurements:

The antenna is simply connected to the analyzer antenna terminal and the analyzer is set to the desired frequency. The readout gives the resultant SWR, impedance, reactance and resistance. If the frequency is tuned across a ham band, the minimum SWR point (resonance) can be found as well as the SWR end points (usually 2:1) yielding the bandwidth of the antenna system.

Measure feed point impedance of antenna:

Connecting the analyzer directly at the antenna terminals or remotely through a half-wavelength of transmission line allows direct measurement of the antenna terminal impedance. This is often useful with vertical antennas.

A matching network can be connected to the antenna and then adjusted for best SWR on the analyzer.

Measure ground loss:

With short vertical antennas measuring the impedance directly at the feedpoint allows estimation of ground loss or loading coil loss. For example a ¼ wave vertical will have a resistance of about 36 ohms at resonance. Any higher reading indicates ground loss. Similarly shorter antennas (when resonated) will have lower resistance values. Reading a good SWR may mean excess loss and measuring the actual impedance allows gauging just how much loss.

Adjust antenna tuners:

The analyzer can be used to adjust an antenna tuner for a perfect match without the need to transmit a strong signal from the station rig. The analyzer uses only milliwatts of power lessening the possibility of causing interference.

Measure inductors, capacitors and tuned circuits :

The analyzer can measure the values of inductors and capacitors connected across its antenna terminal. Series resonance of a tuned circuit can be accurately measured. The series combination is connected across the analyzer antenna terminal and the analyzer is tuned for the lowest resistance. The frequency where this occurs is the resonant frequency.

Measure coax transmission line factors:

SWR, length, velocity factor, loss, resonant frequency, and impedance

Measure and determine optimum settings for tuning stubs:
SWR, resonant frequency, bandwidth, impedance

Measure and determine optimum settings for tuning stubs:
Resonant frequency

9.0 ADVANCED USES

The analyzer is an instrument that can be used for a number of uses well beyond simple SWR and impedance measurements. The following list presents some of these advanced uses.

Tuned Circuit Resonance

Resonance of a tuned circuit can be measured in several ways.

1. The most accurate method is to connect it as series resonant circuit by putting it in series with a non-inductive (carbon compostion or film) ¼ or ½ watt 51 ohm resistor as shown in Figure 1.
   Now connect this to J3 on the Analyzer and tune for lowest SWR.
   The frequency at which this is seen is the tuned circuit resonant frequency.

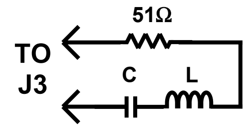


Figure 1

2. If the individual L and C are connected as a parallel resonant circuit and cannot be connected is series as above (for example an antenna trap) the parallel resonance can be estimated.   Connect the parallel resonant circuit as shown in Figure 2.

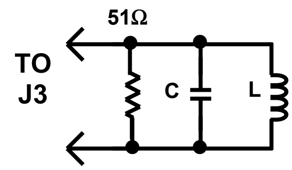


Figure 2

3. Connect the circuit to J3 on the Analyzer and again tune for lowest SWR. The measured frequency is slightly lower than the tuned circuit resonant frequency due to stray capacitance of the test setup.

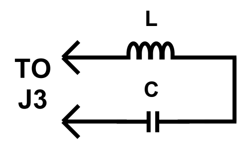


Figure 3

Inductor Q

The Q of an RF inductor can be measured with a very simple setup.
First measure the inductive reactance XL of the inductor and record this value. Now connect it to the Analyzer as shown in Figure 3. Capacitor C must be chosen to resonate with L at the frequency where you want to measure the inductor's Q. The Inductor and Capacitor Measurement section of this manual shows how this capacitor value can be determined.

Now tune the Analyzer for the lowest R (resistance) value with a reading of zero X (reactance). If R is above 10 ohms you can now calculate inductor Q using the formula:

$$O = \frac{XL}{R}$$

If R is less than 10 ohms a slightly different method needs to be used. In this case use the test setup shown in Figure 1. Adding the non-inductive (carbon compostion or film) ¼ or ½ watt 51ohm resistor allows more accurate measurement of the series resistance of the inductor.

