

## 500 mA - Fixed Output Boost Converter for Single or Dual Cell

### DESCRIPTION

SiP12502 is a boost converter IC with fixed output voltage for single or double cell NiMH or Alkaline battery pack. Featuring with an internal low resistance power MOSFET, it is capable of starting up with a low battery voltage of 0.85 V. It only needs four external components (an inductor, a diode and two capacitors) to construct a step-up converter. For best efficiency performance, it is designed to operate in PWM mode with a 300 kHz switching frequency under normal load and in PFM mode under light load. The voltage-mode control loop is internally compensated, simplifying converter design and reducing external parts count. It accepts input voltages from 0.85 V to 5 V, providing fixed output voltages of 2.0 V, 3.3 V, and 5.0 V. It also features low shutdown current of under 1  $\mu$ A, over voltage protection, thermal shutdown protection, a power good output and antiringing control to minimize EMI.

SiP12502 is available in a lead (Pb)-free 6-pin, PowerPAK MLP33 package and is specified to operate over the industrial temperature range of - 40  $^{\circ}$ C to 85  $^{\circ}$ C.

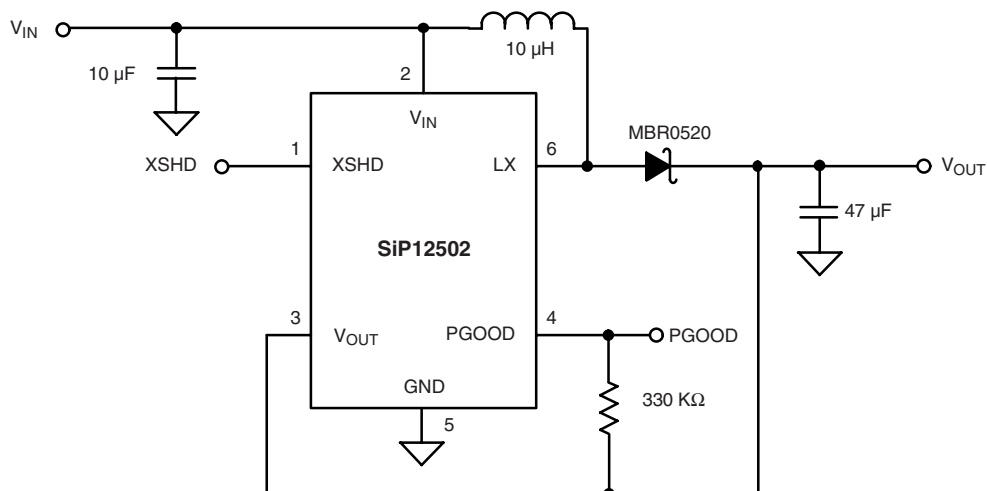
### FEATURES

- Voltage mode control with internal frequency compensation
- 0.85 V to 5.0 V input voltage range
- Fixed output voltage options - 2.0 V, 3.3 V, and 5.0 V
- Other voltages available upon request
- PWM control with 300 kHz fixed switching frequency
- PFM control for light load
- Powered from the output voltage supply
- Integrated UVLO and soft-start
- Logic controlled shutdown (< 1  $\mu$ A)
- 85 % typical efficiency
- Internal power MOS switch: 0.2  $\Omega$  at 3.3 V output
- Antiringing switch to minimize EMI
- Power good output
- Shutdown input
- Minimum external components
- PowerPAK<sup>®</sup> MLP33-6 package, (DFN-6, 3 x 3)
- Over voltage protection

### APPLICATIONS

- Portable applications
- Battery-powered equipment
- Handheld devices
- Digital cameras
- Wireless handsets
- LCD and OLED bias

### TYPICAL APPLICATION CIRCUIT



<b>ABSOLUTE MAXIMUM RATINGS</b> (all voltages referenced to GND = 0 V)			
Parameter		Limit	Unit
Input Voltage, $V_{IN}$		- 0.3 to 6	V
LX Voltage		- 0.3 to $V_{OUT} + 0.5$	
Output Voltage, $V_{OUT}$		- 0.3 to 6	
XSHD Voltage		- 0.3 to $V_{IN} + 0.5$	
PGOOD Voltage		- 0.3 to 6	
Maximum Junction Temperature		150	°C
Storage Temperature		- 55 to 150	
Operating Junction Temperature		125	
Power Dissipation <sup>a</sup>	PowerPAK MLP33-6 ( $T_A = 70\text{ °C}$ ) <sup>a</sup>	1100	mW
Thermal Resistance <sup>b</sup>	PowerPAK MLP33-6	50	°C/W

Notes:

a. Derate 20 mW/°C above 70 °C.

b. Device mounted with all leads soldered or welded to PC board.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

