SCHOOL of BUSINESS AND TECHNOLOGY
Department of Engineering and Aviation Sciences

Design of Scalar Network Analyzer

Colin Anderton

Tayveon Lee

Advisor: Dr. Zhang

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By

Colin Anderton, Tayveon Lee

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Date

Authors _____Colin Anderton, Tayveon Lee____

Signature ____

Date ____

Department of Engineering and Aviation Sciences

Certified by ____

List of Contents

1.1 Background/Motivation....5
Fig 1.1 SA124B Spectrum Analyzer....6
Fig 1.2 TG124A Tracking Generator....6
1.2 Objective....6
1.3 Design Requirements....6
1.4 Design Constraints....7
1.5 Design Methods....7
1.6 Standards....8
2.1 System Description....9
2.2 System Diagram (or Flow Chart)....9
Figure 2.2 LabView Logic Diagram....9
2.3 System Functions....9
3.1 Tasks....10
3.2 Team Organization....10
1.1.1 Responsibility of Colin Anderton....10
1.1.2 Responsibility of Tayveon Lee....10
3.3 Timeline/Milestones/Delivery Plan....10
4.1 Implementation of Task 1.1:....13
Figure 4.1 Task 1.1 Labview Diagram....13
4.2 Implementation of Task 1.3....14

List of Figures

1.1 Background/Motivation **5**
Fig 1.1 SA124B Spectrum Analyzer 6
Fig 1.2 TG124A Tracking Generator 6
1.2 Objective **6**
1.3 Design Requirements **6**
1.4 Design Constraints **7**
1.5 Design Methods **7**
1.6 Standards **8**
2.1 System Description **9**
2.2 System Diagram (or Flow Chart) **9**
Figure 2.2 LabView Logic Diagram 9
2.3 System Functions **9**
3.1 Tasks **10**
3.2 Team Organization **10**
1.1.1 Responsibility of Colin Anderton 10
1.1.2 Responsibility of Tayveon Lee 10
3.3 Timeline/Milestones/Delivery Plan **10**
4.1 Implementation of Task 1.1: **13**
Figure 4.1.1 LabView and Signal Hound API Connection 13
Figure 4.1.2 Configuration of the Signal Hound Hardware in LabView 14
Figure 4.1.3 Sweeping data from the Signal Hound Hardware in LabView 14
4.2 Implementation of Task 1.2 **14**
Figure 4.2.1 Setup of Data going into Waveform Graph VI 15
Figure 4.2.2 Origination of Data utilized for Waveform Graph 15
Figure 4.2.3 LabView setup of calculating Peak Amplitude and Frequency 16
4.3 Implementation of Task 1.3 **16**
4.4 Implementation of Task 1.4 **16**
4.5 Implementation of Task 2.1 **16**
Figure 4.5.1 The ports of the Tracking Generator (Bottom) and the Spectrum Analyzer (Top) 16
Figure 4.5.2 A diagram of how the Signal Hounds are set up to collect data 17
4.6 Implementation of Task 2.2 **17**
Figure 4.6.1 An image of the Scalar Network Analyzer fully connected 17
Figure 4.6.2 A graph of the Scalar Network Analyzer confirming the system functions. 18

List of Tables

Table 1. Project Timeline and Delivery Plan 10

ABSTRACT

CHAPTER 1. INTRODUCTION

The project objective is to design a Scalar Network Analyzer system that includes signal capturing equipment from Signal Hound, LabView software to display and save the acquired data, and an RF Circuit to test the equipment thoroughly.

1.1 Background/Motivation

The purpose of this project is to develop a scalar network analyzer that contains all capabilities and requirements as defined in section 1.3. With these specific requirements in mind, there will be a scalar network analyzer designed to eliminate wasteful features and provide new more useful features. This scalar network analyzer will also be a cost efficient solution in comparison to the Keysight 8757D.

The system that is to be designed is intended to be a custom made Scalar Network Analyzer system, LabView Software, and an RF test circuit for the purposes of capturing output data from a Magnetron and displaying it for visual inspection. The RF test circuit is intended to be a test circuit for the system to allow for calibration and testing during the project.

Currently, there are devices that can achieve the goals of collecting and displaying data such as the Keysight/Agilent 8757D, however these devices lack the on-board ability to store the data for later use, and does not contain a test circuit to test the system's calibration before use. Having these additional abilities will streamline the workflow process and allow for data to be easily managed and viewed.

To achieve these goals the project has been split into three different sections of the system. The first goal is to develop the LabView software solution to gathering, displaying, and saving data collected from the system hardware. The second goal is to develop a scalar network analyzer system utilizing components from Signal Hound such as the SA124B and the TG124A. These components by themselves will be unable to be a fully functional scalar network analyzer, however developing a system of these components and the software will create the scalar network analyzer system. The final section of the project is to develop an RF Test Circuit capable of testing our scalar network analyzer system to its full capabilities and to be able to test quickly.

For the hardware system, the SA124B and the TG124A were picked due to their ability to capture such high frequency of waves, and they both are compatible with each other so there can be a created system that will function well together. These were also picked as the solution due to the ability to connect them to the LabView solution to manipulate the data collected from these two pieces of equipment. These two pieces of equipment will require development to integrate them fully together to create our scalar network analyzer.

