

Design and Construction of Electrical Power Supply System: The Local Content Addition

***Olojuolawe Rufus Sunday, Awolumate Emmanuel Olorunfemi, Omotola Babatunde**

Industrial Technology Education Department, Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Nigeria

***Corresponding Author**

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ABSTRACT

This paper presents the design and construction of an electrical power supply extension box intending to incorporate local content addition as an alternative to imported boxes. The local content addition is aimed at reducing the importation of off-the-shelf electrical power supply extension boxes and replacing them with locally sourced components. The design process began with a review of the literature on the current uses of extension boxes in the electrical power supply. This was followed by the selection of the various components and the construction of the box. To test the efficacy of the local content addition, a series of tests were conducted to ascertain the box's performance and general reliability. The results of the tests revealed that the designed extension box was able to outperform the off-the-shelf boxes in terms of safety, durability, and efficiency. The advantages of the local content addition design in comparison to the off-the-shelf boxes were also discussed. This study is expected to open up the use of locally sourced components in the electrical power supply industry and to bring about a reduction in the cost of power supply systems. The paper provides a methodological approach to the design and construction of an Electrical Power Supply Board with the addition of local content.

Keywords: Design, Construction, Local Content, Electrical, Extension Box

BACKGROUND

The use of electrical appliances and devices has become an integral part of modern life, both in residential and commercial settings. As a result, the demand for electrical power outlets has increased significantly. Extension boxes are essential components of electrical systems that allow multiple devices to be connected to a single power source. These extension boxes provide convenience and flexibility in electrical connectivity. An electrical extension box is an enclosure housing electrical connections. Extension boxes protect the electrical connections from excessive current, as well as prevent people from accidental electric shocks. AC power plugs and sockets Cable tray Electrical conduit Mineral-insulated copper-clad cable Multiway switching Steel wire armoured cable Ring main unit Ring circuit Thermoplastic-sheathed cable (Alani, 2021).

Despite the enormous use of extension boxes in the developing nations of the world, there has been over-reliance on the importation of the commodity from the technologically developed worlds thereby constituting a great number of menace to the developing world and their citizens. The national GDP is constantly being depleted; there is acute poverty among the citizens due to the high rate of unemployment. This is despite the avalanche of human and material resources in these countries. To break this yoke, this paper seeks to design an electrical power supply box with a blend of locally sourced raw materials and illustrate the procedures for achieving the connection. To achieve this, the following objectives guided the project;

1. Design a six-gang extension box that meets the requirements of modern electrical systems.
2. Select appropriate materials for the construction of the extension box, considering factors such as durability, electrical conductivity, and safety.
3. Construct a reliable extension box and adhere to safety standards.

Concept of Electrical Extension Box

Electrical extension boxes are indispensable components in electrical systems, serving the purpose of extending power sources to multiple devices or areas. They play a vital role in modern households, commercial buildings, and industrial facilities by providing additional power outlets, thereby improving convenience and flexibility (Smith, 2020). These boxes are used extensively in residential, commercial, and industrial settings to ensure the safe and organized connection of electrical appliances and equipment. They serve as a means to extend the reach of electrical outlets and provide additional sockets for various applications. Electrical extension boxes are available in a variety of designs and configurations to meet diverse electrical needs.

The term extension box may also be used for a larger item, such as a piece of street furniture. In the UK, such items are often called a cabinet. See Enclosure (electrical). extension boxes form an integral part of a circuit protection system where circuit integrity has to be provided, for emergency lighting or emergency power lines, or the wiring between a nuclear reactor and a control room. In such an installation, the fireproofing around the incoming or outgoing cables must also be extended to cover the extension box to prevent short circuits inside the box during an accidental fire. The electrical extension box is in the process of installation. Electrical conduits terminate at the sides and cables pass through or are joined inside the box (Smith, 2021).

An electrical extension box is an enclosure housing electrical connections. Extension boxes protect the electrical connections from the weather, as well as prevent people from accidental electric shocks. AC power plugs and sockets Cable tray Electrical conduit Mineral-insulated copper-clad cable Multiway switching Steel wire armoured cable Ring main unit Ring circuit Thermoplastic-sheathed cable (Wikipedia, 2021).

