# 500mA, 3.3V Linear Regulator with Auxiliary Backup

FEATURES

- ■ "Tiny" DFN Package Offers Excellent Thermal Characteristics (also available in NSOIC)
- ■ "Glitch Free" Transition between Two Supplies
- ■ 3.3V Fixed LDO Output Voltage
- ■ 400µA Quiescent Current @ 500mA Load
- ■ Fast Transient Response
- ■ Current Limit Protection
- ■ Thermal Shutdown Protection with Hysteresis
- ■ Auxiliary Supply Control
- ■ Internal 0.2Ω PFET Switch Eliminates External FETs
- ■ Kelvin Connection with 3.3V Feedback

V_{SENSE} 1		8	GND
V_{IN} 2	**SP6231**	7	GND
V_{OUT} 3	**8 Pin nSOIC**	6	GND
V_{AUX} 4		5	GND
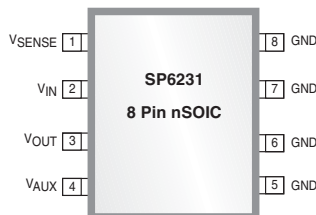
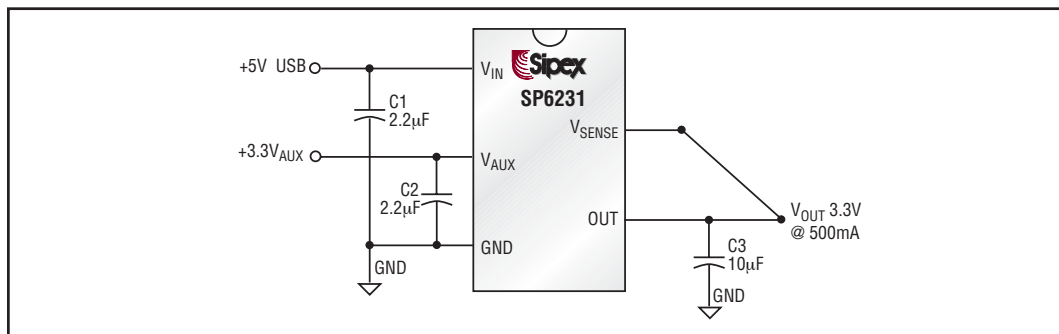*Now Available in Lead Free Packaging*

APPLICATIONS

- ■ USB Peripherals
- ■ NIC Cards
- ■ PCMCIA/PCI Cards
- ■ Desktop Computers
- ■ Dual Power Systems

DESCRIPTION

The SP6231 is a 500mA, 3.3V LDO with an integrated auxiliary voltage input switch. During normal operation, the SP6231 acts as a standard LDO with an output voltage of 3.3V delivering up to 500mA. When the 5V input drops below 4.4V, the 3.3V, V_{AUX} input is switched to the output through an internal PFET, maintaining a constant "glitch free" output voltage.

The SP6231 is ideally suited for NIC cards and portable battery powered equipment. When a desktop computer reverts to sleep mode, its 5V bus is removed, leaving only the 3.3V bus. The SP6231's auxiliary output passes the 3.3V bus through, keeping the NIC card available for any Wake-On-LAN command. In battery powered applications, the SP6231 draws power from any available 5V USB connection and reverts to battery power when the USB power is removed.

TYPICAL APPLICATION CIRCUIT

V$_{IN}$ .... 0.3V to 7V
V$_{OUT}$ .... 0.3V to 6V
V$_{AUX}$ .... 0.3V to 7V
Storage Temperature .... -65°C to 150°C
Power Dissipation .... internally limited
Lead Temperature (Soldering) .... 60 sec. max above
183°C,230°C Peak

These are stress ratings only and functional operation of the device at these ratings or any other above those indicated in the operation sections of the specifications below is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

ELECTRICAL CHARACTERISTICS

Unless otherwise specified: -40°C < T$_A$ < 85°C, 4.75V≤ V$_{IN}$ < 6V, C$_{OUT}$ ≥ 10μF with ESR <1Ω, I$_{OUT}$ = 10mA, V$_{AUX}$ = 3.3V

