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Design and Construction of a Portable Solar Mobile Charger

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Abstract— The state of incessant power failure accompanied with the increase in pump price of petroleum in Nigeria, solar energy becomes the most sought after energy source. Solar chargers are simple, portable and ready to use devices which can be used by anyone especially in remote areas. Going solar can solve the problems of dependence on fuels and the prevalent energy crisis. This project aims to make a portable solar charger which can be used on the go. A portable solar mobile phone charger is simply a power electronic device that converts solar radiation into electrical current for the purpose of charging the batteries of mobile phones. This charger is made by converting, controlling and conditioning the flow of electrical energy from source to load according to the requirements of the load; this technology is called power electronics. An external adjustable voltage regulator is used to obtain the desired constant voltage. A zener diode switches on to ensure charging is cut off at the saturation point. Two 3.7V lithium ion batteries are used as backup; an operational amplifier works here as a comparator to signify when backup is fully charged. Ultimately, 11V and 160mA is supplied by the panel under full sunlight. This charger has an output voltage of 5V and an average of 800mA current to charge a mobile phone, this system charges a phone fully between 4-5hours and it has a capacity of 4800mAh. This device charges all mobile phones by all manufacturers using a universal serial bus connector. It is the only viable solution to charging mobile phones as it is portable, light-weight and does not cause pollution.

Keywords— Solar Energy, Power Electronics, Energy Crisis, Renewable Energy, Power Failure, Solar Charger, Comparator

I. INTRODUCTION

Portable Solar Mobile Phone Charger is a power electronic device that converts the sun's radiation into electrical energy for the purpose of charging the batteries of mobile phones. It does this by converting, controlling and conditioning the flow of electrical energy from source (solar panel) to load (mobile phone) according to the requirements of the load[1].

In a densely populated, poverty stricken country with a population of over 160 million people in the case of Nigeria, it is unarguable that the epileptic state of power supply is an issue of great concern to Nigerians. Citizens find it very difficult to charge their phones when they eventually have a flat battery. We are now left with the option of putting on a generating set (Generator) which causes air pollution and depletion of the atmospheric ozone layer (green house effect), generators are also very expensive to operate due to the hike in price of petrol in the country[2]. The option of charging through public charging centers is inconvenient as most times these centers are crowded and employ the use of a generator as well. Theft of mobile phones is prevalent with charging centers and fire outbreaks in many cases due to overload of supplying cables and very unprofessional connections done in order to realize money as quickly as possible[3].

The aim of this project is to design and construct a portable solar mobile phone charger.
In order to achieve this aim, the following objectives were set;

i. To design a portable solar charger.
ii. To construct the designed solar mobile phone charger.
iii. To evaluate the performance of the designed charger.

Section I of this paper contains the introduction, Section II contains review of related works, section III explains the methodology with flow chart, Section IV describes results and discussion of result and Section V concludes research work with future directions).

II. RELATED WORK

[4] presents a work titled "The Solar Charging Backpack". This idea was suggested by his teacher on Applied Science Research, Dr. James Dann. Ali Nahm had interest in the project because he wanted to solve the problem of people always getting frustrated when they cannot contact friends because of a dead phone. The backpack built stores energy from solar cells placed on its exterior which could then be used to charge peoples' electronic devices, such as cell-phones and iPod. He did this by using four blocks of three solar cells in parallel which made up a panel and the panel is connected to the charging circuit which has a voltage regulator within. He also explored the use of two ultra-capacitors to help store charges and a backup battery for storing power as well. The obtained result was a portable solar charging backpack. This system's strength is in the use of ultra-capacitors and backup which supplied adequate current to the load. However, this system has a challenge, specific 550Ω resistor was used in the voltage

regulator circuit instead of a potentiometer so that a user can vary the output voltage setting and charge different devices.