Since the advent of extension box manufacturing in developing countries like Nigeria, a solution has been found for power conservation or regulation. There is yet to be an effective extension box for timing domestic extension boxes. The failure to have an operational timer for the extension box has caused a lot of electrical hazards. This has claimed the lives and properties of many people. The user often forgets to look after what he/she had connected and due to incessant power outages, he/she often forgets to switch off appliances earlier connected to power when leaving his/her home or due to carelessness of the user. Due to this negligence, the connected appliances continue to build up, when power is restored, even after completing their purpose of connection, and when it gets beyond control, it damages the appliances. Repeated occurrences of these hazards have led to the loss of valuable things worth millions of naira.

However, with the help of a timer extension box, an effective solution is provided to these problems. An effective control timer for the extension box makes it safer and easier to use and also helps to reduce the hazard rate. The use of a microcontroller comes into play in this motivation. Every microcontroller has a timer unit inside. A timer is nothing more than a time-counting device fabricated inside the microcontroller unit. A wide range of practical applications require a timer in action. For example, we need to turn a motor ON for 5 minutes and then turn it OFF, how will we do that? A timer inside a microcontroller unit aids us in implementing this perfectly.

The primary distinction among extension boxes is their types. Common types include power strips, cable

reels, weatherproof extension boxes, industrial extension boxes, and surge-protected extension boxes (Williams, 2018). Each type caters to different applications and environments, making it crucial to choose the right one based on the intended use.

A small metal or plastic extension box may form part of an electrical conduit or thermoplastic-sheathed cable (TPS) wiring system in a building. If designed for surface mounting, it is used mostly in ceilings, under floors, or concealed behind an access panel, particularly in domestic or commercial buildings. An appropriate type may be buried in the plaster of a wall (although full concealment is no longer allowed by modern codes and standards) or cast into concrete—with only the cover visible (Wikipedia, 2021). It sometimes includes built-in terminals for the joining of wires. A similar, usually wall-mounted, container used mainly to accommodate switches, sockets, and the associated connecting wiring is called a pattress.

The increasing focus on electrification for a cleaner environment has fueled the need for electric power in different forms. Power electronics is the branch of electrical engineering that deals with the processing of high voltages and currents to deliver power that supports a variety of needs. From household electronics to equipment in space applications, these areas all need stable and reliable electric power with the desired specifications. Power supply in one form is processed using power semiconductor switches and control mechanisms in another form, supplying regulated and controlled power. While switched-mode power supplies are a common application of power electronics where power density, reliability, and efficiency are of prime importance, motor control is gearing up with more electrification in transportation systems. Precise control and efficiency are key characteristics of power control applications (Synopsys, 2021).

In power generation, especially in renewable energy, the generated power must be processed to meet the AC voltage specification of the power grid. For instance, a solar cell generates DC power whose output power varies with the operating voltage and incident solar irradiation. It is important to extract the maximum power available at the output of the cell and transfer it to the grid with the highest possible efficiency. So, the interface that connects the solar cell to the grid should provide AC power that matches the grid specifications and draws input power that operates the solar cell at its maximum power point. In addition to this, the conversion of this DC power to AC power should be with higher efficiency to minimize the losses in power generation. This is possible using power semiconductor devices with advanced control mechanisms that monitor the output and input parameters and control the switches (Synopsys, 2021).

Advancements in power semiconductor devices have paved the path for newer devices such as silicon carbide, gallium nitride field effect transistors (FETs), and power diodes. These devices have superior characteristics in terms of wide band gap that allows for high-voltage operation, thermal management, and efficiency. This has resulted in the widespread usage of power electronics even in noise-sensitive areas, replacing the lossy linear power supplies and voltage regulators. The main advantage of these devices is that they can withstand high voltage when compared to silicon devices. Thus, the systems can be designed with high-voltage capabilities, which, in turn, reduces the current and improves efficiency, for the same power to be delivered. In addition to this, operating the devices at higher switching frequencies helps in reducing the size of passive components, making the systems compact. The ability to handle higher temperatures simplifies thermal designs (Synopsys, 2021).