PARAMETER	UNITS	MIN	TYP	MAX	CONDITIONS
LINEAR REGULATOR					
Output Voltage	V	3.200	3.300	3.400	10mA < I$_{OUT}$ < 500mA
Line Regulation	mV		1	5	V$_{IN}$ = 4.75V to 6V
Load Regulation	mV		5	25	V$_{IN}$ = 5V, I$_{OUT}$ = 10mA to 500mA
Ground Current	μA μA		110 400		I$_{OUT}$ = 10mA I$_{OUT}$ = 500mA
Current Limit	A	0.55	1.0	1.5	0V < V$_{OUT}$ < 3.2V
Thermal Shutdown	°C	140	165		V$_{IN}$ = 5V or V$_{IN}$ = 0V
Thermal Shutdown Hysteresis	°C		15		
V$_{SENSE}$ Pin Current	μA		15		
AUXILIARY BACKUP					
Upper V$_{IN}$ Threshold	V	4.35	4.5	4.65	V$_{IN}$ increasing
Lower V$_{IN}$ Threshold	V	4.25	4.4	4.55	V$_{IN}$ decreasing
V$_{IN}$ Threshold Hysteresis	mV		100		
Ground Current	μA		40		V$_{IN}$ < 4.25V, V$_{AUX}$ = 3.3V, I$_{OUT}$ = 0mA
R$_{DS(ON)}$	Ω		0.2	0.4	V$_{IN}$ < 4.25V, V$_{AUX}$ = 3.3V, I$_{OUT}$ = 500mA
Current Limit	A		1.1		0V < V$_{OUT}$ < 3.2V
Maximum Junction Temperature, T$_{J(MAX)}$	°C			125	
Thermal Resistance, θ$_{JA}$	°C/W		57		DFN package

8 Pin NSOIC	6 Pin DFN	PIN NAME	DESCRIPTION
1	4	V_{SENSE}	Kelvin connection with 3.3V feedback. Always tiethis pin to the point of regulation
2	5	V_{IN}	Main 5V input.
3	6	V_{OUT}	V_{OUT} = 3.3V when V_{IN} > 4.5V; V_{OUT} = V_{AUX} when V_{IN} ≤ 4.4V
4	1	V_{AUX}	3.3V auxiliary backup supply that is switched in through an internal PMOS when V_{IN} drops below 4.4V typically.
5-8	3	GND	6 pin MLP is grounded.
-	2	NC	No connect

