Application Note

Design Considerations in TLV61290

Given Ding, Aurora Tie, Eric Jia

ABSTRACT

The TLV61290 is a synchronous boost converter that includes a bypass function. This operates from very low input voltages (the UVLO falling threshold is 2V) and delivers high efficiency. The device uses hysteretic current control combined with adaptive compensation to obtain better load transient performance. Because of this control architecture, the switching frequency varies with operating conditions. This application note explains the relationship between switching frequency and output voltage, analyzes how the output capacitor influences the ripple of output voltage, and describes the control logic of the active-discharge circuit. This provides valuable guidance for practical applications.

Table of Contents

Trademarks

All trademarks are the property of their respective owners.

1 TLV61290 Introduction

The TLV61290 is TI's newest-generation boost converter with an integrated bypass function, making it especially suitable for single-cell-battery-powered applications. When the battery voltage is higher than the desired output voltage (i.e., the input voltage exceeds the boost-mode target), the device can operate in bypass mode through an internal bypass FET. This not only improves efficiency but also extends battery life. Compared with traditional parts that provide a pass-through function (e.g., the TPS61253 series), the TLV61290 is more efficient because there is no inductor in the bypass path, and there is no need to consider the losses caused by inductor DC resistance (DCR).

TLV61290 employs a hysteretic current control mode combined with adaptive compensation techniques to achieve better load transient performance. The device supports an I^2C interface, allowing users to configure key parameters, such as output voltage, operating mode and current limit values, which significantly enhance ease of use. Furthermore, users can utilize the I^2C interface to configure the device to force entry into bypass mode under any input voltage condition.

A typical application circuit diagram is shown below. For more detailed design information, please refer to the TLV61290 datasheet.

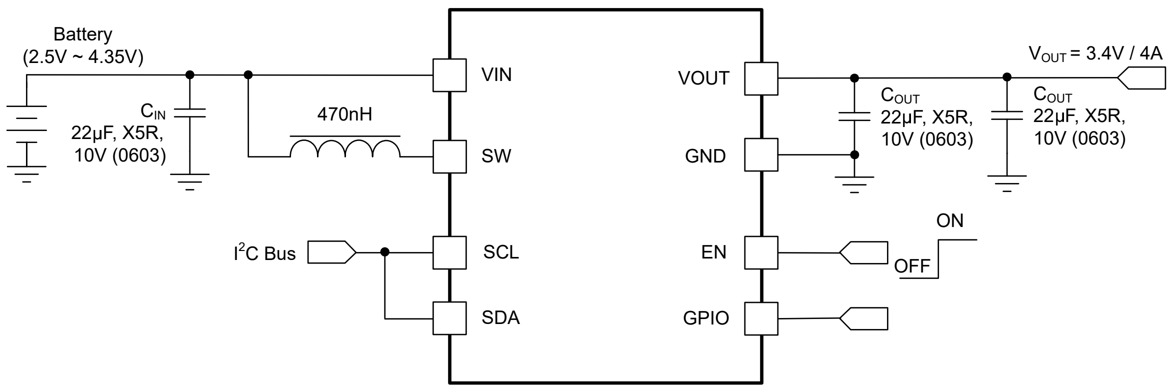

Figure 1-1. TLV61290 Typical Circuit

There are several points require attention:

1. Output capacitor selection

The effective capacitance of the output capacitor (Cout) must be greater than or equal to 14 µF. TLV61290EVM uses only two 22 µF MLCC capacitors for Cout. Because the chosen parts have a sufficiently high effective capacitance, the evaluation board meets the specification.

In practical applications, many customers choose capacitors with similar rated voltages, but their effective capacitance is far below the requirements. Therefore, when selecting components, the decision should be based on the actual effective capacitance rather than simply referring to the number of capacitors used on the evaluation board.

2. Inductor selection

Inductor selection for the TLV61290 requires extra care. The device employs hysteretic current control and does not use a fixed switching frequency. Additionally, its internal loop compensation is optimized for a specific range of inductance values. Therefore, the inductor must be chosen strictly according to the values recommended in the datasheet. The TLV61290 is designed for inductances between 330nH and 560nH (the typical value is 470nH).

