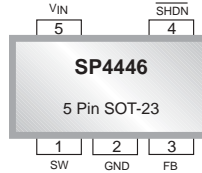


High Output Voltage Boost Regulator LCD Bias Regulator

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

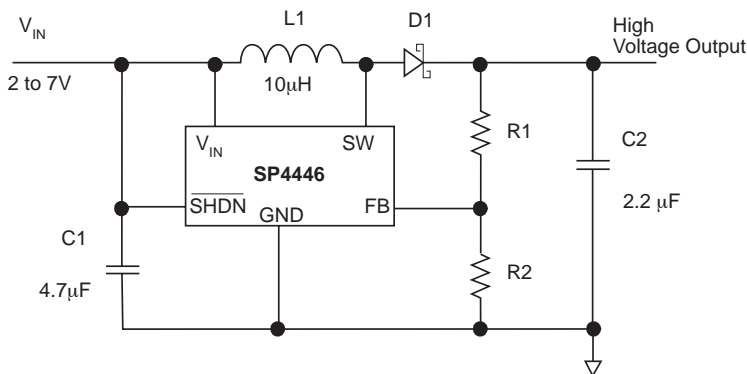
- LCD Bias
- Tuner Pin Voltage
- White LED Driver
- High Voltage Bias
- Digital Cameras
- Cell Phone
- Battery Backup
- Handheld Computers

DESCRIPTION

The SP4446 is a micro power Boost Regulator 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	$\pm 1mA$
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.

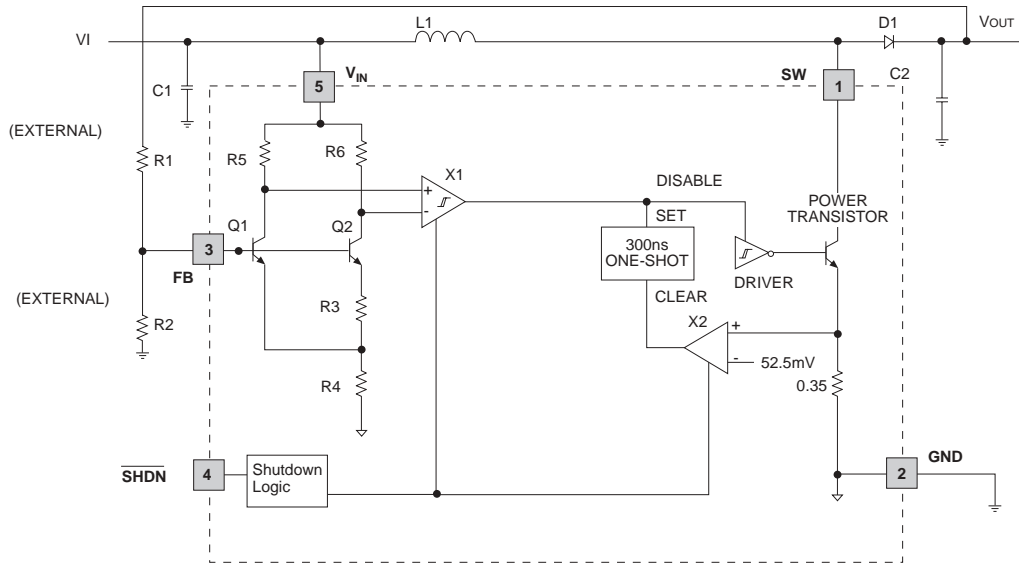
ELECTRICAL CHARACTERISTICS

Specifications are at $V_{IN} = 3.3V$, $V_{SHDN} = V_{IN}$, $T_A = 25^\circ C$, ♦ 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	$\overline{SHDN} = 0V$
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_{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	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, driver transistor is again allowed to turn on which ramps the current back up to the 150mA level. Comparator X2 clears the latch, it's output turns off the driver transistor, and this allows delivery of 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 start-up 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 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 in 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.

Table 1. Suggested Low ESR inductor

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

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, 4.7μF input capacitor and 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 (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.

Table 2. Suggested Low ESR Capacitor

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

Output Voltage Program

The SP4446 can be programmed as voltage source, the SP4446 requires 2 feedback resistors R_1 & R_2 to control the output voltage. As shown in Fig. 19.