Safety considerations in extension box design are of paramount importance to ensure the protection of both users and connected electrical devices. Properly designed extension boxes incorporate various safety features to mitigate potential hazards. Here, we explore these safety considerations in detail.

1. **Grounding:** Adequate grounding is a fundamental safety feature in extension box design. Grounding helps to prevent electrical shocks and ensures that any fault currents are safely directed into the ground. Extension boxes should include grounding terminals, and users must connect them to a reliable ground source (Smith, 2019).

2. **Overload Protection:** Extension boxes should incorporate overload protection mechanisms, such as circuit breakers or fuses. These devices automatically cut off the power supply if the current exceeds safe levels, preventing overheating, fires, and damage to connected devices (Johnson, 2020).
3. **Load Capacity:** Each extension box has a specified load capacity that should not be exceeded. Users must be aware of this limit and avoid plugging in more devices than the extension box can safely handle. Overloading can lead to overheating and pose significant fire hazards (Davis, 2018).
4. **Fire Resistance:** The materials used in extension box construction should be fire-resistant. Fires caused by electrical faults or overheating can have catastrophic consequences. Fire-resistant extension boxes are designed to withstand high temperatures, reducing the risk of fire propagation (Clark, 2019).
5. **Surge Protection:** In areas prone to voltage surges and spikes, extension boxes equipped with surge protection features are essential. These devices divert excess voltage away from connected devices, preventing damage to sensitive electronics (Miller, 2021).
6. **IP Ratings:** For extension boxes used in outdoor or wet environments, having an appropriate Ingress Protection (IP) rating is crucial. Higher IP ratings indicate better protection against moisture and dust, ensuring safe electrical connections even in adverse conditions (Garcia, 2020).
7. **Child Safety:** Extension boxes should feature childproof designs, including tamper-resistant outlets and safety covers for unused sockets. This prevents children from inserting foreign objects or fingers into the sockets, reducing the risk of electric shocks (Roberts, 2021).
8. **Clear Labeling:** Extension boxes should be clearly labeled with important information, including the maximum load capacity, usage instructions, and safety warnings. This labeling helps users avoid overloading the extension box and ensures safe operation (Wilson, 2017).
9. **Cable Management:** Adequate cable management features, such as cable clips or organizers, should be incorporated into extension box designs. Tangled and cluttered cords can pose tripping hazards and increase the risk of damage to cables (Anderson, 2019).
10. **Quality Assurance:** Extension boxes should undergo rigorous quality testing and adhere to safety standards and regulations established by relevant authorities. Users should look for certification marks, such as UL (Underwriters Laboratories), to ensure the product's safety and reliability (Brown, 2020).
11. **Regular Inspection:** Users should periodically inspect extension boxes for signs of wear, damage, or overheating. Any damaged extension box should be immediately replaced to prevent potential hazards (Smith, 2021).
12. **Avoid Daisy Chaining:** Daisy chaining, which involves connecting multiple extension boxes in series, should be avoided whenever possible. It can lead to overloading and increased fire risks. Instead, users should consider using extension boxes with a higher number of outlets or opting for a power distribution unit (PDU) for more extensive setups (Johnson, 2021).
13. **Proper Placement:** Extension boxes should be placed in well-ventilated areas and kept away from flammable materials. Avoid covering extension boxes with blankets or other objects that can trap heat and increase the risk of overheating (Clark, 2021).
14. **Education and Awareness:** Users should be educated about the safe use of extension boxes, including load limits and safety precautions. Raising awareness about electrical safety practices is essential for accident prevention (Davis, 2021).
15. **Training for Professionals:** Electricians and maintenance personnel should receive training on the correct installation and use of extension boxes. Proper installation ensures that extension boxes are grounded and used safely within specified limits (Garcia, 2021).