<b>RECOMMENDED OPERATING RANGE</b> (all voltages referenced to GND = 0 V)			
Parameter		Limit	Unit
Input Voltage, $V_{IN}$		0.85 to 5.0	V
Output Voltage, $V_{OUT}$		2.0 to 5	
XSHD Voltage		0 to $V_{IN}$	
LX Voltage		0 to $V_{OUT} + 0.5$	
PGOOD Voltage		0 to 5	
Operating Temperature Range		- 40 to 85	°C

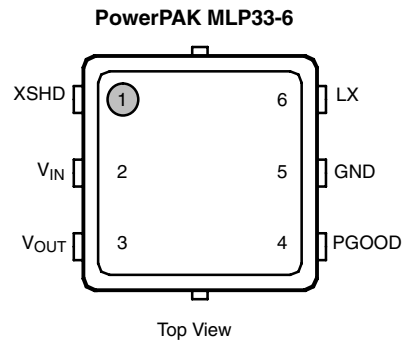
<b>SPECIFICATIONS</b>							
Parameter	Symbol	Test Conditions Unless Specified $V_{IN} = 1.2\text{ V}$ , $V_{OUT} = V_{nom}^e$ , $T_A = 25\text{ °C}$	Temp. <sup>a</sup>	Limits			Unit
				Min. <sup>b</sup>	Typ. <sup>c</sup>	Max. <sup>b</sup>	
Minimum Start-Up Voltage	$V_{START}$	$I_{LOAD} = 1\text{ mA}$	Full		0.65	0.85	V
Minimum Operating Voltage <sup>d</sup>	$V_{HOLD}$	$XSHD = V_{IN}$			0.55		
Output Voltage Accuracy	$V_{OUT}$			- 1.5		+ 1.5	%
			- 25 °C to 85 °C	- 3.0		+ 3.0	
			Full	- 3.5		+ 3.5	
UVLO	$V_{UVLO}$	Rising $V_{OUT}$	Full		1.8	2	V
UVLO Hysteresis	$V_{UVLOHYST}$		Full		0.100		
Maximum PWM Duty Cycle	MAXDTY		Full	80	87		%
PWM Switching Frequency	$f_{OSC}$		Full	225	300	375	kHz

<b>SPECIFICATIONS</b>							
Parameter	Symbol	Test Conditions Unless Specified $V_{IN} = 1.2\text{ V}$ , $V_{OUT} = V_{nom}^e$ , $T_A = 25\text{ }^\circ\text{C}$	Temp. <sup>a</sup>	Limits			Unit
				Min. <sup>b</sup>	Typ. <sup>c</sup>	Max. <sup>b</sup>	
Supply Current 1	$I_{OUT1}$	$V_{OUT} = V_{nom} \times 0.95$	Full		330	620	$\mu\text{A}$
Supply Current 2	$I_{OUT2}$	$V_{OUT} = 6\text{ V}$ , $V_{nom} + 0.6\text{ V}$ , $V_{LX} > V_{IN}$			150		
Supply Current 3	$I_{OUT3}$	$V_{OUT} = V_{nom} + 0.5\text{ V}$ , $V_{LX} < V_{IN}$			75		
Stand-By Current	$I_{STB}$	XSHD = 0 V, not including switch leakage	Full			1	
NMOS Switch Leakage	$I_{LEAK}$	LX = 5 V			1	2	$\Omega$
			Full				
NMOS Switch On Resistance	$R_{DS(on)}$	$V_{OUT} = 3.3\text{ V}$			0.2		$\Omega$
PWM to PFM Current Threshold	$I_{WTOF}$				3		mA
PFM to PWM Current Threshold	$I_{FTOF}$				22		
XSHD Input High Level	$V_{XSHDH}$	$0.8\text{ V} \leq V_{IN} \leq 0.9\text{ V}$	Full	0.55			V
		$0.9\text{ V} < V_{IN} \leq 2\text{ V}$	Full	0.8			
		$2\text{ V} < V_{IN} \leq 5\text{ V}$	Full	1.2			
XSHD Input Low Level	$V_{XSHDL}$		Full			0.2	
Softstart Time	$t_{START}$	$V_{IN} = 1.8\text{ V}$			1.6		ms
Over Voltage Threshold	$V_{OV}$				110		%
Over Voltage Hysteresis	$V_{OVHYST}$				10		
Thermal Shutdown	$T_{SHD}$				160		$^\circ\text{C}$
Thermal Shutdown Hysteresis	$T_{HYST}$				20		
PGOOD Threshold	$V_{PGOOD}$			85	90	95	%
PGOOD Hysteresis	$V_{PGOODHYST}$				2		
PGOOD Output Voltage Low	$PG_{GOODL}$	$V_{OUT} = 3.3\text{ V}$ , $I_{PGOOD} = 1\text{ mA}$	Full		0.15	0.2	V
PGOOD Output Leakage Current	$PG_{GOOD}$	$V_{PGOOD} = 5\text{ V}$	Full		0.01	1	$\mu\text{A}$

Notes:

- a. Full = - 40 °C to 85 °C.
- b. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum (- 40 °C to 85 °C).
- c. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- d. Minimum operating voltage is determined by the battery's capability to provide energy as it is deeply discharged.
- e.  $V_{nom}$  equals voltage output for part selected.

