SOLAR POWERED STREET LIGHTING SYSTEM EFFICIENCY IMPROVEMENT WITH SINGLE-ENDED PRIMARY INDUCTANCE CONVERTER BY REDUCING RIPPLE CONTENTS

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ABSTRACT

Buck converter is being used in the central system as well as in decentralized PV street-lights. It can step-down the input voltage. The buck converter requires a single capacitor and an inductor. But the first problem in this converter is that due to switching, it suffers from a high amount of current ripple contents approximately 1-ampere inside the buck converter. This 1 ampere current ripple contents causes large amount of heat in electrical components, this can be equipment failure. The ripple current is power loss due to which the efficiency reduced to 87%. In this study, the DC-DC Single Ended Primary Inductance Converter (SEPIC) with Linear Technology LT1371HV I.C has simulated and analyzed that the current ripple contents are reduced to 224mA due to which efficiency of the proposed PV street lighting system increased to 97%.

Keywords: *DC-DC Converter, Renewable Energy, LT1371HV I.C, SEPIC Converter.*

INTRODUCTION

The supply of electricity from fossil fuels is not enough to meet the demand of all people, so all the people need to achieve sustainable electricity development and poverty reduction. The PV system is one of productions of electricity using renewable energy sources (solar energy).In order to increase the proportion of energy production/cost of installation, so, it is valuable that the PV panel work at the maximum power point (MPP) to consume the maximum power possible. The photovoltaic (PV) module is the type of equipment used to convert sunlight into electricity. As the sun shines solar cells light energy turns directly into electrical energy without any mechanical effort. It can be used for home lighting and solar-powered street lights on a large scale in developed countries, solutions (Kamala & Ashwariya, 2015).

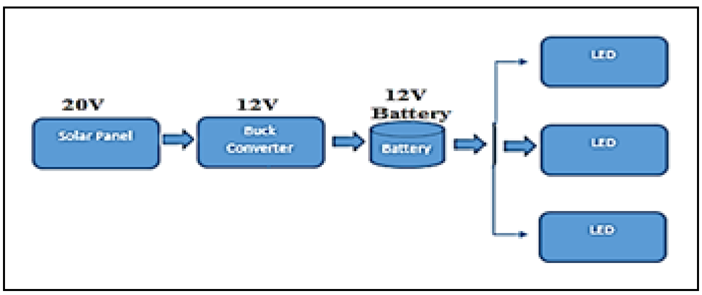
These street lights take input power from a solar panel that is used to charge the battery and at night time it is consumed by street lights. In a LED Street lighting system LED lights are used in place of conventional lights. So that solar energy can be actively used for the defined purpose. The conversion from DC-AC causes a huge loss of power, therefore an important technique to make the DC generated power more efficient is to use DC-DC converters to store and utilize the energy. Many types of DC-DC converters can be used for the purpose and every converter has its own advantages over others (Vijayalaksh, Arthika

& Shanmuga, 2015). The aim of this study is to make the Centralized architecture of PV LED street lighting system more efficient using SEPIC converter. Research work includes design, simulation and analysis of the proposed system (Xuliang & Sun, 2014; Vansay, Syafrudin & Soib, 2014).

Present Centralized PV Street Lighting System

Figure 2 displays the structure for charging the battery and photovoltaic. The voltage of solar panels is almost 20 volts .This voltage solar panels used to withdraw with the help of Buck converter for charging 12v battery and output current is 1A for charging.

Figure 1. Present Solar Powered street lighting system



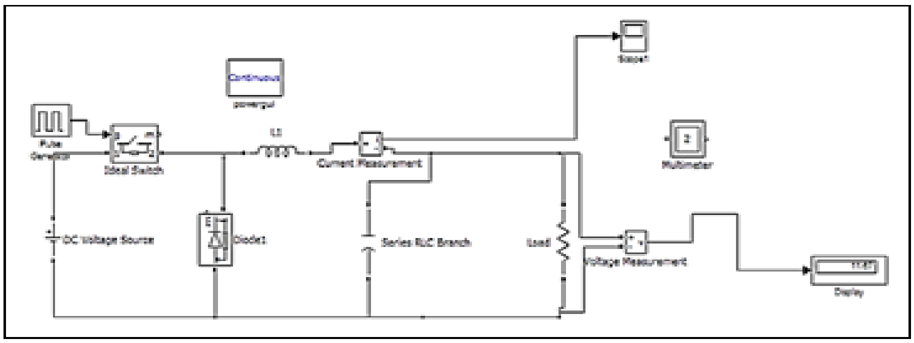
Simulation and Results of Present Buck Converter in MATLAB

