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Design & Performance Analysis of a Smart Portable PV Charger

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Abstract

In this paper a smart and simple PV charger for portable applications is presented. This proposed charger is low cost, low volume and light weight. Moreover this charger can realize three charging modes including the MPPT mode, the CV mode and the current limited mode. It can be integrated into an IC chip to reduce the size due to the simple structure. At last, a 60W prototype is built and tested to confirm the validity and applicability of the proposed system.

Keywords: *PV charger, Smart switch, Control circuit, Driver circuit.*

1. Introduction

The traditional charger is the component, which transfers the power from the grid to the battery. In normal condition, the grid can supply continuing and stable energy to the battery. Therefore, the battery can be charged according to its self-condition by the traditional charger. Normally, the charging process includes two stages: in the first stage, the battery is charged in the constant-current mode. When the voltage of the battery is up to the floating voltage, the charging mode is changed to the constant-voltage (CV) mode as the second stage. During the whole charging process, only the charging current and the voltage of the battery need to be controlled.

2. PV charger

Photovoltaic or in short term PV is one of the renewable energy resources that recently has become broader in nowadays technology. PV has many benefits especially in environmental, economic and social. In general, a PV system consists of a PV array which converts sunlight to direct-current electricity, a control system which regulates battery charging and operation of the load, energy storage in the form of secondary batteries and loads or appliances. A charge controller is one of functional and reliable major components in PV systems.

3. Proposed Smart and simple PV charger

To design an efficient photovoltaic charger we use some basic part to complete the design successfully. Main part of our design consists of PV array, smart switch, and control circuit, sample and hold circuit, driver circuit.
We can say our PV charger design is more smart system than other PV charger. In our design, PV array is used to reduce the system size. Step down buck converter is used as the charging circuit due to its simple structure and low cost. The overall block diagram consist of one PV array, three control loop, one smart switch, one insulation driver, one diode, one inductor, one capacitor and one lithium ion battery. So it can be smarter than other system.
The block diagram of proposed smart and simple charger circuit is given in **figure 1**:

3.1. PV array

Photovoltaic identifies the direct conversion of sunlight into energy by means of solar cells. The conversion process is based on the photoelectric effect. The photoelectric effect describes the release of positive and negative charge carriers in a solid state when light strikes its surface.
Here PV array is used to reduce the system size. Step down buck converter is used as the charging circuit due to its simple structure and low cost. The overall block diagram consist of one PV array, three control loop, one smart switch, one insulation driver, one diode, one inductor, one capacitor and one lithium ion battery.

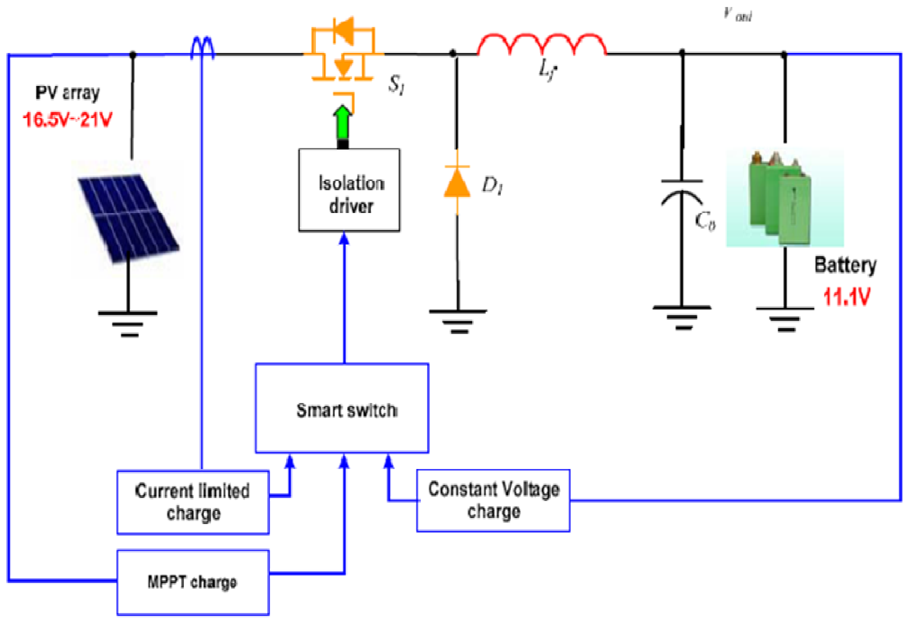

Fig. 1. Block diagram of proposed smart and simple PV charger

3.2. Smart switch

Here smart switch performs important role in case of selecting control loop for proper functions of PV charger. For three level of value of PV array it chooses three value of control loop.