FUNCTIONAL DIAGRAM
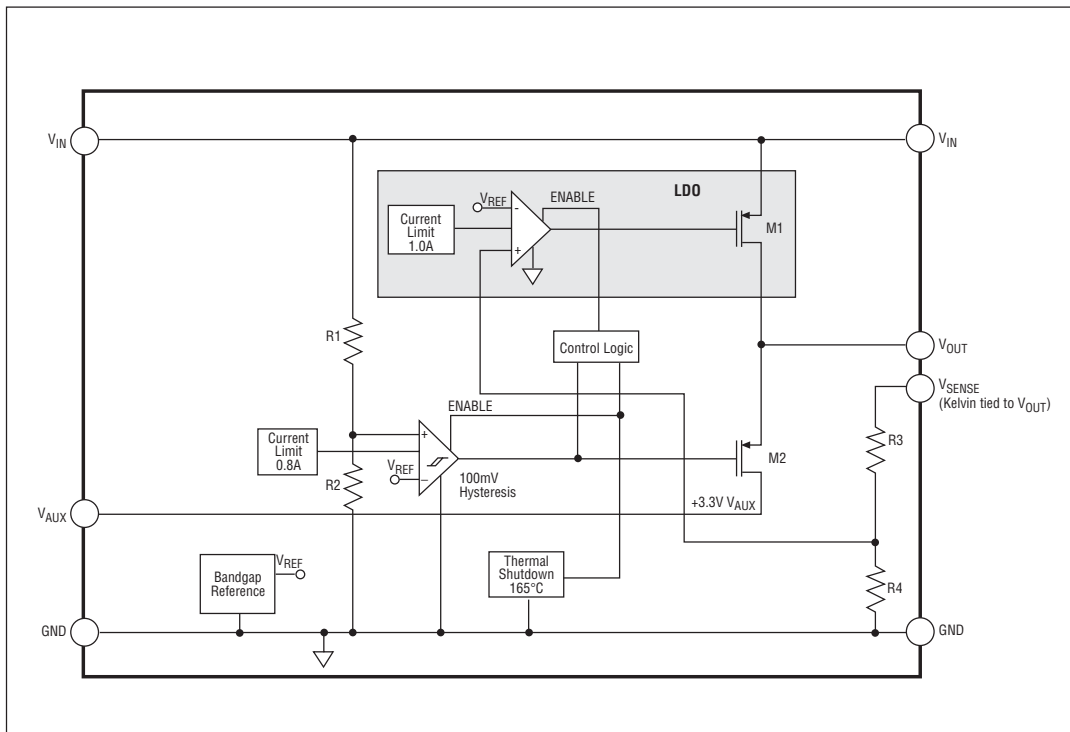
General Overview

The SP6231 combines a linear regulator with an auxiliary backup. When the main supply voltage is applied at V_{IN}, the SP6231 acts as a regulator. It supplies 3.3V at its output and sources up to 500mA with an overall accuracy of ±3%. Full protection with both current limit and thermal shutdown is provided. When the main supply drops below 4.4V, the output is switched through an internal PFET to the auxiliary supply input.

A typical application is a USB peripheral (for instance a digital camera) that in normal operation draws power from a battery supply (V_{AUX}) but when it is plugged into the USB port will recognize the main power supply availability (V_{IN}) and draw its power from there, switching over from the battery to the main power supply. When the USB peripheral is removed from the USB port, the output is switched back "glitch free" to the battery supply so the peripheral sees no supply interruption. Other applications include NIC cards, desktop computers, power supplies with multiple input sources and PCMCIA/PCI interface cards.

Modes of Operation

There are 2 modes of operation. The first mode is the LDO mode when the main supply (V_{IN}) is above 4.5V. At this point (independent of what voltage the auxiliary supply is at) the SP6231 acts as an LDO with an output of 3.3V capable of delivering up to 500mA. In this mode all circuitry is powered off of the main supply V_{IN}. The second mode, the backup switch mode, occurs when V_{IN} drops below the auxiliary supply (and below the 4.4V LDO mode). In this mode the output is directly connected to the auxiliary input through an internal 0.2Ω PFET switch. All circuitry is powered off of the auxiliary supply. When the main supply is below 4.4V but still greater then the auxiliary supply, the output is connected to the auxiliary supply but most internal circuitry is still powered off of the main supply. How this effects quiescent currents can be seen in Figure 1.
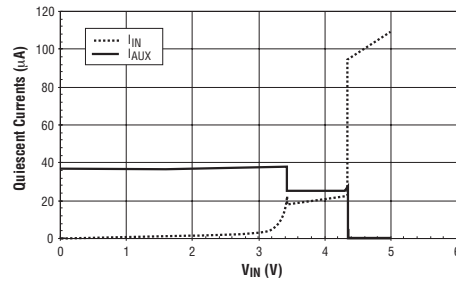

Figure 1. Ground pin current vs. input voltage (V_{AUX} = 3.3V, no load)

Linear Regulator Mode

When the main supply of the SP6231 (V_{IN}) is above 4.5V, the part is in linear regulated LDO mode (regardless of the auxiliary supply level). It sources 3.3V (±3%) up to 500mA.

+3.3V Auxiliary Switch Mode

When the main supply falls below 4.4V, the output is connected to the auxiliary supply through an internal 0.2Ω PFET switch.