Fig 1.1 SA124B Spectrum Analyzer

Fig 1.2 TG124A Tracking Generator

The software portion of this project is going to be done via LabView due to the compatibility between the signal hound equipment and the data acquisition and manipulation abilities of the LabView software. LabView was also picked due to its capabilities when it comes to storing and calibration of the signal hound equipment and how easily it can recall historical data and display that data. Lastly, the LabView software also has the display capabilities that were required by this project, and LabView can display the data extremely well.

1.2 Objective

To create a functioning and efficient Scalar Network Analyzer utilizing Signal Hound equipment that is able to read the frequency range, and be able to display, save, and recall historical data.

1.3 Design Requirements

Task 1 - LabView Software Design

- Store and Recall data
- Analyze data to retrieve Attenuation, Gain, VSWR, and Return Loss

- Display live data with minimal system lag.
- Utilize calibration standards sent by Hill Park Engineering.

Task 2 - Scalar Network Analyzer Hardware System Development

- Develop the Hardware to be efficient in signal processing.
- Reduce loss in signal strength/properties via the use of proper and efficient cables.

Task 3 - RF Test Circuit Design

- Design the RF Test Circuit to be Discreet.
- Signal Range of 100khz to 12.4ghz.
- Designed to be repeatable

Task 4 - Scalar Network Analyzer Enclosure Design

- Construct Enclosure to allow portability of the Scalar Network Analyzer.
- Ensure that the Enclosure does not thermally compromise the Scalar Network Analyzer.

Task 5 - Testing, Comparison, and Revisions (Not a Design Task)

- Test and compare system to a Keysight/Agilent 8757D.
- Make revisions to make the signal hound system comparable to the 8757D

1.4 Design Constraints

- Loss of accuracy between the spectrum analyzer and the tracking generator via connections/wires.
- How compact the enclosure can be due to heat output of the spectrum analyzer and tracking generator.

1.5 Design Methods

Steps to be taken for each task to be completed

Task 1 - LabView Development

1. Investigate LabView's connections and determine what actions are needed to complete the project
2. Generate the block diagram based on the conclusions about LabView
3. Create each part of LabView starting with the Conditional Blocks
4. Create the Action Blocks that gather information, do calculations, and calibrate the system.
5. Lastly, Create rough display blocks, don't worry about making it perfect.
6. Test the LabView software and fix any issues that come up.
7. After confirmation from testing, then go back and re-design the display blocks to look professional and improve functionality.

Task 2 - Signal Hound Hardware

1. Investigate the Hardware and it's connections that are required.
2. Generate a block diagram of how the system connects together.
3. Connect the system together and ensure connections are all correct.
4. Connect the Signal Hound to the LabView software to confirm the system is properly connected.
5. Connect the RF test circuit to the Signal Hound Hardware and confirm operability between Signal Hound and LabView.

Task 3 - RF Test Circuit

1. Research RF Test Circuits and what components are required to complete the circuit.
2. Pick components based on the design requirements for the RF test circuit.
3. Build RF test circuit.
4. Connect RF Test circuit to a scalar network analyzer to confirm the RF test circuit's operability before testing the Signal Hound and LabView software.

Task 4 - Enclosure

1. Take measurements of the Signal Hound system to determine the minimum space required in the enclosure.
2. Ensure there is enough airflow into and out of the enclosure to hit temperature specifications for the Signal Hound.
3. Build enclosure out of material that meets UL94 V-2 rating and integrate hardware systems into the enclosure.

Task 5 - Testing, Comparison, and Revisions (Not a Design Task)

1. Perform testing on a pre-built spectrum analyzer that is utilized today for a baseline to compare the Signal Hound Spectrum Analyzer to. (Keysight/Agilent 8757D)
2. Perform testing on the custom Signal Hound Spectrum Analyzer solution and compare to the Keysight/Agilent 8757D.
3. Analyze the comparison of the two systems and make revisions to the Signal Hound Spectrum Analyzer to improve functionality and accuracy.

1.6 Standards

- Enclosure Materials - UL 94 Rated, at least a V-2 Rating : burning stops in less than 30 seconds on a vertical specimen; flaming particle drips are allowed. This is to prevent using a flammable material for the enclosure just in case.

CHAPTER 2. PROJECT DESCRIPTION

2.1 System Description

2.1.1 Software System Description

The software is run off of a Windows Laptop/Desktop connected to the Signal Hound Hardware via two USB cables. The software is handled by LabView and utilizes drivers that are given from the Spike software. The data is handled via LabView and stored into a file that is locally stored and can be backed-up/accessed to any system with the LabView software and our custom-made software installed.

2.1.2 Hardware System Description

The Signal Hound Hardware are two separate modules which are the SA124B Spectrum Analyzer and the TG124A Tracking Generator. These two modules use 3 separate connections to be able to turn the two modules into one functioning Scalar Network Analyzer. A BNC cable is used to connect the Sync ports on both the SA124B and the TG124A, and they also use SMA ports on both of them to connect attenuators to be tested or any other devices that can be tested by the system. Lastly, both have a USB port that must be connected to a computer with the Spike software installed to be able to read the results of the Scalar Network Analyzer.

