Novel Design and Implementation of Portable Charger through Low-Power PV Energy System

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Abstract This paper proposes a novel design for a solar-powered charger for low-power devices. The level of the charging current is controllable and any residue power is saveable to a rechargeable 9V battery. Two power sources (AC and solar) are used, and two charging speeds are possible. Quick charging is 20% of the battery output current (almost 180mA/hr) so the current is limited to 34 mA. Two types of cellular batteries (5.7V and 3.7V) can be charged. Normal charging is 10% of the cellular battery output current (almost 1,000mA/hr), so the charging current is limited to 100mA. The design uses only a few components so the system is cost effective besides being highly portable. It was simulated on MultiSim Ver. 11 before being implemented practically to validate it. The results from the simulation and the experiment show the design's sufficient feasibility for practical implementation.

Introduction

Batteries are nowadays the main energy provider to portable devices. They are used for their high power density and ease of use. Their disadvantages, however, limit their application. Their energy density can drop to as low as 200Wh/kg and their technology seem to improve slower than do other technologies [1-6].

Depleting fossil fuel and increased demand for energy have spurred the search for other sources of energy such as solar, wind, ocean thermal, tidal, biomass, geothermal, nuclear energy, etc. The abundance and widespread availability of solar energy, however, make it the most attractive among other energies that can be feasibly extracted. It can be converted into electricity through low-power PV energy systems, for portable applications (charging of mobile phones) and used in rural areas (solar lamps). The high cost of PV panels and their low efficiency, however, reduce solar energy's competitiveness in the energy market as a major source of power generation. It still, however, is better than conventional energy sources where portability is required [7-12].

This paper considers a novel design for, and the physical implementation of, a solar-charger-based PV energy system for charging of cellular and rechargeable batteries. The charger current can be controlled and any residue power saved in a rechargeable battery (9V). Sources for the design are a solar panel (3W, 18V) and an AC power supply. Two charging speeds are possible (slow and fast). The paper next presents the design of the novel system and its simulation, the experiment results, and the practical implementation [13-16].

Novel Design of the Solar-Powered Portable Charger with Current Limiter

Fig. 1 is a block diagram of the proposed charger. The solar and dc power sources join through two decoupling diodes. The meeting point provides the dc supply voltage to the main part of the design, which has two charging circuits of different specifications. One charging circuit delivers suitable voltage and (limited) charging current to a rechargeable battery, whereas the other is for charging of two types of mobile devices (3.7V and 5.7V).

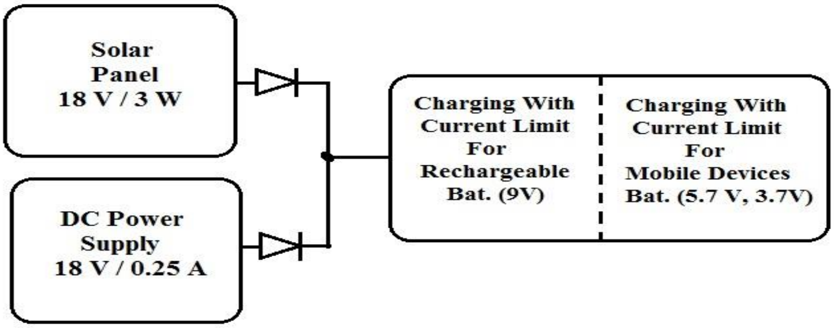

Fig. 1. The proposed portable charger

- *DC Power Supply Circuit*

Fig. 2 shows an 18V/250mA dc power source supplying two successive charging circuits. The power supply circuit is a full-wave rectifier with a step-down transformer (T1: 220 / 15V, 250mA).

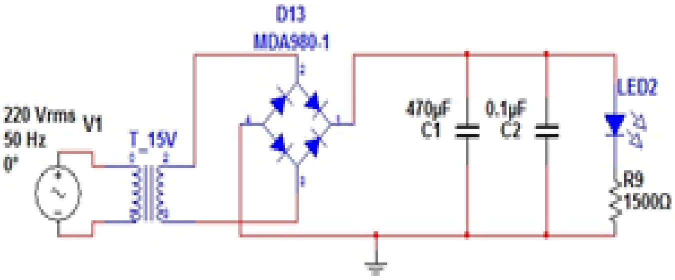

Fig. 2. The 18V / 0.25A, DC Power Supply

- *Charging with the Current Limiter Circuit*

The circuit delivers the higher power supply between the two to the next part of the circuit. Its second function is to provide a suitable charging voltage to a 9V rechargeable battery and supply a high level of charging current (20% of the battery output current, i.e., almost 180mA/hr, so the proposed design limits the current to 34mA, for which the shunt resistor controlling the charging limit should be R3=20Ω. The maximum voltage Vbe must be 0.7V. Of the transistor, R3 = Rbe = (0.7V / 34mA) = 20.5Ω.

