DC-DC Converter Solution for Uninterrupted Air-Conditioning

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Declaration

We affirm that all the effort and information in this thesis, except for mosaic plagiarism, are our own. Additionally, this thesis was not submitted to obtain a new professional certification.

Signed: ______________________

Signed: ______________________

Date: 22-07-2023

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This project is dedicated to our dear parents, whose sacrifices and prayers enabled us to complete it. We also dedicate our effort to our society to help reduce pollution and climate change caused by global warming.

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Abstract:

The investigation of creative solutions that make use of renewable energy sources has been motivated by the rising need for uninterruptible power supply in air-conditioning systems. This project presents a DC-DC boost converter solution created to supply air conditioning systems with a steady and uninterrupted power source. The initiative seeks to overcome the drawbacks of conventional power sources and advance sustainability by utilizing renewable energy sources, such as solar photovoltaic (PV) arrays.

The DC-DC Buck-Boost converter, which effectively transforms lower input voltages from renewable energy sources to the higher output voltage required by the air conditioning system, is the main part of the suggested solution. The converter assures compliance with the voltage needs of the air conditioning system with a target output voltage of 360 volts. To fulfil the power requirements of the air-conditioning system, the converter is also built to deliver a steady current of 10 Ampere.

The DC-DC boost converter is built into a PCB (Printed Circuit Board) as we go into the prototype stage. The prototype is made to increase input voltages between 12 and 60 volts. To provide the best performance and safety, the PCB layout and component choice are thoroughly thought out. The prototype efficiently transforms the input voltage, which ranges from 12 to 60 volts. Additionally, it provides a constant 5 Ampere output current.

The project includes several important components. A thorough literature research and evaluation of existing solutions served as the foundation for the choice and design of the DC-DC boost converter. The input voltage range, output voltage range, maximum current, efficiency, and cost-effectiveness are all considered. A thorough process is created, covering hardware setup, component selection, system design, and implementation.

The implementation and experimentation phase includes extensive testing and assessment. The DC-DC boost converter system consists of a converter, a PV array, and an air conditioning system. The system is tested for stability, efficiency, and reliability as well as for voltage control, current supply, and the ability to maintain an uninterrupted power supply during both normal operation and power outages. Experimental data is obtained, reviewed, and compared against the project's objectives to gauge the implementation's effectiveness

Chapter # 1

Introduction

1.1 Background and Significance:

1.1.1 Background:

Air conditioning systems are crucial to provide comfort in homes and commercial buildings. However, traditional air conditioning units use a lot of energy, which results in high power costs and carbon emissions. On the other hand, solar systems are gaining popularity as a substitute energy source for running different appliances, such as air conditioners. However, the need for a dependable and effective DC-DC converter solution that can convert the DC voltage generated by the photovoltaic system into the required voltage to power the air conditioning system is one of the main issues with using photovoltaic systems to power air conditioning systems.

1.1.2 Significance:

The planned project is important for several reasons. Its primary objective is to create a DC-DC converter system that effectively and dependably powers air conditioners using a solar system. By reducing the energy use and carbon dioxide emissions produced by traditional air conditioning systems, this approach may result in considerable financial savings as well as environmental advantages. To determine the benefits and constraints of the proposed solution, the project also seeks to compare the performance of the proposed solution with other approaches already in use for powering air conditioning systems using solar systems and DC-DC converters. Finally, the initiative may help promote study and development in the fields of green power and environmentally friendly construction practices.

1.2 Objective and scope:

1.2.1 Objectives:

- The development of a unique DC-DC Buck-Boost converter that can effectively and consistently power an air conditioning system using a solar system.
- To determine the suggested DC-DC Buck-Boost converter system's efficiency, dependability, and economics.
- To evaluate how well the suggested solution performs in comparison to other options for using solar systems and DC-DC converters to power air conditioning systems.

1.2.2 Scope:

- The project's main objective is to design and create a DC-DC converter system that can convert the DC voltage produced by the solar system into the necessary voltage to power the air conditioning system.
- The research project will involve an analysis of the available literature on solar systems, air conditioners, and DC-DC converters.
- The project will involve simulations and experiments to evaluate the performance of the proposed solution and compare it with existing solutions.

1.3 Overview of the Project:

With the help of a photovoltaic system and a DC-DC converter, our project's innovative DC-DC converter solution seeks to deliver continuous air cooling throughout the daytime without the need for batteries. The solar panel may provide a steady supply of DC electricity during the day that can be utilized to power the air conditioner.

In hot areas, air conditioning usage is a substantial source of energy consumption. The project's objective is to use solar energy directly to reduce energy usage while maintaining continuous air conditioning.

Solar energy is transformed into DC electricity by the photovoltaic system to produce power. The DC-DC converter receives the produced power and adjusts the voltage to make sure it is safe to use for air conditioning.

The voltage of the electricity may also be changed by the DC-DC Buck-Boost converter to meet the air conditioner's power requirements. Regardless of changes in the solar energy intake, this function makes sure that the power output is steady and appropriate for the air conditioner.

This project's capacity to maintain air conditioning while consuming the least amount of energy is an interesting feature. A sustainable and effective energy future is made possible through the utilization of renewable energy sources like photovoltaic systems, which lessens reliance on traditional energy sources.

In conclusion, this project intends to deliver continuous air conditioning without the need of batteries by utilizing a photovoltaic system and a DC-DC converter. With this approach, energy consumption is decreased, and the use of renewable energy sources is encouraged, paving the way for a sustainable and effective energy future.

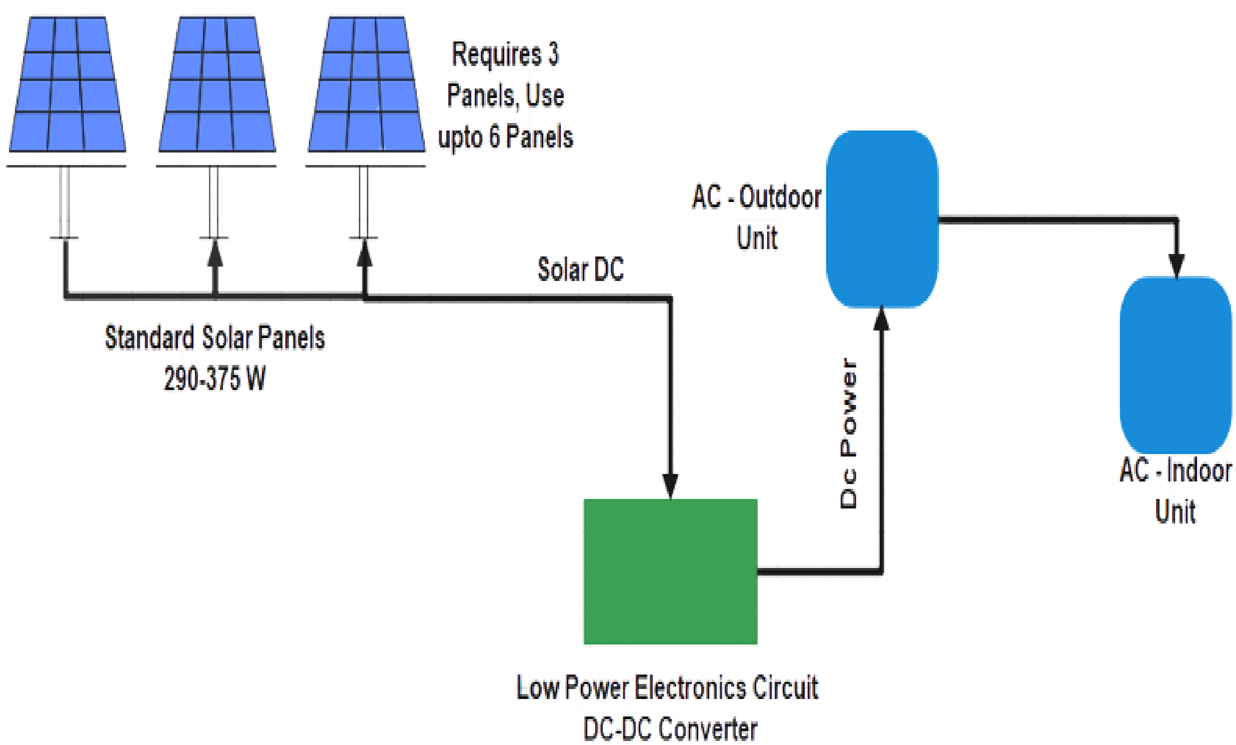


Fig # 1: Overview of Project

Chapter # 2

2.1 Motivation

2.1.1 Addressing energy efficiency concerns:

Air conditioning systems use a lot of energy, and there is an increasing need desire to reduce energy use to address environmental issues. Making a DC-DC converter solution for continuous air conditioning with a solar system might assist lower energy use and improve the energy efficiency of air conditioning systems.

2.1.2 Meeting the demand for uninterrupted power supply:

Uninterrupted power supply is critical for air-conditioning systems, especially in areas with unreliable power grids. Developing a solution that can ensure uninterrupted air-conditioning with a photovoltaic system could meet this demand.

2.1.3 Providing cost-effective solutions:

There is a need to create cost-effective solutions that can lower the overall running expenses of conventional air-conditioning systems because they can be expensive to operate. For continuous air conditioning with a solar system, an inventive DC-DC converter technology might perhaps offer a cost-effective solution.

