Closed Loop Control Of Dc-Dc Boost Converter

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Abstract: This research focuses on the development and testing of a closed-loop controlled DC-DC boost converter designed to step up a 9V input to a stable 24V output. The aim is to achieve consistent voltage regulation under varying load and input conditions, which is critical for many modern electronic systems. A PWM-based switching technique is used, where the duty cycle is automatically adjusted through a feedback control mechanism. The output voltage is continuously monitored and compared with a set reference, and the resulting error is processed using a PID controller to fine-tune the converter's switching behavior. The system has been implemented on hardware, and performance is evaluated based on output stability, efficiency, and transient response. Results confirm that the closed-loop control significantly improves voltage regulation and overall converter performance. This design can be adapted for various low-to-high voltage conversion needs in embedded and portable electronic applications.

Index Terms – Inductor, Capacitor, Voltage source, PWM Control, Closed-Loop Control, Variable Load, Matlab Simulation.

1. Introduction

2.1 Why Boost Converters Are Needed
In many practical situations, electronic devices require a higher voltage than what is available from the power source. For example, a 9V battery may need to power a device that operates at 24V. In such cases, a boost converter is used to step up the voltage to the required level. These converters are essential in battery-powered systems, renewable energy setups, and embedded circuits, where efficiency and size are important. They allow the system to run properly without changing the power supply source.

2.2 What is a Closed-Loop Converter
A closed-loop converter is a system that constantly monitors the output voltage and automatically adjusts the switching action to maintain a stable output. It uses feedback to compare the output with a reference voltage. If any deviation is detected due to load changes or fluctuations in input voltage, the controller adjusts the duty cycle of the switching signal to correct the output. This makes the converter more reliable, accurate, and self-regulating compared to open-loop systems, which do not respond to output changes.

2.3 Why SG3525A is Used
The SG3525A is a widely used PWM controller IC in power electronics. It is chosen for this project because it integrates key features required for closed-loop control, including two internal error amplifiers, a 5V reference, an oscillator, and output transistors. It simplifies the design of PWM-based systems by offering built-in control and flexibility. Additionally, SG3525A is inexpensive, readily available, and capable of directly driving MOSFETs. Its stability and ease of use make it ideal for implementing the feedback-controlled boost converter.

2.4 Overview of Component Ratings

The selection of components for this boost converter has been made with careful consideration of current handling, switching speed, and voltage levels. The key components are:

● **Inductor**: 220µH, rated for 3A to 5A — to store and transfer energy during switching.
● **MOSFET**: IRF540N — capable of switching high currents up to 20A efficiently.
● **Diode**: 1N5822 Schottky — fast recovery and low forward voltage drop.
● **Output Capacitor**: 1000µF, 35V — used to smooth out the output voltage.
● **Input Capacitor**: 470µF, 25V — for reducing input ripple.
● **Gate Resistor**: 100Ω — to protect the MOSFET and filter switching noise.
● **PWM Timing Components**: 10kΩ resistor and 2.2nF capacitor — to set the switching frequency around 45kHz.
● **Voltage Divider**: 22kΩ and 4.7kΩ — to scale down the output voltage for feedback into SG3525A.

These components have been selected to match the performance requirements of the converter and ensure safe and stable operation.

2. Literature Review / Existing Work

Over the years, DC-DC converters have been a significant area of research in power electronics due to their wide applications in portable devices, battery systems, and renewable energy systems. Among the various types of converters, the boost converter is widely studied and implemented because of its ability to step up voltage levels efficiently.

Several research papers and projects have explored the design of boost converters using both analog and digital control techniques. Traditionally, open-loop converters were used in low-cost systems, but they often failed to maintain a stable output under varying load or input conditions. This limitation led to the adoption of closed-loop systems, where feedback is used to regulate the output.

One commonly referenced method uses microcontrollers (such as Arduino or PIC) to generate PWM signals based on feedback. These designs offer flexibility but can become complex due to programming, sensor calibration, and higher cost. In contrast, using an analog controller like the SG3525A PWM IC offers a more straightforward and cost-effective solution for implementing closed-loop control, especially in hardware-level applications.

Past studies have demonstrated the effectiveness of SG3525A in applications such as:
● Simple DC-DC power supplies
● Motor speed controllers
● Inverter systems
● Battery charging circuits

What sets this project apart is its focus on fully analog implementation using SG3525A, without any microcontroller, while still achieving automatic voltage regulation through feedback. The chosen design simplifies the circuit and ensures efficient performance, making it suitable for students and practical applications in low-power systems.

