Application Report

A Topical Index of TI Low-Power Buck-Boost Converter Application Notes

Milos Acanski

ABSTRACT

This report presents a summary of application notes discussing buck-boost converter and its use. Each application note is presented with a short abstract, categorized by topic and identified by its title and unique TI literature number. The summary description of the article or report also contains a link to the Texas Instruments website (www.ti.com) where the full article can be accessed.

Table of Contents

Trademarks

All trademarks are the property of their respective owners.

1 Introduction

The purpose of this report is to provide a quick reference document for application designers and other users who are interested in TI buck-boost converters. Each application report discussed in this document is identified by its title and unique TI literature number. This list of application notes is categorized by topic, and is regularly maintained to ensure that the available information is up-to-date. To access the complete version of a given report, click the document literature number (Sxxxxxx). This tag provides a hyperlink to the document location on www.ti.com, where you can either read the document in its entirety or download it for personal use.

For questions not covered in this report, contact the TI E2E Community (Note that this link requires a secure log on.)

2 Summary Table

Fundamentals of Switching Converters	
Switching Regulator Fundamentals	SNVA559
Under the Hood of a Noninverting Buck-Boost Converter	SLUP346
Understanding Inverting Buck-Boost Power Stages in Switch Mode Power Supplies	SLVA059
Basic Calculations of a 4-Switch Buck-Boost Power Stage	SLVA535
Basic Calculation of an Inverting Buck-Boost Power Stage	SLVA721
Design Support	
Understanding the Absolute Maximum Ratings of the SW Node	SLVA494
I_Q: What It Is, What It Isn't, and How to Use It	SLYT412
Understanding Undervoltage Lockout in Power Devices	SLVA769
Extending the Soft Start Time Without a Soft Start Pin	SLVA307
Achieving a Clean Startup by Using a DC/DC Converter With a Precise Enable-Pin Threshold	SLYT730
Methods of Output-Voltage Adjustment for DC/DC Converters	SLYT777
Design Considerations for a Resistive Feedback Divider in a DC/DC Converter	SLYT469
Prevent Battery Overdischarge With Precise Threshold Enable Pin	SLVAE79
Precise Start-Up Delay Using Enable Pin with Precise Voltage Threshold	SLVAEA3
Choosing an Appropriate Pull-Up and Pull-Down Resistor for Open Drain Outputs	SLVA485
Optimizing Transient Response of Internally Compensated DC-DC Converters With Feedforward Capacitor	SLVA289
Improving Load Transient Response of DC/DC Converters Powering Controlled Loads	SLVAEE0
Extending Battery Life With Low Quiescent Current and Dynamic Voltage Scaling	SLVAER8
PCB Layout and Thermal Considerations	
QFN Layout Guidelines	SLOA122
PowerPAD™ Layout Guidelines	SLOA120
DSBGA Wafer Level Chip Scale Package	SNVA009
Five Steps to a Great PCB Layout for a Step-Down Converter	SLYT614
Five Steps to a Good PCB Layout of a Boost Converter	SLVA773
Semiconductor and IC Package Thermal Metrics	SPRA953
EMI Considerations	
EMI/RFI Board Design	SNLA016
Layout Tips for EMI Reduction in DC/DC Converters	SNVA638
Simple Success with Conducted EMI from DC/DC Converters	SNVA489
Minimizing Ringing at the Switch Node of a Boost Converter	SLVA255
Layer Design for Reducing Radiated EMI of DC to DC Buck-Boost Converters	SLVAEP5
Device Specific Technical Discussions	
High Efficiency Battery Powered High Brightness LED Driver Using the TPS63000	SLVA268
Supercapacitor Backup Power Supply With TPS63802	SLVAE52
Dynamically Adjustable Output Using TPS63000	SLVA251
How to Use VSEL Function of TPS63070	SLVAE62
Using Input Current Limiting to Extend Battery Life	SLVAES7
TPS63802HDKEVM - Hardware Development Kit	SLVUBU0
Measurement Techniques	
Accurately Measuring Efficiency of Ultralow-I_Q Devices	SLYT558
Performing Accurate PFM Mode Efficiency Measurements	SLVA236
How to Measure the Loop Transfer Function of Power Supplies	SNVA364
Simplifying Stability Checks	SLVA381
Techniques for Accurate PSRR Measurements	SLYT547
Buck-Boost Converter Applications	