2.2 Problem Statement

The usage of conventional air conditioning systems has resulted in high utility prices and energy consumption. In addition, air conditioning disruptions can be caused by power outages and variations in energy supply, particularly in areas with unstable power networks. The objective of this project is to create a DC-DC converter that works without batteries to provide continuous air conditioning. The suggested converter would ensure steady and dependable performance even during times of low solar radiation by converting DC power from the photovoltaic panels into the appropriate DC voltage for air conditioning using a buck-boost architecture. Designing a converter that can function over a broad variety of input voltages and produce a steady DC voltage suited for air conditioning loads is the key problem. For the converter to be a practical option for general usage, it must also be small, effective, and affordable. The unique difficulties in developing the converter can be covered in more detail in the problem statement. A few of these include.

i. **Wide Input Voltage Range:** The level of solar radiation will have a significant impact on the converter's input voltage. Over a wide variety of input voltages, the converter must be able to function effectively and maintain a consistent output voltage.

ii. **Constant DC Output Voltage:** DC voltage must be steady for air conditioning loads to function properly. Under a variety of load circumstances, the converter must be built to deliver a consistent output voltage.

iii. **Efficiency:** The converter must be built with efficiency in mind so that it may function with a smaller solar array and run at a lower cost as a whole.

iv. **Size and Cost:** For the converter to be a practical option for general usage, it must be small and reasonably priced.

In addition, solar energy is used to make DC power. We convert DC electricity into AC power using an inverter. The rectifier converts the AC voltages required to operate the compressor and air conditioner motor into DC voltages in a DC inverter air conditioner. All conversions result in a great deal of losses, including those related to power, iron, copper, and other materials. By creating a DC-DC Converter for the Low Power Electronic Circuit of an Air Conditioner, we lower the losses. The goal of this project is to develop and build a solar and direct current (DC) air conditioning system.

A thorough grasp of DC-DC converter topologies and control strategies will be necessary to meet these problems. Using simulation tools, the suggested buck-boost converter topology may be improved, and experiments can validate it. All things considered, we are aware that the suggested DC-DC converter solution can deliver continuous air conditioning with lower energy usage, costs, and environmental effects.

2.3 Literature Review

2.3.1 Photovoltaic (PV) Systems:

Solar panels are used in PV systems to turn sunlight into energy. Within solar cells, photons (light particles) and electrons interact to produce the process. Electric current is produced when sunlight strikes the solar panel and may be utilized to power electrical loads. There are several types and configurations of PV systems, including thin-film, monocrystalline, and polycrystalline ones. They may be used to power a wide range of things, including tiny devices, enormous structures, and even whole towns. Due to its cleanliness, sustainability, and abundance, solar power systems are a well-liked renewable energy source.

2.3.2 DC-DC Buck-Boost Converters:

A DC-DC converter known as a "buck-boost" may increase or decrease input voltage based on the demands of the electrical load. It is a practical technique since it effectively adjusts a DC power source's voltage to the voltage needed by the load. Electronics, battery chargers, and LED lights are a few examples of applications that frequently employ buck-boost converters to produce a constant DC voltage. Different topologies, including inverting and non-inverting configurations, and a variety of control techniques, including pulse-width modulation (PWM) and hysteretic control, are available for Buck-Boost converters.

2.3.3 Applications of PV systems and DC-DC Buck-Boost Converters:

Small electronics to huge industrial machines may all be powered by the combination of PV systems and DC-DC Buck-Boost converters. An electric car or an air conditioner, for instance, might be powered by a PV system and a Buck-Boost converter. The Buck-Boost converter adjusts the voltage and makes sure that the power is appropriate for the load after the PV system produces electricity from the sun. In hybrid renewable energy systems like wind and solar systems, PV systems and DC-DC Buck-Boost converters are also utilized to control power production and improve system efficiency. In off-grid applications, such as isolated locations and poor nations, PV systems, and DC-DC Buck-Boost converters are also utilized to give access to energy when the grid is unavailable.

2.4 Identification of the Research Gap

The lack of an effective and trustworthy DC-DC buck-boost converter solution for air conditioning systems that integrate with a photovoltaic system to provide uninterrupted air conditioning supply is the research gap that our project, "Innovative DC-DC buck-boost Converter Solution for Uninterrupted Air-Conditioning with a Photovoltaic System," seeks to fill.

They have used DC-DC buck-boost converters and solar systems independently up to now, but there is a void in the literature about the combined use of both technologies for supplying an uninterruptible supply of air conditioning. In addition, "nobody has ever been able to raise the voltage of a buck-boost converter to such a high level and maintain it steady by controlling it, regardless of how much variance there is in the input voltage, prior to our project. But the output voltage will be regulated by our circuit. Therefore, the goal of our study is to close this gap by creating an inventive solution that can successfully combine both technologies to deliver a constant supply of air conditioning, which can lower power prices and minimize carbon emissions.

Chapter # 3

3.1 Proposed Approach

3.3.1Introduction:

Over the past few years, there has been a sharp increase in the demand for a steady power supply, notably for equipment used for air conditioning. In this situation, using DC-DC converters to provide a reliable power source for air-conditioning systems is a realistic solution. In this project, our goal is to develop a DC-DC converter that will allow for continuous air conditioning.

3.3.2 Buck-Boost Converter Topology:

Because it can step up or step down the input voltage to the necessary output voltage level, the buck-boost converter architecture is perfect for this project. To control the output voltage, this design employs two switches (MOSFETs), an inductor, a capacitor, and a diode. The inductor, which stores energy when the switch is on and releases it when the switch is off, is used to regulate the flow of current through the device using switches. The capacitor is used to tame and lessen waves in the output voltage. The diode is used to stop the passage of the reverse current.

3.3.3 Design Concerns for the PCB:

There are a few factors to consider while designing the PCB for the buck-boost converter. First, it's important to carefully consider the components' sizes, shapes, and locations to make sure they suit the given space and do not conflict with one another.

Second, resistance and inductance, which can result in power loss and have an impact on the converter's efficiency, must be minimized in the input and output traces' routing design. To reduce resistance and inductance, it is crucial to keep the input and output traces short and broad.

Thirdly, the PCB design depends greatly on the component selection. The circuit's MOSFETs, diodes, inductors, capacitors, and resistors must be able to handle the converter's high voltage and current demands. To reduce power loss and increase efficiency, it is also crucial to use components with low equivalent series resistance (ESR) and equivalent series inductance (ESL).

Fourth, to protect the converter from any defects like overcurrent, overvoltage, or overheating, safety circuits must be included in the PCB. Overcurrent protection, overvoltage protection, and thermal protection circuits are a few examples of protective circuits.

Fifth, suitable grounding is essential for the circuit's functionality and stability. All ground connections should be kept short and broad, and the ground planes should be constructed to minimize resistance and inductance.

Sixth, since the circuit's high current and voltage may produce a lot of heat, adequate thermal control is crucial. Heat sinks, thermal vias, and other cooling strategies can be used to achieve this.

Seventh, the PCB should be carefully tested and verified to make sure it complies with the necessary requirements before the design is finalized. Simulations, prototyping, and testing under actual settings can all be used to achieve this.

3.3.4 MOSFETs vs. Transistors:

MOSFETs have been selected over transistors for this project because they provide several benefits. MOSFETs are more efficient and produce less heat than transistors because they have a lower on-resistance. They can operate more quickly and efficiently since they also have faster switch speeds. In addition, MOSFETs are more robust and long-lasting than transistors.

3.3.5 Design and Analysis of Buck-Boost Converter for PV Array:

Consider the following diagram of a traditional DC-DC Buck-Boost converter.

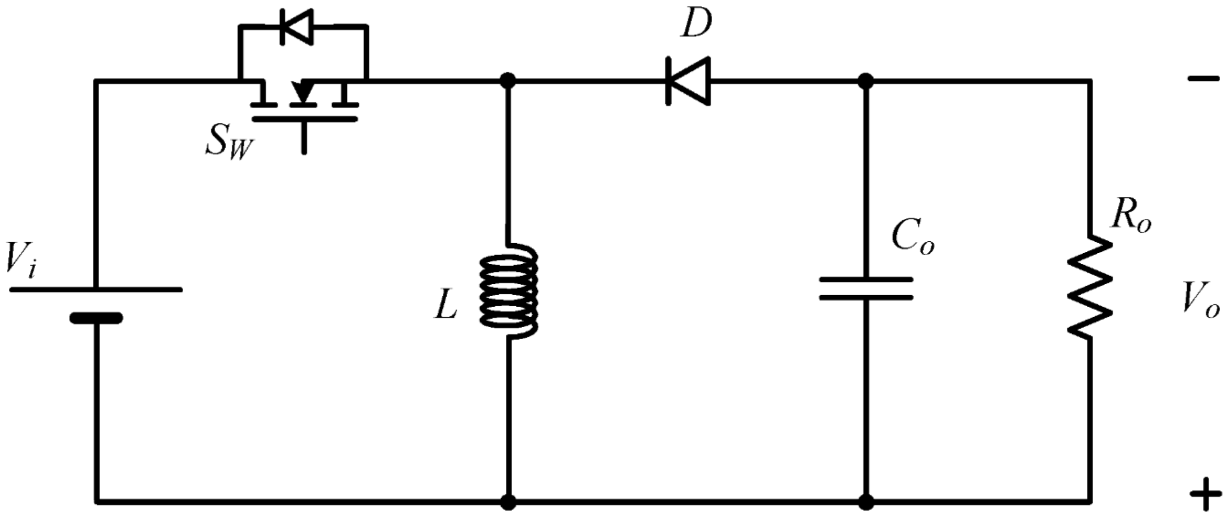


Fig # 2: Circuit Diagram Buck-Boost Converter

Conventional DC-DC Buck-Boost converter:

These equations are used to compute the duty ratio, inductor, and capacitor values in the traditional buck-boost converter.

