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DESIGN AND DEVELOPMENT OF A POWER SUPPLY CARD FOR X-RAY BAGGAGE SCANNER

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PROJECT REPORT

DESIGN AND DEVELOPMENT OF A POWER SUPPLY CARD FOR X-RAY BAGGAGE SCANNER

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I begin with the name of Allah, the most merciful, the might, the creator of creations. Before all else, it is acknowledged by all of us that what so ever we have achieved so far has been bountied to us by Allah Almighty.

We owe our gratitude to our parents that have proven to our backbones in hour of need by the display of their love, support and care towards us.

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ABSTRACT

The project focuses on the design and development of a power supply card specifically tailored for an x-ray baggage scanner system. The aim is to enhance the overall performance and reliability of the system by providing a stable and efficient power source. The project involves meticulous analysis of power requirements, circuit design, component selection, and prototype testing. Through thorough evaluation and optimization, the developed power supply card ensures consistent and uninterrupted power delivery, thereby improving the scanning accuracy and operational efficiency of x-ray baggage scanners, leading to enhanced security and passenger safety.

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LIST OF SYMBOLS

Latin Letters

V – Volts

$V_{measured}$ – measured voltage

$V_{specified}$ – specified voltage

A – Amperes

Greek Letters

η efficiency

Ω resistance

Acronyms

ATX - ATX- Advanced Technology eXtended

CEAE - International Conference on Communication, Electronics and Automation Engineering

ECTI-CON - International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology

EDAPS - Electrical Design of Advanced Packaging and Systems Symposium

EMC - Electromagnetic compatibility

EMI- Electromagnetic interference

ICEEE- International Conference on Electrical and Electronics Engineering

ICIT- International Conference on Industrial Technology

ICMA- International Conference on Mechatronics and Automation

ICPICS - International Conference on Power, Intelligent Computing and Systems

ICSGCE - International Conference on Smart Grid and Clean Energy Technologies

ICSPCC - International Conference on Power, Intelligent Computing and Systems

IEEE - Institute of Electrical and Electronics Engineers

IMCEC - Advanced Information Management, Communicates, Electronic and Automation Control Conference

ITNEC - Information Technology, Networking, Electronic and Automation Control Conference

LED - light-emitting diode

MEIC - Mechatronics, Electronic, Industrial and Control Engineering

MOSFET - Metal Oxide Silicon Field Effect Transistors

PCB- printed circuit board

PFC- power factor correction

PWM – pulse width modulation

RMS – Root Mean Square

SMPS – Switch mode power supply

SOP – Standard Operating Procedures

SVS - Static VAR System

UPS – Uninterrupted Power Supply

YAC - Youth Academic Annual Conference of Chinese Association of Automation

Chapter 1 - INTRODUCTION

1.1. Background And Motivation

X-ray baggage scanners have become indispensable in today's transportation, security, customs, and logistics sectors. These scanners play a critical role in ensuring safety, detecting prohibited items, and expediting the screening process. However, the existing power supply solutions used in X-ray baggage scanners face several limitations that hinder their overall effectiveness.

One of the primary drawbacks of current power supply solutions is their inefficiency and lack of adaptability to different voltage and output requirements. Many scanners still rely on outdated linear power supplies that are bulky, inefficient, and contribute to increased size and weight. These power supplies struggle to meet the demands of modern X-ray baggage scanners, which require more efficient and compact solutions.

Fortunately, recent advancements in power supply design and technology present an opportunity to develop a power supply card that can significantly enhance the overall performance of X-ray baggage scanners. By leveraging switch mode power supplies, high-frequency transformers, and innovative power management techniques, it is possible to achieve improved efficiency, reduced size, and increased reliability.

Switch mode power supplies offer higher efficiency by converting the input voltage into the required output voltage through a more efficient switching process, resulting in reduced energy losses. High-frequency transformers enable smaller form factors and lighter weight, making them ideal for compact and portable X-ray baggage scanners. Innovative power management techniques further enhance efficiency by dynamically adjusting the power output based on the scanner's operational needs, thereby optimizing energy consumption.

Integrating these advancements into a power supply card for X-ray baggage scanners has the potential to overcome the limitations of current solutions. The enhanced efficiency, reduced size, and increased reliability of such a power supply card would not only improve the performance of X-ray baggage scanners but also contribute to their overall effectiveness in ensuring safety and streamlining security processes.

1.2. Objectives of the Project

The primary aim of this project is to undertake the design and development of a power supply card that is tailored to meet the precise voltage and current needs of X-ray baggage scanners. This power supply card will be meticulously engineered to ensure not only high efficiency but also the incorporation of essential protection features and compatibility with the electrical system of the scanners. By actively addressing the limitations observed in existing power supply solutions, the proposed power supply card has the potential to bring about a significant transformation in the performance, energy consumption, and operational efficiency of X-ray baggage scanners.

To achieve this objective, the design process will focus on meticulous attention to detail, considering the specific voltage and current requirements of X-ray baggage scanners. Efforts will be made to optimize efficiency, reduce energy losses, and minimize the size and weight of the power supply card.

In addition, the power supply card will be equipped with essential protection features to safeguard the scanner and its components against overvoltage, overcurrent, and other potential electrical hazards. The design will also ensure compatibility with the electrical system of X-ray baggage scanners, facilitating seamless integration and reliable operation.

By successfully developing a power supply card that addresses the limitations of existing solutions, the project aims to revolutionize the overall performance, energy consumption, and operational efficiency of X-ray baggage scanners. This will contribute to enhancing the safety, security, and efficiency of transportation, customs, and logistics operations, thereby benefiting various sectors that rely on these critical security systems.

1.3. Significance Of The Research

The pursuit of an optimized power supply card for X-ray baggage scanners holds great potential and presents a multitude of advantages. The successful development of such a solution has the capacity to yield substantial benefits, including improved scanner performance, reduced energy consumption, heightened safety measures, cost savings, and heightened operational efficiency. The primary objective of this research is to make a valuable contribution to the advancement of power supply technology specifically tailored for X-ray baggage scanners. By achieving this goal, various industries and sectors that heavily depend on efficient and dependable screening systems will reap the rewards, further bolstering their operations and overall effectiveness.

Chapter 2 - LITERATURE REVIEW

2.1. Overview of X-Ray Baggage Scanner

X-ray baggage scanners are widely used across industries and sectors to ensure the safety and security of transportation systems, public spaces, and critical infrastructure. These scanners utilize X-ray technology to generate images of baggage contents, providing valuable information to operators and security personnel.

The operation of an X-ray baggage scanner involves transmitting X-ray beams through luggage, which are then detected and analyzed to produce images. These images help identify potential threats, such as weapons, explosives, and contraband items, based on their distinct shapes, densities, and material compositions.

Modern X-ray baggage scanners consist of key components: an X-ray source that emits controlled X-ray beams, detectors placed on the opposite side to capture transmitted X-rays, and advanced algorithms and image enhancement techniques to process and reconstruct detailed images.

By employing X-ray technology and sophisticated image processing, X-ray baggage scanners play a vital role in enhancing security measures across various industries and sectors.

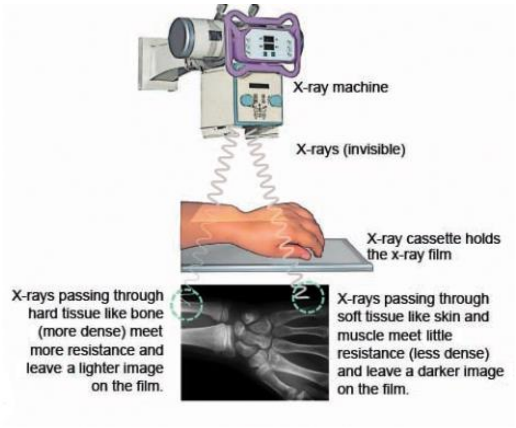

Figure 1. X-ray Capture

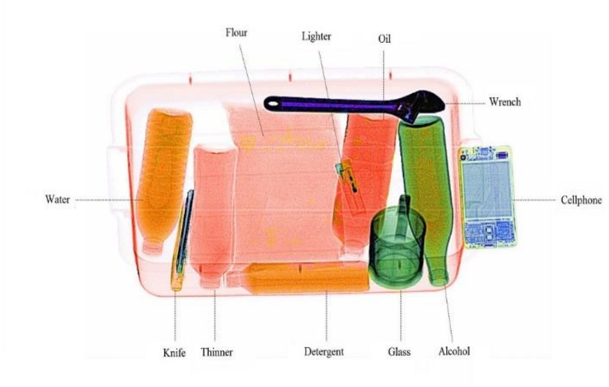

Figure 2. X-ray of Baggage

Two primary types of X-ray baggage scanners are commonly used: dual-energy scanners and multi-energy scanners. Dual-energy scanners employ two X-ray beams with different energy levels to distinguish between organic and inorganic materials. This capability enhances detection accuracy and reduces false alarms. Conversely, multi-energy scanners utilize multiple energy levels to generate more detailed and comprehensive images, enabling operators to analyze baggage contents with greater precision.

User-friendly interfaces are integrated into X-ray baggage scanners, allowing operators to view and interpret the generated images. These interfaces often incorporate advanced image analysis algorithms, such as automated threat detection and object recognition, to assist operators in quickly and efficiently identifying potential threats.

Continuous advancements in X-ray technology have resulted in significant improvements in the performance and capabilities of baggage scanners. High-resolution imaging, enhanced image processing algorithms, and faster scanning speeds have revolutionized the field, enabling more efficient and accurate threat detection.

The integration of X-ray baggage scanners into security protocols has become indispensable for transportation hubs, airports, government buildings, and other critical infrastructure facilities. They provide a vital layer of defense against potential security threats, facilitating swift and effective screening processes while ensuring the safety and well-being of individuals.

Comprehending the operational principles, components, and advancements in X-ray baggage scanner technology is crucial for the development of efficient and reliable power supply solutions. This knowledge serves as the foundation for designing a power supply card that meets the specific requirements and electrical characteristics of X-ray baggage scanners, thereby enhancing their overall performance and contributing to the security and safety of various industries and sectors.Main components of X-ray baggage scanner includes:

- X-ray Source
- X-ray detectors
- Conveyor Belts
- Gantries
- Control units
- Computer Systems

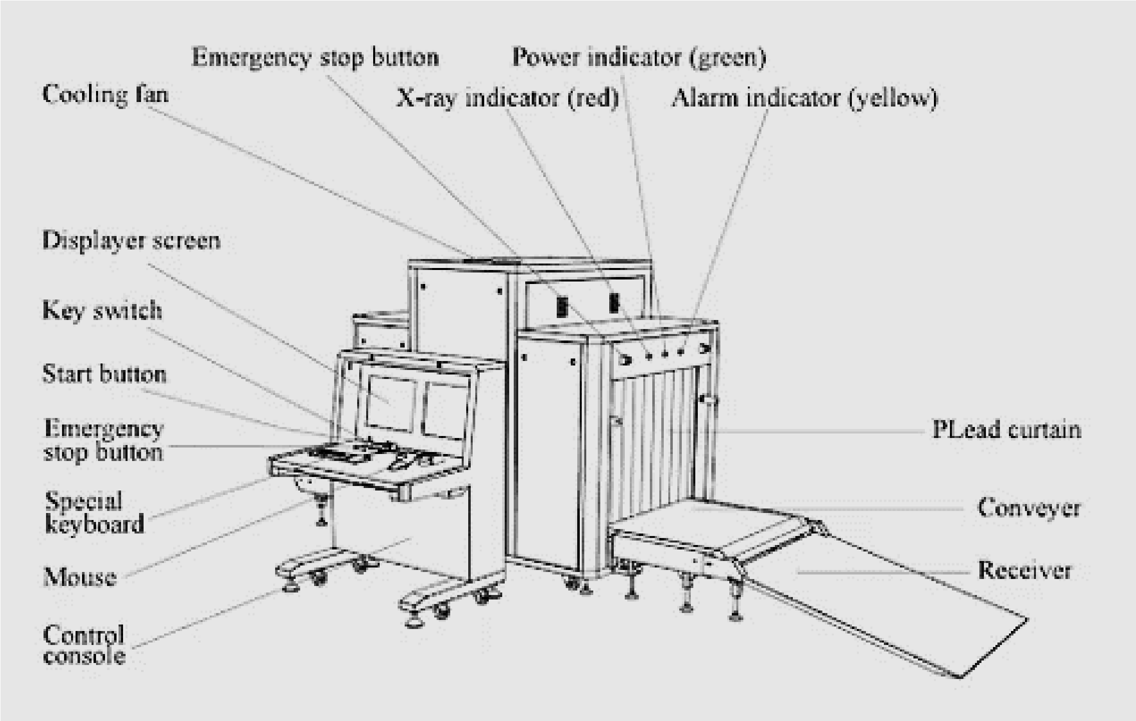

Figure 3. Components of Baggage X-ray

2.2. Power Supply Requirements of X-Ray Scanners

The voltage range for the scanner's operating system is 100-240 Volts AC. Within the machine, a power supply card is responsible for delivering power to various electronic components. The power requirements can vary based on factors such as the speed of the motor conveyor, the number of active x-ray tubes, and the type of computer system employed. Different power supplies are utilized for distinct system groups, including conveyor and cooling fans, x-ray tubes, and computer systems. Our project specifically focuses on the power supply circuitry of the computer systems connected to the x-ray baggage scanner.

