Sweep-N-Go 3.0

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ABSTRACT

This project improves the current performance of the Sweep-N-Go LabVIEW program used in Cal Poly electrical engineering laboratories. Sweep-N-Go expedites the laboratory data collection process through automated testing. The new version of the program (Sweep-N-Go Version 3.0) reduces user debugging time, improves sustainability, increases efficiency, and considers all new lab bench equipment. Sweep-N-Go Version 3.0 includes an enhanced Graphical User Interface (GUI) to optimize user-efficiency and user-friendliness according to student survey feedback. To further achieve usability, this program has been well documented online, outlining LabVIEW functions, such as how to open the program in LabVIEW, how to run an executable command, and which parameters to set in the GUI. The Sweep-N-Go LabVIEW program interfaces with all instruments on standard Cal Poly electrical engineering lab benches through both USB and GPIB communication. After users run the program, they have the capability to capture and graph collected data and export the data to a CSV file for further analysis.

CHAPTER 1

Introduction:

The custom-designed LabVIEW software program known as “Sweep-N-Go” (Version 2.0), previously installed on electrical engineering laboratory computers at Cal Poly, simplifies and expedites the data collection process utilized in electrical engineering laboratories [13]. The software program implements automated testing protocols and tools, thereby increasing the efficiency and accuracy of the data collection process. Generally, automated testing tools perform repetitive tasks that people would otherwise complete manually. While slower and less accurate, manual testing can provide certain benefits by allowing students time manipulating the data. This can help students draw insights that they might miss otherwise if they used automated data collection [11]. This concern should not negatively impact the use of Sweep-N-Go, however, since Cal Poly students have several lab courses throughout their four-year EE curriculum providing them with multiple opportunities to gain experience manually inputting data and gaining this experience. Additionally, the lab experiments requiring the use of Sweep-N-Go often do so, because the assignments require the collection of large amounts of data over long periods of time to limit the changes in the circuit due to external factors (heat, magnetic waves, noise from jumper cables, etc.). Manual entry of large data sets can take too much time to implement and compromise data integrity.

Student exposure to Sweep-N-Go not only enhances the data collection process, but it also introduces the student to an important product market. Exposure to automated testing makes student education more representative of the current industry. According to a PR Newswire article, the automated test industry will be worth $28.8 billion dollars in 2024 [12]. Sweep-N-Go aims to provide students with an understanding of new circuit concepts in laboratories via automated testing. For this reason, Sweep-N-Go requires students to select the instruments and input the values over which to sweep. In this setup, students do not merely press a button after making relevant circuit connections that says, “take data for EE 346 lab 3”. Students experience the capabilities of the lab equipment and the speed at which instruments collect data from the creation of a standardized test.

The current version of the Sweep-N-Go program communicates with the following laboratory instruments: an oscilloscope, power supply, source meter, multimeter, and a waveform generator. The user inputs the parameters from which she wants to collect data (such as changing the input voltage from 0 to 10 volts in 0.5 V steps). The program automatically controls the instruments, stores the data in a file and displays the data in a graphical format [1]. For labs requiring significant data collection and analysis, this program can greatly reduce the time needed for students to compete the lab.

That said, however, the current version of Sweep-N-Go often leaves students and professors frustrated and wanting more. Student complaints include reference to several programming bugs, causing the user to restart the program and try again. Furthermore, several students complained about the lack of an intuitive Graphical User Interface (GUI) [3] in Sweep-N-Go, noting confusion when trying to navigate the program for the first time. Finally, the program stores collected data in Excel, which requires tabular analysis – an unnecessary two-step approach requiring additional time to process analytical efforts. This project aims to reduce user frustrations and create a program that provides a more efficient data analysis process.

This project intends to create a durable, user-friendly update to the Sweep-N-Go program (Version 2.0) with minimal programming bugs. The updated version of Sweep-N-Go includes an intuitive Graphical User Interface and a detailed user guide. Additionally, the developer designed the program with proper coding documentation practices allowing other developers to easily make future changes. Overall, Sweep-N-Go 3.0 aims to introduce students to a functional automated testing system and enhance learning in Cal Poly labs by improving students' and professors' experiences with the program. These customers of the program express several concerns and requests which drive the purpose of improving the existing Sweep-N-Go code.

CHAPTER 2

Customer Needs Assessment

Sweep-N-Go 3.0 users (customers) include Cal Poly electrical/computer engineering students and faculty. To explore customer needs, I asked electrical engineering students what frustrates them about the current version of Sweep-N-Go. They reported frustration with debugging issues related to equipment or code errors that cause the system to fail. Furthermore, the customers identified a need for an improved, more intuitive user interface. Students also reported a desire for the program to sweep through the data more quickly and for the program to save data more easily in a table/Excel document for streamlined interpretation. Faculty also expressed a need for a more consistent working version of Sweep-N-Go. They identified a need to debug the system as it relates to GPIB addresses (communication with lab equipment) and expressed similar frustrations as students regarding the lack of a user-friendly interface and user guidance. Faculty members experience stress since students look to their professors for solutions and repeatedly ask faculty for assistance fixing the same Sweep-N-Go problems in every lab section.

Circumstantial Customer Needs Assessment

An additional customer needs due to the coronavirus pandemic includes remote lab access and data collection. Sweep-N-Go facilitates this need even though that was not the original purpose of improving it. After a lab instructor builds and connects a circuit, students could run Sweep-N-Go and collect data points to analyze and gain understanding of the circuit. Sweep-N-Go could also serve to take just one data measurement even though it facilitates a larger data collection set. This could allow students to still interact with the laboratory equipment remotely and have the Cal Poly “learn by doing” experience during the pandemic.

Requirements and Specifications

The customer needs specified above determine the following marketing requirements in Table 1. Several instruments on the bench determine the speed and limitations of the program [6-10]. The program uses the Agilent Oscilloscope exclusively as a voltmeter for Sweep-N-Go functionalities. Furthermore, each laboratory computer does not consistently map the same GPIB addresses for each instrument causing additional hurdles. Since efficiency vitally impacts the marketability of the project, it follows the program must run without causing further debugging frustrations. The engineering specifications follow in Table I from the abstract with additional details.

Table 1: Sweep-N-Go 3.0 Requirements and Specifications

Marketing Requirements	Engineering Specifications	Justification
7	Program sets all voltage and current outputs to 0 after a sweep concludes.	To ensure that the instruments stop powering the relevant circuit, the program sets these values to

		output voltage and current to 0 after sweep completes.
7	Program sets all voltage and current outputs to 0, when a sweep gets interrupted.	In case of a malfunction or error, the code stops powering the circuit. This avoids unnecessary potential danger.
5	Sweep-N-Go 3.0 interfaces with at least the following instruments using the indicated GPIB addresses [13]: Instrument GPIB Address Fluke 8840A DMM 1 Agilent E3640A DC Power Supply 5 Agilent 54622A Oscilloscope 7 Agilent 33120A Function Generator 10 Agilent 34401A DMM 22 Keithley 2400 SourceMeter 24	Laboratory computers generally configure these intruements with these specific GPIB addresses for the program to work. If any of addresses change, the program fails to communicate with the instruments on the bench causing the program to malfunction.
1, 2	EE/CPE students can complete setup of software in under 10 minutes.	Several students say that they spend entire lab periods trying to get Sweep-N-Go to work. This specification implies students could figure out the usage of the program significantly faster.
2, 5	Allow for communication with new lab equipment (Rigol DP832 DC Power Supply and Keysight MSO-X 2022A InfiniVision Scope) [14], [6] using USB.	Since the EE department purchased new equipment for select lab benches, Sweep-N-Go must account for these new instruments. This requirement ensures all students have access to a working program.
3	No components need to be purchased for project completion.	Any project considers costs and affordability important factors because this determines the success of selling the product to customers. Because Cal Poly already pays for LabVIEW, this project does not cost anything to make and is free for student use. Labor constitutes the only cost of the project.
1, 2	Collected data from the sweep outputs as a CSV (comma separated values) file with only relevant data.	This allows the user to graph the data in Excel or find exact points of interest.

1, 2	The information needed to use the program (User Guide) is documented and available online.	Since most students do not have familiarity with LabVIEW, the documentation of the process to open and run the program helps students efficiently set up the program and collect data without frustration.
1, 6, 9	Failure rate of the program (need for the program to be restarted) less than 5%.	Since the solution to several bugs in the current software requires restarting the program, the new version aims to ensure fewer bugs and a higher performance rate.
9	All instruments powered before starting the program.	Since two-thirds of the instruments on a high-speed GPIB daisy chain connection must be powered, students must power all instruments on the bench to assure this does not interfere with the program's performance.
6, 4	Increase programming comments currently in code by 50%.	To further help future students and professors make changes to the program, the code contains well-documented and understandable comments.
Marketing Requirements 1. User Friendly 2. Efficient 3. Free for student use 4. Sustainable 5. Implementable in all lab setups 6. Long-lasting 7. Promotes Lab Safety 8. Fosters Student Learning 9. Reliable		

Table 2: Sweep-N-Go 3.0 Deliverables

Delivery Date	**Deliverable Description**
1/21/2020	Design Review
2/25/2020	EE 461 Demo
3/13/2020	EE 461 Report
5/12/2020	EE 462 Demo
5/25/2020	ABET Sr. Project Analysis
6/05/2020	Sr. Project Expo Poster
6/12/2020	EE 462 Report

[1] R. Ford and C. Coulston, *Design for Electrical and Computer Engineers*, McGraw-Hill, 2007, p. 37
[2] *IEEE Std 1233*, *1998 Edition*, p. 4 (10/36), DOI: 10.1109/IEEESTD.1998.88826

These specifications show an outline of what the code should accomplish. To better understand how the code works generally, a simple block diagram shows the inputs and outputs to the program.

CHAPTER 3

Level 0 Block Diagram

The following level 0 block diagram in Figure 1 demonstrates the overall functionality of the system. Table 3 describes the functionality of Sweep-N-Go, which has two inputs and one output. The user sets data points which constitute the inputs to the program. The user enters values they wish to sweep as an input to the relevant circuit. A specified instrument on the bench reads the data from the circuit and sends that data to the program which it stores in an Excel, Comma Separated Value, document. These data points update to a graph with clearly labeled axis after the sweep completes.

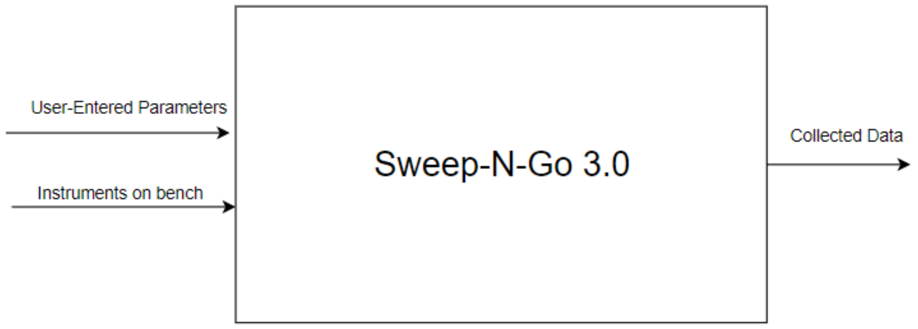


Figure 1: Level 0 Block Diagram

TABLE 3
LEVEL 0 BLOCK DIAGRAM FUNCTION TABLE
Table 3: Level 0 Block Diagram Function Table

Module	Sweep-N-Go 3.0
Inputs	-User-Entered Parameters First, the user chooses instruments from which to collect data. Then the user chooses what instrument (Agilent Supply, SourceMeter, Function Generator, and RIGOL power supply) they want to sweep and specify start, stop, and step values. Finally, the user enters further device options offered. -Instruments on bench Oscilloscope Power Supply Function Generator

	Agilent Multimeter Fluke Multimeter Keithley Source Meter These instruments communicate through GPIB (General Purpose Instrument Bus). They send measured data to the program to read.
Outputs	-Collected data After the user runs the program, they see the data collected in an excel spreadsheet as a CSV file. Furthermore, the program plots the data points on a graph with the swept values on the x-axis and the measured data on the y-axis.
Functionality	The program automatically queries which instruments exist on the bench and establishes communication accordingly. Then the user enters the range of values for which they wish to measure data and the program outputs the collected data.

This basic outline shows the overall functionality, but going one level deeper helps to better explain how the program completes the functionality previously specified.

Level 1 Block Diagram

Figure 2 shows the level one block diagram of Sweep-N-Go 3.0. Since LabVIEW interfaces the hardware, this diagram demonstrates the interaction of the software and the instruments on the lab bench. First, the software establishes communication with the instruments and initializes parameters based on the user inputs mentioned in the level 0 function table. Once the user sets the parameters, the program begins reading data received from the equipment and stores it. Then, as the name of the program implies, the code then updates swept instrument values and continues this process until it collects all the intended data.

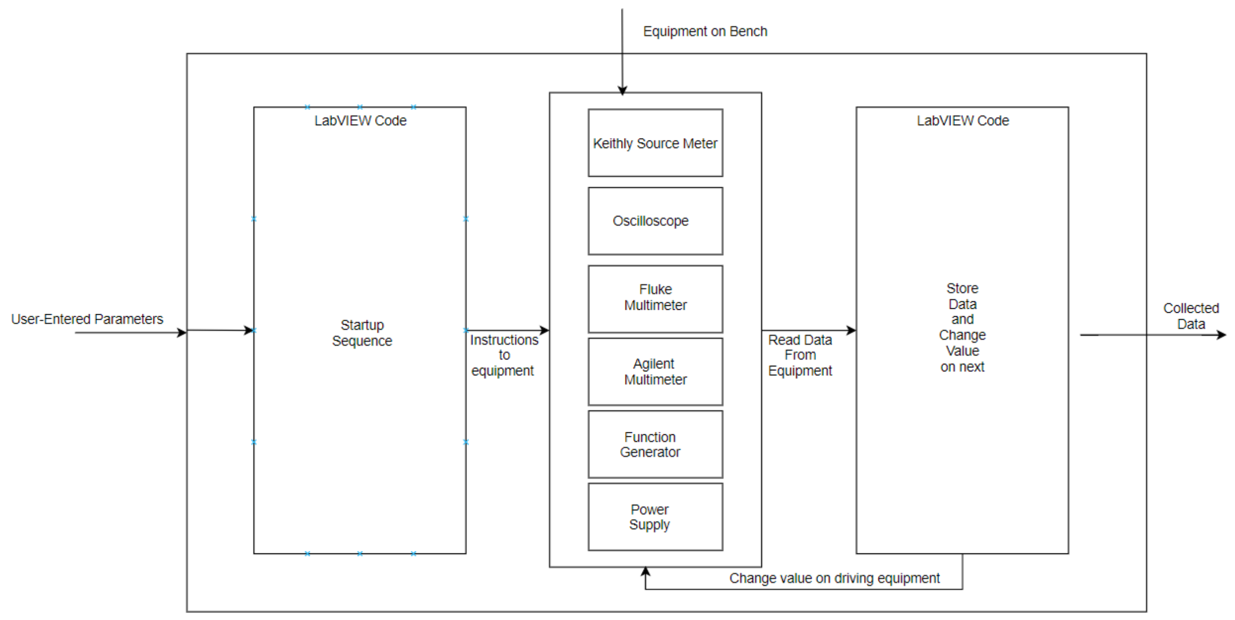


Figure 2: Level 1 Block Diagram

Table 4: Level 1 Block Diagram Function Table

Module	**Startup Sequence**
Inputs	After the user powers all bench instruments, they choose instruments from which to collect data. The user also selects which instrument (Agilent Supply, SourceMeter, Function Generator, and RIGOL power supply) he wants to sweep and specify start, stop, and step values. Finally, the user selects further device options offered.
Outputs	Instructions for instrument setup and communication.
Functionality	Establishes communication protocols with the instruments on the bench via GPIC and USB. Sets initial values of the outputs on the relevant instruments based upon user inputs.
Module	**Instruments**
Inputs	-Instructions for instrument setup and communication.

	-Instructions from the iterative part of the code setting a new value on an instrument output.
Outputs	Data read from the selected instrument. Usually a voltage or current value.
Functionality	The instruments read instructions from code and sets appropriate outputs. They then report the measured data to the software to be saved.
Module	**Store and Sweep**
Inputs	This module of code reads the measured data from the specified instrument.
Outputs	Sends instructions to the appropriate instrument to change the output value of the instrument. Keeps sending these values iteratively until the program collects all data. Once the sweep completes, the program saves data and outputs is as both a graph and in an Excel spreadsheet.
Functionality	The block of code reads measured data, saves it, then instructs the relevant instrument to change its output value by a variable value. The block of code does this iterative process until the program collects all data and outputs the results to the user.

The next section gives a temporal breakdown of the project design.

CHAPTER 4

Gantt Chart

Figure 3 represents the estimated timeline and project plan for making improvements to the current Sweep-N-Go (Version 2.0). Fall quarter entails preparing the project report and refining requirements and specifications. Winter quarter starts by familiarizing myself with the current version of Sweep-N-Go and recognizing common bugs. I anticipate this to only take a week to complete, and then plans to create a programmatic flow diagram. By week 4, I plan to have interfaced with all the relevant lab equipment and have developed a plan for software changes. By the end of Winter quarter, I complete version one of the software and acquire student and faculty feedback. At the start of Spring quarter, I begin on version two of the software to accommodate for the feedback received Winter quarter. I plan to complete the final second version by week six of Spring quarter.

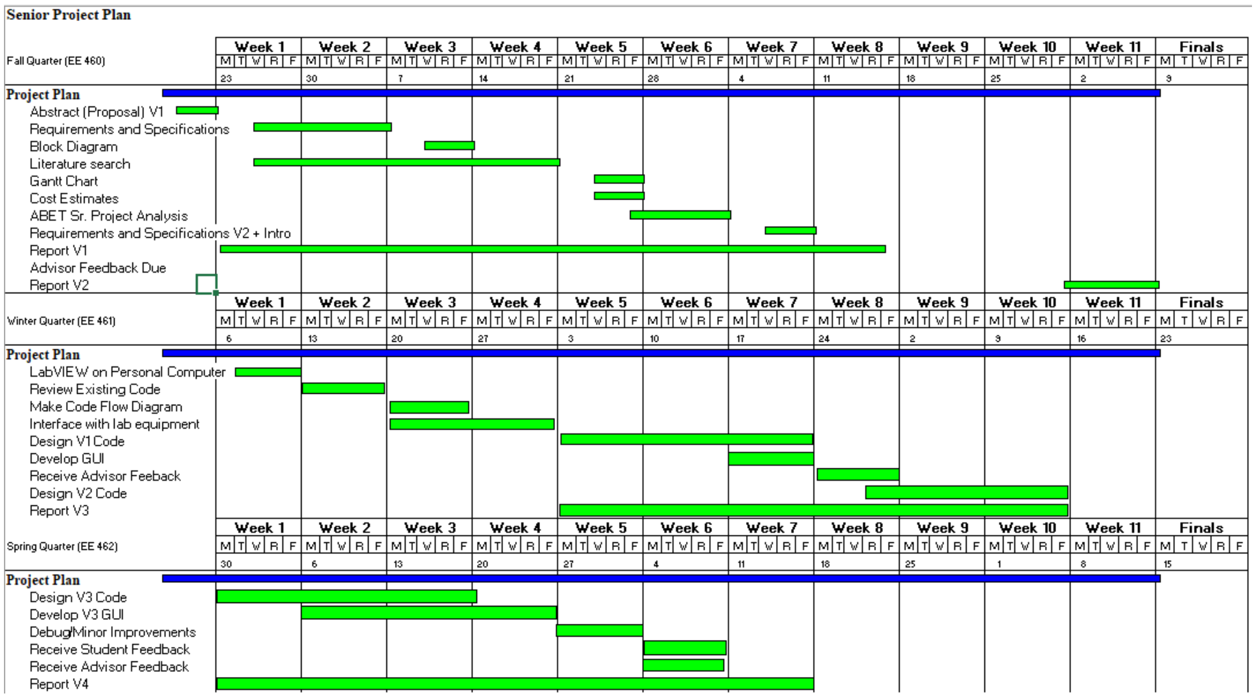


Figure 3: Gannt Chart

Cost Estimate

The following table, Table 5, identifies a comprehensive list of the anticipated costs entailed in implementing this project. Since Cal Poly already pays for LabVIEW and the developer of Sweep-N-Go wrote it in LabVIEW, the only new project costs include the cost of labor. Furthermore, Cal Poly provides the equipment used in this project. The only cost the students encounter when using the software occurs when purchasing a laboratory kit (usually around $8) to build the circuits analyzed in the labs using this program. The most conservative estimate of the time required to finish this project will take to complete yields approximately 200 hours. The optimistic view of the time spent on the project yields 120 hours. Realistically, I anticipate spending somewhere around 150 hours on the project. Using the PERT analysis, the estimated overall time the project takes to complete is $time = \frac{180+120+4(150)}{6} = 153$. Conceptually, I would charge $75/hour as a competitive salary for an engineer.

