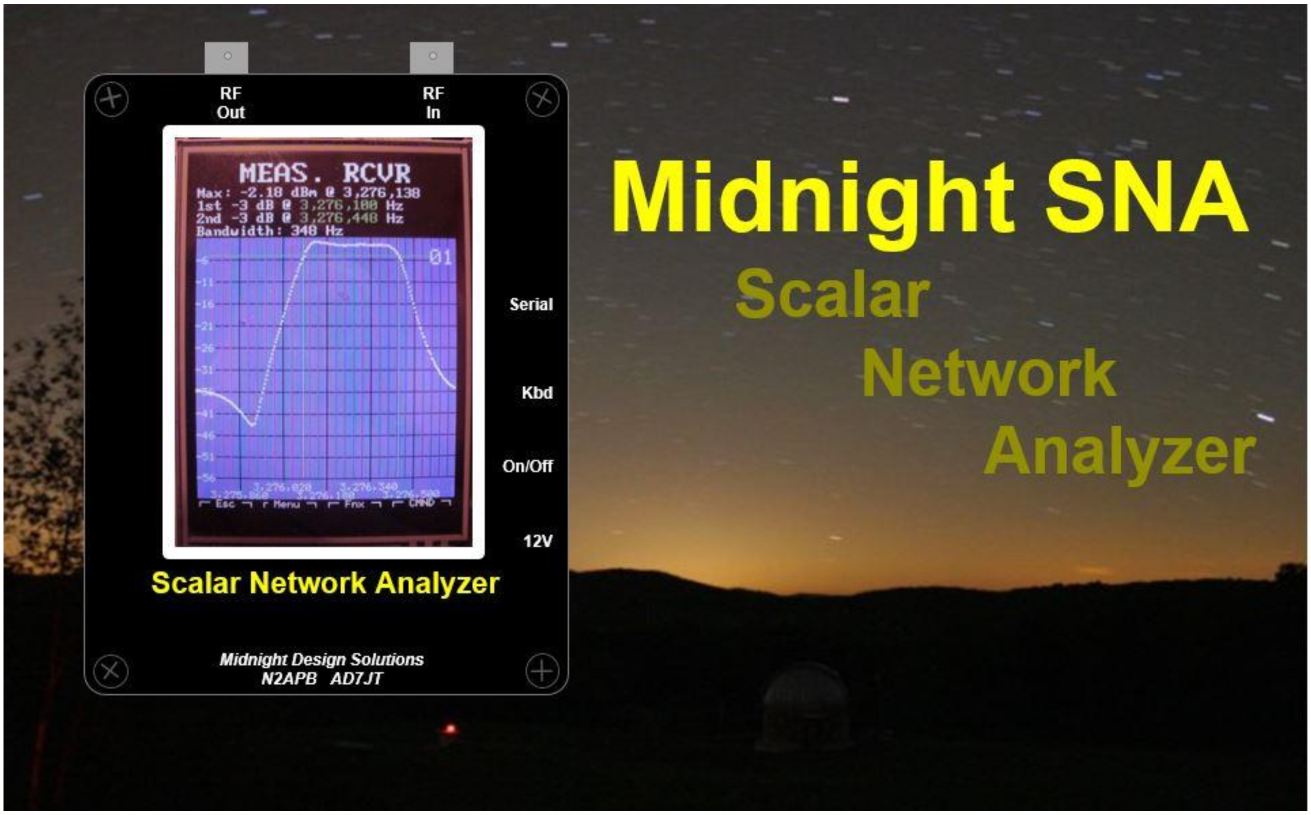
RF
Out
RF
In
MEAS. RCVR
Serial
Kbd
On/Off
12V
Scalar Network Analyzer
Midnight Design Solutions
N2APB AD7JT
Midnight SNA
Scalar
Network
Analyzer

User Guide


Midnight
SNA
Scalar Network Analyzer
Version: 4.00
2015-04-01
Dave Collins - AD7JT
George Heron - N2APB
Baud rate: 38400 bps
Slope: 0.02877698
Intercept: -78.96
Midnight Design Solutions
Copyright(C) 2015

CONTENTS

User Guide Revision History:

1 May 2015 V4.00 ....Initial Release

1 GENERAL INFORMATION

Test instruments, radios and bench accessories for the electronics experimenter these days are increasingly using the PC to augment the instrument's control, data processing and display capabilities. Whether for remote operation, remote display or post processing, the PC adds much computational power to the instrument. However, this extension of the instrument's capabilities comes at a price, considering the size of the PC, the complexity of making the serial connections work, and the updating and configuration of the PC application being used for the enhanced capabilities.

Enter the Midnight Scalar Network Analyzer (MSNA) … designed to serve as a convenient, compact, inexpensive, and dedicated terminal and SNA controller. The cost of bright, multi-color, and moderate-resolution VGA displays has come down in recent years to enable a small form-factor device such as the MSNA to be developed. Further, the display's touch-sensitive surface will allow the developer to implement "soft keys", thus eliminating the need for mechanical pushbuttons and other controls. Lastly, adding a jack to accept low-cost, industry standard, mini keyboards allows the terminal to be "bidirectional" for the operator to conveniently enter textual information, numeric calibration data or whatever specific input the application requires.

The small-sized PCBA (approx 4.8" x 3.3" x 1.3") can be installed in a dedicated enclosure for use as a handheld, free-standing, full function, scalar network analyzer or even added to the front panel of an enclosure that may house additional instrumentation.

The MSNA platform incorporates mass storage in the form of an SD card to provide spooling of data, thus enabling at-speed operation of the instrument, long multi-point scanning capability, and convenient/extensible data storage. The user can also use the SD card for transfer of instrument data to other platforms either by inserting the SD card into a card reader in the other platform or by transferring files between platforms over a serial interface. Further, the SD card offers a convenient way to upgrade the MSNA firmware in the field … just load the latest firmware release or an entirely different application onto the card and then command the MSNA to re-flash itself using that file!

While initially designed as an optional accessory for the PHSNA platform, the Network Analyzer Terminal (or "NAT") has evolved into a free-standing, full featured, Scalar Network Analyzer. In addition to the standard SNA functions, the MSNA can serve as an attractive standalone VFO, QRP power meter, and display/control head for commonly used equipment in Amateur Radio.

With the Network Analyzer Terminal, the capabilities of many bench instruments and accessories are instantaneously expanded, and many interesting new applications are made possible!"

Please direct any and all questions, comments, suggestions, critiques, etc to the authors:

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David Collins – AD7JT
ad7jt@dnbrealty.com

2 INTRODUCTION

At this time, the MSNA firmware is not open source. It currently consists of nearly 16,000 lines of (mostly C) code organized into 42 source code files. It is based on a collection of general firmware modules developed to support a 3.2-inch QVGA (quarter VGA) 16-bit color display module that includes the display, display controller, EEPROM, resistive touch screen, touch screen controller, and SD card interface connector on a single PCB assembly.

This document describes the MSNA basic hardware design and the functions and operating procedures provided by the firmware version and revision level identified on the cover page. The primary intent of the MSNA is to be a tool for analyzing the frequency response characteristics of hardware networks such as filters and low-power amplifiers

General MSNA Specifications

- PCB: *4.47" x 3.31"*
- Enclosure: *4.82" x 3.77" x 1.39"*
- Data rates: *1.2 to 115.2 kbaud*
- Power: *8-12V DC @ 400ma (typical)*
- Weight: *7 oz (approximate)*

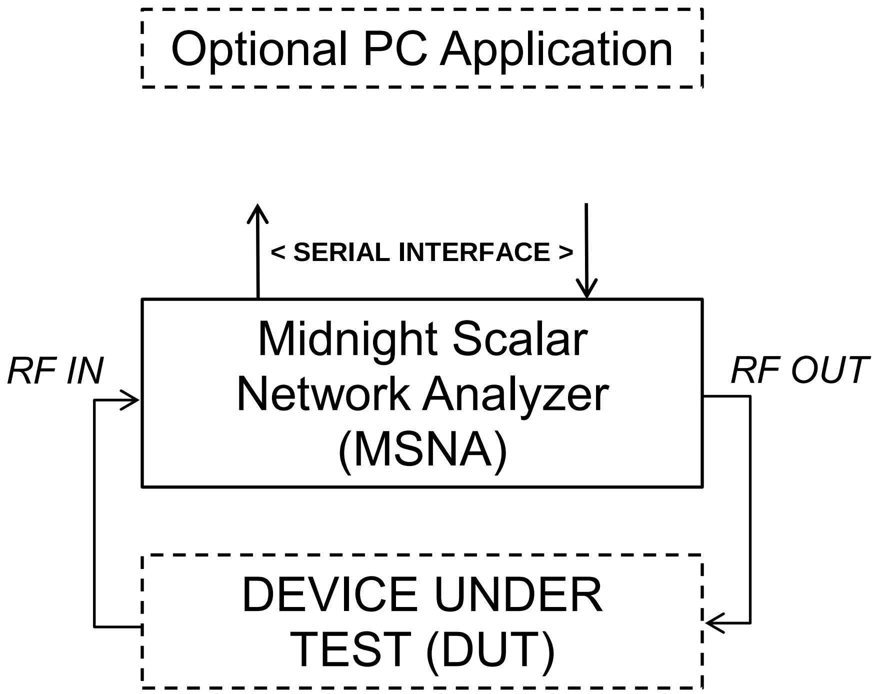
Major MSNA Features

- Graphic operator interface for display and control of SNA functions
- 3.2 inch, 240 x 320, 16-bit color graphic LCD display w/touch panel
- User-friendly operator interface
- Field upgradable firmware
- Serial port (digital UART 3.3V)
- PS2 keyboard interface with support for US and UK layouts
- 32KB EEPROM for persistent storage of settings and options
- 14 Macros (in EEPROM) for defining operating parameters
- PLX-DAQ (Excel) mode for test automation and PHSNA compatibility
- Simplified calibration (no curve fitting required)
- Built-in calibration signal generator
- Measurement & Plot Capabilities:
    - *Testing and evaluating filters*
    - *Measuring crystal parameters*
    - *Return Loss Measurement*
    - *VSWR and antenna tuning*
    - *Continuous/repeated operation options*
    - *QRP RF Power Meter*
    - *Signal generator functions with manual and remote control*
- SD card mass storage up to 1 GB provides:
    - *FAT16 file system compatibility*
    - *Subdirectory support for easy file management*
    - *Data spooling and playback*
    - *Calibration data storage and reloading*
    - *Direct data exchange with Windows and Linux apps*
    - *Easy and efficient firmware upgrades*
    - *DOS–like commands to manage and playback data files*
    - *File transfers to/from PC over the serial port*

Additional information including technical details, ordering, online documentation, schematic, etc. are located here: http://www.midnightdesignsolutions.com/nat

3 GENERAL DESCRIPTION

The following is a simplified block diagram showing how the MSNA interfaces to a Device Under Test (DUT) and an optional PC application:



During normal operation, the MSNA generates an RF signal of a known power level (RF OUT) which is input to the DUT. The output of the DUT is input (RF IN) to the MSNA RF Power Meter. The MSNA does a frequency scan to record the frequency response of the DUT. The frequency range and frequency-per-step/number-of-steps are defined by parameters in a form called a "macro".

The frequency and power level at RF IN is recorded for each step in the frequency scan. The data is stored in a data buffer in the MSNA and, optionally, spooled to a data file on the SD card. After the frequency scan is completed, the data is scaled and plotted on the MSNA display.

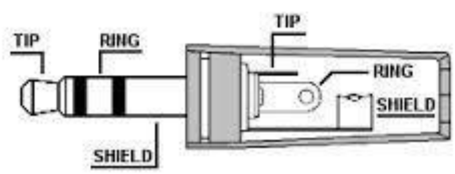
The spooled data file may be played back and the data re-plotted on the MSNA display or may be transferred to a PC application. The data file may be transferred directly over the serial interface to an application on the PC or the SD card may be inserted in the PC's SD card slot and read by the PC's file system. The file data format is Comma Separated Values (CSV) which is a common data format for tabular data and is supported by many graphic analysis applications and spread sheets such as MS Excel.

The MSNA may also be operated remotely over the serial interface. In this case a PC application can set the RF OUT frequency, turn the RF OUT signal on and off, and read the RF IN power level.

The standard MSNA is housed in a plastic case. Four screws hold the top cover in place. Inside, four screws hold the electronic assembly in place. The display assembly plugs into the main board with a 40-pin connector. The following figure shows the MSNA interface connectors.

The connector and control functions are:

- **RF Out** - An RF sine wave digitally controlled by the microcontroller over a frequency range of 1 MHz to over 60 MHz. The output power level is normally set to 0.00 dBm (1mW) at 1 MHz.
- **RF In** - The RF output from the DUT, input to the RF Power Meter.
- **PWRCAL** - A precision square wave for calibrating the RF Power Meter.
- **Serial** - A standard 3.5 mm, stereo audio jack with the MSNA's receive (RxD) data line connected to the tip terminal and the MSNA's send (TxD) data line connected to the ring terminal. The default data rate is 38.4 kbaud and there are no provisions for flow control. The character format is 8 data bits, no parity, and 1 stop bit (8-n-1). The serial interface operates in full-duplex mode so the TxD and RxD signal lines can be connected for data loop back testing. A 600-character FIFO is used to buffer received data.



- **Kbd** - The keyboard interface is a standard PS2 keyboard interface. The MSNA firmware assumes a standard U.S. or UK (optional) key layout. The above photograph shows a USB to PS2 adaptor being used to interface a common USB interfaced keyboard. Inexpensive USB to PS2 adaptors are available from many sources such as:

  http://www.frys.com/product/3470833?site=sr:SEARCH:MAIN_RSLT_PG

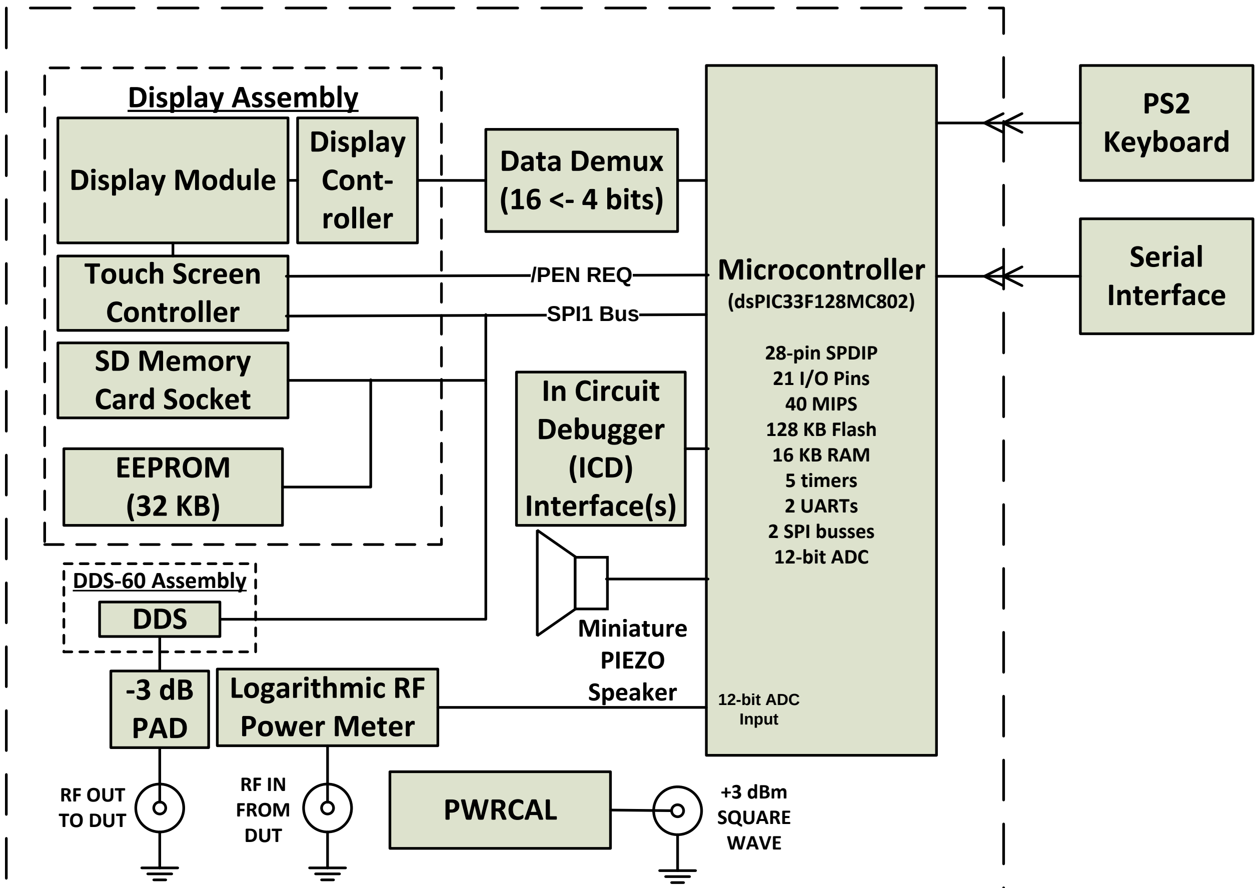
- **On/Off** - The power switch is a push-on/push-off switch.
- **12V** - The power connector is a standard 5.5x2.1 mm male center pin jack. Matching plugs are available from many sources. The MSNA power requirements are 8 – 12 VDC at 500 ma, center pin positive. The current draw includes current used by the keyboard which depends on the model keyboard used.

- The SD card socket is located between the RF Out and RF In connectors. The user may optionally cut an opening in the case to provide access to the card or leave it sealed in the enclosure to be used as a HDD on a PC. The socket accepts a standard size SD card or a micro SD card in a full-sized adapter.

The MSNA firmware includes an implementation of an abbreviated FAT16 file system. The implemented file system will only work with SD card capacities up to 1 GB formatted with the standard 512 byte sector size. The SD card must be formatted before using it in the MSNA; the MSNA is not able to format an SD card. In addition to the basic file system, the firmware includes a small number of DOS-like commands that are provided to aid file maintenance and playback.

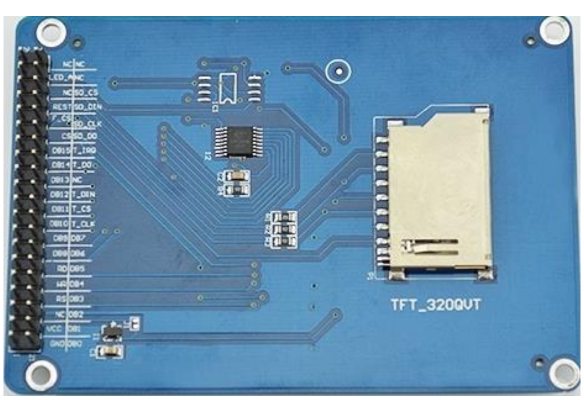
4 MIDNIGHT SCALAR NETWORK ANALYZER ARCHITECTURE

The following block diagram illustrates the basic architecture of the MSNA:



4.1 DISPLAY ASSEMBLY

The heart of the display assembly is, of course, the 3.2" (diagonal) TFT LCD display. It is a quarter VGA (QVGA) display which means it has a 240x320 pixel array. It supports 16-bit color (5R-6G-5B) and is covered with a slightly oversized, 4-wire, resistive touch screen. The oversize allows for a row of buttons below the display area.

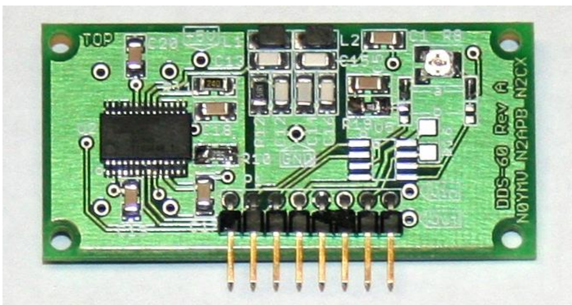


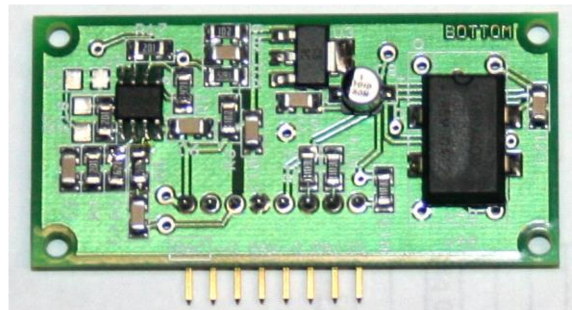
In addition to the LCD display, the display assembly has, on the back side of the PCBA, a touch screen controller, an SD card socket, and the pads for mounting an EEPROM. The display controller is integral to the LCD display and presents a 16-bit parallel data interface. A Small Peripheral Interface (SPI) bus is used to access the touch screen controller, the SD card, and the EEPROM.

All display module device interfaces are presented on a single 40-pin (2x20), male connector.

