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Battery Charging System: Application of Photovoltaic Module in Commercial GSM handset battery charger.

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Abstract

The low reliability of electric power supply in Nigeria and the quest for alternative power supply have driven consumers to seek for various ways of generating electricity most commonly through the use of fossil fuel generators. This paper describes an application of photovoltaic module in multiple commercial Global System for Mobile communication (GSM) handset battery charging points as a possible replacement for the small 650VA, 230VAC petrol generator prevalent in Lagos State of Nigeriawhich has a very high Population because of the advantages of using solar energy in comparison to fossil fuel, some of these advantages includes absence of Carbon(iv)Oxide emission and no fuel cost. Various active and passive electronic components were locally sourced and wired on printed circuit board to ensure that GSM handset batteries are charged at 4.3 VDC from the solar panel. The charging system is designed in a manner thatit can be easily set up at the inception of the day's business and dismantled for safe keep at the close of the day's business. Also, it is equipped with charge monitoring circuit. The test on the constructed GSM handset battery charger showssatisfactory performance.

Keywords: solar, battery, charging, GSM, generator,

1.0 Introduction

One of the most populous countries in the continent of Africa is Nigeria with very low electricity consumption per capital [1]. The Nigeria power supply system over the years is characterised by demand that exceeds generation resulting in epileptic supply[2]. Thus, residential, commercial and industrial ventures in the country do not rely on it hundred percent in their operation. In order to ensure the availability of power, customers result to the use of alternative sources of electric power.These sources are commonly stand-by fossil fuel generators that make use of petrol or diesel. It is noticed that acquiring and use of small /large generators is common amongst households [3] and businesses. These sources as have been widely research are not environmentally friendly and sometimes there is acute shortage of power supply. Thus, a small business that requires power supply finds it difficult to operate even with the self-generated power supply. Also, there are remote rural settlements that have only 10% connected to the national grid and also only 40% of the population have access to power supply [4]but some have diesel-operated GSM base stations installed in their community.The high cost of power generation and grid extension as well as the isolation of the rural areas make renewable energy a competitive option. This reduces their greenhouse gas emissions. In addition, solar energy, instead of diesel or petrol alternatives, is used. Solar powered solution for rural dwellers is being advocated by the Federal Government [4]

Since the inception of the global system for mobile communication (GSM) in Nigeria, the cell phone has become a household appliance. It is the bed rock of all personal and business transactions. The GSM battery is a lithium-ion battery which discharges after some hours of usage.Unfortunately the GSM has to be recharged, sometimes on a daily basis for it to be of any significance. As a result of the epileptic source of power supply in Nigeria, the Lithium-ion phone's battery sometimes remains uncharged for a long time thereby making communication difficult.Most of the Lithium-ion cells are charged upto a voltage of 4.20 Volts+/-0.05V/cell. When the batteries are only charged to 4.10V, theircapacity is reduced by 10% but provides a longer service life[5]. Newer cells are capable of delivering a good cycle count with a charge of 4.20 volts per cell. The charge time of most chargers is about 3 hours[6]. Full charge is attained after the voltage threshold

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has been reached and the current has dropped to 3% of the rated current or has levelled off.Increasing the charge current does not shorten the charge time by much [6]. Although the voltage peak is reached quicker with higher charge current, the topping charge will take longer.When charging above 4.30V, the cell causes plating of metallic lithium on the anode; the cathode material becomes an oxidizing agent, loses stability and releases oxygen. Overcharging causes the cell to heat up. If left unattended, the cell could vent with flame. The open circuit voltage can be used to estimate the battery state-of-charge of lithium, alkaline and lead-based batteries [6].