2.2 System Diagram (or Flow Chart)

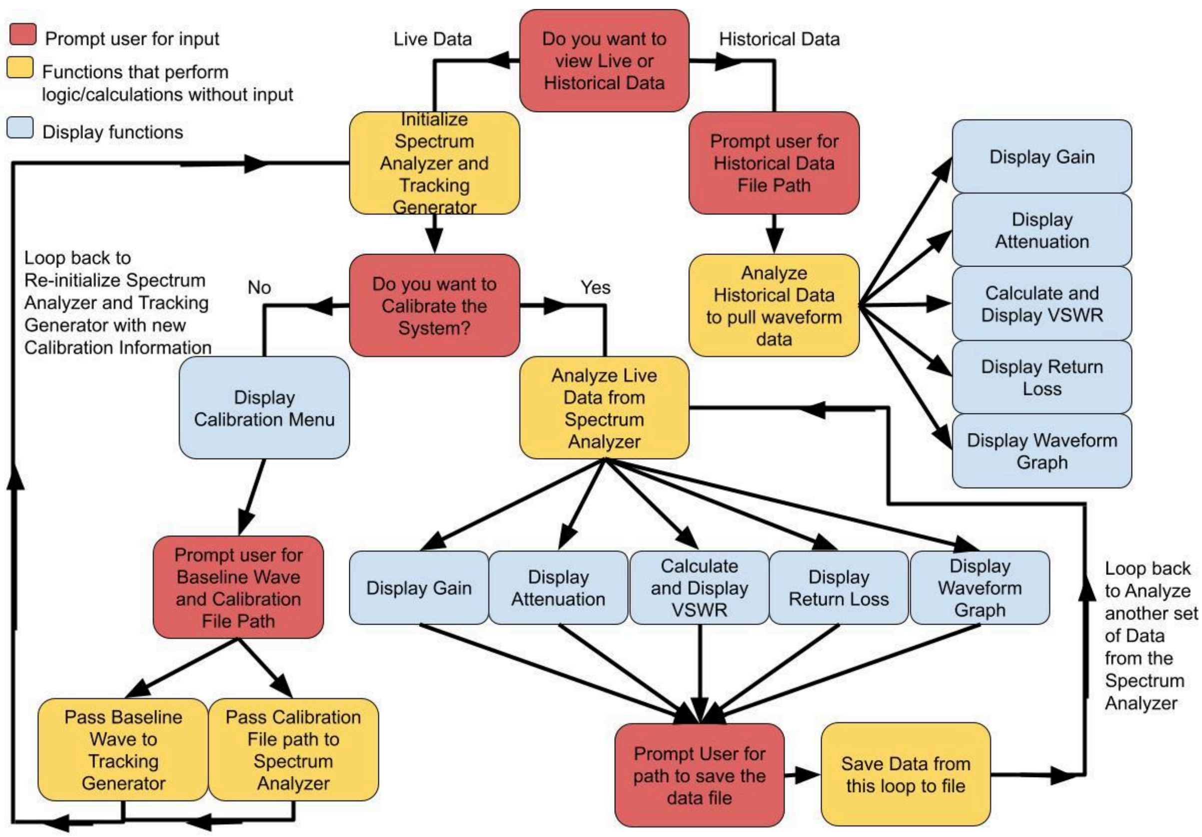

Figure 2.2 LabView Logic Diagram

2.3 System Functions

CHAPTER 3. IMPLEMENTATION PLAN

3.1 Tasks

Task 1 - LabView Software Design

1.1 - Design LabView software to interface with Signal Hound Hardware.

1.2 - Develop Functions in LabView to manipulate collected data.

1.3 - Create a method of storing data from LabView to an external file.

1.4 - Design a GUI for ease of use and test software fully.

Task 2 - Scalar Network Analyzer Hardware System Development

2.1 - Create a block diagram of connections and logic flow for Hardware.

2.2 - Develop the Signal Hound equipment into a functioning Scalar Network Analyzer and test system.

Task 3 - RF Test Circuit Design

3.1 - Design an RF Test Circuit system diagram adhering to the design specifications defined.

3.2 - Create the RF Test Circuit and test it.

Task 4 - Scalar Network Analyzer Enclosure Design

4.1 - Design a Scalar Network Analyzer enclosure that adheres to the design requirements and standards.

4.2 - Create the enclosure and integrate the Scalar network analyzer hardware into the enclosure.

3.2 Team Organization

There will be two team members, Colin Anderton and Tayveon Lee.