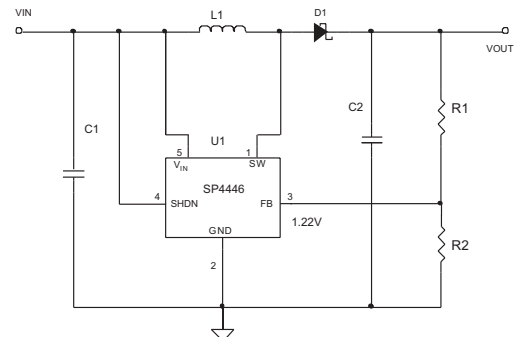


Figure 19. Using SP4446 as Voltage Source

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

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

Table 3. Divider Resistor Selection

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

Layout Consideration

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 ripples. 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.

Load Disconnect in Shutdown

When SP4446 was 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 20. 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.

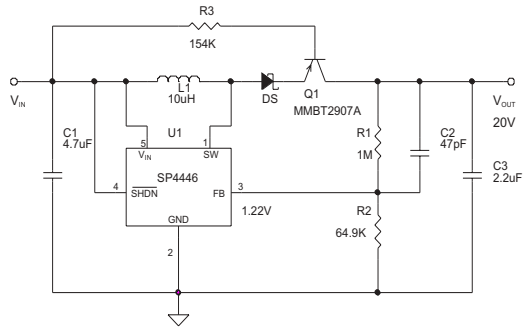


Fig. 20. Load Disconnect in Shutdown

PIN Diode Driver

The SP4446 can be used as PIN diode driver as shown in Fig. 21. Two Resistors (R₁=1MΩ, R₂=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.

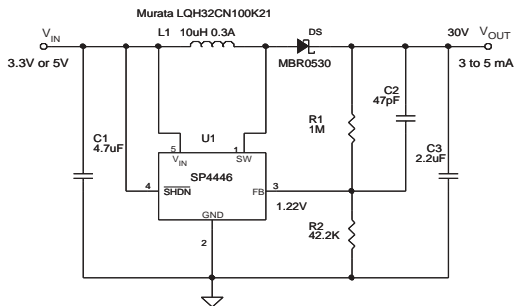


Fig. 21. Pin Diode Driver

PERFORMANCE CHARACTERISTICS

Refer to the typical application circuit, $T_{AMB} = 25^{\circ}\text{C}$, unless otherwise specified.

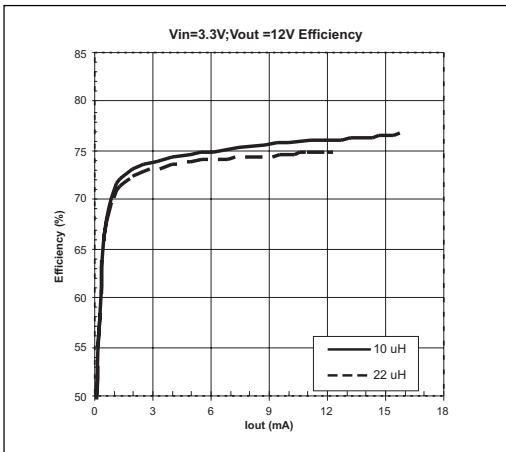


Figure 1. 12V Output Efficiency ($V_{IN}=3.3\text{V}$)

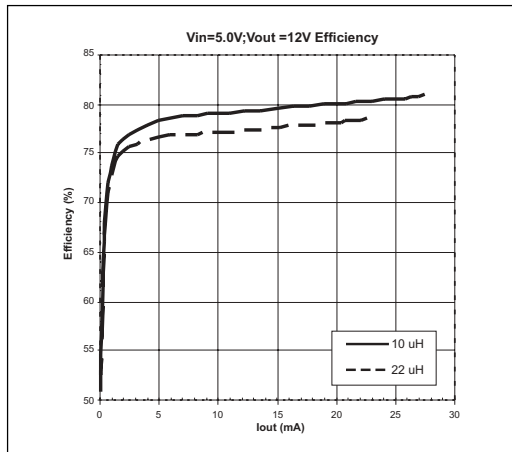


Figure 2. 12V Output Efficiency ($V_{IN}=5\text{V}$)

