APPLICATION NOTE

Create Test Automation without Programming

Using digital learning suite test automation feature for diode characterization in basic electronics learning

KEYSIGHT

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Introduction

This application note explains how to use the Keysight SR101EDUA Digital Learning Suite software Test Automation, along with a DC Power Supply and Digital Multimeter, to characterize a diode's I-V characteristic graph, which can be a useful project or assignment for students studying basic electronics. The Test Automation tool can also be used for multi-device and real-time analysis, depending on the testing needs. By incorporating test automation into the curriculum, students can gain a deeper understanding of how real-world systems interact, as well as learn about data collection and analysis, and other performance improvement techniques. This can better prepare them for careers in electronics engineering or related fields. Overall, the use of the Test Automation tool can enhance the learning experience by providing a versatile and customizable platform for conducting various types of experiments in basic electronics and beyond.

Test Automation is a comprehensive and user-friendly tool in the Digital Learning Suite that provides automated instrument control, testing and data processing capabilities. It offers key benefits for school assignments and projects.

- **Time-saving**: Test Automation can save a significant amount of time by executing tests faster than manual testing. This can be particularly beneficial for large or complex projects, where testing can be time-consuming.
- **Accuracy**: Automated tests can reduce the risk of human error that can occur in manual testing, ensuring greater accuracy in results. This can be crucial for school assignments, projects and research activities that require precise and accurate results.
- **Repeatability**: Automated tests can be run multiple times with the same level of accuracy, making it easier to catch errors and track changes. This can be particularly helpful for iterative projects, where changes and updates need to be tested regularly.
- **Scalability**: Automated tests can be easily scaled up to accommodate more complex systems and larger test suites. This can be beneficial for school assignments and projects that require testing across multiple platforms or devices.
- **Consistency**: Automated tests can ensure that the same tests are run in the same way every time, making it easier to identify and fix issues consistently. This can be especially useful for group projects where multiple team members need to execute and interpret test results.

Diode Introduction

The P-N junction diode is a popular type of solid-state device that is made by combining a P-type semiconductor with an N-type semiconductor, with the P-type end serving as the anode and the N-type end serving as the cathode. The diode can be represented by a schematic symbol and has a typical appearance, as shown in Figure 1.

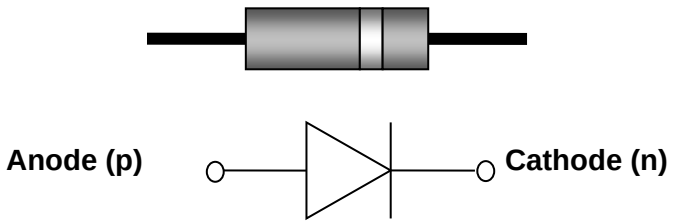


Figure 1. Diode Symbol and Appearance

The P-N junction diode is a one-way device offering low resistance when forward biased and behaving as an insulator when reverse biased. Hence, diodes are mostly used as rectifiers. When the diode is forward biased and the applied voltage is increased from zero, there is no current flow in the beginning as the external voltage is being opposed by the internal barrier voltage, V_B with values of 0.7 V for Si and 0.3 V for Ge. As soon as V_B is neutralized, the current flowing through the diode increases rapidly with increasing applied voltage.

When the diode is reverse biased, majority carriers are blocked and only a small current due to minority carriers will flow through the diode. As the reverse voltage is increased from zero, the reverse current very quickly reaches its maximum value, I_S which is also known as leakage current. When the reverse current exceeds a certain value called breakdown voltage, V_{BR}, the leakage current increases suddenly and sharply. The current-voltage characteristic graph is shown in Figure 2.

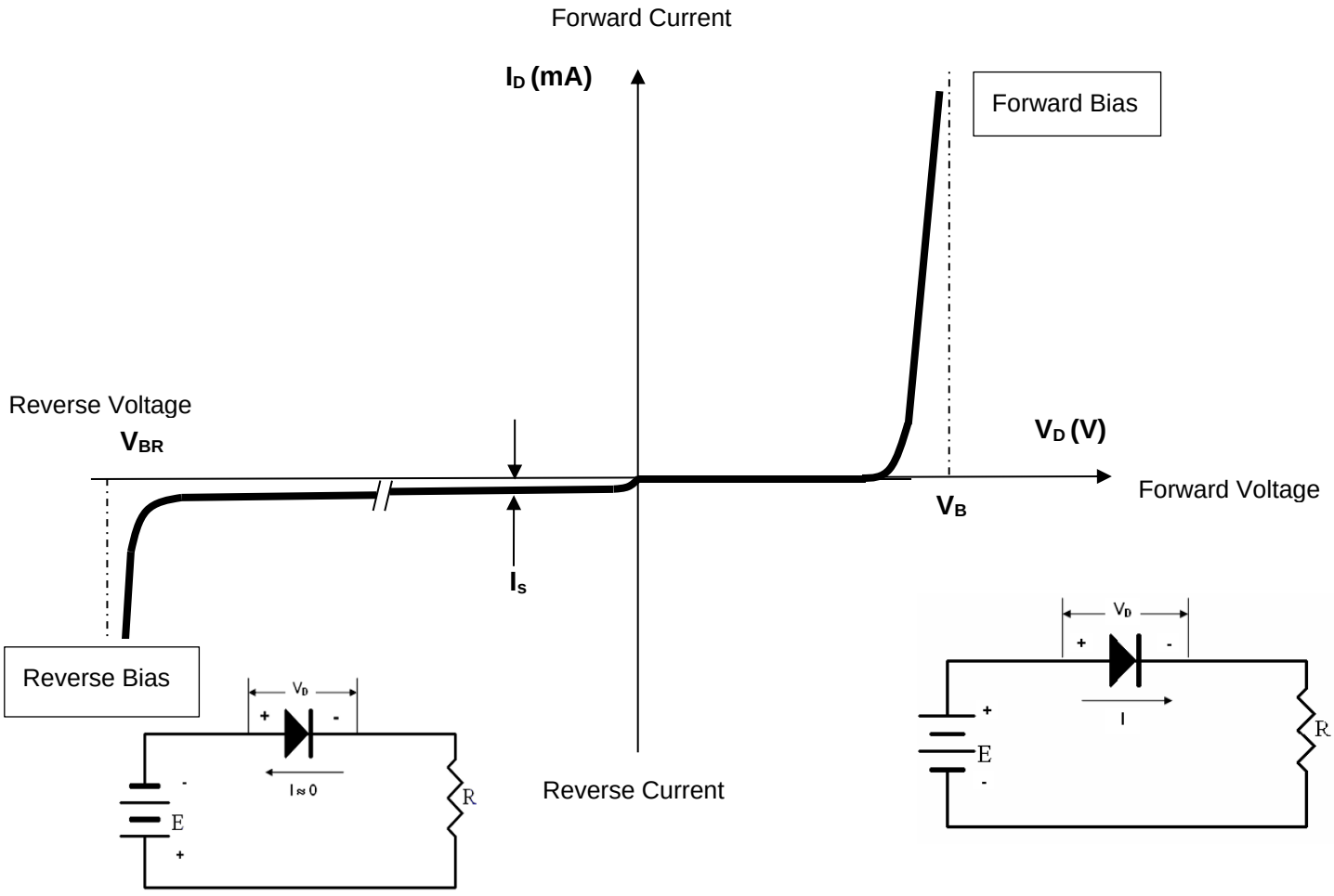


Figure 2. I-V Characteristic Graph

Diode Characteristics

The process of measuring the forward and reverse bias regions of a diode typically involves using a multimeter probe to manually take measurements on the V_R. The process is typically carried out by increasing the voltage from 0.1V to 0.8V in increments of 0.1V.

