Application Report
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A Topical Index of TI LDO Application Notes

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ABSTRACT

This document summarizes a collection of application notes from Texas Instruments that discuss low-dropout (LDO) regulators. This report provides a short abstract of each application note and categorizes the series of documents by topic. These application notes are arranged in such an order that less experienced readers can work through these documents from beginning to end without the need to go back and forth.

Each application report reviewed in this document is identified by title and a unique TI literature number. The summary description of the article or report also contains a link to the Texas Instruments web site (www.ti.com). Unless otherwise noted, all materials summarized in this document can be downloaded from www.ti.com.

Contents

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 low-dropout regulators. Each TI application report discussed in this document is identified by title and by a unique TI literature number, as shown in Example 1. If you wish to access a complete version of a given report, click on the document literature number (SBxx### or SLxx###). 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.

Example 1. Sample Entry

Thermal Parameters and Metrics

Using New Thermal Metrics: SBVA025.

This report discusses the practical application of two new thermal metrics, Ψ_{JT} and Ψ_{JB}, to estimate silicon junction temperature using an illustrated analogy of Ohm's law. Additionally, this application report explains why traditional thermal parameters (such as θ_{JA} or θ_{JC}) are not recommended for determining the actual thermal performance of many linear power-management devices.

For assistance with LDO product selection, refer to the LDO Quick Reference Selection tool, also available on www.ti.com.

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This report is divided into these topical areas:

- Basic Overview of LDO Architecture
- Technical Reviews of LDO Performance
- Recent LDO Technology Trends
- Real-World LDO Applications
- TPS75005-Specific Notes
- Older-Generation PMOS LDOs and ESR

If you have an application question, contact the Linear Regulator Forum on the TI E2E Community. (Note that this link requires a secure log-in.)

2 Basic Overview of LDO Architecture

This section reviews several application notes that explain the architecture of LDOs or present a general discussion of LDO technology.

Terms and Definitions for LDOs

Understanding the Terms and Definitions of LDO Voltage Regulators: SLVA079.

This document is a good starting point to learn about LDO devices. Even though it is somewhat dated, it clearly describes key terminologies related to LDOs using a good range of examples. This note makes a good foundation from which to read the other application notes introduced in this document. One important point to note is that contemporary device vendors (including Texas Instruments) use both PMOS and NMOS as pass elements between IN and OUT on a case-by-case basis, although this note only refers to PMOS elements.

LDO Technical Textbook

Technical Review of Low-Dropout Voltage Regulator Operation and Performance: SLVA072.

This document can be seen as an LDO textbook when coupled with *Understanding the Terms and Definitions of LDO Voltage Regulators* (SLVA079). This note is somewhat dated as well. After reading this document, it is recommended to review the reports listed in Section 3.

The textbook contains a series of application reports that explain the specific performance characteristics and parameters of LDOs.

Linear and Switching Voltage Regulator Fundamental Part 1: SNVA558 is also a textbook-style document that explains the basics of linear regulators.

Fundamental Theory of P-Type Pass FET LDOs

Fundamental Theory of PMOS Low-Dropout Voltage Regulators: SLVA068.

This document explains how the PMOS-pass FET functions with LDO devices. Although this note focuses on PMOS LDOs, it helps readers understand NMOS LDOs as well.

Control-Loop Theory Behind LDO Operation

Application Note 1148 Linear Regulators: Theory of Operation and Compensation: SNVA020A and *Application Note 1482 LDO Regulator Stability Using Ceramic Output Capacitors*: SNVA167.

These documents explain the control theory behind LDO operation in detail but in an easy-to-understand way.

3 Technical Review of LDO Performance

This section provides a summary of application notes that explain specific LDO performance parameters.

Low Dropout

Understanding Low Drop Out (LDO) Regulators: SLUP239.

This report explains the differences between series regulators and LDOs. It also discusses typical concerns about low dropout operation.

Dropout Voltage

Understanding LDO Dropout: SLVA207.

This document explains how to use the dropout specifications for a given LDO device to align with a customer's specific application requirements.

Noise From LDO

Understanding Noise in Linear Regulators: SLYT201.

This article explains the types of noise generated from an LDO device itself, and discusses the major noise sources within a device. Note that the total amount of noise on the output of an LDO device is the sum of noise from the LDO and any noise coming from the LDO input voltage. This article only discusses internal LDO noise. As for output noise coming from the input voltage, we must look at PSRR, and consider the LDO as a noise filter from IN to OUT.

Minimizing LDO Noise

LDO Noise Examined in Detail: SLYT489 in the *4Q 2012 Issue Analog Applications Journal*: SLYT486.

