Data Sheet

LT4423

28V, 2A Ideal Diode and Load Switch

FEATURES

- Internal 200mΩ Power Path
- Wide Operating Voltage Range: 1.9V to 28V
- Reverse Current Protection
- Load Switch Capability
- Low 10µA Quiescent Current
- Fast 3µs Response to Load Steps
- Low 500nA Off State Current
- Smooth Switchover in Diode-OR Applications
- Integrated Thermal Protection
- 10-Lead (3mm x 2mm x 0.75mm) LDFN Package

APPLICATIONS

- Schottky Diode Replacement
- Battery and Wall Adapter Diode ORing
- Backup Battery Diode ORing
- Industrial and Consumer Hand-Held Applications

GENERAL DESCRIPTION

The LT®4423 is a 1.9V to 28V ideal diode and load switch with integrated P-channel MOSFETs. When enabled, 15mV forward voltage regulation minimizes power dissipation while increasing operating headroom and efficiency compared to a Schottky diode.

Using two LT4423s in diode-OR applications provide a seamless transfer to the highest available voltage under varying input supply conditions. A non-enabled LT4423 blocks up to 28V in either direction or polarity while exhibiting less than 1µA (typical) leakage current, providing orders of magnitude improvement over typical Schottky diodes, which leads to extended battery life.

Fast OUT to IN reverse bias detection minimizes reverse current, preventing undesired charging of input batteries. The open-drain STATUS output pulls low when the LT4423 is in shutdown, reverse bias, or under thermal protection. Integrated thermal detection protects from overtemperature conditions by disabling the power path.

SIMPLIFIED APPLICATION DIAGRAM

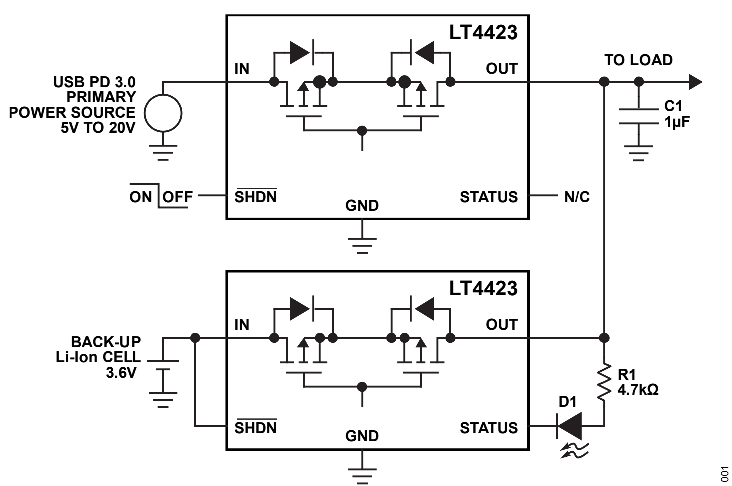


Figure 1. USB PD 3.0 and Back-Up Battery Supply

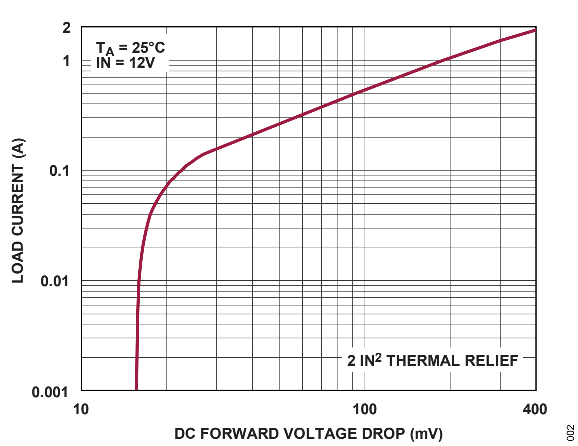


Figure 2. LT4423 I-V CURVE

One Analog Way, Wilmington, MA 01887-2356, U.S.A. | Tel: 781.329.4700

TABLE OF CONTENTS

REVISION HISTORY

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	08/24	Initial Release	—

SPECIFICATIONS

Table 1. Electrical Characteristics

(Specifications are at T_A = 25°C, IN = $\overline{SHDN}$ = 8.4V, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS/COMMENTS		MIN	TYP	MAX	UNITS
Operating Voltage Range	V_{IN}	-40°C ≤ T_J ≤ 125°C		1.9		28	V
Quiescent Current in Forward Regulation	I_{CC}	I_{OUT} = -10mA Measured Through GND	-40°C ≤ T_J ≤ 125°C		-10	-18	µA
Quiescent Current in Shutdown	I_{SD}	$\overline{SHDN}$ = GND Measured Through GND	-40°C ≤ T_J ≤ 125°C		-0.1	-2	µA
Reverse Leakage Current to IN	$I_{REV(IN)}$	IN = GND, OUT = 28V, $\overline{SHDN}$ = GND	-40°C ≤ T_J ≤ 125°C		-0.1	-0.5	µA
Reverse Leakage Current to OUT	$I_{REV(OUT)}$	IN = GND, OUT = 28V, $\overline{SHDN}$ = GND	-40°C ≤ T_J ≤ 125°C		0.1	3	µA
Forward Regulation Voltage (IN - OUT)	V_{REG}	I_{OUT} = -10mA	-40°C ≤ T_J ≤ 125°C	5	15	25	mV
Internal Path On-Resistance	R_{ON}	I_{OUT} = -1A	-40°C ≤ T_J ≤ 125°C	115	200	400	mΩ
Reverse Turn-Off Time	t_{REV}	Step OUT from 8.4V to 8.6V STATUS Falling	-40°C ≤ T_J ≤ 125°C		15	25	µs
Response Time to Load Step	t_{FON}	Step I_{OUT} from –10mA to -1A	-40°C ≤ T_J ≤ 125°C		3	7	µs
$\overline{SHDN}$ Rising Threshold	V_{SRT}	-40°C ≤ T_J ≤ 125°C		1	1.3	1.6	V
$\overline{SHDN}$ Hysteresis	V_{HYST}	-40°C ≤ T_J ≤ 125°C		-75	-130	-230	mV
$\overline{SHDN}$ Input Current	$I_{\overline{SHDN}}$	$\overline{SHDN}$ = 28V	-40°C ≤ T_J ≤ 125°C		1	2	µA
$\overline{SHDN}$ Delay to Power Path Enable	t_{ON}	Step $\overline{SHDN}$ from GND to IN STATUS Released	-40°C ≤ T_J ≤ 125°C		570	1000	µs
$\overline{SHDN}$ Delay to Power Path Disable	t_{OFF}	Step $\overline{SHDN}$ from IN to GND STATUS Falling	-40°C ≤ T_J ≤ 125°C		85	160	µs
STATUS Output Voltage Low	$V_{OL(STAT)}$	I_{STATUS} = 1mA, $\overline{SHDN}$ = GND	-40°C ≤ T_J ≤ 125°C		180	410	mV
STATUS Output High Leakage	$I_{OH(STAT)}$	STATUS = 28V	-40°C ≤ T_J ≤ 125°C		±5	±200	nA
Temperature when Power Path Disabled[4]	T_{TSD}			145	160	175	°C

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C[5], unless otherwise specified.