4.2 DDS-60 ASSEMBLY

The DDS-60 is a digitally controlled RF signal generator based on the AD9851 Direct Digital Synthesizer and built on a separate, plug-in PCBA. The DDS-60 includes a 30 MHz oscillator. A 6 times frequency multiplying PLL in the AD9851 timing circuitry increases the basic oscillator frequency to 180 MHz which is used as the DDS time base and reference frequency. To increase the accuracy of the frequency output, the MSNA includes aids to help identify the true reference frequency which can be off by as much as 20 ppm

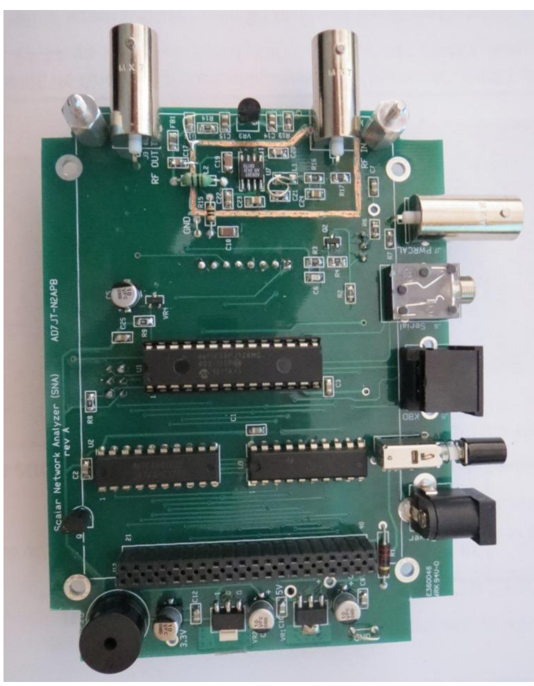


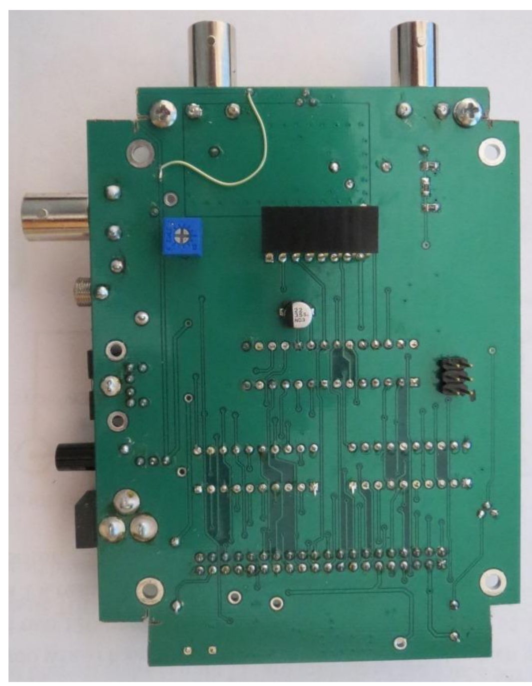


The DDS-60 circuit includes a low-pass filter to assure the output is a well-formed sine wave. The MSNA assembly uses a -3 dB pad to attenuate the DDS output. A variable output, linear RF amplifier follows the filter and allows the attenuated DDS-60 RF output to be adjusted from below 0 dBm to over 10 dBm. We recommend setting the RF OUT level to 0 dBm at 1 MHz. Detailed instructions are available in the form of a tutorial for doing so without the need for expensive test equipment.

4.3 MSNA MAIN ASSEMBLY

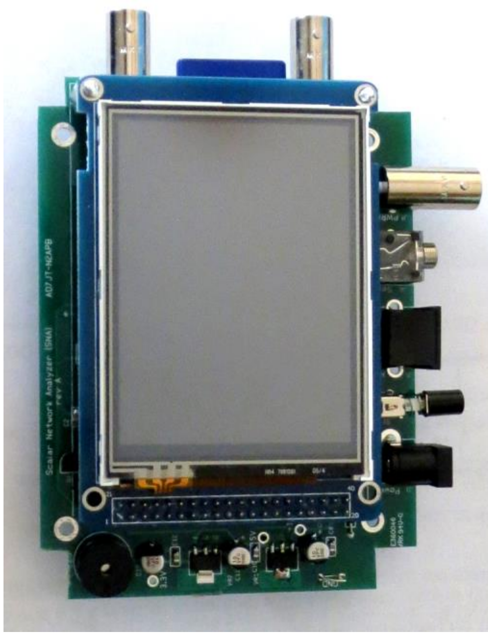
The main assembly is shown here without the display module and the DDS-60.

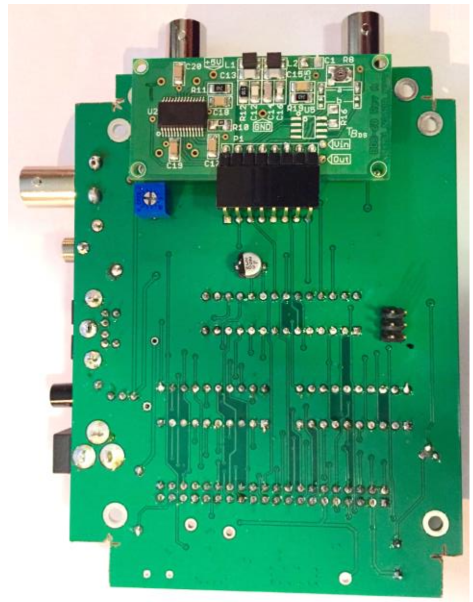




Top **Bottom**

The display and DDS-60 assemblies plug into connectors on the MSNA main assembly PCBA as shown here.





Top **Bottom**

Four mounting holes are provided in the main PCB which can be mounted with either 4x40 or 2x56 hardware from either above or below the board. If mounted from above the PCB, The display module PCB must be notched to clear the two upper standoffs as shown here. This is easily done with a nibbler and there is no circuitry any where nearby.

5 MSNA OPERATING MODES

The MSNA has four main operating modes as follows:

- Terminal mode - display, send and receive text over the serial interface.
- Macro mode - performs SNA operations defined by macro forms stored in EEPROM
- Command mode - Enter and edit a number of operating parameters and macro forms, initiate a couple diagnostic utility functions, activate the QRP power meter, and initiate DOS mode.
- DOS mode - select file system operations to be performed with/on files on the SD card.

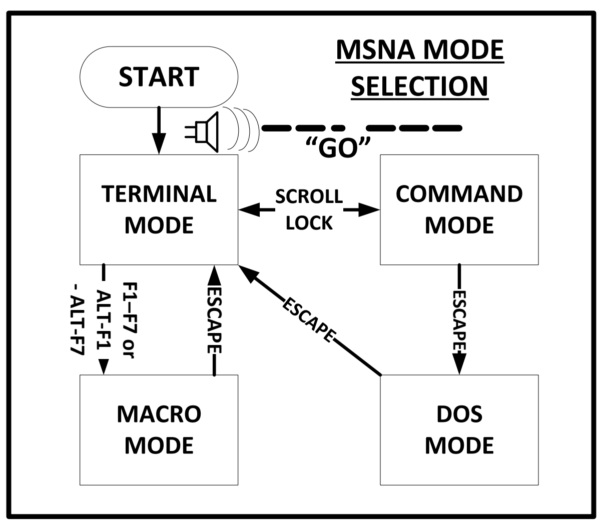
In most cases, pressing the hot-key sequence Ctrl-M (or tapping Menu) will bring up a context menu listing the currently available hot-key sequences or commands (DOS mode only). Context menus are rendered with a red background color and selections can be made by touch as well as keying the hot-key sequence. Context menus are rendered as overlays to the output text display area of the screen. In most cases, pressing any key other than those listed (e.g., Enter), will clear the context menu and refresh the underlying display without any other action.

5.1 MSNA START UP AND BEEPS

When the MSNA is first turned on, it displays a splash screen for a few seconds. A screen shot of the splash screen is shown on the cover page of this document. It identifies the product and the version and revision level of the installed firmware. Just before the splash screen is cleared, the MSNA uses the speaker to send the Morse code sequence "GO" to indicate the start of the hardware and firmware initialization sequence. The hardware is initialized and, if plugged in, the keyboard is reset (the keyboard LEDs will flash briefly). At the completion of the keyboard initialization sequence, the MSNA will sound an audible indicator (BEEP) and begin normal operation. If a keyboard is not attached, there will be no BEEP before normal operation begins. During normal operation, the MSNA will sound BEEPs to alert the operator to abnormal conditions such as entering an invalid key stroke. A BEEP will also be sounded to alert the operator of the initiation and/or completion of some normal operations such as an over-plot.

5.2 MODE SELECTION

The MSNA firmware always starts in Terminal mode. Pressing and releasing the Scroll Lock key or touching CMND switches the MSNA to Command mode. In Command mode, keyed data are processed by a command processor in the MSNA firmware. The serial interface is ignored. Pressing ESCAPE or tapping Esc in Command mode will switch to DOS mode. Pressing ESCAPE or tapping Esc in DOS mode will switch back to Terminal mode.



Pressing one of the function keys F1 through F7 or ALT-F1 through ALT-F7 while in Terminal mode will switch to Macro mode. In Macro mode, pressing the ESCAPE key will return to Terminal mode.

There are a number of hot-key sequences to do special functions in each mode. In most cases, a context menu is provided for reference and for use with touch screen operation. The current context menu can be displayed by keying CTRL-M or tapping Menu (see below).

5.3 CONTEXT MENUS

In most cases, entering CTRL-M will bring up a menu of hot keys available in the current operating mode. These context menus are rendered with a red background and will be turned off with the next keystroke entered. If the keystroke is a valid hot key for the current context, it will be accepted and acted on. If the keystroke is not valid for the current context, it will be ignored. In either case, the previous screen will be restored when possible. Tapping a line on the context menu will generally enter the associated hot key. Hot keys and context menus are summarized in APPENDIX F.

5.4 PERMANENT BUTTONS

In all modes, the bottom line of the display is reserved for a set of four "permanent buttons" for entering necessary control characters from the touch screen. These buttons are the same for Terminal, Command, and Macro modes and function as follows:

- Esc - tapping is the same as pressing the ESCAPE key on the keyboard.
- Menu - tapping is the same as pressing the hot-key combination CTRL-M and will call up a context menu if one is available for the current mode.
- Fnx - tapping will call up a listing of the macros currently in EEPROM. Tapping a line in the list will be the same as pressing the associated FUNCTION key.
- CMND - tapping is the same as pressing and releasing the SCROLL LOCK key and will toggle between Terminal and Command modes.

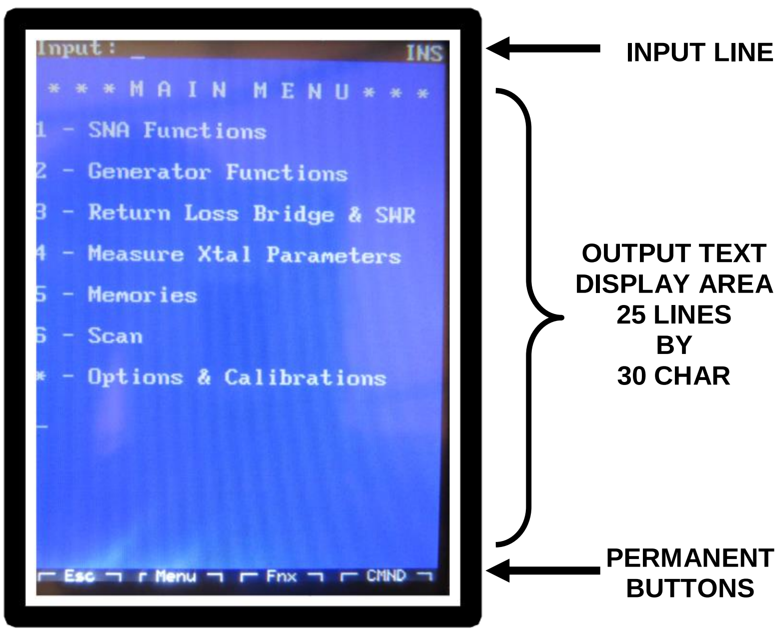
In DOS mode, the Fnx button is changed to LEFT ARROW and the CMND button is changed to RIGHT ARROW. These buttons are used by some DOS operations to navigate through sectors of a file or directory.

6 TERMINAL MODE

Terminal mode may be used with devices that generate menus and prompts to solicit input from the operator. Standard ASCII encoding is used with an extension (Special Extension Codes or "SEC") to cover special characters such as Home, End, arrow keys, etc. as well as all the ALT and CTRL key combinations. The SEC set is described in Appendix A and the Terminal mode serial interface protocol is described in Appendix B. All text is displayed using an 8x12 character font.

The top line of the display is the input (from the MSNA) line. Text entered here can be edited using the arrow and backspace keys. Data can be entered in either insert or overwrite mode depending on the indicator at the end of the input line ("INS" or "OVR"). The indicator (and the input mode) can be toggled with the INS key or by tapping the indicator on the touch screen. Once the data has been entered on the input line, entering ENTER will input it on the serial interface and clear the input line.

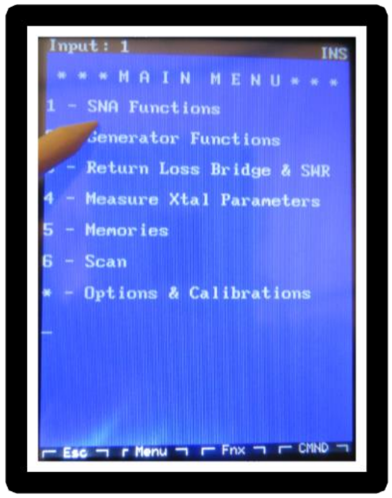
The remainder of the display (blue background) displays output data received on the serial interface. When a newline is received and the cursor is on the last line, the display will scroll up one line.



Pressing the HOME key will clear the input line. Pressing ALT-HOME will clear the output text display area.

6.1 MENU ITEM SELECTION BY TOUCH

The above screen shot shows the modified PHSNA firmware V3.02 main menu displayed on the MSNA in Terminal mode when the PHSNA controller is in Menu mode. This menu is used as an example to illustrate menu mode operation. In terminal mode, there are actually three ways to generate input data. We have already discussed using the keyboard. The other two involve using the touch screen. The first of these inputs the first character on a line in the output text display (the menu) area when that line or a blank line immediately below it is touched. The two line selection is provided as an aid to using the touch screen on the small display. It is recommended that, wherever possible, menus be double-spaced to simplify item selection and to loosen the requirements on touch screen calibration.



To further aid item selection, when a line is touched, the character to be input is displayed on the input line. The character is not transmitted until the stylus is raised. This allows you to place the stylus down on the touch screen and drag it to the line and then raise the stylus. The position of the stylus just before it is raised is used to make the line selection.

6.2 MENU ITEM SELECTION AND DATA ENTRY BY NUM PAD

The third option for making menu selection involves using a virtual numeric keypad (NUM PAD) which is activated by touching the input line. Since the NUM PAD can only enter numeric characters, plus sign, minus sign (hyphen) and periods, the menu design must be limited to these choices to be able to use the NUM PAD with it. Some menu designs cannot handle a Carriage Return (CR) after the input character. In that case, enter ALT-ENTER to input the character(s) without a trailing CR.

The NUM PAD is more suited to enter numeric values in response to prompts. The value being entered is displayed on the input line and the NUM PAD editing keys may be used to edit the input before sending it. The following edit keys are provided:

- H .... HOME Clears the input line
- DEL......................... DELETE deletes the character at the cursor
- BS .... BACKSPACE deletes the character immediately preceding the cursor
- LEFT ARROW ...... moves the cursor one place left
- RIGHT ARROW.... moves the cursor one place right
- E............................ END moves the cursor to the character position just past the last character on the input line

6.3 RECORDING DATA IN TERMINAL MODE

One of the prime functions of the MSNA is to record and plot data. Here “recording” refers to storing received data points in the MSNA’s data buffer; “spooling” refers to saving received data to a file on the SD card. The MSNA does not automatically record data in Terminal mode; the operator must manually initiate the recording operation. Data recording is turned on by the operator keying the hot key sequence CTRL-R or ALT-R or touching the corresponding line on a displayed context menu. Once initiated, the data will be recorded and plotted automatically; no further operator actions are needed. The MSNA firmware does, however, validate the format of the data records and will ignore any that do not meet the validation criteria. Once recorded and plotted, the data remains available in the data buffer until another data set is received or the MSNA power is cycled.

```
4000000, -6.9, 839
4050000, -6.6, 842
4100000, -6.6, 842
4150000, -6.6, 842
4200000, -6.6, 842
4250000, -6.6, 842
4300000, -6.6, 842
4350000, -6.6, 842
4400000, -6.7, 841
4450000, -6.7, 841
4500000, -6.7, 841
4550000, -6.7, 841
4600000, -6.7, 841
4650000, -6.7, 841
4700000, -6.7, 841
4750000, -6.7, 841

  - - - - - - - -

27150000, -51.2, 357
27200000, -51.2, 357
27250000, -51.2, 357
27300000, -51.2, 357
27350000, -51.2, 357
27400000, -51.2, 357
27450000, -51.2, 356
27500000, -51.2, 356
27550000, -51.2, 356
27600000, -51.2, 356
27650000, -51.2, 356
27700000, -51.2, 356
27750000, -51.2, 356
27800000, -51.2, 356
27850000, -51.2, 356
27900000, -51.3, 355
27950000, -51.3, 355
28000000, -51.4, 354
```

The expected data format is a series of data points representing the frequency response of the DUT. The listing on the left shows the start and end of a sample data stream. Each data point consists of two or more fields, separated by commas and terminated with a CARRIAGE RETURN (CR = 0x0D). Note that CR-LINE FEED character pairs (0x0D-0x0A) are used in some systems (e.g., Windows) to mark the end of a line in text files. The MSNA also accepts this sequence as a valid end of line. Blank lines (two or more consecutive end of line character(s)) are ignored. The first character following the end of line character(s) must a numeric digit. This field is assumed to be a frequency expressed in Hz so it must be an unsigned, positive number. One decimal point is allowed. The value is translated on the fly to double precision floating point. The numeric value is terminated by the first non-decimal character. Any following characters are ignored until the comma separator is detected indicating the start of the second field. This allows comments or unit definitions (e.g., "Hz" or "KHz") to be included in the data field.

The second data field is assumed to be the power level detected at the output of the DUT when the frequency in the first data field was applied to the DUT input. Leading spaces (0x20) are allowed in this field and will be ignored. This field is assumed to be an ASCII representation of a signed, floating-point number. The value may be prefixed with either a minus sign (‘-‘), a plus sign (‘+’), or neither. Unsigned values are assumed to be positive. One decimal point is allowed This field is evaluated on the fly and the resulting floating-point value is recorded in a RAM buffer in the MSNA.

Only the power levels (second data field) are buffered by the MSNA firmware. Starting frequency is read from the first field of the first data record (4,000,000 Hz in this case). The frequency step is calculated by subtracting the starting frequency from the frequency in the second data record (50,000 Hz in this case). From then on, the frequency information is ignored. The number of data records received (481 in this case) is used to determine the ending frequency (needed for plotting). The MSNA data buffer can hold up to 960 data points. Only the first 960 data points received will be retained in the buffer. The data is retained in the buffer until overwritten by another data recording operation. The data buffer is cleared to all zeroes at power on. Any fields following the power level are ignored but may be spooled (see below).

As stated above, all output (to the MSNA) is generally displayed on the MSNA screen in Terminal mode. Normally, when the text area is full, each new line of text causes the display to scroll up one line. When **recording** data in Terminal mode, display scrolling is disabled as soon as the MSNA firmware recognizes it is receiving data. When data is received with data recording **not** enabled, scrolling is not disabled. Scrolling the 750 character display is very time consuming and the MSNA firmware may not be able to keep up with the data flow.

6.4 SPOOLING DATA IN TERMINAL MODE

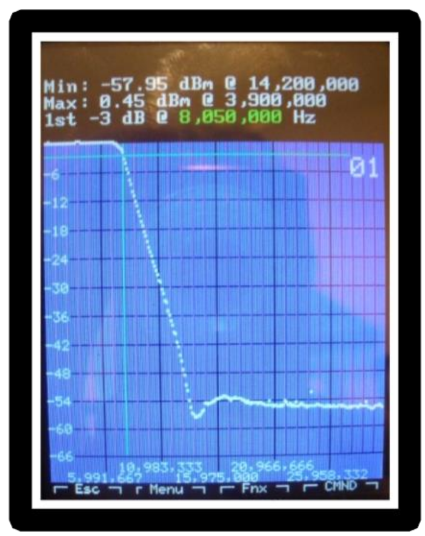
When data recording is started with a CTRL-R, all data records will be spooled to a file (the “log file”) on the SD card if such a file is specified and a file having the same name does not already exist in the current directory or sub-directory. When the recording session is started with ALT-R, an existing log file having the same name will be deleted and a new file with that name will be created. If the recording session is started with CTRL-R and the log file already exists, an error will be posted and the new data will not be spooled. In this case, the data will be recorded (buffered) and held for plotting. If the recording session is started with ALT-R and the log file does not exist, a warning that the named file could not be found will be displayed before the new file is be created.

Data is spooled exactly as received. All data received will be spooled, even if the internal data buffer is full. Note that the data file is opened when recording is first enabled (CTRL-R or ALT-R) and closed when recording mode is terminated. Spool data is buffered by the MSNA firmware in blocks of 512 bytes and written to the SD card file only when the buffer is full or when the file is closed. For this reason it is important for the recording session to end in an orderly way to assure all data gets written to the SD card and the file control (directory) data on the SD card is properly updated. Spooled data may be transferred to a PC for further analysis and processing. It may also be played back and plotted on the MSNA.

WARNING

Turning MSNA power off during a recording session could damage the file system on the SD card causing the loss of all data on the SD card and could make the SD card unusable until it is reformatted.

6.5 PLOTTING DATA IN TERMINAL MODE



Any time there is data in the MSNA’s data buffer, the operator can initiate a plot of that data by pressing the hotkey sequence CTRL-P. The plot is rendered in a 240x240 pixel area with a blue background. Major grid lines are rendered in black, minor grid lines (vertical only) are rendered in gray. The major and minor grid line positions in the plot area are the same for all plots; the scales are changed according to the ranges included in the data. Horizontally there are six major divisions and five minor divisions per major division. Vertically there are eleven divisions. The horizontal scale is in Hz, the vertical scale is in dB (signed).

Before plotting, the data is analyzed to determine minimum and maximum values for each axis. The ranges are then scaled to compute label values for the major grid lines. The data is analyzed to determine the type of plot.