The second part of the circuit provides charging voltages to 5.7V and 3.7V cellular batteries during suitable selection of the Zener diode connections D2 (ZDP7.5) and D6 (ZDP6.2), also supplies 100mA of charging current when the shunt resistor (R6, 7Ω) is connected.

The current-limiting action is effected from measuring the current that passes through the shunt resistor. If it reaches the value lead to the voltage across the base and emitter equal 0.7V in will effect directly on the load voltage to make continuous current control on the load current (Charging Current), this action was done for 9V rechargeable battery during transistors Q1 and Q3. The same was done for cellular battery, with transistor Q4 and Darlington transistors Q9 and Q10. Fig. 3 is the proposed practical electronic circuit and all the distributed meters for the complete simulated measurements.

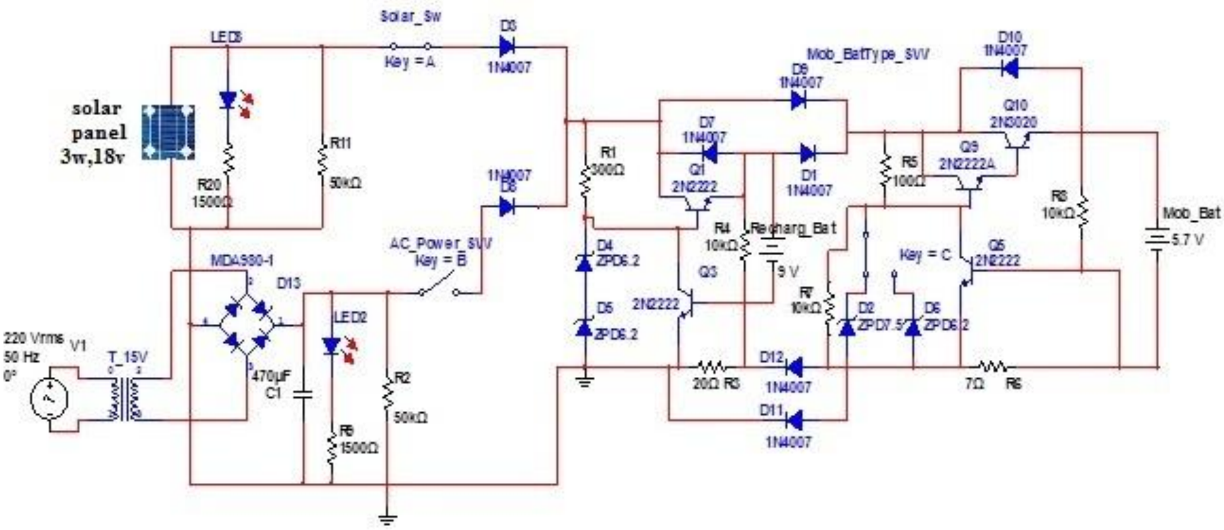

Fig. 3. The Proposed Design for the Solar Charger with Current Limiter

Simulation Results

The secondary coil of the stepdown transformer provided 15Vac, the load current was 124.79mA, the load resistance was 150Ω, and the dc load voltage was 18.7V; all these were measured by the third meter. The dc power supply delivered the required load currents in normal charging of rechargeable battery and cellular device.

- *The Complete Charging Circuit with Current Limiter*

Fig. 3 shows the complete simulations for the proposed charger. One is for rechargeable-battery charging current limited to 34mA (high-speed charging level), the other for cellular-battery charging current limited to 100mA (normal level). Calculations for the charging current levels were based on these: base emitter resistor R3=0.7V for transistor Q3 forward voltage (limiting to 34mA the rechargeable battery charging current). The value for a suitable base resistor will thus depend on the following: *R(be) = Vbe / I(pass through Rbe).* The maximum value for Vbe was limited to 0.7V. After correct selection of the current to pass through the resistor (for rechargeable battery, we selected the current level to equal the high-speed charging limit of 34 mA), a suitable resistor value would be Rbe = Vbe / Ibe = (0.7V) / (34mA) = 20.5Ω.

Through the same procedure but for different levels of charging current, the resistor selected to limit the maximum charging current was 7Ω. Fig. 4 include all related records as a drawings data came from distributed multimeters, the reads cover different case with suitable range of dc input voltage which came from the meeting point of diodes connection of the switching supply and DC power supply, from data and the related drawing in the Fig. 4 that fixed zeners voltages for range of Vdc input, It explains the charging current level around the current value of 34mA for rechargeable battery, and It explains the controlling of the level of charging current came from the designed value of resistor and the effect of the base emitter voltage, by same principle the recorded data of the charging current (XMM8) in mobile devices battery not pass more than 100mA.