Again tune the analyzer for lowest R (resistance) value with a reading of zero X (reactance). Next subtract 51 ohms from the measured R value and use This new resistance in the above formula to calculate the Q value.

Transmission line Stub Lengths

Measurement of quarter and half wave transmission line stubs can be performed regardless of the transmission line characteristic impedance. The method relies on the fact that an open-circuited quarter wavelength line or a short-circuited line acts like a precise short circuit at the chosen frequency of operation.

With either type of feedline first cut the feedline to about 10% longer than the desired length, taking the appropriate velocity factor into account. The velocity factor of common feedlines is available from manufacturer's literature or references such as the ARRL Antenna Book. If you cannot find the value or if you are using a custom type of feedline, the section in this manual titled "Velocity Factor Measurement" provides a way to determine this value.

The following formulas can be used to estimate the length of transmission line required.

For a half-wavelength stub the length is:

$$L = \frac{5904 * VF}{F}$$

Where L is the length in inches, VF is the velocity factor and F is the operating frequency in MHz for the stub.

Similarly for a quarter-wave stub use the formula:

$$L = \frac{2952 * VF}{F}$$

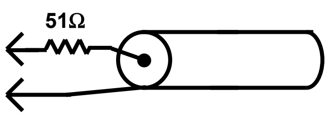


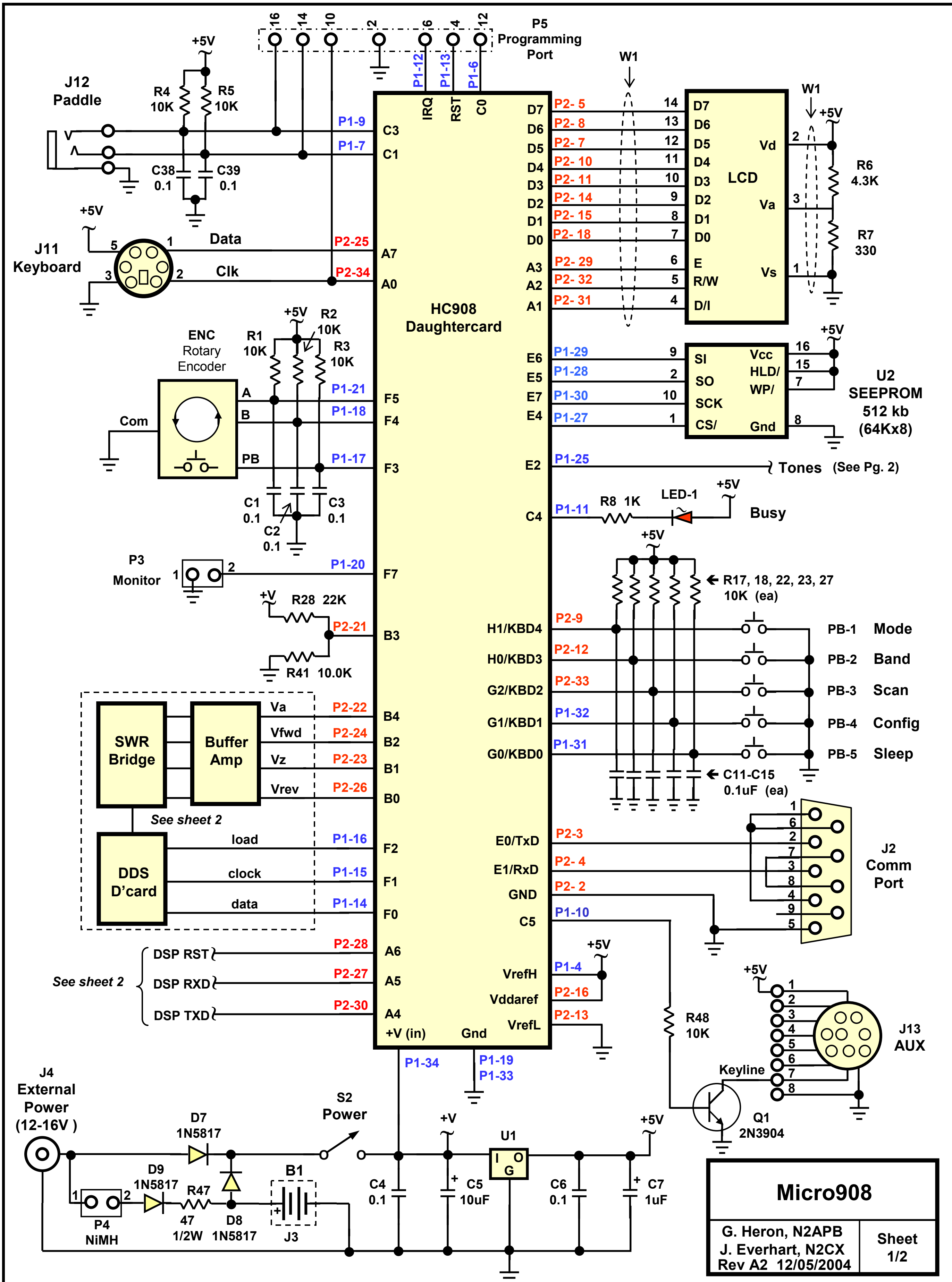
Figure 3

10.0 TECHNICAL ASSISTANCE

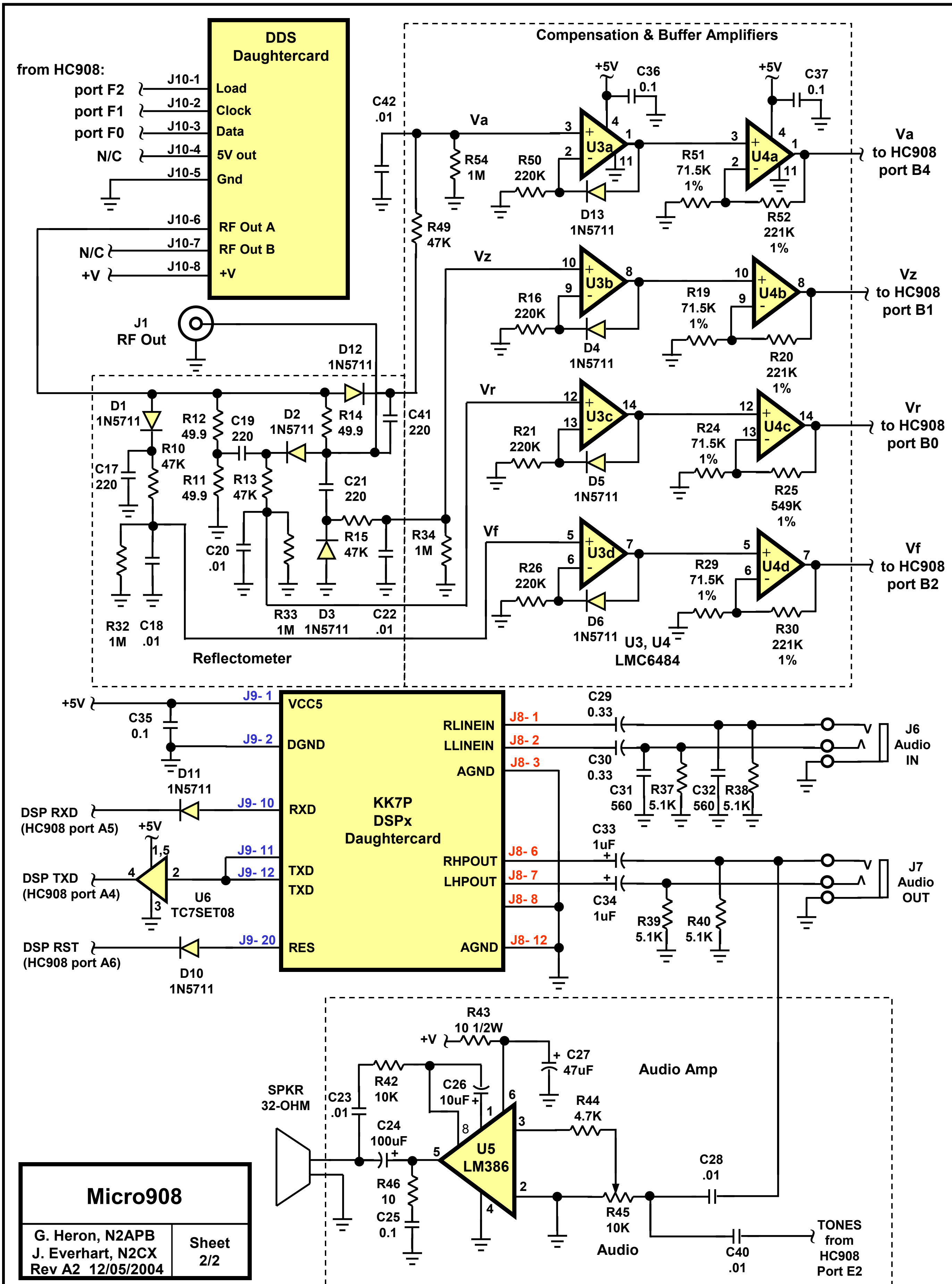
If you experience any problems with this instrument, or if you have any questions relative to its operation or specifications, please contact the designers: George Heron, N2APB (n2apb@amqrp.org) or Joe Everhart, N2CX (n2cx@amqrp.org). Be sure to visit the Antenna Analyst website at www.amqrp.org/kits/micro908 to check for Analyst product updates and other technical information

