

FEATURES

- ▶ Internal 50mΩ Power Path
- ▶ Wide Operating Voltage Range: 1.9V to 28V
- ▶ Reverse Current Protection
- ▶ Low 10μA Quiescent Current
- ▶ Fast 3μs Response to Load Steps
- ▶ Low 500nA Off State Current
- ▶ Smooth Switchover in Diode-OR Applications
- ▶ 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[®]4422 is an ideal 1.9V to 28V diode with integrated P-channel MOSFET. When enabled, 15mV forward voltage regulation minimizes power dissipation while increasing operating headroom and efficiency compared to a Schottky diode.

The LT4422 easily ORs power supplies together to increase system reliability and prevent reverse conduction. A non-enabled LT4422 blocks up to 28V at the output 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 LT4422 is in shutdown or reverse bias.

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SIMPLIFIED APPLICATION DIAGRAM

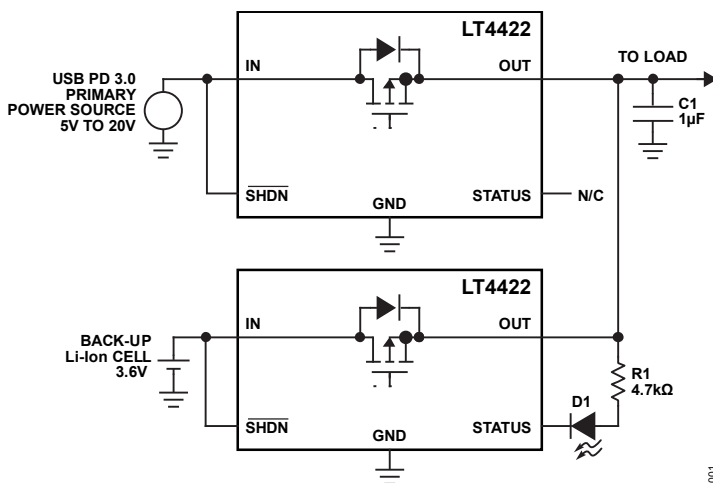


Figure 1. USB PD 3.0 and Back-Up Battery Supply

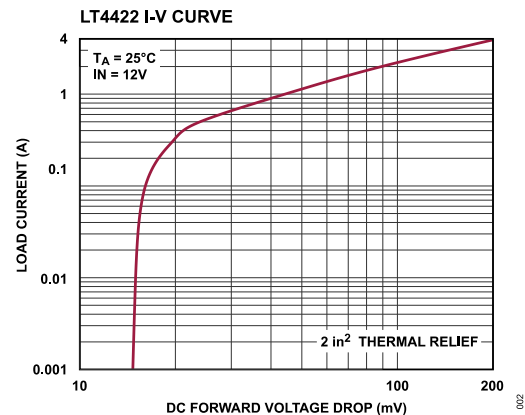


Figure 2. LT4422 I-V CURVE

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REVISION HISTORY

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	09/24	Initial Release	—

SPECIFICATIONS

Table 1. Electrical Characteristics

(Specifications are at $T_A = 25^\circ\text{C}$, $I_N = \overline{\text{SHDN}} = 8.4\text{V}$, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS/COMMENTS		MIN	TYP	MAX	UNITS
Operating Voltage Range	V_{IN}	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		1.9		28	V
Quiescent Current in Forward Regulation	I_{CC}	$I_{OUT} = -10\text{mA}$ Measured Through GND	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		-10	-18	μA
Quiescent Current in Shutdown	I_{SD}	$\overline{\text{SHDN}} = \text{GND}$ Measured Through GND	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		-0.1	-2	μA
Reverse Leakage Current to IN	$I_{REV(IN)}$	IN = GND, OUT = 28V, $\overline{\text{SHDN}} = \text{GND}$	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		-0.1	-2	μA
Reverse Leakage Current to OUT	$I_{REV(OUT)}$	IN = GND, OUT = 28V, $\overline{\text{SHDN}} = \text{GND}$	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		0.1	4	μA
Forward Regulation Voltage (IN - OUT)	V_{REG}	$I_{OUT} = -10\text{mA}$	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$	5	15	25	mV
Internal Path On-Resistance	R_{ON}	$I_{OUT} = -2\text{A}$	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$	29	50	100	$\text{m}\Omega$
Reverse Turn-Off Time	t_{REV}	Step OUT from 8.4V to 8.6V STATUS Falling	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		15	30	μs
Response Time to Load Step	t_{FON}	Step I_{OUT} from -10mA to -1A, $C_{OUT} = 10\mu\text{F}$	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		3	4	μs
$\overline{\text{SHDN}}$ Rising Threshold	V_{SRT}	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		1	1.3	1.6	V
$\overline{\text{SHDN}}$ Hysteresis	V_{HYST}	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		-75	-130	-230	mV
$\overline{\text{SHDN}}$ Input Current	$I_{\overline{\text{SHDN}}}$	$\overline{\text{SHDN}} = 28\text{V}$	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		1	2	μA
$\overline{\text{SHDN}}$ Delay to Power Path Enable	t_{ON}	Step $\overline{\text{SHDN}}$ from GND to IN STATUS Released	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		570	1000	μs
$\overline{\text{SHDN}}$ Delay to Power Path Disable	t_{OFF}	Step $\overline{\text{SHDN}}$ from IN to GND STATUS Falling	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		85	160	μs
STATUS Output Voltage Low	$V_{OL(STAT)}$	$I_{STATUS} = 1\text{mA}$, $\overline{\text{SHDN}} = \text{GND}$	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		180	410	mV
STATUS Output High Leakage	$I_{OH(STAT)}$	STATUS = 28V	$-40^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$		± 5	± 200	nA

