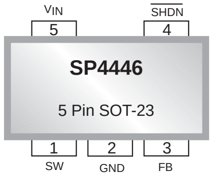
**SP4446**

# High Output Voltage Boost Regulator
# LCD Bias Regulator

## FEATURES

- High Output Voltage: Up to 30V
- High Efficiency
- Low Quiescent Current: ~20uA
- Miniature Package: (5-lead SOT-23)
- Single Battery Cell Operation
- Programmable Output Voltage
- 1Ω Switch (150mV at 150mA)



*Now Available in Lead Free Packaging*

## APPLICATIONS

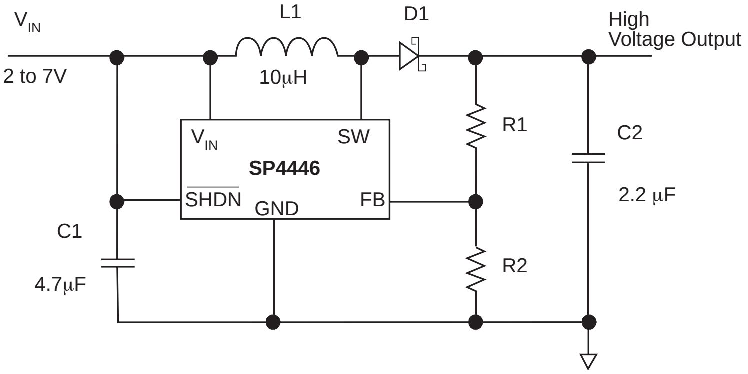
- LCD Bias
- Tuner Pin Voltage
- White LED Driver
- High Voltage Bias
- Digital Cameras
- Cell Phone
- Battery Backup
- Handheld Computers

## DESCRIPTION

The SP4446 is a micro power Boost Regualtor in a 5-lead SOT-23 package. It is a current limited, fixed off-time regulator configured for use in boost mode applications. The operating voltage can be less than 3V and is capable of generating voltages as high as 30 Volts.

The SP4446 is to be supplied in a SOT-23-5 and permits the construction of complete regulators that occupy < 0.2 square inches of board space.

## TYPICAL APPLICATION SCHEMATIC



## ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| $V_{IN}$ | 15V |
| SW Voltage | -0.4 to 34V |
| FB Voltage | 2.5V |
| All other pins | -0.3 to $V_{CC}$ + 0.3V |
| Current into FB | ±1mA |
| $T_J$ Max | 125°C |
| Operating Temperature Range | -40°C to 85°C |
| Peak Output Current < 10us SW | 500mA |
| Storage Temperature | -65°C to +150°C |
| Power Dissipation. | 200mW |
| Lead Temperature (Soldering, 10 sec) | 300°C |
| ESD Rating | 2kV HBM |

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.

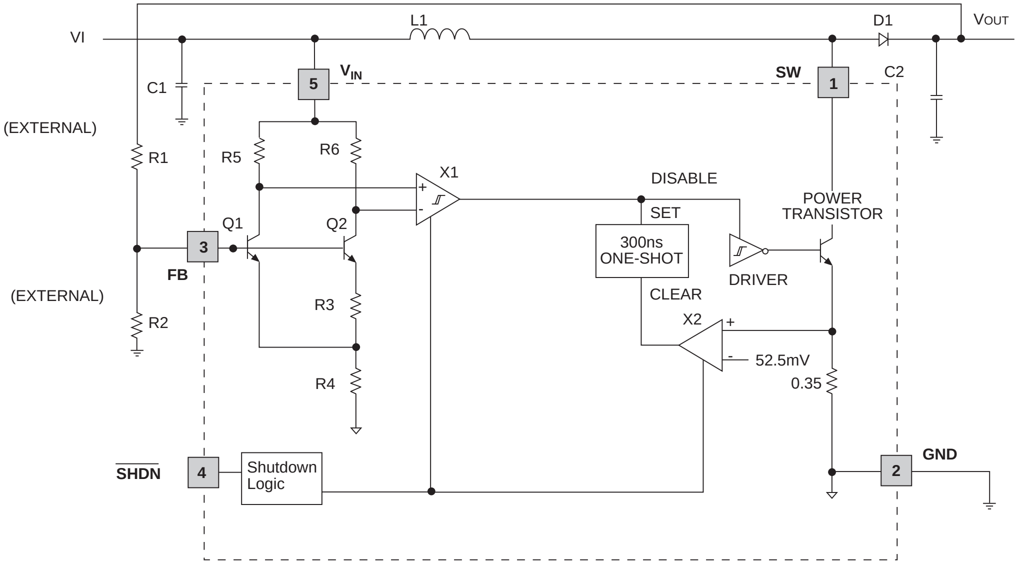
## ELECTRICAL CHARACTERISTICS

Specifications are at $V_{IN}$ = 3.3V, $V_{SHDN} = V_{IN}$, $T_A$ = 25°C, ♦ denotes the specifications which apply over the full operating temperature range, unless otherwise specified.

