A study on the development of DC-DC converter for low-power DSC

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Abstract— In this research, we have studied the development of dc-dc converter suitable for the driving of mobile instruments by using a dye-sensitized solar cell(DSC). We also have designed a interlocking circuit. The circuit makes power generation be saved in one battery and concurrently be discharged in the other battery. As this application, mobile devices such as MP3, cellular phone are operated by using power generator from DSC during the daytime and they can be operated by using the saving energy of the daytime during the night. Consequently, it has a simple and robust circuit configuration. Besides, we designed dc-dc converter circuit to drive low power instruments by using NMOS switch and PMOS rectifier. Operational modes are analysed, and then validity of the proposed interface circuit is verified through DCS.

Index Terms— DSC, solar power system, inter-lockingg device

I. INTRODUCTION

Energy sources have been exhausted and environmental problems have been rising all over the world. Those reasons make solar energy as permanent energy sources come to issue. Especially, the solar energy is one of the positive choices. The existing solar cell using silicon have been used widely due to its high efficiency and easy manufacturing process. As the existing silicon solar cell requires high cost ingredient and equipment for its manufacture, dye sensitized solar cell(DSC) attracts public attention. In other words, the efficiency of silicon solar cell is higher than that of DSC by 15%, but the cost of DSC is one fifth times to that of the existing solar cell. Moreover, DSC has the advantage of long lifetime, 20 years or so. These merits of DSC make many researchers and companies research it actively.

In photovoltaic power generation systems, the cost reduction of solar cells and interface circuit between a solar array and a utility line is still a major issue. To alleviate the cost problem, we developed low power DC to DC converter.

In addition, a charging and discharging circuit was designed. That is, one battery drives our electronic devices and simultaneously the other battery is charged from the power of DSC. And we suggest a interlocking switch system, which gets the other consumed battery charged automatically when one is charged completely.

II. Dye-sensitized Solar Cell

Fig. 1 presents the structure of DSC. First of all, Stain the white side of a glass plate which has been coated with titanium dioxide(TiO_2). This glass has been previously coated with a transparent conductive layer (SnO), as well as a porous TiO film. Crush fresh blackberries, raspberries, pomegranate seeds, or red Hibiscus tea in a tablespoon of water. Soak the film for 5 minutes in this liquid to stain the film to a deep red-purple color. If both sides of the film are not uniformly stained, then put it back in the juice for 5 more minutes.

Wash the film in ethanol and gently blot it dry with a tissue. The solar cell needs both a positive and a negative plate to function. The positive electrode is called the counter electrode and is created from a "conductive" SnO coated glass plate.

A Volt - Ohm meter can be used to check which side of the glass is conductive. When scratched with a finger nail, it is the rough side.

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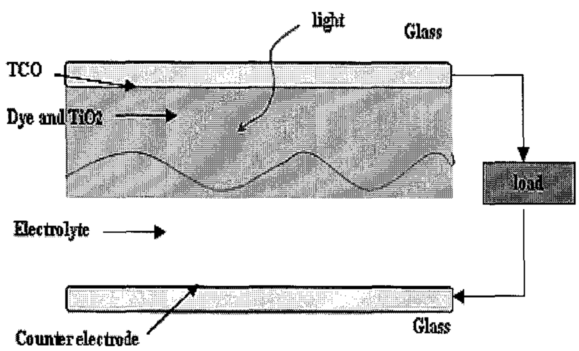
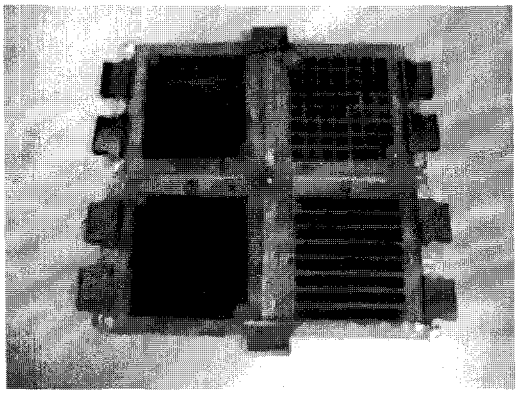
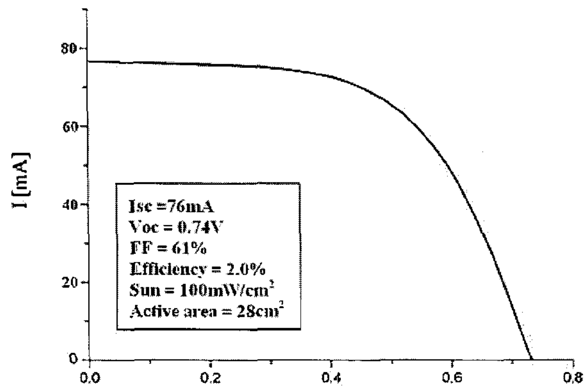


