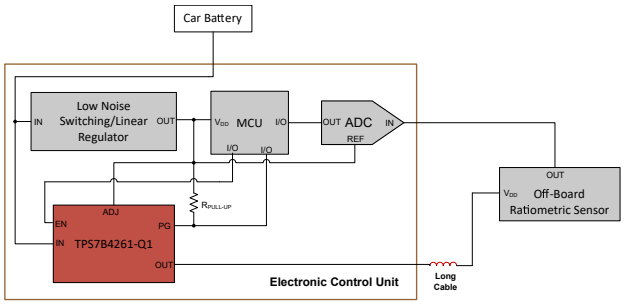
TPS7B4261-Q1 Automotive, 300mA, 40V, Voltage Tracking LDO With PG

1 Features

- AEC-Q100 qualified for automotive applications:
  - Temperature grade 1: –40°C to +125°C, T_A
  - Junction temperature: –40°C to +150°C, T_J
- Wide input voltage range:
  - Absolute maximum range: –40V to 45V
  - Operating range: 3.3V to 40V
- Wide output voltage range: 2V to 40V
- Maximum output current: 300mA
- Very tight output-tracking tolerance: 6mV (max)
- Low dropout voltage: 330mV at 200mA
- Independent enable pin functionality
- Power-good functionality detects under- and overvoltage conditions
- Low quiescent current at light load: 55µA
- Stable over a wide range of ceramic output capacitor values:
  - C_{OUT} range: 1µF to 100µF
  - ESR range: 1mΩ to 2Ω
- Integrated protection features:
  - Reverse current protection
  - Reverse polarity protection
  - Overtemperature protection
  - Protection against output short circuit to ground and supply
- Available in a low thermal resistance, 8-pin package:
  - HSOIC (DDA), $R_{\theta JA}$ = 48°C/W

2 Applications

- Powertrain pressure sensors
- Powertrain temperature sensors
- Powertrain exhaust sensors
- Powertrain fluid concentration sensors
- Body control modules (BCM)
- Zone control modules (ZCM)
- HVAC control modules



Typical Application

3 Description

The TPS7B4261-Q1 is a monolithic, integrated low-dropout voltage tracker. The device is available in an 8-pin HSOIC package. The TPS7B4261-Q1 is designed to supply off-board sensors in an automotive environment. The high 300mA current rating of the device potentially allows a single TPS7B4261-Q1 to power multiple off-board sensors simulataneously. 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 short to battery, reverse polarity, output short to ground (current limit), and overtemperature (thermal shutdown). The device incorporates a back-to-back P-channel metal-oxide semiconductor field-effect transistor (PMOS) topology. This topology eliminates the need for an otherwise required external diode that helps protect against fault conditions that result in flow of reverse current. 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 adjustable input pin (ADJ) is tracked with a very tight 6mV (max) tolerance across line, load, and temperature at the OUT pin. This tight tracking tolerance enables the TPS7B4261-Q1 to deliver a power-supply voltage with high precision for loads up to 300mA. The TPS7B4261-Q1 features an independent enable pin (EN) and power-good functionality that detects both under- and overvoltage fault conditions.

By setting the EN input pin low, the TPS7B4261-Q1 switches to standby mode, in which the quiescent current consumption of the low-dropout regulator (LDO) reduces to less than 3.8µA (max).

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
TPS7B4261-Q1	DDA (HSOIC, 8)	6mm × 4.9mm

(1) For more information, see the *Mechanical, Packaging, and Orderable Information*.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.

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The TPS7B4261-Q1 provides an effective buffer to the reference voltage of an ADC and securely transmits this voltage (or a scaled version thereof) over a long cable to power off-board sensors. If the sensor is ratiometric and the output is sampled by the ADC, the described features of the TPS7B4261-Q1 help significantly improve the reliability and accuracy of the sensor measurements.

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4 Pin Configuration and Functions

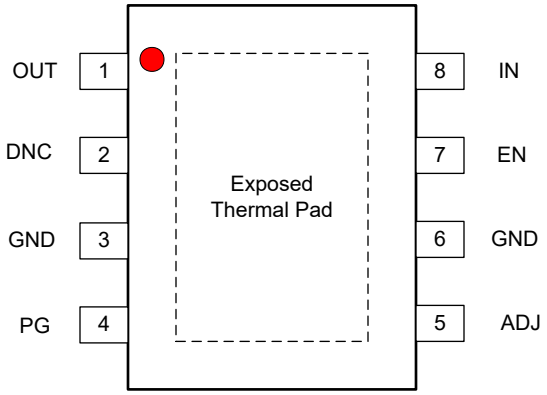

Figure 4-1. DDA Package, 8-Pin HSOIC (Top View)

Table 4-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	DDA		
ADJ	5	I	Adjustable input pin. Connect the external reference voltage to this pin, either directly or with a voltage divider for lower output voltages. This pin connects to the inverting input of the error amplifier internally. To compensate for line influences, place a 0.1µF capacitor close to this pin.
DNC	2	—	Do not connect a voltage source to this pin. Leave this pin floating or connect to GND to improve thermal performance.
EN	7	I	Enable pin. A low signal below V_{IL} disables the device, and a high signal above V_{IH} enables the device. Do not leave this pin floating.
GND	3, 6	G	GND pin. Connect this pin to a low impedance path to ground.
IN	8	I	Input power-supply voltage pin. For best transient response and to minimize input impedance, use the recommended value or larger ceramic capacitor from IN to GND. See the *Recommended Operating Conditions* table. Place the input capacitor as close to the input pin of the device as possible to compensate for line influences. See the *Input and Output Capacitor Selection* section for more details.
OUT	1	O	Regulated output voltage pin. A capacitor is required from OUT to GND for stability. For best transient response, select a ceramic capacitor within the range of C_{OUT} values provided in the *Recommended Operating Conditions* table. Place this capacitor as close to output of the device as possible. See the *Input and Output Capacitor Selection* section for more details.
PG	4	O	Active-high, open-drain based power-good pin. Connect this pin to a positive voltage via a pullup resistor. After device start-up, the pin assumes a logic low level only if the tracker output voltage fall below or exceeds the nominal V_{OUT} value by the under- or overvoltage threshold, respectively. This feature helps identify possible fault conditions on the tracker output. See the *Power Good* section for more details.
Thermal Pad	—		Thermal pad. Connect the pad to GND for best possible thermal performance.

5 Specifications

5.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
V_{IN}	Unregulated input pin voltage	–40	45	V
V_{OUT}	Regulated output pin voltage	–5	45	V
V_{EN}	Enable pin voltage	–40	45	V
V_{PG}	Power-good pin voltage	–0.3	45	V
V_{ADJ}	Adjustable reference input pin voltage	–40	45	V
T_J	Operating junction temperature	–40	150	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may effect the device reliability, functionality, performance, and shorten the device lifetime.

5.2 ESD Ratings

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002(1)		±2500	V
		Charged-device model (CDM), per AEC Q100-011	All pins	±1000	
			Corner pins		

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

5.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	TYP	MAX	UNIT
V_{IN}	Input voltage	3.3		40	V
V_{OUT}	Output voltage	2		40	V
I_{OUT}	Output current	0		300	mA
V_{EN}	Enable pin voltage	0		40	V
V_{ADJ}	Adjustable reference pin voltage	2		40	V
V_{PG}	Power-good pin voltage	0		40	V
C_{IN}	Input capacitor(1)		1		µF
C_{OUT}	Output capacitor(2)	1		100	µF
ESR	Output capacitor ESR requirements	0.001		2	Ω
T_J	Operating junction temperature	–40		150	°C

(1) For robust EMI performance the minimum input capacitance recommended is 500nF.
(2) Effective output capacitance of 500nF minimum is required for stability.

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5.4 Thermal Information

THERMAL METRIC(1) (2)		TPS7B4261-Q1	
		DDA (HSOIC)	UNIT
		8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	48	°C/W
$R_{\theta JCtop}$	Junction-to-case (top) thermal resistance	71.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	23.5	°C/W
ψ_{JT}	Junction-to-top characterization parameter	9.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	23.3	°C/W
$R_{\theta JCbot}$	Junction-to-case (bottom) thermal resistance	11.5	°C/W

(1) The thermal data is based on the JEDEC standard high-K board layout, JESD 51-7. This is a two-signal, two-plane, four-layer board with 2-oz. copper on the external layers. The copper pad is soldered to the thermal land pattern. Also, correct attachment procedure must be incorporated.
(2) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application note.