Table 2. Absolute Maximum Ratings

PARAMETER	RATING
Supply Voltage IN	−0.3V to 30V
Supply Voltage OUT	−30V to 30V
Supply Voltage |IN – OUT|	30V
Input Voltage $\overline{SHDN}$	−30V to 30V
Output Voltage STATUS	−0.3V to 30V
Input Current IN	3A
Output Current OUT	−3A
Operating Junction Temperature Range LT4423A	−40°C to 125°C
Storage Temperature Range	−65°C to 150°C

1 All currents into pins are positive; all voltages are referenced to GND unless otherwise noted.

2 The LT4423 is tested under pulsed load conditions such that $T_J \approx T_A$. The junction temperature (T_J in °C) is calculated from the ambient temperature (T_A in °C) and power dissipation (P_D in Watts) according to the formula: $T_J = T_A + (P_D \bullet \theta_{JA})$.

3 The LT4423 includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 150°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

4 Determined by design, not tested in production.

5 Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

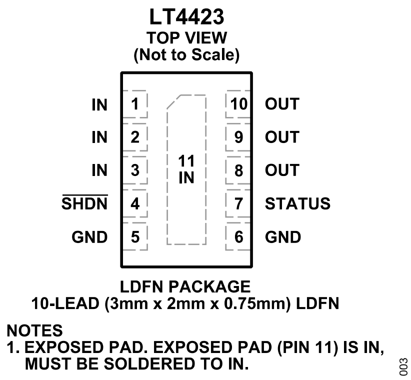


Figure 3. Pin Configurations

Table 3. Pin Descriptions

PIN	NAME	DESCRIPTION
1, 2, 3, 11	IN	Positive Input Supply and Ideal Diode Anode. Connect the IN pin to the power source that supplies power to the load. The exposed pad is also connected to IN. Use a copper plane connected to the exposed pad for thermal management (see *Applications Information* – *Layout and Thermal Considerations* for sizing details). Bypass IN with a 0.1µF or larger capacitor to suppress undesired reverse turn-off in applications with load transient ringing.
4	$\overline{SHDN}$	Shutdown Control Input. Driving $\overline{SHDN}$ low disables the ideal diode and load switch between IN and OUT, placing the part in a low quiescent current mode. $\overline{SHDN}$ may be connected to IN for automatic turn-on applications. Do not leave $\overline{SHDN}$ open.
5, 6	GND	Device Ground.
7	STATUS	Open-Drain Status Output. When IN or OUT is greater than 1.9V, STATUS pulls low when 1) $\overline{SHDN}$ is pulled low, 2) when OUT exceeds IN by approximately 20mV, or 3) when thermal protection circuitry is active. Connect STATUS to a pull-up resistor connected to OUT or an external supply. Leave STATUS open or connect to GND if not used.
8, 9, 10	OUT	Ideal Diode Cathode Output. In diode-OR applications using multiple LT4423s, connect the common output node to OUT. Bypass OUT with a 0.1µF or larger capacitor to suppress undesired reverse turn-off in applications with load transient ringing.