This article explains how to reduce LDO noise from the viewpoint of a practical application circuit. The conclusion states each LDO device has a unique minimum noise level for each device after optimizing its application circuitry.

Power-Supply Ripple Rejection (PSRR)

Understanding Power-Supply Ripple Rejection in Linear Regulators: SLYT202.

This report explains the performance parameter, PSRR, as a reasonable measure of the ability of an LDO to work as a noise filter.

External Resistor Tolerances on Output Voltage Accuracy

Effect of Resistor Tolerances on Power Supply Accuracy: SLVA423.

This report examines how external resistor tolerances affect the accuracy of output voltage from regulator devices.

Basic Thermal Management

Digital Designer's Guide to Linear Voltage Regulators and Thermal Management: SLVA118.

This document explains the basic principles of thermal management in a step-by-step manner with many examples; it presents the information in a *…for Dummies*-style approach. After reading this document, it is recommended to follow up with *Using New Thermal Metrics*, SBVA025.

Thermal Parameters and Metrics

Using New Thermal Metrics: SBVA025.

This report discusses the practical application of two new thermal metrics, Ψ_{JT} and Ψ_{JB}, to estimate silicon junction temperature using an illustrated analogy of Ohm's law. Additionally, this application report explains why traditional thermal parameters (such as θ_{JA} or θ_{JC}) are not recommended for determining the actual thermal performance of many linear power-management devices.

Package Selection, Power Loss, and Thermal Parameters

Packaging Limits Range of Linear Regulators: SBVA027.

This application note explains the importance of package selection in terms of the package capability to handle heat (power dissipation) correctly. This note cautions users to avoid simply selecting the smallest package option without calculating power loss.

LDO Performance Near Dropout

LDO Performance Near Dropout: SBVA029.

This application note explains how the performance of a PMOS LDO regulator changes when the input-to-output voltage decreases to approach the dropout voltage.

Pros and Cons of Using a Feedforward Capacitor

Pros and Cons of Using a Feed-Forward Capacitor with a Low Dropout Regulator: SBVA042.

In LDO applications, a feed-forward capacitor (C_{FF}) improves the stability, output noise, load transient response, and power-supply rejection ratio (PSRR) of the LDO. These advantages justify using C_{FF} in most applications; however, there are several issues that must be addressed. This document discusses these necessary considerations.

4 Recent LDO Technology Trends

This section reviews several application notes that address recent technologies used in TI LDO devices.

Very High PSRR and Very Low-Noise LDO Device

Get Low-Noise, Low-Ripple, High-PSRR Power with the TPS717xx: SLYT280.

This report introduces the TPS717xx, one of the highest-performance LDOs from TI. It also describes how the TPS717xx device can offer high PSRR and low noise.

Very High-Efficiency (Ultralow Dropout) LDO Device

A 3-A, 1.2-V_{OUT} Linear Regulator with 80% Efficiency and P_{LOST} < 1 W: SLYT254.

This document introduces the TPS742xx, TPS743xx, and TPS744xx series of devices: ultralow dropout LDOs for applications with over 1-A output current. It describes the device family features as a higher output current LDO.

Sophisticated LDO Current Limit

Inrush Current Limit in the TPS720xx: SBVA021.

This application note discusses a new implementation of the current-limit function, which gives constant power-up time depending only on the output capacitor value, regardless of the load current connected during the device ramp-up.

Dual-Output Voltage-Selection (Dynamic Voltage Scaling) LDO

Saving Valuable Board Space with Dynamic Voltage Scaling in Portable Devices: SBVA020.

This article introduces a function that allows two preset output voltages to be switched by one logic input. This feature is very valuable when using supply processors that require two voltages: one for a normal or active state, and the second for a sleep state. Compared with traditional methods to achieve this type of configuration using external components, this dynamic voltage-scaling function saves both board space and overall component cost.

Output Capacitor-Free LDO Devices

DMOS Delivers Dramatic Performance Gains to LDO Regulators: SBVY001.

This document describes the history and details of output capacitor-free LDO devices, such as the REG101, REG102, REG103, TPS731, TPS736, and TPS742xx, TPS743xx, and TPS744xx series. Even though this document is not a recent publication, and refers primarily to the REG10x series, it offers an excellent explanation of how a capacitor-free LDO operates.

Application Note 1824 FlexCap Technology Simplifies LDO Design: SNVA337 also covers the same subject.

Integrated LDO Soft-Start

Taming Linear-Regulator Inrush Currents: SLYT332.

This report compares the process of inrush current control by using external components and an integrated circuit. It also illustrates the benefit of an integrated soft-start function.