5.5 Electrical Characteristics

specified at T_J = –40°C to +150°C, V_{IN} = 13.5V, I_{OUT} = 100µA, C_{OUT} = 1µF, C_{IN} = 1µF, V_{EN} = 2V and V_{ADJ} = 5V (unless otherwise noted); typical values are at T_J = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_Q	Quiescent current	V_{IN} = 5.4V to 40V, I_{OUT} = 100µA, T_J = 25ºC			75	µA
		V_{IN} = 5.4V to 40V, I_{OUT} = 100µA, –40ºC < T_J < 85ºC			80	
		V_{IN} = 5.4V to 40V, I_{OUT} = 100µA			85	
I_{GND}	Ground current	V_{IN} = 5.4V to 40V, I_{OUT} = 300mA			3.2	mA
$I_{SHUTDOWN}$	Shutdown supply current	$V_{ADJ/EN}$ = 0V			3.8	µA
I_{ADJ}	ADJ pin current	I_{OUT} = 100µA			0.9	µA
$V_{UVLO\ (RISING)}$	Rising input supply UVLO	V_{IN} rising, I_{OUT} = 5mA	2.6	2.7	2.85	V
$V_{UVLO\ (FALLING)}$	Falling input supply UVLO	V_{IN} falling, I_{OUT} = 5mA	2.3	2.4	2.5	V
$V_{UVLO\ (HYST)}$	$V_{UVLO(IN)}$ hysteresis			300		mV
ΔV_{OUT}	Output voltage tracking accuracy	V_{IN} = V_{OUT} + 1.2V to 40V, I_{OUT} = 100µA to 300mA (1)	–6		6	mV
$\Delta V_{OUT\ (\Delta VIN)}$	Line regulation	V_{IN} = V_{OUT} + 1.2V to 40V, I_{OUT} = 100µA	–0.4		0.4	mV
$\Delta V_{OUT\ (\Delta IOUT)}$	Load regulation	V_{IN} = V_{OUT} + 1.2V, I_{OUT} = 100µA to 300mA (1)			2.1	mV
V_{DO}	Dropout voltage	I_{OUT} = 200mA, V_{ADJ} ≥ 3.3V, V_{IN} = V_{ADJ}		330	700	mV
I_{CL}	Output current limit	V_{IN} = V_{OUT} + 1.2V, V_{OUT} short to 90% x V_{ADJ}	301	430	560	mA
$V_{PG\ UV-TH}$	Power-good undervoltage threshold, V_{ADJ} - V_{OUT}	V_{OUT} decreasing, V_{IN} = V_{ADJ} = 0.5V, V_{IN} reducing	40	80	120	mV
$V_{PG\ OV-TH}$	Power-good overvoltage threshold, V_{OUT} - V_{ADJ}	V_{OUT} increasing, V_{IN} ≥ $V_{ADJ/REF}$ + 0.5V	40	80	120	mV
$V_{PG-HYST}$	Power-good hysteresis			25		mV
t_{PG}	Power-good reaction time		20	50	80	µS
$V_{PG,\ LOW}$	Power-good output low voltage	I_{PG} = 1.8mA			0.4	V
$I_{PG,\ LEAKAGE}$	Power-good pin leakage current	V_{PG} = 5V			2	µA
$V_{EN,\ OFF}$	Device disable voltage range				0.8	V
$V_{EN,\ ON}$	Device enable voltage range		1.8			V
I_{EN}	Enable pin leakage current	V_{EN} = 5V			1	µA
PSRR	Power-supply ripple rejection	V_{RIPPLE} = $1V_{PP}$, frequency = 100Hz, I_{OUT} ≥ 5mA		80		dB
V_n	Output noise voltage	V_{OUT} = 3.3V, I_{OUT} = 1mA, BW = 10Hz to 100KHz, a 5µV_{RMS} reference is used for this measurement		150		μV_{RMS}
I_{REV}	Reverse current at V_{IN}	V_{IN} = 0V, V_{OUT} = 32V	–0.6		0.6	µA
I_{REV-N1}	Reverse current at negative V_{IN}	V_{IN} = –20V, V_{OUT} = 20V	–1.2		1.2	µA

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5.5 Electrical Characteristics (continued)

specified at T_J = –40°C to +150°C, V_{IN} = 13.5V, I_{OUT} = 100µA, C_{OUT} = 1µF, C_{IN} = 1µF, V_{EN} = 2V and V_{ADJ} = 5V (unless otherwise noted); typical values are at T_J = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$T_{SD(SHUTDOWN)}$	Junction shutdown temperature			175		°C
$T_{SD(HYST)}$	Hysteresis of thermal shutdown			15		°C

(1) Because the power dissipation is potentially large, this specification is measured using pulse testing with a low duty cycle. See the thermal information table for more information on how much power the device dissipates while maintaining a junction temperature below 150°C.

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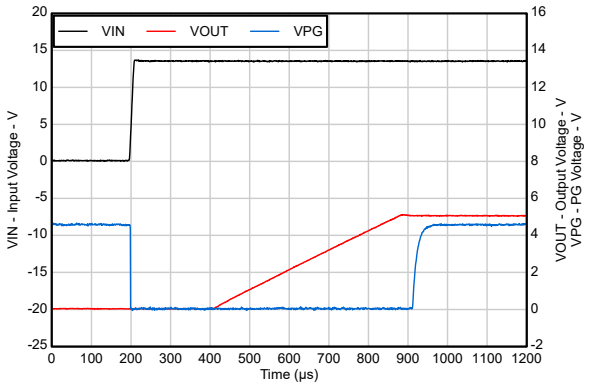
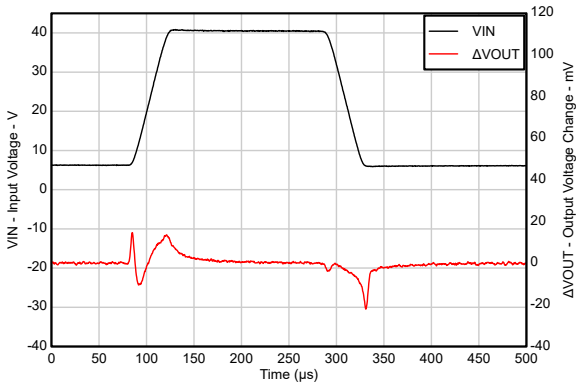
5.6 Typical Characteristics



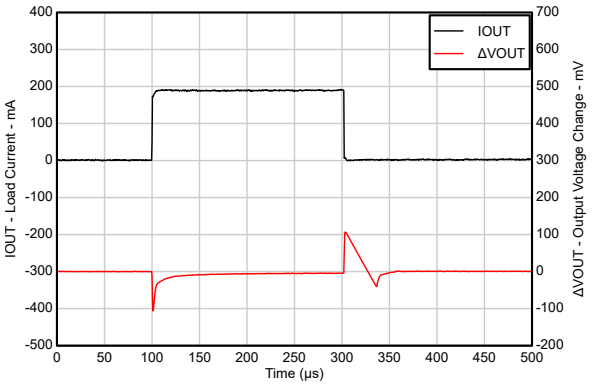
V_{IN} = 0V to 13.5V at a rate of 1V/µs, V_{ADJ} = 5V, V_{EN} = 2V, C_{OUT} = 1µF, I_{OUT} = 200mA

Figure 5-1. Start-Up Profile



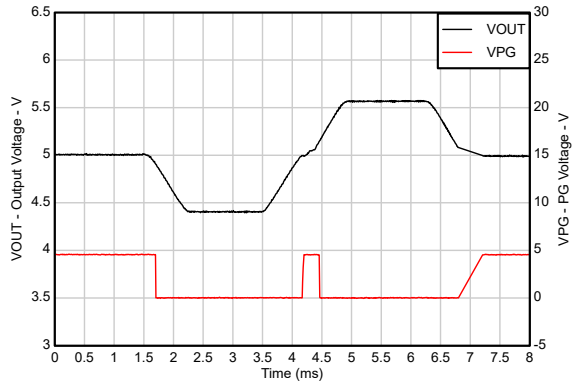
V_{IN} = 6V to 40V at a rate of 1V/µs, V_{ADJ} = 5V, V_{EN} = 2V, C_{OUT} = 1µF, I_{OUT} = 200mA

Figure 5-2. Line Transient



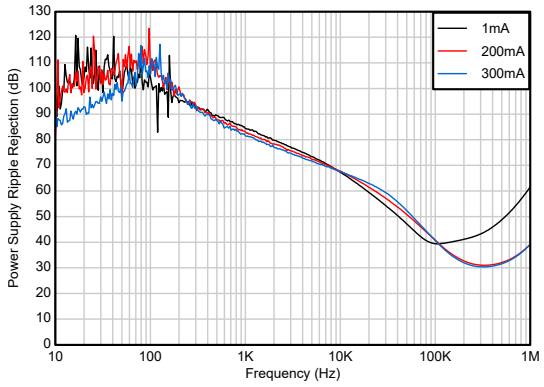
V_{IN} = 13.5V, V_{ADJ} = 5V, V_{EN} = 2V, C_{OUT} = 1µF, I_{OUT} = 1mA to 200mA at 1A/µs