2 TLV61290 Benefits

Compared to the widely used TPS6128x series, the TLV61290 has achieved significant improvements in many aspects. A detailed comparison table is shown in Table 2-1

Table 2-1. Comparison Table of TLV61290 and TPS6128x Series

	TLV61290	TPS6128x Series
Vin range	2~5V (Startup: 2.2V)	2.3~4.8V
Vout range	2.35~5V	2.85~4.4V
Current limit	8A (average input current)	4.5A (valley current)
Efficiency (Vin=2.7 V Vout=3.4 V Io=3A)	92.95%	90%
Iq_BYP	30μA	27μA
Rdson(HS/LS/Bypass)	10mΩ / 10mΩ / 10mΩ	45mΩ / 40mΩ / 35mΩ
Light load mode	FPWM/PFM/Ultrasonic mode	FPWM/PFM
True shutdown	√	× (It's related with nBYP pin status)
Load Transient (Vin=2.7 V Vout=3.4 V Io=0 to 3A SR=0.2A/μs) 2pcs 22μF/10V/0603 Cout	Vout_drop=288mV	Vout_drop=348mV
Short protection	√	×
Package	16-ball WCSP (1.58mm × 1.58mm)	16-ball WCSP (1.66mm × 1.66mm)
Inductor	0.47μH	0.47μH

Compared with the TPS6128x series, the TLV61290 accepts a wider input-voltage range, and its minimum input voltage after start-up is as low as 2 V. This range matches the requirements of silicon-anode batteries, which are now widely used in consumer-electronics products such as smartphones and tablets. The application of this type of battery is gradually expanding. Compared to conventional batteries, this new type of battery is capable of providing energy even at low voltages (approximately 2.5 V or lower). A boost converter is required to step the battery voltage up to the level needed by the downstream load. This fully leverages the advantages of silicon anode batteries and extends battery life. A typical application is shown in Figure 2-1.

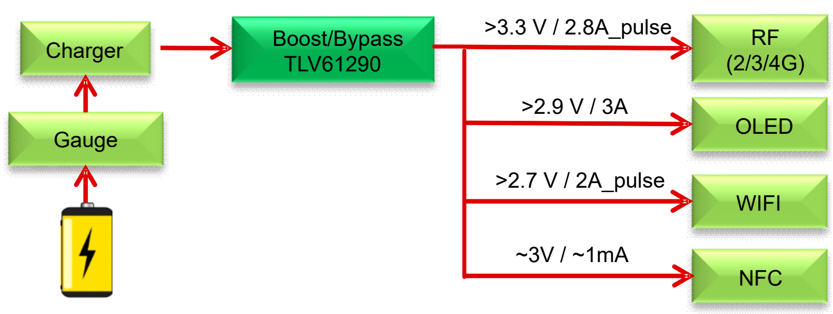

Figure 2-1. Typical Applications of Silicon Anode Battery

Because the TLV61290 employs a hysteresis current control scheme and adaptive compensation techniques, its load transient performance is significantly improved. For practical applications, the minimum operating voltage at TLV61290's output is fixed. If the device has better load transient performance, it can operate in bypass mode for longer periods. Compared to boost mode, TLV61290 has higher efficiency under bypass mode, which can reach approximately 99%. Therefore, this advantage can extend battery life by improving total efficiency.Figure 2-2 shows a specific example. Compared to the previous generation TPS61280x series, the TLV61290 can operate in bypass mode for a longer periods under the same conditions. (Test condition: Vin=2.7 V, Vout=3.4 V, Io=0 to 3A, slew rate=0.2A/μs)