ABSOLUTE MAXIMUM RATINGS

$T_A = 25^\circ\text{C}$ ⁴, unless otherwise specified.

Table 2. Absolute Maximum Ratings

PARAMETER	RATING
Supply Voltage IN	-0.3V to 30V
Supply Voltage OUT	-0.3V to 30V
Supply Voltage (IN – OUT) ³	-30V to 0.3V
Input Voltage $\overline{\text{SHDN}}$	-30V to 30V
Output Voltage STATUS	-0.3V to 30V
Input Current IN	6A
Output Current OUT	-6A
Operating Junction Temperature Range LT4422A	-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 LT4422 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: $T_J = T_A + (P_D \cdot \theta_{JA})$.
- ³ This voltage is set by the power path MOSFET's body diode and will safely exceed 0.3V during start-up for a limited time determined by the body diode thermal dissipation.
- ⁴ 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

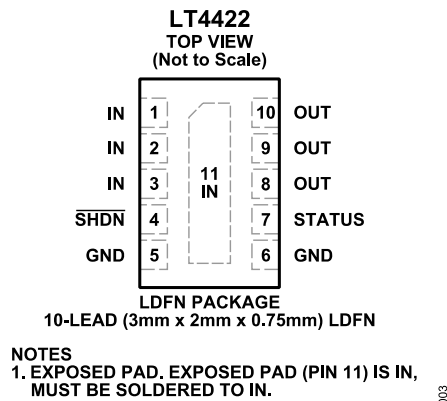


Figure 3. Pin Configurations

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 0.1 μ F or larger capacitor to suppress undesired reverse turn-off in applications with load transient ringing.
4	$\overline{\text{SHDN}}$	Shutdown Control Input. Driving $\overline{\text{SHDN}}$ low disables the ideal diode between IN and OUT, placing the part in a low quiescent current mode. $\overline{\text{SHDN}}$ may be connected to IN for automatic turn-on applications. Do not leave $\overline{\text{SHDN}}$ open. Note that the power path body diode provides a conducting path between IN and OUT when in shutdown.
5, 6	GND	Device Ground.
7	STATUS	Open-Drain Status Output. When IN or OUT is greater than 1.9V, STATUS pulls low when $\overline{\text{SHDN}}$ is pulled low or when OUT exceeds IN by approximately 20mV. Connect STATUS to OUT or an external supply through a pull-up resistor. Leave STATUS open or connect to GND if not used.
8, 9, 10	OUT	Ideal Diode Cathode Output. In diode-OR applications using multiple LT4422s, connect the common output node to OUT. Bypass OUT with a 0.1 μ F or larger capacitor to suppress undesired reverse turn-off in applications with load transient ringing.