| PARAMETER | SYMBOL | MIN | TYP | MAX | UNITS | | CONDITIONS |
|---|---|---|---|---|---|---|---|
| Input voltage | $V_{IN}$ | 1.0 | | 8.0 | V | | Switch Current Limit = 150mA |
| Supply Current | $I_Q$ | | 20 | 30 | µA | ♦ | No Switching |
| | | | 0.01 | 1 | µA | | $\overline{SHDN}$ = 0.0V |
| Reference Voltage | $V_{FB}$ | 1.17 | 1.22 | 1.27 | V | ♦ | |
| FB Hysteresis | HYST | | 8 | | mV | | |
| $V_{FB}$ Input Bias Current | $I_{FB}$ | | 15 | 80 | nA | ♦ | $V_{FB}$ = 1.22V |
| Line Regulation | $\Delta V_o/\Delta V_I$ | | 0.04 | | %/V | | $1.2 \leq V_{IN} \leq 8V$ |
| Switch Off Time | $T_{OFF}$ | | 300 | | nS | | $V_{FB} > 1V$ |
| | | | 1200 | | nS | | $V_{FB} < 0.3V$ |
| Switch Saturation Voltage | $V_{CESAT}$ | | 50 | | mV | ♦ | $I_{SW}$ = 50mA |
| | | | 150 | | mV | | $I_{SW}$ = 150mA |
| Switch Current Limit | $I_{LIM}$ | 100 | 150 | 200 | mA | ♦ | |
| $\overline{SHDN}$ Bias Current | $I_{\overline{SHDN}}$ | | 5 | 12 | µA | ♦ | $V_{SHDN}$ = 5V |
| $\overline{SHDN}$ High Threshold (on) | $V_{IH}$ | 0.9 | | | V | | |
| $\overline{SHDN}$ Low Threshold (off) | $V_{IL}$ | | | 0.25 | V | | |
| Switch Leakage Current | $I_{SWLK}$ | | 2 | 5 | µA | ♦ | Switch Off, $V_{SW}$ = 5V |

## PIN DESCRIPTION

| PIN NUMBER | PIN NAME | DESCRIPTION |
|---|---|---|
| 1 | SW | Switch input to the internal power switch. |
| 2 | GND | Ground |
| 3 | FB | Feedback |
| 4 | $\overline{SHDN}$ | Shutdown. Pull high (on) to enable. Pull low (off) for shutdown. |
| 5 | $V_{IN}$ | Input Voltage. Bypass this pin with a capacitor as close to the device as possible. |



## THEORY OF OPERATION

### General Overview:

Operation can be best understood by referring to the above block diagram. Q1 and Q2 along with R3 and R4 form a band gap reference. The input to this circuit completes a feedback path from the high voltage output through a voltage divider, and is used as the regulation control input. When the voltage at the FB pin is slightly above 1.22V, comparator X1 disables most of the internal circuitry. Current is then provided by capacitor C2, which slowly discharges until the voltage at the FB pin drops below the lower hysteresis point of X1, about 6mV. X1 then enables the internal circuitry, turns on chip power, and the current in the inductor begins to ramp up. When the current through the driver transistor reaches about 150mA, comparator X2 clears the latch, which turns off the driver transistor for a preset 0.3μs. At the instant of shutoff, inductor current is diverted to the output through diode D1. During this 0.3μs time limit, inductor current decreases while its energy charges C2. At the end of the 0.3μs time period, the driver transistor is again allowed to turn on which ramps the current back up to the 150mA level. Comparator X2 clears the latch, its output turns off the driver transistor, and this allows delivery of inductor L1's stored kinetic energy to C2. This switching action continues until the output capacitor voltage is charged to the point where FB is at band gap (1.22V). When this condition is reached, X1 turns off the internal circuitry and the cycle repeats. The SP4446 contains circuitry to provide protection during startup and while in short-circuit conditions. When FB pin voltage is less than approximately 300mV, the switch off time is increased to about 1.2μs and the current limit is reduced to about 70% of its normal value. While in this mode, the average inductor current is reduced and helps minimize power dissipation in the SP4446, the external inductor and diode.