Fig. 1 DSC structure.



(a)



(b)

Fig. 2 Current-voltage characteristics of a DSC; (a) fabricated DSC and (b) *I-V* curve of DSC.

The "non-conductive" side is marked with a "+." Use a pencil lead to apply a thin graphite (catalytic carbon) layer to the conductive side of plate's surface. The Iodide solution serves as the electrolyte in the solar cell to complete the circuit and regenerate the dye. Place the stained plate on the table so that the film side is up and place one or two drops of the iodide/iodine electrolyte solution on the stained portion of the film. Then place the counter electrode on top of the stained film so that the conductive side of the counter electrode is on top of the film. Offset the glass plates so that the edges of each plate are exposed. These will serve as the contact points for the negative and positive electrodes so that you can extract electricity and test your cell. Use the two clips to hold the two electrodes together at the corner of the plates[1]~[5].

Fig. 2 shows the current-voltage characteristics of the normal series interconnected DSCs.

The basic DSCs with Ag grid are a structure embedded Ag grid on the substrate without the scribing and its active area is 28cm^2.

III. DC-DC converter design concept

I proposed the synchronous boost converter. Able to operate from an input voltage below 1V, the devices feature fixed frequency, current mode PWM control for exceptional line and load regulation. With its low R_{DS} and gate charge internal MOSFET switches, the devices maintain high efficiency over a wide range of load current.

In this study, DC to DC converter module designed suitably for portable electronic devices such as MP3 player or digital camera or GPS would like to be introduced. In general, portable electronic devices usually require the voltage of 3.3[V] ~ 3.8[V] and 100[mA] ~ 3.8[mA] or so. As our manufactured DSC generates the voltage of 0.8~1.5[V] and 15[mA] or so per a unit, development of dc to dc converter suitable for portable electronic device is in need.

Fig. 3 shows our dc-dc converter block diagram capable of supplying 3.3V at 100[mA] from a single AA or AAA cell input. That is, input voltage source is a AA or AAA cell input. The device gets its start-up input bias from Vin. Once Vout exceeds Vin, bias comes from Vout. Thus, once started, operation is completely independent from. The operation of Vin is only limited by the input power level and the battery's internal series resistance voltages below 4.5[V], and will increase converter efficiency by 2% to 3%. And GND trace lengths between SW and Vout was designed as short and wide as possible to reduce EMI and voltage overshoot[6].

The inductor current ripple is typically set for 20% to 40% of the maximum inductor current. High frequency ferrite core inductor materials reduce frequency dependent power losses compared to powdered iron types, improving efficiency. The inductor should have low ESR (series resistance of the windings) to reduce the I^2R power losses, and must be able to handle the peak inductor current without saturating. To minimize radiated noise, use a toroid, pot core or shielded bobbin inductor. Also, low ESR(equivalent series resistance) capacitors should be used to minimize the output voltage ripple. Multilayer ceramic capacitors are an excellent choice as they have extremely low ESR and are available in small footprints.