Five plot types are recognized:

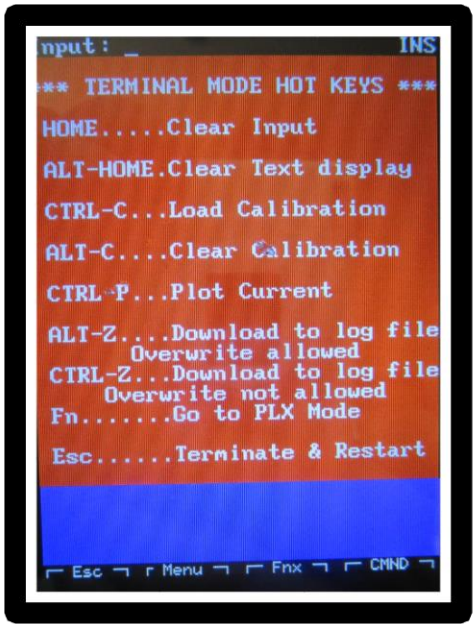
- Low-Pass-Filter (LPF)
- High-Pass-Filter (HPF)
- Notch Filter (NF)
- Band-Pass Filter (BPF)
- None of the above (Free-Form)

A “free-form” plot is one that does not fit into any of the other categories which usually means the difference between the high and low readings is less than 4 dBm. Note that the plot type may be unknowable if the sweep frequency range is too narrow to cover significant response areas.

Depending on the plot type, no, one, or two Roll-off Power Level (-3 dBm here) points may be calculated and shown on the plot as the intersection of two green lines. This example is a low-pass LPF so there is only one point shown. The frequency at this point is displayed at the top of the chart along with the maximum value and the frequency at which it was detected. A plot from an HPF would also have one point BPF and

NF plots have two. Free-form plots have none. Neither do notch and band-pass plots when the end level of the plot is not within a 6 dBm band centered on the start level. The Roll-off Power Level can be edited by the operator in Command mode.

6.6 TERMINAL MODE CONTEXT MENU AND HOT KEYS



The hot keys active in Terminal mode function as follows:

HOME.................. Clears any text on the input line.

ALT-HOME.......... Clears the text area.

CTRL-C................ Transfers the contents of the data buffer to the calibration data buffer and to the EEPROM.

ALT-C .... Clears the contents of the calibration data buffer and the calibration data EEPROM area.

CTRL-P................ Plots the current contents of the data buffer. The data buffer may have been loaded in any mode (Terminal, Macro, or DOS) A warning is displayed if the data buffer has not been loaded.

ALT-Z................... Download a file from the serial interface to the currently named log file on the SD card. If the log file already exists, it will be cleared and rewritten.

CTRL-Z .... Same as ALT-Z except if the log file already exists, it will be protected and an error posted.

Fn.......................... Pressing any of F1 through F7 or ALT-F1 through ALT-F7 will load and run the associated macro. Tapping this line will bring up the macro selection screen.

Esc......................... Clears the display and restarts Terminal mode. The ESCAPE character is transmitted on the serial port to indicate the resetting of Terminal mode and request a remote device reset and restart.

7 MACRO MODE

Macro operations are defined by entering scan parameters on a two-page form. Up to fourteen Macros may be defined. All Macro forms are stored in EEPROM. Macros are selected with the Function keys F1 through F7 and ALT-F1 through ALT-F7. A Macro is activated (run or executed) by selecting it in Terminal mode. A Macro form can be edited by selecting it in Command mode.

7.1 MACRO SELECTION

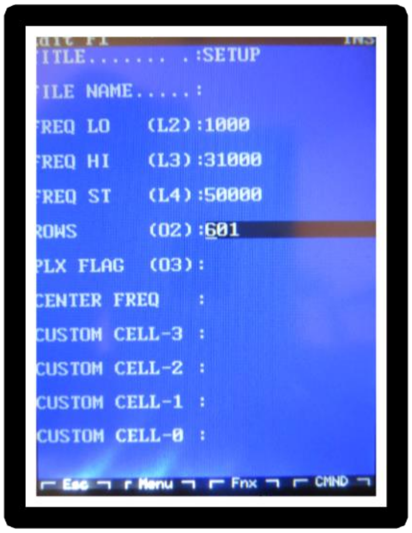
A Macro can be selected by entering the associated Function key or selecting it on the touch screen from the Macro selection list. The Macro selection list will be displayed when CTRL-F is entered from the keyboard or the Fnx permanent button is tapped on the touch screen. The list has two formats as follows:

The two formats are provided to simplify touch screen selection. There are not enough lines on the display to double space all fourteen Macros so each format lists seven Macros double-spaced and seven Macros single-spaced. Touching any item in the single-spaced portion of the list will change to the other format. Touching an item or the blank line below it in the double-spaced portion of the list will select the associated Macro. The left side of the list identifies the Function key associated with the Macro; the right side of the list is the content of the TITLE field in the Macro form (see below).

7.2 MACRO FORM EDITING

Open a Macro form for editing by selecting it in Command mode. Use the PAGE DOWN and PAGE UP arrow keys to save the current page to EEPROM and display the other page for editing. Entering ENTER will save the displayed page to EEPROM and return to Terminal mode. The macro edit screens are shown below. The left half of each line in the form contains the name of the field; the right half contains the field's current value. The field being edited is shown with a black background. The field to be edited is selected using the UP and DOWN arrows. The OP MODES field on the second page takes a number of codes defining special operating modes. The lower half of the display shows a list of the available op modes. Op modes may be entered as either single letters (case insensitive) or decimal digits. Letters are easier to remember; numbers can be entered using the NUM PAD.

Most of the field names on page one of the basic Macro form can be edited in Command mode. This may be convenient, for example, if the user prefers different names for the fields. The functions of the fields, however, cannot be changed as they are determined by their position in the form. Page two field names cannot be edited.



The third screen shot shows the NUM PAD being used to make entries in the Macro form. Touching the right side of a line on the form will select that line for editing and bring up the NUM PAD. Since the NUM PAD covers most of the form lines, this version of the NUM PAD includes a copy of the edit line just above the keypad button array. The four keys in the upper right corner of the button array are the UP and DOWN arrows and the PAGE UP and PAGE DOWN functions.

The following subsections describe each field in the Macro form:

7.2.1 TITLE

The TITLE is used to identify the macro in the macro selection list and as a heading on the plot screen.

7.2.2 FILE NAME

The FILE NAME is the name of a file on the SD card to which the data from a frequency scan will be spooled. When FILE NAME is blank, data will not be spooled. When FILE NAME is not blank, the data will be spooled according to the state of the W op mode. When op mode W is specified and a file exists with the same name as FILE NAME, the file will be deleted and a new file written. When a file exists with the same name as FILE NAME and op mode W is **not** specified, an error will be displayed and the data will not be spooled. In any case, the Macro will be run.

The FILE NAME must conform to the old DOS 8.3 file name format. That is it may contain no more than eight characters optionally followed by a period (dot) and a file name extension of at most three characters. Only the following characters are valid in a FILE NAME:

- Upper case letters A through Z
- Numbers 0 through 9
- ! # $ % & ' ( ) - @ ^ _ { } ~

All other characters are not valid and may make the file unreadable. There is no check on the characters entered into this field.

7.2.3 FREQ LO

This is the lowest and starting frequency for a frequency scan. It is expressed in KHz and can have up to three decimal places enabling the frequency to be specified to a one Hz resolution.

7.2.4 FREQ HI

This is the highest frequency for a frequency scan. It is expressed in KHz and can have up to three decimal places enabling the frequency to be specified to a one Hz resolution.

7.2.5 FREQ ST

This is the frequency increment used for each step in the frequency scan expressed in Hz. The scan is done by setting the DDS frequency to FREQ LO and stepping the DDS frequency by FREQ ST until it is greater than FREQ HI.

7.2.6 ROWS

This is the number of steps in the frequency scan. Obviously, this value is redundant since the frequency scan is completely defined by FREQ LO, FREQ HI, and FREQ ST. Therefore, if these three values are entered, the firmware will compute and enter the value for ROWS. In fact, if any three of these four values are entered and the fourth is blank, the firmware will compute and enter the value for the fourth field.

7.2.7 PLX FLAG

This field is a flag to an external SNA controller such as the PHSNA controller in PLX mode. When PLX FLAG is set to any value except 100, the external controller is directed to access other fields on the first page of the Macro form, perform the specified frequency scan, and return the results using a simple serial interface protocol. Fields that can be accessed are addressed using the two character ID shown in parentheses just before the colon at the end of the field name. Only those fields having a properly formatted ID in this position can be accessed.

Each field ID consists of a letter and a number that represents a cell in an Excel spread sheet. The serial interface protocol can also be used to access spreadsheet cells in a PC running Excel with a special VB macro installed that allows access to spread sheet cells using one of the PC's ports. Appendix D describes the serial interface protocol used in macro mode and provides more information about the VB macro and operation with the PHSNA controller in PLX mode. Field IDs can be edited along with the field names as described above.

7.2.8 CENTER FREQ

In some cases it is more convenient to specify the center frequency of a scan rather than the low and high frequencies. When a value is entered in the CENTER FREQ field with values in FREQ ST and ROWS fields, the firmware will calculate and enter FREQ LO and FREQ HI. CENTER FREQ is expressed in KHz and can have up to three decimal places enabling the frequency to be specified to a one Hz resolution.

7.2.9 CUSTOM CELL-n

These fields are reserved for future use or for custom applications using an external controller.

7.2.10 AUTO DELAY(ms)

This field specifies a delay in ms to be inserted between Macro executions when Automatic start (A) op mode is specified.

7.2.11 XTAL PREFIX

The XTAL PREFIX field, when not empty, also acts as a flag to direct the firmware to spool measured crystal parameters instead of the usual plot data when the plot shape is that of a band pass filter. Crystal sorting and matching is described in detail in a later section. When sorting and matching a batch of crystals, this field prefixing the current plot number will be the first field in each data row in the spooled data file. This is an aid to matching specific result data to individual crystals.

7.2.12 ...reserved...

These fields are reserved for future expansion.

7.2.13 OP MODES

The codes in this field modify the macro execution sequence for specific cases. The op modes are listed for reference on the lower half of the second page of the macro form. Combinations of op modes may be entered in the op mode field by entering either the alpha character (case insensitive) or the number shown in parentheses. The numeric codes can be entered using the NUM PAD as shown in the above screen shot.

7.2.13.1 Op Mode (A) Automatic start

Normally, when a Macro is started it is executed once and the results are displayed as a plot. The macro can be restarted by pressing the SPACE bar or tapping the plot screen. When op mode A is specified, each time the Macro completes, it will restart automatically after the delay specified by the AUTO DELAY field (plus about 250 ms). Once a macro has been started, Automatic start mode can be turned on by pressing the A key and turned off by pressing the M (manual) key. Each time the macro is run, the results will be plotted. The plot mode is determined by op mode R.

When over plotting (op mode R not specified), the plot number in the upper right corner of the plot area is incremented by one for each over-plot. Each over plot is done in a different color using eight colors in sequence. The plot number is only two digits so it will increment from 99 to 00. When this happens, the plot screen is cleared and the new data is used to rescale the plot and the plot number is set to 01.

7.2.13.2 Op Mode (R) Reinitialize each plot

Normally, when a Macro is rerun, the results are plotted over the previous plot(s). The results of the first run determines the plot scaling. When op mode R is specified, the plot screen is cleared and the data rescaled each time the macro is run and the plot number is not displayed.

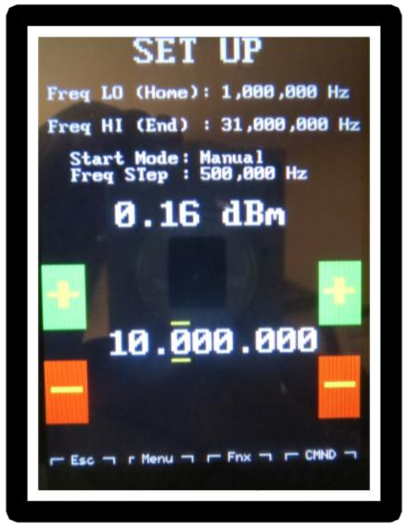
7.2.13.3 Op Mode (V) VSWR plot

When op mode V is specified and the plot shape is recognized as a notch filter (NF) shape, the firmware will assume a return loss bridge is being used and will plot the return loss as a power curve and will calculate and plot the VSWR. The power curve is plotted in white with the normal scale along the left side of the plot area. The VSWR is plotted in green with its scale (also in green) along the right side of the plot area. The return loss bridge and making VSWR plots are covered in detail in a later section.

7.2.13.4 Op Mode (W) over Write existing file

When FILE NAME is specified, the firmware will attempt to spool the data to a file of that name. If op mode W is specified, an existing file with the same name will be deleted and a new file written. If op mode W is not specified, an existing file with the same name will be protected and not deleted. In this case a warning will be displayed and the data will not be spooled. The Macro will always be executed and the results will always be plotted.

7.2.13.5 Op Mode (S) Signal generator mode



Op mode S specifies signal generator (or "sig gen") mode. This mode gives the operator manual control of the DDS frequency within the limits defined by FREQ LO and FREQ HI. The DDS frequency may be incremented and decremented between these limits by an amount specified by FREQ ST. Once the macro is started, the step value may be changed. The LEFT and RIGHT ARROW keys will change the step value up or down by a decade. The current most-significant digit in the step value is indicated by the yellow bars marking a digit position in the frequency display. The step value can also be changed by tapping a digit in the frequency display.

When op mode A is not enabled, the start mode is "Manual" and the current RF Power Meter reading will be displayed every time the SPACE bar is pressed or the touch screen is tapped just below the frequency display. Enabling op mode A sets the start mode to "Automatic" and power level readings are taken and displayed approximately four times per second. The op mode field in the Macro form determines the initial start mode setting. Pressing M will change the start mode to Manual; pressing A will change the start mode to Automatic; tapping in the area around "Start Mode" on the touch screen will toggle the start mode.

The signal generator operation may be controlled remotely using the serial interface. In sig gen mode, the serial interface is monitored looking for special signal generator commands. The remote control commands and the serial interface protocol are described in APPENDIX C.

7.2.13.6 Op Mode (E) External SNA Controller

Normally the frequency scan is done using the DDS-60 and reading the RF Power Meter directly. When an external SNA controller (such as the PHSNA controller) is used, op mode E is specified and fields in the macro form can be accessed by the external controller and it performs the frequency scan and returns the results to the MSNA. Repeat operations are requested by sending a single SPACE character to the external controller during the idle periods between scans. See Appendix D for more information about using an external SNA controller.

7.2.13.7 Op Mode (P) Power Meter Calibration

Op mode P activates the PWRCAL circuit to generate a +3 dBm RF signal used to calibrate the RF Power Meter. Once the first power level is sampled with a direct connection from the PWRCAL connector to the RF IN connector, the user is prompted to add a 20 dB attenuator to the circuit and take a second reading. The power meter slope and zero intercept point are then calculated and saved in EEPROM.

Note that op mode P can only be used in sig gen mode so op mode S must also be specified.

7.3 MACRO EXECUTION

Macros are executed from Terminal mode simply by selecting the macro. Once selected, the macro will be executed and, if op mode S is not specified, the results will be plotted and, optionally, spooled to a file on the SD card. When op mode S is specified, the resulting RF Power Meter reading will be displayed. The macro will be repeated each time the SPACE bar is pressed, the display is tapped, or continuously if op mode A is specified. In manual mode and not in sig gen mode, the firmware will generate a single BEEP each time the macro completes and the results are plotted. No BEEPs are generated when op mode A is active.

When results are spooled and the macro is executed more than once, all data is recorded in the spool file with delimiters inserted between the result sets. The delimiter records the number of rows in the preceding result set. When a delimiter is encountered while playing back the spool file, the firmware over-plots the result set before reading the next result set.

Macro execution may be terminated at any time by entering ESCAPE. If op mode A is active, two ESCAPEs will be required to terminate the Macro. The first will just deactivate op mode A and switch to manual start mode. The second will switch to Terminal mode. In any event, an in-process scan will complete normally.

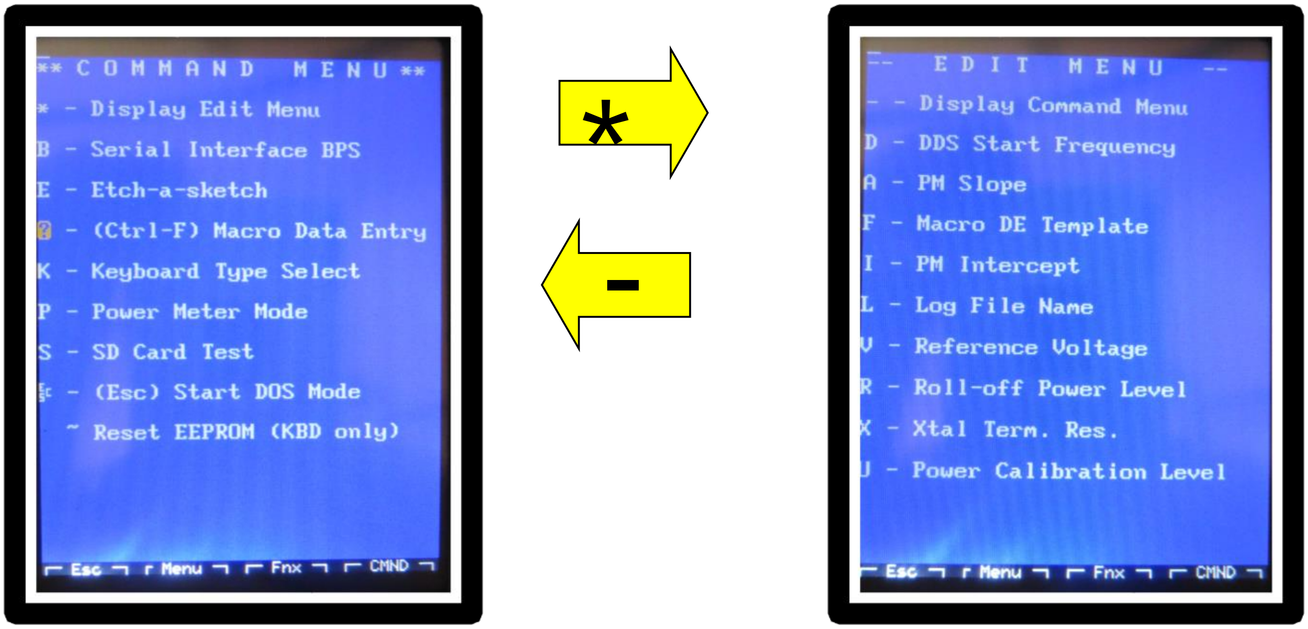
7.4 MACRO MODE CONTEXT MENU AND HOT KEYS

The hot keys active in Macro mode function as follows:

- A .... Enables automatic start mode; the macro will be restarted repeatedly after approximately one-quarter second delay plus the delay specified in AUTO DELAY (if any).
- M .... Disables automatic start mode; the macro will only restart when you press the SPACE bar or tap the touch screen.
- ALT-HOME .... Clears the text area. This function will only work when using an external SNA controller (op mode E).
- CTRL-C................. Transfers the contents of the data buffer to the calibration data buffer and to the EEPROM.
- ALT-C .... Clears the contents of the calibration data buffer and the calibration data portion of the EEPROM.
- CTRL-S .... Set the RF Power Meter slope and intercept (see MSNA CALIBRATON).
- CTRL-T .... Determine the DDS-60 reference clock frequency (see MSNA CALIBRATION).

Esc.........................Clears the display and restarts in Terminal mode. The ESCAPE character is transmitted on the serial port to indicate the resetting of Terminal mode and request a remote device reset and restart.

8 COMMAND MODE



Command mode is entered by pressing and releasing the Scroll Lock key or by touching the CMND permanent button in the lower right corner of the touch screen. The Scroll Lock LED on the keyboard will remain on as long as the MSNA is in Command mode. Command mode has a two-part menu: COMMAND MENU and EDIT MENU. Any command may be entered when either menu part is displayed; it really is only one menu. The COMMAND MENU will be displayed initially showing the available commands. Entering '*' (asterisk) will display the EDIT MENU showing a list of parameters that can be edited by the operator. Entering '-' (hyphen) will display the COMMAND MENU again.

In Command mode all keyed data is passed to a command processor and not to the serial interface. The serial interface is ignored and all displayed text is generated by the command processor. All commands are initiated by pressing a single key (or key combination). Command mode will be terminated and the MSNA returned to monitor mode at the end of a single command execution.

All information entered in Command mode is stored in the EEPROM when ENTER is entered. This preserves settings between power cycles and avoids the need to reenter parameters and data each time the MSNA is restarted. Entering ESCAPE will terminate Command mode without making any changes Where appropriate, the touch screen and/or the NUMPAD may be used to make entries.

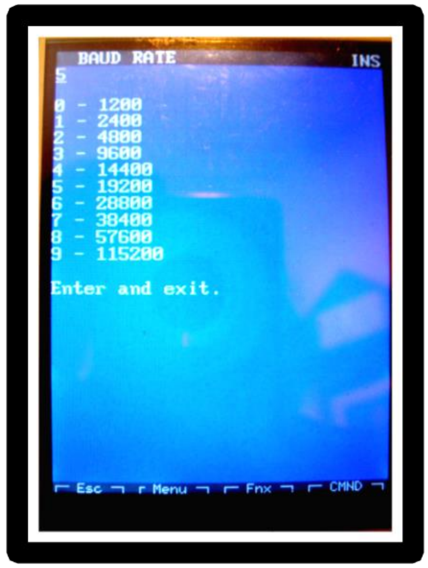
There are no hot keys or context menus available in Command mode. Entering CTRL-M will exit Command mode and return to Terminal mode.

