TPS65131-Q1 Positive- and Negative-Output DC-DC Converter

1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
  - Device Temperature Grade 2: –40°C to 105°C Ambient Operating Temperature Range
  - Electrical Characteristics Tested Over –40°C to 125°C Junction Temperature Range
  - Device HBM ESD Classification Level H2
  - Device CDM ESD Classification Level C4B
- Dual Adjustable Output Voltages up to 15 V and down to –15 V
- 2–A Typical Switch-Current Limit for Boost and Inverter Main Switches
- High Conversion Efficiency
  - Up to 91% at Positive Output Rail
  - Up to 85% at Negative Output Rail
  - Power-Save Mode at Low Load
- Independent Enable Inputs for Power-Up and Power-Down Sequencing
- Control Output for External PFET to Support Complete Supply Disconnect When Shut Down
- 2.7-V to 5.5-V Input-Voltage Range
- Minimum 1.25-MHz Fixed-Frequency PWM Operation
- Thermal Shutdown
- Overvoltage Protection on Both Outputs
- 0.2-µA Typical Shutdown Current
- Small 4-mm × 4-mm QFN-24 Package (RGE)

2 Applications

- Small- to Medium-Size OLED Displays
- (TFT) LCD, CCD Bias Supply

3 Description

The TPS65131-Q1 device is dual-output dc-dc converter generating a positive output voltage up to 15 V and a negative output voltage down to –15 V with output currents of typically 200 mA, depending on input-voltage to output-voltage ratio. With a total efficiency up to 85%, the device is ideal for portable battery-powered equipment. The input-voltage range of 2.7 V to 5.5 V allows, for example, 3.3-V and 5-V rails to power the TPS65131-Q1 device. The TPS65131-Q1 device comes in a QFN-24 package with thermal pad. Requiring few and small external components, the overall solution size can be small.

The converter operates with a fixed-frequency PWM control topology and, with power-save mode enabled, uses a pulse-skipping mode at light load currents. In operation, the typical overall device quiescent current is only 500 µA. In shutdown, the device draws typically 0.2 µA. Independent enable pins allow power-up and power-down sequencing for both outputs. The device has an internal current limit, overvoltage protection, and a thermal shutdown for highest reliability under fault conditions.

The TPS65131-Q1 device is qualified for automotive applications, according to AEC-Q100 temperature grade 2. The electrical characteristics are tested over –40°C to 125°C device junction temperature. This, combined with lowest shutdown currents, small solution size, package with thermal pad, plus good efficiency and protection features, targets automotive and industrial applications.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS65131-Q1	VQFN (24)	4 mm × 4 mm

(1) For all available packages, see the orderable addendum.

Application Schematic

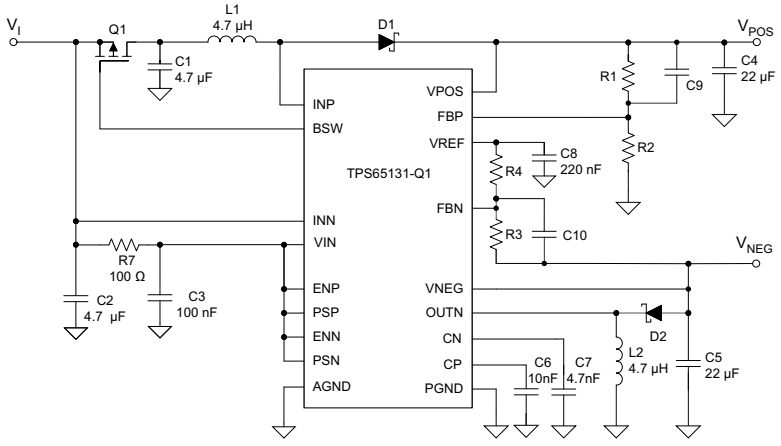


Table of Contents

4 Revision History

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

Changes from Revision C (March 2014) to Revision D — **Page**

- Global editorial changes bringing the datasheet into the new format ... 1
- Changed max. efficiency from 89% to 91% and from 81% to 85% ... 1
- Deleted "Minimum 1.25 MHz" ... 1
- Changed 1-µA shutdown current to typ. 0.2 µA ... 1
- Relocated and renamed the pin Functions table ... 4
- Added thermal pad to pin Functions Table ... 4
- Added Thermal Pad to Absolute Maximum Ratings. Added min./max. values where missing ... 5
- Added $V_{(VIN)}$, $V_{(INN)}$, V_{NEG}, V_{POS}, $V_{(ENN)}$, $V_{(ENP)}$, $V_{(PSN)}$ to Recommended Operating Conditions table ... 5
- Changed symbol names to JEDEC compliance ... 6
- Added frequency and duty cycles to Switching Characteristics table. Removed from Electrical Characteristics table ... 7
- Added Rectifier Diode Selection Guide ... 15
- Added P-MOSFET Selection Guide ... 15

Changes from Revision B (February 2013) to Revision C — **Page**

- Added "Electrical Characteristics tested over –40°C to 125°C Junction Temperature Range" ... 1
- Deleted T_A table row ... 5
- Changed I_{NN} to V_{INN}, added pin names VIN and INN ... 5
- Added pin name VPOS ... 5
- Added pin name VNEG ... 5
- Changed I_{NP} to V_{INP}, added pin name INP ... 5
- Changed "between pins OUTN to V_{INN}" to "between pins OUTN to INN" ... 5
- Added operating junction temperature ... 5
- Added "In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may reqiuire derating. See Thermal Information for details." ... 5
- Deleted "virtual" from "Operating virtual junction temperature range" ... 5

- Changed Electrical Characteristics condition statement to "This specification applies over the full recommended input voltage range V_I = 2.7 V to 5.5 V and over the temperature range $T_J = T_A$ = –40°C to 125°C unless otherwise noted. Typical values apply for V_I = 3.6 V and $T_J = T_A$ = 25°C." 6
- Changed $I_{LIM,min}$ = 1800 mA to 1700 mA 6
- Deleted V_{POS} = 5 V (105°C) row 6
- Changed $r_{DS(on)P,max}$ (V_{POS} = 5 V) = 300 mΩ to 390 mΩ 6
- Changed $r_{DS(on)P,max}$ (V_{POS} = 10 V) = 200 mΩ to 230 mΩ 6
- Changed $I_{LIMP,min}$ = 1800 mA to 1700 mA 6
- Changed $I_{LIMP,max}$ = 2200 mA to 2250 mA 6
- Added T_A = –40°C to 85°C 6
- Changed minimum f = 1250 kHz to 1150 kHz 7
- Editorially updated Block Diagram 9
- Changed "The maximum recommended junction temperature (T_J) of the TPS65131-Q1 is 125°C." to "The recommended device junction temperature range, T_J, is -40°C to 125°C." 16
- Changed $R_{\theta JA}$ = 37.8°C/W to $R_{\theta JA}$ = 34.1°C/W 16
- Changed "Specified regulator operation is ensured to a maximum ambient temperature T_A of 105°C." to "The recommended operating ambient temperature range for the device is T_A = –40°C to 105°C." 16
- Changed "Therefore, the maximum power dissipation is about 1058 mW" to "Use Equation 13 to calculate the maximum power dissipation, $P_D$max, as a function of T_A. In this equation, use T_J = 125°C to operate the device within the recommended temperature range, use $T_J = T_{(TS)}$ to determine the absolute maximum threshold when the device might go into thermal shutdown." 16
- Changed Equation 13 16

Changes from Revision A (November 2012) to Revision B **Page**

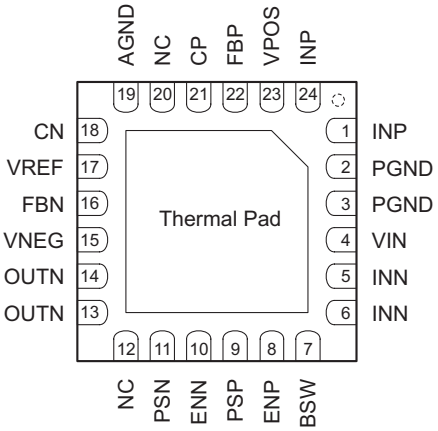
- Changed CDM ESD rating from C3B to C4B. 1

Changes from Original (May 2012) to Revision A **Page**

- Device is going from Preview to Production 1
- Added thermal information table values. 6
- Added V_{POS} = 5 V (105°C) row and values to Electrical Characteristics table. 6

5 Pin Configuration and Functions

24-pin VQFN With PowerPAD™ Package
RGE Package
(Bottom View)



NC – No internal Connection

(Top View)

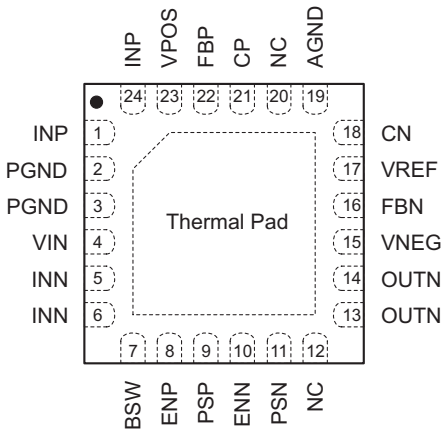


Table 1. Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
AGND	19	—	Analog ground pin
BSW	7	O	Gate-control pin for external battery switch. This pin goes low when ENP is set high.
CN	18	I/O	Compensation pin for inverting converter control
CP	21	I/O	Compensation pin for boost converter control
ENN	10	I	Enable pin for the negative-output voltage (0 V: disabled, VIN: enabled)
ENP	8	I	Enable pin for the positive-output voltage (0 V: disabled, VIN: enabled)
FBN	16	I	Feedback pin for the negative-output voltage divider
FBP	22	I	Feedback pin for the positive-output voltage divider
INN	5, 6	O	Inverting converter switch pin
INP	1, 24	O	Boost converter switch pin
NC (1)	12, 20	—	Not connected
OUTN	13, 14	I/O	Inverting converter switch output
PGND	2, 3	—	Power ground pin
PSN	11	I	Power-save mode enable for inverter stage (0 V: disabled, VIN: enabled)
PSP	9	I	Power-save mode enable for boost converter stage (0 V: disabled, VIN: enabled)
VIN	4	I	Control supply input
VNEG	15	I	Negative-output voltage-sense input
VPOS	23	I	Positive-output voltage-sense input
VREF	17	O	Reference output voltage. Bypass this pin with a 220-nF capacitor to ground. Connect the lower resistor of the negative-output voltage divider to this pin.
Thermal pad			Thermal pad for thermal performance, connect to PGND (1)

(1) NC - No internal connection

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature, unless otherwise noted (1)

		VALUE		UNIT
		MIN	MAX	
	Input voltage range at pins VIN, INN (2)	–0.3	6	V
	Voltage at pin VPOS (2)	–0.3	17	V
	Voltage at pin VNEG (2)	–17	$V_{(VIN)}$ + 0.3	V
	Voltage at pins ENN, ENP, FBP, FBN, CN, CP, PSP, PSN, BSW (2)	–0.3	$V_{(VIN)}$ + 0.3	V
	Input voltage at pin INP (2)	–0.3	17	V
	Differential voltage between pins OUTN to INN (2)	–0.3	24	V
	Thermal pad (2)	–0.3	0.3	V
T_J	Operating junction temperature	–40	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to the network ground pin, unless otherwise noted.

6.2 Handling Ratings

			MIN	MAX	UNIT
T_{stg}	Storage temperature range		–65	150	°C
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002 (1)	–2	2	kV
		Charged device model (CDM), per AEC Q100-011	–750	750	V

(1) AEC Q100-002 indicates HBM stressing is done in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

over operating free-air temperature, unless otherwise noted

		MIN	MAX	UNIT
V_I , $V_{(VIN)}$, $V_{(INN)}$	Application input voltage range, input voltage range at VIN and INN pins	2.7	5.5	V
V_{POS}	Adjustable output voltage range for the boost converter	V_I + 0.5	15	V
V_{NEG}	Adjustable output voltage range for the inverting converter	–15	–2	V
$V_{(ENN)}$, $V_{(ENP)}$	Enable signals voltage	0	5.5	V
$V_{(PSN)}$, $V_{(PSP)}$	Power-save mode enable signals voltage	0	5.5	V
T_A	Operating free-air temperature range (1)	–40	105	°C
T_J	Operating junction temperature range	–40	125	°C

(1) In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may require derating. See *Thermal Information* for details.

6.4 Thermal Information

THERMAL METRIC[1]		TPS65131-Q1 RGE PACKAGE 24 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	34.1	°C/W
$R_{\theta JCtop}$	Junction-to-case (top) thermal resistance	36.8	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	12.2	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.4	°C/W
ψ_{JB}	Junction-to-board characterization parameter	12.3	°C/W
$R_{\theta JCbot}$	Junction-to-case (bottom) thermal resistance	2.8	°C/W

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics

This specification applies over the full recommended input voltage range V_I = 2.7 V to 5.5 V and over the temperature range $T_J = T_A$ = –40°C to 125°C unless otherwise noted. Typical values apply for V_I = 3.6 V and $T_J = T_A$ = 25°C.