### Inductor Selection

For SP4446, the internal switch will be turned off only after the inductor current reaches the typical DC current limit ($I_{LIM}$=150mA). However, there is typically a propagation delay of 200nS between the time when the current limit is reached and when the switch is actually turned off. During this 200nS delay, the peak inductor current will increase, exceeding the current limit by a small amount. The peak inductor current can be estimated by:

$$I_{PK} = I_{LIM} + \frac{V_{IN(MAX)}}{L} \cdot 200nS$$

The larger the input voltage and the lower the inductor value, the greater the peak current.

In selecting an inductor, the saturation current specified for the inductor needs to be greater than the SP4446 peak current to avoid saturating the inductor, which would result in a loss of efficiency and could damage the inductor. Choosing an inductor with low DCR decreases power losses and increase efficiency.

Refer to Table 1 for some suggested low ESR inductors.

| MANUF. | PART NUMBER | DCR (Ω) | Current Rating (mA) |
|---|---|---|---|
| MURATA<br>770-436-1300 | LQH32CN100K21<br>(10μH) | 0.44 | 300 |
| MURATA<br>770-436-1300 | LQH32CN220K21<br>(22μH) | 0.71 | 250 |
| TDK<br>847-803-6100 | NLFC453232T-100K<br>(10μH) | 0.273 | 250 |
| TDK<br>847-803-6100 | NLC453232T-100K<br>(22μH) | 0.9 | 370 |

Table 1. Suggested Low ESR inductors

### Diode Selection

A schottky diode with a low forward drop and fast switching speed is ideally used here to achieve high efficiency. In selecting a Schottky diode, the current rating of the schottky diode should be larger than the peak inductor current. Moreover, the reverse breakdown voltage of the Schottky diode should be larger than the output voltage.

### Capacitor Selection

Ceramic capacitors are recommended for their inherently low ESR, which will help produce low peak to peak output ripple, and reduce high frequency spikes.

For the typical application, a 4.7μF input capacitor and a 2.2μF output capacitor are sufficient. The input and output ripple could be further reduced by increasing the value of the input and output capacitors. Place all the capacitors as close to the SP4446 as possible for layout. For use as a voltage source, to reduce the output ripple, a small feedforward capacitor (47pF) across the top feedback resistor can be used to provide sufficient overdrive for the error comparator, thus reduce the output ripple.

Refer to Table 2 for some suggested low ESR capacitors.

| MANUF. | PART NUMBER | CAP/ VOLTAGE | SIZE/ TYPE |
|---|---|---|---|
| MURATA<br>770-436-1300 | GRM32RR71E<br>225KC01B | 2.2μF/25V | 1210/X5R |
| MURATA<br>770-436-1300 | GRM31CR61A<br>475KA01B | 4.7μF/10V | 1206/X5R |
| TDK<br>847-803-6100 | C3225X7R1E<br>225M | 2.2μF/25V | 1206/X7R |
| TDK<br>847-803-6100 | C3216X5R1A<br>475K | 4.7μF/10V | 1206/X5R |

Table 2. Suggested Low ESR Capacitor

### Output Voltage Program

In order for the SP4446 to be programmed as a voltage source, the SP4446 requires 2 feedback resistors $R_1$ & $R_2$ to control the output voltage, as shown in Figure 1.

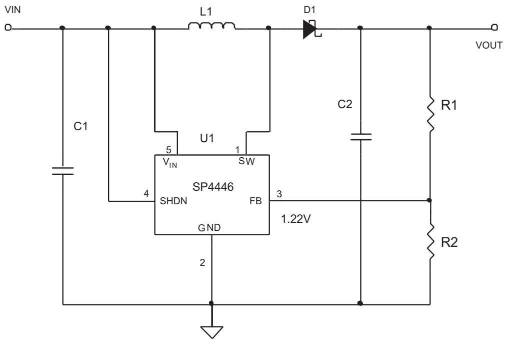


***Figure 1. Using SP4446 as Voltage Source***

The formula and table for the resistor selection are shown below:

$$R_1 = \left(\frac{V_{OUT}}{1.22} - 1\right) \cdot R_2$$

| $V_{OUT}$ (V) | $R_1$ (Ω) | $R_2$ (Ω) |
|---|---|---|
| 12 | 1M | 113K |
| 15 | 1M | 88.7K |
| 18 | 1M | 73.2K |
| 20 | 1M | 64.9K |
| 30 | 1M | 42.2K |

Table 3. Divider Resistor Selection

### Layout Considerations

Both the input capacitor and the output capacitor should be placed as close as possible to the IC. This can reduce the copper trace resistance which directly effects the input and output ripple. The feedback resistor network should be kept close to the FB pin to minimize copper trace connections that can inject noise into the system. The ground connection for the feedback resistor network should connect directly to the GND pin or to an analog ground plane that is tied directly to the GND pin. The inductor and the Schottky diode should be placed as close as possible to the switch pin to minimize the noise coupling to the other circuits, especially the feedback network.

