Application Note

AC-DC Converter for Low Power Applications

AN-CM-290

Abstract

This application note presents a low-cost AC-DC converter for low-power always connected applications. It implements a capacitor-coupled switched shunt converter controlled by a GreenPAK SLG46110 for voltage regulation.

This application note comes complete with design files which can be found in the References section.

Contents

Figures

Tables

1 Terms and Definitions

Off-line regulator	An electronic voltage regulator that is designed to directly accept electric power from an AC current source
CCSS	Capacitor-Coupled Switched Shunt Converter
ACMP	Analog Comparator
DFF	D-type Flip-Flop

2 References

For related documents and software, please visit:

GreenPAK™ Programmable Mixed-Signal Products | 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 modify the design into your own customized IC in a matter of minutes. Find out more in complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the GreenPAK IC.

[1] GreenPAK Designer Software, Software Download and User Guide
[2] AN-CM-290 AC-DC Converter for Low Power Applications.gp, GreenPAK Design File
[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage
[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage
[5] SLG46110, Datasheet
[6] AN-H65, Synchronous CCSS Regulator, Application Note, Supertex Inc.

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3 Introduction

Modern devices have driven the need for compact, low-cost off-line regulators. Off-line regulators which use inductors are efficient but are often large and costly. This application note will describe how to implement a circuit that instead uses a capacitor-coupled switched shunt regulator controlled by the GreenPAK SLG46110. This circuit can provide a low-cost AC-DC converter for low-power applications such as smart lighting.

4 Operation Principle of CCSS Topology

At a basic level shunt regulators consist of two elements: a voltage regulator in parallel with the load (shunt) and a current-limiting element in series between the supply and load. The shunt regulator used in this application note is specifically a capacitor-coupled switched shunt (CCSS) regulator (Figure 1). When the switch is closed, it short circuits the input current to ground. When it is open, diode D5 diverts the input current to the load. Besides the series capacitor (C_s), the highest voltage seen by the other components is one diode drop above V_{out}.

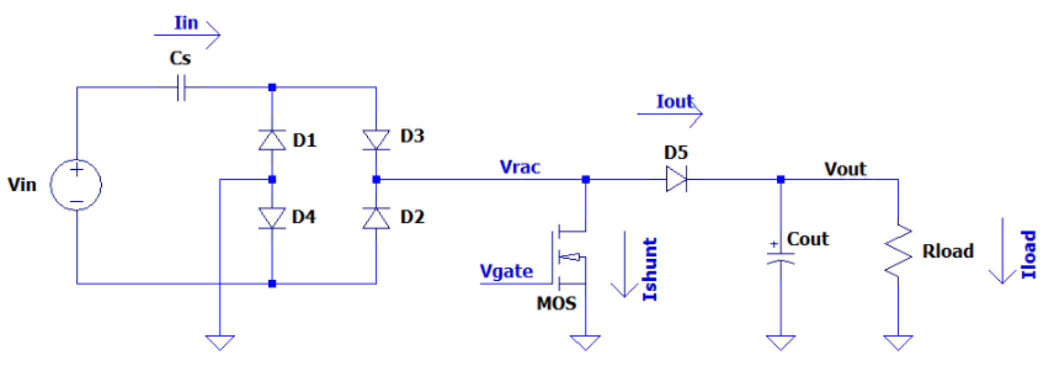

Figure 1: Capacitor-Coupled Switched Shunt Regulator

As with all shunt regulators, input current to a CCSS regulator is constant regardless of load but varies with input voltage and the series capacitance. Although current will always be drawn even under no-load conditions this current is mainly reactive with a small real. Input current can be estimated with the following equation:

$$I_{in} = \frac{V_{in}}{X_c}$$

Output voltage regulation is achieved by controlling the duty cycle of the switched shunt. The MOSFET shunt turns off when the V_{out} is below the desired regulation threshold, sending all the input current to the output. When V_{out} exceeds that threshold, the MOSFET shunt turns on, sending all the input current instead to ground and back to the input. The shunt is synchronized to turn on when the voltage across it (V_{rac}) is low to minimize the applied voltage step across C_s resulting in a more efficient operation.

The following diagram shows the operation of this control manner from a timing perspective.