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
DC-DC STAGE ($V_{(VPOS)}$, $V_{(VNEG)}$)							
V_{ref}	Reference voltage		I_{ref} = 10 µA	1.2	1.213	1.225	V
$I_{(FBP)}$	Positive feedback input bias current		$V_{(FBP)} = V_{ref}$		50		nA
$I_{(FBN)}$	Negative feedback input bias current		$V_{(FBN)} = 0.1\ V_{ref}$		50		nA
$V_{(FBP)}$	Positive feedback regulation voltage			1.189	1.213	1.237	V
$V_{(FBN)}$	Negative feedback regulation voltage			–0.024	0	0.024	V
	Total output dc accuracy				3%		
$r_{DS(on)(N)}$	Inverter switch on-resistance		$V_{(VIN)}$ = 3.6 V		440	620	mΩ
			$V_{(VIN)}$ = 5 V		330	530	
$I_{(LIM-N)}$	Inverter switch current limit		$V_{(VIN)}$ = 3.6 V	1700	1950	2200	mA
$r_{DS(on)(P)}$	Boost switch on-resistance		$V_{(POS)}$ = 5 V		230	390	mΩ
			$V_{(POS)}$ = 10 V		170	230	
$I_{(LIM-P)}$	Boost switch current limit		$V_{(VIN)}$ = 3.6 V, $V_{(POS)}$ = 8 V	1700	1950	2250	mA
CONTROL STAGE							
V_{IH}	High-level input voltage, ENP, ENN, PSP, PSN			1.4			V
V_{IL}	Low-level input voltage, ENP, ENN, PSP, PSN					0.4	V
	Input current, ENP, ENN, PSP, PSN		ENP, ENN, PSP, PSN connected to GND or VIN		0.01	0.1	µA
$R_{(BSW)}$	Output resistance				27		kΩ
I_Q	Quiescent current	VIN	$V_{(VIN)}$ = 3.6 V, $I_{(POS)} = I_{(NEG)}$ = 0, ENP = ENN = PSP = PSN = $V_{(VIN)}$, $V_{(POS)}$ = 8 V, $V_{(NEG)}$ = –5 V		300	500	µA
		VPOS			100	120	
		VNEG			100	120	
I_{SD}	Shutdown supply current		ENN = ENP = LOW, T_A = –40°C to 85°C		0.2	1.5	µA
$V_{(UVLO)}$	Undervoltage lockout threshold			2.1	2.35	2.7	V
$T_{(TS)}$	Thermal shutdown				150		°C
$T_{(TS-HYS)}$	Thermal shutdown hysteresis		Junction temperature decreasing		5		°C

6.6 Switching Characteristics

The specification applies over the full recommended input voltage range V_I = 2.7 V to 5.5 V and over the temperature range $T_J = T_A$ = –40 °C to 125°C unless otherwise noted. Typical values apply for V_I = 3.6 V and $T_J = T_A$ = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
FREQUENCY						
f	Oscillator frequency		1150	1380	1500	kHz
DUTY CYCLE						
$D_{(MAX-P)}$	Maximum-duty-cycle, boost converter			87.5%		
$D_{(MAX-N)}$	Maximum-duty-cycle, inverting converter			87.5%		
$D_{(MIN-P)}$	Minimum-duty-cycle, boost converter			12.5%		
$D_{(MIN-N)}$	Minimum-duty-cycle, inverting converter			12.5%		

6.7 Typical Characteristics

At 25°C, unless otherwise noted.

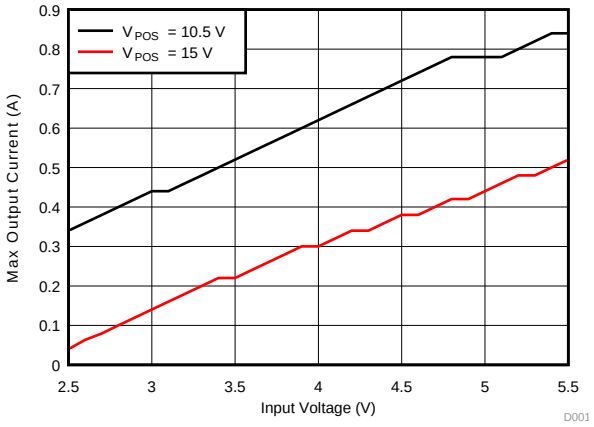


Figure 1. Boost Converter (V_{POS}) Maximum Output Current vs Input Voltage

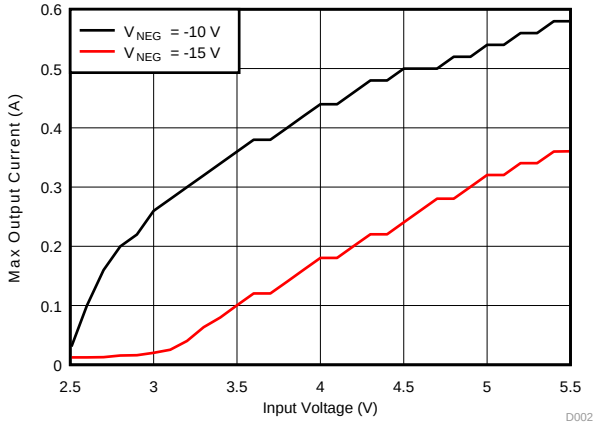


Figure 2. Inverting Converter (V_{POS}) Output Current vs Input Voltage

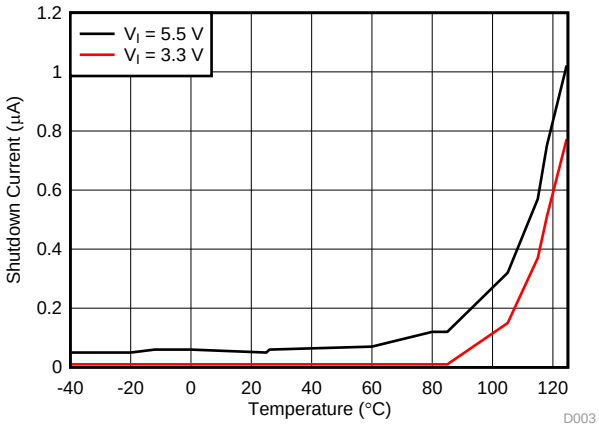
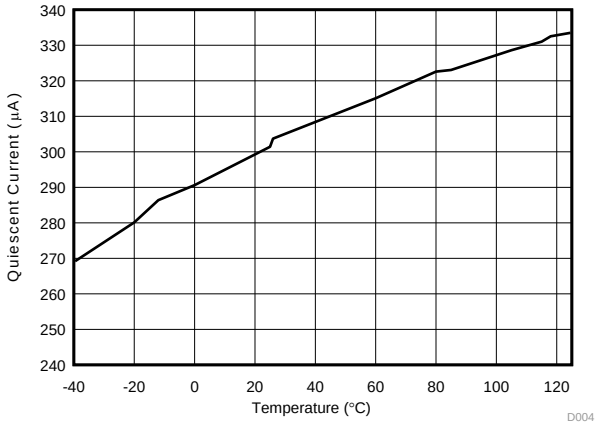


Figure 3. Shutdown Current (Into VIN and INN) Over Input Voltage



V_I = 3.6 V

Figure 4. Quiescent Current (Into VIN and INN) Over Input Voltage

7 Parameter Measurement Information

Table 2. List of Components

REFERENCE	SETUP	VALUE, DESCRIPTION
C1, C2	—	4.7 µF, ceramic, 6.3 V, X5R
C3		0.1 µF, ceramic, 10 V, X5R
C4, C5		4 x 4.7 µF, ceramic, 25 V, X7R
C6		10 nF, ceramic, 16 V, X7R
C7		4.7 nF, 50 V, C0G
C8		220 nF, ceramic, 6.3 V, X5R
R1	V_{POS} = 10.5 V	1 MΩ
	V_{POS} = 15 V	975 kΩ
R2	V_{POS} = 10.5 V	130 kΩ
	V_{POS} = 15 V	85.8 kΩ
R3	V_{NEG} = –10 V	1 MΩ
	V_{NEG} = –15 V	1.3 MΩ
R4	V_{NEG} = –10 V	121.2 kΩ
	V_{NEG} = –15 V	104.8 kΩ
R7	—	100 Ω
D1, D2		Schottky, 1 A, 20 V, Onsemi MBRM120
L1, L2		4.7 µH, Epcos B82462-G4472
Q1		MOSFET, p-channel, 12 V, 4 A, Vishay Si2323DS

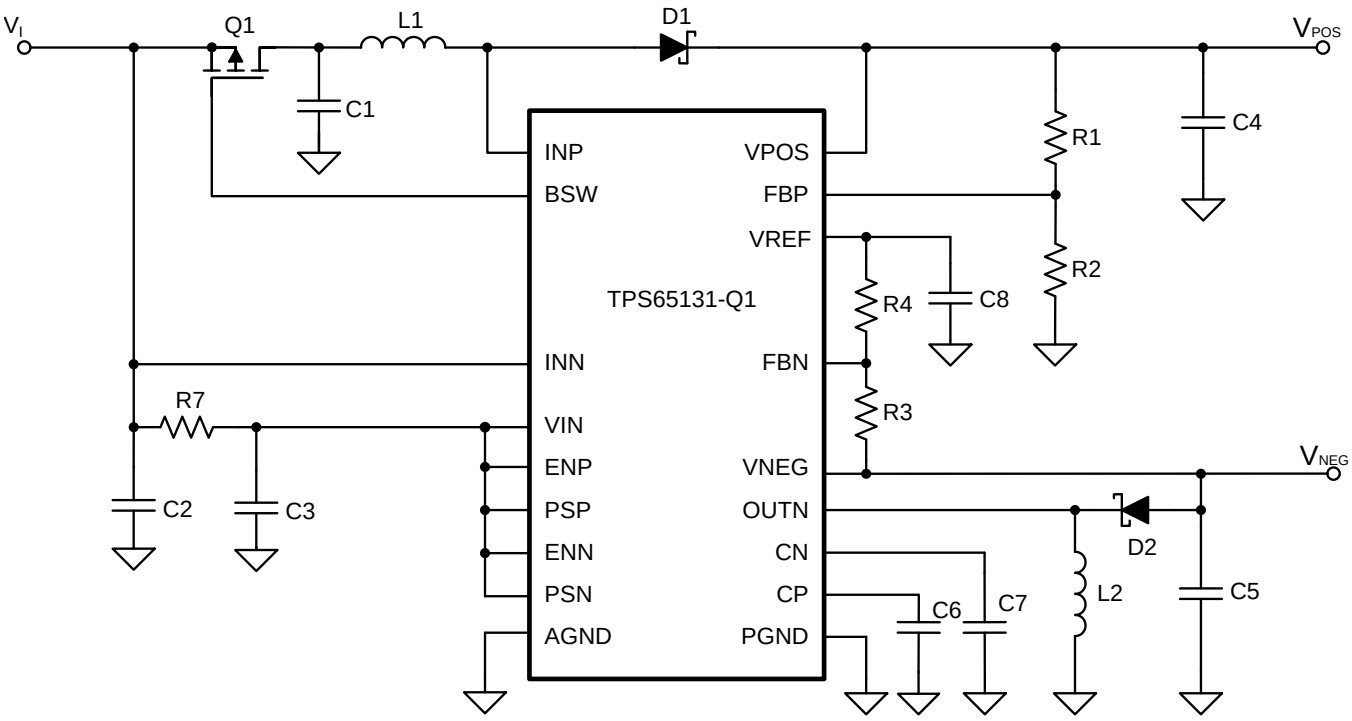


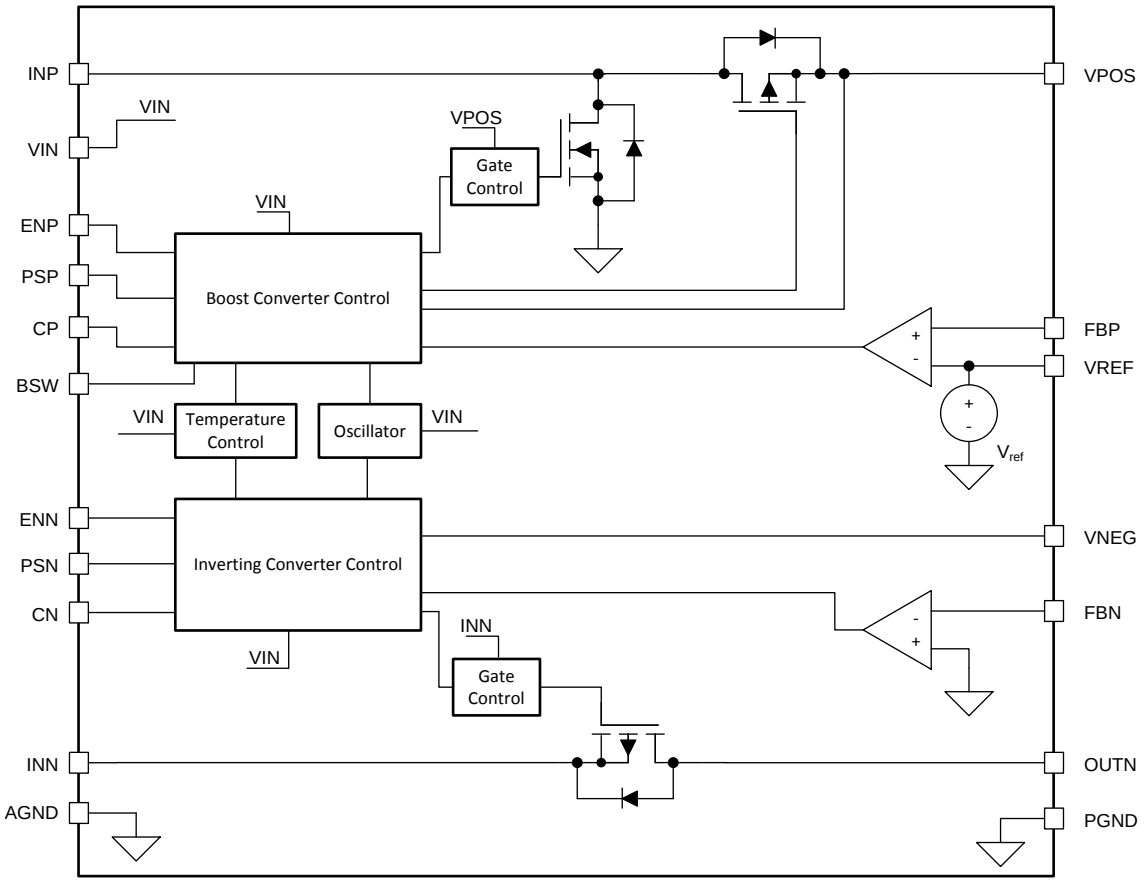
Figure 5. Parameter Measurement Setup

8 Detailed Description

8.1 Overview

The TPS65131-Q1 is a dual-output dc-dc converter that generates two adjustable output voltages. One output voltage is positive (boost converter), the other is negative (inverting converter). The positive output is adjustable up to 15 V, the negative output is adjustable down to –15 V. The device operates with an input voltage range of 2.7 V to 5.5 V. Both converters (positive and negative output) work independently of each other. They share a common clock and a common voltage reference. A fixed-frequency, pulse-width-modulated (PWM) regulator controls both outputs separately. In general, each converter operates in continuous-conduction mode (CCM). To improve efficiency at light loads, the converters can operate in discontinuous-conduction mode (DCM). When the power-save mode is enabled, the converters automatically transition between CCM and DCM operation: As the load current decreases, the converter enters DCM mode. Power-save mode is individually configurable for both outputs. The transition as a function of the load current works independently for each converter.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Power Conversion

