

DESIGN AND ANALYSIS OF HIGH STABILITY SWITCH MODE POWER SUPPLY FOR REVERSE OSMOSIS WATER PURIFIER

Kaustubh Pise*, and Anandrao Kakade

Received: May 23, 2024; Revised: July 29, 2025; Accepted: July 30, 2025

Abstract

Design and development of a switch-mode power supply tailored for reverse osmosis (RO) water purifiers is presented, delivering a regulated 24V, 2.5A DC output. A flyback converter topology was selected due to its compact size, inherent galvanic isolation, and suitability for medium-power applications. The system operates in Continuous Conduction Mode (CCM), ensuring steady energy transfer between the transformer's windings, which reduces output ripple and enhances dynamic response under variable loads. The SMPS maintains voltage regulation within $\pm 1.2\%$ across a broad AC input range of 150V to 260V, addressing common variations in residential voltage. Efficiency exceeds 82% at nominal load, while output ripple remains below 60 mV—adequate for sensitive RO components, such as pumps, solenoids, and control modules. The initial prototype was built on a breadboard, followed by realization on a custom PCB optimized for electromagnetic interference mitigation and thermal performance. Integration with a domestic RO system confirmed the design's reliability. Under prolonged operation, the power supply stabilized thermally at approximately 60°C without requiring active cooling. Cost-effectiveness, compactness, and electrical stability are key strengths of this design. The use of CCM flyback operation, precise feedback control, and robust filtering techniques contributes to efficient and reliable long-term performance. This implementation offers a practical and replicable approach for engineers developing SMPS units for low- to medium-power applications where space, efficiency, and stable output are critical.

Keywords: Continuous Conduction Mode (CCM); Current-Mode Control; Efficiency; Flyback Converter; OB2269 IC; RO water purifier; SMPS design; Switch-mode power supply

Introduction

The increasing demand for safe, clean drinking water has accelerated the adoption of reverse osmosis (RO) systems in both residential and industrial environments. RO technology, which relies on a semi-permeable membrane to remove dissolved salts and contaminants from water, has become a cornerstone of modern water purification. However, the effectiveness and longevity of RO systems significantly depend on the reliability of the power supply that drives essential components such as pumps, solenoid valves, and control circuits. Inconsistent or unstable voltage can result in

Department of Electronics Engineering, Rajarambapu Institute of Technology, Islampur, India.
Email: kaustubhpise007@gmail.com*; anandrao.kakade@ritindia.edu

* Corresponding author

DOI: <https://doi.org/10.55766/sujst9986>

Suranaree J. Sci. Technol. 33(1):010396(1-11)

underperformance, premature component failure, or even damage to the entire system. This necessity underlines the importance of a robust and efficient power supply tailored specifically to meet the operational needs of RO purifiers.

Traditionally, many RO systems have used linear power supplies due to their simplicity and low noise characteristics. However, these come with considerable drawbacks, such as bulky size, excessive heat generation, and poor energy efficiency. The energy lost in the form of heat not only affects operational efficiency but also poses a risk to surrounding components and increases the cooling requirements. As a solution to these challenges, switch-mode power supplies (SMPS) have emerged as the preferred alternative, offering a compact form factor, higher energy efficiency, better thermal management, and the ability to handle a wide range of input voltages with minimal output variation.

In this research, a 24V, 2.5A SMPS design is proposed and implemented to power an RO water purifier. The target specification of 60 watts was chosen to match the typical power demand of commercially available domestic RO units, which often integrate booster pumps, flow controllers, and solenoid-operated valves. Unlike generic SMPS modules, the proposed design is application-specific and optimized for long-duration operation with high reliability and minimal output ripple.

The design employs a flyback topology, which is particularly suitable for medium-power applications requiring electrical isolation between the input and output. Flyback converters offer several advantages, such as low component count, inherent short-circuit protection, and the ability to provide multiple output voltages if required. Additionally, they allow for relatively simple feedback and control mechanisms. For this study, the OB2269 integrated circuit is selected as the core PWM controller due to its high level of integration, built-in protections, and cost-effectiveness. The IC includes features such as overvoltage protection (OVP), overcurrent protection (OCP), and over-temperature protection (OTP), which contribute to the overall robustness of the system.

Component selection plays a critical role in the design and performance of the SMPS. The IRF840 N-channel power MOSFET is utilized for its high voltage tolerance and fast switching characteristics, enabling efficient energy transfer. Schottky diodes (20100) are chosen for rectification due to their low forward voltage drop and fast recovery times, which help in reducing conduction losses and improving overall efficiency. The TL431 programmable shunt regulator is employed for precise voltage reference and regulation, and an opto-isolator (PC817)

provides galvanic isolation between the primary and secondary sides, ensuring user safety and circuit protection.

The transformer design is another crucial aspect of the flyback converter, as it directly affects the output voltage and system efficiency. An EE25 ferrite core transformer with custom winding is designed, incorporating an auxiliary winding to power the controller IC and facilitate feedback regulation. Careful attention is given to minimizing leakage inductance and achieving good coupling between windings.