Sense Pin

In the LDO mode, a sense pin provides a Kelvin connection with a 3.3V feedback (always tie this pin to the point of regulation). If an accurate 3.3V supply is needed some distance away from the SP6231, a drop in voltage might occur due to the resistance of the length of the trace from the SP6231 to where the supply is needed. For a 0.5Ω trace carrying 500mA the drop would be 0.25V leaving 3.05V at the supply destination. By Kelvin connecting the sense pin to the supply destination the SP6231 will adjust its output voltage (to 3.55V) so that the voltage is 3.3V at the supply destination. If this accuracy is of no concern, the sense pin can simply be tied to the output pin. The sense pin draws 15µA of current.

Thermal and Overcurrent Protection

Both the LDO switch and the backup switch have overcurrent and thermal protection. The overcurrent protection will limit the output current to 1A for the LDO and 0.8A for the backup switch typically. When the SP6231 heats up above 165°C (due to power consumption in the chip), both switches will be opened so the part can cool down. Once the temperature drops by 15°C, the SP6231 will turn on again.
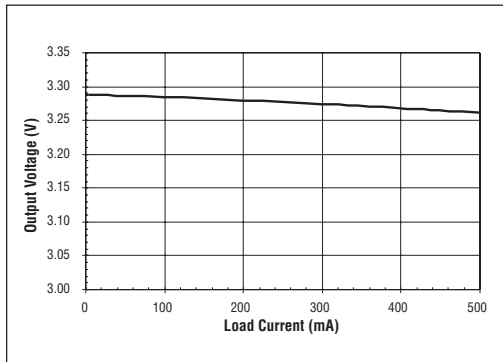
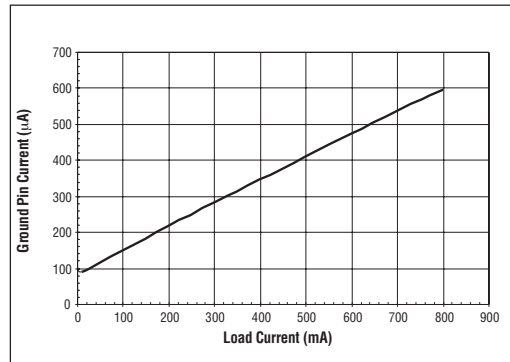*Figure 2. DC load regulation (includes thermal heating of the die), Vin=5V*

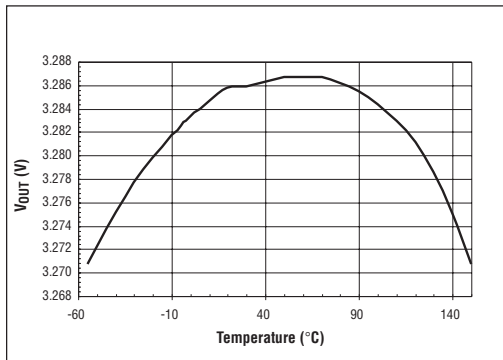*Figure 3. Ground pin current vs. load in LDO mode, V_{IN} = 5V, V_{AUX} = 3.3V.*

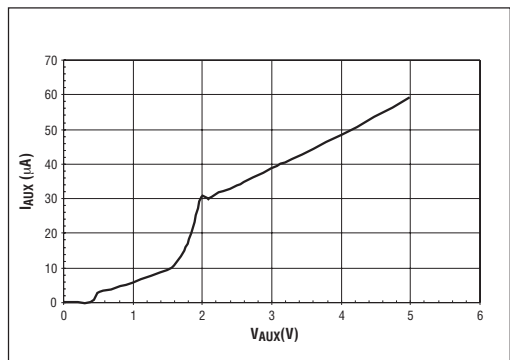*Figure 4. V_{OUT} over temperature, V_{IN} = 5V, I_L = 10μA.*