It is a common sight in the most populous city in Nigeria, Lagos to find a small commercial businesses outfit located at busy junctions that consist of a 650VA,230VAC,50Hz petrol-driven generator connected to multiple socket outlet, an umbrella, a table and chair for the purpose of charging GSM handset batteries .A customer whose GSM handset battery is partially or completely discharged, pays a token for it to be re-charged.In this paper, photovoltaic module is used to harness solar energy from the sun and its output DC voltage used for charging GSM hand set batteries. Since it has near zero operating and maintenance cost, environmentally friendly and readily available, this will greatly improve the business of GSM hand set battery charging and also provide means of charging GSM hand set batteries in rural areas not connected to the National grid.

2.0 Materials and Methods

The solar GSM phone battery charger is designed with basic electronics components such as could be found in the Benin electronic market. The method used is to generate a DC voltage by the use of solar panels. The solar panel is rated 16.9 V and 65 Watts. This voltage is regulated to 5 volts which is a suitable voltage to recharge GSM phones. Then two indicator circuits were constructed to ensure that the batteries do not get over charged

3.0 Analysis and Results

The block diagram of the charging system is as shown in Fig.1.

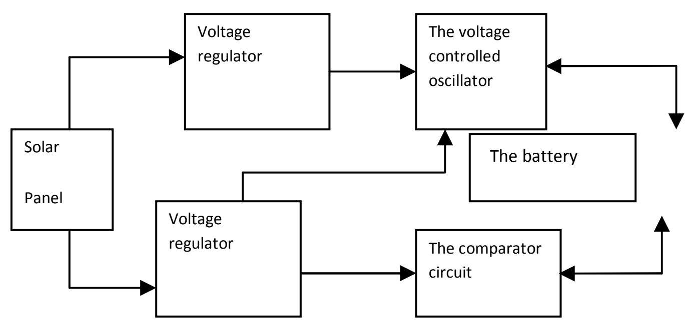

Figure1 The block diagram of the solar charging system.

As seen from the diagram, the solar panel supplies the main power to the circuit. This voltage is regulated to a lower voltage of 5V suitable to charge the GSM battery. The circuit has two major indicators designed and constructed to ensure that the battery is not over charged. The circuits are the voltage controlled oscillator(VCO) and the comparator circuit that trips off supply when the battery is charge to 4.3V and an indicator is triggered on. The major circuits are the solar panel, the DC voltage regulator circuit, the voltage controlled oscillator also called voltage to frequency converter and the battery charging/full indicator circuits.

3.1 The Solar Panel

The solar panel rated specification are:
Open Circuit Voltage -16.9V
Power output-65 Watts
The current is given as

$$I = \frac{P}{V} = \frac{65}{16.9} = 3.846A \text{ ---------------------------(1)}$$

It has been shown that for slow charge that will prolong the life of batteries, batteries should be charged at one-tenth of their rating[7].Given a nokia, BL-5C,1020mAh, 3.7V, 3.8Wh battery, using the three hours charge time of most chargers [5] and End of Charge voltage of 4.3 V, the required charging current, I_g is given as

$$I_g = \frac{1020}{4.3x10x3} = 7.9mA$$

3.2 The DC Voltage regulator

The LM7805 voltage regulator is as shown Fig.2.Capacitors C_1 and C_O are standard values of 0.33 µF and 0.1 µF respectively.

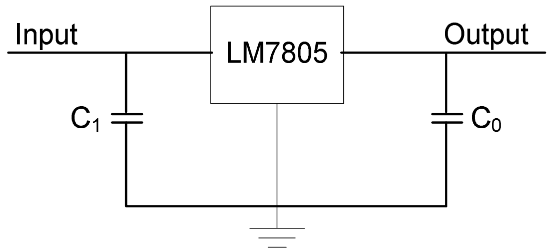

Figure 2 The DC Voltage regulator

The circuit drops the DC voltage from the solar panel from 16.9 Volts to the required 5 Volts needed for the charging of the battery. The circuit is built around the LM7805 positive voltage regulator which is capable of delivering a regulated voltage output of +5 Volts,1A. The voltage input range is 7-20V,Output current is 5mA to 1 A and maximum power output is 15 W.The input voltage for perfect regulation is given as

$V_{out} = V_{min} - V_{ref}$ …………………………………....(2)

Where V_{out} = the required output voltage (5 Volts)
V_{ref} = 3V as given by the manufacturers datasheet
V_{min} = the minimum input voltage for perfect regulation
Therefore, equation 2 becomes
$5 = V_{min} - 3V$
$V_{min} = 5 + 3 = 8$ volts.

