# 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




*Now Available in Lead Free Packaging*

## APPLICATIONS

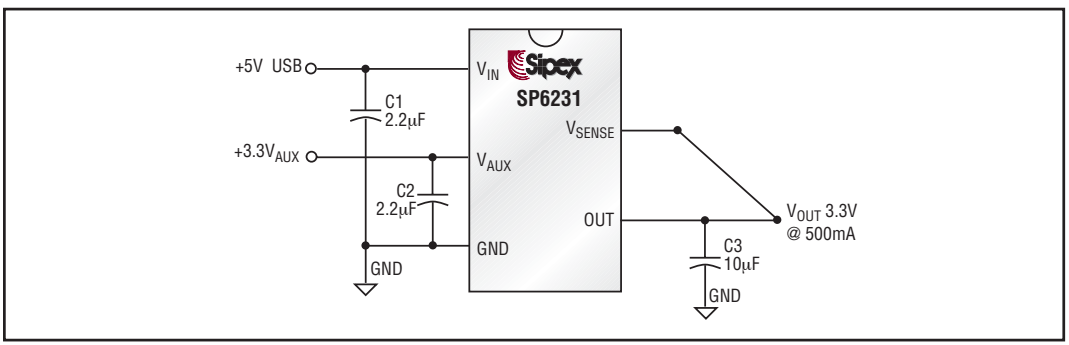
- USB Peripherals
- NIC Cards
- PCMCIA/PCI Cards
- Desktop Computers
- Dual Power Systems

## 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




 © Copyright 2004 Sipex Corporation

## ABSOLUTE MAXIMUM RATINGS

$V_{IN}$ ..... 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

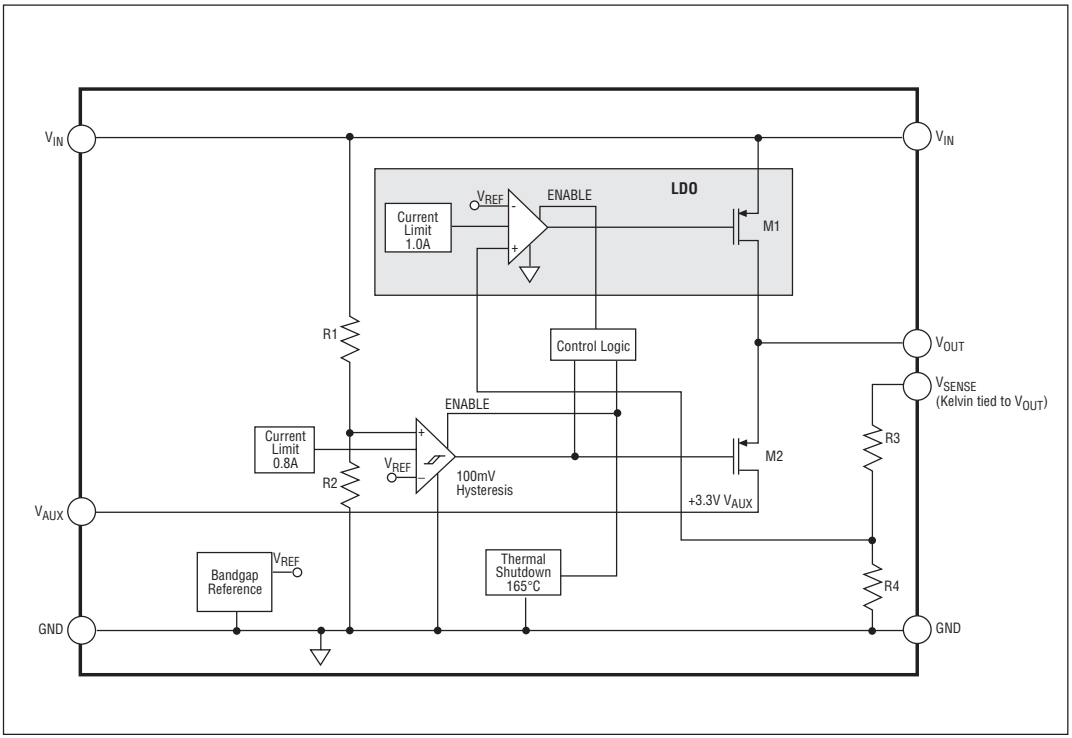
| PARAMETER | UNITS | MIN | TYP | MAX | CONDITIONS |
|---|---|---|---|---|---|
| **LINEAR REGULATOR** | | | | | |
| Output Voltage | V | 3.200 | 3.300 | 3.400 | 10mA < $I_{OUT}$ < 500mA |
| Line Regulation | mV | | 1 | 5 | $V_{IN}$ = 4.75V to 6V |
| Load Regulation | mV | | 5 | 25 | $V_{IN}$ = 5V, $I_{OUT}$ = 10mA to 500mA |
| Ground Current | µA<br>µA | | 110<br>400 | | $I_{OUT}$ = 10mA<br>$I_{OUT}$ = 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, $\theta_{JA}$ | °C/W | | 57 | | DFN package |


