

## Boost Converter for Single/Double AA Cell or NiMH Battery for White LED Applications

### DESCRIPTION

SiP12501 is a boost converter IC for single or double cell NiMH or Alkaline battery pack, which can drive white LEDs connected in parallel to provide backlight in hand-held devices. Designed with an internal low threshold power MOSFET, it is capable of starting up with a low battery voltage of 0.65 V. For best efficiency performance, the SiP12501 is designed to operate in PWM mode with 600 kHz switching. The voltage-mode PWM design is internally compensated, reducing the external parts count. It accepts input voltages from 0.65 V to 3.3 V, regulates output current of up to 60 mA from a 0.9 V input. The LED current can be adjusted externally for its brightness control. SiP12501 features low shutdown current of under 1  $\mu$ A, internal power MOS, thermal shutdown protection and antiringing control.

SiP12501 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

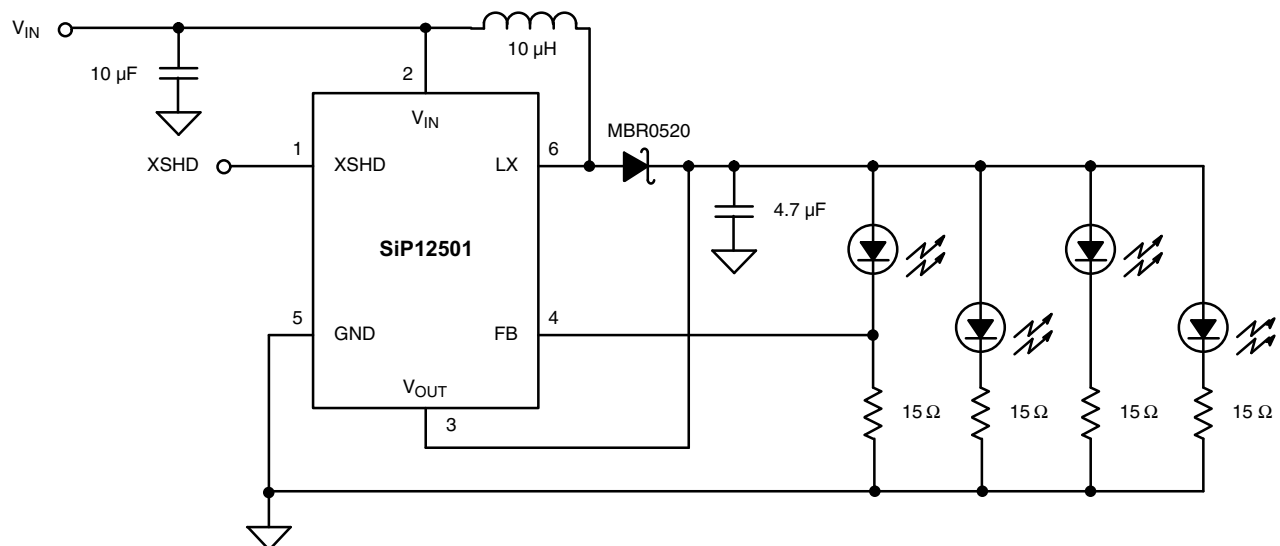
- Voltage mode control with internal frequency compensation
- 0.65 V to 3.3 V input voltage range
- Low startup voltage: 0.65 V
- PWM control with 600 kHz fixed switching frequency
- Analog control of LED intensity
- Power supply from output voltage
- Regulated output current
- Integrated UVLO and soft-start
- Logic controlled shutdown ( $< 1 \mu$ A)
- High efficiency: typical 75 %
- Internal power MOS
- Antiringing switch to minimize EMI
- Thermal shutdown
- Minimum external components
- PowerPAK<sup>®</sup> MLP33-6 package



### APPLICATIONS

- White LED backlighting
- Handheld devices
- Digital cameras
- Portable applications
- LCD bias supplies