2.3. Existing Power Supply Solutions

2.3.1. Switched-Mode Power Supply (SMPS)

A Switched-Mode Power Supply (SMPS) is a power supply topology that utilizes a high-frequency switching technique to convert electrical power efficiently and effectively from one form to another. By employing this switching mechanism, SMPS achieves precise control and regulation of the output voltage and current, enabling the design of more compact and energy-efficient systems compared to traditional linear power supplies. SMPS finds extensive application across a wide range of electronic devices, including computers, televisions, and mobile phones. The key advantage of SMPS lies in its remarkable efficiency, which can reach an impressive level of up to 95%, far surpassing the typical efficiency of linear power supplies, which is around 60%. This heightened efficiency translates into a substantial reduction in power losses converted into heat, resulting in cooler operating temperatures and enhanced reliability of the overall system. In technical terms, the core principle of SMPS involves rapidly switching an input voltage or current at high frequency using semiconductor devices, such as transistors or MOSFETs, to achieve efficient energy conversion. This switching action allows the SMPS to regulate the output voltage and current through pulse width modulation (PWM) or other control techniques. The high-frequency operation of SMPS allows for smaller and lighter passive components, such as transformers and capacitors, contributing to the compact design. Furthermore, the switching nature of SMPS allows for higher power density and reduced electromagnetic interference (EMI) compared to linear power supplies. The superior efficiency of SMPS stems from the reduced power dissipation associated with the switching operation. In linear power supplies, the excess voltage difference between the input and output is dropped across a linear regulator, dissipating the excess power as heat. In contrast, SMPS achieves voltage regulation by rapidly switching between a fully on and fully off state, minimizing the power losses. Additionally, SMPS can employ advanced control algorithms and feedback mechanisms to dynamically adjust the switching frequency and duty cycle, optimizing efficiency under varying load conditions. The heightened efficiency of SMPS not only leads to energy savings but also contributes to the overall performance and reliability of electronic systems. With reduced heat generation, the thermal stress on components is minimized, enhancing their longevity and reducing the risk of failure. Moreover, the efficient power conversion of SMPS translates to a smaller form factor, enabling sleek and portable designs for various consumer electronics. Switched-Mode Power Supplies (SMPS) encompass various types of converters, namely the flyback converter, forward converter, half-bridge converter, and full-bridge converter. Each of these converters exhibits distinct advantages and limitations, rendering them suitable for diverse application scenarios. The flyback converter represents the simplest and most cost-effective SMPS variant, garnering popularity in low-power applications. However, its efficiency is relatively low, and it possesses limitations concerning output power capacity, making it unsuitable for high-power applications. On the other hand, the forward converter provides a higher level of efficiency and reliability, making it well-suited for high-power applications. Nonetheless, it entails increased complexity and cost compared to the flyback converter. The half-bridge converter serves as a compromise between the flyback and forward converters, striking a favorable balance between cost and efficiency. Consequently, it finds applicability in medium-power applications where a satisfactory trade-off between these factors is sought. The full-bridge converter emerges as the most efficient and reliable SMPS type, rendering it ideal for high-power applications. However, owing to its increased complexity and higher cost, it finds less popularity in low-power applications. Each of these SMPS types operates on similar principles involving the rapid switching of electrical signals through semiconductors, controlling voltage and current through regulation techniques such as pulse width modulation (PWM). By employing appropriate topologies, such as transformer-based isolation and inductor-based energy storage, these converters achieve efficient power conversion while minimizing losses and heat dissipation. The selection of an SMPS type depends on the specific requirements of the application, including power level, cost constraints, efficiency demands, and form factor considerations. Engineers must carefully evaluate these factors to determine the most suitable SMPS topology that meets the desired performance objectives and aligns with the overall system design. Although Switched-Mode Power Supplies (SMPS) offer numerous benefits, there is a legitimate concern regarding potential electromagnetic interference (EMI) resulting from the high-frequency switching mechanism employed. However, through meticulous design considerations and the incorporation of EMI filters, these concerns can be effectively addressed and mitigated. SMPS undeniably stands as a highly efficient and compact power supply solution, well-suited for a diverse array of applications. Its superiority over traditional linear power supplies lies in its ability to convert electrical power with enhanced efficiency, resulting in reduced energy wastage and a smaller form factor. This efficiency advantage, reaching up to 95% compared to the typical 60% efficiency of linear power supplies, translates to cost savings, improved thermal management, and increased overall system reliability. Nonetheless, the high frequency switching operation inherent to SMPS can potentially generate electromagnetic interference that may adversely affect the performance of nearby electronic components or systems. EMI refers to the disturbance caused by the electromagnetic radiation or conducted emissions emitted by the SMPS during its operation. These emissions can interfere with the operation of sensitive equipment, leading to undesirable consequences such as decreased signal integrity, increased noise levels, and compromised system functionality. To address this concern, careful design practices play a crucial role. Designers must pay meticulous attention to factors such as layout, component selection, grounding techniques, and shielding to minimize EMI emissions. Employing appropriate trace routing, utilizing low-impedance paths, and implementing proper decoupling and bypass capacitors are some of the strategies that can be employed during the design phase to mitigate EMI issues. Additionally, incorporating EMI filters into the SMPS circuitry can significantly reduce unwanted electromagnetic emissions. These filters are designed to attenuate the high-frequency noise generated by the SMPS, ensuring that it remains within acceptable levels and compliant with electromagnetic compatibility (EMC) regulations. EMI filters typically consist of passive components, such as inductors, capacitors, and resistors, strategically placed to suppress or divert electromagnetic noise and maintain electromagnetic compatibility. By adopting these measures, designers can successfully address the concerns associated with EMI in SMPS designs. With careful design considerations and the integration of effective EMI filters, the advantages of SMPS, including its high efficiency and compact design, can be fully realized without compromising the overall electromagnetic compatibility and performance of the system. In conclusion, SMPS represents a remarkable power supply solution, delivering notable benefits in terms of efficiency and compactness across a wide range of applications. While the potential for electromagnetic interference exists due to the high frequency switching system, this concern can be effectively managed through meticulous design practices and the utilization of appropriate EMI filters. By striking the right balance between performance, efficiency, and electromagnetic compatibility, SMPS proves to be a valuable and reliable choice for modern power supply requirements.

Figure 4. SMPS

2.3.2. Uninterruptible Power Supply (UPS)

Uninterruptible Power Supply (UPS) plays a vital role in modern engineering systems by ensuring uninterrupted power availability during main power supply failures. A UPS system comprises essential components such as a battery, an inverter, and a charger. The battery serves as an energy storage unit, while the charger maintains its charge. In the event of a power outage, the inverter converts the DC power from the battery into AC power, which is utilized to power critical systems such as computers and communication equipment. UPS systems are classified into three primary categories: offline UPS, line-interactive UPS, and online UPS. Each category offers varying levels of protection and operational modes to address specific power supply challenges. The offline UPS, also known as a standby UPS, activates the battery and inverter only when a power outage occurs. This type of UPS represents the most basic form of protection and provides limited defense against power fluctuations. It is typically employed in environments where power interruptions are infrequent and where moderate protection is sufficient. The line-interactive UPS takes a step further in protection capabilities. In this configuration, the battery and inverter remain continuously connected to the main power supply. However, the UPS system actively regulates voltage fluctuations and compensates for minor power disruptions. By closely monitoring the input power, the line-interactive UPS ensures a stable output voltage, delivering improved protection against voltage sags, surges, and frequency variations. The online UPS offers the highest level of power protection. In an online UPS configuration, the battery and inverter are permanently connected to the load, ensuring continuous power availability. The input power is consistently rectified to DC power, which charges the battery and simultaneously powers the inverter to generate clean and stable AC power for the connected systems. This setup provides robust protection against power outages, fluctuations, and disturbances, making it suitable for critical applications where uninterrupted power is paramount. The selection of the appropriate UPS category depends on the specific requirements of the application. Factors such as the criticality of the load, frequency of power interruptions, and desired level of power protection dictate the choice. While offline UPS systems offer basic protection, line-interactive UPS systems provide intermediate defense against power fluctuations. However, when maximum power protection and continuous power availability are essential, online UPS systems are the preferred choice. Uninterruptible Power Supply (UPS) systems play a crucial role in the reliable operation of critical engineering systems, encompassing data centers, hospitals, and industrial facilities. These systems serve as a safeguard against power outages, voltage irregularities, and surges, effectively protecting sensitive equipment. Furthermore, UPS systems act as a backup power source during emergency situations, working in tandem with generators to provide prolonged power supply during extended outages. While UPS systems offer significant advantages, they are not without their limitations. Regular maintenance is necessary to uphold their optimal functionality and performance. The batteries employed in UPS systems possess a finite lifespan and must be periodically replaced to ensure uninterrupted power availability. Additionally, UPS systems generate heat and noise during operation, which may pose concerns in certain applications where noise reduction and thermal management are critical considerations.

To summarize, UPS systems represent a pivotal and indispensable element within contemporary engineering systems. Their primary role lies in furnishing vital protection against power outages and fluctuations, guaranteeing uninterrupted operation of critical systems during emergency scenarios. It is of utmost importance for engineers to meticulously evaluate the specific requirements of each application to determine the appropriate type of UPS system, considering the desired level of protection and the associated cost implications. Moreover, proper maintenance practices are imperative to sustain the optimal functionality and longevity of UPS systems. Regular inspections, comprehensive testing, and proactive measures must be undertaken to ensure the continuous and reliable operation of UPS units. Particular attention should be paid to battery performance and lifespan, necessitating timely replacements to maintain uninterrupted power availability. By adhering to meticulous maintenance procedures and selecting the most suitable UPS system, engineers can ensure the seamless operation of critical engineering systems, enhancing overall reliability and mitigating the potential risks associated with power interruptions.

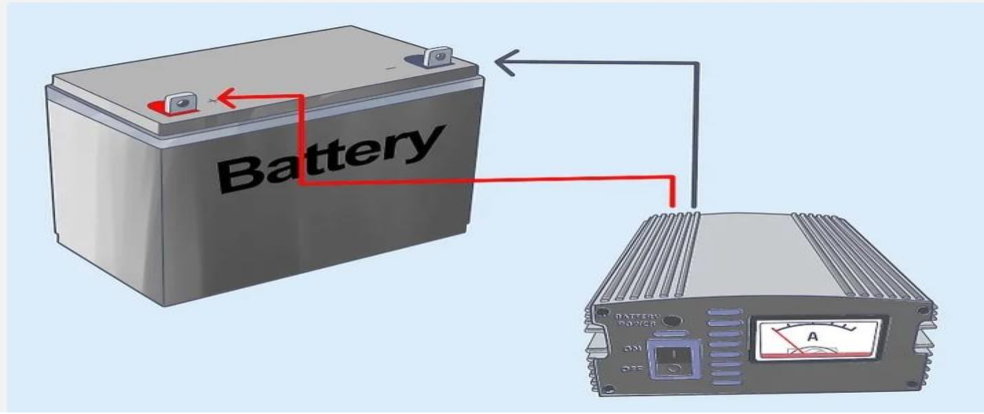

Figure 5. UPS

2.3.3. Power Distribution Units (PDUs)

Power Distribution Units (PDUs) are crucial elements within contemporary engineering systems as they play a pivotal role in ensuring dependable power distribution to electronic devices. PDUs are categorized into two types: basic and intelligent. While basic PDUs primarily serve the purpose of distributing power to IT equipment, intelligent PDUs go a step further by actively monitoring, managing, and controlling power consumption across multiple devices. These intelligent PDUs provide valuable infrastructure data remotely to data center professionals, empowering them to make well-informed decisions. Intelligent PDUs come equipped with several advanced features such as outlet level monitoring, environmental monitoring, and customized alert and alarm systems based on user-defined thresholds. By continuously monitoring power usage, these PDUs help minimize downtime by promptly identifying potential issues or anomalies. In dynamic and complex data center environments, PDUs have become increasingly vital due to their ability to optimize power usage and maintain efficient operations. The popularity of high-density PDUs has soared due to their cost-effectiveness, consistent performance, and reliability. These PDUs are specifically designed to accommodate a large number of outlets in a compact size. They prove particularly advantageous in situations where space is limited, yet there is a high demand for power distribution. To enhance power efficiency and achieve optimal load balancing, the introduction of three-phase PDUs has been instrumental. These innovative PDUs facilitate the delivery of three alternating currents through a single circuit, empowering data center professionals to evenly distribute loads and maximize power utilization. As the density of outlets increases, so does the power consumption and heat generation.

