DESIGN AND IMPLEMENTATION OF ISOLATED POWER SUPPLY FOR TLP 250 GATE DRIVER IC USING MULTI-TAP TRANSFORMER FOR MULTILEVEL INVERTERS.

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ABSTRACT:
Multilevel inverters often operate with multiple voltage levels, necessitating isolation between the control circuitry and power stages to prevent ground loops and ensure safe operation. Isolation ensures that the system meets safety regulations by preventing hazardous voltages from affecting the operation of gate driver IC. Without isolation, differences in ground potential between control and power circuits can lead to ground loops. This can result in unwanted currents that disrupt normal operation and potentially damage sensitive components. Non-isolated gate drivers struggle with high-side switching due to the need for level shifting and the absence of a stable reference voltage, leading to complex and unreliable designs. This paper presents the design, implementation, and comprehensive analysis of a modular isolated power supply system utilizing a 16-tap transformer, full-bridge rectifiers, linear voltage regulation using 7812 ICs, and TLP250 isolated gate drivers. The system is designed to produces 16 independent +12V regulated DC supplies for applications such as modular multilevel converters (MMCs), neutral point clamped (NPC) inverters, and cascaded H-bridge (CHB) inverters. Each tap of the transformer is independently rectified and regulated, ensuring galvanic isolation, modular expandability, and improved fault tolerance. Experimental validation is carried out to analyse parameters such as output voltage regulation, thermal characteristics, ripple rejection, and gate signal integrity. The results confirm the reliability, modularity, and performance of the system, highlighting its applicability in advanced power electronic converters.
Keywords: Multi-tap transformer, Full-bridge rectifier, 7812 voltage regulator, TLP250 gate Driver, isolated power supply, modular multilevel converter, NPC inverter, CHB inverter.

INTRODUCTION:
Power electronics converters are widely used in industries for various types of applications. The increasing demand for efficient, compact, and high-performance energy systems has driven significant advancements in the field of power electronics. The number of switches may depend on the type of converters. At the heart of most modern energy conversion and control systems lies the power converter, a critical component that enables the transformation of electrical energy from one form to another. These converters are responsible for regulating voltage levels, improving power quality, and enabling bidirectional power flow in advanced applications such as renewable energy systems, electric vehicles (EVs), industrial motor drives, and power supplies. Power converters are generally categorized based on the type of conversion they perform—namely, DC-DC, AC-DC, DC-AC, and AC-AC converters. Where ever there is a converter, there will be a large number of semiconductor switches used for them. To achieve high efficiency and precise control in power converters, high-speed switching of power semiconductor devices such as MOSFETs (Metal Oxide Semiconductor Field Effect Transistors) and IGBTs (Insulated Gate Bipolar Transistors) is essential. However, directly interfacing these high-power switches with low-voltage digital control platforms such as

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microcontrollers, DSPs, or FPGAs is not feasible due to voltage level mismatches, insufficient current drive capability, and the risk of electrical noise or damage. This is where gate drivers become indispensable**.** Gate driver circuits act as intermediaries between control logic and power devices. They provide the necessary voltage and current to turn the power semiconductor switches on and off rapidly and safely. In many designs, gate drivers also provide electrical isolation, protecting the control circuitry from high voltages and disturbances in the power stage. Gate drivers can be implemented using discrete components, integrated circuits, or opto-isolated modules, depending on the system requirements for voltage, frequency, and isolation. The TLP250 is especially well-suited for single and three-phase inverter circuits**,** DC-AC converters**,** motor drive systems**,** and uninterruptible power supplies (UPS) where isolation and reliable switching are critical. It is capable of driving power MOSFETs and IGBTs with peak output currents of up to 1.5A, and supports operating voltages up to 30V. In multilevel inverters, numerous switches are used for making multiple levels. Number of switches not only increase the complexity of circuit, but also the need of isolated gate driver supply [1]. For each gate driver IC TLP 250, separate power supply is needed for providing them a 12V for their working in case of multilevel inverter [2]. A single gate driver supply cannot provide sufficient voltage required for turning ON the high side switches [3]. The TLP250 isolated gate driver incorporates both NPN and PNP transistors internally to enable effective control of power switches such as MOSFETs and IGBTs [4]. When a control signal activates the input LED, its light triggers a photodetector at the output, which in turn switches the internal transistors [5]. The PNP transistor sources current to the gate of the power device, turning it on by driving the gate voltage high, while the NPN transistor sinks current, pulling the gate voltage low to turn the device off [6]. This complementary arrangement allows for precise, bidirectional control of the gate voltage, ensuring fast switching and reduced power dissipation [7]. Importantly, this operation is fully electrically isolated from the input side due to the optical coupling, protecting low-voltage control electronics from high-voltage switching noise and hazards [8]. In this paper, isolated gate driver is designed and implemented for a 16 switch multilevel inverter. This gate driver circuit is applicable to all types of converter circuits where ever gate driver IC is TLP 250 and switching device used is IRF 540. The hardware circuit and testing results are explained in detail.