Both converters operate in a fixed-frequency, PWM control scheme. The on-time of the internal switches varies depending on the input-to-output voltage ratio and the load. During the on-time, the inductors connected to the converters charge with current. In the remaining time, the off-time with a time period set by the fixed operating frequency, the inductors discharge into the output capacitors through the rectifier diodes. Usually at higher loads, the inductor currents are continuous. At lighter loads, the boost converter uses an additional internal switch to allow current to flow back to the input. This avoids inductor current becoming discontinuous in the boost converter. At the inverting converter, during light loads, the inductor current can become discontinuous. In this case, the control circuit of the inverting controller output automatically takes care of these changing conditions to operate always with an optimum control setup.

8.3.2 Control

The controller circuits of both converters employ a fixed-frequency, multiple-feedforward controller topology. These circuits monitor input voltage, output voltage, and voltage drop across the switches. Changes in the operating conditions of the converters directly affect the duty cycle and must not take the indirect and slow way through the output voltage-control loops. A self-learning control corrects measurement errors in this feedforward system. An external capacitor damps the output to avoid output-voltage steps due to output changes of this self-learning control system.

The voltage loops, determined by the error amplifiers, must only handle small signal errors. The error amplifiers feature internal compensation. Their inputs are the feedback voltages on the FBP and FBN pins. The device uses a comparison of these voltages with the internal reference voltage to generate an accurate and stable output voltage.

8.3.3 Output Rails Enable or Disable

Both converters can be enabled or disabled individually. Applying a logic HIGH signal at the enable pins (ENP for the boost converter, ENN for the inverting converter) enables the corresponding output. After enabling, internal circuitry, necessary to operate the specific converter, then turns on, followed by the *Soft Start*.

Applying a low signal at the enable ENP or ENN pin shuts down the corresponding converter. When both enable pins are low, the device enters shutdown mode, where all internal circuitry turns off. The device now consumes shutdown current flowing into the VIN pin. The output loads of the converters can be disconnected from the input, see *Load Disconnect*.

8.3.4 Load Disconnect

The device supports completely disconnecting the load when the converters are disabled. For the inverting converter, the device turns off the internal PMOS switch. If the inverting converter is turned off, no dc current path remains which could discharge the battery or supply.

This is different for the boost converter. The external rectifying diode, together with the boost inductor, form a dc current path which could discharge the battery or supply if any load connects to the output. The device has no internal switch to prevent current from flowing. For this reason, the device offers a PMOS gate control output (BSW) to enable and disable a PMOS switch in this dc current path, ideally directly between the boost inductor and battery. To be able to fully disconnect the battery, the forward direction of the parasitic backgate diode of this switch must point to the battery or supply. The external PMOS switch, which connects to BSW, turns on when the boost converter is enabled and turns off when the boost converter is disabled.

8.3.5 Soft Start

Both converters have implemented soft-start functions. When each converter is enabled, the implemented switch current limit ramps up slowly to its nominal programmed value in typically 1 ms. The device includes this function to limit the input current during start-up to avoid high peak input currents, which could interfere with other systems connected to the same battery or supply.

If the application includes the *Load Disconnect* PMOS switch, a current flows from the input to the output of the boost converter at the moment the PMOS switch becomes conducting.

Feature Description (continued)

8.3.6 Overvoltage Protection

Both built-in converters (boost and inverter) have implemented individual overvoltage protection. If the feedback voltage under normal operation exceeds the nominal value by typically 5%, the corresponding converter shuts down immediately to protect any connected circuitry from possible damage.

8.3.7 Undervoltage Lockout

An undervoltage lockout prevents the device from starting up and operating if the supply voltage at the VIN pin is lower than the undervoltage lockout threshold. For this case, the device automatically shuts down both converters when the supply voltage at VIN falls below this threshold. Nevertheless, parts of the control circuits remain active, which is different than device shutdown using EN inputs. The device includes the undervoltage lockout function to prevent device malfunction.

8.3.8 Overtemperature Shutdown

The device automatically shuts down both converters if the implemented internal temperature sensor detects a chip temperature above the thermal shutdown temperature. It automatically starts operating again when the chip temperature falls below this threshold plus hysteresis threshold. The built-in hysteresis avoids undefined operation caused by ringing from shutdown and prevents operating at a temperature close to the overtemperature shutdown threshold.

8.4 Device Functional Modes

8.4.1 Power-Save Mode

The power-save mode can improve efficiency at light loads. In power-save mode, the converter only operates when the output voltage falls below an device internally set threshold voltage. The converter ramps up the output voltage with one or several operating pulses and goes again into power-save mode once the inductor current becomes discontinuous.

The PSN and PSP logic level selects between power-save mode and continuous-conduction mode. If the specific pins (PSP for the boost converter, PSN for the inverting converter) are HIGH, the power-save mode for the corresponding converter operates at light loads. Similary, a LOW on the PSP pin or PSN pin disables the power-save mode for the corresponding converter.

9 Applications and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

The TPS656131-Q1 boost converter output voltage, V_{POS}, and the inverting converter output voltage, V_{NEG}, require external components to set the required output voltages. The valid output voltage ranges are as shown in *Recommended Operating Conditions*). The passages below show typical application examples with different output voltage settings and guidance for external component choices.

9.2 Typical Applications

9.2.1 TPS65131-Q1 With V_{POS} = 10.5 V, V_{NEG} = –10 V

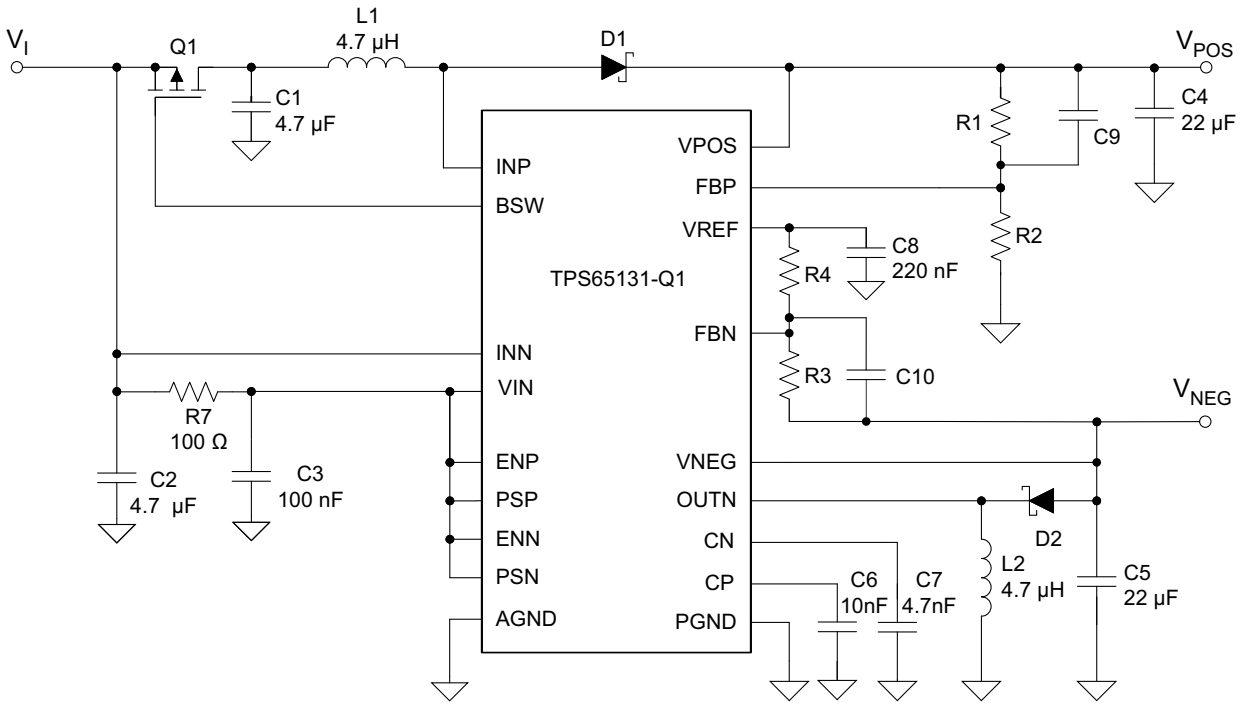


Figure 6. Typical Application Schematic With V_{POS} = 10.5 V, V_{NEG} = –10 V

9.2.1.1 Design Requirements

This design example uses the following parameters:

Table 3. Design Parameters

Design Parameter	Example Value	
Input voltage range	2.7 V to 5.5 V	
Boost converter output voltage, V_{POS}	R1 = 1 MΩ R2 = 130 kΩ C9 = 6.8 pF	10.5 V
Inverting converter output voltage, V_{NEG}	R3 = 1 MΩ R4 = 121.2 kΩ C10 = 7.5 pF	–10 V

In this example, the converters operate with power-save mode both enabled and disabled (see *Power-Save Mode*).

9.2.1.2 Detailed Design Procedure

9.2.1.2.1 Programming the Output Voltage

9.2.1.2.1.1 Boost Converter

An external resistor divider adjusts the output voltage of the TPS65131-Q1 boost converter stage. Connect this divider to the FBP pin. The typical value of the voltage at the FBP pin is the reference voltage, which is 1.213 V. The maximum recommended output voltage at the boost converter is 15 V. To achieve appropriate accuracy, the current through the feedback divider should be about 100 times higher than the current into the FBP pin. Typical current into the FBP pin is 0.05 µA, and the voltage across R2 is 1.213 V. Based on those values, the recommended value for R2 should be lower than 200 kΩ in order to set the divider current at 5 µA or higher.

Calculate the value of resistor R1, as a function of the needed output voltage (V_{POS}), with Equation 1:

$$R1 = R2 \times \left(\frac{V_{POS}}{V_{ref}} - 1 \right) \quad (1)$$

In this example, with R2 = 130 kΩ, choose R1 = 1 MΩ to set V_{POS} = 10.5 V.

9.2.1.2.1.2 Inverting Converter

An external resistor divider adjusts the output voltage of the TPS65131-Q1 inverting converter stage. Connect this divider to the FBN pin. Unlike the feedback divider at the boost converter, the reference point of the feedback divider is not GND, but V_{ref}. So the typical value of the voltage at the FBN pin is 0 V. The minimum recommended output voltage at the inverting converter is –15 V. Feedback divider current considerations are similar to the considerations for the boost converter. For the same reasons, the feedback divider current should be in the range of 5 µA or higher. The voltage across R4 is 1.213 V. Based on those values, the recommended value for R4 should be lower than 200 kΩ in order to set the divider current at the required value.

Calculate the value of resistor R3, as a function of the needed output voltage (V_{NEG}), with Equation 2:

$$R3 = -R4 \times \left(\frac{V_{NEG}}{V_{ref}} \right) \quad (2)$$

In this example, with R4 = 121.2 kΩ kΩ, choose R3 = 1 MΩ to set V_{NEG} = –10 V.