TYPICAL PERFORMANCE CHARACTERISTICS

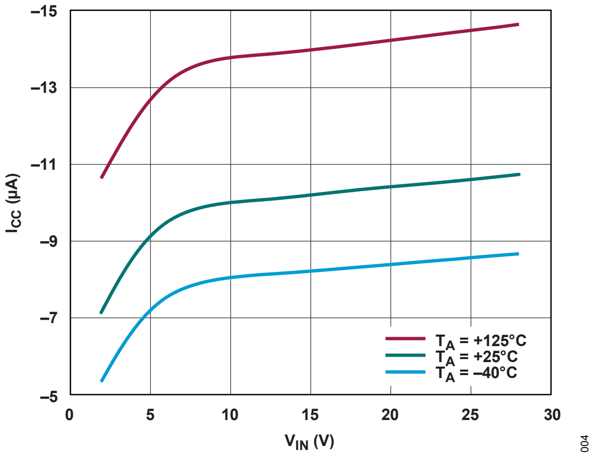


Figure 4. Supply Current to GND vs IN Voltage

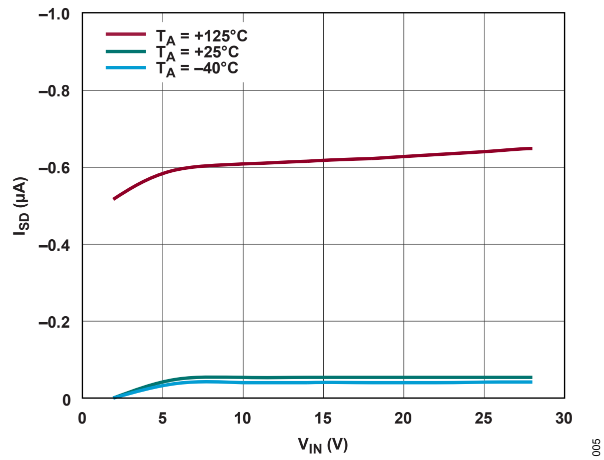


Figure 5. Supply Current to GND vs IN Voltage in Shutdown

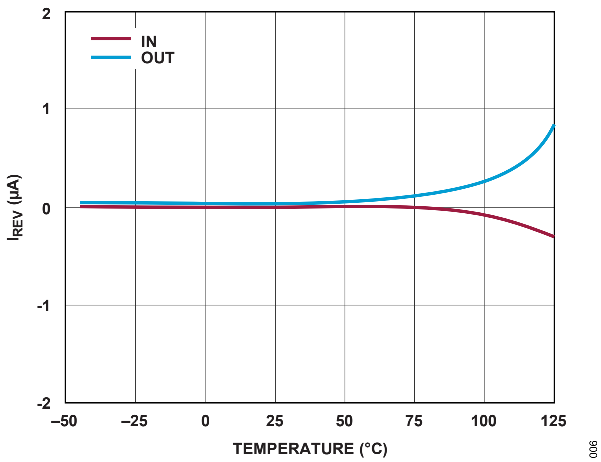


Figure 6. Reverse Leakage Current vs Temperature

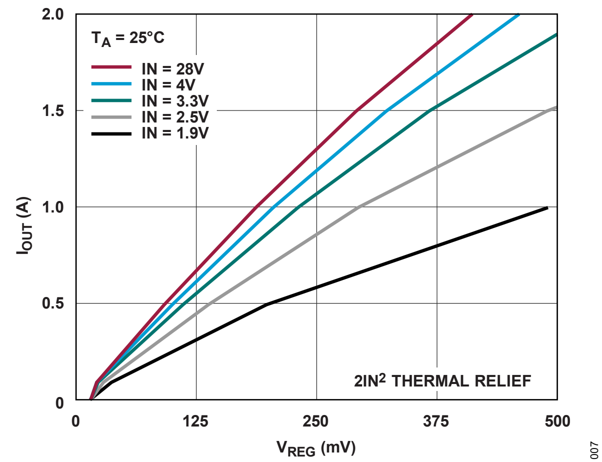


Figure 7. Load Current vs Forward Voltage Drop

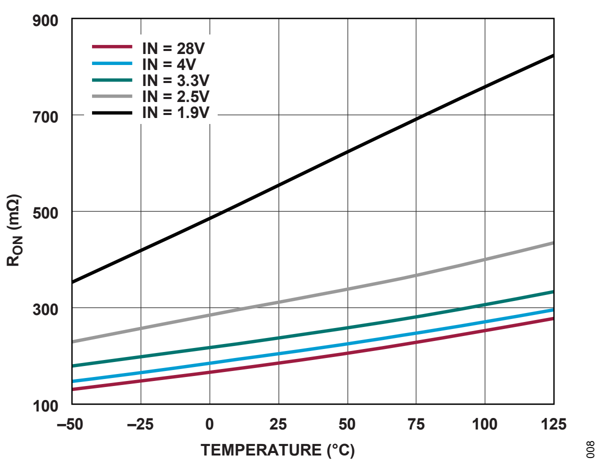


Figure 8. On-Resistance vs Temperature

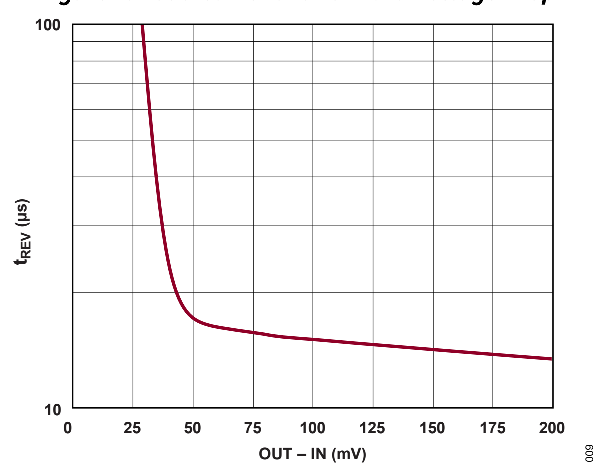


Figure 9. Turn-Off Time vs Reverse Voltage

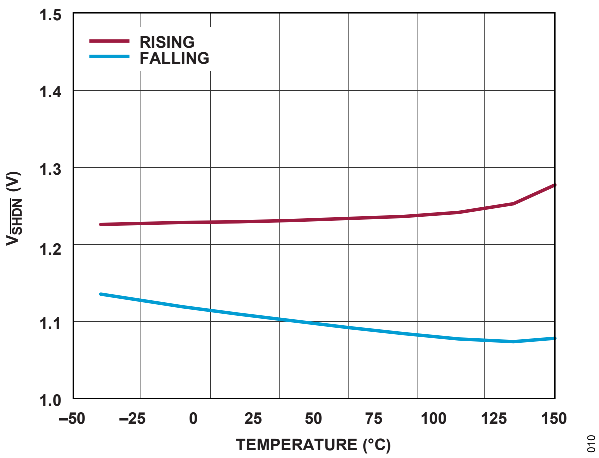


Figure 10. Shutdown Threshold vs Temperature

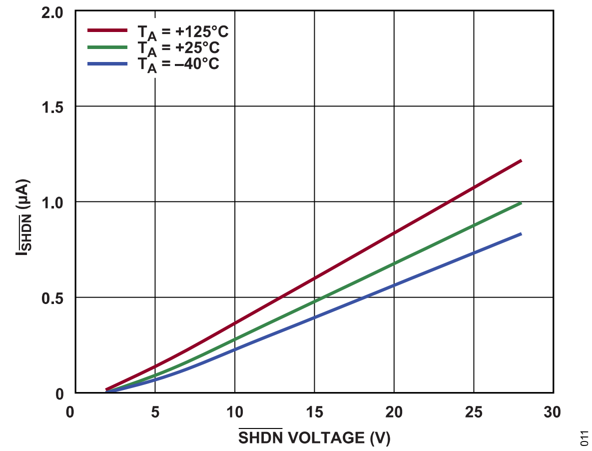


Figure 11. $I_{\overline{SHDN}}$ vs $\overline{SHDN}$ Voltage

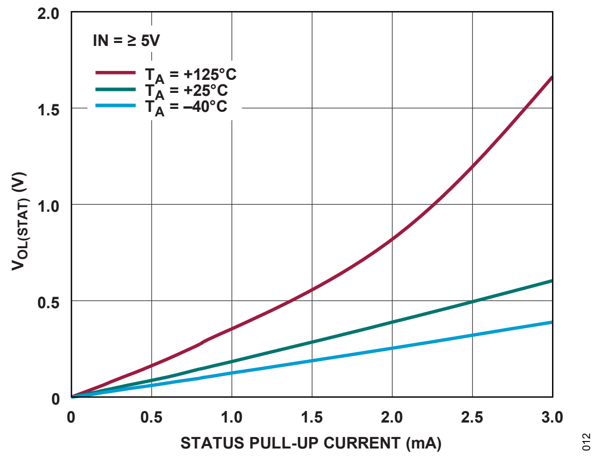
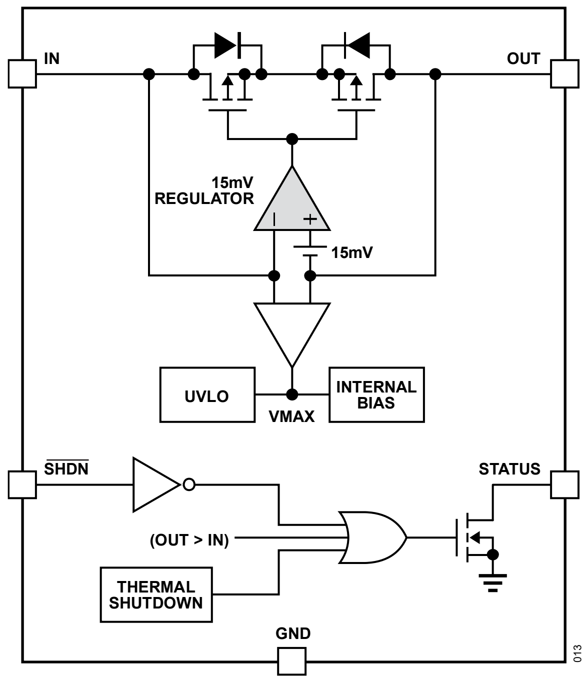


Figure 12. STATUS V_{OL} vs Pull-Up Current

BLOCK DIAGRAM



THEORY OF OPERATION

The LT4423 is a single positive voltage ideal diode, utilizing two integrated back-to-back P-channel power MOSFETs with a R_{ON} of 200mΩ. The IN pins form the anode, while the OUT pins form the cathode and are typically connected in parallel with other diode cathodes in an ORing configuration.

By applying an input power supply to IN, between 1.9V and 28V, a load can be powered at OUT. An internal gate drive amplifier (see *Block Diagram*) attempts to regulate the forward (IN - OUT) voltage drop to 15mV. The MOSFET gate overdrive voltage adjusts to maintain the 15mV drop. At load currents above approximately 75mA, the internal MOSFETs are fully on, and the forward voltage drop is governed by the ohmic relationship of $I_{LOAD} \cdot R_{ON}$.

Typical on-resistance (200mΩ) is achieved when IN ≥ 4V. Below IN = 4V, diminishing gate drive causes R_{ON} to increase, as shown in the Typical Performance Curves. Operating with high R_{ON} and high currents will cause large forward drops and temperature rise.

If the OUT voltage exceeds the IN voltage by approximately 20mV, the internal power MOSFET turns off quickly through a fast comparator, disabling the power path. Once disabled, OUT is disconnected from IN.

The LT4423 is placed in shutdown mode by driving $\overline{\text{SHDN}}$ low. In shutdown, the device consumes very little quiescent current (typically less than 500nA), the power path disables, and OUT is disconnected from IN. Driving $\overline{\text{SHDN}}$ high enables the power path, connecting the load at OUT to the input power supply connected to IN.

Integrated thermal protection disconnects the power path when the junction temperature exceeds 160°C (typical). While the power path is disabled due to the overtemperature condition, the device remains active and consumes power. Once the device cools down to about 145°C, the power path is restored (assuming the OUT voltage does not exceed the IN voltage by approximately 20mV, and the device has not been placed into shutdown mode by driving $\overline{\text{SHDN}}$ low).