1.1.1 Responsibility of Colin Anderton

Task 1 and Task 2

1.1.2 Responsibility of Tayveon Lee

Task 3 and Task 4

3.3 Timeline/Milestones/Delivery Plan

Table 1. PROJECT TIMELINE AND DELIVERY PLAN

Time	Task		Comments
	Colin Anderton	Tayveon Lee	
Week 1	Subtask 1.1	Subtask 1.1	Design LabView software to interface with Signal Hound Hardware.
Week 2	Subtask 1.1	Subtask 1.1	Design LabView software to interface with Signal Hound Hardware.
Week 3	Subtask 1.1	Subtask 1.1	Design LabView software to interface with Signal Hound Hardware.
Week 4	Subtask 1.2	Subtask 1.2	Develop Functions in LabView to manipulate collected data.
Week 5	Subtask 1.2	Subtask 1.2	Develop Functions in LabView to manipulate collected data.
Week 6	Subtask 1.2	Subtask 1.2	Develop Functions in LabView to manipulate collected data.
Week 7	Subtask 1.3	Subtask 1.3	Create a method of storing data from LabView to an external file.
Week 8	Subtask 1.3	Subtask 1.3	Create a method of storing data from LabView to an external file.
Week 9	Subtask 1.3	Subtask 1.3	Create a method of storing data from LabView to an external file.
Week 10	Subtask 1.4	Subtask 1.4	Design a GUI for ease of use and test software fully.
Week 11	Subtask 1.4	Subtask 1.4	Design a GUI for ease of use and test software fully.
Week 12	Subtask 2.1	Subtask 2.1	Create a block diagram of connections and logic flow for Hardware.
Week 13	Subtask 2.1	Subtask 2.1	Create a block diagram of connections and logic flow for Hardware.
Week 14	Subtask 3.1	Subtask 2.1	Create a block diagram of connections and logic flow for Hardware. Design an RF Test Circuit system diagram adhering to the design specifications defined.
Week 15	Subtask 3.1	Subtask 2.2	Develop the Signal Hound equipment into a functioning Scalar Network Analyzer and test system. Design an RF Test Circuit system diagram adhering to the design specifications defined.
Week 16	Subtask 3.2	Subtask 2.2	Develop the Signal Hound equipment into a functioning Scalar Network Analyzer and test system. Create the RF Test Circuit and test it.
Week 17	Subtask 3.2	Subtask 2.2	Develop the Signal Hound equipment into a functioning Scalar Network Analyzer and test system. Create the RF Test Circuit and test it.
Week 18	Subtask 3.2	Subtask 2.2	Develop the Signal Hound equipment

			into a functioning Scalar Network Analyzer and test system. Create the RF Test Circuit and test it.
Week 19	Subtask 4-1	Subtask 4.1	Design a Scalar Network Analyzer enclosure that adheres to the design requirements and standards.
Week 20	Subtask 4.1	Subtask 4.1	Design a Scalar Network Analyzer enclosure that adheres to the design requirements and standards.
Week 21	Subtask 4.2	Subtask 4.2	Create the enclosure and integrate the Scalar network analyzer hardware into the enclosure.
Week 22	Subtask 4.2	Subtask 4.2	Create the enclosure and integrate the Scalar network analyzer hardware into the enclosure.

CHAPTER 4. IMPLEMENTATION

4.1 Implementation of Task 1.1:

The Signal Hound Hardware and the LabView software's integration firstly has to start with how to connect the Signal Hound API to LabView so it can properly interface with the Hardware. To do this, installing the Signal Hound's Spike software has the required API drivers that are needed for LabView to be able to interface with the Hardware.

After LabView has been properly connected to the API drivers, the Signal Hound Hardware can now properly interface with the LabView software. The next step is to set up the LabView software to properly initialize and configure the hardware to properly collect data from the hardware. To do this, there are some built-in VI's that can be utilized to allow us to easily connect to these APIs to be able to initialize the hardware. Below is a screenshot of how the device is initialized/opened and then the device data variable is passed to our custom made Live Data Sweeping VI.

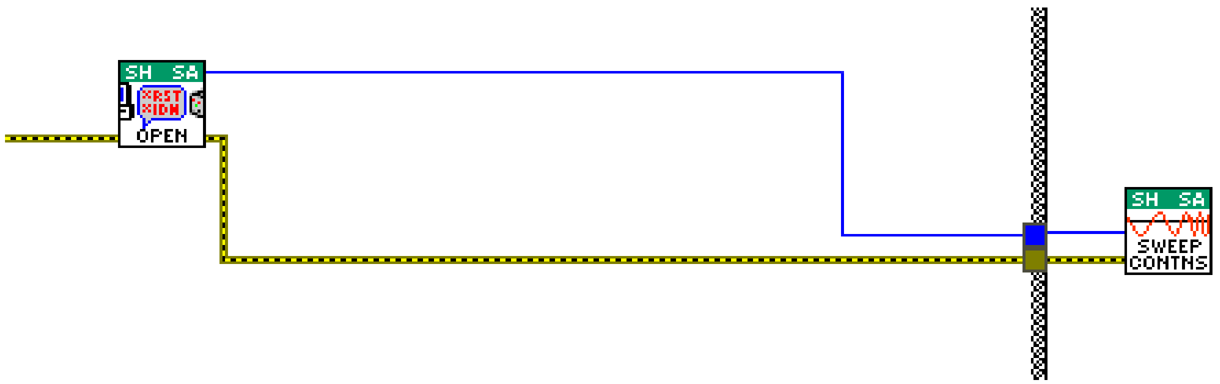

Figure 4.1.1 LabView and Signal Hound API Connection

Once the device data variable has been passed to our custom VI, we can then begin setting up the device and calibrating it to be able to accurately collect data according to our needs and the parameters that we set. This will give the program the ability to be modified easily and collect different ranges and resolutions of data. This is done with a VI provided by Signal Hound called Quick Configure Sweep. This VI intakes a few variables that we can utilize for the user to be able to customize the sweep that is grabbed by the program, these variables are VBW, RBW, Center Frequency, Span, and Reference Level. Below is a screenshot of how the program is set up with the Quick Configure Sweep VI.