WORKING METHODOLOGY OF ISOLATED POWER DC SUPPLY USING MULTI-TAP TRANSFORMER.

In the system, a multiple tapped transformer with 32 separate tapping is used. The transformer is powered using a 230V AC supply and the output will be 12V DC which is supplied to gate driver ICs [9]. The output of transformer is given to a rectifier to convert AC into DC and then after filtering it is given to a 12V voltage regulator. The final output of voltage regulator will be a 12V DC which is required to power a gate driver IC [10]. By using a single transformer with 16 pair of secondary wires, each connected to a full-bridge rectifier, linear regulator (7812), and a TLP250 gate driver, the design meets the need for multiple isolated 12V supplies essential for modular inverter designs [11]. In the block diagram shown in Fig.1, the working of isolated power supply for TLP 250 is clearly mentioned.

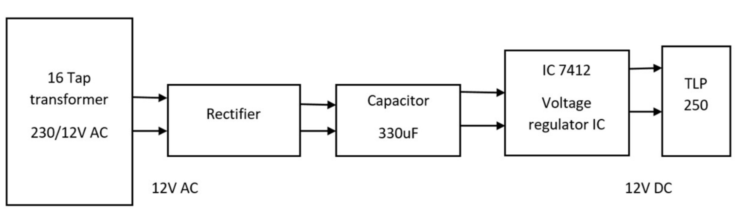

Fig.1 Block diagram representation of multi-tap transformer based

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In power electronics applications, especially in systems involving multilevel inverters, the provision of multiple isolated DC power supplies is a fundamental requirement. These supplies are essential for driving the gate terminals of semiconductor switching devices such as MOSFETs and IGBTs through isolated gate driver ICs like the TLP250. To address this need efficiently, a multi-tap transformer-based approach is widely adopted, which ensures galvanic isolation and allows for the generation of multiple regulated DC outputs from a single AC source. The core of this system is a single-phase, multi-tap step-down transformer, which is designed with a single primary winding connected to the AC mains input and multiple independent secondary windings (or taps). Each secondary winding is electrically isolated from the others and is responsible for delivering an AC voltage to a dedicated gate driver supply channel. The primary function of the transformer here is two. Step down the input AC voltage to a suitable lower level and to provide galvanic isolation between the high-voltage input side and each low-voltage gate driver unit. Galvanic isolation is critical in multilevel inverters because each switch may operate at different reference potentials, and any direct electrical connection could lead to unwanted ground loops or damage due to floating voltages. Each of the transformer's secondary taps is connected to a full-bridge rectifier circuit. In this design**,** sixteen full-bridge rectifier modules are used, one for each isolated output. A full-bridge rectifier consists of four diodes arranged in a bridge configuration, which allows both halves of the AC waveform to be used, effectively converting the AC input into pulsating DC. The choice of a full-bridge rectifier ensures higher efficiency and better transformer utilization compared to a half-wave configuration.After rectification, the pulsating DC still contains a significant ripple component. To smooth this ripple and obtain a stable DC voltage**,** filter capacitors are placed at the output of each rectifier. These capacitors are typically electrolytic or polypropylene capacitors selected based on the load current and desired ripple voltage. Once filtered, the voltage is passed through a linear voltage regulator**,** specifically the **7**812 voltage regulator IC, which is a popular three-terminal device that provides a fixed 12V DC output. Sixteen such regulators are used, one for each output channel so as to ensure that all gate drivers receive a clean and regulated 12V supply, regardless of any small variations in rectified voltage or load. The final stage in each isolated channel is the TLP250 opto-isolated gate driver unit**.** The TLP250 is an integrated optocoupler with a built-in driver stage, capable of directly driving MOSFETs or IGBTs. It provides optical isolation between the control signal (from a microcontroller or DSP) and the power switch, ensuring that any high-voltage disturbances or noise do not affect the control circuitry. Each TLP250 requires a stable 12V supply for its operation, which is now independently provided via this isolated power supply architecture. This isolation is especially important in multilevel inverter topologies such as the Cascaded H-Bridge (CHB), Neutral Point Clamped (NPC), and Modular Multilevel Converter (MMC), where different switches float at various voltage levels and cannot share a common power supply without risking malfunction or damage. An important advantage of using a multi-tap transformer-based approach is simplicity and cost-effectiveness. Compared to using sixteen separate isolated DC-DC converters, a single multi-tap transformer combined with discrete rectifiers and regulators provides an economical and space-efficient solution, particularly suitable for prototype development, laboratory experiments, and low- to medium-power inverter applications. Additionally, it simplifies PCB layout and wiring by localizing each isolation channel while maintaining electrical separation between them. This approach also improves system reliability and modularity**.** If one power channel fails, the others continue functioning independently, and troubleshooting becomes easier as each supply path can be tested in isolation. Furthermore, the use of standard components like 7812 regulators and the robust TLP250 gate drivers makes the system easy to assemble and maintain.