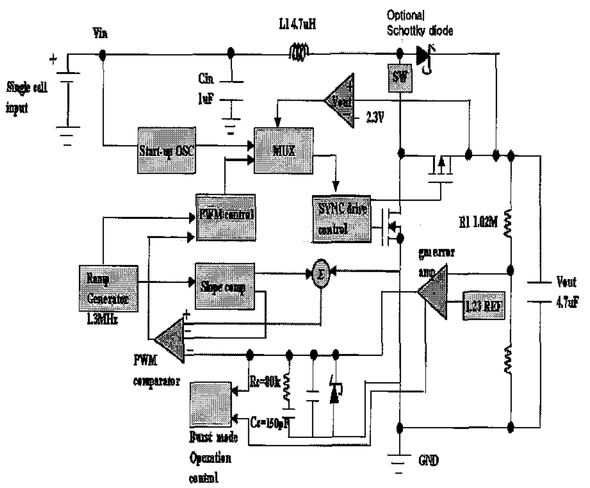


Fig. 3 DC-DC converter operational block diagram of low-power DSC

Low ESR input capacitors reduce input switching noise and reduce the peak current drawn from the battery.

The indicated feedback is an input to the gm Error Amplifier. The internal 1.23 reference voltage is compared to the voltage at the feedback voltage to generate and error signal at the output of the error amplifier. As the resistor divider tap, the output voltage can be adjusted from 2.5[V] to 5[V] by :

$$V_{out} = 1.23V \times [1 + (\frac{R1}{R2})]$$

As showed in Fig. 3, switching frequency is set at 1.2MHz. This frequency minimizes solution footprint by allowing the use of tiny, low profile inductors and ceramic capacitors.

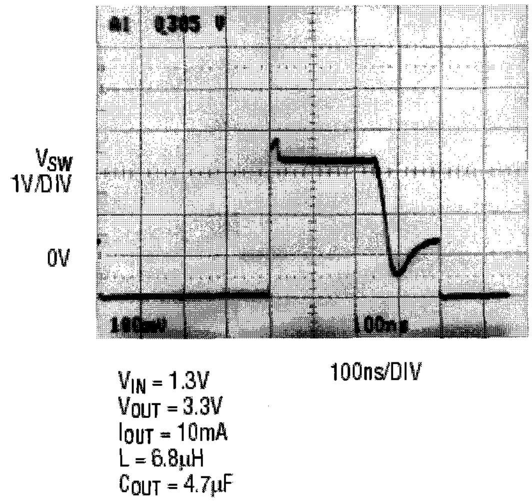


Fig. 4 Anti-ringing waveform of DC-DC converter

Anti-ringing control circuit is applied by damping inductors in the discontinuous mode in order to reduce EMI[7~8].

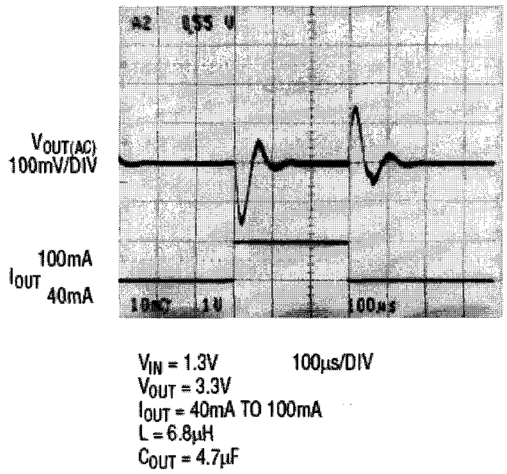


Fig. 5 The output waveform of transient response

Fig. 4 shows the anti-ringing operation at switch.

Anti-ringing control circuitry reduce EMI concerns by damping the inductor in discontinuous mode, and the devices feature low shutdown current.

Fig.5 shows the output waveform of transient reponse.

It is very important to protect DSC.