© Copyright 2004 Sipex Corporation

## PIN DESCRIPTION

| 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 $V_{IN} \leq$ 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




 © Copyright 2004 Sipex Corporation

## 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.

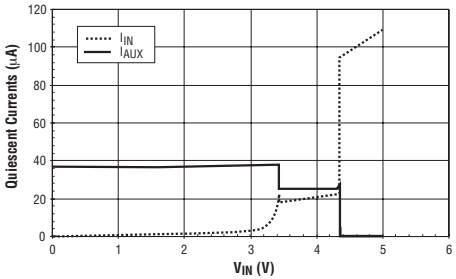



*Figure 1. Ground pin current vs. input voltage ($V_{AUX}$ = 3.3V, no load)*

## 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.

 © Copyright 2004 Sipex Corporation

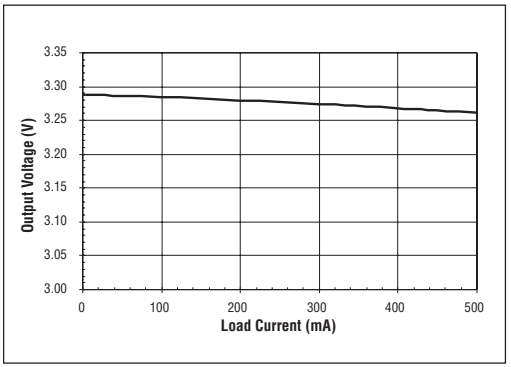



*Figure 2. DC load regulation (includes thermal heating of the die), Vin=5V*

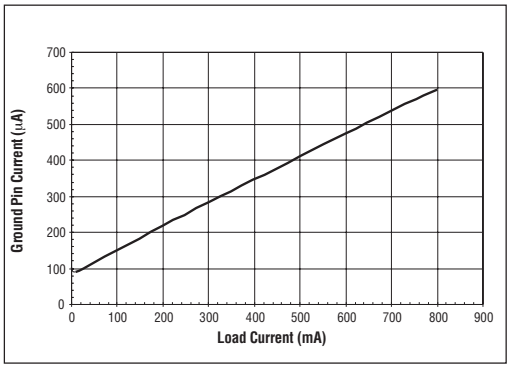



*Figure 3. Ground pin current vs. load in LDO mode, $V_{IN}$ = 5V, $V_{AUX}$ = 3.3V.*