[5] Presents a proposed system titled “Mobile Charger Based on Coin by using Solar Tracking System”. This paper describes the mobile charger using solar tracking system with coin as the method of payment. This is designed based on ATMEL 89c51 a 40-pim microcontroller that does the count-down timings with LCD display showing the actual time left. Light sensors (Light Dependent Resistors) are placed for detecting the intensity of radiation thereby sending this data to the microcontroller so that the drivers move the panel for efficient solar tracking. Lead acid battery is used for backup (that is, storing power). A coin-based IR sensor detects coin to be placed for service payment. A 37W solar panel capable of supplying 2A current is used as the source of power here. The system has an advantage because it effectively receives maximum energy from the sun towards earth rotation. It is quite an intelligent solar tracking system. On the other hand, it is not absolutely excellent as its weakness is that it is bulky, as a large-sized solar panel was used and this is owing to the large power requirements of components as the motor drivers.

[6] Presents a work titled “Solar Mobile Charger”. This paper presents the design of a solar mobile charger meant for recharging the batteries of mobile phones. The proposed system consists of AC input, main input unit, DC input from solar cell and battery for storage. A PIC microcontroller 16F877A was used as the CPU. There is an LCD display which shows all parameters relating to battery. They chose a buck converter due to its low heat dissipation, simplicity and high efficiency. The PIC controller directs the buck converter by employing hardware based PWM module and an exterior current detecting resistor. This system brings an easy way to charging mobile phones as it is very dense in blueprint and allows a simplified environmental mobility. The system is versatile as it can charge all types of mobile phones. This system, however, is quite expensive and takes large charging time (takes six to eight hours) to get mobile phones charged fully.

[7] Presents a proposed system by some students of the electronics and communications engineering department of the American university of Ras AlKhaimah, UAE. They proposed a mobile charging solution titled “Portable Solar Charger with Controlled Charging Current for Mobile Phone Devices”. In this paper, a solar charger was designed and simulated using Multi-Sim. The constructed device was a portable charging system deriving its source of power from solar radiation. A zener diode was used to ensure cut off at saturation point to avoid breakdown of the system. The components employed in building this system are; solar panel (with specifications: 5W, 17.6V, 0.28A), Darlington NPN transistor, NPN transistor type 2N2222, zener diode (with breakdown voltage, V = 5.6V), Diodes (3 1N4001 types), LED, potentiometer (3Ω/0.25W), capacitor (10uF) and Resistors. The strength of this system is in the use of Darlington configuration which leads to an increased current gain so that the emitter gives enough mobile battery charging current. But then this system is never perfect as heat dissipation which may lead to damage of the system is present. Hence, the need for a large heat sink and indirectly increasing physical size of the system.

[8] Presents a work titled “Solar Mobile phone Charging System”. This work is aimed at evaluating already existing solar mobile chargers. He carried out this work because he thought electricity crisis is a major problem.

III. METHODOLOGY

The method used in realizing this device is in terms of modular design and implementation and carried out in the laboratory in the year 2016. This system consists of units and blocks which make up the entire solar charging device. Figure 1 shows a well simplified block diagram of the system.

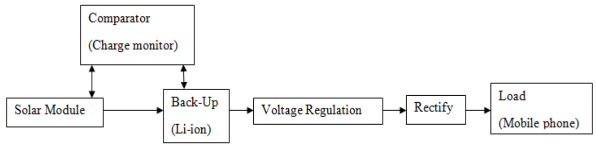

Figure 1: Block diagram for the Portable Solar Mobile Phone Charger.

The power source of this system is solar radiation that is converted into electricity by a solar panel. The supply received from the solar panel’s output is a DC. DC-DC conversion using a power electronic converter called a chopper is used to provide the regulated power to the backup for storage. It is the backup that in turn charges the mobile phone. The backup system consists basically of two lithium ion batteries. Figure 2 shows the Flowchart.