8.1 COMMAND MENU ITEMS

The non-edit commands are as follows:

- * - Display Edit Menu
- B – Select serial port baud rate
- E - Etch-a-sketch
- Fnx - (Ctrl-F) Macro Data Entry
- K - keyboard Type Select (US or UK)
- P - Power Meter Mode
- S - SD Card Test
- Esc – Switch to DOS mode
- ~ Reset EEPROM (KBD only)

8.1.1 B – Select Serial Port Baud Rate

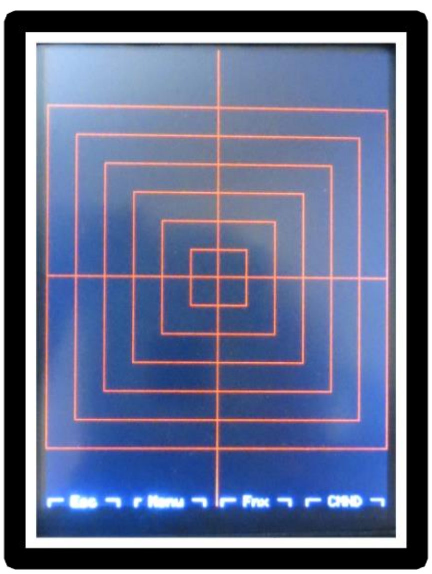


The default baud rate is 38.4 kbaud (option 7). Command code "B" displays a number representing the current setting and a list of baud rate selections. When the user makes a selection and presses Enter, the selection is stored in the EEPROM and the serial interface is reinitialized to the selected baud rate the next time it powers up. Each time the MSNA is restarted, the baud rate selection is read from EEPROM and the serial interface set to the corresponding baud rate.

NOTE

The MSNA and any external controller or PC application using the serial interface should be restarted after changing the serial port baud rate. Both devices must operate at the same baud rate.

8.1.2 E - Etch-A-Sketch



The Etch-a-sketch (EAS) function is provided to test touch screen calibration (described later). The initial EAS screen has full-size cross hair exactly centered on the screen. The center is located at x,y coordinates 119, 159. The center is surrounded by six concentric squares ranging in size from 40x40 pixels to 240x240 pixels in increments of 40 pixels. When the screen is touched by a stylus, the x,y coordinates of the touch point are displayed in the upper left corner of the display and a 2x2 pixel, white dot is rendered at that point. The x,y coordinates are displayed as the raw values read from the touch screen controller with the calibrated coordinates following arrows ("**->**"). The cross hairs and the concentric squares provide visual references for checking the accuracy of the touch screen calibration. Moving the stylus on the touch screen will draw a series of dots showing the path taken. Pressing the Home key will clear the screen and start over.

The touch screen extends a ways below the LCD display allowing a larger target area for the permanent buttons while minimizing the display area used. When the stylus is dragged along just below the button legends, the trace will be a straight line along the bottom of the LCD display which is the limit for the display. When the touch screen indicates a position below pixel row 319, the dot is placed on pixel row 319. Note that the permanent buttons along the bottom of the display do not function in EAS. The EAS session must be terminated using the keyboard or by cycling power.

8.1.3 Fnx – Macro Data Entry

Selecting a macro in Command mode will open the macro edit window with the current contents of the macro fields displayed. A Macro may be selected directly using the Function keys or using the Macro selection list described earlier in the MACRO MODE Section of this document. That section also describes the purpose of each field in the Macro form and the type of data to be entered.

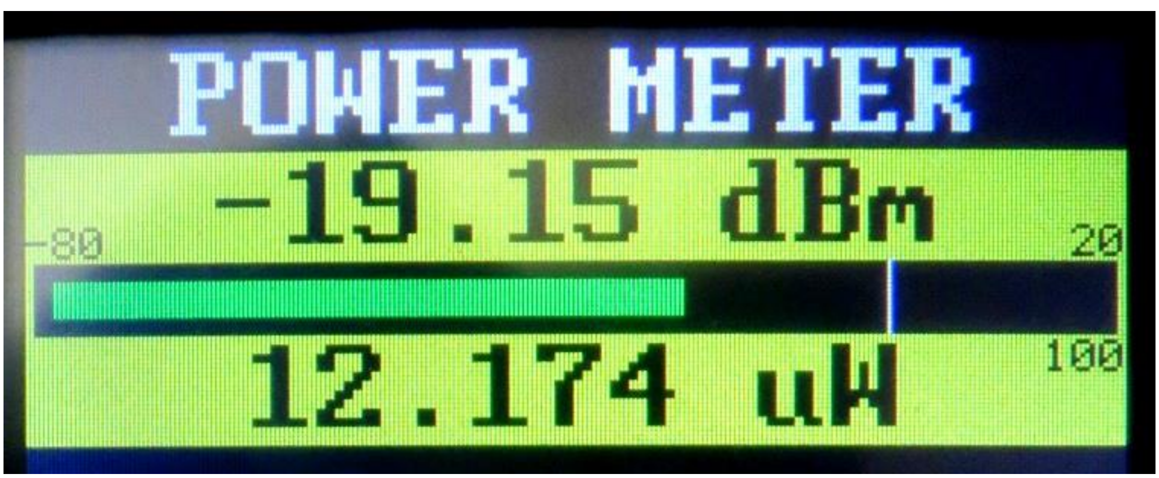
8.1.4 K - Keyboard Type Select

Selects between the US (selection 0) and the UK (selection 1) keyboard layout. The US keyboard is the standard IBM Model M (Enhanced) 101-key layout. The UK keyboard is the Model M (Enhanced) 102-key layout. The differences are as follows:

- The ' @ ' position on the US keyboard becomes ' " ' on the UK keyboard
- The ' \ ' position on the US keyboard becomes ' # ' on the UK keyboard
- The ' | ' position on the US keyboard becomes ' ~ ' on the UK keyboard
- The ' " ' position on the US keyboard becomes ' @ ' on the UK keyboard

There is no font for the British Pound Sterling sign, it will display as a pound sign (' # ').

8.1.5 P - QRP Power Meter Mode



This is the QRP power meter reading for a -19.15 dBm RF signal. The QRP power level is displayed in dBm and watts. The watts reading is scaled for nanowatts (nW), picowatts (pW), microwatts (uW), milliwatts (mW) and watts depending on the power level. An analog representation of the power level is shown as a green bar between the two power level displays. The small numbers above and at both ends of the analog meter show the dBm levels at the end points of the meter. The range shown here is the nominal range of the RF Power Meter with no attenuation (-80 dBm to +20 dBm). The actual range is reduced somewhat due to roll off at both ends. The actual dynamic range is about 95 dBm. The white vertical bar in the meter is the 0.00 dBm point. The number below the analog meter and at the far right is the upper limit expressed in milliwatts (100 in this case).

Power levels are sampled 200 times per second (every 5 ms). Three types of power are displayed. The first is the current power level which is a 10-point running average of the power samples and is updated every 5 ms. The second is the average power which is a 200-point running average and is also updated every 5 ms. The third is peak power and is the highest power reading over the last 200 readings and is updated every second. In the following examples, all three meters are reading about the same since the RF signal is not modulated which would affect the average and peak readings.

Note that the upper limit for the RF Power Meter is less than +20 dBm which is about 0.1 watt. This is a little too low for measuring the power output from a typical QRP transmitter. The range can be shifted by putting an attenuator in the RF Power Meter input but the QRP power meter must be calibrated. Normally the DDS is turned off in QRP power meter mode to keep the noise floor as low as possible. It can, however, be turned on temporarily to help recalibrate the QRP power meter. To do this, connect the RF OUT to the RF IN connector through an attenuator. Entering CTRL-G or tapping the gain button at the bottom of the display will turn on the DDS, capture and save the power reading, display it in the gain button legend, and turn off the DDS. The power level read is then used to recalibrate the QRP power meter display. The following example uses a 20 dB attenuator to shift the upper limit up by two decades (to 10 watts):

Note that the upper end of the power scale is now about 10 watts and the zero marker has moved to the left. The meter range is from -60 dBm to + 40 dBm, (still 100 dBm). The legend on the gain button shows approximately -20 dB. Entering CTRL-G or tapping the gain button again will clear the gain setting back to 0.000 dB and the meter scales back to their original settings.

WARNING

When using attenuators to shift the power meter range be aware that the attenuator must be able to handle the input power and the attenuated power level must not exceed the 20 dBm limit of the RF Power Meter. Trying to measure the power output of your full legal-limit power amplifier with a 70 dB attenuator is asking for a disaster.

8.1.6 SD Card Test

Starts an SD Card Test that writes a series of ten files named F00 through F09 then reads and verifies the data. Then deletes the first file and verifies the remaining nine files. This continues until all ten files have been deleted. The test pauses after each phase until a key is pressed or the screen is tapped. Errors are displayed in red followed by a BEEP and a pause of several seconds before proceeding with the test. The test sequence always starts by trying to delete all ten files in case a earlier test was terminated before all files were deleted. The number of files found and deleted is displayed.

See Appendix E for detailed description of the test sequence and the data patterns used. If data errors are encountered, the file data can be read and displayed on a PC for detailed analysis.

8.1.7 (Esc) Start DOS Mode

Switches to DOS mode and executes a DIR command to display the contents of the first sector of the current directory. DOS mode operations and DOS commands are described in detail in a later section of this document.

8.1.8 ~ - Reset EEPROM (KBD only)

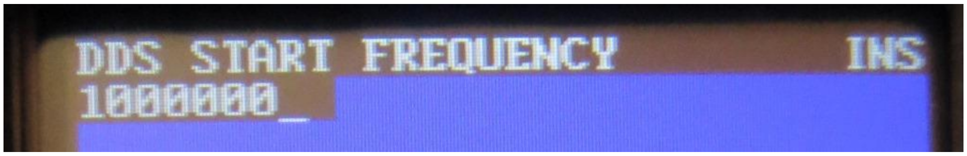
When the MSNA is first powered up or the EEPROM has been replaced, the EEPROM contents are unknown. Selecting this command will force the EEPROM contents to be initialized to all default values. It may also be necessary to use this command when a new firmware release is installed that changes or adds new EEPROM locations.

8.2 EDIT MENU ITEMS

The edit commands are as follows:

- * - Display Command Menu
- D - DDS Start Frequency
- A - PM Slope
- F - Macro DE Template
- I - PM Intercept
- L - Log File Name
- V - Reference Voltage
- R - Roll-off Power Level
- X - Xtal Term. Res.
- U - Power Calibration Level

8.2.1 D - DDS Start Frequency



The DDS start frequency is the frequency used to initialize the DDS when power is first turned on. It is entered in Hz as a whole number. The value entered must be no greater than 60000000 (60 MHz). If a greater value is entered, it will be changed to 60 MHz. There is no lower limit but the DDS-60 may not produce a reliable output wave form below about 750 KHz.

8.2.2 A - PM Slope

The RF Power Meter output is a voltage level that is a function of power level at its input. The general equation used to convert this voltage to dBm is linear and has the following general form:

P = SC + I

Where

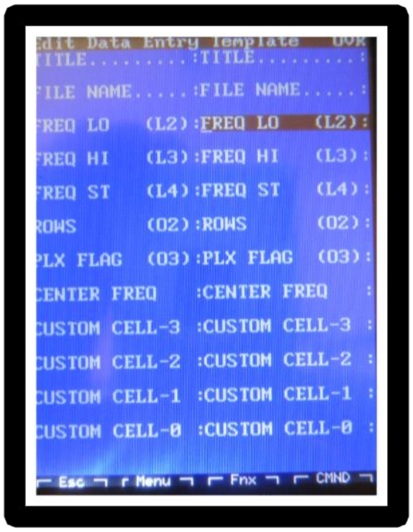
P is the power level in dBm
S is the slope in units of dB/ADC count
C is the ADC count, each count represents 1/4096 of the ADC reference voltage(12-bit ADC)
I is the zero intercept which is the power level in dBm where C is zero.

Normally the PM Slope value will be generated by the firmware during calibration using the PWRCAL output signal. The edit option is provided for diagnostic testing and, possibly, experimentation. The PM Slope is shown on the Splash screen and may be needed by some PC applications processing data from the MSNA.

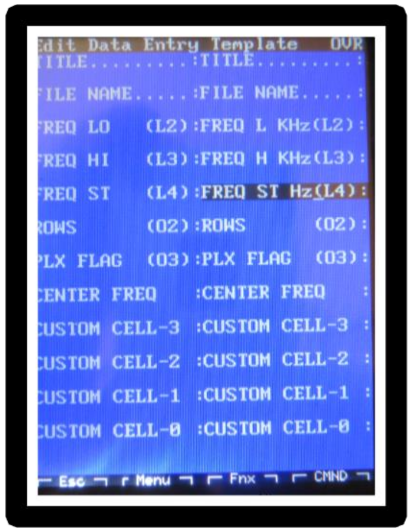
8.2.3 F – Macro DE Template

Editing the macro data entry format template is essentially the same as editing the parameters in the data entry form. When initiated, the data entry screen is displayed but, in this case, the variables listed on the right half of the display will be the same as the field names on the left side of the display. With the exception of the first two labels, the labels can be edited as described above. When ENTER is entered, the new template is saved in EEPROM and all future parameter data entry displays will display the edited template labels on the left half of the display. The field names in the second page of the form cannot be edited.

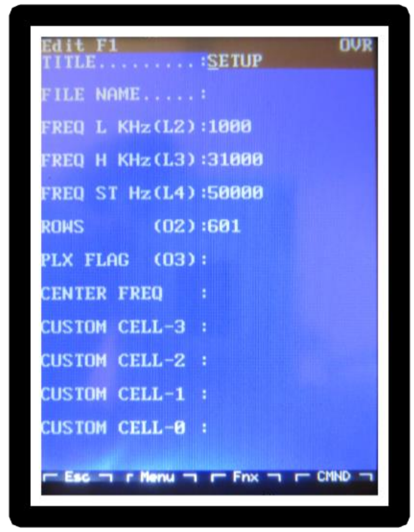
As an example, suppose we want to add the frequency units to the field names for FREQ LO, FREQ HI, and FREQ ST. When we select F from the Edit Menu we will get the data entry form with each field containing its field name from the left side of the form. We can edit the three entries as we would edit the field in any Macro form. After editing the three fields, enter ENTER to save the changes to EEPROM. The changes will be in all data entry edit forms even if they were generaed before these changes were made. To see the result, call up the edit screen for an existing macro form.



DEFALT FORM



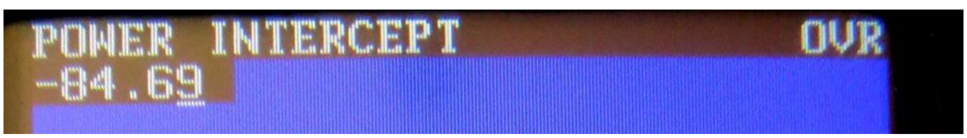
EDCITED FORM



RESULT

If the EEPROM has not been initialized (validation code not found in first two locations), the template in EEPROM will not be used. Instead, the default template (shown above, BEFORE EDITING) will be used.

8.2.4 I - PM Intercept



The RF Power Meter output is a voltage level that is a function of THE power level at its input. The general equation used to convert this voltage to dBm is linear and has the following general form:

$P = SC + I$

Where

P is the power level in dBm
S is the slope in units of dB/ADC counts
C is the ADC count, each count represents 1/4096 of the ADC reference voltage (12-bit ADC)
I is the zero intercept which is the power level in dBm where C is zero.

Normally the PM Intercept value will be generated by the firmware during calibration using the PWRCAL output signal. The edit option is provided for diagnostic testing and, possibly, experimentation. The PM Intercept is shown on the Splash screen and may be needed by some PC applications processing data from the MSNA.

8.2.5 L – Log File Name

The log file is used in Terminal mode to spool data received from the serial interface. Since there is no macro form to guide Terminal mode operation, the specified log file is used for all transfers. The log file name, however, can be edited to spool data from different sweep parameters to different files. When L is pressed in Command mode, the Log File Name Edit screen is displayed containing the current log file name with the cursor positioned after the last character in the name. All editing modes and functions are available. Pressing Enter saves the edited log file name to EEPROM and closes the edit screen.

The log file name is also used to name files generated from data down loaded from the serial interface such as firmware updates. When down loading a firmware update, make sure the log file name follows the DOS 8.3 file naming rules and the file extension must be "HEX" or the firmware load operation will reject it.

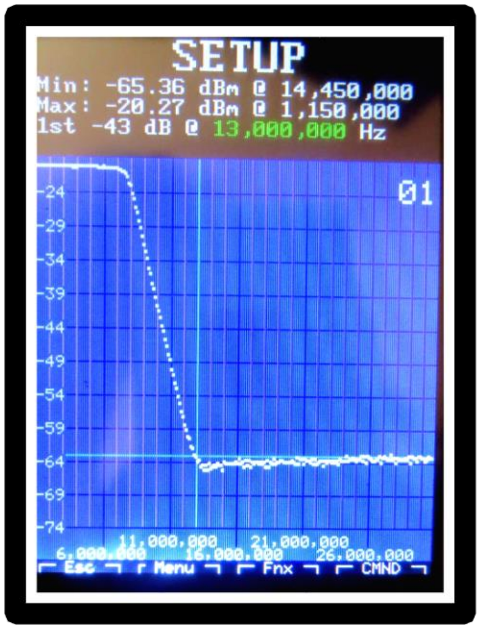
8.2.6 V - Reference Voltage

The basic MSNA design includes a precision 3.0 volt reference voltage regulator for the analog to digital converter. However, the user may choose a different reference voltage. In that case, the reference voltage must be entered in this parameter and saved to EEPROM to assure accurate RF Power Meter readings.

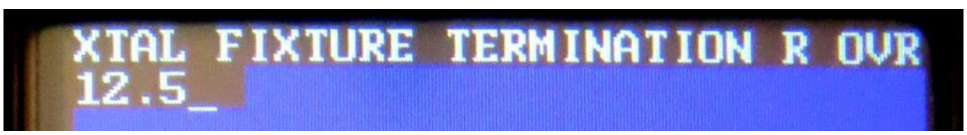
8.2.7 R - Roll-off Power Level

The roll-off power level sets a marker on plots. It defines a power level on the plot with reference to the highest power level plotted. A green horizontal bar is added to the plot at the roll-off power level. Each point (2 maximum) the plot crosses this power level is marked with a green vertical bar. Low and High pass filter plots should have one vertical bar and band pass and notch filters should have two. The plot heading will list the roll-off level and the frequency for up to two occurrences.

For example, if our low pass filter has a 20 dB insertion loss in the pass band (or has a 20 dB attenuator in series with it) and the roll-off power level is set to -43 dB, the roll-off point will be plotted at -63 dBm.



8.2.8 X - Xtal Term. Res.



This parameter is used as both a flag and a parameter value. When greater than one, it is assumed that all band pass filter (BPF) plots are made using a quartz crystal as the DUT and additional information is added to the plot display. The parameter is the termination resistance of the fixture used to hold the crystal under test. The most common values for the termination resistance are 12.5 and 50 ohms. The edit function allows entries from 0.0 to 999.9 ohms; five characters maximum, one decimal place allowed. Entering Enter saves the edited crystal fixture termination resistance to EEPROM and closes the edit screen.

8.2.9 U - Power Calibration Level

Two points are needed to calibrate the RF Power Meter. The first one is normally the raw output of the PWRCAL circuit. The second one uses the same signal source with a 20 dBm attenuator in the circuit. Normally the PWRCAL circuit is adjusted to produce a + 3 dBm signal level. This means the first power point will be +3 dBm and second power point will be -17 dBm. This parameter is set to the higher of the two power levels used; the second level is always assumed to be 20 dB lower. It is, however, possible to set the PWRCAL output level to something other than 3 dBm or to use some other calibrated RF power source to calibrate the RF Power Meter. In these cases, this parameter must be set to the upper power level used to assure proper calibration of the RF Power Meter. This number may be positive or negative.

9 DOS MODE

Pressing the Esc key while in Command mode switches the MSNA to DOS mode. The name “DOS” was chosen because the available commands are similar to and were modeled after the old Microsoft DOS commands. They are provided primarily to enable the operator to access and maintain data files on the SD card that were generated by MSNA sweeps. The file format is standard FAT16 so the SD card files may also be accessed and manipulated by most any MS DOS/Windows or compatible systems (even including many digital cameras). The FAT16 file system limits the MSNA to SD cards of 1GB capacity or less. The card must be formatted on another system (or a digital camera); the MSNA cannot perform a format function. The format must be a basic FAT16 format with only one partition. SD Cards with special formatting, such as multiple device emulation or built-in hubs, will probably not work with the MSNA.

The following DOS mode commands are implemented:

CD <Directory Name>.. Change Directory. Subdirectories are supported.

DEL <File Name> .... Deletes the specified file from the current directory.

DIR .... Displays the contents of the first sector of the current directory.

DUMP .... Displays physical sectors in a combined hex and ASCII format.

DUMP <File Name> .... Displays file data in the dump format.

PENn .... Render Penguins in a snow drift.

PLOTP <File Name> ... Plots the power data in the named file.

PLOTV <File Name> ... Plots the VSWR data in the named file.

SDLD <File Name> ..... Reload the MSNA Firmware from the named file.

TYPE <File Name> ..... Displays the contents of the specified file as text.

UPLD<File Name> ...... Upload file data to the serial port (can be binary)

UPLF<File Name> ...... Upload file text data to the serial port

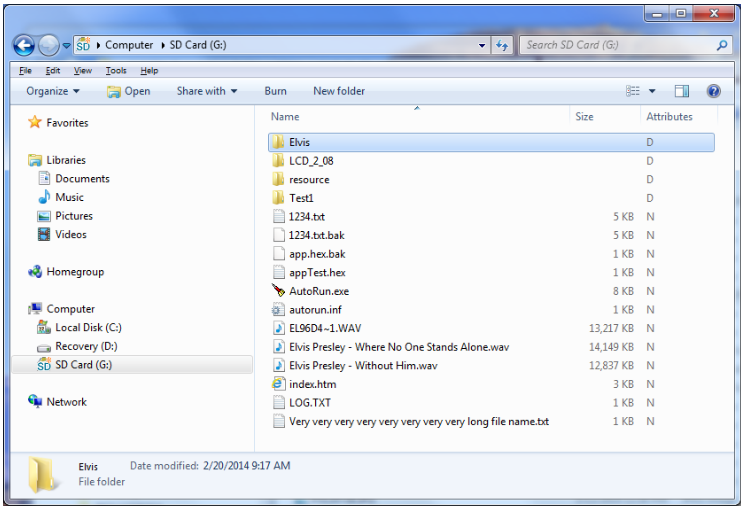
Note that DOS commands followed by "<File Name>" operate on an SD card file and require a file name. The CD command requires a directory name. The remaining commands do not require a file name and will ignore anything following the command. Attempting to execute a command with no name specified but requiring a file or directory name will generate a BEEP.