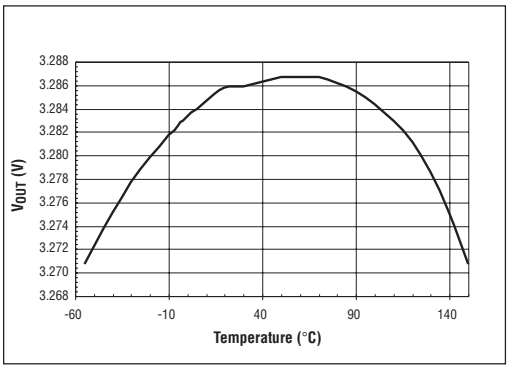



*Figure 4. $V_{OUT}$ over temperature, $V_{IN}$ = 5V, $I_L$ = 10µA.*

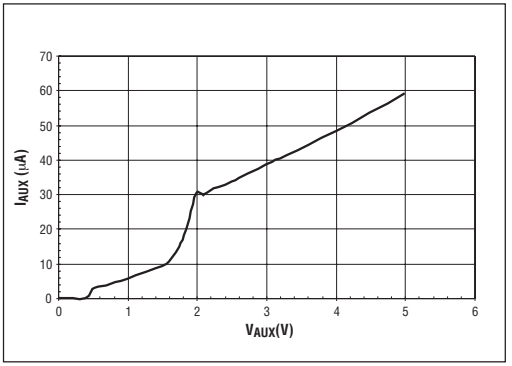



*Figure 5. Ground pin current vs. $V_{AUX}$ backup switch mode, $V_{IN}$ is floating, no load.*

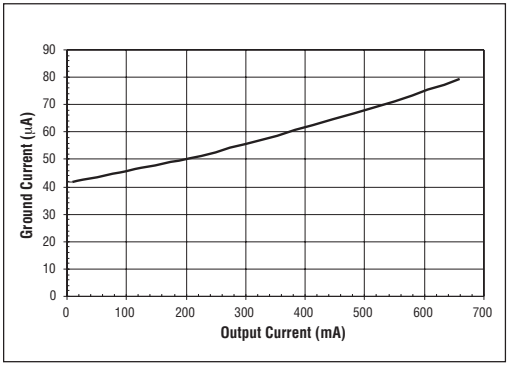



*Figure 6. Ground pin current vs. load in backup switch mode, $V_{AUX}$ = 3.3V, $V_{IN}$ is floating.*

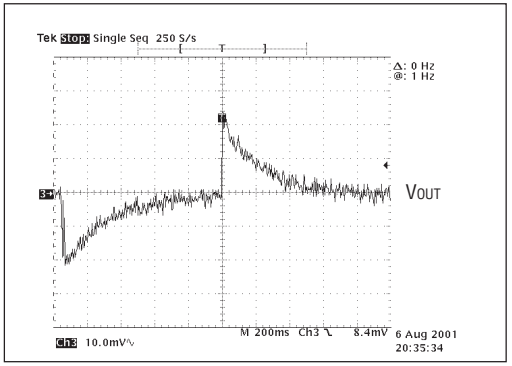



*Figure 7. Glitch Free Operation: Switching from $V_{AUX}$ to $V_{IN}$ and vice versa. $V_{AUX}$ = 3.3V, $I_{LOAD}$ = 100mA.*

 © Copyright 2004 Sipex Corporation

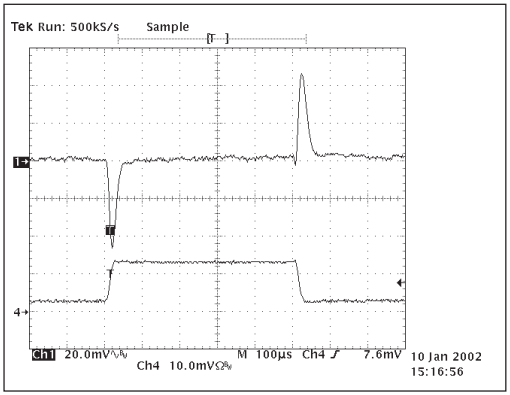



*Figure 8. Load transients. 1 - $V_{OUT}$, 4 - $I_{LOAD}$ (500mA/div)*

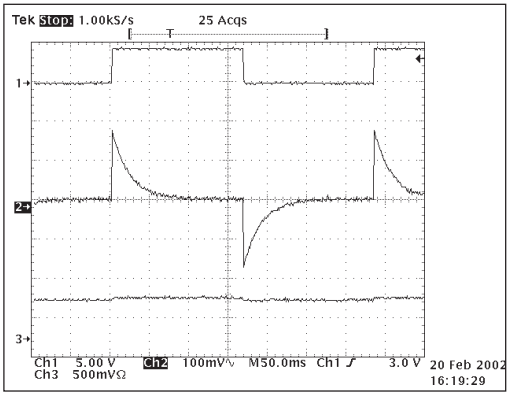



*Figure 9. Supply Switching under full load, Vaux=3.3V. Ch 1=Vin; Ch 2=Vout; Ch 3=Iload (500mA/div).*