### PIN Diode Driver

The SP4446 can be used as PIN diode driver as shown in Figure. 2.

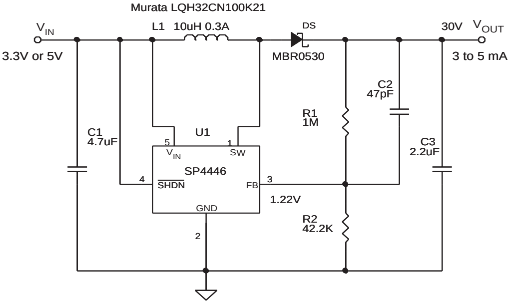


*Fig. 2. Pin Diode Driver*

Two Resistors ($R_1$=1MΩ, $R_2$=42.2KΩ) are used to program the output voltage to be 30V. When input voltage is 3.3V or 5V, it can supply a maximum current of 3mA and 5mA to the load.

### Load Disconnect in Shutdown

When SP4446 is shut down, the load is still connected to the input. In applications that require output isolation during shutdown, an external PNP transistor (for example MMBT2907A) can be added as shown in Figure 3.

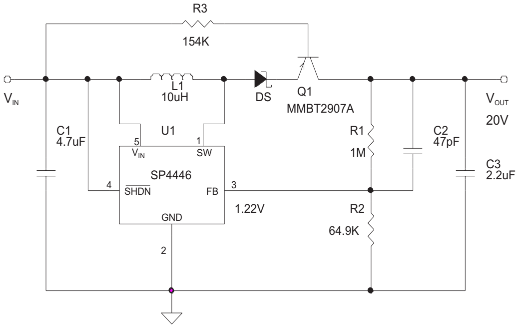


*Fig. 3. Load Disconnect in Shutdown*

When the SP4446 is active, the voltage set at the emitter of the transistor exceeds the input voltage, forcing the transistor into the saturation region. When the SP4446 is shut down, the input voltage exceeds the emitter voltage, thus the transistor becomes inactive and provides high-impedance isolation between the input and load. Efficiency will be slightly sacrificed because of the saturation voltage and base current of the PNP transistor.

Refer to the typical application circuit, $T_{AMB}$ = 25°C, unless otherwise specified.