STATUS is an open-drain output intended to indicate power path conditions. STATUS is designed for connection to a power supply through a pull-up resistor. STATUS pulls low whenever the internal power path is disabled. STATUS may pull low for the following reasons. First, driving $\overline{\text{SHDN}}$ low pulls STATUS low. Second, when the power path is reverse biased (the OUT voltage exceeds the IN voltage by approximately 20mV), STATUS also pulls low. When the power path is enabled, the STATUS pull-down is removed.

APPLICATIONS INFORMATION

The LT4423 is intended for power path control applications, including diode ORing of multiple power supplies, load sharing between multiple batteries or power sources, automatic switch-over from a primary to an auxiliary power source, charging of multiple batteries from a single charger, or acting as a high-side load switch.

USB PD 3.0 and Back-Up Battery Supply

The front-page schematic demonstrates the LT4423 in an application with USB PD (Power Delivery) 3.0 and a backup lithium-ion battery cell. The input voltage from the USB 3.0 connector can range from 5V to 20V, all easily handled by the LT4423. On the other hand, the single lithium-ion cell can be down at 3V to 3.6V, which is easily handled by the LT4423. The application has a logic control signal on $\overline{\text{SHDN}}$ for the primary power path. When this signal switches low, the primary power path from the USB is disabled, and the backup battery takes over the delivery of power to the load. The common output automatically biases to the higher of the two input voltages.

The configuration of STATUS in this application allows the LED to indicate that the USB power path is active, ensuring that the higher power consumption associated with the LED occurs when the USB power source is present. Even if the USB power source is disconnected without a $\overline{\text{SHDN}}$ control signal coming first, the application seamlessly switches to the backup power source. Note that the LED and STATUS functions are optional and easily removed for simplicity by leaving STATUS open.

The LT4423 $\overline{\text{SHDN}}$ rising threshold is 1.6V (maximum). To obtain the fastest turn-on response time, it is recommended that $\overline{\text{SHDN}}$ swing to at least the minimum device operating voltage of 1.9V for strong overdrive of the $\overline{\text{SHDN}}$ threshold. To obtain the fastest turn-off of the power path, pulling $\overline{\text{SHDN}}$ well below the minimum 1V threshold (or close to GND) is also recommended. $\overline{\text{SHDN}}$ should never be left open. If logical on/off control is not required, automatic turn-on is achieved by connecting $\overline{\text{SHDN}}$ to IN.

Automatic Power Path Control

The automatic switchover from a battery to a wall adapter or other power source is shown in *Figure 13*. Initially, with only the battery applied, the load is powered purely through the LT4423 from the battery. If the wall adapter is applied and is greater than the battery voltage, the OUT voltage rises above the IN voltage. The LT4423 senses this increase, disables the IN to OUT connection, and electrically isolates the battery from the power path. Now, only the wall adapter powers the load, and the battery remains protected.