- Duty Ratio $\frac{-V_0}{-V_0+V_I}$
- Inductor $\frac{V_I \times D}{\Delta I_L + f_s}$

  Where $\Delta I_L = (0.2 - 0.4) \times \ I_L$

  $$I_L = \frac{I_0}{1 - D}$$
- Capacitor $\frac{I_0 \times D}{\Delta V_0 \times f_s}$

Because the input voltage is constant in traditional designs and the rated power and desired output voltage are usually known we can readily compute the values of loud resistance, load current, and duty ratio by plugging input & output voltage values into these equations. As a result, inductor and capacitor values may be easily computed in a traditional circuit.

3.3.6 Buck Boost converter connected to PV Array:

Now consider a photovoltaic system in which the PV array is connected to a buck-boost converter.

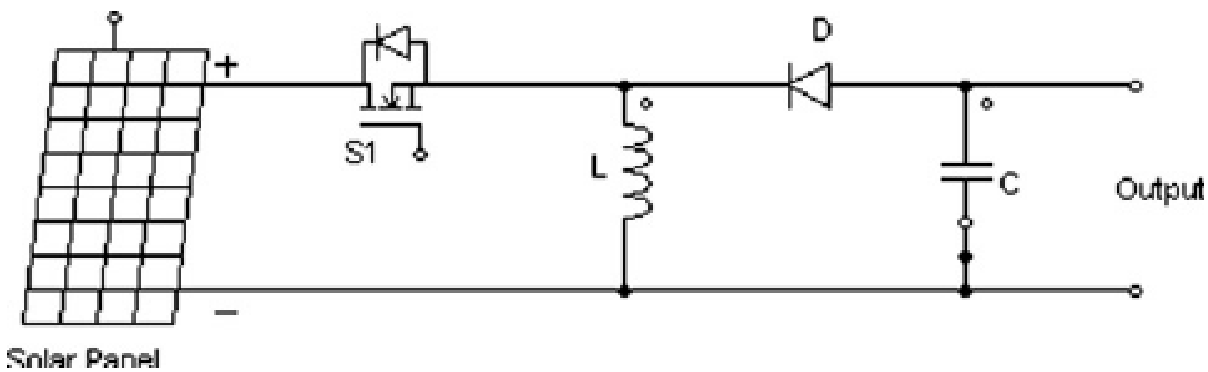


Fig # 3: Buck-Boost Converter with PV

- Because the value of array power and voltage vary from 0 watts to maximum power.
- And 0 volt to open circuit voltage the value of buck-boost converter input voltage is not fixed or constant.
- As a result, the output voltage is also not constant.
- And the value of a duty ratio fluctuates furthermore due to the variable supply of power from the PV array.

The value of load resistance and load current cannot be determined even if the duty ratio is known as a result traditional buck-boost converter equations cannot be utilized to design the parameters of a PV system. For example, C_1, C_0, L, R_0.

Although there is no standard procedure for designing buck-boost converters for photovoltaic systems. Engineers usually design converters through a trial-and-error method.

In this chapter, I will show you how to design buck-boost converter parameters for photovoltaic systems using a systematic method.

3.3.7 Design of Buck-Boost converter for Photovoltaic system:

The **first step** in designing a buck-boost converter is to assess the PV array specification and understand and test conditions that are 1000 watts per meter square and 25-degree centigrade as well as worst-case conditions such as 50 watts per meter square and 25-degree centigrade.

I mean the preceding remark that understanding the specifications of the photovoltaic (PV) array that will supply power to the converter is the first stage in developing a buck-boost converter for a solar system. The intensity of sunlight falling on the PV cells, which is commonly expressed in terms of irradiance in watts per square meter (W/m2), and the temperature of the cells are the two main characteristics to consider.

The standard testing conditions (STC) for PV cells are 1000 W/m2 irradiance and a cell temperature of 25 degrees Celsius (°C). These settings indicate the best working conditions for the cells and are used to compare different PV modules.

However, it's crucial to build the converter to function not just in the best circumstances, but also in the worst ones, including low irradiance levels that might happen on low or overcast days. The statement lists 50 W/m2 irradiances and 25°C cell temperature among the worst-case scenarios. To maintain a constant supply of electricity to the load, the converter must be able to function well even under dim lighting.

Therefore, to ensure that the buck-boost converter can successfully convert the variable input voltage from the solar panel into a stable and regulated output voltage, we must understand the specifications and characteristics of the PV cells and modules that will be used in the system as well as the anticipated operating conditions.

The following values for standard testing conditions are used in this project.

- Maximum Power is 3600W (P_{mps})
- Maximum Power Voltage is 106V (V_{mps})
- Maximum Power current is 33.8A (I_{mps})

Where S means the standard test condition. These parameters can be obtained from the datasheet of a PV module and then scaled to the size of the PV array.

Using standard testing condition values, we can calculate corresponding values for the worst-case scenario. 50 watts per meter square is 5 percent of a thousand watts per meter square.

- W/m^2 is 5% (0.05) of $1000W/m^2$.

Hence, maximum power for the worst case.

$$P_{mpw} = 0.05 \times \ P_{mps}$$

$$P_{mpw} \ = \ 0.05 \times 3600$$

$$P_{mpw} = 180 watts$$

Because irradiance changes have little effect on the value of array voltages in principle. The maximum power voltage in the first case V_{mpw} will be in the 90% to 110% range of V_{mps}. In this case I will assume that V_{mpw} equal 0.9 times V_{mps}.

$$V_{mpw} = 0.9 \times \ V_{mps}$$

$$V_{mpw} = 0.9 \times 106.5$$

$$V_{mpw} = 96.85V$$

The maximum power current for the worst case.

$$I_{mpw} = \frac{P_{mpw}}{V_{mpw}}$$

$$I_{mpw} = \frac{180}{95.85}$$

$$I_{mpw} = 1.88A$$

The **second step** is to define the buck boost converter switching frequency which is set at 25 kilohertz in this circuit.

- Switching frequency (f_s) : 25kHz

The ripple in current and voltage are also specified the voltage ripples for the converters input and output voltages are designed by ΔV_I and ΔV_0 respectively and are equivalent to 0.2% of the input and output voltages.

- $\Delta V_I = 0.2\%\ of\ V_{mp}$
- $\Delta V_0 = 0.2\%\ of\ V_0$

ΔI_L is the ripple in the inductor current waveform and is chosen as 4% of the inductor average current I_L which can be calculated using this equation.

- $\Delta I_L = 4\%\ 0f\ I_L = \left|\frac{I_0}{1-D_{mp}}\right|$

The **third step** is to determine the PV arrays internal resistance at MPPT which is indicated as R_{mp} and equals V_{mp} and I_{mp}.

PV arrays internal resistance at MPPT:

- $R_{mp} = \frac{V_{mp}}{I_{mp}}$

This number is determined for both standard testing conditions and worst-case scenario.

$$R_{mps} = \frac{V_{mps}}{I_{mps}}$$

$$R_{mps} = \frac{106.5}{33.8}$$

$$R_{mps} = 3.2\Omega$$

R_{mps} equaling 3.2 Ω.

$$R_{mpw} = \frac{V_{mpw}}{I_{mpw}}$$

$$R_{mpw} = \frac{95.85}{1.88}$$

$$R_{mpw} = 51\Omega$$

R_{mpw} equaling 51Ω respectively.

The **fourth step** is to determine the value of the load resistance R_o. Which is equal to 0.2 times R_{mps} and 1.25 times R_{mpw}.

$$R_0 = \left(0.2 \times R_{mps}\right) + (1.25 \times R_{mpw})$$

$$R_o = (0.2 \times 3.2) + (1.25 \times 51)$$

$$R_o = 64.4\ \Omega$$

The value of R_o is 64.4Ω.

The value of the duty ratio at MPPT presented by D_{mp} and given by 1 divided by sum of 1and square root of R_{mp} by R_0.

Duty-ratio:

$$D_{mp} = \frac{1}{1 + \sqrt{R_{mp}/R_o}}$$

The **fifth step** is also determined Duty-Ratio for both standard and worst-case scenario.

$$D_{mps} = \frac{1}{1 + \sqrt{R_{mps}/R_o}}$$

$$D_{mps} = \frac{1}{1 + \sqrt{3.2/62.4}}$$

$$D_{mps} = 0.8177$$

Worst case scenario

$$D_{mpw} = \frac{1}{1 + \sqrt{R_{mpw}/R_o}}$$

$$D_{mpw} = \frac{1}{1 + \sqrt{51/_{64.4}}}$$

$$D_{mpw} = 0.5291$$

Load voltage:

Calculate load voltage and current values at MPPT in the **sixth step**.

V_o stands for load voltage and is calculated by using equation for both standard and worst conditions.

$$V_{os} = \frac{-V_{mps}}{\frac{1}{D_{mps}} - 1}$$

$$V_{os} = \frac{-106}{\frac{1}{0.8177} - 1}$$

$$V_{os} = -360V$$

For worst condition

$$V_{ow} = \frac{-V_{mpw}}{\frac{1}{D_{mpw}} - 1}$$

$$V_{ow} = \frac{-95.85}{\frac{1}{0.5291} - 1}$$

$$V_{ow} = -107.7V$$

Load Current:

I_o stands for load current and is calculated by using equation for both standard and worst conditions.

$$I_{os} = \frac{V_{os}}{R_o}$$

$$I_{os} = \frac{-360}{47.96}$$

$$I_{os} = -7.5A$$

For Worst Condition

$$I_{ow} = \frac{V_{ow}}{R_o}$$

$$I_{ow} = \frac{-107.7}{64.4}$$

$$I_{os} = -1.67A$$

The values of Inductor current ripple, Ripple voltages and ripple current are determined in this **seventh step** as follows.