### 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 $V_{IN} + 0.5$	
FB 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, $V_{IN}$		0.65 to 3.3	V
Output Voltage, $V_{OUT}$		3.5 to 5	
XSHD Voltage		0 to $V_{IN}$	
LX Voltage		0 to $V_{OUT} + 0.5\text{ V}$	
FB Voltage		0 to 5	
Operating Temperature Range		- 40 to 85	°C

<b>SPECIFICATIONS<sup>a</sup></b>							
Parameter	Symbol	Test Conditions Unless Specified $V_{IN} = 1.2\text{ V}$ , $V_{OUT} = 3.9\text{ V}$ , $T_A = 25\text{ °C}$	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 = $V_{IN}$	Full		0.55		
Feedback Voltage	$V_{FB}$		Full	0.291	0.3	0.309	
Feedback Input Current	$I_{FB}$	$V_{FB} = 0.3\text{ V}$			1		nA
Maximum PWM Duty Cycle	MAXDTY			80	87		%
PWM Switching Frequency	$f_{OSC}$		Full	425	600	775	kHz
Quiescent Current	$I_Q$	$V_{FB} = 0.4\text{ V}$	Full		200	300	µA
Stand-By Current	$I_{STB}$	XSHD = 0 V, not including switch leakage	Full			1	
NMOS Switch Leakage	$I_{LEAK}$	LX = 5 V	Full		1	2	
NMOS Switch On Resistance	$R_{DS(on)}$	$V_{OUT} = 3.3\text{ V}$			0.24		Ω
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	
Thermal Shutdown	$T_{SHD}$				160		°C
Thermal Shutdown Hysteresis	$T_{HYST}$				20		

## Notes:

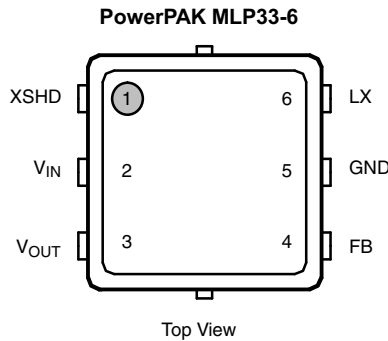
a. Full = - 40 °C to 85 °C.

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.

**PIN CONFIGURATION AND TRUTH TABLE**



<b>ORDERING INFORMATION</b>		
Part Number	Temperature Range	Marking
SiP12501DMP-T1-E3	- 40 °C to 85 °C	2501

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

**PIN FUNCTIONS**

**XSHD (Pin 1)**

XSHD is the logic controlled shutdown input pin. When XSHD is low, the IC is shutdown 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 battery input voltage. The IC gets its start-up bias from V<sub>IN</sub> at the beginning. Once V<sub>OUT</sub> exceeds V<sub>IN</sub>, bias will come from V<sub>OUT</sub>. Thus, once started, operation is completely independent from V<sub>IN</sub>. Operation is only limited by the output voltage level and the battery's internal series resistance.

**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.

**FB (Pin 4)**

FB is the feedback voltage pin, it senses the LED current through the ballast resistor, the difference between it and the internal 0.3 V reference is amplified by the error amplifier.