With STATUS connected, as shown in *Figure 13*, the LED indicator turns on with the wall adapter present. When the wall adapter is not present and the battery powers the load, STATUS pulls high, and the LED indicator turns off. This configuration allows the higher power consumption of the LED to be supplied by the wall adapter when it is connected.

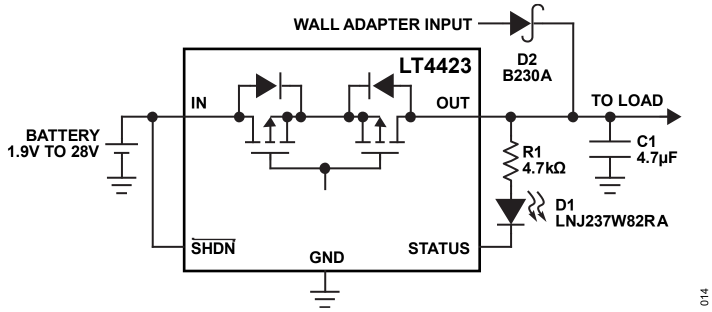


Figure 13. Automatic Switchover of Load Between a Battery and a Wall Adapter

5V Power Ride-Through

In a diode-OR configuration, multiple diode cathodes are connected in parallel, with the final output voltage set by the highest cathode potential. The LT4423 is well suited for these applications, with its ability to disable the power path whenever OUT exceeds IN by approximately 20mV or more, allowing no more than 1µA of reverse current. The low reverse leakage and the ability to stand-off 28V, and turn off under reverse bias make the LT4423 a high-performance diode replacement.

Figure 14 demonstrates a diode-OR application with a super-cap charger to provide load power ride-through in the event of input power loss. The LTC3625 charges two supercapacitors to a sum of 4.8V. Two LT4423s form a diode-OR circuit between the main 5V input and the supercapacitor 4.8V output. The cathodes of the LT4423s connect to a load or a downstream voltage regulator. If the main 5V supply is operating, load power is delivered from the 5V supply. Should the main 5V supply be removed, the 4.8V path turns on, and load power is derived from the supercapacitors.

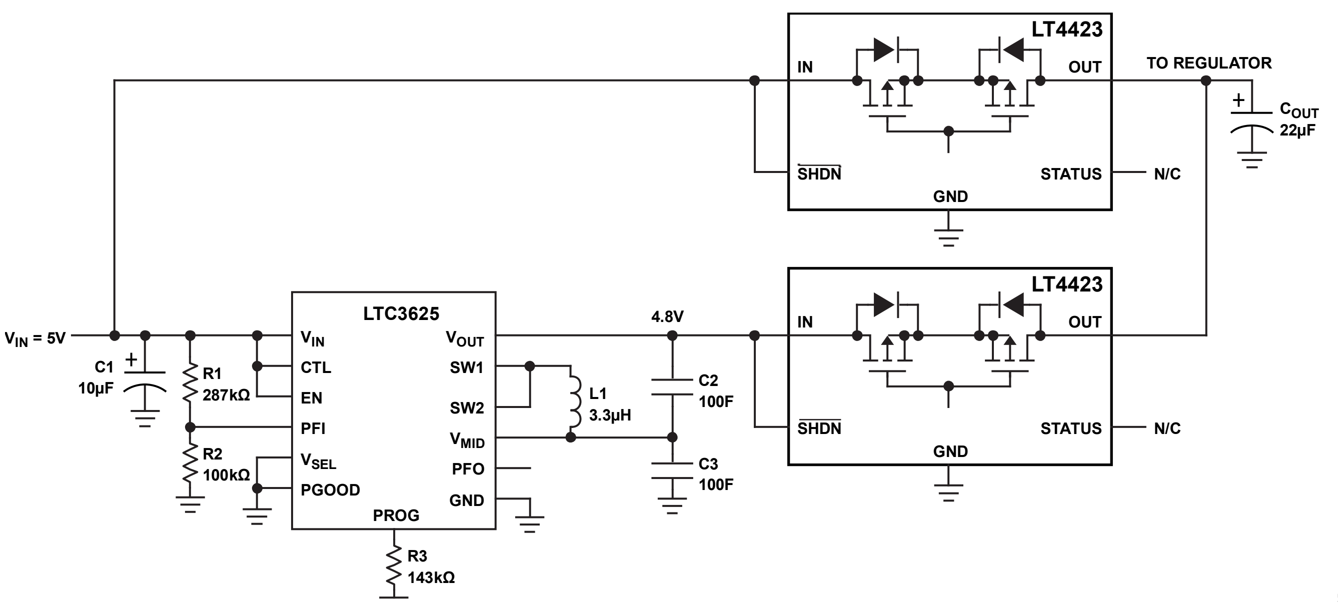


Figure 14. Riding through Loss of Primary Power Supply

High-Voltage Load Switch with Load Sharing and Undervoltage Lockout

Figure 15 demonstrates a high-voltage load switch and load-sharing application with a precision undervoltage lockout using an LTC2965 voltage supervisor. Two LT4423s are connected in parallel to the load. The power paths are enabled only when the 24V input supply is above 20V. If the 24V source is removed, the load is disconnected from the input.