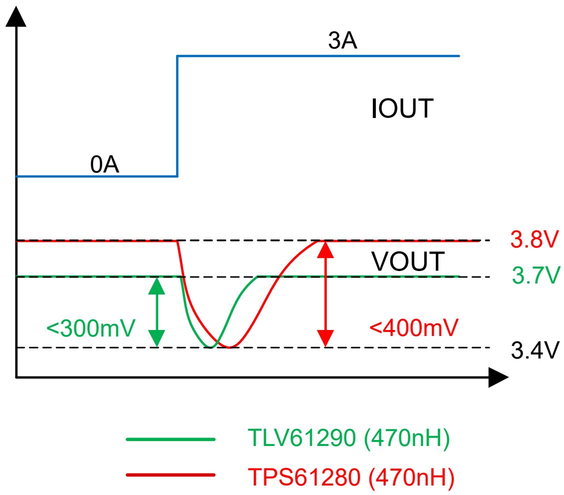

Figure 2-2. Examples of How Good Load Transient Response Extends Battery Life

In addition, the TLV61290 can achieve true disconnection, meaning that the input and output are completely isolated when the device is disabled. This characteristic is very important in applications where the system is sensitive to power consumption during device shutdown. In a conventional boost circuit, true disconnection generally cannot be achieved due to the presence of rectifier diodes or the body diode of the rectifier FET. However, the TLV61290 employs TI's proprietary "switchable-body-diode NMOS FET" to replace rectifier FET, which achieves true disconnection function. The specific diagrams are shown in Figure 2-3.

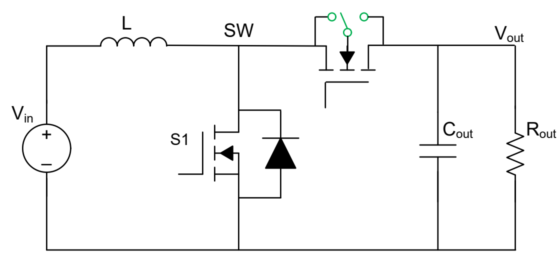

Figure 2-3. TLV61290 High Side FET (NMOS) with Switchable Body-Diode

When the output voltage is higher than the input voltage, the body diode orientation is as shown in Figure 2-4. Conversely, the body diode orientation is as shown in Figure 2-5.

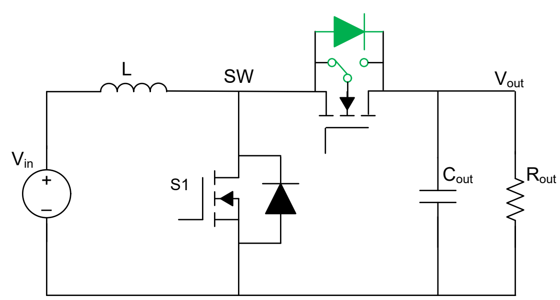

Figure 2-4. Operation Condition: Vout > Vin

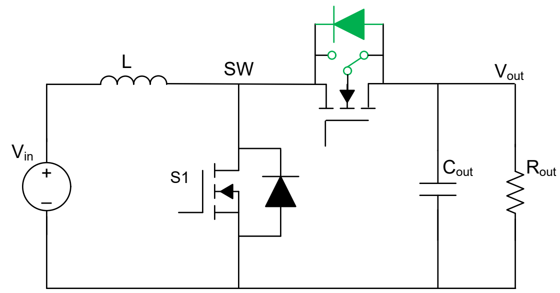

Figure 2-5. Operation Condition: Vout < Vin

3 TLV61290 Switching Frequency

The TLV61290 uses a hysteresis current control method. The following is the formula for calculating the switching frequency in continuous current mode (CCM).

$$f = \frac{V_{IN} \times (V_{OUT} - V_{IN} \times \eta)}{L \times I_{LH} \times V_{OUT}} \quad (1)$$

where

- L is the inductor value
- V_{IN} is the input voltage
- V_{OUT} is the output voltage
- η is the converting efficiency
- *f* is the switching frequency
- I_{LH} is the inductor ripple current

The inductor current ripple of the TLV61290 is dynamically adjusted according to changes in input voltage, output voltage, and load (typical value is 1A). Based on the formula above, the operating frequency of the TLV61290 is not a fixed value, and this helps improve load transient performance. However, variations in switching frequency may introduce performance challenges in practical implementations, particularly when powering certain RF devices.

