Design Guide: TIDA-050071

Off-Battery Processor Power Reference Design for ADAS and Infotainment Applications

Description

The automotive off-battery processor power reference design provides a versatile protected power tree for supplying common Advanced Driver Assistance Systems (ADAS) and Infotainment processors, such as TDA4x-Q1 and AM6x-Q1. The processors described in this guide work with sensor fusion systems, camera modules, and domain controllers. Detailed guidance helps designers create protected power systems. Additional power rails are provided for Double Data Rate (DDR) memory and auxiliary loads. The design contains an onboard MSPM0 microcontroller (MCU) for programming the power rail voltages and sequencing.

Resources

TIDA-050071	Design Folder
TPS6521905-Q1, LM74900-Q1	Product Folder
LMQ66430-Q1, TPS22995H-Q1	Product Folder
TPS51200A-Q1, TPS7B4255-Q1	Product Folder

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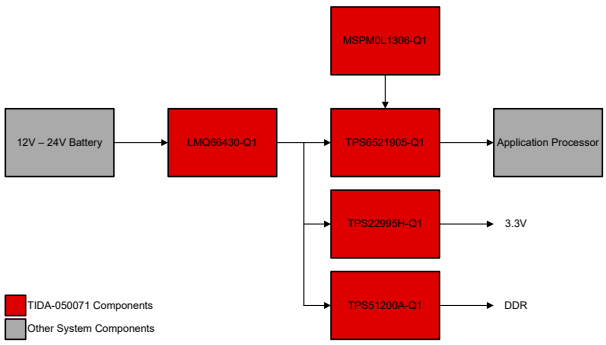
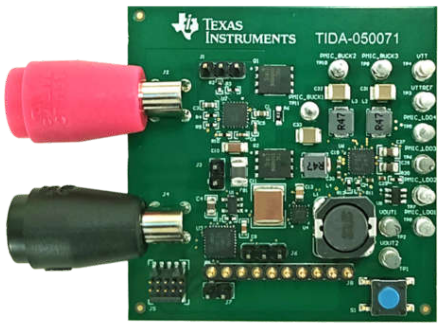
Features

- Fully integrated power supply rails for TDA4x-Q1, AM69x-Q1, AM62x-Q1, and more processors
- Compact design size (54mm × 54mm)
- Supports cold-cranking down to 3V
- Low bill of materials (BOM) count
- Additional power rails for driving auxiliary loads
- Onboard programmability

Applications

- ADAS domain controller
- Autonomous driving module
- Surround view system ECU
- Head-up display





1 System Description

This reference design can power all rails of an automotive application processor directly from a standard 12V battery. The input to this system is protected by an LM74900-Q1 ideal diode, which provides reverse polarity protection with a low equivalent forward voltage (10.5mV). Undervoltage and overvoltage protection, overcurrent protection, current monitoring, and fault reporting are also provided in a small design with low-I_Q size. The protected 12V is then sent to two voltage regulators: one LMQ66430-Q1 switching buck converter and one TPS7B4255-Q1 tracking LDO. The switching regulator provides a regulated 3.3V output to the TPS6521905-Q1 PMIC, two TPS22995H-Q1 load switches, and the TPS51200A-Q1 Double Data Rate (DDR) termination regulator. The LDO provides a stable 3.3V to the onboard MSPM0L1306-Q1 MCU.

This design focuses on compact size, minimal components, low electromagnetic interference (EMI), and affordability without sacrificing functionality or flexibility.

2 System Overview

2.1 Block Diagram

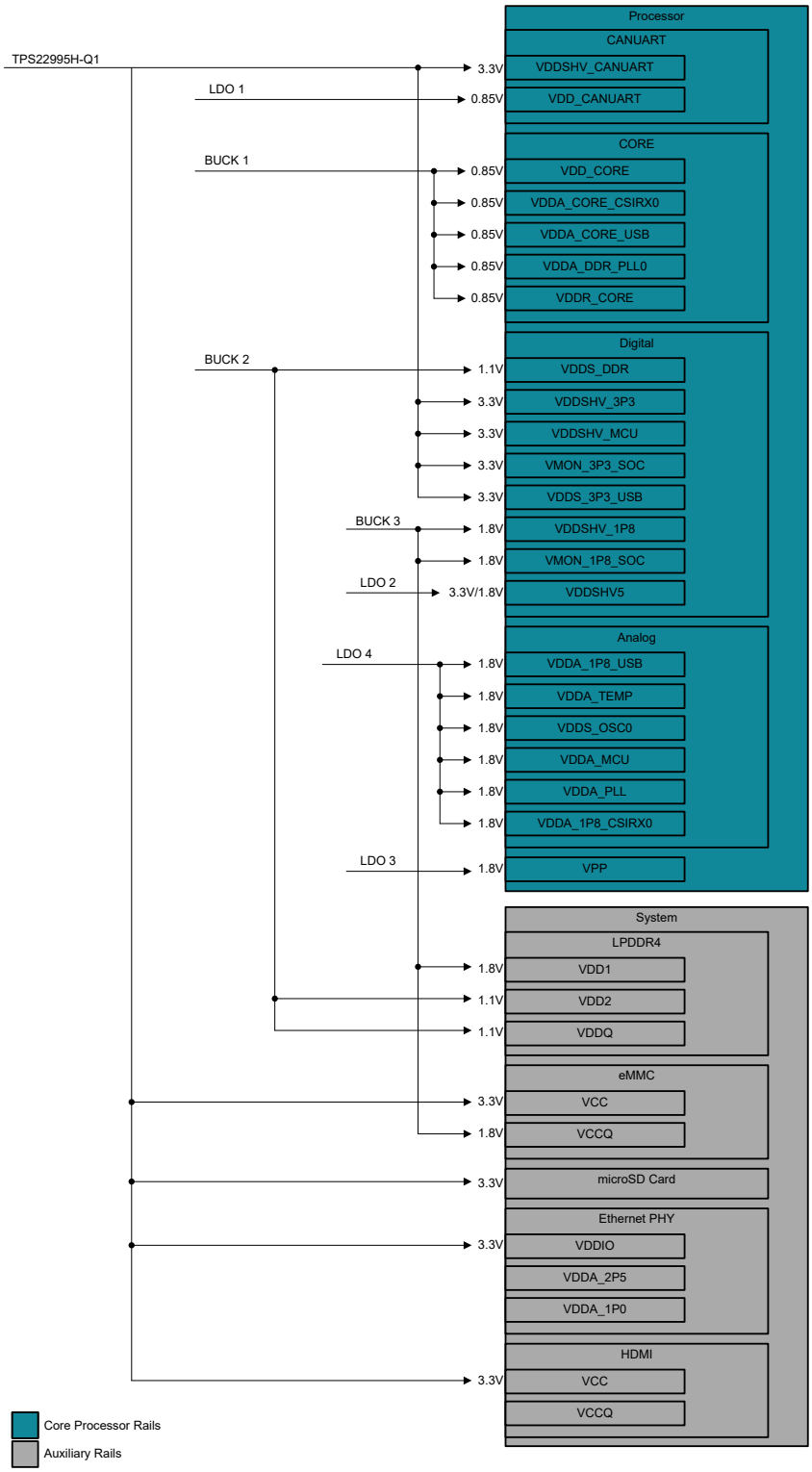


Figure 2-1. TIDA-050071 Block Diagram

2.2 Design Considerations

Complex processors such as those used in the following list require numerous unique rails to supply the varied internal circuitry blocks:

- ADAS domain controllers
- Vision processing systems
- Sensor fusion and perception systems
- Communication gateways

To meet this requirement, PMICs with multiple high-performance integrated buck converters and LDOs are used to derive and distribute the necessary voltages to the processor and the surrounding components. Additionally, as the required rail voltages vary across specific processors and applications, a high level of configurability is desired.

This reference design is centered around TPS6521905-Q1, a fully configurable high-performance PMIC with three buck converters and four LDOs. All the voltages and power-up sequencing characteristics of the output rails can be programmed through I2C, requiring minimal external components. Furthermore, the non-volatile memory (NVM) of this device can be user-programmed, allowing for completely standalone operation.

The PMIC and output rail power supply is sourced by an LMQ66430-Q1 3A, low-EMI, high-efficiency buck converter with low ripple, low overshoot, and a fast transient response. The board input, typically connected directly to a battery, is protected by a highly configurable LM74900-Q1 ideal diode to protect the downstream circuitry from overvoltage, reverse battery, and short-circuit conditions.

Additional output rails are provided by two TPS22995H-Q1 load switches, a TPS51200A-Q1 DDR sink termination regulator or source termination regulator, and a TPS7B4255-Q1 tracking LDO.

An MSPM0L1306-Q1 is used to interface with the TPS6521905-Q1 and all onboard digital signals, allowing for rapid evaluation, high application-specific customization, and configurable fault detection and response.

All this is designed within a tiny 54mm × 54mm PCB.

2.3 Highlighted Products

- *TPS6521905-Q1*
- *LM74900-Q1*
- *LMQ66430-Q1*
- *TPS22996H-Q1*
- *TPS51200A-Q1*
- *TPS7B4255-Q1*
- *MSPM0L1306-Q1*

2.3.1 TPS6521905-Q1

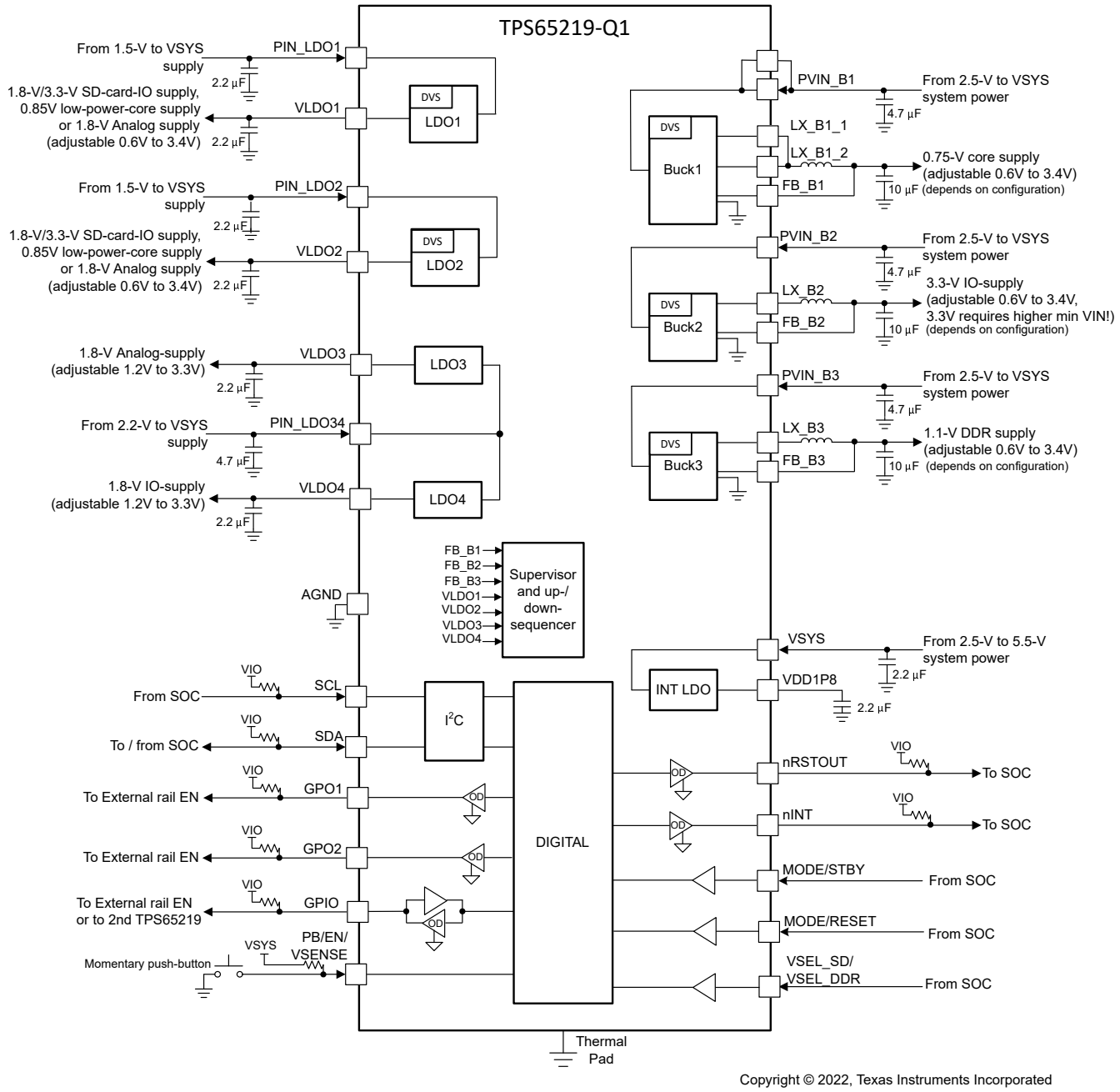


Figure 2-2. TPS6521905-Q1 Functional Block Diagram

The TPS6521905-Q1 is a Power Management IC (PMIC) designed to supply a wide range of SoCs in automotive applications. The device is characterized across an ambient temperature range of –40°C to +125°C, making the PMIC an excellent choice for automotive applications. The device includes three synchronous step-down DC-DC converters and four linear regulators. The DC-DC converters are capable of 1 × 3.5A and 2 × 2A. The converters require a small 470nH inductor, 4.7µF input capacitance, and a minimum 10µF output capacitance per rail depending on the switching mode configuration. Two of the LDOs support output currents of 400mA at an output voltage range of 0.6V to 3.4V. These LDOs support bypass mode, acting as a load-switch, and allow voltage changes during operation. The other two LDOs support output currents of 300mA at an output voltage range of 1.2V to 3.3V. These LDOs also support load-switch mode. The I2C-interface, IOs, General-Purpose Inputs and Outputs (GPIO) and multi-function-pins (MFP) allow a seamless interface to a wide range of SoCs.