- Inductor Current (I_L)
- Ripple Voltages ($\Delta V_I, \Delta V_o$)
- Ripple Current (ΔI_L)

Inductor current for Standard testing Condition:

$$I_{LS} = \left|\frac{I_{os}}{1 - D_{mps}}\right|$$

$$I_{LS} = \left|\frac{-7.42}{1 - 0.8177}\right|$$

$$I_{LS} = 40.7\ A$$

Ripple voltage for worst test condition:

$$\Delta V_{\boldsymbol{Iw}} = 0.002 \times V_{mpw}$$

$$\Delta V_{\boldsymbol{Iw}} = 0.002 \times 95.85$$

$$\Delta V_{\boldsymbol{Iw}} = 0.1917\ V$$

Output Ripple voltage for worst condition:

$$\Delta V_{\boldsymbol{ow}} = |0.002 \times V_{ow}|$$

$$\Delta V_{\boldsymbol{ow}} = |0.002 \times (-107.7)|$$

$$\Delta V_{\boldsymbol{ow}} = 0.2154\ V$$

Inductor current for worst testing Condition:

$$I_{Lw} = \left|\frac{I_{ow}}{1 - D_{mpw}}\right|$$

$$I_{Lw} = \left|\frac{-1.67}{1 - 0.5291}\right|$$

$$I_{Lw} = 3.55\ A$$

Ripple Current:

$$\Delta I_{\boldsymbol{Lw}} = 0.4 \times I_{Lw}$$

$$\Delta V_{\boldsymbol{Lw}} = 0.4 \times 3.55$$

$$\Delta V_{\boldsymbol{Lw}} = 1.42\ V$$

In the final and **8th step** the following equations are used to compute the values of input capacitor, inductor, and output capacitor of the buck boost converter.

$$C_{input} = \frac{I_{LS} \times D_{mps}}{8 \times \Delta V_{IW} \times f_s}$$

$$C_{input} = \frac{40.7 \times 0.8177}{8 \times 0.1917 \times 25000}$$

$$C_{input} = 868\ \mu F$$

For Output Capacitor:

$$C_{output} = \frac{I_{oS} \times D_{mps}}{8 \times \Delta V_{oW} \times f_s}$$

$$C_{output} = \frac{-7.42 \times 0.8177}{8 \times 0.2154 \times 25000}$$

$$C_{output} = 141\ \mu F$$

For Inductor:

$$L = \frac{V_{mps} \times D_{mps}}{2 \times \Delta I_{LW} \times f_s}$$

$$L = \frac{106.5 \times 0.8177}{2 \times 1.42 \times 25000}$$

$$L = 1.23\ mH$$

These equations yield input capacitor, inductor, and output capacitor values of $868\ micro\ farad$, 1.23 milli Henry, and $141\ micro\ farad$ respectively. These figures can be rounded up to make them more practical. So, the buck-boost converter final design parameters are:

- $C_{input} = 1000\ \mu F$
- $C_{output} = 150\ \mu F$
- $L = 1.3\ mH$
- $R_o = 64.4\ \Omega$
- $f = 25000\ Hz$

Conclusion:

In conclusion, the proposed approach for this project is to design a buck-boost DC-DC converter that can provide an uninterrupted power supply to air-conditioning systems. The design considerations for the PCB must be considered to ensure optimal performance and reliability of the converter. Additionally, MOSFETs have been chosen over transistors due to their advantages in terms of efficiency, speed, and durability. The goal of this project is to create an efficient and reliable DC-DC converter solution that can provide uninterrupted power to air-conditioning systems, even when the power supply is unstable or prone to interruptions.

Chapter # 4

4.1 Hardware Selection/ Brief Hardware Working

4.1.1 PV-Arrays:

The PV system that was chosen for the project has a maximum voltage of 80 volts, a maximum current of 33.8 amps, and a maximum output power of 2700 watts. Several solar panels are linked in series and parallel to provide the necessary voltage and current. The DC-DC Converter input is connected to the photovoltaic system. This generates a switch voltage and switch current that change according to the amount of sunlight.

4.1.2 Air Conditioner:

The split-type air conditioner chosen for the project requires 10 amps of power and a regulated voltage of 360 volts to work. To obtain a regulated DC voltage and current, the air conditioner is linked to the output of the DC-DC buck-boost converter. The compressor, condenser, evaporator, and fan are some of the parts that make up the air conditioner. To chill the air, the compressor compresses the refrigerant and then pumps it through the condenser and evaporator. Cooled air is blown into the room by the fan.

4.1.3 DC-DC Boost Converter:

An effective converter that can step up the input voltage to boost the output voltage is the DC-DC Boost Converter. It is made up of a controller, a diode, a capacitor, a switch, and an inductor. To manage the output voltage, the inductor stores energy during switch-on and releases it during switch-off. The output voltage and duty cycle are adjusted by the controller by regulating the switch. During the switch-off interval, the diode gives the inductor current a route. The capacitor is used to filter the output voltage and lessen ripples. To maintain the required voltage, the controller monitors the output voltage and modifies the switch duty cycle.

Initially, the project was going to use a Buck-Boost converter, however problems that arose during the hardware development stage convinced the team that the Boost converter would be a better option. Compared to the Buck-Boost converter, the Boost converter has fewer parts and is typically simpler to build and test.

A switch, a diode, an inductor, a capacitor, and an integrated feedback loop make up the Boost converter. Mathematical formulae are used to compute the values of these components depending on the required output voltage, output current, and output frequency. Any project requiring the design and building of a system or device must carefully consider the hardware that will be used. To guarantee that the parts can carry out the necessary functions and satisfy the specifications, careful selection is important. The report will provide comprehensive details on the hardware selection process, including the components chosen and their intended uses.

A boost converter (or step-up converter) circuit can be used when there is a requirement to raise the output voltage when the input voltage is low. A switching DC-DC converter is used to increase the voltage while preserving a steady power balance. Efficiency is the key characteristic of a boost converter.

The well-known TL494 integrated circuit will be used in this project to calculate, test, and construct a high-efficiency boost converter circuit. The TL494 may be supplied with voltages as low as 7V and as high as 40V. Additionally, by using the IRFP250 MOSFET as a switch, the circuit can support a maximum current of 19 Amps.

4.2 Understanding the Boost Converter's Operating Mechanism

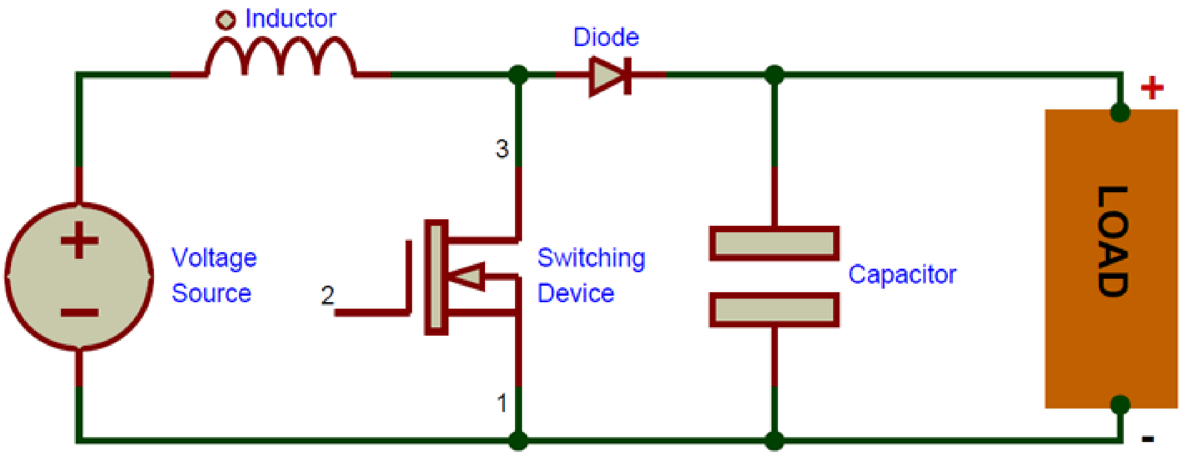


Fig # 4: Boost Converter Basic Diagram

The boost converter circuit's basic idea is depicted in the above image. We may split this circuit's operation into two categories based on the MOSFET's state, when it is ON and when it is OFF.