During the measurement process, the multimeter probe is connected to the diode, and the voltage is gradually increased to obtain a range of measurements. By taking manual measurements at various voltage levels, it is possible to determine the voltage and current characteristics of the diode and ensure that it is operating within its intended range. Overall, the typical process of measuring a diode using a multimeter probe involves manual measurement and gradually increasing the voltage. Figure 3 shows a setup of diode characteristics.

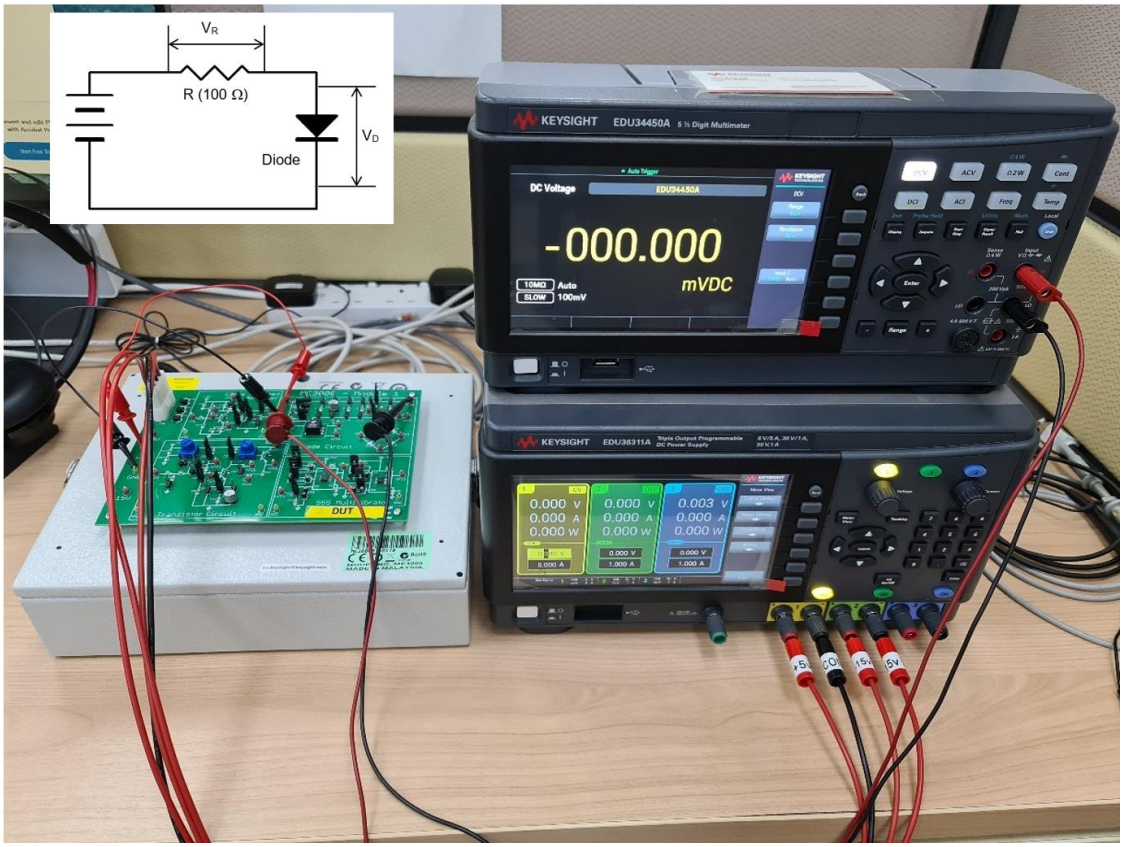


Figure 3. Diode Characteristics setup

Measuring a diode typically involves taking manual measurements of its forward and reverse bias regions using a multimeter probe.

1. Connect a multimeter to the diode using the two probes.
2. Set the multimeter to measure voltage (V) in DC mode.
3. Place the diode in forward bias by connecting the positive terminal of the multimeter to the anode of the diode and the negative terminal to the cathode.
4. Increase the voltage from 0.1V to 0.8V in increments of 0.1V.
5. Record the voltage and calculate the current flow for each incremental of voltage.
6. Repeat the process for the reverse bias by switching the probes and recording the readings in the opposite direction.
7. Plot the data on a graph to obtain the current-voltage (I-V) curve.
8. Analyze the curve to determine the operating range of the diode and any abnormalities in its behavior.

Manual diode characterization involves gradually increasing voltage and recording data, which can be shortened with Digital Learning Suite Test Automation and ensure consistency

Table 1 shows the manual calculation of current flow through a diode in the forward bias region. To calculate the current flow, the voltage across the diode (V_D) is gradually increased in 0.1V increments while manually measuring the voltage across the resistor (V_R). The current (I) across the circuit can then be calculated using the formula $I = \frac{V_R}{R}$.

Table 1. Current flow calculation

V_D (Voltage)	V_R (Voltage across R)	Current flow ($I = \frac{V_R}{R}$)
0.2	0V	0A
0.3	0V	0A
0.4	0V	0A
0.5	0V	0A
0.6	297mV	2.97mA
0.7	700mV	7mA
0.8	4.32V	43.2mA

Digital Learning Suite Test Automation

The Digital Learning Suite Test Automation is a powerful software application that utilizes a flow-chart style interface to allow users to create automated tests with ease. Users can create these tests without the need for programming skills, by simply dragging and dropping properties and measurements into a sequence. This makes it an accessible tool for a wide range of users, regardless of their technical abilities.

One of the most significant advantages of this software is its compatibility with a diverse range of Keysight instruments. Users can connect, control, and capture data from their preferred Keysight instruments, such as digital multimeters, oscilloscopes, power supplies, function generators, RF signal sources, and analyzers, among others. This flexibility enables users to customize their testing equipment to suit their unique needs.

Moreover, the list of supported Keysight instruments continues to grow, giving users access to even more options for data capture and analysis. The software is also compatible with non-Keysight instruments, further enhancing its versatility and usability.

- Easy drag and drop to add instrument settings and retrieve measurements into a sequence
- Creating loops, delays, prompts and simple “if-then-else” conditions
- Using mathematical operations
- Automatically exporting data and images to Microsoft Excel, CSV, PNG or XML files
- Controlling non-Keysight equipment

Using Test Automation to Characterize Diode

By using Test Automation, it is possible to automate the process of analyzing the characteristics of a diode. The Test Automation software allows the user to easily connect and control various instruments by dragging and dropping the required test steps.

To automate the diode characteristics analysis, the software can be used to create repeat loops that sweep the voltage across the diode in the range of forward bias in increments of 0.1V. This allows the user to obtain a range of measurements and data quickly and efficiently on the diode's behavior in different conditions.

By using the same setup but simplifying the process of analyzing the diode, Test Automation can be used to automate the testing process without requiring any modifications to the connections or manual measurement of the voltage across the resistor. This significantly saves time, and ensures accuracy and accuracy in obtaining measurements and data on the diode's characteristics.