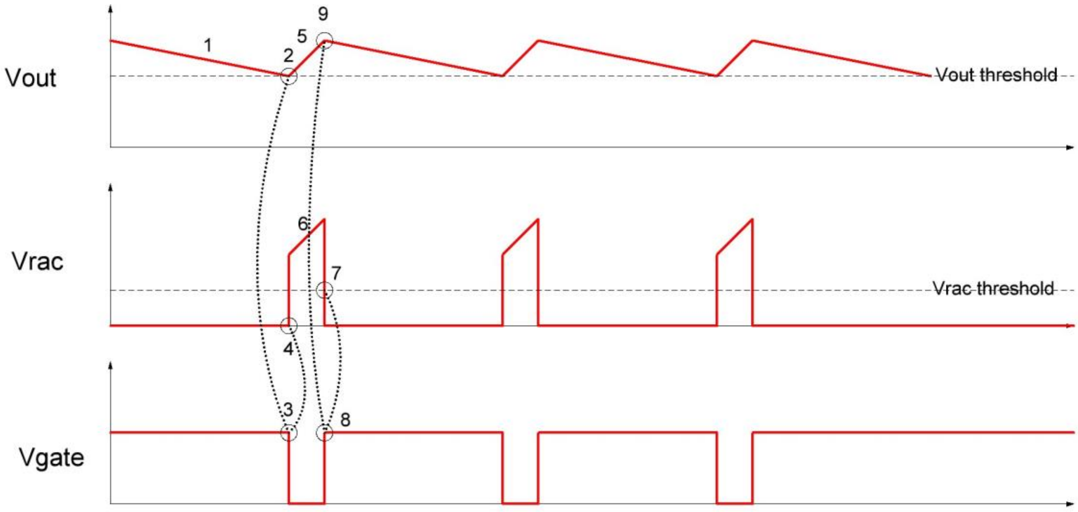

Figure 2: CCSS Regulator Timing

Figure 2 describes the CCSS timing diagram:

Output voltage decays under load until

It hits the V_{out} threshold which

Turns off the shunt

Freeing the V_{rac} from GND

V_{rac} is clamped by D5 (Vout-0.6V) when V_{out} starts to rise until

V_{rac} falls below V_{out} as AC input

V_{rac} falls to V_{rac} threshold …

The shunt is turned on, V_{rac} is clamped by GND …

Output voltage decays under load and the cycle repeats.

The MOSFET cannot turn-on immediately when V_{out} exceeds the threshold, which results in overshoot at the output. A larger capacitance for C_{out} or operating the regulator over a narrower input voltage range can minimize the overshoot.

5 Circuit Schematic and Layout

Figure 3 depicts the circuit schematic of the low power AC-DC converter module. It uses the SLG46110 (U1) to control the CCSS. The module operates at an input AC voltage range from 90V to 260V(CN1), and over a non-isolated output of 3.3V (CN2). An optional LDO (U2) is added after the V_{out} to further stabilize the output voltage. The SLG46110 device generates the control signal that switches the MOSFET shunt (Q1) based on the V_{out} and V_{rac} threshold levels. 1N5817 Schottky diodes were used for D1 and D2. Since the dissipation factor (DF) of C_S has a large effect on the efficiency of the circuit, a 1μF capacitor with a relatively small DF of 40 x 10^{-4} is used for C_S. Figure 4 shows a picture of the PCB Layout of the board. Figure 5 shows a photograph of the complete design PCB described in this app note.