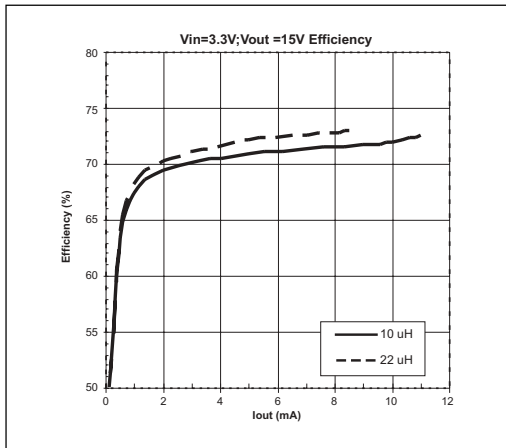


Figure 3. 15V Output Efficiency ($V_{IN}=3.3\text{V}$)

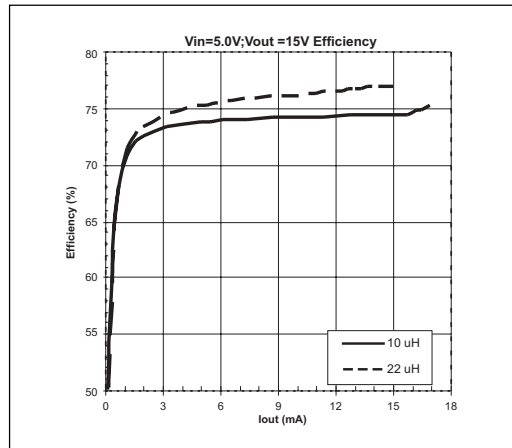


Figure 4. 15V Output Efficiency ($V_{IN}=5\text{V}$)

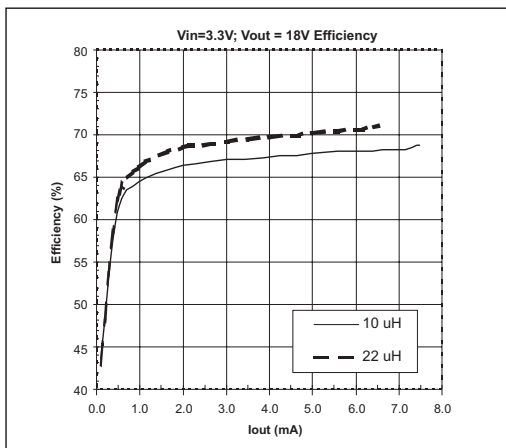


Figure 5. 18V Output Efficiency ($V_{IN}=3.3\text{V}$)

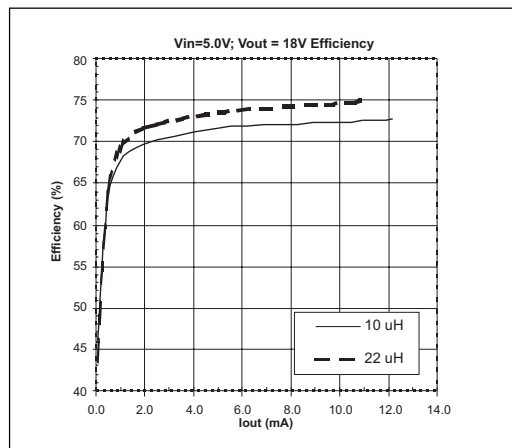


Figure 6. 18V Output Efficiency ($V_{IN}=5\text{V}$)

PERFORMANCE CHARACTERISTICS

Refer to the typical application circuit, $T_{AMB} = 25^{\circ}\text{C}$, unless otherwise specified.

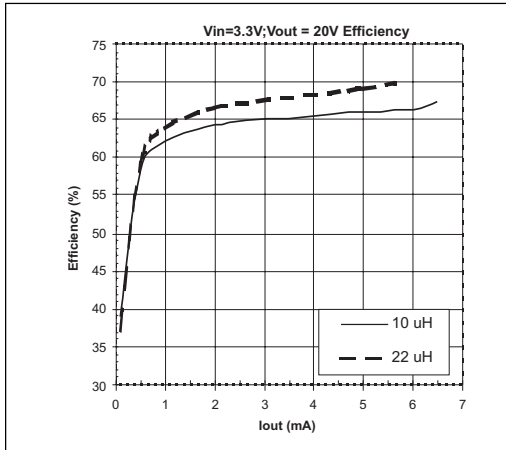


Figure 7. 20V Output Efficiency ($V_{IN}=3.3\text{V}$)