The minimum input voltage for perfect regulation is 8 Volts.The datasheet stipulates that the maximum input voltage is 20 Volts.Therefore, given the above parameters, the LM7805 is suitable for ourapplication.

3.3The Voltage Controlled Oscillator (VCO)

The schematic for the VCO [8] is presented in Fig.3.

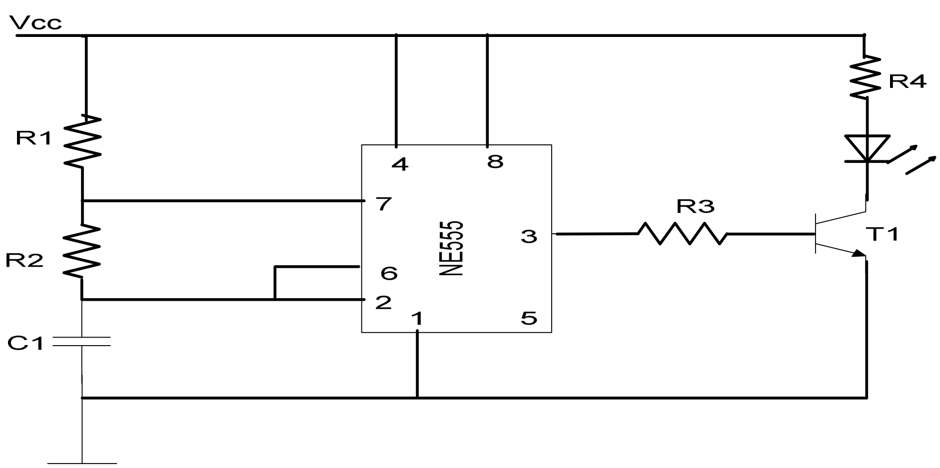

Figure3The Voltage Controlled Oscillator

The natural frequency of the astable multivibrator is given as

$$F = \frac{1.44}{(2R_2 + R_1)C_1} \quad \text{-----------------------(3)}$$

Choosing a period of time (T) of 0.15 seconds, the estimated frequency is

$$F = \frac{1}{T} = \frac{1}{0.15} = 6.79Hz$$

Choosing C_1 and R_1 as 100µF and 1kΩ respectively in equation 3, we have R_2=560Ω

The duty cycle is given as

Duty cycle = (R1 + R2)/(R1 + 2R2) …………………(4)

Substituting the values of R1 andR2 in equation (4) the duty cycle is obtained as 73.6%

As the voltage at the control terminal multivibrator pin increases, the output frequency decreases. The exponential charging and discharging of the capacitor determines the output frequency.

In order to limit the current through the light emitting diode (LED) , a resistor is connected whose value is given by equation 5.

$$R_4 = \frac{(V_S - V_D)}{I_D} \quad \text{………………………………..… (5)}$$

Where :V_S = 5V,V_D = 2V and I_D = 10mA,Therefore, R_4 = 300 Ω.However due to availability 330 Ω was used.

3.4The Design of the Comparator Circuit

The comparator [8]circuit monitor the battery charging and output or switch on an LED when the battery is full. The schematic is shown in Fig. 4.