<u>4.2.1 What happens when the MOSFET is ON:</u>

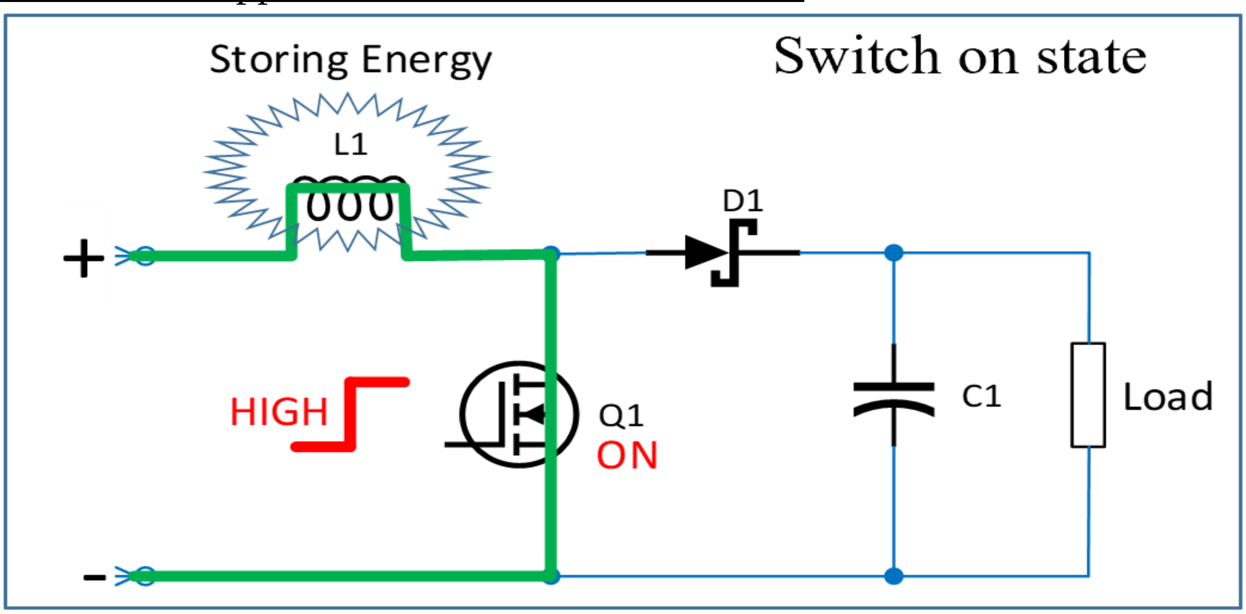


Fig # 5: Boost Converter MOSFET on state 1

The circuit is shown in the up top figure in the MOSFET-ON state, which is indicated by the dashed line. As more current passes through the inductor in this condition, it charges up. Conducting MOSFET makes it possible for this current to flow, which permits the inductor to create a magnetic field that can store energy.

4.2.2 What happens when the MOSFET is Off:

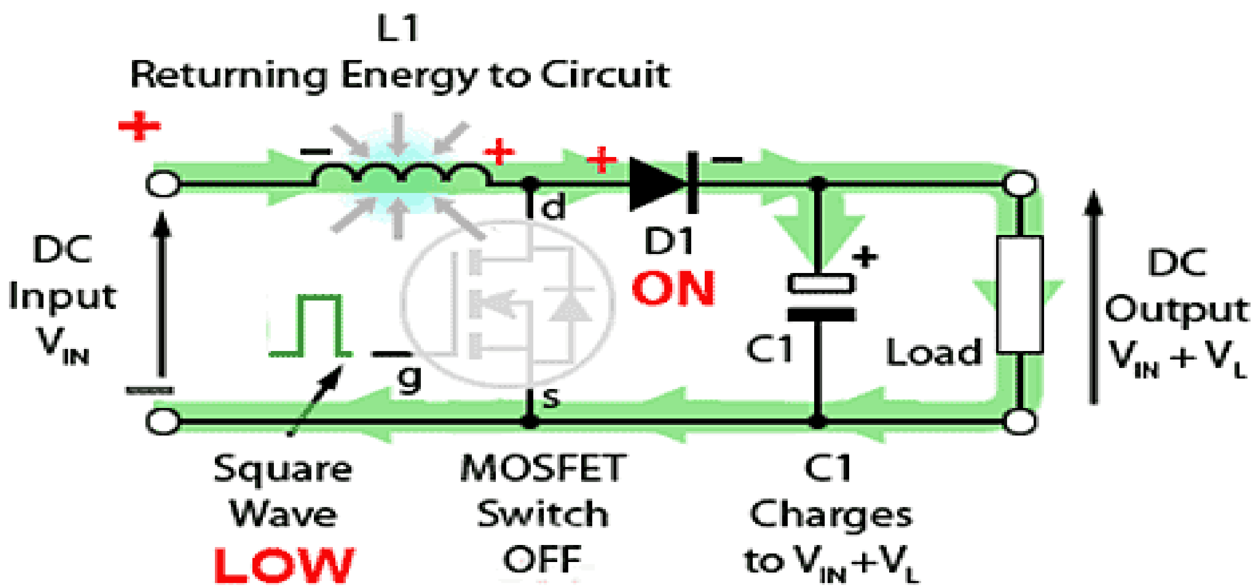


Fig # 6: Boost Converter MOSFET OFF

Because inductor current cannot quickly shift, it may store energy as a magnetic field. The magnetic field reduces when the MOSFET is turned off, which allows the current to flow in the other direction and charge the capacitor. We create an output voltage greater than the input voltage by repeatedly turning the MOSFET on and off. By altering the MOSFETs' on and off periods in the main circuit, the output voltage may be regulated.

4.3 Understanding how the TL494 operates.

It is important to know how the TL494 PWM controller works before starting to develop a circuit that uses it. There are 8 functional blocks in the TL494 IC, each of which impacts the device's operation in a different way. Let's look more closely at these useful basic segments.

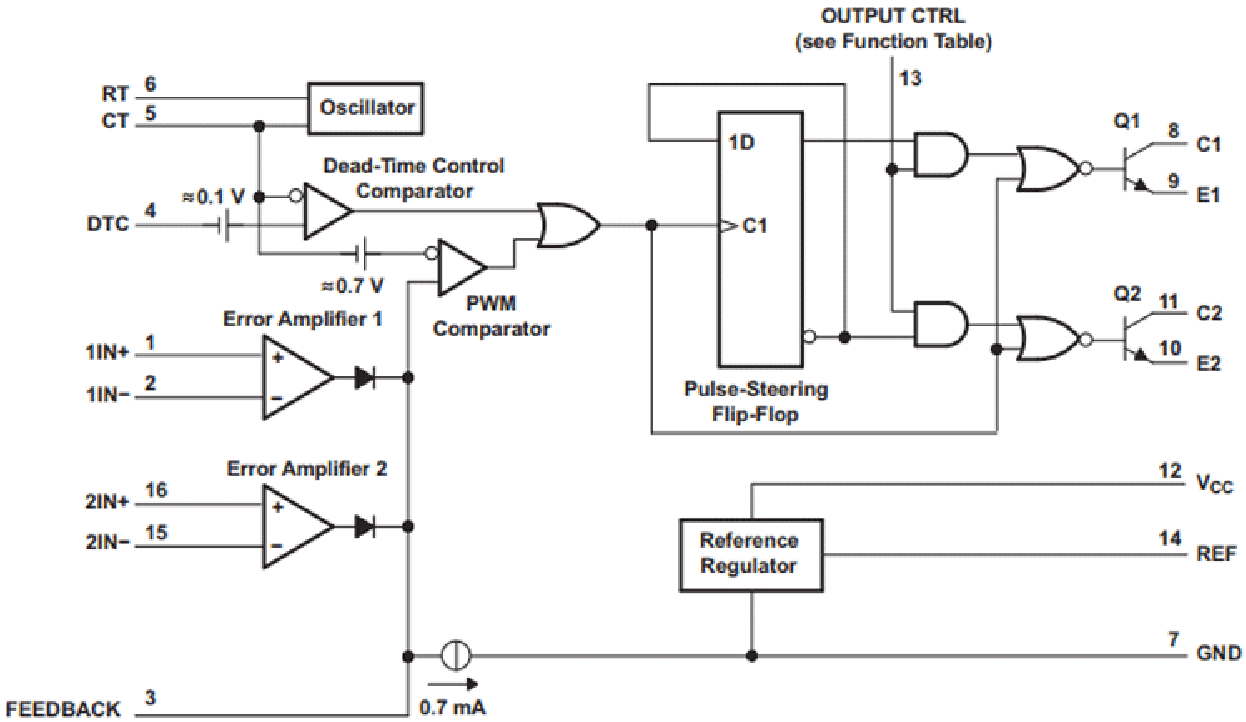


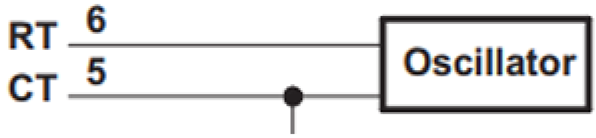
Fig # 7: TL494 Function's Diagram

4.3.1 5-V Reference Regulator:

The output of the internal 5V reference regulator is located on pin 14 of the TL494 IC, sometimes referred to as the REF pin. This regulator directs delivering a steady current to the oscillator, dead-time control comparator, PWM comparator, pulse-steering flip-flop, and reference regulator itself, among other internal components of the IC. Furthermore, this reference

regulator serves as the drive for the error amplifiers, which are essential for controlling the output. The reference regulator's job is to maintain stability over a broad input voltage range of 7V to 40V. Internally, it is predetermined to have a 5% initial accuracy. In addition, the regulator saturates when the input voltage is less than 7V and 1V above its maximum value, and it monitors the input voltage otherwise.

4.3.2 Oscillator:

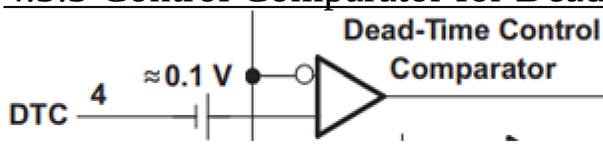


The oscillator produces a sawtooth waveform that is used by the TL494 IC's numerous control signals. It offers this waveform to the dead time controller and PWM comparators. Modifying the timing elements RT and CT will change the oscillator's frequency.