2.3.2 LM74900-Q1

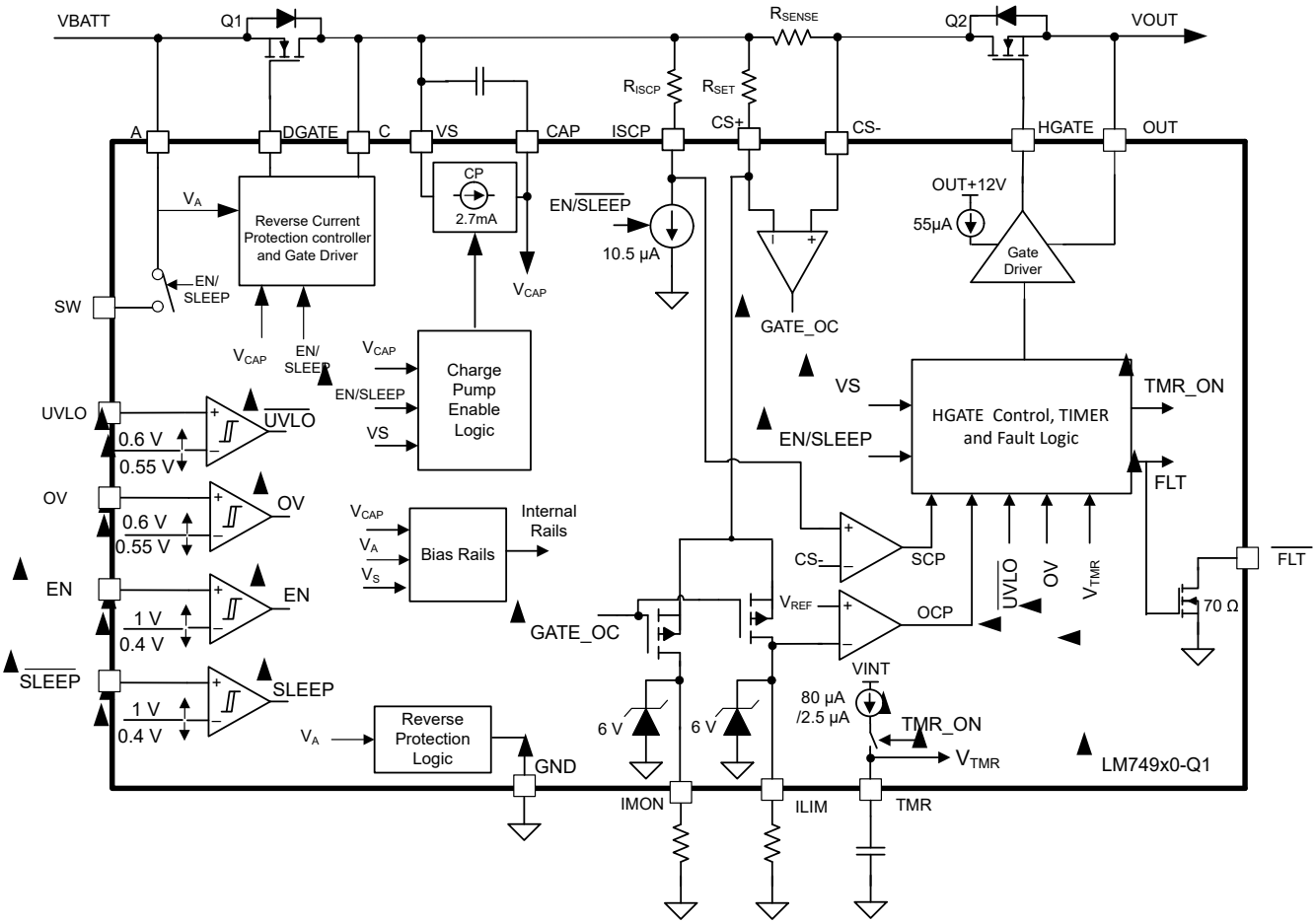


Figure 2-3. LM74900-Q1 Functional Block Diagram

The LM74900-Q1 ideal diode controller drives and controls external back to back N-channel MOSFETs to emulate an ideal diode rectifier with power path ON/OFF control with overcurrent and overvoltage protection. The wide input supply of 3V to 65V allows protection and control of 12V and 24V automotive battery powered ECUs. The device can withstand and protect the loads from negative supply voltages down to –65V. An integrated ideal diode controller (DGATE) drives the first MOSFET to replace a Schottky diode for reverse input protection and output voltage holdup. With a second MOSFET in the power path the device allows load disconnect (ON/OFF control) in case of overcurrent and overvoltage events using HGATE control. The device has integrated current sense amplifier which provides accurate current monitoring with adjustable overcurrent and short circuit thresholds. The device features an adjustable overvoltage cut-off protection feature. The device features a SLEEP mode which enables ultra-low quiescent current consumption (6µA) and at the same time providing refresh current to the always ON loads when vehicle is in the parking state. The LM74900-Q1 has a maximum voltage rating of 65V.