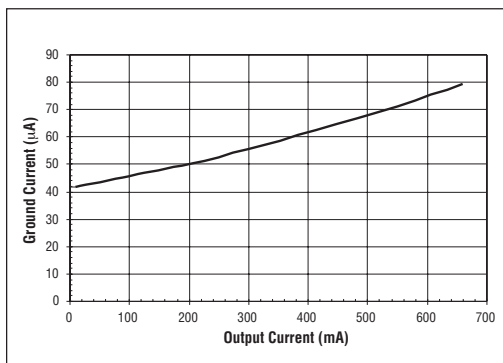*Figure 5. Ground pin current vs. V_{AUX} backup switch mode, V_{IN} is floating, no load.*

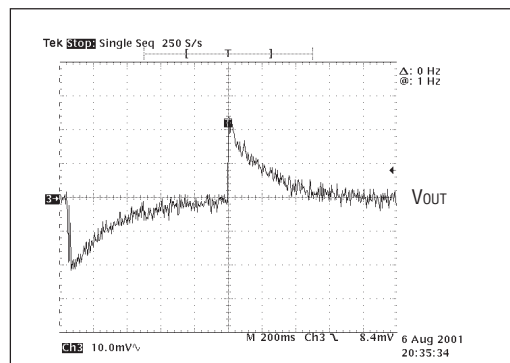*Figure 6. Ground pin current vs. load in backup switch mode, V_{AUX} = 3.3V, V_{IN} is floating.*

Figure 7. Glitch Free Operation: Switching from V_{AUX} to V_{IN} and vice versa. V_{AUX} = 3.3V, I_{LOAD} = 100mA.
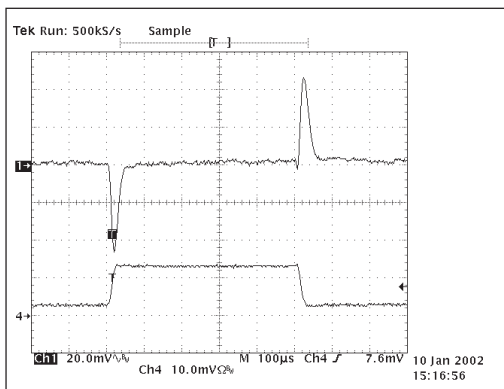
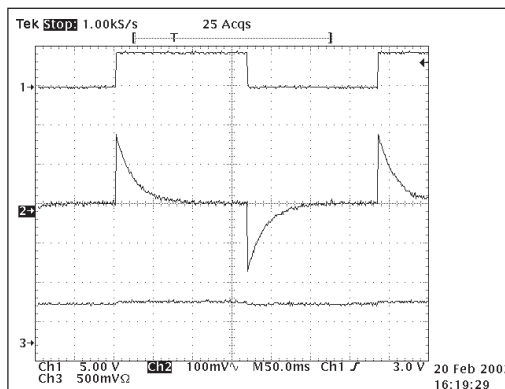*Figure 8. Load transients. 1 - V_OUT, 4 - I_LOAD (500mA/div)*

Figure 9. Supply Switching under full load, Vaux=3.3V. Ch 1=Vin; Ch 2=Vout; Ch 3=Iload (500mA/div).

Input Capacitor

A small capacitor 2.2µF or higher, is required from V_{IN} to GND and V_{AUX} to GND to create a high frequency bypass for the LDO amplifier. Any ceramic or tantalum capacitor may be used at the inputs. Capacitor ESR (equivalent series resistance) should be smaller than 1Ω.

Output Capacitor

An output capacitor is required between V_{OUT} and GND to prevent oscillations. A 2.2µF capacitor ensures unconditional stability from no load to full load over the entire input voltage and temperature range. Larger capacitor values improve the regulator's transient response. The output capacitor value may be increased without limit. The output capacitor should have an ESR below 3Ω and a resonant frequency above 1MHz.

Thermal Considerations

The SP6231 is designed to provide 500mA of continuous current. Maximum power dissipation can be calculated based on the output current and voltage drop across the device. To determine the maximum power dissipation in the package, use the junction-to-ambient thermal resistance of the device and the following basic equation:

$$P_{D(max)} = (T_{J(max)} - T_A) / \theta_{JA}$$

$T_{J(max)}$ is the maximum junction temperature of the die and is 125°C. T_A is the ambient operating temperature. θ_{JA} is the junction-to-ambient thermal resistance for the regulator and is layout and package dependent.