The formula below may be used to calculate the oscillator's frequency:

$$F_{osc} = \frac{1}{(RT * CT)}$$

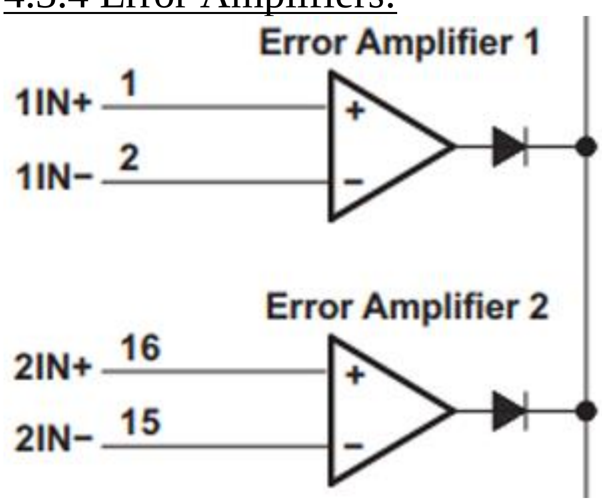
4.3.3 Control Comparator for Dead - Time:



The TL494 IC's dead time control function enables modification of the circuit's minimum amount of dead time or off-time. When the input voltage exceeds the oscillator's ramp voltage, this control turns off the switching transistors. We may add dead time ranging from 3% to 100%, corresponding to an input voltage range of 0V to 3V, by supplying a voltage to the DTC (Dead Time Control) pin. It's crucial to remember that the dead time control functions independently of the error amplifiers and offers a way to change the output waveform's duty cycle without influencing the way the error amplifiers behave.

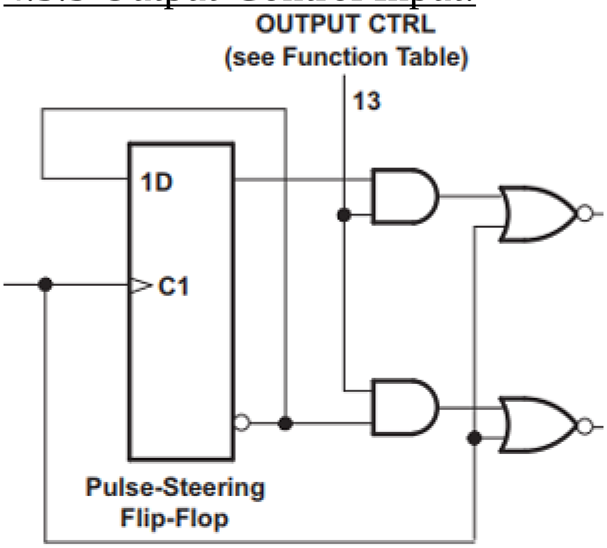
Note: Additionally, when the dead-time control input is grounded, a minimum dead time of 3% is guaranteed due to an internal offset of 110 mV.

4.3.4 Error Amplifiers:



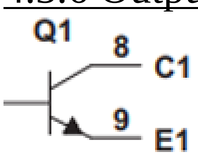
The high-gain error amplifiers of the TL494 IC are biased by the VI supply rail. With the help of this biassing, a common-mode input voltage range between -0.3V and 2V below the VI voltage is possible. The error amplifiers function similarly to single-ended single-supply devices since each output is only active high.

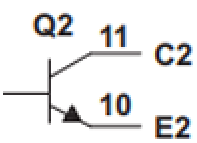
4.3.5 Output-Control Input:



The output control input determines whether the output transistors operate in parallel or push-pull arrangement. The output transistors are switched to operate in parallel mode when the output control pin (pin 13) is connected to the ground. To force the output transistors into push-pull operation, this connection must be made to the 5V-REF pin.

4.3.6 Output Transistors:





Two inbuilt open-collector and open-emitter output transistors are included into the TL494 IC. These transistors have a maximum current sinking or sourcing capacity of 200mA. In the common-emitter design, these transistors have a saturation value of less than 1.3V, and in the emitter-follower configuration, less than 2.5V.

4.4 Required Components of IC TL494 Based Boost Converter Circuit:

- 1x TL494 IC
- 1x IRFP250 MOSFET
- 2x Screw Terminal 5X2 mm
- 4x 220uF, 63V Capacitor
- 1x 50K, 1% Resistor
- 1x 560R Resistor
- 4x 10K, 1% Resistor
- 1x 3.3K, 1% Resistor
- 1x 330R Resistor
- 1x 0.1uF Capacitor
- 1x MBR20100CT Schottky Diode
- 1x 150uH (27 x 11 x 14) mm Inductor
- 2x Potentiometer (10K) Trim Pot
- 2x 0.22R Current Sense Resistor Clad Board Generic 50x 50mm - 1
- 2xPSU Heat Sink Generic

4.4.1 N-channel MOSFET: (Metal – Oxide – Semiconductor Field – Effect Transistor)

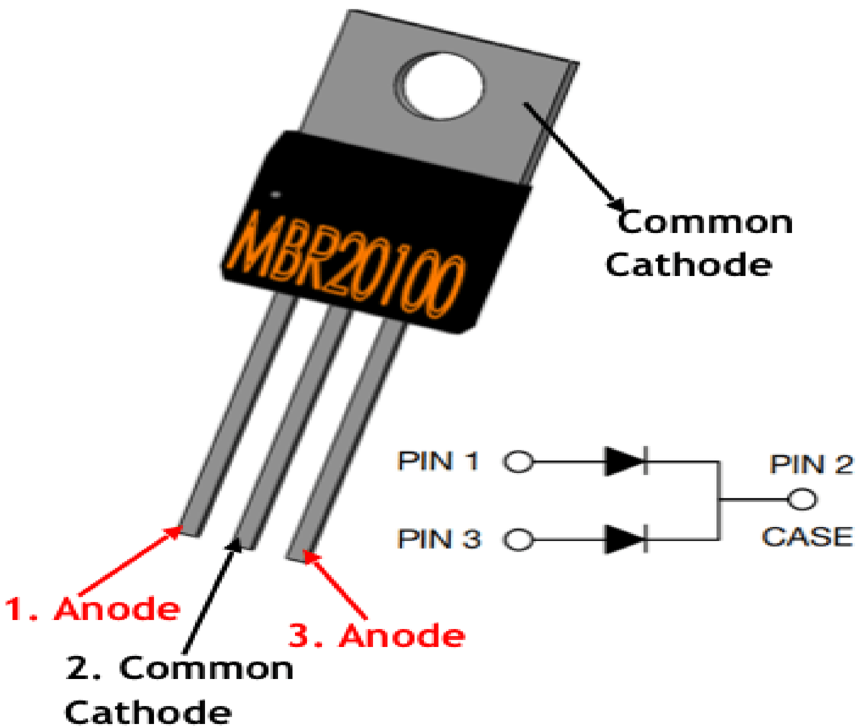
- MOSFET has three terminals: a gate (G), a drain (D), and a source (S).
- It is essential to use the IRFP240, which acts as the switching component. It overall controls both the output voltage and the current flowing through the inductor.

An overview of the MOSFET's function in a boost converter is given below:

1. **Switching Operation:** The MOSFET acts as an electrical switch that swiftly toggles on and off to regulate the flow of power. The conducting ON state and the non-conducting OFF state are its two operational modes.
2. **Voltage Control:** Current can flow from the input source to the inductor when the MOSFET is switched ON. As a result, the inductor's energy is boosted. When the MOSFET turns off, the energy stored in the inductor is released into the load, raising the output voltage.
3. **Control and Efficiency**: The boost converter may control the output voltage by adjusting the switching frequency and duty cycle of the MOSFET. The duty cycle regulates the voltage gain of the converter by determining the ratio of ON time to total switching duration.
4. **Current Handling:** The MOSFET must be chosen depending on its capacity to carry the appropriate boost converter output current. Because it can handle reasonably large currents and is a high-power MOSFET, the IRFP240 is a good choice for applications that call for more potent power levels.

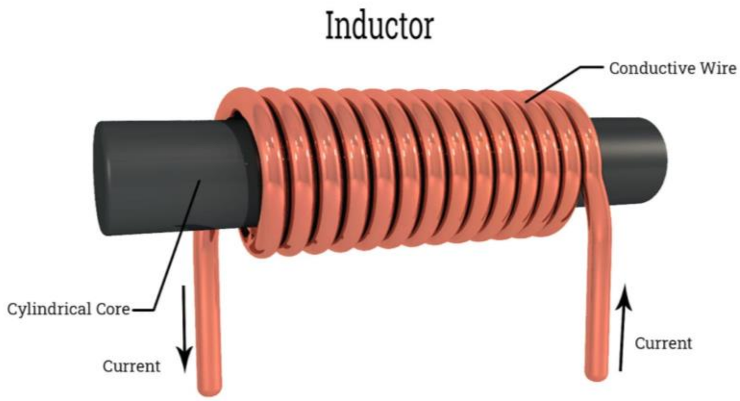
4.4.2 Schottky Diode:

- A diode is a semiconductor device that effectively switches current in a single direction. While significantly limiting current flow in the opposite direction, it permits easy flow in one direction.
- Diodes have a forward bias and a reverse bias.
- The MBR20400 diode is used in this project. The Schottky diode, a semiconductor with low forward voltage drops and quick switching speed, is a kind that includes the MBR20400. Schottky diodes are frequently employed in power electronics applications, such as voltage regulators, power converters, and inverters, where high efficiency and quick switching are crucial. The maximum working temperature of the MBR20400 Schottky diode, which can withstand high current and voltage levels, is 175 °C.



