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DESIGN AND CONSTRUCTION OF UNINTERRUPTIBLE POWER SUPPLY

CHIMEZIE GRACE ODIRICHUKWU.

Abstract

The project adopted the research and development design approach. The system was made up of 4 units, these are, the rectifier/charger, the battery, the inverter and the switch units. The rectifier/charger unit is responsible for the stepping down of the 220V AC from the main source to 12V DC and for charging the 12V lead acid battery, provision was made for the external battery so that the system can use high capacity batteries to provide longer backup period during the power outage. The inverter unit of this ***UPS*** *was made up of both the oscillator and power circuit, the oscillator which performs the major function of converting DC to AC was built with NPN transistors of various values and power transistors. The output unit was made of a self-wounded step-up transformer that steps the voltage up to 220V AC and capacitor that removes the ripples which may occur at the output unit. The switch inform of a relay was used to build change-over such that immediately there is power failure it changes over to the* ***UPS.*** *The constructed 1.5KVA (500V AC) was given out from the 12V DC lead acid battery during power failure.*

Keywords: UPS, DC, Oscillator, Capacitor, Battery

Introduction

The human desire to have a steady power supply for domestic and industrial purposes gave rise to an uninterrupted Power supply (UPS). Globally, the need and demand for computers, electronics, and other electrical devices are on the rise. These types of equipment required quality, high stability, and uninterrupted power supply.

The fundamental operation of most sensitive electronic devices and electrical equipment is a clean alternative current (AC) source. Any disturbance in an AC source will lead to malfunction or operation failure of the equipment. Circuits are designed and deployed to prevent and fix a slight surge main AC supply. Also, when there is a power outage to protect a sensitive system from losing information and malfunction. It required an alternative power source that could switch into operation immediately when the interruption occurs. This alternative source is known as an Uninterruptible Power Supply (UPS).

Even as blackouts roll through power-starved communities, the threat to you and your computer is not the lack of electricity, but the change in power. When you start or working on any industrial or computer-based projects. And suddenly, there is a power outage. Your efforts will be a waste. For instance, when a system acts as the server and shutdown suddenly could disrupt the processing of information and data loss. You can make your work immune to a power outage and protect against many other types of an unexpected power surge. The antidote is the ***uninterruptible power supply or uninterruptible power source (UPS)***.

UPS differs from an auxiliary emergency power system or standby generator that provides instantaneous or near-instantaneous protection from interrupted input power interruptions, utilizing one or more attached batteries and associated electronic circuitry for low power users. Or using diesel generators and flywheels for high power users. However, UPS is not limited to protecting any equipment. The on-battery runtime of most uninterruptible power source is relatively short (only a few minutes) but sufficient to start a standby power source or properly shut down the protected
equipment.

UPS unit comes in different sizes. For instance, there are small units designed to protect a single computer without a video monitor (around 200VA rating, and also large units designed to power entire data centers, buildings, or an entire city. Fairbanks in Alaska has the biggest UPS in the world with 46MW battery electric storage system (BESS) [1]. It powers the entire city and nearby rural communities during outages [2]. The main focus of this project is converting AC to DC and also from DC to AC power inverters, which aim to efficiently transform a DC power source to a voltage AC source, similar to power that would be available at an electrical wall outlet. We can use inverters for many applications, as in situations where low voltage DC sources such as batteries, solar panels, or fuel cells must be converting electrical power from a car battery, powering a laptop, TV, or cell phone.

What is ups?

An uninterruptible power supply is a device that has the ability to convert and control direct current (DC) energy to alternating current (AC) energy [1]. UPS is a battery backup for PC, when the power goes off the UPS kicks in and continues to supply power for some period of time to the particular system. This device is a cleaver threefold package-a set of battery, an inverter that transforms the low-voltage direct current of the batteries into the standard alternating current equivalent to your wall outlet, and a battery charger that assures that reserve power storage system (the batteries) in some designs, with interfaces to match it to utility power and your computer system.

UPS generally consists of a rectifier, battery charger, a battery bank and an inverter circuit which converts the commercial ac input into dc suitable for input to the battery bank and the inverter [3]. The rectifier should have its input protected and should be capable of supplying power to the inverter when the commercial supply is either slightly below or above the normal voltage. A UPS differ from an auxiliary or emergency power system or standby generator in that it will provide near-instantaneous protection from input power interruptions, by supplying energy stored in the batteries, super capacitors or flywheels.