## PIN CONFIGURATION AND TRUTH TABLE



ORDERING INFORMATION			
Part Number	Voltage Output	Temperature Range	Marking
SiP12502DMP-20-E3	2.0 V	- 40 °C to 85 °C	<b>502A</b>
SiP12502DMP-33-E3	3.3 V		<b>502E</b>
SiP12502DMP-50-E3	5.0 V		<b>502G</b>

PIN DESCRIPTION		
Pin Number	Name	Function
1	XSDH	Logic controlled shutdown input, XSHD = high: normal operation, XSHD = low: shutdown
2	V <sub>IN</sub>	Input voltage
3	V <sub>OUT</sub>	Output of the boost converter and power source for the IC battery
4	PGOOD	Power good comparator output
5	GND	Signal and power ground
6	LX	Switch pin

## PIN FUNCTIONS

### XSHD (Pin 1)

XSHD is a logic-level shutdown control pin. When XSHD is low, the IC's switching is disabled and an antiringing switch is connected between LX and V<sub>IN</sub>. When XSHD is high, the IC is working in normal operation.

### V<sub>IN</sub> (Pin 2)

V<sub>IN</sub> is the pin connected to the battery input voltage. At start-up, SiP12502 is powered from the voltage at the V<sub>IN</sub> pin. Once V<sub>OUT</sub> exceeds V<sub>IN</sub>, the SiP12502 is powered from V<sub>OUT</sub>. This increases the drive to the gate of the internal power switch, to allow higher maximum output currents and higher converter efficiency.

### V<sub>OUT</sub> (Pin 3)

V<sub>OUT</sub> is the output of the boost converter and also the power source for the IC.

### PGOOD (Pin 4)

PGOOD is the open-drain output pin of the power good comparator. It is low when V<sub>OUT</sub> is 10 % lower than its regulation voltage. After the soft start is finished and V<sub>OUT</sub> is higher than 90 % of its regulation voltage, PGOOD will go high. Its hysteresis is 2 %.

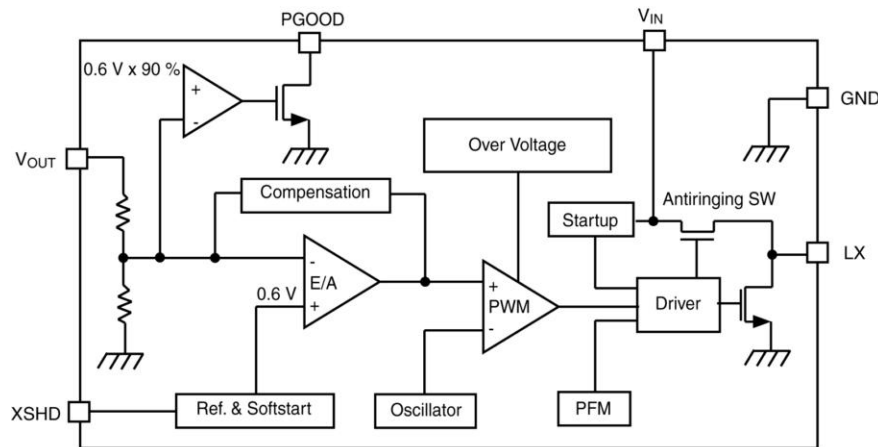
### GND (Pin 5)

GND is the ground pin for signal and power ground.

### LX (Pin 6)

LX is connects to the drain of the internal power MOSFET (boost switch). Externally, the LX pin should be connected to the boost inductor and Schottky diode. If the inductor current falls to zero, or XSHD is low, an internal antiringing switch is connected from LX to V<sub>IN</sub> to minimize EMI.

## FUNCTIONAL BLOCK DIAGRAM



## DETAILED OPERATION

SiP12502 is a 300 kHz boost converter IC, packaged in 6-pin MLP33 PowerPAK™ package. With start-up from input voltages as low as 0.65 V, this device features fixed frequency voltage mode PWM control with internal frequency compensation. With its low  $r_{DS(on)}$  internal power MOSFET, this device maintains high efficiency over a wide range of load currents. Under light load conditions, it switches to PFM mode to maintain high efficiency. A power good signal is available to monitor the output voltage.

### Low Voltage Start-Up

SiP12502 is designed to start-up at input voltage of typically 0.65 V. At start-up,  $V_{OUT}$  is lower than  $V_{IN}$  due to the voltage drop of the Schottky diode. Therefore, the device uses  $V_{IN}$  as the power source for its control logic and internal gate drive, until  $V_{OUT}$  exceeds  $V_{IN}$ . During the start-up interval, the boost switch's conduction interval during each cycle is determined by the time taken for the inductor current to reach internal current limit, followed by a fixed off time before the switch is allowed to turn on again. Once  $V_{OUT}$  exceeds  $V_{IN}$ , the device uses  $V_{OUT}$  as the IC's power source. When  $V_{OUT}$  exceeds 1.89 V, the device engages its built-in soft-start circuitry.