## APPLICATION INFORMATION

### 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. $\theta_{JA}$ 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 for the 3x3 MLP package)

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

 © Copyright 2004 Sipex Corporation

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 ($I_{GND}$ = 400µA 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:

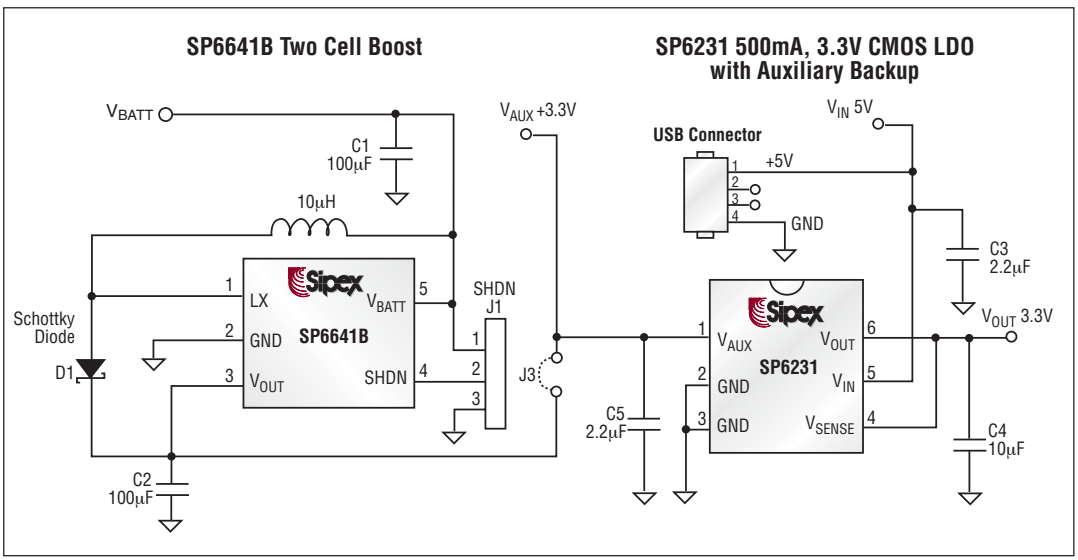
$$V_{IN} = (1754mW + 1650mW) / 500.2mA$$

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.

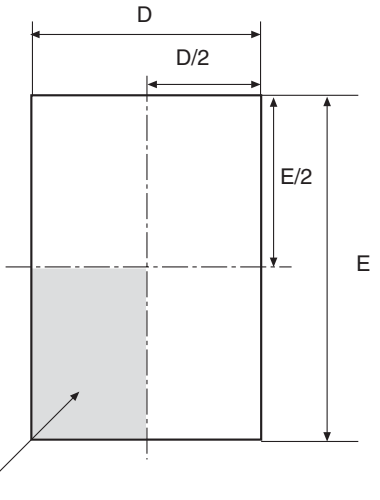
## Portable Application Circuit: SP6231 and SP6641B




This application circuit is available as the evaluation board SP6231EB and is described in detail in the SP6231 Evaluation Board Manual.

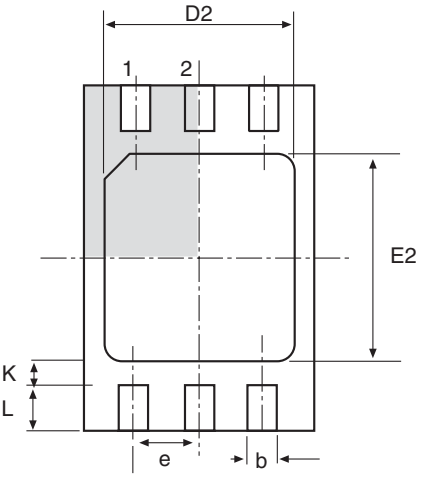
 © Copyright 2004 Sipex Corporation

Top View

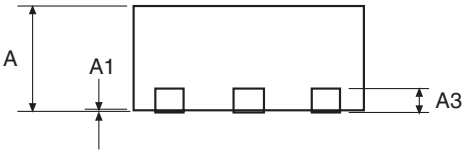



Pin 1 identifier to be located within this shaded area.
Terminal #1 Index Area (D/2 * E/2)