To tackle these challenges head-on, PDUs are manufactured using high-temperature materials that possess the ability to endure the demanding conditions typically encountered in data center environments. This ensures the PDUs remain sturdy and dependable, even under high heat levels and intense operational circumstances. PDUs also present invaluable solutions for addressing power distribution challenges within industrial electrical systems. By incorporating PDUs, industrial systems can enhance overall efficiency, boost reliability, and optimize performance. The advanced monitoring and control capabilities offered by PDUs enable industrial professionals to effectively manage power distribution, guaranteeing that each device receives the necessary power while minimizing the risk of downtime or equipment failures. To put it briefly, PDUs play a crucial role in contemporary engineering systems. Intelligent PDUs offer advanced monitoring and control features, while high-density and three-phase PDUs enhance power distribution capabilities. By employing PDUs, professionals in both data center and industrial settings can maximize power efficiency, guarantee dependable operations, and make well-informed decisions using vital infrastructure data.

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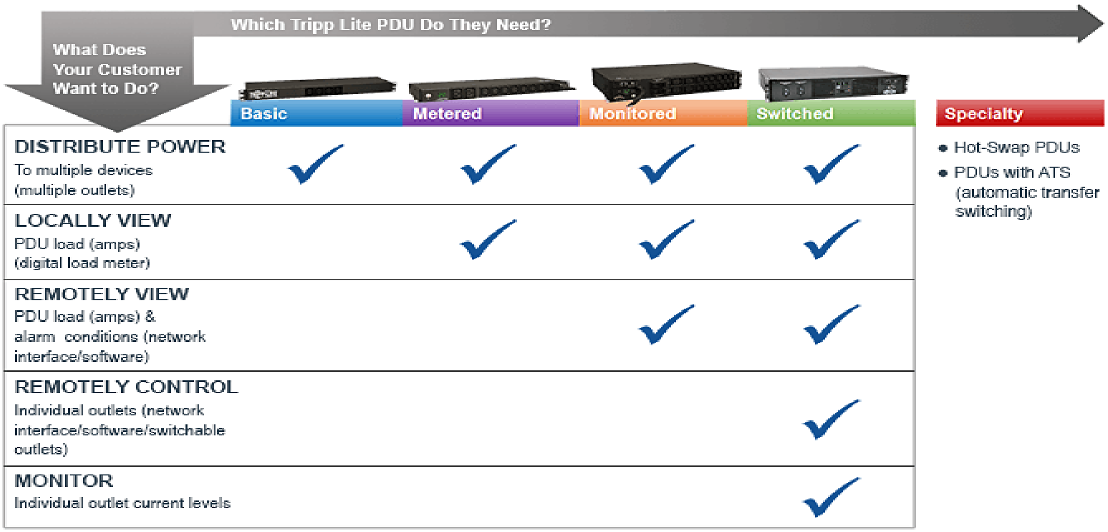
The chart below compares the features and benefits of each type of PDU:



Which Tripp Lite PDU Do They Need?

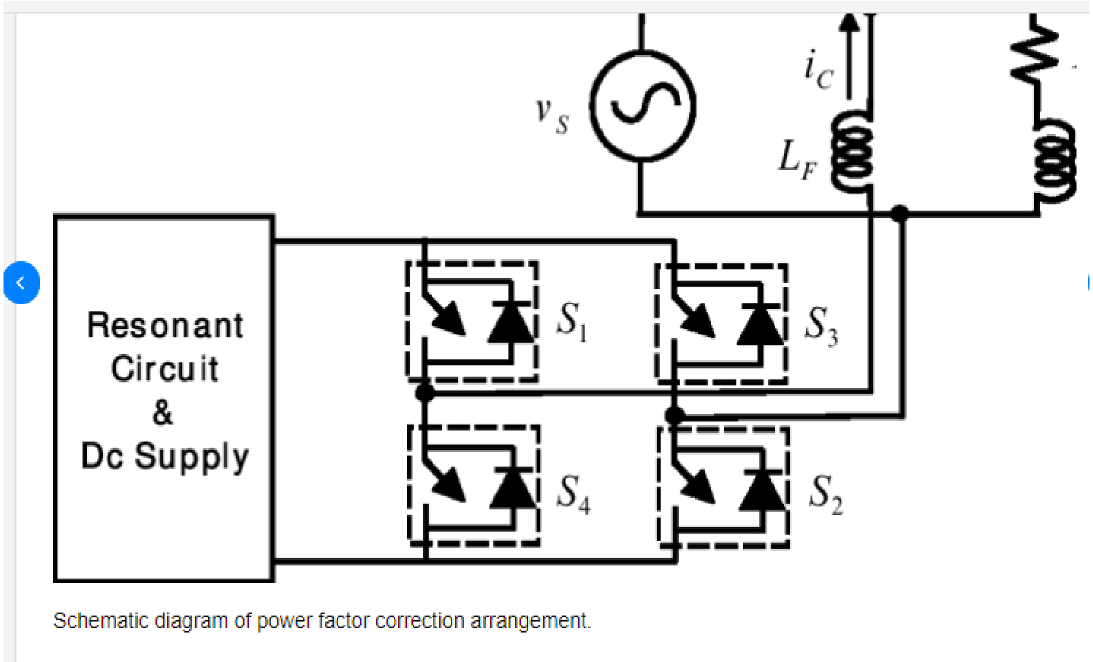
What Does Your Customer Want to Do?	Basic	Metered	Monitored	Switched	Specialty
DISTRIBUTE POWER To multiple devices (multiple outlets)	✓	✓	✓	✓	• Hot-Swap PDUs • PDUs with ATS (automatic transfer switching)
LOCALLY VIEW PDU load (amps) (digital load meter)		✓	✓	✓	
REMOTELY VIEW PDU load (amps) & alarm conditions (network interface/software)			✓	✓	
REMOTELY CONTROL Individual outlets (network interface/software/switchable outlets)				✓	
MONITOR Individual outlet current levels				✓	

Figure 6. Features and Benefits of PDUs

2.3.4. Power Factor Correction (PFC)

Power Factor Correction (PFC) is an essential technique employed in electrical engineering to enhance the efficiency of power distribution systems. The power factor, defined as the ratio of real power to apparent power, serves as a measure of how effectively power is being utilized within a system. A low power factor signifies that a significant portion of power is being dissipated, resulting in escalated energy expenses and an augmented carbon footprint. PFC addresses this issue by mitigating the reactive power present in the system, thereby enabling more efficient utilization of electrical power. Reactive power is the power consumed by inductive loads, such as motors and transformers, which do not contribute directly to the productive output of the system. PFC achieves this correction by incorporating capacitors, which counterbalance the reactive power, consequently minimizing energy wastage and ameliorating the power factor. There are two main types of PFC: passive and active. Passive PFC employs capacitors that are connected in parallel to the load. These capacitors offset the reactive power, resulting in a higher power factor. Reactive power is the power that oscillates between the power source and the load, without actually performing useful work. By offsetting this reactive power, passive PFC reduces power losses and increases the overall efficiency of the system. On the other hand, active PFC takes a more sophisticated approach by utilizing a control circuit. This circuit actively adjusts the current flowing to the load, maintaining a consistently high power factor. Active PFC is known to be more efficient than passive PFC since it actively regulates the current, minimizing power losses and optimizing power distribution. However, this increased efficiency comes at the cost of added complexity and higher expenses. The implementation of PFC in high-density data centers and industrial electrical systems brings several advantages. Firstly, it significantly reduces energy costs by minimizing power losses and maximizing the utilization of electrical power. Wasted energy due to low power factors is minimized, resulting in significant savings in electricity expenses. Moreover, PFC improves the overall efficiency of the system. By maintaining a high power factor, electrical equipment operates more effectively and delivers power to the load more efficiently. This not only reduces energy waste but also enhances the performance and productivity of the electrical system as a whole. Furthermore, PFC plays a crucial role in reducing the carbon footprint of high-density data centers and industrial electrical systems. By optimizing power distribution and minimizing energy losses, the environmental impact of these systems is reduced. This aligns with the increasing focus on sustainability and energy efficiency in today's world. Another benefit of PFC is the potential to extend the lifespan of electrical equipment. Reactive power can introduce additional stress on components, leading to increased wear and tear.

By reducing the presence of reactive power through PFC, the strain on electrical components is diminished, resulting in improved durability and a longer operational lifespan.



Schematic diagram of power factor correction arrangement.

Figure 7. Schematic Diagram of Power Factor Correction

2.3.5. Voltage Stabilizers

Voltage stabilizers, also referred to as voltage regulators, are electrical devices that possess the capability to automatically uphold a constant voltage level within a power supply circuit. These devices find widespread usage in industrial, commercial, and residential environments in order to safeguard delicate electronic equipment against voltage fluctuations and surges, which can potentially cause damage. The fundamental operation of voltage stabilizers involves the detection of variations in the input voltage, followed by adjustments to the output voltage in order to maintain a predetermined level. In residential settings, this predetermined level is typically set within the range of 220-240V. Two primary categories of voltage stabilizers exist: automatic voltage regulators (AVRs) and static voltage stabilizers (SVSs). AVRs rely on the implementation of electromagnetic coils to regulate the voltage. These coils can dynamically adjust the voltage levels to ensure a steady output. AVRs are generally more commonly employed in low-power applications where the voltage regulation requirements are relatively less demanding. The incorporation of solid-state electronics within SVS offers a multitude of advantages. Solid-state components are widely recognized for their exceptional transient response, enabling them to swiftly detect and counteract voltage perturbations. Furthermore, these components exhibit remarkable power efficiency, operating with minimal energy consumption while delivering peak performance. The extended lifespan of solid-state electronics further enhances the dependability and longevity of SVS systems, establishing them as a cost-effective solution for voltage stabilization. In its entirety, SVS systems excel in accurately and efficiently managing voltage levels within high-power contexts. This superiority positions SVS as the preferred choice for sustaining unwavering and dependable power supply across industrial and commercial sectors. Through the integration of solid-state electronics, SVS systems contribute to the establishment of steadfast and consistent power distribution, effectively safeguarding delicate equipment and optimizing the overall operational performance of systems that operate in demanding environments. Voltage stabilizers play a crucial role in electrical systems by providing precise and consistent voltage regulation, resulting in various technical advantages. These include enhanced efficiency and reliability of electrical equipment, safeguarding against power surges and voltage fluctuations, and extending the operational lifespan of equipment. By maintaining optimal voltage levels, voltage stabilizers reduce the energy wastage associated with inefficient voltage, thus reducing energy costs and mitigating the carbon footprint. However, it is important to acknowledge certain limitations of voltage stabilizers. Firstly, the upfront cost of acquiring and installing these devices can be significant, warranting careful evaluation of the economic feasibility. Additionally, regular maintenance and calibration are often required to ensure the continued effectiveness and accuracy of voltage stabilization. Failure to properly maintain and calibrate voltage stabilizers can lead to suboptimal performance or even equipment damage. Furthermore, specific types of voltage stabilizers may introduce unwanted distortions or noise into the power supply, potentially affecting the functionality and performance of sensitive electronic equipment. Careful consideration should be given to selecting a voltage stabilizer that minimizes such issues, particularly in applications where high precision and low noise are critical. In summary, voltage stabilizers are indispensable components within modern electrical systems. They provide reliable and efficient voltage regulation, protecting sensitive equipment and improving overall energy efficiency. While there are cost considerations and potential performance implications, the benefits of voltage stabilizers make them essential in achieving optimal electrical system operation and equipment longevity.

