An Automated Easy to Fabricate Approach to Characterize Various Diodes Using Arduino UNO

Abhijit Bar

Assistant Professor, Department of Physics, Jogesh Chandra Chaudhuri College

Abstract

This paper introduces a fully automated Arduino based low-cost data acquisition system for studying I-V characteristics of diodes. For that, a Virtual instrument has been developed using the LabVIEW platform and LabVIEW LINX toolkit. The VI incorporates a 12-bit digital-to-analog converter (DAC) with model number MCP4921, which is connected to an Arduino UNO board to generate analog voltage signals for real-time visualization of the current-voltage (I-V) characteristics of both a silicon diode (1N4007) and a germanium diode (1N34). The system includes optocoupler relays, enabling automated diode selection and facilitating seamless transitions between the two diodes during experiments. Notably, the VI accurately records the cut-in voltages of the respective diodes, demonstrating strong agreement with theoretical calculations. This comprehensive VI offers a valuable tool for researchers and engineers in the field of semiconductor device characterization, providing an efficient and user-friendly solution for visualizing and analyzing diode I-V characteristics.

Keywords: Arduino, DAC MCP4921, LabVIEW LINX, Optocoupler Relays

1. Introduction

The field of physics education has been transformed by technology, presenting new avenues beyond conventional teaching practices. Through digital instruments and simulations, interactive learning opportunities emerge, nurturing active participation and the development of analytical reasoning. These advancements enhance accessibility, allowing students to overcome geographical and resource limitations. Additionally, coding skills are recognized as valuable alongside theoretical knowledge, equipping students for a technology-driven world. In this context, the Arduino microcontroller [1] has risen in popularity due to its versatility, especially within the realm of physics education. Lately, there has been a noteworthy surge in research employing the Arduino platform for a variety of physics experiments [6][7][8].

Among a multitude of basic electronic circuit components, diodes are indispensable. Diodes find applications in numerous physics experiments, with the determination of simple harmonic motion, transient phenomena being notable examples [4][5]. Understanding their junction behavior is essential for comprehending circuit operations [6]. Therefore, having a comprehensive understanding of diode characteristics holds utmost importance in the field of physics education.

This paper presents a fully automated Arduino-based system for studying diode current-voltage (I-V) characteristics. The system utilizes LabVIEW and the LabVIEW LINX toolkit to develop a Virtual

Instrument (VI) that enables real-time visualization of diode behavior. By incorporating a 12-bit digital-to-analog converter (DAC) (MCP4921) connected to an Arduino UNO board, the VI accurately represents the (I-V) characteristics of both silicon (1N4007) and germanium (1N34) diodes. Optocoupler relays automate diode selection, facilitating seamless transitions between the two diodes during experiments. Notably, the VI records the diodes' cut-in voltages with strong agreement to theoretical calculations. Alongside revamping learning methods, this comprehensive and cost-effective solution provides researchers and engineers with an efficient tool for analyzing I-V characteristics in semiconductor device characterization.

2. Theoretical Background

A P-N junction serves as the division between p-type and n-type semiconductor materials, existing within a semiconductor structure. Once the forward voltage goes beyond the intrinsic barrier voltage of the PN junction (typically around 0.5-0.7V for silicon diodes and 0.2-0.3V for germanium diodes), a noticeable electric current begins to course through. Even a slight elevation in the potential difference results in a significant surge in the current. In a p-n junction diode, the current I can be expressed as

$$I = I_0 \left(e^{\frac{qV}{\eta k_B T}} - 1\right)$$

where I_0 is called the reverse saturation current, V is the voltage across the diode and is positive for forward bias and negative for reverse bias, and I is the current through the diode, k_B is the Boltzmann constant $(8.6 \times 10^{-5}\ eV/K)$ and T is the absolute temperature. The reverse saturation current and ideality factor η significantly depends on many external factors for example doping concentration and temperature.