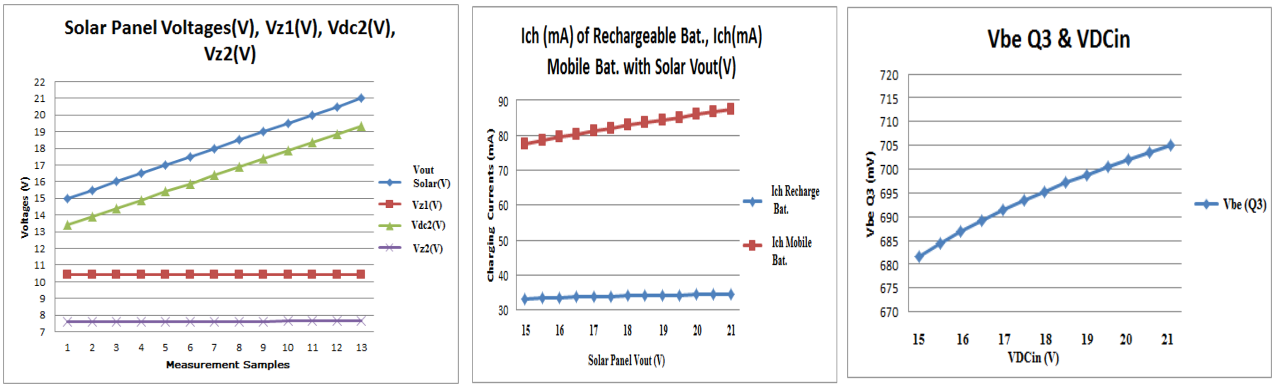

Fig. 4. Simulation Data for the Charging Circuit, the Charging Current, and the Controlling Voltage

Implementing the Design

The design is a PV-based (3W, 18V) energy system for mobile applications. It contains a PV array, a circuit design model, an oscilloscope, and a 9V DC battery for charging (see Fig. 5). After full charging, the battery starts converting energy through the 9V DC battery (which is used when the solar source dries up or at night). Control of the battery charging involves maintaining the current level at the high-speed charging limit equaling 34mA.

Different levels of charging current are possible (the normal charging level is 100mA). The rechargeable battery was charged to 34mA and the results fully correspond with the simulation results. Fig. 5 also shows the final display of the mobile charger. The selection for the source type (either solar energy or AC) depends on the source available. The level of charging of the external battery also shows up on the panel.

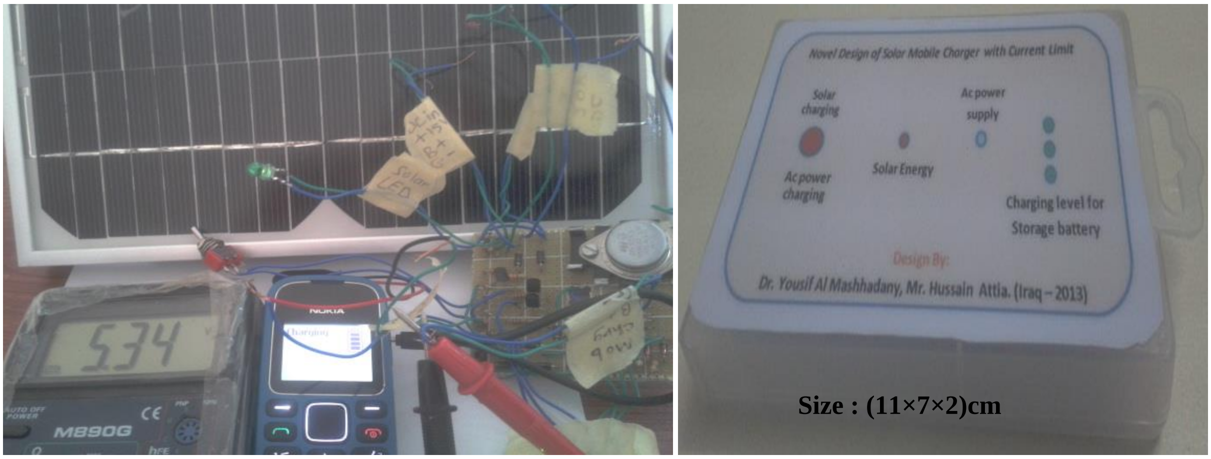

Fig. 5. Practical Implement of System Design and Final Product Form.

Conclusion

The proposed design is novel. It is simple and cheap but high performance. It also functions on two sources. Its simulation and experiment results show:

- Above 95% charging efficiency (proving solar energy's feasibility in supplying energy to mobile phones).
- Its current limiter circuit extending battery life and it is safe even after full charging.
- Possible future work in increasing the solar panel efficacy and reducing the system size.

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