3. Circuit Diagram
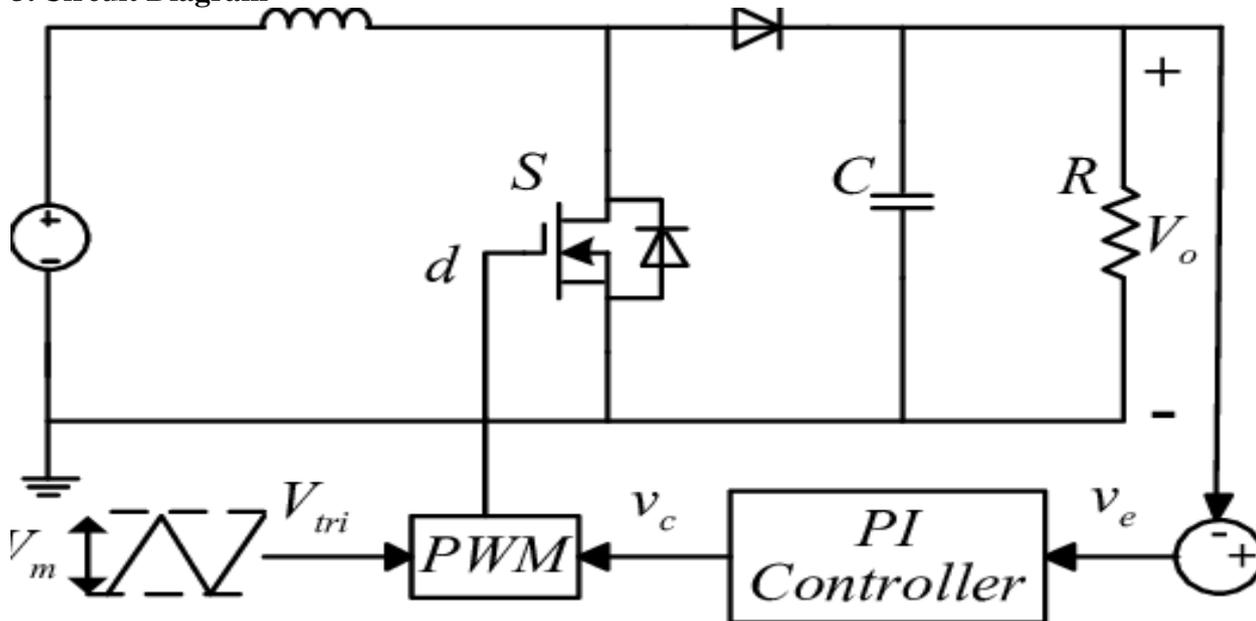
4. Components Used
Here is a neat and professional table of components used in your closed-loop DC-DC boost converter project using SG3525A.

Table: Components Used in Closed-Loop DC-DC Boost Converter

Components Name	Selected Rating	Calculated Ratings	Quantity	Purpose
Inductor (L1)	220µH, 3-5A	141µH, 3A	1	Stores and transfers energy to step up voltage
MOSFET (Q1)	IRF540N, 20A, 100V	≥ 30V, ≥ 4.7A	1	Acts as a high-speed electronic switch
Output Capacitor (C1)	1000µF, 35V	27.8µF, 35V	1	Smooths and filters the output voltage
Input Capacitor (C2)	470µF, 25V	86.8µF, 25V	1	Filters input voltage and reduces ripple
SG3525A PWM Controller	Dual PWM Controller IC	PWM controller	1	Generates PWM signal and controls duty cycle in closed-loop mode
Gate Resistor (R3)	100Ω		1	Limits current to MOSFET gate and prevents high-frequency noise

Timing Resistor (RT)	10Ω	To get 45kHz	1	Sets PWM frequency in SG3525A
Timing Capacitor (CT)	2.2nF	To get 45kHz	1	Works with RT to set oscillator frequency
Feedback Resistors	22kΩ and 4.7kΩ	R1 = 22kΩ, R2 = 4.7kΩ	1 each	Forms voltage divider for output voltage feedback into SG3525A
Bypass Capacitor	100nF		1	Noise filtering near SG3525A power pins
Load Resistor	1kΩ, 2W		1	Simulates load for testing purposes

5. Component Selection and Rating Calculations
Design Specifications

- **Input Voltage (V_{in})** = 9V
- **Output Voltage (V_{out})** = 24V
- **Load Current (I_{out})** = 1A (assumed load)
- **Switching Frequency (f)** = 45 kHz (controlled by SG3525A)

6. SG3525A Analysis

8.1. About

The SG3525A pulse width modulator control circuit offers improved performance and lower external parts count when implemented for controlling all types of switching power supplies. The on−chip +5.1 V reference is trimmed to - 1% and the error amplifier has an input common−mode voltage range that includes the reference voltage, thus eliminating the need for external divider resistors. A sync input to the oscillator enables multiple units to be slaved or a single unit to be synchronized to an external system clock. A wide range of deadtime can be programmed by a single resistor connected between the CT and Discharge pins. This device also features built−in soft−start circuitry, requiring only an external timing capacitor. A shutdown pin controls both the soft−start circuitry and the output stages, providing instantaneous turn off through the PWM latch with pulsed shutdown, as well as soft−start recycle with longer shutdown commands. The under voltage lockout inhibits the outputs and the changing of the soft−start capacitor when VCC is below nominal. The output stages are totem−pole design capable of sinking and sourcing in excess of 200 mA. The output stage of the SG3525A features NOR logic resulting in a low output for an off−state.

8.2. Features & Pin Diagram

- 8.0 V to 35 V Operation
- 5.1 V ±1.0% Trimmed Reference
- 100 Hz to 400 kHz Oscillator Range
- Separate Oscillator Sync Pin
- Adjustable Deadtime Control
- Input Undervoltage Lockout
- Latching PWM to Prevent Multiple Pulses
- Pulse−by−Pulse Shutdown
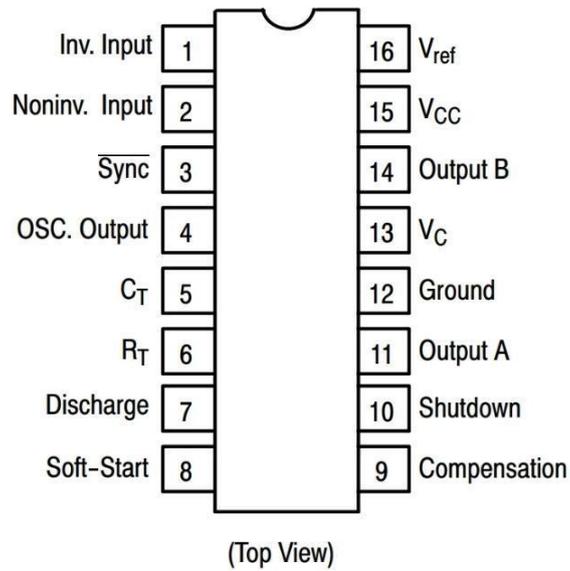- Dual Source/Sink Outputs: ±400 mA Peak