Table 1. Parameters and Values of Present Buck Converter

PARAMETERS	VALUES
Input Voltage (V.IN)	20V
Output Voltage (V.OUT)	12V
Output Current (I.OUT)	1A
Switching frequency (TLP_250 I.C)	25KHz
L	200uH
C	200uF

The DC-DC buck converter was implemented in the MATLAB/ Simulink. The MOSFET switch is used to turn on and off the circuit. Duty cycle is the percentage of time period due to which a signal or system will active. The Buck converter was used to step down the voltage to charge the 12V battery working as shown in figure 2. Using the designed values the MATLAB/Simulink model is simulated and the buck converter reduces the 20V input voltage to 12V output voltage in figure 3 and the product current of the step-down buck converter is 1A as shown in figure 4. Such ripple current manifests itself as electromagnetic interference. In figure 5, these current ripple contents make stress on the components that cause system failure, and increased power losses (Poon, Liu, Tse & Pong, 2014).

Figure 2. Present DC-DC Buck Converter Circuit in MATLAB/Simulink



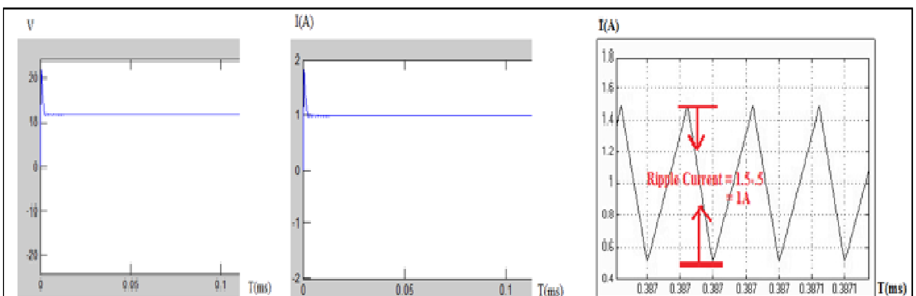


Figure 3. 12V Output Voltage of Buck Converter Figure 4. 1A Output Current of Buck Converter Figure 5.1A Ripple Current of Buck Converter

Power losses and Efficiency Calculation of Present Buck Converter

a) <u>TLP_250 MOSFET Driver I.C</u>

So, Power dissipated in TLP250 I.C = .33W

b) <u>IRF_9530 MOSFET Power loss</u>

$$\text{Psw} = \text{Coss x } V^2 \text{off x FSW} \qquad (1)$$

$$\text{Psw} = 340\text{p x } (20)^2 \text{ x } 25{,}000$$

= 0.0024W

c) <u>Ripple Current</u>

$$\Delta I = \frac{(V..OUT)(V.IN - V.OUT)}{(F.SW \times L \times V.IN} \qquad (2)$$

$$\Delta I = \frac{(12)(20-12)}{(25K \times 200u \times 20)}$$

$$\Delta I = \ 1A$$

d) <u>Inductor Power Loss</u>

$$P = I^2R \quad (3)$$
$$= (1A)(1)$$
$$= 1W$$

e) Schottky Diode MBR1545

$$P = VI \quad (4)$$
$$= (.6)(1)$$
$$= .6W$$

f) Total Power Loss

=1+.3+.6+0.0022

= 1.9022W

g) Efficiency of Buck Converter

$$\text{Efficiency} = \frac{\text{POUT}}{\text{POUT} + \text{PLosses}} \quad (5)$$

$$\text{Efficiency} = \frac{12}{12 + 1.9022}$$

= 86.67%

LITERATURE REVIEW

There are different type of techniques to step-up or step-down the dc voltage i.e. If we use Resistors then we can divide the voltage. We can change step-down the voltage using Voltage Regulator LT317 I.C. Switch mode power supply is also being used for step-up or step-down the voltage (Mohamed & Akkila, 2015). The voltage divider is two resistors connected in parallel with the input voltage. Voltage dividers can also be used a voltage reference, or to mitigate the content of the voltage so that using multimeter, it can be measured, and can be used as a signal for sound damping at narrow frequencies (Anasudeen, 2015). For direct current and relatively narrow frequency, the voltage divider can be accurate enough, if only the resistor; where required the frequency response over a broad degree, and the voltage divider may have capacitance components combined to make restitution for the load capacity. In power transmission line, a high voltage can be measured using capacitance voltage divider (Soedibyo & Ashari, 2015). The energy lost as a heat can be higher than that provided for in the circle for the high voltage differences.