Different Methods to Drive LEDs Using TPS63xxx Buck-Boost Converters	SLVA419
Low-Power TEC Driver	SLVA677
Buck-Boost Converters Solving Power Challenges in Optical Modules	SLVAEB2
Improve Efficiency in TWS and Hearing Aid Earbuds With a Buck-Boost Converter	SLVAED7
High-Efficiency Backup Power Supply	SLVA676
Smart Electricity Meter Supercapacitor Backup Power Supply With Current Limit	SLVAEI4
Using Non-Inverting Buck-Boost Converter for Voltage Stabilization	SLVAEA2

3 Fundamentals of Switching Regulators

This section lists several application notes that discuss fundamental operation of switching converters and present basic calculations for buck-boost converter.

Switching Regulator Fundamentals: SNVA559

This application report presents basics of commonly used converter topologies, including the inverting buck-boost. Some practical tips are shown, such as guidelines for PCB layout and measurements.

Under the Hood of a Noninverting Buck-Boost Converter: SLUP346

Various topologies used in non-inverting buck-boost designs are presents in this application report, with a focus on four-switch, non-inverting buck-boost converter. A practical design example illustrates a four-switch buck-boost application design including the PCB layout and the performance achievable with this topology.

Understanding Inverting Buck-Boost Power Stages in Switch Mode Power Supplies: SLVA059

This application report describes and analyzes the operation of the inverting buck-boost power stage. Two modes of operation, continuous conduction mode and discontinuous conduction mode, are examined, together with steady-state and small-signal analysis.

Basic Calculations of a 4-Switch Buck-Boost Power Stage: SLVA535

This application note provides equations to calculate the power stage of a non-inverting buck-boost converter with integrated switches, operating in continuous conduction mode. One practical design example is presented as well.

Basic Calculation of an Inverting Buck-Boost Power Stage: SLVA721

This application note provides basic formulas needed to design the power stage of a non-synchronous inverting buck-boost converter with integrated switches. It provides formulas and considerations for selecting external components and an estimation for the maximum output current.

4 Design Support

This section summarizes documents that help the application designer to understand the capabilities and limitations of buck-boost devices, apart from the basic topology calculations given in the previous section.

Understanding the Absolute Maximum Ratings of the SW Node: SLVA494

This application note explains the operation of a synchronous converter, demonstrates why the switch-node negative rating might be exceeded during switching operation, gives guidance for properly measuring the node voltage, and provides good PCB layout practices. The report discusses buck converter, but the same basic principles are also valid for buck-boost converter.

I_Q: What It Is, What It Isn't, and How to Use It: SLYT412

This article discusses one of the most misunderstood parameter, the quiescent current I_Q. The article shows how I_Q is defined and measured, and how I_Q translates to the no-load input current and the efficiency at light loads.

Understanding Undervoltage Lockout in Power Devices: SLVA769

Many integrated circuits include an undervoltage lockout (UVLO) function to disable the device at low supply voltages. Below the minimum supply voltage the function and performance of a device may be undefined, making it impossible to predict system behavior. This application note explains how to correctly understand the undervoltage lockout specification in the data sheets of TI's power products.

Extending the Soft Start Time Without a Soft Start Pin: SLVA307

In many applications, extending the soft start time can be crucial to a glitch-free start-up. This application report demonstrates a simple circuit that extends the soft start time and reduces the inrush current, taking a boost converter as an example. The same principle can be applied to buck-boost converters as long as the output voltage is set with a resistive feedback divider.