Bottom View



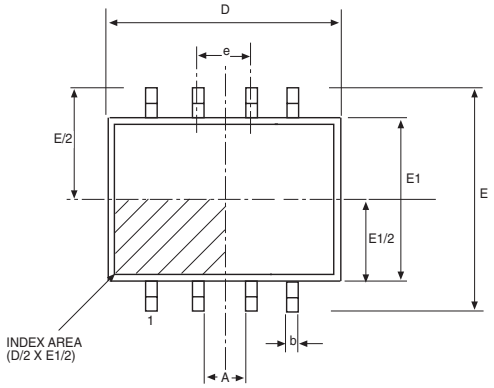

Side View



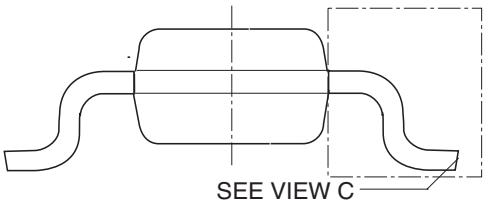

| 6 Pin DFN JEDEC mo-229C (VEEA-2) Variation | Dimensions in (mm) | | |
|---|---|---|---|
| Symbol | MIN | NOM | MAX |
| A | 0.80 | 0.90 | 1.00 |
| A1 | 0 | 0.02 | 0.05 |
| A3 | - | 0.20 | - |
| b | 0.23 | 0.25 | 0.30 |
| D | 3.00 BSC | | |
| D2 | 2.20 | - | 2.60 |
| e | - | 0.50 | - |
| E | 3.00 BSC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

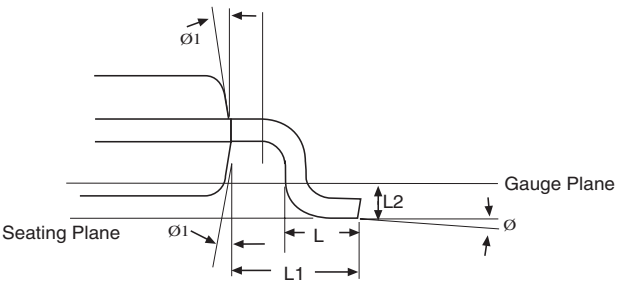
6 Pin DFN

 © Copyright 2004 Sipex Corporation

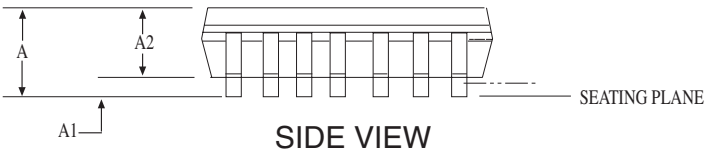



TOP VIEW



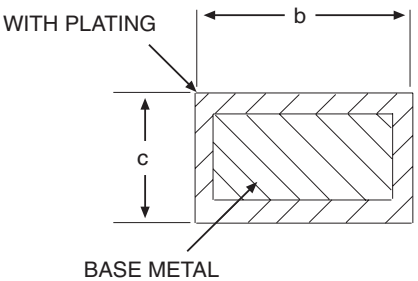




VIEW C




SIDE VIEW

| 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 |




CONTACT AREA

**PACKAGE: 8 PIN NSOIC**

 © Copyright 2004 Sipex Corporation

## ORDERING INFORMATION

| 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.

Sipex Corporation

ANALOG EXCELLENCE

**Sipex Corporation**

**Headquarters and Sales Office**
233 South Hillview Drive
Milpitas, CA 95035
TEL: (408) 934-7500
FAX: (408) 935-7600

Sipex Corporation reserves the right to make changes to any products described herein. Sipex does not assume any liability arising out of the application or use of any product or circuit described herein; neither does it convey any license under its patent rights nor the rights of others.

 © Copyright 2004 Sipex Corporation