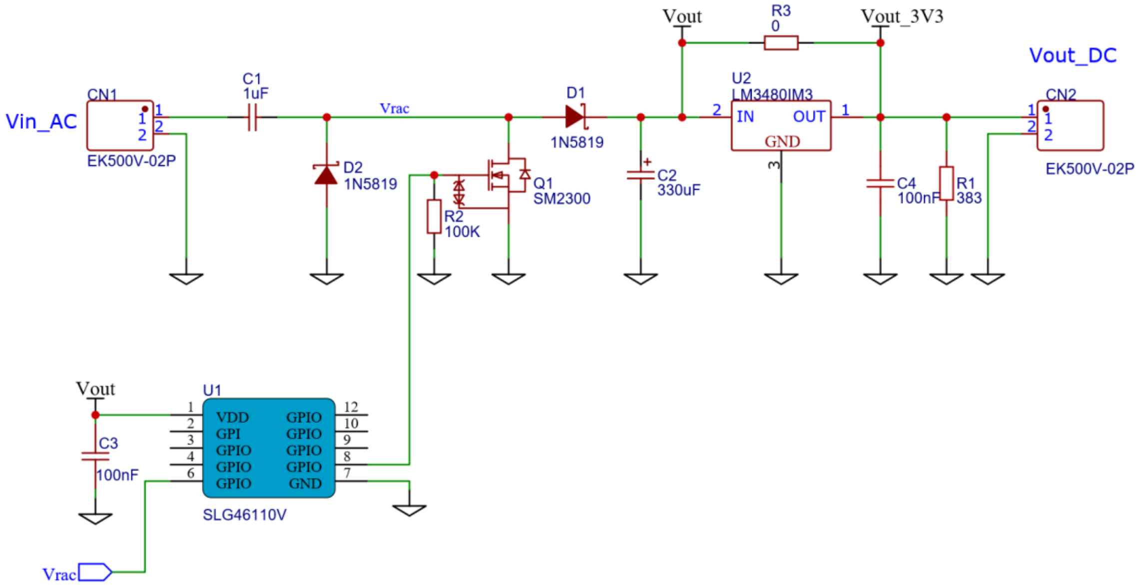

Figure 3: CCSS Regulator Schematic

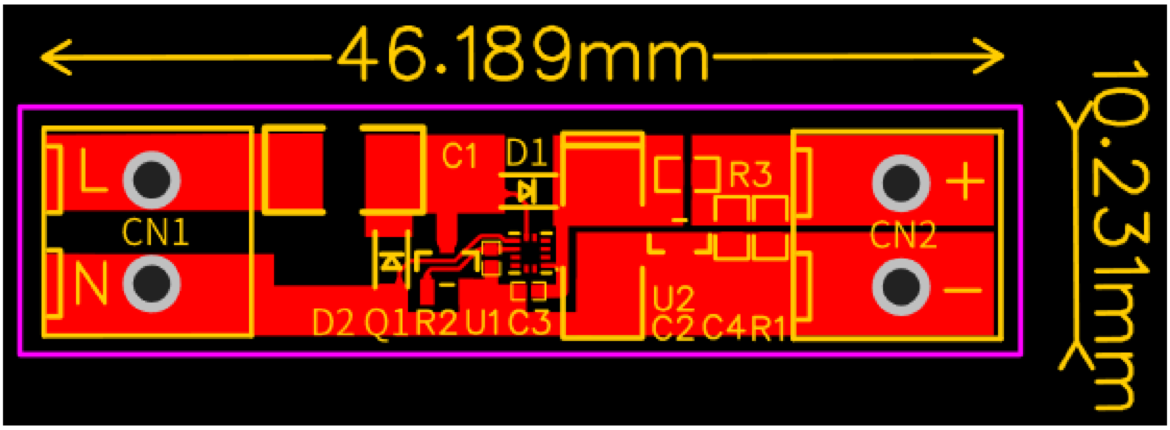

Figure 4: CCSS Regulator PCB Layout

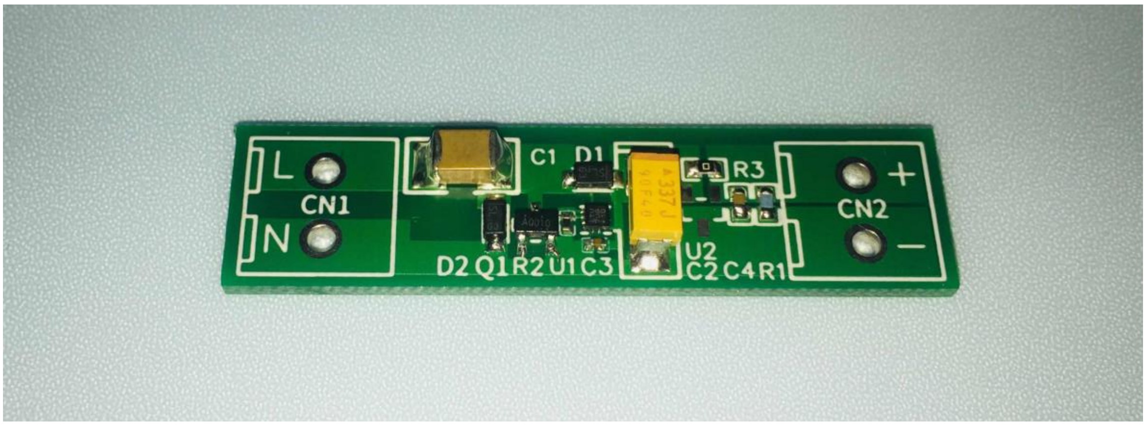

Figure 5: CCSS Regulator Prototype

6 GreenPAK Design

The project design developed in GreenPAK Designer is shown in Figure 6.

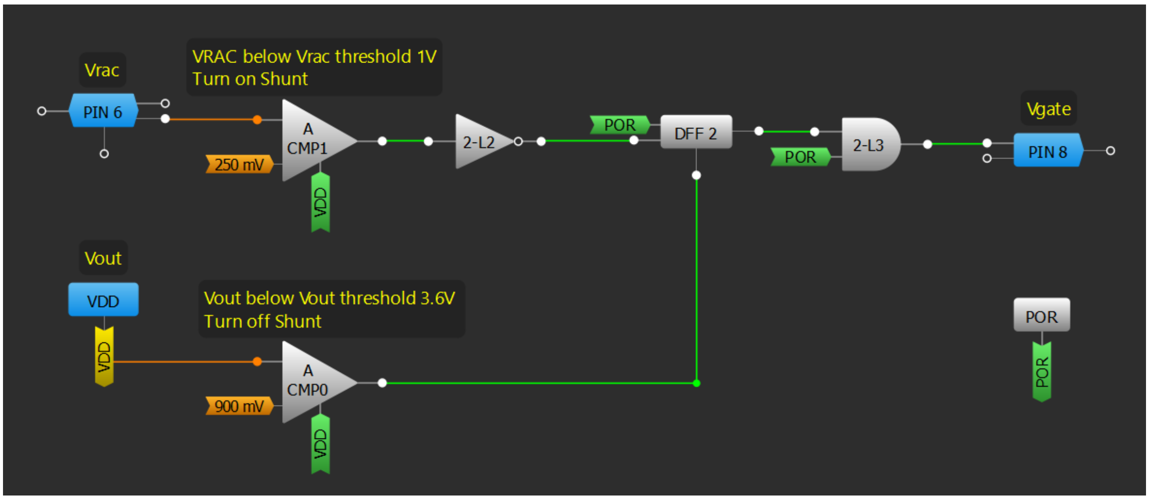

Figure 6: SLG46110 GreenPAK Design

6.1 Comparator Configuration

As shown on Figure 3 VDD of the SLG46110 device is connected to V_{out} and PIN6 to V_{rac}. ACMP0 is used to sense