Boost Converter. Single AA or AAA Cell Flashlight

SLG47513

This application note describes how to design and build a fully functional single AA or AAA cell flashlight.

The converter is built on the SLG47513. The IC is a low voltage programmable mixed signal matrix that is designed to be powered from a supply in a range of 1 to 1.65 V, ideal for a single non-rechargeable battery or a NiMH cell. In addition, the SLG47513 contains a huge amount of different macrocells which allows to easy create the circuit up to the task.

The application note comes complete with a design file that can be found in the Reference section.

Contents

1. Terms and Definitions

ACMP	Analog Comparator
CNT/DLY	Counter-Delay
DC	Direct current
DFF	D Flip-flop
ESR	Equivalent Series Resistance
GPO	General Purpose Output
IC	Integrated Circuit
I/O	Input / Output
LED	Light Emitting Diode
LUT	Look-up Table
MF	Multi-function Macrocell
MOSFET	Metal-oxide-semiconductor Field-effect Transistor
OSC	Oscillator
PCB	Printed Circuit Board
PWM	Pulse Width Modulation

2. References

For related documents and software, please visit:

SLG47513 - GreenPAK™ Programmable Mixed-signal Matrix | Renesas

Download our free GreenPAK Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Renesas provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the Renesas IC.

[1] GreenPAK Designer Software, Software Download and User Guide, Renesas

[2] AN-CM-362 Boost Converter. Single AA or AAA Cell Flashlight.gp, GreenPAK Design File, Renesas

[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage, Renesas

[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage, Renesas

[5] SLG47513 Datasheet, Renesas Electronics

[6] https://en.wikipedia.org/wiki/Boost_converter

3. Introduction

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input to the load. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and an energy storage element, an inductor in our case. To reduce voltage ripple, simple filters made of capacitors are normally added to such a converter's output and input.

A boost converter could be used to drive a powerful white LED, which requires a voltage of 2.7 to 3.6 V (depending on the type) from a single 1.2 or 1.5 V battery cell. Such a device is described in this paper.

4. The Design

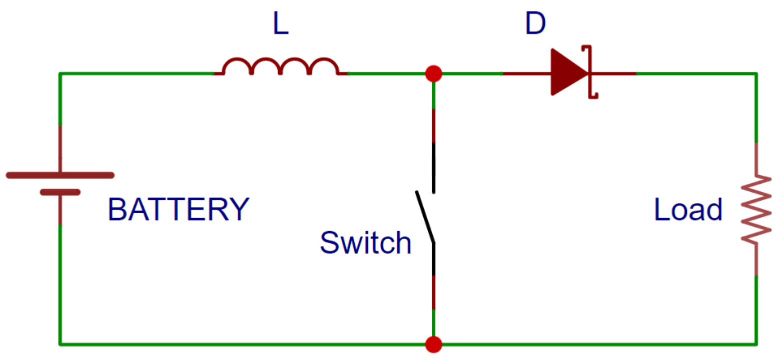

Figure 1: Boost DC-DC Converter Basic Diagram

Figure 1 shows a basic schematic diagram. The relationships between input and output voltage, current, and power are as follows:

- $U_{out} > U_{in}$
- $I_{out} < I_{in}$
- $P_{out} = P_{in} – P_{loss}$

When the switch turns ON and OFF, coil L will generate a voltage spike which is added to the V_{bat} boosting voltage on the load. If the output voltage rises above the desired, the switch's turn-on period will reduce enough to maintain a stable output voltage.