Figure 5-3. Load Transient



V_{ADJ} = 5V, V_{EN} = 2V, C_{OUT} = 1µF, V_{OUT} ramped down to 4.4V from nominal value of 5V and then ramped up to 5.6V

Figure 5-4. Power-Good Functionaility



V_{IN} = 13.5V, V_{ADJ} = 5V, V_{EN} = 2V, C_{OUT} = 1µF

Figure 5-5. PSRR vs Frequency

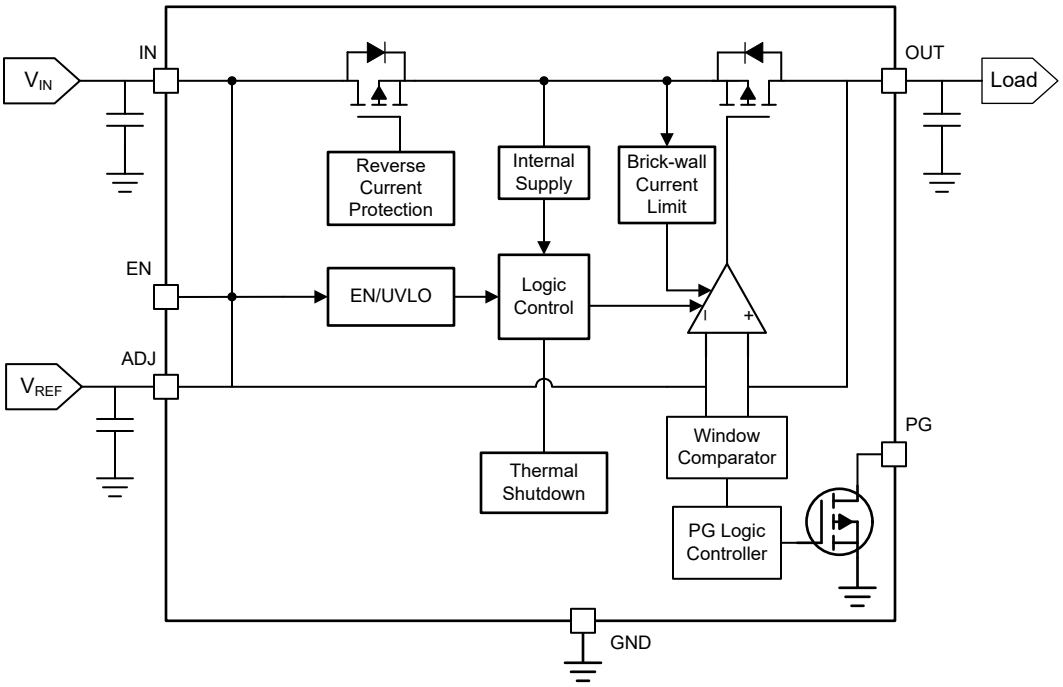
6 Detailed Description

6.1 Overview

The TPS7B4261-Q1 is an integrated, low-dropout (LDO) voltage tracker with ultra-low tracking tolerance. Because of the high risk of cable shorts when powering off-board sensors, multiple features are built into the LDO. These features protect against fault conditions resulting in short to battery, short to GND, and reverse current flow.

In addition, this device also features thermal shutdown protection, brick-wall current limiting, undervoltage lockout (UVLO), reverse polarity protection, and under- and overvoltage detection.

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 Tracker Output Voltage (V_{OUT})

Because this device is a tracking LDO, the output voltage is equal to the voltage provided to the ADJ pin, so long as sufficient voltage is provided to the ADJ pin (≥2V) and EN pin (≥1.8V). The LDO remains enabled as long as both V_{EN} and V_{ADJ} exceed $V_{EN,\ ON}$ and is disabled when either of V_{EN} or V_{ADJ} become less than $V_{EN,\ OFF}$. The values of $V_{EN,\ ON}$ and $V_{EN,\ OFF}$ can be found in the *Electrical Characteristics* table. The device has a soft-start feature incorporated, which allows the output voltage to rise linearly and limits the in-rush current at start-up. After start-up and upon attaining steady state, the output voltage V_{OUT} remains within ±6mV from the voltage set on the ADJ pin V_{ADJ} over all specified operating conditions.

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6.3.1.1 Output Voltage Equal to Reference Voltage

Figure 6-1 shows the external reference voltage applied directly to the ADJ pin. Under these conditions, the LDO output voltage is equal to the reference voltage, as given in Equation 1.

$$V_{OUT} = V_{REF} \quad (1)$$

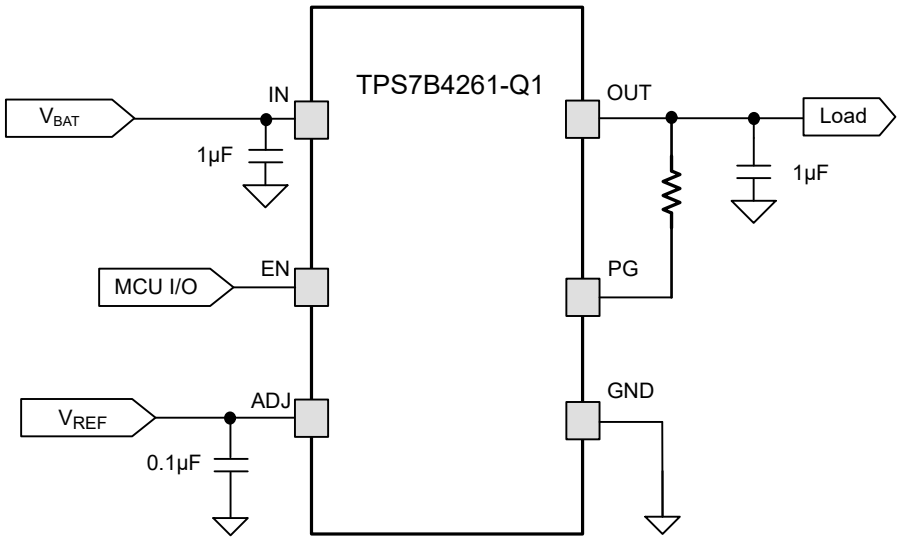

Figure 6-1. Tracker Output Voltage Equal to Reference Voltage

6.3.1.2 Output Voltage Less Than the Reference Voltage

Connecting an external resistor divider at the ADJ pin, as shown in Figure 6-2, helps generate an output voltage that is lower than the reference voltage. Both R_1 and R_2 must be less than 100kΩ to minimize the error in voltage caused by the ADJ pin leakage current, I_{ADJ}. Equation 2 calculates V_{OUT}.

$$V_{OUT} = \frac{(V_{REF} \times R_2)}{R_1 + R_2} \quad (2)$$

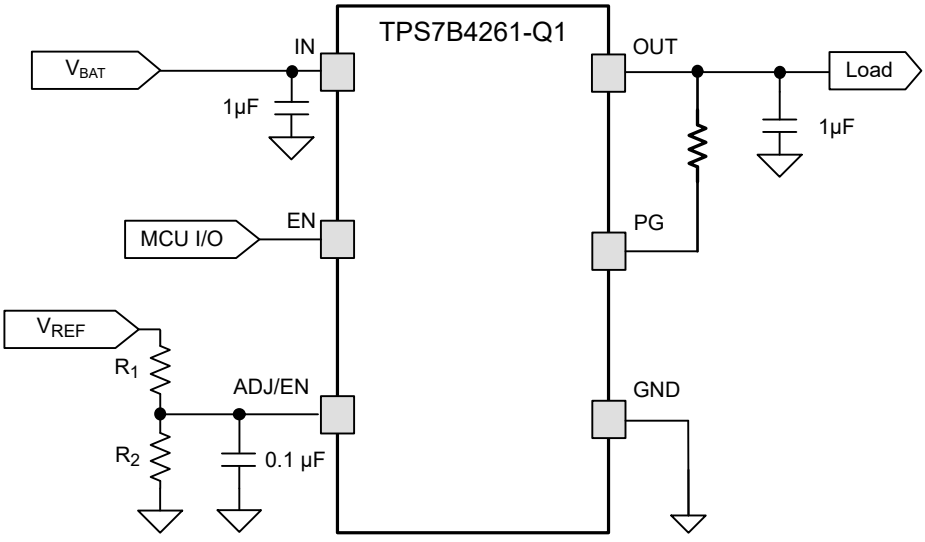

Figure 6-2. Tracker Output Voltage Less Than the Reference Voltage

6.3.2 Reverse Current Protection

The TPS7B4261-Q1 incorporates a back-to-back PMOS topology that protects the device from damage against a fault condition, resulting in V_{OUT} being higher than V_{IN} and the subsequent flow of reverse current. No damage occurs to the device if this fault condition occurs, provided the *Absolute Maximum Ratings* are not violated. This integrated protection feature eliminates the need for an external diode. The reverse current comparator typically responds to a reverse voltage condition in 10µs, and along with the body diode of the blocking PMOS transistor, limits the reverse current to I_{REV}, as specified in the *Electrical Characteristics* table.