3.3. Control circuit

The smart switch is achieved by two small diodes. At the beginning of the charging, the battery voltage is lower than the floating voltage, so the output of CV control loop is high. The diode D2 is reversed to block the CV control loop. And the Buck converter is controlled by the MPPT control loop. When the battery voltage reaches the floating voltage, the CV control loop takes effect to keep the output voltage steady instead of the MPPT control loop. The current limited control loop is realized by a control IC with current peak mode (CPM). The slope compensation is added to provide the circuit stability. So whichever control loop is chosen, the charge current will not be higher than the maximum charge current of the battery. The block diagram of driver circuit is given in **figure 2**.

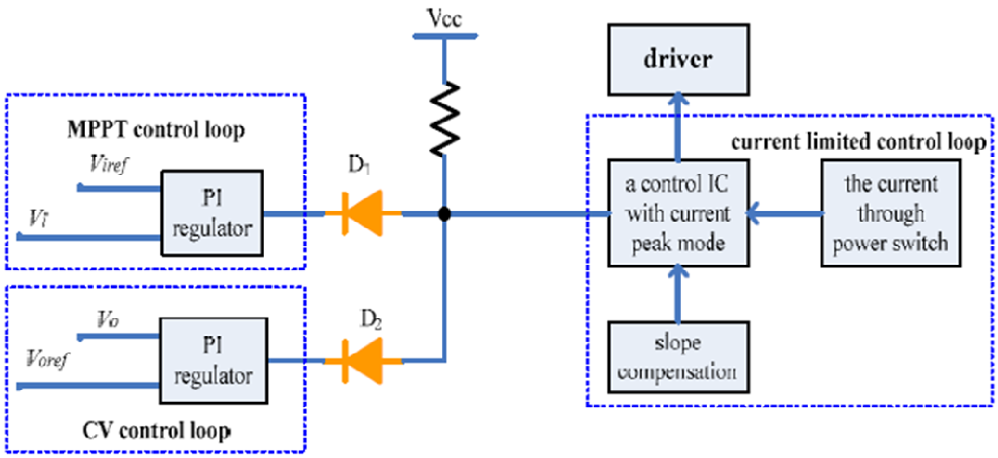

Fig. 2. Block diagram of driver circuit

3.4. Sample& hold circuit

The FOCV method is selected in this paper to realize MPPT. The block diagram of the sample & hold (S/H) circuit is shown in **Fig.3**. The open-circuit voltage is acquired by shutting down the power switch in Buck converter periodically. The 555 timer is used to generate the sampling pulse signal periodically. When its output is a high level, on one hand, it affects the control IC with CPM to shut down the power switch. On the other hand, the high level affects the S/H chip LF398 to make its output equal to the input voltage of Buck. At this time, as the power switch is shut down, the input voltage of Buck converter is just right the PV array open-circuit voltage. Thus the output voltage of LF398 is the sampling open-circuit voltage of the PV array. After the short sampling time, the output of 555 timer is a low level, the converter operates as normal Buck converter. Furthermore LF398 is in hold state to keep the output voltage invariable no matter how the input voltage of Buck changes. The voltage held by LF398 is still the sampling open-circuit voltage of the PV array. Then it is easily to obtain 80% of the sampling open-circuit voltage by applying divided resistors. This voltage is used as the reference voltage in MPPT control loop.