2.3.3 LMQ66430-Q1

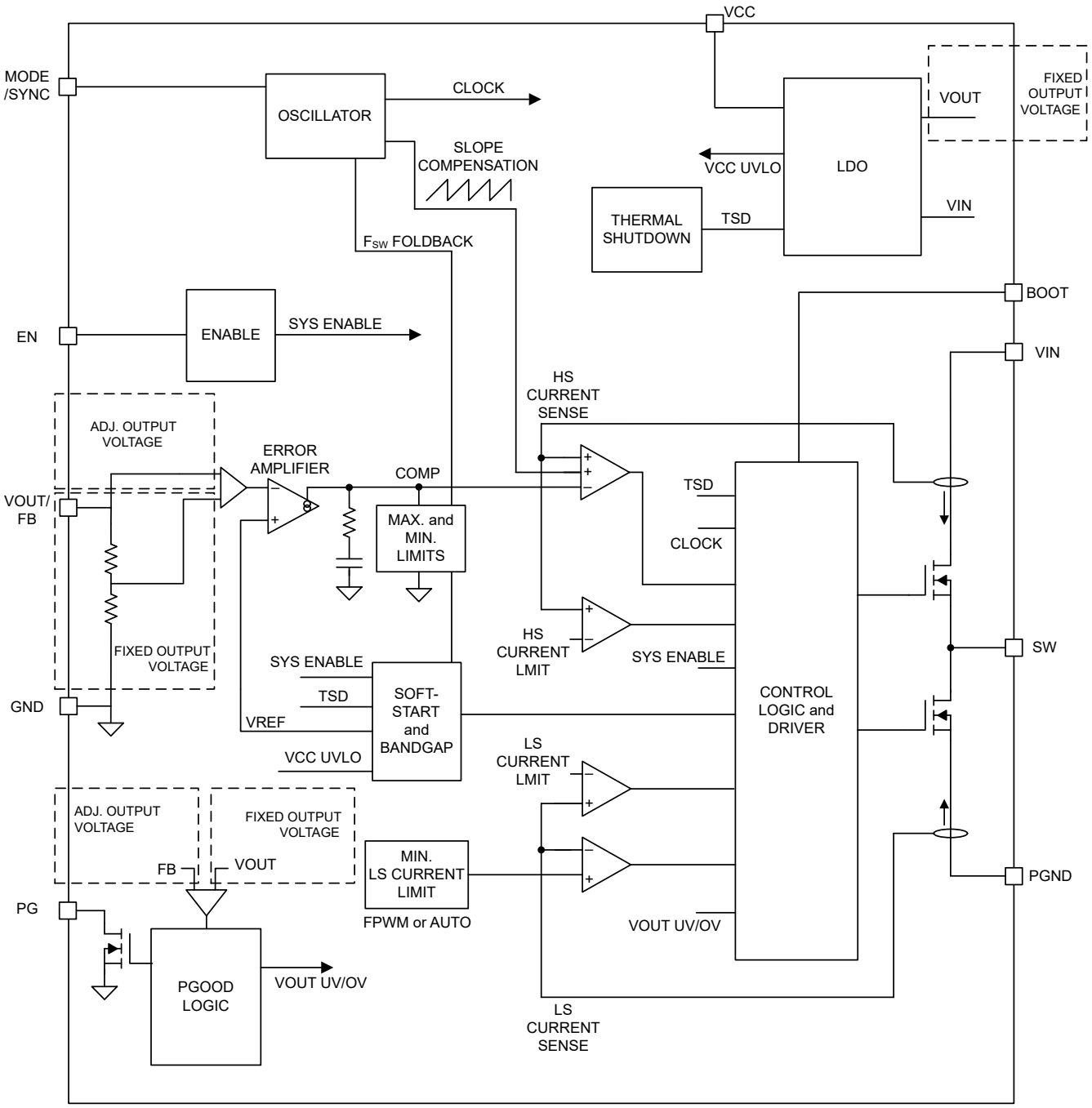


Figure 2-4. LMQ66430-Q1 Functional Block Diagram

The LMQ66430-Q1 is the industry smallest 36V, 3A (available in 2A and 1A variants) synchronous step-down DC/DC converter with an integrated bypass and bootstrap capacitor in an enhanced HotRod QFN package. This easy-to-use converter supports a wide input voltage range of 2.7V to 36V (after start-up or after operating) with transients up to 42V. The LMQ66430-Q1 is specifically designed to meet low standby power requirements for always-on, automotive applications. Auto mode enables frequency foldback when operating at light loads, allowing an unloaded typical current consumption of 1.5µA at 13.5V_{IN} and high light-load efficiency. A seamless transition between PWM and PFM modes along with very low MOSFET ON resistances makes sure there is exceptional efficiency across the entire load range. The control architecture (peak current mode) and feature set are optimized for an ultra-small design size with minimal output capacitance. The device minimizes input

filter size by using dual-random spread spectrum (DRSS), a low-EMI enhanced HotRod QFN package, and an optimized pinout. The MODE/SYNC pin can be used to set or synchronize the frequency to avoid noise sensitive frequency bands. There are NC pins between critical high voltage pins, reducing potential failures (excellent choice pin FMEA). The rich feature set of the LMQ66430-Q1 is designed to simplify implementation for a wide range of automotive end equipment.