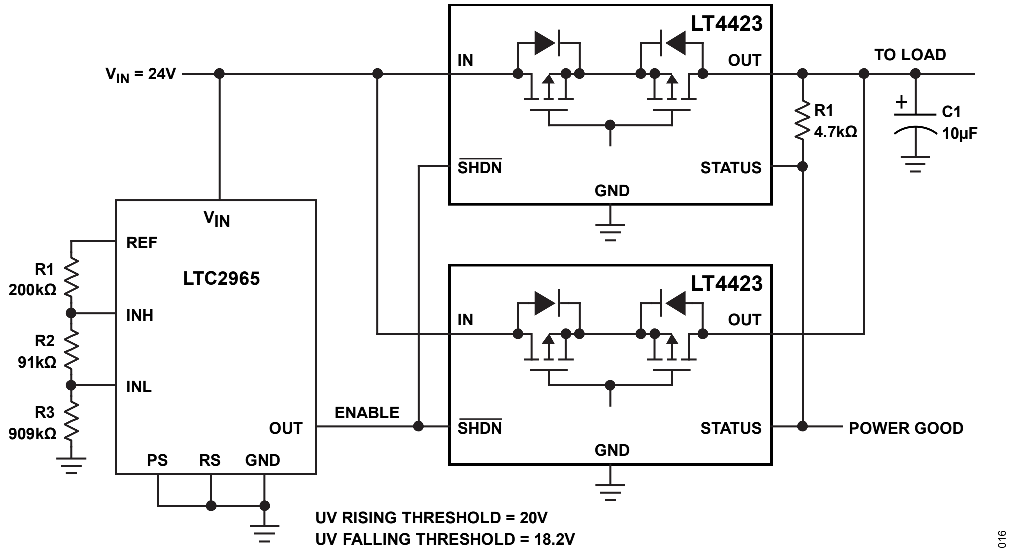


Figure 15. High-Voltage Load Switch and Load Sharing with UVLO

Layout and Thermal Considerations

The following advice should be considered when laying out a printed circuit board for the LT4423. First, connect the exposed pad (also connected to IN) to a sufficiently large copper plane for thermal relief. Use *Figure 16* to find the minimum copper area (connected to IN) required to limit junction temperature for a given load current and ambient temperature.

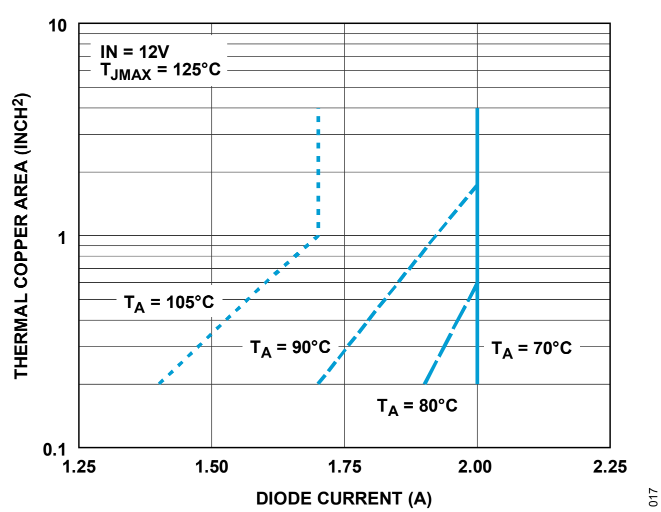


Figure 16. Minimum Thermal Copper vs Load Current and Ambient Temperature

PCB traces to the IN and OUT pins should be wide and short to minimize series resistance and inductance. *Figure 17* demonstrates a copper layout strategy for effective thermal and electrical performance.

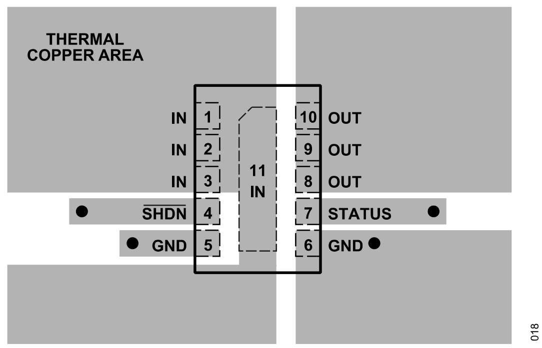


Figure 17. PCB Layout Strategy for Thermal Management

TYPICAL APPLICATIONS

High-Load Current Application

Some applications may require a power path that exceeds the 2A capability of the LT4423. The STATUS output may be used to enable an alternate power path. For example, consider the application shown in *Figure 18*. The LT4423 provides an automatic power path from the battery input to the 4Ω load when the 28V supply is not present. When the 28V supply (V_{IN2}) becomes available, V_{OUT} begins to charge through the MOSFET body diode, and the LT4423 shuts off due to the reverse bias from V_{OUT} to V_{IN1}. STATUS pulls low, allowing the P-channel MOSFET to turn on, providing a low-loss power path to the load.

Without protection components, the P-channel MOSFET V_{GS} could see 28V, which would be beyond the MOSFET absolute maximum rating. The zener diode limits the maximum V_{GS} on the MOSFET to 5.1V. R1 provides a discharge path for the MOSFET gate charge and a pull-up path for the STATUS output when the MOSFET is off.

If a logic-level STATUS voltage is required, R2 may be added to limit the voltage swing at the STATUS pin. When the LT4423 power path is on, STATUS pulls up to the battery voltage. When the LT4423 power path is off and R2 is not present, STATUS pulls to 4 or 5V (V_z) below the 28V supply. With R2 in place, the STATUS pull-down current causes a voltage drop on R2, allowing the STATUS output to pull near ground. The pull-down current (28V - V_Z)/R2 is shared between R1 and the zener diode.

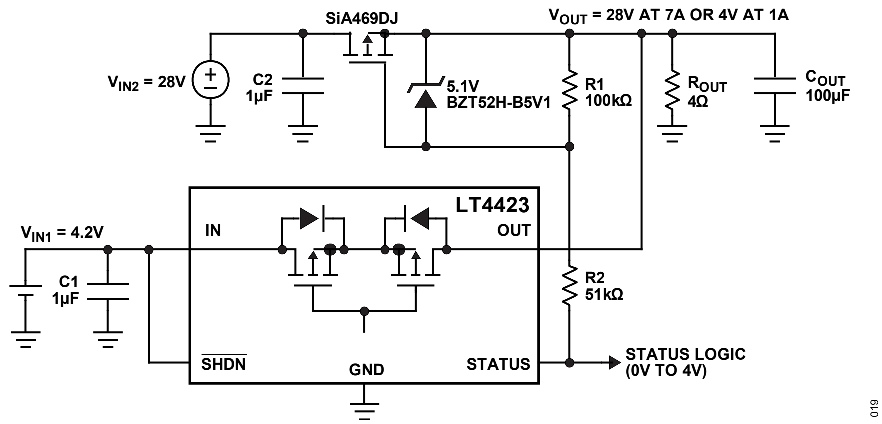


Figure 18. Using an External MOSFET for Switching to High Current Loads

Reverse Input Voltage Protection

Some applications must tolerate momentary accidental reversed voltage connections or negative voltage transients at the IN pin. Although the IN pin absolute maximum rating is limited to -0.3V, *Figure 19* and *Figure 20* demonstrate how a resistor or simple diode may be added to permit reverse input voltage tolerance.