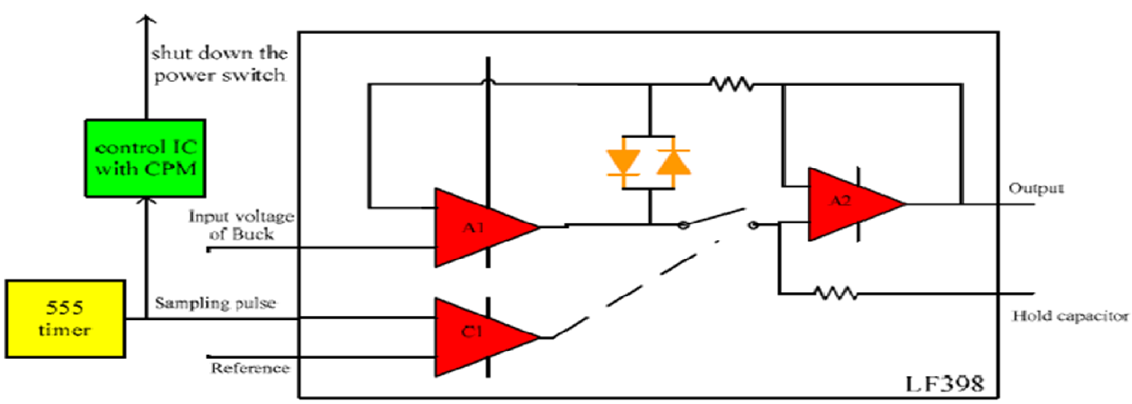

Fig. 3. Block diagram of sample and hold circuit

3.5. Driver circuit:

The MOSFET can't be driven as a normal one because its source is floated in the Buck converter. The gate driver methods can be divided as the isolation way and non-isolation way. In the non-isolation driver methods, the bootstrap is a good candidate. However, the load is the battery for PV charger. In this circumstance, before the converter starts, the voltage level of the source of the MOSFET is kept the same as the voltage of the battery. Therefore it is difficult to start the converter. The transformer driver circuit is shown in **Fig.6**. The transistors Q1 and Q2 are used to enhance the drive capability. The capacitors C1 and C2 are applied to strain away the dc component. D1 is the freewheeling diode. The transistor Q3 and the diode D2 are helpful to accelerate to turn-off speed of the MOSFET. The duty ratio can be changed in a wide scope in this transformer driver circuit shown in **figure 4**.

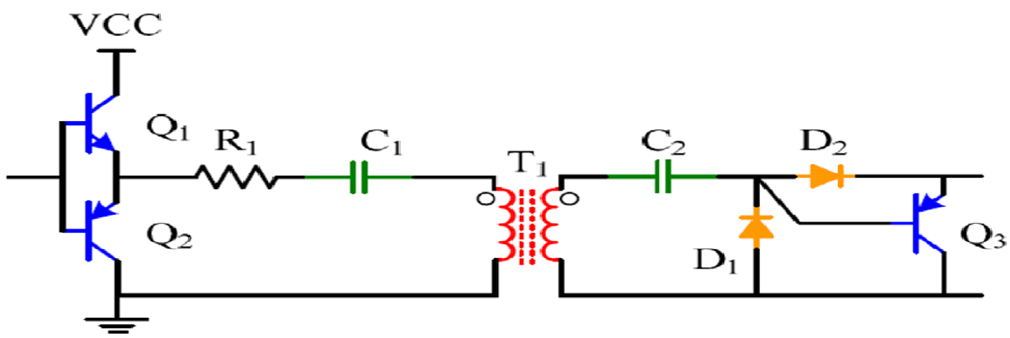

Fig. 4. Transformer driver circuit

4. Simulation waveform of the driver circuit:

The simulation wave form of the driver circuit is shown in **Fig 5** below. From this simulation wave form we can see that the output power changes periodically with time .With the change in time 10 micro second the output power changes 0w to 13w and again 13w to 0w.So the period is 10 micro second.

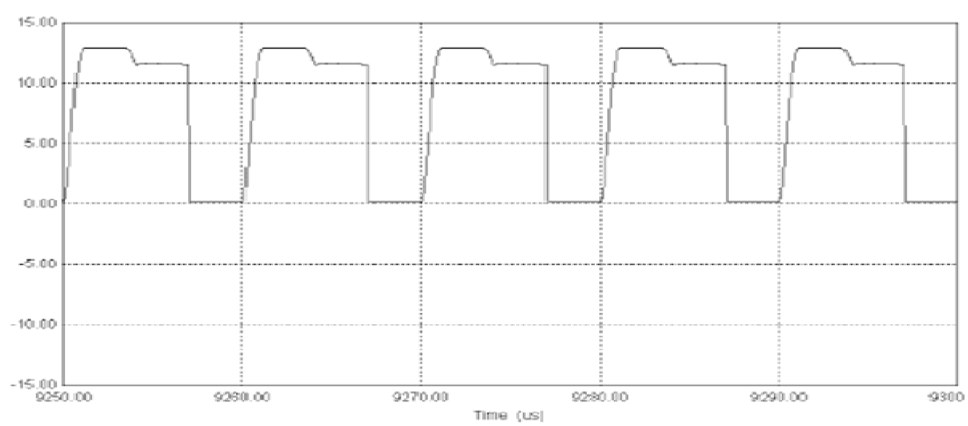

Fig. 5. Simulations waveforms of driver circuit

5. Wave forms of the driver circuit:

The experimental wave form of the drover circuit is shown in **Fig.6**. Here the gate to source voltage variation with time is shown. In this case the period is 8 micro second. i. e., after every 8 micro second the recurrence of voltage variation occurs. The maximum value of gate to source voltage is 14 V.