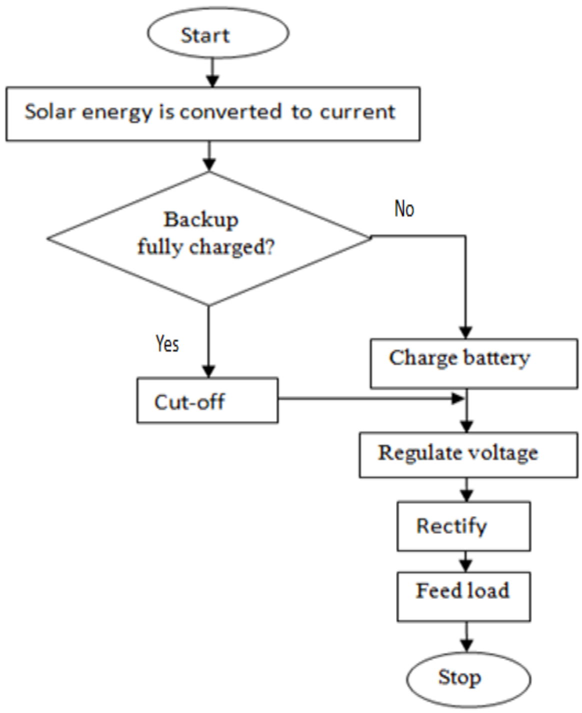

Figure 2: Flowchart of the portable solar mobile phone charger

3.1 Materials and Software used- Solar panel, LM358 Operational amplifier, 1N4007 diode, Light emitting diodes, Universal serial bus connector, Zener diode, 7805 voltage regulator, Resistors, lithium ion batteries and Proteus software for simulation.

3.2 Solar Module- The solar module consists of two 5.5V operating voltage solar panels connected in series to give 11V operating voltage. A current value of 160mA is obtained and used to charge the back-up Li-ion batteries. For current to flow from source to sink, the source voltage must be higher than the sink voltage. Therefore, 11V at source pushes 160mA current to charge battery rated 8V. D1 is a Red LED that indicates that solar panel is receiving and converting solar energy into electrical energy and charging the back-up. R1 is a small-valued 330Ω fixed resistor that limits current flow to the LED D1. D2 is a blocking diode (1N4007) that ensures current does not flow in the reverse direction to the solar panel in order to avoid damage to the panel. So, D2 ensures flow of current only to the back-up and otherwise is not permitted.

3.3 Back-Up Module- The back-up module consists of two 3.7V Lithium-ion batteries connected in series to give a total voltage of 7.4V and 8V when fully charged. As one 3.7V Li-ion battery gets to 4.2V when fully charged. The blocking diode, D2 ensures current delivery to the back-up. The switch on the right hand side is used to deliver power or not to deliver power to the regulator circuit.

3.4 Voltage Regulation Unit- The voltage regulation unit consists basically of U1 (LM7805 voltage regulator) that regulates the voltage from the back-up and gives an output of 5V as shown in fig 3.18. C1 is a 10uF capacitor that filters the output from the back-up before feeding the regulator, R5 is a 1kΩ resistor which limits the current into D5 (a blue LED) used to indicate when load is charging. When mobile phone is charging, D5 is ON. C2 is a 47uF polarised capacitor that further filters the output from the regulator before feeding the load.

3.5 Rectification Unit-This unit consists of a blocking diode 1N4007, D6. D6 is used to ensure current flows in only the direction of back-up to load and not otherwise. This is to ensure the mobile phone's battery does not discharge when back-up battery is LOW. The USB female connector, USBCONN delivers power to the phone for charging.

3.6 Comparator Unit-With respect to the op-amp (LM358) circuit , If $V_{IN} > V_{REF}$ then $V_{OUT} = +V_{CC}$ while when $V_{IN} < V_{REF}$ then $V_{OUT} = -V_{CC}$. V_{REF} is the voltage of the negative, pin 2 (INVERTING PIN), V_{IN} is the input voltage at the positive, pin 3 (NON-INVERTING PIN) and pin1 is the OUTPUT of the op-amp. The reference voltage is 8V i.e the battery voltage. As the non-inverting (positive) input of the comparator is less than the inverting (negative), output becomes LOW and this implies that the Green LED D4 will be OFF due to negative saturation of the output. As input voltage increases such that V_{IN} goes above reference voltage V_{REF} (at the inverting pin), the output voltage abruptly changes to HIGH in the direction of the positive supply voltage which is $+V_{CC}$ and this causes the Green LED D4 to be ON due to positive saturation of the operational amplifier's output [22]. These ensure that the Green LED glows when the battery voltage is at 7.99V or 8V (i.e when fully charged) and LED does not glow at less than 7.99V battery voltage. The zener diode D3 (1N4731A) ensures cut-off when saturation is reached as battery voltage tries to go above 8V. This is in order to avoid damage to the electrodes of the battery cell. The system circuit diagram is shown in figure 3.