This is a compromise to use linear regulators that are a simple way to ensure a stable voltage with several additional components (Shahida, 2014). The resulting model SEPIC has simulated for various input specifications, and the product of combined and unbound are distinguished. Bode plot of the duty cycle of product voltage transfer functions are built, and the result has been used in different utilizations for design Closed Loop controller for voltage product (Swagata & Siddharth, 2014). This work represents a step-up converter with the suggested inductor circuits mitigating surge. Step-up converter is a narrow inductor and narrow capacitor based are combined as the network ripple/surge mitigation in the suggested converter (Arunkumar & Elangovan, 2015). Narrow signal and active aspects analysis proves that the suggested converter has the distinct fixed and active response as the CBC, and the cancellation of surge current at the input side can be accomplished in all power degrees without a significant increase in losses (Uthen, Suparak & Surasak, 2013).

DC-DC converter is a variable structure control system due to the inherent characteristics of the power switch. Sliding mode control technology is ideal for variable structure control system. In this paper, a sliding mode controller was designed based on the hysteresis modulation. Simulation is built coal based Saber to check sliding mode controller (Werulkar & Kulkarni, 2012). In this paper, the growth of high ability boost converter for photovoltaic utilizations is bestowed. Typical applications of the boost converter to give DC power to the inverter (alter) or grid-connected or stand-alone system (Radak & Chitralekha, 2015). Chip UA3843A is used to target specification. 120 W inverter was established with 1.3% of maximum product or output voltage surge and efficiency and the performance to achieve more than 85% (Sidharth, Basab, Ashis & Renu, 2015). The pic microcontroller was used as a sliding mode controller with dc-dc buck converter implemented in PROTEUS software to get the output voltage constant to make the system efficient. PIC microcontrollers are a family of specialized microcontroller chips. The acronym PIC stands for peripheral interface controller, although that term is rarely used nowadays (Khurshedul & Azim, 2015).

MATERIALS AND METHODS

Proposed SEPIC converter is replaced with present buck converter to decrease the complication, to reduce the current ripple contents so power losses are also reduced. In addition, SEPIC converter will also charge the 24V 4.5Ah Lead acid battery to drive the light emitting diodes. The overall setup is shown in figure 6 in that way, the input is provided by the solar panel which delivers to the SEPIC converter .The converter provided the illumination loads at 27V by suitable power conversion (Boost application). The switching pulse for the converter is produced by LT1371HV I.C.

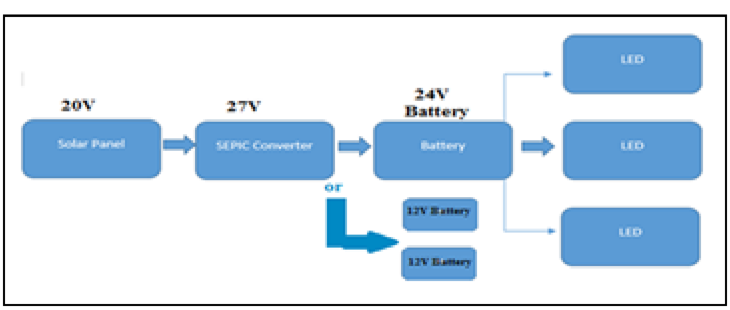


Figure 6. Proposed PV street lighting system

Working Principle of Single Ended Primary Inductance Converter

The Single ended primary inductance converter as proved in figure 7. When the MOSFET switch SW is activated, the power supply fills energy in inductor L1 and inductor L2 supplied energy to the Cs. The diode will opened. So no energy will give to the load.