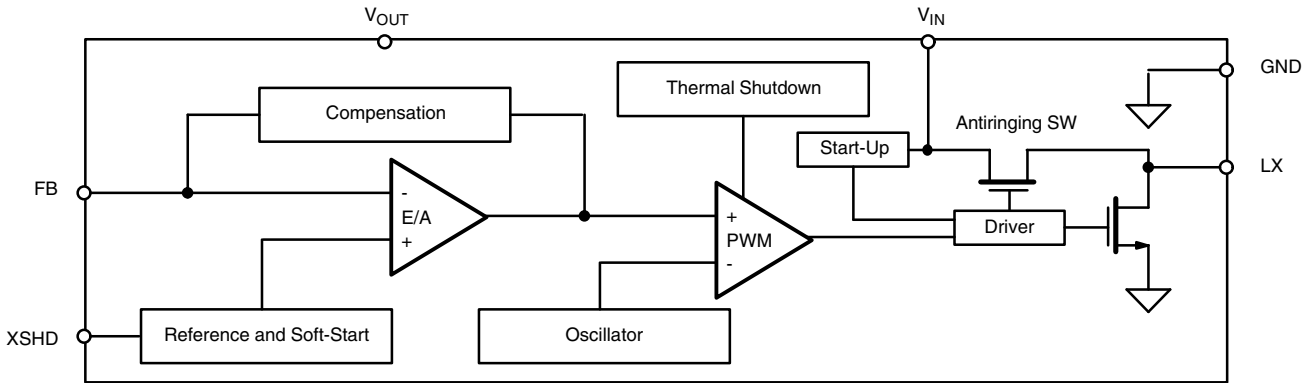
**GND (Pin 5)**

GND is the pin for signal and power ground.

**LX (Pin 6)**

LX is the pin of the drain for internal power MOS. LX is also connected to 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**

SiP12501 is a 600 kHz boost converter IC, packaged in 6 pin MLP33, for white LED applications. With start-up from low battery input voltage of 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 current.

**Low Voltage Start-Up**

SiP12501 is designed to start-up at input voltage of typically 0.65 V. In the beginning,  $V_{OUT}$  is lower than  $V_{IN}$  because of the voltage drop of the Schottky diode, the device uses  $V_{IN}$  as the power source for the start-up circuit and uses current limit with fixed off-time to control the increase of the output voltage. Once  $V_{OUT}$  exceeds  $V_{IN}$ , the device uses  $V_{OUT}$  as the power source. When  $V_{OUT}$  exceeds 1.89 V, the device switches to soft-start.

**Soft-Start**

During soft-start, the loop compensation guarantees the slow increase of the output voltage and inrush current, so that no large voltage overshoot and inrush current occur when the soft-start is ended.

**PWM operation**

After soft-start, the device works in PWM operation with a fixed frequency of 600 kHz.

**Thermal Shutdown Protection**

If the temperature of the device is above 160 °C, the device will turn off the internal power MOSFET and wait until the temperature drops below 140 °C, then the device goes into the soft-start process again and finally the system recovers. During thermal shutdown, the output voltage drops below 1.89 V minus UVLO hysteresis, start-up will be triggered to keep the output voltage above 1.89 V.

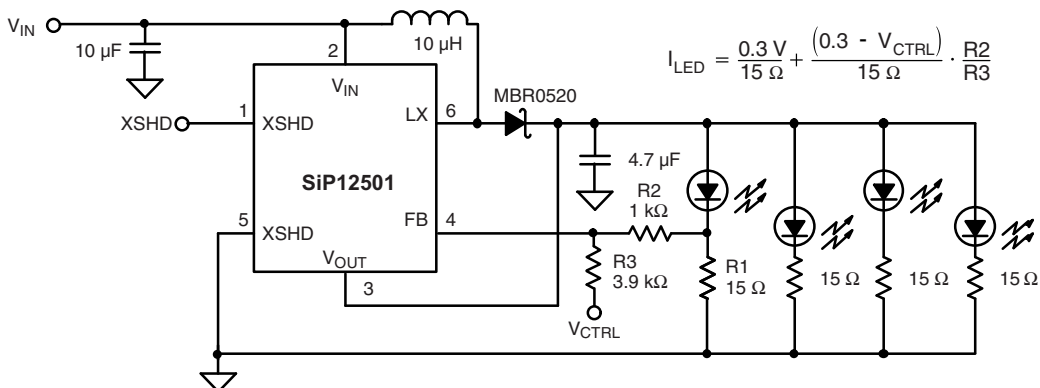
**Antiringing Control**

The antiringing control circuitry prevents high frequency ringing of 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.