APPENDIX A: Schematics

See the following pages for the detailed schematic of the Micro908 Antenna Analyst.



P5
Programming
Port
16
14
10
2
6
4
12
P1-12
P1-13
P1-6
+5V
J12
Paddle
R4
10K
R5
10K
C38
0.1
C39
0.1
P1-9
P1-7
C3
C1
IRQ
RST
C0
+5V
J11
Keyboard
Data
Clk
P2-25
P2-34
A7
A0
W1
D7
D6
D5
D4
D3
D2
D1
D0
A3
A2
A1
P2- 5
P2- 8
P2- 7
P2- 10
P2- 11
P2- 14
P2- 15
P2- 18
P2- 29
P2- 32
P2- 31
14
13
12
11
10
9
8
7
6
5
4
LCD
E
R/W
D/I
Vd
Va
Vs
W1
+5V
R6
4.3K
R7
330
HC908
Daughtercard
ENC
Rotary
Encoder
R1
10K
+5V
R2
10K
R3
10K
Com
A
B
PB
P1-21
P1-18
P1-17
F5
F4
F3
C1
0.1
C2
0.1
C3
0.1
E6
E5
E7
E4
P1-29
P1-28
P1-30
P1-27
SI
SO
SCK
CS/
Vcc
HLD/
WP/
Gnd
16
15
7
8
+5V
U2
SEEPROM
512 kb
(64Kx8)
E2
P1-25
Tones
(See Pg. 2)
C4
P1-11
R8 1K
LED-1
+5V
Busy
P3
Monitor
P1-20
F7
+V
R28 22K
P2-21
B3
R41 10.0K
+5V
R17, 18, 22, 23, 27
10K (ea)
H1/KBD4
H0/KBD3
G2/KBD2
G1/KBD1
G0/KBD0
P2-9
P2-12
P2-33
P1-32
P1-31
PB-1 Mode
PB-2 Band
PB-3 Scan
PB-4 Config
PB-5 Sleep
C11-C15
0.1uF (ea)
SWR
Bridge
Buffer
Amp
Va
Vfwd
Vz
Vrev
P2-22
P2-24
P2-23
P2-26
B4
B2
B1
B0
See sheet 2
DDS
D'card
load
clock
data
P1-16
P1-15
P1-14
F2
F1
F0
E0/TxD
E1/RxD
GND
C5
P2-3
P2- 4
P2- 2
P1-10
J2
Comm
Port
See sheet 2
DSP RST
DSP RXD
DSP TXD
P2-28
P2-27
P2-30
A6
A5
A4
VrefH
Vddaref
VrefL
P1-4
P2-16
P2-13
+5V
+V (in)
Gnd
P1-34
P1-19
P1-33
R48
10K
+5V
J13
AUX
Keyline
Q1
2N3904
J4
External
Power
(12-16V)
D7
1N5817
S2
Power
D9
1N5817
R47
47
1/2W
D8
1N5817
B1
J3
P4
NiMH
+V
U1
I O
G
+5V
C4
0.1
C5
10uF
C6
0.1
C7
1uF
Micro908
G. Heron, N2APB
J. Everhart, N2CX
Rev A2 12/05/2004
Sheet
1/2