### Soft-Start

During soft-start, the loop compensation guarantees the slow increase of output voltage, so that no large voltage overshoot or inrush current transients occur when the soft-start period ends.

### PWM operation

After the soft-start interval is over, the device works in PWM operation with a fixed frequency of 300 kHz, with automatic switch-over to PFM operation during light load conditions.

### PFM Operation

When operating into light loads, the SiP12502 automatically switches to PFM operation. This reduces gate charge losses in the boost switch, hence raising converter efficiency.

### Over Voltage Protection

If the output voltage is above 10 % of the regulation voltage, the device will turn off the internal power MOSFET and wait until the output voltage falls below the regulation voltage, then the PWM operation is enabled again.

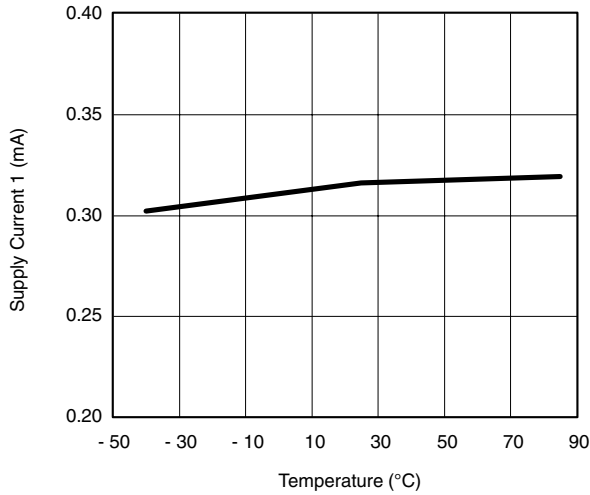
### Thermal Shutdown Protection

If the internal device temperature rises above 160 °C, the device will turn off the internal power MOSFET. Once the die temperature falls below 140 °C, the device performs a new soft-start cycle, the converter resumes normal operation.

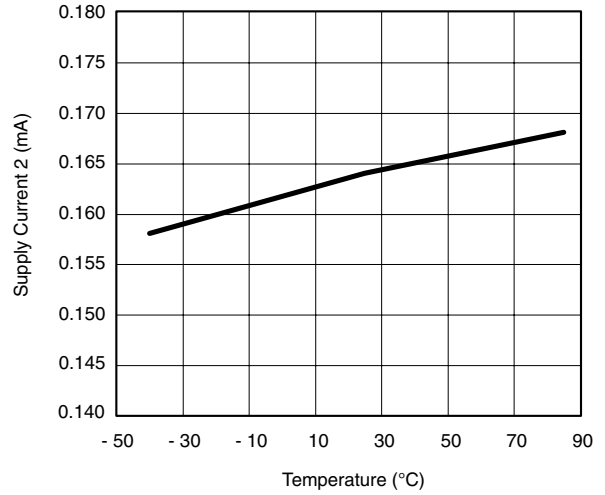
### Antiringing Control

The antiringing control circuitry prevents high frequency ringing at the LX pin as the inductor current goes to zero by damping the resonant circuit formed by L and  $C_{LX}$  (capacitance on LX pin). When the IC is shutdown, this antiringing switch is also turned on.

