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Development of a Low Power Energy Harvesting Using Solar Input for Portable Electronic Devices

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Abstract

This document presents the design of Low Power Solar Energy Harvesters (LPSEH) using solar with one power management circuit. The solar input targeted to power up any portable electronics devices such as laptop or notebook from light. The output power harvested from solar will extend the battery lifespan with total passive components used in this LPSEH system is minimized as well as the cost and power losses. This paper aims to develop of a portable powers backup charger that will be very useful during a power failure and the main function is to create a backup power that generates zero emission for electricity by using the natural source. The photovoltaic modules and the components for energy storage are applied to integrate to each other with the optimum energy level to maximize the efficiency of solar harvesting. A photovoltaic solar panel used to capture the light energy and to be converted to electrical energy and save it to the battery. The charging controller PCB board is developed and designed to produce 12 V output voltage to charge the backup battery pack. The backup battery is used to charge and store more energy up to 20 V in the battery when power is not available so that the stored energy can be used to charge up to two cells due to its high storage capability. This architecture of LPSEH can be used for to charge and to power up the notebook, laptop or any other portable electronic devices.

Keywords: Low Power Solar Energy Harvester (LPSEH); Self-Powered; Solar; Charge Controller;

INTRODUCTION

Energy harvesting is the application that captures and exploits the unused and depleted energy and converts it to a more usable from renewable energy. Energy harvesting technology is currently one of the most promising techniques to overcome the global energy problem without affecting the natural resources. Nowadays, laptops and notebook computers usually come with battery packs that enable to run without using the AC power source. However, the batteries must be recharged every few hours. Most of the electronic devices are given a specific voltage and current rating which shows the limitations and the duration of that battery [8]. The input voltage, V_{in} of the electronic device shows the total energy of the device's battery consumes. For example, the industry standards for input and output voltage are 12V and 19V respectively for most of the laptop brands as shown in Table 1. The output voltage also depends on the required input voltage for the laptop. Nowadays, most laptops need not more than a total power of 70W. However, there are a few portable electronic devices such as notebooks or laptops that need more than 90W power, especially the latest edition of laptops that comes together with latest technology graphics or having more robust multiple capabilities [8].

Table 1: Majoring brand of laptop powering system [6].

LAPTOP BRAND	CAPACITY	NORMINAL INPUT VOLTAGE (V)	NORMINAL INPUT CURRENT (A)
HP	47WH	19	1.7
ACER	4500mAH	19	1.7
COMPAQ	47WH	19	1.7
DELL	5200mAH	19.5	1.5
ASUS	6600mAH	19	2.64
SONY	3600mAH	19.5	1.3
BENQ	4400mAH	19	1.5
FUJITSU	5200mAH	19	1.2
TOSHIBA	4300mAH	19	1.7
GATEWAY	6600mAH	18.5	1.6
IBM/LENOVO	7800mAH	20	1.6
PANASONIC	6600mAH	19	1.5
AVERAGE		19.125	1.64

Thus, energy efficiency can be improved through scavenging technologies using solar can reduce the need for batteries. The solar source will be operating when the main source is insufficient to provide enough power for the laptop or notebook. In this paper, the architecture of LPSEH or known as portable power backup charger is developed which consists of solar panel, a boost converter, power charging controller, battery and inverter. A converter is used to ensure the laptop can be working at any location and not only depending on AC power source or its battery pack. The converter will accept any alternative resources as low as a 5V input voltage to produce a constant output voltage up to 20V and sufficient power to switch on a laptop as tabulated in Table 1 for the majoring brand of laptop powering system.

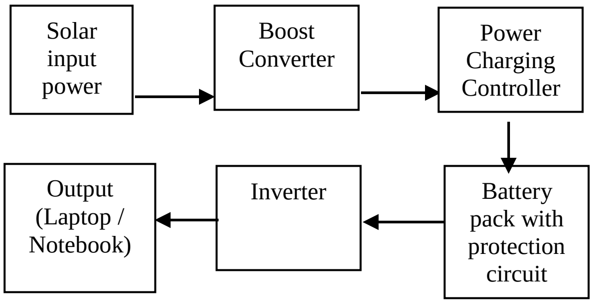

Figure 1: The block diagram for LPSEH

In this research, the LPSEH system used one power electronic based converter with low power control as shown in Fig. 1. The total components used and the total operational cost in the LPSEH system are reduced power losses are lessened. This can be achieved by integrating the power management units for the solar input source.

THE MATERIAL AND METHOD

A. Solar Energy Harvesting System

Solar is used as another source of energy to provide sufficient electrical supply. Solar energy harvesting has become as one of the most rapidly growing renewable sources of electricity. Photovoltaic is also one of the most efficient energy sources. Light from solar that shines on a crystal produces electricity [5]. The solar source is completely free, renewable and widely distributed. It is also available in every country and can be used by everyone in the world. In thin slices of a solar cell or sometimes called photovoltaics, the light will cause the electrons to flow from one point to another point through a semiconductor silicon materials such as crystalline silicon, gallium arsenide, or other semiconductor materials. The solar radiation causing the flow of electrons will directly be converted into electricity [4] and produce an electric current. Thus, in this research, a solar panel is used and it represents the most important electrical conversion of a solar power system [2]. In other words, a solar panel is a device with the photovoltaic effect that converts the energy of solar into electricity.