Uses Of UPS

Most of us take the mains (AC supply) for granted and use it almost casually without giving the slightest thought to its inherent shortcomings and danger posed to sophisticated and sensitive electronic instruments or equipment. UPS is typically used to protect computers, data center, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, fatalities, serious business disruption and/or data loss. For ordinary household appliances such as incandescent lamps, bulbs, fans, TV and fridge, the mains supply does not make much difference, but when used for computers, medical equipment and telecommunication systems, a clean, stable interruption free power supply is of utmost importance, of the myriad of devices, processes and systems which rely on AC power, computers are probably the most sensitive to power disturbances and failures. Interruptions in power supply may cause the contents of the memory to be lost or corrupted, the entire system to malfunction or fail, or even variety of component's failures to occur, all of which not only results in inconveniences but also loss of money.

Why UPS?

There is rising pressing need for a continuous quality power supply. In addition, most UPS units also provide power conditioning like a power strip or a surge protector; they prevent power spikes from coming through and hitting sensitive electronic components. Indeed, the devices to power up have an increasingly key critical role for businesses for people safety, for data storage, processing and for communications.

These functions are carried out by sophisticated and sensitive devices that may be affected by the disturbance coming from the mains power supply. There are various types of electrical events that constantly endanger electronic equipment as there are various effects on the availability of the load.

Common power problems includes;

- Voltage spike or sustained overvoltage.
- Momentary or sustained reduction in input voltage.
- Noise, defined as a high frequency transient or oscillation usually injected into the line by nearby equipment.
- Instability of the mains frequency.
- Harmonic distortion, defined as a departure from the ideal sinusoidal waveform expected on the line.

UPS Categories

UPS units are divided into categories based on which of the power problems they address and some manufacturers categorize their product in accordance with the number of power related problems they address. The three general categories of modern UPS systems are;

1. On- line UPS
2. Line –interactive
3. Standby.

An on-line UPS uses a ‘double conversion’ method of accepting AC input, rectifying to DC for passing through the rechargeable battery/battery strings, then inverting back to 220V/230V AC for powering the protected equipment.

The line-interactive UPS maintains the inverter in line. It redirects the battery’s DC current path from the normal charging mode to supplying current when power is lost. Also, in a standby (off-line) system, power the load directly by the input power and the backup power circuitry is only invoked when the utility power fails.

Further classification:

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Some the UPS below 1KVA are mainly of the line interactive or standby varieties which are usually less expensive. For larger power units, Dynamic uninterruptible power supply (DUPS) are sometimes used, a synchronous motor/alternator is connected on the mains via a choke. Energy is stored in a flywheel, when the mains supply fails; an eddy-current regulation maintains the power on the load as long as the flywheels energy is not exhausted. DUPS are sometimes combined or integrated with a brief delay, forming a DRUPS (diesel rotation uninterruptible power supply). A fuel cell UPS has been developed in recent years using hydrogen and fuel cell as a power source, potentially providing long run times in a small space.

Material and Method

The Procedures for This Design

1. Complete block diagram of ups
2. Stage by stage design is divided into four sections, they are
   - ✓ The oscillator section.
   - ✓ The device/switching section.
   - ✓ The output section.
   - ✓ The changeover section.
3. Designs and the construction of a ups

Complete Block Diagram Of UPS

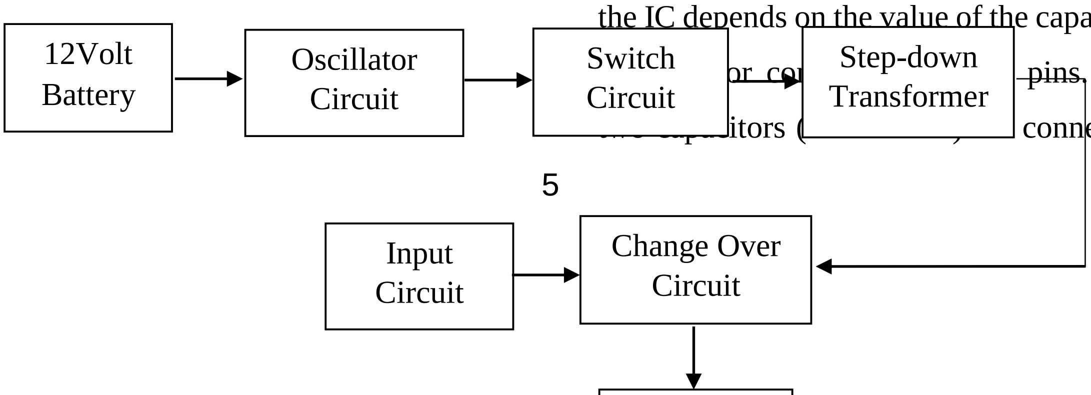


Fig 1.0 UPS Circuit Diagram

Stage By Stage Design

The stages involved in this **UPS** design is as follow;