Table 5: Cost Estimates

Item	**Cost**
Labor	153 hours*$75/hour = $11,475
Lab Kit	$8
Total	$11,483

The developer works diligently to develop a functional program during this time. The next section gives background on the software and design of the final project.

CHAPTER 5

Programing Language

The original developer of Sweep-N-Go, Arthur Young, chose to write the program in LabVIEW. People commonly use LabVIEW for data acquisition and instrument control, since there exist several built-in functions which communicate with connected instruments. This makes LabVIEW a perfect fit for Sweep-N-Go functionalities. The program communicates with the standard IEEE-488 communication protocols for GPIB (General Purpose Interface Bus). GPIB protocols mandate that two thirds of all instruments on the bus must be powered on to ensure communication. Therefore, Sweep-N-Go asks students to power all instruments on the bench to ensure proper communication. LabVIEW also communicates through USB connections which correlates to the Rigol Power Supply on most Electrical Engineering lab benches and other new laboratory equipment such as Rigol Multimeters. Through these communication capabilities, a LabVIEW program can write commands to instruments and read the values they report to save them in a file. Figure 4 shows the communication lines through which Sweep-N-Go operates.

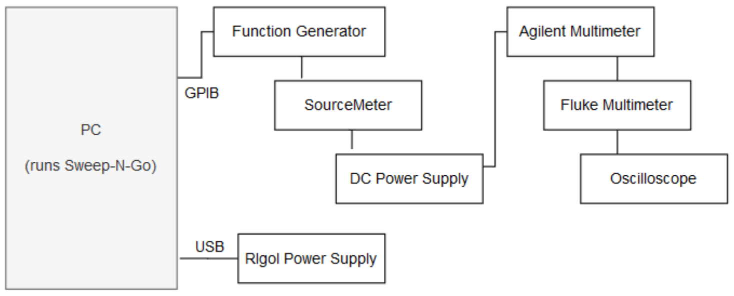


Figure 4: Bench Connections

LabVIEW uses a visual programming language in which they call functions "virtual instruments" or VIs. The language operates very similarly to C, but instead of coding through text, the programmer codes using visual blocks. Figure 5 shows LabVIEW's basic coding blocks: FOR loop, WHILE loop, case statement, and basic arithmetic operations.

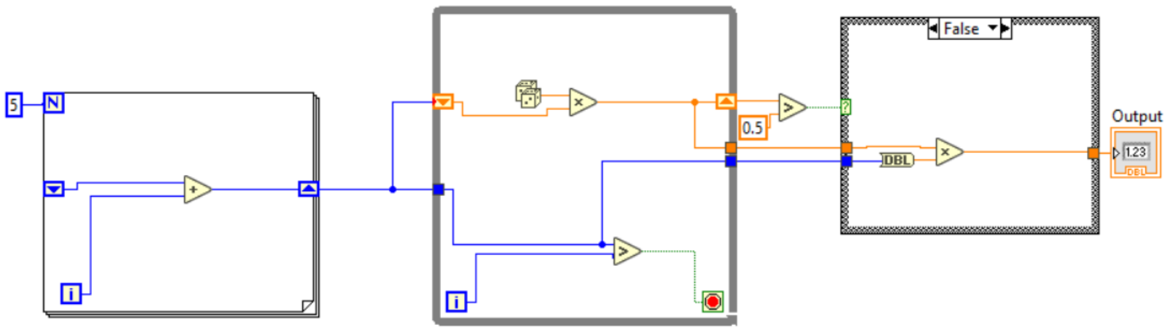


Figure 5: Example LabVIEW Code

The logic moves from left to right and outputs a number in the indicator. LabVIEW represents VIs as small boxes that have different icons with input and output connections. Once the developer obtained a basic understanding of the software, she works to understand the overall design of Sweep-N-Go 2.0 and make improvements.

Design

Arthur Young's design of Sweep-N-Go in 2003 implements a basic structure of waiting in a while loop until the user presses the "SWEEP" button to start. The program then moves into a FOR loop iterating a calculated number based on the user-input sweep parameters. In each iteration, a VI sets output voltages/currents and then reads the data to be saved to a file. Another VI in the FOR loop reports that data to a graph updated every iteration. Figure 6 shows the basic LabVIEW design structure of Arthur's code.

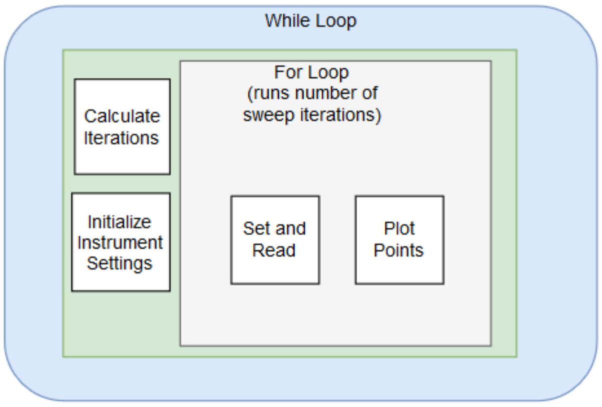

While Loop
Calculate Iterations
Initialize Instrument Settings
For Loop (runs number of sweep iterations)
Set and Read
Plot Points

Figure 6: Sweep-N-Go 2.0 Design Structure

This code structure works well but does not allow for other features. Furthermore, this design uses hard-coded values for GPIB and USB instrument addresses which causes problems if there exist any discrepancies for different lab benches.

In the design for Sweep-N-Go 3.0, there exists a preliminary VI before the WHILE loop to initialize and query the instrument connection addresses. The program disables all user-interface interactions until this process completes. Once in the WHILE loop, the program has an event structure which acts as an interrupt system for different user interactions. Depending on what the user clicks, the program makes different options available to limit user error. The event structure checks for fourteen different user-defined actions including an “EXIT” option which stops the program entirely. When the user presses the “SWEEP” button, the event structure initializes instrument settings and enqueues the sweep data to run in a parallel WHILE loop. This parallel structure allows the user to enqueue several sweeps and still interact with the UI. Figure 7 shows the LabVIEW design structure of Sweep-N-Go 3.0.

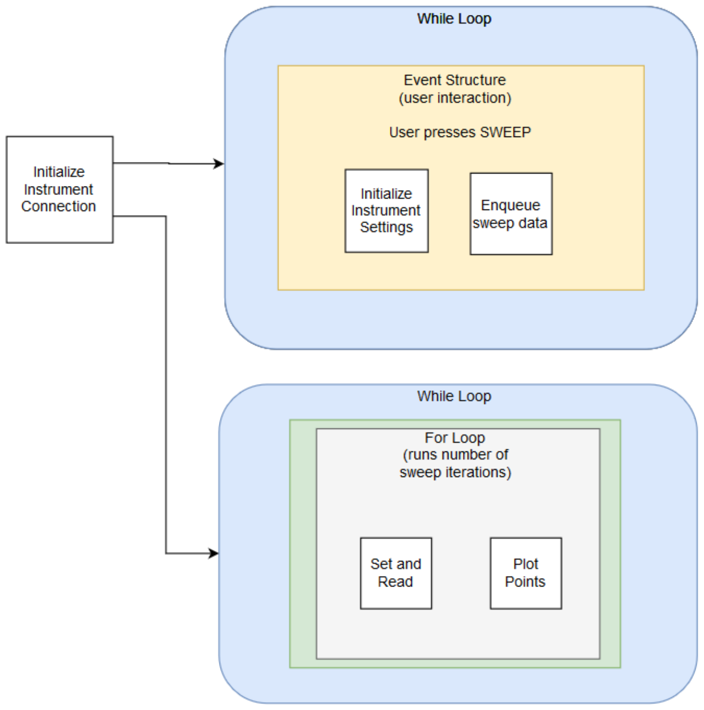


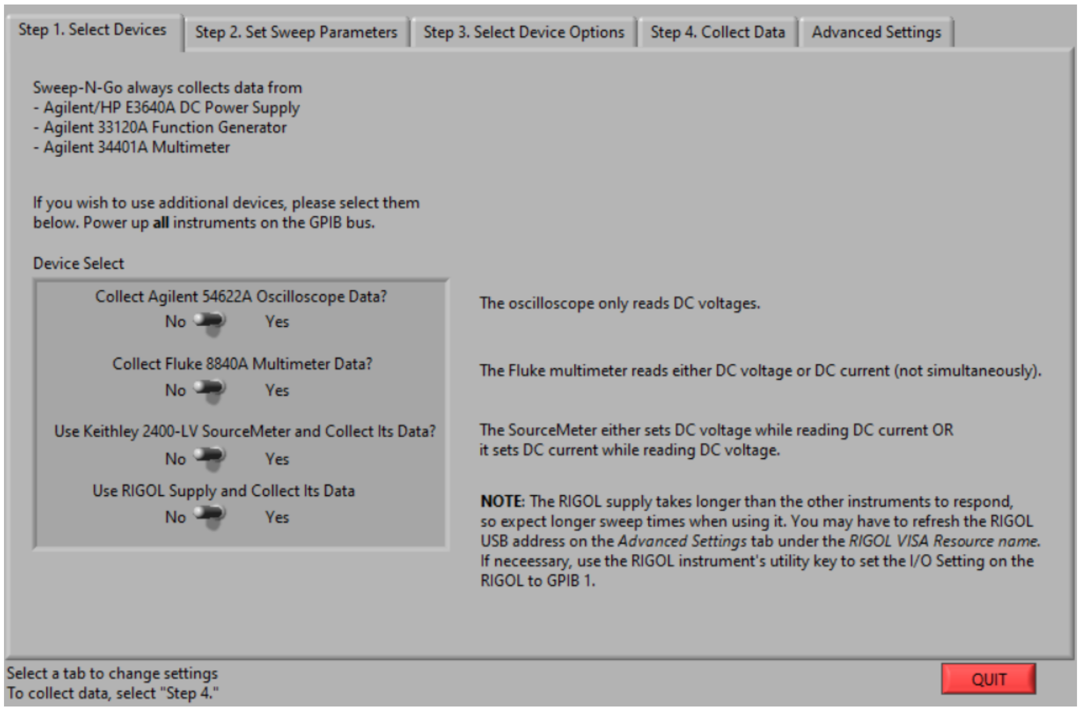
Figure 7: Sweep-N-Go 3.0 Design Structure

After determining the structure of Sweep-N-Go 3.0, the developer first focused on creating an effective user interface to set data types which propagate throughout the program.

CHAPTER 6

User Interface

Sweep-N-Go 2.0 requires the user to take four steps to run the program. The user goes through these steps by clicking on consecutive tabs. The first tab in Sweep-N-Go 2.0, shown in Figure 8, requires the user to indicate which instruments they intend to use during the sweep. However, three instruments (the Agilent Power Supply, Agilent Multimeter, and the Function Generator) always run in Sweep-N-Go 2.0. In the updated version, no instruments automatically run during the sweep to decrease user confusion and increase efficiency during the sweep.



Sweep-N-Go always collects data from
- Agilent/HP E3640A DC Power Supply
- Agilent 33120A Function Generator
- Agilent 34401A Multimeter

If you wish to use additional devices, please select them below. Power up **all** instruments on the GPIB bus.

Device Select

Collect Agilent 54622A Oscilloscope Data? No Yes

Collect Fluke 8840A Multimeter Data? No Yes

Use Keithley 2400-LV SourceMeter and Collect Its Data? No Yes

Use RIGOL Supply and Collect Its Data No Yes

The oscilloscope only reads DC voltages.

The Fluke multimeter reads either DC voltage or DC current (not simultaneously).

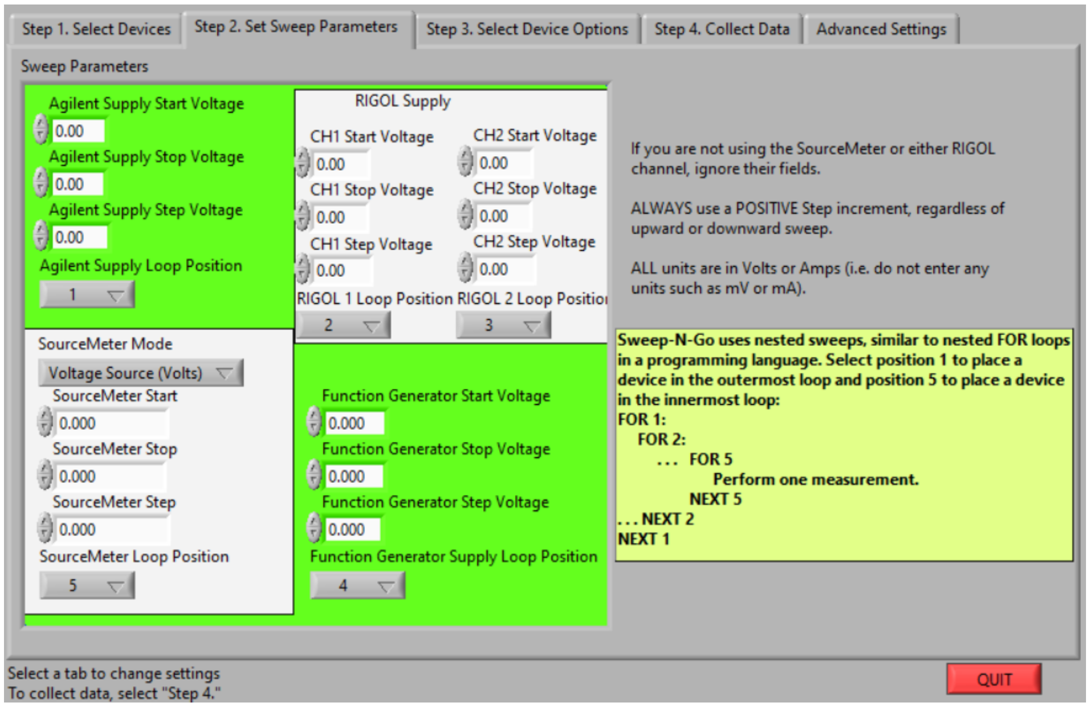
The SourceMeter either sets DC voltage while reading DC current OR it sets DC current while reading DC voltage.

NOTE: The RIGOL supply takes longer than the other instruments to respond, so expect longer sweep times when using it. You may have to refresh the RIGOL USB address on the *Advanced Settings* tab under the *RIGOL VISA Resource name*. If neceessary, use the RIGOL instrument's utility key to set the I/O Setting on the RIGOL to GPIB 1.

Select a tab to change settings
To collect data, select "Step 4."

Figure 8: Sweep-N-Go 2.0 Step 1 UI

Figure 9 shows the user interface for the next step in Sweep-N-Go 2.0 which requires the user to set the sweep parameters they need for relevant instruments. Since the user does not need to specify these parameters for unused instruments, many parameters can be neglected. However, the user could potentially have forgotten which instrument they chose to use during the sweep or accidentally set parameters for the Agilent Power Supply not thinking it would run.



Agilent Supply Start Voltage 0.00
Agilent Supply Stop Voltage 0.00
Agilent Supply Step Voltage 0.00
Agilent Supply Loop Position 1

CH1 Start Voltage 0.00
CH2 Start Voltage 0.00
CH1 Stop Voltage 0.00
CH2 Stop Voltage 0.00
CH1 Step Voltage 0.00
CH2 Step Voltage 0.00
RIGOL 1 Loop Position 2
RIGOL 2 Loop Positio 3

SourceMeter Mode Voltage Source (Volts)
SourceMeter Start 0.000
SourceMeter Stop 0.000
SourceMeter Step 0.000
SourceMeter Loop Position 5

Function Generator Start Voltage 0.000
Function Generator Stop Voltage 0.000
Function Generator Step Voltage 0.000
Function Generator Supply Loop Position 4

If you are not using the SourceMeter or either RIGOL channel, ignore their fields.

ALWAYS use a POSITIVE Step increment, regardless of upward or downward sweep.

ALL units are in Volts or Amps (i.e. do not enter any units such as mV or mA).

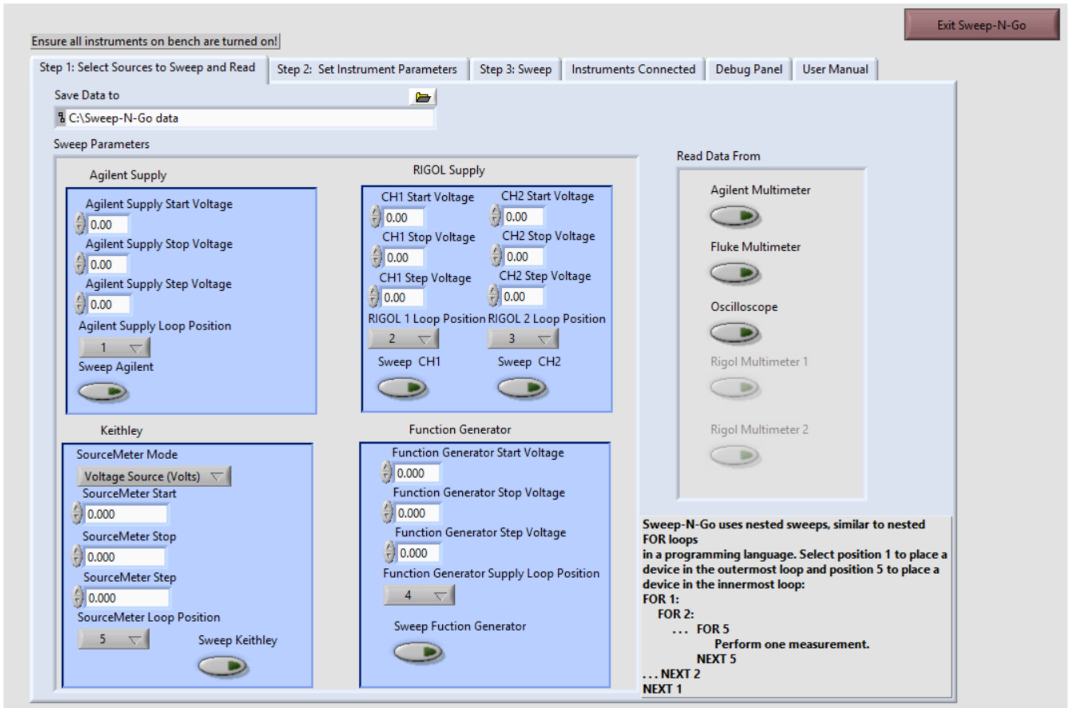
Sweep-N-Go uses nested sweeps, similar to nested FOR loops in a programming language. Select position 1 to place a device in the outermost loop and position 5 to place a device in the innermost loop:

```
FOR 1:
  FOR 2:
    ... FOR 5
          Perform one measurement.
        NEXT 5
... NEXT 2
NEXT 1
```

Select a tab to change settings
To collect data, select "Step 4."