The SMPS is tested under various line and load conditions to validate performance. It is subjected to input voltage variations from 150V to 260V AC, simulating real-world grid fluctuations common in many developing regions. Despite the input changes, the output voltage remains within a tight regulation window of $\pm 1.2\%$, confirming the effectiveness of the feedback and regulation loop. Load testing is conducted using resistive loads corresponding to different operating conditions of the RO system, demonstrating that the output current capability aligns with the design goal of 2.5A while maintaining voltage stability and low ripple.

Furthermore, efficiency measurements reveal a peak efficiency of over 82% under nominal load conditions, which is a significant improvement over typical linear power supplies, which rarely exceed 60% efficiency. This higher efficiency translates to reduced energy consumption and heat generation, making the system more environmentally friendly and extending the lifespan of internal components.

In addition to electrical testing, the SMPS is implemented on a printed circuit board (PCB) after initial prototyping on a breadboard. The PCB layout is carefully optimized to reduce EMI (electromagnetic interference), improve thermal performance, and ensure long-term reliability. Passive filtering elements, including a PI filter at the output, are incorporated to suppress noise and improve output voltage quality. The final assembled SMPS is compact, lightweight, and capable of continuous operation without the need for active cooling, which is ideal for integration into compact RO systems.

The novelty of this work lies in tailoring a flyback-based SMPS specifically for RO systems, optimizing it for long-duration operation, dynamic load handling, and low output ripple, with full integration and validation in a real purifier setup—unlike many generic modules available commercially.

In summary, this paper details the comprehensive design methodology, simulation, component selection, practical implementation, and

validation of a dedicated 24V SMPS using the OB2269 controller IC for RO water purifiers. The developed system offers a reliable and efficient power supply solution that meets the operational demands of the application, supporting both improved performance and sustainability. The results of this study not only validate the functionality of the design but also provide a blueprint for future improvements and applications in similar low-to-medium power embedded systems requiring regulated DC power with electrical isolation.

Literature Review

For reverse osmosis (RO) water purifier applications, the OB2269 PWM controller is a highly suitable choice due to its integrated protection features, frequency jittering for reduced EMI, and efficient performance in quasi-resonant flyback topologies, offering enhanced reliability and energy efficiency compared to basic control circuits. While such advanced ICs are ideal for consumer-grade appliances, the study by Fauzi *et al.* (2022) explores a more fundamental approach by designing and implementing a switch-mode power supply (SMPS) using a flyback converter topology with a 555 timer-based pulse width modulator. The research demonstrates the effectiveness of this setup in delivering a stable 5V DC output from a 24V AC input, validated through both simulation and experimental results. The flyback topology, known for its simplicity and cost-effectiveness, especially in isolated low-power scenarios, proved to be efficient for the application. Despite minor deviations between theoretical and practical outcomes due to component tolerances and circuit impedance, the system functioned reliably. However, in practical, long-term applications like RO purifiers, integrating a dedicated IC like the OB2269 would provide superior performance, protection, and compliance with modern power safety standards (Fauzi *et al.*, 2022).

The reliability of switch-mode power supplies (SMPS) is essential in applications such as RO water purifiers, where consistent performance and minimal downtime are critical. Traditional methods of estimating the remaining useful life (RUL) of SMPS often rely on parameters like output or ripple voltage, which can be unreliable due to regulation circuitry or require expensive high-speed monitoring. Addressing these issues, Zhao *et al.* proposed a novel method that uses the case temperature variance (VOCT) as an indicator of SMPS degradation. Their technique employs an improved particle filter algorithm that automatically

adapts across different stages of degradation-identified as stable, linear, and exponential growth phases. The method demonstrated robust predictive accuracy, maintaining errors below 5% under varied thermal and electrical conditions. Incorporating this approach into the RO water purifier SMPS design can significantly improve fault prediction and maintenance planning. Since RO systems are often exposed to high ambient temperatures and continuous operation, real-time health monitoring based on case temperature variance can enable timely maintenance actions, reduce the risk of sudden failure, and extend the service life of the system. Additionally, the method's reliance on low-cost thermal sensing makes it suitable for embedded applications without increasing system complexity or cost (Zhao *et al.*, 2023).

Jian *et al.* highlighted the transition from traditional analog methods to digital current regulation, which offers higher efficiency, improved precision, and better thermal management. Key elements discussed include digital pulse-width modulation (PWM), feedback loop stabilization, and current sensing techniques optimized for high-load operating conditions. These advancements are particularly beneficial in systems such as RO (Reverse Osmosis) water purifiers, where a stable and constant 24 V power supply is required for diaphragm pumps and control electronics. Integrating high-performance digital constant current sources into RO SMPS units can improve energy efficiency, extend component lifespan, and enhance overall system reliability, particularly under variable load conditions. Therefore, this work is highly relevant for modern RO purifier power supply designers seeking to meet increasing efficiency and reliability requirements (Jian *et al.*, 2025).

Vračar (2024) investigates the structure and operations of industrial research and development laboratories involved in SMPS design. His study outlines the essential components and stages of the SMPS development process, including the use of advanced simulation software, precision testing setups, EMI analysis, and thermal performance evaluation. The work also discusses cross-functional collaboration, quality assurance procedures, and the importance of regulatory compliance. These industrial practices are highly relevant to the development of SMPS modules for RO water purifiers, which require power supplies that are compact, thermally efficient, low-noise, and capable of handling varying loads reliably. By following the structured approach described in this study—from initial design to final product testing—engineers can develop power supplies that meet the stringent performance and safety requirements of

RO systems. Integrating such methodologies results in improved product durability, reduced design time, and better alignment with industrial standards (Vračar, 2024).