Figure 4 illustrates the configuration of a training kit that includes a Diode circuit, Digital Multimeter, and Triple Output Power Supply. The purpose of the training kit is to provide a practical platform for users to learn about the characteristics and behavior of diodes.

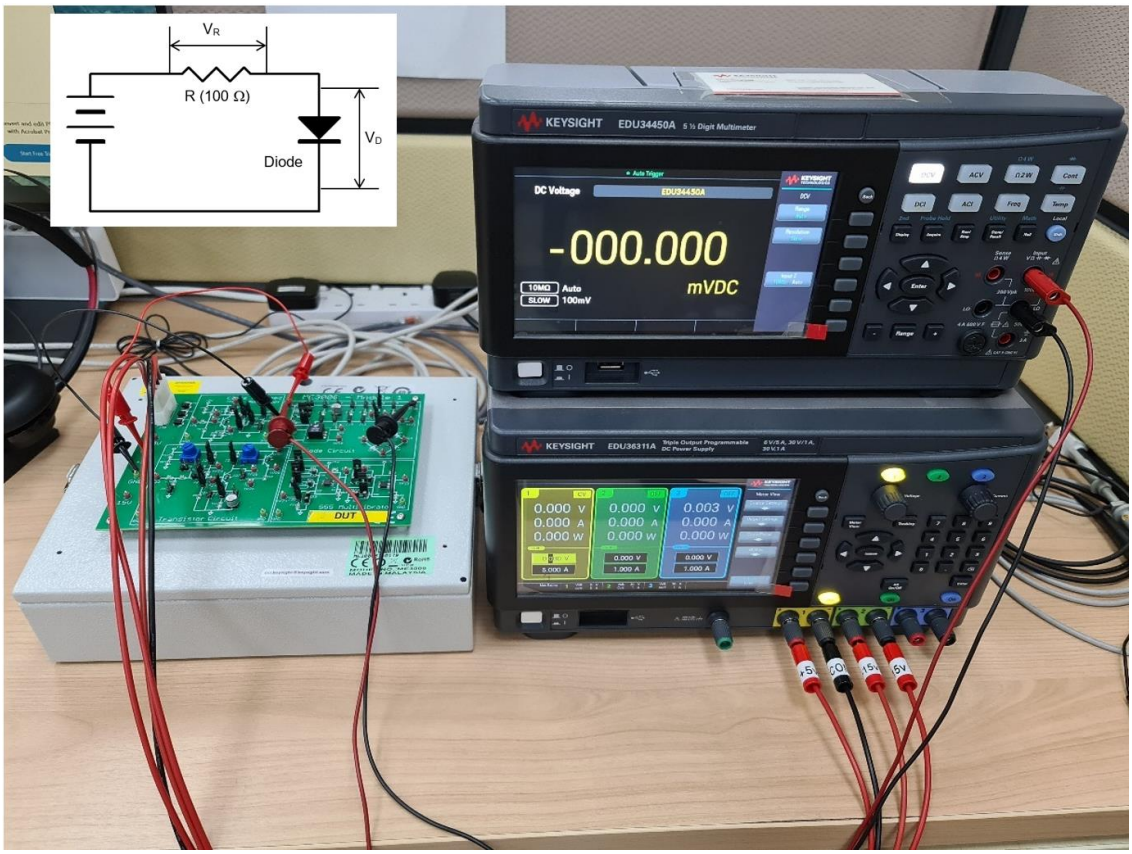


Figure 4. Diode circuit training kit, Digital Multimeter and Triple Output Power Supply

Startup

Figure 5 shows the Digital Learning Suite homepage, which offers two ways to access the Test Automation feature for instrument control.

The first is Remote Test Automation, which enables users to control instruments remotely over the same local area network. The second is Local Test Automation, which allows users to control instruments directly connected to their PC.

This application note will employ Local Test Automation to characterize the Diode using the built-in Test Automation.

Figure 6 shows Test Automation Homepage and its features.