Application Note 1815 LDOs Ease the Stress of Start-Up: SNVA333 also covers the same subject.

LDO Voltage-Tracking Function

Simultaneous Power-Down Sequencing with the TPS74x01 Family of Linear Regulators: SLYT281.

This document introduces a voltage-tracking function of the TPS74301 device. With this tracking feature, a device power-down sequence can be achieved very easily.

Very-Accurate LDO Regulation

Achieving Ultimate Regulation with Fixed Output Voltage Versions of TPS742xx/TPS743xx/TPS744xx: SBVA024.

This note introduces the possibility of a very accurate output voltage solution using a fixed-voltage version of the TPS742xx, TPS743xx, and TPS744xx series of LDOs.

LDO Supplies Low-Noise Power to the Clock Oscillator

Supply Noise Effect on Oscillator Phase Noise: SLWA066.

This note discusses the low-noise power rail for RF clock devices and concludes that a low-noise LDO (such as the TPS742xx) is preferable for the application.

LDO PSRR and Noise in RF Applications

LDO Noise Demystified: SLAA412.

This note discusses the difference of two important LDO parameters: noise and PSRR. These are important parameters for RF applications and are commonly confused.

LDO Supplies High-Speed Devices in Communication Systems (Magazine Article)

Gregory Waterfall, Masashi Nogawa, and Dheepan Sundaram, Power supply challenges in data and voice communication systems, ECN, Apr 19, 2012.

This article discusses LDO power cleanliness and performance of downstream, high-speed devices.

LDO with Wide-Bandwidth PSRR (Magazine Article)

Nogawa, Masashi and Van Renterghem, Kyle, *"Wide Bandwidth PSRR of LDOs"*, Bodo's Power Systems, pp. 46-49, Mar 2011 issue.

This article discusses PSRR bandwidth and real-world ripple rejection of switching regulator noise.

LDO Operation Without Enough Headroom (Magazine Article)

Stokes, William, "What Gives at Dropout? Low dropout regulator performance near dropout", ECN, Dec 15, 2010.

This article discusses LDO performance without enough headroom.

A Pair of High-Voltage, Low-Noise, Positive and Negative LDO (Magazine Article)

Hunter, Pat, "Designing an ultra-low-noise supply for analog circuits", Electronic Products, Mar 1, 2011.

This article introduces a pair of high-voltage positive and negative LDOs (TPS7A4901 and TPS7A3001).

5 Real-World LDO Applications

This section reviews several application notes that present *how-to* subjects.

How to Measure PSRR

LDO PSRR Measurement Simplified: SLAA414.

This document explains how to measure PSRR in different ways. It also presents a working measurement circuit example.

How to Check Feedback Loop Stability

Simplifying Stability Checks: SLVA381.

This report explains how to check feedback loop stability on a target application board.

Even though a thorough way to check the loop stability is to use a frequency-response analyzer, this approach involves a lot of difficulty for engineers who wish to check stability quickly. A frequency-response analyzer is not always common equipment in many labs, and is also fairly expensive. The frequency-response analyzer method must open the feedback loop by cutting the printed circuit board (PCB) pattern; these loops are unable to be cut with some recent high-performance LDO devices because these devices have multiple loops within the device. Furthermore, this loop-cutting procedure may also affect the actual working conditions on an application board.

The techniques discussed in this note enable loop stability to be checked with common lab equipment. The loop can be checked in normal operating conditions on the unmodified PCB. This technique is also based on a firm academic theory, and it is not just an experimental rule.

How to Extend LDO Input Voltage

Extending the Input Voltage Range of an LDO Regulator: SLVA119.

This article explains how to use an LDO with an input voltage that exceeds the device specifications. This technique is helpful for using a preferred or performance LDO in a wider range of application conditions.

How to Expand LDO Output Voltage Under Its Reference

Regulating V_{OUT} Below 1.2 V Using an External Reference: SLVA216, *High-Current LDO Linear Regulators (UCCx81-ADJ, UCx82-ADJ, UCCx83-ADJ, UCx85-ADJ)*: SLUA256, and *Low Power 150-mA LDO Linear Regulators. Extended Output Voltage Adjustment Range*: SLVA071.

These three documents explain how to use an LDO that supplies an output voltage lower than its reference voltage by tweaking the feedback circuitry with external components.

How to Expand LDO Output Current by Parallel (Load Sharing) Operation

Ballast Resistors Allow Load Sharing Between Two Parallel DC/DC Converters: SLVA250.

This report explains how to use multiple regulators in parallel to achieve greater output current. Despite the title, this document is fully relevant to LDOs.