DESIGN AND SPECIFICATIONS ISOLATED POWER SUPPLY FOR GATE DRIVER :
A single-phase, multi-tap step-down transformer, Sixteen full-bridge rectifier circuits, Sixteen linear voltage regulators (7812), Sixteen isolated gate driver units based on TLP250 are used in this system for making 16 isolated DC supply of 12V[12].

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This architecture ensures galvanic isolation per gate driver unit, which is a critical requirement in multilevel inverters for safety and signal integrity. The schematics of the system is shown in Fig.2.

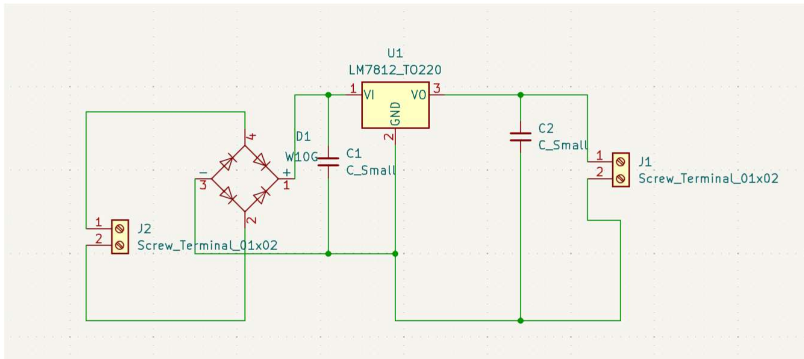

Fig 2: Schematic diagram of Isolated DC supply

HARDWARE TESTING OF MULTI-TAP TRANSFORMER BASED ISOLATED POWER SUPPLY :

In advanced multilevel inverter systems, ensuring isolated gate driver supplies is essential for achieving safe, effective, and reliable switching of power semiconductor devices such as MOSFETs and IGBTs. A widely adopted approach to address this requirement involves the use of a multi-tap transformer-based isolated DC supply, which provides multiple independent 12V DC outputs. Each output supplies an optically isolated gate driver circuit, specifically using the TLP250 gate driver IC. The architecture is modular, low-cost, and especially well-suited for lab-scale prototyping, academic research setups, and medium-power inverter applications.

At the heart of the system is a custom-designed single-phase multi-tap step-down transformer, which is wound on a laminated EI core. The choice of an EI core is based on its cost-effectiveness, availability, and adequate performance in low to medium frequency applications such as 50Hz AC power supplies. The primary winding of the transformer is designed to handle the standard Indian AC mains voltage of 230V at 50Hz, and consists of 1100 turns of 28 SWG (Standard Wire Gauge) copper wire. This winding ensures sufficient insulation and copper cross-section to safely manage the voltage and current levels without excessive heating or saturation of the magnetic core.