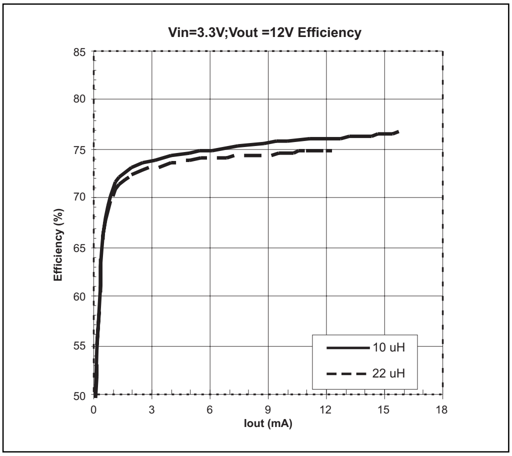


*Figure 4. 12V Output Efficiency ($V_{IN}$=3.3V)*

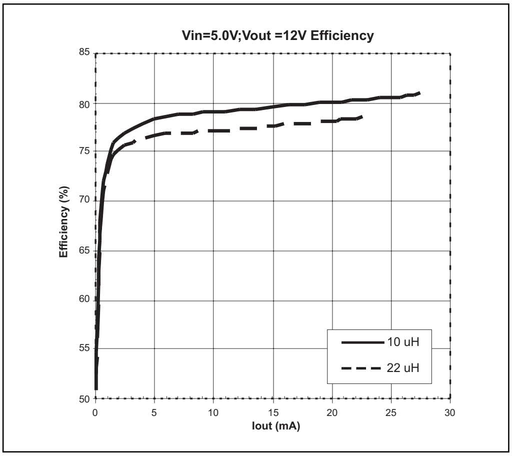


*Figure 5. 12V Output Efficiency ($V_{IN}$=5V)*

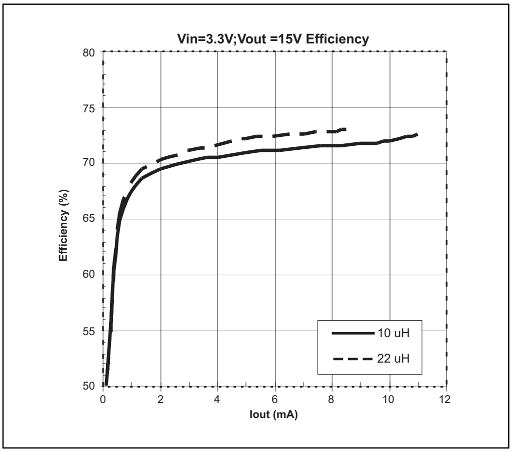


*Figure 6. 15V Output Efficiency ($V_{IN}$=3.3V)*

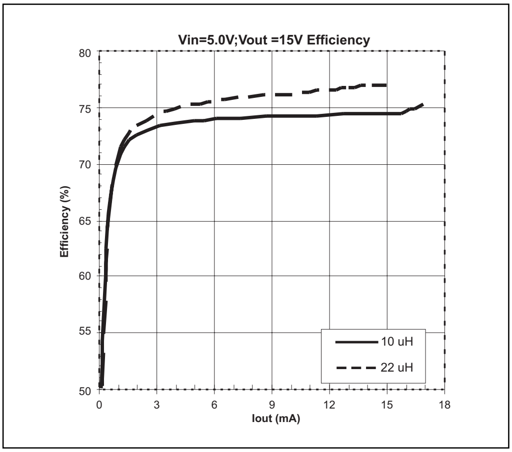


*Figure 7. 15V Output Efficiency ($V_{IN}$=5V)*

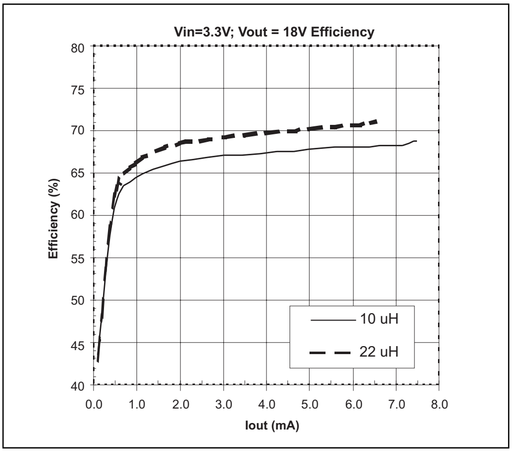


*Figure 8. 18V Output Efficiency ($V_{IN}$=3.3V)*

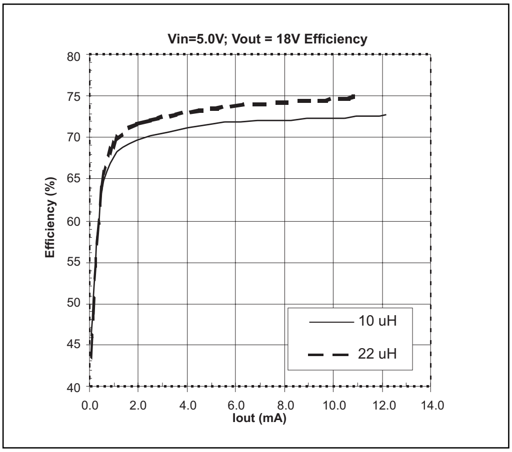


*Figure 9. 18V Output Efficiency ($V_{IN}$=5V)*

Refer to the typical application circuit, $T_{AMB}$ = 25°C, unless otherwise specified.