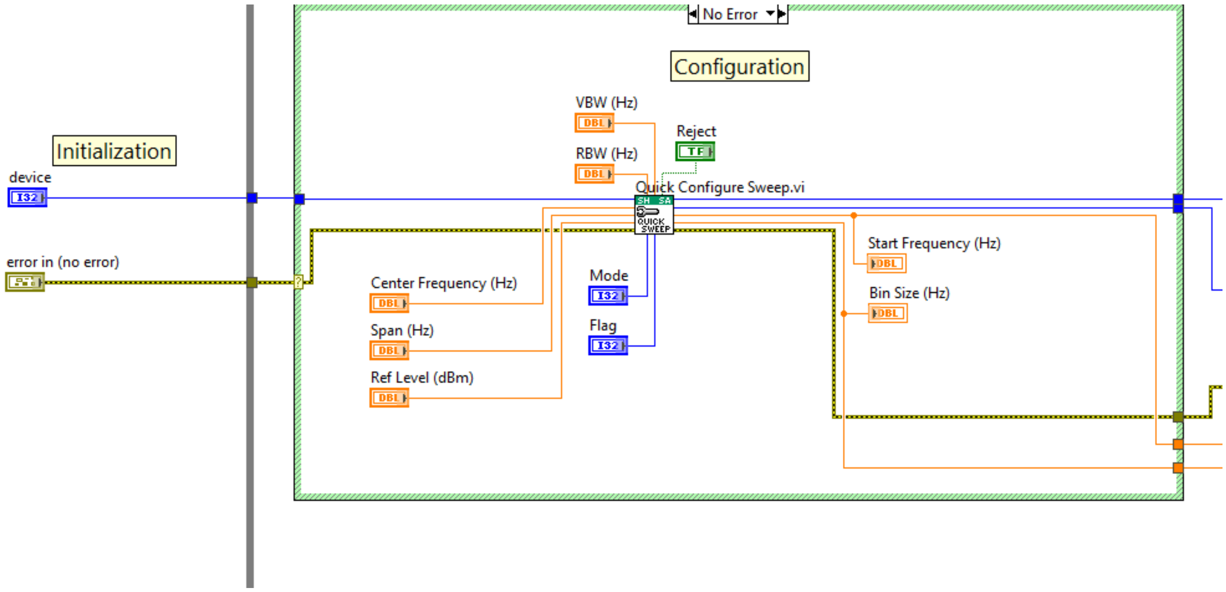

Figure 4.1.2 Configuration of the Signal Hound Hardware in LabView

The final step that involves interfacing with the Hardware from the Signal Hounds involves setting up and utilizing the Get Sweep VI. This VI is the one that actually gathers the data from the Hardware and gives the data to us in the form of an array of data. We must first allocate the array sizes depending on the previous Quick Configure Sweep VI's output data. This allows us to make sure we have an array big enough to support the data that we will be collecting when sweeps are made. Below is a screenshot of where the array sizes are allocated for the Get Sweep VI, and all the connections that go into the Get Sweep VI. This is the final step that requires a connection to the Signal Hound API, all the other VI's don't require Signal Hound's API and can be changed/implemented independently.

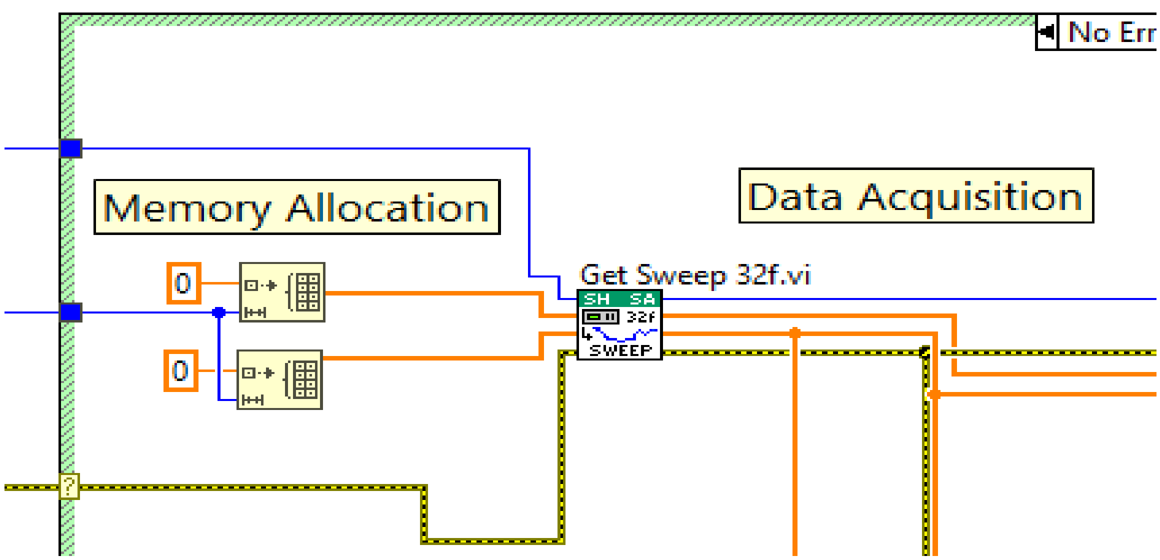

Figure 4.1.3 Sweeping data from the Signal Hound Hardware in LabView

4.2 Implementation of Task 1.2

Implementation of Task 1.2 starts with how Data would have to be displayed and working backwards from there to determine what functions would need to be created so that we can properly display the data. The first step was determining how data would be passed to the Waveform Graph VI so that the data can be correctly visualized in the Software for the users. Through testing, I found that the best way to pass data to the Waveform Graph VI when used as a Scalar Network Analyzer is a Bundle of different data so that large amounts of data points can be passed at the same time. Below is a screenshot showing the Waveform Graph VI and the Bundle VI to show how the two connect together.