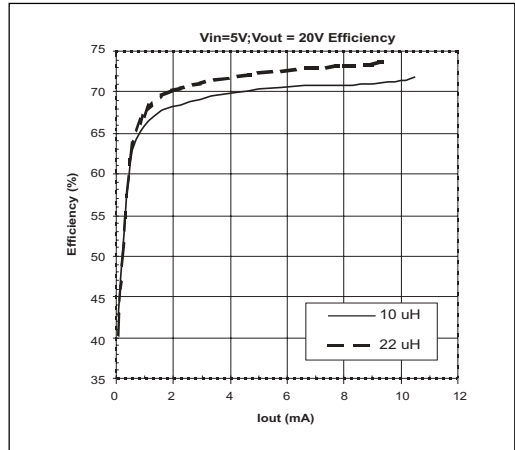


Figure 8. 20V Output Efficiency ($V_{IN}=5\text{V}$)

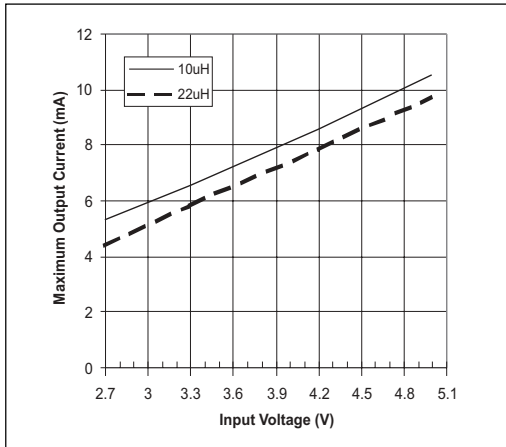


Figure 9. Maximum Output Current vs. V_{IN} ($V_{OUT}=20\text{V}$)

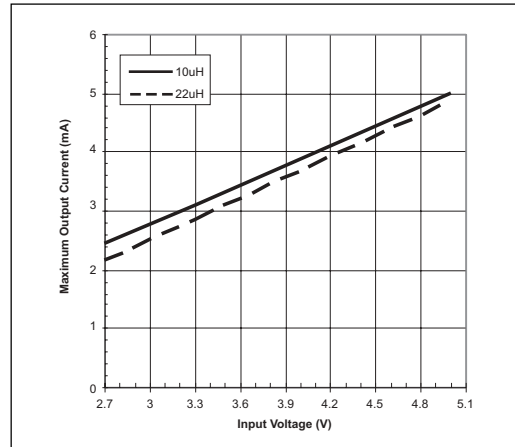


Figure 10. Maximum Output Current vs. V_{IN} ($V_{OUT}=30\text{V}$)

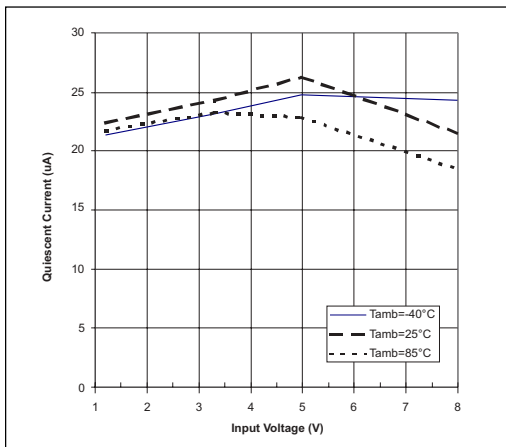


Figure 11. Quiescent Current I_Q vs. V_{IN}

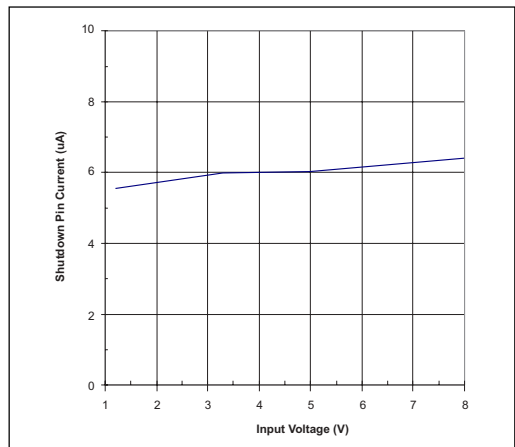


Figure 12. Shutdown Pin Current vs. V_{IN}

PERFORMANCE CHARACTERISTICS

Refer to the typical application circuit, $T_{AMB} = 25^{\circ}\text{C}$, unless otherwise specified.