3. Experimentation

Full automation for studying I-V characteristics of diodes is the primary aim here. For that we have used Arduino UNO, a command driven potential divider MCP4921 DAC and LabVIEW LINX toolkit and optocoupler relays for auto-selection of Silicon and germanium diodes.
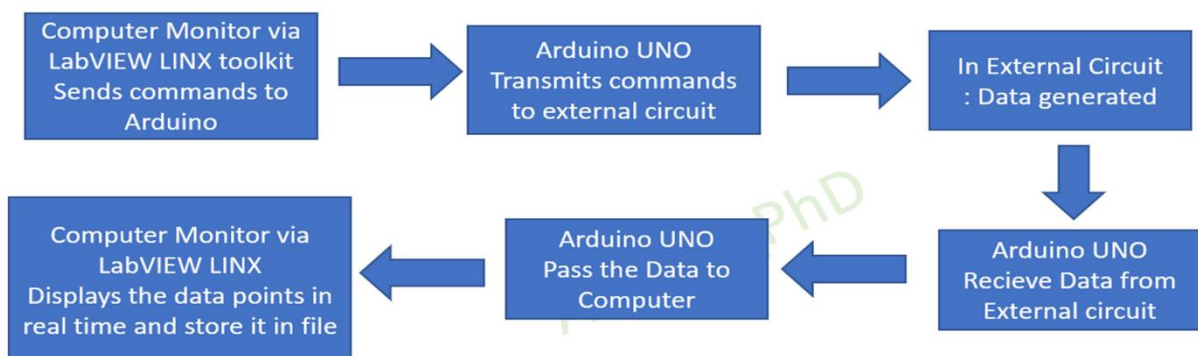

Figure 1 : Data Flow of Automated Data Acquiring system

No Arduino IDE is required for this purpose. Figure 1 and Figure 2 describe the data flow and the fritzing diagram of the circuit respectively. LabVIEW LINX [2] serves as the platform to send

commands to Arduino. Arduino, the microcontroller, is connected to an external circuit consisting of MCP4921, optocoupler relays and Silicon diode and germanium diode. Arduino transmits the command to the external circuit and receives the required data.
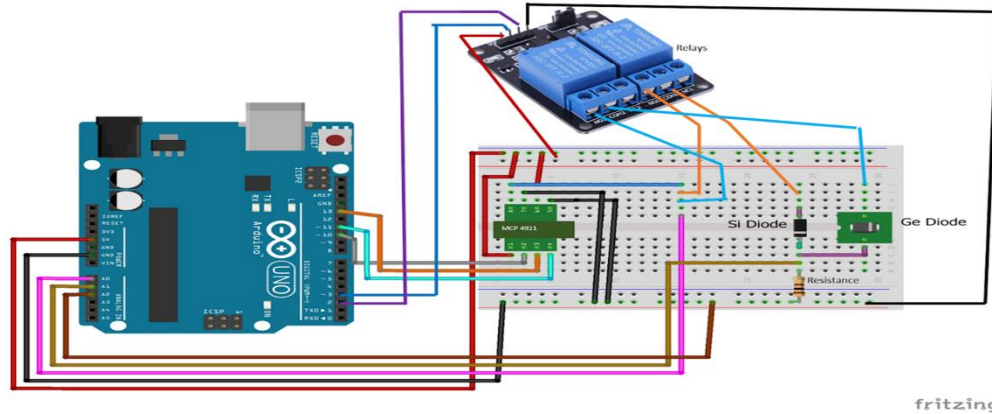