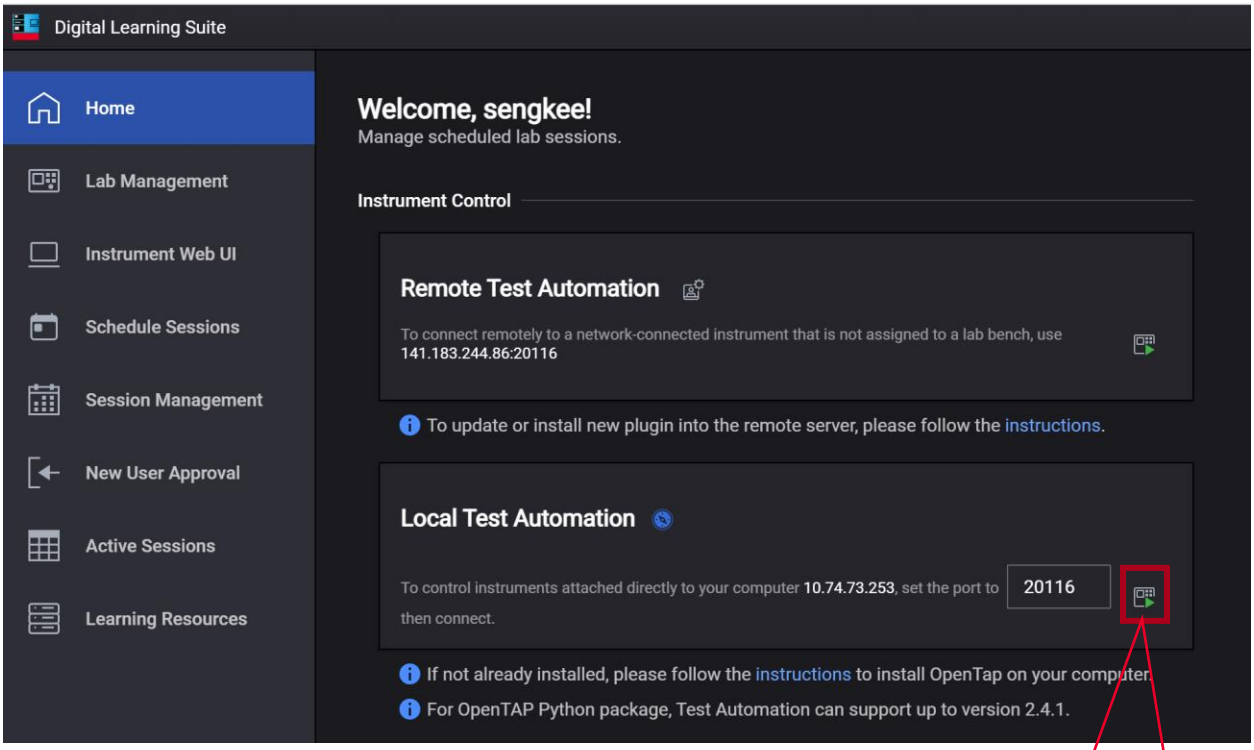


Figure 5. Digital Learning Suite Homepage

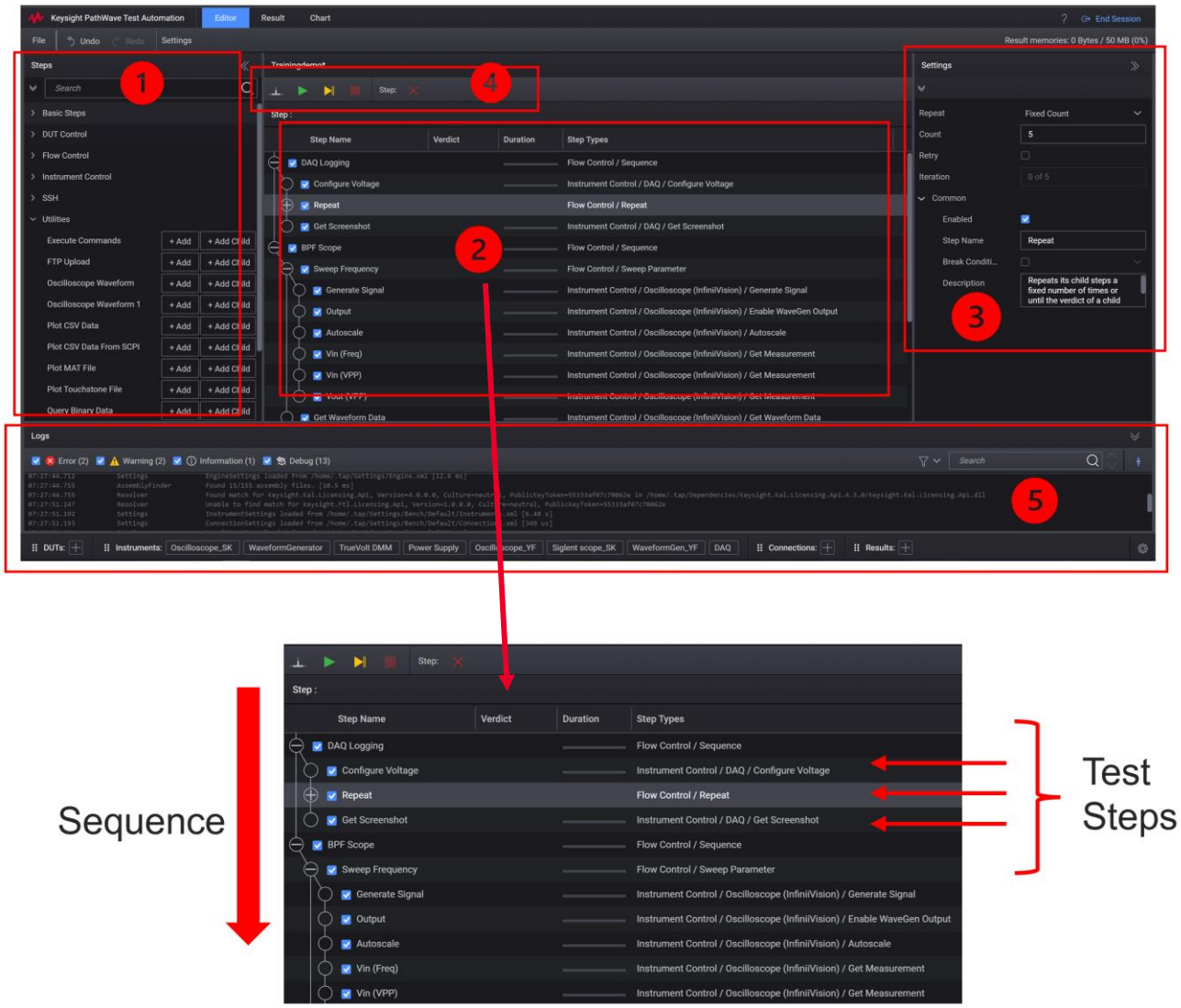
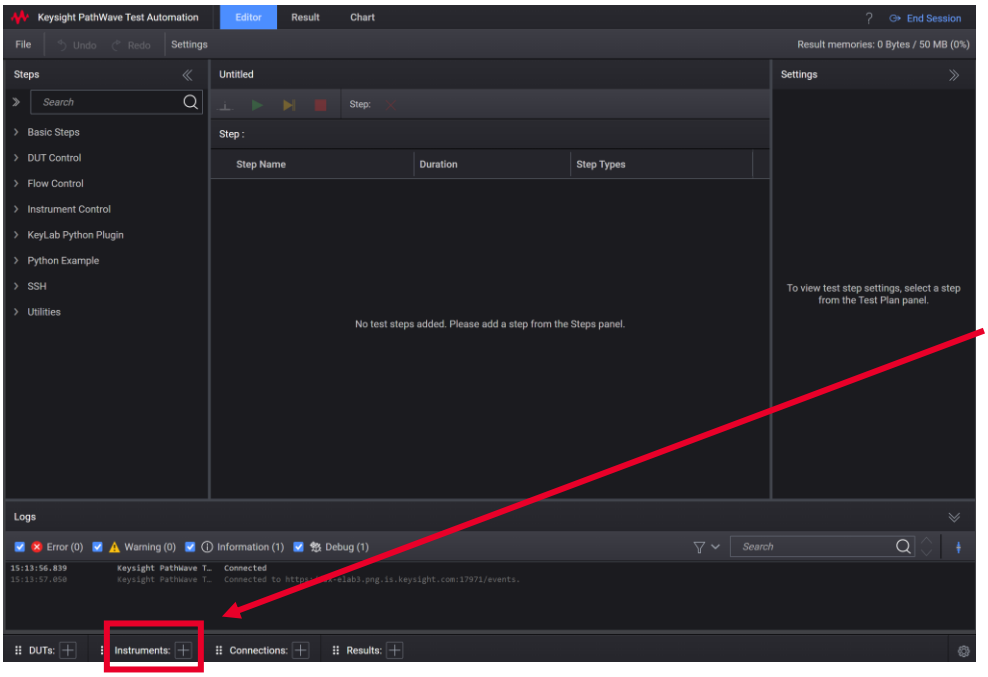


Figure 6. Test Automation Homepage and the features.

1. Test Steps and Instruments control
2. Test Plan and sequence
3. Instrument setting and properties
4. Execution button for current Test Plan
5. Log panel and Instruments connection

Adding an Instrument



To add an instrument to a test automation in the Digital Learning Suite software, click the '+' add sign at the bottom of the Test Automation homepage and select the type of instrument.

Figure 7. Add instrument

This opens a list of supported instruments that can be connected to the software.