Achieving a Clean Startup by Using a DC/DC Converter With a Precise Enable-Pin Threshold: SLYT730

This article explains some common EN-pin threshold specifications found in device data sheets and describes several application circuits that provide a clean startup, with or without using a converter with a precise EN-pin threshold.

Methods of Output-Voltage Adjustment for DC/DC Converters: SLYT777

Changing the output voltage can optimize power delivery, reduce power consumption, or properly bias analog circuits. This article demonstrates three basic techniques to adjust the output voltage of a device that uses voltage feedback divider for setting the output voltage.

Design Considerations for a Resistive Feedback Divider in a DC/DC Converter: SLYT469

The resistive feedback divider is the most common network in any DC/DC converter's feedback system. However, it is often misjudged as a circuit that simply sets the output voltage by scaling it down to a reference voltage. This article discusses the design considerations for the resistive divider in a feedback system and how the divider affects a converter's efficiency, output voltage accuracy, noise sensitivity, and stability

Prevent Battery Overdischarge With Precise Threshold Enable Pin: SLVAE79

This application report shows how to set precise battery cut-off voltage in order to protect a battery from overdischarge, by using precise EN-pin thresholds.

Precise Start-Up Delay Using Enable Pin with Precise Voltage Threshold: SLVAEA3

This application report shows how to set precise start-up delay for devices that implement precise EN-pin thresholds.

Choosing an Appropriate Pull-Up and Pull-Down Resistor for Open Drain Outputs: SLVA485

Many TI buck-boost devices have open drain output pins to indicate proper operation. These outputs require the use of an external pull-up resistor to keep the digital output in a defined logic state. This application report discusses factors that should be considered when selecting a pull-up resistor, and how to calculate a valid range for the value of the resistor.

Optimizing Transient Response of Internally Compensated DC-DC Converters With Feedforward Capacitor: SLVA289

This application report describes how to choose the feedforward capacitor value of an internally compensated DC/DC converter to achieve optimum transient response. The described procedure provides guidance in optimizing transient response by increasing converter bandwidth while retaining acceptable phase margin.

Improving Load Transient Response of DC/DC Converters Powering Controlled Loads: SLVAEE0

This application report shows a way of improving the load transient response that can be used when other methods are not effective or possible. This method can be used for a DC/DC converter that supplies a controlled load and uses an external voltage feedback divider.

Extending Battery Life With Low Quiescent Current and Dynamic Voltage Scaling: SLVAER8

When designing a battery powered system, maximizing battery life is often one of the most important design goals. Selecting the right converter to obtain a fixed system voltage in such a case is often based on the quiescent current parameter I_Q. This application report shows that, besides having low quiescent current, the battery life can be further extended by dynamically scaling the output voltage.

5 PCB Layout and Thermal Considerations

Printed circuit board (PCB) layout and thermal management are crucial for reliable operation of switching converters. This section lists application notes discussing PCB design guidelines and PCB and IC package thermal considerations.

QFN Layout Guidelines: SLOA122

Layout and stencil information for TI Quad Flat No-Lead (QFN) devices is provided in their data sheets. This document helps PCB designers to understand and better use this information for optimal designs.

PowerPAD™ Layout Guidelines: SLOA120

This application report focuses on helping PCB designers to understand and better use board layout and stencil information for Texas Instruments PowerPAD™ devices.

DSBGA Wafer Level Chip Scale Package: SNVA009

This application note provides information on handling, assembly, and usage of the die-sized ball grid array (DSBGA) wafer chip scale package (WCSP), common for many TI buck-boost devices.

Five Steps to a Great PCB Layout for a Step-Down Converter: SLYT614

Five Steps to a Good PCB Layout of a Boost Converter: SLVA773

A good PCB layout is critical for switching converters. These application notes present five simple steps to ensure that the converter's PCB layout is robust and ready for prototyping. The reports refer to buck and boost converters, however the same principles are also valid for buck-boost converters.