Figure 2 : Fritzing diagram of Automated Data Acquiring system

Arduino UNO lacks a built-in DAC required for generating analog voltage becomes a pivotal aspect within this undertaking. In Figure 3, we present a section of LabVIEW code that we have developed for interfacing the MCP4921 with Arduino UNO through the LINX toolkit. The process begins taking a value ranging from 0 to 4096 and convert it into an unsigned 16-bit integer data type. Subsequently, the high byte of this number is extracted and subject it to a bitwise AND operation with an unsigned 8-bit integer equivalent to the decimal value 15.
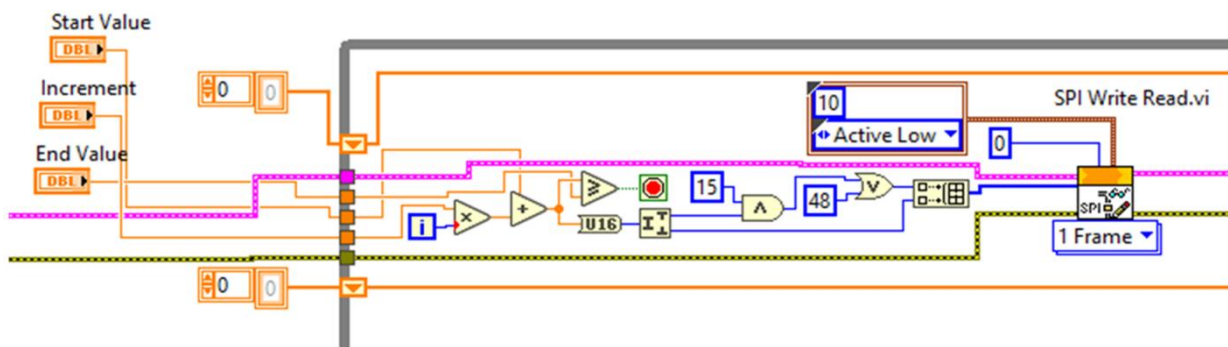

Figure 3 : A segment of the LabVIEW code interfacing DAC MCP4921

The resulting outcome is then subjected to a bitwise OR operation with another unsigned 8-bit integer equivalent to the decimal value 48. This process prepares the high byte of the conclusive 16-bit data intended for transmission to the DAC. The low byte of the ultimate 16-bit data meant for the DAC coincides with the low byte of the original unsigned 16-bit integer. We compile an array consisting of both the high and low bytes and dispatch it to the DAC by means of the chip select pin. The process is initiated by lowering the CS pin to trigger the write command. Subsequently, the 16-bit data, comprising four configuration bits and twelve data bits, is synchronized into the SDI pin on the rising edge of the SCK signal. Upon completion, raising the CS pin leads to the data being latched into the input registers of the DAC.

4. Findings

Real-time automated I-V characteristic curves for both silicon and germanium diodes were created using Arduino UNO, DAC MCP4921 and optocoupler relays through LabVIEW LINX. The forward characteristic curves indicated a notable current (approximately 0.1% of the maximum permissible current) close to 0.64V for silicon diodes and 0.24V for germanium diodes.
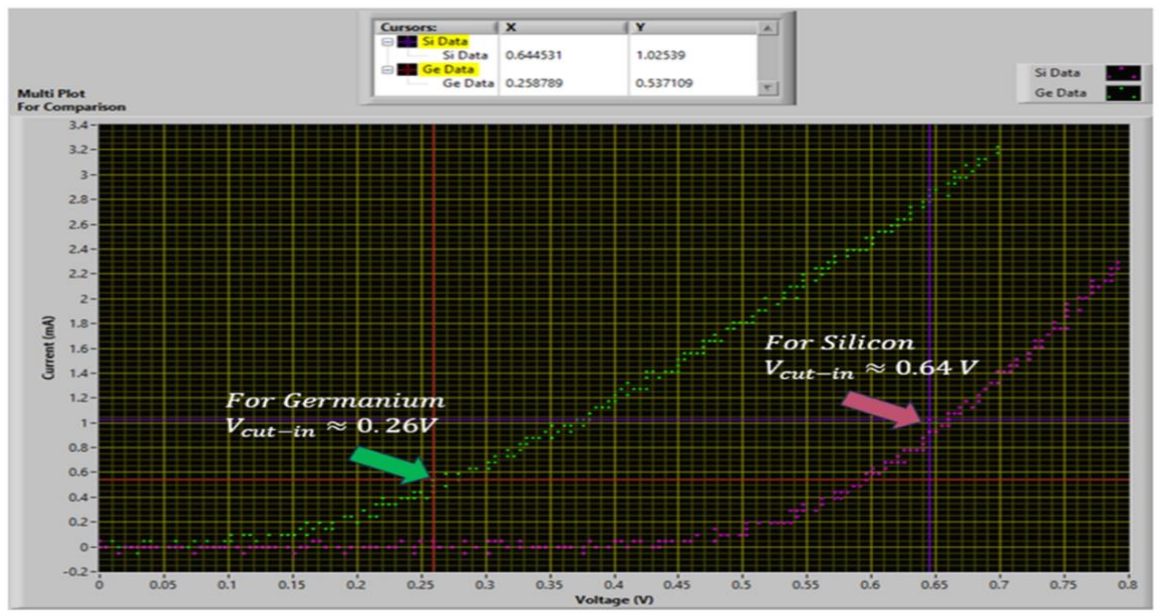
Figure 4 : Real-time multiplot of I-V characteristics of Silicon and germanium diode using Arduino based Automated data acquisition system