Solar panel components are one of the fundamental criteria to be considered in the architecture and construction of the solar energy harvester circuit. The light intensity level, solar cell temperature and load resistance will contribute to the electrical output power delivered by a solar panel [2]. In order to figure out the electronic characteristics of a photovoltaic (PV) module, it is convenient to build a circuit that is electrically equivalent and is based on discrete electrical components whose characteristics is well known. An ideal PV module is built by connecting a current source, Ip in parallel with a diode. A shunt resistance, Rs and a series resistance component are combined in the circuit [3]. The equivalent model of a PV module is presented as in Figure 2.

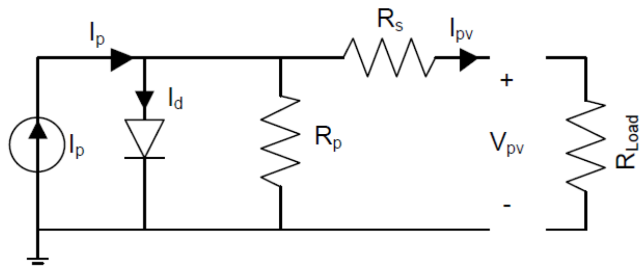

Figure 2: Equivalent electrical circuit for a solar panel

There are various mathematical models that interpret the operational process of solar cells, from a simple to more complicated circuits which serve as different reverse saturation currents. In this research, an electrical model consists of one diode is implemented as the equivalent solar PV module [9]. Resistor Rs and Rp represents the power losses in the solar panel. For infinite shunt resistance, Rs, as presented in Fig. 2, the current-voltage characteristic of the PV module may be expressed with one diode as stated by (1)

$$I_{pv} = I_p - I_O\left[\exp\left(\frac{V_{pv} + R_s I_{pv}}{V_T}\right) - 1\right] - \frac{V_{pv} + R_s I_{pv}}{R_p} \quad (1)$$

where I_L is the current generated by light or known as photocurrent and *Io* are the reverse saturation current. *Rs* is the series resistance of the PV module while *Ipv* and *Vpv* are the output current and output voltage of the solar panel respectively [1]. *Vt* is the junction terminal thermal voltage which depends on the PV module absolute temperature as expressed in (2)

$$Vt = kTc/q \quad (2)$$

where Tc is the cell absolute temperature (K), k is the Boltzmann's constant (1.3807×10^{-23} JK^{-1}), and q is the charge of the electron (1.6022×10^{-19} C) [7].

B. Hardware Development of LPSEH

Solmax 18V solar panel is used to support the output regulated voltage up to 18V. IC 7806 will regulate the output voltage up to 6V while the ICM7556 will regulate the output voltage up to 6V. Therefore, the total output voltage from the solar controller will produce up to 12V desired output voltage. The major considerations in choosing the solar cells in this research are the output power, strength, durability, performances and user safety. Considering the output power, strength, durability and performance as the main requirements with the cheaper price, Solmax 18V solar panel is selected. This solar panel is weatherproof, strong, with solid tempered glass protected and thermal electric insulated coating on the rear side.

In this paper, the converter used is a simple boost converter and the main advantage of this converter are its compact size, simple and affordable. The DC-DC converters are power electronic circuits that convert a dc voltage to a different value of dc voltage level which produces a regulated output voltage. The required output voltage, V_o is 12V to charge the battery pack which can produce up to 20V output. The battery used is a standard Lead Acid battery. This is the most suitable type of battery for solar charging. Some lead acid batteries are used in a backup condition in which they are not often cycled but kept continually charging. The main advantage using the backup battery is during the daytime, a unit can charge for a longer time and stored more energy in the battery when power is not available, the stored energy can be used to charge up to two cells due to its high storage capability. The solar charge controller PCB board is produced to regulate the voltage and current from the PV modules which is located in between a solar panel and a battery as shown in Fig. 3.

It is used to control the suitable charging voltage of the batteries. The charge controller regulates the charge to the batteries preventing any over-charging as the V_{in} from the PV module increases. Electric current is produced from electric batteries, which a charge controller will limit the charge rate. This will prevent overcharging and may avoid from overvoltage. Overvoltage will lessen the performance of the battery and the duration of the operating system. It may also trigger a safety risk. It will avoid complete draining of a battery or operate the controlled discharges, depends on the type of battery. Charge regulator or charge controller can be referred as a stand-alone device or a control network implemented in one battery pack, battery-powered device, or battery recharger.