Safety considerations in extension box design are essential for preventing electrical hazards and accidents. Users and designers alike must prioritize grounding, overload protection, load capacity awareness, and adherence to safety standards to ensure the safe operation of extension boxes in various settings. By following these safety guidelines, extension boxes can contribute to safer and more efficient electrical distribution.

METHODOLOGY

The design methodology for this project is the ring form connection method. This method was adopted because it gives room for other sectors of the circuit to receive supply in the event of a fault at any point in the circuit. To successfully execute the project, the following accessories and tools were used as contained in Table 1.

S/No	Accessory	Quantity	Tools
1	13 Amps Socket outlet	6	Hammer
2	15 Amps Socket outlet	1	Mallet
3	13 Amps Plug	1	Screwdrivers
4	2.5 mm 3205 mm 2 core cable	1 ¹ / ₂ yards	Plier
5	3.5 mm 3205 mm 3-core cable	2 ¹ / ₂ yards	Tester
6	Plastic Clip	8	Multimeter
7	2-inch screw	18	Hacksaw
8	High-Density Fibre board	30 mm*15 mm	

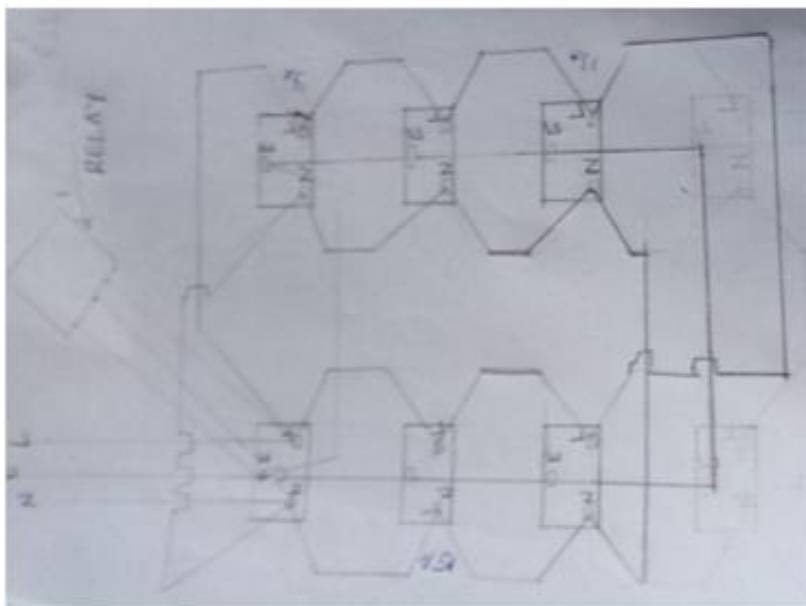


Figure 1: Ring Connection

The ring connection was adopted to ensure that current flow is available in the box regardless of the section where faults might occur except the supply cord. The introduction of the relay was aimed at preventing the effects of surges and low current that may cause extreme damage to appliances. The ring circuit is shown in Figure 1.

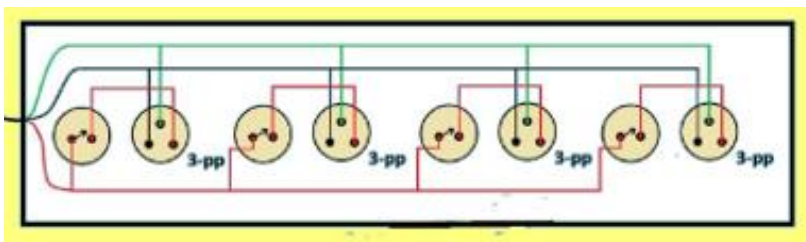


Figure 2: The Wiring Diagram

Figure 2: explains the cable laying procedure for the project. Each socket was connected end-to-end for continuous current flow. By the arrangement, the current at any point in the circuit is the same. The algebraic sum of the current drop along the resistors equals zero.

