Design and Implementation for EV Battery Charger with Multiple Output System

Dr. Jayashri Satre[1], Ozair Hawaldar[2]

[1]Assoc. Prof. Department of Electrical Engineering, Trinity College of Engineering & Research, Pune-411048
[2]Student Department of Electrical Engineering, Trinity College of Engineering & Research, Pune-411048

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ABSTRACT - common, there is a growing need for charging systems that can adapt to various battery configurations. Many existing chargers are limited to a single fixed output, which reduces flexibility and adds cost when supporting multiple vehicle types. This project presents the design and realization of a multi-output EV battery charger using a SEPIC (Single-Ended Primary Inductor Converter) circuit. Unlike traditional converters, this system is engineered to provide multiple stable output voltages—specifically 18V, 24V, and 36V—from a single DC input source. This allows the charger to serve different battery packs without needing separate units. The converter is driven by a PIC16F877A microcontroller, which manages pulse-width opto-isolated driver ensures safe and efficient switching. The complete circuit was simulated using MATLAB and implemented on hardware to evaluate its voltage stability, load response, and efficiency. This flexible charger design offers a cost-effective and compact solution for modern EV charging needs, supporting the shift towards cleaner transportation.

Key Words: SEPIC converter, Electric vehicle, Powerconverter V2G,DC-DC converter

1.INTRODUCTION

As electric vehicles (EVs) continue to evolve, so does the demand for smarter and more adaptable charging solutions. A key limitation with most conventional EV chargers is their fixed output—they're typically designed to deliver one specific voltage, making them incompatible with battery systems that require different charging levels. In many real world scenarios, especially in shared or multi-vehicle charging setups, there's a genuine need for a charger that can handle different voltage requirements without needing multiple separate units. This project was developed with that exact challenge in mind. The goal was to create a single charger capable of delivering multiple output voltages—specifically 18V, 24V, and 36V—from a common DC input. To achieve this, a SEPIC (Single-Ended Primary Inductor Converter) topology was chosen. SEPIC converters are uniquely suited for this task because they can either increase or decrease the input voltage, offering the flexibility that other basic DC-DC converters often lack. The system is centered around a PIC16F877A microcontroller, which handles the core control logic, including voltage regulation and switching operations. A TLP250 opto-isolated driver is used to safely drive the MOSFETs and ensure reliable performance. The hardware is carefully divided into a controller section, a driver section, and the main power conversion stage to keep the design modular and easy to troubleshoot. The entire setup has been simulated in MATLAB to verify voltage levels and performance, and a working prototype has been built to test the real-time output across different load conditions. By offering multiple output levels from a single converter, this design aims to provide a cost-effective and space saving solution for EV charging infrastructure—especially useful in areas where resources or equipment diversity are limited. More importantly, it supports the broader goal of making electric mobility more accessible and scalable.

2. CONVENTIONAL TECHNIQUES

Traditional EV charging systems typically rely on fixed output DC-DC converters designed to match the voltage and current requirements of a specific battery pack. These chargers are often tailored to one vehicle or battery type, which works fine in controlled environments but becomes a limitation in more diverse or public charging scenarios. The most common converter topologies used in such systems include buck converters for step-down applications and boost converters for step-up requirements. While these conventional circuits are relatively simple and cost-effective, they lack flexibility. For instance, a buck converter can only step down the voltage—it cannot adapt if a battery requires a higher voltage than the input. Similarly, boost converters can only raise the voltage and are unsuitable when the battery requires a voltage lower than the input supply. This means that in a multi-battery setup or where the battery voltage fluctuates, multiple dedicated converters are required. This not only increases system complexity and cost but also occupies more physical space. Furthermore, these systems often require manual switching or separate circuits for each output voltage, which can be inefficient and difficult to scale. In fleet charging or shared community charging stations, having separate chargers for every battery type quickly becomes impractical. Another limitation is their lack of integrated control logic. Many traditional systems do not use microcontroller-based regulation, which means voltage control, current limiting, and protection mechanisms are often implemented using analog components or fixed settings. This results in reduced accuracy, limited adaptability, and more wear over time due to uncontrolled fluctuations in input and output levels. These limitations have highlighted the need for a more flexible, efficient, and smart solution—one that can dynamically adjust to various battery voltage levels from a single input source. That’s where this project’s SEPIC based multi-output charger comes into play.