4.1 Circuit Design

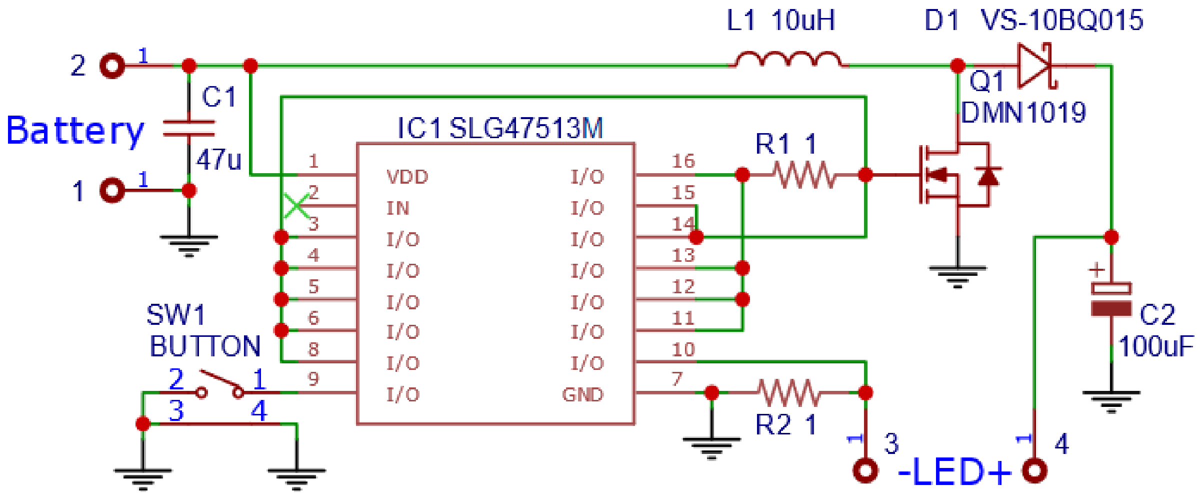

Figure 2: Flashlight Circuit Using SLG47513

As an example, a boost converter was designed using the SLG47513 IC and Go Configure software, see Figure 2**.** The design is a fully functional flashlight with two brightness modes and a single pushbutton operation. It has the following parameters

- Input voltage range (Vin- 0.9 to 1.65 V
- Output voltage (Vout)- 2.75 to 3.0 V
- Output current (Iout)- 25 and 100 mA PWM regulated
- PWM frequency- 400 kHz for 25 mA
- PWM frequency- 200 kHz for 100 mA

Calculated values for 25 mA:

- Min. Duty Cycle – 40%
- Max. Duty Cycle – 68%
- Min. Inductor size – 11 µH
- Peak Inductor current – 83 mA
- Filter Capacitor – 10 µF

Calculated values for 100 mA:

- Min. Duty Cycle – 40%
- Max. Duty Cycle – 67%
- Min. Inductor size – 9.9 µH
- Peak Inductor current – 333 mA
- Filter Capacitor – 100 µF

In both cases, a 10 µH 1A inductor and 100 µF low ESR capacitor will be up to the task. Also, in this circuit, a low gate threshold voltage power MOSFET must be used. Such as DMN1019UVT and BSL802SN. And it is recommended to use a lowest maximum forward voltage drop Schottky rectifier for example VS-10BQ015-M3.