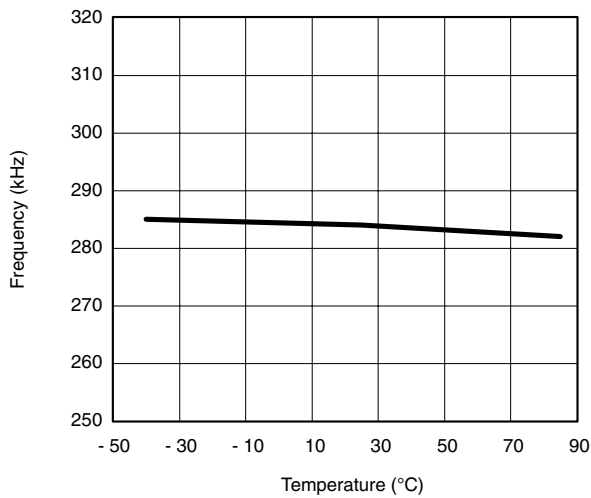
**TYPICAL CHARACTERISTICS**



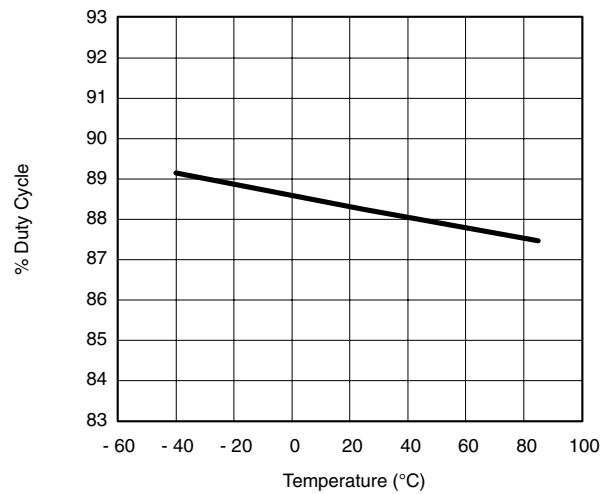
**Supply Current 1 vs. Temperature**



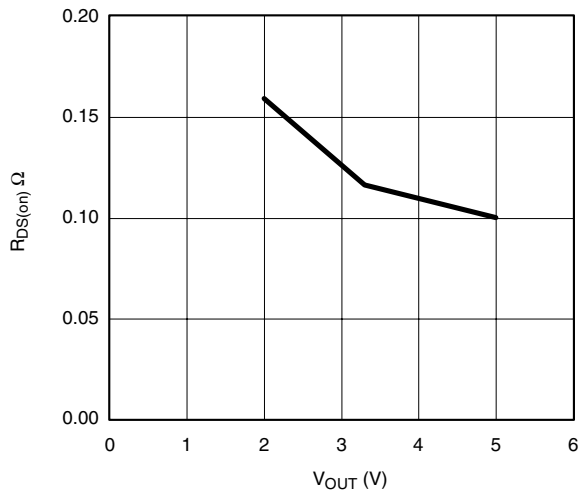
**Supply Current 2 vs. Temperature**



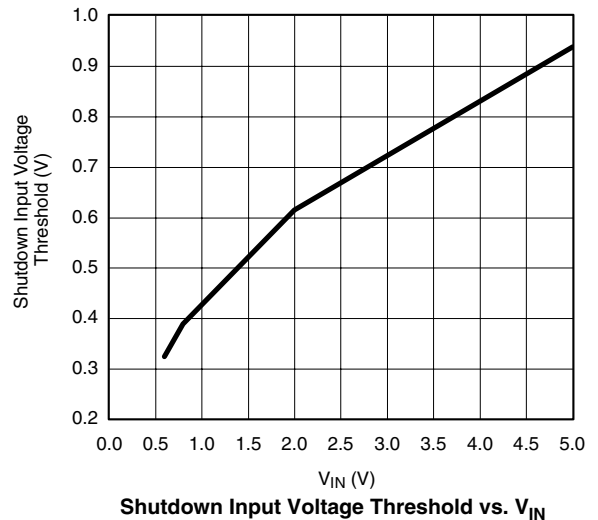
**Frequency vs. Temperature**



**Maximum PWM Duty Cycle vs. Temperature**

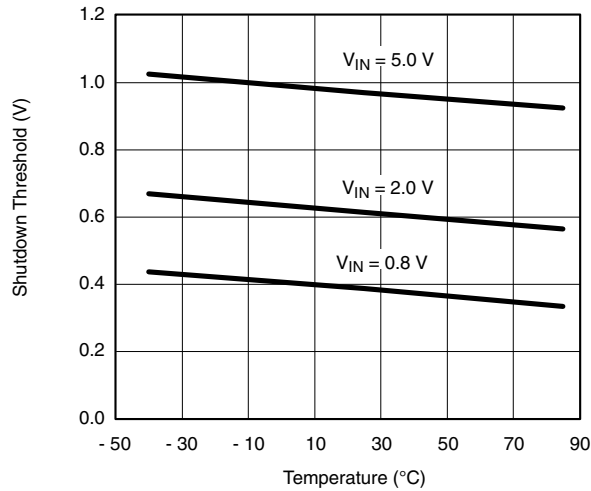


**R<sub>DS(on)</sub> vs. Output Voltage**

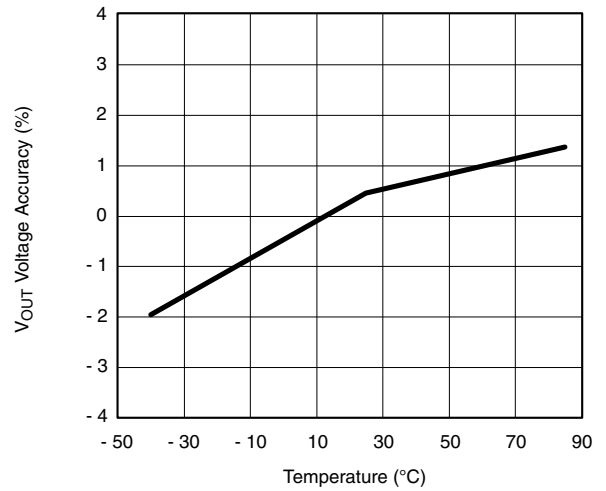


**Shutdown Input Voltage Threshold vs. V<sub>IN</sub>**

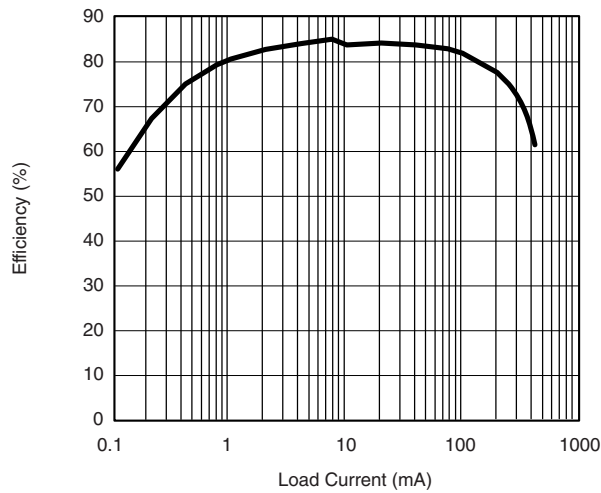
**TYPICAL CHARACTERISTICS**



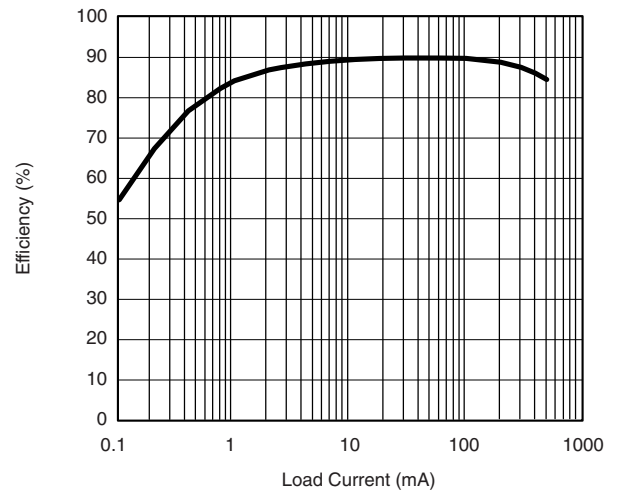
**Shutdown Threshold vs. Temperature**



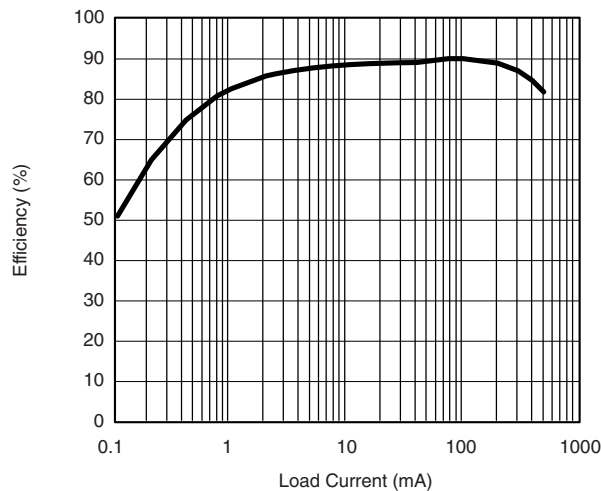