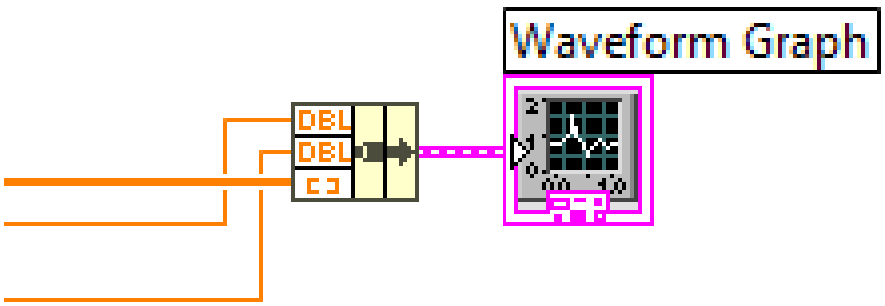

Figure 4.2.1 Setup of Data going into Waveform Graph VI

The next step was now determining what data would need to be passed into the Bundle to be able to accurately display the data in the Waveform Graph to achieve the graph we are looking for. During research it was found that the data required to be able to display a proper Waveform of a Scalar Network Analyzer was the Bin Size, Start Frequency, and lastly an array of Max Output values. The Start Frequency and Bin Size both come from the Quick Configure Sweep VI as outputs from the input parameters that the user determines before the system starts sweeping. Then, the array of Max Output values comes from when the sweep of data is actually made by the Get Sweep VI. Below is where you can see the values going into the Bundle and the originations of each of the values.

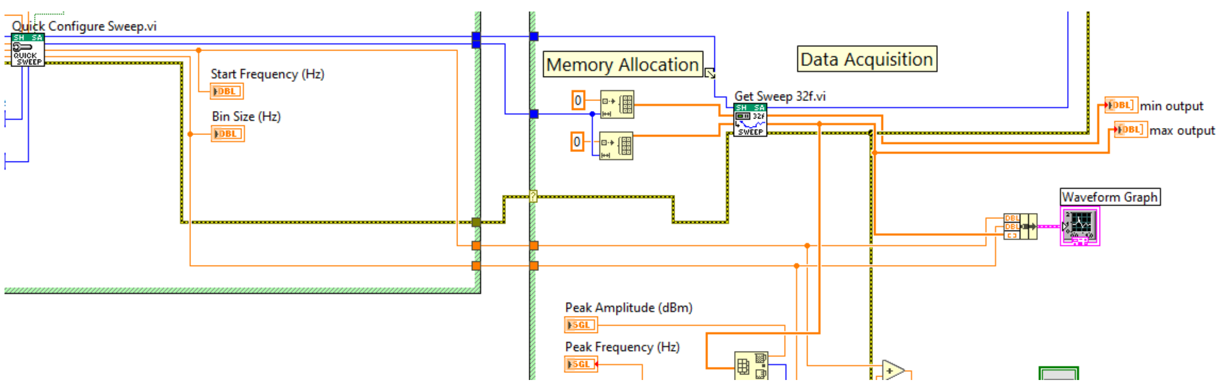

Figure 4.2.2 Origination of Data utilized for Waveform Graph

For the data manipulation, there are two last variables that we wanted to display to the user so that they can be used for their analysis. The two variables are Peak Amplitude and Peak Frequency, and we have determined that these two would require a few calculations in order for them to be obtained. Obtaining the Peak Amplitude is easier because we simply have to take the Max Output array from the Get Sweep VI and put it through the Array Max & Min VI to get the maximum value from the array which would result in giving us the maximum Amplitude for that sweep. Lastly, for our calculations we have the Peak Frequency, which we calculated by Multiplying the index value of the largest value in the array by the Bin Size, and then adding the Start Frequency to achieve our Peak Frequency. Below is a screenshot of our cluster of calculation VIs to achieve these two values.