Figure 3-1 shows an example. The customer's application requires 4.5V output and maximum load capacity of 2A. When the input voltage is 3.7V, as shown in the test waveform below, a spurious signal exceeding RF specifications appears at ~1.3 MHz. Based on Figure 3-2 from actual testing, it can be seen that under this condition, the switching frequency of the device matches the frequency of the parasitic signal. This results in noise generated by the switching frequency affecting RF performance, even when the spread spectrum function is enabled.

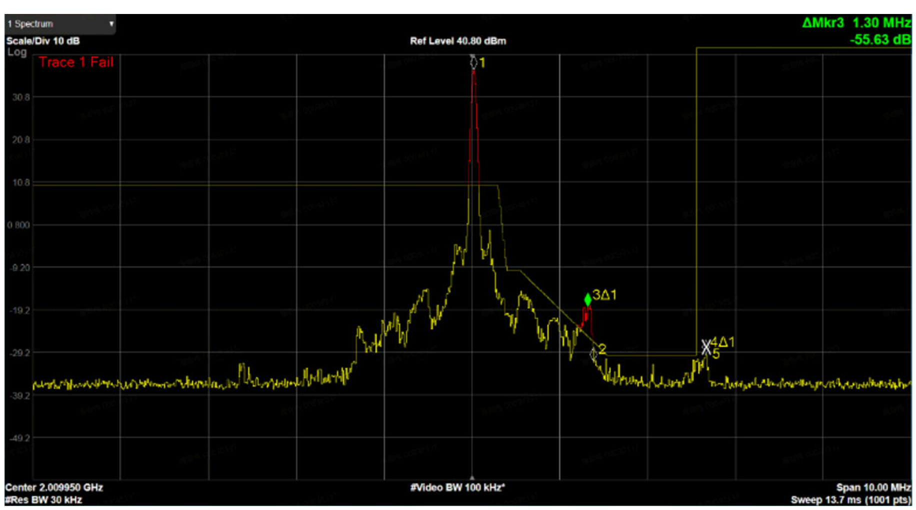

Figure 3-1. RF Test Result (TLV61290 as Power Supply for RF Device)

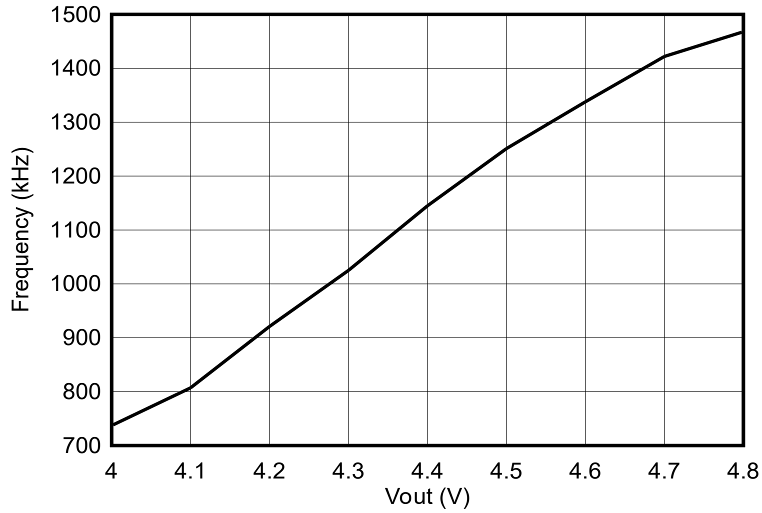

Figure 3-2. Curve of Switching Frequency vs. Output Voltage

In summary, there are two ways to solve this problem:

1. Adjust the output voltage to avoid specific frequency band.

As shown in Figure 3-2, the switching frequency of the TLV61290 varies with changes in the output voltage. For example, when the switching frequency is 1.1 MHz, the radio frequency (RF) specifications have a large margin. So Vout can be adjusted to a lower value (such as 4.4V) to optimize RF performance.

2. Increase the output capacitance.

The frequency of the output voltage ripple corresponds to the switching frequency. If the output voltage ripple can be reduced, the energy amplitude at the fundamental frequency can also be reduced, thereby optimizing RF performance. Based on actual test results in Table 3-1, using four pieces 22µF output capacitors is sufficient to pass the RF test. The output capacitor model used is GRM188R61A226ME15D.