**$V_{OUT}$  Voltage vs. Temperature**



**$V_{IN} = 1.2\text{ V}, V_{OUT} = 2\text{ V}$**

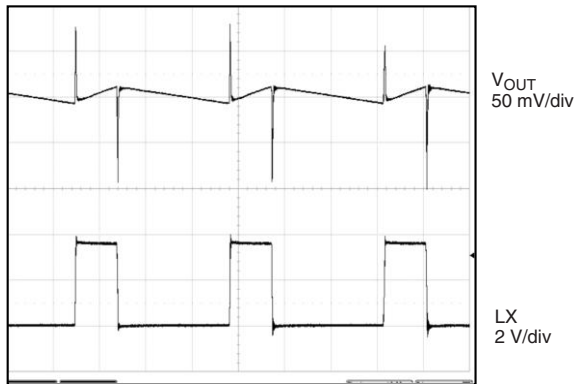


**$V_{IN} = 2.4\text{ V}, V_{OUT} = 3.3\text{ V}$**

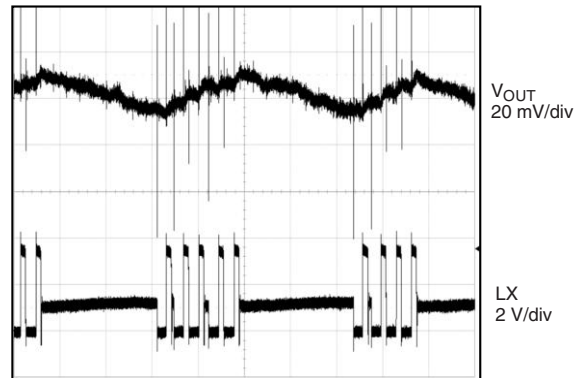


**$V_{IN} = 2.4\text{ V}, V_{OUT} = 5\text{ V}$**

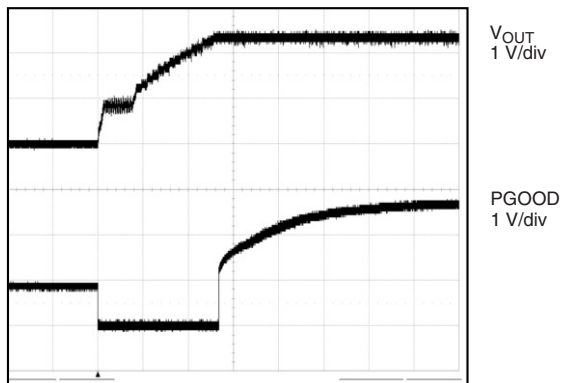
## TYPICAL WAVEFORMS

1  $\mu$ s/div**Typical Switching Waveform PWM Mode**

$V_{IN} = 1.2$  V,  $V_{OUT} = 3.3$  V, Load Current = 150 mA,  
 $L = 10$   $\mu$ H;  $C_{OUT} = 47$   $\mu$ F

100  $\mu$ s/div**Typical Switching Waveform PFM Mode**

$V_{IN} = 1.2$  V,  $V_{OUT} = 3.3$  V, Load Current = 10 mA,  
 $L = 10$   $\mu$ H;  $C_{OUT} = 47$   $\mu$ F