Kuang *et al.* (2020) introduced a Switched-Mode Power Supply (SMPS) design assistant system based on Fuzzy Cognitive Maps (FCMs), aiming to enhance both technical performance and human decision-making in power supply design. Their approach goes beyond conventional SMPS design tools, which typically emphasize circuit-level specifications like efficiency, voltage stability, and thermal behavior. Instead, their system incorporates expert insights and design knowledge into a causal framework consisting of 69 interconnected components. Using methods such as factor analysis and expert interviews, the authors built a model capable of evaluating and guiding SMPS design by simulating different design scenarios. This methodology is particularly suitable for applications such as Reverse Osmosis (RO) water purifiers, where SMPS circuits must ensure compactness, energy efficiency, and thermal safety under variable loads. By integrating technical analysis with cognitive modelling, the assistant system helps reduce design errors, supports debugging, and provides structured recommendations-beneficial for improving the reliability and performance of SMPS circuits commonly used in RO systems, such as buck or flyback converters (Kuang *et al.*, 2020).

Thwe Zin Tun presents the design and implementation of a high-efficiency AC-DC switch-mode power supply (SMPS) using the flyback converter circuit for low-power applications. The proposed design delivers 52.8 W at 24 V, and a nominal efficiency of 90% at full load is achieved using this topology. The start-up and bias supply circuit provides the operating voltage for the control IC and power switch drive sections. The transistor TIP41C operates as a starved (highly current-limited) linear regulator. The proposed circuit diagram is based on an SMPS-based flyback DC-DC converter. The paper discusses the analysis and design of an offline flyback converter for low-power switch-mode power supplies. The implementation results match the mathematical calculations, and the proposed converter is suitable for high-frequency, isolated DC-DC converters (Thwe Zin Tun, 2017).

Azis *et al.* (2019) present a comparative analysis between a switch-mode power supply (SMPS) using an IC TL494CN transformer and a linear power supply transformer. The study shows that SMPS experiences minimal voltage drop to the load, but the output voltage drop changes significantly in linear power supply transformer-based parameters. The paper concludes that SMPS

is not perfect due to low efficiency caused by the modified switching transformer not meeting quality standards and other factors. The study suggests improving the performance of SMPS to obtain better results in the future.

Wang *et al.* (2021) present the design of a wide-range high-input voltage flyback power supply for low-voltage DC equipment in PV power plants. The designed power supply has an input operating voltage range of 200-1200 VDC and an output power of 200W. The main circuit and flyback transformer design are provided, and the prototype trial production results show that the designed power supply meets the low-voltage DC power supply requirements of equipment in the PV field area of the PV grid-connected power generation system. The paper also includes technical details on the control circuit design and the input over-voltage protection circuit.

Cui and Cui (2016) propose a new type of switching power supply that combines flyback and half-bridge resonant topology. It includes an input protection circuit, an EMI suppression filter, and an active power factor correction circuit, and has good voltage stabilizing performance with small ripple and higher power factor. The power supply has three outputs (5V, 12V, 24V) and has been tested for efficiency, power factor, cross-loading, ripple and noise, and output voltage overshoot and time-to-climb. The proposed power supply demonstrates higher precision of output voltage, higher power factor, smaller ripple, and improved load-carrying capacity compared to ordinary switching power supplies.

Ozdemir *et al.* (2009) present a study on the design of a filter solution for common-mode noises in a switched-mode power supply (SMPS). The study focuses on designing and implementing a common-mode filter to reduce noise in SMPS outputs. The use of a common mode choke to reduce electrical noise and the origins of common mode noises are discussed. The designed filter consists of a common-mode choke and capacitors. Experimental studies were conducted to evaluate its effectiveness, showing a significant reduction in common mode noise from 200 mV to 20 mV. The study highlights its relevance for low-noise applications such as medical devices, audio equipment, and instrumentation.

Kalpana *et al.* (2014) present the design and implementation of a high-frequency isolated AC-DC converter for switched-mode power supplies in telecommunication systems. The converter is designed for near-unity power factor and low total harmonic distortion (THD) under varying load conditions. Closed-loop voltage control is implemented using a DSP controller and tested for

sudden load variations. A full-bridge buck topology and high-frequency transformer provide galvanic isolation. The design process is detailed, and results demonstrate high efficiency (up to 95%) and low THD (maximum 3%). The output voltage regulation is within 1% even under load transients.

Rathy and Balaji (2018) discuss the use of DC electronic loads in testing various power sources, including SMPS. They present a variable electronic load using MOSFET switching to load the SMPS, with the current controlled via a comparator-based circuit. Heat-sinking methods using IRF250 MOSFETs, cooling fans, and metal casings are essential to prevent damage. The results validate the load's performance on a 24V SMPS, supporting up to 6A load variation. The study underscores the importance of heat management and scalability for testing and battery development applications

Mohan and Ang (1994) introduced a digital signal processor (DSP)-based controller for switching converters, utilizing the Texas Instruments TMS320C30 DSP. Their design enabled real-time control and improved dynamic performance, offering a flexible and programmable alternative to traditional analog controllers. The study demonstrated enhanced voltage regulation and transient response, highlighting the potential of DSPs in power electronics applications.