**APPLICATION INFORMATION**

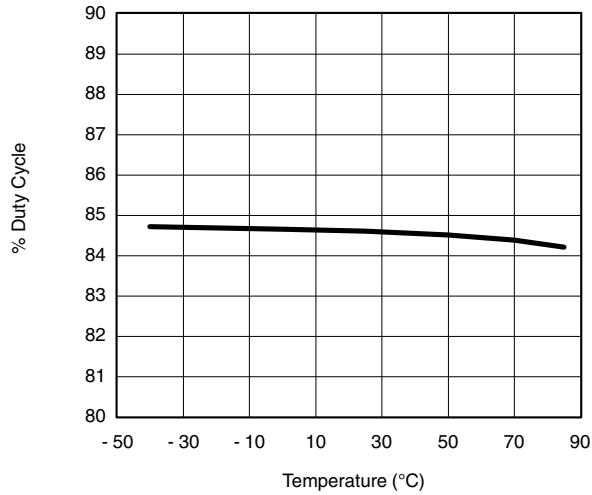
**White LED Brightness Control**

The current of white LED can be adjusted by a PWM signal on XSHD or by a variable dc voltage to control its brightness. (see Figure 1.) As control voltage  $V_{CTRL}$  increases, the voltage drop on R2 increases and the voltage drop on R1 decreases. Thus, the LED current decreases. The selection of R2 and R3 will make the current from  $V_{CTRL}$  much smaller than LED current and much larger than the FB pin bias current.