2.3.4 TPS22995H-Q1

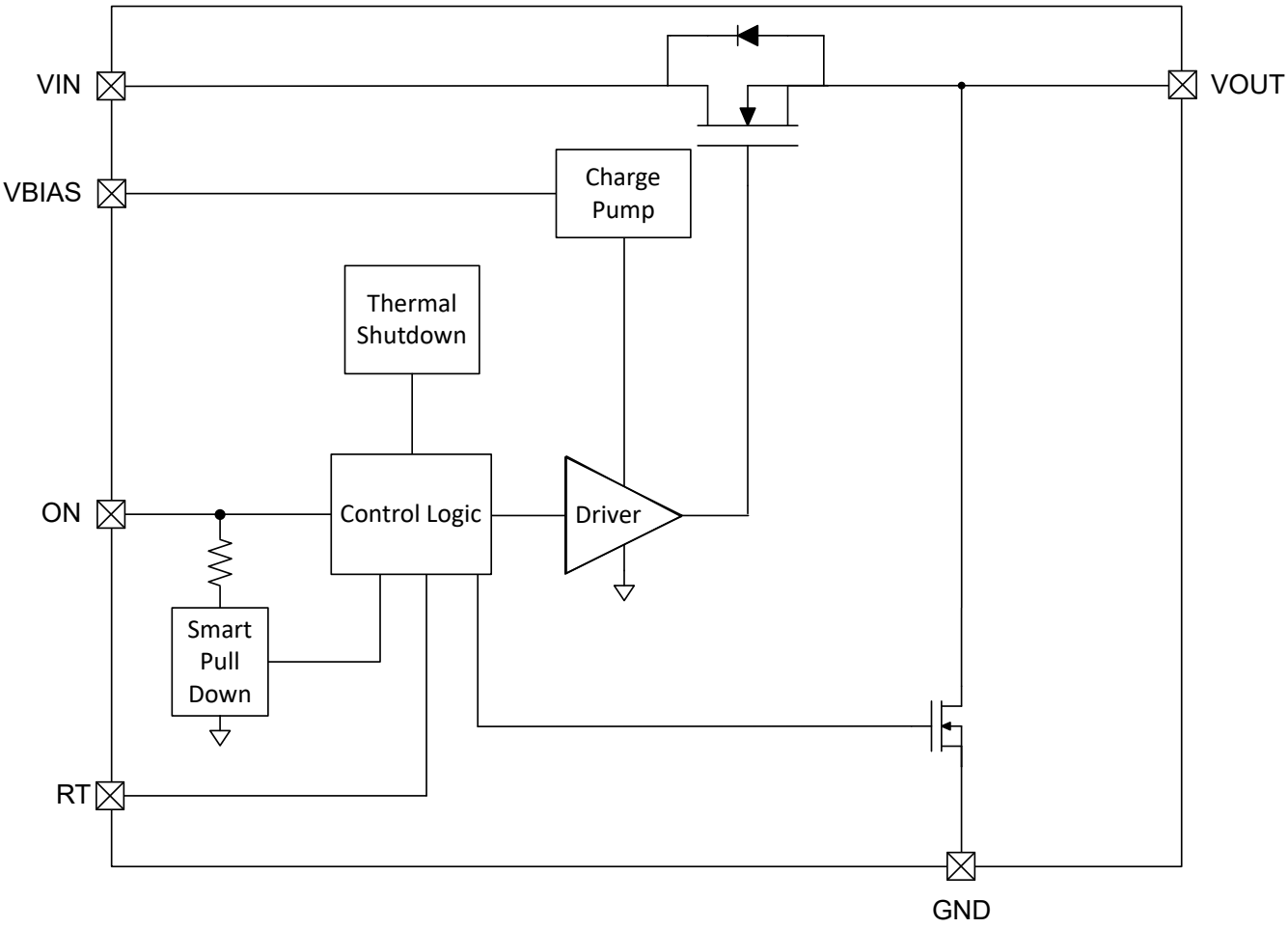


Figure 2-5. TPS22995H-Q1 Functional Block Diagram

The TPS22995H-Q1 is a single-channel load switch that contains a 19mΩ N-channel MOSFET that can operate over an input voltage range of 0.8V to 5.5V and can support a maximum continuous current of 3A. The switch is controlled by an on and off input (ON), which is capable of interfacing directly with low voltage GPIO signals. The TPS22995H-Q1 has a Quick Output Discharge when switch is turned off, pulling the output voltage down to a known 0V state. Additionally, the device provides an adjustable rise to limit inrush currents with high capacitive loads. The pins of the TPS22995H-Q1 are resistant to high humidity conditions, meaning that the device is able to function with a 100kΩ short from any pin to GND or power. When the timing pin (RT) is affected by high humidity, timing is expected to stay within ±20%. The TPS22995H-Q1 is available in a 2.8mm × 2.9mm, 0.5mm pitch, 6-pin SOT package. The device is characterized for operation over the free-air temperature range of –40°C to +125°C.

2.3.5 TPS51200A-Q1

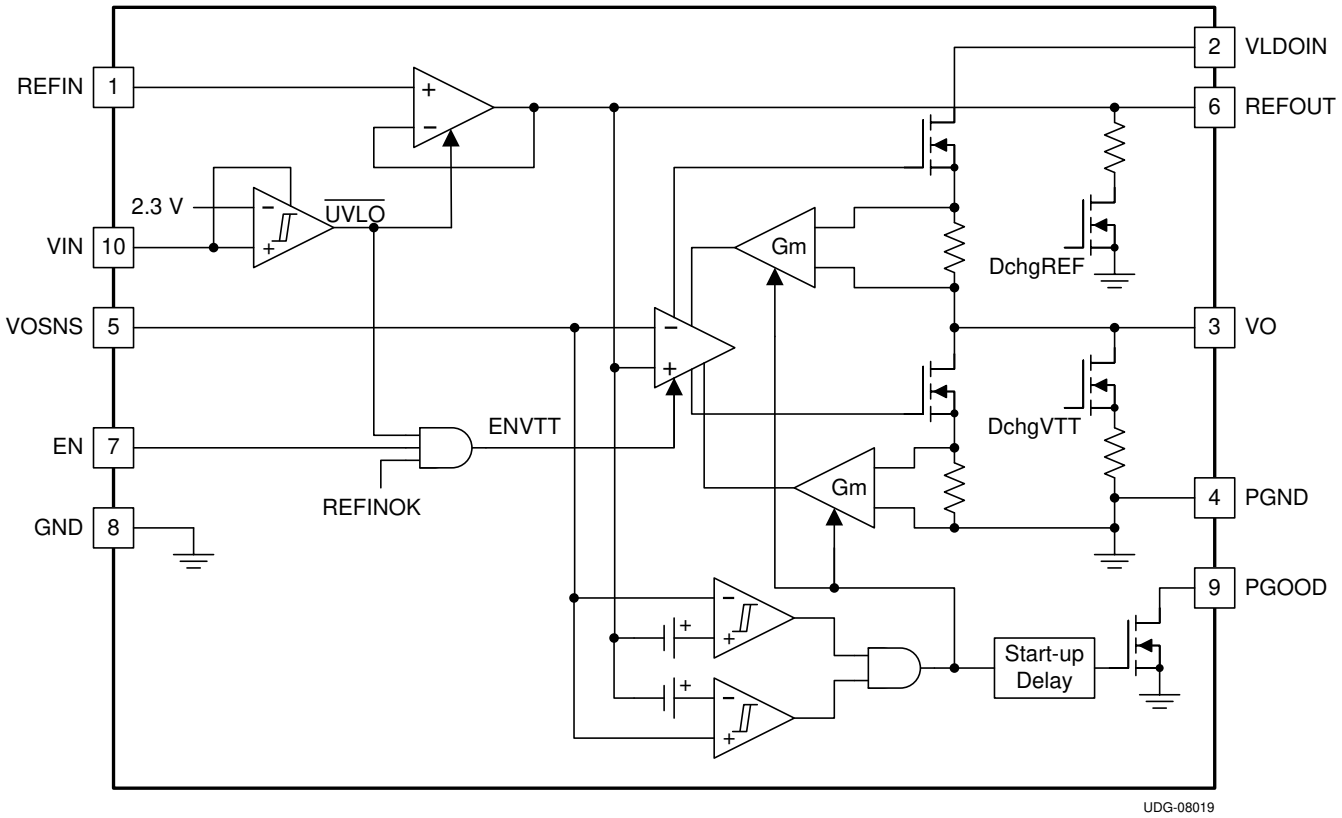


Figure 2-6. TPS51200A-Q1 Functional Block Diagram

The TPS51200A-Q1 device is a sink and source double-data-rate (DDR) termination regulator specifically designed for low input voltage, low-cost, low-noise systems where space is a key consideration. The device maintains a fast transient response and only requires a minimum output capacitance of 20µF. The device supports a remote sensing function and all power requirements for DDR, DDR2, DDR3, and low power DDR3 and DDR4 VTT bus termination. In addition, the device provides an open-drain PGOOD signal to monitor the output regulation and an EN signal that can be used to discharge VTT during S3 (suspend to RAM) for DDR applications.