4.4.3 Inductor:

- An inductor, also known as a coil, choke, or reactor, is a two-terminal passive electrical component that stores energy in a magnetic field when a current runs through it.
- In the buck-boost converter, the inductor stores energy when the switch is turned on and releases it when the switch is turned off. For effective energy transmission, the inductor should have a high saturation current and a low DC resistance.

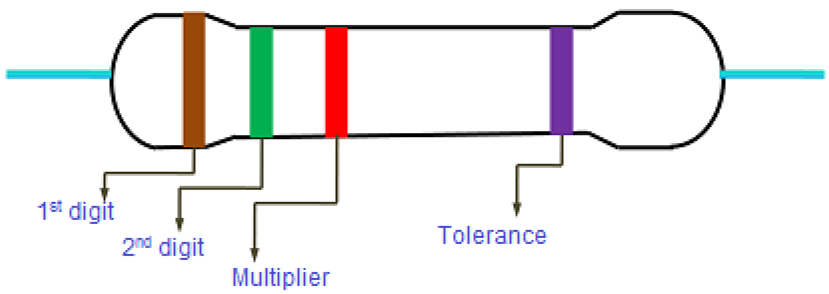


4.4.4 Capacitor:

- In an electrical field, a capacitor is a device that stores electrical energy. It has two terminals and is a passive electrical component.
- The capacitor is used to tame and lessen waves in the output voltage. To reduce power loss and increase efficiency, the capacitor's capacitance should be large and its ESR and ESL should be low.

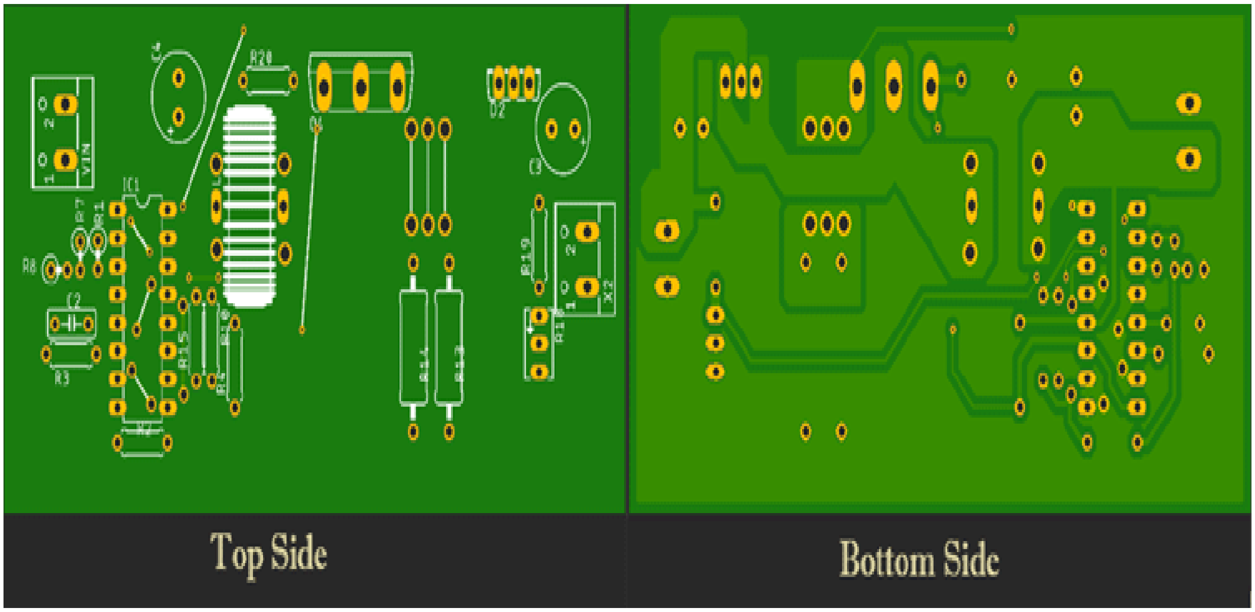
4.4.5 Resistor:

- The circuit uses resistors for voltage division, current detection, and feedback. For precise and dependable functioning, the resistors should have a high-power rating and a low tolerance.

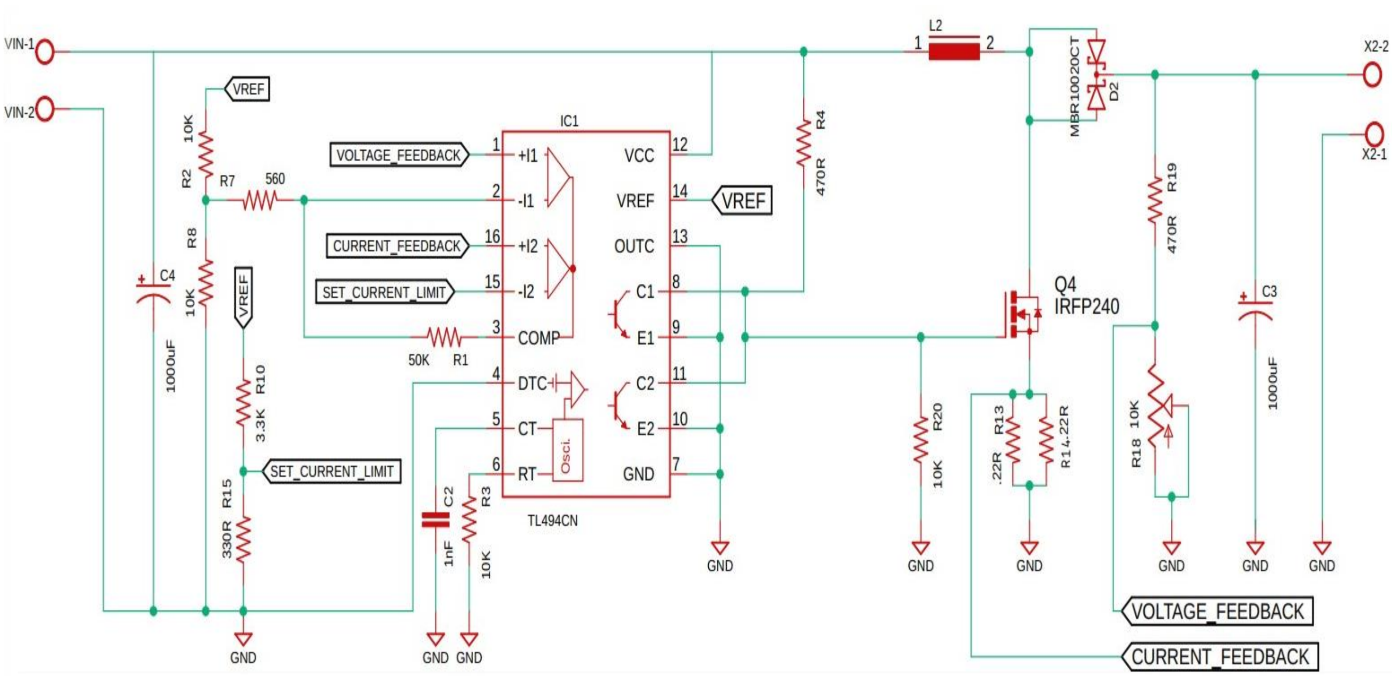


4.4.6 Printed Circuit Board:

- The circuit's components are connected to one another via the PCB. To reduce resistance and inductance and increase efficiency, the PCB should be built with the components' sizes, locations, and routing in mind.



4.4.7 Single line Diagram:



4.5 Brief Hardware Working:

The Boost DC-DC converter maintains a steady output voltage level. The input voltage is applied across the inductor, which stores energy in its magnetic field, when the MOSFET switch is turned on. The magnetic field collapses when the switch is switched off, releasing the energy into the load.

The output voltage is adjusted and held constant, the MOSFET switch is activated, and the inductor stores energy. By combining the input voltage and the voltage across the inductor, the output voltage is computed. The MOSFET switch is disengaged during step-down operation, and the inductor releases its stored energy into the load.

The capacitor dampens and reduces output voltage ripples. Due to the inductor's charging and discharging cycle, the output voltage varies during switching. By storing and releasing energy during the charging and discharging cycles, the capacitor lowers ripples.

A DC-DC boost converter requires an **inductor** as a component. The converter's output voltage is completed by the inductor, which also functions as a filter component. The current and the period the inductor is allowed to function affect how much energy is stored there.

When the switching transistor is switched off, the converter's boost mode stores energy in the inductor. When the transistor is turned on, the stored energy in the inductor is released to the output load. As a result, the output voltage surpasses the input voltage. When the transistor is turned on, the inductor current reduces and increases when it is turned off.

The performance of the converter is significantly influenced by the size of the utilized inductor. The needed output voltage, the converter's switching frequency, and the maximum current that may pass through it are all factors considered when choosing the value of an inductor. A larger inductor results in a smoother output voltage and less ripple current, but it also makes the converter bigger and more expensive.

Finally, a DC-DC boost converter's inductor is essential to its functionality. By storing and transmitting energy between the input and output sides of the circuit, it aids in controlling the output voltage. Based on the requirements and performance of the converter, the inductor value is carefully selected.

The circuit uses a **diode** to stop reverse current flow. The inductor transfers its stored energy to the load when the MOSFET switch is switched off. The diode allows energy to pass from the inductor to the load, but it is unable to return to the input source.