TYPICAL PERFORMANCE CHARACTERISTICS

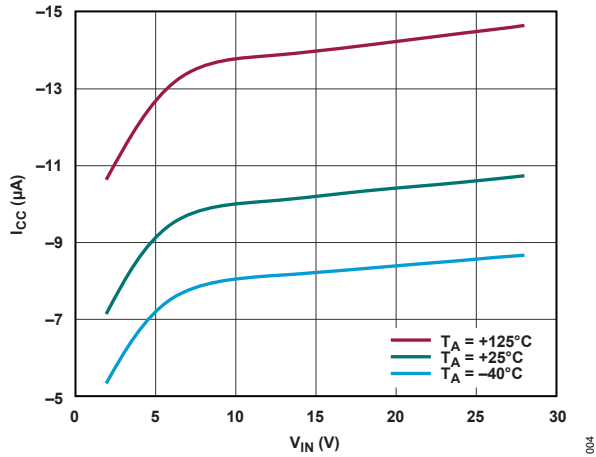


Figure 4. Supply Current to GND vs IN Voltage

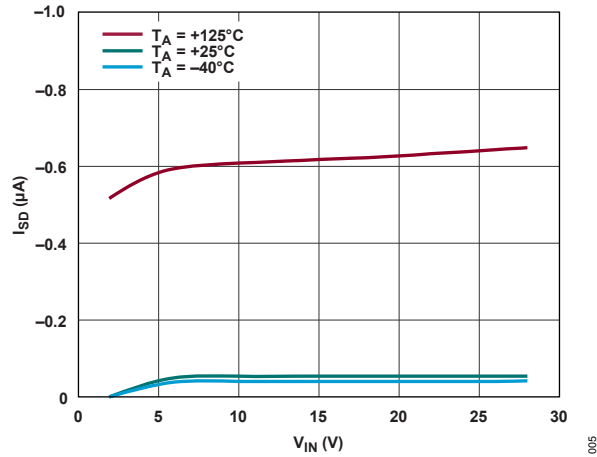


Figure 5. Supply Current to GND vs IN Voltage in Shutdown

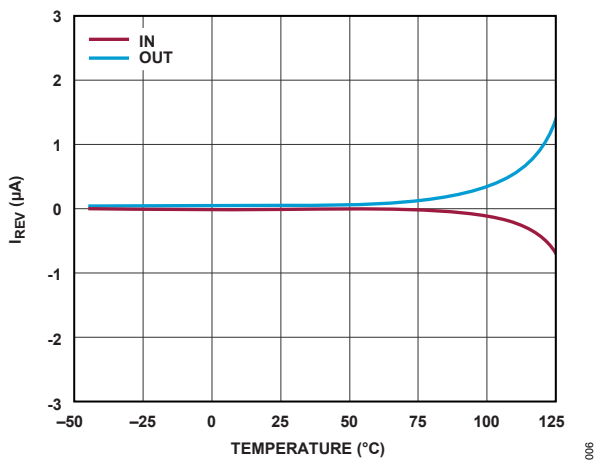


Figure 6. Reverse Leakage Current vs Temperature

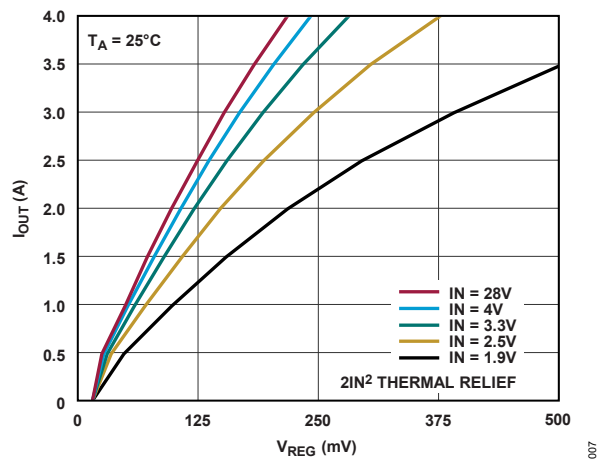


Figure 7. Load Current vs Forward Voltage Drop

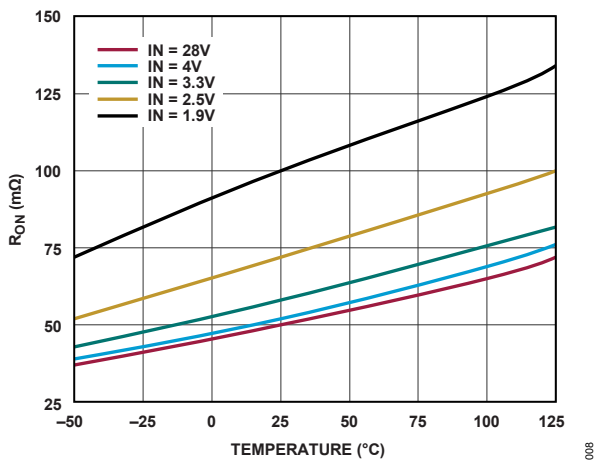


Figure 8. On-Resistance vs Temperature

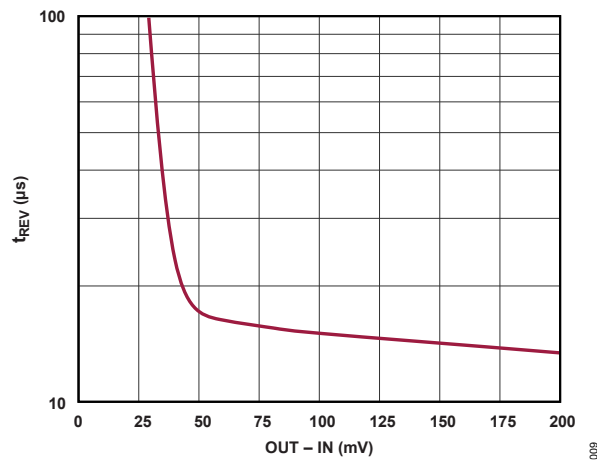


Figure 9. Turn-Off Time vs Reverse Voltage

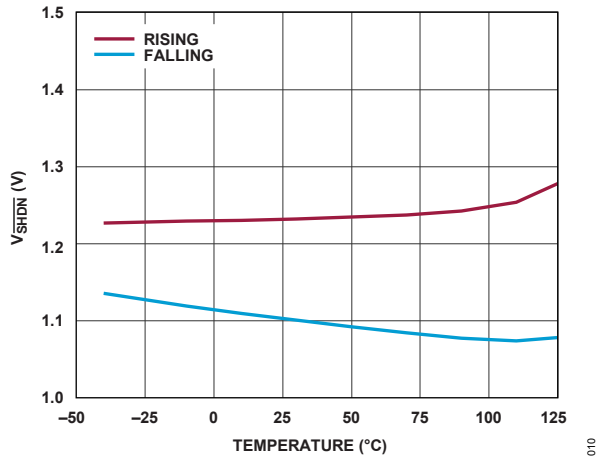


Figure 10. Shutdown Threshold vs Temperature

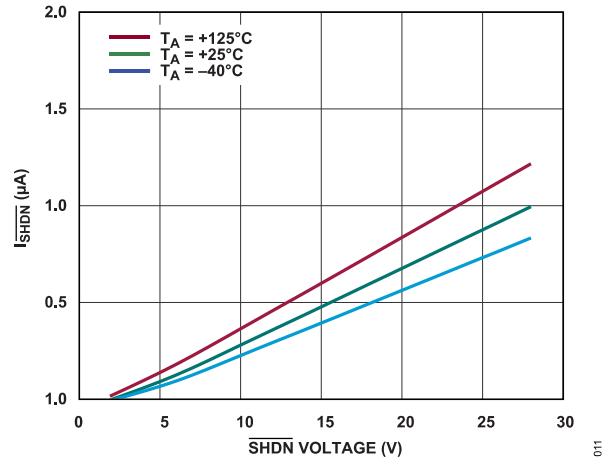


Figure 11. I_{SHDN} vs S_{SHDN} Voltage

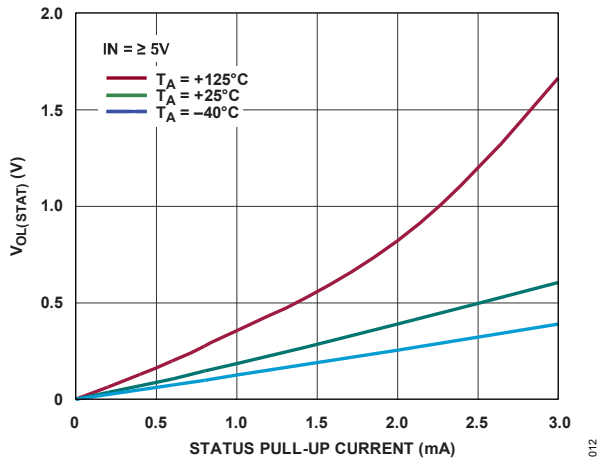


Figure 12. STATUS V_{OL} vs Pull-Up Current

BLOCK DIAGRAM

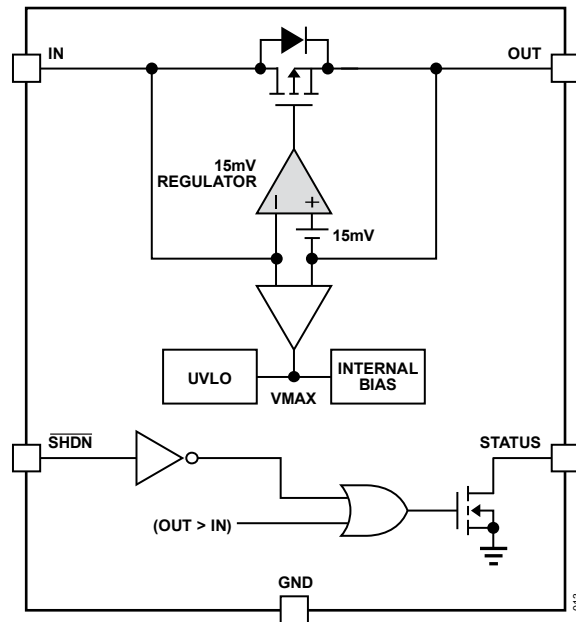


Figure 13. Block Diagram

THEORY OF OPERATION

The LT4422 is a single positive voltage ideal diode, utilizing a P-channel power MOSFET with a R_{ON} of 50m Ω . 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 300mA, the internal MOSFET is fully on, and the forward voltage drop is governed by the ohmic relationship of $I_{LOAD} \cdot R_{ON}$.

Typical on-resistance (50m Ω) is achieved when $IN \geq 4V$. 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 low dropout power path.

The LT4422 is placed in shutdown mode by driving \overline{SHDN} low. In shutdown, the device consumes very little quiescent current (typically less than 500nA). It is important to note that the \overline{SHDN} input, while disabling the LT4422 and reducing its current consumption, does not disconnect the load from the input since the internal MOSFET's body diode is ever-present. External MOSFETs may be added to configure load-switching applications.

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{SHDN} low pulls STATUS low. Second, when the power path is reverse biased (the OUT voltage exceeds the IN voltage by at approximately 20mV), STATUS also pulls low. When the power path is enabled, the STATUS pull-down is removed.