Figure 8. Voltage Stabilizer

2.4. Linear Power supplies

Linear power supplies are a prevalent type of power supply utilized in electronic systems that necessitate characteristics such as minimal noise, superior regulation, and low levels of electromagnetic emissions. These power supplies are responsible for transforming the alternating current (AC) voltage obtained from a wall outlet into a stable direct current (DC) voltage. Linear power supplies are known for their simplicity, reliability, and cost-effectiveness. Unlike other types of power supplies, linear power supplies do not employ any switching components in their conversion process. It is important to note that linear power supplies possess certain limitations. They tend to be bulky and heavy, which can make them impractical for high-power applications that demand compactness and portability. Furthermore, their efficiency levels are generally lower compared to other types of power supplies, leading to increased energy wastage. Additionally, linear power supplies have limitations in terms of their capacity to provide high output currents, rendering them more suitable for low-power applications.

Linear power supplies consist of fundamental building blocks that enable their operation. These blocks include a transformer, rectification circuitry, filtering components, and a voltage regulator. The transformer plays a crucial role in the power supply by stepping down the AC voltage obtained from the wall outlet to a lower voltage level suitable for further processing. This step-down process helps ensure the safety and efficiency of the power supply. After the voltage has been stepped down, the rectification stage converts the

AC voltage into a pulsating DC voltage. This conversion is achieved using diodes or other rectifying elements, allowing the power supply to convert the alternating current into a unidirectional flow. Next, the filtered stage removes any residual AC components or ripple present in the pulsating DC voltage. This is accomplished through the use of capacitors and inductors, which help smooth out the waveform and provide a cleaner and more stable DC output. To achieve precise voltage regulation, a voltage regulator is employed in the linear power supply. The voltage regulator ensures that the output voltage remains constant even when there are fluctuations in the input voltage or changes in the load. This ensures that the power supply delivers a reliable and stable DC voltage to the connected electronic devices. While linear power supplies offer advantages such as simplicity, reliability, low noise levels, and cost-effectiveness, they do have limitations. One notable limitation is their suitability for low-power applications due to their lower efficiency compared to other types of power supplies. Additionally, linear power supplies typically require a dedicated AC power transformer, which can add to their overall cost and size. However, the resistance of linear power supplies to noise and electromagnetic interference makes them well-suited for applications that demand high-frequency operations or require minimal electrical disturbances. Their simplicity and reliability make them a preferred choice in various industries, including telecommunications, audio systems, and other sensitive electronic devices.

2.4.1. Series Regulator

Figure 9. Linear Power Supply

2.4.2. Shunt Regulator

Shunt regulators operate by creating an alternate route for surplus current to bypass the load. These regulators rely on a voltage reference and a shunt component, like a zener diode, to uphold a consistent voltage across the load. While shunt regulators are not as prevalent in power supply scenarios, they find frequent utilization in smaller circuits and serve as reliable voltage references.

2.5. Switch mode power supplies

2.5.1. Operating Principle

SMPS operates by using a high-frequency switching circuit to convert the input AC voltage to a high-frequency AC signal. This AC signal is then rectified and filtered to obtain the desired DC output voltage. The switching action allows for efficient voltage conversion and regulation.

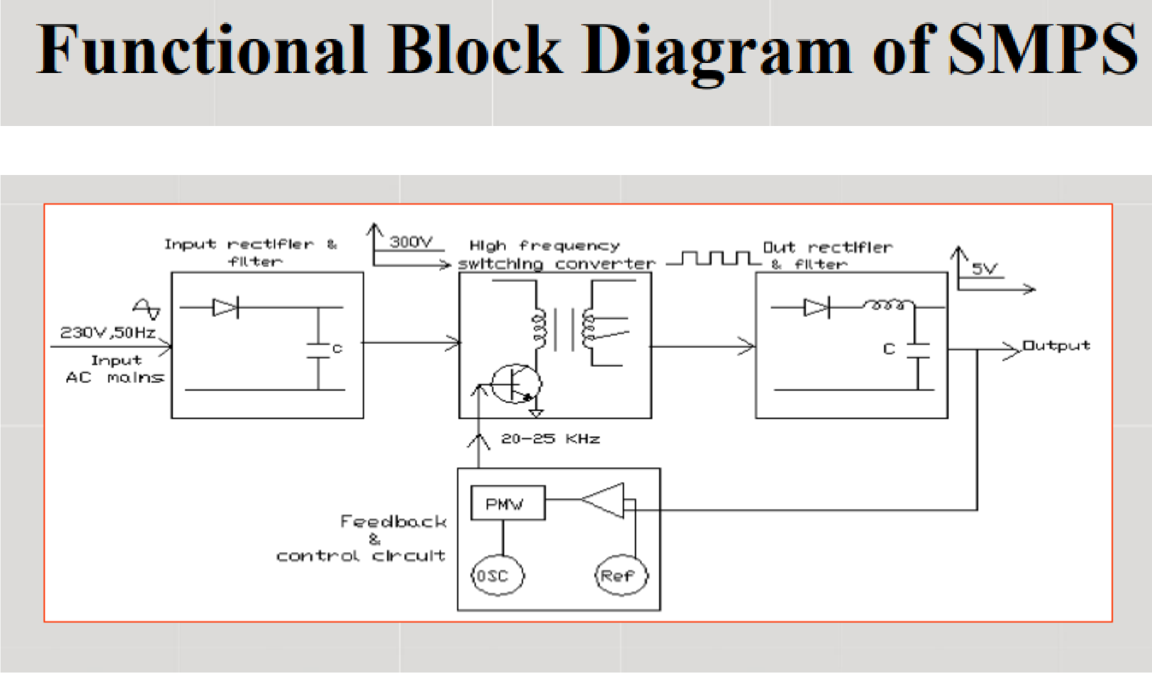


Figure 10. Functional Block Diagram of SMPS

2.5.2. Components of SMPS

2.5.2.1. Power Switch

The power switch is usually a transistor which controls the action of switching by rapidly turning on and off the input.

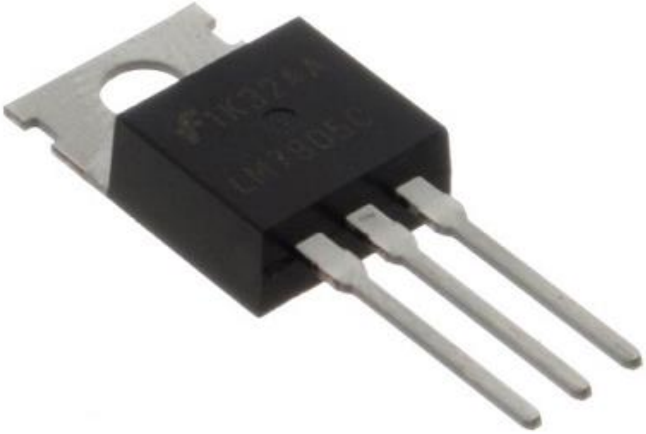


Figure 11. Power Switch

The following figure shows the construction of a MOSFET.

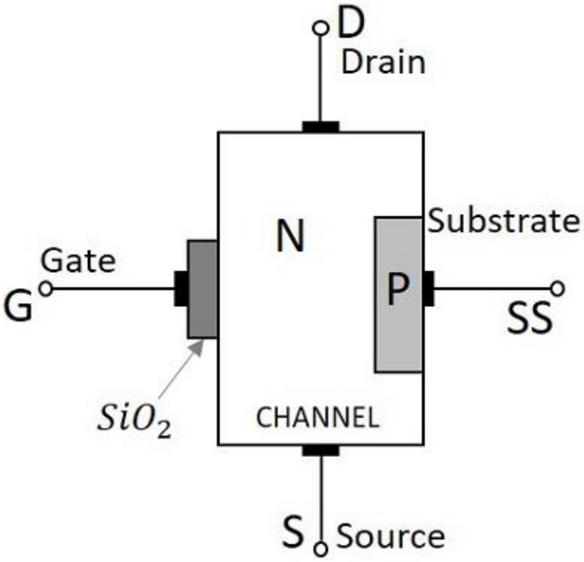


Figure 12. Construction of MOSFET

2.5.2.2. Transformer

The transformer allows for voltage step-up or step-down, depending on the desired output voltage. Some common transformer specifications are shown below.

Table I. Common Transformer Specifications

Specification	**Value**
Primary Voltage	120V
Secondary Voltage	12V
Power Rating	50VA
Frequency	60Hz
Turns Ratio	10:1
Isolation Voltage	1500V

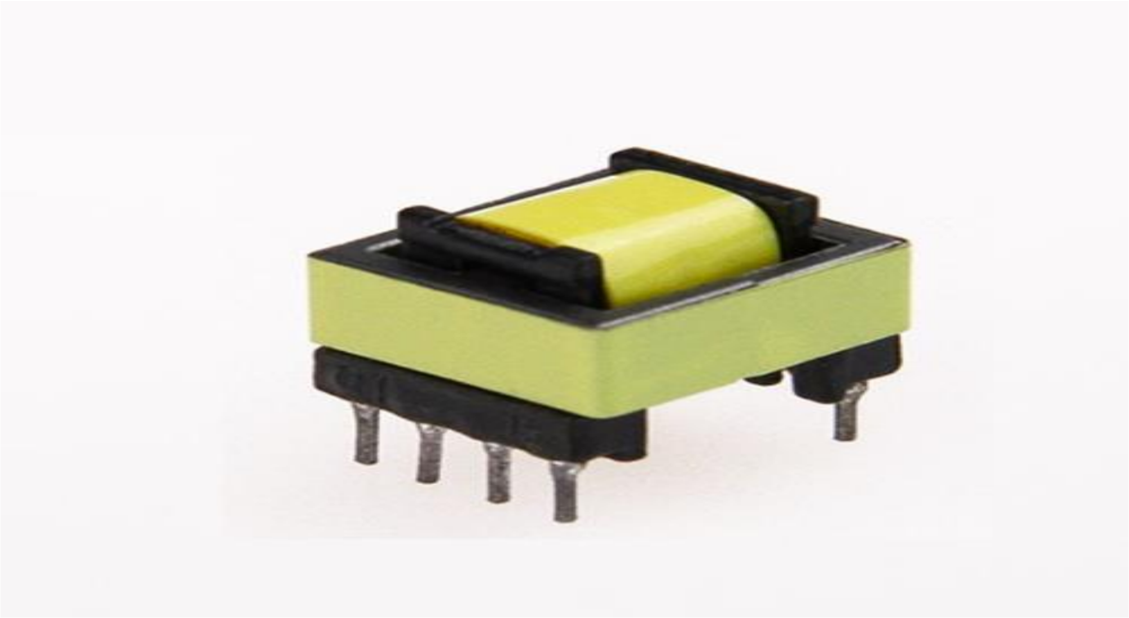


Figure 13. Transformer Component

2.5.2.3. Rectifier and Filter

The rectifier converts the AC signal to DC, and the filter removes any remaining ripple or noise from the output voltage.

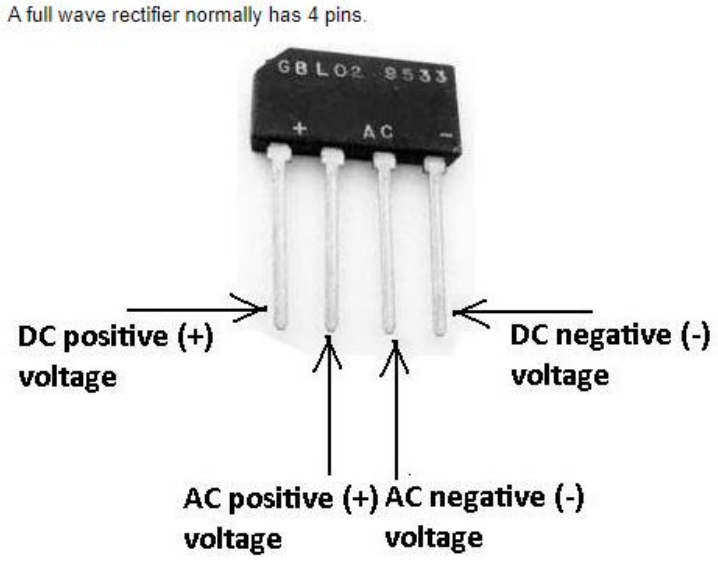


Figure 14. Configuration of Rectifier

2.5.2.4. Controller

The controller monitors the output voltage and adjusts the switching action to regulate the output voltage within a specified range.

2.5.3. Advantages of SMPS

2.5.3.1. Higher Efficiency

SMPS can achieve higher efficiency compared to linear power supplies. The switching action reduces power dissipation, resulting in less energy loss and higher overall efficiency.

2.5.3.2. Compact Size

SMPS are more compact and lightweight due to their high-frequency operation and the absence of bulky transformers used in linear power supplies.

2.5.3.3. Wide Input Voltage Range

SMPS can often operate over a wide input voltage range, making them suitable for different power supply standards worldwide.