Saravana Prakash and Kalpana (2016) explored configurations of modular push-pull buck DC-DC converters tailored for 12 kW telecom switch-mode power supplies (SMPS). Their design emphasized scalability and modularity, facilitating maintenance and redundancy. The converters achieved high efficiency and power density, making them suitable for high-demand telecom infrastructures.

Design and Operational Principles of the SMPS

1. Simulation of proposed SMPS

The proposed SMPS was initially designed and simulated using LTspice to verify its functional behavior before hardware implementation, as shown in Figures 1 and 2. The simulation focused on validating output voltage regulation, transformer magnetics, and switching timing performance under different load and input conditions. By accurately modelling the flyback converter topology-including the MOSFET switch, optocoupler feedback, and snubber circuit-the design team could observe waveform behaviours. Such as switch node voltage, primary and secondary current ripple, and output voltage transients. These simulations ensured that the converter operated within safe switching limits

and provided insight into possible stress points in the design.

The LTspice results were critical in optimizing key components, such as selecting the appropriate transformer turns ratio, core material, and switching frequency. Parameters like peak inductor current, transformer saturation limits, and snubber losses were examined to fine-tune the efficiency and thermal profile of the system. By iterating through simulations, the design was refined to improve voltage stability, minimize EMI, and ensure robust operation across varying input voltages (180 - 260V AC). This simulation phase helped reduce development time and cost by minimizing trial-and-error in the hardware stage and increasing the overall reliability of the final SMPS design.

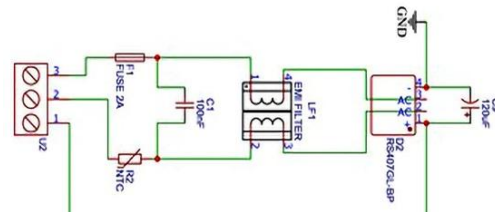


Figure 1. EMI filter, Rectifier, and filter in LTspice simulation

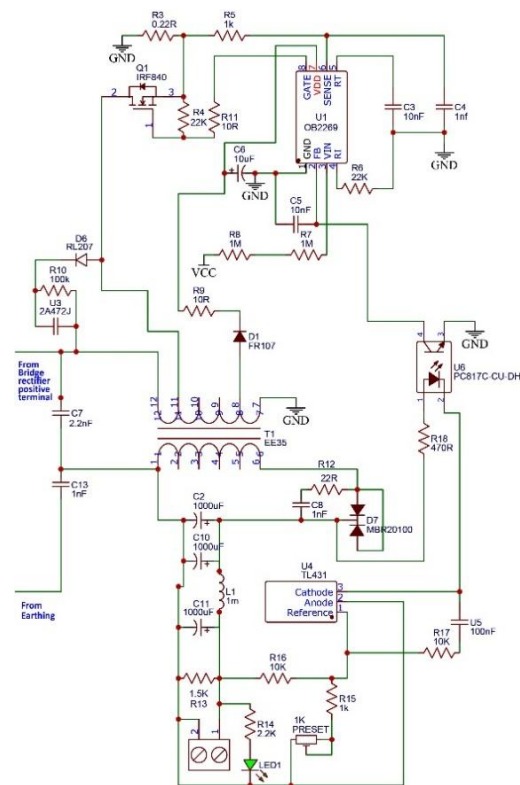


Figure 2. Proposed circuit diagram of 60W flyback converter in LTspice

2. Testing the SMPS Circuit in Breadboard and Simulation Results

After successful simulation, the OB2269-based SMPS circuit was assembled and tested on a breadboard to validate real-world performance, with special focus on the controller IC's behavior. Figure 3 illustrates the OB2269 IC under test conditions, where the chip successfully generated a stable 80 kHz switching frequency, as expected from the design specifications. This initial testing phase helped confirm that the IC's internal oscillator, start-up circuitry, and gate drive functionality were operational.

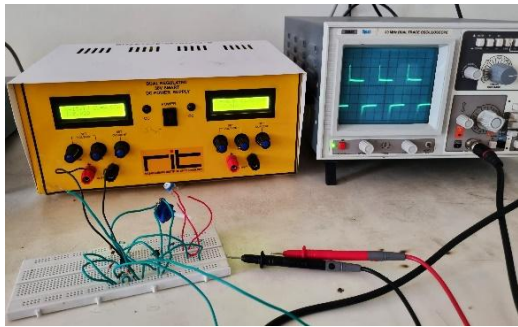


Figure 3. OB2269 IC testing with its generated 80 KHz frequency

Oscilloscope probes were used to monitor key nodes, such as the drain of the switching MOSFET and the VDD pin of the IC, ensuring that the IC started up correctly and drove the gate signal with clean, sharp transitions. This stage was crucial for verifying that the frequency generation, PWM control, and soft start mechanisms of the OB2269 were functioning properly before moving to PCB prototyping.