Fig. 6 shows output voltage(Vout) depending on temperature. Output current was 100[mA]. As showed, output voltage(Vout) is rising gradually depending on temperature rising.

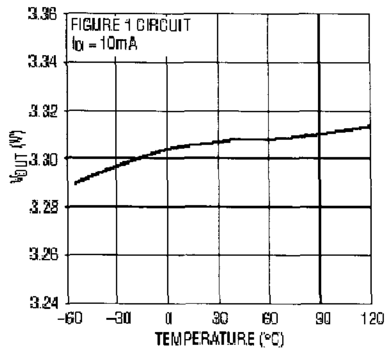


Fig. 6 Output voltage Vout verse temperature

Fig. 7 shows the 2-phase charging and discharging circuit system. As you see, while the device is driven through one battery, the other battery is charged from DSC. At this time, interlocking switch is also used.

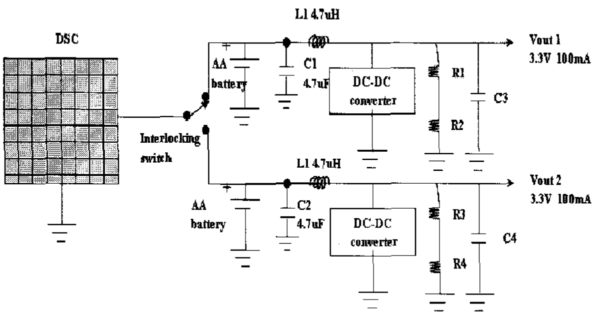


Fig. 7 2-phase charging and discharging circuit system using interlocking switch

In Fig. 8 and Fig. 9, our suggesting dc-dc converter system was converted to be applicable to various electronic devices.

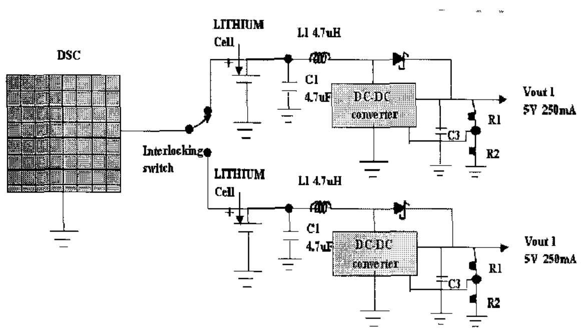


Fig. 8 Single Lithium Cell to 5V, 250mA

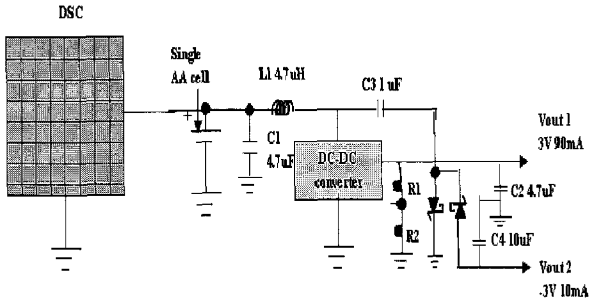


Fig. 9 Single Cell AA cell to +3V,-3V synchronous boost converter

Inductor is connected between Switch(SW) and Vin. Optional Schottky diode is connected between Switch(SW) and Vout. Here, schottky diode, 1N25817, is used since ordinary rectifier diode has slow recovery time and it will compromise efficiency. A schottky diode is also strongly recommended for output

IV. Results and Conclusion

In this study, dc-dc converter system designed suitably for portable electronic devices was suggested and dye-sensitized solar cell was applied to the converter system. Also, 2-phase charging and discharging circuit system were introduced. Besides, some circuits applicable to various output voltage and current were showed.

Hereafter, DSC system ensuring uniform solar input will be in need independent of varied solar condition. The stability and reliance of DSC in itself will be required in terms of its voltage, current and the span of life.

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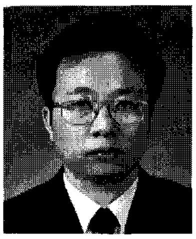

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