2.5.3.4. Better Voltage Regulation

SMPS typically offer better voltage regulation and stability, ensuring a consistent output voltage even with variations in the input voltage or load conditions.

2.5.3.5. Multiple Output Voltages

Some SMPS designs can provide multiple output voltages simultaneously, making them suitable for applications requiring different voltage levels.

2.5.4. SMPS Power Supply Types

A summary of different SMPS Power Supply Types is shown below and will be discussed in detail later.

Table II. SMPS Power Supply Types

Power Supply Type	Description
Buck Converter	Converts high voltage to low voltage by using a series switch and diode to regulate the output voltage.
Boost Converter	Converts low voltage to high voltage by using a series switch and diode to regulate the output voltage.
Buck-Boost Converter	Converts both high and low voltage to a desired output voltage by using a switch and inductor to regulate the output voltage.
Flyback Converter	Converts DC input voltage to AC voltage, which is then stepped up or down and rectified to produce the desired output voltage.
Forward Converter	Similar to a flyback converter

2.5.4.1. Buck Converter

The buck converter, also known as a step-down converter, is a widely used SMPS topology. It steps down the input voltage to a lower output voltage. It consists of a power switch (usually a transistor), an inductor, a diode, and a capacitor. Buck converters are efficient and commonly used in applications where the output voltage is lower than the input voltage. Buck converters are conventionally DC to DC converters that operate by stepping down the voltage from input to output. Usually these have 4 modes of operation.

- Continuous mode
- Discontinuous mode
- Continuous mode to discontinuous mode
- Discontinuous mode to continuous mode

During the cycle if the current through inductor (I_L) never drops down to zero, Buck converter shall work in a **continuous mode**. In this mode energy stored in inductor is calculated by:

$$E = \frac{1}{2} L {I_L}^2$$

In discontinuous mode, the energy required by the load used is too small and so the current through the inductors drops downs to zero for some duration through the cycle. But this causes the output capacitor to discharge during each cycle which in turn becomes the reason for switching loss. A technique called pulse frequency modulation can be used to minimize this effect.

While on other hand when during the low current cycle the buck mode operates in discontinuous mode and at higher current cycle in continuous mode the converter is said to operate in discontinuous mode. This is applicable in vice versa situation and that makes it continuous to discontinuous mode buck converter.

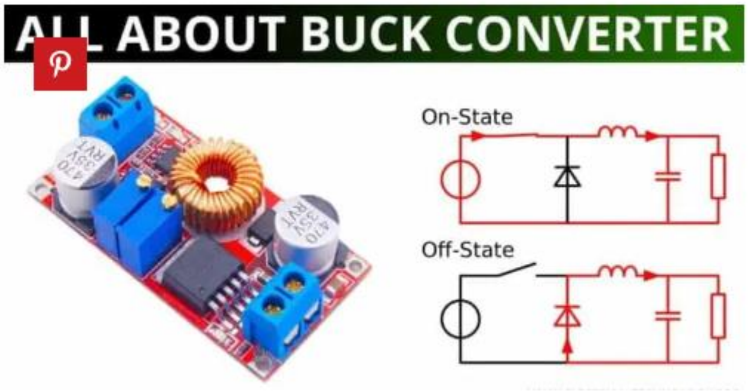


Figure 15. Buck Converter Circuit Configuration During Operation

2.5.4.2. Boost Converter

It is a DC to DC power converter. The step-down converter, also referred to as a buck converter, is commonly employed in situations where the input voltage is insufficient for the desired output voltage. Similar to the buck converter, this converter comprises a power switch, an inductor, a diode, and a capacitor.

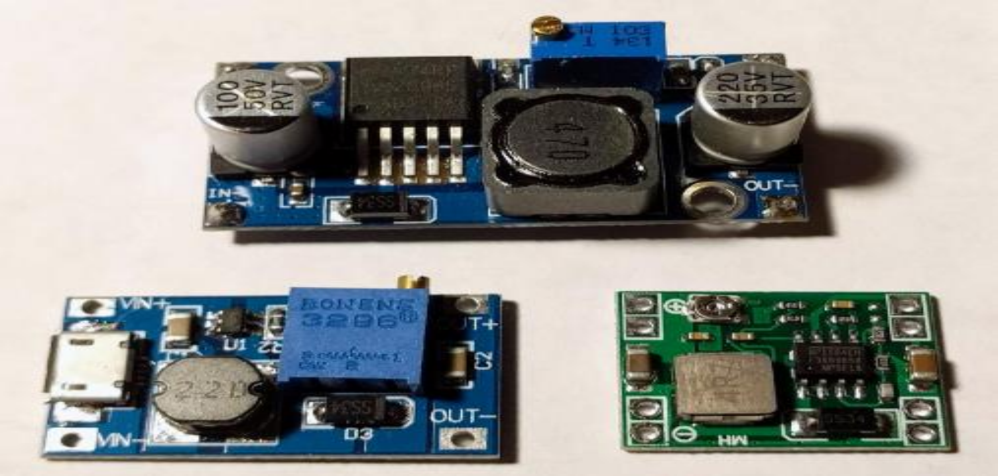


Figure 16. Boost Converter

2.5.4.3. Buck-Boost Converter

The buck-boost converter is a versatile voltage converter that can step up or step down the input voltage to produce an output voltage that is either higher or lower than the input voltage. This feature makes it suitable for a variety of applications that require a wide range of output voltage levels.

Figure 17. Buck Boost Converter

2.5.4.4. Flyback Converter

A flyback converter is a type of power supply that utilizes a transformer which stores energy and release it when it is required. The primary winding used in this transformer acts as an inductor while the secondary winding as always provides the output. This type of voltage converter circuit is used in both AC to DC and DC to DC conversion with galvanic isolation between the input and outputs. The flyback converter is capable of generating multiple outputs with little additional circuitry, but output voltages have to match each other through the turn ratio. The flyback transformer is designed to store energy and to operate at high frequencies of about 50 kHz using a ferrite core with a non-magnetic air gap. Advantages of flyback converters include being able to give multiple output voltages, all isolated and separated from the primary, and being able to operate on a wide range of input voltages. However, the flyback converter has the disadvantage of a lower bandwidth voltage feedback loop and a current feedback loop that is sensitive to input voltage variations. Flyback converters are commonly used in various electronics applications, such as in AC adapters, battery chargers, LED drivers, and computer power supplies.

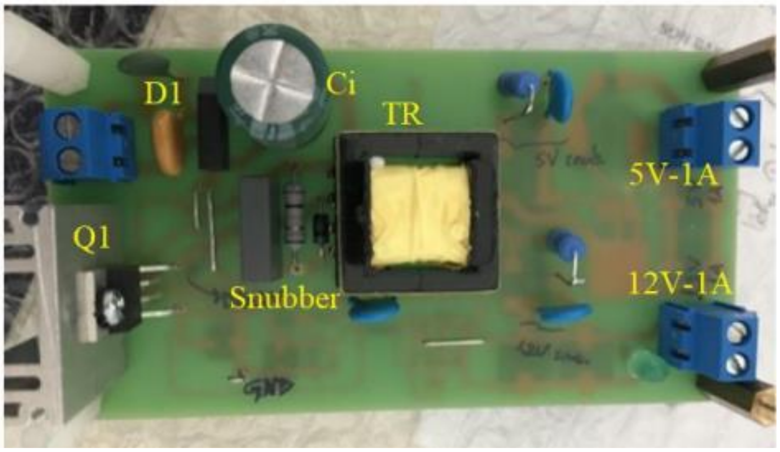


Figure 18. Flyback Converter

2.5.4.5. Forward Converter

A forward converter is a type of DC/DC converter that utilizes a transformer to increase or decrease the voltage and provide galvanic isolation for the load. It is commonly used in electronics applications, particularly in intermediate power output levels of 100-200 watts. It differs from the flyback converter in that it transfers energy directly to the output during the switch conduction phase instead of storing energy in the magnetic field. A forward converter has a higher cost, faster transient response time, higher power efficiency, and lower ripple on the output compared to a flyback converter. The circuit diagram of a typical forward converter is shown, including the primary simulations involved in analyzing a forward converter. Regulation is achieved through applying a PWM signal to the gate of a transistor. The two commonly used topologies in a forward converter are the single switch and two-switch forward converters, with the latter being more preferred for its reliability and efficiency in ATX power supply units with outputs of between 150 and 750 W.

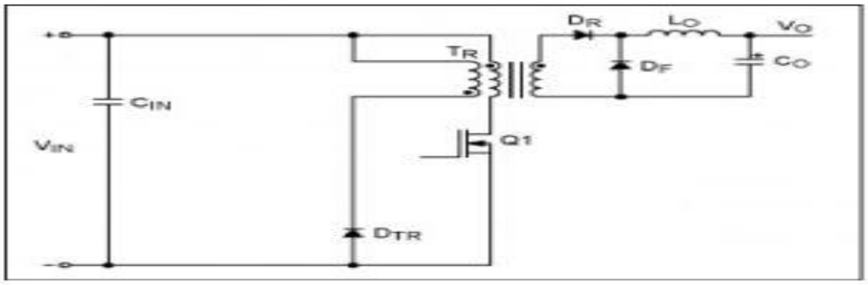


Figure 19. Forward Converter

2.5.4.6. Half-Bridge Converter

A DC to DC type converter, called half bridge converter, is used to convert a DC voltage into a different DC voltage level. It is a cliché device that is very vastly and widely used in many electrical appliances such as drivers for motos, inverters of many sort, and UPS systems. This half bridge converter is highly acknowledged for is highly efficient outputs, cost cutting and ease of use. It is based on components such as two switches may it be MOSFETs or IGBTs connected to a transformer that is center tapered. When one of the switches is set high, current begins to flow through the transformer and in form of magnetic field energy is stored then. And contrary to this as soon as the current stops to flow the magnetic field is turned down, it induces a voltage in the secondary winding of the transformer. The resultant voltage produced is filtered and used as output voltage. Now it is to be highlighted that the half bridge converter is highly efficient as mentioned before. It is because of the transformer used, which either steps up or steps down the voltage maintaining minimum loss. Moreover, the use of two switches allows for better control of the output voltage and current, which improves overall system performance. Another advantage is that half-bridge converter holds the ability to handle high power levels. By using many transformers in parallel configuration, it is possible to scale the converter to handle very high power levels, making it ideal for use in industrial applications. Half-bridge converter proves to be a disadvantage in its complexity. Since it uses transformers, hence to minimize the power losses, the transformers have to be carefully designed and the use of methods to reduces power losses are to be implemented. Additionally, the use of multiple switches can increase the cost of the overall system. In motor drivers it is used to control the speed and torque of motors. It is also used in solar inverters, where it is used to convert the DC power from solar panels into AC power for use in homes and businesses.

2.5.4.7. Full-Bridge Converter

Power electronics converters play a vital role in modern power systems, enabling efficient power conversion and management. One such converter is the full-bridge converter, which is a type of DC/DC converter that is widely used in various applications. The full-bridge converter comprises of four switches, two diodes, and a transformer. The components are nearly as same as the half bridge but the operations and the construction is different. The switches used are typically MOSFETs or IGBTs, while the diodes used are fast recovery diodes. The transformers used have primary winding and a couple of secondary winding. The primary winding connects to the input voltage source, whereas the two secondary windings are connected to the output end. During the first half of the switching cycle, switches s1 and s4 are turned high, while switches s2 and s3 are turned low. In transformer the input voltage is applied to the primary winding and then the current flow through the primary winding generates a magnetic field. The magnetic field will induce a voltage across the two secondary windings, connected in series. Then diodes are used to rectify this voltage and applied to the load.

During the second half of the cycle, switches s2 and s3 are turned high, while switches s1 and s4 are turned low. The input voltage is now applied to the other end of the primary winding, and current flows through it, generating a magnetic field in the opposite direction. The magnetic field induces a voltage across the two secondary windings, which are again connected in series. This voltage is rectified by the diodes and applied to the load. The full-bridge converter has several advantages over other converters. It provides galvanic isolation between the input and output, which is essential in many applications. It also has a high efficiency, typically in the range of 90-95%, which makes it ideal for high-power applications. The full-bridge converter can also generate multiple outputs with little additional circuitry, making it flexible and versatile. The full-bridge converter also has some disadvantages. It requires four switches instead of two, which increases the cost and complexity of the circuit. It also generates more electromagnetic interference (EMI) than other converters, which can be a problem in some applications. The full-bridge converter is commonly used in various applications, including motor drives, solar inverters, and uninterruptible power supplies (UPS) just as half bridge converters. It is also used in high-power applications such as welding machines and induction heating systems. The full-bridge converter is a versatile and efficient DC/DC converter that is widely used in various applications.