2.3.6 TPS7B4255-Q1

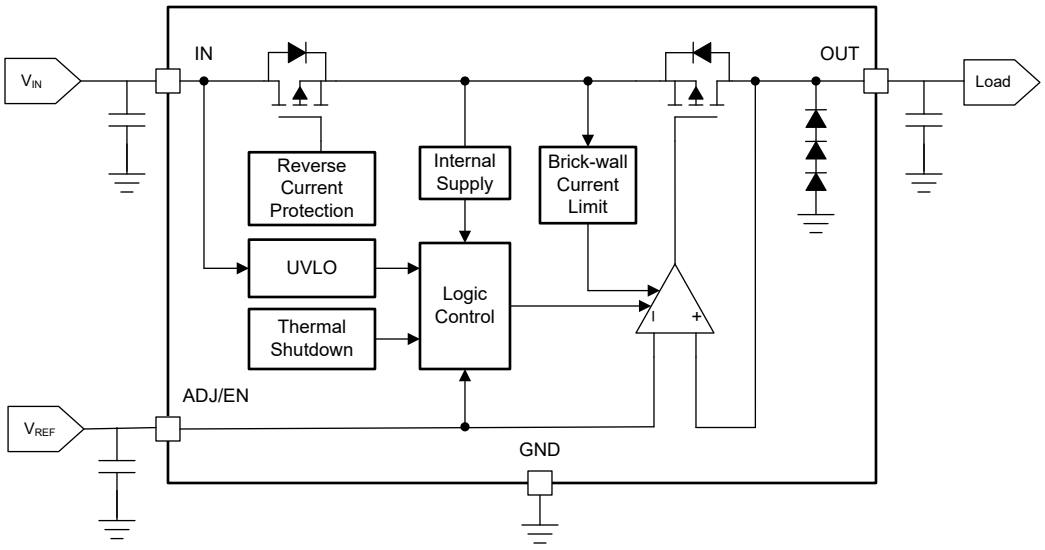


Figure 2-7. TPS7B4255-Q1 Functional Block Diagram

The TPS7B4255-Q1 is a low-dropout (LDO) voltage-tracking regulator, with high tracking accuracy and excellent load and line transient response. The device is available in two 5-pin, SOT-23 packages (DBV and DYB). The TPS7B4255-Q1 is designed to supply off-board sensors in automotive applications such as powertrain systems. Because the risk of failure in cables that deliver off-board power is high, the device comes with integrated protection features against fault conditions such as reverse current (short to battery), reverse polarity, output short to ground (current limit), and overtemperature (thermal shutdown). The device is designed to handle a 45V (absolute maximum) input voltage and survive the automotive load dump transient conditions. A reference voltage applied at the ADJ/EN pin is effectively tracked at the OUT pin with very tight tolerance for loads up to 70mA. The TPS7B4255-Q1 can therefore deliver the power-supply voltage to the off-board sensors with high precision, which can help improve the reliability and accuracy of measurements made using ratiometric sensors. By setting the ADJ/EN input pin low, the TPS7B4255-Q1 switches to standby mode and reduces the quiescent current of the LDO to less than 3.25µA.

2.3.7 MSPM0L1306-Q1

The MSPM0L1306 microcontrollers (MCUs) are a part of the MSP highly integrated, ultra-low-power 32-bit MSPM0 MCU family based on the enhanced Arm® Cortex®-M0+ core platform operating at up to 32MHz frequency. These cost-optimized MCUs offer high-performance analog peripheral integration, support extended temperature ranges from –40°C to 125°C, and operate with supply voltages ranging from 1.62V to 3.6V. The MSPM0L1306 devices provides up to 64KB embedded flash program memory with up to 4KB SRAM. These MCUs incorporate a high-speed on-chip oscillator with an accuracy up to ±1.2%, eliminating the need for an external crystal. Additional features include a 3-channel DMA, 16- and 32-bit CRC accelerator, and a variety of high-performance analog peripherals such as one 12-bit 1.68-MSPS ADC with configurable internal voltage reference, one high-speed comparator with built-in reference DAC, two zero-drift zero-crossover operational amplifiers with programmable gain, one general-purpose amplifier, and an on-chip temperature sensor. These devices also offer intelligent digital peripherals such as four 16-bit general purpose timers, one windowed watchdog timer, and a variety of communication peripherals including two UARTs, one SPI, and two I 2Cs. These communication peripherals offer protocol support for LIN, IrDA, DALI, Manchester, Smart Card, SMBus, and PMBus. The TI MSPM0 family of low-power MCUs consists of devices with varying degrees of analog and digital integration allowing for customers find the MCU that meets the needs of the project. The architecture combined with extensive low-power modes are optimized to achieve extended battery life in portable measurement applications.