9.2.1.2.2 Inductor Selection

An inductive converter normally requires two main passive components to store energy during the conversion. Therefore, each converter requires an inductor and a storage capacitor. To select the right inductor, it is recommended to keep the possible peak inductor current below the current-limit threshold of the power switch in the chosen configuration. For example, the current-limit threshold of the switch for the boost converter and for the inverting converters is nominally 1950 mA. The highest peak current through the switches and the inductor depends on the output load (I_{POS}, I_{NEG}), the input voltage (V_I), and the output voltages (V_{POS}, V_{NEG}). Use Equation 3 to estimate the peak inductor current in the boost converter, $I_{(L-P)}$. Equation 4 shows the corresponding formula for the inverting converter, $I_{(L-N)}$.

$$I_{(L-P)} = \frac{V_{POS}}{V_I \times 0.64} \times I_{POS} \quad (3)$$

$$I_{(L-N)} = \frac{V_I - V_{NEG}}{V_I \times 0.64} \times I_{NEG} \quad (4)$$

The second parameter for choosing the inductor is the desired current ripple in the inductor. Normally, it is advisable to work with a ripple of less than 20% of the average inductor current. A smaller ripple reduces the losses in the inductor, as well as output voltage ripple and EMI. But in the same way, output voltage regulation gets slower, causing higher voltage changes during fast load changes. In addition, a larger inductor usually increases the total system cost. Keep those parameters in mind and calculate the possible inductor value with Equation 5 for the boost converter (L1) and Equation 6 for the inverting converter (L2).

$$L1 = \frac{V_I \times (V_{POS} - V_I)}{\Delta I_{(L-P)} \times f \times V_{POS}} \quad (5)$$

$$L2 = \frac{V_I \times V_{NEG}}{\Delta I_{(L-N)} \times f \times (V_{NEG} - V_I)} \quad (6)$$

The parameter f is the switching frequency. For the boost converter, $\Delta I_{(L-P)}$ is the ripple current in the inductor, that is, 20% of $I_{(L-P)}$. Accordingly, for the inverting converter, $\Delta I_{(L-N)}$ is the ripple current in the inductor, that is, 20% of $I_{(L-N)}$. V_I is the input voltage, which is 3.3 V in this example. So, the calculated inductance value for the boost inductor is 5.1 µH and for the inverting converter inductor is 5.1 µH. With these calculated values and the calculated currents, it is possible to choose a suitable inductor.

In typical applications, the recommendation is to choose a 4.7-µH inductor. The device is optimized to work with inductance values between 3.3 µH and 6.8 µH. Nevertheless, operation with higher inductance values may be possible in some applications. Perform detailed stability analysis in this case. Be aware of the possibility that load transients and losses in the circuit can lead to higher currents than estimated in Equation 3 and Equation 4. Also, the losses caused by magnetic hysteresis and conductor resistance are a major parameter for total circuit efficiency.

The following table shows inductors from different suppliers used with the TPS65131-Q1 converter:

Table 4. List of Inductors

VENDOR	INDUCTOR SERIES
EPCOS	B8246284-G4
Wurth Elektronik	7447789XXX
	744031XXX
TDK	VLF3010
	VLF4012
Cooper Electronics Technologies	SD12

9.2.1.2.3 Capacitor Selection

9.2.1.2.3.1 Input Capacitor

As a recommendation, choose an input capacitors of at least 4.7 µF for the input of the boost converter (INP) and accordingly for the input of the inverting converter (INN). This improves transient behavior of the regulators and EMI behavior of the total power-supply circuit. Choose a ceramic capacitor or a tantalum capacitor. For the use of a tantalum capcitor, an additonal, smaller ceramic capacitor (100 nF) in parallel is required. Place the input capacitor(s) close to the input pins.

9.2.1.2.3.2 Output Capacitors

One of the major parameters necessary to define the capacitance value of the output capacitor is the maximum allowed output voltage ripple of the converter. Two parameters, which are the capacitance and the equivalent series resitance (ESR), affect this ripple. It is possible to calculate the minimum capacitance needed for the defined ripple, supposing that the ESR is zero. Use Equation 7 for the boost-converter output capacitor (C4min) and Equation 8 for the inverting-converter output capacitor (C5min).

$$C4\,min = \frac{I_{POS} \times (V_{POS} - V_I)}{f \times \Delta V_{POS} \times V_{POS}} \quad (7)$$

$$C5\,min = \frac{I_{NEG} \times V_{NEG}}{f \times \Delta V_{NEG} \times (V_{NEG} - V_I)} \quad (8)$$

The parameter f is the switching frequency. ΔV_{POS} and ΔV_{NEG} are the maximum allowed ripple voltages for each converter.

Choosing a ripple voltage in the range of 10 mV requires a minimum capacitance of 12 µF. The total ripple is larger due to the ESR of the output capacitor. Use Equation 9 for the boost converter and Equation 10 for the inverting converter to calculate this additional ripple component.

$$\Delta V_{(ESR-P)} = I_{POS} \times R_{(ESR-C4)} \quad (9)$$

$$\Delta V_{(ESR-N)} = I_{NEG} \times R_{(ESR-C5)} \quad (10)$$

In this example, an additional ripple of 2 mV is the result of using a typical ceramic capacitor with an ESR in the 10-mΩ range. The total ripple is the sum of the ripple caused by the capacitance and the ripple caused by the ESR of the capacitor. In this example, the total ripple is 10 mV.

Load transients can create additional ripple. When the load current increases rapidly, the output capacitor must provide the additional current until the inductor current increases by the control loop which sets a higher on-time (duty cycle) of the main switch. The higher duty cycle results in longer inductor charging periods. The inductance itself also limits the rate of increase of the inductor current. When the load current decreases rapidly, the output capacitor must store the excess energy (stored in the inductor) until the regulator has decreased the inductor current by reducing the duty cycle. The recommendation is to use higher capacitance values, as the foregoing calculations show.

9.2.1.2.4 Rectifier Diode Selection

Both converters (the boost and inverting converter) require rectifier diodes, D1 and D2. As a recommendation, to reduce losses, use Schottky diodes. The forward current rating needed is equal to the maximum output current. Consider that the maximum currents, I_{POS}max and I_{NEG}max, might differ for V_{POS} and V_{NEG} when choosing the diodes.

9.2.1.2.5 External P-MOSFET Selection

During shutdown, when connected to a power supply, a path from the power supply to the positive output conducts through the inductor and an external diode. Optionally, in oder to fully disconnect the positive output V_{POS} during shutdown, add an external p-MOSFET (Q1). The BSW pin controls the gate of the p-MOSFET. When choosing a proper p-MOSFET, the V_{GS} and V_{GD} voltage ratings must cover the input voltage range, the drain current rating must not be lower than the maximum input current flowing into the application, and conditions of the p-MOSFET operating area must fit.

If there is no intention to use an external p-MOSFET, leave the BSW pin floating.

9.2.1.2.6 Stabilizing the Control Loop

9.2.1.2.6.1 Feedforward Capacitors

As a recommendation, to speed up the control loop, place feedforward capacitors in the feedback divider, parallel to R1 (boost converter) and R3 (inverting converter). Equation 11 shows how to calculate the appropriate value for the boost converter, and Equation 12 for the inverting converter.

$$C9 = \frac{6.8\ \mu s}{R1} \quad (11)$$

$$C10 = \frac{7.5\ \mu s}{R3} \quad (12)$$

In this application example, C9 = 6.8 pF and C10 = 7.5 pF match the choices of R1 and R3.

To avoid coupling noise into the control loop from the feedforward capacitors, it is possible to place a series resistor to limit the bandwidth of the feedforward effect. Any value between 10 kΩ and 100 kΩ is suitable. The higher the resistance, the lower the noise coupled into the control loop system.

9.2.1.2.6.2 Compensation Capacitors

The device features completely internally compensated control loops for both converters. The internal feedforward system has built-in error correction which requires external capacitors. As a recommendation, use a 10-nF capacitor at the CP pin of the boost converter and a 4.7-nF capacitor at the CN pin of the inverting converter.

9.2.1.3 Thermal Information

Implementation of integrated circuits in low-profile and fine-pitch surface-mount packages typically requires special attention to power dissipation. Many system-dependent issues, such as thermal coupling, airflow, added heatsinks and convection surfaces, and the presence of heat-generating components affect the power-dissipation limits of a given component.

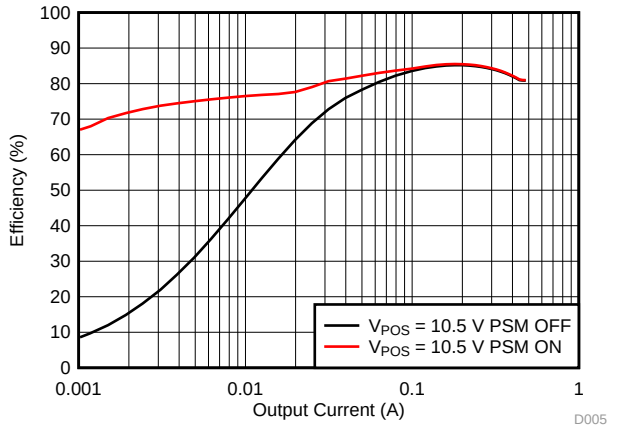
Three basic approaches for enhancing thermal performance follow.

- Improving the power dissipation capability of the PCB design
- Improving the thermal coupling of the component to the PCB
- Introducing airflow to the system

The recommended device junction temperature range, T_J, is –40°C to 125°C. The thermal resistance of the 24-pin QFN, 4–mm × 4–mm package (RGE) is $R_{\theta JA}$ = 34.1°C/W. The recommended operating ambient temperature range for the device is T_A = –40°C to 105°C. Use Equation 13 to calculate the maximum power dissipation, $P_D$max, as a function of T_A. In this equation, use T_J = 125°C to operate the device within the recommended temperature range, use $T_J = T_{(TS)}$ to determine the absolute maximum threshold when the device might go into thermal shutdown. If the maximum ambient temperature of the application is lower, more heat dissipation is possible.

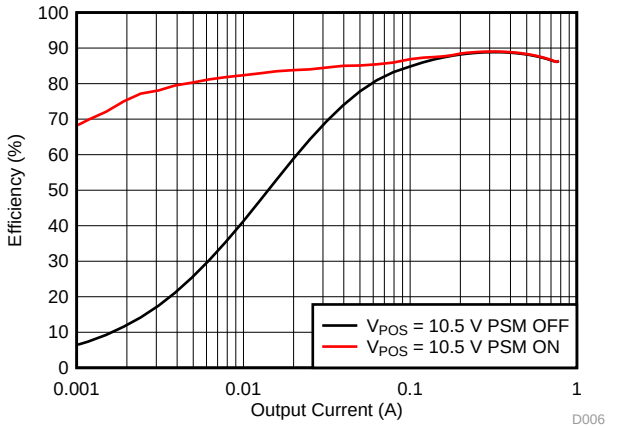
$$P_D \max = \frac{T_J - T_A}{R_{\theta JA}} \tag{13}$$

9.2.1.4 Application Curves



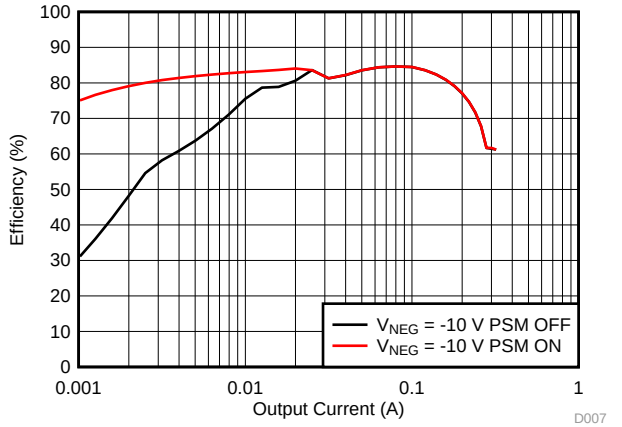
V_I = 3.3 V V_{POS} = 10.5 V Power-save mode on and off

Figure 7. Boost Converter (V_{POS}) Efficiency vs Output Current



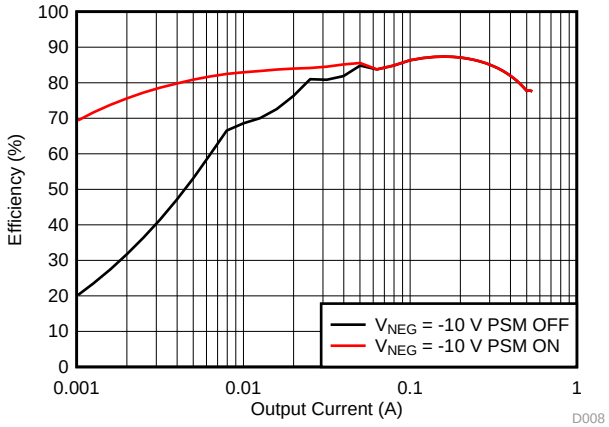
V_I = 5 V V_{POS} = 10.5 V Power-save mode on and off

Figure 8. Boost Converter (V_{POS}) Efficiency vs Output Current



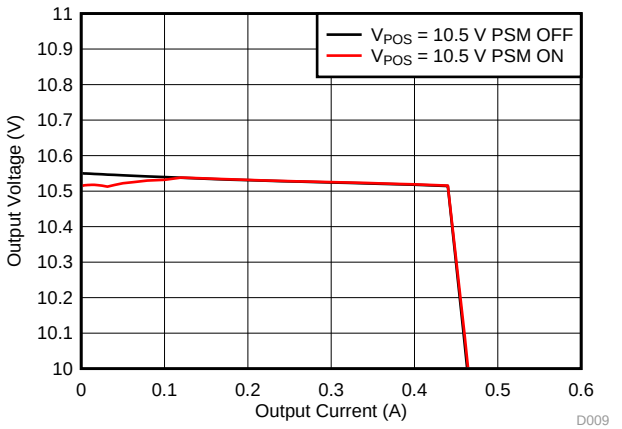
V_I = 3.3 V V_{NEG} = –10 V Power-save mode on and off