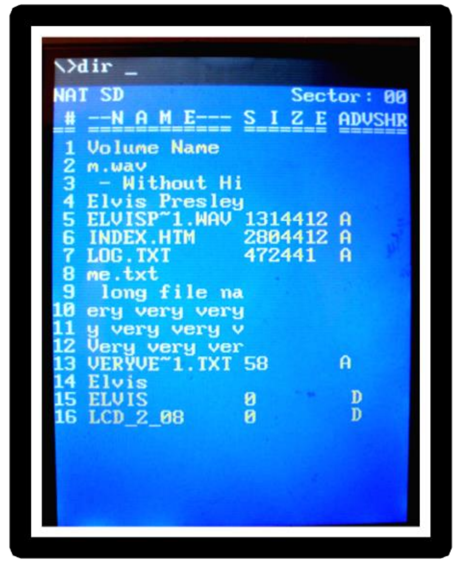
When DOS mode is first entered, the command line starts with the standard DOS prompt “\>” indicating the current directory is the root directory. The contents of the first sector of the current directory will be shown (automatic DIR command execution). When accessing subdirectories, the prompt is enlarged to show the complete path. There is no limit on the level of subdirectories; however, the command line is limited to 30 characters and will not allow entering more than this limit including the prompt.

If a file system error is encountered during the execution of a command, a one or two-line error message will be displayed in red letters. In most cases, when a command is successfully executed, it will remain on the command line until a key is pressed. Then, the command line will be cleared and the new keystrokes entered.

9.1 DIR – DISPLAY DIRECTORY

File names are limited to the original DOS format of 8-characters plus an optional 3-character file name extension (often referred to as the “8 point 3" format). The names of files created on the MSNA are forced to all caps. The MSNA handles longer file names and mixed-case file names indirectly. This is best understood by looking at an SD card DIR display on a windows system and on the MSNA.





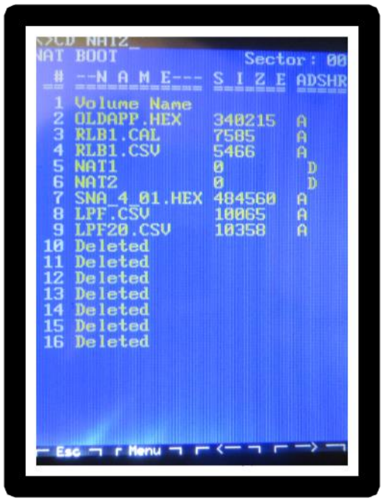
The PC displays a sorted list of directory and file names along with some file characteristics. The MSNA display is simpler. It shows a list of all the directory entries (16 maximum) in only one sector of the directory along with some file characteristics (sizes and attributes). The FAT file system handles long file names by using extra directory entries to hold the names, 13 characters to an entry. This method is also used to handle mixed case and extended ASCII characters. These file name entries use two-bytes (16-bits) per character which is why a 32-byte directory entry is limited to 13, 2-byte characters. The other 6 bytes are used to hold additional information about the file name. The PC file system uses an algorithm to generate a standard 8.3 file name from longer and mixed case file names. The generated name is used in a standard directory entry which is the one the file system uses to access the file. The directory entries holding the long or mixed case file name characters are only used by the PC to translate the real name to the generated one. The extra directory entries are located just in front of the "real" directory entry, in reverse order. For example, consider the file named "Elvis Presley – Without Him.wav" in the above directory examples. The Windows system lists the complete file name on one line and it is accessed by clicking it in the explorer display. The MSNA lists the long name in directory entries 4, 3, and 2 and the generated file name ("ELVISP~1.WAV") in directory entry 5 which is the "real" entry for this file. In the MSNA, this file is accessed by entering the generated name.

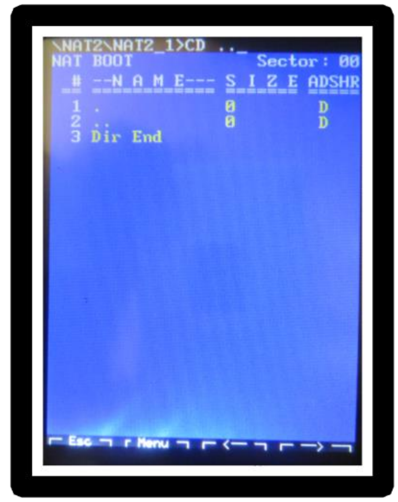
In the DIR display, the volume name ("NAT SD" in this case) is shown in the upper left corner of the display and the directory sector number ("00") in the upper right corner. Entering a RIGHT ARROW will move to the next sector in the directory; LEFT ARROW will move to the previous sector. The last line of the last sector is marked "Dir End" to indicate the end of the current directory.

The DIR display also shows the size of the file and the file attributes. The size is the actual file size; it may occupy more space on the SD card because storage is allocated in clusters of 512-byte sectors. A cluster is typically 32 sectors. The only attribute of interest to the MSNA is the 'D" or directory entry which identifies that entry as a subdirectory, not a file. The PC shows 'N' for no attributes, the MSNA just shows nothing.

9.2 CD – CHANGE DIRECTORY

The MSNA file system supports subdirectories to any level. The only limitation is the 30-character command line length. The following displays illustrate the CD command. This is the first sector of the root directory. This directory contains entries for six files and two subdirectories ('D' attribute).





In the first display the operator has entered a "CD NAT2" command. The second display comes up when ENTER is entered. Note the prompt has been expanded to show the current directory ("\NAT2>") and the content of the subdirectory is displayed. The operator now enters "CD NAT2_1" and when ENTER is entered, the third display comes up. Note the subdirectory listings all start with directory entries named "." (dot) and ".." (dot-dot). These "names" represent the current and parent directories. The ("CD ..") command in the third display will change back to the previous display when ENTER is entered.

The command prompt includes the total path to the currently active directory. When a sub-directory name is entered in a CD command without additional path information, the sub-directory must be in the currently active directory or a "FILE NOT FOUND" file error will be displayed. The complete directory name is constructed by concatenating the path part of the command line prompt with the keyed directory name. The keyed directory name can contain additional path information. For example, in the above CD displays, the command "CD NAT2/NAT2_1" entered in the first display will go directly to the third display. Similarly, the command "CD \" will always return to the root directory. Note that the MSNA will accept either '\' or '/' as the name delimiter in a path specification. Also, note that commands can be entered in either upper case or lower case letters but will always be forced to upper case.

DOS commands will only look for a specified file in the currently active directory. If necessary, the CD command must be used to navigate to the directory containing the file before the command is entered. The active directory is retained and will remain the active directory even after exiting and returning to DOS mode as long as the MSNA is not reset (power cycled). The CD command must be used to change the currently active directory.

9.3 DEL – DELETE FILE

This command deletes the named file in the current directory and frees the storage spaced for reuse. The directory entries for deleted files are identified as "Deleted" in the DIR display (see previous examples). When a new file is created, the MSNA searches the directory from the beginning looking for either an entry for a deleted file or the first unused entry in the directory. The unused entries are always at the end of the directory and identified by "Dir End" in the DIR display. This is a little different than the way a PC does it. The PC always uses an unused entry to create a new file unless there are none. This is why there may be a number of deleted entries in a directory if the SD card has been used in a PC. If the proliferation of deleted files becomes annoying, the only cure is to save the files to a PC then reformat the SD card and restore the files to it.

9.4 DUMP – DISPLAY DATA IN HEX AND ASCII

The DUMP command is mainly provided to trouble shoot problems with file data and will probably rarely, if ever, be used by the average user. The following is a brief description of the command.

There are two DUMP command formats. One specifies a file name, the other does not. Without a file name specification the DUMP command displays data from physical sectors. The first display always shows sector 0. Only 64 bytes at a time are shown. The up and down arrows move one 8-byte row up or down; the Page up and Page down move one full sector (64 rows) up and down the sector data. Left and right arrows move one screen (8 rows) up and down. The operator can also key in a sector's LBA (Large Block Address). The display is eight double-lines of eight characters. The first line of the double line displays the characters as hex values. The second line displays the characters as ASCII characters if one has been assigned and it is in the MSNA's font table. Note that the MSNA has some unique fonts to represent things like Function keys and they will probably show up in dumps of binary data files.

When a file name is specified, the named file is opened and the sector data from that file are displayed in the dump format. The arrow keys provide the same navigation as described above but only within sectors in the named file.

9.5 PLOT(P) – PLOT POWER DATA FROM A FILE

The PLOT command action is similar to the plotting done in Terminal and Macro modes described above except the data comes from an SD card file and not from the serial interface. The "P" at the end of the command is optional; "PLOT" and "PLOTP" are the same commands. When a PLOT command is entered, the data read from the file is displayed as it was when it was spooled in Terminal or Macro mode. Scrolling is turned off when the actual plot data is read. Instead, the last line of the display is repeatedly updated with the plot data. At the end of the file, the data is plotted as described above. Once plotted, the plot remains on the screen until a key is pressed other than CTRL-C (which loads the calibration constant buffer from the data buffer) and ALT-C (which clears the calibration constant buffer).

This command can be particularly useful to restore calibration constants without having to redo the calibration sweep each time. The file can be generated once for a given set of scan parameters or test fixture and then loaded every time those scan parameters or the test fixture are used. A different file name can be used for each set of scan parameters. It may be helpful to use a different name extension for calibration data files such as ".CAL" instead of ".CSV".

9.6 PLOTV– PLOT VSWR DATA FROM A FILE

This command is the same as the PLOT(P) command with a plot of the VSWR added to the returned power loss plot. Plotting data from a Return Loss Bridge is described later in this document.

9.7 SDLD – RELOAD MSNA FIRMWARE FROM SD CARD FILE

The MSNA firmware may be updated from a file in the root directory of the SD card. The SDLD command must include the name of a file located in the **root** director of the SD card. If the named file cannot be opened, the command posts an error and terminates execution. The actual load requirements and operation details are covered in a later section of this document (see **UPDATING MSNA FIRMWARE**).

9.8 TYPE – DISPLAY TEXT

The TYPE command displays text files in blocks of 18 display lines. The display is scrolled up and another 18 lines of text displayed every time either ENTER, SPACE, or RIGHT ARROW is entered. Entering ESCAPE ends the command. This DOS command can be useful to validate recorded data and data formats as well as for reading text files.

9.9 UPLD - UPLOAD FILE DATA

This command will read data from a file on the SD card and transmit it over the serial interface. The data is transferred exactly as read from the SD card; nothing is added or removed. The data can be binary and of any length.

9.10 UPLF - UPLOAD FILE TEXT

This command will read text data from a file on the SD card and transmit it over the serial interface. The data is assumed to be text intended for uploading to a PC Windows application. Many PC applications require each line of text to end with a two character sequence: CR LF. Other systems only require the CR. As data is read from the SD card, it is scanned to make sure all CRs are followed by an LF. If a CR is found without an LF immediately following it, an LF will be inserted at that point in the data stream.

9.11 DOS MODE CONTEXT MENU AND HOT KEYS

With one exception, there are no context menus and hot keys available in DOS mode. Entering CTRL-M will normally bring up the command menu. The one exception is if there is a plot displayed after executing a PLOTP or PLOTV command.

The hot keys active in DOS mode with a plot displayed function as follows:

CTRL-C.................Transfers the contents of the data buffer to the calibration data buffer and to the EEPROM.

ALT-C...................Clears the contents of the calibration data buffer and the calibration buffer EEPROM area.

CTRL-P.................Re-plots the current contents of the data buffer.

Esc.........................Clears the display and restarts in Terminal mode. The ESCAPE character is transmitted on the serial port to indicate the resetting of Terminal mode and request a remote device reset and restart.

10 SPECIAL TEST FIXTURES

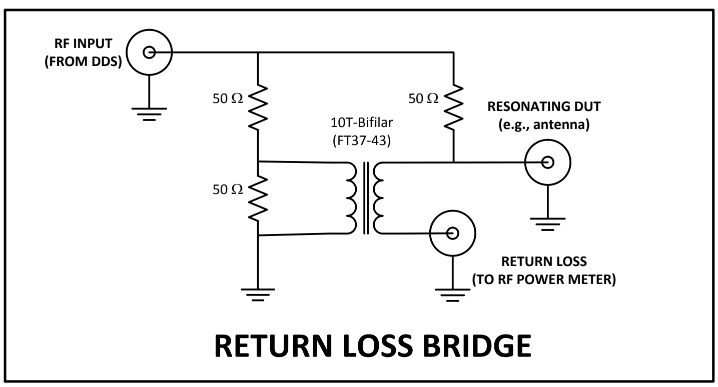
Up to now we have been discussing DUTs that connect direct to the RF OUT and RF IN connectors with the possible addition of an attenuator. The functionality of the MSNA can be significantly expanded with special test fixtures in the circuit between the MSNA and the DUT. Test fixtures generally serve one or more purposes: impedance transformations, signal attenuation, load reduction, and RF signal component separation. Test fixtures generally need specialized firmware support. The following test fixtures are currently supported by the MSNA:

- Return Loss Bridge (RLB) - Antenna analysis and tuning
- Crystal Test Fixture (CTF) - Sorting and matching crystals for use in filters

10.1 RETURN LOSS BRIDGE - ANTENNA ANALYSIS

When power is fed to an antenna, we would like all of it to be radiated from the antenna. If our antenna system was perfect all the power will be radiated, however, no antenna system is perfect. Power that is not radiated is reflected or returned back to the source. The amount of reflected power depends on how well our source (transmitter) matches our antenna system at the operating frequency. The better the match the less power is reflected. Comparing the amount of power fed into an antenna with the amount of power reflected is a measure of the efficiency of the antenna and is often expressed as a Voltage Standing Wave Ratio or "VSWR".

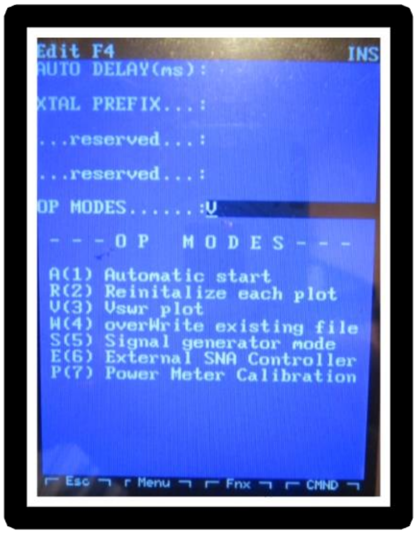
A Return Loss Bridge (RLB) is able to separate the reflected power from the incident power at the connection to the antenna system. Therefore it can be used to measure the reflected power and the MSNA firmware can calculate and plot the VSWR. The RLB we use is a very simple device consisting of a single toroid with a single bifilar winding, three resistors, three BNC connectors, and something to mount them al on or in.

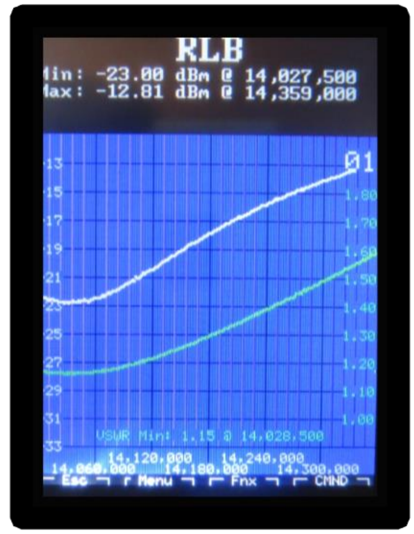


The RLB shown here is a homebrewed unit based on a design from Experimental Methods in RF Design (Figure 7.41). It is packaged so that the RF INPUT and RETURN LOSS BNC connectors are spaced the same as the RF OUT and RF IN connectors on the MSNA. Male-to-Male BNC adaptors are used to connect the RLB's RF INPUT and RETURN LOSS connectors to the MSNA's RF OUT and RF IN, respectively.

Before using the RLB, it must be calibrated to account for any insertion loss and to compensate for the DDS output power level variation with frequency. This is done by doing a frequency scan with the antenna connector either open or shorted so that all incident power will be reflected. After the scan, entering CTRL-C will load the data into the calibration buffer. The contents of the calibration buffer will be subtracted from future scan data to normalize the results and give accurate values the return loss and the VSWR values.

The following example is a scan of a 20M vertical antenna across the entire 20M band (14.00 MHz to 14.36 MHz). The second page of the macro form (F4 in this case) has op mode V specified so that the VSWR will be plotted along with the return loss. (Note that the return loss is shown as a negative value making it the equivalent of the reflection coefficient.)





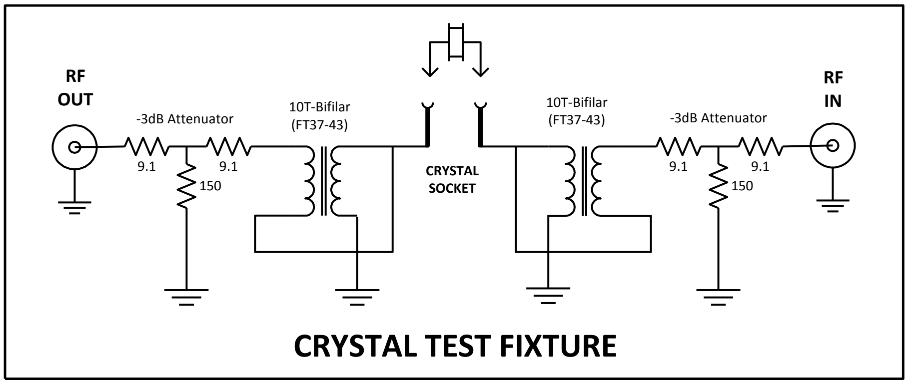
After the macro is started, the sig gen screen is displayed. In manual start mode the scan will not start until the SPACE bar is pressed or the screen is tapped in the area below the frequency. In this case it will make one scan each time. In automatic start mode, scans will be made repeatedly with approximately one-quarter second between scans.

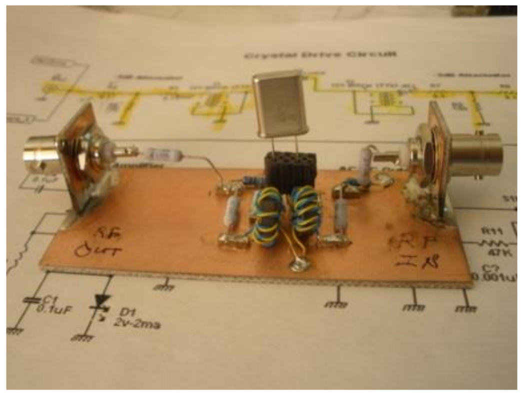
After the scan, the return loss is plotted in white and the VSWR is plotted in green. The VSWR at the resonant frequency is shown in green at the bottom of the plot area. The power scale is on the left side of the plot area, the VSWR scale is on the right side of the plot area in green. Repeated scans will over-plot the new values for the return loss in colors; the VSWR is always plotted in green.

10.2 CRYSTAL TEST FIXTURE - CRYSTAL MATCHING

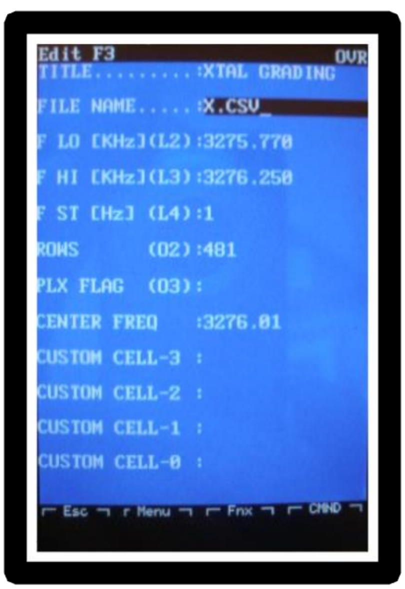
When designing crystal filters it is important to characterize the crystals and select crystals that match as close as possible. Besides the series resonant frequency the motional parameters Rm, Lm, and Cm are often considered when selecting crystals for a filter. These are the equivalent series resistance, inductance, and capacitance. The quality factor (Q) is also an important parameter used in grading crystals.

When a sweep is done on a crystal, the crystal is generally held in a special test fixture which presents a well-defined termination resistance to the RF power source while matching the impedance of the crystal. Crystals generally have natural impedance of 12.5 ohms, about one fourth of the impedance the MSNA RF interfaces are designed for. Crystals generally operate better under conditions of very low power input and low output loading. Our crystal test fixture (CTF) therefore has attenuator pads on input and output and impedance matching transformers before and after the crystal. It is built on copper clad using Manhattan style construction.