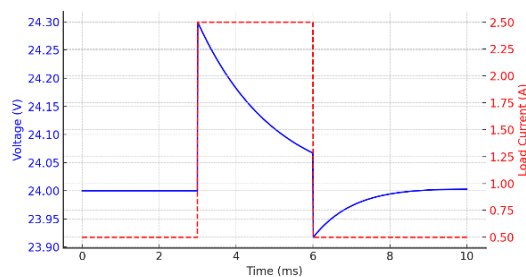


Figure 4. Simulated transient response graph of the SMPS under a step change in load conditions

The above Figure 4 illustrates the transient response of the SMPS when subjected to a sudden change in load conditions, simulating real-world behavior in an RO water purifier system. At 3 milliseconds, the load current sharply increases from 0.5A to 2.5A, representing the activation of the

booster pump. This step change causes a brief voltage undershoot, where the output voltage momentarily drops below the nominal 24V due to the sudden surge in demand. The control loop within the OB2269 controller responds by adjusting the duty cycle, and the voltage quickly recovers to its steady-state value. At 6 milliseconds, the load reverts to its original light condition, causing a brief voltage overshoot followed by rapid stabilization. These transitions demonstrate the SMPS's ability to maintain voltage regulation under dynamic load variations, which is essential for ensuring consistent performance and reliability in sensitive RO system components such as pumps, solenoid valves, and sensors.

3. Operational Principles

The switch-mode power supply (SMPS) is a sophisticated circuit that efficiently converts the input voltage to the desired output voltage while providing stable and regulated power to the load. The SMPS consists of several stages and components that work together to achieve this conversion.

Input Stage: The SMPS takes an alternating current (AC) input voltage from the main power supply. The input voltage is first rectified using diodes to convert it to a pulsating direct current (DC) voltage.

This pulsating DC voltage is then filtered using capacitors to smooth out the ripples and obtain a stable DC voltage. Also, it has an EMI filter, which filters out the unwanted signal from the AC signal shown in Figure 1.

Power Conversion Stage: The power conversion stage is where the main operation of the SMPS takes place. It involves the IC OB2269, MOSFET switching, transformer operation, rectification, filtering with the PI filter, and voltage regulation with the TL431 shunt regulator shown in Figure 2.

PWM Control: The IC OB2269 serves as a pulse-width modulation (PWM) controller in the SMPS. It generates a high-frequency PWM signal that controls the switching operation of the MOSFET. The duty cycle of the PWM signal determines the ON and OFF times of the MOSFET, regulating the energy transfer from the input to the output.

The OB2269 IC was configured with a switching frequency of 80kHz and external components chosen to enable undervoltage lockout (UVLO), over-voltage protection (OVP), and primary-side current limiting. Feedback was implemented via a PC817 opto-isolator and TL431 shunt regulator, ensuring tight voltage regulation across varying loads.

MOSFET Switching: The MOSFET, specifically the IRF840 in this design, is used as the main switch in the SMPS. The PWM signal from the OB2269 controls the ON and OFF states of the MOSFET. When the MOSFET is turned ON, it allows current to flow from the input side to the primary winding of the transformer. When it is turned OFF, the current stops flowing, and energy stored in the transformer is transferred to the secondary winding. Also tested IC OB2269 in a breadboard as shown in Figure 3.

Transformer Operation: The EE25 transformer with specific winding details is an essential component in the SMPS. It provides galvanic isolation between the primary and secondary sides and also steps down the voltage to the desired level. The primary winding, consisting of 96 turns of $1 \times 0.5\text{mm}$ wire, receives the input voltage and generates a magnetic field when the MOSFET is turned ON. The secondary winding, comprising 8 turns of $8 \times 0.5\text{mm}$ wire, produces the desired 24V output voltage. The auxiliary winding, consisting of 4 turns of $1 \times 0.5\text{mm}$ wire, serves auxiliary purposes.

Rectification and Filtering: After the energy transfer in the transformer, the secondary winding voltage is rectified using Schottky diodes. In this design, 20100 Schottky diodes are used in a half-bridge rectifier configuration. The rectified voltage contains some high-frequency components and ripple. To further improve the filtering and obtain a smoother output voltage, a PI filter is added after the rectification stage. The PI filter consists of an inductor (L) and capacitors (C) arranged in a specific configuration. The inductor, placed between the diode bridge and the output capacitors, helps to reduce high-frequency noise and ripple by smoothing the current flow. The capacitors provide additional smoothing and help maintain a low level of ripple. Figure 5 shows the proposed circuit diagram of a 60-Watt SMPS.

Voltage Regulation: The TL431 shunt regulator is employed for voltage regulation in the SMPS. It compares the actual output voltage with a reference voltage and provides feedback to the PWM controller (OB2269). The PWM controller adjusts the duty cycle of the PWM signal accordingly to regulate the output voltage. This feedback loop helps maintain a stable and precise output voltage of 24V, even under varying input conditions and load changes.

Output Stage: The regulated and stabilized output voltage of 24V is supplied to the 24V 2.5A RO water purifier shown in Figure 5, providing it with the required power for operation. The output stage ensures that the voltage delivered to the water

purifier remains constant and within the desired range, enabling reliable and consistent performance.

The working of the SMPS involves a continuous switching process. The PWM controller generates the PWM signal, controlling the ON and OFF states of the MOSFET. During the ON state, energy from the input source is stored in the transformer's magnetic field. When the MOSFET switches to the OFF state, the stored energy is transferred to the secondary winding. This energy transfer occurs at a high frequency, typically in the range of tens or hundreds of kilohertz.