Figure 9. Inverting Converter (V_{NEG}) Efficiency vs Output Current



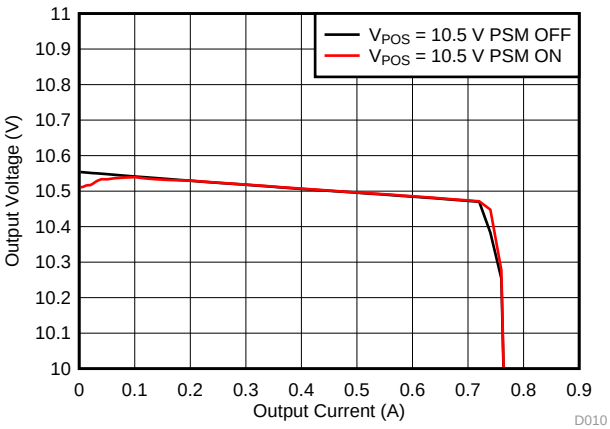
V_I = 5 V V_{NEG} = –10 V Power-save mode on and off

Figure 10. Inverting Converter (V_{NEG}) Efficiency vs Output Current



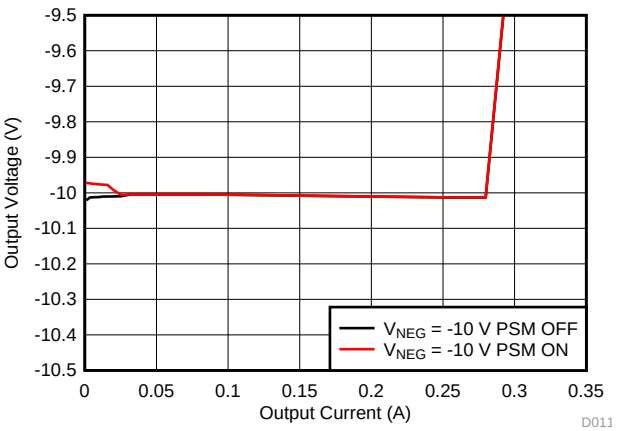
V_I = 3.3 V V_{POS} = 10.5 V Power-save mode on and off

Figure 11. Boost Converter (V_{POS}) Output Voltage vs Output Current



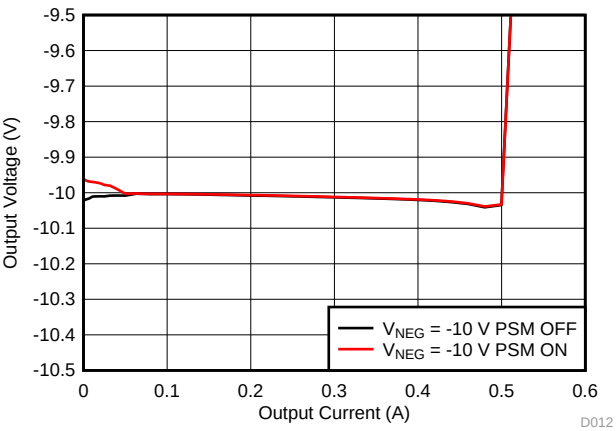
V_I = 5 V V_{POS} = 10.5 V Power-save mode on and off

Figure 12. Boost Converter (V_{POS}) Output Voltage vs Output Current



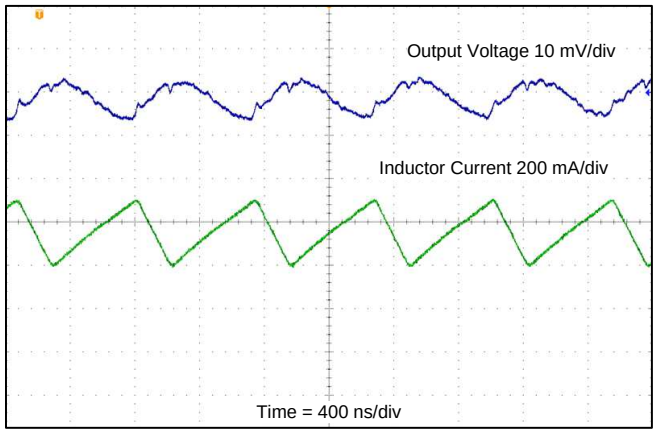
V_I = 3.3 V V_{NEG} = –10 V Power-save mode on and off

Figure 13. Inverting Converter (V_{NEG}) Output Voltage vs Output Current



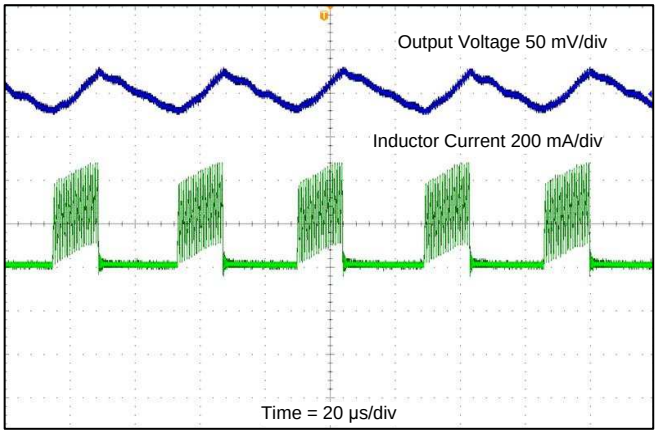
V_I = 5 V V_{NEG} = –10 V Power-save mode on and off

Figure 14. Inverting Converter (V_{NEG}) Output Voltage vs Output Current



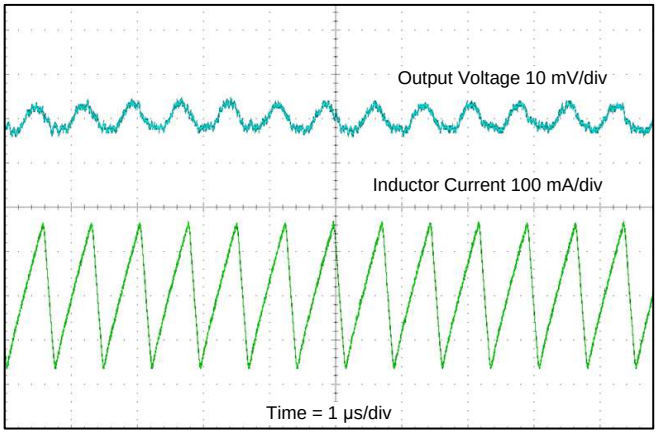
V_I = 3.3 V V_{POS} = 10.5 V I_{POS} = 200 mA Power-save mode off

Figure 15. Boost Converter (V_{POS}) Output Ripple



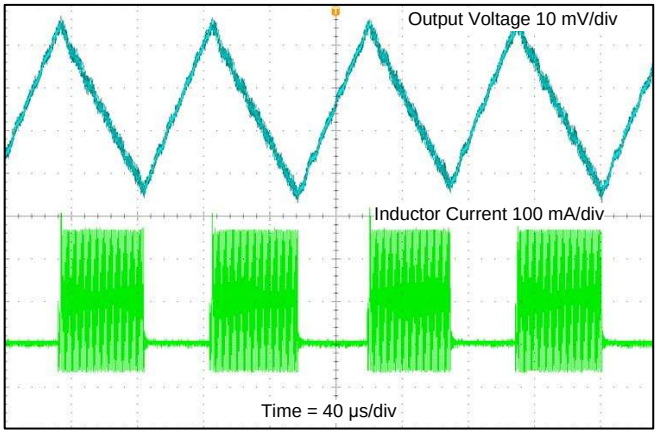
V_I = 3.3 V V_{POS} = 10.5 V I_{POS} = 20 mA Power-save mode on

Figure 16. Boost Converter (V_{POS}) Output Ripple



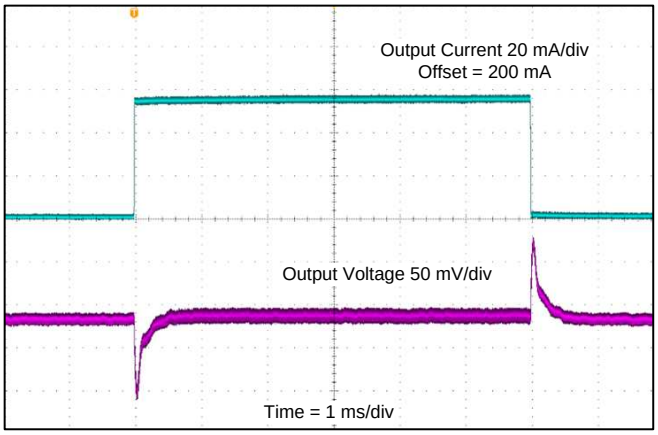
V_I = 3.3 V V_{NEG} = –10 V I_{NEG} = 200 mA Power-save mode off

Figure 17. Inverting Converter (V_{NEG}) Output Ripple



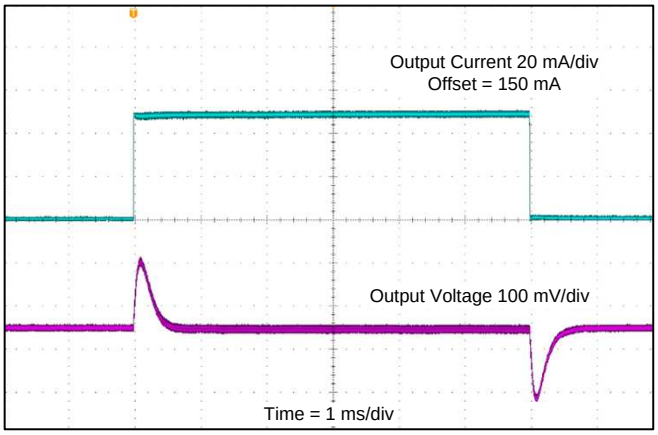
V_I = 3.3 V V_{NEG} = –10 V I_{NEG} = 20 mA Power-save mode on

Figure 18. Inverting Converter (V_{NEG}) Output Ripple



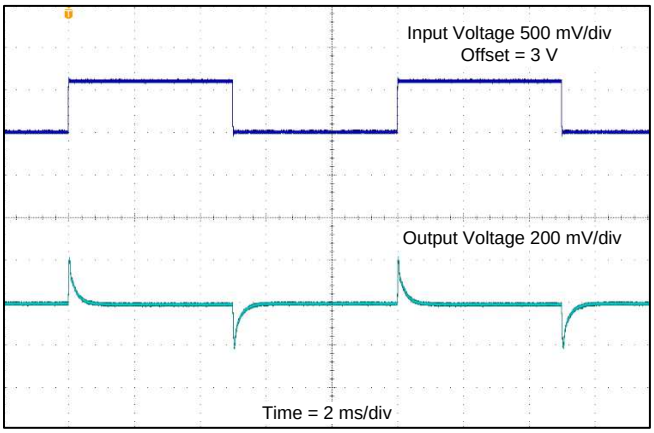
V_I = 3.3 V V_{POS} = 10.5 V I_{POS} = 200 mA to 250 mA

Figure 19. Boost Converter (V_{POS}) Load Transient Response



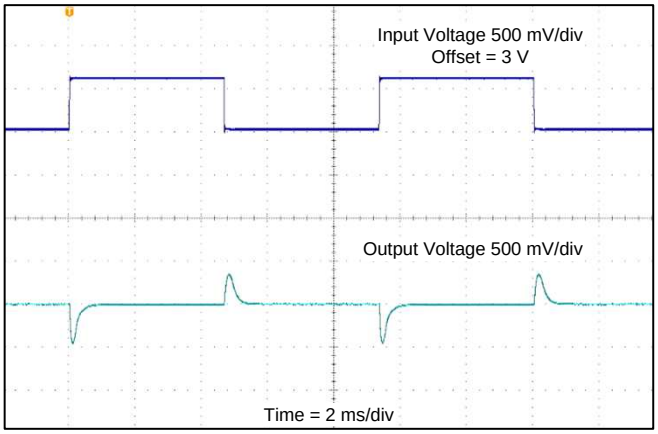
V_I = 3.3 V V_{NEG} = –10 V I_{NEG} = 150 mA to 200 mA

Figure 20. Inverting Converter (V_{NEG}) Load Transient Response



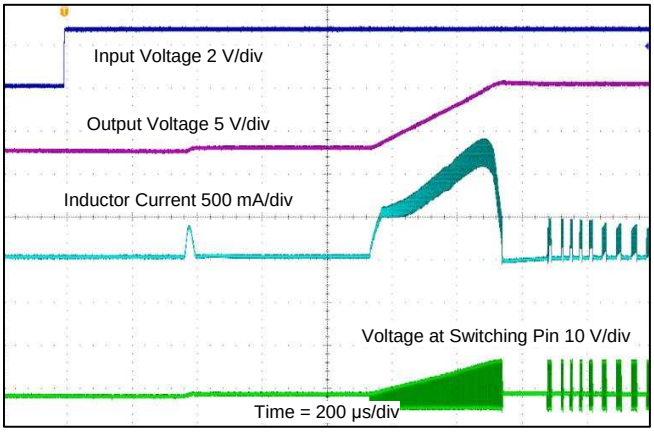
V_I = 3 V to 3.6 V V_{POS} = 10.5 V I_{POS} = 150 mA