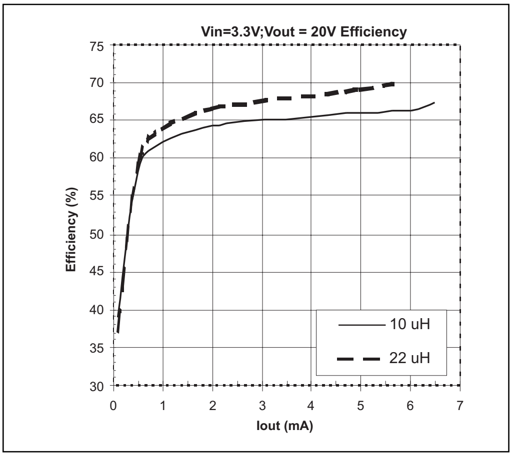


*Figure 10. 20V Output Efficiency ($V_{IN}$=3.3V)*

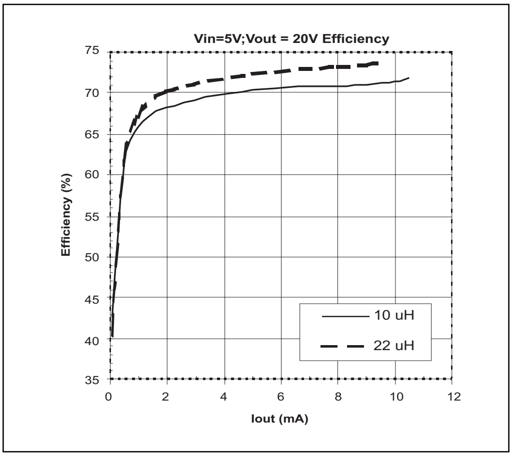


*Figure 11. 20V Output Efficiency ($V_{IN}$=5V)*

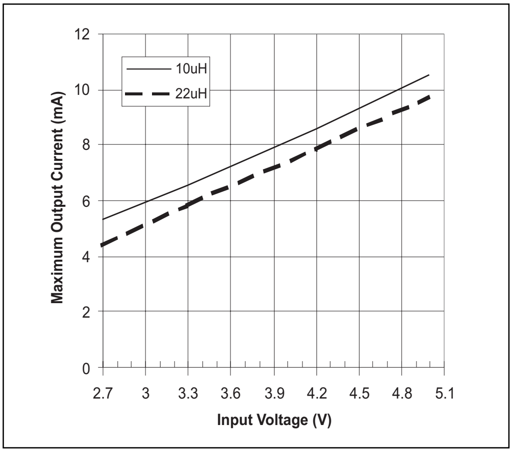


*Figure 12. Maximum Output Current vs. $V_{IN}$ ($V_{OUT}$=20V)*

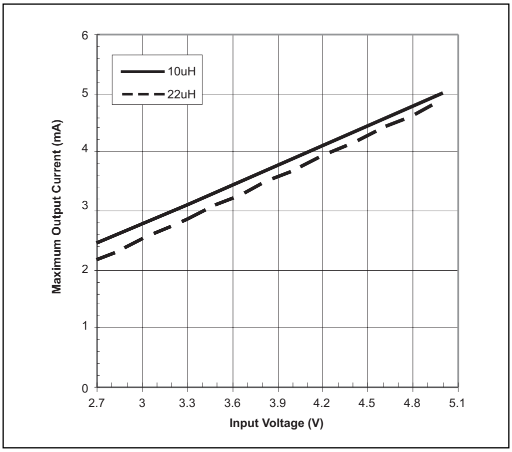


*Figure 13. Maximum Output Current vs. $V_{IN}$ ($V_{OUT}$=30V)*

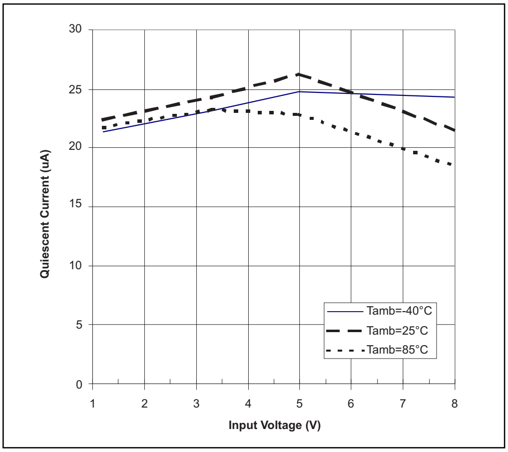


*Figure 14. Quiescent Current $I_Q$ vs. $V_{IN}$*

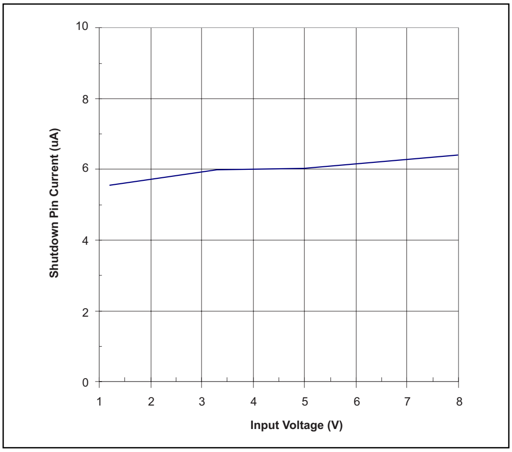


*Figure 15. Shutdown Pin Current vs. $V_{IN}$*

Refer to the typical application circuit, $T_{AMB}$ = 25°C, unless otherwise specified.