5 ms/div

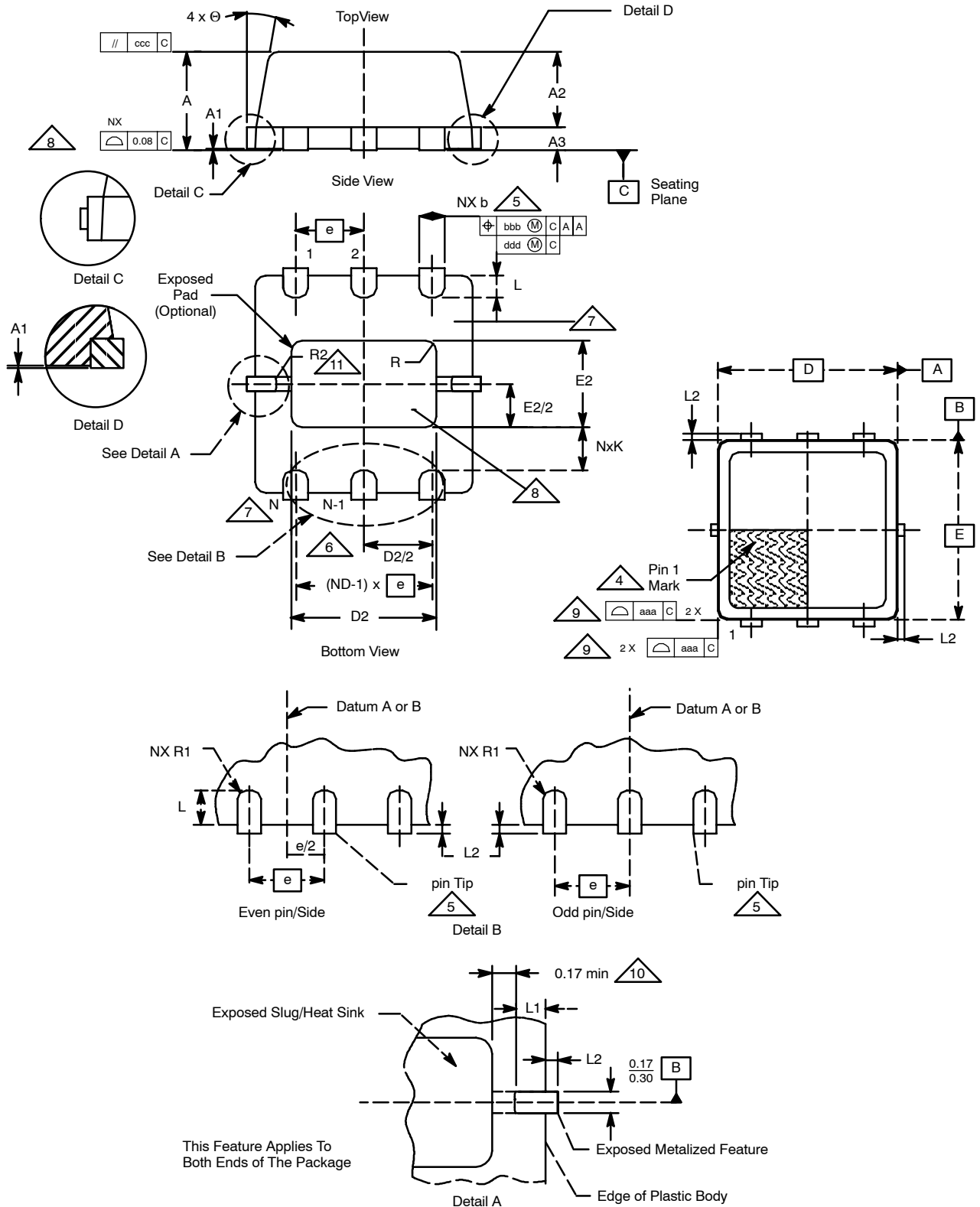
**Soft Start and PGOOD**

$V_{IN} = 1.2$  V,  $V_{OUT} = 3.3$  V, Load Current = 50 mA,  
 $L = 10$   $\mu$ H;  $C_{OUT} = 47$   $\mu$ F





**PowerPAK® MLP33-6, 8 and 10 (POWER IC ONLY)**



# Package Information



## Vishay Siliconix

### PowerPAK® MLP33-6, 8, 10

**N = 6 PITCH: 0.95 mm**  
**N = 8 PITCH: 0.65 mm**  
**N = 10 PITCH: 0.50 mm**

Dim	MILLIMETERS*				INCHES				Notes
	Basic	Min	Nom	Max	Basic	Min	Nom	Max	
A	-	0.80	0.90	1.00	-	0.031	0.035	0.039	1, 2
A1	-	0.00	0.025	0.05	-	0.000	0.001	0.002	1, 2
A2	-	0.65	0.70	0.75	-	0.026	0.028	0.030	1, 2
A3	-	0.15	0.20	0.25	-	0.006	0.008	0.010	1, 2
aaa	-	-	0.10	-	-	-	0.004	-	1, 2
b-6	-	0.33	0.35	0.43	-	0.013	0.014	0.017	1, 2, 8
b-8	-	0.285	0.305	0.385	-	0.011	0.012	0.015	1, 2, 8
b-10	-	0.18	0.20	0.28	-	0.007	0.008	0.011	1, 2, 8
bbb	-	-	0.10	-	-	-	0.004	-	1, 2
ccc	-	-	0.10	-	-	-	0.004	-	1, 2
D	3.00	-	-	-	0.118	-	-	-	1, 2, 8
D2	-	1.92	2.02	2.12	-	0.076	0.080	0.083	1, 2, 8
ddd	-	-	0.05	-	-	-	0.002	-	1, 2
E	3.00	-	-	-	0.118	-	-	-	1, 2, 8
E2	-	1.10	1.20	1.30	-	0.043	0.047	0.051	1, 2, 8
e-6	-	-	0.95	-	-	-	0.037	-	1, 2
e-8	-	-	0.65	-	-	-	0.026	-	1, 2
e-10	-	-	0.50	-	-	-	0.020	-	1, 2
K	-	0.20	-	-	-	0.008	-	-	5, 11
L	-	0.20	0.29	0.45	-	0.008	0.011	0.018	1, 2, 8
L1-6	-	0.16	0.24	0.40	-	0.006	0.009	0.016	1, 2, 8
L1-8	-	0.16	0.24	0.40	-	0.006	0.009	0.016	1, 2, 8
L1-10	-	-	-	-	-	-	-	-	1, 2, 8
L2	-	-	-	0.125	-	-	-	0.005	5, 11