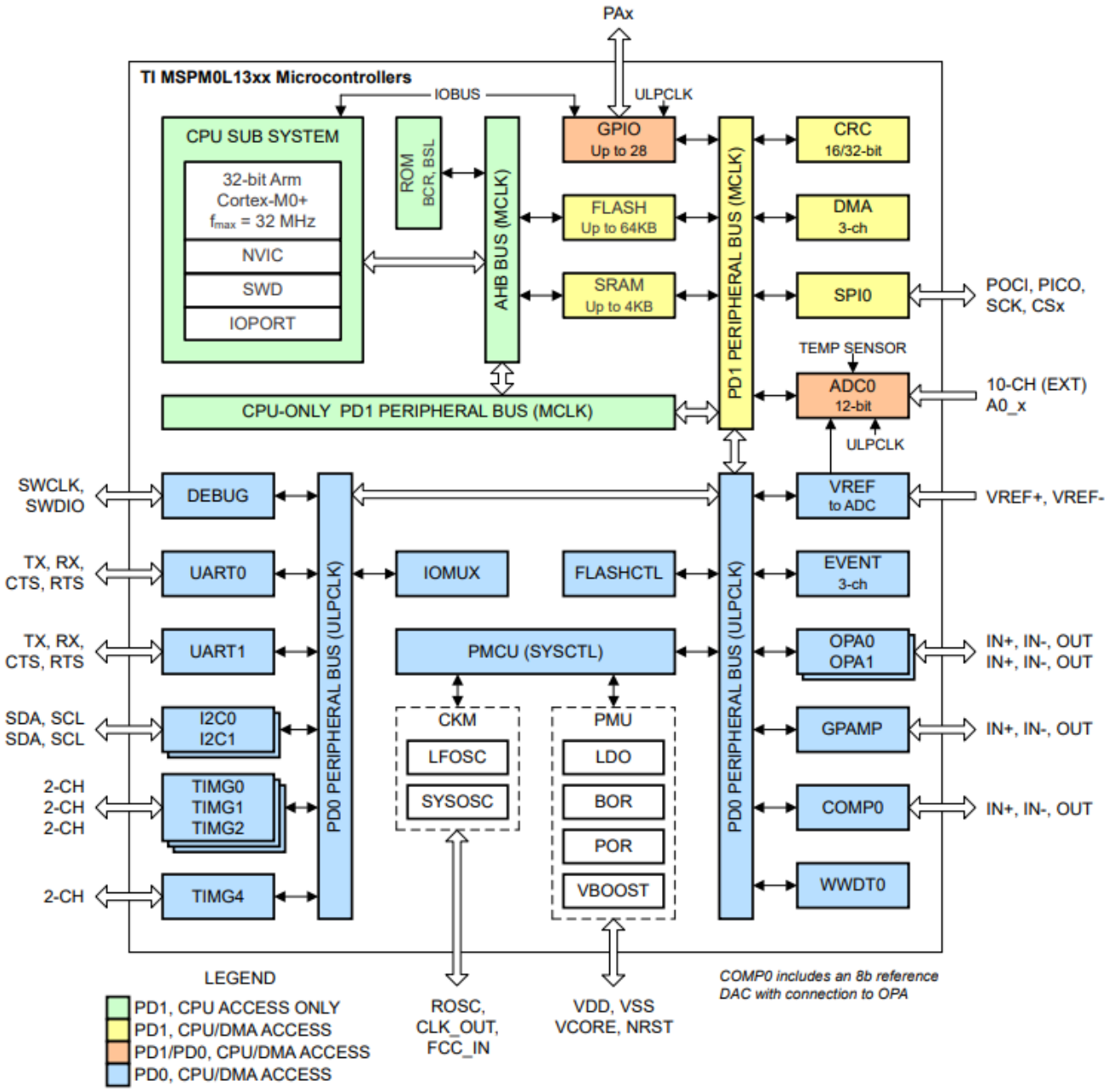


Figure 2-8. MSPM0L1306 Functional Block Diagram

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Hardware Requirements

To employ the full capabilities of this board, the following equipment is needed:

- One TIDA-050071 PCB
- Shunt jumpers or solder bridges
- JTAG debugger
- Power supply from 5V to 36V
- Oscilloscope
- Processor or other load
- Hooked cables

3.2 Software Requirements

A JTAG debugger in conjunction with an integrated development environment (IDE) such as TI's Code Composer Studio™, Arm® Keil®, or IAR Embedded Workbench® is required.

3.3 Test Setup

The test conditions are as follows:

- V_{IN} = 13.5V
- I_{LOAD} = 0A → 2A (500µs) → 0A for buck converters; 0A → 200mA (500µs) → 0A for LDOs

When testing load transient step response, the load is connected at the respective output connector and the output voltage is measured across the respective output capacitor.