Figure 21. Boost Converter (V_{POS}) Line Transient Response



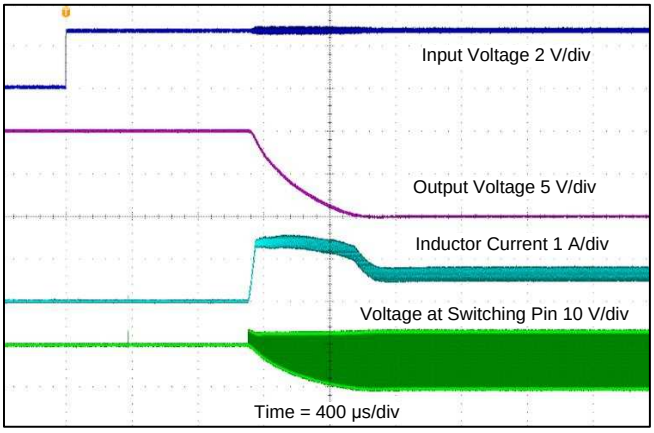
V_I = 3 V to 3.6 V V_{NEG} = –10 V I_{NEG} = 100 mA

Figure 22. Inverting (V_{NEG}) Converter Line Transient Response



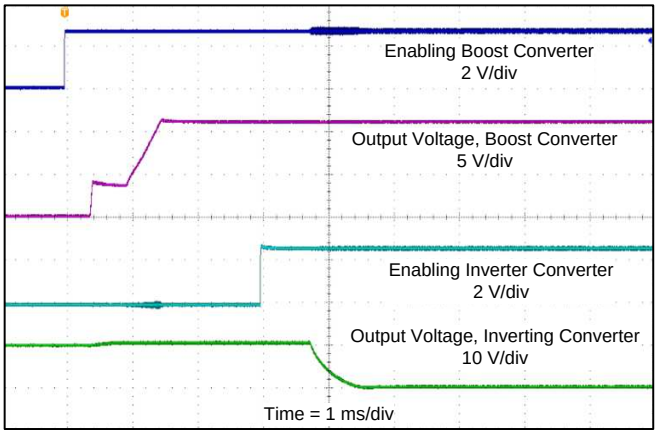
V_I = 3.3 V V_{POS} = 10.5 V I_{POS} = 46 mA

Figure 23. Boost Converter (V_{POS}) Start-Up Into Load



V_I = 3.3 V V_{NEG} = –10 V I_{NEG} = 150 mA

Figure 24. Inverting Converter (V_{NEG}) Start-Up Into Load



V_I = 3.3 V V_{POS} = 10.5 V V_{NEG} = –10 V
I_{POS} = I_{NEG}= 160 mA

Figure 25. Boost and Inverting Converter Start-Up Into Load

9.2.2 TPS65131-Q1 With V_{POS} = 5.5 V, V_{NEG} = –5 V

9.2.2.1 Design Requirements

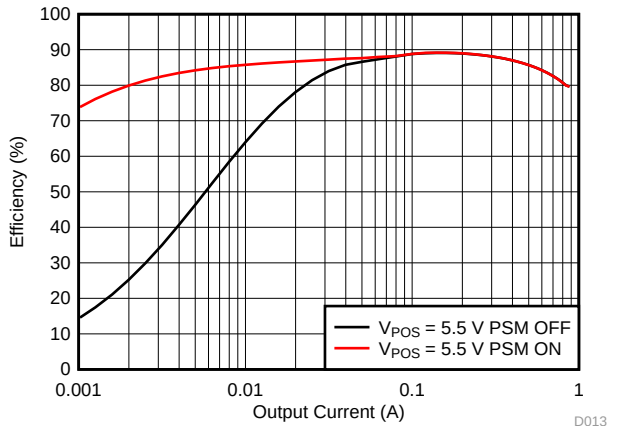
The design procedure for this setup is similar to the first example, see *Detailed Design Procedure*. Change the feedback dividers to set the output voltage, see *Programming the Output Voltage*. Further, choose the feed-forward capacitors according to *Feedforward Capacitors*. Table 5 shows the components being changed. See Figure 6.

Table 5. Design Parameters

Design Parameter	Example Value	
Input voltage range	2.7 V to 5.5 V	
Boost converter output voltage, V_{POS}	R1 = 390 kΩ R2 = 110 kΩ C9 = 18 pF	5.5 V
Inverting converter output voltage, V_{NEG}	R3 = 620 kΩ R4 = 150 kΩ C10 = 12 pF	–5 V

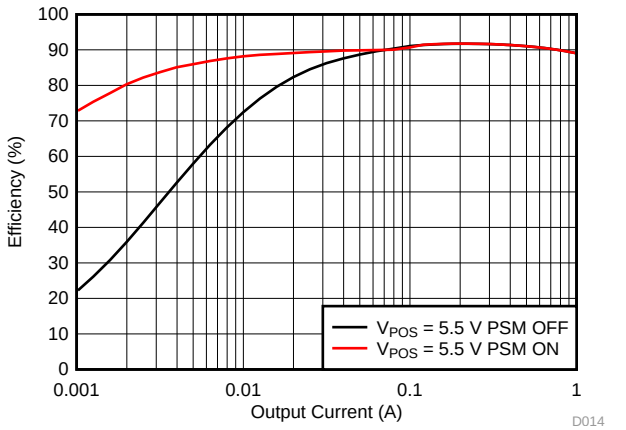
In this example, the converters are operated with power-save mode both enabled and disabled (see *Power-Save Mode*).

9.2.2.2 Application Curves



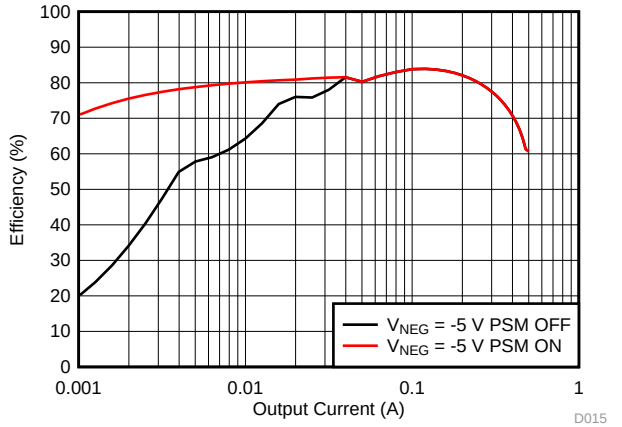
V_I = 3.3 V V_{POS} = 5.5 V Power-save mode on and off

Figure 26. Boost Converter (V_{POS}) Efficiency vs Output Current



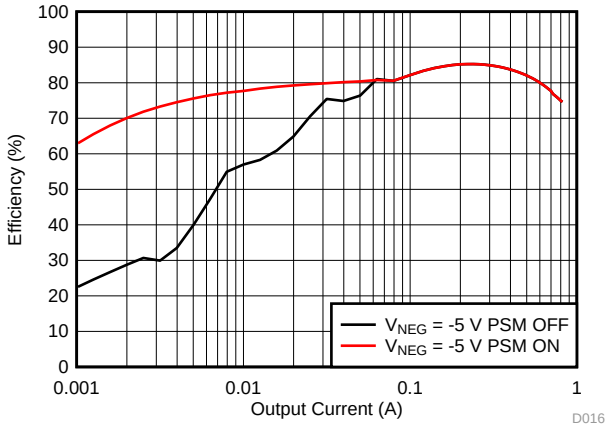
V_I = 5 V V_{POS} = 5.5 V Power-save mode on and off

Figure 27. Boost Converter (V_{POS}) Efficiency vs Output Current



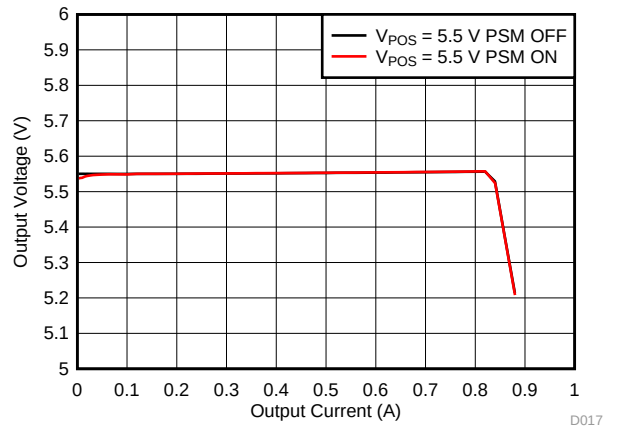
V_I = 3.3 V V_{NEG} = –5 V Power-save mode on and off

Figure 28. Inverting Converter (V_{NEG}) Efficiency vs Output Current



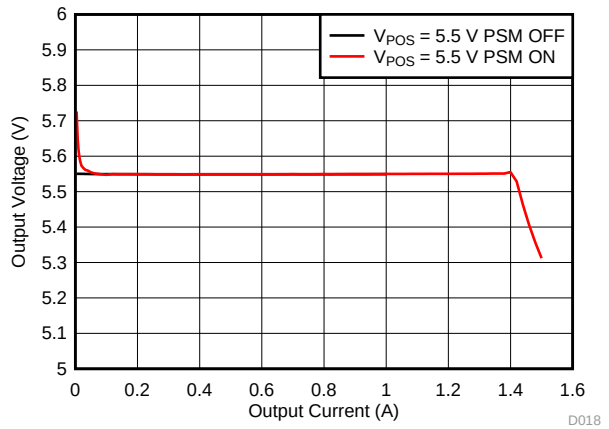
V_I = 5 V V_{NEG} = –5 V Power-save mode on and off

Figure 29. Inverting Converter (V_{NEG}) Efficiency vs Output Current



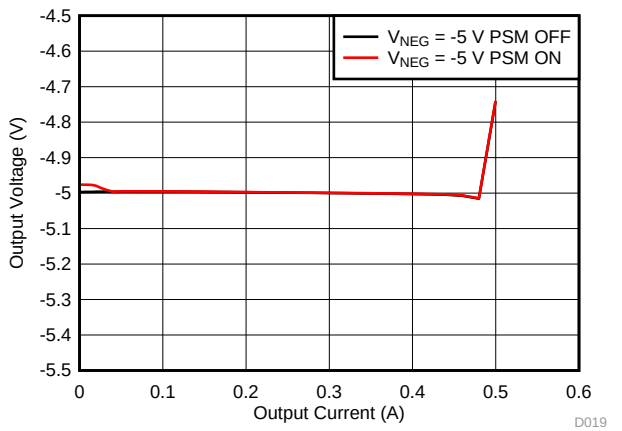
V_I = 3.3 V V_{POS} = 5.5 V Power-save mode on and off

Figure 30. Boost Converter (V_{POS}) Output Voltage vs Output Current



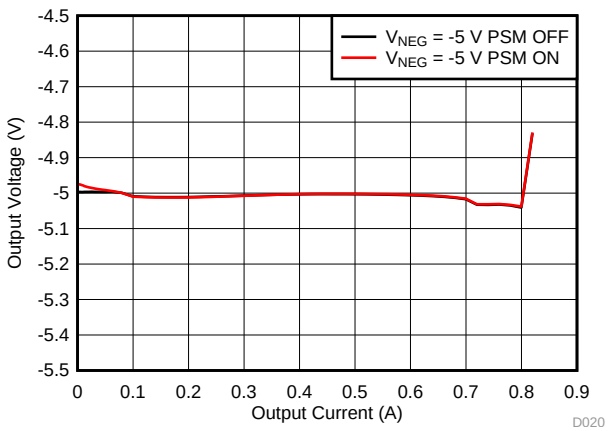
V_I = 5 V V_{POS} = 5.5 V Power-save mode on and off

Figure 31. Boost Converter (V_{POS}) Output Voltage vs Output Current



V_I = 3.3 V V_{NEG} = –5 V Power-save mode on and off

Figure 32. Inverting Converter (V_{NEG}) Output Voltage vs Output Current



V_I = 3.3 V V_{NEG} = –5 V Power-save mode on and off

Figure 33. Inverting Converter (V_{NEG}) Output Voltage vs Output Current

9.2.3 TPS65131-Q1 With V_{POS} = 15 V, V_{NEG} = –15 V

9.2.3.1 Design Requirements

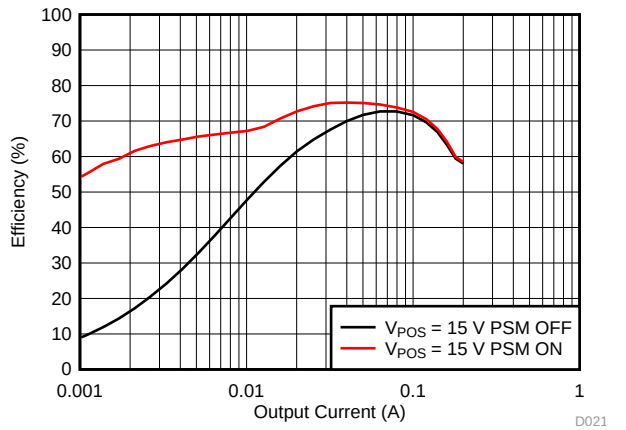
The design procedure for this setup is similar to the first example, see *Detailed Design Procedure*. Change the feedback dividers to set the output voltage, see *Programming the Output Voltage*. Further, choose the feedforward capacitors according to *Feedforward Capacitors*. Table 6 shows the components being changed. See Figure 6.