Oscillator Section

The IC SG3524 is used in the oscillation section of this UPS. This IC is used to generate the $50H_z$ frequency required to generate AC supply by the inverter. To start this process, battery supply is given to the pin-15 of the SG324 through on/off switch which passes through the normally close contact of the relay. Pin-8 is connected to the negative terminal of the battery. A voltage regulator LM7812 is connected across the battery through two capacitors connected in parallel and grounded as shown in the circuit below. This regulates the 12V supply from the battery.

Pin-5 and 7 of the IC are the oscillation section pins. The frequency generated by the IC depends on the value of the capacitor [illegible] pins. The [illegible]itors [illegible] connected to pin-7. These capacitors decide the 50Hz frequency output by the IC. Pin-5 is timing resistance pin. The resistance at this pin keeps the oscillator frequency constant. Pre-set variable resistor is connected to ground from pin-6 of the IC this pre-set is used so that the value of the output frequency can be adjusted to a constant 50Hz. A fixed resistor of is connected in series with the variable resistor to give a given frequency as shown by the relation:

$$F = \frac{1.30}{RT \times CT}$$

Where F is the frequency in KHz

RT is the total resistance at pin-6

CT is the total capacitance at pin-7

Therefore, to obtain a frequency of 50Hz

$$Given\ that\ C_1 + C_2 = CT$$

$$CT = 0.1 + 0.1$$

$$CT = 0.2$$

Making RT subject formula

Therefore, we have that

$$RT = \frac{1.3}{0.05 \times 0.2}$$

$$RT = \frac{1.31}{0.01} = 131k$$

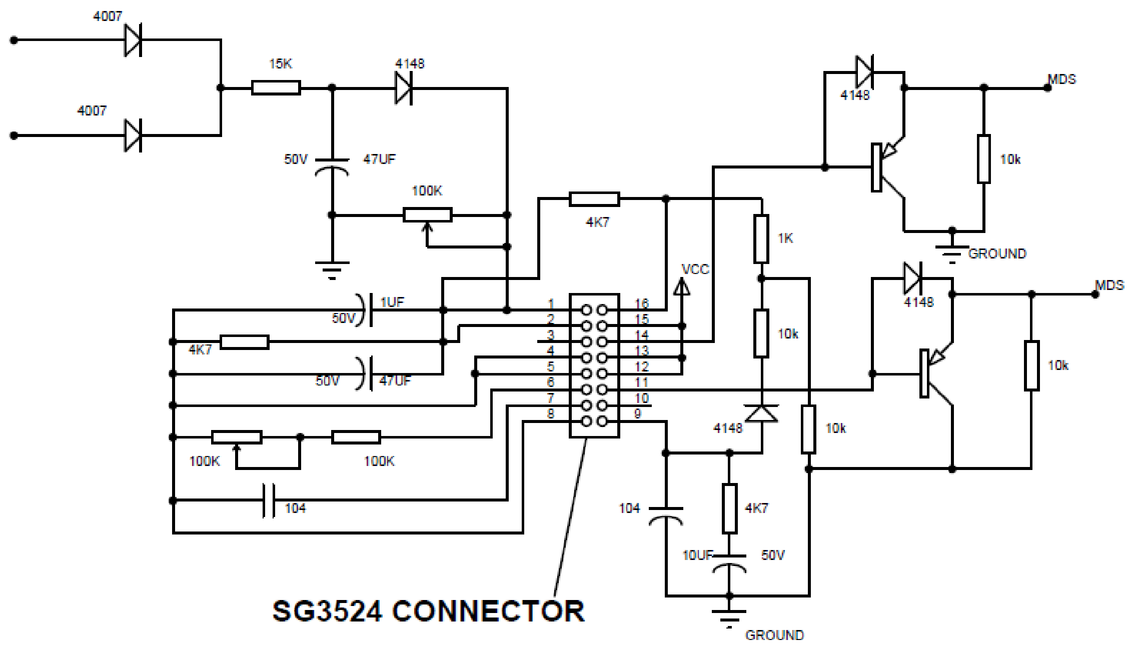
Hence, RT must be varied at 131k to obtain a frequency of 50Hz.