Semiconductor and IC Package Thermal Metrics: SPRA953

Many thermal metrics for IC packages can be found in the device data sheets, such as $R_{\theta JA}$ or Ψ_{JT}. These thermal metrics are often misused when trying to use them to estimate junction temperatures in a system. This document describes traditional and new thermal metrics and puts their application in perspective with respect to system-level junction temperature estimation.

6 EMI Considerations

In switching power supplies, electromagnetic interference (EMI) noise is unavoidable due to the switching actions of the semiconductor devices and resulting discontinuous currents. This section defines and discusses electromagnetic interference and describes ways to mitigate its effects.

EMI/RFI Board Design: SNLA016

This application report introduces EMI and describes how it relates to the performance of a system. Examples of inter-system and intra-system noise and present techniques that can be used to ensure EMI compatibility throughout a system and between systems are shown.

Layout Tips for EMI Reduction in DC/DC Converters: SNVA638

This application note explores how the layout of a DC/DC power supply can significantly affect the amount of EMI that it produces. It discusses several variations of a layout, analyzes the results, and provides answers to some common EMI questions such as whether or not to use a shielded inductor.

Simple Success with Conducted EMI from DC/DC Converters: SNVA489

Conducted and radiated EMI arise from the normal operation of switching circuits, and EMI control is one of the main challenges in SMPS design. This application report focuses on the theory and mitigation techniques of the conducted portion of EMI.

Minimizing Ringing at the Switch Node of a Boost Converter: SLVA255

This application report explains how to use proper board layout and/or a snubber network to reduce high-frequency ringing at the switch of a boost converter. The same principle applies to buck-boost converters.

Layer Design for Reducing Radiated EMI of DC to DC Buck-Boost Converters: SLVAEP5

This application note gives guidelines for improving EMI performance for PCB design of TPS63xxx devices. The main radiation sources for non-inverting buck-boost converters are briefly explained. Three different solutions are proposed and their effectiveness is validated by anechoic chamber measurements.

7 Device-Specific Technical Discussions

In this section, some application examples with specific buck-boost devices are presented.

High Efficiency Battery Powered High Brightness LED Driver Using the TPS63000: SLVA268

This application report show how to use the TPS6300x to drive a high-brightness LED with constant current, using 1-cell Li-Ion/Li-Polymer battery or 2-/3-cell Alkaline/NiCd or NiMH batteries as the power supply.

Supercapacitor Backup Power Supply With TPS63802: SLVAE52

In this application, the TPS63802 is used to charge the backup capacitor while the main power supply is available. When the main power fails, the TPS63802 automatically supplies the system with the stored energy out of the backup capacitor. The report describes the feasibility of a backup power supply implementation with the TPS63802.

Dynamically Adjustable Output Using TPS63000: SLVA251

This application report provides a schematic and design procedure for implementing a dynamically adjustable output voltage for the TPS63000 buck-boost converter using a digital-to-analog converter or other voltage source.

How to Use VSEL Function of TPS63070: SLVAE62

Changing the output voltage of a DC/DC converter during operation can be a useful feature in battery operated applications to increase the battery lifetime. This report shows how to use the TPS63070 dynamic voltage scaling feature via VSEL pin in order to dynamically change the output voltage between two user-configurable levels.

Using Input Current Limiting to Extend Battery Life: SLVAES7

If a converter overloads the supply battery, either due to heavy load or due to inrush current during start-up, the capacity and lifetime of the battery can be significantly reduced. This application report shows how the input current limit feature of the TPS63900 can effectively limit the input current with several preset limit values, down to 1 mA, making it an ideal match for low-current coin cell batteries.

TPS63802HDKEVM - Hardware Development Kit: SLVUBU0

In this report, a universal development tool designed to help easily and quickly evaluate and test the most common buck-boost converter use cases is presented. The use cases include backup power, input current limit, LED driver, digital voltage scaling, bypass mode, and precise enable. Different use cases can be easily selected by changing jumpers and dip-switches, without any soldering.