The actual power dissipation of the regulator circuit can be determined using one simple equation:

$$PD = (V_{IN} - V_{OUT}) * I_{OUT} + V_{IN} * I_{GND}$$
$$\cong (V_{IN} - V_{OUT}) * I_{OUT}$$

Substituting $P_{D(max)}$ for P_D and solving for the operating conditions that are critical to the application gives the maximum operating conditions for the regulator circuit. For example if we are operating the SP6231 at room temperature, with a minimum footprint layout, we can determine the maximum input voltage for a set output current.

$$P_{D(max)} = (125°C - 25°C) / 57°C/W = 1754mW$$
$$(\theta_{JA} = 57°C/W \text{ for the 3x3 MLP package})$$

Notice that the LDO in the MLP package has a much smaller θ_{JA} than in comparable dimensions. For comparison, $\theta_{JA} = 220°C/W$ for a SOT-23 package.

To prevent the device from entering thermal shutdown, maximum power dissipation can not be exceeded. Using the output voltage 3.3V and an output current of 500mA, the maximum input voltage can be determined. Ground pin current can be taken from the electrical characteristics table ($I_{GND} = 400\mu A$ at $I_{OUT} = 500mA$). The maximum input voltage is determined as follows:

$$1754mW = (V_{IN} - 3.3V) * 500mA + V_{IN} * 0.4\,mA$$

Solving for V_{IN}, we get:

$$V_{IN} = (1754mW + 1650mW) / 500.2mA$$

After calculations, we find that the maximum input voltage of a 500mA application in a 3x3 MLP package, with a minimum footprint layout, is 6.8V.