In my design I used a fixed resistor of 100K and a variable resistor of 20k.

Signal generated at the oscillator section of the IC reaches the flip-flop section if the IC.

This section converts the incoming signal into signal with changing polarity. This signal with changing polarity means that when the first signal is positive the second would be negative and when the first signal goes negative the second would be positive.

Therefore, to achieve a frequency of 50Hz this process most repeat 50 times per second at a regular interval i.e. it will generate an alternating signal with 50Hz frequency inside the flip-flop section of the IC. This 50Hz frequency alternating signal has an output at pin-11 and 14 of the IC. This alternating signal may also be known as the MOS drive signal. This MOS drive signal at pin-11 and 14 are between 3-4V. Voltage at these pins should be same, because any variation in the voltage at these pins could damage the MOSFET at the output [10]. The circuit diagram of the oscillation section is shown below.



OSCILLARTOR CIRCUIT WITH FEED-BACK CIRCUIT CONNECT TO PIN 1

Fig 1.1 Oscillator Circuit

Driver/ Switching Section

The MOS drive signal from the pin-11 and 14 of the IC are given to the base of the transistor T1 and T2. This results in the MOS drive signal getting separated into two different channels. Transistor T1 and T2 amplify the 50Hz MOS drive signal at their base to a sufficient level and output them from the emitter while the collectors are grounded 50Hz signal from the emitter of T1 is given to the gate of each MOSFET in the MOSFET channel, through resistance RA4-2K. Each MOSFET gate receives the 50Hz signal through a resistor (RA6-RA9). And also 50Hz signal from the emitter of T2 is given to the gate of each MOSFT in the second MOSFET channel, through resistance RA19-2K. Each MOSFET gate receives the 50Hz signal through a resistor

(RA14 –RA17). When the first MOSFET is on, the current flows through the first half of the inverter transformer bifilar winding. When the second MOSFET channel turns ON, the current flows through the second half of the inverter transformer winding. This switching on/off of the MOSFET channels will start an alternating current in the bifilar winding of inverter transformer. This AC current in the bifilar winding will induce an AC current of 50Hz, in the 220 and 240v tapings of the transformer. The AC voltage output from the transformer is connected to the normally close of the relay to the output socket. This can be shown by the circuit below.