APPLICATIONS INFORMATION

The LT4422 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, and charging multiple batteries from a single charger.

USB PD 3.0 and Back-Up Battery Supply

The front-page schematic demonstrates the LT4422 in an application with USB PD (Power Delivery) 3.0 along with 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 LT4422. On the other hand, the single lithium-ion cell can be at 3V to 3.6V, which is also easily handled by the LT4422. 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 LT4422 $\overline{\text{SHDN}}$ 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 14](#). Initially, with only the battery applied, the load is powered purely through the LT4422 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 LT4422 senses this increase, disables the IN to OUT connection, and electrically isolates the battery from the power path. Only the wall adapter powers the load, and the battery remains protected.

With STATUS connected, as shown in [Figure 14](#), 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.

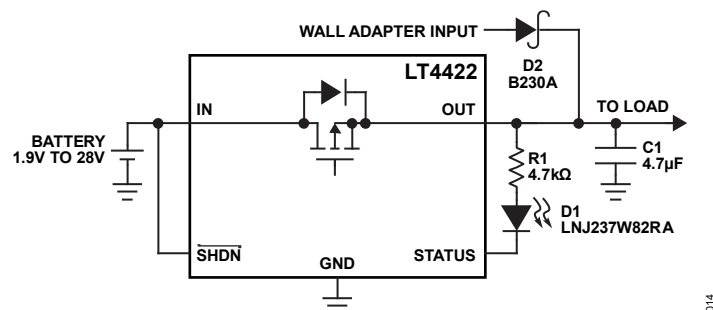


Figure 14. Automatic Switchover of Load Between a Battery and a Wall Adapter

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 LT4422 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 1 μ A of reverse current. The low reverse leakage and the ability to stand-off 28V and turn off under reverse bias make the LT4422 a high-performance diode replacement.

Figure 15 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 LT4422s form a diode-OR circuit between the main 5V input and the supercapacitor 4.8V output. The cathodes of the LT4422s 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.

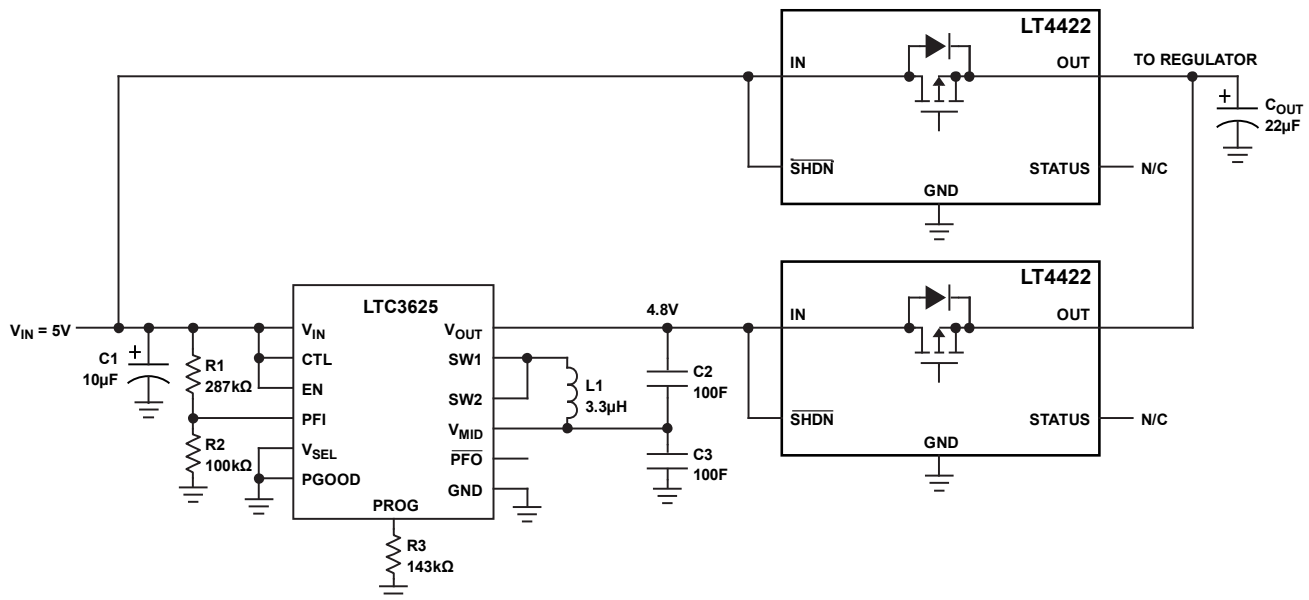


Figure 15. Riding through Loss of Primary Power Supply

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High-Voltage Diode-OR

The outputs of two or more LT4422s can be combined for redundancy or for droop sharing as shown in [Figure 16](#).