PIN CONNECTIONS

Inv. Input	1		16	V_{ref}
Noninv. Input	2		15	V_{CC}
$\overline{Sync}$	3		14	Output B
OSC. Output	4		13	V_C
C_T	5		12	Ground
R_T	6		11	Output A
Discharge	7		10	Shutdown
Soft–Start	8		9	Compensation

(Top View)

Figure 1.0

8.3. Representative Block Diagram
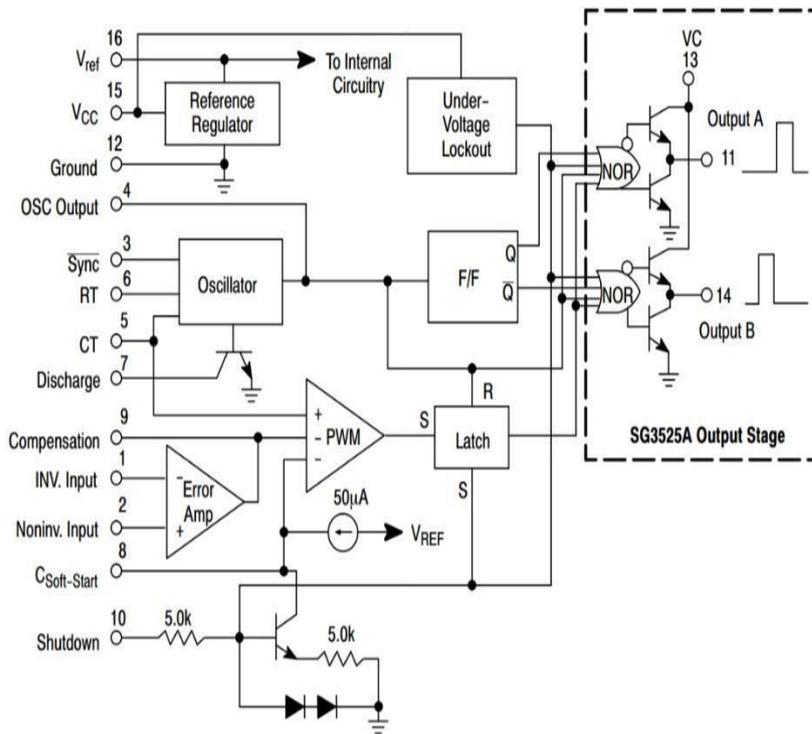
Figure 2.0

8.4. Maximum Ratings

Rating	Symbol	Value	Unit
Supply Voltage	V	+40	Vdc
Collector Supply Voltage	V_{cc}	+40	Vdc
Logic Inputs		−0.3 to +5.5	V
Analog Inputs		−0.3 to VCC	V
Output Current, Source or Sink	I_o	500	mA
Reference Output Current	I_{ref}	50	mA
Oscillator Charging Current		5.0	mA
Power Dissipation TA = +25C (Note 1) TC = +25C (Note 2)	P_d	1000 2000	mW
Thermal Resistance, Junction−to−Air	$R_{\theta JA}$	100	°C/W
Thermal Resistance, Junction−to−Case	$R_{\theta JC}$	60	°C/W
Operating Junction Temperature	T_j	+150	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C
Lead Temperature (Soldering, 10 seconds)	T_{Solder}	+300	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.
● Derate at 10 mW/C for ambient temperatures above +50C.
● Derate at 16 mW/C for case temperatures above +25C.