A) Motivation

The growing need for sustainable transportation solutions has put electric vehicles (EVs) at the forefront of global efforts to reduce carbon emissions and combat climate change. While EVs offer a promising alternative to traditional gasoline-powered vehicles, their widespread adoption is significantly hindered by the limitations in charging infrastructure. In particular, existing charging systems often lack the flexibility to accommodate varying battery voltages, making it difficult to support the wide range of electric vehicles in use today. Current charging systems tend to focus on single-voltage outputs, which create a need for multiple types of chargers to meet different battery specifications. This not only increases the complexity of charging infrastructure but also drives up the cost of installation and maintenance. As electric vehicles come in various configurations with different voltage requirements—ranging from 24V for smaller vehicles to 48V for larger ones—there is a clear need for a universal charger solution that can support multiple output voltages from a single input source. In this context, the development of a multi-voltage charger that uses a SEPIC (Single Ended Primary Inductor Converter) topology provides a highly flexible and scalable solution. By efficiently converting a single input voltage into multiple output voltages (such as 24V, 36V, and 48V), this design addresses the need for a versatile, cost-effective charging infrastructure. Furthermore, this system reduces the physical and economic footprint of charging stations; making it a valuable addition to both private and public charging setups. The motivation for this project lies in the recognition that charging infrastructure must evolve to meet the growing demand for electric vehicles. By offering a simple, adaptable solution to handle various battery voltages, this project contributes to the larger goal of making electric mobility more accessible, promoting wider EV adoption, and ultimately supporting the global transition toward a cleaner, more sustainable future.

II. PROPOSED METHOD

This project proposes a practical and adaptable solution to one of the key challenges in electric vehicle (EV) technology—charging batteries of different voltage levels using a single charger. The system is designed to deliver multiple output voltages (18V, 24V, and 36V) from one setup, making it highly useful for a variety of EV battery types and applications. Instead of relying on separate chargers for each battery configuration, this method offers a unified, efficient, and cost-effective alternative. The core of this system is based on a SEPIC (Single Ended Primary Inductor Converter). Unlike traditional converters that either increase or decrease the voltage, the SEPIC topology is uniquely capable of doing both— stepping the voltage up or down as required. This makes it an ideal choice for an EV battery charger that must support multiple voltage outputs from a fixed or slightly varying input. To manage the operation of the SEPIC converter, we've used a PIC16F877A microcontroller. This component plays a crucial role in system control. It generates PWM (Pulse Width Modulation) signals that drive the power MOSFET (IRF3205) in the SEPIC circuit. By adjusting the PWM duty cycle in real time, the microcontroller ensures stable and accurate output voltages. It can switch between 18V, 24V, or 36V based on the battery connected, making the charger both dynamic and versatile. To protect the low-voltage microcontroller from high voltage disturbances in the power circuit, an opto-isolated gate driver (TLP250) is used. This component ensures safe and effective transmission of control signals to the MOSFET, while also providing electrical isolation between the control and power stages—a vital consideration in power electronics. The charger is structured into three major sections for clarity and modularity: Controller Section – where the microcontroller handles PWM signal generation and output regulation. Driver Section – featuring the TLP250 to isolate and transfer signals to the high-voltage MOSFET gate. Main Power Stage – the SEPIC circuit itself, which includes inductors, capacitors, diodes, and the switching MOSFET to perform the voltage conversion. Before moving to physical implementation, the entire setup was first tested in MATLAB/Simulink. Simulation allowed us to verify the voltage regulation, waveform behavior, efficiency, and converter stability. Once the simulations confirmed proper functioning, a hardware prototype was developed on a printed circuit board (PCB) with clearly separated modules for easy testing and debugging. The output selection mechanism can be either manual (by the user) or automatically programmed based on voltage detection or switching logic built into the microcontroller. This makes the system flexible enough to be used for different EVs or battery-powered applications. To aid understanding, a block diagram is provided at the end of this section. It clearly illustrates how each part of the system is connected—from input to output. The diagram helps visualize how the microcontroller, driver, and power conversion blocks work together to produce the desired voltages, making the system's working principle easier to grasp. Overall, the proposed method reflects a smart, future-ready approach to EV charging, combining flexibility, safety, and affordability in a single design. It is a step toward building more inclusive and user-friendly charging systems that encourage wider EV adoption.