3.4 Test Results

3.4.1 LMQ66430-Q1

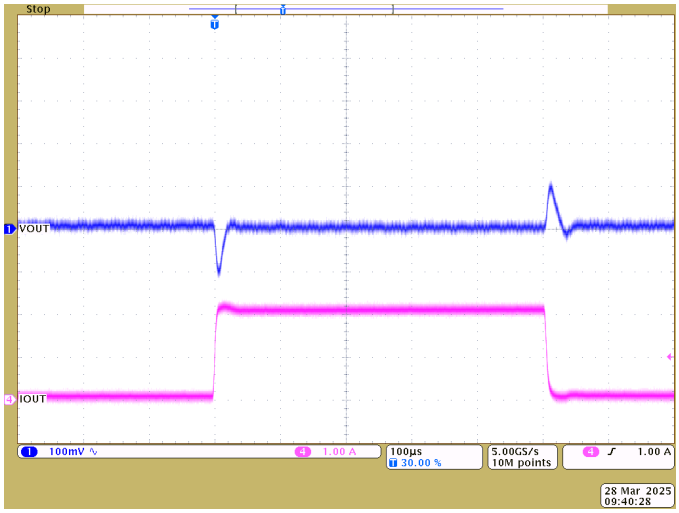


Figure 3-1. LMQ66430-Q1 Load Transient Response

3.4.2 TPS65219-Q1

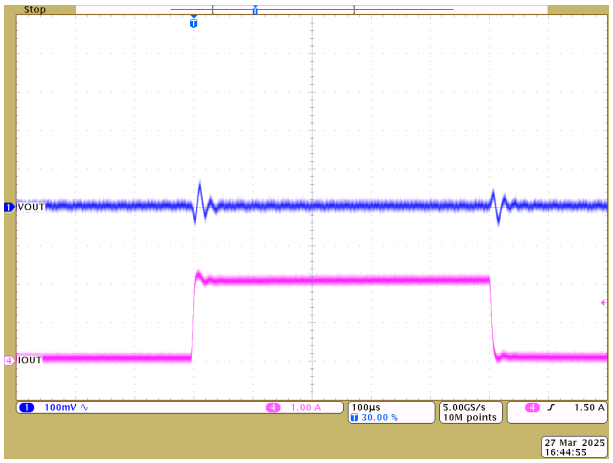


Figure 3-2. Buck 1 Load Transient Response

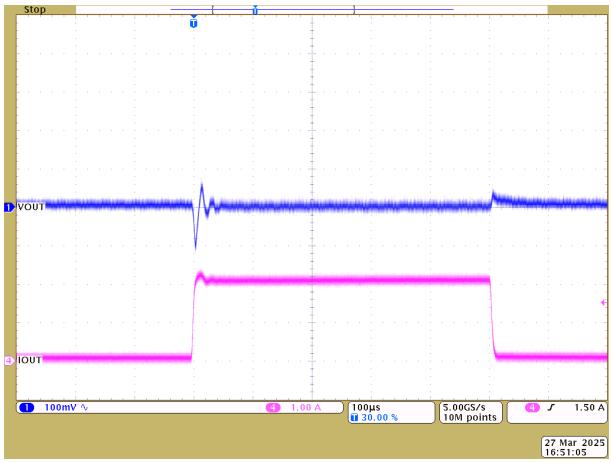


Figure 3-3. Buck 2 Load Transient Response

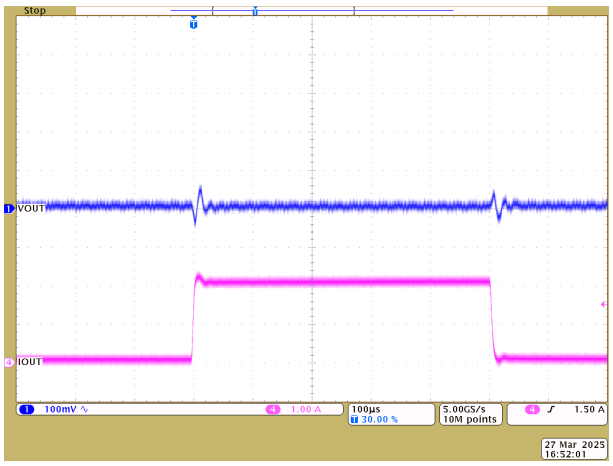


Figure 3-4. Buck 3 Load Transient Response

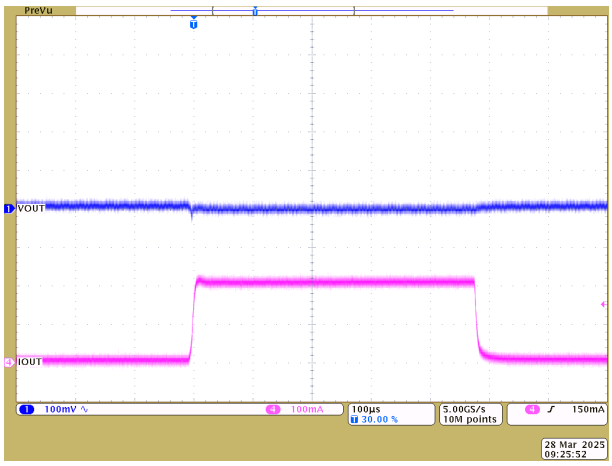


Figure 3-5. LDO 1 Load Transient Response

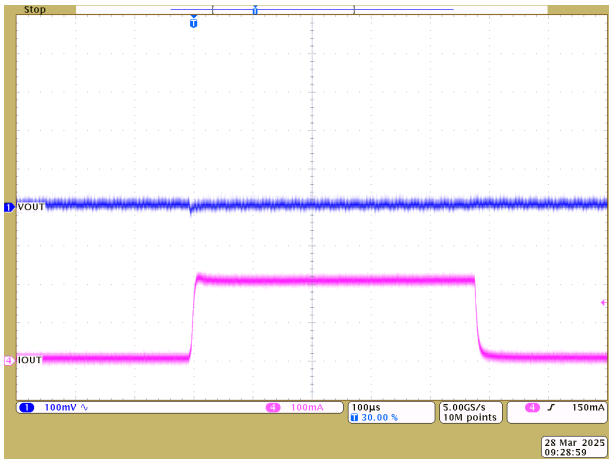


Figure 3-6. LDO 2 Load Transient Response

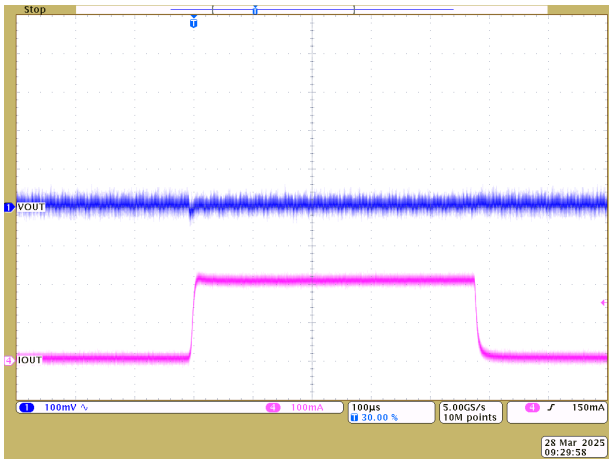


Figure 3-7. LDO 3 Load Transient Response

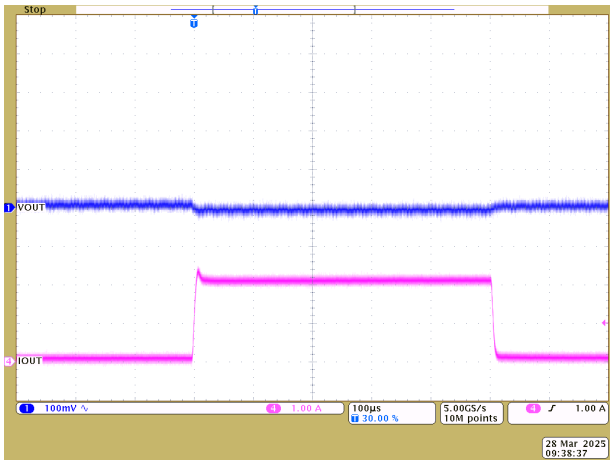


Figure 3-8. LDO 4 Load Transient Response

3.5 Quick Start Guide

TIDA-050071 is powered by a single 3V to 36V input source, connected between the J2 and J4 input connectors. The following list details the jumper functions:

J1	LM74900-Q1 enable, connect middle and right header for always-enabled (EN to VS), connect middle and left header for MCU-controlled or externally-controlled EN.
J3	TPS7B42-Q1 input supply, connect two headers together to power LDO from filtered VIN.
J6	LMQ66430-Q1 enable, connect middle and left header for always-enable during normal operation (EN to LM74900-Q1 nFLT pin), connect middle and left header for MCU-controlled or externally-controlled EN.

Connect JTAG programmer to J5 to program the onboard MSPM01306-Q1. S1 is connected to the MCU nRST pin.

Test points TP1–TP11 can be used for output connection or system evaluation, and are referenced with respect to J4, system GND.

4 Design and Documentation Support

4.1 Design Files

All files, including schematic, PCB layout, Gerber files, and software project are found at TIDA-050071.

4.1.1 Schematics

To download the schematics, see the design files at TIDA-050071.

4.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-050071.

4.2 Tools and Software

Tools

CCSTUDIO	TI Code Composer Studio
MSPM0-SDK	MSPM0 Software Development Kit

Software

TIDA-050071 Firmware	Source code for TIDA-050071

4.3 Documentation Support

1. Texas Instruments, *Automotive User Programmable Power Management IC (PMIC) With Three Step-down DC/DC Converters and Four LDOs Data Sheet*
2. Texas Instruments, *LM749x0-Q1 Automotive Ideal Diode With Circuit Breaker, Undervoltage, and Overvoltage Protection With Fault Output Data Sheet*
3. Texas Instruments, *LMQ664x0-Q1, 36V, 1A, 2A, and 3A, Ultra-Small, Synchronous Automotive Step-Down Converter With Integrated V_{IN} Bypass and C_{BOOT} Capacitors Data Sheet*
4. Texas Instruments, *TPS22995H-Q1 5.5V, 3A, 19mΩ On-Resistance Automotive Load Switch Data Sheet*
5. Texas Instruments, *TPS51200A-Q1 Sink and Source DDR Termination Regulator Data Sheet*
6. Texas Instruments, *TPS7B4255-Q1 Automotive, 70mA, 40V, Voltage-Tracking LDO With 5mV Tracking Tolerance Data Sheet*

4.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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