Figure 3: Solar charge controller PCB board

RESULTS AND DISCUSSION

Fig. 4a and Fig. 4b shows the printed PCB layout solar charge controller. The solar charge controller will regularly control the battery voltage, which will open or close the array circuit in series after the battery attains the optimum set point regulation voltage. After a pre-set period of time, or when battery voltage reduced to the array reconnect voltage set point, the array and the battery will be reconnected and the cycle will repeat. After the battery is almost fully charged, the time taken for the battery voltage to attain the regulation voltage is reduced in every cycle. Thus, the total current flowing into the battery will be reduced. The main function of a charge controller in an LPSEH is to control the battery at the highest possible state of charge. The charge controller controls the battery from overcharge and cut off the load to avoid deep discharge when the solar cell charges the battery.

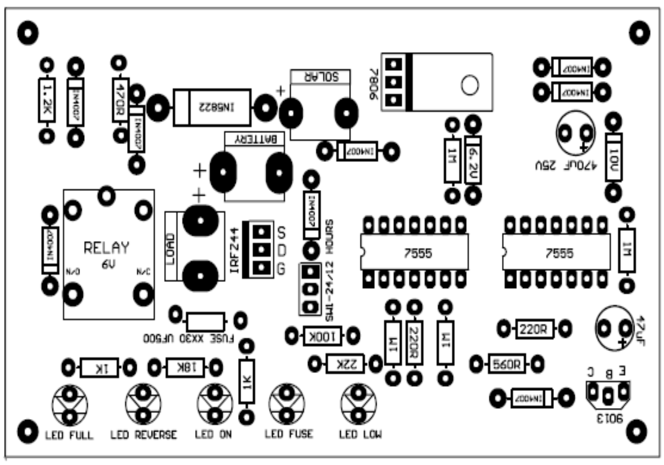

Figure 4a: Solar charge controller PCB layout (top view)

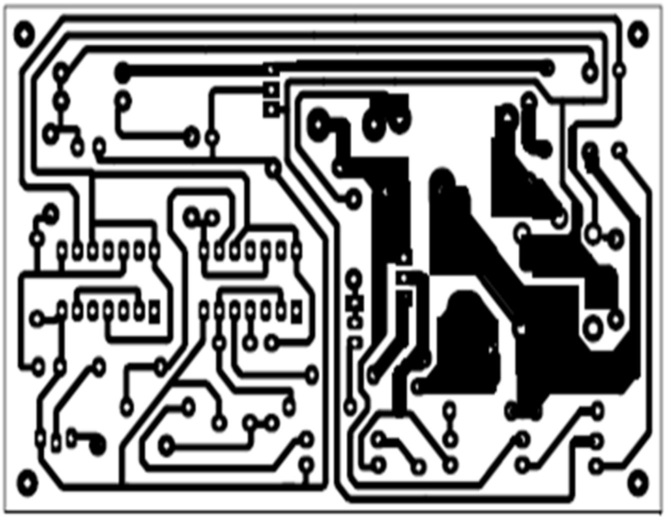

Figure 4b: Solar charge controller PCB layout (bottom view)

The charge controller will directly control the state of charge of the battery. When there is no charge controller, the current flow from the solar cell will keep on flowing into a battery in proportion to the irradiance without considering whether the battery needs to be charged or not. When the battery is completely charged, the unregulated charging will make the battery voltage to exceed the higher voltage which may cause major gassing, electrolyte destruction, internal temperature increase and increased grid corrosion.

The ICM7555 is CMOS RC timers which enhanced the performance and widely used in most applications. It also improves the parameters with low input current, broad operating supply voltage range, with reduced trigger and reset currents, low threshold, no crowbarring of the supply current during output transitions with higher frequency performance with no requirement to decouple control voltage for stable operation.

The ICM7555 is precisely a stable controllers that manage to produce the accurate time delays or frequencies. The ICM7556 can also be used as a dual ICM7555, with the two timers operating independently of each other, sharing only V+ and GND. The IC7806 is a voltage regulator used to restrain the voltage to a particular limit. This IC will maintain the output voltage steady at 6V. IN5822 is a low drop Power Schottky Rectifier suitable for switch mode power supplies with a high frequency of DC to DC converters which act as a polarity protection and small battery charger.

CONCLUSION

The design of LPSEH has been produced with the source from solar. This LPSEH solar charge controller has been developed and designed into PCB board using Proteus ISIS and ARES Professional software. The power losses of this LPSEH is reduced and the energy conversion efficiency is increased by the implementation of solar energy harvesting. This research has contributed to the renewable energy technology as an alternative to using solar to power up any portable electronic devices such as notebooks, laptops, cell phones and thus it will get rid of the need for an external power source. This designed solar charge controller managed to step up the output voltage and produced the maximum power as required by most of the portable electronic devices. The solar panel and the components for energy storage are integrated to each other with the optimum energy level to maximize the efficiency of solar harvesting. The final result is obtained with an output regulated voltage up to 20V and the electronics devices such as notebooks, laptops and cell phones can be powered up and operated without the usage of any external power source.

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