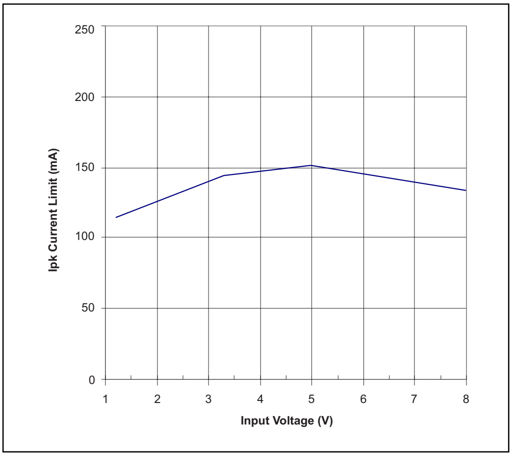


***Figure 16. $I_{PK}$ Current Limit vs. $V_{IN}$***

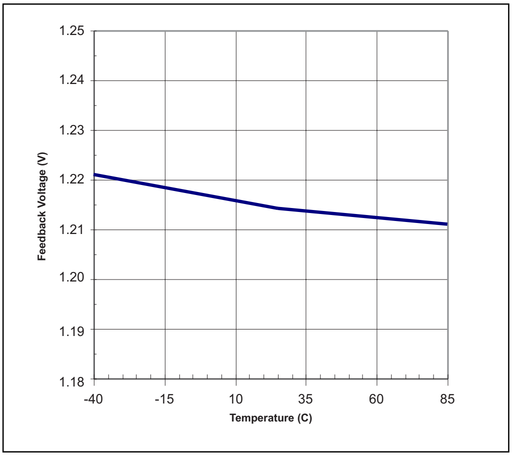


***Figure 17. Feedback Voltage vs. Temperature***

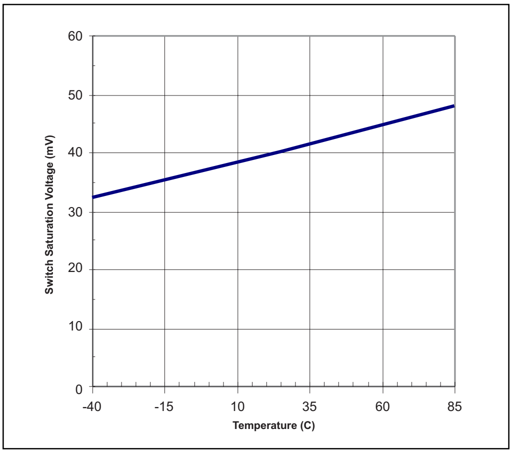


***Figure 18. Switch Saturation Voltage $V_{CESAT}$ vs. Temperature ($I_{SW}$=50mA)***

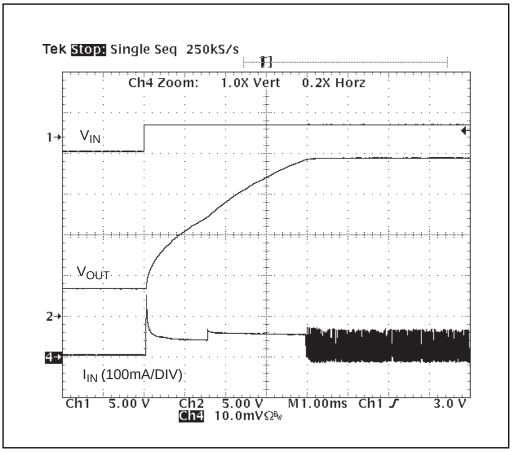


***Figure 19. Startup Waveform ($V_{IN}$=3.3V, $V_{OUT}$=20V, $I_{OUT}$=2mA)***

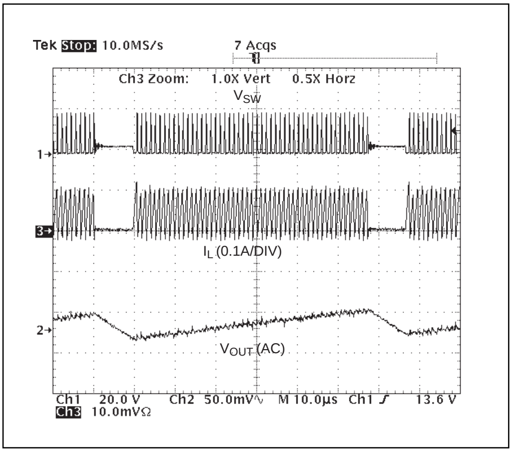


***Figure 20. Typical Switching Waveforms ($V_{IN}$=3.3V, $V_{OUT}$=20V, $I_{OUT}$=5mA)***

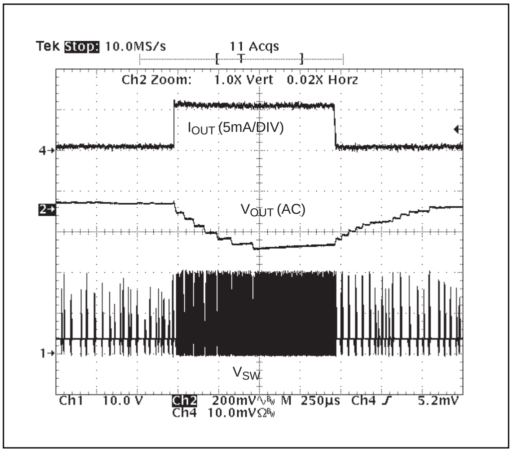
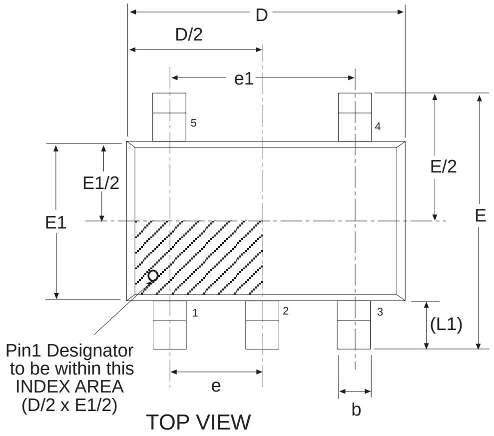
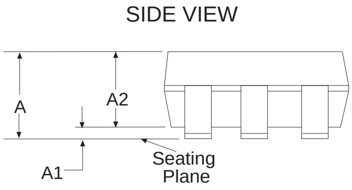
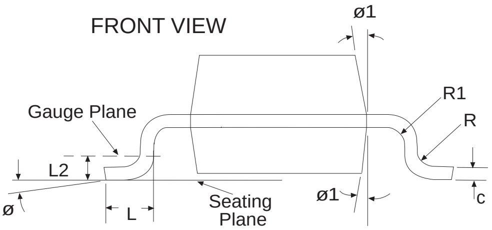


***Figure 21. Load Step Transient ($V_{IN}$=3.3V, $V_{OUT}$=20V, $1_O$=100µA~5mA)***







| 5 Pin SOT-23 JEDEC MO-178 Variation AA | | | | | | |
|---|---|---|---|---|---|---|
| SYMBOL | Dimensions in Millimeters:<br>Controlling Dimension | | | Dimensions in Inches<br>Conversion Factor:<br>1 Inch = 25.40 mm | | |
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | - | - | 1.45 | - | - | 0.057 |