8 Measurement Techniques

This section presents an overview of techniques to perform accurate measurements of the performance of buck-boost converters.

Accurately Measuring Efficiency of Ultralow-I_Q Devices: SLYT558

Performing Accurate PFM Mode Efficiency Measurements: SLVA236

There are important considerations when measuring the efficiency of a low-I_Q device when operating in PFM mode. These reports review the basics of measuring efficiency, discuss common mistakes in measuring the light-load efficiency of ultralow-I_Q devices, and demonstrate how to overcome them in order to get accurate efficiency measurements.

How to Measure the Loop Transfer Function of Power Supplies: SNVA364

This application report shows how to measure the critical points of a bode plot with a signal generator and an oscilloscope. The method is explained in an easy to follow step-by-step manner so that a power supply designer can start performing these measurements in a short amount of time.

Simplifying Stability Checks: SLVA381

This application report explains a method for verifying relative stability of a circuit by showing the relationship between phase margin in an AC loop response and ringing in a load-step response. This allows for a simple stability check without the need to perform loop gain measurements.

Techniques for Accurate PSRR Measurements: SLYT547

Although PSRR measurement of a converter is simple in concept, the setup is of great significance in achieving an accurate result. This article explores commonly encountered setup issues that limit PSRR measurement and offers a method to overcome them using high-fidelity signal injectors and a highly sensitive/selective vector network analyzer.

9 Buck-Boost Converter Applications

This section presents guidelines for specific applications involving buck-boost converters.

Different Methods to Drive LEDs Using TPS63xxx Buck-Boost Converters: SLVA419

This application note shows different methods to drive LEDs using buck-boost converters from the TPS63xxx converter family. The presented methods are compared in terms of different design aspects, such as complexity, cost and solution size. The same basic principles can also be be applied to other devices or topologies.

Low-Power TEC Driver: SLVA677

The ability of the non-inverting buck-boost converter to increase or decrease voltage can be used to control the current flow through a Peltier element. This application report explains how the buck-boost converter can be used to drive the Peltier element in order to implement active thermoelectric cooling or heating.

Buck-Boost Converters Solving Power Challenges in Optical Modules: SLVAEB2

This application note gives a short introduction to optical modules and the need for an optimized power tree in them. The use cases and benefits of four-switch and inverting buck-boost converters inside optical modules are discussed.

Improve Efficiency in TWS and Hearing Aid Earbuds With a Buck-Boost Converter: SLVAED7

To improve efficiency when charging one battery from another, a buck-boost converter can be used to track the voltage of the charged battery. By keeping the voltage headroom of the linear charger to the minimum, the charging efficiency can be significantly improved. This report shows the advantages of using buck-boost converter in true wireless stereo (TWS) headphones.

High-Efficiency Backup Power Supply: SLVA676

This application report describes a circuit which addresses instantaneous protection of main power interruptions by using a buck-boost converter and a backup capacitor. It also provides the design, schematic, key components, and measurement results showing the performance of the circuit.

Smart Electricity Meter Supercapacitor Backup Power Supply With Current Limit: SLVAEI4

A simple and low-cost design of a backup power supply for smart electricity meters using buck-boost converter is presented in this application report. The design provides output current of up to 2 A for meter's high-power RF communications, and an adjustable charge limit to reduce system heating concerns.

Using Non-Inverting Buck-Boost Converter for Voltage Stabilization: SLVAEA2

Having a stable and accurate voltage supply is crucial for proper operation of electronic devices. This application note presents the buck-boost converter as a voltage stabilizer, and discusses several parameters that have to be taken into account when selecting the right device for voltage stabilization.

10 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision * (May 2020) to Revision A (June 2021)	Page
• Updated the numbering format for tables, figures and cross-references throughout the document	1