Overview of the MSA

12/30/10

Introduction

The purpose of this document is to provide an overview of the capabilities and construction of the MSA to help potential builders get oriented. Much more detailed information is on Scotty's website. (See the Links section of the Yahoo Spectrum Analyzer site.)

The MSA (Modular Spectrum Analyzer) is constructed from a number of "SLIM" modules, which are 1.2" square or multiples of that size. It can be built to one of three levels, starting with a spectrum analyzer, then adding a tracking generator, and finally adding modules to make it function both as a spectrum analyzer (SA) and a vector network analyzer (VNA).

The SA provides standard spectrum analysis, with some extras. Scanning can be done forward, backward or alternating, to evaluate circuits with hysteresis. The Tracking Generator, if implemented, can literally track the SA tuning frequency, or can track at an offset. It can even reverse-track, for testing of IF circuits that use an inverting IF scheme.

As a VNA it can measure both the magnitude and phase of signals, and therefore can measure impedance. Functions of the VNA include measuring the values of passive components, determining crystal parameters, analyzing antenna characteristics, measuring input/output impedances of amplifiers, determining gain or loss of devices, analyzing characteristics of coax cables and other transmission lines, determining the dielectric constant of printed circuit board materials, and many other applications.

The dynamic range of the MSA depends on the resolution bandwidth filter in use. With a modest 2 kHz filter its ability to measure signal strength easily exceeds a range of 100 dB. Phase measurement in VNA mode has about 90 dB range.

The basic frequency range of the MSA is about 100 kHz to 1 GHz, though in SA mode it is also useful below 100 kHz. Without any modifications, it also functions from 2-3 GHz both as an SA and VNA, with somewhat reduced performance. With a cabling change, or a band switch, it can operate from 1-2 GHz as an SA or VNA, though as an SA there will be "images" present in that range.

Much more detail is available on Scotty's website.

Test Run

It is possible to get an idea of the capabilities of the MSA by installing the software and performing the "Walk-Throughs" that are available at http://www.wetterlin.org/sam. The software will operate fine without the hardware; it has a provision for generating its own test data to use for the walk-throughs.

The MSA software can be downloaded via the links in the Links section of the Yahoo Spectrum Analyzer site.

Basic Concept of the Hardware
In the basic <1GHz operating range, the MSA upconverts the input signal to a first IF (IF1) of 1013.3 MHz. IF1 is filtered through a coaxial cavity filter and then downconverted to the second IF (IF2) of 10.7 MHz. That IF2 is amplified, filtered through the selected resolution bandwidth filter and fed to a detecting log amplifier, which outputs both an amplified/limited 10.7 MHz signal, and a DC signal indicating the strength of the original signal. The DC signal is fed to an ADC, normally 16-bits. The limited IF2 signal can be fed to a phase detector module if the full VNA is implemented. The phase detector output, 0-5V, also runs to the ADC module. An internal 10.7 MHz phase reference is generated for the VNA.

Circuit Modules
Two or three internal RF signals are generated (two for the plain SA; three for the Tracking Generator or VNA). These are each generated by Phase Locked Oscillator modules (PLOs), labeled PLO1, PLO2 and PLO3. PLO1 and PLO3 are clocked by DDS modules that provide fine tuning; PLO2 is clocked directly by the Master Oscillator module, which also clocks the two DDS modules. These RF signals are mixed in various combinations with each other and with the input signal. Four simple mixer modules are used in the full VNA build, using very inexpensive Mini-Circuits ADE-11X mixers.

There are two signals that ultimately come out of the above modules: IF2 and the phase reference (if implemented), both near 10.7 MHz. As mentioned above, IF2 is run through an amplifier module, a filter switching module, the resolution bandwidth filters, the log amp, the ADC and the phase detector module (if implemented).

Communication with the MSA software is accomplished through a control board with a parallel port interface. (USB is in the works.) The control board also provides regulated 10V power for the modules that require power. It sends control signals to the DDS and PLO modules, reads data from the ADC module, and controls various switches, such as resolution bandwidth and the video filters.

SLIM Construction
The SLIM modules are assembled by hand soldering, or by using solder paste and hot-air soldering with a heat gun. Most passive components are size 0805 surface-mount components—small, but easy to get used to. None of the larger ICs are extremely fine-pitch styles. Typically, each SLIM module shielded with side fences and a cover made of brass or tin. The modules can be fit with SMA connectors to cable them together, or a direct-solder method can be used to attach cables to boards.

Individual SLIM boards are solder-tacked to a grid made by cutting holes in a large PCB, or by soldering together strips of brass reinforced on the bottom with tiny brass shapes such as angle or channel. It is possible to assemble all modules on the grid and test them without having them installed in an enclosure.

PCB layouts are available in ExpressPCB format, and it only requires 2-3 people (who can organize through the group site) to place a joint order for PCBs at reasonable prices. Many of the parts are made by Mini-Circuits, which has made available a package quote (in the Files Section of the Yahoo site) to purchase all their parts in one order, with quantity discounts. SMA connectors have become very cheap on eBay through Chinese suppliers. The remaining parts are readily available from Digi-Key, Mouser and equivalent non-US distributors.

Boards can be tested as they are finished. In theory, it is possible to do testing with just a voltmeter, but it is a lot easier if you have a basic scope and a power meter or even a crude peak detector. A signal generator is also a plus but is not critical. If you have temporary access to another spectrum analyzer, testing is especially easy. 90% of all errors are found by checking DC voltages and the current draw of each SLIM module.

All these modules and filters can be fit into a 10" x 10" x 5" enclosure, or even a smaller enclosure. There is no standardized enclosure required.

Scotty has information on his web site about how to test the modules. The following overview illustrates the sequence of construction and testing.

The first board to construct is the control board, as it provides the 10V supply and control signals to other boards. There is a simple program to verify with a voltmeter that the latch pins in the control board are being properly set to 1's and 0's.

With the ADC attached to the control board, the MSA software can read the ADC output even though the signal-generation modules are not yet in place. The ADC can be checked with a couple of resistors and a pot wired to make a potential divider with the slider connected to the ADC input, both MAG and PHASE, and then with the MSA software running you can vary the pot and see the response go up or down. Frequency range is of no matter at this stage; just look for the graph line going up and down as you adjust the pot.

To test the log detector, connect its DC output to the ADC and apply a RF signal from a signal generator (or wait until you have a DDS operating and use its output signal). Look for the response varying as you alter the RF level. To test the IF2 amplifier, interpose it between the signal source and the log amp.

With the control board operational the DDS and PLO modules can be commanded from the regular MSA software, so they will be set to known frequencies for testing. Even if some boards are missing, those connected to the control board will be properly commanded, as long as their clock sources are connected.

The output of the DDS boards (10.7 MHz) and Master Oscillator (64 MHz) can be verified with a voltmeter, which will read 0 if stuck low, 1 if stuck high, and 1.5-2.5V if things are operating properly. Alternatively, the DDS output can be run through the previously assembled log detector/ADC. The output of the PLOs can be verified as to signal strength with a power meter or a crude handmade peak detector (example). Frequency accuracy can be verified by mixing two PLOs in a mixer module to get a low frequency output that is easier to check. The cavity filter can be checked and tuned using a PLO signal and a power meter or peak detector, or you can just wait until everything is assembled and tune the cavity filter by using the MSA software.

Conclusion

The use of SLIM modules provides excellent performance, and also facilitates spreading the construction over several months of part-time weekend work. Individual boards can be tested as they are finished. The completed product is an unusual combination of spectrum analyzer/vector network analyzer capabilities with the ability to reach all RF frequencies to at least to 3 GHz.