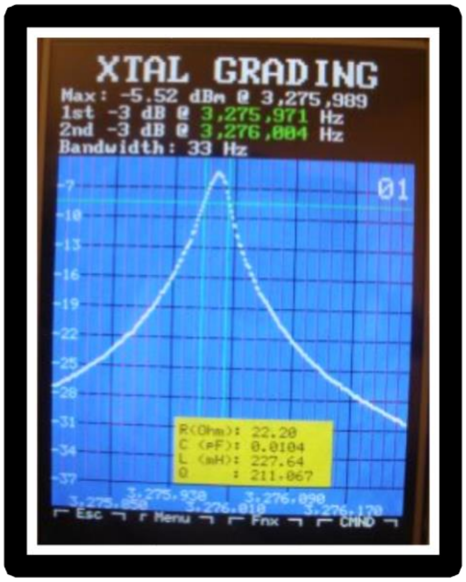


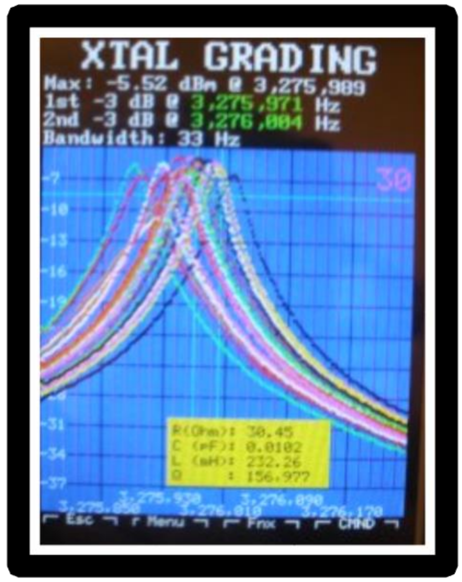


Before using the CTF, it must be calibrated to account for the insertion loss and the DDS-60 power level variation with frequency. The calibration is done taking a sweep with a jumper shorting out the crystal socket pins. After the scan, CTRL-C will store the results in the calibration buffer to be used to normalize data from future scans. It is also necessary to make sure the crystal termination resistance (item ' X ' on the EDIT MENU) is set to the test fixture's impedance (12.5 ohms in this case).



Some special considerations are also necessary when setting up the macro form for crystal grading and matching. First, you will probably always want to spool the data for sorting and grading so the FILE NAME field should be filled in (X.CSV here). Second, the band pass of a crystal is very narrow so to maximize the accuracy of our readings, FREQ ST should be very low, usually 1 Hz. Third, it is usually more convenient to specify CENTER FREQ instead of FREQ LO and FREQ HI. When working with a batch of crystals you may have to make several trial runs to locate the center frequency that will allow analysis of all the crystals in the batch. You may also find it more convenient to specify op mode W so you don't have to keep deleting the files after each trial run.





When the test fixture termination resistance read from EEPROM is greater than 1.0 and the MSNA recognizes a band pass plot (which is what we are looking for in a crystal), the three motional parameters and the quality factor are computed and displayed in a window in the lower center of the plot. These values are not displayed on any other plot type. Setting the crystal fixture termination resistance to zero inhibits the display of these values. When all these conditions are met, the MSNA will spool the resonant frequency, the motional parameters, and the Q in a single data row for each scan. Each data row will start with an ID for the crystal being tested.

The data from each sweep is plotted without reinitializing the plot display. The data from each sweep will be plotted on top of the preceding plots. The spooled file data format is as follows:

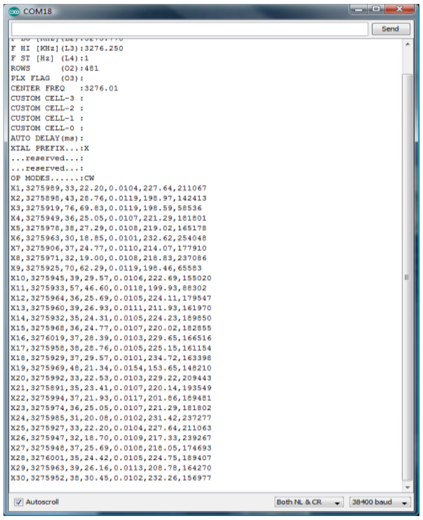
```
ID,Fs,BW, R(Ohm),C (pF),L (mH),Q
X1,4913764,104,17.41,0.0162,64.90,115104
X2,4913768,108,17.32,0.0153,65.73,115085
X3, . . . . . . . .
```

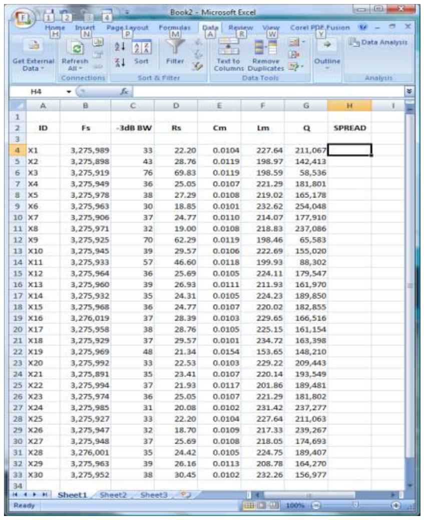
Each line ends with a CR character (0x0D). The first line is just a heading line to show the placement of the parameters in each line. It could be used as a heading row on a spreadsheet or just ignored. The frequency shown (Fs) is the frequency at which the RF Power Meter registered maximum power out. This is the series resonance frequency of the crystal. The third column, BW, is the bandwidth measured at the -3 dB points.

Each line after the heading starts with the crystal ID for that data point. The prefix is derived from the second page parameter labeled “XTAL PREFIX”. If the prefix is not defined, the sweep data will be processed normally; the sweep data will be spooled (assuming a new spool file is specified), not the crystal parameters. When the XTAL PREFIX is defined the crystal parameters will be spooled, not the sweep data.

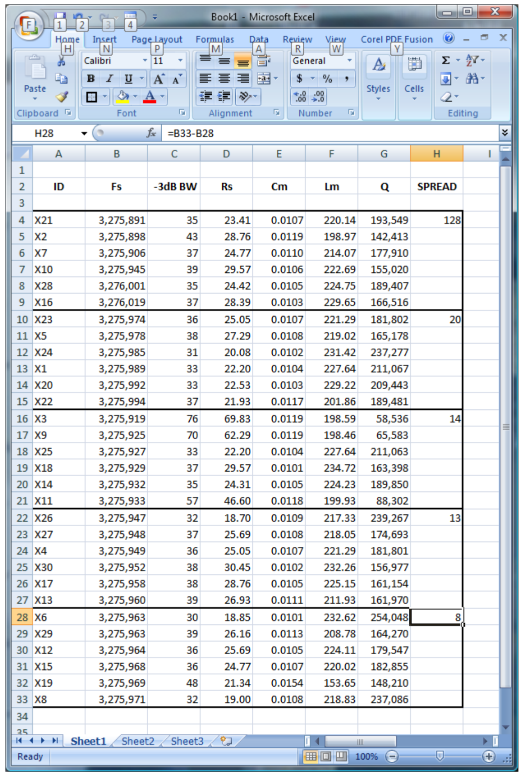
The plot number is appended to the XTAL PREFIX and spooled as the first field of each data row. The plot number is reset to zero when the Macro first starts and is incremented by one after each plot but before spooling the data. This means the first data line will always have a plot number of 1. As each data set is added to the plot, the crystal parameter window is updated to reflect the parameters for the current plot. Note that when the plots are overlaid, the final plot will give the user a feel for the variation in resonant frequency, maximum power out, and bandwidth for the batch of crystals. The green lines showing the roll-off power level points are generated when the plot display is first initialized so they only apply to the first crystal in the batch.

In the example we are using here, we are looking for six crystals to use in a crystal filter with a target band pass of 400 Hz. A rule of thumb says the frequency spread of the crystals in the filter should be less than 10% of the desired filter bandwidth. That means we must find six crystals with a total frequency spread of less than 40 Hz. To do this, we used 30 crystals purchased as a single lot and ran them through our CTF, one at a time. We then used the UPLF DOS command to upload the data to a terminal emulator running on a PC. We then copied and pasted the results into an Excel spread sheet and expanded the data into columns.





We then sorted the data by frequency, lowest to highest. Another column was then added to the table which computed the difference between the frequency in the fifth row below with the frequency in this row. The group of six crystals with the tightest frequency spread is identified by the lowest number in this column. After isolating the data rows for that group and compressing the table, we selected the next lowest frequency spread. This was continued until we had divided the crystals into five groups of six and ranked them by frequency spread. The best group had a frequency spread of only 8 Hz. There were three more groups that met our criteria of having a frequency spread of less than 40 Hz. The fifth group had a spread of 128 Hz so it exceeded our limit by over three times.



ID	Fs	-3dB BW	Rs	Cm	Lm	Q	SPREAD
X21	3,275,891	35	23.41	0.0107	220.14	193,549	128
X2	3,275,898	43	28.76	0.0119	198.97	142,413	
X7	3,275,906	37	24.77	0.0110	214.07	177,910	
X10	3,275,945	39	29.57	0.0106	222.69	155,020	
X28	3,276,001	35	24.42	0.0105	224.75	189,407	
X16	3,276,019	37	28.39	0.0103	229.65	166,516	
X23	3,275,974	36	25.05	0.0107	221.29	181,802	20
X5	3,275,978	38	27.29	0.0108	219.02	165,178	
X24	3,275,985	31	20.08	0.0102	231.42	237,277	
X1	3,275,989	33	22.20	0.0104	227.64	211,067	
X20	3,275,992	33	22.53	0.0103	229.22	209,443	
X22	3,275,994	37	21.93	0.0117	201.86	189,481	
X3	3,275,919	76	69.83	0.0119	198.59	58,536	14
X9	3,275,925	70	62.29	0.0119	198.46	65,583	
X25	3,275,927	33	22.20	0.0104	227.64	211,063	
X18	3,275,929	37	29.57	0.0101	234.72	163,398	
X14	3,275,932	35	24.31	0.0105	224.23	189,850	
X11	3,275,933	57	46.60	0.0118	199.93	88,302	
X26	3,275,947	32	18.70	0.0109	217.33	239,267	13
X27	3,275,948	37	25.69	0.0108	218.05	174,693	
X4	3,275,949	36	25.05	0.0107	221.29	181,801	
X30	3,275,952	38	30.45	0.0102	232.26	156,977	
X17	3,275,958	38	28.76	0.0105	225.15	161,154	
X13	3,275,960	39	26.93	0.0111	211.93	161,970	
X6	3,275,963	30	18.85	0.0101	232.62	254,048	8
X29	3,275,963	39	26.16	0.0113	208.78	164,270	
X12	3,275,964	36	25.69	0.0105	224.11	179,547	
X15	3,275,968	36	24.77	0.0107	220.02	182,855	
X19	3,275,969	48	21.34	0.0154	153.65	148,210	
X8	3,275,971	32	19.00	0.0108	218.83	237,086	

FINAL RESULTS

11 MSNA CALIBRATION

There are a lot of variables in an SNA system that must be accounted for to assure the accuracy of the results. The MSNA hardware and firmware provide enough functionality to enable you to accurately calibrate the MSNA with nothing more than a digital volt meter (DVM) capable of measuring millivolts and everyone has one of those, right?

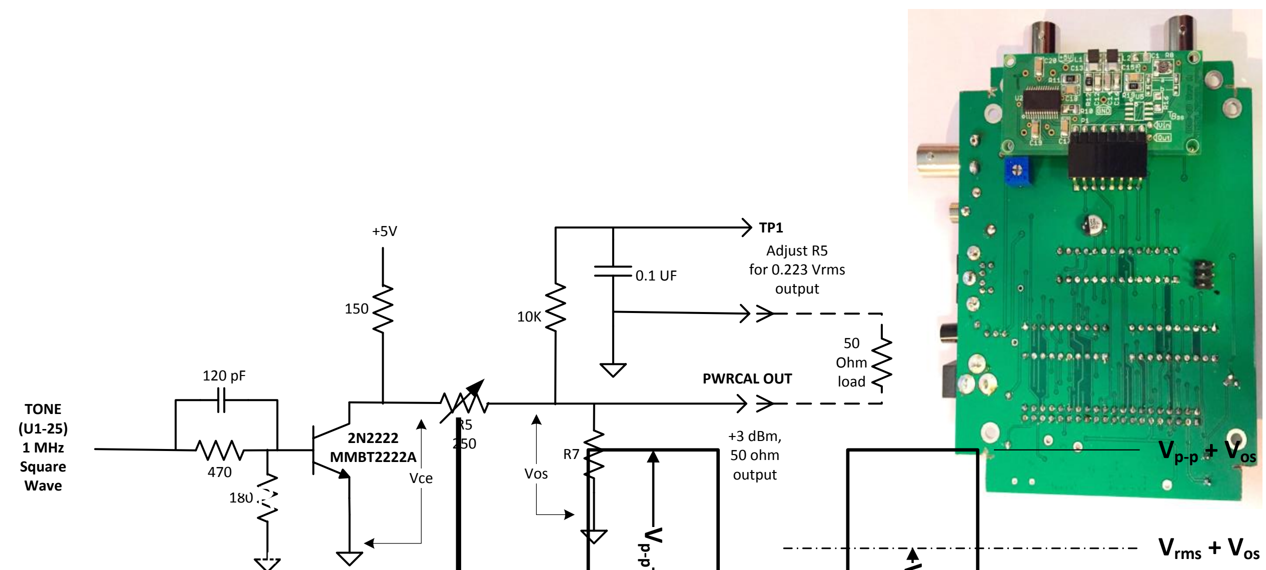
There are a number areas that need to be addressed here:

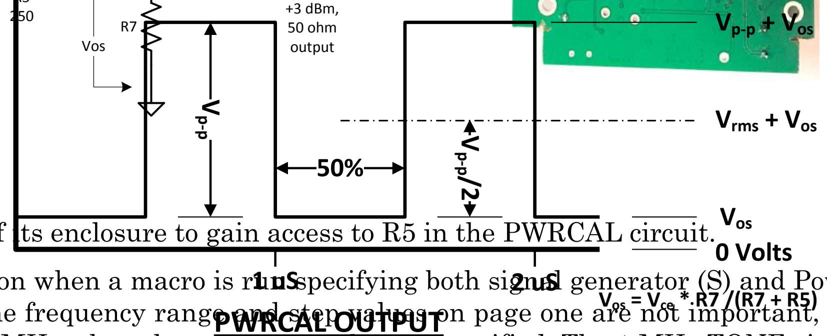
- Setting the PWRCAL output level to +3 dBm
- Calibrating the RF Power Meter to accurately read dBm
- Setting the attenuated DDS-60 output level to 0.00 dBm at 1 MHz
- Determining the actual DDS-60 reference frequency
- Compensating for the DDS-60 output level variations with frequency

All power level settings and measurements assume a 50-ohm load. The RF Power Meter has an input impedance of 50 ohms. It is recommended that all calibrations be made with the RF signal being used connected to the RF Power Meter input to assure a proper impedance match.

11.1 PWRCAL OUTPUT LEVEL

The MSNA firmware generates a logic level, 1 MHz square wave to drive the following circuit:





The MSNA assembly must be out of its enclosure to gain access to R5 in the PWRCAL circuit.

The 1 MHz TONE signal is turned on when a macro is run specifying both signal generator (S) and Power Meter Calibration (P) op modes. The frequency range and step values on page one are not important, the output frequency is always set to 1 MHz when these two op modes are specified. The 1 MHz TONE signal will be turned off when the macro is terminated and the transistor will be turned on again.

The PWRCAL OUT signal level must be set to +3 dBm (about 2 milliwatts) before it can be used to calibrate the RF Power Meter. The signal is generated by toggling the TONE signal every 500 ns thus assuring a 50% duty cycle at 1 Mhz. When the transistor is turned on, the PWRCAL output level is the collectoremitter voltage (V_{ce}) scaled by the R5-R7 voltage divider. This offset voltage (V_{os}) must be accounted for. When the transistor is turned off, the output level is scaled by the same divider with V_{ce} pulled towards +5 V by the 150 ohm resistor. The 10K resistor and 0.1 UF capacitor form a high impedance voltage probe that converts the V_{rms} of PWRCAL to millivolts on TP1. This value, however, is shifted up by V_{os}. Since the value of R5 affects both of these values, the setting of the output level can be an iterative process.

Normally, when a macro specifying the S and P op modes is **not** active, TONE is held at a positive voltage level and the transistor is turned on and TP1 is held at V_{os} which is typically about 20 millivolts. So the first step is to power up the MSNA and adjust R5 for a reading of 20 millivolts at TP1.

It turns out that a square wave signal level of +3 dBm into a 50-ohm load has a V_{rms} of 223 millivolts which is half the peak-to-peak voltage. The next step, then, is to turn on the 1 MHz TONE signal and adjust R5 to read 223 millivolts plus 20 millivolts (V_{os}) or 243 millivolts at TP1. Next, turn off the 1 MHz TONE signal and recheck V_{os}. If it has changed, turn on the 1MHz TONE signal and adjust R5 until the voltage on TP1 reads 223 millivolts plus the new value for V_{os}. Repeat this process until there is little or no change in the voltage level observed with the 1 MHz TONE turned off.

11.2 RF POWER METER SLOPE AND INTERCEPT

The following are prerequisites to setting the RF Power Meter slope and intercept values:

- Set the PWRCAL output to +3.0 dBm as described above
- Set the ADC reference voltage (SCROLL-LOCK > V) to 3.00 volts.
- Set the upper power calibration level (SCROLL-LOCK > U) to + 3 dBm
- Connect PWRCAL to the RF IN with a short piece of coax.
- Clear the calibration data buffer (ALT-C in Terminal mode)

The RF Power Meter uses an AD8307 logarithmic amplifier/detector to generate an analog voltage level that is a linear function of the power level of the signal received on the RF IN connector. This plot from the AD8307 Data Sheet shows the relationship between input power level in dBm and the output voltage.

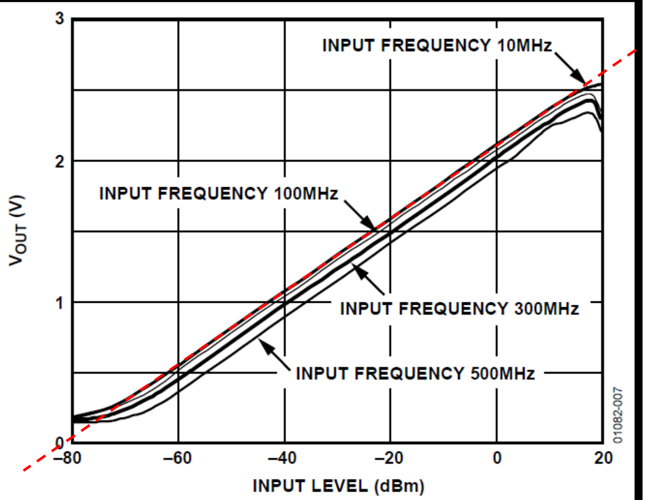


Figure 7. V_{OUT} vs. Input Level (dBm) at Various Frequencies

Note that the slope is linear over its length except for at the very ends. The non-linearity at the ends reduces the usable dynamic range to about 95 dB. The output voltage level is first processed by a 12-bit analog to digital converter that produces the ADC count which is then converted to dBm by the firmware. Two constants are needed to do the conversion from the ADC count to dBm: the slope of the above curve and the zero intercept point which is where the curve would cross the 0 volt V_{out} level if it were a straight line all the way down (the dashed line in the above figure). When V_{out} is expressed in ADC count, the dashed line follows the general form of this linear equation:

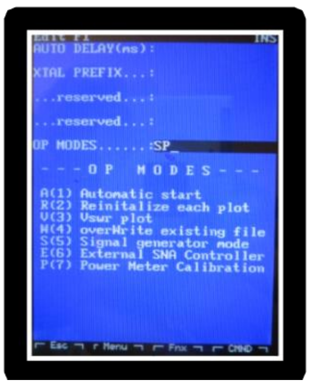
$$P = S*C + I$$

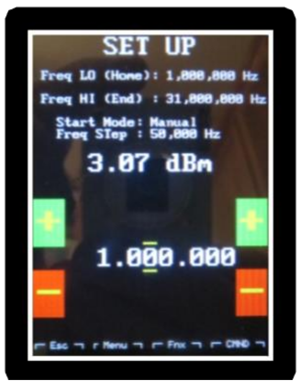
Where:

P is the power level in dBm
S is the slope of the linear part of the curve in dBm per ADC count
C is the 12-bit count generated by the ADC
I is the zero intercept point in dBm.

Since there are two unknowns in this equation (S and I), they can be calculated by solving the equation for two points on the line as defined by two power levels (P) and the corresponding ADC counts (C).

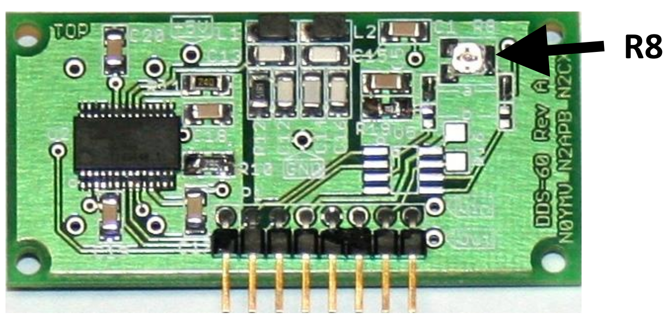
To get the slope and intercept values, start a macro with FREQ LO set to 1000 KHz and S and P op modes specified. Enter CTRL-S to capture the ADC count for +3 dBm. You will then be prompted to add a 20 dBm attenuator to the circuit. After the 20 dBm attenuator is installed, enter ENTER to capture the ADC count for -17 dBm. The firmware will use the captured ADC counts to compute the slope and intercept points and will save the values to EEPROM to be used to compute all future power level readings.





11.3 RF OUTPUT LEVEL

After the RF Power Meter has been calibrated, it can be used to set the DDS-60 output level to give an RF OUT signal level of 0.00 dBm (1 milliwatt). The DDS-60 output level is controlled by R8 on the DDS-60 PCBA.



This trim pot is very small and very sensitive to nearby metal. If you must use a metal screw driver to adjust R8, check the level after the screw driver has been moved away from the DDS-60.