In summary,

Table III. Advantages and Disadvantages of Different Power Supplies

Type of SMPS Power Supply	Advantages	Disadvantages
Flyback Power Supply	Simple design, low cost, lightweight, and efficient at low power levels	Limited power output range, produces electromagnetic interference, and requires additional components for noise reduction
Forward Power Supply	High efficiency, low noise, and suitable for high power output applications	Complex design, high cost, and requires careful attention to transformer design to avoid saturation
Push-Pull Power Supply	High efficiency, low noise, and suitable for high power output applications	Complex design, high cost, and requires careful attention to transformer design to avoid saturation
Half-Bridge Power Supply	High efficiency, low noise, and suitable for high power output applications	Complex design, high cost, and requires careful attention to transformer design to avoid saturation
Full-Bridge Power Supply	High efficiency, low noise, and suitable for high power output applications	Most complex design, highest cost, and requires careful attention to transformer design to avoid saturation

2.6. Reverse Engineering of the Existing Circuit (Part Of Literature Review)

The main objective of the project was to improve upon the shortcomings of a power supply circuit obtained from the 502 Workshop. In order to achieve this goal, several steps were taken.

2.6.1. Opening and examination of the circuit

Firstly, a reverse engineering process was initiated to understand the inner workings of the circuit. The circuit was opened with caution to expose its internal components and connections without any damage. This was quite crucial to make sure no component was damaged and no trace altered because whilst opening the circuit we had to make use of heat operated equipment to the likes of a high temperature soldering iron. If any component would have gotten excessive heat than it could have sustained, it would have been rendered inoperable and we would then be clueless as to its working inside the circuit. Thus, this first step was carried out quite carefully and meticulously.

After visually examining the circuit, key components such as resistors, capacitors, transistors, and integrated circuits were identified. The components that we were able to extract are shown in Table IV.

Table IV. Components of Power Supply

Component	Symbol	Function
Transformer	T	Converts AC voltage to DC voltage
Rectifier	D	Converts AC voltage to DC voltage
Capacitor	C	Filters out AC voltage
Regulator	R	Regulates voltage output
Voltage Divider	VD	Divides voltage output
Inductor	L	Filters out AC voltage
Transistor	Q	Amplifies or switches voltage

1. Transformer
2. Rectifier
3. Filter
4. Regulator circuits
5. Resistors
6. Capacitors
7. Diodes
8. Transistors
9. Miscellaneous integrated circuits

2.6.2. Taking voltage and current measurements

Secondly, voltage and current measurements were taken at various pins and nodes to gather crucial information about the circuit's operational behavior. This helped in determining the voltage levels required for different components to function properly and provided insights into the current flow through different parts of the circuit.

During the analysis and replication process, the second step involved conducting voltage and current measurements at different pins and nodes of the circuit. These measurements provided crucial information regarding the circuit's operational behavior.

Measuring the voltage levels at various points within the circuit allowed gaining significant insights into the optimal voltage levels required for different components to function effectively. These measurements helped determine whether the supplied voltage met the specified requirements of individual components, ensuring their proper operation. Any deviations from the expected voltage levels indicated the need for adjustments or modifications to ensure reliable performance.

Furthermore, the measurement of current flow through different parts of the circuit provided to be tantamount in determining critical information about the functioning of individual components as well as their power consumption. Analyzing the current flow also helped us identify areas that exhibited higher power demands or potential inefficiencies, which helped us in enabling the assessment of the circuit's overall power distribution and consumption characteristics.

The combination of voltage and current measurements provided a comprehensive understanding of how the circuit operated and interacted with various components. This analysis offered valuable insights into potential areas of improvement and optimization. By carefully examining the measured values, any discrepancies or limitations within the original circuit design that needed to be addressed during the replication and enhancement process could be identified.

2.6.3. Technical Documentation Consultation for Individual Components

In the third step of the analysis and replication process, a detailed examination was conducted on each individual component employed in the circuit. This meticulous inspection encompassed a thorough assessment of the components' physical attributes, identifying any visible irregularities that could potentially impact their functionality. Additionally, close attention was paid to the markings etched on the components, such as part numbers, manufacturer logos, and polarity indicators, to aid in accurate identification and verification.

To gain a comprehensive understanding of the components' performance characteristics, extensive consultation of reliable datasheets and technical documentation was undertaken. These authoritative resources served as valuable references, providing intricate details pertaining to the components' electrical specifications, operational ranges, tolerances, and recommended usage conditions. Key parameters, including voltage ratings, current ratings, capacitance values, frequency response, and temperature dependencies, were meticulously scrutinized to ascertain the components' capabilities and limitations.

By thoroughly examining the components and analyzing pertinent datasheets and technical documentation, a comprehensive understanding of their performance characteristics was attained. This critical knowledge formed the basis for making well-informed decisions regarding component selection, potential substitutions, or enhancements, thereby facilitating the desired improvements in the replicated power supply circuit.

2.6.4. Tracing PCB Paths

Last of all, a meticulous analysis was conducted by carefully tracing the paths of the printed circuit board (PCB). This systematic approach aimed to gain a comprehensive understanding of the intricate interconnections between components and subsystems, thereby facilitating a more profound comprehension of the signal flow and the overall design of the circuit.

The process involved a detailed examination of the PCB layout, with a focus on identifying and following the intricate traces that established the connections between different components. By mapping out the interconnections, a clearer picture emerged of how signals were transmitted and received, and how they traversed various parts of the circuit.

By closely inspecting the PCB traces, valuable insights were gained into the routing decisions made during the circuit design phase. This examination shed light on the intentions behind the placement of components and the optimization of signal paths, contributing to a better understanding of the overall circuit architecture.

The meticulous tracing of PCB paths helped unravel the complex web of interconnections, enabling a deeper analysis of the signal flow within the circuit. This information was crucial for identifying potential bottlenecks, areas of signal interference, or inefficient routing that could impede the circuit's performance.

By employing this methodical approach, a comprehensive understanding of the signal flow and overall circuit design was achieved. This knowledge laid the groundwork for identifying areas of improvement and implementing enhanced strategies during the replication and enhancement process of the power supply circuit.

2.6.5. Derivations from reverse engineering of the circuit

By diligently following the systematic methodologies described above, a thorough and comprehensive understanding of the original power supply circuit was achieved. This deep comprehension formed the basis for a meticulous evaluation, enabling the identification of inherent limitations and areas in need of improvement within the circuit.

Drawing upon the accumulated knowledge of the circuit's internal workings, operational behavior, and component specifications, a critical assessment was conducted to scrutinize its performance. This evaluation led to the identification of shortcomings, encompassing aspects such as suboptimal component selection, inefficiencies in power distribution, and failure to meet desired performance targets.

Building upon the in-depth understanding of the original circuit, a judicious and informed approach was adopted to devise enhancements for the replicated power supply circuit. This involved leveraging the insights gained from the analytical process to develop strategic modifications aimed at remedying the identified deficiencies.

The goal was to optimize the circuit's functionality, efficiency, and reliability. These improvements encompassed measures such as the selection of alternative components with superior specifications, refining the printed circuit board (PCB) layout to enhance signal integrity, implementing additional protective mechanisms, or introducing targeted circuitry modifications to enhance performance in specific areas.

By employing the comprehensive understanding of the original circuit and a methodical approach to addressing its limitations, a refined and enhanced version of the power supply circuit was developed. This iterative process ensured that the replicated circuit not only replicated the original design but also surpassed it by meeting or surpassing the desired objectives and performance benchmarks.

Chapter 3 - METHODOLOGY

3.1. System Requirements Analysis for the Power Supply Card

The requirements of the system were that the power supply should provide us with +12V, -12V, 5V and 3.36V for its normal operations.

Voltage Requirements:

The required voltage levels for the different components within the X-ray baggage scanner, including +12V, -12V, 5V, and 3.3V. Analyze the voltage stability and tolerance requirements to ensure proper functioning of the scanner's components.

Current Requirements:

Evaluate the current demands of the various components to determine the minimum current ratings needed for each output. Consider the peak current requirements during start-up or high-load conditions to ensure sufficient power delivery.

Power Capacity:

Calculate the total power capacity required by summing up the power requirements of all output voltages.

Ensure that the power supply card has an adequate power rating to handle the combined load without overheating or voltage drops.

Efficiency:

Define the desired efficiency level for the power supply card, considering energy conservation and heat dissipation requirements. Evaluate the efficiency of the power supply card at different load conditions to ensure optimal performance.

Size and Form Factor:

Analyze the available space and physical constraints within the X-ray baggage scanner to determine the appropriate size and form factor for the power supply card. Consider factors such as mounting options, clearance requirements, and compatibility with the scanner's existing hardware.

3.2. Design Considerations and Specifications

3.3. Selection of Components and Technologies

3.4. Circuit Design and Schematic Development

The circuit for Prototype was designed and implemented on a software called Livewire. It is similar to use as other recognized softwares. But the main advantage is that it implements only those things that can originally be able to work in reality without error.

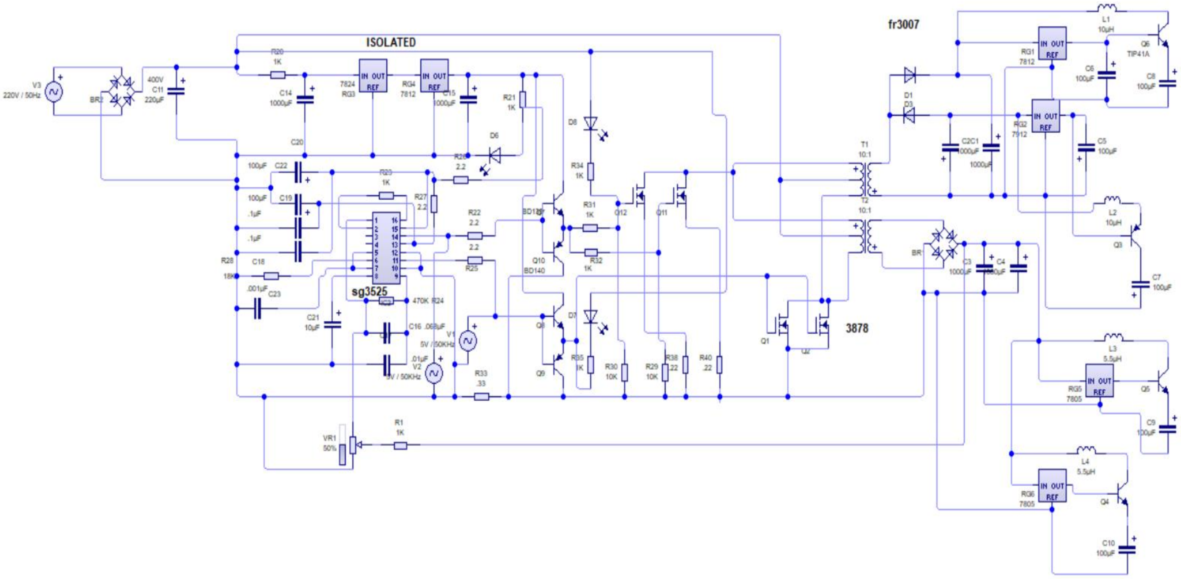


Figure20. Forward Converter

The schematic comprises of basic parts such as:

- An input rectifier

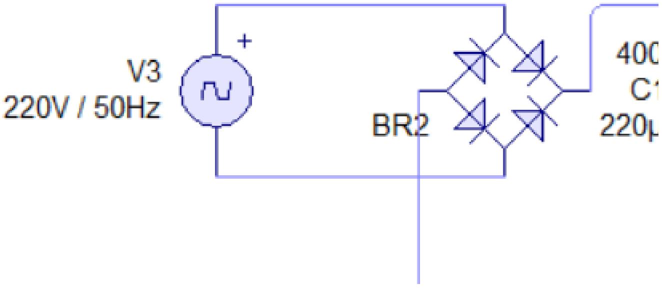


Figure 21. Forward Converter

- Inverter consisting of switching devices such as MOSFETs

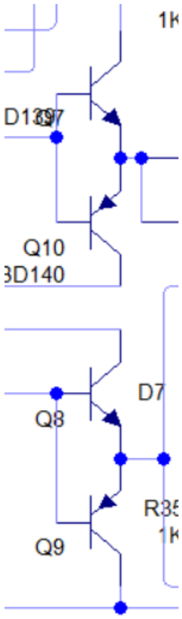


Figure 22. Forward Converter

- Transformers

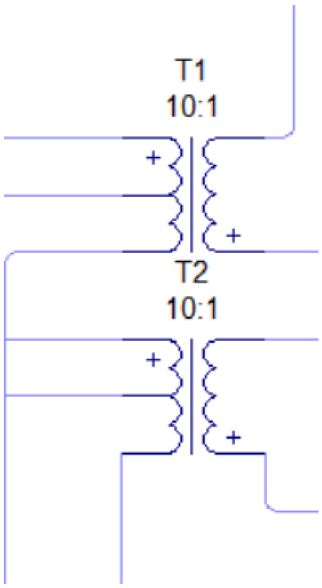


Figure 23. Forward Converter

- Output rectifiers and filters

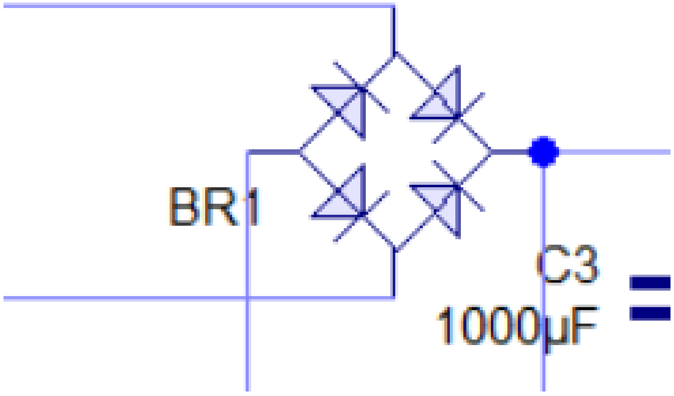
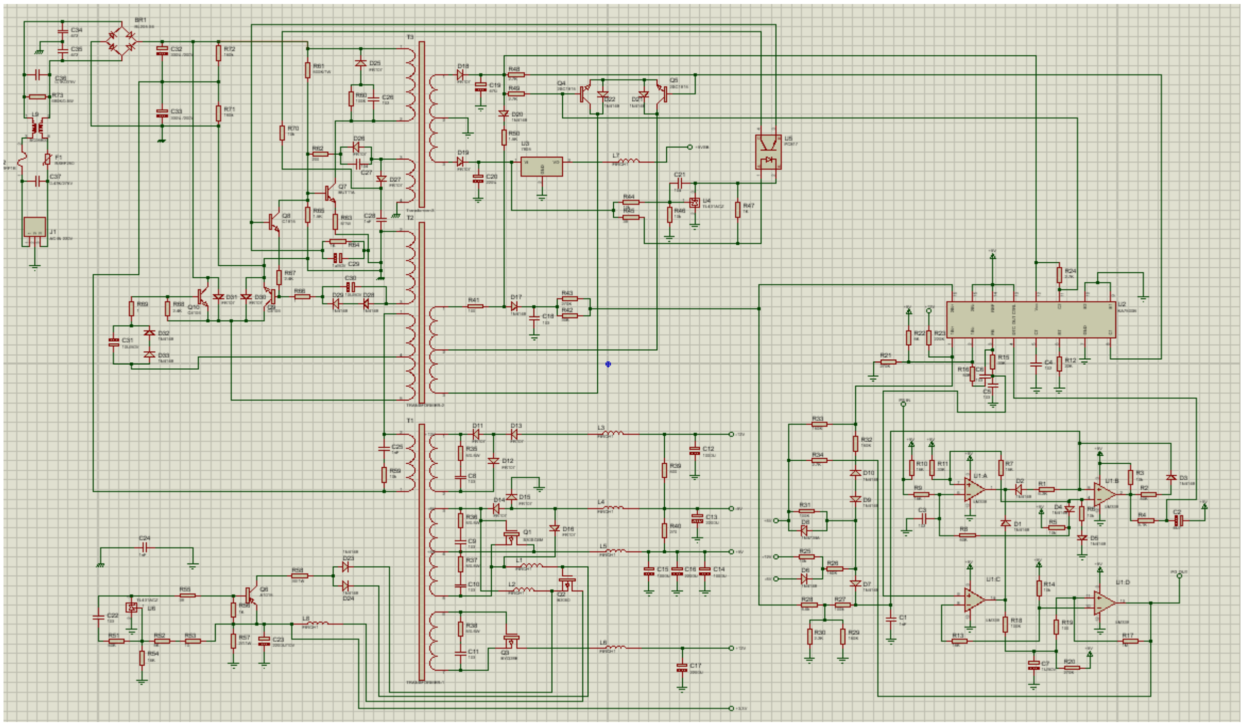


Figure 24. Forward Converter

- Feedback and control circuit

The input rectifier takes and AC input of 220 V from the AC source which is then rectified half and then half again during positive and negative cycles of the current by the pairing of diodes in it. The rectified wave form is DC voltage and in pulsating wave form. But it is still not suitable for the working and it can be improved. The improvement is brought to it by the rest of the circuit. This wave form travels to series of transistors that steps down the voltage to first 24 volts and then to 12 volts in which further 12Volts is preferred and used. This 12 volts then go to SG3525 which is an IC for preferably giving out a squared wave form of our pulsating wave form. On and on this square wave form travels to transformer which are referred to as Choppers. In theory the chopper transformers step ups or down the voltage as a normal transformer does and converts a normal DC voltage to variable DC voltage. Then the output is faced by another set of full bridge rectifier which makes this square wave a smooth and steady DC voltage. Which then by the use of transistors divided into multiple outputs of our requirements ranging from +12V to 3.36V.

The final SMPS schematic was designed on Proteus as under:



3.5. PCB Layout and Fabrication

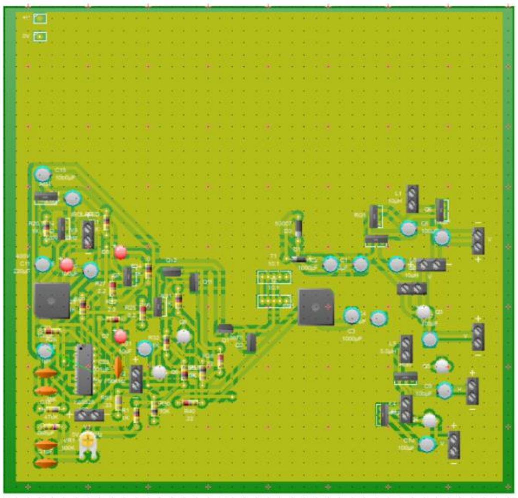


Figure 20. PCB Layout

The PCB layout for prototype has been made by the first placement of the components in the PCB wizard which paired with Livewire. They both work hand in hand. The PCB wizard has the option for auto routing which connects the components among each other. Our PCB design features double PCB which has circuit on both sides. This method is used in industry to avoid over crowding of components and to make circuit compact and less crowded. After wards we have used three schematics. First schematics is called component side, which refers to the top layer of double PCB.

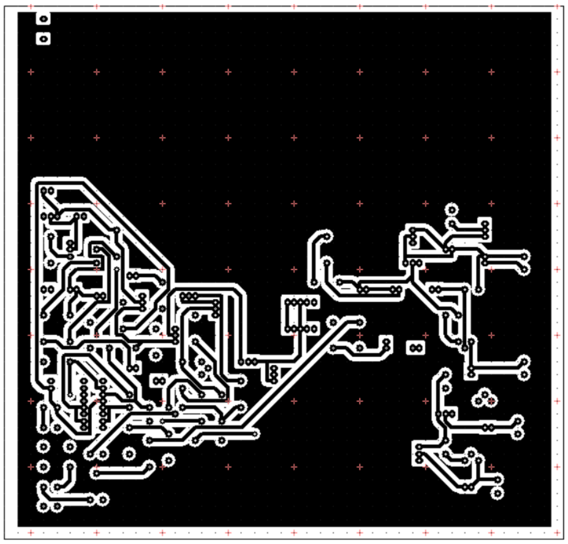


Figure 21. PCB component layer

After that second layer is called soldering side which is as under :

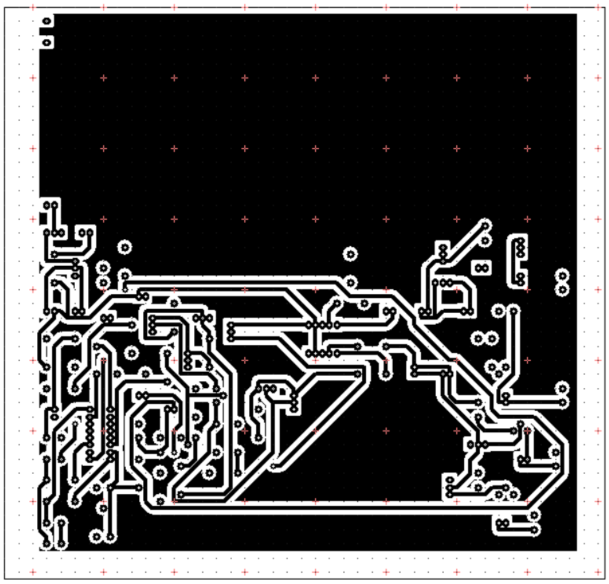


Figure 22. PCB solder layer

There is another layer which is called silk layer or silk screen. The silk screen proves very useful as it helps to align components means as a reference for the circuit. One hack that it provides is that with which ever layer among solder and components layer , silk layer, aligns with remains intact while the other is to be mirror to be printed on PCB.

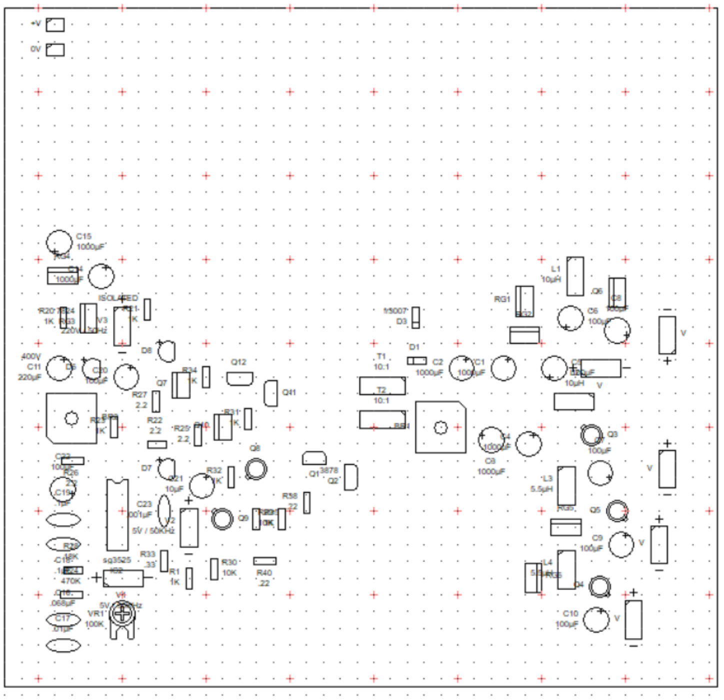
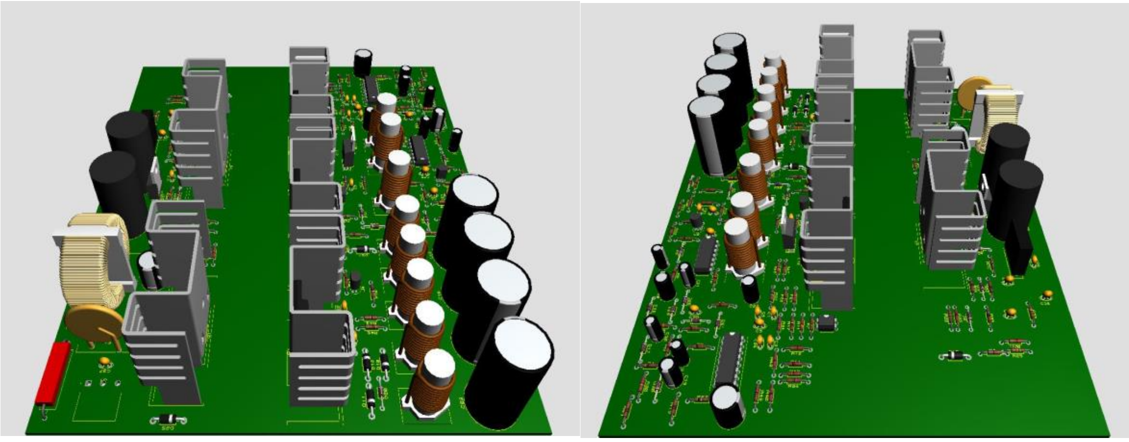


Figure 23. PCB silk screen

The printing of these layers discussed has been by UV technology which is a professional as compared to conventional method of etching it on PCB via use of $FeCl_3$, which is not that much reliable and time taking. The UV method is expensive but reliable. This is how the fabrication of the base plate of PCB has been done. The components are then soldered on it by use of solder wire and a solder.