4.2 Go Configure Project

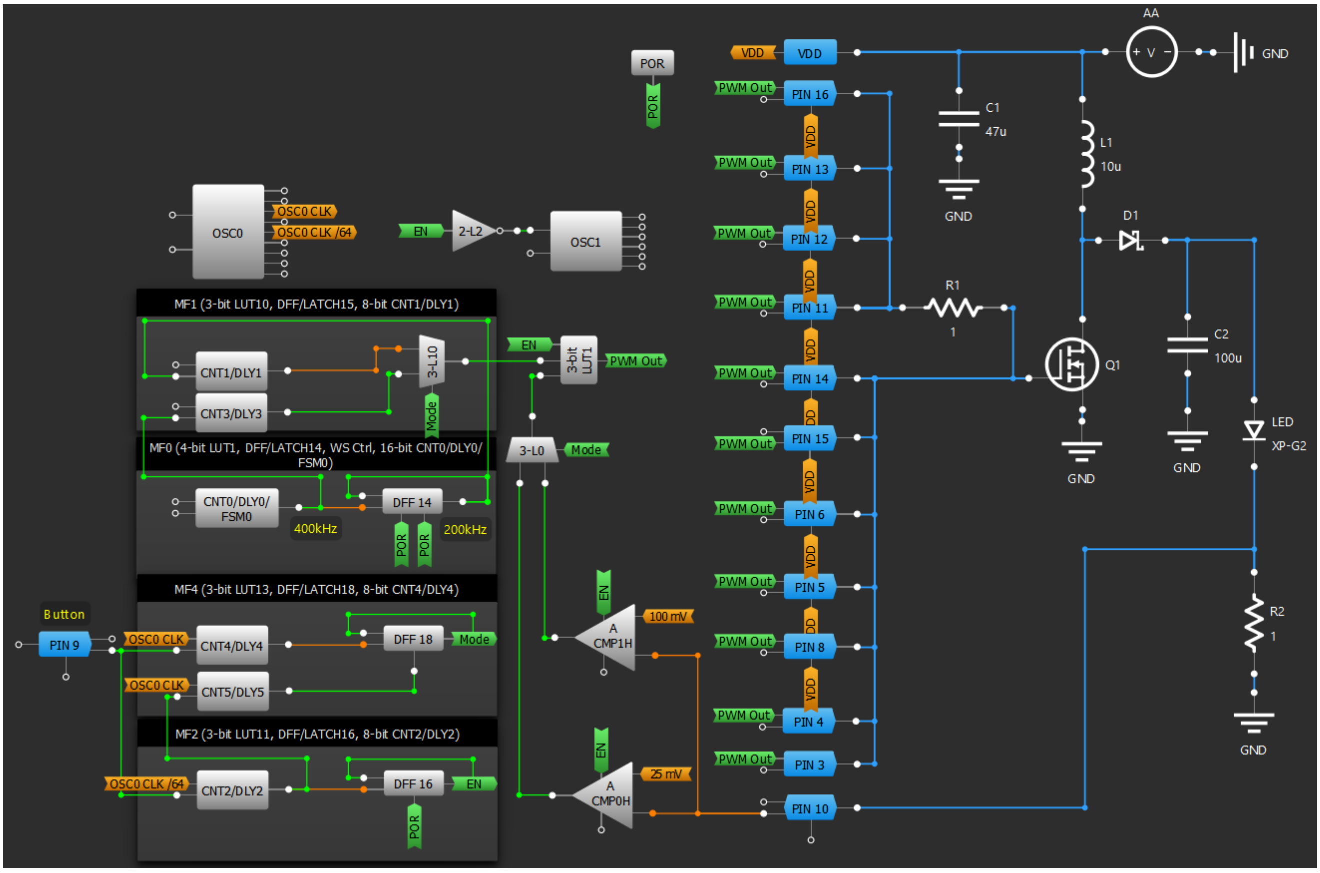

Figure 3: Boost DC-DC Converter Project

Since this boost regulator is designed to have two brightness modes (25A and 100 mA) and only one inductor, there must be two different PWM frequencies for each mode in order to ensure high efficiency. MF0 serves as a frequency divider with two outputs. CNT0/DLY0/FSM0 outputs 400 kHz for 25 mA mode and DFF14 outputs 200 kHz for 100 mA mode. The PWM logic is built on MF1 (CNT1/DLY1 and 3-L10) CNT3/DLY3, and 3-bit LUT1. The CNT3/DLY3 and CNT1/DLY1 sets the maximum duty cycle for both modes respectively. It remains at a maximum unless the feedback signal from either ACMP0H or ACMP1H through 3-L0 MUX cuts it to the width when the voltage on the current sense resistor is equal to the Vref maintaining a constant load current.