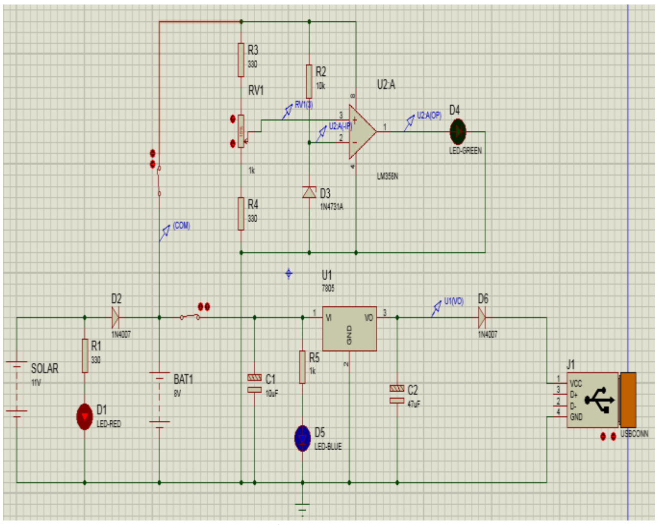

Figure 3: Circuit Diagram for the Portable Solar Mobile Charger

IV. RESULTS AND DISCUSSION

The working circuit was designed and simulated on the ISIS environment of Proteus simulator. The simulation is captured while running and shown in Figure 4. Virtual Ammeter was placed in series with the load to measure the current through, which is 884mA. A Voltmeter from the Proteus environment was connected in parallel to the load to measure the voltage across the load terminals as 5V.

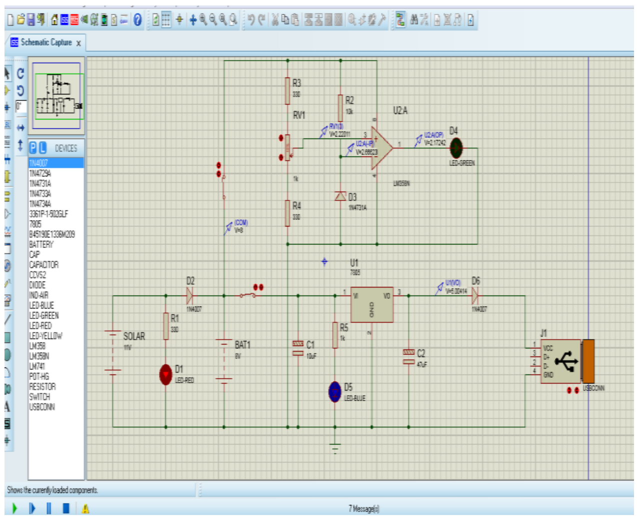
Figure 4: Proteus Simulation

4.1 Breadboard Test

Components were connected to form the overall circuit on a breadboard as shown in Figure 5 for a more reliable test; this is as a result of the inconsistencies in simulations by Proteus.

The output from the solar panels in series: 160mA, 11V. Parameters associated with each small panel used are: operating current; 160mA, floating current; 200mA. Operating voltage; 5.5V. Dimension; 63 by 63mm.

Output current through USB female connector to the mobile phone at a load voltage of 3.7V is between 800 – 884mA.

Figure 5: Circuit on Breadboard

4.2 Construction Test

After a level of assurance was attained from the preliminary examinations on Proteus and Breadboard, the respective components were soldered to form the device as shown in Figure 6. The Green LED D4 comes ON as soon as the output voltage at pin1 of the Op-Amp was greater than or equal to 2.17242V. Blue LED D5 glows to show delivery to load while the Red LED D1 glows throughout as it indicates the presence of a D.C source as the Solar Panel.