Figure 9: Sweep-N-Go 2.0 Step 2 UI

Sweep-N-Go 3.0 removes this first step and instead has buttons indicating instrument usage next to the places the user sets sweep parameters as seen in Figure 10.



Ensure all instruments on bench are turned on!

Save Data to C:\Sweep-N-Go data

Agilent Supply Start Voltage 0.00
Agilent Supply Stop Voltage 0.00
Agilent Supply Step Voltage 0.00
Agilent Supply Loop Position 1
Sweep Agilent

CH1 Start Voltage 0.00
CH2 Start Voltage 0.00
CH1 Stop Voltage 0.00
CH2 Stop Voltage 0.00
CH1 Step Voltage 0.00
CH2 Step Voltage 0.00
RIGOL 1 Loop Position 2
RIGOL 2 Loop Position 3
Sweep CH1
Sweep CH2

SourceMeter Mode Voltage Source (Volts)
SourceMeter Start 0.000
SourceMeter Stop 0.000
SourceMeter Step 0.000
SourceMeter Loop Position 5
Sweep Keithley

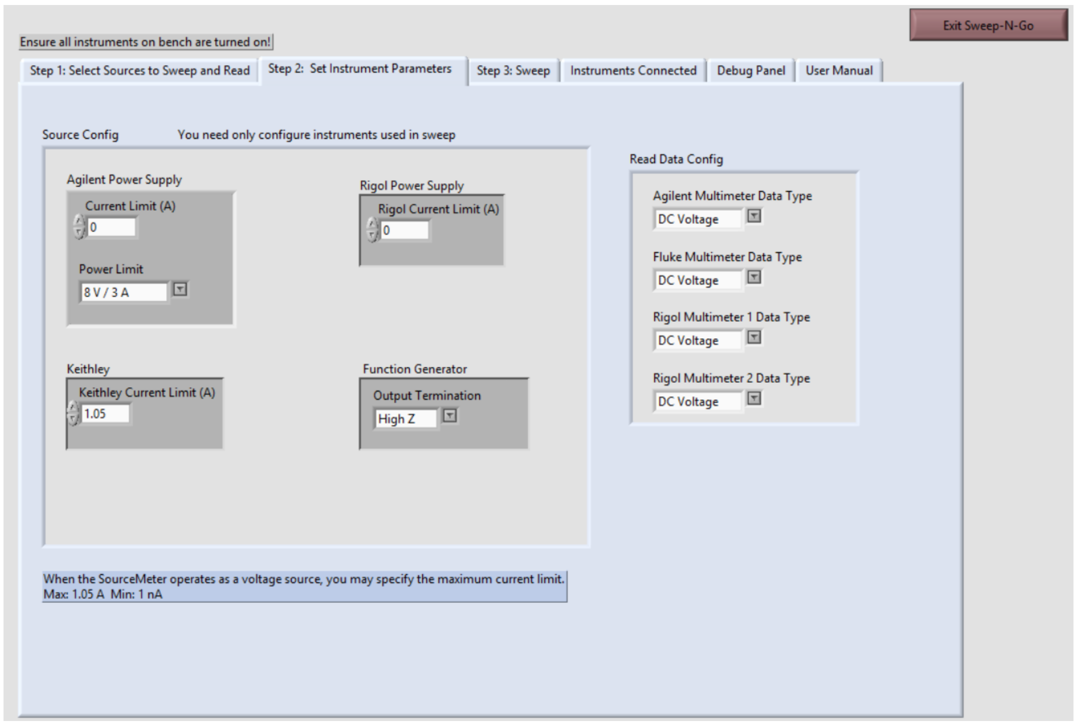
Function Generator Start Voltage 0.000
Function Generator Stop Voltage 0.000
Function Generator Step Voltage 0.000
Function Generator Supply Loop Position 4
Sweep Fuction Generator

Agilent Multimeter
Fluke Multimeter
Oscilloscope
Rigol Multimeter 1
Rigol Multimeter 2

Sweep-N-Go uses nested sweeps, similar to nested FOR loops in a programming language. Select position 1 to place a device in the outermost loop and position 5 to place a device in the innermost loop:

```
FOR 1:
  FOR 2:
    ... FOR 5
          Perform one measurement.
        NEXT 5
... NEXT 2
NEXT 1
```

Figure 10: Sweep-N-Go 3.0 Step 1 UI


Exit Sweep-N-Go
Step 1: Select Sources to Sweep and Read
Step 2: Set Instrument Parameters
Step 3: Sweep
Instruments Connected
Debug Panel
User Manual

Ensure all instruments on bench are turned on!

Source Config — You need only configure instruments used in sweep

Agilent Power Supply
Current Limit (A): 0
Power Limit: 8 V / 3 A

Rigol Power Supply
Rigol Current Limit (A): 0

Keithley
Keithley Current Limit (A): 1.05

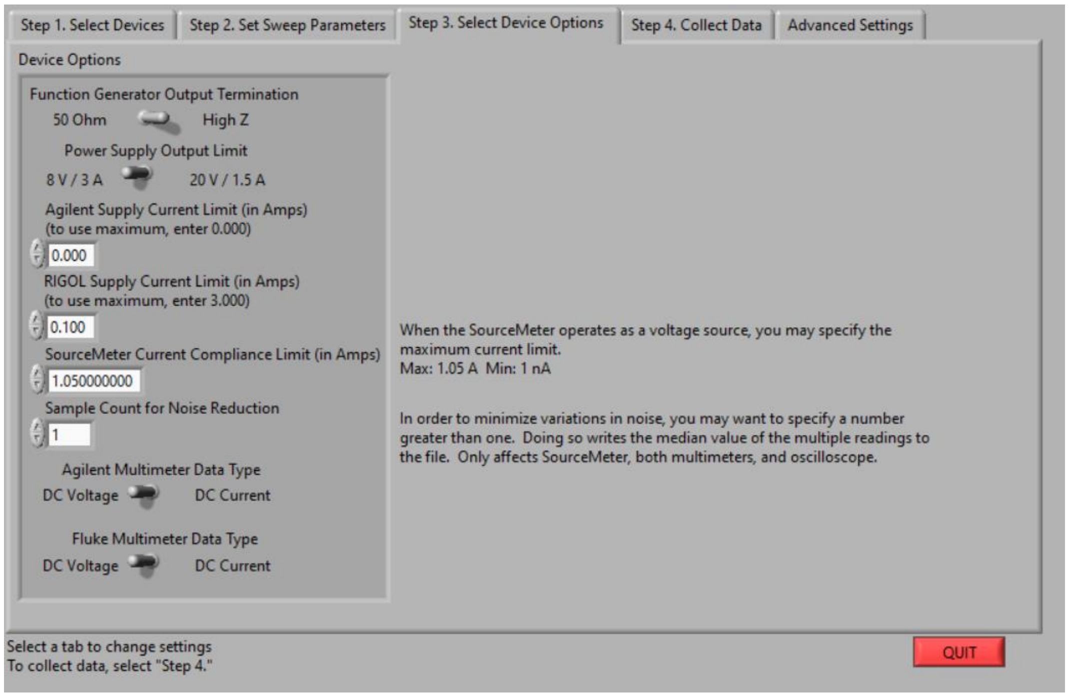
Function Generator
Output Termination: High Z

Read Data Config
Agilent Multimeter Data Type: DC Voltage
Fluke Multimeter Data Type: DC Voltage
Rigol Multimeter 1 Data Type: DC Voltage
Rigol Multimeter 2 Data Type: DC Voltage

When the SourceMeter operates as a voltage source, you may specify the maximum current limit.
Max: 1.05 A Min: 1 nA

Figure 11: Sweep-N-Go 3.0 Step 2 UI

Furthermore, Sweep-N-Go 3.0 includes a separate box adjacent to the "sweep parameters" for the user to indicate which read-only instruments they use in their data collection. The same configuration and placement of instruments correlates to the next tab in "Step 2. Set Instrument Parameters" shown in Figure 11. This helps the user navigate to relevant settings they wish to adjust, since parameters only apply to used instruments. Figure 12 shows Sweep-N-Go 2.0's tab for device options which contains a list that does not separate which options correlate to each instrument. This list not only requires more reading but could potentially cause the user to miss an important configuration, since the interface sandwiches different instrument configurations between others.



Device Options

Function Generator Output Termination
50 Ohm High Z

Power Supply Output Limit
8 V / 3 A 20 V / 1.5 A

Agilent Supply Current Limit (in Amps)
(to use maximum, enter 0.000)
0.000

RIGOL Supply Current Limit (in Amps)
(to use maximum, enter 3.000)
0.100

SourceMeter Current Compliance Limit (in Amps)
1.050000000

Sample Count for Noise Reduction
1

Agilent Multimeter Data Type
DC Voltage DC Current

Fluke Multimeter Data Type
DC Voltage DC Current

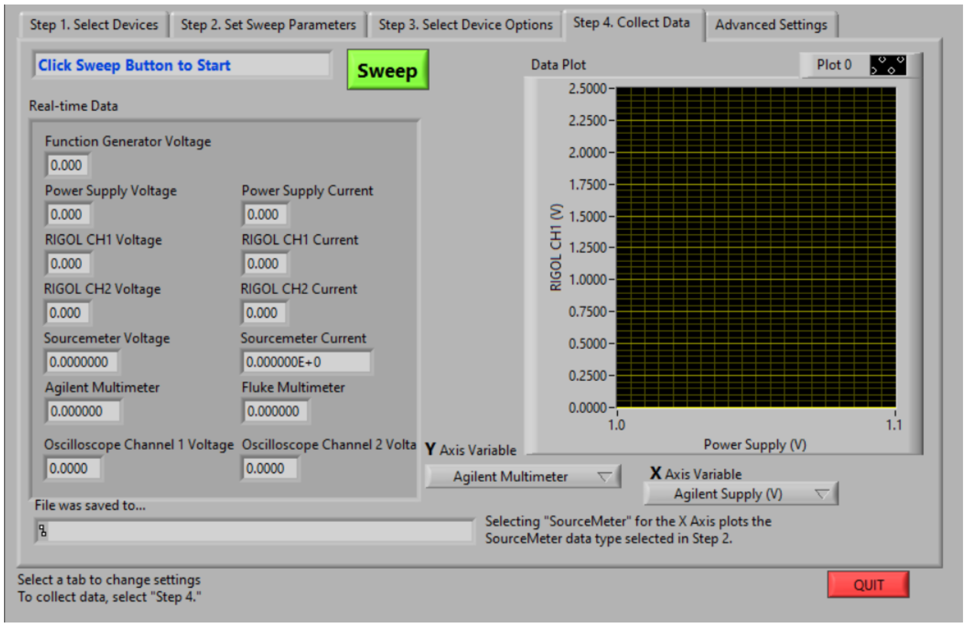
When the SourceMeter operates as a voltage source, you may specify the maximum current limit.
Max: 1.05 A Min: 1 nA

In order to minimize variations in noise, you may want to specify a number greater than one. Doing so writes the median value of the multiple readings to the file. Only affects SourceMeter, both multimeters, and oscilloscope.

Select a tab to change settings
To collect data, select "Step 4."

Figure 12: Sweep-N-Go 2.0 Step 3 UI

Finally, the user collects the data according to what they specify in the x and y axis drop-down menu. Sweep-N-Go 2.0 shows real-time numerical data for all instruments during the sweep and next to this, updates the graph. However, Sweep-N-Go 3.0 moves the numerical values to the “debug panel” tab to create more space for the graph. Figure 13 shows the busy 2.0 user interface versus Figure 14 which show the improved, neat interface.



Click Sweep Button to Start

Real-time Data

Function Generator Voltage 0.000
Power Supply Voltage 0.000
Power Supply Current 0.000
RIGOL CH1 Voltage 0.000
RIGOL CH1 Current 0.000
RIGOL CH2 Voltage 0.000
RIGOL CH2 Current 0.000
Sourcemeter Voltage 0.0000000
Sourcemeter Current 0.000000E+0
Agilent Multimeter 0.000000
Fluke Multimeter 0.000000
Oscilloscope Channel 1 Voltage 0.0000
Oscilloscope Channel 2 Volta 0.0000

Y Axis Variable: Agilent Multimeter

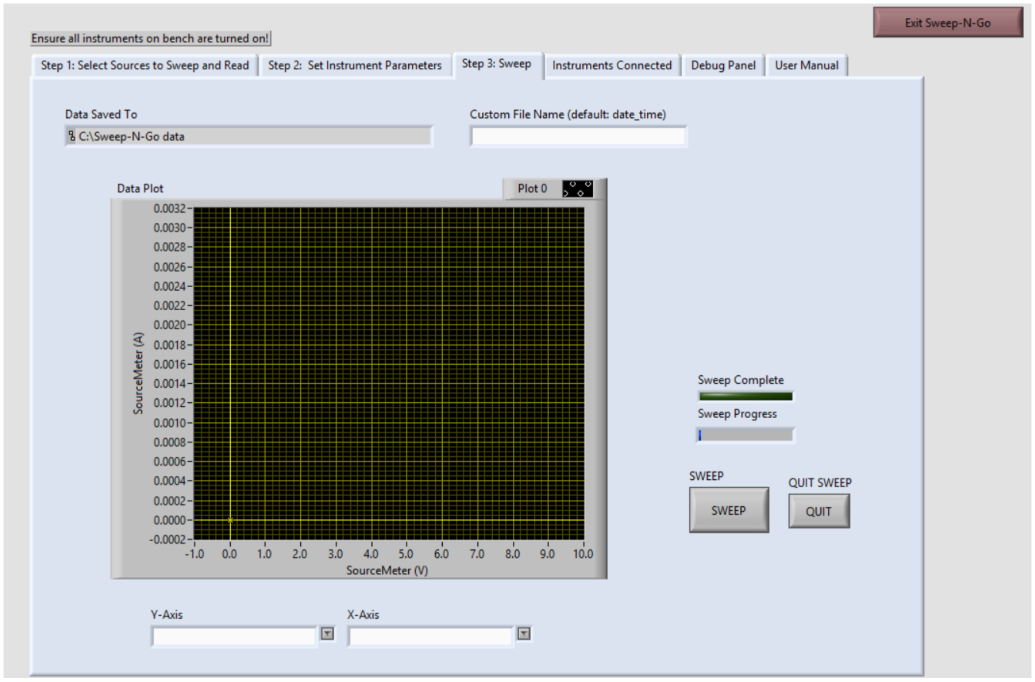
X Axis Variable: Agilent Supply (V)

File was saved to...

Selecting "SourceMeter" for the X Axis plots the SourceMeter data type selected in Step 2.

Select a tab to change settings
To collect data, select "Step 4."

Figure 13: Sweep-N-Go 2.0 Step 4 UI



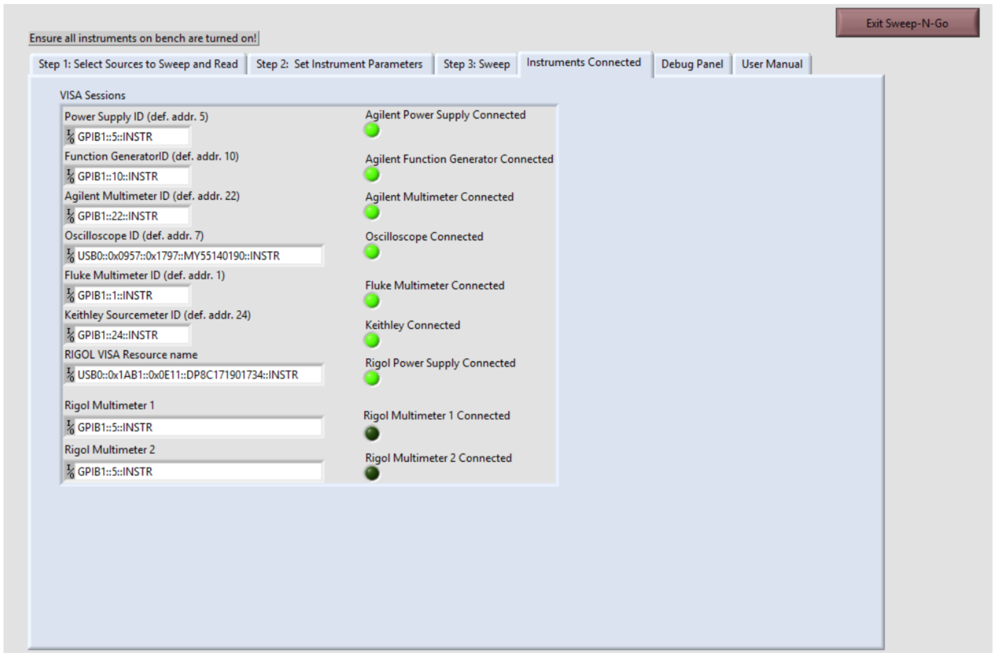
Ensure all instruments on bench are turned on!

Data Saved To: C:\Sweep-N-Go data

Custom File Name (default: date_time)

Figure 14: Sweep-N-Go 3.0 Step 3 UI

As discussed in the previous section, Sweep-N-Go relies on instrument connectivity. Sweep-N-Go 3.0 adds a tab “Instruments Connected”, as seen in Figure 15, to inform the user the current instrument addresses and connectivity status. This creates ease in debugging Sweep-N-Go errors due to a lack of instrument communication, which an advanced user can make changes to in the “Debug Panel”.


Exit Sweep-N-Go

Ensure all instruments on bench are turned on!

Step 1: Select Sources to Sweep and Read | Step 2: Set Instrument Parameters | Step 3: Sweep | Instruments Connected | Debug Panel | User Manual

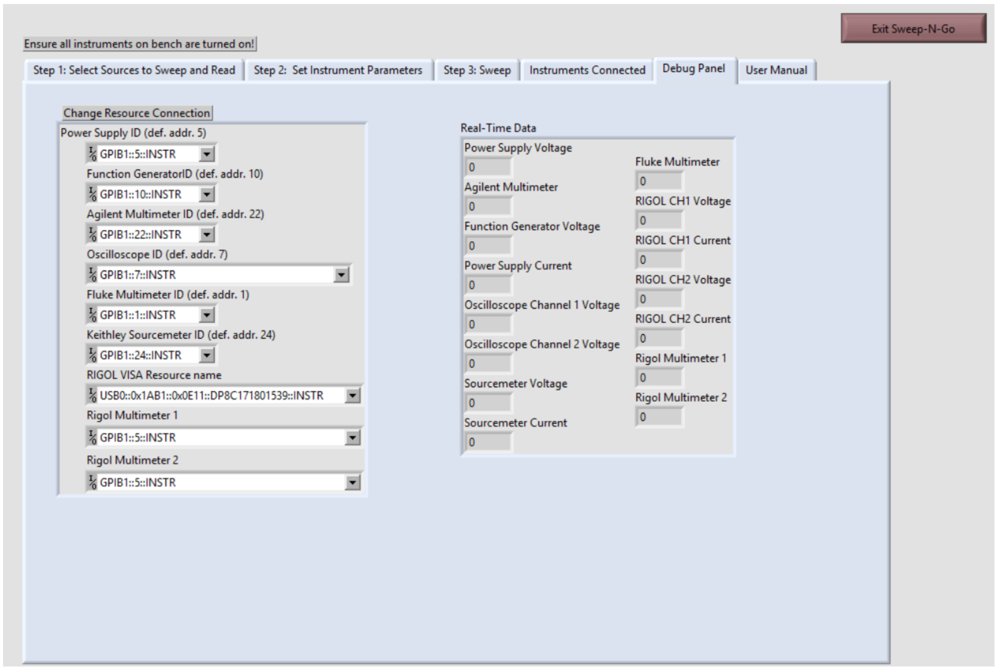
VISA Sessions

Power Supply ID (def. addr. 5)
GPIB1::5::INSTR
Function GeneratorID (def. addr. 10)
GPIB1::10::INSTR
Agilent Multimeter ID (def. addr. 22)
GPIB1::22::INSTR
Oscilloscope ID (def. addr. 7)
USB0::0x0957::0x1797::MY55140190::INSTR
Fluke Multimeter ID (def. addr. 1)
GPIB1::1::INSTR
Keithley Sourcemeter ID (def. addr. 24)
GPIB1::24::INSTR
RIGOL VISA Resource name
USB0::0x1AB1::0x0E11::DP8C171901734::INSTR
Rigol Multimeter 1
GPIB1::5::INSTR
Rigol Multimeter 2
GPIB1::5::INSTR

Agilent Power Supply Connected
Agilent Function Generator Connected
Agilent Multimeter Connected
Oscilloscope Connected
Fluke Multimeter Connected
Keithley Connected
Rigol Power Supply Connected
Rigol Multimeter 1 Connected
Rigol Multimeter 2 Connected

Figure 15: Sweep-N-Go 3.0 "Instruments Connected" Tab

Figure 16 shows the debug panel which the user can manually change the instrument addresses to fix connectivity problems. Furthermore, the user can see the numeric real-time data values to understand why potential discrepancies may appear during the sweep.