SP6231 with SP6641 in a Portable Application

In a portable application, the power sources are often switched between batteries and USB 5V supplies. Utilizing USB power eliminates the loading on the batteries when the device is connected to computers, and thus can significantly increase battery life. When the device is powered by single or dual alkaline batteries, a boost regulator, such as SP6641A/B, converts the battery voltages to a regulated 3.3V. SP6641A/B is packaged in a tiny SOT-23 package and requires less than 10μA quiescent current. When the output of SP6641A/B is connected to SP6231 as an auxiliary supply, SP6231 will automatically disconnect its load when the presence of USB power is detected. However, when the portable device is disconnected from USB, SP6231 seamlessly reconnects SP6641A/B output to the load.
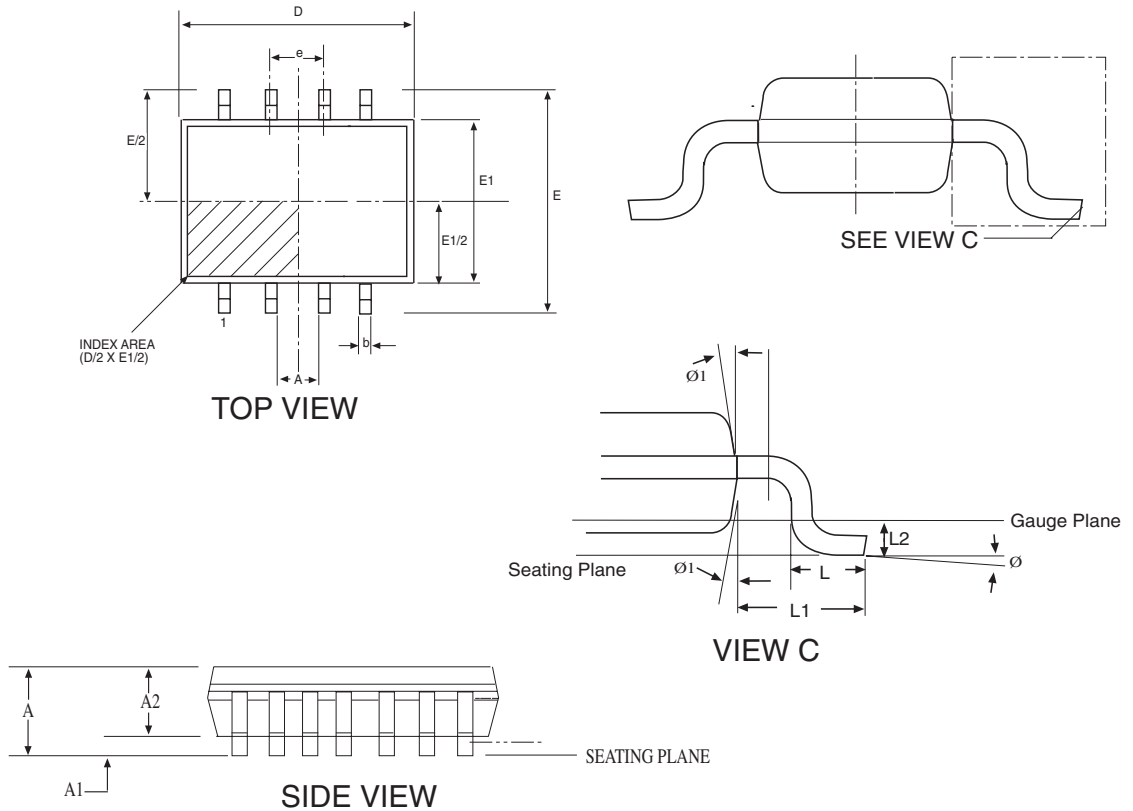
Portable Application Circuit: SP6231 and SP6641B
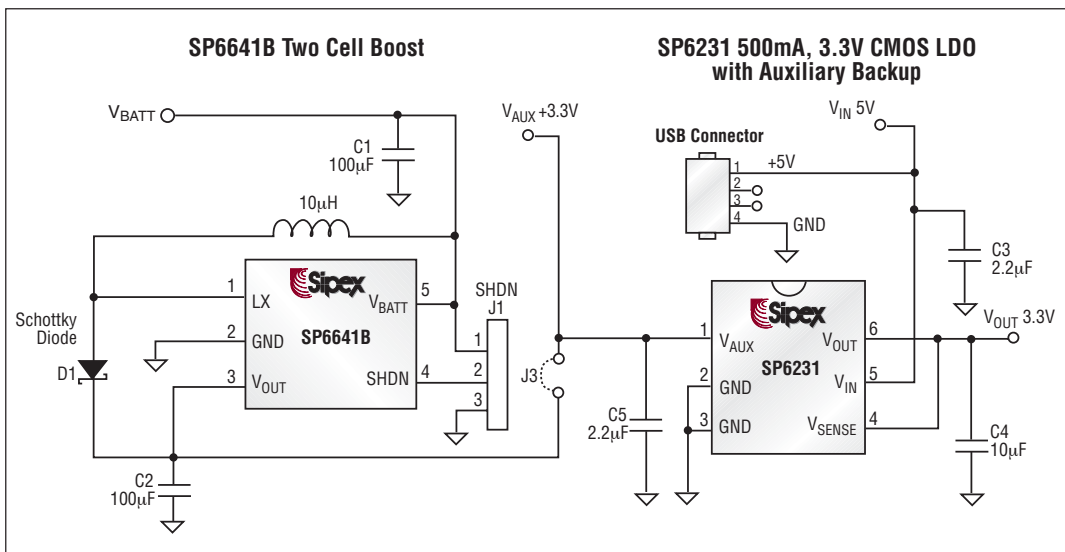
This application circuit is available as the evaluation board SP6231EB and is described in detail in the SP6231 Evaluation Board Manual.
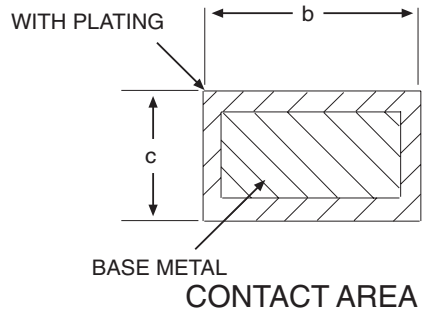
Top View