8.5. Internal Circuit Diagram of SG3525A
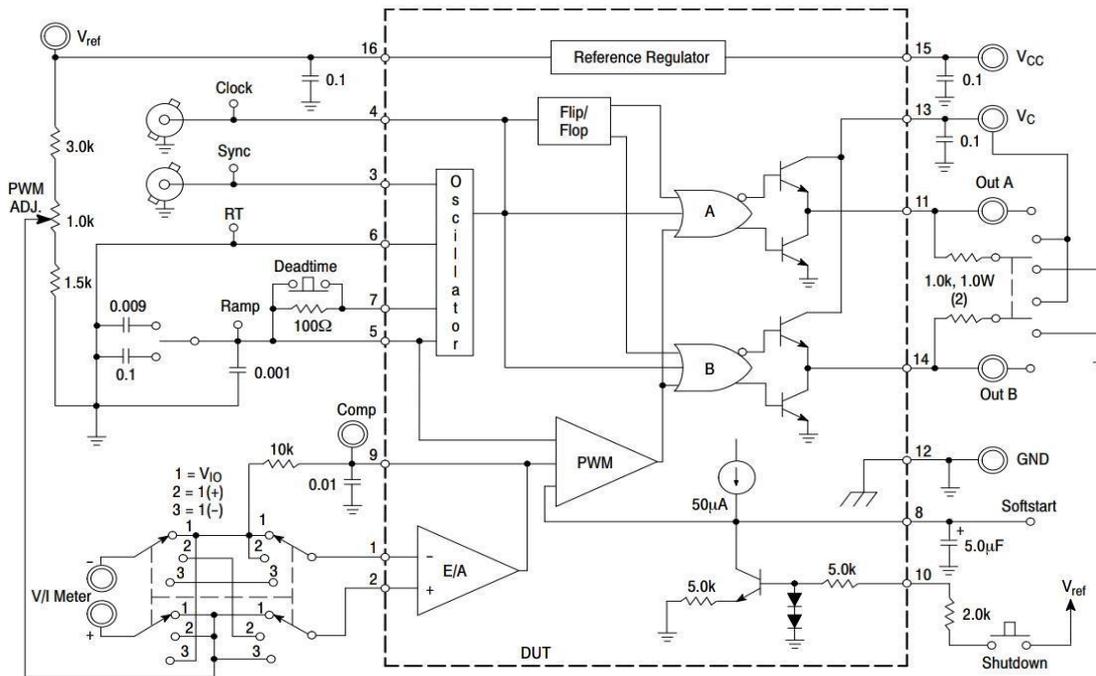
Figure 3.0

8.6. Electrical Characteristics
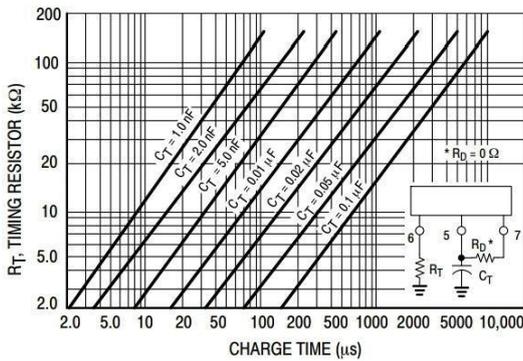
Figure 4. Oscillator Charge Time versus RT **Figure 5. Oscillator Discharge Time versus RD**
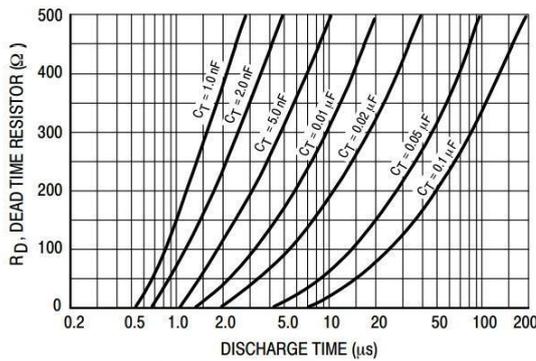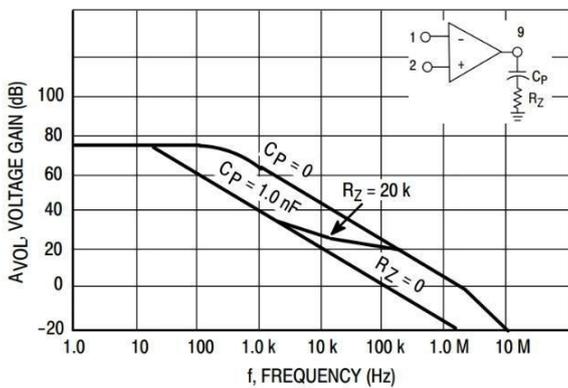
