Development of a Closed-Loop Controller for an Arduino-Based DC Chopper using Proteus and LabVIEW

Mutmainnah[1,a], Sukriyah Buwarda[2,b], Lutfi[3,*,c]
[1,2,3] Electrical Engineering, Politeknik ATI Makassar, 220 Sunu St, Makassar, 90211, Indonesia
[a] mutmainnah@atim.ac.id, [b] sukriyah.buwarda@atim.ac.id, [*,c] lutfi@atim.ac.id (Corresponding Author)

***Abstract*— This research focuses on developing a DC-DC converter voltage regulation system using an Arduino microcontroller, addressing the instability inherent in renewable energy sources like solar panels and wind turbines. Utilizing Proteus and LabVIEW, the study employs a quantitative deductive approach to experimentally simulate and model the system over four months at the Control and Automation Laboratory of Politeknik ATI Makassar. Key challenges of conventional converters, including limited PWM flexibility, output stability, and ripple reduction, are addressed through a closed-loop control system with voltage feedback. The methodology involves extensive parameter calculations derived from literature review and expected testing scenarios to ensure precise component selection and system performance. Specific calculations guide the determination of minimum component values, facilitating the desired input and output voltage levels with minimal ripple. Simulation testing validates the system's effectiveness, demonstrating successful integration between LabVIEW and Proteus through additional library utilization. The resulting DC-DC converter voltage regulation system enables more robust control through Arduino microcontroller, enhancing stability and efficiency in renewable energy applications.**

***Keywords*—Arduino, DC Chopper, Proteus, LabView**

I. Introduction

Renewable energy sources like solar panels and wind turbines are limitless and environmentally friendly resources. However, they generate unstable power due to their reliance on natural conditions, such as solar panels depending on sunlight and wind turbines depending on wind speed. As a result, each type of renewable energy generator has different current and voltage characteristics. To maintain a consistent DC voltage value that meets specific needs, DC-DC converter technology is required to accurately adjust the voltage value. [1]

The DC-DC Converter or DC Chopper has several main functions, namely increasing DC voltage (Buck Converter), decreasing DC voltage (Boost Converter), maintaining stability of DC voltage (Voltage Regulation), and isolating the load from the DC voltage source (Isolation). DC choppers are widely used in various applications such as electronic systems, electric vehicles, telecommunications, renewable energy, and the medical field. Their usage continues to increase with the development of electronic technology and the demand for stable and efficient DC power supplies. [2], [3]

Conventional DC choppers have several drawbacks. Firstly, the PWM duty cycle is not flexible. To enhance flexibility, Arduino can be employed, but its PWM output pins operate at frequencies below 1 kHz. Secondly, the input current and output voltage still exhibit significant ripple, which can diminish the converter's reliability. Lastly, the output becomes unstable under load variations, necessitating feedback to maintain stability. [4]

To address these shortcomings, a close-loop controller with output voltage feedback can be employed to regulate voltage against load variations. Moreover, for high-frequency requirements (50 kHz), the timer interrupt feature of the ATMega microcontroller in Arduino can be utilized. To minimize voltage ripple, the selection of capacitor component values should be tailored to specific needs. [5], [6]

Tackling the challenges of voltage regulation at 50 kHz necessitates a firm grasp of fundamental power electronics principles. LabVIEW plays a pivotal role in data analysis and real-time loop control implementation, while Proteus facilitates design testing and validation prior to physical realization. Arduino, powered by the ATMega microcontroller, serves as the control system's core, managing hardware operations and meeting high-frequency requirements. [7], [8]

This research investigates the development of a DC-DC converter voltage regulation simulation using an Arduino microcontroller with output voltage feedback from the load. The simulation environment leverages Proteus to model both the plant (converter) and the controller (Arduino), while LabVIEW provides a supervisory interface for monitoring and analysis.