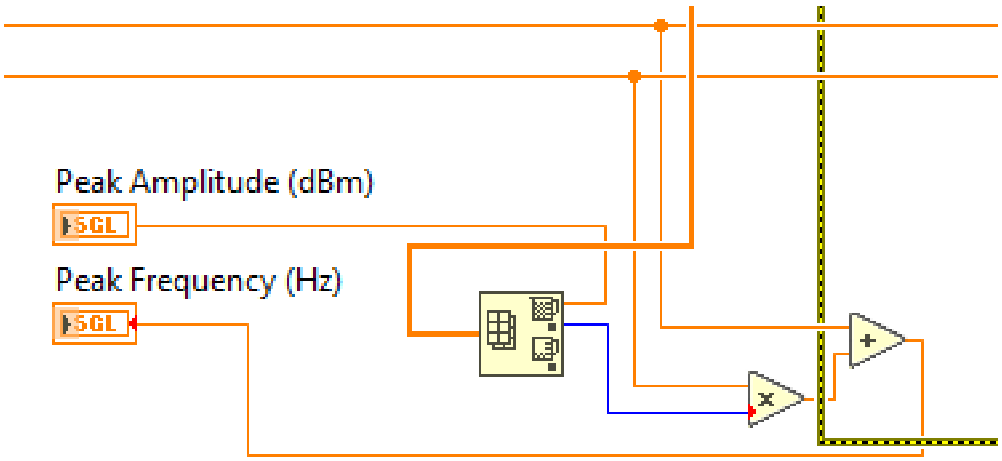

Figure 4.2.3 LabView setup of calculating Peak Amplitude and Frequency

4.3 Implementation of Task 1.3

4.4 Implementation of Task 1.4

4.5 Implementation of Task 2.1

The Signal Hound Hardware setup is fairly straightforward. Through our research we found that the Tracking Generator and the Spectrum Analyzer both are connected to each other in two different ways. This is done via the Sync port that both pieces of hardware have, and then the Output of the Tracking Generator through our test equipment/Attenuator, and then back into the Input of the Spectrum Analyzer. Lastly, the Tracking Generator and the Spectrum Analyzer are both using a USB cable to connect to the computer. Below are two pictures of the ports on both the Tracking Generator and Spectrum Analyzer.

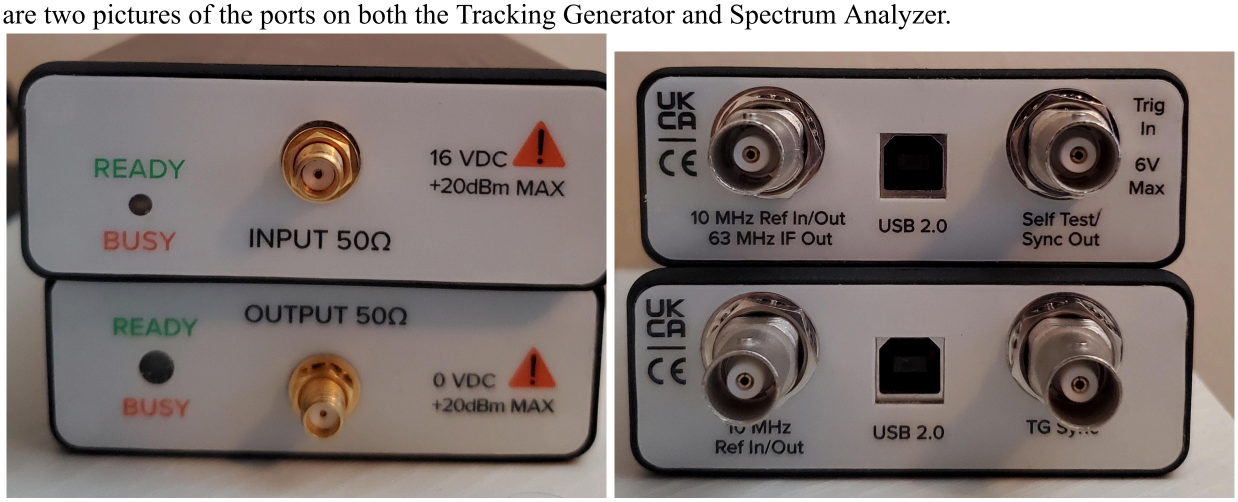

Figure 4.5.1 The ports of the Tracking Generator (Bottom) and the Spectrum Analyzer (Top)

Next we made a block diagram based on the inputs/outputs of the two Signal Hound Hardware pieces. This diagram includes both the Hardware, all the connections, the Attenuator, and the connection to the PC. Below is an image of the diagram.