| A1 | 0.00 | - | 0.15 | 0.000 | - | 0.006 |
| A2 | 0.90 | 1.15 | 1.30 | 0.036 | 0.045 | 0.051 |
| c | 0.08 | - | 0.22 | 0.004 | - | 0.009 |
| D | 2.90 BSC | | | 0.115 BSC | | |
| E | 2.80 BSC | | | 0.111 BSC | | |
| E1 | 1.60 BSC | | | 0.063 BSC | | |
| L | 0.30 | 0.45 | 0.60 | 0.012 | 0.018 | 0.024 |
| L1 | 0.60 REF | | | 0.024 REF | | |
| L2 | 0.25 BSC | | | 0.010 BSC | | |
| R | 0.10 | - | - | 0.004 | - | - |
| R1 | 0.10 | - | 0.25 | 0.004 | - | 0.010 |
| Ø | 0º | 4º | 8º | 0º | 4º | 8º |
| ø1 | 5º | 10º | 15º | 5º | 10º | 15º |
| b | 0.30 | - | 0.50 | 0.012 | - | 0.020 |
| e | 0.95 BSC | | | 0.038 BSC | | |
| e1 | 1.90 BSC | | | 0.075 BSC | | |
| SIPEX Pkg Signoff Date/Rev: JL Oct3-05 / Rev A | | | | | | |

## ORDERING INFORMATION

| Part Number | Operating Temperature Range | Package Type |
|---|---|---|
| SP4446EK | -40°C to +85°C | 5 Pin SOT-23 |
| SP4446EK/TR | -40°C to +85°C | 5 Pin SOT-23 |

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

Example: SP4446EK/TR = standard; SP4446EK-L/TR = lead free

/TR = Tape and Reel

Pack quantity is 2,500 for SOT-23.

ANALOG EXCELLENCE

**Sipex Corporation**

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