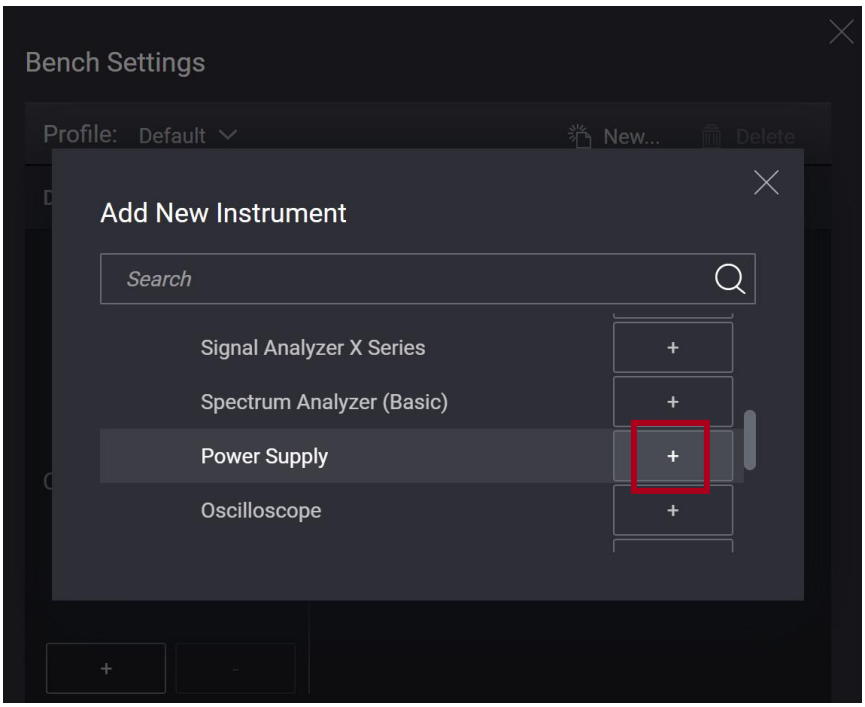


Figure 8. Instrument List

To establish a connection between the Digital Learning Suite software and an instrument in test automation, fill in the VISA Address from Keysight Connection Expert according to the type of instrument as shown in Figure 9.

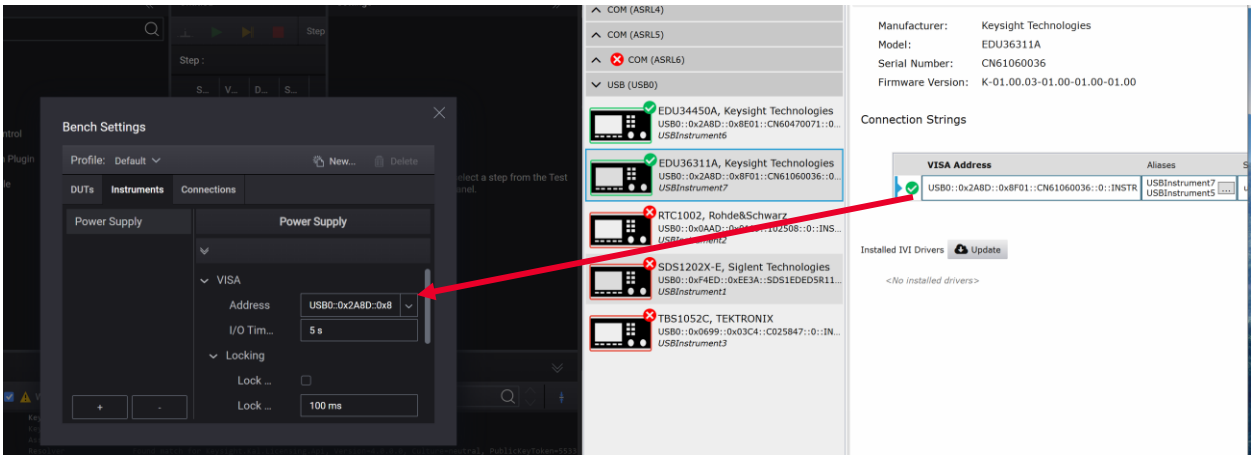


Figure 9. Keysight Connection Expert VISA address

Creating a Test automation

To create a test automation in Digital Learning Suite, drag and drop the required steps from the Instrument Control to the test panel. Once the necessary steps are added, the test automation will execute from top to bottom when the Start button is hit. This allows automated instrument control and data acquisition without the need for programming knowledge or manual operation. The drag-and-drop interface can easily customize and modify the test automation as needed for specific applications. Figure 10 shows the test automation panel.

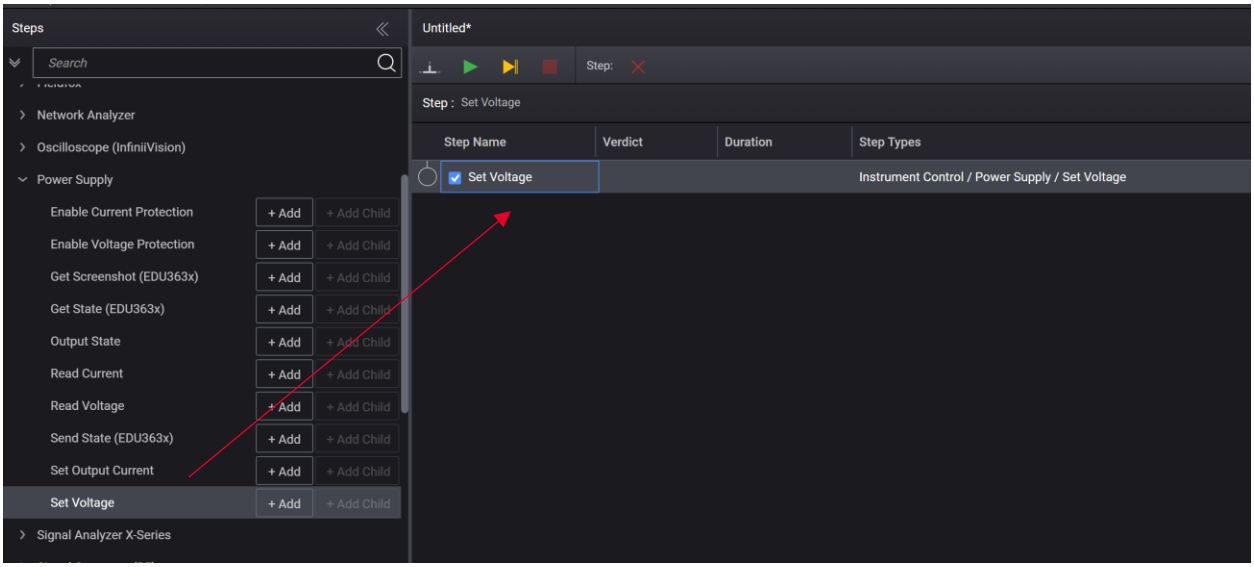


Figure 10. Test Automation panel

To perform forward bias sweeping in diode characterization, a voltage is applied across the diode and the current flowing through the diode is measured at various voltage levels. The voltage is increased in increments of 0.1V and is measured at each step. This allows for the creation of a current-voltage (IV) characteristic curve, which shows how the current through the diode varies with increasing voltage. Figure 11 shows the Test Automation steps used to measure the diode forward bias region automated.