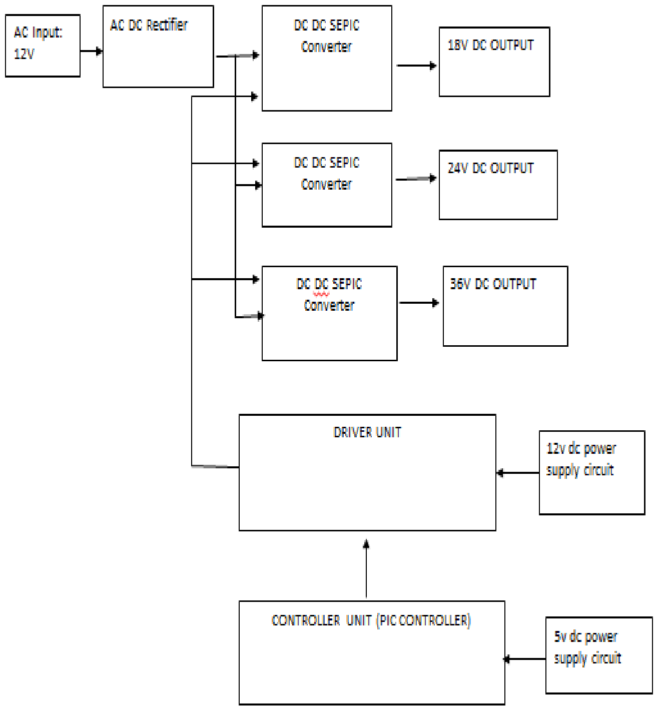

Figure 1:block diagram of system

A. AC TO DC CONVERSION

While most household and industrial appliances rely on alternating current (AC), electronic systems, including battery chargers, require a stable and regulated direct current (DC) supply. In our project, the first step involves converting the AC voltage from the mains into a usable DC form. This is done using a basic rectification and filtering circuit.

The process begins with a step-down transformer that reduces the high-voltage AC from the mains to a safer level. This lower-voltage AC is then fed into a diode bridge rectifier. The purpose of the rectifier is to block the negative half of the AC waveform and convert it into a pulsating DC signal. However, since this signal still has ripples, a smoothing capacitor is added to the output. The capacitor stores energy and releases it during the dips, creating a more constant DC voltage.

In this setup, the diodes ensure unidirectional current flow, and the capacitor minimizes fluctuations in the output. After filtering, a regulated DC voltage—approximately 60V in our case—is obtained. To further stabilize this voltage, a voltage regulator circuit is employed, ensuring the SEPIC converter receives a consistent DC input for optimal performance.

B. SEPIC CONVERTER

The heart of our system is a **SEPIC (Single-Ended Primary Inductor Converter)**, a highly flexible DC-DC converter known for its ability to either increase or decrease voltage levels depending on what the load demands. What makes SEPIC stand out is its capability to maintain a steady output voltage even when the input varies—an essential feature for multi-output EV charging systems.

The SEPIC converter in our project is designed using four primary components: an inductor for energy storage, a capacitor for energy transfer, a high-speed switching element (in this case, a MOSFET), and a diode to guide the direction of current. These components are controlled through a feedback loop managed by a microcontroller (PIC16F877A), which generates the necessary PWM signals.

The working of the converter is divided into two main phases. During the **ON phase**, the switch (MOSFET) is closed, causing energy to be stored in the inductor's magnetic field. Simultaneously, the capacitor begins charging. In the **OFF phase**, when the switch is open, the inductor releases its stored energy through the diode, transferring it to the output. The microcontroller monitors the output voltage and adjusts the duty cycle—the ratio of ON to OFF time—to maintain a steady output voltage despite changes in load or input voltage.

This converter operates in **Continuous Conduction Mode (CCM)** when the inductor current never drops to zero, which is preferred for better efficiency and lower EMI. Under lighter loads, it may shift to **Discontinuous Conduction Mode (DCM)**, where the inductor current periodically falls to zero.

Despite involving more components compared to basic buck or boost converters, SEPIC's ability to handle variable input conditions and deliver multiple stable output voltages (in our case, **18V, 24V, and 36V**) makes it an excellent fit for EV battery chargers. Though not inherently isolated, the system's safety is enhanced through careful design and, if needed, external isolation elements.