The integration of specific components such as the IC OB2269, MOSFET, transformer, rectification with Schottky diodes, PI filter with an inductor, and voltage regulation with the TL431 shunt regulator ensures efficient power transfer, precise voltage regulation, and improved filtering capabilities. These components work together harmoniously to provide a reliable and stable power supply to the RO water purifier.

A prototype was initially developed on a breadboard to verify the design, followed by comprehensive performance testing. After confirming the expected voltage and current outputs under load, a printed circuit board (PCB) layout was created. The final SMPS unit was assembled and underwent further verification to ensure consistent functionality. The compact and optimized final product is depicted in Figure 5, demonstrating its suitability for integration into RO purifier systems.



Figure 5. Compact 24 V, 2.5 A, 60 W final working prototype of the SMPS

Results and Discussions

In this project, a Switch Mode Power Supply (SMPS) was designed and developed to meet the power requirements of a Reverse Osmosis (RO) water purifier system. The SMPS was configured to deliver an output of 24V DC at 2.5A, resulting in a

total power output of 60 watts. The design process involved a detailed analysis of the RO system's electrical requirements and careful selection of high-performance components to ensure reliability, stability, and efficiency.

The tested RO system includes a 24V pump (1.8A max), a solenoid valve (0.3A), and a TDS controller and sensors (~0.2A combined), resulting in a peak load of ~2.3-2.5A. The proposed SMPS consistently delivered this current range without voltage drop or instability.

1. Voltage Testing Under Varying Input Conditions

Voltage testing was carried out to evaluate the performance of the SMPS under varying AC input voltage conditions, both in no-load and load scenarios. The input voltage was varied from 150V AC to 260V AC, and the corresponding output voltages were recorded.

Table 1. Output Voltage Variation with Input AC Voltage

Sr No.	Input Voltage (V AC)	Output Voltage (V DC) without Load	Output Voltage (V DC) with Load
1	150	24.0	23.8
2	180	24.2	23.8
3	200	24.1	23.7
4	220	24.0	23.8
5	240	24.3	23.9
6	260	24.2	23.8

Based on the data presented in Table 1, the output voltage of the SMPS remained largely stable across a broad range of input voltages. Without load, the output voltage varied between 24.0V and 24.3V DC, and under load conditions, it slightly decreased to a range of 23.5V to 23.9V DC. Figure 6, derived from this table, further illustrates the SMPS's capability to regulate voltage effectively, demonstrating its reliability and suitability for consistent performance in real-world RO water purifier applications.

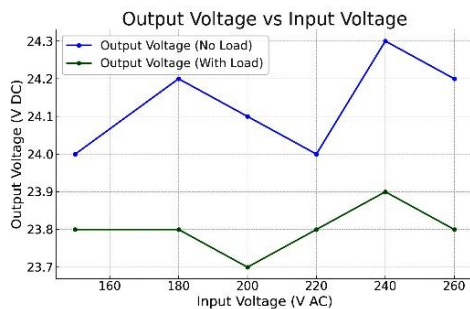


Figure 6. Output DC Voltage vs. Input AC Voltage under No-Load and Load Conditions

2. Current Testing and Load Regulation

To evaluate the load-handling capacity of the SMPS, current testing was conducted using variable resistive loads. The objective was to assess how the output current responds to different load conditions while ensuring that the output voltage remains constant.

Table 2. Output Voltage and Current for Varying Load Resistance

Load Resistance (Ω)	Output Current (A)	Output Voltage (V)
10	2.2	23.6
20	1.1	23.7
30	0.7	23.8
40	0.5	24
50	0.4	24

From Table 2 above, it is evident that as the load resistance increases, the output current decreases proportionally, while the output voltage remains nearly constant around 24V. This behavior demonstrates excellent load regulation characteristics of the SMPS.

Additionally, the developed SMPS was tested in conjunction with a 24V solenoid valve connected at the output, and a fan regulator connected in series. The circuit maintained a consistent output voltage, thereby validating its integration potential with RO water purifier components.

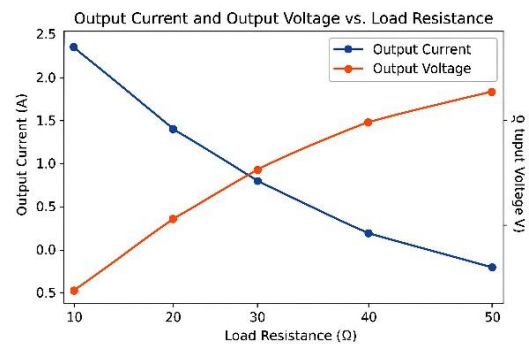


Figure 7. Current Testing and Load Regulation Graph

The graph illustrates Figure 7 the relationship between load resistance and the corresponding output voltage and output current of the SMPS is derived from Table 2. As load resistance increases from 10 Ω to 50 Ω , the output current (blue curve) shows a decreasing trend, while the output voltage (orange curve) increases steadily. This behavior aligns with Ohm's Law, where for a constant power supply, increasing the load resistance results in lower current draw and higher terminal voltage. At lower resistances, the SMPS supplies higher current, which causes a voltage drop due to internal losses

and regulation limits. Conversely, at higher resistances, the current demand is reduced, allowing the output voltage to approach the nominal regulated value. This trend validates the SMPS's ability to adjust and maintain regulation across a wide range of load conditions, demonstrating effective load handling and stable voltage output characteristics.