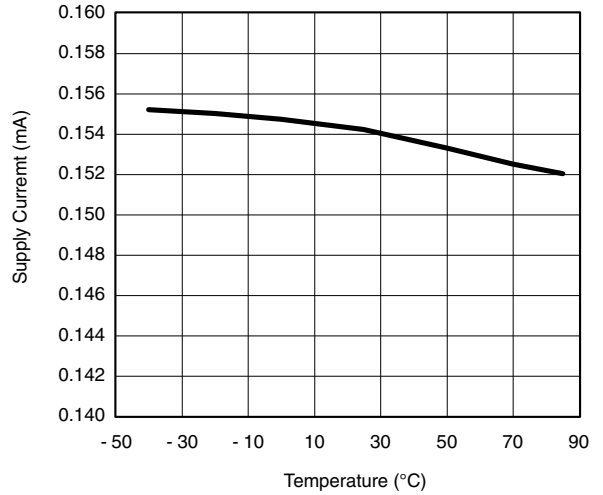




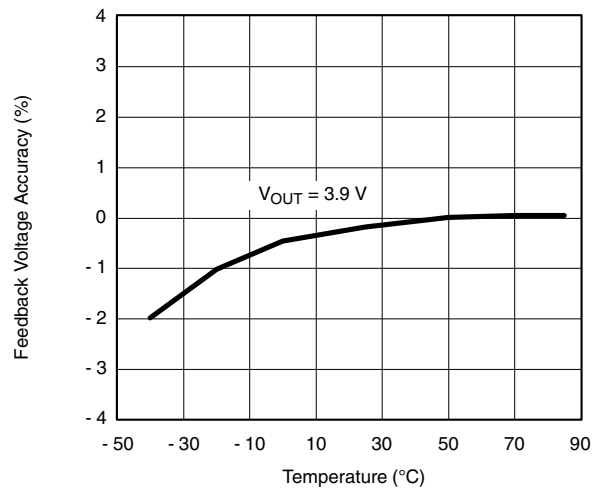
**TYPICAL CHARACTERISTICS**



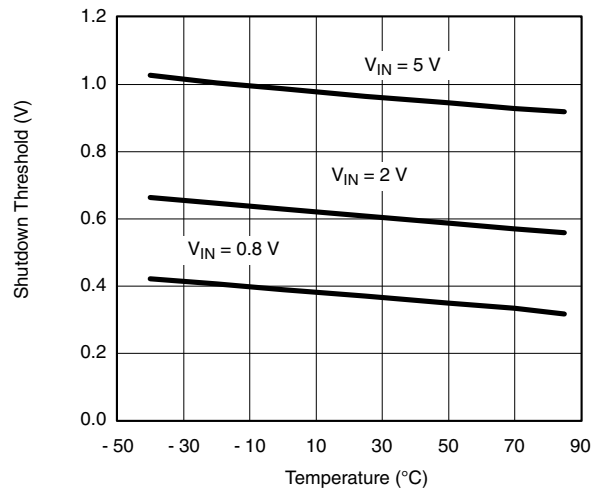
**Maximum PWM Duty Cycle vs. Temperature**