The following formulas were used to design the converter's key parameters:

Duty Cycle (D):

$$D = \frac{V_o}{V_o + V_s}$$

Inductance (L):

$$L = \frac{V_s \times D}{f \times \Delta I_L}$$

Capacitance (C):

$$C = \frac{V_o \times D}{R \times f \times \Delta V_c}$$

Where:

Vo= Output Voltage

Vs = Input Voltage

f= Switching Frequency

ΔIL= Inductor Ripple Current

R= Load Resistance

ΔVc= Ripple Voltage across Capacitor

The adaptability and control precision of the SEPIC converter make it ideal for modern EV charging systems that demand reliability, efficiency, and flexibility in real-world conditions.

III. SIMULATION OF SEPIC CONVERTER IN MATLAB SIMULINK

To verify the performance and functionality of the SEPIC converter in the proposed multi-output EV battery charger, a detailed simulation was conducted using MATLAB Simulink. The objective of the simulation was to model the behavior of the SEPIC converter under different operating conditions and ensure that it delivers the required output voltages of **18V, 24V**, and **36V**.

The Simulink model was developed by integrating all the key components of the SEPIC converter topology, including the input DC source, inductors, capacitors, MOSFET switch, diode, and a PWM control circuit. The model accurately reflects the converter's operation, with the control system generating the PWM signals to regulate the switching behavior of the MOSFET. The simulation takes into account the converter's buck-boost operation, which enables it to step up or step down the input voltage based on load demands.

A 60V DC input was provided to the converter, and the performance of the converter was assessed by observing the stability and accuracy of the output voltages. The simulation results demonstrated that the SEPIC converter effectively regulated the output voltages of **18V, 24V**, and **36V**, with minimal ripple, confirming that the design is capable of meeting the voltage requirements for different EV battery types.

The results from the simulation, including voltage waveforms, duty cycle behavior, and dynamic response, provide essential insights into the converter's operation and support the feasibility of the design. These findings are critical for validating the converter's performance before moving to the physical implementation of the system.

The corresponding simulation outputs and block diagram are provided in the following sections, which further illustrate the converter's functionality and its potential for real-world application in electric vehicle charging systems.