Table 6. Design Parameters

Design Parameter	Example Value	
Input voltage range	2.7 V to 5.5 V	
Boost converter output voltage, V_{POS}	R1 = 975 kΩ R2 = 85.8 kΩ C9 = 6.8 pF	15 V
Inverting converter output voltage, V_{NEG}	R3 = 1.3 MΩ R4 = 104.8 kΩ C10 = 5.6 pF	–15 V

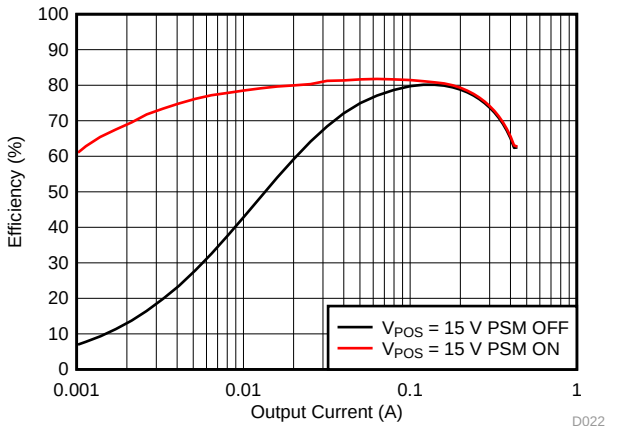
In this example, the converters operate with power-save mode both enabled and disabled (see *Power-Save Mode*).

9.2.3.2 Application Curves



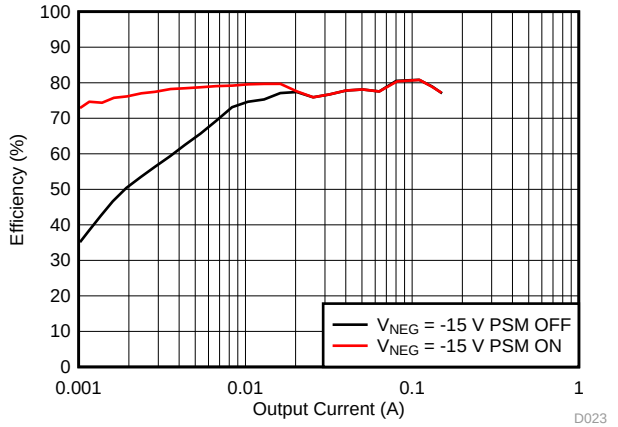
V_I = 3.3 V V_{POS} = 15 V Power-save mode on and off

Figure 34. Boost Converter (V_{POS}) Efficiency vs Output Current



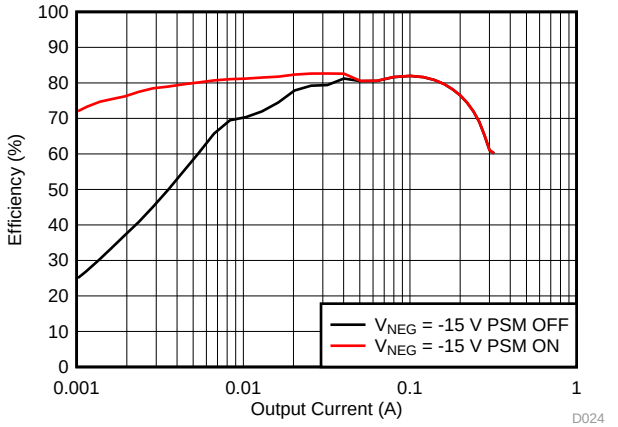
V_I = 5 V V_{POS} = 15 V Power-save mode on and off

Figure 35. Boost Converter (V_{POS}) Efficiency vs Output Current



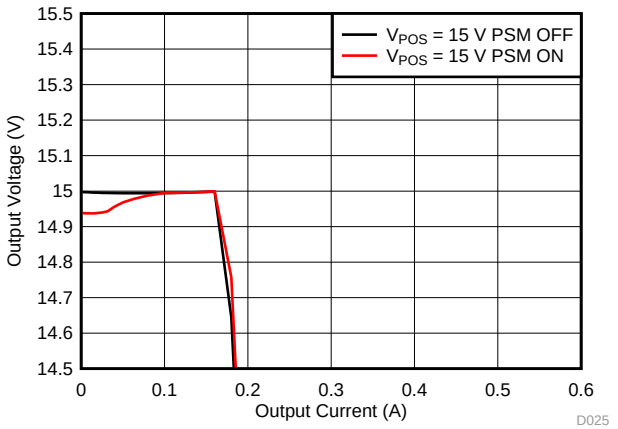
V_I = 3.3 V V_{NEG} = –15 V Power-save mode on and off

Figure 36. Inverting Converter (V_{NEG}) Efficiency vs Output Current



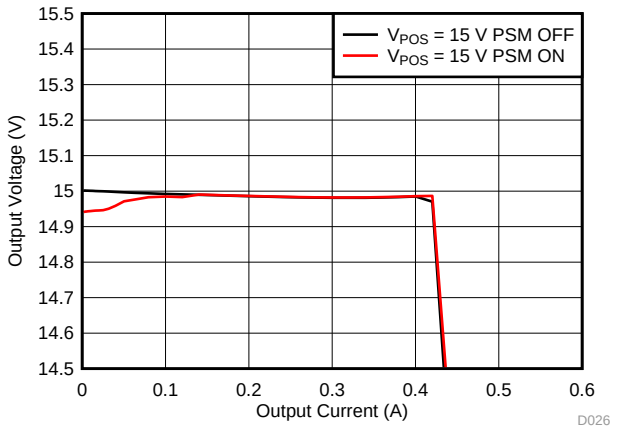
V_I = 5 V V_{NEG} = –15 V Power-save mode on and off

Figure 37. Inverting Converter (V_{NEG}) Efficiency vs Output Current



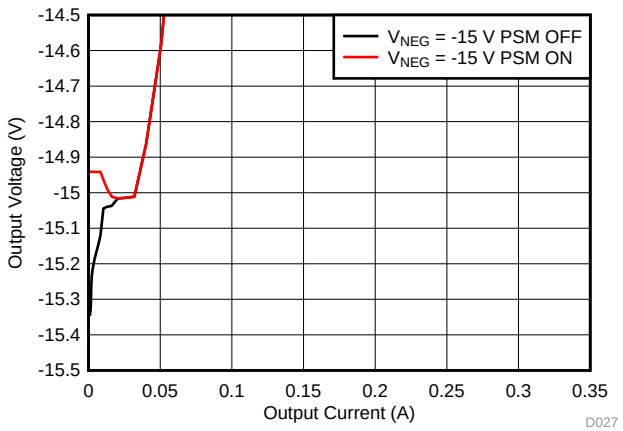
V_I = 3.3 V V_{POS} = 15 V Power-save mode on and off

Figure 38. Boost Converter (V_{POS}) Output Voltage vs Output Current



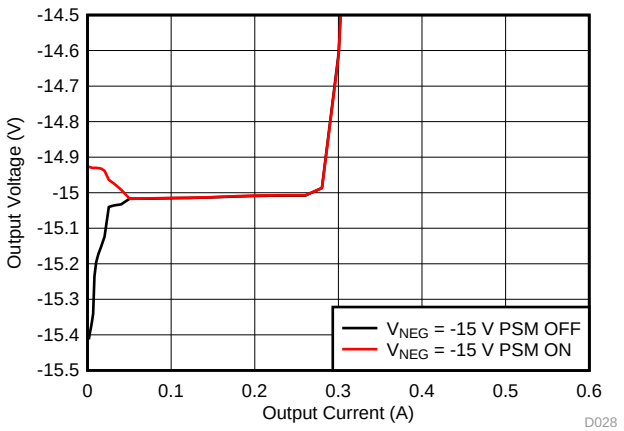
V_I = 5 V V_{POS} = 15 V Power-save mode on and off

Figure 39. Boost Converter (V_{POS}) Output Voltage vs Output Current



V_I = 3.3 V V_{NEG} = –15 V Power-save mode on and off

Figure 40. Inverting Converter (V_{NEG}) Output Voltage vs Output Current



V_I = 5 V V_{NEG} = –15 V Power-save mode on and off

Figure 41. Inverting Converter (V_{NEG}) Output Voltage vs Output Current

10 Power Supply Recommendations

The TPS65131-Q1 input voltage ranges from 2.7 V to 5.5 V. Consequently, the supply can come, for example, from a 3.3-V or 5-V rail. If the device starts into load during the *Soft Start* phase, the drawn input current can be higher than during post-start operation. Consider the application requirements when selecting the power supply.

To avoid unintended toggling of the *Undervoltage Lockout*, connect the TPS65131-Q1 via a low-impedance path to the power supply.

11 Layout

11.1 Layout Guidelines

As for all switching power supplies, the layout is an important step in the design, especially at high peak currents and high switching frequencies. Improper layout might show the symptoms of poor line or load regulation, ground and output voltage shifts, stability issues, unsatisfying EMI behavior or worsened efficiency. Therefore, use wide and short traces for the main current paths and for the power ground tracks. The input capacitors (C1, C2, C3), output capacitors (C4, C5), the inductors (L1, L2), and the rectifying diodes (D1, D2) should be placed as close as possible to the IC to keep parasitic inductances low. Use a wide PGND plane. Connect the analog ground pin (AGND) to the PGND plane. Further, connect the PGND plane with the exposed thermal pad. Place the feedback dividers as close as possible to the control pin (boost converter) or the VREF pin (inverting converter) of the IC.

Figure 42 provides an layout example which is recommended to be followed.

11.2 Layout Example

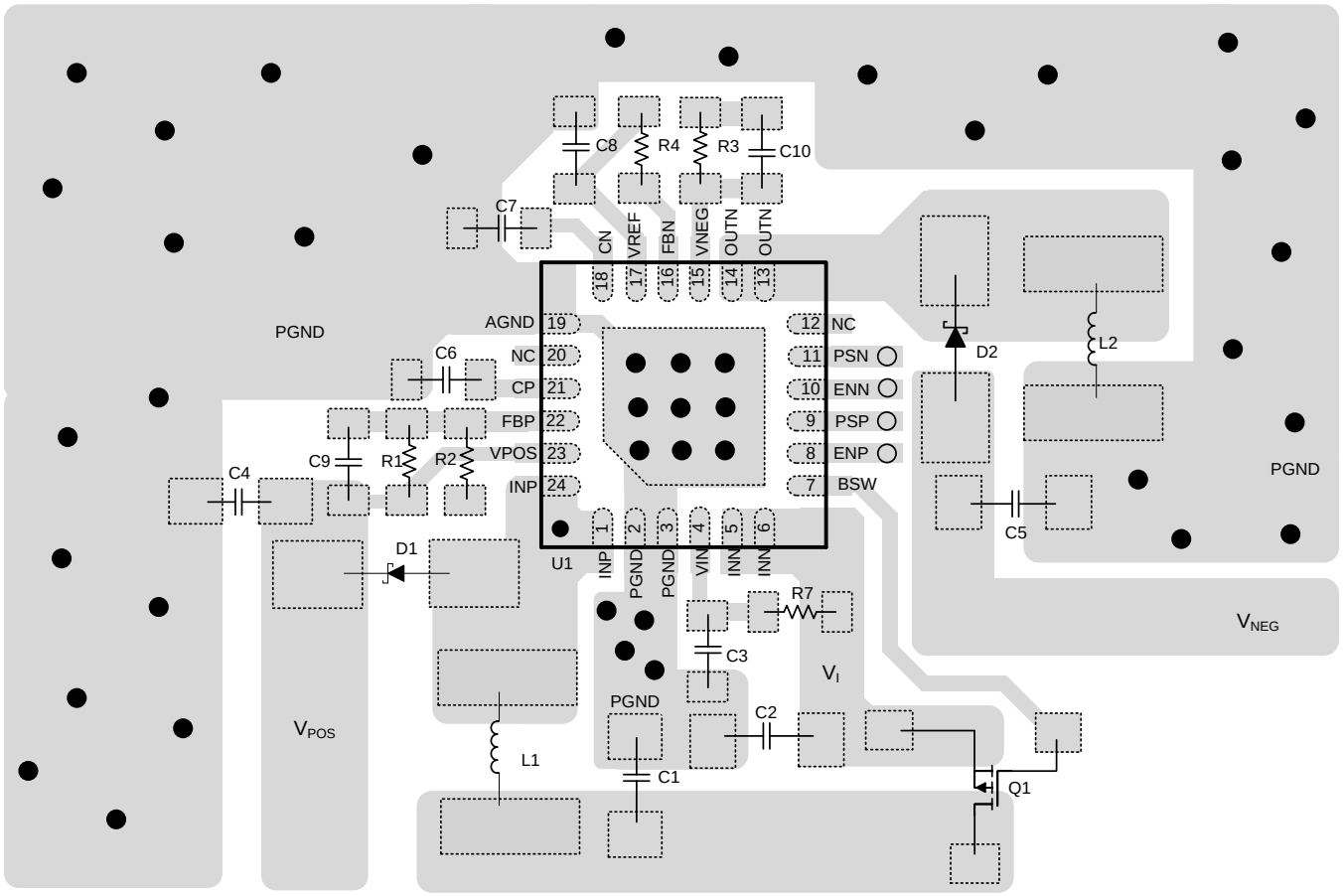


Figure 42. TPS65131-Q1 Layout Recommendation

12 Device and Documentation Support

12.1 Device Support

12.1.1 Third-Party Products Disclaimer

TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

12.2 Trademarks

PowerPAD is a trademark of Texas Instruments.