Side View

Bottom View
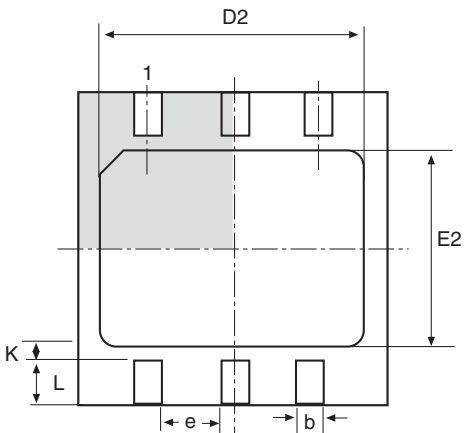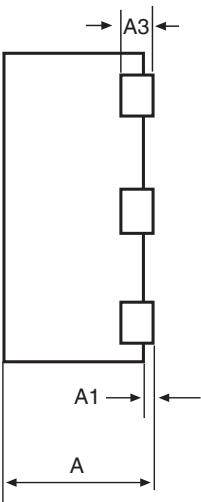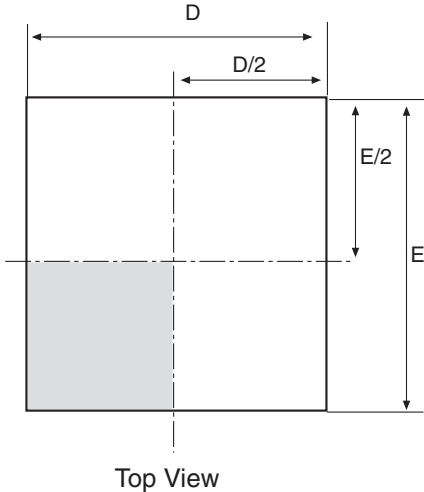
6 Pin DFN JEDEC mo-229C (VEEA-2) Variation	Dimensions in (mm)		
Symbol	MIN	NOM	MAX
A	0.80	0.90	1.00
A1	0	0.02	0.05
A3	-	0.20	-
b	0.23	0.25	0.30
D	3.00 BSC		
D2	2.20	-	2.60
e	-	0.50	-
E	3.00 BSC		
E2	1.40	-	1.75
K	0.20	-	-
L	0.30	0.40	0.50

TOP VIEW

INDEX AREA
(D/2 X E1/2)

SEE VIEW C

VIEW C

Gauge Plane

Seating Plane

SIDE VIEW

SEATING PLANE

WITH PLATING

BASE METAL

CONTACT AREA

8 Pin NSOIC (JEDEC MS-012, AA - VARIATION)	DIMENSIONS Minimum/Maximum (mm)		
COMMON HEIGHT DIMENSION			
SYMBOL	MIN	NOM	MAX
A	1.35	-	1.75
A1	0.10	-	0.25
A2	1.25	-	1.65
b	0.31	-	0.51
c	0.17	-	0.25
D	4.90 BSC		
E	6.00 BSC		
E1	3.90 BSC		
e	1.27 BSC		
L	0.40	-	1.27
L1	1.04 REF		
L2	0.25 BSC		
Ø	0º	-	8º
Ø1	5º	-	15º

PACKAGE: 8 PIN NSOIC

Part Number	Temperature Range	Package Type
SP6231ER-3.3	-40°C to 85°C	6 Pin DFN
SP6231ER-3.3/TR	-40°C to 85°C	6 Pin DFN
SP6231EN-3.3	-40°C to 85°C	8 Pin NSOIC
SP6231EN-3.3/TR	-40°C to 85°C	8 Pin NSOIC

Available in lead free packaging. To order add   "-L" suffix to part number.

Example: SP6231ER-3.3/TR = standard; SP6231ER-L-3.3/TR = lead free

/TR = Tape and Reel

Pack quantity is 2,500 for NSOIC and 3,000 for DFN.

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