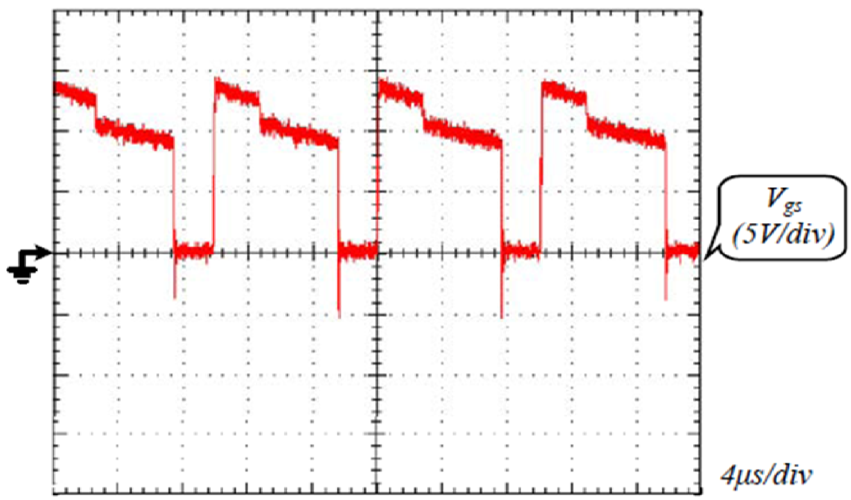

Fig. 6. Experimental waveforms of driver circuit

6. Simulation waveform of sampling open circuit voltage:

The simulation wave form of sampling open circuit voltage is shown in **Fig.7**. The sampling voltage Vsample can track the open-circuit voltage of the PV array Voc when it changes.

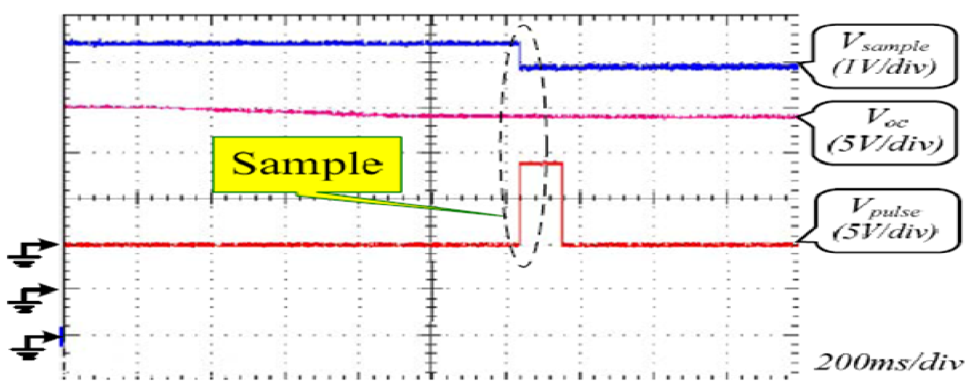

Fig. 7. Wave shape of sampling open circuit voltage

7. Simulation waveform when the charger works

The simulation wave form of PV charger when it works is shown in **Fig 8** below.During the sampling time (the sampling pulse Vpulse is given), the MOSFET is shut down, and the input voltage of Buck converter Vin is equal to the PV array open-circuit voltage Voc. During the holding time (Vpulse is low), the charger circuit works and Vin is equal to the operating voltage of PV array Vp. If the charger works in MPPT mode, Vp is equal to about 80% of Voc.

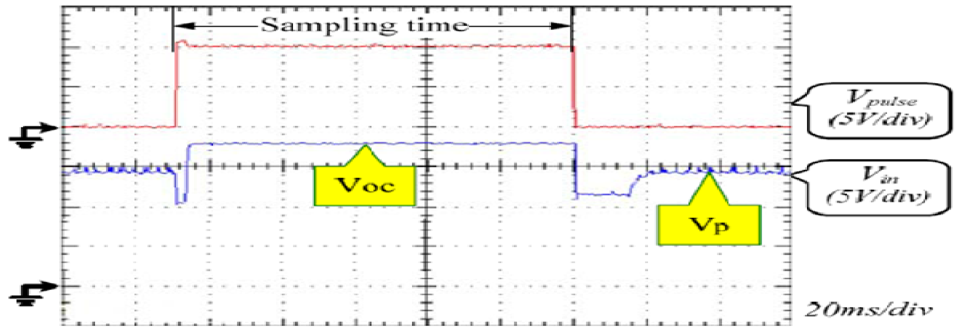

Fig. 8. Sampling waves when the charger works

8. Input and output voltages of buck converter:

The input voltage Vin and output voltage Vout of Buck converter are shown in **Fig.9**. Both of them demonstrate the proposed charger circuit works well.