Table 3-1. The Impact of Different Cout on Vout Ripple

Vin=3.7V, Vo=4.2V, Vo_ripple (test 40ms)		3pcs 22µF/10V/0603 Cout	4pcs 22µF/10V/0603 Cout	5pcs 22µF/10V/0603 Cout
PFM	Io=10mA	36.06mV	27.34mV	24.12mV
	Io=2.8A	41.42mV	32.19mV	27.11mV
FPWM without Spread Spectrum	Io=10mA	15.56mV	13.51mV	11.92mV
	Io=2.8A	47.54mV	37.89mV	30.27mV
FPWM with Spread Spectrum	Io=10mA	21.70mV	20.06mV	17.54mV
	Io=2.8A	52.88mV	41.23mV	36.35mV

4 Output Discharge Circuit

The TLV61290 has an active discharge function which is enabled by default. And the active discharge circuit will operate under the following conditions:

1. Vin < UVLO or EN = low;
2. RESET bit is 1;
3. DISCHG bit is 1 and ENABLE bit is modified to 11 to enter shutdown mode but I^{2}C active.

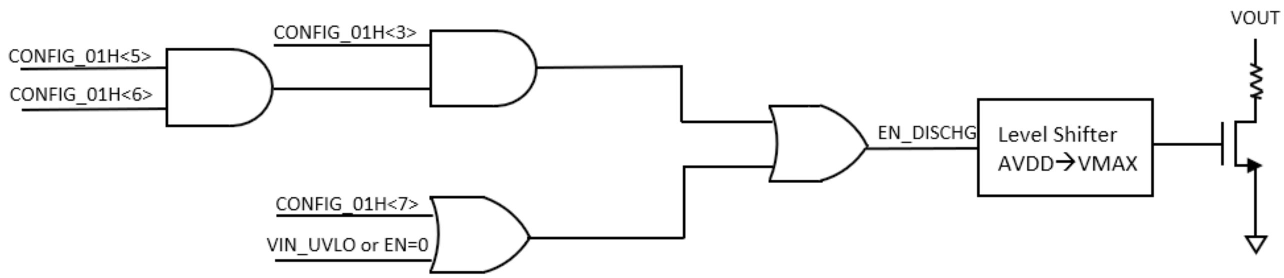

Figure 4-1. Control Logic of TLV61290 Discharge Circuit

Table 4-1. CONFIG Register Related Field Descriptions

Memory location: 0x01

Bit	Field	Type	Reset	Description
7	RESET	R/W	0	Device reset bit. 0: Normal operation. or line breaks 1: Default values are set to all internal registers. The device operation is cycled (ON-OFF-ON), that is, the converter is disabled for a short period of time and the output is reset.
6:5	ENABLE	R/W	01	Device enable bit. 00 or 01: Device operates in automatic boost mode. 10: Device forced in true bypass mode. 11: Device is in shutdown mode but I^{2}C active.
3	DISCHG	R/W	1	Output discharge enable bit. 0: Disable VOUT discharge when the device is in I^{2}C shutdown mode. 1: Enable VOUT discharge when the device is in shutdown mode.

In certain applications, it is sometimes necessary to disable the discharge function in shutdown mode. Based on the above conditions, the ENABLE bits of TLV61290 can be written to 11 via I^{2}C to let the device working into shutdown mode. At the same time, setting the DISCHG bit to 0 can disable the discharge function.

5 Summary

TLV61290 is a high power density boost with bypass mode and I2C interface. This application note not only describes the device's advantages and control method, but also clarifies several considerations for circuit design. It presents test results that serve as a useful reference for practical applications.

6 References

- Texas Instruments, *TLV61290 Wide-voltage Battery Front-End DC/DC Converter for Single-Cell Li-Ion, Ni-Rich, Si-Anode Applications*, datasheet.
- Texas Instruments, *TLV61290 EVM User's Guide*, EVM user's guide.