How to Expand LDO Output Current by External PNP

External PNP Transistor Boosts TPS71501 Output Current: SBVA015.

This document explains how to expand the LDO output current by connecting a PNP under the control of the primary LDO device.

Application Brief 11 High-Efficiency Regulator has Low Drop-Out Voltage: SNOA587A also covers the same subject.

How to Make an LDO Soft-Start

Soft-Start Circuits for LDO Linear Regulators: SLYT096 and *Monotonic, Inrush Current Limited Start-Up for Linear Regulators*: SLVA156.

These two documents explain how to achieve the soft-start function of an LDO output with the configuration of external components. Even though there are some LDO devices with an integrated soft-start function, the range of available devices does not cover all possible applications. This technique is useful for adding a soft-start function to the closest device for a given application.

How to Use a Ceramic Capacitor for Tantalum-Only LDOs

Ceramic Capacitors Replace Tantalum Capacitors in LDOs: SLVA214A.

This note explains how to use a ceramic capacitor at the output of an LDO that requires tantalum or electrolytic capacitors.

How to Estimate LDO Junction-to-Ambient Thermal Resistance

Measuring the Thermal Impedance of LDOs in Situ: SLVA422.

This note explains how to estimate $R_{\theta JA}$ from the thermal shutdown function of LDO devices.

Using ANY-OUT™ LDO as I^2C controlled power solution

ANY-OUT™ LDO Controlled by I 2 C™ IO Expander Device: SBVA035.

This note shows the demo of an ANY-OUT LDO working as I^2C power with I^2C IO expander device.

How to Use Power Solutions to Extend MSP430 Application Battery Life

Using Power Solutions to Extend Battery Life in MSP430 Applications: SLYT356.

This report shows two simple but effective power solutions that further minimize MSP430 power consumption and extend battery life.

How to Pick a Linear Regulator for Noise-Sensitive Applications

How to Pick a Linear Regulator for Noise-Sensitive Applications: SLYT504.

Noise-sensitive applications require a power supply that generates low internal noise and rejects noise from the power source. This document addresses criteria and parameters to consider in designing such a power solution, including important specifications for picking a linear regulator.

6 C2000™ Power Solution, TPS75005-Specific Notes

Combined LDO Accuracy and Its Voltage Monitor

TPS75005 Advanced Information: LDO+SVS Combined Accuracy: SBVA032.

This note explains the benefit of combined LDO accuracy and supply voltage supervisor (SVS) to meet TI's C2000 controller power requirements.

TPS75005 State Machine

TPS75005 Advanced Information: Sequencer and State Machine: SBVA031.

This note explains the TPS75005 state machine details to understand device behavior.

TPS75005 Spike Noise Handling

TPS75005 Advanced Information: Voltage Monitor Sensitivity for Noise: SBVA033.

This note explains how the TPS75005 treats spike noise caused by logic circuitry, thus avoiding unneeded resets of C2000 controllers.

TPS75005 Quick-Start Guide

TPS75005 Quick-Start Guide with C2000™ Controllers: SBVA030.

This note explains how to connect the TPS75005 to C2000 controllers.

7 Older-Generation PMOS LDOs and ESR

This section suggests several older application notes for PMOS LDOs that discuss equivalent series resistance (ESR) issues. With recent LDO devices, these application notes are not required, but this knowledge is quite applicable when working with older legacy boards.

PMOS LDOs and Output Capacitor ESR

Stability Analysis of Low-Dropout Linear Regulators with a PMOS Pass Element: SLYT194; *Understanding the Stable Range of Equivalent Series Resistance of an LDO Regulator*: SLYT187; and *ESR, Stability, and the LDO Regulator*: SLVA115.

These documents explain PMOS LDO stability in regard to the ESR of its output capacitor.

(10 Years Ago) Advantage of PMOS LDOs Over Bipolar LDOs

Advantage of Using PMOS-type Low-Dropout Linear Regulators in Battery Applications: SLYT161.

This document explains why PMOS LDOs are widely used in battery-operated applications. 10 years ago, long battery-life cell phones began to boom, and every phone maker used multi-channel integrated PMOS LDOs inside. This document discusses the reasons for such extensive use of PMOS LDOs.

ESR, Load Transient, and PMOS LDOs

Understanding the Load-Transient Response of LDOs: SLYT151.

This *Analog Applications Journal* article explains the relationship between ESR and the transient response on PMOS LDO devices. An old tantalum capacitor-required, PMOS LDO has difficulty achieving good transient response because of ESR. This document describes how to choose an appropriate output capacitor.

Revision History

Changes from D Revision (October 2012) to E Revision **Page**

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

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