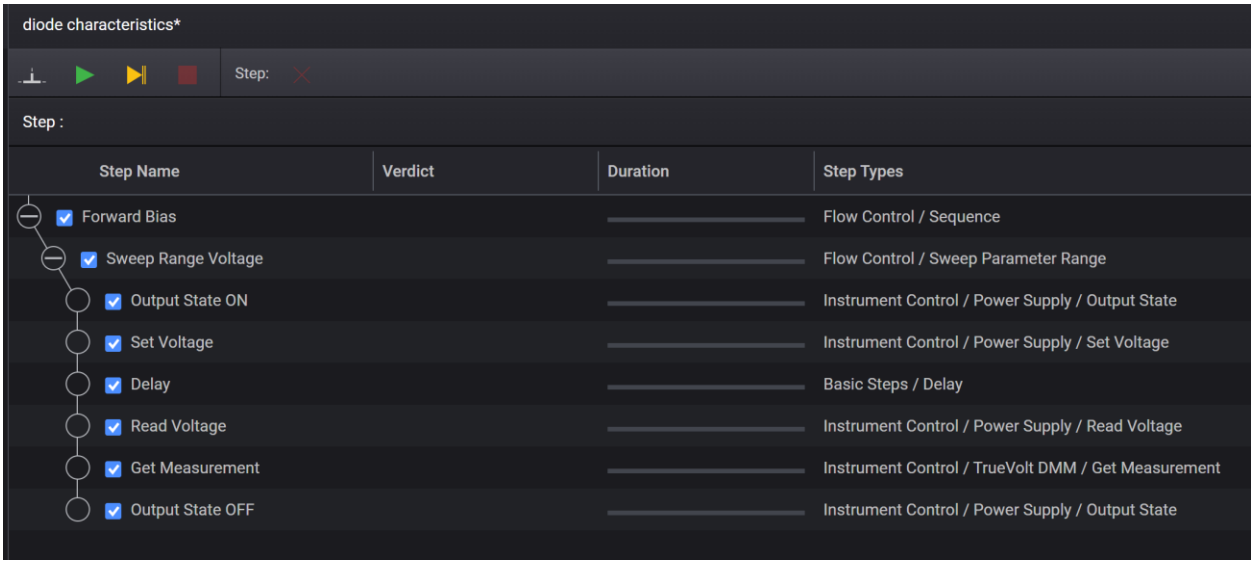


Figure 11. Test Automation flow

Test Automation flow

1. Set the power supply by sweeping the voltage from 0.1V to 0.8V in step size of 0.1V. The properties and parameters can be set at the Settings of each Test Step.
2. Turn on the power supply
3. Set Channel Voltage
4. Set a delay amount of time before continuing
5. Read power supply output voltage
6. Take a measurement, of voltage across the resistor
7. Turn off the power supply

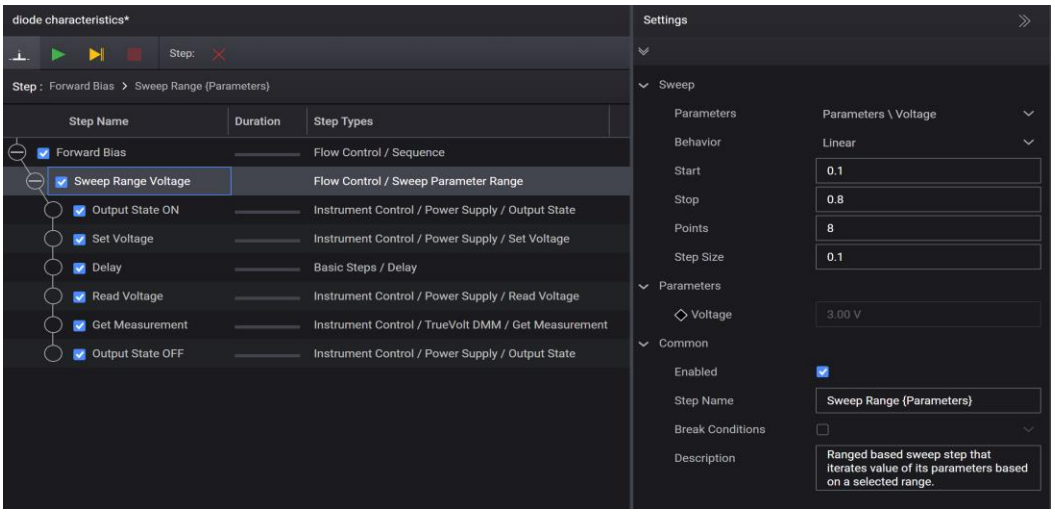


Figure 12. Test Step properties/settings

The test automation displays the time taken for each test step and sequentially performs them, starting from the top.

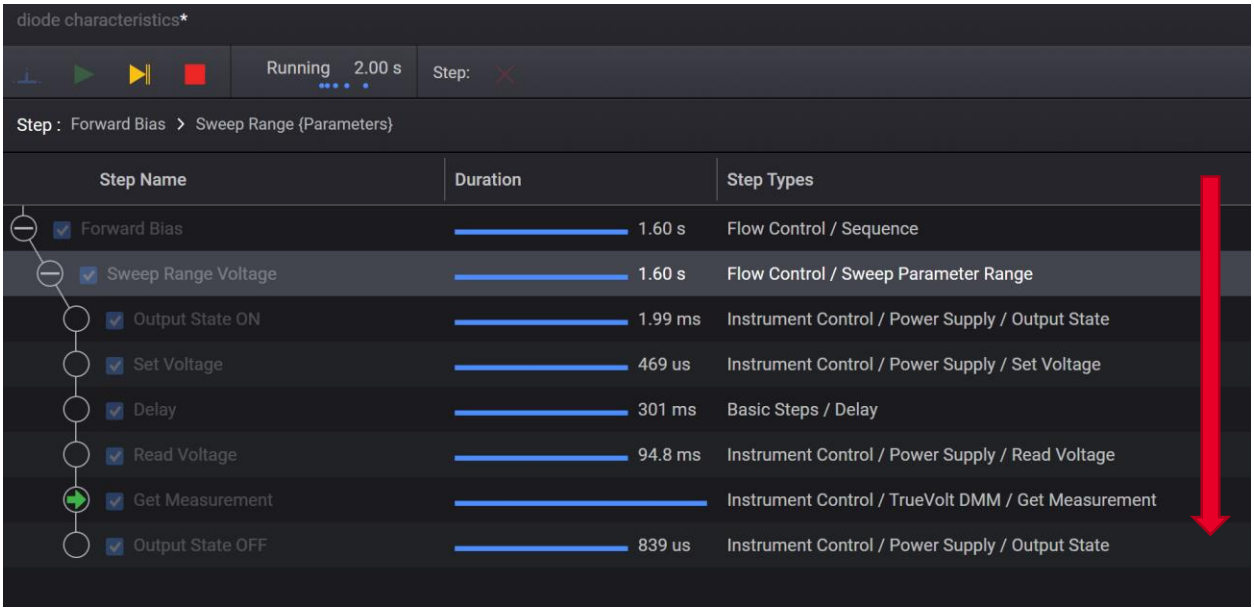


Figure 13. Test automation running in sequential

Data processing

The data processing at the result viewer is a feature that allows users to graph and visualize the results of a test plan. These results are stored in a database every time the plan is executed. Users can view and compare multiple data sets across different test runs. The measurement data can also be exported or

imported to an external file for plotting. Overall, this feature makes it easy to analyze and compare data from different test runs in a user-friendly way.