The secondary section of the transformer features sixteen separate secondary windings, each consisting of 58 turns of 29 SWG copper wire. The turn ratio is calculated to step down the 230V input to approximately 12V AC RMS at each output, which is ideal for further rectification and regulation. The use of separate windings for each channel ensures full galvanic isolation between all sixteen outputs. This isolation is critical in multilevel inverter applications where switches operate at different voltage levels, and shared supplies could introduce unwanted current paths or floating references that may damage sensitive components or create safety risks.

Each set of the sixteen secondary windings is independently connected to a full-bridge rectifier circuit. The W10G is a single-phase full-bridge rectifier module is used. W10 G is chosen for its ability to handle high-speed switching and reverse recovery time characteristics, making it suitable for applications where the DC output is supplied to gate drivers that operate at moderate to high switching frequencies. The rectifier converts the 12V AC input into pulsating DC, which still contains a significant ripple component, particularly under full load conditions.

To smooth the rectified output, a 330µF/25V electrolytic capacitor is placed immediately after each bridge rectifier. This capacitor acts as a first-stage filter, effectively reducing the ripple voltage caused by the rectification process. The sizing of the capacitor is chosen based on the expected load current (up to 500mA per channel) and the allowable ripple voltage, which is designed to be below 2V peak-

to-peak. This ripple level is within acceptable limits to ensure the proper functioning of the subsequent voltage regulation stage.
Following the filter capacitor, each DC line is fed into a 7812 linear voltage regulator IC, a popular three-terminal regulator that provides a fixed 12V DC output. The 7812 is known for its ease of use, internal protection features (such as thermal shutdown and short-circuit protection), and clean voltage regulation when operated within its input and thermal limits. Since the input voltage to the 7812 is only slightly above its dropout voltage (~2V), power loss in the form of heat is minimized, and the regulator can operate without a heatsink for short durations or low current conditions.
To further enhance the performance of the output, a second-stage filtering capacitor of 100µF is placed at the output of the 7812. This capacitor helps to suppress any high-frequency switching noise or transient voltage spikes, ensuring that the supply remains stable even under dynamic switching conditions. The presence of both input and output filtering capacitors ensures that the 7812 regulator operates within its optimal range, maintaining a consistent and ripple-free 12V DC output for the gate driver ICs.
Each 12V output from the regulator is connected to a TLP250 opto-isolated gate driver IC, which in turn drives the gate terminal of a power switch in the multilevel inverter. The TLP250 includes an integrated photodiode and gate driver stage, providing both optical isolation and sufficient current drive (up to 1.5A) to ensure fast switching. The isolation provided by the TLP250, combined with the transformer-based isolation of the supply, creates a robust and noise-resistant environment for the inverter control signals.
The modular design of this supply system allows each channel to operate independently. If one channel fails or is under maintenance, the others can continue to operate without interference. This isolation enhances system reliability and simplifies fault diagnosis and testing. Additionally, the design is scalable; more outputs can be added by increasing the number of secondary windings and associated circuitry, making it adaptable for future expansions.
During hardware testing, the AC input to the rectifier was measured to be 11.77V RMS, which is within the expected range based on the winding ratio and losses. After rectification and filtering, the DC output voltage was observed to be 12.03V, demonstrating the effectiveness of the filter and regulation stages in achieving the target output. This 12V supply was then successfully used to power the TLP250 gate driver, which operated stably in a 3-level inverter test setup.
Figures 3 to 7 in the experimental section illustrate the various stages of this supply architecture. In Figure 3, a Digital Storage Oscilloscope (DSO) reading shows a clean 50Hz

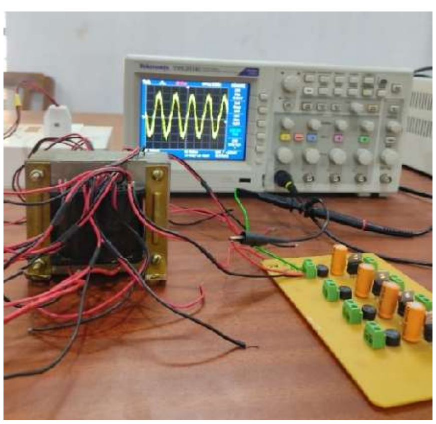

Fig.3 Input AC voltage from transformer

Fig 4: Input voltage of rectifier

AC waveform of approximately 12V RMS at the output of one of the secondary windings. This waveform confirms the proper operation of the transformer and indicates that all sixteen windings are functioning similarly. Figure 4 captures the same output using a digital multi meter, validating the measured voltage.