Additionally, the tested SMPS circuit was integrated into a practical setup where it was connected in series with a fan regulator to simulate varying input conditions. A 24V solenoid valve was connected at the output to represent the typical load encountered in RO water purifier systems. Throughout the testing, the SMPS successfully maintained a consistent output voltage of 24V, even under varying input conditions introduced by the regulator.

This consistent performance, as shown in Figure 8, demonstrates the robustness of the SMPS design in delivering regulated power to critical components such as solenoid valves, which require stable voltage for proper operation. The ability of the SMPS to function reliably in such a configuration underscores its suitability for real-world applications, where fluctuations in supply voltage and dynamic loads are common.

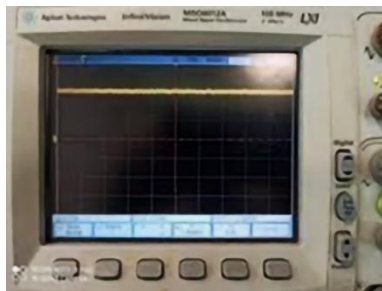


Figure 8. 24V DC output on CRO with a load

3. Thermal Testing During RO Integration

To assess thermal stability, the SMPS was connected to a fully functional domestic RO system and run continuously for 8 hours. A thermocouple

probe was attached to the heat sink of the IRF840 MOSFET, and temperature was recorded hourly.

As shown in Figure 9, the temperature gradually increased during the first 4 hours and stabilized around 60°C, indicating thermal equilibrium. No thermal runaway or excessive heating was observed. Ambient room temperature remained at approximately 28°C. The SMPS continued to deliver 24V output without triggering thermal protection or performance degradation.

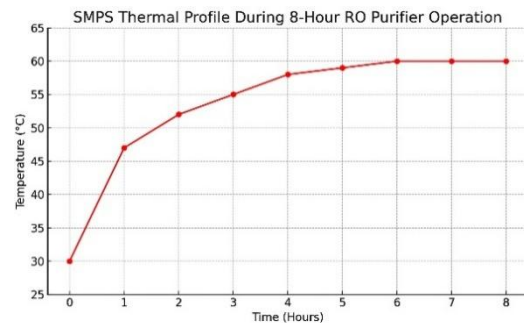


Figure 9. Thermal Testing with RO Integration

4. Performance Comparison

The linear power supply, although simple and noise-free, suffers from low efficiency and excessive heat generation. It also requires large heat sinks and transformers, increasing system weight and cost.

The generic SMPS improves on efficiency and size but often lacks tight regulation, advanced protection (OCP, OVP), or EMI filtering. These units are generally not optimized for specific loads like diaphragm pumps or solenoid valves used in RO systems.

In contrast, the proposed SMPS design using the OB2269 IC and a flyback topology achieves superior performance across all metrics. Its compact form factor, integrated protections, and high efficiency make it highly reliable and energy-efficient for long-duration RO water purifier applications. Table 3 shows the performance comparison of these power supplies.

Table 3. Performance Comparison

Parameter	Linear Power Supply	Generic SMPS Module	Proposed SMPS (This Work)
Output Voltage (V)	24V $\pm$ 5%	24V $\pm$ 3%	24V $\pm$ 1.2%
Output Current (A)	2.5	2.5	2.5
Efficiency (%)	~58%	~70-75%	>82%
Power Loss (W)	~25W	~15-18W	~10-11W
Output Ripple (mVpp)	<50 mV	80-100 mV	<60 mV
Size & Weight	Bulky, heavy	Moderate, larger PCB	Compact, optimized layout
Heat Dissipation	High (needs heatsink)	Moderate (some airflow required)	Low (passive cooling only)
EMI/Noise Management	Minimal filtering	Basic filtering	EMI filter + PI filter
Reliability under Load Variations	Low	Moderate	High

5. Performance Under Undervoltage and High Current Load

Tests were conducted at 130V and 140V AC input while drawing a load current of 2.4A to 2.5A. The output remained stable at 23.3V and 23.6V, respectively, indicating acceptable performance under stress. This confirms that the proposed SMPS handles undervoltage conditions without loss of regulation or triggering fault mechanisms. The detailed results of the undervoltage and high current load testing are summarized in Table 4.

Table 4. Performance under undervoltage and high-current load conditions

Input Voltage (V AC)	Load Current (A)	Output Voltage (V DC)
130	2.4	23.3
140	2.5	23.6

Conclusion

This paper presented the design, simulation, and experimental validation of a high-stability 24V, 2.5A switch-mode power supply (SMPS) tailored specifically for reverse osmosis (RO) water purifier systems. The design is based on a flyback converter topology operating in continuous conduction mode (CCM), which offers improved energy transfer, tighter voltage regulation, and isolation in a compact and cost-effective form.

Key components and stages-such as the EMI filter, rectifier, switching control, transformer configuration, and output filtering-were carefully designed and simulated using LTspice software prior to hardware implementation. Simulation results provided early confirmation of voltage regulation and switching behavior, ensuring a smooth transition to physical prototyping.