**Supply Current vs. Temperature**

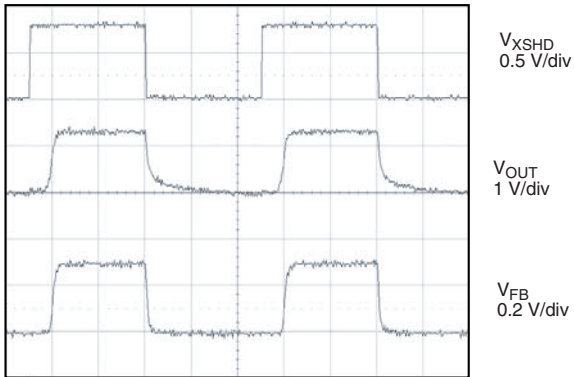


**Feedback Voltage vs. Temperature**



**Shutdown Threshold vs. Temperature**

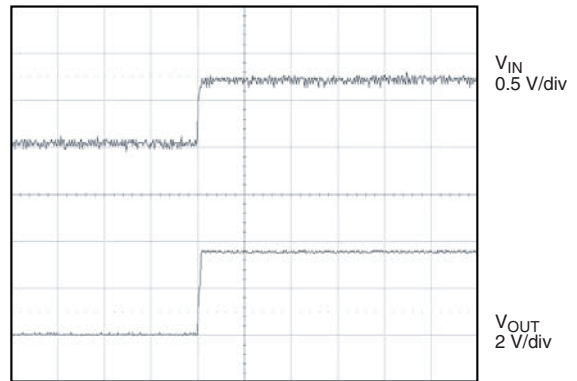
**TYPICAL WAVEFORMS**



$V_{IN} = 0.8\text{ V}$       1 ms/div

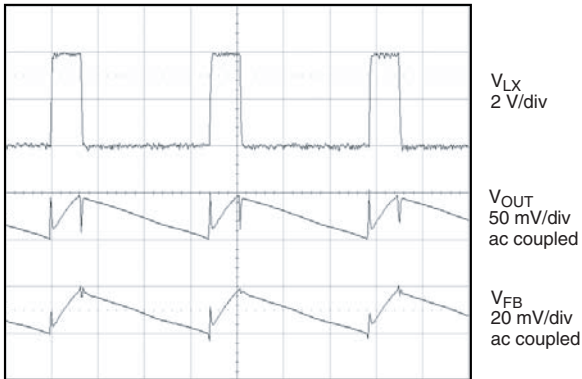
Four LEDs in series

**Figure 2. PWM Dimming Control**  
200 Hz 50 % Duty Cycle PWM Signal on XSHD Pin



100 ms/div

**Figure 3. Startup**  
 $V_{IN} = V_{XSHD} = 0\text{ V to }0.8\text{ V}$

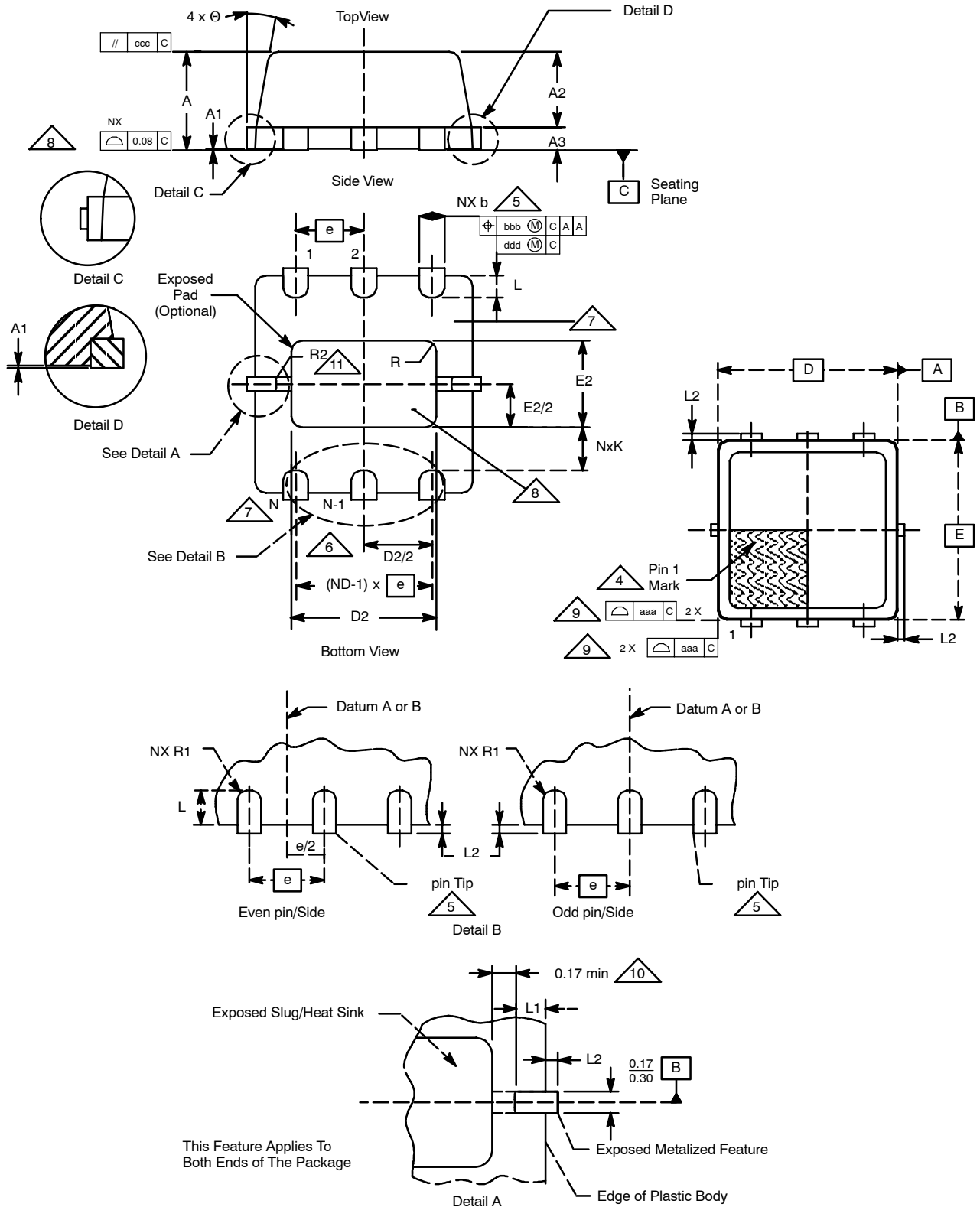


0.5  $\mu\text{s/div}$

**Figure 4. Switching Waveforms:  $V_{LX}$ ,  $V_{OUT}$  and  $V_{FB}$**   
 $V_{IN} = 0.8\text{ V}$ ,  $L = 10\ \mu\text{H}$ ,  $C_{OUT} = 4.7\ \mu\text{F}$ , Four LEDs in Parallel

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### 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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