Application Note

Collection of DC/DC Buck Regulator Technical Documentation

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ABSTRACT

TI's diverse portfolio of DC/DC buck switching regulators provides best-in-class power solutions for any application. This extensive family of products spans power modules, converters, and controllers, and includes the SIMPLE SWITCHER® and SWIFT™ converter brands. The portfolio is supported by WEBENCH® Designer software, evaluation modules, and a variety of technical resources, leading to shorter design cycles and a faster time-to-market. This guide serves as an aggregation of all of the most critical technical documents for engineers designing with TI's DC/DC buck regulator portfolio.

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Trademarks

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1 Low Noise

The term *low noise* means a lot of different things to a lot of different designer. Below are the most common types of noise experienced in noise-sensitive applications.

- **Low Output Voltage Ripple (μV_{PP}):** the residual periodic variation of the DC voltage within a power supply, usually periodic, and originates as the output of a rectifier or from generation and commutation of DC power.
- **Phase Noise (μV_{RMS}):** represented in the frequency domain of a waveform and consists of rapid, short-term, random fluctuations in the phase (frequency). This is caused by time-domain instabilities (jitter).
- **1/f noise**: low frequency noise for which the noise power is inversely proportional to the frequency.
- **Power Supply Rejection**: measure of how well a circuit rejects ripple coming from the input power supply at various frequencies. Basically is is log 20 of the open-loop gain of the regulator feedback divided by the gain from VIN to VOUT with the regulator feedback loop open.
- **Electromagnetic Interference (EMI):** an electronic emission that interferes with components, RF systems, and most electronic devices.

Table 1-1. Low Noise Documentation

Document Title	Literature Number
Reduce Buck-Converter EMI and Voltage Stress by Minimizing Inductive Parasitics	SLYT682
Output Ripple Voltage of Buck Switching Regulators	SLVA630A
Reducing Noise on the Output of a Switching Regulator	SLYT740
Not All Jitter is Created Equal	SLUA747A
Controlling the Switch-node Ringing of Synchronous Buck Converters	SLYT465
Simplify Low-EMI Design with Power Modules	SLYY123
Seminar 900 Topic 2 – Snubber Circuits: Theory, Design and Application	SLUP100
Minimizing Output Ripple During Startup	SLVA866
Measuring Various Types of Low-frequency Noise from DC/DC Switching Converters	SLYY134
Output Noise Filtering for DC/DC Power Modules	SNVA871
Reducing Output Ripple and Noise with the TPS84259 Module	SLVA549
Using a 4MHz switching regulator w/o a Linear Regulator to Power a Data Converter	SLYT756
Extend Battery Life with < 100 nA IQ Buck Converter Achieving < 150 µV Voltage Ripple (with PI filter design)	SLVAEG1
Analysis and Design of Input Filters for DC-DC Circuits	SNVA801
Calculating Output Capacitance to Meet Transient and Ripple Requirements of an Integrated POL Converter Design Based on D-CAPx™ Modulators	SLVA874
Controlling Output Ripple and Achieving ESR Independence with Constant On-Time Regulators	SNVA166A
Power Tips: Designing a two-stage LC filter	Blog
Design a Second-stage Filter for a Power Module in Noise-sensitive Applications	Blog
How You Measure Ripple Can Make or Break You	Blog
Measuring Noise Requirements for an A-to-D Converter's Power Supplies	Blog
How to Filter Out Noise in Your DC/DC Design	Blog
LDO or Switcher - That is the Question	TI Training
Understanding, Measuring and Reducing Output Noise of a DC/DC Switching Regulator	TI Training
Measuring Vout Ripple of DC/DC Converters	TI Training

2 Power Density

While power demands increase, board area and height are becoming limiting factors. Power designer must squeeze more circuitry into their applications to differentiate their products, while increasing efficiency and enhancing thermal performance. TI continues investing in advanced technology and develops solutions enabling designers to attain best-in-class power density. Higher power levels in smaller form-factors are now achievable using TI's advanced circuit-design, process, and packaging technology.

Table 2-1. Power Density Documentation

Document Title	Literature #
Maximizing power density and thermal performance in power-module designs	SLYT761
Space Optimized, "Clam Shell" Layout for Step-Down DC/DC Converters	SLVA818
Breakthrough Power Delivery for Space-Constrained Applications	SSZY023

3 Thermals

All electronics contain semiconductor devices, capacitors and other components that are vulnerable to thermally accelerated failure mechanisms. Thermal design becomes vital to improving the reliability of any design.

Table 3-1. Thermal-related Documentation

Document Title	Literature Number
Semiconductor and IC Package Thermal Metrics	SPRA953
Thermal Design by Insight, not Hindsight	SNVA419C
Techniques for Thermal Analysis of Switching Power Supply Designs	SNVA207A
How to Evaluate Junction Temperature Properly with Thermal Metrics	SLUA844B
Improving the Thermal Performance of a MicroSiP™ Power Module	SLYT724
Understanding the thermal-resistance specification of DC/DC converters with integrated power MOSFETs	SLYT739
Method of Graphing Safe Operating Area (SOA) Curves for DC-DC Converters	SLVA766

4 Control-Mode Architectures

TI is active in the development of leading-edge control circuits to help engineers address specific design challenges. Since no control mode is optimal for every application, various control modes for non-isolated step-down controllers and converters are discussed with their advantages and how to learn more about each mode. The TI portfolio contains 12 types of control architectures for non-isolated buck switching DC/DC modules, converters and controllers.