Exit Sweep-N-Go

Ensure all instruments on bench are turned on!

Step 1: Select Sources to Sweep and Read | Step 2: Set Instrument Parameters | Step 3: Sweep | Instruments Connected | Debug Panel | User Manual

Change Resource Connection

Power Supply ID (def. addr. 5)
GPIB1::5::INSTR
Function GeneratorID (def. addr. 10)
GPIB1::10::INSTR
Agilent Multimeter ID (def. addr. 22)
GPIB1::22::INSTR
Oscilloscope ID (def. addr. 7)
GPIB1::7::INSTR
Fluke Multimeter ID (def. addr. 1)
GPIB1::1::INSTR
Keithley Sourcemeter ID (def. addr. 24)
GPIB1::24::INSTR
RIGOL VISA Resource name
USB0::0x1AB1::0x0E11::DP8C171801539::INSTR
Rigol Multimeter 1
GPIB1::5::INSTR
Rigol Multimeter 2
GPIB1::5::INSTR

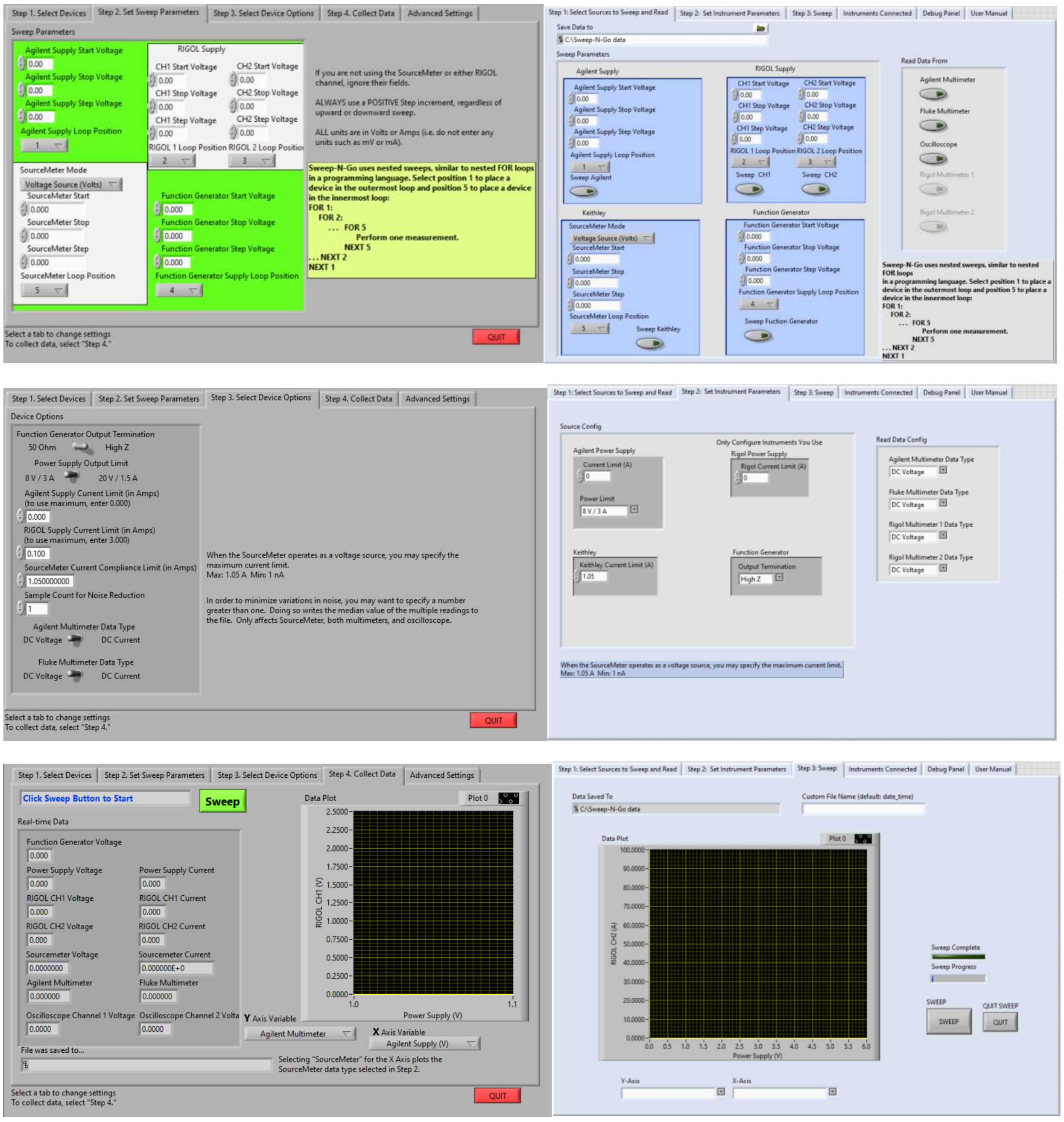
Real-Time Data

Power Supply Voltage	0
Agilent Multimeter	0
Function Generator Voltage	0
Power Supply Current	0
Oscilloscope Channel 1 Voltage	0
Oscilloscope Channel 2 Voltage	0
Sourcemeter Voltage	0
Sourcemeter Current	0
Fluke Multimeter	0
RIGOL CH1 Voltage	0
RIGOL CH1 Current	0
RIGOL CH2 Voltage	0
RIGOL CH2 Current	0
Rigol Multimeter 1	0
Rigol Multimeter 2	0

Figure 16: Sweep-N-Go 3.0 "Debug Panel" Tab

Finally, Sweep-N-Go 3.0 features a "User Manual" tab, which serves to help users understand the program within the program. This way, students can easily find instructions instead of clicking on a website or referencing their lab manuals.

Additionally, the developer made some aesthetic choices to improve Sweep-N-Go. Firstly, instead of using the toggle switches, the developer replaced them all with drop-down menus. The developer also changed the color from bright green to periwinkle for improved visual interpretation. Figure 17 shows the overall changes made to the user interface with Sweep-N-Go 2.0 on the left and Sweep-N-Go 3.0 on the right.


Step 1. Select Devices
Step 2. Set Sweep Parameters
Step 3. Select Device Options
Step 4. Collect Data
Advanced Settings
Step 1: Select Sources to Sweep and Read
Step 2: Set Instrument Parameters
Step 3: Sweep
Instruments Connected
Debug Panel
User Manual
QUIT
Sweep
SWEEP

If you are not using the SourceMeter or either RIGOL channel, ignore their fields.

ALWAYS use a POSITIVE Step increment, regardless of upward or downward sweep.

ALL units are in Volts or Amps (i.e. do not enter any units such as mV or mA).

```
Sweep-N-Go uses nested sweeps, similar to nested FOR loops
in a programming language. Select position 1 to place a
device in the outermost loop and position 5 to place a device
in the innermost loop:
FOR 1:
   FOR 2:
      ... FOR 5
            Perform one measurement.
          NEXT 5
... NEXT 2
NEXT 1
```

Select a tab to change settings
To collect data, select "Step 4."

When the SourceMeter operates as a voltage source, you may specify the maximum current limit.
Max: 1.05 A Min: 1 nA

In order to minimize variations in noise, you may want to specify a number greater than one. Doing so writes the median value of the multiple readings to the file. Only affects SourceMeter, both multimeters, and oscilloscope.

Click Sweep Button to Start

Selecting "SourceMeter" for the X Axis plots the SourceMeter data type selected in Step 2.

Save Data to: C:\Sweep-N-Go data

Figure 17: GUI DIfference 2.0 vs 3.0

The developer made several additional changes to improve the user experience of Sweep-N-Go.

User Inputs

To reduce errors when inputting instrument instructions, Sweep-N-Go 2.0 and 3.0 both coerce user-input values. They both ensure that the user cannot enter negative voltages when entering sweep parameters. Furthermore, the programs set a maximum voltage range coercion according to instrument limitations.

However, Sweep-N-Go 2.0 also coerces the “step” inputs, so the user cannot input anything less than 0. This requirement does not prevent the user from sweeping a higher value to a lower one, but they must input a positive step increment. In Sweep-N-Go 3.0, the user may enter positive values to indicate a positive sweep and negative step values to indicate a backwards sweep. This makes more logical sense to users, and, if the user mistakenly entered the wrong-signed step value, Sweep-N-Go 3.0 automatically corrects this to continue the sweep.

Figure 18 shows the logic which fixes potential user errors regarding step values. The program subtracts the stop voltage from the start voltage to see if the user wants intends a positive or negative sweep. Then, the program multiplies this value and the step value. If the user intends a negative sweep and inputs a negative step size value, the program outputs a positive value. Same with a positive sweep and a positive step size. However, if the value is negative, then the program changes the step value sign by multiplying it and -1. Then, the program outputs the correctly incremented voltage. Therefore, the user cannot enter a value that causes the sweep to increment outside the start and stop values.

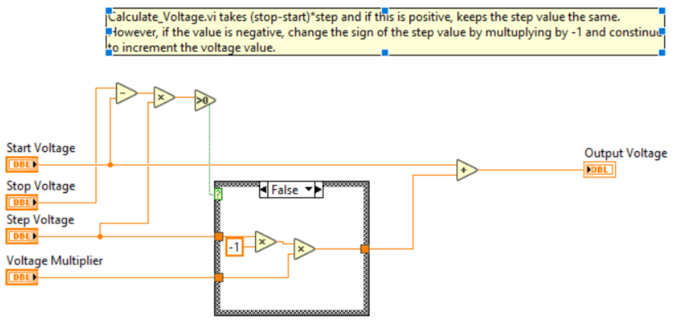

Calculate_Voltage.vi takes (stop-start)*step and if this is positive, keeps the step value the same. However, if the value is negative, change the sign of the step value by multuplying by -1 and constinue to increment the voltage value.

Figure 18: Increment Sweep Logic "Calculate_Voltage.vi"

Once the user sets all parameters they need to sweep, then they move to “Step 3: Sweep” to collect data and see it update the graph. The user must only specify the axis data and press the “Sweep” button.

Data Options

Another development which improves the user experience shows only relevant data options on the x and y axis drop-down menus when the user chooses what data to plot. Since the user specifies each instrument they use during the sweep, the data options need to reflect those specifications. The event structure waits to see if the user clicks a Boolean button indicating instrument use and then runs the INIT_DROP_MENU VI as seen in Figure 19.

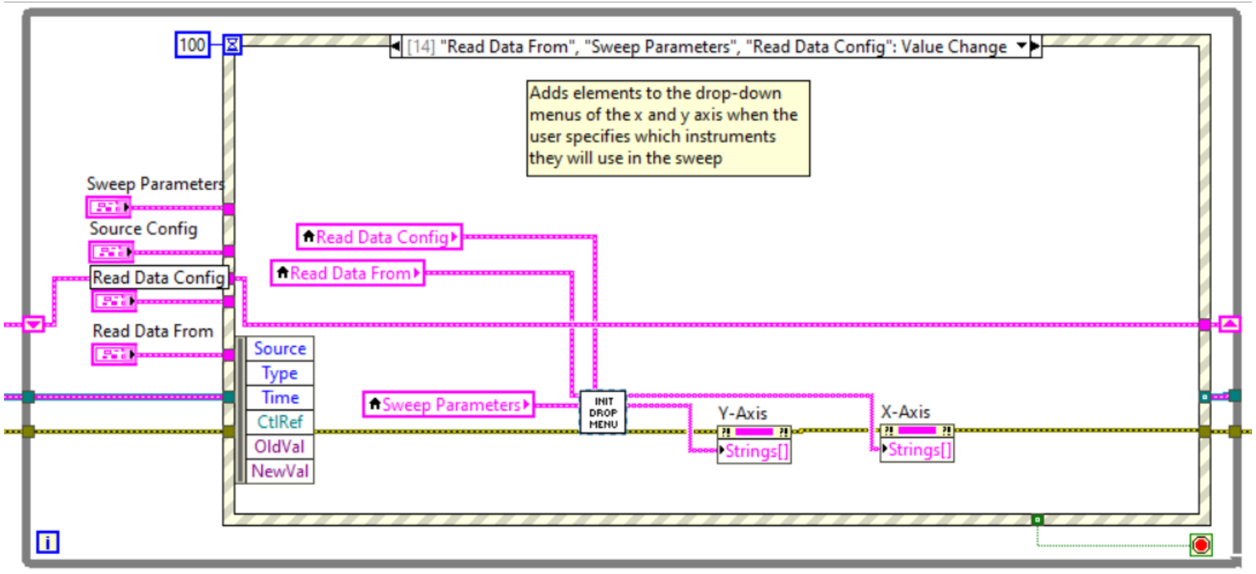

100
[14] "Read Data From", "Sweep Parameters", "Read Data Config": Value Change
Adds elements to the drop-down menus of the x and y axis when the user specifies which instruments they will use in the sweep
Sweep Parameters
Source Config
Read Data Config
Read Data From
Read Data Config
Read Data From
Source
Type
Time
CtlRef
OldVal
NewVal
Sweep Parameters
INIT DROP MENU
Y-Axis
Strings[]
X-Axis
Strings[]

Figure 19: Update X and Y axis Menus

This VI checks each Boolean indicating whether the user intends to implement an instrument in the sweep and adds a string representing data accordingly. The VI takes inputs “Read Data Config”, “Read Data From”, and “Sweep Parameters”. “Read Data Config” reports whether the user intends to read DC Voltage or DC Current from the multimeters or oscilloscope. The “Read Data From” and “Sweep Parameters” inputs include data about which instruments the user wishes to implement in their sweep. The VI outputs arrays of strings “X-Axis” and “Y-axis”. The strings output to the “X-Axis” only include instruments defined in the “Sweep Parameters” input since the program should plot instrument sources on the x axis. The “Y-Axis” string array output includes all potentially relevant data including the actual source voltage and current. Figure 20 shows the VI which checks if the user does not use an instrument in the sweep and within the case statement adds an empty string to the string array. Finally, the two for loops remove any empty string cases so the string array size matches the relevant data.

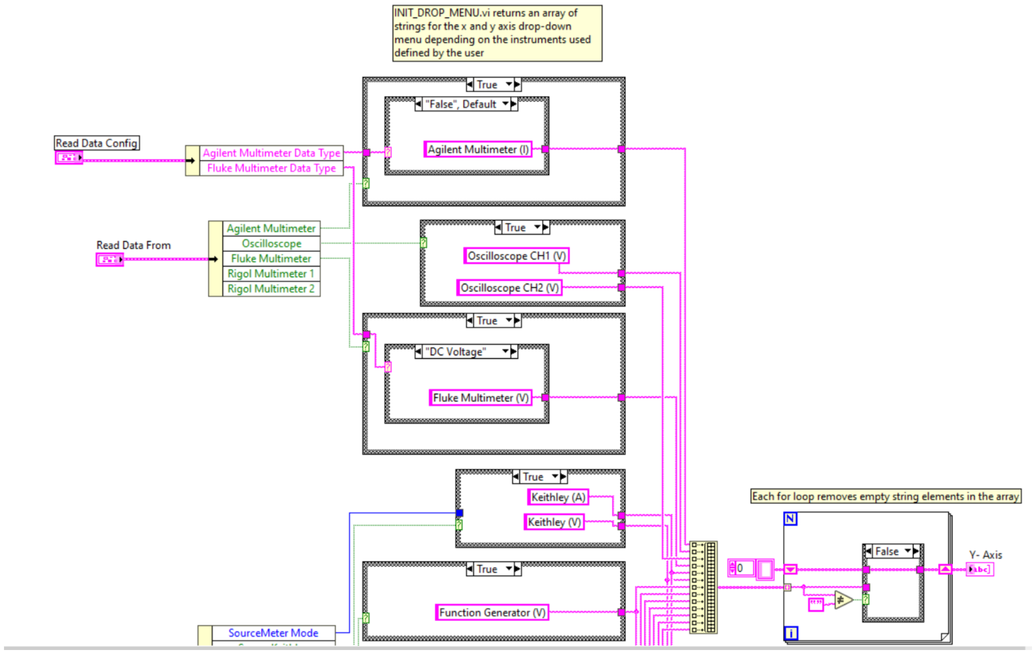


Figure 20: INIT_DROP_MENU.vi

This feature reduces user error when selecting data to plot on each axis. Furthermore, the drop-down menus do not contain so many options that the user might overlook the required data. Additionally, this reminds the user to select the Boolean indicators according to which instruments they intend to implement in the sweep since the drop-down menus remain empty until the user specifies this information.

However, during testing, the developer realized the drop-down menus keep the default values previously selected if the user de-selects all used instruments. Therefore, when the event structure times out (when the user does not interact with the other cases for .1 milliseconds) the drop-down menu checks to ensure that there exists at least one instrument selected. If the string array is empty, the program re-writes the drop-down menus to hold no values as seen in Figure 21.

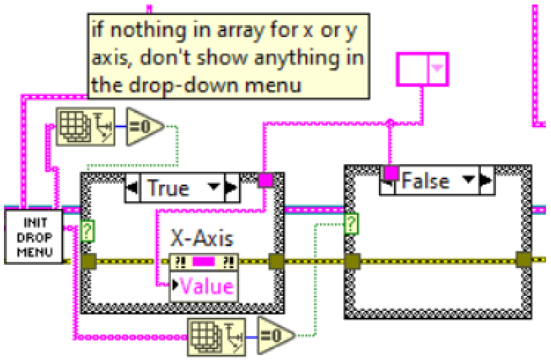

if nothing in array for x or y axis, don't show anything in the drop-down menu
INIT DROP MENU
True
X-Axis
Value
False

Figure 21: Empty Drop Menu Check

This way the user cannot sweep using default values in the drop-down menus. This addition to Sweep-N-Go creates an easily navigated user interface and reduces potential user error.

Furthermore, if the user does not select data to read from the drop-down menus of the x and y axis the program stops the sweep if either the x or y axis drop down menus remain empty. The user receives the message “Please select data to display on the x and y axis then hit the "Sweep" button. If options are not available, check to ensure that you have selected the devices you are using for the sweep. Also consider restarting the computer to reset instrument communications.”

The user must then make the appropriate changes to start the sweep. Once the user has appropriately selected the data to read and set other parameters accordingly, they press the “Sweep” button to start the data collection.

User Experience During Sweep

Depending on what parameters the user set, the sweep could potentially take several seconds and potentially a couple minutes. To indicate this time commitment, Sweep-N-Go 3.0 provides a progress bar to inform the user approximately how much remaining time exists. Since the program calculates the number of iterations for a sweep, it updates the progress bar accordingly. The program divides the current iteration count by the total iterations and multiplies by 100 to output the percentage complete. The progress bar updates every iteration of the FOR loop and appears directly above the “SWEEP” button in the user interface.

Furthermore, instead of prompting the user with a dialog box to inform them the sweep completed, Sweep-N-Go 3.0 instead shows a Boolean indicator labeled “Sweep Complete” which lights up green when complete. The program resets this indicator at the beginning of every sweep and when the program first runs. This feature informs the user without using an annoying pop-up.

