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.

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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.

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: SNVA020 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.

LDO Basics

LDO Basics: SLYY151

This document provides a comprehensive overview of the basic knowledge needed for LDO operation. These chapters short, to the point, and easy to digest.

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.

Board Layout and LDO Thermal Performance

An Empirical Analysis of the Impact of Board Layout on LDO Thermal Performance: SLVAE85

This application report investigates the impact of the printed circuit board (PCB) layout on LDO regulators thermal performance, specifically the junction-to-ambient thermal resistance, θ_{JA}. This parameter is measured for the TPS745 (WSON package), TPS7B82-Q1 (TO-252 package), and TLV755P (SOT-23 package) devices.

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, 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).

Dual Bipolar Power-Supply Considerations for Amplifiers

Dual Bipolar Power-Supply Considerations for Amplifiers: SBVA049

Dual bipolar power supplies are paired with amplifiers to widen their input and output ranges. Additionally well-designed, dual-power supplies like the TPS7A39 can also prevent power supply noise from adversely affecting conditioned signals. This document covers these benefits and other considerations regarding bipolar supplies.

Fundamentals of Designing LDOs in Automated Industrial Systems

Linear Power for automated industrial systems: SLYY067

Designing a robust power management system for industrial automated equipment requires thorough understanding of the surroundings and conditions that affect the functionality. This document introduces the various challenges that designers need to track in order to refresh their designs.

Fundamentals of Designing LDOs in Automotive Battery Direct Connect Applications

Fundamentals of designing with LDOs in automotive battery direct connect applications: SLYB232

In the automotive world, an LDO offers good voltage ripple suppression and electromagnetic compatibility (EMC) performance. During operation, the LDO powers the target load through a printed circuit (PCB) trace in an on-board system or through a cable in an off-board system. For off-board systems, the LDO must protect itself from different kinds of potential cable failures. This document describes various LDO specifications in the context of automotive applications, with a key focus on battery-direct-connection and driving an off-board load system.

Automotive Off-Board Sensor Power Considerations

Automotive Off-Board Sensor Power Considerations: SBVA050

This article describes the various challenges when designing power supplies for off-board sensors in automobiles.

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: SLVA214

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 I²C 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 I²C power with I²C 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.

How to Use an LDO as a Load Switch

Use of an LDO as a Load Switch for Space Applications: SLVA894

This application note highlights the similarities and differences of function and architecture between load switches and low-dropout (LDO) regulators.

How to Power a Dual-supply Op Amp with One LDO

Power a Dual-supply Op Amp with One LDO: SBAA252

This design shows a power supply that can be used to create a positive operational amplifier (op amp) supply and a small negative op amp supply. This small negative voltage is adjustable and is necessary in many operation amplifiers in order to ensure linearity down to ground. This design shows the TPS7A39 as the power supply for creating the positive and negative voltage rails for the operational amplifier circuits.

How to Use Voltage-tracking LDO for Various Applications

Various Applications for Voltage-Tracking LDO: SLVA789

Voltage-tracking LDOs are widely used in automotive off-board sensors and small current off-board modules for its off-board protection and high voltage-tracking accuracy advantages. This application note describes in detail the various applications for voltage-tracking LDOs in different electronic systems.

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

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