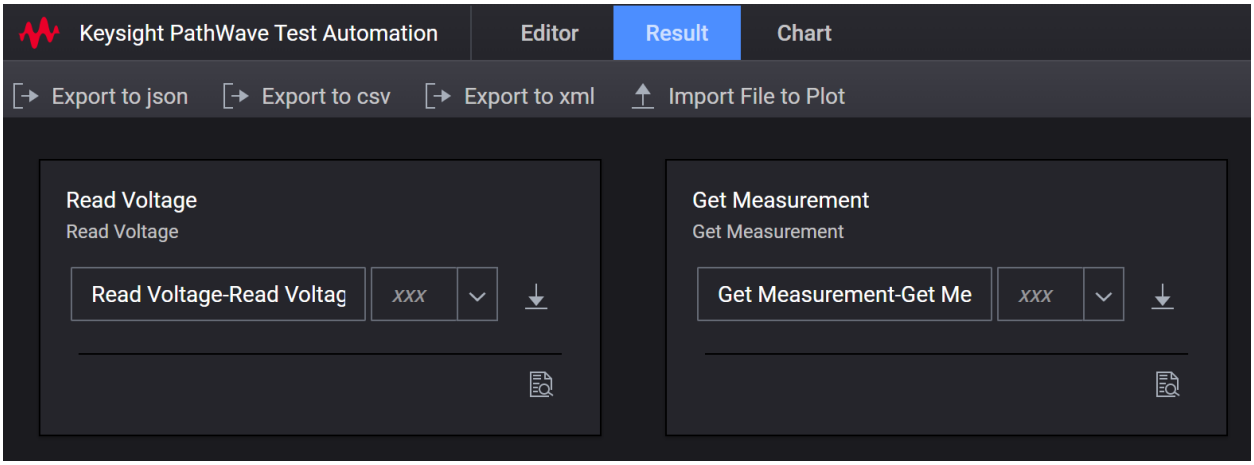


Figure 14. Result Viewer

Real-time charting tools

The Digital Learning Suite has interactive charting tools built with a web-based application that allows users to create, modify, and analyze charts and graphs in real time. These tools provide a flexible and interactive environment for visualizing data.

One of the key features of interactive charting tools is data visualization. These tools allow users to create a variety of charts to visualize data and trends. With interactive charting tools, users can easily adjust the visual properties of charts and graphs.

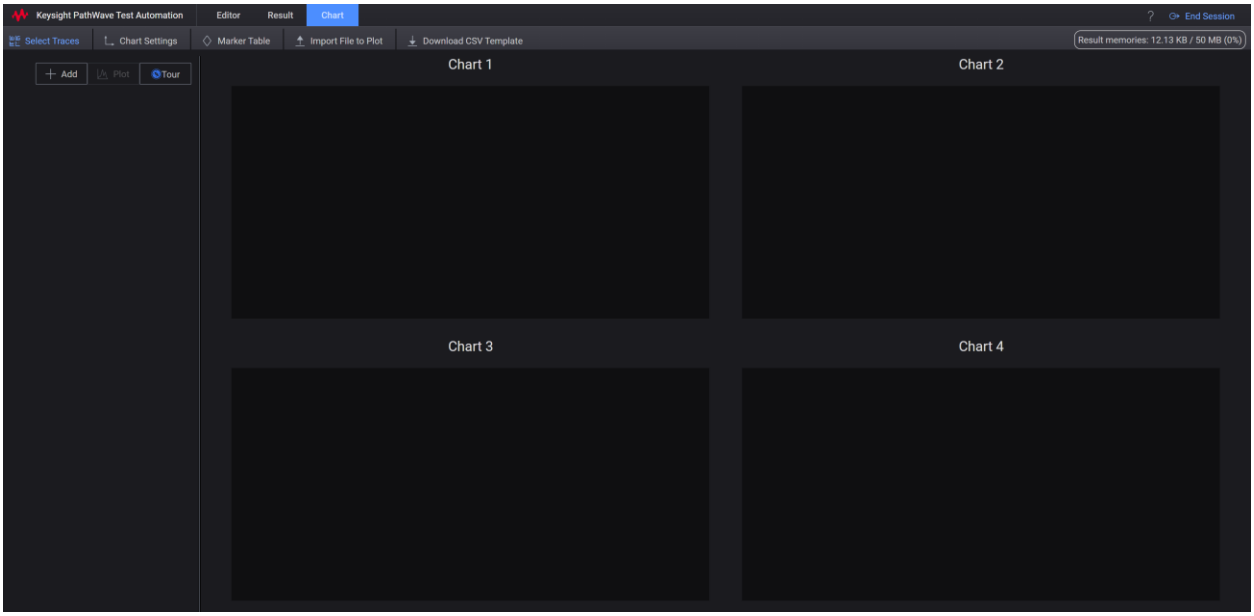


Figure 15. Charting tools interface

Plot a chart from the measurement data by selecting the data column. Figure 16 illustrates selecting the X-axis with the measurement voltage across R.

In Digital Learning Suite, users can select and manipulate traces from measurement data in real time. For instance, if users have collected voltage and current data from a circuit, they can select the voltage and current traces and display them on a chart. Then, they can customize the color, line style, and other properties of each trace to make them easier to distinguish. They can also adjust the scaling and range of the chart to zoom in on specific areas of interest.

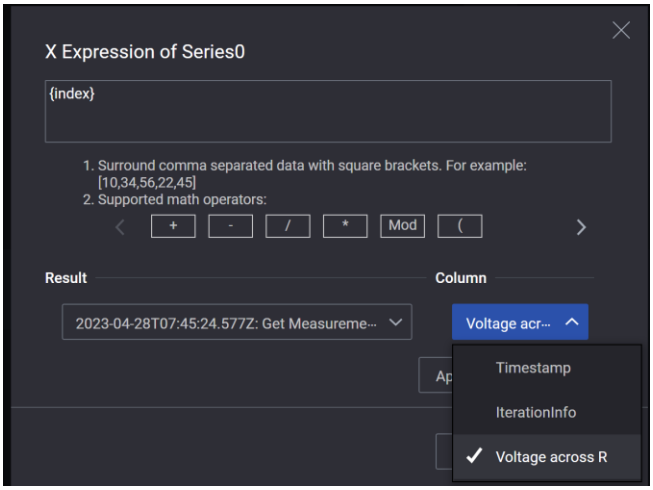


Figure 16. Select data and trace

Figure 17 refers to a chart that displays the input voltage on the X-axis and the voltage across the diode on the Y-axis.

Calculate the current flow through the diode by using a math operator from the charting tools to divide the resistance value of 100Ω, $I = \frac{V_R}{R}$, as shown in Figure 18.