Additionally, the “Quit Sweep” button stops the sweep while allowing the program to continue running. When the user presses this button, the progress bar informs the user the of the data not collected, but the “Sweep Complete” indicator turns green to indicate the stopped sweep. The collected data still saves to a unique file even when the user aborts the sweep early.

Saving Data

Sweep-N-Go 3.0 saves data to a new file every sweep. To accomplish this, the program creates a unique file name using the time and date to name every file. If the user wishes to add their custom name to a file, the date and time stamp appends to the end of the custom name to ensure uniqueness. The unique file names ensure the user never overwrites data they took from a previous sweep. Figure 22 shows the coding process of creating the unique names.

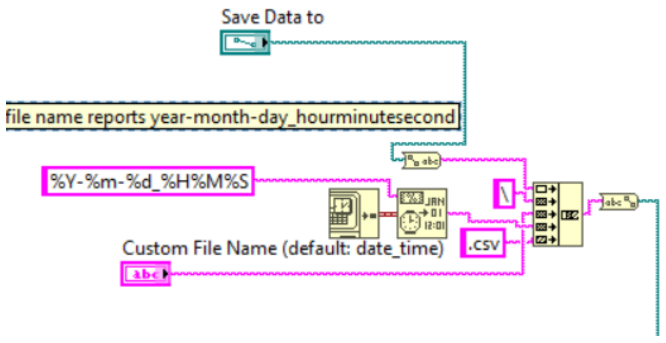

Save Data to
file name reports year-month-day_hourminutesecond
%Y-%m-%d_%H%M%S
Custom File Name (default: date_time)
.csv

Figure 22: Create Timestamp File Name

Furthermore, the program saves each file to a designated “Sweep-N-Go data” folder so all the files exist in the same place. The program saves the file as a CSV, or comma separated value. This way users can analyze and graph all the data saved in this tabular form.

Like the INIT_DROP_MENU.vi, the program selects the file headers according to instruments used in the sweep. This way, the user only saves relevant data and does not need to parse out columns of useless data. The program initializes the headers before entering the FOR loop in which the program appends the data to the file.

The data appends to the file in the SET_AND_READ.vi in which the program saves all the data in a string array and removes the empty strings to output an array the length of relevant data. Figure 23 shows this process within the SET_AND_READ function.

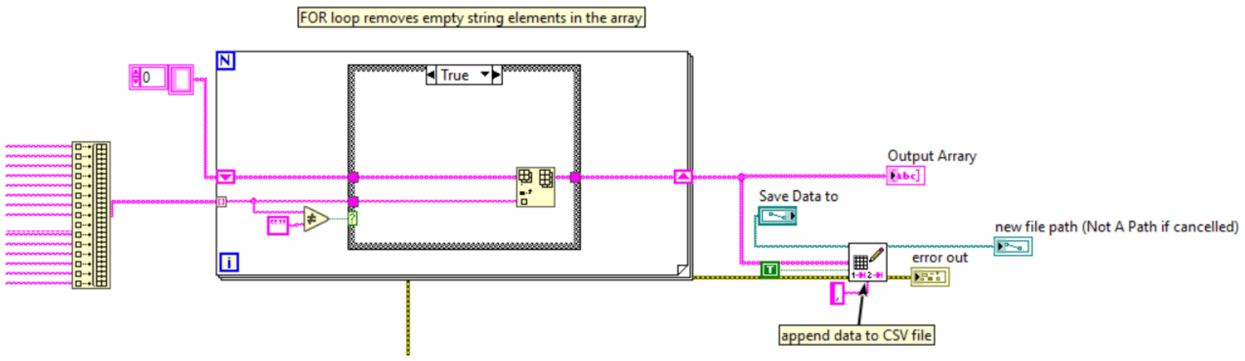

FOR loop removes empty string elements in the array
True
Output Array
Save Data to
new file path (Not A Path if cancelled)
error out
append data to CSV file

Figure 23: Append Data to File

Compared to Sweep-N-Go 2.0, this file-saving process reduces errors, since Sweep-N-Go 3.0 uses LabVIEW’s “Write Delimited Spreadsheet.vi” instead of the “Write Characters to File.vi” as seen in Figure 24. In version 2.0, Sweep-N-Go stops the program to prompt the user for a file path using this method. This happens because the vi does not have an error path (seen in gold) to report any errors that may occur during the file-saving process. Sweep-N-Go 3.0 allows for error-handling and reduces pop-up annoyances.

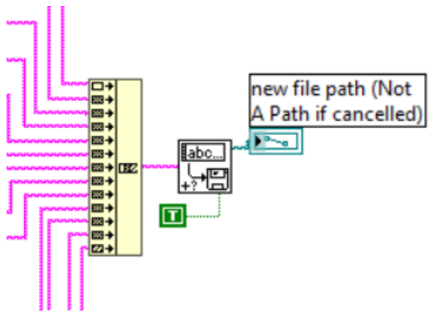


Figure 24: Sweep-N-Go 2.0 Write to File

Furthermore, once the program saves all relevant data to the file, it can read this file to adjust the data plotted on the graph.

Switching Data on Axis

Users may accidentally choose x and y axis data they do not wish graphed. Sweep-N-Go 3.0 allows users to change the data graphed during or after a sweep. When the user changes the x or y axis value, the upper-WHILE loop event structure triggers and the program updates the graph.

The function “Get_Data_From_File”, seen in Figure 25, has inputs “file path” and “axis string value” and outputs “data array” to replace the current graph data. This function reads the data from the saved file and returns a string array of file headers. For each header, the function checks the desired string axis value. When the desired value equals the string header value, the TRUE case reads the numerical file values corresponding to the column header. After removing the header information, the function outputs the desired data array.

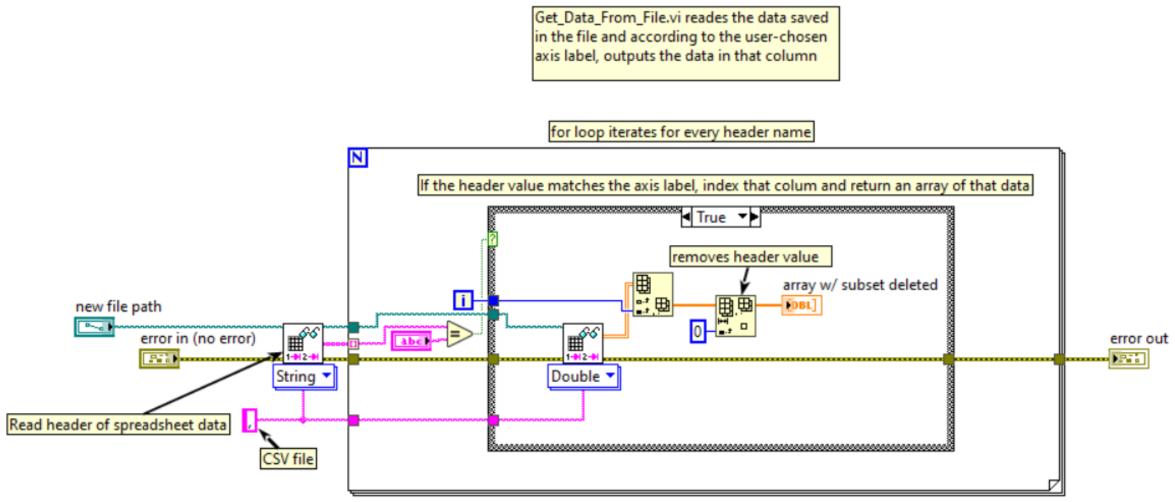

Get_Data_From_File.vi reades the data saved in the file and according to the user-chosen axis label, outputs the data in that column
for loop iterates for every header name
N
If the header value matches the axis label, index that colum and return an array of that data
True
removes header value
array w/ subset deleted
new file path
error in (no error)
String
Double
Read header of spreadsheet data
CSV file
error out
i
0

Figure 25: Get_Data_From_File.vi

The output data then replaces the current x or y axis plotted data. Since the sweep runs parallel to this operation, the graph updates new data during the sweep if either the x or y axis string value changes. This feature helps users to not re-run the sweep if they clicked the wrong value in the drop-down menus. This could potentially save users minutes and reduce the power used to re-run sweeps.

However, Sweep-N-Go 3.0 reduces programmatic errors in the previous version which ultimately saves the user the most time. Through deliberate consideration and testing, the next section covers the program’s error-handling measures.

CHAPTER 7

Instrument Addresses

Sweep-N-Go 2.0 commonly breaks due to incorrect addressing of the bench instruments, leading to failed communication. Therefore, the developer designed a dynamic query of instrument addresses to ensure ongoing instrument communication. Figure 26 shows the program's process of first finding a list of all the USB addresses and then writing them to the correct instrument. The program then completes the same process for GPIB addresses.

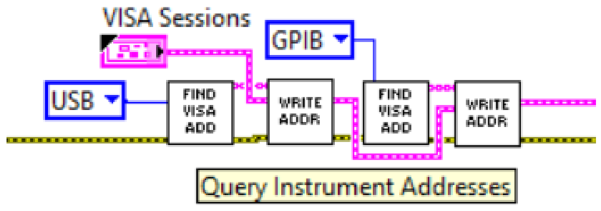


Figure 26: LabVIEW Code Queries Instrument Addresses

To find the list of USB or GPIB addresses, the program queries the computer's localhost. Figure 27 shows the code for the VI named "FIND_VISA_ADDRESS" which has the input "Bus Type" and returns the output "VISA RESOURCE NAMES" which is an array of strings containing the relevant addresses. The program then inputs this array to the next VI to pair each address to the appropriate instrument. To accomplish this, the program communicates with each address and asks for the instrument's identification.

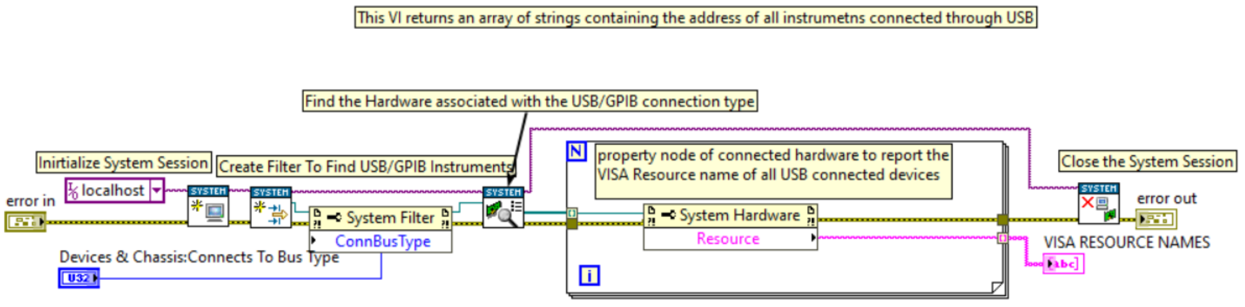

This VI returns an array of strings containing the address of all instrumetns connected through USB
Find the Hardware associated with the USB/GPIB connection type
Inirtialize System Session
Create Filter To Find USB/GPIB Instruments
property node of connected hardware to report the VISA Resource name of all USB connected devices
Close the System Session
error in
localhost
SYSTEM
System Filter
ConnBusType
Devices & Chassis:Connects To Bus Type
U32
N
System Hardware
Resource
i
error out
VISA RESOURCE NAMES

Figure 27: FIND_VISA_ADDRESS.VI

The program writes the "*IDN?" command which returns a comma separated instrument identification of the form "Company Name",<model number>,<serial "number>,<software revision>. As seen in Figure 28, the program parses this data and, according to the output, sets the address in the "VISA Sessions" cluster containing all the instrument address information. Furthermore, once the program establishes the address in this matter, it sets the Boolean "Instrument Connected" indicator "true".

However, when testing the developer found some lab benches for which there exist several addresses that do not connect to any instrument and make this process very slow. Therefore, there exists a condition that checks if this process takes longer than 5 seconds and aborts the FOR loop of “*IDN?” commands.

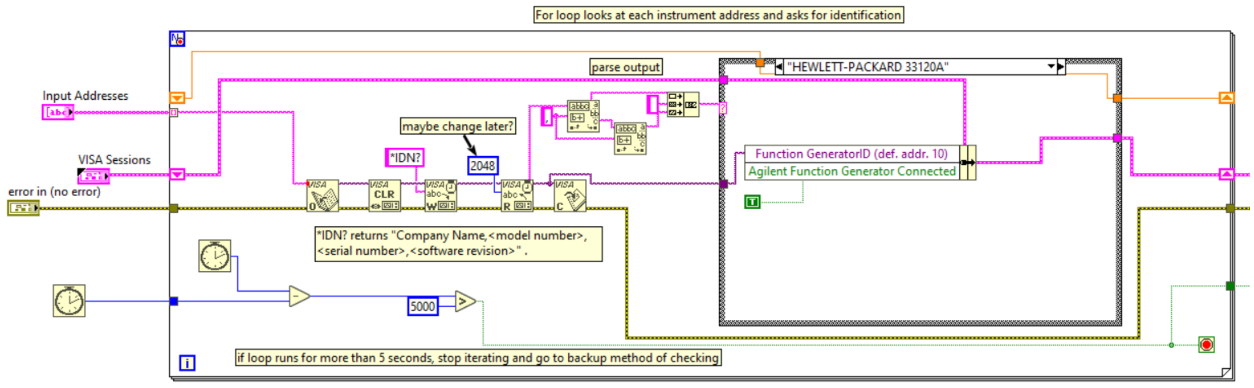

For loop looks at each instrument address and asks for identification
Input Addresses
VISA Sessions
error in (no error)
parse output
"HEWLETT-PACKARD 33120A"
maybe change later?
*IDN?
2048
Function GeneratorID (def. addr. 10)
Agilent Function Generator Connected
*IDN? returns "Company Name,<model number>,<serial number>,<software revision>" .
5000
if loop runs for more than 5 seconds, stop iterating and go to backup method of checking

Figure 28: WRITE_GPIB VI

Once the loop stops because of the time condition, another VI runs and uses the hard-coded GPIB/USB addresses to check individual instrument connection. Furthermore, in the case that the computer does not find any addresses, there exists a case that checks all instruments still not connected with two default cases. The first case checks GPIB1 and then secondly checks GPIB0 default connections if the instrument is still not connected. Figure 29 shows the process in which the program queries a default address using the *IDN? command if there exists no instrument connectivity. If the query reports identification equal to the expected (hard-coded) instrument identification, the Boolean reports TRUE and the program updates the address. This process serves as a last check before starting user-interaction with the program.

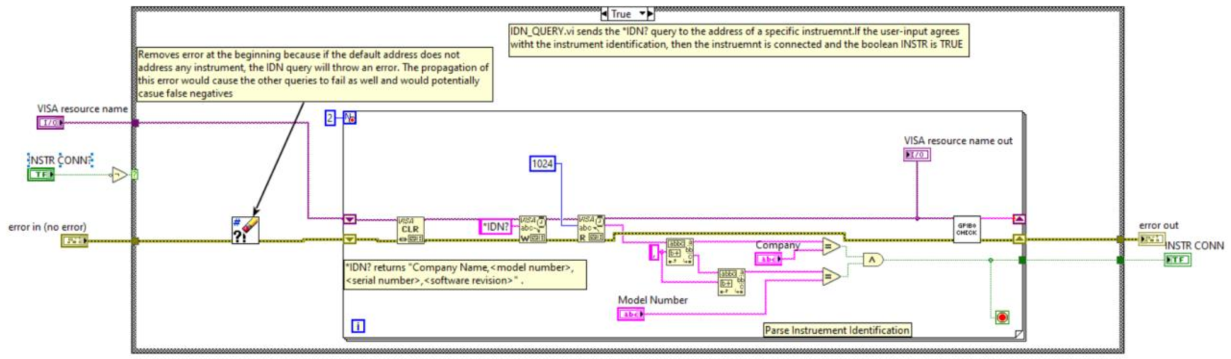

True
IDN_QUERY.vi sends the *IDN? query to the address of a specific instruemnt.If the user-input agrees witht the instrument identification, then the instruemnt is connected and the boolean INSTR is TRUE
Removes error at the beginning because if the default address does not address any instrument, the IDN query will throw an error. The propagation of this error would cause the other queries to fail as well and would potentially casue false negatives
VISA resource name
INSTR CONN
error in (no error)
2
1024
VISA resource name out
*IDN?
*IDN? returns "Company Name,<model number>,<serial number>,<software revision>" .
Company
Model Number
Parse Instruement Identification
error out
INSTR CONN

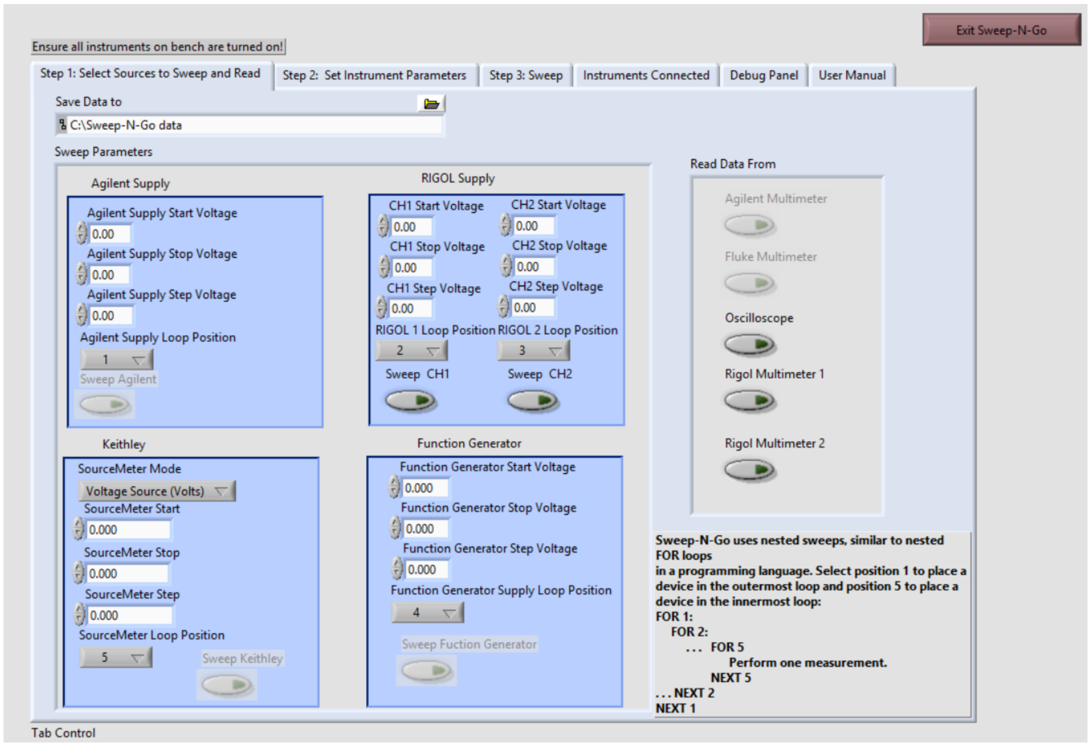
Figure 29: IDN_QUERY

Furthermore, since this process can take several seconds, the program updates a progress bar at each step to inform the user how long they must wait, until they can interact with the program. The process should take no longer than 15 seconds due to the timeout conditions set in place. The progress bar updates in quarters since there exist four VIs to complete this process.

This initialization process mostly improves the addressing USB connected devices, since every bench has a unique address. Therefore, benches holding new, USB connected instruments can run Sweep-N-Go as well.

New Laboratory Equipment

Not all benches in the electrical engineering laboratories house the same equipment. Therefore, Sweep-N-Go must accommodate these differences allowing all lab groups to efficiently complete their laboratory experiments. For example, bench 9 in room 148 houses a Rigol Power Supply, two Rigol multimeters, and an oscilloscope. There exist no instruments connected through GPIB on this bench. Hard-coded address values would lead to zero instrument connectivity. Figure 30 shows the user interface in which the program only allows users to work with the instruments on bench 9.