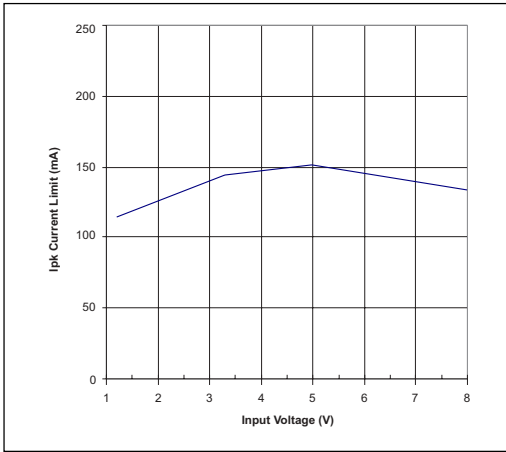


Figure 13. I_{PK} Current Limit vs. V_{IN}

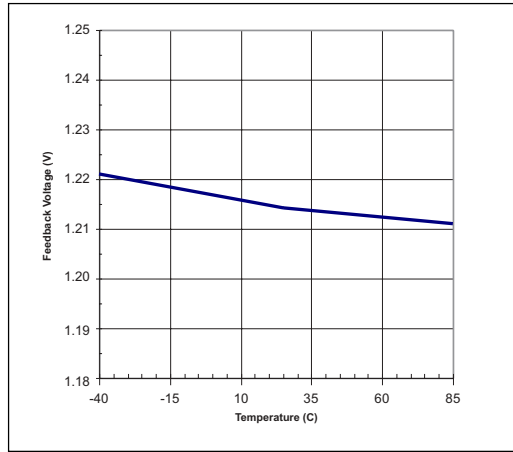


Figure 14. Feedback Voltage vs. Temperature

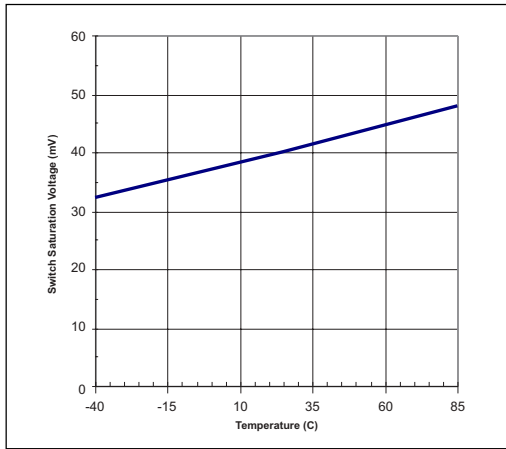


Figure 15. Switch Saturation Voltage V_{CESAT} vs. Temperature ($I_{SW}=50\text{mA}$)

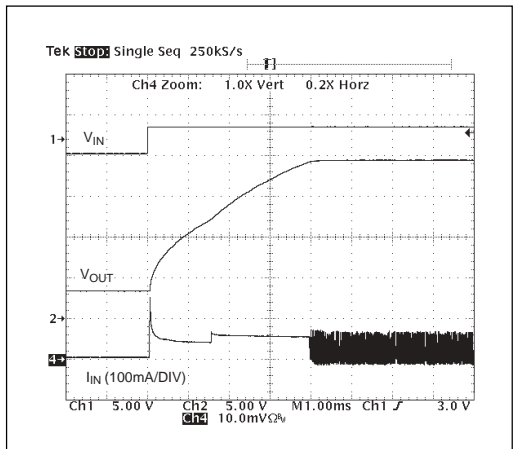


Figure 16. Startup Waveform ($V_{IN}=3.3\text{V}$, $V_{OUT}=20\text{V}$, $I_{OUT}=2\text{mA}$)