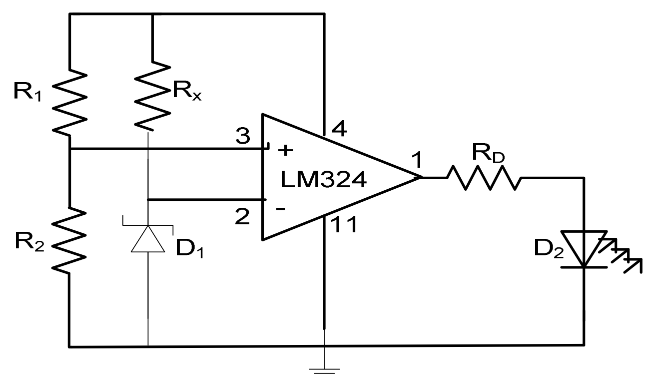

Figure 4The Comparator Circuit

The values of these resistors,R_1 and R_2obtained from the solution of the simultaneous equation of equations (6) and (7).

$$(R_2 / (R_1 + R_2))V_{max} = V_{ref} \text{ ………………………(6)}$$
$$V_{max} / (R_1 + R_2) = I_{ref} \text{ …………………………..(7)}$$

Where V_{ref} isthe voltage of the chosen Zener diode =3.9 V

V_{max} is the voltage at which the battery will be fully charged. 4.3V

I_{ref} is the reference current given as 1mA.

Therefore,

$$4.3R_2 / (R_1 + R_2) = 3.9$$
$$4.3/(R_1 + R_2) = 1 x 10^{-3}$$

From which R_2 = 3.9kΩ and R_1= 0.4kΩ.

$$R_x = (V_s - Vz)/I_z \quad \text{.................................} \quad (8)$$

Where : V_s = 4.3V, V_z = 3.9V, I_z = 10mA

$$R_x = (4.3 - 3.9)/10^{-3} = R_x = 0.4/10^{-3} \; R_x = 400\ \Omega$$

The current limiting resistor protecting the LED, R_D, is given as

$$R_D = (V_s - V_D)/I_D \quad \text{.................................} \quad (9)$$

Where: V_S = 4.3V, V_D = 2V, I_D = 10mA

Therefore, R_D = 230 Ω.

3.5 The Principle of Operation

The circuit is designed to recharge a GSM battery using solar panel. The solar panel used is rated 16.9 Volts. The voltage regulator regulates the voltage output to 5 Volts. The circuit has two battery monitoring indicator, the voltage controlled oscillator (VCO) i.e voltage to frequency converter and the comparator circuit. The circuit of the VCO is such that as the voltage in the control terminal of the multivibrator IC (pin 5) is approaching the supply voltage, the frequency of the output is reduced. The power supply that charges the battery is fed in to the control terminal of the VCO. This ensures that the battery voltage determines the frequency of the output. This is a monitoring device in the sense that as the battery voltage is increasing, the pulsing of the LED becomes slower and as the battery is fully charged, the LED will stop pulsating. The frequency of the 555 timer is set by the resistors (R_1 and R_2) and the capacitor, C_1.

The comparator circuit functions as a battery monitoring circuit in the sense that if the battery voltage gets to its maximum, the LED at the output turns on. This is achieved by the appropriate biasing of the inverting and non inverting terminals of the comparator. The Zener diode sets the reference voltage at the inverting terminal and holds it at 3.9 Volts. The series resistor forms a voltage divider and sets the variable voltage at the non-inverting terminal. When the battery is under charged, the voltage at the non inverting terminal will be lower than the voltage at the inverting terminal and the LED will remain off. As the voltage of the battery gets full, the voltage at the inverting terminal will be lower than that of the non-inverting and the LED turns on. The complete circuit diagram is shown in Fig.5.

4.0 Results And Discussions

The results of the test carried out on the constructed solar charger are presented in Table 1.Three batteries of 3.6V, 4.1V and 4.2V End of Discharge (EODV) voltages were charged to 4.28 V. The difference in charging time is as a result of difference in EODV. The lower the EODV the more time required to charge upto the full voltage. Though the charger was design to charge at 4.3 V but the charging voltage obtained on test is 4.28V.