Save Data to: C:\Sweep-N-Go data

Agilent Supply Start Voltage: 0.00
Agilent Supply Stop Voltage: 0.00
Agilent Supply Step Voltage: 0.00
Agilent Supply Loop Position: 1

CH1 Start Voltage: 0.00
CH2 Start Voltage: 0.00
CH1 Stop Voltage: 0.00
CH2 Stop Voltage: 0.00
CH1 Step Voltage: 0.00
CH2 Step Voltage: 0.00
RIGOL 1 Loop Position: 2
RIGOL 2 Loop Position: 3

SourceMeter Mode: Voltage Source (Volts)
SourceMeter Start: 0.000
SourceMeter Stop: 0.000
SourceMeter Step: 0.000
SourceMeter Loop Position: 5

Function Generator Start Voltage: 0.000
Function Generator Stop Voltage: 0.000
Function Generator Step Voltage: 0.000
Function Generator Supply Loop Position: 4

Sweep-N-Go uses nested sweeps, similar to nested FOR loops in a programming language. Select position 1 to place a device in the outermost loop and position 5 to place a device in the innermost loop:

```
FOR 1:
   FOR 2:
      ... FOR 5
            Perform one measurement.
          NEXT 5
... NEXT 2
NEXT 1
```

Figure 30:Bench 9 User Interface

Sweep-N-Go 3.0 incorporates the new multimeter equipment through querying the USB addresses and checking for its identification: “Rigol Technologies DM3058E” as seen in Figure 31. The user can select these instruments instead of the Agilent or Fluke multimeter.

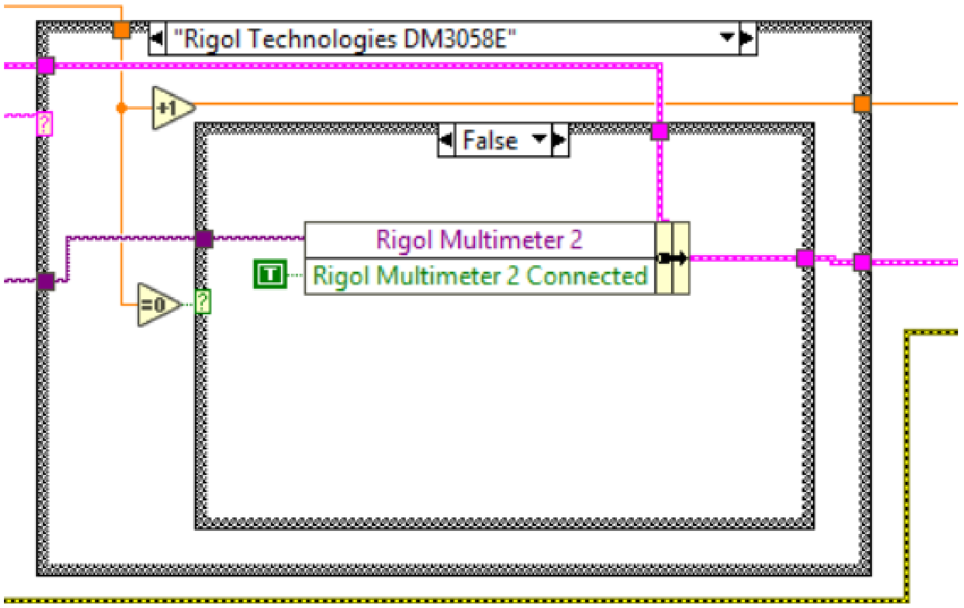


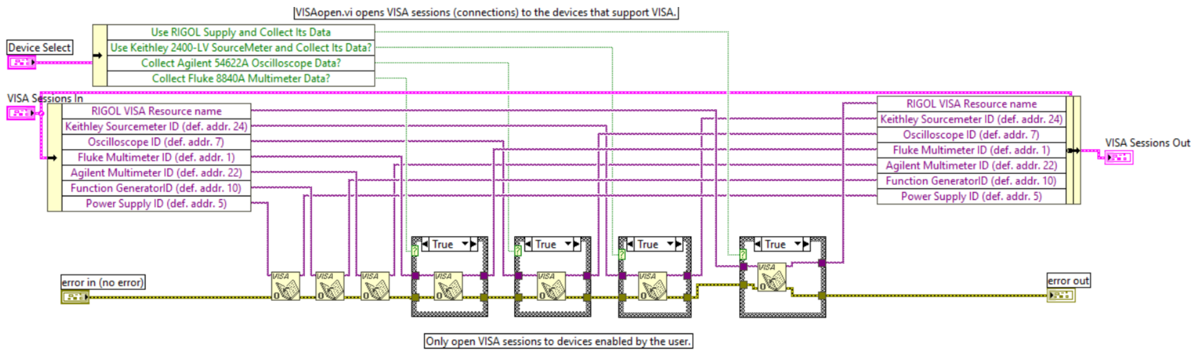
Figure 31: Rigol Multimeter Identification

To include these multimeters in the sweep, the developer made several VIs to initialize, read, and close the instruments. To do this, the developer referenced SCPI commands to set the multimeter to read voltage or current and when to report the value read [16].

While the initialization process eliminates hard-coding issues, there existed several areas in the Sweep-N-Go 2.0 code where errors could occur. Therefore, the next section covers information relating to reducing propagating errors.

Reducing Errors

Many users of Sweep-N-Go 2.0 find themselves frustrated when they enter all the correct parameters, follow the user manual procedures, and hit the "sweep" button only for the program to fail. Even if the user only selects properly connected instruments to sweep, other instruments not connected can cause the program to fail through error propagation. For example, Sweep-N-Go 2.0 executes a function "Open VISA", as seen in Figure 32, where the program always opens the implicit instruments (Agilent Power Supply, Agilent Multimeter, and Agilent Function Generator) during a sweep. Attempting to open a VISA connection for these instruments when the address is incorrect causes an error that propagates throughout the program.


VISAopen.vi opens VISA sessions (connections) to the devices that support VISA.

Only open VISA sessions to devices enabled by the user.

Device Select
Use RIGOL Supply and Collect Its Data
Use Keithley 2400-LV SourceMeter and Collect Its Data?
Collect Agilent 54622A Oscilloscope Data?
Collect Fluke 8840A Multimeter Data?
VISA Sessions In
RIGOL VISA Resource name
Keithley Sourcemeter ID (def. addr. 24)
Oscilloscope ID (def. addr. 7)
Fluke Multimeter ID (def. addr. 1)
Agilent Multimeter ID (def. addr. 22)
Function GeneratorID (def. addr. 10)
Power Supply ID (def. addr. 5)
error in (no error)
True
True
True
True
VISA Sessions Out
error out

Figure 32: Sweep-N-Go 2.0 VISA_open.vi

This error causes other functionalities to fail as well causing the whole sweep to crash. To remedy this, there exist no implicit instruments in Sweep-N-Go 3.0. The user specifies each instrument they wish to use in the sweep and the program only opens those instruments. The CHECK_OPEN_ERROR.vi function, as seen in Figure 33, checks if the user specified to use the instrument in the sweep and outputs the error status.

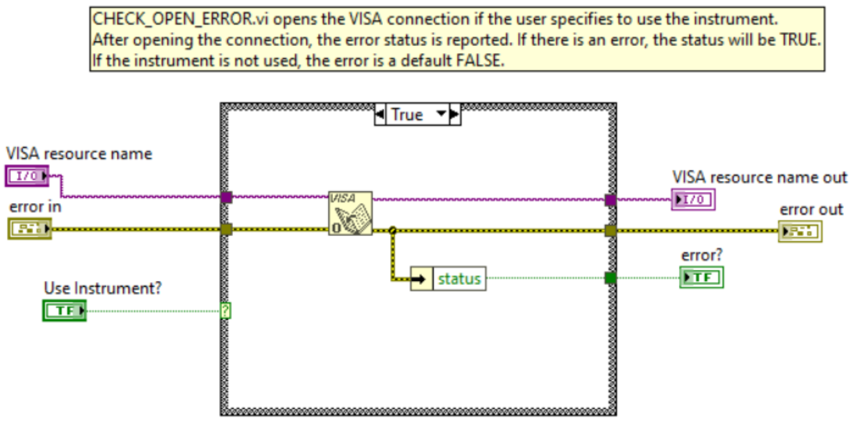

CHECK_OPEN_ERROR.vi opens the VISA connection if the user specifies to use the instrument.
After opening the connection, the error status is reported. If there is an error, the status will be TRUE.
If the instrument is not used, the error is a default FALSE.

Figure 33:CHECK_OPEN_ERROR.vi

If an error appears, the program then identifies the first problematic instrument and notifies the user which instrument does not have proper connectivity. Furthermore, the program prevents the sweep from continuing and instructs the user on how to check instrument connectivity. Figure 34 shows the message the user receives when the program detects an error.

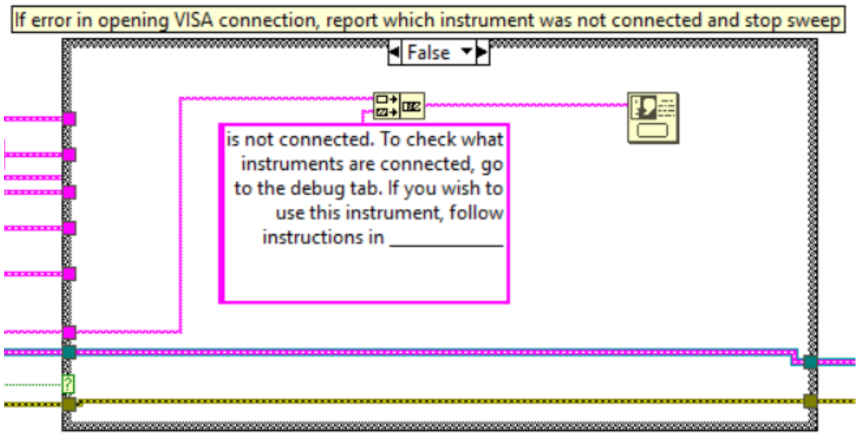

If error in opening VISA connection, report which instrument was not connected and stop sweep
False
is not connected. To check what instruments are connected, go to the debug tab. If you wish to use this instrument, follow instructions in ___________

Figure 34: Instrument Connectivity Error Message

If there exist no errors, the program goes to the "TRUE" case and initializes the sweep. However, to prevent the user from selecting an unconnected instrument, the function HIDE_UNCONNECTED, in Figure 35, checks each instrument connectivity status and greys out and disables buttons thereby not allowing the user to select unconnected instruments. This prevents errors and reduces user responsibility to examine the "Connected Instruments" tab.

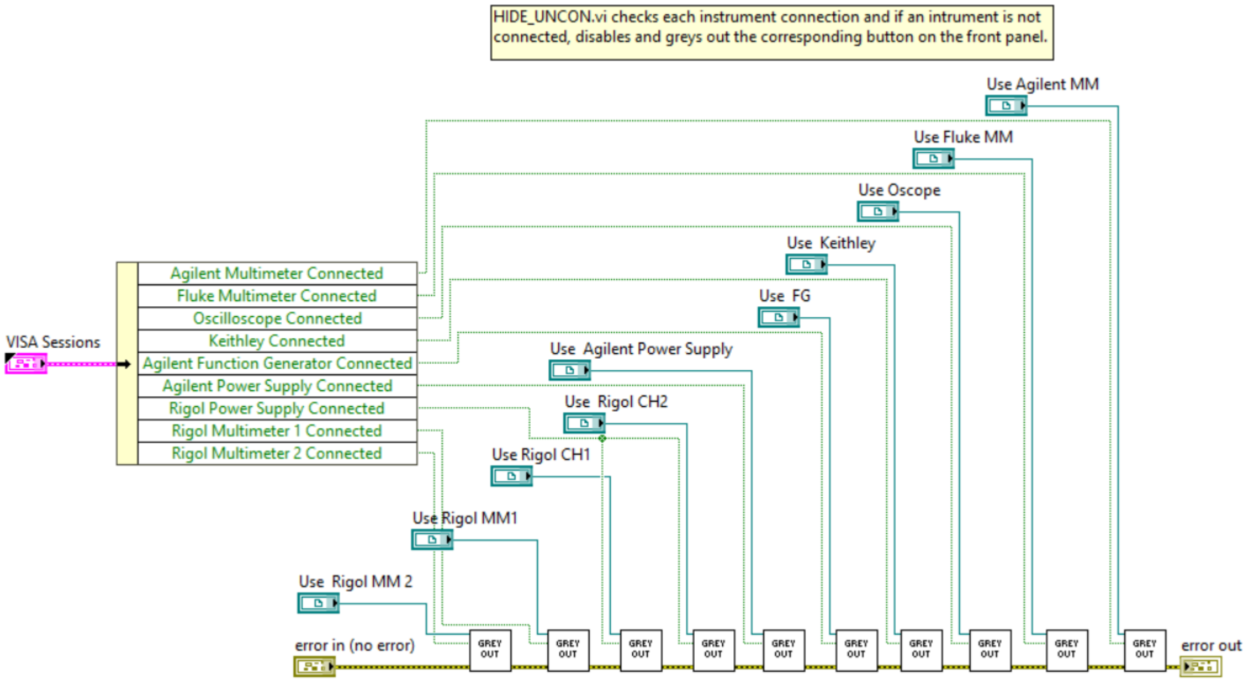

HIDE_UNCON.vi checks each instrument connection and if an intrument is not connected, disables and greys out the corresponding button on the front panel.
VISA Sessions
Agilent Multimeter Connected
Fluke Multimeter Connected
Oscilloscope Connected
Keithley Connected
Agilent Function Generator Connected
Agilent Power Supply Connected
Rigol Power Supply Connected
Rigol Multimeter 1 Connected
Rigol Multimeter 2 Connected
Use Agilent MM
Use Fluke MM
Use Oscope
Use Keithley
Use FG
Use Agilent Power Supply
Use Rigol CH2
Use Rigol CH1
Use Rigol MM1
Use Rigol MM 2
error in (no error)
GREY OUT
error out

Figure 35: HIDE_UNCONNECTED.vi

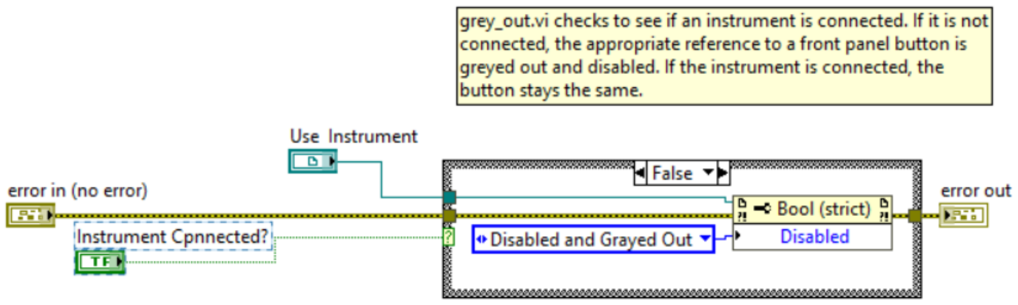
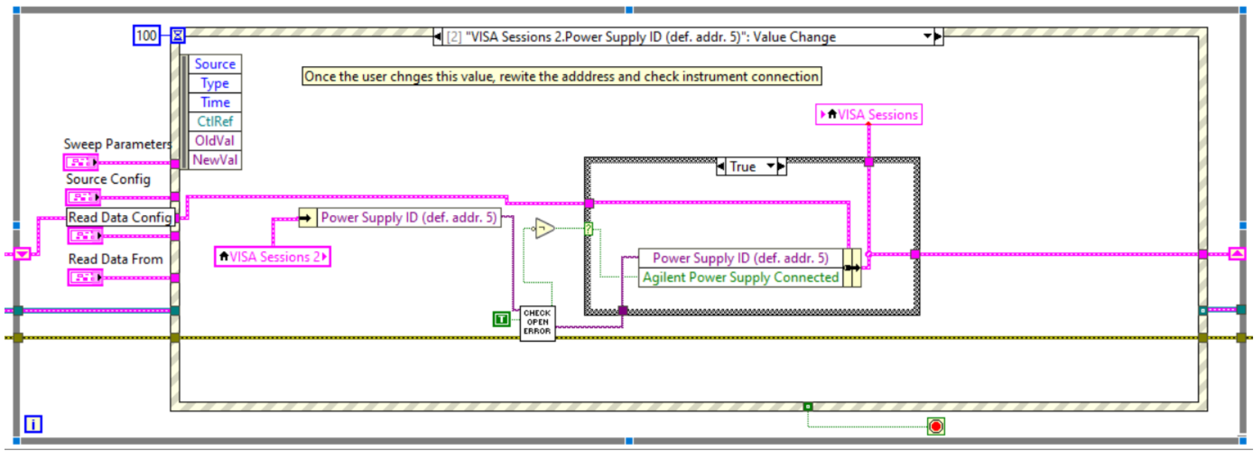

grey_out.vi checks to see if an instrument is connected. If it is not connected, the appropriate reference to a front panel button is greyed out and disabled. If the instrument is connected, the button stays the same.

Figure 36: grey_out.vi

However, this caused some concern for the case in which the program found no connectivity with any the bench instruments. Therefore, as a fail-safe, on the "Debug Panel" tab the user can input an instrument address they found through manually querying the instrument or looking on NI MAX. While the average user would probably not execute this feature, it would pose useful for any laboratory assistant who possesses advanced knowledge of Sweep-N-Go. The event structure waits until the user causes a value change corresponding to a specific instrument's address and checks errors in opening the VISA connection to the input address. If there exists no error, the program sets the new address for the specified instrument and sets the Boolean instrument connection TRUE. Furthermore, if the input address produces an error when opening the VISA connection, the program does not set the new address and sets the Boolean indicator FALSE. To accommodate this change, the above HIDE_UNCONNECTED function updates every loop iteration when the event structure is in the "timeout" case. Figure 37 shows the relevant code for the event in which the user changes the Agilent Power Supply address.


Once the user chnges this value, rewite the adddress and check instrument connection

100
[2] "VISA Sessions 2.Power Supply ID (def. addr. 5)": Value Change
Source
Type
Time
CtlRef
OldVal
NewVal
Sweep Parameters
Source Config
Read Data Config
Read Data From
Power Supply ID (def. addr. 5)
VISA Sessions 2
VISA Sessions
True
Power Supply ID (def. addr. 5)
Agilent Power Supply Connected
CHECK OPEN ERROR
T
i

Figure 37:Update Agilent VISA Address

CHAPTER 8

Testing

Although the coronavirus pandemic impeded laboratory testing spring quarter, Dr. Braun worked to create a lab bench the developer could access remotely. Dr. Braun powered the room 148, bench 5 instruments for initial testing. Since the developer spent several weeks writing code without lab bench access, the testing process initially required ironing out logic flaws and realizing new code requirements. After the developer adequately tested the program, Dr. Braun set up two circuits seen in Figure 38 and Figure 39 to see Sweep-N-Go 3.0's capabilities. Firstly, the developer tested the diode circuit by sweeping the Rigol Channel 1 Power Supply from 0 to 3 V while measuring the voltage across the 982Ω with the Agilent Multimeter.