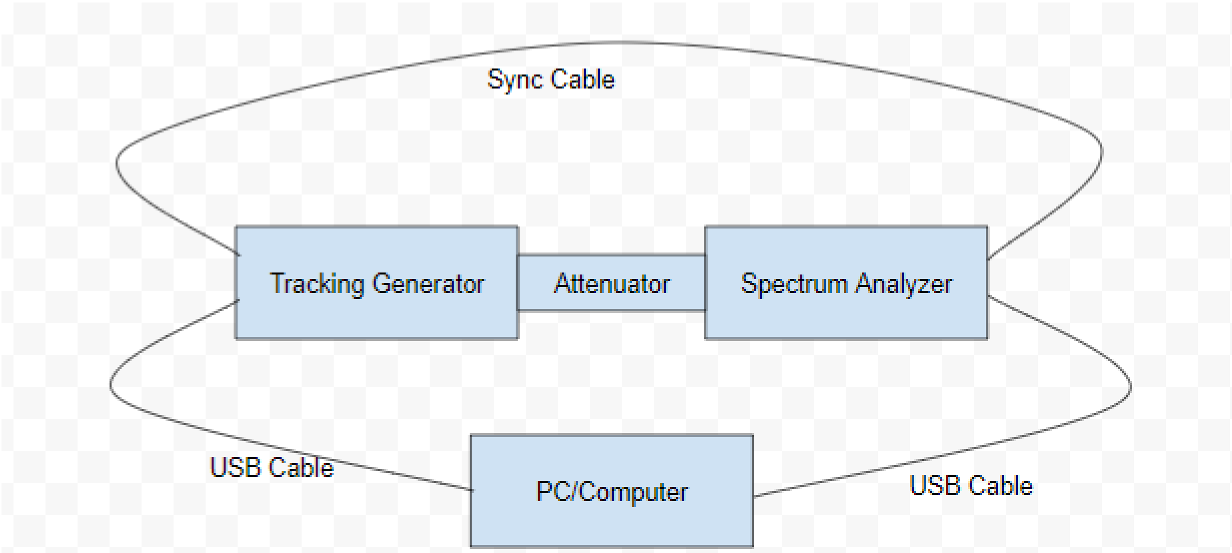

Figure 4.5.2 A diagram of how the Signal Hounds are set up to collect data

4.6 Implementation of Task 2.2

The next step for setting up the Signal Hound hardware is to make all the connections properly according to the block diagram that we had developed. Below is an image of the Scalar Network Analyzer system fully connected.

Figure 4.6.1 An image of the Scalar Network Analyzer fully connected

After the system was set up, we now had to verify the system was operating correctly. We did this by connecting the system to a Laptop and using the Signal Hound's Spike software to collect data quickly to make sure that they functioned properly. Below is a screenshot of the Spike software showing a wave that was collected by the Scalar Network Analyzer.

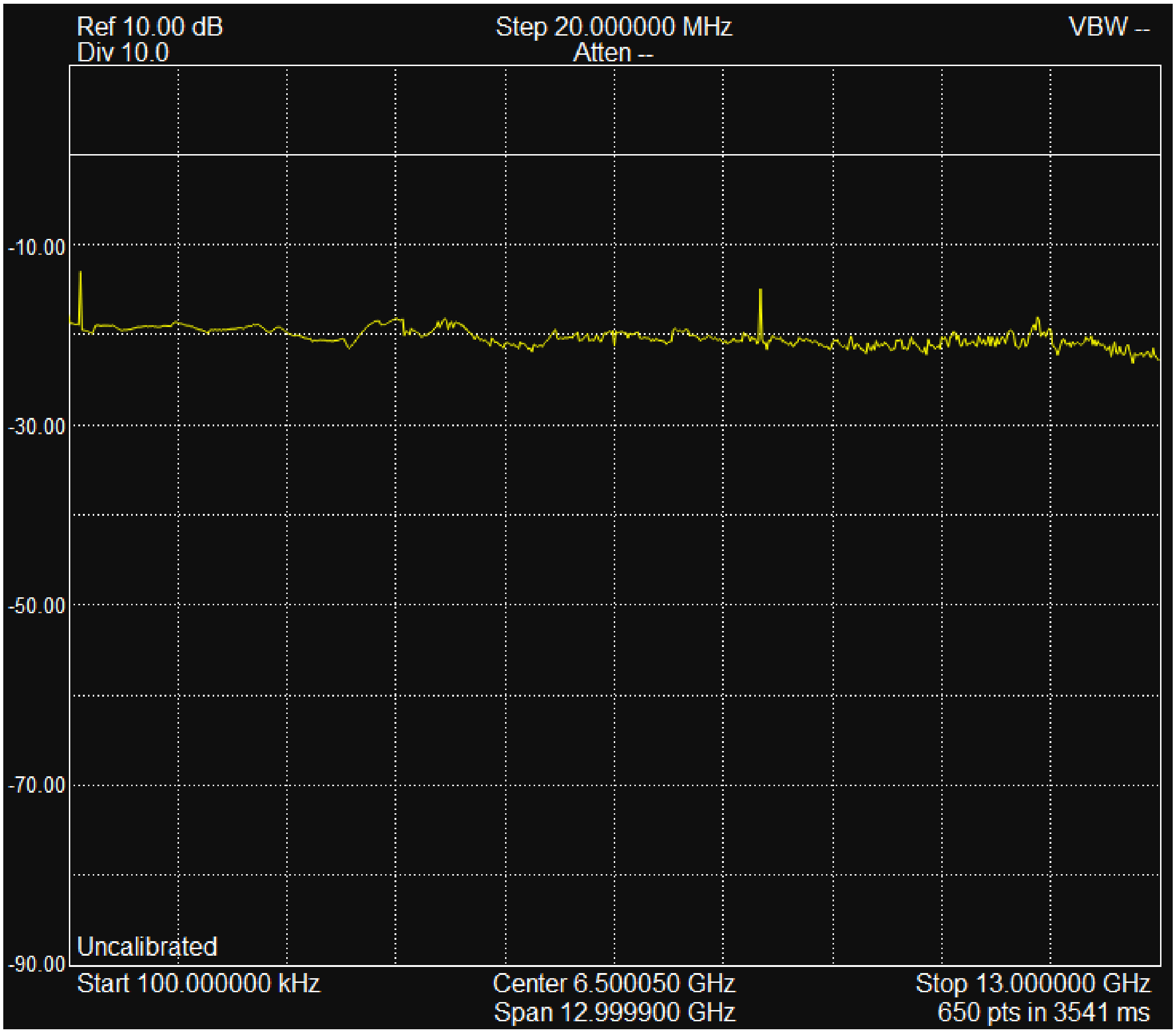

Figure 4.6.2 A graph of the Scalar Network Analyzer confirming the system functions.

CHAPTER 5. PROJECT EVALUATION

CHAPTER 6. CONCLUSION

ACKNOWLEDGEMENT

APPENDIX

REFERENCES