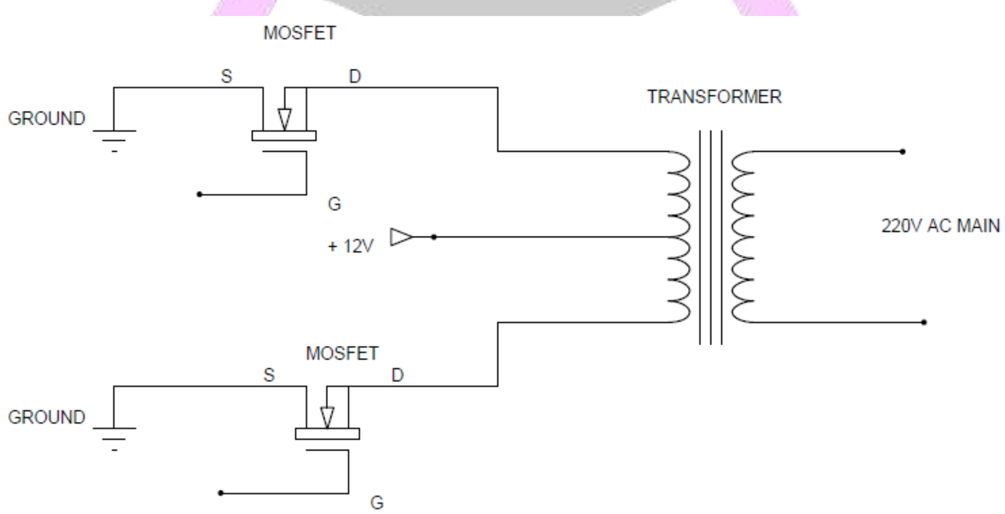


Fig 1.2. Drive/Switching Section

The Output Section

The 50Hz alternating MOS drive signal reaches each MOSFET channel separately. This result in the MOSFET channels being alternating on and off i.e. when the first channel is ON the second channel will be OFF, and when the second channel is ON, the first will be OFF. This on/off switching is repeated 50 times per second. The drain (D) of all the MOSFETs of one channel is connected together and one end of the inverter transformer’s bifilar winding is connected to this connection. Likewise, the drain of the MOSFET of the second channel is also connected together and the other end of the inverter transformer’s bifilar winding is connected to this connection. The position terminal of the battery is connected to the centre tapping of the bifilar winding. This results in the positive supply reaching drain of each MOSFET transistor through each end of the bifilar winding. Source (S) terminal of each MOSFET is connected to the negative terminal of the battery through a shunt of low value resistance. Because polarity of the 50Hz MOS drive signal at pin-11 and 14 are different, at a time only one channel from the output channel remains ON, the other channel stays OFF.

The Changeover Section

The changeover section is used to

- Switch on the inverter when the AC mains supply switches off and
- Turn off the inverter when power is through the AC main source again.

When the UPS receives AC mains supply, it stops drawing the battery supply, and the AC mains supply at the UPS input is directly sent to the UPS output socket. The change-over circuit adopted for this design is very simple. It consists of 12V step down transformer. This change over as the name implies can be divided into two states i.e when there is Power supply from AC source the inverter would be switch off and

When there is no supply it goes back and switches the inverter.

This process happens like this, when there is AC supply, the oscillator which is connected to the output of the normally close of the relay connects the oscillator with power sources and the switching process starts. But when power supply comes back on, a 12V signal is sent to the coil of the relay through the diodes D1 and D2. The common of transformer is connected to the negative terminal of a 220uf capacitor and the positive terminal is connected to the cathode of D1. The coil energizes in the process and contacts the normally open the relay thereby connected the load to the AC supply. During this process a 12V signal is sent to the shutdown pin of the IC SG3524 to shut down the inverter and hence stop its switching process. This is shown by the circuit below

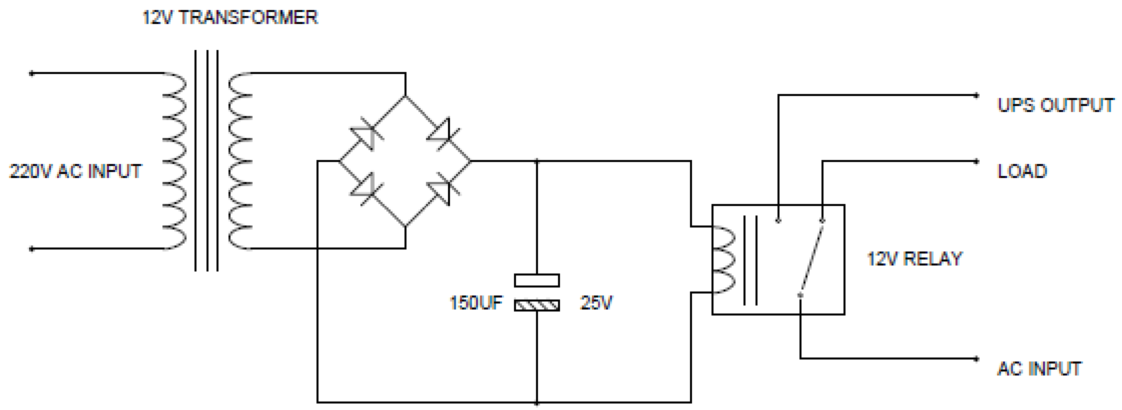


Fig 1.3 Changeover Circuit of the UPS

Test and Analysis

Before a new UPS is assembled, it needs to be tested properly; its various presets should be set properly.

When testing a UPS, one should test its inverter section (the section which operates on battery supply) first. Next, is the charging section (section which operates on AC mains supply). Requirement for the testing inverter section:

- Connect a fully charged battery to the inverter
- A current meter or ampere meter is required to check the load current and charging current. For this, connect a 50 Amp Meter in series between the positive terminal of inverter.
- Connect a 0 -300V AC voltmeter parallel to the inverter output socket.
- To check the AC supply frequency of inverter output, connect a frequency meter parallel to the output socket

Testing and Setting The Inverter Section

- Remove the battery wires from this section.
- Outer ends of 12-0-12 winding of inverter–cum charger transformer are connected to the heat sink. Remove these connections from the heat sink. Now, if the battery is reconnected, MOSFET drains will not receive any battery supply.
- Reconnect the battery
- Remove the 3- pin MOSFET drive connector between the mains PCB and the MOSFET PCB.
- Do not connect the inverters mains supply from reaching the inverter. Without AC mains supply, 220V/18V transformer will not produce the 18V AC supply.