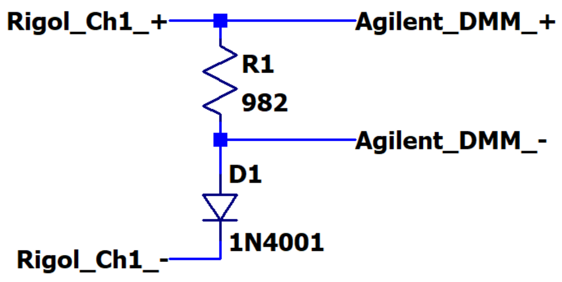


Figure 38: Diode Connected Circuit

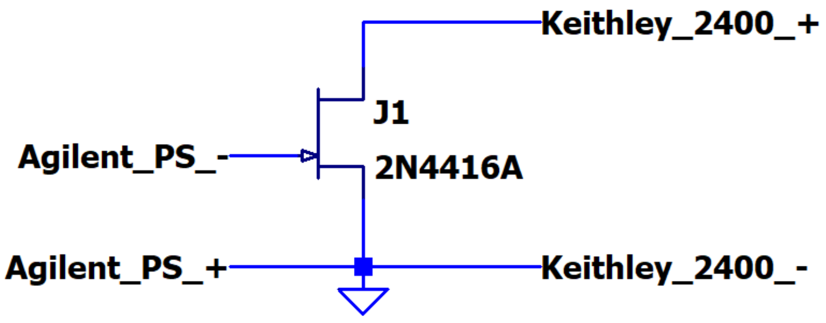
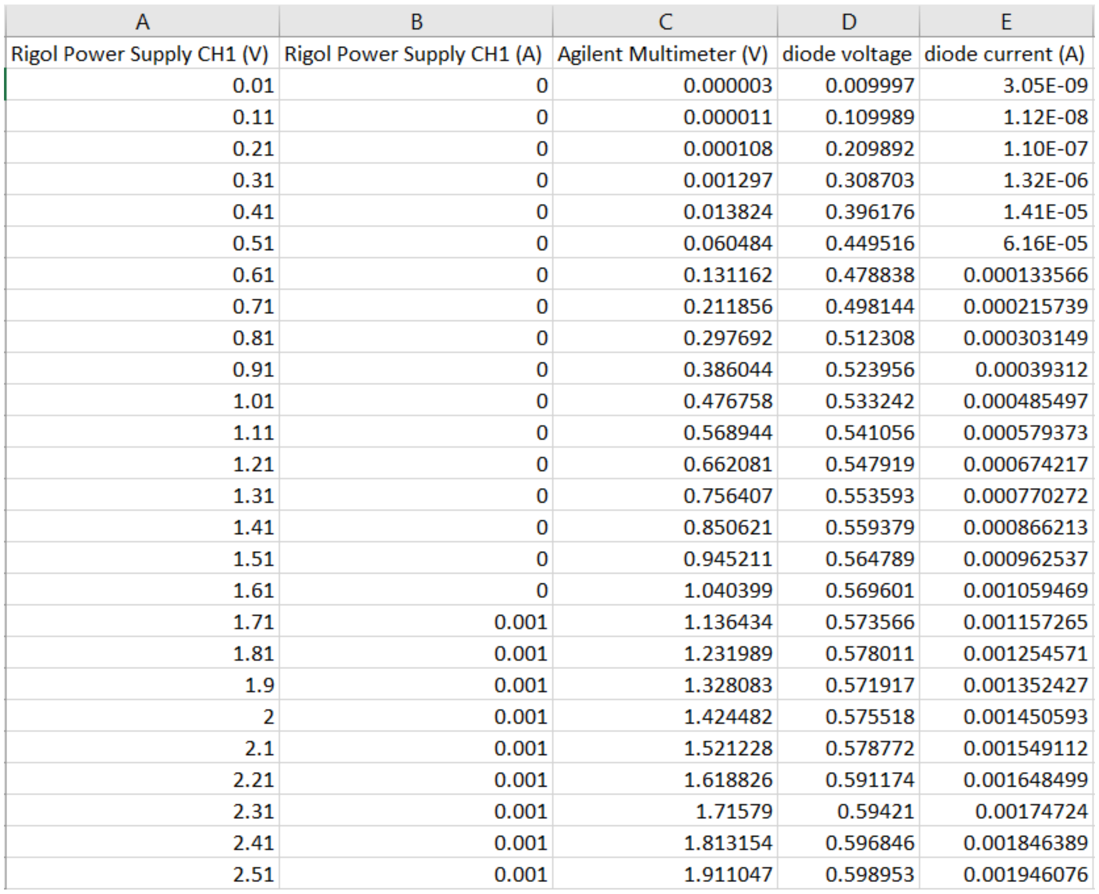


Figure 39: JFET Connected Circuit

To measure and plot the diode characteristics, however, students must find the voltage across and current through the diode. The voltage across the diode equals the Rigol Power Supply Voltage – Multimeter Voltage reading the voltage across the resistor. The current through the diode equals the voltage across the resistor divided by the resistance. Sweep-N-Go users, therefore, must open the CSV file to interpret and plot this data instead. Even though Sweep-N-Go plots the data read, this graph does not show students anything analytical about the diode's characteristics.

Therefore, after the sweep completes, the developer opens the CSV file to interpret the data. Figure 40 shows the file and including Sweep-N-Go data and the interpreted diode voltage and current data. Plotting the current versus voltage, Figure 41 shows the diode characteristics.



A	B	C	D	E
Rigol Power Supply CH1 (V)	Rigol Power Supply CH1 (A)	Agilent Multimeter (V)	diode voltage	diode current (A)
0.01	0	0.000003	0.009997	3.05E-09
0.11	0	0.000011	0.109989	1.12E-08
0.21	0	0.000108	0.209892	1.10E-07
0.31	0	0.001297	0.308703	1.32E-06
0.41	0	0.013824	0.396176	1.41E-05
0.51	0	0.060484	0.449516	6.16E-05
0.61	0	0.131162	0.478838	0.000133566
0.71	0	0.211856	0.498144	0.000215739
0.81	0	0.297692	0.512308	0.000303149
0.91	0	0.386044	0.523956	0.00039312
1.01	0	0.476758	0.533242	0.000485497
1.11	0	0.568944	0.541056	0.000579373
1.21	0	0.662081	0.547919	0.000674217
1.31	0	0.756407	0.553593	0.000770272
1.41	0	0.850621	0.559379	0.000866213
1.51	0	0.945211	0.564789	0.000962537
1.61	0	1.040399	0.569601	0.001059469
1.71	0.001	1.136434	0.573566	0.001157265
1.81	0.001	1.231989	0.578011	0.001254571
1.9	0.001	1.328083	0.571917	0.001352427
2	0.001	1.424482	0.575518	0.001450593
2.1	0.001	1.521228	0.578772	0.001549112
2.21	0.001	1.618826	0.591174	0.001648499
2.31	0.001	1.71579	0.59421	0.00174724
2.41	0.001	1.813154	0.596846	0.001846389
2.51	0.001	1.911047	0.598953	0.001946076

Figure 40: Diode Data Saved CSV File

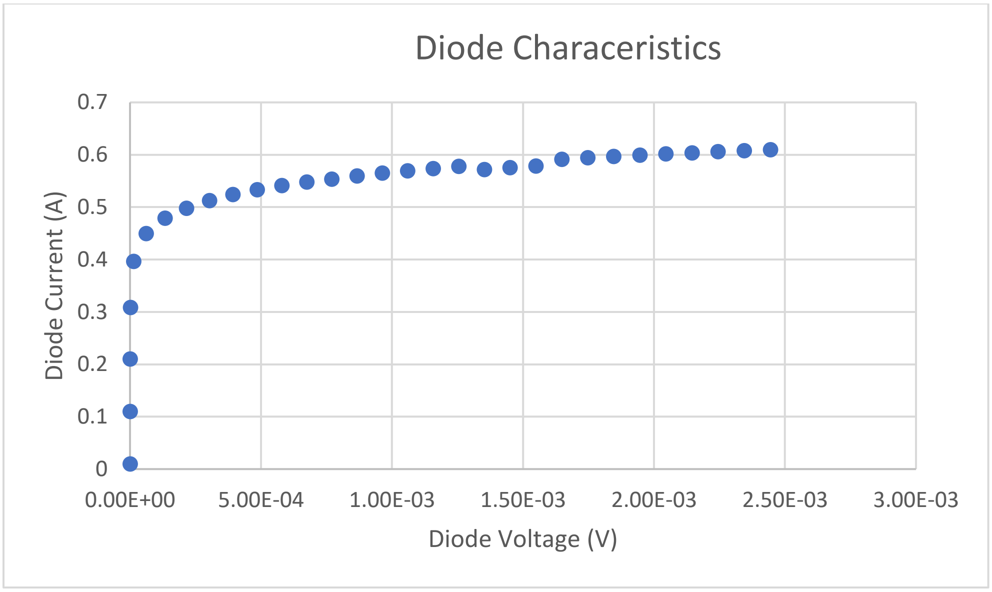


Figure 41: Diode Characteristics

From this graph, the student can determine the threshold voltage for this diode to be approximately 0.57V. This one graph plots 31 data points and the sweep took 1 minute and 43 seconds to complete. This sweep took longer since the Rigol took five measurements at each increment and averaged the values. This means the sweep took 155 measurements in that time. Therefore, even though the sweep takes a couple minutes to complete, the user collects more accurate data faster than if they took this data manually. Furthermore, the sweep duration depends on how fast the computer runs. This variable causes some lab benches to take longer than others.

Next, the developer tested the JFET circuit in Figure 42 by sweeping the Agilent Power Supply (-VGS) from 0 to 3V and the Keithley from 10 to 0V (VDS) for each VGS. The user sets the Agilent Power Supply to loop position 1 and sets the Keithley loop position to 2. Then, the user sets the x axis to read the Keithley voltage and the y axis to read the Keithley current. Figure X shows the Sweep-N-Go graph displaying the JFET characteristics for four different VGS values. This sweep on the same computer took 1 minute and 23 seconds one week and 2 minutes the next week to read 44 data points. The variable time most likely results from network bandwidth and or variable computer speed.

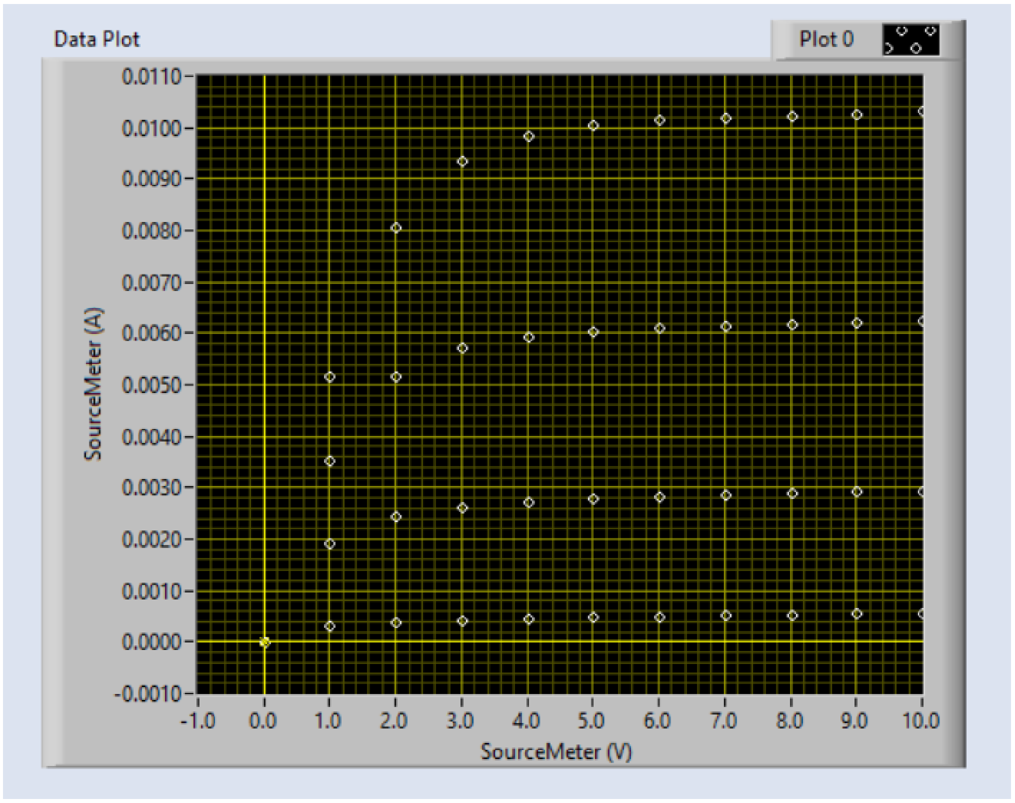
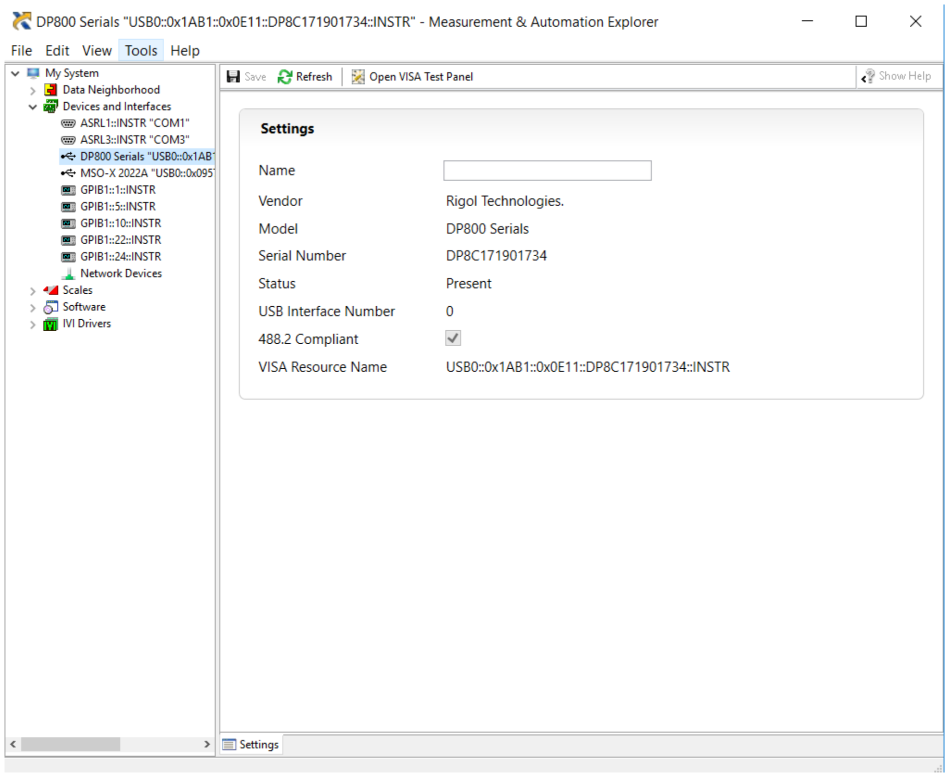


Figure 42: JFET Characteristics

Students learn about both these circuit components in EE306 and test them in the 336 laboratory. Sweep-N-Go 3.0 helps students efficiently learn about diodes and transistors. Unfortunately, since the developer fell behind schedule and due to COVID-19, no other students tested Sweep-N-Go 3.0 in the laboratory. However, the developer asked few electrical engineering peers to attempt to break the program to account for user errors the developer did not consider. Through this process, the developer made appropriate changes. However, the developer not only tested the user-experience, but instrument connectivity as well.

Testing Instrument Connectivity

To test instrument connectivity, the developer must work on all relevant lab benches to ensure the dynamic instrument queries function for all Sweep-N-Go equipment. The developer notes any discrepancies which result in small changes to the code, accounting for instrument outliers. One testing utility widely used to see the interface of connected equipment is called “NI MAX”, and is a corollary software to LabVIEW. This software readily identifies all GPIB and USB connected devices under the tab called “Devices and Interfaces” as demonstrated below in Figure 43.



Settings

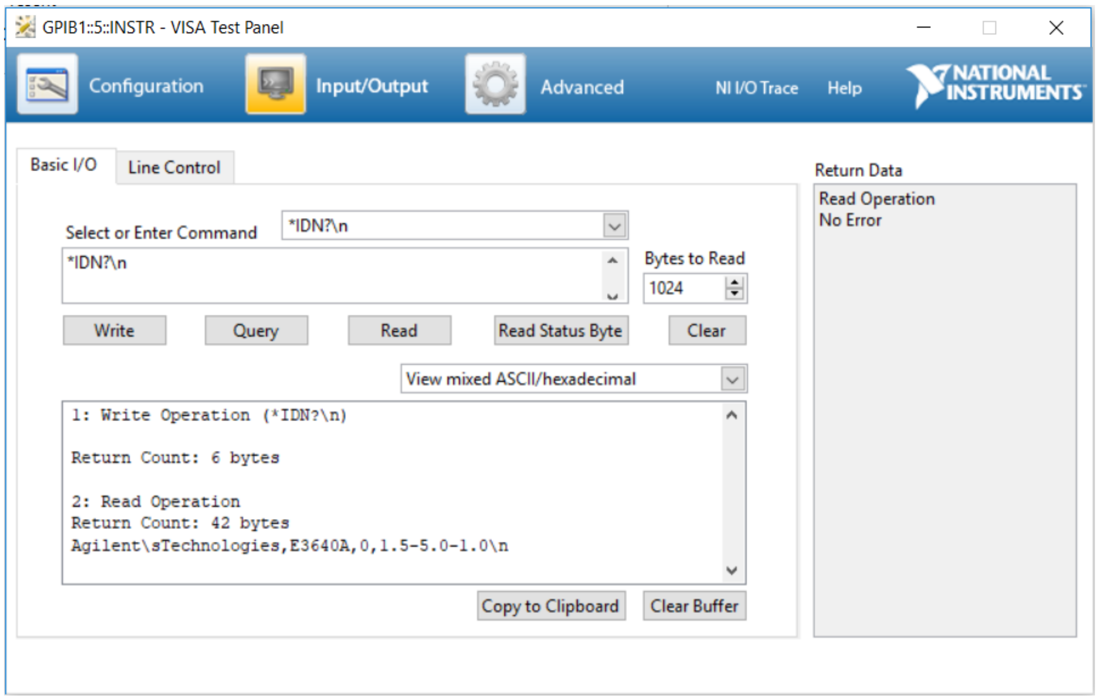
Name	
Vendor	Rigol Technologies.
Model	DP800 Serials
Serial Number	DP8C171901734
Status	Present
USB Interface Number	0
488.2 Compliant	✓
VISA Resource Name	USB0::0x1AB1::0x0E11::DP8C171901734::INSTR

Figure 43:NI MAX Debugging Interface

One can query the devices to ensure connectivity and discover the address correlating to each instrument. Sweep-N-Go queries and discovers every instrument listed in NI MAX. However, NI MAX does not always recognize the connected instruments. Therefore, the developer created default instrument addresses to check each instrument. Furthermore, the list sometimes contains up to 50 addresses even though the electrical engineering benches only connect to at most seven instruments. To remedy potentially querying all these addresses (which would take quite some time), the program quits this process and the checks the default cases instead.

Furthermore, if the user finds all instruments unconnected, the user manual instructs them to go to NI MAX to find the addresses. Then, with the new capabilities, the user cab manually input this address and check its connectivity within the Sweep-N-Go 3.0 program. If NI MAX does not find any connected instruments, an advanced user could check all physical cable connections and restart the computer.

While testing instrument connections, NI MAX does not show which instrument correlates to which address. To find this information, the developer opens the "Open VISA Test Panel" on NI MAX and writes the *IDN? command to find instrument identification. Figure 44 shows the panel where the developer clicks "Query" and reads the output, which shows the Agilent Power Supply correlates to GPIB address 5.