6.3.3 Power Good

The TPS7B4261-Q1 has an open-drain based power-good pin, that can help detect undervoltage and overvoltage fault conditions at the tracker output. This pin can be pulled up to a regulated rail via a pullup resistor, and the maximum value of this $V_{PULL-UP}$ rail can be inferred from the V_{PG} range of values listed in the *Recommended Operating Conditions* . The input voltage V_{IN} must be higher than $V_{UVLO\ (RISING)}$, for V_{PG} to have a valid value.

So long as the device is enabled ($V_{EN} > V_{EN,\ ON}$) and sufficient V_{IN} & V_{ADJ} are provided ($V_{IN} \geq V_{IN\ MIN}$, $V_{ADJ} \geq V_{ADJ\ MIN}$), the PG pin asssumes a high-impedence state when the tracker output voltage remains within the $V_{PG\ UV-TH}$ and $V_{PG\ OV-TH}$ values of V_{ADJ} and is pulled up to $V_{PULL-UP}$.

Variations in tracker output voltage beyond the power-good swithching thresholds, that also last longer than t_{PG}, takes the PG pin low, to a voltage $V_{PG} < V_{PG,\ LOW}$. Transients in V_{OUT} that last less than t_{PG} are not flagged as errors by the PG pin. The PG pin remains low when the device is disabled ($V_{EN} < V_{EN,\ OFF}$), even if sufficient V_{IN} and V_{ADJ} are provided. The values of $V_{PG\ UV-TH}$, $V_{PG\ OV-TH}$, t_{PG}, and $V_{PG,\ LOW}$ are specified in the *Electrical Characteristics* table.

6.3.4 Undervoltage Lockout

The device has an internally fixed undervoltage lockout (UVLO) threshold. Undervoltage lockout activates when the input voltage V_{IN} drops below the undervoltage lockout level (see the $V_{UVLO(FALLING)}$ parameter in the *Electrical Characteristics* table). This activation makes sure the regulator is not latched into an unknown state during a low input supply voltage. If the input voltage has a negative transient that drops below the UVLO threshold and recovers, the regulator shuts down and powers up in the standard power-up sequence when the input voltage recovers to the required level (see the $V_{UVLO(RISING)}$ parameter in the *Electrical Characteristics* table).

6.3.5 Thermal Protection

Thermal protection disables the output when the junction temperature rises to approximately 175°C, which allows the device to cool. When the junction temperature cools to approximately 160°C, the output circuitry enables. Based on power dissipation, thermal resistance, and ambient temperature, the thermal protection circuit can cycle off and on until the condition that causes excessive power dissipation is removed. This cycling limits the dissipation of the regulator, thus protecting the regulator from damage as a result of overheating.

The internal protection circuitry of the TPS7B4261-Q1 is designed to protect against overload conditions. The circuitry is not intended to replace proper heat sinking. Continuously running the TPS7B4261-Q1 into thermal shutdown degrades device reliability.

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6.3.6 Current Limit

The device has an internal current limit circuit that protects the device during overcurrent or shorting conditions. The current-limit circuit, as shown in Figure 6-3, is a brick-wall scheme. When the device is in current limit, the device sources I_{CL} and the output voltage is not regulated. In this scenario, the output voltage depends on the load impedance.

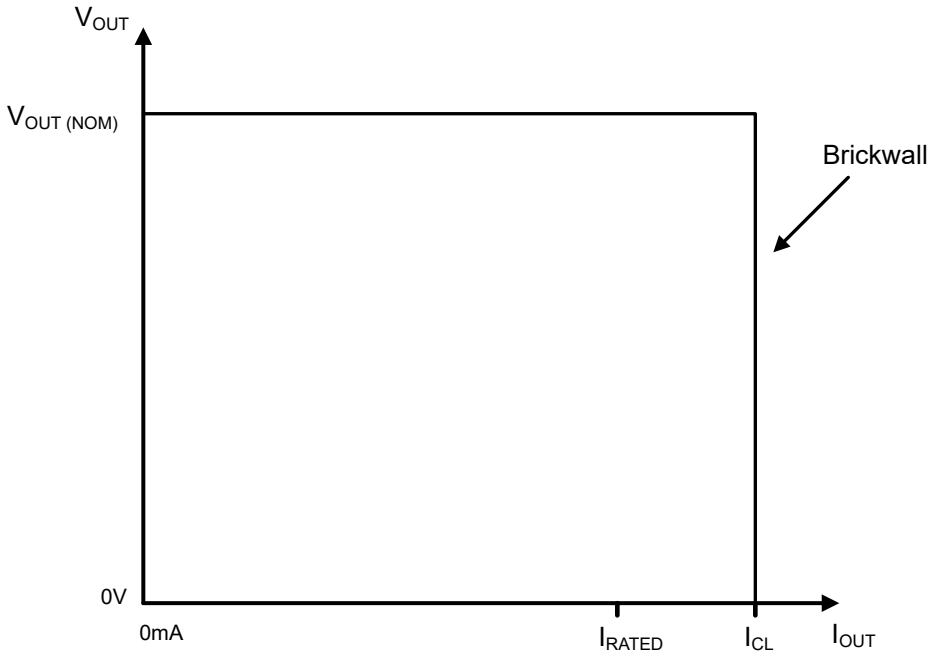

Figure 6-3. Brickwall Current Limit Scheme

During current-limit events, the potential for high power dissipation exists because of the elevated current level and the increased input-to-output differential voltage (V_{IN} – V_{OUT}). If the heat dissipation is substantial, the device enters thermal shutdown. If the current-limit condition is not removed when the device turns back on after cooling, the device enters thermal shutdown again. This cycle continues until the current-limit condition is removed. The device survives this fault, but repeatedly operating in this mode degrades long-term reliability.

6.3.7 Output Short to Battery

When the output is shorted to the battery (see Figure 6-4), the TPS7B4261-Q1 survives and no damage occurs to the device. A short to the battery also occurs when the device is powered by an isolated supply (see Figure 6-5) at a lower voltage. In this example, the TPS7B4261-Q1 supply input voltage is set at 7V when a short to battery (14V typical) occurs on V_{OUT}, which typically runs at 5V. The back-to-back PMOS topology helps limit the continuous reverse current flowing through V_{IN} to I_{REV}, as provided in the *Electrical Characteristics* table.

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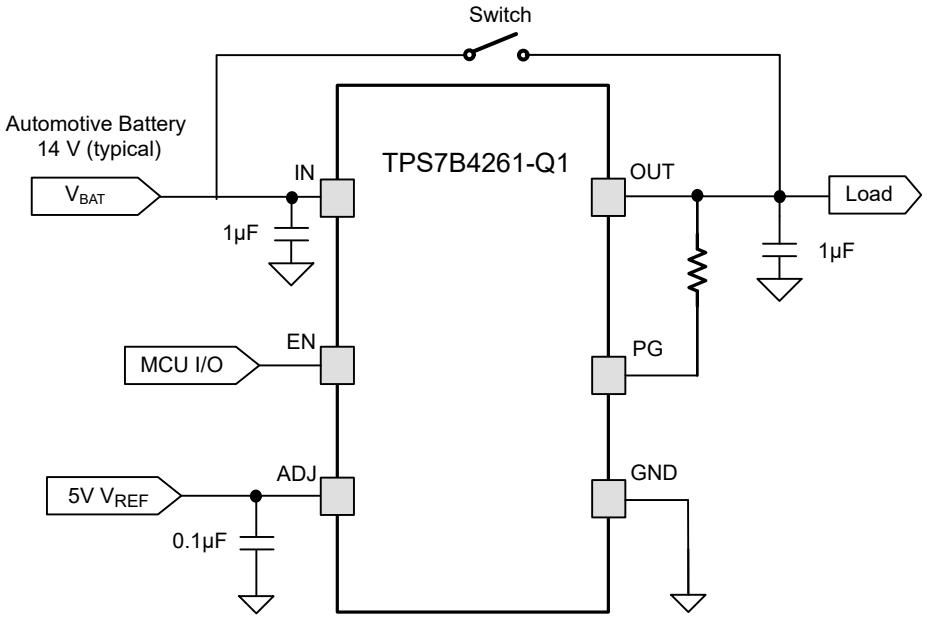