Without 18V AC supply, 12V

Regulated DC supply is not produced and the charging circuit will not operate.

- Switch on the inverter switch. 12V supply from battery will reach pin -15 of IC (SG3524).
- If the oscillator section is operating, pin -11 and 14 should have equal MOS drive voltage
- To check the MOS drive voltage, set the multimeters at 10V AC range, and check the voltage between pin – 11 of IC2 ground. Multimeter should show a voltage between 4V-5V
- Voltage at pin – 11 and 14 should be equal
- If these voltages are OK then reconnect the 3-pin connector between the mains PCB and the MOSFET
- Make sure that the voltage at pin- 11 and 14 of 1C2 (SG3524) should be equal. If there is difference in the voltage on these pins, or if the MOS drive voltage is missing, then there is some fault in the circuit.
- If the MOS drive voltage is OK at pin – 11 and 14 of 1C2 then check the MOSFET transistor gates for MOS drive voltage.
- If the MOS drive voltage is missing from all the MOSFET gates, then check that the 3- pin connector joining the output plate with MOS drive signal
- If the MOS drive signal is missing from one of the MOSFET gate then check the 22E resistance at the gate.
- If the MOS drive signal is missing from all the MOSFETs in one channel, then check the transistors and other components in that channel.
- When proper MOS drive signal is available at the gate of all the MOSFET transistors of both channels, switch off the inverter
- Remove the battery connection
- Reconnect the end points of 12-0-12 inverter cum-charger transformer to the heat sinks, i.e. to the MOSFET drain.
- Keeping the inverter on/off switch in off position connect the battery to the inverter.
- Connect the voltmeter and frequency meter to the inverter output. Connect two 100W/ 250 V bulbs to the UPS output socket.
- Switch on the UPS. If the bulb starts to glow, the UPS is working properly. All the components of the UPS MOSFET transistor, relay,

inverter transformer, changeover circuit, etc. are working properly.

- If the bulb does not glow than check the inverter transformer for 220V AC supply.
- 270V tapping of inverter transformer is connected to the N/O-2 terminal of relay. Check the AC supply by keeping the Multimeter in 250V AC range.
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Table 1.0: Bill Of Engineering Measurement And Evaluation

S/NO	Item Specification	Quantity	Unit cost	Total cost
1	RESISTORS	20	N5	N 100
2	Capacitor 10 uf	2	N20	N 40
3	Capacitor 0.1uf	6	N20	N 120
4	Capacitor 47 uf	2	N20	N 40
5	10000uf 35v capacitor	2	N 80	N 160
6	MOSFET IRT 3205	2	N 200	N 400
7	Transformer step-up	1	N 3000	N 3000
8	220-12v step-down Transformer	1	N 500	N 500
9	Relay	2	N 300	N600
10	Connecting Wires		N 250	N250
11	A digital multi meter	1	N 900	N 900
12	A voltmeter	1	N 150	N150
13	AC socket	1	N100	N 100
14	Transistor BC557B	3	N 50	N50
15	Battery IC	1	N 3000	N3000
16	SG3524 IC	1	N 600	N600
17	Opto coupler 4N35	1	N 250	N250
18	Rocker on/off switch	1	N 50	N50
19	Transport			
20	Variable resistor	2		
21	Vero board	2		
	TOTAL COST			

Conclusion

It is obvious that UPS are indispensable power units in virtually every scale of establishment. Its features such as noiseless working condition, availability of storage elements, numerous system compatibility etc, have not in any way marred its acceptance. This device is really dominating in computer establishment but in no due time will find use in many other applications where it is still under consideration. The cost of buying new and imported ones is very high, its economical and wise to encourage upcoming engineers to do more research and development on design and construction of uninterruptible power supply systems.

Recommendation

I strongly recommend a restructuring in our department's project condition. I think conducting this project in group will give a room for wider and in-depth research, sharing of ideas between group members and taking and non-execution of infant projects or better still low-grade projects.

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