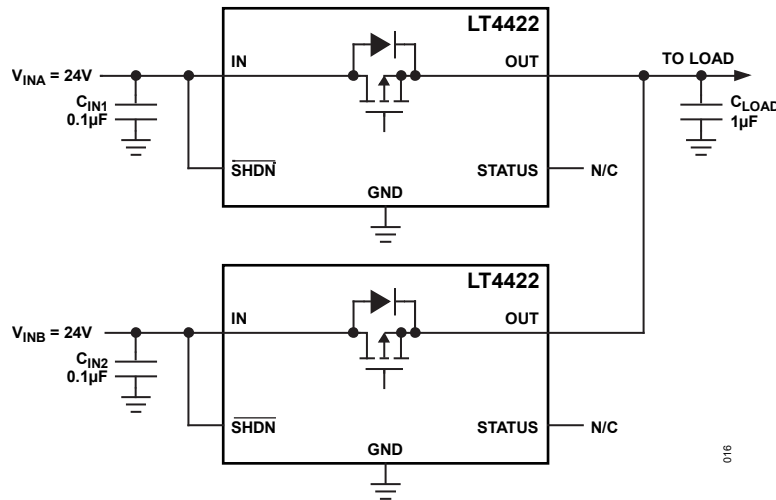


Figure 16. High Voltage Diode-OR

Layout and Thermal Considerations

The following advice should be considered when laying out a printed circuit board (PCB) for the LT4422. First, connect the exposed pad (also connected to IN) to a sufficiently large copper plane for thermal relief. Use [Figure 17](#) to find the minimum copper area (connected to IN) required to limit junction temperature for a given 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 18](#) demonstrates a copper layout strategy for effective thermal and electrical performance.

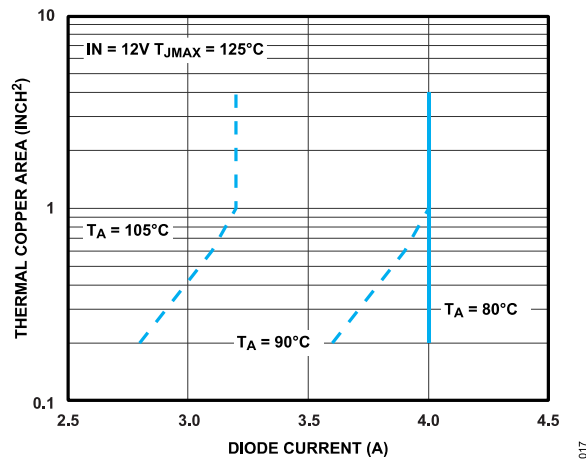


Figure 17. Minimum Thermal Copper vs Load Current and Ambient Temperature

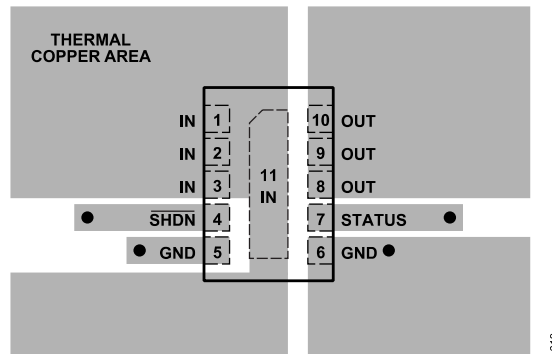


Figure 18. PCB Layout Strategy for Thermal Management

TYPICAL APPLICATION

High-Load Current Application

Some applications may require a power path that exceeds the 4A capability of the LT4422. The STATUS output may be used to enable an alternate power path. For example, consider the application as shown in Figure 19. The LT4422 provides an automatic power path from the battery input to the 4Ω load when the 28V supply is absent. When the 28V supply (V_{IN2}) becomes available, V_{OUT} begins to charge through the MOSFET body diode, and the LT4422 shuts off due to the reverse bias from V_{OUT} to V_{IN1} . STATUS pulls low, allowing the P-channel MOSFET to turn on and 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.

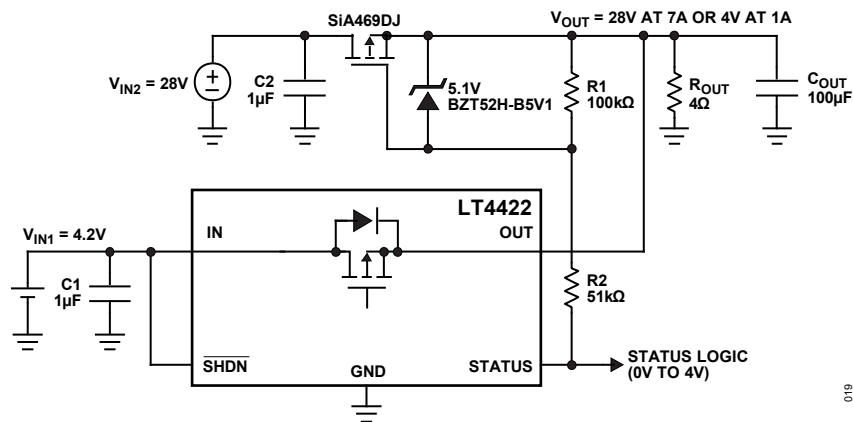


Figure 19. Using an External MOSFET for Switching to High Current Loads

If a logic-level STATUS voltage is required, R2 may be added to limit the voltage swing at the STATUS pin. When the LT4422 power path is on, STATUS pulls up to the battery voltage. When the LT4422 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.