5.0 Conclusion

A multiple commercial solar GSMcharger has been designed, constructed and tested.The performance upon test shows a charging voltage of 4.28V against a design voltage of 4.3V. This paper has shown the possibility of replacing the use of petrol generator for commercial Global System for Mobile communication (GSM) handset battery charging with a Photovoltaic Module

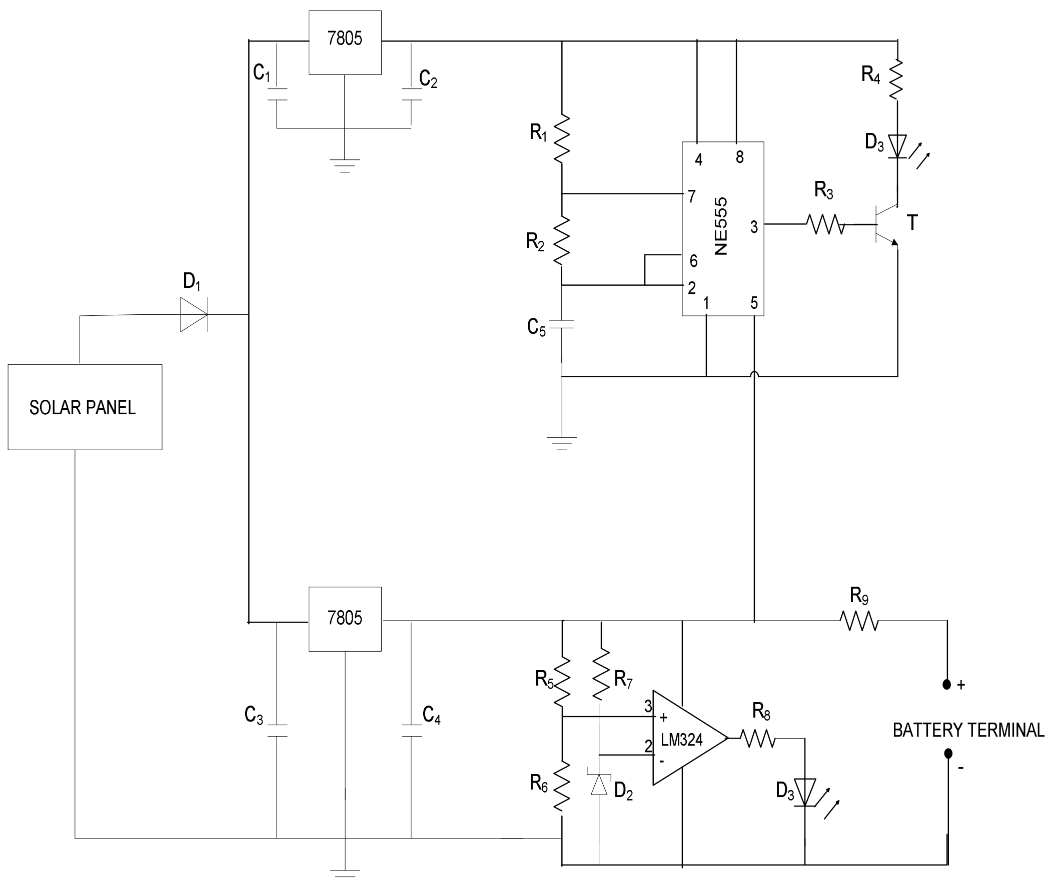

Figure 5The complete circuit Diagram of the photovoltaic solar charger
The circuit shown in Fig.5 is duplicated for eight charging ports.

Table 1 Test Results

End ofDischarge Voltage(V)	**End of Charge Voltage(V)**	**Beginningof Charge time(hrs)**	**End of Charge time(hrs)**	**Duration of Charge(minutes)**
3.6	4.28	12.15	15.16	181
4.1	4.28	12.15	13.17	62
4.2	4.28	12.15	13.01	31

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