Figure 6. Error Amplifier Open Loop. **Figure 7. Frequency Output Saturation**
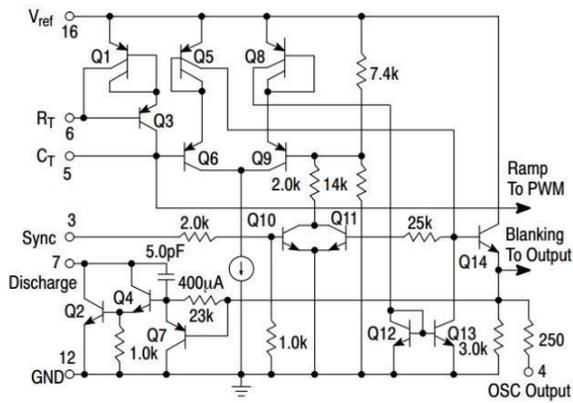**Characteristics** **Characteristics**
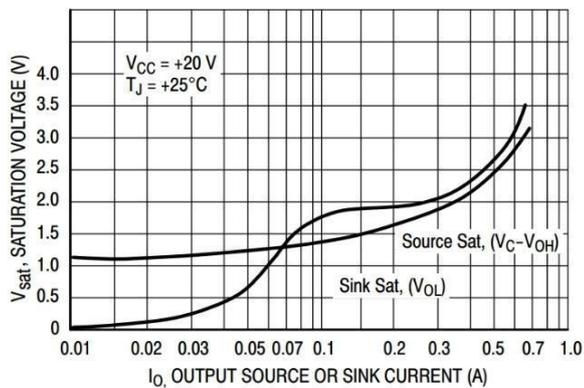
Figure 8. Oscillator Schematic   **Figure 9.Error Amplifier Schematic**
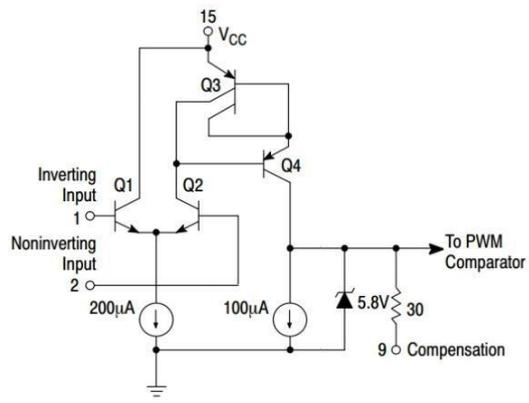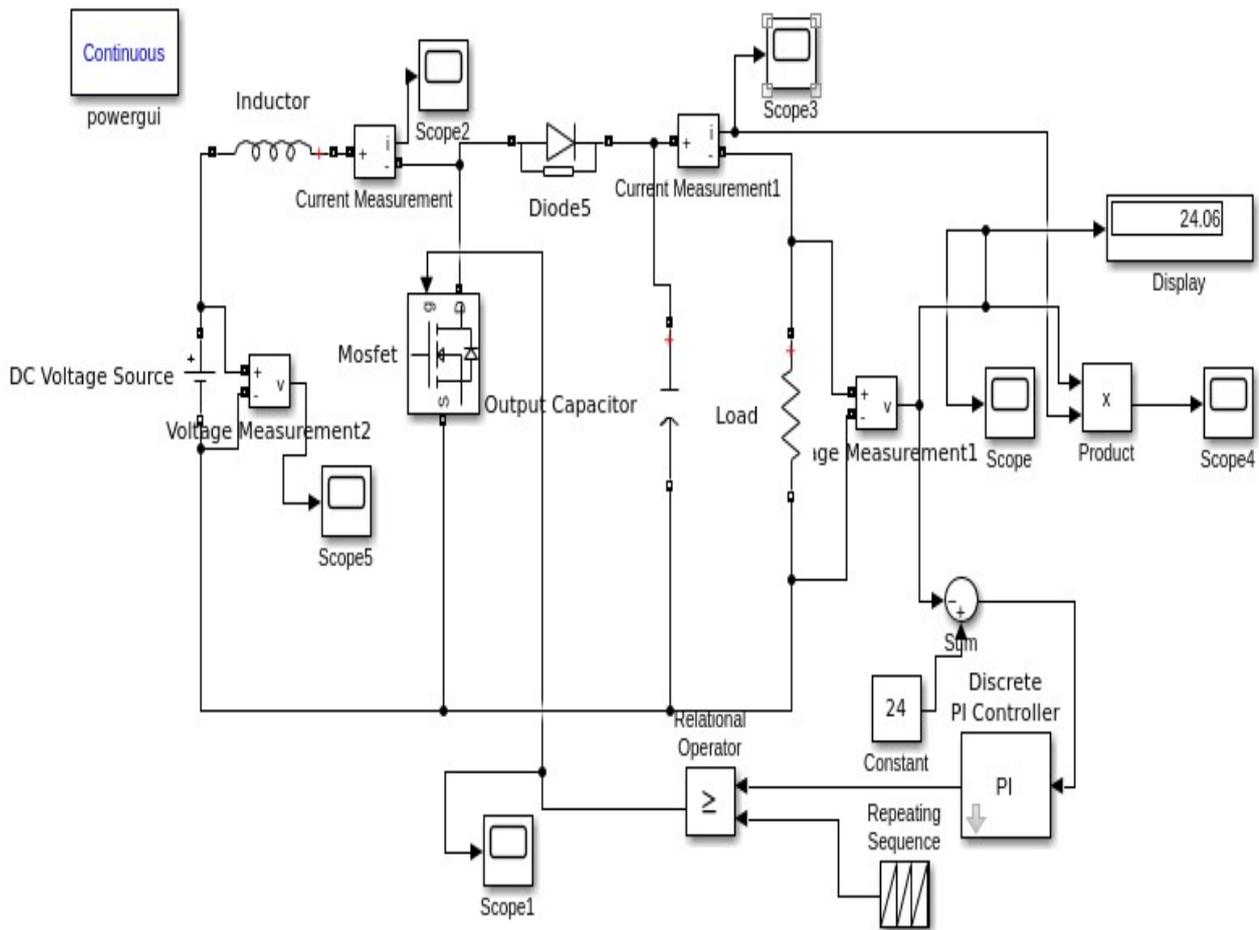
7. Matlab Simulation