II. Research Methodology

This research employs a quantitative deductive approach using experimental simulation modeling guided by relevant theories and hypotheses related to the parameters of the utilized components.

The study was conducted at the Control and Automation Laboratory of Politeknik ATI Makassar over a four-month period during the practice of process control systems and power electronics.

The research utilized several tools to support the research process, including Proteus Version 8.7 SP3 (including the Arduino library), HHD Virtual Serial Port Tools Version 5.27.00.1156, and NI LabVIEW 2020 (including the Module Mathscript and the Module Visa: Virtual Instrument Software Architecture).

A. Data Analysis

The data collection technique in this research involves obtaining parameter values for components, voltage, current, and duty cycle from the calculated formulas derived from literature review and expected testing scenarios. The sampled data studied through simulation is an input voltage value of 12 volts obtained from a DC battery. The desired DC output voltage is 5 volts. Hence, the duty cycle value for PWM is found to be 31.4286%. If a switching frequency of N-type MOSFET is used at 50 KHz, assuming a ripple current tolerance of 2% and a voltage ripple of 40%, the minimum component values are calculated as follows: L1 at 1.81 mH, L2 at 0.754 mH, Cs at 149.66 µF, Co at 157.143 µF, and R at 1Ω.

B. Design Technique

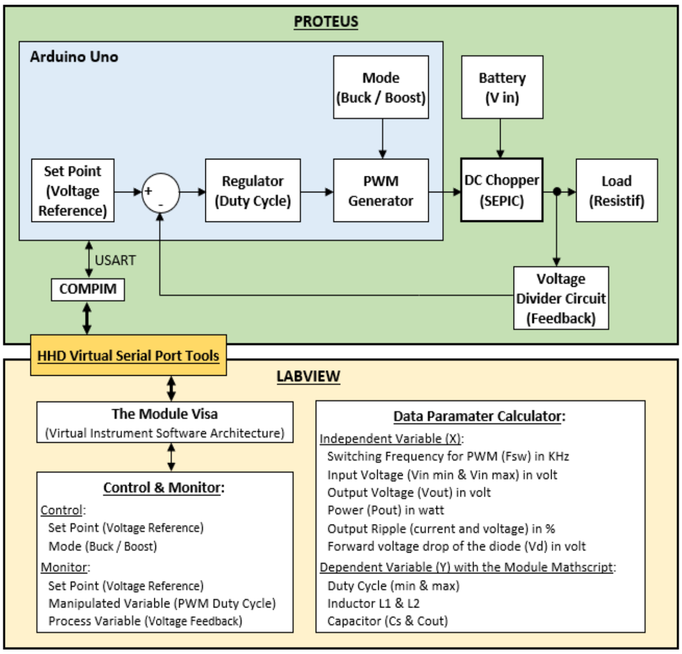

Figure 1. The overall system block diagram

III. Results and Discussion

The results of developing a simulation of a closed-loop control system for an Arduino-based DC Chopper using Proteus and LabVIEW can be seen in the following images:

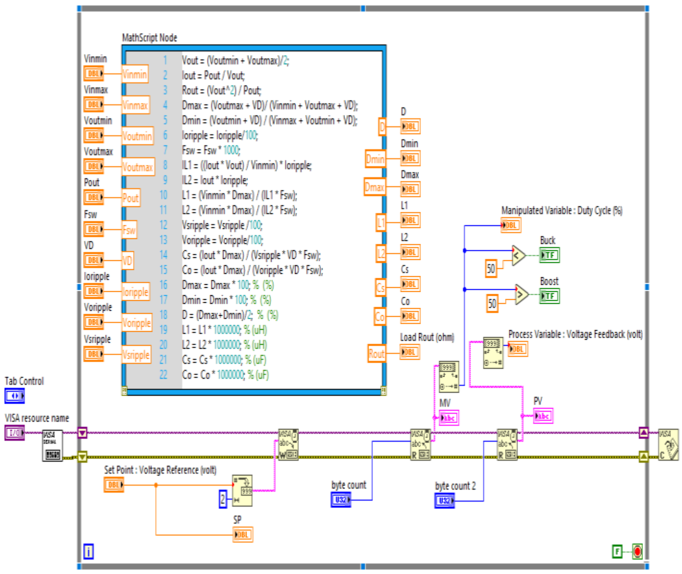

Figure 2. LabVIEW Block Diagram.

```
Vout = (Voutmin + Voutmax)/2;
Iout = Pout / Vout;
Rout = (Vout^2) / Pout;
Dmax = (Voutmax + VD)/ (Vinmin + Voutmax + VD);
Dmin = (Voutmin + VD) / (Vinmax + Voutmin + VD);
Ioripple = Ioripple/100;
Fsw = Fsw * 1000;
IL1 = ((Iout * Vout) / Vinmin) * Ioripple;
IL2 = Iout * Ioripple;
L1 = (Vinmin * Dmax) / (IL1 * Fsw);
L2 = (Vinmin * Dmax) / (IL2 * Fsw);
Vsripple = Vsripple /100;
Voripple = Voripple/100;
Cs = (Iout * Dmax) / (Vsripple * VD * Fsw);
Co = (Iout * Dmax) / (Voripple * VD * Fsw);
Dmax = Dmax * 100; % (%)
Dmin = Dmin * 100; % (%)
D = (Dmax+Dmin)/2; % (%)
L1 = L1 * 1000000; % (uH)
L2 = L2 * 1000000; % (uH)
Cs = Cs * 1000000; % (uF)
Co = Co * 1000000; % (uF)
```

Figure 2. LabVIEW MathScript : “DC Chopper - Sepic”

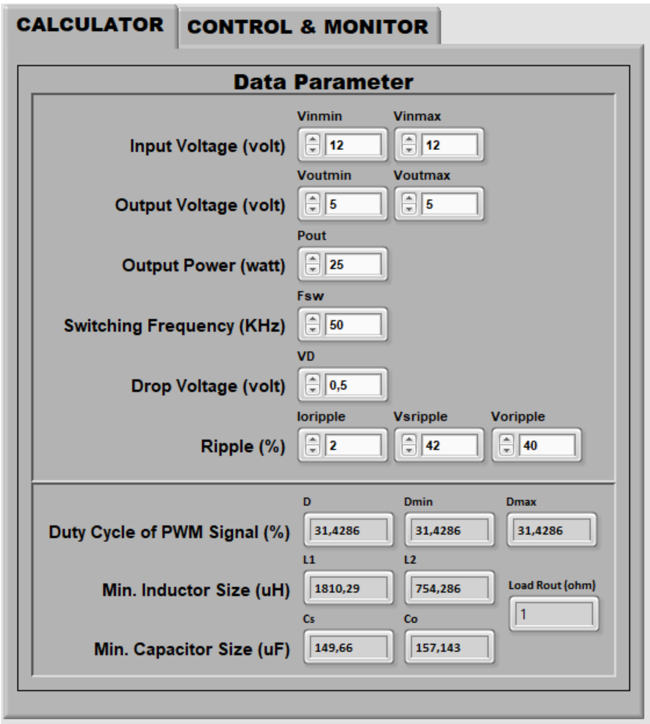

Figure 3. LabVIEW front panel: "Calculator" subsistem.