Figure 6-4. Tracker Output Short to Battery

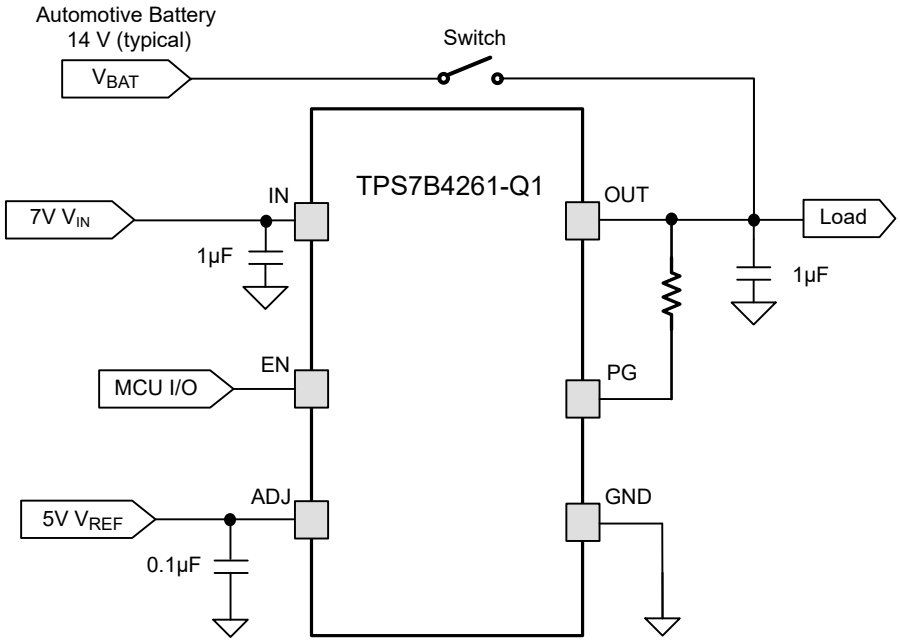

Figure 6-5. Tracker Output Voltage Higher Than Input Voltage

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6.4 Device Functional Modes

Table 6-1 shows the conditions that lead to the different modes of operation. See the *Electrical Characteristics* table for parameter values.

Table 6-1. Device Functional Mode Comparison

OPERATING MODE	PARAMETER(1)				
	V_{IN}	V_{ADJ}	V_{EN}	I_{OUT}	T_J
Normal operation	$V_{IN} > V_{OUT(Nom)} + V_{DO}$ and $V_{IN} \geq V_{IN(min)}$	$V_{ADJ} > V_{EN, ON}$	$V_{EN} > V_{EN, ON}$	$I_{OUT} \leq I_{OUT(max)}$	$T_J \leq 150°C$
Dropout operation	$V_{IN(min)} < V_{IN} < V_{OUT(nom)} + V_{DO}$	$V_{ADJ} > V_{EN, ON}$	$V_{EN} > V_{EN, ON}$	$I_{OUT} \leq I_{OUT(max)}$	$T_J < T_{SD(shutdown)}$
Disabled (any true condition disables the device)	$V_{IN} < V_{UVLO}$	$V_{ADJ} < V_{EN, OFF}$	$V_{EN} < V_{EN, OFF}$	Not applicable	$T_J > T_{SD(shutdown)}$

(1) The device turns on when V_{IN} is greater than $V_{UVLO(RISING)}$ and both V_{ADJ} and V_{EN} are greater than the enable rising threshold $V_{EN, ON}$.

6.4.1 Normal Operation

The device output voltage $V_{OUT(Nom)}$ tracks the reference voltage at the ADJ pin when the following conditions are met:

- The input voltage is at least 3.3V ($V_{IN(min)}$) and greater than the nominal output voltage plus the dropout voltage ($V_{OUT(nom)} + V_{DO}$).
- The reference voltage at the ADJ pin and the enable pin voltage V_{EN} are both greater than the enable rising threshold $V_{EN, ON}$. The voltage on the ADJ pin stays stable at the appropriate V_{REF} value.
- The output current is less than $I_{OUT(max)}$ ($I_{OUT} \leq 300mA$).
- The device junction temperature is less than the thermal shutdown temperature ($T_J < T_{SD}$).

6.4.2 Dropout Operation

If the input voltage is lower than the nominal output voltage plus the specified dropout voltage, the device operates in dropout mode. In this mode, the output voltage tracks the input voltage. In this mode, the transient performance of the device becomes significantly degraded. During this mode, the pass transistor is driven fully on. Line or load transients in dropout potentially result in large output voltage deviations.

When the device is in a steady dropout state (defined as when the device is in dropout, $V_{IN} < V_{OUT(NOM)} + V_{DO}$, directly after being in a normal regulation state, but *not* during start up), the pass transistor is driven into the ohmic or triode region. When the input voltage returns to a value greater than or equal to the nominal output voltage plus the dropout voltage ($V_{OUT\ (NOM)} + V_{DO}$), the output voltage can overshoot for a short period of time while the device pulls the pass transistor back into the saturation region.

6.4.3 Operation With V_{IN} < 3.3V

For input voltages below 3.3V and above $V_{UVLO(FALLING)}$, the LDO continues to operate but certain circuits potentially do not have proper headroom to operate within specification. When the input voltage drops below $V_{UVLO\ (FALLING)}$ the device shuts off.

6.4.4 Disable With ADJ and EN Controls

Both the ADJ and EN pins are independently able to disable the device. Shutdown the output of the device by forcing either V_{ADJ} or V_{EN} to less than $V_{EN, OFF}$. When disabled, the pass transistor is turned off, the internal circuits are shutdown, and the LDO is in a low-power mode.

ADVANCE INFORMATION

7 Application 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, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information

7.1.1 Dropout Voltage

Dropout voltage (V_{DO}) is defined as the input voltage minus the output voltage ($V_{IN} – V_{OUT}$) when the pass transistor is fully on. This condition arises when the input voltage falls to the point where the error amplifier drives the gate of the pass transistor to the rail. During this condition, there is no remaining headroom for the control loop to operate. The pass transistor is in the ohmic or triode region of operation, and acts as a switch. Dropout voltage directly specifies a minimum input voltage greater than the nominal programmed output voltage where the output voltage is expected to stay in regulation. If the input voltage falls to less than the nominal output regulation, then the output voltage follows, minus the dropout voltage (V_{DO}).

In dropout mode, the output voltage is no longer regulated, and transient performance is severely degraded. The device loses PSRR, and load transients potentially cause large output voltage deviation.

For a CMOS regulator, the dropout voltage is determined by the drain-source on-state resistance ($R_{DS(ON)}$) of the pass transistor. Therefore, if the linear regulator operates at less than the rated output current (I_{RATED}, see the *Recommended Operating Conditions* table), the dropout voltage for that current scales accordingly. The following equation calculates the $R_{DS(ON)}$ of the device.

$$R_{DS(ON)} = \frac{V_{DO}}{I_{RATED}} \tag{3}$$

7.1.2 Reverse Current

The TPS7B4261-Q1 incorporates reverse current protection that prevents damage from a fault condition, resulting in V_{OUT} being higher than V_{IN}. During such a fault condition, where the V_{IN} and V_{OUT} absolute maximum ratings are not violated and $V_{OUT} – V_{IN}$ is less than 40V, no damage occurs and less than 1.2µA (max) of reverse current flows through the LDO. The reverse current comparator typically responds to a reverse voltage condition and, along with the body diode of the blocking PMOS transistor, limits the reverse current in 10µs.

ADVANCE INFORMATION

7.2 Typical Application

Figure 7-1 shows a typical application circuit for the TPS7B4261-Q1.

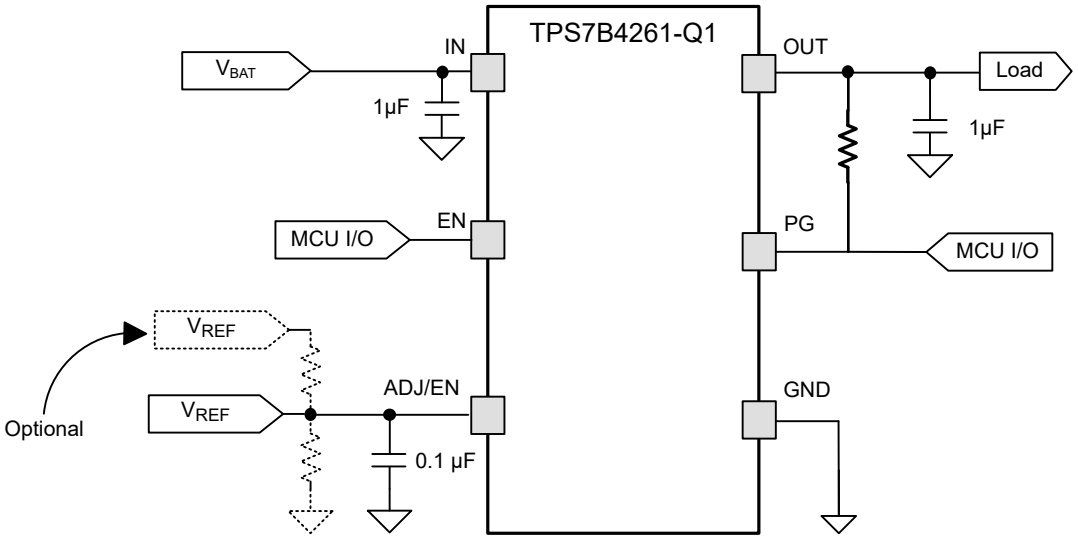


Figure 7-1. Typical Application Schematic

7.2.1 Design Requirements

Use the parameters listed in Table 7-1 for this design example.