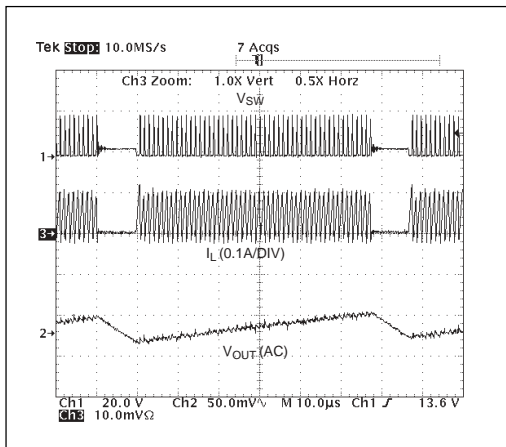


Figure 17. Typical Switching Waveforms ($V_{IN}=3.3\text{V}$, $V_{OUT}=20\text{V}$, $I_{OUT}=5\text{mA}$)

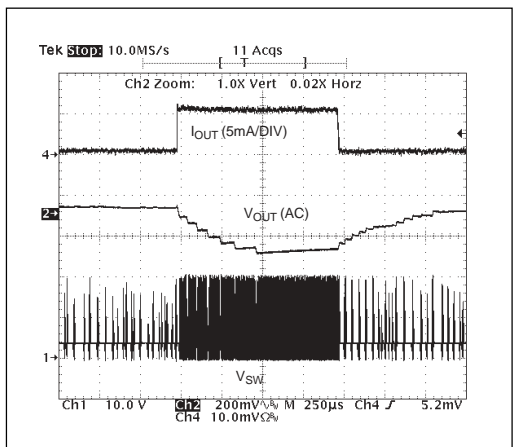
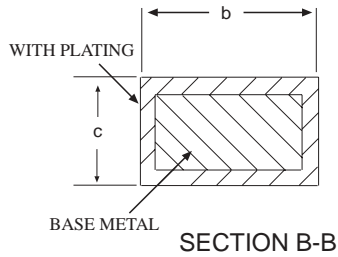
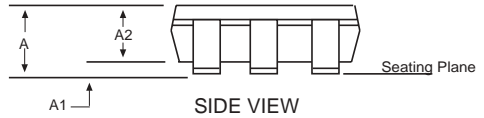
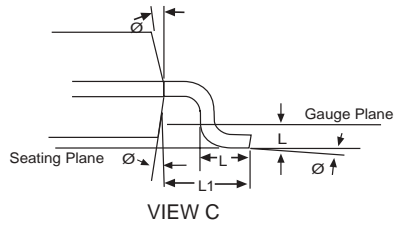
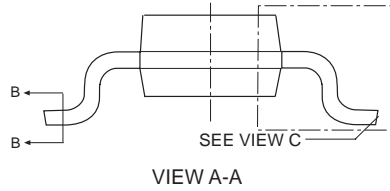
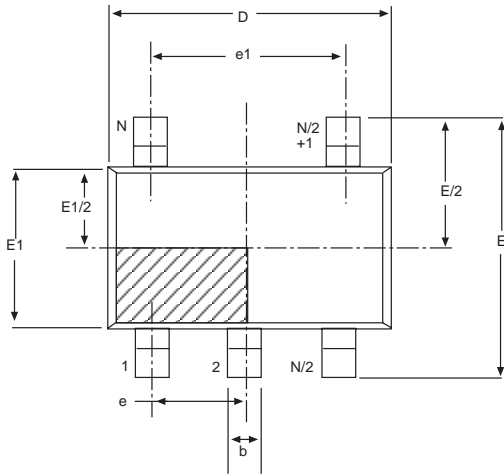


Figure 18. Load Step Transient ($V_{IN}=3.3\text{V}$, $V_{OUT}=20\text{V}$, $I_O=100\mu\text{A}\sim 5\text{mA}$)



5 Pin SOT-23 JEDEC MO-178 (AA) Variation			
SYMBOL	MIN	NOM	MAX
A	-	-	1.45
A1	0	-	0.15
A2	0.9	1.15	1.3
b	0.3	-	0.5
c	0.08	-	0.22
D	2.90 BSC		
E	2.80 BSC		
E1	1.60 BSC		
e	0.95 BSC		
e1	1.90 BSC		
L	0.3	0.45	0.6
L1	0.60 REF		
L2	0.25 BSC		
Ø	0°	4°	8°
ø	5°	10°	15°

Note: Dimensions in (mm)

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.

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ANALOG EXCELLENCE

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