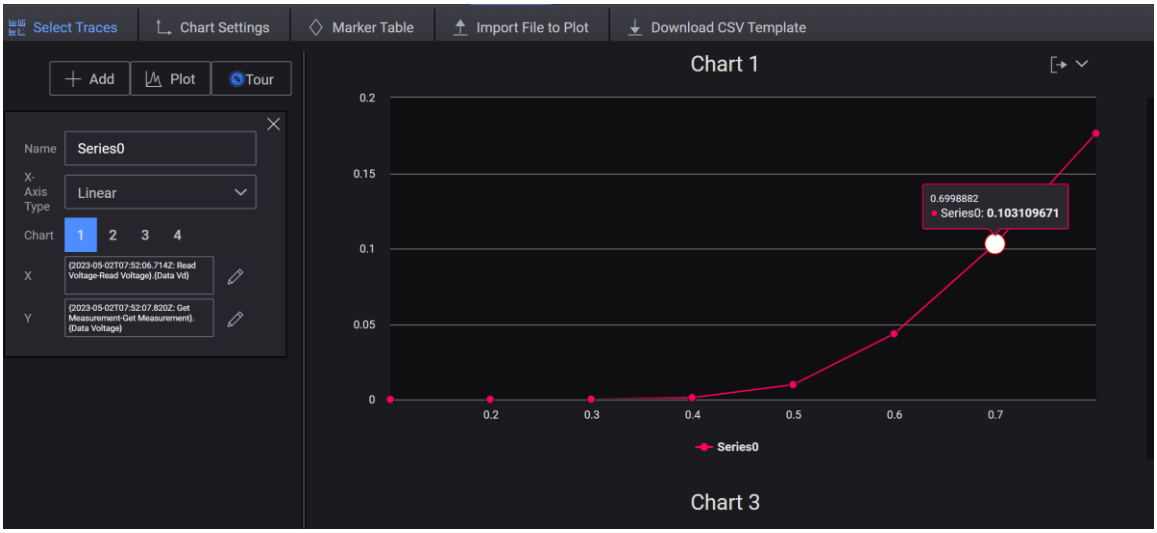


Figure 17. Chart of Input Voltage vs Voltage across the diode (R)

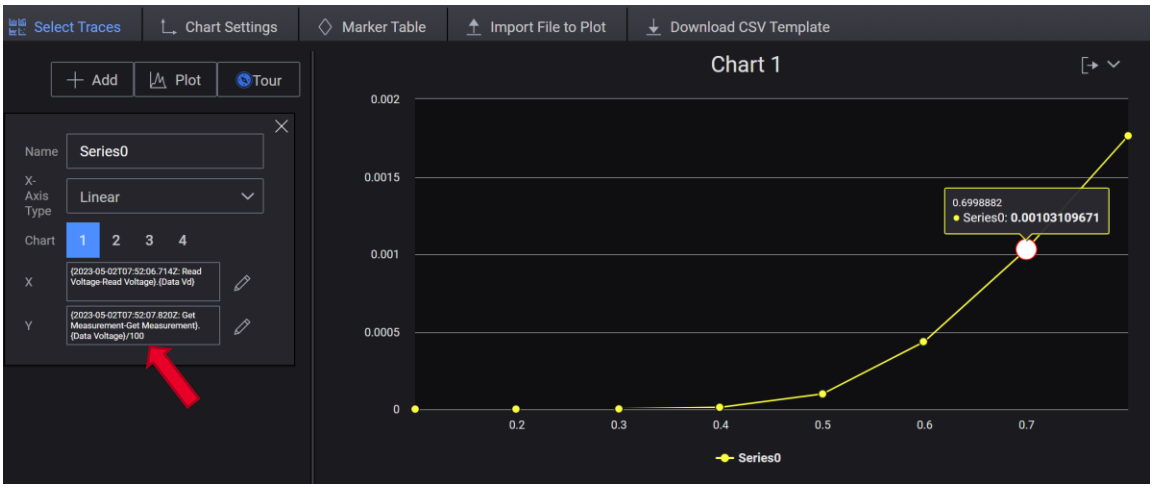


Figure 18. Chart of Input Voltage vs Voltage across the diode (R) / 100 Ω

In the Digital Learning Suite, the Marker Table as shown in Figure 19, is a great feature to compare the delta between the data sets.

This feature allows users to create markers on the chart to highlight specific data points and then view the difference between those points in a table. The table shows the delta value, which is the difference between the selected data points, as well as the absolute value of the delta. This can be a useful tool for analyzing the differences between data sets and identifying trends or patterns in the data. The marker table can be exported to a CSV file for further analysis or sharing with others.

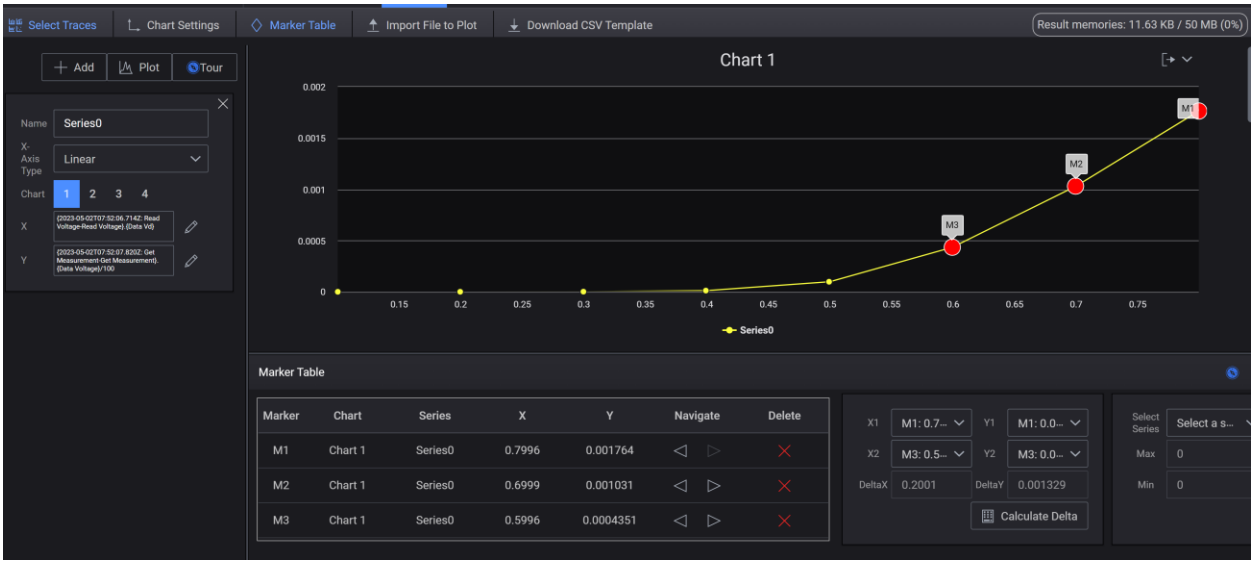


Figure 19. Marker table

Versatile Test Automation Platform

The Test Automation platform is not limited to diode experiments and provides a versatile and customizable environment to conduct various types of Basic Electronics experiments and research activities. Other experiments such as

- Transistor Output Characteristics

  Common-Emitter Output characteristics curve
- Rectifier Circuits

  Sketch different conditions waveform at different power supply voltage
- DC Biasing circuits

  Plot voltage gain vs frequency

Conclusion

In conclusion, the Digital Learning Suite provides an all-encompassing solution for accelerating test performance. It allows for quick and efficient test software development, streamlined test execution, and easy optimization of test procedures. The platform provides significant time savings, with a 10x reduction in the time required for lab validation and characterization, as well as a 3x increase in lab resources and software utilization. The Digital Learning Suite is well-suited for both project and system-level tests, and its user-friendly interface, built-in Test Automation, Data Processing, and interactive charting tools make it easy to create, modify, and analyze test data in real-time.

In addition to its ease of use, the platform is also highly flexible and scalable, allowing users to customize their test flows quickly and easily using the Test Automation engine and an ever-growing number of plugins available from the ecosystem.

Overall, the Digital Learning Suite is an excellent tool to optimize test automation capabilities, making it an ideal solution for educational settings and industrial applications. The platform also provides ample self-paced learning resources through the Keysight University modules and courseware, further enhancing its value as a comprehensive test automation solution.