12.3 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most-current data available for the designated device. This data is subject to change without notice and without revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS65131TRGERQ1	ACTIVE	VQFN	RGE	24	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 105	2U65131 Q1	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

OTHER QUALIFIED VERSIONS OF TPS65131-Q1 :

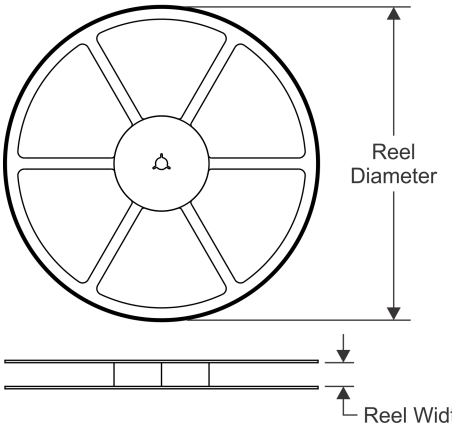
- Catalog: TPS65131

NOTE: Qualified Version Definitions:

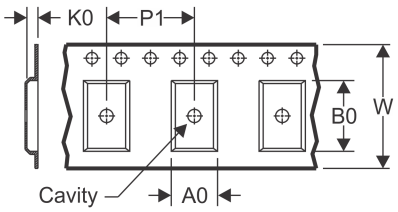
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

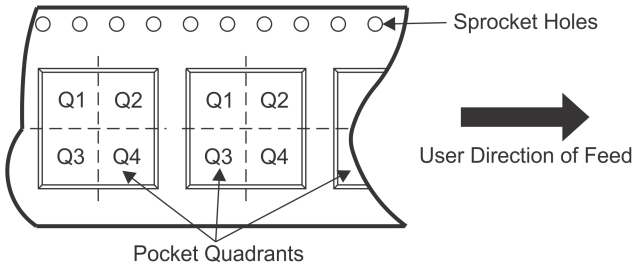


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

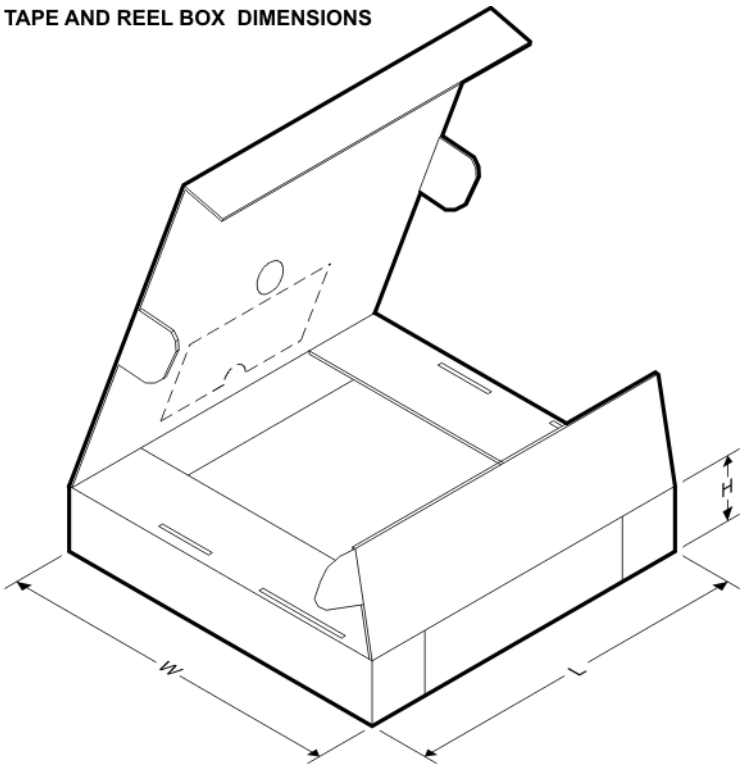
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS65131TRGERQ1	VQFN	RGE	24	3000	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2

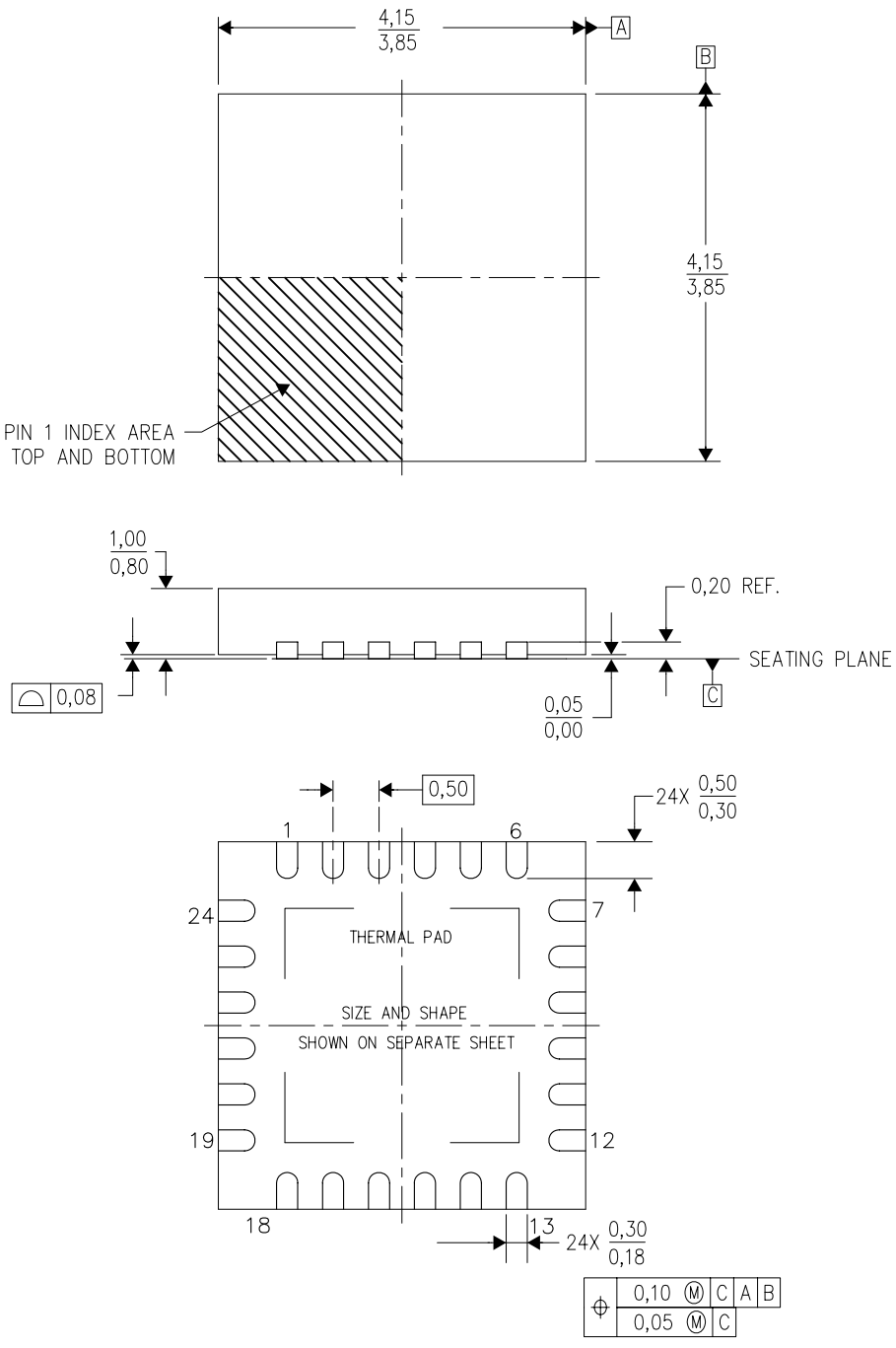
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS65131TRGERQ1	VQFN	RGE	24	3000	367.0	367.0	35.0

RGE (S–PVQFN–N24) PLASTIC QUAD FLATPACK NO–LEAD



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Quad Flatpack, No–Leads (QFN) package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
F. Falls within JEDEC MO–220.

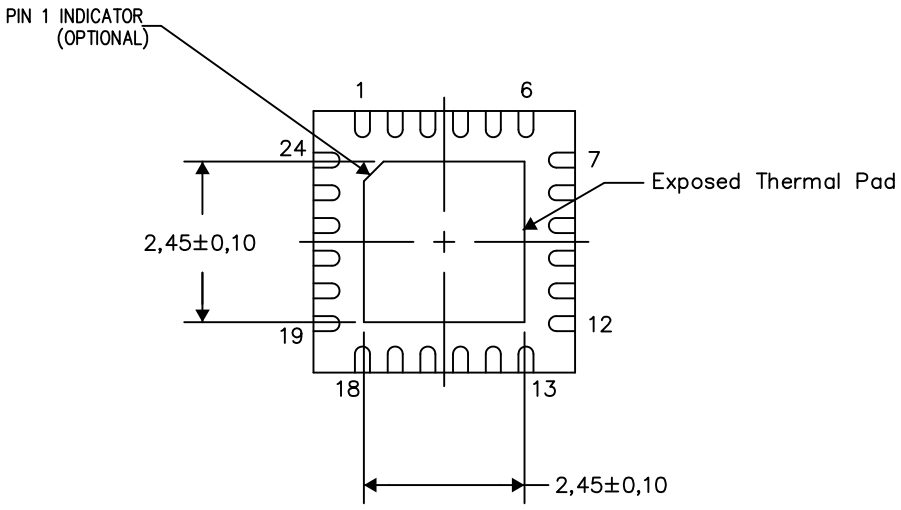
RGE (S–PVQFN–N24) PLASTIC QUAD FLATPACK NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



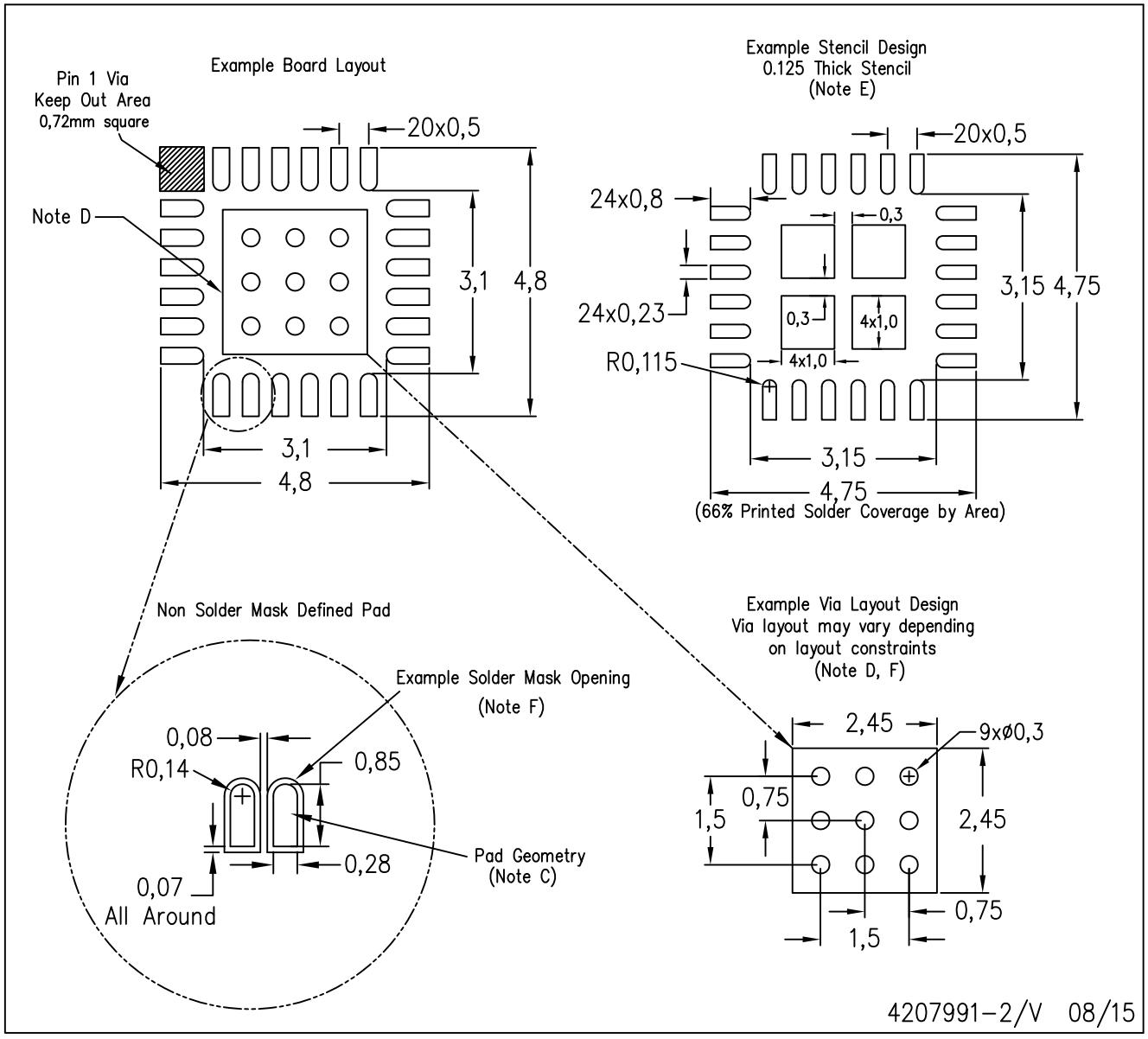
Bottom View

Exposed Thermal Pad Dimensions

4206344–3/AK 08/15

NOTES: A. All linear dimensions are in millimeters

RGE (S–PVQFN–N24) PLASTIC QUAD FLATPACK NO–LEAD



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265