Table 4-1. Control-Mode Documentation

Document Title	Literature Number
Choosing the Right Variable-Frequency Buck-Regulator Control Strategy	SLUP319
Choosing the Right Fixed-Frequency Buck-Regulator Control Strategy	SLUP317
Internally Compensated Advanced Current Mode (ACM) Overview	SLYY118
Understanding Frequency Variation in the DCS-Control™ Topology	SLYT646
Comparing Internally-compensated Advanced Current Mode (ACM) with D-CAP3™ Control	SLYT732A
How to Measure the Loop Transfer Function of Power Supplies	SNVA364A
Control-Mode Quick Reference Guide	SLYT710A
Practical Comparisons of DC/DC Control Modes: 21-Part Training Series	On-line training
Survey of Control Modes for Step Down Converters and Controllers	On-line training

5 Powering Performance FPGAs, ASICs, and SoC

Today's FPGAs tend to operate at lower voltages and higher currents than their predecessors. Consequently, power supply requirements may be more demanding, requiring special attention to features deemed less important in past generations. Failure to consider the output voltage accuracy, sequencing, power-on, and soft-start requirements can result in unreliable power-up or potential damage to FPGAs.

Table 5-1. Processor Power Documentation

Document Title	Literature Number
Power-Supply Sequencing for FPGAs	SLYT598
Power Supply Design Considerations for Modern FPGAs (Power Designer 121)	SNOA864
Calculating Output Capacitance to Meet Transient and Ripple Requirements of Integrated POL	SLUA874
V_{out} Accuracy-Enhanced Ramp-Generation Design for D-CAP3™ Modulation	SLUA762A
Remote Sensing for Power Supplies	SLYT467
Effect of Resistor Tolerances on Power Supply Accuracy	SLVA423
Body Braking for Less Overshoot	Blog
Kollman Power Tip #18: Regulator Output Voltage Accuracy	Blog
How to meet FPGA's DC voltage accuracy and AC load transient specification	On-line training

6 Light-Load and Full-Load Efficiency

Power-supply efficiency is a critical criterion for many applications whether at full-load or light-load operation. The efficiency of the chosen power solutions relates to system power loss and the thermal performance of integrated circuits (ICs), printed circuit boards (PCBs), and other components, which determines the power-usage effectiveness or extending battery life.

Table 6-1. Efficiency-related Documentation

Document Title	Literature Number
Understanding Eco-Mode™ Operation	SLVA388
MOSFET Power Losses and How They Affect Power-Supply Efficiency	SLYT664
Accurately Measuring Efficiency of Ultralow-IQ Devices	SLYT588
IQ: What it is, What it isn't, and How to use it	SLYT412
Agency Requirements for Standy Power Consumption with Off-line and PoL Converters	SLYT665
Calculating Efficiency	SLVA390A

7 Layout

The printed circuit board (PCB) layout is a critical but often under-appreciated step in achieving proper performance and reliability, especially for switch-mode power supplies. Errors in the PCB layout cause misbehavior including poor output voltage regulation, switching jitter, and even device failure.

Table 7-1. Layout-related Documentation

Document Title	Literature Number
Five Steps to a Great PCB Layout for a Step-Down Converter	SLYT614
Layout Tips for EMI Reduction in DC/DC Converters	SNVA683A
A Guide to Board Layout for Best Thermal Resistance for Exposed Packages	SNVA183B
Improve High-Current DC/DC Regulator EMI Performance for Free With Optimized Power Stage Layout	SNVA803
Layout Guidelines for Switching Power Supplies	SNVA021C
Reduced Size, Double-Sided Layout for High-Current DC/DC Converters	SLVA963
Reducing Ringing Through PCB Layout Techniques	SLPA005
SEM1600 Topic 4: Constructing Your Power Supply – Layout Considerations	SLUP230
How to Correctly Layout a 40A Power Supply: Copper, Vias and Loop-path	Blog
How to do a PCB Layout Review	Blog
Layout, power loss, and packaging to address thermal concerns with integrated FET DC/DC converters: 7 part series	On-line Training

8 Power Supply Topology

Buck converters, controllers, and modules can be configured into other useful topologies without additional components. Documentation is available to explain the operation and theory of buck converters as well as isolated and inverting buck/boost (negative output) topologies.

Table 8-1. Power Supply Topology Documentation

Document Title	Literature Number
Designing a Negative Boost Converter from a Standard Positive Buck Converter	SLYT516
Create a Split-Rail Power Supply with a Wide Input Voltage Buck Regulator	SLVA369A
Understanding Buck Power Stages in Switchmode Power Supplies	SLVA057
Designing an Isolated Buck (Fly-Buck™) Converter	SNVA674C
Fly-buck Converter PCB Layout Tips	Blog

9 Packaging

TI's broad packaging portfolio supports thousands of diversified products, packaging configurations and technologies, including traditional ceramic and leaded options, to advanced chip scale packages (Quad Flat No Lead (QFN), Wafer Chip Scale Package (WCSP) or Die-Size Ball Grid Array (DSBGA)), using fine pitch wire bond and flip chip interconnects, with SiP, module, stacked and embedded die formats offered.

Table 9-1. Packaging-related Documentation

Document Title	Literature Number
QFN/SON PCB Attachment	SLUA271B
PowerPAD™ Thermally Enhanced Package	SLMA002H
Benefits and Trade-offs of Various Power-Module Package Options	SLYY120
HotRod™ QFN Package PCB Attachment	SLUA715
SMT Guidelines for Stacked Inductor (Inductor On Top) on Voltage Regulator IC	SLVA764
Find TI packages	TI Website

10 Revision History

Changes from Revision * (June 2022) to Revision A (November 2022)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document	1