Additional figures show the filtered DC output from the rectifier and the regulated 12V DC voltage being supplied to the TLP250. These results confirm that the system operates within design expectations and delivers the required isolation, stability, and voltage quality. The overall architecture, combining transformer-based isolation, high-speed rectification, voltage regulation, and optical gate driving, provides a dependable platform for developing and testing multilevel inverters and other power electronic circuits.

The multi-tap transformer-based isolated DC power supply offers a cost-effective, scalable, and modular solution for providing multiple independent 12V supplies. By leveraging standard components and proven design techniques, this system ensures safe and effective gate driver operation in high-performance inverter applications. Its successful implementation and testing validate its suitability for academic, experimental, and low-to-medium power industrial applications.

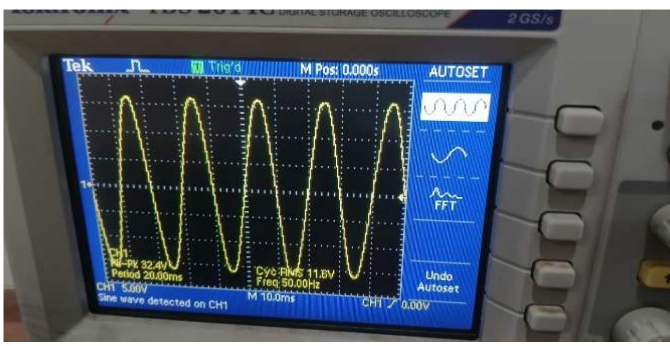

Fig.5 Input AC voltage from transformer

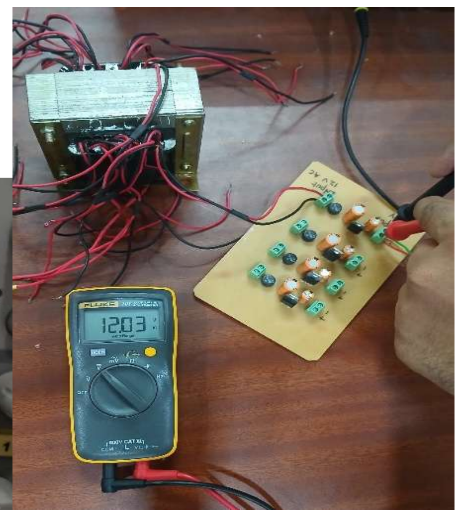

Fig.6 Output voltage of rectifier

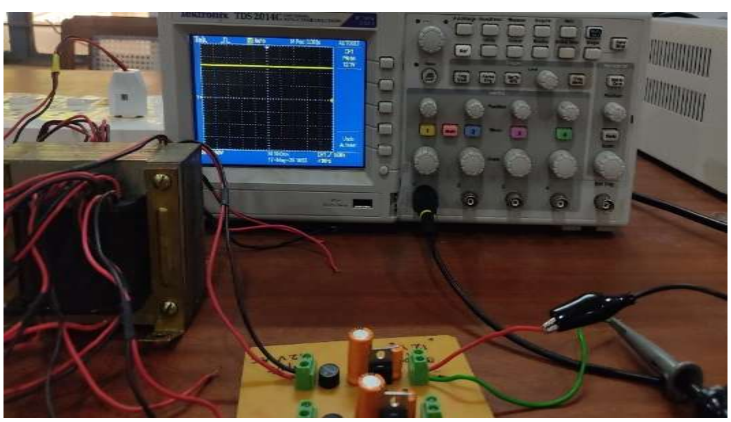

Fig.7 Output voltage waveform of rectifier

CONCLUSION :

The paper presents a robust, scalable, and simple isolated power supply design using a 16-tap transformer, 16 full-bridge rectifiers, and 7812 regulators powering 16 TLP250 gate drivers. This system is validated for multilevel inverters like NPC and CHB, offering modularity, galvanic isolation, and clean gate driver performance. This system forms a foundation for future extensions using more efficient regulation techniques or digital control enhancements. There are many other options to make isolated DC supply including bootstrap circuit, which requires bootstrap capacitors and diodes for implementing those circuits. The rectification and voltage regulation method used in this system provides visible results in each step which can be tested using simple multi meter in a step by step manner. Whenever an issue is caused in this system, the part in which the issue is caused can be easily detected using multi meter.

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