Table 7-1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUES
Input voltage	3.3V to 40V
Adjustable reference voltage	2V to 40V
Enable Voltage	1.8V to 40V
Output voltage	2V to 40V
Output current rating	300mA
Output capacitor range	1µF to 100µF
Output capacitor ESR range	1mΩ to 2Ω

ADVANCE INFORMATION

7.2.2 Detailed Design Procedure

7.2.2.1 Input and Output Capacitor Selection

Depending on the end-application, different values of external components can be used. Some applications require a larger output capacitor during fast load steps to prevent a reset from occurring. Use a low equivalent series resistance (ESR) ceramic capacitor with a dielectric of type X5R or X7R for better load transient response.

The TPS7B4261-Q1 requires an output capacitor of at least 1µF (500nF or larger capacitance) for stability and an ESR between 0.001Ω and 2Ω. Without the output capacitor, the regulator oscillates. For best transient performance, use X5R- and X7R-type ceramic capacitors because these capacitors have minimal variation in value and ESR over temperature. When choosing a capacitor for a specific application, be mindful of the DC bias characteristics for the capacitor. Higher output voltages cause a significant derating of the capacitor. For most applications, a low ESR, 10µF ceramic capacitor on the OUT pin is sufficient to provide excellent transient performance.

Use a minimum 100nF input capacitor for the TPS7B4261-Q1. Some input supplies have a high impedance, thus placing the input capacitor on the input supply helps reduce the input impedance. This capacitor counteracts reactive input sources and improves transient response, input ripple, and PSRR. If the input supply has high impedance over a large range of frequencies, use several input capacitors in parallel to lower the impedance over frequency. Use a higher-value capacitor if large, fast rise-time load transients are anticipated, or if the device is located several inches from the input power source.

7.2.3 Application Curves

The following images illustrate the functions of $R_{\theta JA}$ and ψ_{JB} versus copper area and thickness for the HSOIC-8 (DDA) package. These plots are generated with a 101.6mm × 101.6mm × 1.6mm printed circuit board (PCB) of two and four layers. For the 2-layer board, the bottom layer is a ground plane of constant size, and the top layer copper is connected to GND and varied. For the 4-layer board, the second layer is a ground plane of constant size and the third layer is a power plane of constant size. The top and bottom layers copper fills are connected to GND and varied at the same rate. For the 4-layer board, inner planes use 1oz copper thickness. Outer layers are simulated with both 1oz and 2oz copper thickness. A 3 × 3 array of thermal vias with a 300µm drill diameter and 25µm copper plating is located underneath the device. The thermal vias connect the top layer, the bottom layer and, in the case of the 4-layer board, the first inner GND plane. *PowerPAD™ Thermally Enhanced Package* application note discusses the impact that thermal vias have on thermal performance.

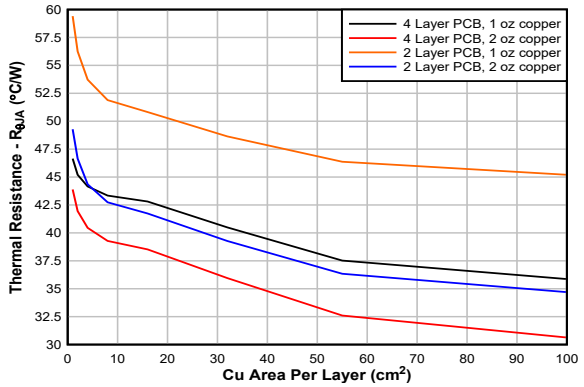


Figure 7-2. $R_{\theta JA}$ vs Copper Area (HSOIC-8 Package)

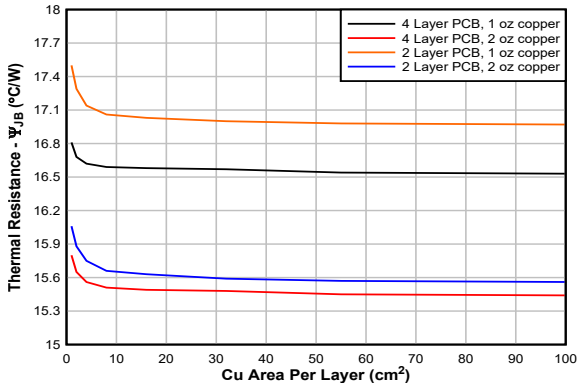


Figure 7-3. ψ_{JB} vs Copper Area (HSOIC-8 Package)

7.3 Power Supply Recommendations

The device is designed to operate from an input voltage supply range from 3.3V to 40V.

ADVANCE INFORMATION

7.4 Layout

7.4.1 Layout Guidelines

For best overall performance, place all circuit components on the same side of the circuit board. Place these components as near as practical to the respective LDO pin connections. Place ground return connections to the input and output capacitor, and to the LDO ground pin as close as possible to each other. Use a wide, component-side, copper surface to make these connections. Using vias and long traces to the input and output capacitors is strongly discouraged and negatively affects system performance. Use a ground reference plane either embedded in the PCB or located on the bottom side of the PCB opposite the components. This reference plane serves to provide accuracy of the output voltage and shields noise. This reference plane also behaves similarly to a thermal plane to spread (or sink) heat from the LDO device when connected to the thermal pad. In most applications, this ground plane is necessary to meet thermal requirements.

7.4.1.1 Package Mounting

Solder-pad footprint recommendations for the TPS7B4261-Q1 are available at the end of this document and at www.ti.com.

7.4.1.2 Board Layout Recommendations to Improve PSRR and Noise Performance

To improve AC performance (such as PSRR, output noise, and transient response), design the board with separate ground planes for V_{IN} and V_{OUT}. Connect each ground plane only at the GND pin of the device. In addition, directly connect the ground connection for the output capacitor to the GND pin of the device.

Minimize equivalent series inductance (ESL) and ESR to maximize performance and provide stability. Place each capacitor as close as possible to the device and on the same side of the PCB as the regulator.

Do not place any capacitors on the opposite side of the PCB from where the regulator is installed. Using vias and long traces is strongly discouraged because of the negative impact on system performance. Vias and long traces potentially cause instability.

If possible, and to provide the maximum performance denoted in this document, use the same layout pattern used for the TPS7B4261-Q1 evaluation board. This evaluation board is available at www.ti.com.

7.4.1.3 Power Dissipation and Thermal Considerations

Equation 4 calculates the device power dissipation.

$$P_D = I_{OUT} \times (V_{IN} - V_{OUT}) + I_Q \times V_{IN} \quad (4)$$

where:

- P_D = Continuous power dissipation
- I_{OUT} = Output current
- V_{IN} = Input voltage
- V_{OUT} = Output voltage
- I_Q = Quiescent current

Because I_Q is much less than I_{OUT}, the term $I_Q \times V_{IN}$ in Equation 4 can be ignored.

Calculate the junction temperature (T_J) with Equation 5 for a device under operation at a given ambient air temperature (T_A).

$$T_J = T_A + (R_{\theta JA} \times P_D) \quad (5)$$

where:

- $R_{\theta JA}$ = Junction-to-junction-ambient air thermal impedance

Equation 6 calculates a rise in junction temperature because of power dissipation.

$$\Delta T = T_J - T_A = (R_{\theta JA} \times P_D) \quad (6)$$

The maximum ambient air temperature (T_{AMAX}) at which the device operates is calculated with Equation 7 for a given maximum junction temperature (T_{JMAX}).

$$T_{AMAX} = T_{JMAX} – (R_{\theta JA} \times P_D) \quad (7)$$

7.4.1.4 Thermal Performance Versus Copper Area

The most used thermal resistance parameter $R_{\theta JA}$ is highly dependent on the heat-spreading capability built into the particular PCB design. $R_{\theta JA}$ therefore varies according to the total copper area, copper weight, and location of the planes. The $R_{\theta JA}$ recorded in the *Thermal Information* table is determined by the JEDEC standard (Figure 7-4), PCB, and copper-spreading area. This parameter is only used as a relative measure of package thermal performance. For a well-designed thermal layout, $R_{\theta JA}$ is actually the sum of $R_{\theta JCbot}$ plus the thermal resistance contribution by the PCB copper. $R_{\theta JCbot}$ is the package junction-to-case (bottom) thermal resistance, as given in the *Thermal Information* table.