The SLG47513 has relatively low current outputs which are not suitable to drive high capacitive loads (like MOSFET gate) at high frequencies. But the abundance of them allows not only to connect them in parallel increasing output current (and ability to drive MOSFET), but make a combination of push-pull and open-drain outputs. That allows controlling the switch-on and off times of the MOSFET separately. In this case, Pins 11, 12, 13, and 16 are configured as 2x push-pull outputs and are charging and discharging the gate through the R1 current limiting resistor. But Pins 3, 4, 5, 6, 8, 14, and 15 are configured as 2x open-drain outputs (1x for Pins 3 and 4) are connected to the gate directly, and are only discharging its capacitance speeding up the turn-off time of the MOSFET improving the converter efficiency.

The ACMPs in this design are used in a current feedback loop. The output current is determined by the ACMP's Vref and the R2 resistance. In this case

$$\boldsymbol{Vref1 = I \times R = 100mA \times 1\ Ohm = 100\ mV}$$

or

$$\boldsymbol{Vref2 = I \times R = 25mA \times 1\ Ohm = 25\ mV}$$

Setting 25 mV referense for ACMP0H and 100mV for ACMP1H.

The combination of macrocells MF2, MF4, and CNT5/DLY5 make up the logic that allows the user to operate the flashlight using only one push button. A long press (> 1 s) will turn on/off the device, and a short press (< 1 s) will switch between the two modes.

Pin 9 is configured as a digital input with a Schmitt trigger and a 10k pull-up resistor. This setting ensures very stable work without any external components.

The CNT4/DLY4 is set as a 32 ms delay filtering out any button noise eliminating the need for an external capacitor. DFF18 latches one of two selected modes. Its output goes to two MUXs: 3-L10 which selects the PWM frequency and 3-L0 selects between ACMPs with different Vrefs. The CNT2/DLY2 is set to 1 s delay and together with DFF14 enables or disables both ACMPs and OSC1. So, when the device is OFF, all digital macrocells are static and analog ones are disabled except OSC0. In this state, current consumption is less than 2 μA. The CNT5/DLY5 ensures the device will not switch modes while powering on/off.

4.3 PCB Design

For testing purposes, a PCB was designed, see Figure 4 and Figure 5.