V_{out} voltage. With the additional logic, it will turn off the MOSFET shunt when $V_{out} <$ 3.6V. ACMP1 is used to sense V_{rac} voltage. It will turn on the MOSFET shunt when $V_{rac} <$ 1V. Refer to Figure 7 for the ACMPs settings.

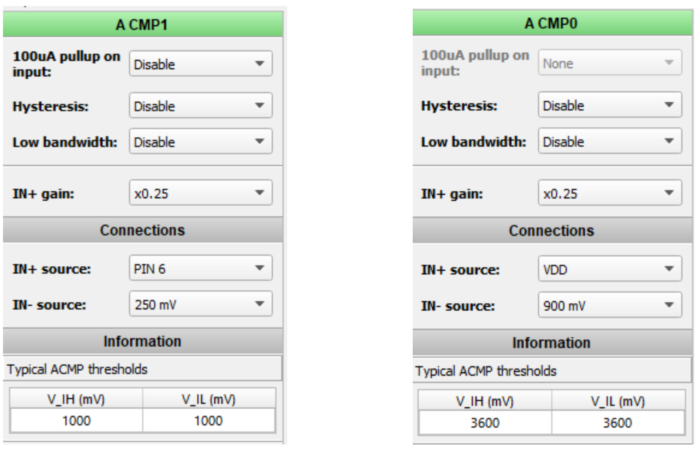

Figure 7: ACMP0 and ACMP1 Configuration Settings

7 Measurements

The module is tested at the 150V AC RMS input voltage. The gate voltage of the MOSFET shunt and the output voltage signal is measured. Figure 8 displays their waveforms. The ripple of the output voltage is about 440mV.