To set the DDS-60 output level, connect RF OUT to RF IN with a short piece of coax and start a macro with FREQ LO set to 1000 KHz and op modes S (signal generator) and A (auto-start) specified. Adjust R8 on the DDS-60 PCBA until the signal generator power level reads 0.00 dBm or as close to that level as possible. There will probably some noise the system causing the reading to vary over a fraction of a dBm. In this case, adjust the DDS-60 output level so that the reading appears to vary in a range centered around 0.00 dBm.

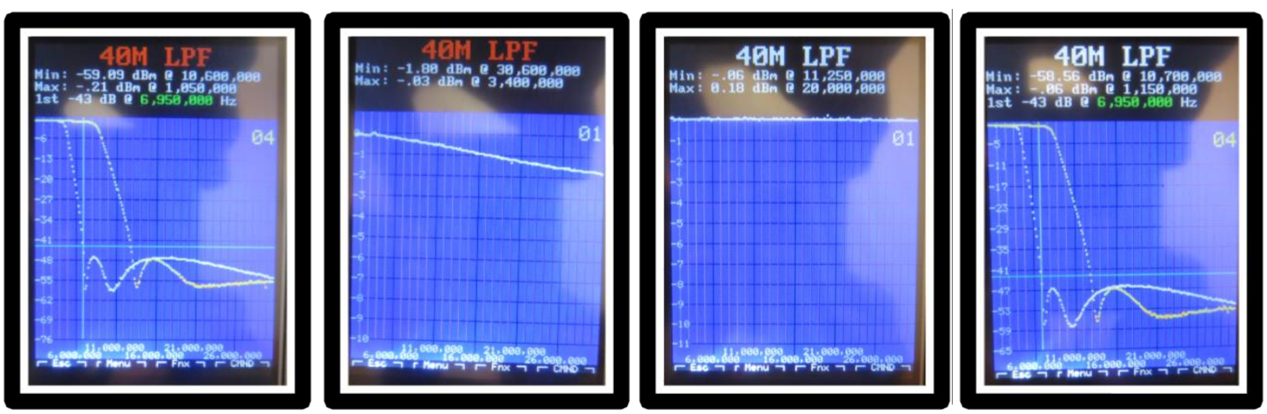
11.4 FREQUENCY CALIBRATION

The DDS-60 reference clock is crystal controlled but the crystal frequency tolerance is +/- 20 ppm or +/- 3600 Hz at 180 MHz. The reference clock frequency is used to calculate values that the AD8307 uses to set the output frequency. The value used for this calculation defaults to the nominal reference clock frequency of 180 MHz. This value can be adjusted to provide a more accurate RF OUT signal frequency. To do this, run a macro with the S (signal generator) and A (auto-start) op modes specified and a frequency range that includes 10000 KHz (10 MHz). With the frequency set to 10 MHz, connect RF OUT to a frequency counter. If you do not have access to a frequency counter, put a short antenna on RF OUT and user your communications receiver tuned to WWV at 10 MHz. Enter CTRL-T and the sig gen display will change to display the current reference clock frequency setting. Use the arrow keys to adjust the reference clock frequency until the frequency counter reads 10 MHz (or your receiver indicates the RF OUT signal is equal to, or "zero beating", WWV's signal). Once the reference frequency has been determined, enter ENTER to capture and save the reference frequency in EEPROM. This new value will now be used to set the DDS frequency.

11.5 COMPENSATION FOR DDS-60 OUTPUT VARIATION

The RF Power Meter is very accurate but the DDS-60 output level may vary significantly as a function of frequency. The MSNA provides a simple way to compensate for this. In addition to the basic data buffer, the MSNA contains a second buffer for calibration constants. During a sweep, each data value is entered into the data buffer minus the value contained in the calibration constant buffer corresponding to a frequency equal to or closest to the data value's frequency. Since the values are logarithmic, this is the equivalent of multiplying the data value by a scaling factor.

To load the calibration buffer when a test fixture is not used, simply replace the DUT with a direct connection between RF OUT and RF IN. Make sure the calibration buffer is cleared (ALT-C) before starting the sweep. With the direct connection in place, run the sweep using a frequency range equal to or greater than that to be used with DUTs and plot the results. The result will indicate the miss-match between the RF OUT and the RF Power Meter over the frequency range. After the sweep has been recorded, pressing the hot key sequence CTRL-C will load the calibration constant buffer with the contents of the data buffer. All future sweep data will be loaded into the data buffer minus the value stored in the calibration constant buffer. The following screen shots illustrates the process:



UN-CALIBRATED LPF SWEEP | **RAW CALIBRATION SWEEP** | **CALIBRATED CALIBRATION SWEEP** | **CALIBRATED LPF SWEEP**

The first display shows un-calibrated plots from two LPF filters, an 80M (white trace) and a 40M (yellow trace). Note that the title is rendered in red indicating the plotted data is not calibrated. The second display shows the raw results of the sweep with a short length of coax cable replacing the DUT. This plot shows that, without compensation, it would appear that the DUT (our coax cable) has zero to nearly 2 dB of insertion loss across the frequency range. (Recall that the DDS-60 output level was set to 0.00 dBm at 1 MHz.) With this plot on the screen, pressing Ctrl-C loaded the data into the calibration constant buffer. The third display was then made with the coax cable still in place resulting in a calibrated plot of the DDS output at essentially 0 dBm across the frequency range. Note the title is now rendered in white indicating the plotted data has been calibrated. The fourth plot was made by rerunning the sweeps on the LPFs. The most noticeable change is at the end of the LPF plots. The un-calibrated plots end at about - 55 dBm and the calibrated plots end at about -53 dBm.

The calibration data is written to EEPROM at the same time the calibration constant buffer is updated. The calibration data buffer will be loaded from EEPROM each time the MSNA powers up. The calibration data buffer can be manually cleared by entering ALT-C. If you only test DUTs that connect direct to the MSNA without a test fixture you will probably only need to run the calibration once.

When a test fixture is used, the procedure is essentially the same as described above except it is run with the test fixture in place and the DUT disconnected and, possibly, replaced with a dead short depending on the type of test fixture. Considering the RLB discussed earlier, the RLB is calibrated with the antenna disconnected so the return loss should be 100%. The CTF is calibrated with a short across the crystal socket. In both cases, the calibration data will compensate for the DDS output level changes with frequency and will compensate for any insertion loss (or intentional attenuation) in the test fixture.

The EEPROM will hold the calibration data from the last calibration operation. The data must be reloaded when adding or removing a test fixture from the network. You may find it convenient to spool the results of the calibration scans to files on the SD card so the calibration data can be reloaded without having to actually rerun the calibration scan. Instead, just plot the calibration from the spool file in DOS mode and enter CTRL-C to load the calibration constant buffer and the EEPROM with the new data.

12 TOUCH SCREEN OPERATION

The touch screen allows nearly all of the MSNA operations to be performed without a keyboard attached. Some preliminary setup operations may require the keyboard to be used to enter alpha text such as plot titles and file names. An on-screen numeric pad allows the user to enter and edit numeric data. Plot titles and file names can also be edited to add and edit numeric suffixes and prefixes to titles and names.

Touch screen support enables operator input through "button" taps and selections from menus. While it may be possible to use the touch screen with finger presses, due to the small size of the screen and the closeness of the objects displayed, touch screen operation will be much easier if a stylus is used. But first a warning about stylus use:

WARNING

The touch surface is plastic, not glass, and can be permanently damaged by using an improper stylus. Never use a sharp metal or hard plastic stylus. A wooden stylus is recommended, however, a metal or plastic stylus can be used as long as the tip is blunt and polished.

HINT

A wooden golf tee makes an excellent stylus.

This section describes the general methods to operate the MSNA with the touch screen. The operations performed are described elsewhere in this document. The touch screen "tools" include buttons and two types of menus. First, however, we need to define the terms we will be using to describe these tools. Then we will cover touch screen calibration and how to use the various touch screen tools the MSNA firmware provides.

12.1 TOUCH SCREEN GLOSSARY

Here is a brief list of touch screen terms and their meaning as used herein:

- Touch Screen – A transparent membrane covering the surface of the display designed so that the position of a **single** touch can be determined by the MSNA firmware.
- Stylus – A pointing device used to improve resolution and accuracy of a touch over that possible with a finger.
- Pen – Another name for a stylus (**NOT A WRITING IMPLEMENT**).
- Pen down – The stylus is touching the touch screen so that the firmware can accurately locate its position on the display.
- Pen up – The stylus is not touching the touch screen and the firmware cannot accurately locate its position.
- Tap – Momentarily touching the screen (pen down followed by pen up). Note that the position of the stylus when it is raised is the captured or "touched" position. You can drag the stylus to the desired position and then raise it.
- Button – A (generally marked) display area where a tap will cause an action such as displaying a menu or changing operating modes.
- Menu – A displayed list of options that can be selected by tapping one row in the option list. MSNA menu selections can also be made from the keyboard.
- Static menu – A fixed menu, the listed options are determined by the MSNA firmware and will be the same every time the menu is displayed.
- Context menu – A static menu that pertains to the current operating context. Context menus generally initiate/perform keyboard hot key functions.

- Dynamic menu – A menu with options that are not determined or defined by the MSNA. For example, a menu generated by an external SNA controller and displayed on the MSNA screen is a “dynamic menu”. The listings generated by the DOS DIR command are also dynamic menus.

12.2 TOUCH SCREEN CALIBRATION

The touch screen membrane is actually two layers of resistive film that are shorted together at the touch point. The touch screen controller measures the resistance between the four edges of the touch screen and provides two values **related** to the touch position. The characteristics of touch screens can and do vary significantly from unit to unit. They can also be affected by temperature and by age. For these reasons, it is necessary to calibrate touch screens individually. This calibration process should be repeated if the accuracy of locating the touch point degrades. The MSNA firmware provides a simple and quick way to calibrate the touch screen and to verify its accuracy.

Calibration is performed by the user touching nine points on the display the positions of which are “known” to the firmware. The relative readings provided by these nine touches are used to solve a set of simultaneous equations to provide a set of calibration parameters. These parameters are stored in the EEPROM. From then on, every time a pen position is read, these values are used to generate the exact coordinates of the touched pixel on the LCD.

The calibration sequence is started by touching (pen down) the touch screen when the MSNA powers up. The screen will clear and, when ready, "TAP EACH CROSS" will be displayed across the top of the display in large green letters. At this point, raise the stylus and the first of the nine points will be displayed as a cross in the upper left corner of the display. Touch the center of the cross and the second cross will appear. Continue until all nine cross have been touched

After the ninth cross has been touched, a simplified Etch-A-Sketch screen is displayed to allow you to test the calibration. If the dot pattern follows your stylus reasonably well, touch the EXIT button to exit and start the main firmware. If you are not satisfied with the calibration, touch the REDO button and the calibration sequence will restart.

RECOMMENDATION

The recommended technique here (and for all touch screen operations) is to hold the pen on the screen and drag it to the center of the cross and then raise the pen to capture the position data.

13 UPDATING MSNA FIRMWARE

An SD card (SDC) boot loader is installed in the MSNA's upper program memory. The boot loader will load firmware updates from files located in the root directory of the SDC. The boot loader is documented in detail elsewhere with the technical details a developer would need to write or modify applications to use the boot loader. The following paragraphs describe how to use the boot loader to load MSNA firmware updates.

The boot loader protects itself and will not to overwrite itself. All standard MSNA firmware releases will contain the boot loader in addition to the MSNA firmware; both in a single HEX file. When the HEX file is loaded by the boot loader, the boot loader portion of the Hex file will be ignored. If the boot loader becomes corrupted and the user has access to a dsPIC programmer, it may be used to load the entire HEX file which will do a total load of the MSNA firmware and the boot loader. After a total load, the boot loader will be restored and can be used to load future firmware updates.

When firmware is loaded, the boot loader saves the starting (reset) address of the new firmware load and replaces it in the reset start vector with its own starting address. Each time the MSNA is reset, the MSNA firmware starts in the boot loader. Once started, the boot loader first attempts to mount the SDC. If the mount is successful, the boot loader examines a specific location in RAM looking for a HEX file name. The file name at this location must adhere to the standard 8.3 DOS file name convention with a file name extension of "HEX". If a conforming file name is found in RAM, the firmware attempts to open the named file in the root directory in read mode. If a conforming file name is not found in RAM or the firmware is unable to open it in the root directory, the firmware searches for a file named "APP.HEX" in the root directory. If found, the firmware then attempts to open that file in read mode. If the boot loader is unable to locate and open a HEX file, the boot loader transfers control to the previously loaded firmware at the starting address saved when that firmware was loaded. This is the normal, MSNA firmware start-up sequence. If any method other than the boot loader (such as using the Microchip In-Circuit Programmer interface) is used to load MSNA firmware, the boot loader will probably not be preserved and will have to be reloaded.

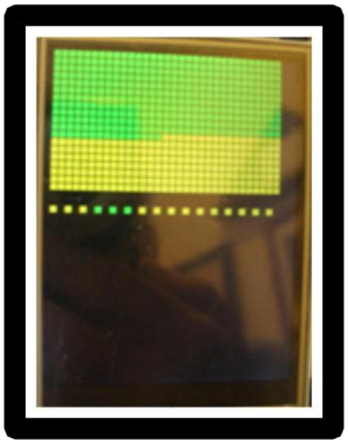
Using an APP.HEX file to boot load the firmware is intended to be used only when the currently loaded firmware cannot start the boot loader either because the capability was not programmed into the application or the firmware has been corrupted. Instead, the boot loader will generally be started from the MSNA firmware using the DOS command SDLD as described elsewhere. In this case, the file to be loaded must be in the SD card root directory but may have any file name with one to eight characters, all caps, and must have a "HEX" file name extension. The recommended file naming format for MSNA firmware boot load files is:

"SNA_v_rr.HEX"

Where "v" is the version number and "rr" is the two-digit revision number. For example, the recommended file name for the current version is "SNA_4_00.HEX".

Before transferring control to the boot loader, the MSNA firmware will verify the named file does exist in the root directory by mounting the SD card and opening the named file in read mode. If either of these operations fails, the firmware will BEEP and will not transfer control to the SDC boot loader leaving control with the current application.

The file to be loaded must be a properly formatted, Intel HEX file and must be located in the SDC root directory. The file is the standard load file exported by the Microchip compiler (actually, the linker). No modifications or preprocessing are required. To avoid the preprocessing needed by many other loaders, the boot loader is a multi-pass loader which reads the complete file several times. The repeated reading is required because there is no guarantee that the object code in the HEX file will be sorted by address, in fact, it usually is not sorted. Each pass assembles a block of code to be loaded in consecutive program memory locations. The Intel HEX file format is well documented and widely used for firmware object code. The file format includes a check sum for each line which the boot loader does check. A typical boot load operation will take about two minutes to complete.



The boot load progress is shown on the MSNA display as several rows of small, colored squares. Each square represents the processing of one line (64 words) of program memory data. Each row of the display represents one block of four pages for a total of 32 squares per row. Lines that do not contain new program data are represented by yellow squares. Lines containing new program data will be represented by green squares. Lines containing new data but one or more checksum errors was detected will be represented by red squares.

If the boot load is terminated (by removing the SDC or turning off power) before any green squares are displayed, the current application may still be viable. In this case, the SDC can be removed and the MSNA power cycled to restart the last loaded application. If one or more green squares have been displayed, the old application may have been corrupted and cannot be restarted without completing a successful load. Note that in either case, cycling power on the microcontroller will restart the boot loader. If the microcontroller is restarted with the SDC removed, it will try to restart the last loaded application.

NOTICE

When an APP.HEX file us used to boot load the MSNA firmware, it should be removed from the SDC to avoid having to wait for a boot load operation each time the MSNA is turned on. This can be done by either removing / replacing the SD card or by deleting the APP.HEX file using the DOS command "DEL APP.HEX".

APPENDIX A. SPECIAL EXTENSION CODES (SECs)

The standard 7-bit ASCII codes have been extended to 8-bit codes by adding Special Extension Codes (SECs) to the code set. All of these codes are in the range of 128 (0x7F) to 255 (0xFF). The following table lists all the SECs and the associated keyboard keys and the associated PS2 keyboard scan codes.

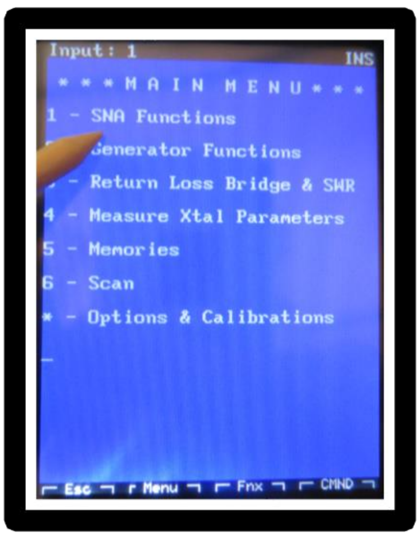
SEC	KEY	SCAN CODE	SEC	KEY	SCAN CODE	SEC	KEY	SCAN CODE	SEC	KEY	SCAN CODE
0x80	(not used)	n/a	0xa0	ALT_Q	0X15	0xc0	Home	0X6C	0xe0	CTRL_Q	0X15
0x81	F2	0X06	0xa1	ALT_R	0X2D	0xc1	PgUp	0X7D	0xe1	CTRL_R	0X2D
0x82	F3	0X04	0xa2	ALT_S	0X1B	0xc2	PgDn	0X7A	0xe2	CTRL_S	0X1B
0x83	F4	0X0C	0xa3	ALT_T	0X2C	0xc3	End	0X69	0xe3	CTRL_T	0X2C
0x84	F5	0X03	0xa4	ALT_U	0X3C	0xc4	F1	0X05	0xe4	CTRL_U	0X3C
0x85	F6	0X0B	0xa5	ALT_V	0X2A	0xc5	ALT_UP	0X75	0xe5	CTRL_V	0X2A
0x86	F7	0X83	0xa6	ALT_W	0X1D	0xc6	ALT_DN	0X72	0xe6	CTRL_W	0X1D
0x87	F8	0X0A	0xa7	ALT_X	0X22	0xc7	ALT_LFT	0X6B	0xe7	CTRL_X	0X22
0x88	F9	0X01	0xa8	ALT_Y	0X35	0xc8	ALT_RT	0X74	0xe8	CTRL_Y	0X35
0x89	F10	0X09	0xa9	ALT_Z	0X1A	0xc9	S_Tab	0X0D	0x69	CTRL_Z	0X1A
0x8a	F11	0X78	0xaa	ALT_0	0X45	0xca	CTRL_LFT	0X6B	0xea	CTRL_0	0X45
0x8b	F12	0X07	0xab	ALT_1	0X16	0xcb	CTRL_DN	0X72	0xeb	CTRL_1	0X16
0x8c	UpArrw	0X75	0xac	ALT_2	0X1E	0xcc	CTRL_RT	0X74	0xec	CTRL_2	0X1E
0x8d	DnArrw	0X72	0xad	ALT_3	0X26	0xcd	CTRL_UP	0X75	0xed	CTRL_3	0X26
0x8e	LftArrw	0X6B	0xae	ALT_4	0X25	0xce	CTRL_TAB	0X0D	0xee	CTRL_4	0X25
0x8f	RtArrw	0X74	0xaf	ALT_5	0X2E	0xcf	CTRL_?	0X4A	0xef	CTRL_5	0X2E
0x90	ALT_A	0X1C	0xb0	ALT_6	0X36	0xd0	CTRL_A	0X1C	0xf0	CTRL_6	0X36
0x91	ALT_B	0X32	0xb1	ALT_7	0X3D	0xd1	CTRL_B	0X32	0xf1	CTRL_7	0X3D
0x92	ALT_C	0X21	0xb2	ALT_8	0X3E	0xd2	CTRL_C	0X21	0xf2	CTRL_8	0X3E
0x93	ALT_D	0X23	0xb3	ALT_9	0X46	0xd3	CTRL_D	0X23	0xf3	CTRL_9	0X46
0x94	ALT_E	0X24	0xb4	ALT_F1	0X05	0xd4	CTRL_E	0X24	0xf4	CTRL_F1	0X05
0x95	ALT_F	0X2B	0xb5	ALT_F2	0X06	0xd5	CTRL_F	0X2B	0xf5	CTRL_F2	0X06
0x96	ALT_G	0X34	0xb6	ALT_F3	0X04	0xd6	CTRL_G	0X34	0xf6	CTRL_F3	0X04
0x97	ALT_H	0X33	0xb7	ALT_F4	0X0C	0xd7	CTRL_H	0X33	0xf7	CTRL_F4	0X0C
0x98	ALT_I	0X43	0xb8	ALT_F5	0X03	0xd8	CTRL_I	0X43	0xf8	CTRL_F5	0X03
0x99	ALT_J	0X3B	0xb9	ALT_F6	0X0B	0xd9	CTRL_J	0X3B	0xf9	CTRL_F6	0X0B
0x9a	ALT_K	0X42	0xba	ALT_F7	0X83	0xda	CTRL_K	0X42	0xfa	CTRL_F7	0X83
0x9b	ALT_L	0X4B	0xbb	ALT_F8	0X0A	0xdb	CTRL_L	0X4B	0xfb	CTRL_F8	0X0A
0x9c	ALT_M	0X3A	0xbc	ALT_F9	0X01	0xdc	CTRL_M	0X3A	0xfc	CTRL_F9	0X01
0x9d	ALT_N	0X31	0xbd	ALT_F10	0X09	0xdd	CTRL_N	0X31	0xfd	CTRL_F10	0X09
0x9e	ALT_O	0X44	0xbe	ALT_F11	0X78	0xde	CTRL_O	0X44	0xfe	CTRL_F11	0X78
0x9f	ALT_P	0X4D	0xbf	ALT_F12	0X07	0xdf	CTRL_P	0X4D	0xff	CTRL_F12	0X07

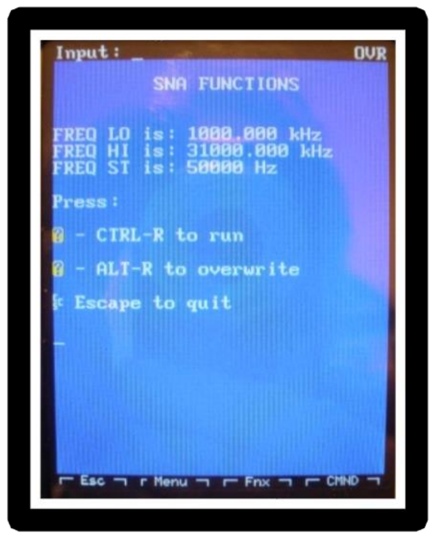
APPENDIX B. TERMINAL COMMUNICATIONS PROTOCOL

In Terminal mode, everything entered by the operator is displayed on the input (top) line of the display and transmitted over the serial interface when ENTER is entered. The text is entered as is including the ending CR (0x0D). In some instance it may be desirable to send the entered text without the ending CR. If, instead of ENTER, the operator enters ALT-ENTER, the text will be sent without the ending CR. It is recommended that receiving controllers be able to accept single-character menu selection responses with or without the ending CR to simplify operation.