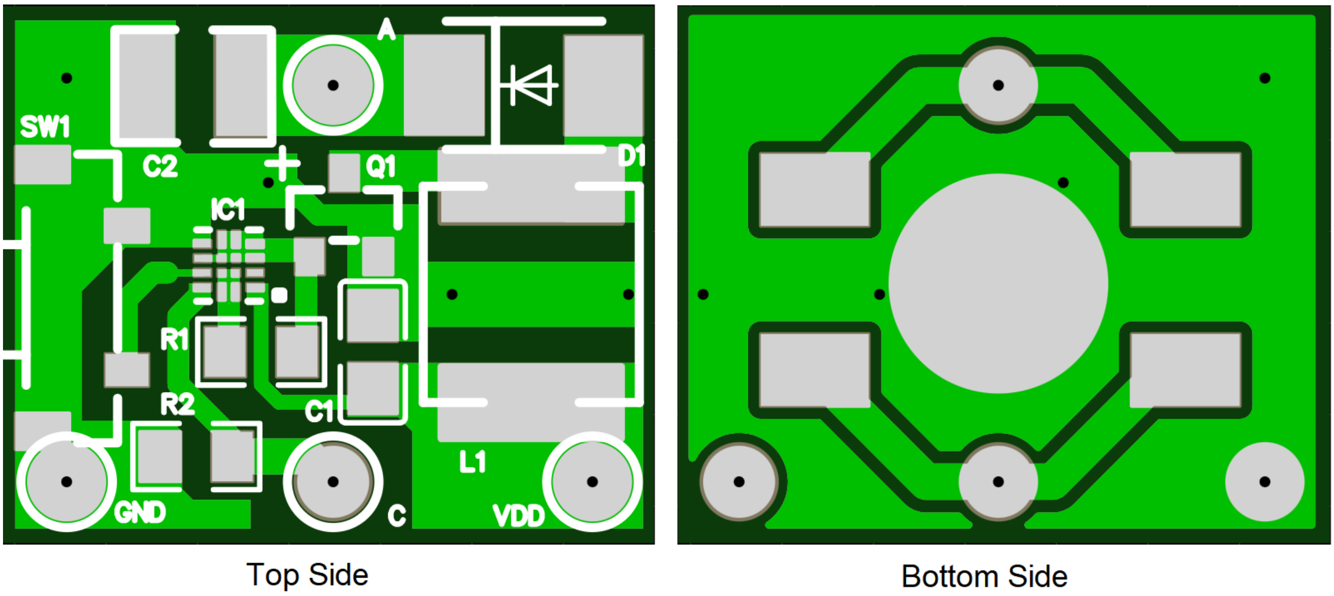

Figure 4: Test PCB

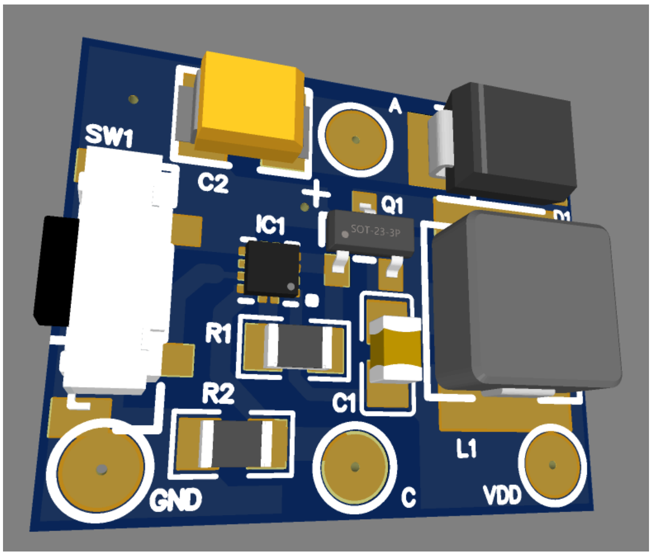

Figure 5: 3D View of the Device

4.4 Testing Results

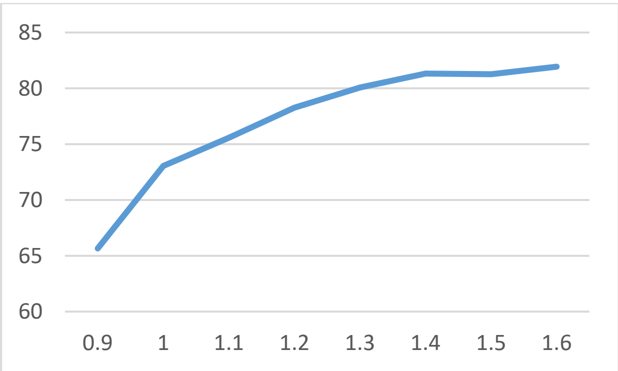

Figure 6: Efficiency vs. Input Voltage at 25 mA

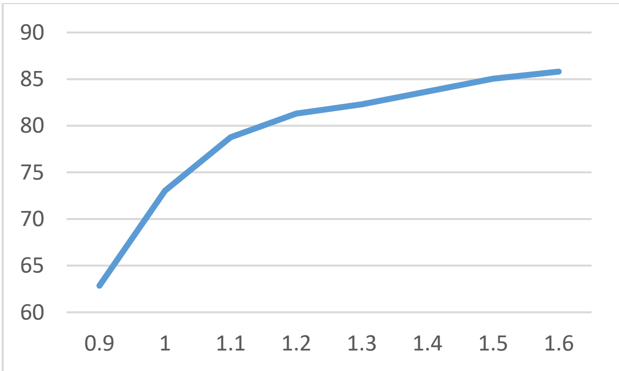

Figure 7: Efficiency vs. Input Voltage at 100 mA

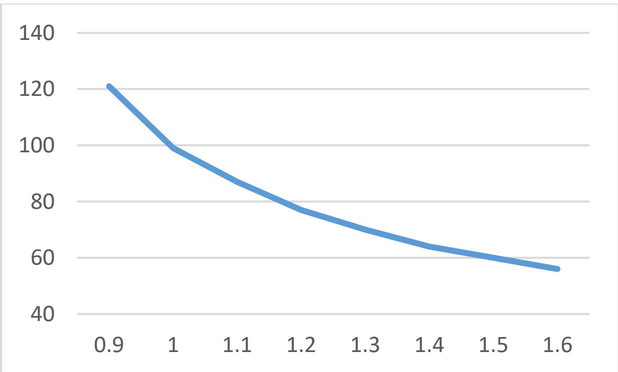

Figure 8: Input Current vs. Input Voltage

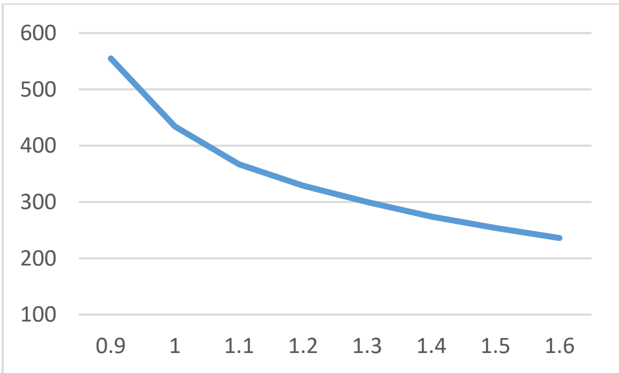

Figure 9: Input Current vs. Input Voltage

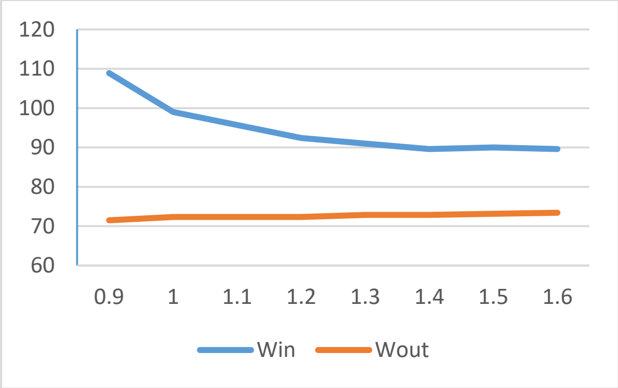

Figure 10: Input and Output Power vs. Input Voltage at 25 mA

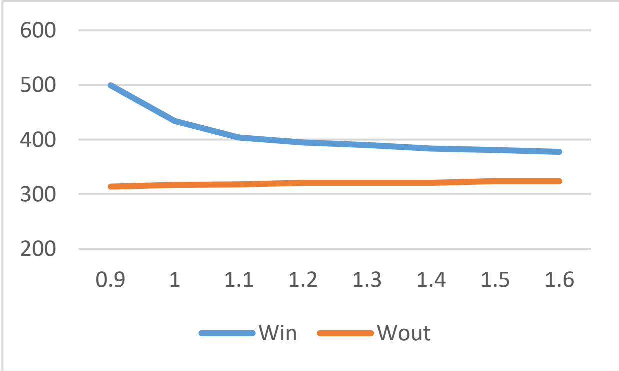

Figure 11: Input and Output Power vs. Input Voltage at 100 mA

5. Conclusions

As can be seen, designing and building a fully functional flashlight powered by a single AA or AAA battery cell is relatively easy using the SLG47513 IC. As an alternative, the SLG47512 IC could be used instead. The only difference is fewer output pins resulting in lower output current but still, it should be enough to drive the MOSFET. Both chips have all required macrocells and the circuit uses minimum external components which makes it very cost-effective. Should be noted that highly flexible Vref settings along with the current sense resistor allow setting almost any output current required by the LED.

6. Revision History

Revision	Date	Description
1.00	May 19, 2023	Initial release.

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