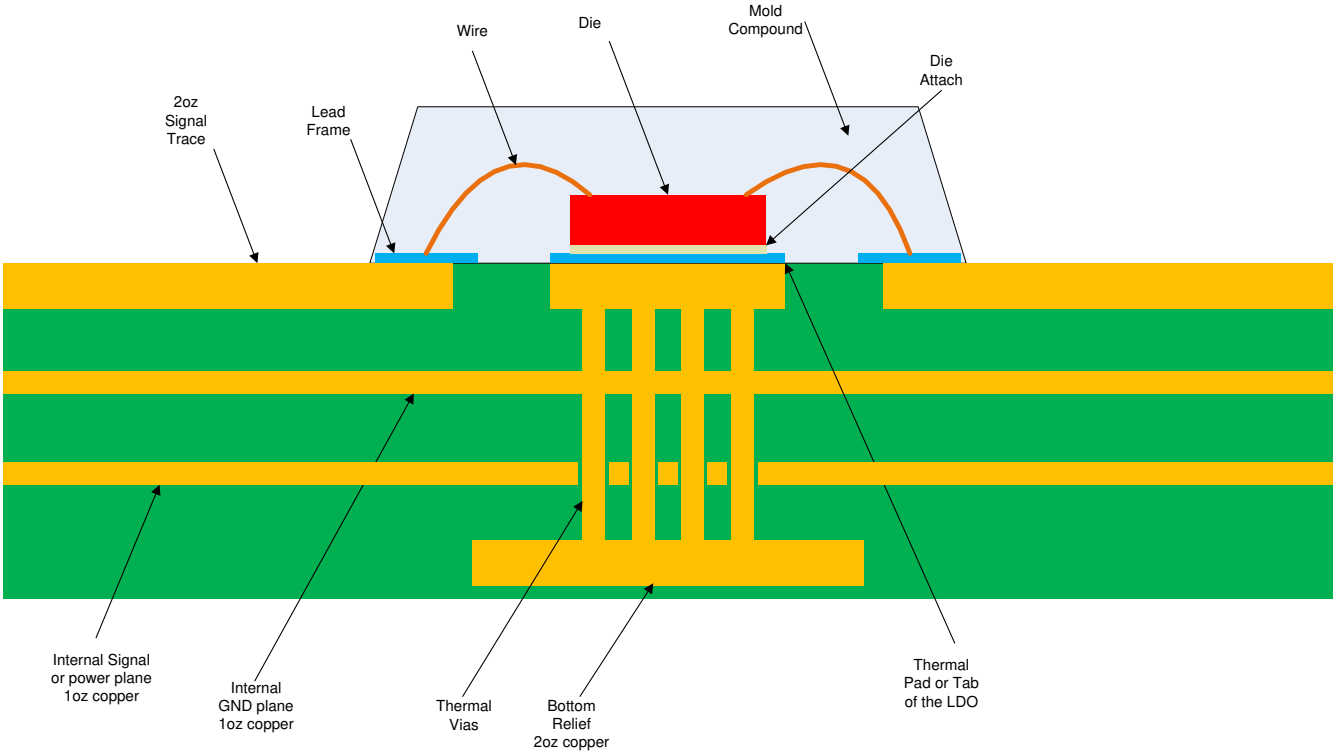


Figure 7-4. JEDEC Standard 2s2p PCB

ADVANCE INFORMATION

7.4.2 Layout Example

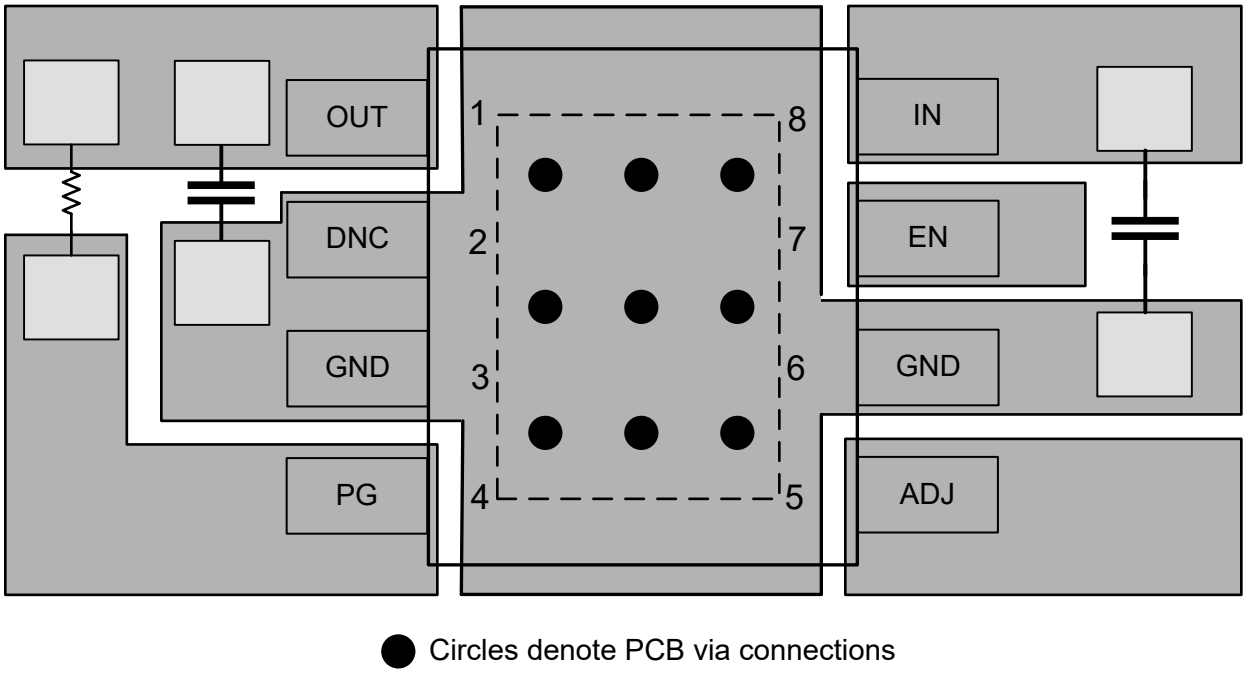


Figure 7-5. Layout Example

ADVANCE INFORMATION

8 Device and Documentation Support

8.1 Device Support

8.1.1 Device Nomenclature

Table 8-1. Device Nomenclature

PRODUCT(1)	V_{OUT}
TPS7B4261**QDDARQ1**	In the HSOIC (DDA) package: **Q** indicates that this device is a grade-1 device in accordance with the AEC-Q100 standard. **R** is the packaging quantity. **Q1** indicates that this device is an automotive grade (AEC-Q100) device.

(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or visit the device product folder on www.ti.com.

8.2 Documentation Support

8.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *PowerPAD™ Thermally Enhanced Package* application note

8.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.4 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.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