Extensive performance evaluation was conducted, including tests under varying AC input voltages (150V-260V), full load (2.5A), and undervoltage conditions (as low as 130V AC). The SMPS demonstrated excellent voltage stability ($\pm 1.2\%$), peak efficiency above 82%, and thermal reliability, with temperatures stabilizing at 60°C during continuous RO operation. Transient response testing showed that the system handled dynamic load changes effectively without overshoot or oscillation.

A practical novelty of this work lies in its real-world integration with an actual RO purifier system, validating the design under typical load conditions-unlike many generic or commercial SMPS modules. A comparative evaluation further confirmed that

the proposed SMPS outperforms both linear regulators and generic SMPS units in efficiency, size, and stability.

Overall, this work contributes a reliable, application-specific SMPS solution for water purification systems and can serve as a reference for future designs requiring compactness, electrical robustness, and real-world applicability.

Acknowledgement

I would like to express my sincere gratitude to all those who contributed to the successful completion of this project on the design and development of a switch-mode power supply for an RO water purifier with a 24 V, 2.5 A output, using IC OB2269 and an 80 kHz switching frequency.

First and foremost, I would like to thank my supervisor, Dr. A. B. Kakade, for his invaluable guidance, support, and encouragement throughout the project. His expertise and insights were instrumental in shaping the direction of the work and ensuring its successful completion.

Lastly, I would like to thank my family and friends for their unwavering support and encouragement. Their love, understanding, and patience have been vital in keeping me motivated and focused during the challenging stages of this project.

Once again, I extend my heartfelt gratitude to everyone who has contributed to this work, and I hope that this design and development of a switch-mode power supply for an RO water purifier will contribute positively to the advancement of water purification technology.

References

- Azis, H. A. A., Cholish, R., Rimbawati, & Evalina, N. (2019). Comparative analysis between the switch mode power supply (SMPS) using IC TL494CN transformer based on power supply linear. *IOP Conference Series: Materials Science and Engineering*, 674(1), 012035. <https://doi.org/10.1088/1757-899X/674/1/012035>
- Cui, Z., & Cui, X. (2016). Research on high-precision high power-factor switching power supply. *AMSE Journals – Series Modelling A*, 89(1), 188-204.
- Fauzi, F., Zaidi, M. E., Udom, U., & Manaf, N. A. A. (2022). Switch mode power supply (SMPS) utilizing flyback converter topology: Simulation and experiment. *Journal of Physics: Conference Series*, 2312(1), 012050. <https://doi.org/10.1088/1742-6596/2312/1/012050>
- Jian, M., Du, W., & Ling, X. (2025). A review of high current digital constant current sources in switch-mode power supplies. *Analog Integrated Circuits and Signal Processing*, 124(2), Article number pending. <https://doi.org/10.1007/s10470-025-02453-6>

- Kalpana, R., Bhuvaneswari, G., Singh, B., & Saravana Prakash, P. (2014). Design and implementation of high-frequency isolated AC–DC converter for switched-mode power supplies. In *Proceedings of the National Power Systems Conference 2014* (pp. 1-6). IEEE. <https://doi.org/10.1109/NPSC.2014.7103804>
- Kuang, Y., Zhang, Z. J., Duan, B., & Zhang, P. (2020). Fuzzy cognitive maps-based switched-mode power supply design assistant system. *IEEE Access*, 8, 183014-183024. <https://doi.org/10.1109/ACCESS.2020.3029090>
- Mohan, N., & Ang, S. S. (1994). A digital-signal-processor-based controller for a switching converter. *International Journal of Electronics*, 77(5), 643-656. <https://doi.org/10.1080/00207219408926092>
- Ozdemir, A., Erdem, Z., & Yazici, İ. (2009). An application study about SMPS design and reduction of common-mode noises. In *Proceedings of the International Conference on Electrical and Electronics Engineering* (pp. 306-310).
- Rathy, G. A., & Balaji, A. (2018). DC variable electronic load for SMPS testing. *International Research Journal of Engineering and Technology*, 5(1), 1070-1074.
- Saravana Prakash, P., & Kalpana, R. (2016). Configurations of modular push-pull buck DC–DC converters for 12 kW telecom SMPS and its design. In *2016 Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy (PESTSE)* (pp. 1-7). IEEE. <https://doi.org/10.1109/PESTSE.2016.7516446>
- Thwe Zin Tun, L., Lwin, K. S., & Tun, H. M. (2017). Design and implementation of offline flyback converter for low power applications. *International Journal of Scientific Engineering and Technology Research*, 6(15), 2905-2909.
- Vračar, D. D. (2024). Industrial R&D laboratory for switch-mode power supplies. *IEEE Access*, 12, Article number pending. <https://doi.org/10.1109/ACCESS.2024.3402822>
- Wang, G., Shi, J., Chen, Y., & Yan, W. (2021). Design of flyback power supply of DC equipment in PV power plant. *Journal of Physics: Conference Series*, 1983(1), 012068. <https://doi.org/10.1088/1742-6596/1983/1/012068>
- Zhao, J., Tang, T., Gao, C., Xiao, X., Luo, M., & Yuan, B. (2023). Improved particle filter remaining life prediction method for switch mode power supply using variance of case temperature. *Microelectronics Reliability*, 142, 114914. <https://doi.org/10.1016/j.microrel.2023.114914>