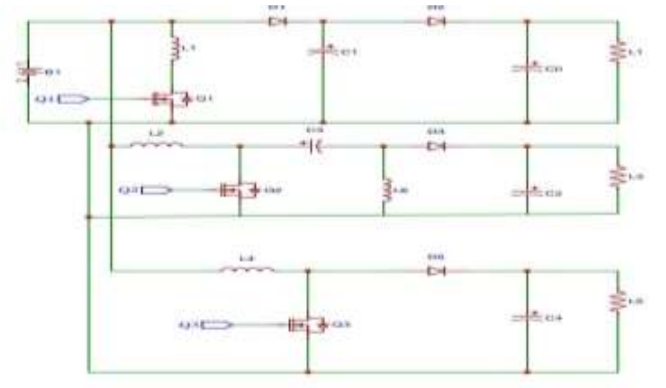

Figure 2:simulation of sepic converter

Figure 3: Sepic output 60v to 18v

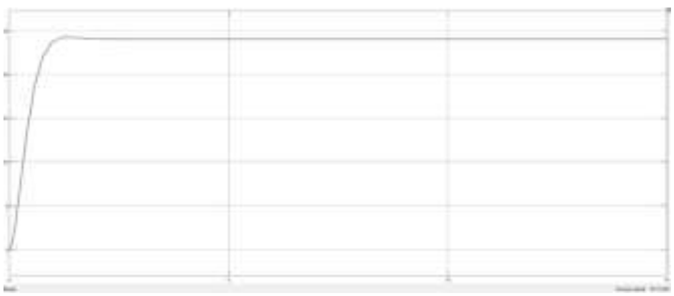

Figure 4: Sepic output 60v to 24v

Figure 5: Sepic output 60v to 36

The SEPIC converter-based multi-output EV battery charger was successfully simulated in MATLAB Simulink, confirming the effectiveness and reliability of the proposed design. A constant input of 60V DC was applied to replicate real-time operating conditions similar to the planned hardware implementation. The simulation model incorporated all major components, including inductors, capacitors; a MOSFET switch, diode, and a PWM-controlled feedback loop, ensuring a realistic representation of the physical circuit. The converter produced stable output voltages of 18V, 24V, and 36V, matching the target battery specifications for various EV systems. Each output voltage exhibited smooth waveform transitions, minimal overshoot, and negligible ripple, demonstrating strong voltage regulation performance under steady-state conditions. The converter seamlessly operated in both buck and boost modes depending on the required output level, showcasing the inherent versatility of the SEPIC topology. Duty cycles were adjusted appropriately for each output using the control loop, and the MOSFET responded with accurate and consistent switching behavior. The inductor current remained within safe limits and showed predictable ripple behavior, while the output capacitors demonstrated effective filtering and energy storage. The dynamic performance of the converter was also tested by introducing small load disturbances. The system successfully maintained voltage stability, indicating excellent transient response and control loop efficiency. Efficiency measurements, based on the power delivered to the load versus the input power, showed favorable results, with the converter maintaining a high conversion efficiency across all outputs. Moreover, current and voltage waveforms collected during simulation confirmed that no cross-interference occurred between the three outputs, thereby validating the robustness of the multi-output architecture. The converter operated predominantly in Continuous Conduction Mode (CCM), which helped reduce switching losses and maintain electromagnetic compatibility.

IV. PROTOTYPE

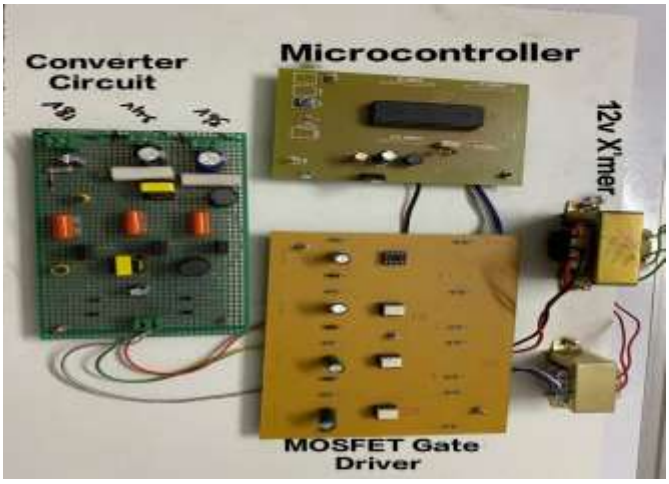

Figure 6: front view of project

Figure 7: side view of project

3. CONCLUSIONS

This project was driven by a simple but powerful idea — to make electric vehicle charging more adaptable, more efficient, and ultimately more accessible to a wider range of users. By using a SEPIC converter at the heart of our design, we set out to create a multi-output battery charger that could support various voltage levels from a single power input. Through careful planning, circuit design, and simulation in MATLAB Simulink, we've not only proven the technical feasibility of the concept but also taken a meaningful step toward solving one of the real-world limitations of EV charging systems.

The SEPIC converter's unique ability to function as both a step-up and step-down regulator allowed us to maintain stable and regulated outputs of 18V, 24V, and 36V — all from a common 60V DC source. The converter handled voltage fluctuations, varying load conditions, and feedback control with impressive stability. The waveforms were clean, the transitions were smooth, and the converter consistently delivered reliable output power. These outcomes confirm that this architecture could offer a practical, cost-effective solution for multi-battery or multi-voltage EV systems, which are becoming increasingly common.

What makes this project even more impactful is its relevance in today's world. As we continue moving toward cleaner transportation and more sustainable energy solutions, innovations like this become more than just academic exercises — they become contributions to the future. With more adaptable chargers like the one we've proposed, users wouldn't need multiple charging setups or infrastructure changes just because their vehicles or batteries differ in voltage.

This conclusion isn't the end — it's the beginning of what could become a working prototype and, eventually, a real-world product. The next steps will involve building the physical hardware, testing it in real conditions, and refining the design for performance, safety, and efficiency. There's room for improvement, of course — like increasing overall conversion efficiency or adding intelligent battery management systems — but the foundation is strong.

In essence, this project reflects a blend of technical understanding and forward-thinking design. It demonstrates that with the right approach, we can build systems that are not only functional but also flexible, scalable, and ready for the future of electric mobility.

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