R Ref	-	-	0.15	-	-	-	0.006	-	1, 2, 8
R1 Ref-6	-	-	0.127	-	-	-	0.005	-	1, 2, 8
R1 Ref-8	-	-	0.15	-	-	-	0.006	-	1, 2, 8
R1 Ref-10	-	-	0.075	-	-	-	0.003	-	1, 2, 8
⊖	-	0°	10°	12°	-	0°	10°	12°	1, 2

\* Use millimeters as the primary measurement.

ECN: S-40082—Rev. A, 02-Feb-04  
 DWG: 5925

#### NOTES:

1. Dimensioning and tolerancing conform to ASME Y14.5M-1994.
2. All dimensions are in millimeters. All angels are in degrees.
3. N is the total number of pins.

4. The pin #1 identifier and pin numbering convention shall conform to JESD 95-1 SPP-012. Details of pin #1 identifier is located within the zone indicated. The pin #1 identifier is marked.

5. Dimension b applies to metallized pin and is measured between 0.15 mm and 0.20 mm from the pin tip.

6. ND refers to the maximum number of pins on the D side.

7. Depopulation of pins is allowed and will be called out on the individual variation.

8. Coplanarity applies to the exposed heat sink slug as well as the pins.

9. Profile tolerance (aaa) will be applicable only to the plastic body and not to the metallized features (such as the pin tips and tie bars.) Metallized features may protrude a maximum of L2 from the plastic body profile.

10. L1 max is not called out, the metallized feature will extend to the exposed pad. Thus, the 0.17-mm gap does not apply.

11. The corner will be sharp unless otherwise specified with radius dimensions.



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