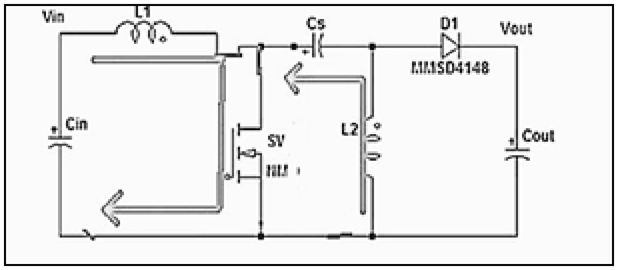


Figure 7: When MOSFET Switch SW Activate

As proved in figure 8, though MOSFET switch SW is stop from operating. The diode will closed. L1 supplied energy to the Cs, and L2 supplied energy to the load [2].

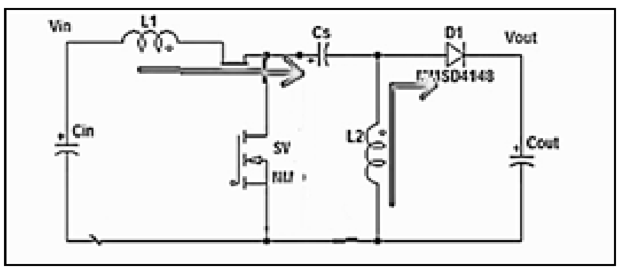


Figure 8. When MOSFET SW Switch Deactivate

Calculation of Components in Proposed SEPIC Converter

V.IN = 14.00/20.00 V.OUT = 27.00V,

I.OUT = 1.00A V.d = 0.6

Switching frequency of LT1371HV I.C is 500 KHz.

$$\text{Max duty cycle; D} = \frac{\text{VOUT} + \text{Vd}}{\text{VINmin} + \text{VOUT} + \text{Vd}} \quad (1)$$

$$\text{Max duty cycle; D} = \frac{27.00 + 0.6}{14.00 + 27.00 + 0.6}$$

= .66

a) <u>Minimum Inductance</u>

$$\text{L1} = \text{L2} \geq \frac{\text{VIN.min} \times \text{D}}{\text{I.OUT} \times \text{F.SW}} \quad (2)$$

$$\text{L1} = \text{L2} \geq \frac{14.00 \times .66}{1.00\text{A} \times 500{,}000}$$

L1, L2 ≥18.3uH

Picked component is 50uH

b) Capacitor Cs

$$\Delta Vc = \frac{I.OUT \times D}{Cs \times F.SW} \quad ; \text{ if } Cs = 10uF \qquad (3)$$

$$\Delta Vc = \frac{1.00A \times 0.66}{10uF \times 500{,}000}$$

$\Delta Vc = 0.13V$

Picked part is 10uF

c) Product Minimum Capacitor

$$\geq \frac{I.OUT \times D}{\Delta V \times F.SW} \qquad (4)$$

$$\geq \frac{1.00A \times .66}{0.023 \times 500{,}000}$$

= 63uF

Picked component is 100uF.

d) Product Voltage Counterpoise

Voltage regulation methodology is given in figure 9.

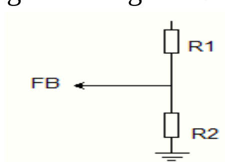


Figure 9. Voltage regulation Feedback Technique

$$V.OUT = V.REF \times \left(\frac{R.1}{R.2} + 1\right) \qquad (5)$$

$$R.1 = R.2 \times \left(\frac{V.OUT}{V.REF} - 1\right)$$

$$R.1 = 6 \times \left(\frac{27}{1.244} - 1\right)$$

R.1=124Ω

Selected components are R.1=124Ω and R.2=6Ω

e) Power I^2R loss

$P \,\alpha\, I^2$ (6)

$P = I^2R$

$P = (.224)^2(1)$

P =50mW.

Schottky diode conduction loss is 0.6W

Quiescent or static losses of the LT1371HV I.C is almost 0.08W [6] [33].

f) Efficiency

$$\eta = \left(\frac{P.OUT}{P.IN}\right) \quad (7)$$

$$= \left(\frac{P.OUT}{P.losses + P.OUT}\right)$$

Where P. losses = I^2R loss+ diode conduction loss +LT1371HV static losses

$$= \left(\frac{27.00}{50mW + .6W + 0.08 + 27.00}\right)$$

$$= \left(\frac{27.00}{.65W + 27.00}\right)$$

= 96.67%

Table 2. SEPIC Converter Parameters and Values

PARAMETERS	VALUES
Input Voltage(V.IN)	14V-20V
Output Voltage(V.OUT)	27V
Output Current	1A
L1,L2	50uH
CIN, CS, COUT	10uF, 10uF, 100uF
R2,R3	124Ω, 6Ω