Under reverse input voltage, an internal substrate diode is turned on, and its current must be limited to below 100mA. In *Figure 19*, a 100Ω 1/4-watt resistor (R_{GND}) is added to the ground path, safely limiting internal power dissipation under the reverse connection of the 4.2V battery.

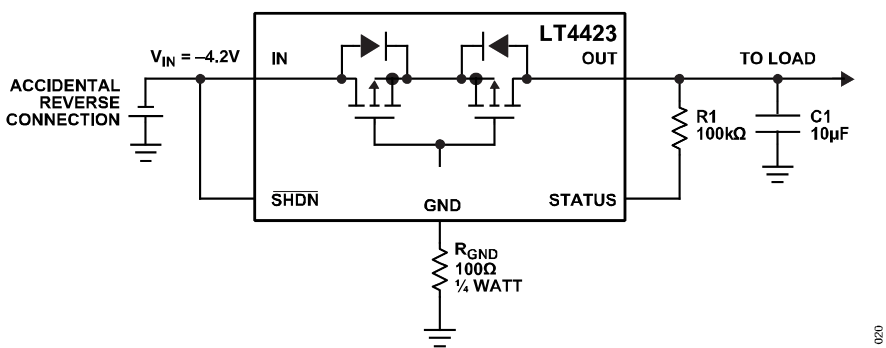


Figure 19. Protecting Against Reverse Input Voltage with a Resistor

Placing the protection resistor in the ground path preserves the low IN to OUT power path resistance. Minor drawbacks to using the protection resistor include a small increase in STATUS V_{OL} and a minor shift in the $\overline{SHDN}$ threshold, both dependent on the current in the STATUS pull-down path.

In the case of persistent reverse voltage, a simple diode (D_{GND}) may be used in place of the ground resistor, as shown in *Figure 20*. Using a diode removes power dissipation concerns at the expense of increased STATUS V_{OL}, a shift in $\overline{SHDN}$ threshold, and an increase in minimum IN voltage by an amount equal to the diode drop voltage in the ground path.