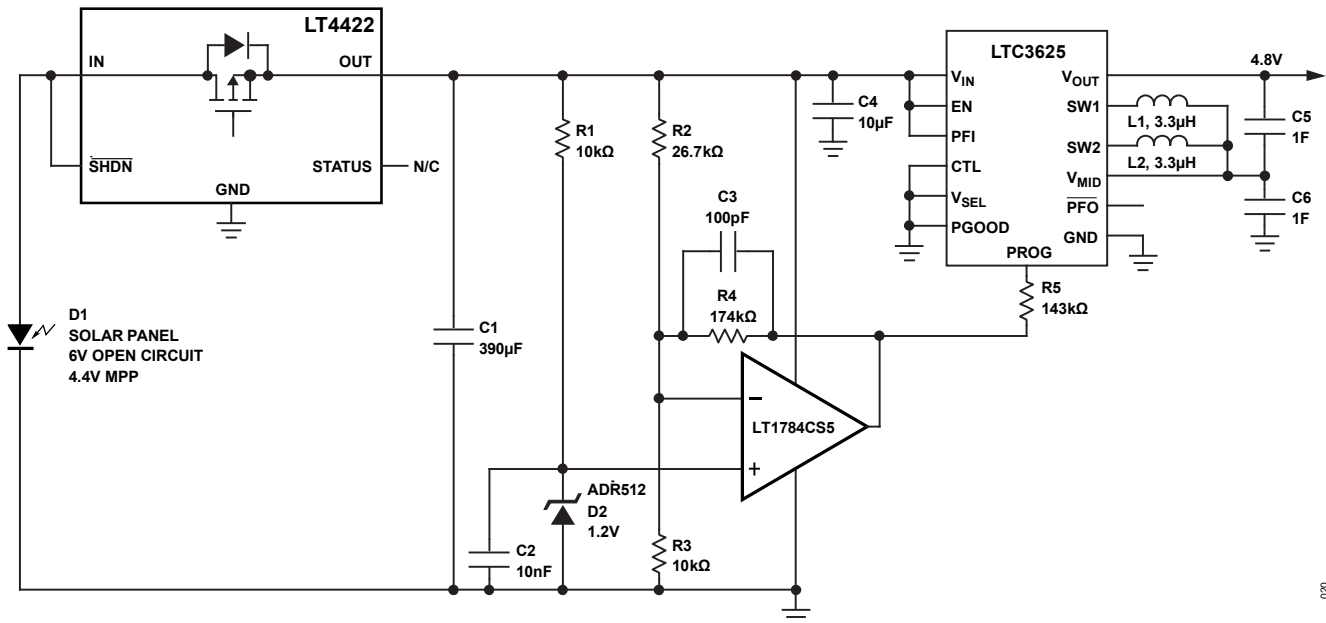


Figure 20. High-Efficiency Solar Powered SCAP Charger with MPPT

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 21](#) and [Figure 22](#) 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 21](#), a 100Ω ¼-watt resistor (R_{GND}) is added to the ground path, safely limiting internal power dissipation under the reverse connection of the 4.2V battery.

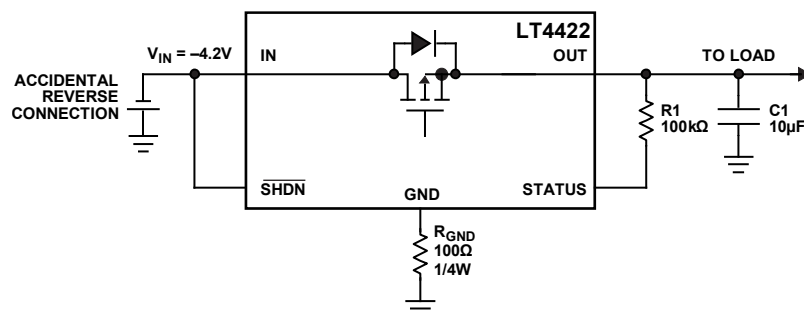


Figure 21. Protecting against Reverse Input Voltage with a Resistor

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 minor shift in $\overline{\text{SHDN}}$ 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 22](#). Using a diode removes power dissipation concerns at the expense of increased STATUS V_{OL} , a shift in $\overline{\text{SHDN}}$ threshold and increase in minimum IN voltage by an amount equal to the diode drop voltage in the ground path.