DDS Daughtercard
from HC908:
port F2
port F1
port F0
N/C
J10-1
J10-2
J10-3
J10-4
J10-5
J10-6
J10-7
J10-8
Load
Clock
Data
5V out
Gnd
RF Out A
RF Out B
+V
N/C
+V
J1
RF Out
C42
.01
Compensation & Buffer Amplifiers
+5V
C36
0.1
+5V
C37
0.1
Va
R54
1M
R50
220K
U3a
D13
1N5711
R51
71.5K
1%
U4a
R52
221K
1%
Va
to HC908
port B4
R49
47K
Vz
R16
220K
U3b
D4
1N5711
R19
71.5K
1%
U4b
R20
221K
1%
Vz
to HC908
port B1
Vr
R21
220K
U3c
D5
1N5711
R24
71.5K
1%
U4c
R25
549K
1%
Vr
to HC908
port B0
Vf
R26
220K
U3d
D6
1N5711
R29
71.5K
1%
U4d
R30
221K
1%
Vf
to HC908
port B2
U3, U4
LMC6484
D12
1N5711
D1
1N5711
R12
49.9
C19
220
D2
1N5711
R14
49.9
C41
220
R10
47K
C17
220
R11
49.9
R13
47K
C21
220
R15
47K
R34
1M
C20
.01
R32
1M
C18
.01
R33
1M
D3
1N5711
C22
.01
Reflectometer
+5V
C35
0.1
D11
1N5711
DSP RXD
(HC908 port A5)
+5V
DSP TXD
(HC908 port A4)
U6
TC7SET08
DSP RST
(HC908 port A6)
D10
1N5711
J9- 1
J9- 2
J9- 10
J9- 11
J9- 12
J9- 20
VCC5
DGND
RXD
TXD
TXD
RES
KK7P
DSPx
Daughtercard
RLINEIN
LLINEIN
AGND
RHPOUT
LHPOUT
AGND
J8- 1
J8- 2
J8- 3
J8- 6
J8- 7
J8- 8
J8- 12
C29
0.33
C30
0.33
C31
560
R37
5.1K
C32
560
R38
5.1K
J6
Audio
IN
C33
1uF
C34
1uF
R39
5.1K
R40
5.1K
J7
Audio
OUT
R43
10 1/2W
+V
C27
47uF
Audio Amp
SPKR
32-OHM
C23
.01
R42
10K
C26
10uF
C24
100uF
R46
10
C25
0.1
U5
LM386
R44
4.7K
R45
10K
Audio
C28
.01
C40
.01
TONES
from
HC908
Port E2
Micro908
G. Heron, N2APB
J. Everhart, N2CX
Rev A2 12/05/2004
Sheet
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