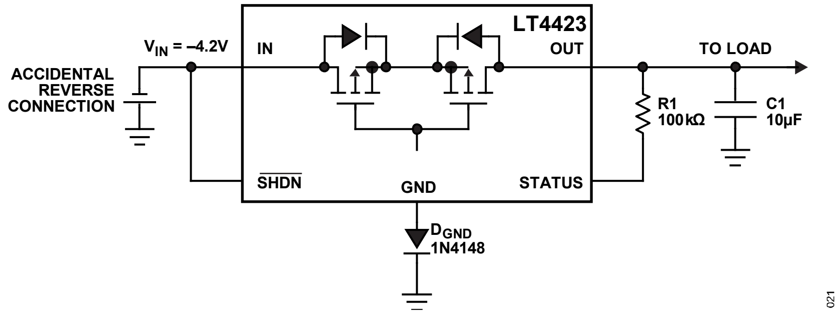


Figure 20. Protecting Against Reverse Input Voltage with a Diode

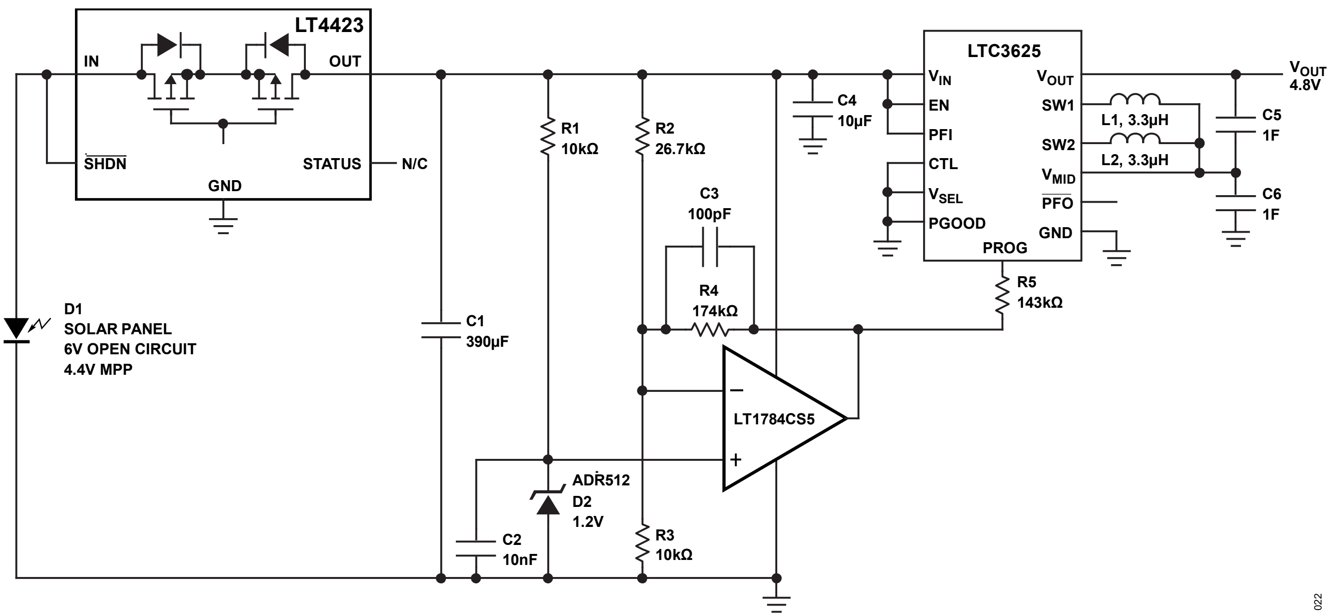


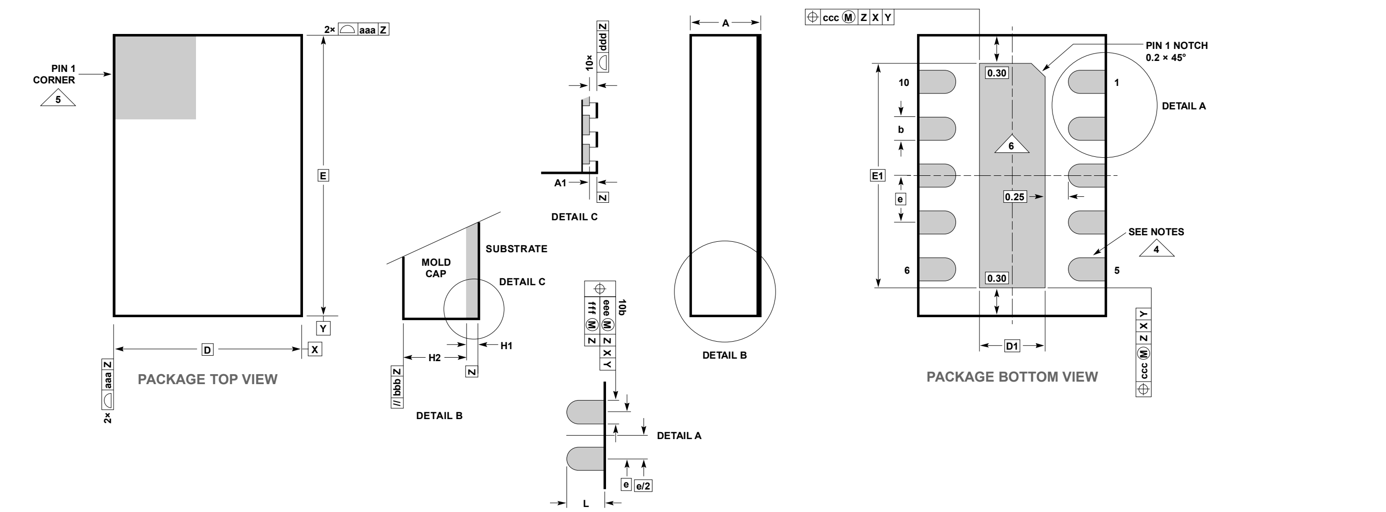
Figure 21. High Efficiency Solar Powered SCAP Charger with MPP

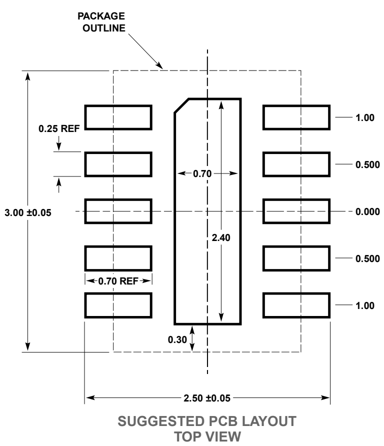
RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC4411	2.6A Ideal Diode, Internal N-Channel MOSFET	2.6V to 5.5V Operation
LTC4413	2.6A Dual Ideal Diode, Internal P-Channel MOSFET	1.7V to 5.5V Operation
LTC4415	4A Dual Ideal Diode, Internal P-Channel MOSFET	2.6V to 5.5V Operation
LT4422	4A Ideal Diode, Internal P-Channel MOSFET	1.9V to 28V Operation, Low Quiescent Current, Low Leakage
LTC4358	5A Ideal Diode, Internal N-Channel MOSFET	9V to 26.5V Operation, Reverse Input Protection
LTC4376	7A Ideal Diode, Internal N-Channel MOSFET	4V to 40V Operation, Reverse Input Protection
LTC4352	Low Voltage Ideal Diode Controller with Monitoring	Controls N-Channel MOSFET, 0V to 18V Operation
LTC4359	Ideal Diode Controller With Reverse Input Protection	4V to 80V Operation, -40V Input Protection, 150µA IQ
LTC4370	Two-Supply Diode-Or Current Balancing Controller	Simple Redundant Supply Current Sharing, 0V to 18V Operation
LTC4353	Dual Low Voltage Ideal Diode Controller	Controls Two N-Channel MOSFETs, 0V to 18V Operation
LTC4371	Dual Negative Voltage Ideal Diode-Or Controller and Monitor	Controls Two MOSFETs, 220ns Turn-Off, Withstands > ±300V Transients
LTC4355	Positive High Voltage Ideal Diode-Or with Input Supply And Fuse Monitors	Dual N-channel, 9V to 80V
LTC4417	Prioritized Powerpath Controller	2.5V to 36V Operation; Ext P-Channel MOSFET; -42V Reverse Protection
LTC4418	Dual Channel Prioritized Powerpath Controller	2.5V to 40V Operation; Ext P-Channel MOSFET; -42V Reverse Protection
LTC4419	18V Dual Input Micropower Powerpath Prioritizer	1.8V to 18V Operation; 0.5A Switches; Freshness Seal
LTC4421	High Power Prioritized Powerpath Controller	0V to 18V Operation, 60V Tolerant
LTC4450	18V, 12A Ideal Diode	Internal N-Channel MOSFET
LTC4451	40V, 7A Ideal Diode	Internal N-Channel MOSFET

OUTLINE DIMENSIONS

LDFN Package
10-Lead (3mm × 2mm × 0.75mm)
(Reference DWG # 05-08-1686)





DIMENSIONS				
SYMBOL	MIN	NOM	MAX	NOTES
A	0.65	0.74	0.83	
A1	0.01	0.02	0.03	
L	0.30	0.40	0.50	
b	0.22	0.25	0.28	PAD DIMENSION
D		2.00		
E		3.00		
D1		0.70		
E1		2.40		
e		0.50		
H1		0.25 REF		SUBSTRATE THK
H2		0.50 REF		MOLD CAP HT
aaa			0.10	
bbb			0.10	
ccc			0.10	
ddd			0.10	
eee			0.15	
fff			0.08	

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
2. ALL DIMENSIONS ARE IN MILLIMETERS
3. PRIMARY DATUM -Z- IS SEATING PLANE
4. METAL FEATURES UNDER THE SOLDER MASK OPENING NOT SHOWN SO AS NOT TO OBSCURE THESE TERMINALS AND HEAT FEATURES
5. DETAILS OF PIN 1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE PIN 1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE
6. THE EXPOSED HEAT FEATURE MAY HAVE OPTIONAL CORNER RADII

LDFN 10 1218 REV Ø

Figure 22. 10-Lead Plastic LDFN

ORDERING GUIDE

Table 4. Ordering Guide

TAPE AND REEL*	PART MAKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LT4423AV#TRPBF	LHKZ	10-Lead LDFN (3mm x 2mm x 0.75mm)	-40°C to 125°C

*For more information on tape and reel specifications, refer to the *Tape and Reel Specifications*. Some packages are available in 500 unit reels through designated sales channels with #TRMPBF suffix.