Select or Enter Command: *IDN?\n

*IDN?\n

Bytes to Read: 1024

View mixed ASCII/hexadecimal

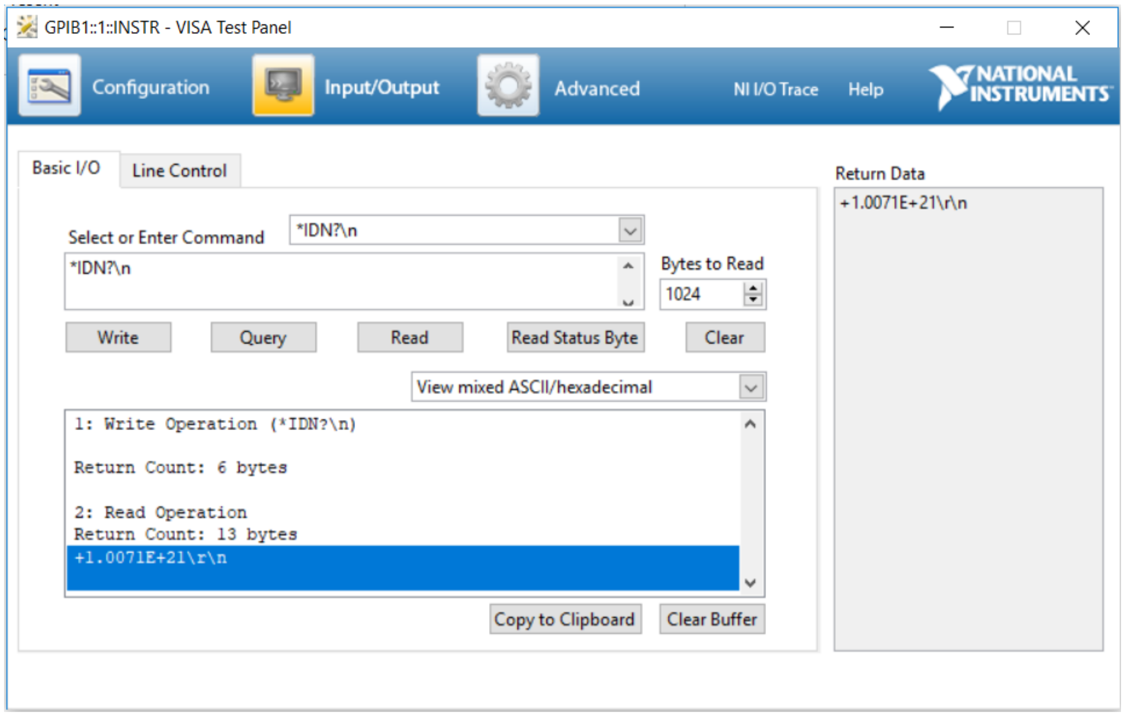
```
1: Write Operation (*IDN?\n)

Return Count: 6 bytes

2: Read Operation
Return Count: 42 bytes
Agilent\sTechnologies,E3640A,0,1.5-5.0-1.0\n
```

Return Data

Read Operation
No Error

Figure 44: VISA Test Panel Agilent Power Supply

However, the older Fluke multimeter does not comply with current SCPI commands. Figure 45 shows the “identification” returned from querying the Fluke multimeter which does not tell the user any useful information. Sweep-N-Go 3.0 queries the Fluke multimeter by checking for the numeric information returned.



Select or Enter Command: *IDN?\n

*IDN?\n

Bytes to Read: 1024

View mixed ASCII/hexadecimal

```
1: Write Operation (*IDN?\n)

Return Count: 6 bytes

2: Read Operation
Return Count: 13 bytes
+1.0071E+21\r\n
```

Return Data

+1.0071E+21\r\n

Figure 45: VISA Test Panel Fluke Multimeter

Overall, testing and debugging instrument connection greatly contributed to the time spent on this project. The tools mentioned above helped the developer to programmatically create an instrument connectivity query.

CHAPTER 9

Unimplemented Features

Although the Sweep-N-Go 3.0 greatly reduces errors and improves the user experience, there still exist areas of improvement. One such improvement would allow users to sweep logarithmically in addition to the current linear sweep. This would greatly expedite data collection in some cases.

Furthermore, student feedback requests improvements to the loop position selection. Sweep-N-Go 2.0 and 3.0 both ensure the user does not pick the same loop position for multiple instruments. The program alerts the user if they make this mistake and does not start the sweep. However, the program does not allow the user to sweep even if the user does not select the instruments that have the same loop position to sweep. An improvement to the program would check the same loop positions only if the user specified the instrument's use.

Additionally, even though Sweep-N-Go 3.0 worked to create a robust querying system, potential issues may arise on other benches for which the developer did not test the program. The commenting throughout Sweep-N-Go 3.0 alleviates potential future development confusions.

Difficulties Encountered

The developer competed Sweep-N-Go 3.0 during the coronavirus pandemic, which caused difficulties in testing. Luckily, Dr. Braun safely accessed the labs and worked to help the developer test remotely. However, while testing remotely, the Fluke multimeter readings did not make sense. The Fluke read values of -19V, -12V, -2V, and 9V randomly even though nothing was connected. After the developer spend hours debugging this issue, she later discovered that issue related to hardware, not software issue. If the developer could test this in-person, the debugging process would not have taken so long.

However, COVID-19 did not solely contribute project difficulties. The developer downloaded LabVIEW version 2019 on their personal computer, but the lab computers run version 2017 of the software. The developer converted the 2019 version to 2017 and back a couple times which caused some lost files along the way. The developer recovered everything eventually, but this file confusion led to burnt time.

Furthermore, as mentioned in the testing chapter, different benches caused different levels of difficulty. When testing pre-COVID, the developer would find empty lab benches during other lab classes to test instrument connectivity. However, the open lab benches were usually the ones no one else wanted to work at for a reason. Several times the developer worked at a bench with an extremely slow computer, which greatly reduced progress. Furthermore, the quest to find empty lab benches sometimes ended promptly, since students already occupies them all.

Planning Results

As typically occurs with most senior project plans, I fell behind on the originally planned schedule in the Gannt Chart shown in Chapter 4. For the first four weeks of Winter quarter, the developer worked ahead of schedule, but fell behind around week 7. Although the developer had three revisions of the instrument connection query and verification functions, she completed version one of the code at the end of Winter quarter. Although the developer should have completed two versions of the project Winter quarter, Spring quarter allowed enough time to finish the project. The rest of the changes are minimal compared to the dynamic ability of the program to communicate with instruments on the bench. Furthermore, due to COVID, Spring quarter consisted of only 9 weeks long. Furthermore, social distancing regulations which restricted students from using laboratory equipment caused delays in bench testing. A revised version of the Gannt Chat can be seen in Figure 46.

FIGURE 8

REVISED GANNT CHART AS OF WINTER QUARTER 2020

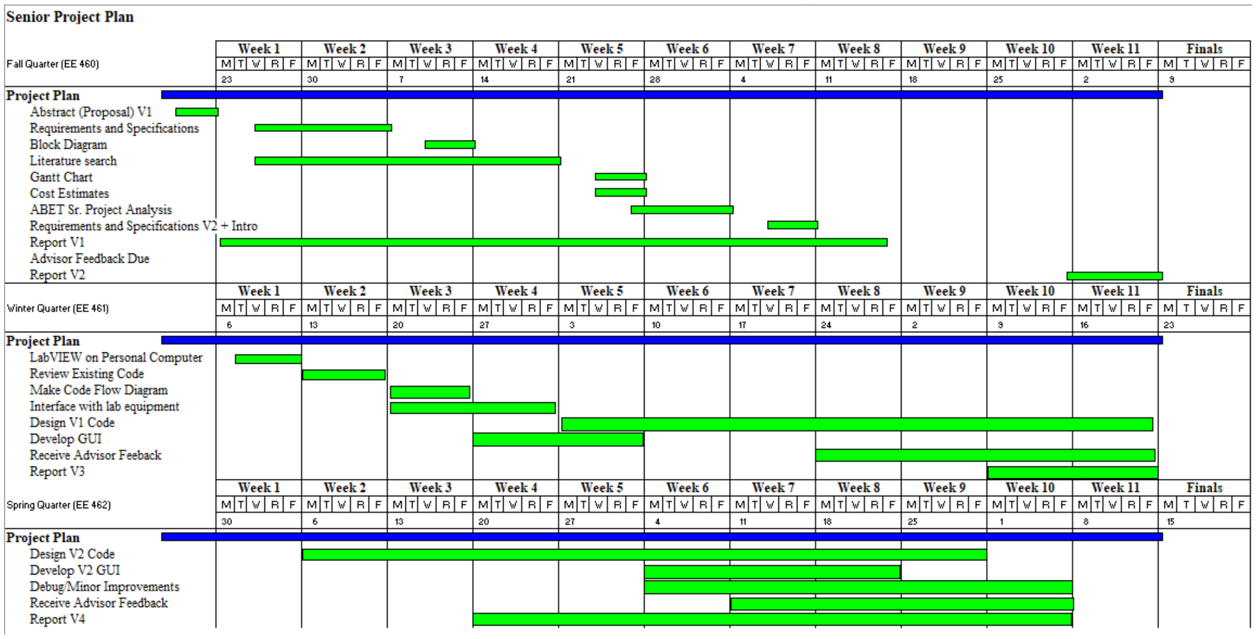


Figure 46:Revised Gannt Chart

Conclusion

While there still exists room for improvement, Sweep-N-Go 3.0 greatly improves the user experience and programmatic reduces errors. The developer referenced past internship experience working with LabVIEW to develop robust code. The improvements made upon Sweep-N-Go 2.0 creates a better learning environment for EE students, faculty, and technical support.

The developer learned how to read existing code and debug errors. Then, the developer identified once errors, she created error handling protocols and preemptive measures. The program successfully developed a dynamic instrument query to reduce instrument connectivity issues. Throughout the coding process, the developer learned about saving data to files, parallel loops, and creating an effective user interface.

Finally, this project would not be possible without Arthur Young's and Dr. Braun's previous work to create this program. Their ideas and existing code helped the developer of Sweep-N-Go 3.0 to build upon and improve. The Sweep-N-Go 3.0 code free download is posted on Arthur's website under the "Downloads" tab for students' and faculties convenience. The link to the reach this webpage is https://courseware.ee.calpoly.edu/~dbraun/ayoung/aa-download.html for the reader's convenience. Throughout the improvement process, Sweep-N-Go 3.0 accomplishes its goal to create an efficient and effective automated data acquisition in electric circuit laboratories.

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TABLE 5

APPENDIX A — ANALYSIS OF SENIOR PROJECT DESIGN

Project Title: Sweep-N-G0 3.0

Student's Name: Maria Pieroni

Student's Signature: Maria Pieroni

Advisor's Name: Dr. Braun

Advisor's Initials: DB

• 1. Summary of Functional Requirements

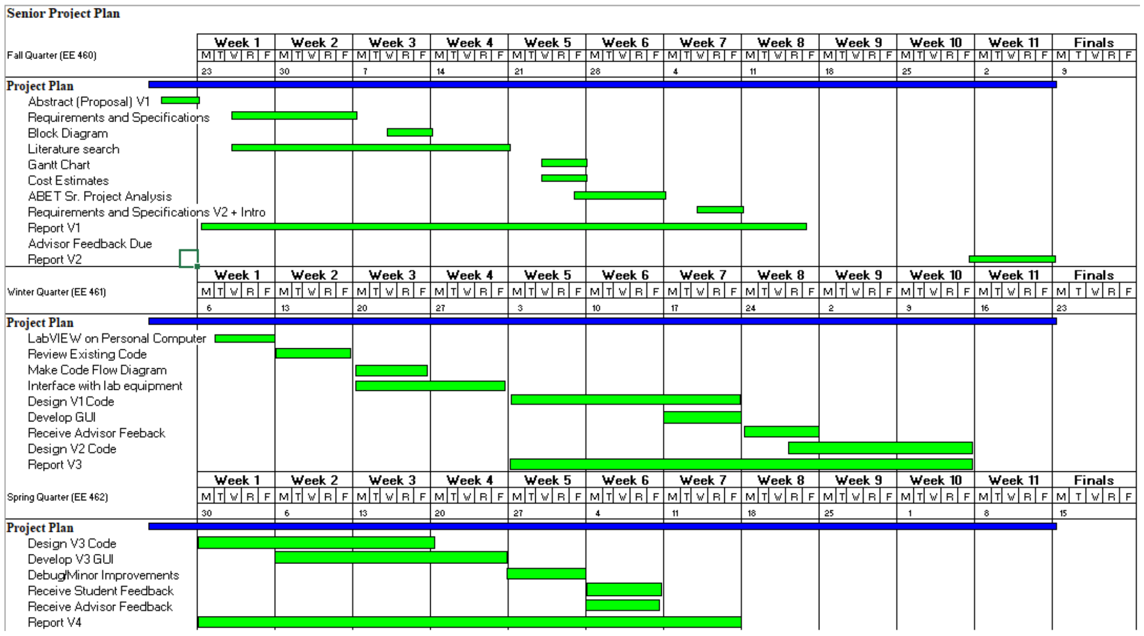
This project improves the current performance of the Sweep-N-Go LabVIEW (Version 2.0) program used in Cal Poly electrical engineering laboratories. Sweep-N-Go expediates the laboratory data collection process through automated testing. The new version of the program (Sweep-N-Go Version 3.0) reduces user debugging time, improve sustainability, increase efficiency, and considers all new lab bench equipment. Sweep-N-Go Version 3.0 includes an enhanced Graphical User Interface (GUI) for which students provided feedback to optimize user-efficiency. The program interfaces with instruments on every standard Cal Poly electrical engineering lab bench through both USB and GPIB communication. After the user runs the program, they have the capability to capture the graph of collected data and export the data to a CSV file for further interpretation.

• 2. Primary Constraints

The original author of Sweep-N-Go in LabVIEW, so the developer of the new version must program in this same language so she can reuse the existing code. Furthermore, the lab equipment with which the program interfaces remains constant with existing lab equipment, so many functions addressing these instruments remain unchanged. The GPIB addresses for each instrument and other constrains can be found in Table I in Chapter 2. The high-speed GPIB standard requires no less than 2/3rds of the instruments must be powered for proper connection. This constraint affects the progress towards a solution that allows students the option to not power on all instruments to run the program. The only development tools available for this project reside in the electronic circuit laboratories on the Cal Poly campus. Students may only access these labs when lab classes occupy them.

• 3. Economic

Since students can use LabVIEW for free and the EE department pays for the lab equipment, there exist no project costs, other than the "donation" of my own time. Students can use Sweep-N-Go at no cost, so no one monetarily profits. However, EE/CPE students experience improved efficiency while using the program, so they profit by saving time. Furthermore, the EE department profits since they see a higher success rate in labs requiring the use of Sweep-N-Go. The Sweep-N-Go 2.0 program already exists, but by the end of June 2020, the new version should come to completion. The developer expects the project to last for a very long time, since the computer saves the code. There may necessitate some maintenance to integrate any new equipment that Cal Poly might purchase in the future. A student or professor might also need to account for any unexpected bugs in the code. According to the Gantt chart included above, the developer expects to finish the project over 200 hours of work.



• 4. If manufactured on a commercial basis:

Students do not need to pay to use the program, so the school does not sell this program. Furthermore, since the program does not require any components other than pre-existing lab equipment, there does not exist a production cost for the product. To produce this product for free on a commercial basis, the developer could publish this code to an open source. Additionally, there would exist instructions as to what equipment the user needs and the GPIB addresses correlating to these instruments. However, large-scale consumers would most likely not have any use for the program, since the instruments provided in the Cal Poly electrical engineering labs are very expensive and not every other lab provides the same equipment.

• 5. Environmental

Environmental impacts related to this project are de minimis since students powering on the lab instruments result in additional power usage which contribute to the release of additional greenhouse gasses. However, the efficiency of the program offsets this additional power usage. Additionally, since I plan to spend 200 hours developing this code, the power I use in this process also negatively impacts the environment. However, the development or use of Sweep-N-Go does not generate any wastewater, air pollution, or other by-products. Unfortunately, due to the coronavirus pandemic and remote testing, this project's advisor left one bench's instruments powered all day. While this allowed the developer to remotely test the program through logging onto that bench's computer, this process led to powering these instruments for essentially half a quarter (5 weeks). Due to the pandemic, the testing process caused a negative impact to power usage and contribution to greenhouse gasses.

• 6. Manufacturability

The long-term viability of Sweep-N-Go 3.0 could be potentially impacted by new computer hardware and software configurations. Furthermore, any addition of new lab equipment would require an upgrade of the code, requiring programming updates. The developer could post the code on an open-source platform for laboratories supplying the same equipment. However, it would be unlikely that laboratories outside Cal Poly supply the same equipment. Therefore, this project would unlikely be manufactured outside of Cal Poly's Electrical Engineering labs.

• 7. Sustainability

This project should last, if it can be saved on a computer for student use. Therefore, this program should not have too many issues maintaining the completed system. However, there exist some potential upgrades, where someone would have to alter the code. Cal Poly might upgrade the lab equipment which would entail someone updating the communication between the equipment in LabVIEW. Furthermore, students may find fault with the GUI or run into a bug that would cause impetus for further improvements to the code. Additionally, some Keysight & Windows updates break Sweep-N-Go, requiring our technical staff or Dr. Braun to debug and repair the issue. If an upgrade is required, it may prove difficult to find someone to complete these improvements since few EE students know how to code in LabVIEW.

• 8. Ethical

From the ethical framework of psychological egoism, people act in their own self-interest. Since Sweep-N-Go increases efficiency in labs and decreases student frustration in debugging the program, students should want to use the upgraded version of the program. However, this program could potentially take away from students learning new circuit concepts through manual data collection process. Therefore, it is recommended that students undertake both manual and automated approaches. Sweep-N-Go allows students to be introduced to the benefits of automated testing, such as improved accuracy and efficiency. The program also shows the characteristics of the circuit for which they are collecting data so the students still see the trends and concepts of the new circuits they study.

Furthermore, since this project allows a senior to graduate, it helps all students taking the EE labs requiring this program, and the professors teaching these labs, the ethical theory of utilitarianism supports this project. While this project takes time input from the developer and the project's advisor, the benefits outweigh this cost. This project creates the greatest good for the greatest number of people.

This project abides by the IEEE code of ethics in that it assists colleagues and co-workers in their professional development. Furthermore, the developer took all necessary health precautions for social distancing while working on this project. This abides by the IEEE standards to “hold paramount the safety, health, and welfare of the public” [17]. Finally, this report honestly represents all Sweep-N-Go 3.0 functionality and testing further abiding by the IEEE code of ethics.

• 9. Health and Safety

Since Sweep-N-Go controls lab bench equipment, students must take precautions to protect against unexpected high voltages or currents set on these instruments. Students should practice common safety practices outlined in all labs when powering the equipment [15]. The program sets all output voltages and current once the sweep is complete, thereby ensuring no equipment has the potential to harm circuit components or people while not running. Furthermore, the documentation outlining how to use the code also covers these safety precautions and warns students of the connections the program has to the equipment.

Due to the coronavirus pandemic, additional safety concerns arose while testing remotely. Since Dr. Braun connected circuits to the instruments controlled remotely through Sweep-N-Go, this posed a fire hazard. If the program set voltage or current levels too high, the circuit components could burn and cause a fire. Communication between the developer and Dr. Braun reduced this hazard.

• 10. Social and Political

This project directly impacts EE/CPE students and professors at Cal Poly. Sweep-N-Go 3.0 benefits professors, since they do not have to spend as much time helping students debug the software, and it helps students measure data more efficiently through automated data collection. This also benefits the people in technical support who must help debug issues with the program when students and faculty cannot achieve a functioning program. Companies looking to hire Cal Poly students would also benefit from students familiar with LabVIEW and automated testing. Sweep-N-Go 3.0 accounts for the new equipment installed at some of the benches, so all students in the lab have access to the program’s full capacity.

• 11. Development

I learned LabVIEW throughout the course of this project. While I started this project with some prior knowledge about the development environment. I had to teach myself several new programming concepts and refer to the “help” page several times throughout the coding process. The article titled “Self-Calibrating Automated Characterization System for Depressed Cladding EDFA Applications Using LabVIEW Software With GPIB” helped me see how someone used GPIB instrument communication with LabVIEW software [1]. From the journal article titled “Inferring Use-cases from GUI Analysis”, I saw general common practices used in designing a graphical user interface [4]. These tips helped to create the updated GUI seen in Sweep-N-Go 3.0. Furthermore, I learned the usefulness of having several stages to code development that includes student and professor feedback since they also use the product. Finally, I have learned about the product development cycle and marketing research previously not covered in other classes.