8.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

8.6 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.7 Glossary

TI Glossary — This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

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

DATE	REVISION	NOTES
January 2025	*	Initial Release

ADVANCE INFORMATION

10 Mechanical, Packaging, and Orderable Information

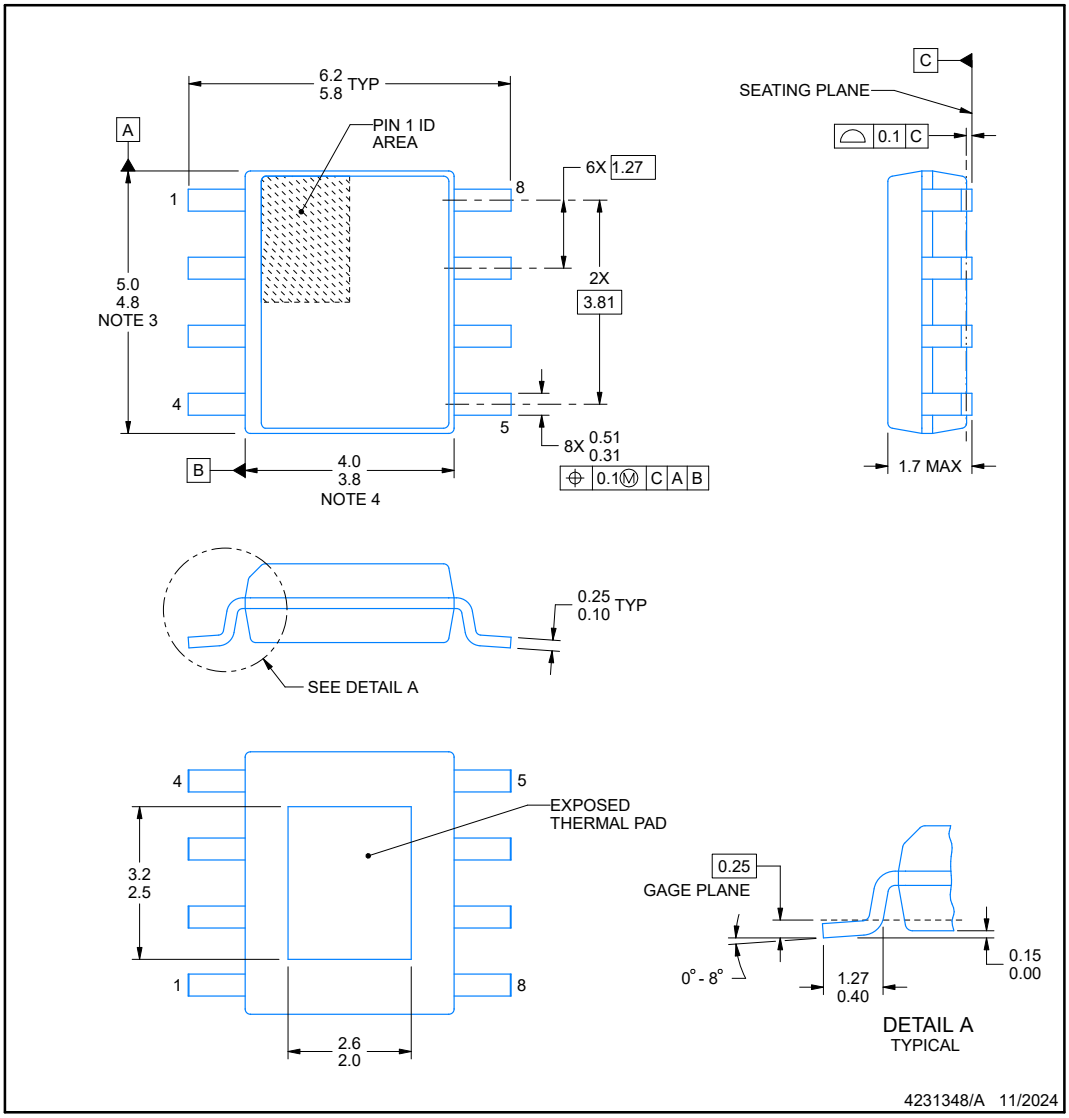
The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand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

10.1 Mechanical Data

PACKAGE OUTLINE

DDA0008J-C02 **PowerPAD™ SOIC - 1.7 mm max height**

PLASTIC SMALL OUTLINE



PowerPAD is a trademark of Texas Instruments.

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MS-012, variation BA.

www.ti.com

ADVANCE INFORMATION

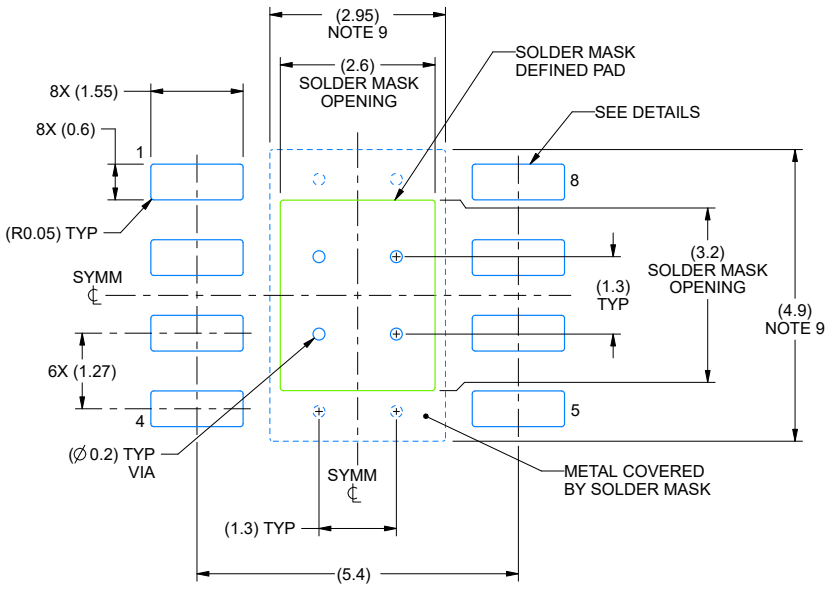
ADVANCE INFORMATION

EXAMPLE BOARD LAYOUT

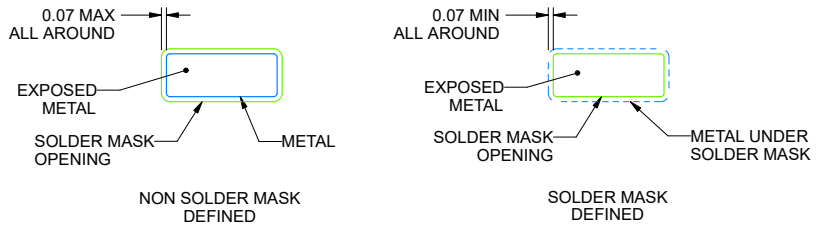
DDA0008J-C02

PowerPAD ™ SOIC - 1.7 mm max height

PLASTIC SMALL OUTLINE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:10X



SOLDER MASK DETAILS

4231348/A 11/2024

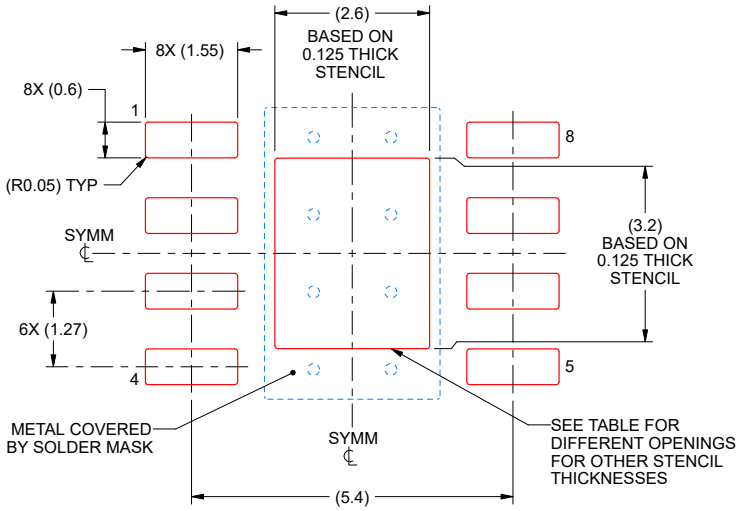
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Size of metal pad may vary due to creepage requirement.

EXAMPLE STENCIL DESIGN

DDA0008J-C02 **PowerPAD ™ SOIC - 1.7 mm max height**

PLASTIC SMALL OUTLINE



SOLDER PASTE EXAMPLE
EXPOSED PAD
100% PRINTED SOLDER COVERAGE BY AREA
SCALE:10X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	2.91 X 3.58
0.125	2.6 X 3.2 (SHOWN)
0.150	2.37 X 2.92
0.175	2.20 X 2.70

4231348/A 11/2024

NOTES: (continued)

10. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
11. Board assembly site may have different recommendations for stencil design.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTPS7B4261QDDARQ1	ACTIVE	SO PowerPAD	DDA	8	2500	TBD	Call TI	Call TI	-40 to 125		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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

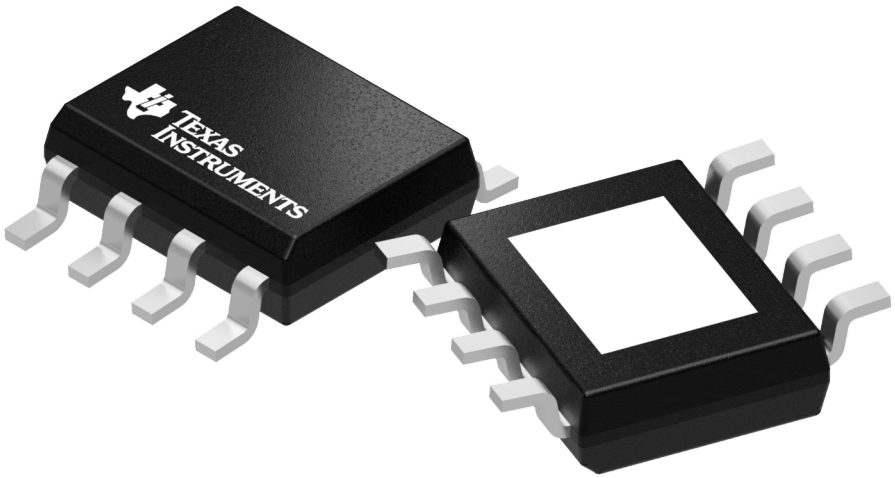
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

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

DDA 8 PowerPAD™ SOIC - 1.7 mm max height

PLASTIC SMALL OUTLINE



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

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