In figure 10, capacitor is used at pin VC to reduce the switching frequency ripples to a few mV because switching may cause the increment in ripples. LT1371HV I.C has a built-in MOSFET. SW is the switching pin is the collector of the power switch (MOSFET) and has flown through large currents. Schottky diode MBR330 has been used because it is a fast switching device can take hundreds of nanoseconds to switch as well as its voltage drop is 0.6v at 3A.

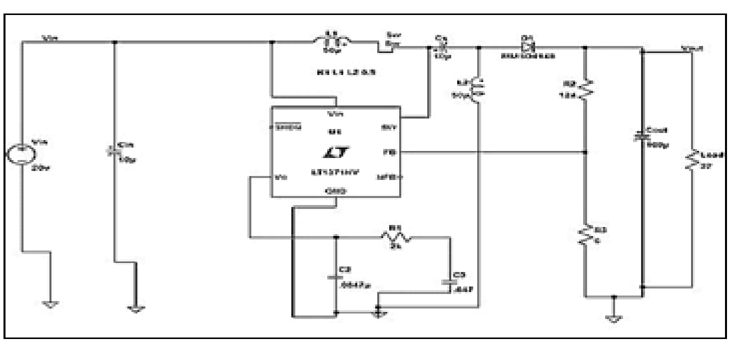


Figure 10. Simulated Circuit of SEPIC Converter

Under this conditions, power loss in this Schottky diode will be 1.8W, and if 1A current is passing through this diode then its conduction power loss will be .6W. The Linear Technology LT1371H I.C typically consume only 4mA quiescent current. The static loss or quiescent loss of LT1371HV is 0.08W. The I.C has a built-in PWM generation property, can give 500 KHz switching frequency and has a high efficiency. So this I.C makes our SEPIC converter circuit simple.

RESULT OF THE STUDY

The SEPIC converter is simulated in LTSPICE software and we have analyzed that in figure 11 and figure 12, the output current of the SEPIC converter with LT1371HV I.C has 1A current and a product voltage is 27V. The benefit of the LT1371HV I.C is that if the input voltage changes, the product voltage will not change. The current surge contents inside the SEPIC converter is now 224mA as shown in figure 13.

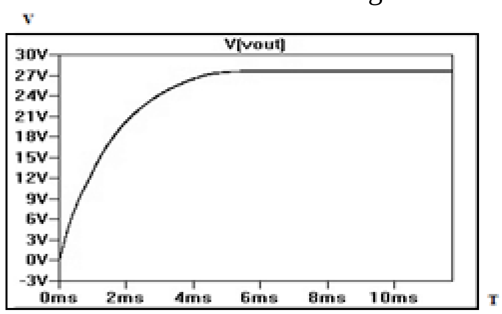


Figure 11. Regulated 27V Output Voltage of SEPIC Converter

The performance of the PV street lighting structure is now 97% if we use SEPIC converter with LT1371HV I.C. SEPIC converter is very competent and be capable of operating in place of buck converter. The life period of the system has increased. The complication of the system is also decreased.

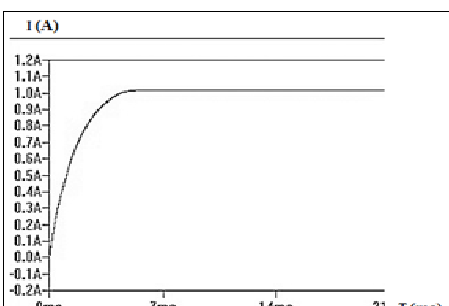


Figure 12. 1A Output Current of SEPIC Converter

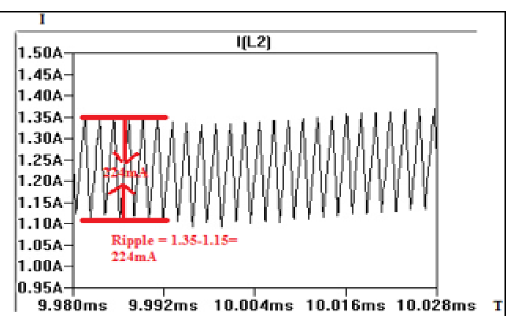


Figure 13. 224mA Current Ripple Contents in Inductor L2

The simulation decisions confirmed the demanding event of the Cs capacitor on the degree of inductor current surges of SEPIC topology. They also uphold the theoretical indications are accurate and minimum input and output capacitance recommended to specify the degree of output and input current surges.