The voltage thresholds of 0.64V and 0.24V for the silicon and germanium diodes, respectively, correspond to their typical forward-biased regions. These values are well-documented in semiconductor physics and reinforce the validity of the automated procedure's outcomes. The presence of significant currents at specific voltage thresholds for both silicon and germanium diodes indicates the proper functioning of the diodes within their respective parameters. The automated nature of the procedure ensured precise voltage control and consistent data acquisition, contributing to the robustness of the results. This approach demonstrates the efficacy of the Arduino and DAC MCP4921 setup in generating reliable I-V curves.

5. Conclusion

In summary, this study utilized Arduino UNO and the DAC MCP4921 interfaced via LabVIEW LINX toolkit to automate the analysis of different diode characteristics. The MCP4921 facilitated digitally controlled voltage increment across diodes via fixed steps. Optocoupler relays automated diode selection, ensuring smooth transitions between both types during experiments. LabVIEW LINX toolkit assisted in obtaining real-time characterization parameters for silicon and germanium diodes, demonstrating close agreement with standard value.

6. REFERENCES

1. Arduino - Home [Internet]. [cited 2023 Aug 23]. Available from: https://www.arduino.cc/

2. LINX [LabVIEW MakerHub] [Internet]. [cited 2023 Aug 23]. Available from: https://www.labviewmakerhub.com/doku.php?id=libraries:linx:start

3. M. Banzi and M. Shiloh, Getting Started with Arduino, 3rd ed.(Maker Media, Sebastopol, 2014). ISBN: 978144936333

4. Tong-on A, Saphet P, Thepnurat M. Simple Harmonics Motion experiment based on LabVIEW interface for Arduino. J Phys Conf Ser [Internet]. 2017 Sep [cited 2023 Aug 23];901:012114. Available from: https://iopscience.iop.org/article/10.1088/1742-6596/901/1/012114

5. Tong-on A, Saphet P. The DIY RC $_s$ circuit box set via Arduino with LabVIEW^{TM} interface for experiment in charging and discharging of a capacitor. Phys Educ [Internet]. 2021 Sep 1 [cited 2023 Aug 23];56(5):055016. Available from: https://iopscience.iop.org/article/10.1088/1361-6552/ac0808

6. Önder F, Önder EB, Oğur M. Determination of Diode Characteristics by Using Arduino. Phys Teach [Internet]. 2019 Apr 1 [cited 2023 Aug 23];57(4):244–5. Available from: https://pubs.aip.org/pte/article/57/4/244/278446/Determination-of-Diode-Characteristics-by-Using

7. Bradley LJ, Wright NG. Electrical Measurements and Parameter Extraction of Commercial Devices Through an Automated MATLAB-Arduino System. IEEE Trans Instrum Meas [Internet]. 2021 [cited 2023 Aug 23];70:1–9. Available from: https://ieeexplore.ieee.org/document/9513284/

8. Das A. An easy-to-fabricate source measure unit for real-time DC and time-varying characterization of multi-terminal semiconductor devices. Eng Res Express [Internet]. 2021 Mar 1 [cited 2023 Aug 23];3(1):015003. Available from: https://iopscience.iop.org/article/10.1088/2631-8695/abd687