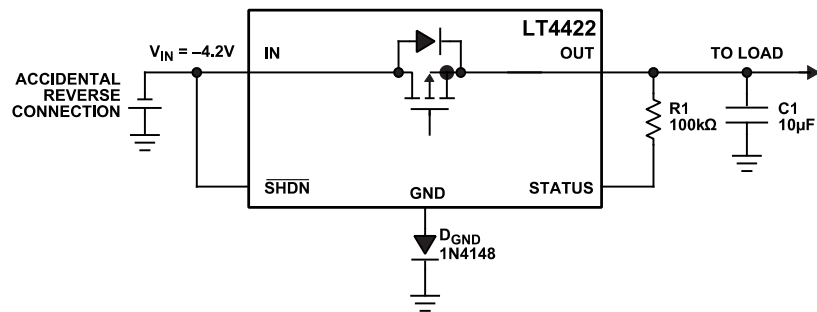


Figure 22. Protecting against Reverse Input Voltage with a Diode

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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
LT4423	2A Ideal Diode, Internal P-Channel MOSFETS	1.9V to 28V Operation, Reverse Input and Output Protection
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, 150 μ A I_Q
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 > \pm 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)

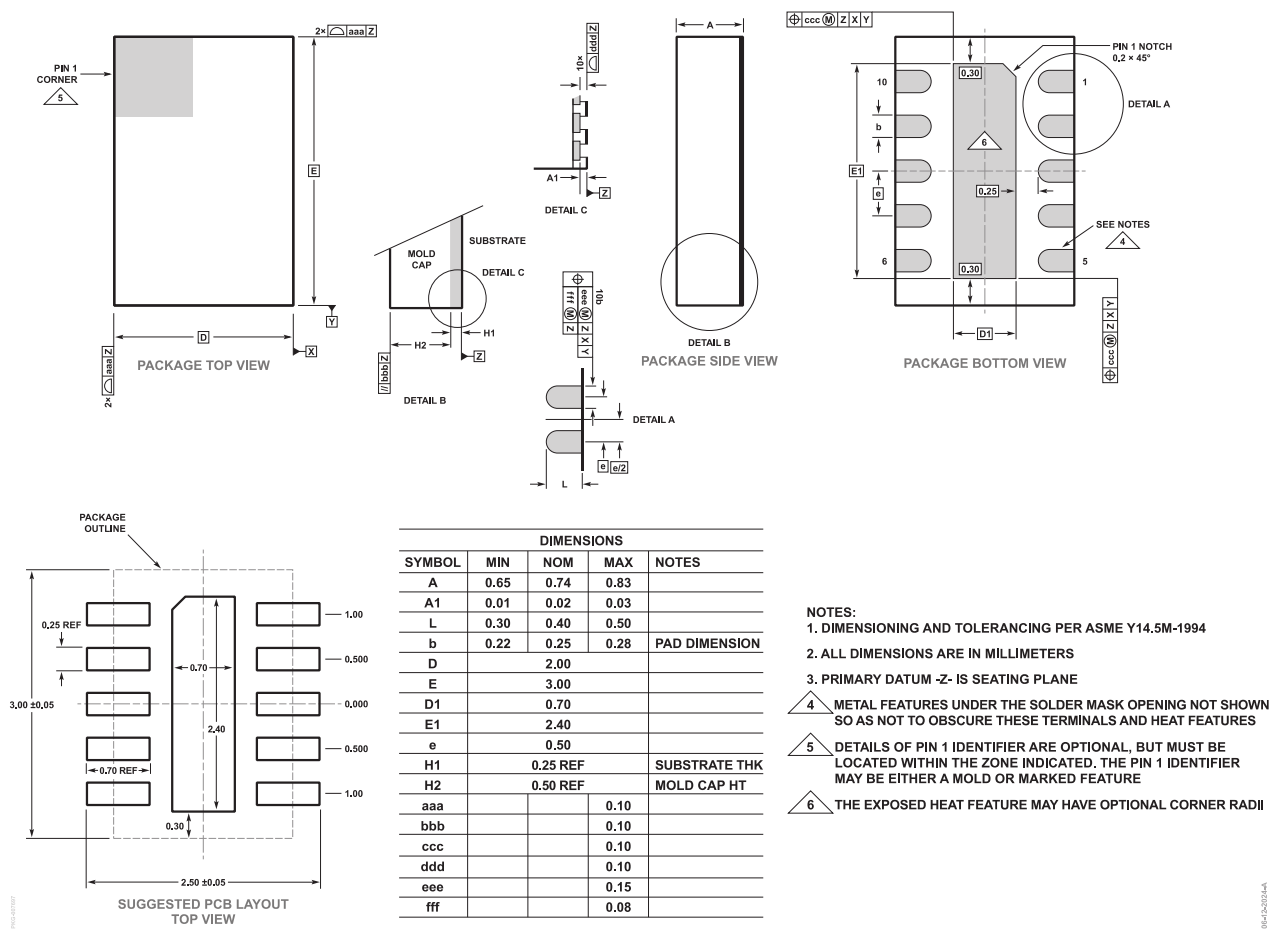


Figure 23. 10-Lead Plastic LDFN

ORDERING GUIDE

Table 4. Ordering Guide

TAPE AND REEL*	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LT4422AV#TRPBF	LHKY	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

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