$$R_T = R_1 + R_2 + R_3 + R_4 + R_5 + R_6 \dots \text{Kirchhoff's Law}$$

Similarly,

$$I = V/R$$

$$V = IR$$

$$R = V/I \dots \text{Ohms' Law}$$

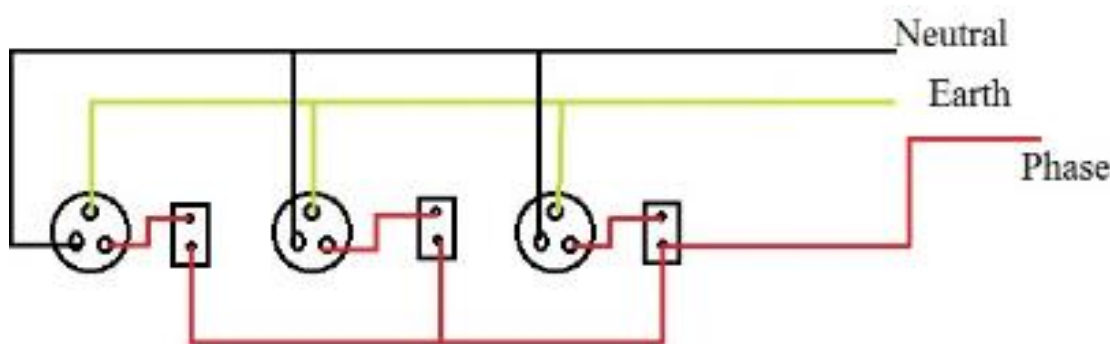


Figure 3: Line Colour Codes

Figure 3, indicates the path and the colour codes for ease of identification to avoid wrong connections and ease of troubleshooting.

Construction Procedure, Findings and Prototype

The use of a wooden box in the construction of the six-gang extension box is a practical choice. Wood is a versatile and readily available material that can be shaped and assembled to create the desired structure. In this case, the wooden box is rectangular, providing ample space for accommodating the electrical components and wiring. The wooden box is designed with careful consideration for the placement of sockets. It features four sockets on its sides and two on the flat top surface. This arrangement allows for multiple electrical devices to be connected simultaneously, enhancing the extension box's functionality. The careful placement of the sockets is crucial to ensure ease of access and safe use.

The wooden construction of the box offers durability and protection for the internal components, ensuring they are shielded from external elements and potential damage. Additionally, wood is a good insulator, which is essential for electrical safety. The choice of wood as the primary material aligns with the traditional and practical approach to constructing extension boxes, making it a suitable option for this project. It provides students with the opportunity to work with a commonly used material while developing essential fabrication and assembly skills.

The construction begins by preparing the six pattress boxes on a 30 mm by 15 mm HDF. Holes are created in the pattress boxes to allow the free passage of cables. These holes are strategically positioned to enable proper cable routing and connection between the pattress boxes. The next step involves temporarily setting up the pattress boxes along with their sockets on the wooden board. During this stage, precise alignment is crucial to ensure that the extension box is constructed accurately and aesthetically. To secure the pattress

boxes in the carved positions, screws are used to fasten them to the wooden board. Proper fastening ensures that the boxes remain in place throughout the construction process. The selection of the cable lengths required for the extension box construction followed. The selected cable has a thickness of 3.5mm in diameter. To prepare the cables for connection, the outer insulation is removed using pliers, exposing the essential cores.

Each core of the cable is colour-coded for identification: the red wire represents the live or positive wire, the black wire signifies the neutral wire, and the yellow wire is designated as the earth wire. The pattress boxes are similarly labeled for clarity, with 'N' indicating Neutral, 'L' indicating Live, and 'E' representing Earth. Following this labeling, the red wire is connected to the 'L' socket, the black wire to the 'N' socket, and the yellow wire is attached to the 'E' socket. This meticulous connection ensures proper electrical routing and safety. Once the cables are correctly connected to the sockets, they are routed through the pattress boxes. The connections are made in a neat and organized manner to avoid any potential electrical hazards. Ensuring that the cables are secure and properly connected is a vital aspect of the construction process.

The construction proceeds with the installation of 13-amp and 15-amp sockets on the pattress boxes. These sockets are securely attached, guaranteeing a reliable and stable power supply connection. The 13-amp plug, representing the output of the Extension Box, is connected to a flexible power supply cable. This connection enables the extension box to be linked to the external power source effectively. With all components securely connected and in place, the extension box construction is completed. The extension box is now ready to provide reliable power distribution and is prepared for safe and efficient operation.