You can also use ALT-ENTER to input strings longer than the 19-character capacity limit of the input line. To do so, input each "chunk" of the input text followed by ALT-ENTER. Enter ENTER to input the last chunk and mark the end of the input string.

When the touch screen is used to enter a menu selection, the character in the first column of the menu line selected is transmitted without the trailing CR. Any ASCII and a few SEC characters can be put in the first column and, when selected, will be processed as if they were entered from the keyboard. When the MSNA does not have a font for the character, an question mark is displayed with inverted font. When such a character is used in a menu it is advisable to follow the character with the name of the character as shown below for CTRL-R and ALT-R.





Any character that is a hot key (e.g., F1 through F7) on the Terminal mode context menu or is an edit key (e.g., the arrow keys) will be processed by the MSNA and will not be transmitted. There are some SEC codes that condition the MSNA for data transfer operations and send a SPACE (0x20) to the serial interface to initiate the transfer operation. In these cases, the MSNA will wait three seconds for the transfer to start. If it does not start within this period, the transfer is aborted. If the transfer starts within the three second period it will continue until there is a pause of over one-half second (500ms) indicating the end of the data transfer.

Output (to the MSNA) data transfers initiated when a log file has been named attempts to spool the received data to the currently named log file on the SD card. If the initiating character is a CTRL character (e.g., CTRL-R), an existing file with the log file name will be protected and a FILE OVERWRITE error posted. In this case the transfer will be completed and (if appropriate) the data recorded for immediate processing/plotting. If the initiating character is an ALT character (e.g., ALT-V), an existing file with the current log file name will be deleted and a new file written with the transferred data. If a file of that name does not exist, a FILE NOT FOUND error will be posted but this error can be ignored. The following SEC characters will initiate data transfers in Terminal mode:

CTRL-Z, ALT-Z .... Spool the data, no additional action.

CTRL-R, ALT-R .... Spool the data and record it for plotting at the end of the transfer.

CTRL-V, ALT-R .... Spool the data and record it for plotting at the end of the transfer. Compute the VSWR and plot it too.

An in-process data transfer will be terminated at the MSNA when the operator enters an ESCAPE. After the transfer has terminated, the ESCAPE character (0x27) will be transmitted to request termination of the data transfer by the other device. The ESCAPE is transmitted immediately, it is not necessary to enter an ENTER to initiate the transfer. Normally when a transfer is initiated, scrolling is turned off. If a transfer is terminated at the MSNA end of the serial interface and the device at the other end does not terminate the transfer the data will still be received. In this case scrolling will have been turned on and the received data will be displayed but not processed. Note that with scrolling turned on, the received data stream may overrun the MSNA receive data buffer causing gaps in the displayed data.

APPENDIX C. REMOTE CONTROL PROTOCOL

In Signal Generator mode the MSNA is receptive to commands received over the serial interface as well as manual commands form the operator. The following commands are implemented:

ENQ (0x05) .... Check for remote control active. If it is, the MSNA will respond with an ACK (0X06); if not, there will be no response.

DC1 (0x11) .... Set DDS phase and frequency from the following 5 character control word (40-bits total). See AD9851 Data Sheet for control word format. Data is received Least Significant Byte (LSB) first. The first four of these five bytes are interpreted as a 32-byte integer (F) specifying the frequency (Freq) using the following equation:

Freq = Reference frequency * F / 2^32

ALT-B (0x91) .... Set DDS frequency from the following four character control word (32-bits total). The phase part of the control word is set to 0x01 indicating clock multiplier on, no power down, and no phase adjustment. The resulting power level is returned in dBm * 100 as a signed 16-bit integer formatted in two binary characters, most-significant first.

DC2 (0x12) .... Request current ADC count. The count is returned as a 10-bit value in two characters, most-significant first. Note, even though the MSNA uses a 12-bit A to D converter, the count is scaled to 10-bits before transmission.

DC3 (0x13) .... Request current MSNA firmware version information. The firmware Version and major revision number are returned in a single character containing two Binary Coded Decimal (BCD) digits, the most-significant being the Version number the least-significant being the major revision number. For example, the current firmware version information (V4.00) is returned as "0x40" and will not change as long as there are no major revisions or version number changes. Minor revisions (V4.01 through V4.09) will not change the response to this command.

DC4 (0x4) .... Send following ASCII character as Morse code. The DDS is keyed to generate a CW signal. This function is provided as an aid to help recognize the DDS output in a receiver when competing with QRM and/or QRN. Before transmission, lower case letters will be converted to upper case. Only letters, numbers and some punctuation marks are allowed. Allowed punctuation marks are: **,** **-** **.** **:**(kn) **;**(kr) **<**(ar) **=**(bt) **>**(sk) **?** **@**(ac). Characters followed by parentheses are used for prosigns and are keyed as the two characters in the parentheses with no inter-character space between them.

SO (0x0E) .... Turn DDS RF on.

SI (0x0F)................ Turn DDS RF off.

APPENDIX D. EXTERNAL CONTROLLER PROTOCOL

In Macro mode with the External controller op mode (E) specified, the MSNA is receptive to a number of command directives received over the serial interface giving access to fields in the macro form to an external controller. The MSNA is also able to receive and plot received blocks of data in this mode.

The interface protocol is based on a set of directives developed by Parallax Corporation to interface to an Excel spread sheet containing a VB macro named "PLX-DAQ" which Parallax Corporation distributes for free at:

http://www.parallax.com/downloads/plx-daq

Not all of the PLX-DAQ directives are implemented. All commands and command parameters are received as strings of ASCII text ending in a carriage return (CR, 0x0D). All received data and directives are displayed in the output text display area; responses from the MSNA are not displayed.

The following directives are implemented:

CLEARDATA............................... Clears the MSNA data buffer and resets the row counter to zero.

CELL,GET,paramid .... Returns the contents of the macro form parameter identified by **paramid**.

CELL,SET,paramid .... Sets the contents of the macro form parameter identified by **paramid**.

DATA,<data row format 1> ...... Enters one data row in the standard data format (1). See below for a description of the data formats.

d<data row format 2> .... Enters one data row in the abbreviated data format (2). See below for a description of the data formats.

LABEL,<label text> .... Spools the **label text** if a spool file is open otherwise, the command is ignored.

MSG,<message text> .... The **message text** is only displayed in the output text display area, no other action is taken. There are no restrictions on the **message text** other than it cannot contain more than one carriage return which marks the end of the text string and the directive.

In Macro mode with op mode E selected, all human input characters are sent to the external controller. With one exception, interpretation of these characters depends on the external controller. The exception is the ESCAPE character.

ESCAPE (0x27) .... Indicates the start of a macro and requests a reset and restart of the External controller.

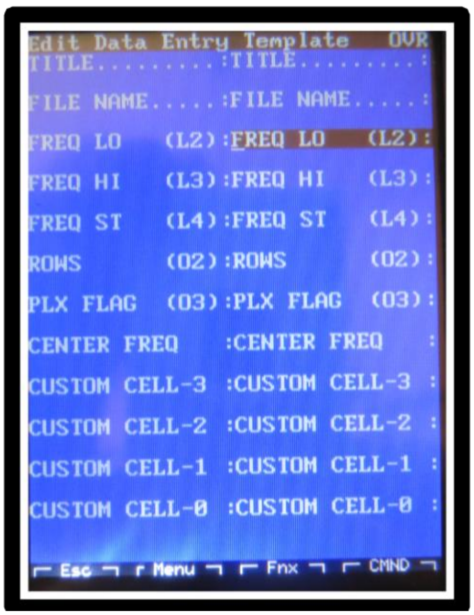
An ESCAPE character is generated and transmitted automatically when a macro is first started. If the operator enters an ESCAPE, the macro will be terminated and the MSNA will return to Terminal mode. The full ASCII character set plus the Special Extension Character set (APPENDIX A) are available for transmission to the External controller. For consistency, it is recommended that External controllers at least accept the SPACE code (0x20) as a restart command. It is also recommended that all characters not assigned a specific function be ignored by the External controller.

A data row consists of up to six fields each of which can contain up to 15 ASCII characters. Each field except the last ends with a comma and the row is terminated with a CR following the last field. Each field is assumed to start with a numeric value which may be signed and may contain one decimal point. String processing ends with the first non-decimal digit character (or second decimal point). Any text following the leading numeric value will be ignored up to the field-ending comma or CR. If the field is blank or does not start with a digit, sign, or decimal point it will be interpreted as zero.

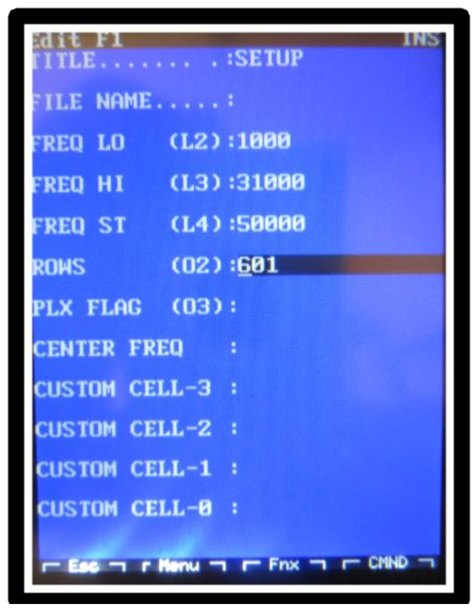
In **data row format 1** the first data field in the data row is the frequency in Hz. The second is the power level in dBm. The remainder of the data row is ignored.

Data row format 2 is not part of the original PLX-DAQ macro, it was added to improve data transfer rates. When the macro form format follows the standard format it specifies the starting (FREQ LO) and ending (FREQ HI) frequencies and the frequency step. Since this information is available to the MSNA firmware, the frequency field (first data row field in **data row format 1**) can be calculated and does not need to be transmitted over the serial interface. Therefore, the first field in **data row format 2** is the power level in dBm, the remainder of the data row is ignored (but will be spooled). Normally, there will only be one field used in **data row format 2**. The frequency for data row i is calculated as FREQ LO + i * FREQ ST where i goes from zero to n-1 and n is the number of rows in the data set.

The parameter identifier ("**paramid**") used by the CELL GET and SET directives refers to a spreadsheet cell coordinates when used with the PLS-DAQ VB macro and an Excel spreadsheet. Here they refer to a macro form row identifier. The identifier is in the name field (left side) of the row containing the macro parameter. The identifier is in parentheses immediately preceding the colon ending the name field. Only ten of the twelve parameters on the first page of the macro form can be assigned row identifiers. The name fields for the first two (FILE and FILE NAME) cannot be edited. Since the identifier is included as part of the name field, the Macro DE Template function on the Edit Menu can be used to enter and edit identifiers.



Macro Form Edit Screen



Default Macro Form

This example shows the default macro form. The parameter identifiers shown are the coordinates of cells in the standard Excel spreadsheet used by the PHSNA in PLX mode. Selecting the macro (F1 in this case) changes the MSNA to Macro mode, initializes a variable set from the form, and sends an ESCAPE character to the external controller requesting a reset and restart.

As an example, consider the following dialog conducted over the serial interface when the above macro is run with the PHSNA as the External controller. Assume that the E op mode is specified on the page two of the F1 macro form and all transmitted strings (not the ESCAPE) are terminated with a CR. Ancillary operations are shown in parentheses.

PHSNA	**MSNA**
	(Switch to Macro mode and initialize from macro form F1) ESCAPE
(Reset and restart) "CELL,GET,O3"	"0"
(Switch to PLX mode)	
"CELL,GET,L2"	"1000"
(Save starting frequency)	
"CELL,GET,L3"	"31000"
(Save ending frequency)	
"CELL,GET,L4	"50000"
(Save frequency step)	
(Perform frequency scan)	
"DATA,1000000,0.03"	(buffer data)
"DATA,1050000,-.06"	(buffer data)
"DATA,1100000,-.06"	(buffer data)
"DATA,1150000,0.00"	(buffer data)
"DATA,1200000,-.06"	(buffer data)
"DATA,1250000,-.06"	(buffer data)
"DATA,1350000,0.00"	(buffer data)
"DATA,1400000,-.03"	(buffer data)
. . . .	
"DATA,30650000,-53.55"	(buffer data)
"DATA,30700000,-53.11"	(buffer data)
"DATA,30750000,-53.73"	(buffer data)
"DATA,30800000,-53.91"	(buffer data)
"DATA,30850000,-53.32"	(buffer data)
"DATA,30900000,-53.35"	(buffer data)
"DATA,30950000,-53.46"	(buffer data)
"DATA,31000000,-53.94"	(buffer data)
"CELL,SET,O2,601"	(Scale and plot buffered data)

The "CELL,SET,O2,601" directive is not a DATA directive so it indicates the end of the data set. The MSNA takes this as a command to scale and plot the data. If the operator enters a SPACE at this point, the PHSNA resets and restarts and repeats the scan and data transfer. In this case, the new data set is plotted over the first data set (in a different color) and the displayed plot count is incremented by one.

The initial "CELL,GET,O3" directive reads the macro parameter named "PLX FLAG". In the case of the PHSNA, if this flag is set to "100", the PHSNA will not go into PLX mode and will remain in Menu mode. When this flag is set to anything other than "100" the PHSNA switches to PLX mode and continues with the above process. When this flag is set to "1", the PHSNA will use the abbreviated data format for the data set transfer (e.g., "d0.03", "d-.06", "d-.06", "d0.00", etc.) which greatly reduces the amount of data transferred on the serial interface.

APPENDIX E. SD CARD TEST DATA FORMATS

The SD Card Test (SCROLL LOCK > S) writes ten files named "F00" through "F09" each containing 128 sectors of known data patterns then performs various tests to assure the files are properly written, read, and deleted. The test sequence is broken into a number of tasks. The test pauses after each task describing the task just completed. The next task is started when the operator presses the SPACE bar. The following tasks are performed in the order shown:

1. Delete any leftover files and post the number of files deleted.
2. Write the ten files displaying the file name being written and a period for each sector written. The text is rendered in white.
3. Verify the data in each file displaying the file name being read and a period for each sector read. The text is rendered in yellow.
4. Delete file F00 and verify the data in the remaining files.
5. Delete file F01 and verify the data in the remaining files.
6. Delete file F02 and verify the data in the remaining files.
7. Delete file F03 and verify the data in the remaining files.
8. Delete file F04 and verify the data in the remaining files.
9. Delete file F05 and verify the data in the remaining files.
10. Delete file F06 and verify the data in the remaining files.
11. Delete file F07 and verify the data in the remaining files.
12. Delete file F08 and verify the data in the remaining files.
13. Delete file F09 and verify all files have been deleted.

Detected errors will be posted and the test will pause at the end of the sector containing the error.

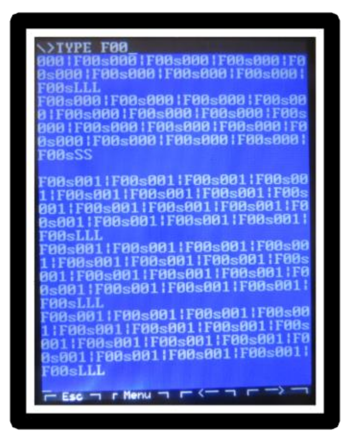
Task 1

Task 2

Tasks 3 - 12

Task 13

The data pattern for each sector of each file consists of repeating the text string containing the file name followed by the sector number separated by a vertical line character ('|'). In each 128th pattern written, the sector number is replaced with LLL followed by a carriage return (0x0D). In the last pattern in the sector, the sector number is replaced with "SS" followed by two carriage returns. When viewed in an editor on a PC, the listing for each sector will consist of four lines of 128 characters. Each group of four lines will be separated by a blank line.



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F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09sLLL
F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09sLLL
F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09sLLL
F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09s126|F09sSS

F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09sLLL
F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09sLLL
F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09sLLL
F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09s127|F09sSS

```

APPENDIX F. HOT KEY SUMMARY

The following lists describe the hot keys available in each of several modes. When a context menu is available it is shown. Context menus are displayed by entering CTRL-M or by touching the Menu permanent button on the touch screen.

EDITING, All Modes

Home .... Clears editable text area and moves cursor to the first editable position.

End .... Moves cursor to the first position past the end of the text in the edit field.

Backspace .... Deletes the character to the left of the cursor position and moves all following characters one position to the left.

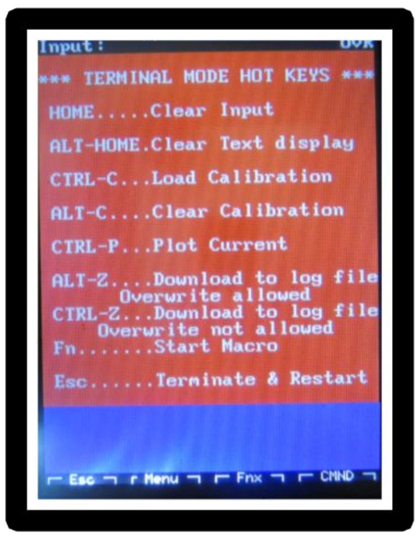
Delete .... Deletes the character at the cursor position and moves all following characters one position to the left.

Insert .... Toggles between Insert (INS) and Overwrite (OVR) entry modes.

Left Arrow .... Moves the cursor one position to the left.

Right Arrow ..... Moves the cursor one position to the right.

TERMINAL MODE



Home .... Clears the input line and moves the text entry point to the first editable character position.

Alt-Home .... Clears the output text display and moves the text entry point to the first character position.

Alt-C .... Clears the calibration constant buffer.

Ctrl-C .... Loads the calibration constant buffer with the current contents of the plot data buffer.

Ctrl-F .... Display Function Key select menu.

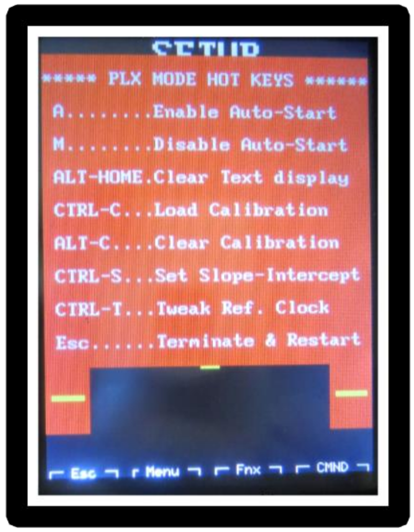
Ctrl-M .... Display Terminal mode context menu.

Ctrl-P .... Plot the current contents of the data buffer (if any).

F1-7, Alt-F1-7.... Switch to Macro mode using the parameter set associated with the hot key pressed.

Esc...................... Terminate an in process operation and reinitialize Terminal mode. Will close an open file, if any, and post any pending error messages.

MACRO MODE



A.......................Sets Start Mode to Automatic

M......................Sets Start Mode to Manual

Alt-Home........(Op mode E only.) Clears the output text display and moves the text entry point to the first character position.

Ctrl-C.............Loads the calibration constant buffer with the current contents of the plot data buffer.

Alt-C................Clears the calibration constant buffer.

Ctrl-S ....Captures the current power level and instructs the user to install a 20 dB attenuator in the RF power meter input (see MSNA CALIBRATION).

Ctrl-T ....Displays the current reference clock frequency and allows determination of the true frequency (see MSNA CALIBRATION).

Esc..................Terminate PLX mode in the MSNA and the PHSNA firmware and return to Terminal mode. If receiving data in automatic operation mode, the termination will wait until the end of the current sweep unless Esc is pressed a second time.

Space ....(or touch a plot) Repeat scan and plot, increment plot number if overplotting.

DOS MODE

No Plot Displayed

Plot Displayed

Ctrl-C..............Transfers the contents of the data buffer to the calibration data buffer and to the EEPROM.

Alt-C................Clears the contents of the calibration data buffer and the calibration buffer EEPROM area.

Ctrl-P..............Re-plots the current contents of the data buffer.

Esc...................Clears the display and restarts in Terminal mode. The ESCAPE character is transmitted on the serial port to indicate the resetting to Terminal mode and request a remote device reset and restart.

SIGNAL GENERATOR MODE

Home ....Set the operating frequency to Freq LO.

End..................Set the operating frequency to Freq HI.

Left Arrow.....Increase frequency step one decade (x10).

Right Arrow..Decrease frequency step one decade (/10).

Plus (‘+’)
Equal (‘=’)
Up Arrow.......Increment frequency by the current frequency step.

Minus (‘-‘)
Underline (‘_’)
Down Arrow .Decrement frequency by the current frequency step.

Space ....Initiate another data sample.

Esc...................Terminate and return to Terminal mode.

APPENDIX G. MSNA SCHEMATIC