9.1 At Fixed Load

Figure 10

9.2 Result & Waveform at Fixed Load
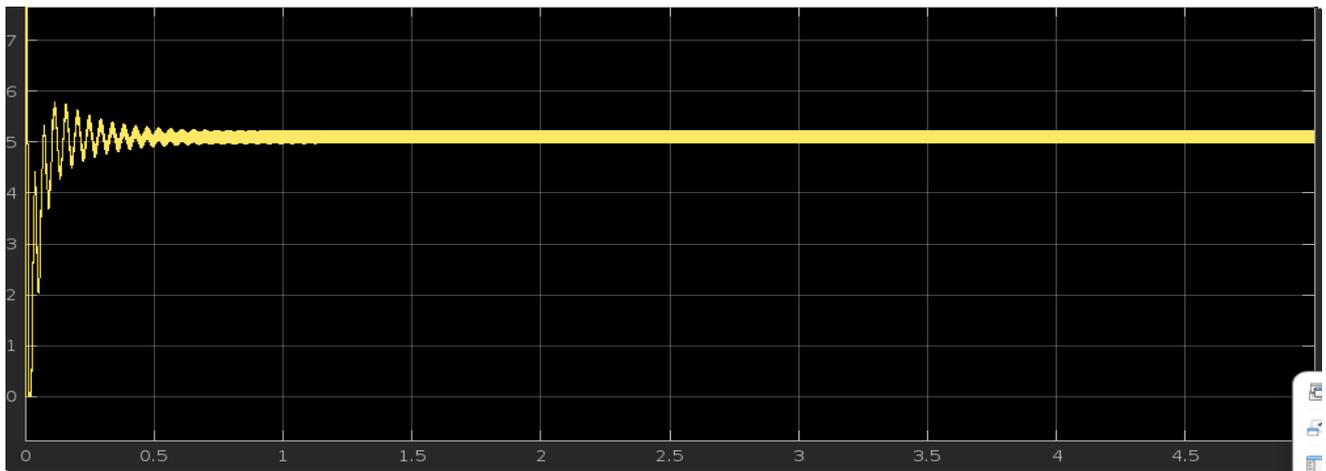
Figure 11. Input Current
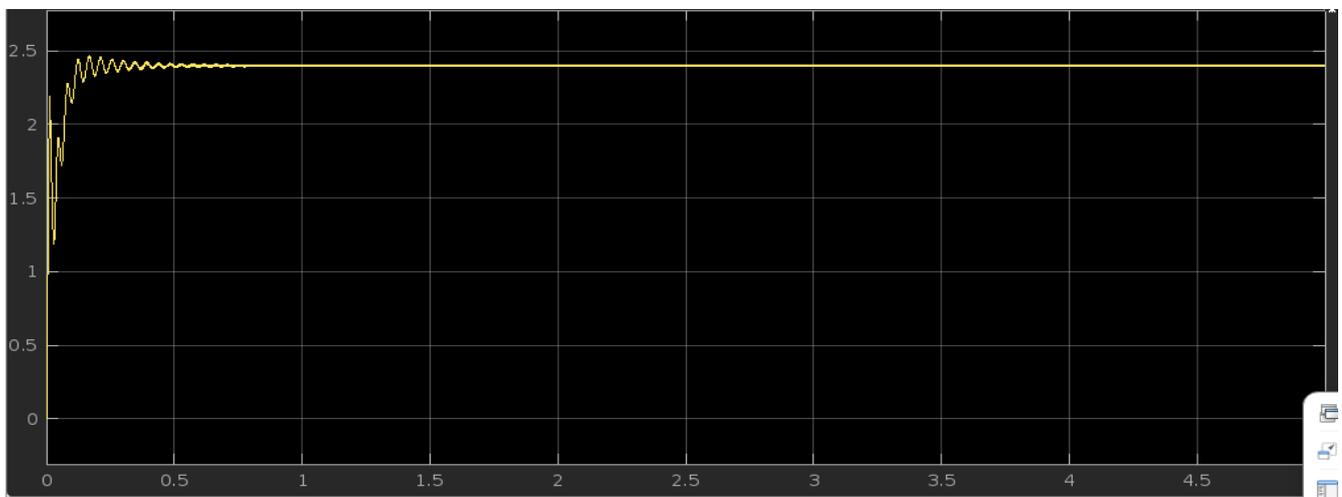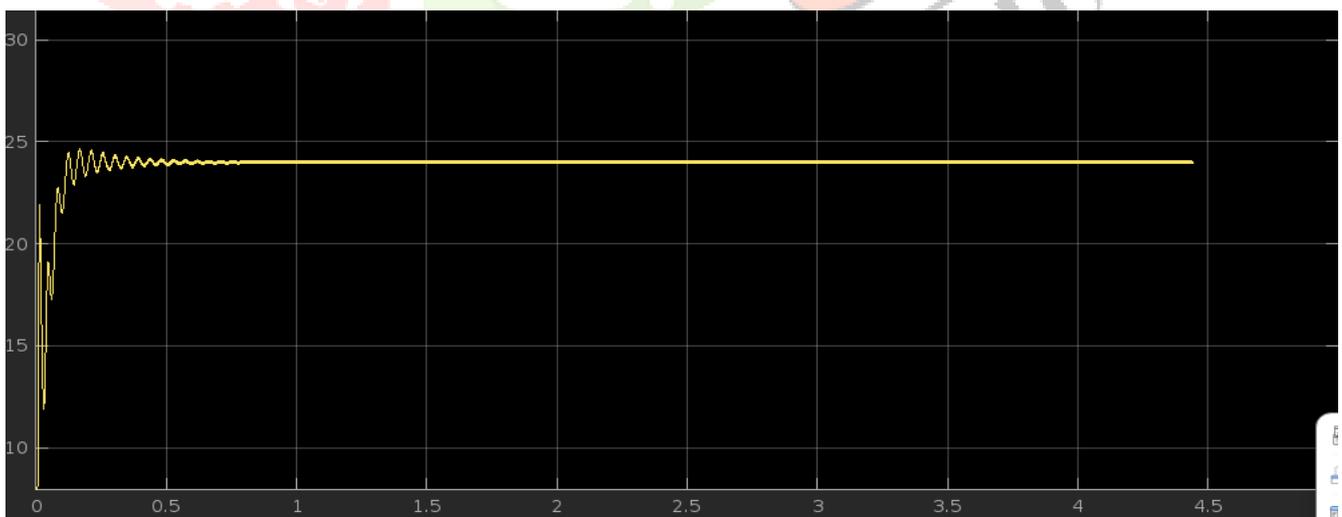