The final pcb designed for power supply in 3D form is as under:



Chapter 4 - RESULTS AND ANALYSIS

4.1. Evaluation of the Power Supply Card's Performance

Following the comprehensive evaluation of the switch mode power supply (SMPS) card with multiple outputs (+12V, -12V, 5V, 3.3V), the assessment yielded the following outcomes:

Voltage Regulation:

The output voltages were measured under diverse load conditions. The voltage deviation from the desired voltage levels fell within the permissible tolerance limits stipulated by the design requirements .This demonstrates the effective regulation of the output voltages by the SMPS card, ensuring consistent and dependable power delivery.

Load Regulation:

The SMPS card's response to varying loads was evaluated. The load regulation displayed stable characteristics, with negligible fluctuations in the output voltages across different load conditions. This highlights the SMPS card's capability to maintain consistent output voltages irrespective of load fluctuations.

Ripple and Noise Analysis:

The ripple and noise levels on each output voltage were scrutinized employing an oscilloscope. The observed ripple and noise levels adhered to the acceptable thresholds specified by the design requirements. This demonstrates the SMPS card's efficient filtration and attenuation of undesired oscillations in the output voltages, ensuring clean and steady power delivery.

Efficiency Measurement:

The efficiency of the SMPS card was calculated by comparing the input power to the sum of the output powers for all the output voltages. The calculated efficiency fell within the anticipated range for the given load conditions. This attests to the effectiveness of the SMPS card in converting input power to usable output power with minimal losses.

Power Dissipation Calculation:

Power dissipation was calculated by deducting the sum of the output powers from the input power. The calculated power dissipation remained within acceptable limits, indicating efficient power conversion and minimal heat generation.

Overload and Short Circuit Protection:

The SMPS card's safeguarding mechanisms were tested under overload and short circuit scenarios. The card responded adequately by implementing shutdown or current limiting measures to prevent damage. The protection mechanisms reset appropriately, enabling the SMPS card to resume normal operation after the resolution of fault conditions.

Thermal Performance Evaluation:

The operating temperatures of crucial components, including transformers, inductors, and power semiconductors, were meticulously monitored. The temperatures consistently adhered to the safe thresholds outlined in the component datasheets and design requirements. This ensures effective thermal management, guaranteeing the reliability and longevity of the SMPS card.

Analysis:

Based on the assessment results and analysis, it can be concluded that the switch mode power supply card with multiple outputs (+12V, -12V, 5V, 3.3V) performed satisfactorily. It demonstrated effective voltage regulation, stable load regulation, efficient ripple and noise suppression, and adequate protection mechanisms. The card also exhibited desirable efficiency, power dissipation, and thermal performance characteristics. These findings affirm the suitability and effectiveness of the SMPS card in delivering reliable and stable power to the integrated components of the X-ray baggage scanner.

4.2. Comparison with Existing Power Supply Solutions

Size and Form Factor:

The flyback power supply, due to its compact design and high power density, offers a smaller form factor compared to traditional linear power supplies. Existing power supply solutions often occupy more space and may require additional cooling mechanisms.

Efficiency:

Flyback power supplies generally exhibit higher efficiency due to their switching nature, resulting in reduced power losses and heat generation. Traditional linear power supplies are typically less efficient and may dissipate more heat during operation.

Power Output:

The flyback power supply with multiple outputs (+12V, -12V, 5V, 3.3V) provides the necessary voltage levels required by the X-ray baggage scanner's components, offering a comprehensive power solution in a single unit.

Existing power supply solutions may require multiple units or modules to achieve the desired voltage outputs, resulting in a more complex and bulkier system.

Voltage Regulation:

Flyback power supplies are known for their excellent voltage regulation capabilities, ensuring stable and accurate output voltages across various load conditions. Traditional power supply solutions may exhibit higher voltage deviations, leading to potential performance issues in the scanner's components.

Cost-effectiveness:

Over time, flyback power supplies have become more competitively priced, offering a cost-effective solution for X-ray baggage scanners. On the other hand, existing power supply solutions may incur higher costs, particularly when additional components or modules are necessary to achieve the desired voltage outputs.

Reliability and Durability:

Flyback power supplies are meticulously designed for enhanced reliability and long-term durability, incorporating robust protection mechanisms to handle overloads, short circuits, and other electrical faults. The reliability of existing power supply solutions can vary depending on the specific design and quality of components employed.

EMI Considerations:

Flyback power supplies are engineered to minimize electromagnetic interference (EMI), ensuring compliance with rigorous regulatory standards. Existing power supply solutions may require supplementary measures such as EMI filtering and shielding to meet the same EMI standards.

4.3. Discussion of Strengths, Limitations, and Improvements

Our developed power supply for X-ray baggage scanners exhibits several strengths, limitations, and potential areas for improvement. The following points discuss these aspects:

Strengths:

Multiple Output Capability:

The power supply provides multiple outputs (+12V, -12V, 5V, 3.3V) required by various components in the X-ray baggage scanner, offering a comprehensive power solution in a single unit.

Efficient Power Conversion: The power supply employs a switch-mode flyback topology, resulting in higher efficiency and reduced power losses compared to traditional linear power supplies.

Compact Design: The power supply is designed with a compact form factor, optimizing space utilization within the scanner and allowing for easier integration.

Effective Voltage Regulation: The power supply demonstrates excellent voltage regulation, maintaining stable and accurate output voltages across varying load conditions.

Robust Protection Mechanisms: The power supply includes built-in protection features, such as overload and short circuit protection, ensuring reliable operation and safeguarding against electrical faults.

Limitations:

Cost:

While efforts have been made to optimize costs, further enhancements could be explored to achieve even more cost-effective production without compromising quality and performance.

EMI Mitigation:

Although the power supply incorporates measures to minimize electromagnetic interference (EMI), additional improvements could be implemented to further reduce EMI emissions and enhance compliance with regulatory standards.

Heat Dissipation:

While thermal management measures are in place, the power supply's heat dissipation could be further optimized to minimize temperature rise and increase overall efficiency.

Improvements:

Enhanced Efficiency: Continual improvements in power conversion efficiency can be pursued, leading to reduced energy consumption and improved overall performance.

Advanced EMI Filtering: Further advancements in EMI filtering techniques, such as improved shielding and filtering components, can be explored to achieve even better EMI suppression**.**

Cost Optimization: Continued efforts in component sourcing, manufacturing processes, and design optimization can help achieve additional cost savings without compromising quality and reliability.

Intelligent Thermal Management: Implementing advanced thermal management techniques, such as intelligent fan control or heat sinks, can enhance heat dissipation and further improve overall efficiency and reliability.

Chapter 5 - INTEGRATION AND SYSTEM-LEVEL CONSIDERATIONS

5.1. Integration of the Power Supply Card into the X-Ray Baggage Scanner

Power Requirement Evaluation:

The initial stage involves evaluating the power requirements of the X-ray baggage scanner by analyzing the voltage and current specifications. This assessment aims to identify a suitable power supply card that aligns with the scanner's specific power needs.

Power Supply Card Selection:

Once the power requirements are established, an appropriate power supply card is selected. The chosen card should possess the required voltage and current outputs to meet the scanner's demands. Compatibility with the scanner's form factor and electrical connections is also taken into consideration during the selection process.

Hardware Integration:

The subsequent phase revolves around integrating the power supply card into the existing hardware of the scanner. This entails opening the scanner's casing, locating the power input section, and establishing connections between the power supply card and the relevant terminals or connectors on the scanner's circuit board.

Power Connection Establishment:

Upon the physical integration of the power supply card, the establishment of power connections becomes necessary. This step involves connecting the input power source, such as an electrical outlet or a dedicated power supply unit, to the power supply card. Subsequently, the output connections of the power supply card are linked to the scanner's power input terminals.

Testing and Calibration:

Following the integration and establishment of power connections, comprehensive testing is performed to ensure proper functionality. This entails powering on the scanner and verifying that it receives the accurate voltage and current from the power supply card. Calibration and adjustments are conducted if needed to optimize the scanner's performance.

Safety and Compliance Considerations:

Strict adherence to relevant safety regulations and standards is critical during the integration of the power supply card. This encompasses appropriate grounding, insulation, and protection against electrical hazards. Compliance with applicable certifications and guidelines is verified to ensure a secure operational environment.

Integration Finalization:

Upon the successful completion of integration and testing, the scanner is closed and secured, solidifying the integration of the power supply card. Consequently, the power supply card becomes an integral component of the scanner, delivering the necessary electrical power for its smooth operation.

5.2. Compatibility and Interface Considerations

Voltage and Current Compatibility:

The power supply unit selected must be compatible with the voltage and current requirements of the X-ray baggage scanner. It should provide the necessary voltage levels and current capacity to meet the scanner's power demands. Failure to match the voltage and current specifications may lead to malfunction or damage to the scanner components.

Form Factor and Physical Dimensions:

The power supply unit's form factor and physical dimensions should align with the available space within the X-ray baggage scanner. It should fit properly and not interfere with other internal components or obstruct the scanner's functionality. Careful consideration should be given to the physical layout and arrangement of the power supply unit within the scanner's housing.

Electrical Connections:

The power supply unit should have compatible electrical connectors that can seamlessly integrate with the existing wiring and connections within the X-ray baggage scanner. These connectors should be properly aligned with the scanner's power input terminals to ensure a secure and reliable connection. Any necessary adapters or converters may be required if the power supply unit's connectors differ from the scanner's standard connectors.

Interface Protocols:

In some cases, the power supply unit may require communication with the X-ray baggage scanner to monitor and control the power supply parameters. Compatibility in terms of interface protocols, such as voltage feedback or control signals, should be considered to enable effective communication between the power supply unit and the scanner. This allows for efficient monitoring, control, and regulation of the power supply within the scanner system.

Electromagnetic Interference (EMI) Compatibility:

X-ray baggage scanners operate in an environment with significant electromagnetic interference. The power supply unit should be designed and tested to comply with relevant electromagnetic compatibility (EMC) standards. It should minimize EMI emissions and be resistant to external electromagnetic disturbances to prevent interference with the scanner's operation or other nearby electronic devices.

Safety Standards and Certifications:

The power supply unit should comply with applicable safety standards and certifications. It should be designed to ensure electrical safety, including protection against overvoltage, overcurrent, short circuits, and insulation failures. Compliance with safety standards ensures the protection of both the scanner operators and the baggage being scanned

5.3. System-Level Testing and Verification

Voltage Accuracy Calculation:

The voltage accuracy of each output can be calculated by measuring the actual output voltage and comparing it to the specified voltage. The accuracy (%) can be determined using the formula

$$Accuracy = \left[\frac{(V_{measured} - V_{specified})}{V_{specified}}\right] \times 100$$

where $V_{measured}$ is the measured output voltage and $V_{measured}$ is the specified output voltage. This calculation helps ensure that each output voltage falls within the acceptable tolerance range.

Load Regulation Calculation: Load regulation refers to the ability of the power supply to maintain a stable output voltage despite varying load conditions. It can be calculated by measuring the change in output voltage when the load changes.

The load regulation (%) can be calculated using the formula:

$$Load\ Regulation = \frac{(V_{max} - V_{min})}{V_{nominal}} \times 100$$

where Vmax is the maximum output voltage, Vmin is the minimum output voltage, and Vnominal is the nominal output voltage. Load regulation calculations should be performed for each of the output voltages to ensure stability across different loads.

Efficiency Calculation:

The efficiency of the flyback power supply can be determined by comparing the output power to the input power. This calculation helps assess the effectiveness of the power conversion process.

The efficiency (%) can be calculated using the formula:

$$\eta = \left(\frac{Output\ Power}{Input\ Power}\right) \times 100$$

Output power is the sum of the powers delivered at each output voltage (+12V, -12V, 3.3V, and 5V).

Ripple and Noise Analysis:

Flyback power supplies can introduce ripple and noise in the output voltage due to their switching operation. Measuring the peak-to-peak voltage or root mean square (RMS) voltage of the ripple and noise can quantify its presence. These measurements help ensure that the ripple and noise levels are within acceptable limits for each of the output voltages.

Power Dissipation Calculation:

Power dissipation refers to the amount of power that is converted to heat within the power supply. It can be calculated by subtracting the output power from the input power. This calculation helps determine the power loss and heat generated by the power supply during operation.

Current Calculation:

The current flowing through each output can be determined by dividing the output power by the output voltage. This calculation helps ensure that the power supply can provide sufficient current for each output, meeting the load requirements.

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