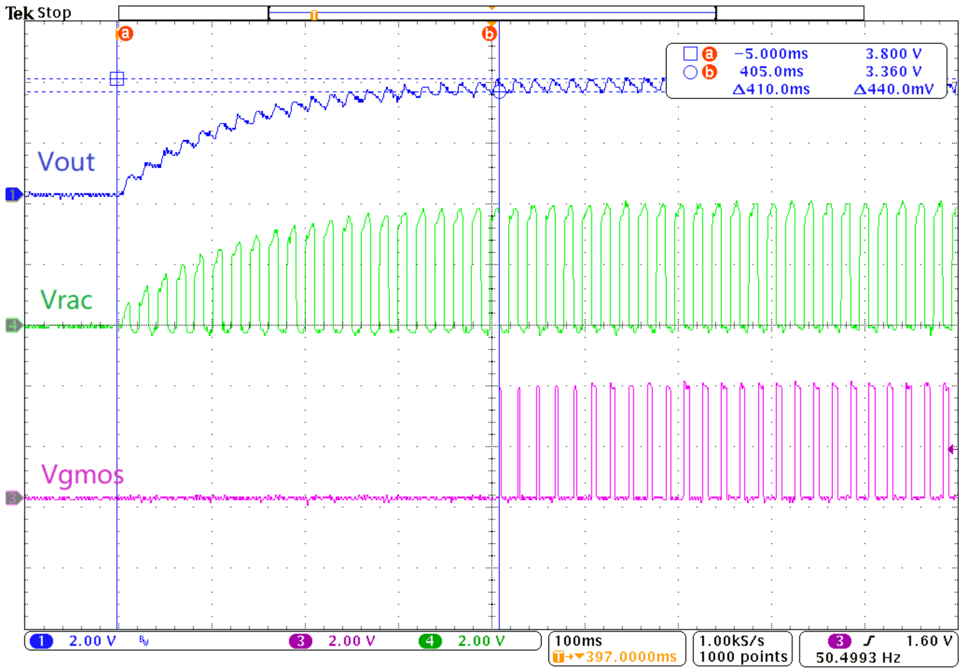

Figure 8: Waveforms of CCSS

Below in Table 1 are the input and output measurements. The input RMS power is calculated with an AC power meter and the output power is calculated by multiplying the output voltage by the squared value of the resistor. As stated previously, C_s is a 1uF capacitor with a DF of 40 x 10^{-4}.

Table 1: Input and Output Measurements

Input Voltage (RMS V)	Input Current (RMS mA)	Input Power (RMS mW)	Output Voltage (V)	Resistor (Ω)	Output Power (mW)
90	35.9	39	3.80	383	37.70
100	38.3	45	3.78	383	37.31
110	41.3	40	3.79	383	37.50
120	44.2	50	3.83	383	38.30
130	46.8	48	3.78	383	37.31
140	49.6	45	3.77	383	37.11
150	53.2	49	4.04	383	42.62
160	56.3	52	4.04	383	42.62
170	59.2	54	4.07	383	43.25
180	62.1	56	4.16	383	45.18
190	65.1	52	4.13	383	44.53
200	67.9	60	4.12	383	44.32
210	70.9	58	4.08	383	43.46
220	73.9	63	4.16	383	45.18
230	76.9	52	4.14	383	44.75
240	80.1	62	4.30	383	48.28

250	83.1	73	4.42	383	51.01
260	86.2	60	4.45	383	51.70

8 Conclusion

This CCSS converter provides a compact, low-cost inductorless alternative to a typical AC-DC converter system, which is ideal for low power applications. The GreenPAK has additional logic and GPIOs available which gives the flexibility to include additional functions to its switching control without buying another device. The switching circuit can be implemented in any GreenPAK with two ACMPs, so a different GreenPAK with the desired functionality could replace the SLG46110. For instance, an SLG46140 could be used instead to provide PWM control to an LED light.

Revision History

Revision	Date	Description
1.0	20-Oct-2019	Initial Version

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