The **resistors** in the circuit are utilized for current sensing, feedback, and voltage division. The control circuit receives feedback from the current detecting resistor, which also measures the inductor current. To keep the output voltage level constant, the feedback resistor monitors the output voltage and modifies the MOSFET switch's duty cycle. The input voltage is decreased by the voltage divider resistor to the necessary level for feedback sensing.

The **PCB** is used to connect all the circuit's components. The size, location, and routing of the components are considered while designing the PCB to reduce resistance and inductance and optimize efficiency. The PCB architecture has a considerable influence on the overall efficacy and dependability of the circuit. To function as effectively and dependably as possible, the PCB must have proper grounding, component placement, heat management, and protective circuits.

Grounding:

The performance and stability of the switch circle depend on proper grounding. All ground connections should be short and wide, and ground plans should be designed to have the least amount of resistance and induction possible. The performance of the converter may be compromised by noise and interference in the circuit, which necessitates grounding reduction.

Component Placement:

It is important to carefully examine the component placement on the PCB to reduce noise and interference. To reduce the traces, high-frequency components like capacitors and inductors should be placed as close as possible to the ICs. Components should be kept apart to prevent the switch circle's ability to handle its heat load from being hampered.

Thermal Management:

Because the circuits' high current and high voltage may generate a lot of heat, effective thermal control is essential. Heat sinks, thermal vias, and other cooling techniques can be used to achieve this. Heat sinks disperse heat from the components, whereas thermal waves carry heat from the PCB to the heat sink. By lowering the temperatures of the components, thermal conduits increase the components' dependability and lifespan.

Protection Circuits:

Protection circuits like overvoltage and overcurrent protection should be implemented to guarantee the circuit's security and longevity. These circuits can assist in keeping the circuit safe and ensure that it operates within acceptable limits. Using a voltage regulator or a Zener diode helps prevent over-voltage. A current-limiting resistor or a fuse can be used to stop over-current.

Chapter # 5

5.1 Implementation and/or Experimentation

5.1.1 Practical Implementation Challenges: There were certain difficulties in putting the Buck-Boost converter into practical. Although the modelling findings indicated positive outcomes, the real prototype fabrication turned out to be more challenging. The hardware configuration grew complicated since the circuit required two MOSFETs and two diodes. It was extremely difficult to synchronize the two MOSFETs' frequencies since it required specialized testing equipment that wasn't easily accessible. Additionally, a sizable input current of around 83.33 Ampere was required for the conversion of 48 volts to a controlled 360 volts. However, it was challenging to supply the converter with the necessary input current because there wasn't a backup power source with such high current capabilities.

5.1.2 Calculation:

Input voltage of the buck-boost converter is 48 volts, and the efficiency of the buck-boost converter is 90%, the calculation for the input current required for an output voltage of 360 VDC and an output of 10A current with an input voltage of 48V would be as follow:

$$\boldsymbol{Output\ Power = Output\ Voltage * Output\ Current}$$
$$\boldsymbol{Output\ Power\ =\ 360V\ \times 10A}$$
$$\boldsymbol{Output\ Power\ = 3600\ watts}$$

$$\boldsymbol{Input\ Power = \frac{Output\ Power}{Efficiency}}$$
$$\boldsymbol{Input\ Power = \frac{3600}{0.9}}$$
$$\boldsymbol{Input\ Power = 4000\ watts}$$

$$\boldsymbol{Input\ Current = \frac{Input\ Power}{Input\ Voltage}}$$
$$\boldsymbol{Input\ Current = \frac{4000}{48}}$$
$$\boldsymbol{Input\ Current = 83.33\ A}$$

5.2 Limitations in Practical Design:

There were several limitations in the Buck-Boost-Converter's practical design that affected how well it performed. One of the biggest drawbacks was the complexity that came with the use of many MOSFETs and diodes in the circuit. Due to the need for precise wiring and connections, the inclusion of these components made it more difficult to build the converter. The converter's overall efficiency and stability were impacted by the inability to precisely synchronize the MOSFETs' frequencies due to a lack of precise measuring tools.

The difficulty in obtaining the requisite voltage output of 360 volts was another important restriction. Practical challenges arose from the need for a larger input current because the available power sources couldn't provide it, making it difficult to adjust the input voltage from 48 volts to 360 volts. As a result, during testing, the prototype could only produce a maximum voltage of 50 volts.

5.2.1 Physical Approach: Several mitigation measures were used to deal with the difficulties encountered during the actual implementation. First, many designs were taken into consideration, such the rise converter, which offered a more straightforward hardware setup while still attaining a sizable voltage rise. The prototype was able to produce a boosted output voltage of up to 50 volts by modifying the design to operate within the constraints of the available input voltage and current. To further maximize the stability and efficiency of the Boost converter within the established restrictions, additional testing and optimization were also carried out. This required optimizing component selection, adjusting the control settings, and guaranteeing correct heat management.

5.2.2 Experimentation: I first utilized the IC 3845 in the PCB design of the boost converter and, through simulation, was able to boost 12 volts to 50 volts with an output current of 5 amps. However, I was unable to produce the anticipated results when I built the prototype using this design. However, I was able to produce the necessary output of 50 volts DC with an output current of 5 Amperes when I created a new prototype utilizing the IC TL494 rather than the IC 3845. This experience made me realize how crucial it is to choose the best IC for a given application and how crucial it is to conduct actual experiments to verify theoretical concepts.

There might be **several reasons** why utilizing the IC 3845 did not result in the expected output of 50 volts whereas using the TL494 IC did. Here are a few such justifications:

i. **Voltage control Capability:** The IC 3845 and TL494 may have different voltage control capabilities. Because of its better voltage regulation potential, the TL494 may be able to maintain the required output voltage of 50 volts more accurately. This might be due to changes in their internal control systems or feedback mechanisms.

ii. **Control Method and Response:** The IC 3845 uses voltage-mode control, whereas the TL494 uses current-mode control, as was previously indicated. The TL494 may have been better able to manage the output voltage and achieve the requisite 50 volts since current-mode control often offers superior dynamic responsiveness and stability.

iii. **Switching Frequency:** The default or customizable switching frequencies of the IC 3845 and TL494 may differ. The switching frequency used can have an impact on the converter's performance, efficiency, and voltage control. It's likely that the switching frequency of the IC 3845 was not appropriate for your unique boost converter design, but the switching frequency of the TL494 was.

iv. **Load control Capabilities:** Different ICs may have varied load control capabilities. The TL494 may have better load regulation properties, allowing it to keep the target output voltage more consistently under varied load situations. This might result in a steadier and more precise 50-volt output voltage.

v. **Component Compatibility:** The boost converter design may have been more compatible with the TL494 integrated circuit. External component selection (inductor, diode, capacitor, etc.) and their values, for example, might have an impact on the overall performance of the converter. The TL494 might benefit from stronger synergy with the selected components, resulting in increased performance and the required output voltage.

Chapter # 6

Future Directions and Conclusions

6.1 Future Improvements:

The Buck-Boost converter's actual application was not without difficulties and restrictions, but it laid the groundwork for later advancements. Utilizing more sophisticated control methods, such as closed-loop feedback systems or pulse-width modulation (PWM), to improve voltage regulation and stability is one possible area for improvement. The MOSFETs might also be controlled more precisely if the requisite measuring tools for exact frequency synchronization were acquired. Additionally, the converter's input current limits may be resolved by investigating alternate power sources or implementing energy storage technologies, such as batteries or capacitors, which would allow the converter to function under a variety of load scenarios. The performance and usefulness of the Buck-Boost converter design would be improved in the future for a wider variety of applications.

To increase the usefulness and adaptability of the Buck-Boost converter design, future research should focus on several development and improvement areas. Increasing the converter's operational range so that it can continue to produce electricity continuously both during the day and at night is a crucial component. The converter's current input source is solar panels, which restricts its use to daylight hours when solar radiation is present.

Future research may explore using energy storage techniques like batteries or backup power systems to overcome this restriction. It would be able to store extra energy produced during the daytime and use it at times of little or no solar irradiation by incorporating these storage devices into the converter design. This would make it possible for the converter to run constantly, supplying electricity without interruption even when it's dark outside or the weather is bad.

When installing a battery system, it is important to carefully evaluate the battery's capacity, charging, and discharging procedures, as well as the implementation of the proper control circuits to regulate the energy flow between the solar panels, converter, and batteries.

6.2 Conclusion:

The DC-DC Boost Converter, which enables the modification of output voltage by stepping up the input voltage, was ultimately determined to be the most effective converter for the project. An inductor, a switch (MOSFET), a diode, a capacitor, and a controller (TL494 PWM controller) are the components of this converter. The output voltage can be controlled because the inductor stores energy during switch-on and releases it during switch-off.

The TL494 IC, IRFP250 MOSFET, capacitors, resistors, inductors, diodes, and other essential components were carefully considered during the hardware selection process. The requisite control and regulatory operations were performed by the TL494 IC, while the IRFP250 MOSFET acted as a dependable switch that could handle the necessary current.

By altering the switch's (MOSFET) on and off periods, it was feasible to build the Boost Converter circuit to produce an output voltage greater than the input voltage. The output voltage control was essential for fulfilling the project's criteria.

In the end, the project's boost converter circuit, which is based on the TL494 PWM controller and has the necessary voltage stepping and regulation capabilities, proved to be an effective and practical solution. The project's overall success and usefulness are influenced by the efficient implementation of this converter.

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