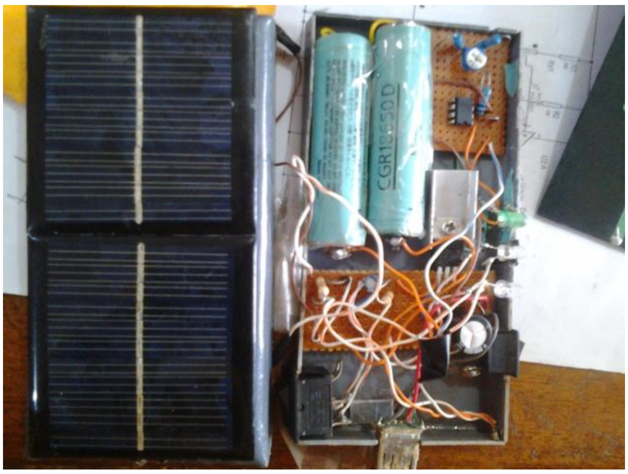

Figure 6: Soldered Circuit

4.3 Result

Figure 7 shows a top view of the device charging a bontel 108 mobile phone having a battery voltage of 3.7V. Table 1 shows the results obtained. The table gives the values of the various parameters of interest which translates to optimum weight, portability, fast charging and larger backup capacity.

The device is able to charge all mobile phones with voltage requirement not greater than 5V. The 11V output voltage from the solar panel implies that the circuitry is able to move charge from source (panel) to sink (battery) provided the battery is rated less than 11V as current only flows from a higher potential to a lower potential. The charging time of the device as a very important parameter depends on the following:

i. The capacity of the backup battery (which is sufficient in this case; 4800mAh).
ii. The capacity of the battery to be charged (the voltage and current ratings which varies with type of device).
iii. The intensity of sunlight depending on solar hours (e.g. Peak solar hours; sunlight is in abundance in Nigeria).

The discharge time (6 hours) of the backup battery depends solely on the number of loads connected; this device only feeds a single load meaning longer discharge time.

Figure 7: Top View of the Solar Charger Charging a mobile Phone

Table 1: Table of Results

S/N	Parameter	Value
1.	Panel Output Voltage (V)	11
2.	Panel Output Current (mA)	160
3.	Device Output Voltage (V)	5
4.	Device Output Current (mA)	800
5.	Length, Breadth, Height (cm)	13.3, 6.8, 2.5
6.	Volume Occupied (cm^3)	226.1
7.	Overall Weight (kg)	0.45
8.	Load Charging Time (Hrs)	4 – 5
9.	Device Discharge Time (Hrs)	6

V. Conclusion and Future Scope

In conclusion, a portable solar mobile charger has been designed, simulated and constructed to have a compact size at low cost and this device has been evaluated to be efficient, reliable, portable, light-weight and an economically viable solution to charging mobile phones in Nigeria. As a country having abundance of sunshine, this device brings an alternative to non-renewable energy sources that are highly expensive and not readily available. This device encourages green technology. A fascinating fact is the incorporation of a heat sink to absorb dissipated heat. This device can be carried around in the pocket and can be used on the go. It is undoubtedly the solution to carbon emissions from generators.

The limitation of this work is the unavailability of Solar Panel on Proteus thereby making it impossible to have an exact software simulation; a DC source is used in place.

The following recommendations have been made for future implementation and improvements:

The device should be incorporated with several LEDs to indicate the exact level of charge in the backup at all points. This can also be achieved using an LCD as a display or indicating component.

A higher power solar panel should be used in order to increase the efficiency of the device, reducing the charging time. This can be done by locally fabricating the panels and applying certain photoconductive chemicals to the layers of silicon: doping.

The device should be built to accommodate charging from electric grids when desired or when out of sunlight, this is to reduce the task on the panel. This can be achieved by building a power supply mechanism into the device.

VI. Acknowledgement

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