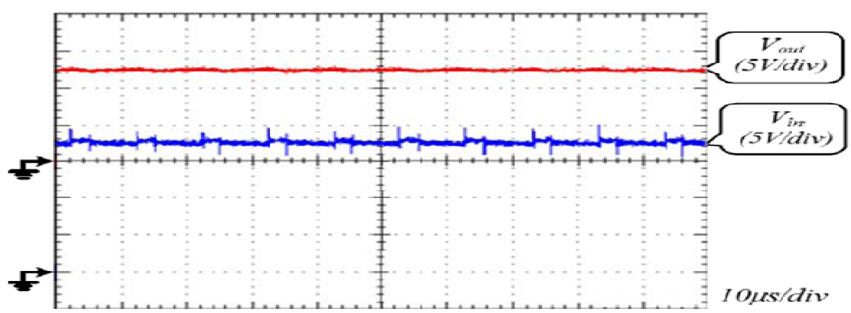

Fig. 9. Input and output voltages of Buck converter

9. Charging voltage and ratio of operational voltage to open circuit voltage

The experimental results of the ratio of the operation voltage Vop and the PV array open-circuit voltage Voc. Charging voltage and Vop/Voc is shown in Fig.14. At the beginning stage of the operation, the ratio is about 82%, which shows that the PV array works at the MPP. When the system changes to operate at CV charging mode, the ratio is bigger than 0.82, which shows that the PV does not work at the MPP any more to protect the battery.

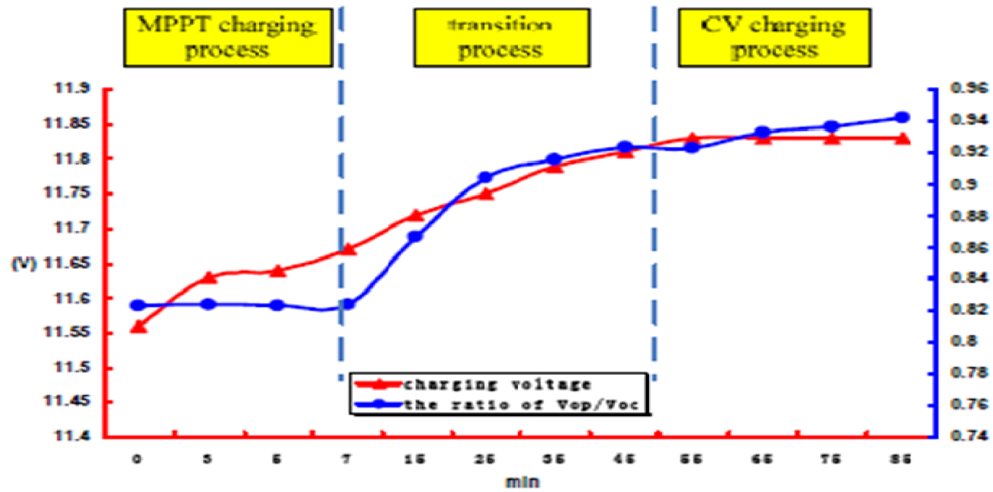

Fig. 10. Charging voltage and ratio of V_{oc}/V_{op}

10. Conclusion:

With the increase of the energy demand and the concern of environmental pollution around the world, photovoltaic (PV) power system is becoming more and more popular. The off-grid PV power generation system is widely used in the portable applications to provide clear and long energy with a high power density. As a part of the off-grid PV power generation system, the PV charger is used to charge the battery from the solar energy. Nowadays, the portable equipment's relying on the solar energy as a power supply is widely used in the daily life. It is more suitable to make the PV charger cheaper, smaller and lighter in the portable applications. As a result, the PV charger should be simple and smart.

11. References

[1] Min Chen, Gabriel A. Rincon-Mora, "Accurate, Compact, and Power-Efficient Li-Ion Battery Charger Circuit," IEEE Transactionson Circuits and Systems, Vol.53, NO.11, November 2006,pp.1180-1184.

[2]] T. Esram, P. L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," IEEE Transactions on Energy Conversion, vol. 22, NO.2, June 2007, pp. 439-449.

[3] Abu Tariq, M.S. Jamil Asghar, "Development of An Analog Maximum Power Point Tracker for Photovoltaic Panel," IEEE PEDS 2005, pp. 251-255.