Quality Control

The wooden box, being the central component of the extension box, demands precision and accuracy during assembly. The dimensions of the wooden box align with the specifications required for the extension box to accommodate all the electrical components effectively. The wooden box serves as the housing for the sockets and switches. During the assembly, the components are systematically arranged within the box. Each socket and switch are positioned accurately to ensure easy access and operation. This process involves making holes or openings in the wooden box to secure these components firmly. As part of the assembly process, the sockets and switches are meticulously connected within the wooden box. The wiring and cabling are carefully arranged to avoid any entanglement or disarray that could lead to electrical issues.

The wooden box is examined for any defects, and all its components, such as screws or bolts, are securely fastened. Before assembly, all materials used in the construction, including the wooden box, sockets, switches, and cables, are thoroughly inspected. This step ensures that all components are free from defects, damage, or wear and tear. Any substandard or damaged materials are replaced to maintain the quality of the extension box. Also, the assembly process ensures that all electrical connections, wiring, and insulation adhere to safety regulations. Proper grounding and isolation of live components are done. Lastly, the extension box is subjected to durability testing, simulating the wear and tear it may encounter during use. This includes testing the sockets and switches for their ability to withstand repeated use without degradation in performance.

One of the initial findings was the use of screw fastening to securely attach components. This is a fundamental practice in electrical wiring, ensuring that junction boxes, switches, and other electrical fixtures are stably fixed to surfaces. The correct use of screws is crucial for safety and longevity. In addition, color coding was a significant aspect of the construction process. The color-coding system involved assigning specific colors to different wires, such as red for live (positive), black for neutral, and yellow for earth. This standard practice ensures uniformity and correctness in electrical connections. It is essential for both safety and troubleshooting. Students had to measure and cut the cable lengths accurately. This process was crucial to ensure that cables fit neatly within the extension box. The precision in measurement is vital to avoid cable

wastage and to ensure a tidy and efficient connection.

The findings also highlighted the correct connection of sockets and plugs. The assignment of specific cables (live, neutral, earth) to the corresponding terminals in the sockets was done accurately. This is essential for the safe functioning of electrical devices connected to the extension box. Students correctly identified and used 13-amp and 15-amp sockets. These sockets are designed to handle specific levels of electrical current. The use of the correct socket rating is important in preventing overloading and electrical hazards.

Prototype



Figure 3: Prototype

CONCLUSION AND RECOMMENDATION

The design and fabrication of the Six-Gang Extension Box were accomplished efficiently. The box is structurally sound and complies with safety standards. The Extension Box demonstrated robust functionality, allowing it to accommodate multiple electrical appliances simultaneously without compromising safety. Several safety features, such as overload protection and surge suppression, were incorporated into the design to safeguard connected devices and users. There is a significant market demand for versatile and safe power distribution solutions. The Extension Box fulfills this demand and has the potential for commercialization. The cost analysis revealed that the construction of the Extension Box is economically feasible and can be produced at a competitive price. The successful construction of the Six-Gang Extension Box implies a potential market for the product. Further steps should be taken to explore commercial opportunities, manufacturing, and distribution. The safety features incorporated into the Extension Box can influence the development of safer and more efficient electrical appliances and accessories.

The construction of a Six-ways Extension Box has provided valuable insights into the field of electrical technology, power distribution, and safety. Consequently, the six-way Extension Box shows great potential for marketability occasioned by its sturdiness, versatility, and safety features. It is recommended that efforts be made to explore the market and commercialization of the product. Collaborations with electrical equipment manufacturers or distributors should be considered to facilitate mass production and distribution. Given the increasing interest in smart homes and energy efficiency, future designs of the Extension Box could incorporate smart power management features. This may include energy monitoring, remote control, and surge protection triggered by smart algorithms. Collaboration with research institutions, universities, and other organizations in the field of electrical technology to improve the aesthetics of the design is

recommended.

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