Figure 12. Output Current

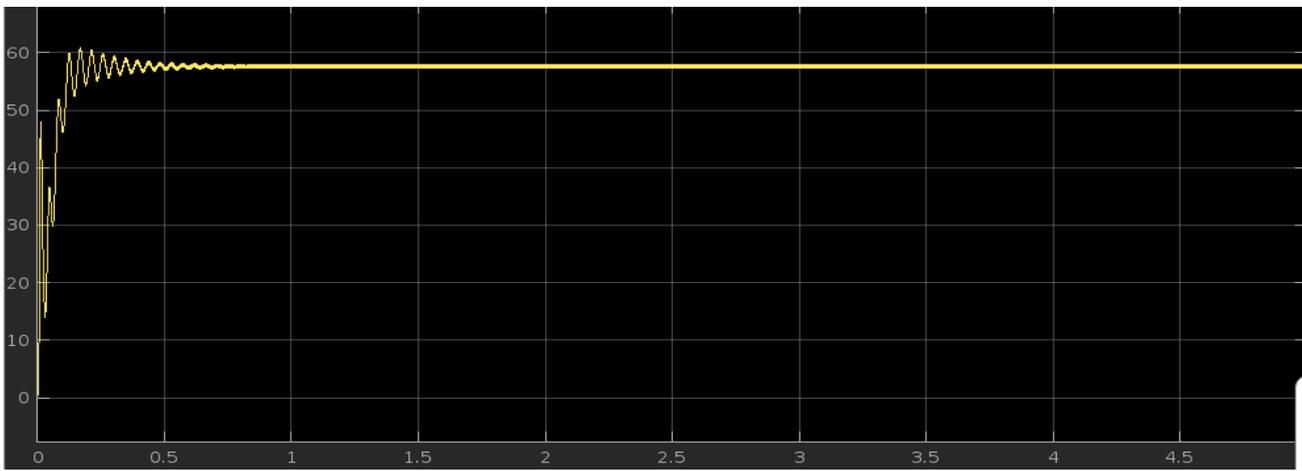**Figure 13. Output Voltage**

Figure 14. Output Power

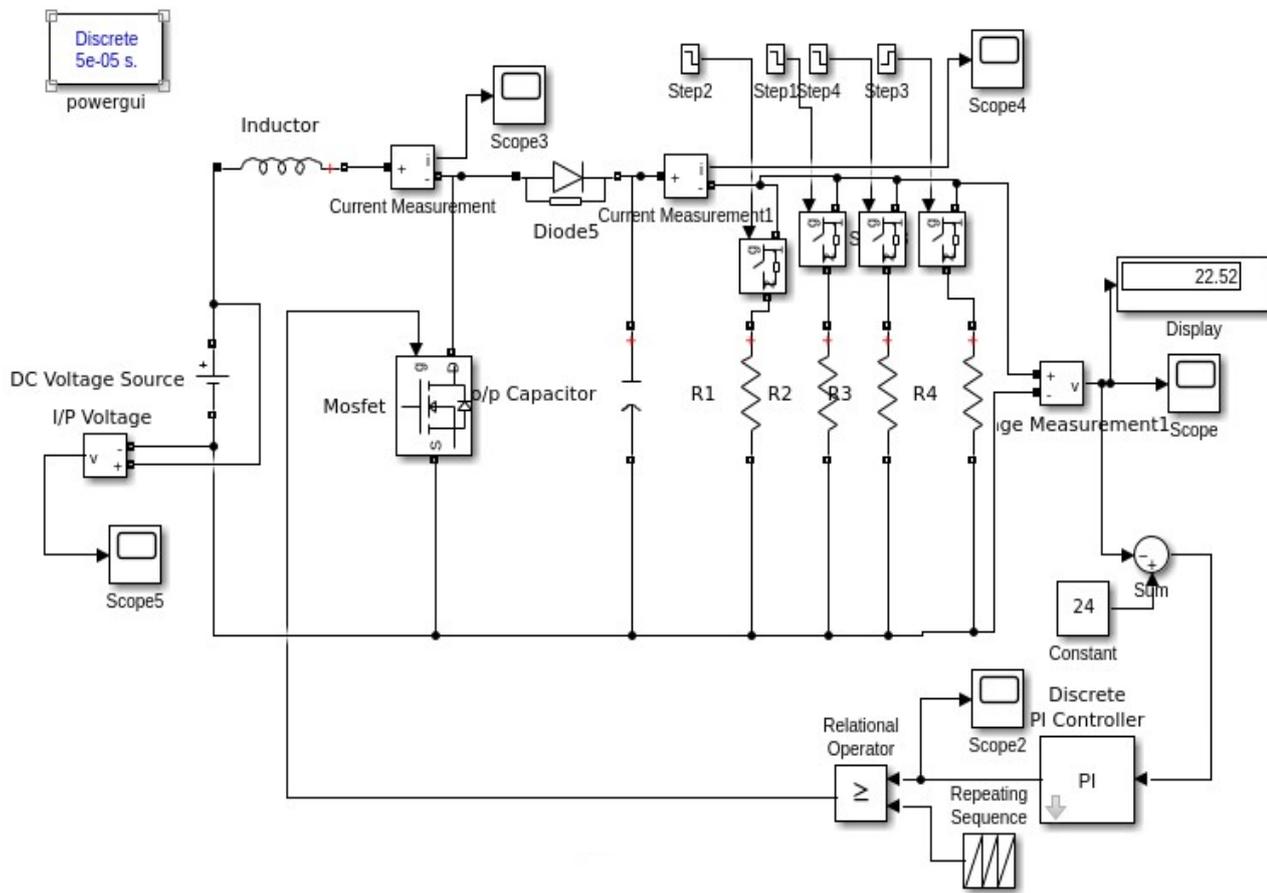## 9.3 At Variable Load

Figure 15

9.4 Result & Waveform at Variable Load
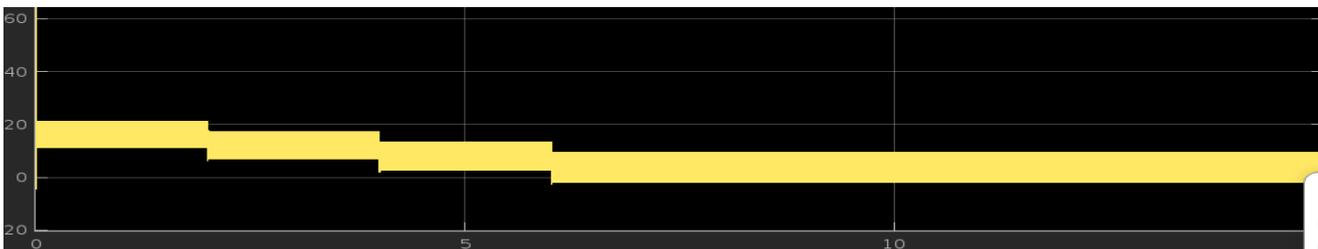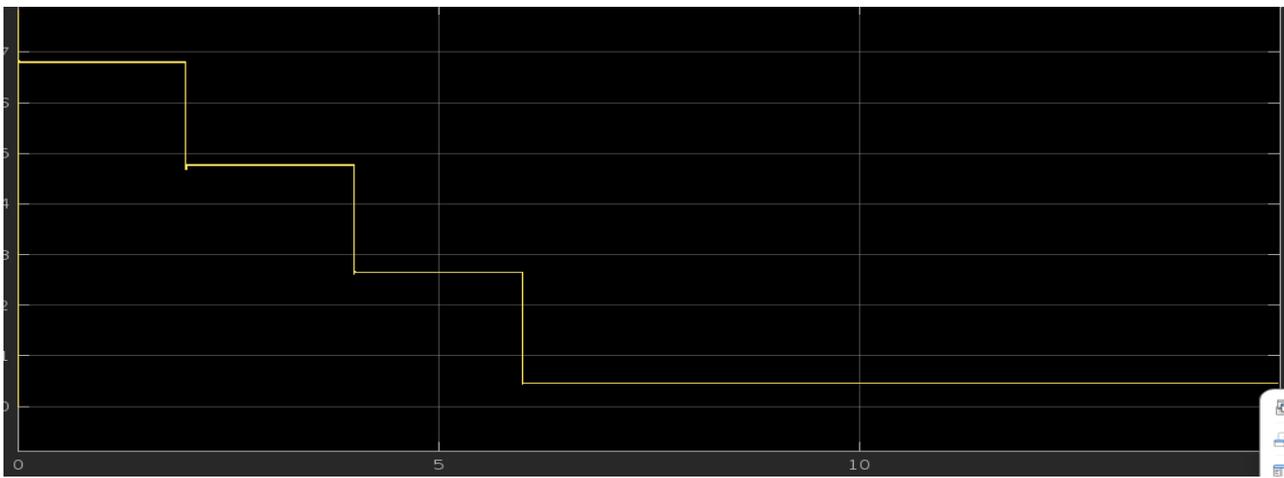

Figure 16. Input Current
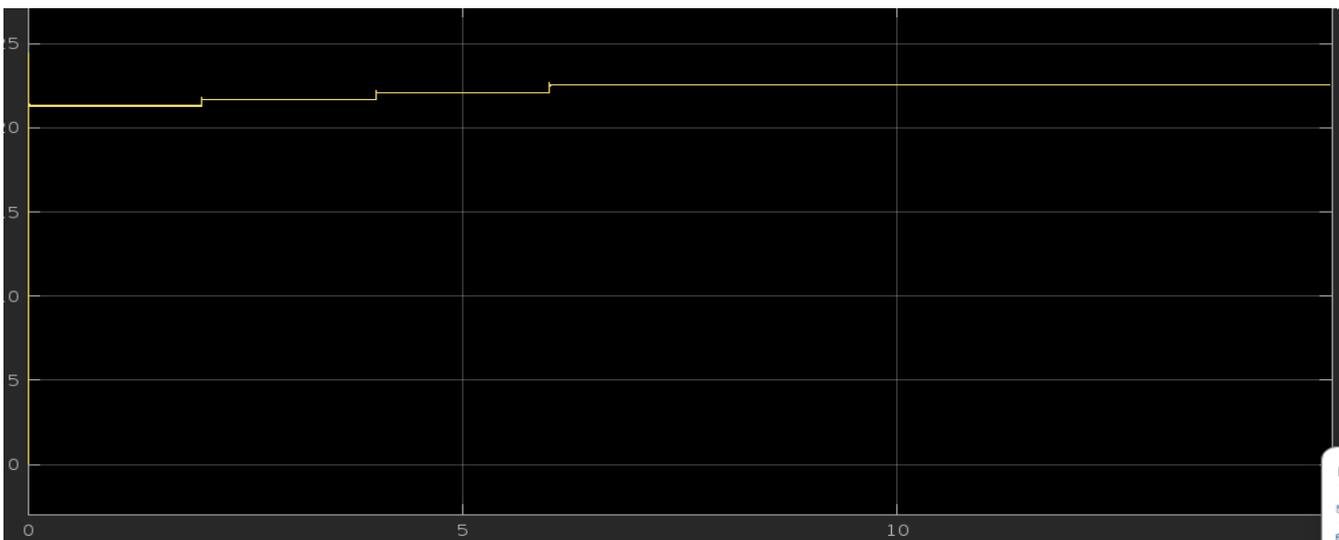
Figure 17. Output Current

Figure 18. Output Voltage

8. Conclusion

In this research, a closed-loop DC-DC boost converter was successfully designed and implemented using the SG3525A PWM controller to step up the input voltage from 9V to 24V. The experimental results demonstrated effective voltage regulation and stable output performance even under varying load conditions. The closed-loop configuration significantly improved both system stability and efficiency. The SG3525A's reliable operation and ease of configuration contributed to optimizing the converter's overall behavior. Future work can focus on enhancing the converter's efficiency and transient response through the adoption of advanced control strategies and soft-switching techniques.

9. Reference

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