DISCUSSIONS

We can now see that if we use single ended primary inductance converter in place of buck converter then it will reduce the complications, reduce the input ripple contents, and reduce the cost and the performance of the SEPIC converter is 97% as correlated to buck converter efficiency i.e. 87%. Furthermore, a single SEPIC converter have a step-up/step-down property. In the existing system, first we charge the 12V battery then step up the battery voltage to 24V to drive the light emitting diode. But if we use SEPIC converter then it can be charge 12V or 24V lead acid battery without any changing in the circuit. In figure 14, the output current is same in existing buck converter and proposed SEPIC converter, the ripple current contents are now reduced from 1A to 224mA as shown in figure 15, due to which the efficiency of the PV street lighting system is now increased from 87% to 97%.

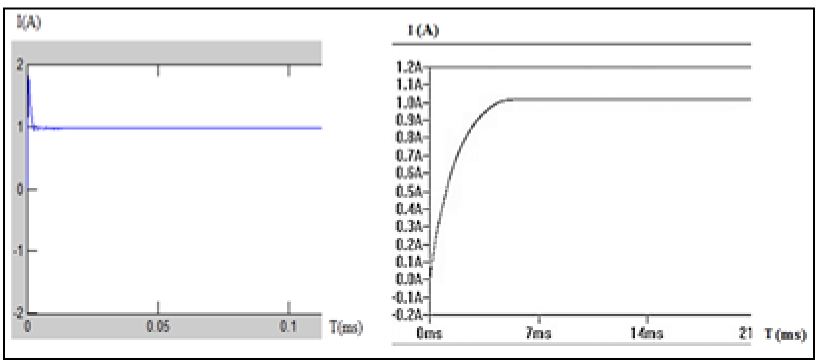


Figure 14. Output Current of Buck Converter & Proposed SEPIC Converter

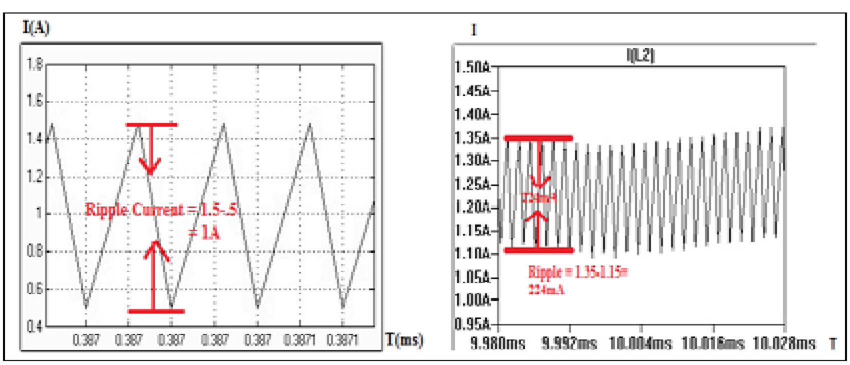


Figure 15. Ripple Current of Buck Converter and Proposed SEPIC Converter

CONCLUSION

In this article, the DC-DC converters have been studied for efficiency enhancement. Buck-boost and Cuk converter are capable of operating as a step-up or step down the solar panel voltage and have same components as SEPIC converter but the polarities of the both output are reversed voltage due to which they needs a transformer to change the polarity of the buck-boost converter output. Another problem in buck- boost converter is that it requires large filter to mitigate the harmonics at the input supply. Therefore we have ignored above converters and have chosen the SEPIC converter. It is observed from figure 15 that the input current surge of the SEPIC with LT1371HV I.C is exceptionally lesser than the input current surge of a buck converter.

The LT1371HV I.C has been used with the Proposed SEPIC converter circuit because it has a built-in MOSFET component and voltage regulation property due to which no exterior wiring needed for voltage adjustment. This SEPIC converter with LT1371HV I.C has reduced the complication of the structure as well as numerous voltage dimension batteries can be used.

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