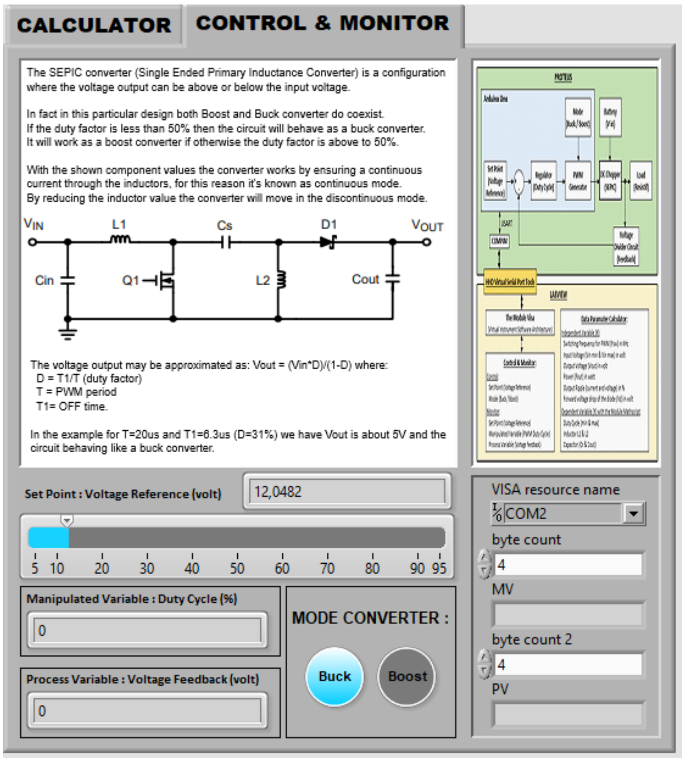

Figure 4. LabVIEW front panel: "Control & Monitor".

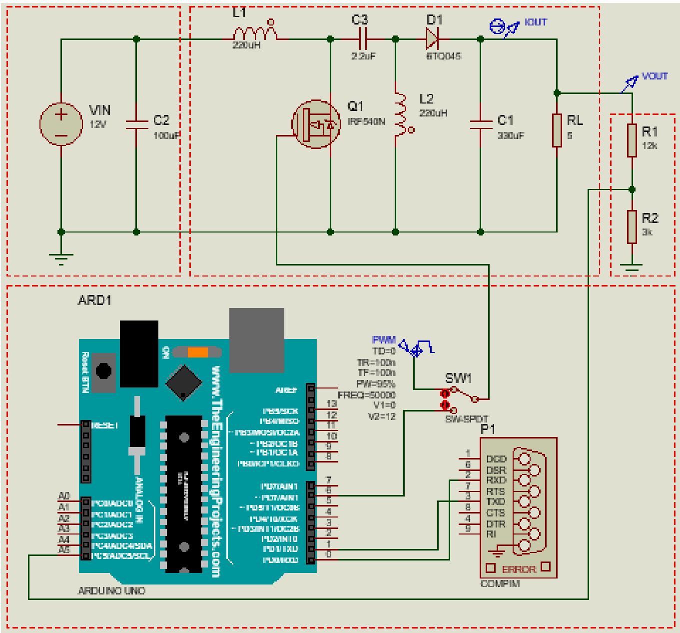

Figure 6. Proteus: DC Chopper-sepic circuit based on arduino

IV. Conclusion

The conclusion of this research is that the system has been successfully developed with the simulation testing results between LabVIEW and Proteus. To achieve effective integration, additional libraries are required from each side: the VISA module for LabVIEW and the CompIM component for Proteus. Both programs communicate via USART using a virtual serial port application. This integration enables the development of a DC-DC converter voltage regulation system with more effective control through an Arduino microcontroller, with output voltage feedback from the load.

Acknowledgement

1. Mr. Ir. Muhammad Basri, MM as the director of the ATI Polytechnic in Makassar.
2. Mrs. Merla Madjid, S.S., M.hum, as the head of the research and community service unit at the ATI Polytechnic in Makassar.
3. Mrs. Dr. Sitti Wetenriajeng Sidehabi, ST., M.MT., as the head of the machinery system automation department at the ATI Polytechnic in Makassar.
4. Mrs. Atikah Tri Budi Utami, ST, MEngsc, as the head of the control and automation laboratory at the ATI Polytechnic in Makassar.

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