

LM3501

Synchronous Step-up DC/DC Converter for White LED Applications

General Description

The LM3501 is a fixed frequency synchronous step-up DC/DC converter in a small 8-bump thin micro SMD package. The LM3501 is ideal for white LED applications for cellular phone back-lighting requiring low current and high efficiency. Its fixed 1MHz operating frequency allows the use of small, low ESR capacitors as well as a more predictable frequency spectrum, which is important in cellular phone applications. The LM3501 can drive 2 to 4 white LEDs in series from a single Li-Ion battery or 3 cell NiMH with no external rectification diode. For white LED applications, a single external resistor is used to set the maximum LED current. The white LED current can easily be adjusted using an external voltage signal from a DAC or micro-controller. The LM3501 uses special protection circuitry on the output to prevent an overvoltage event if the primary white LED network should be disconnected eliminating the need of an extra protection Zener diode. In shutdown, the LM3501 disconnects the input and output creating a true isolation preventing any LED light from emitting over the full input operating voltage range and temperature.

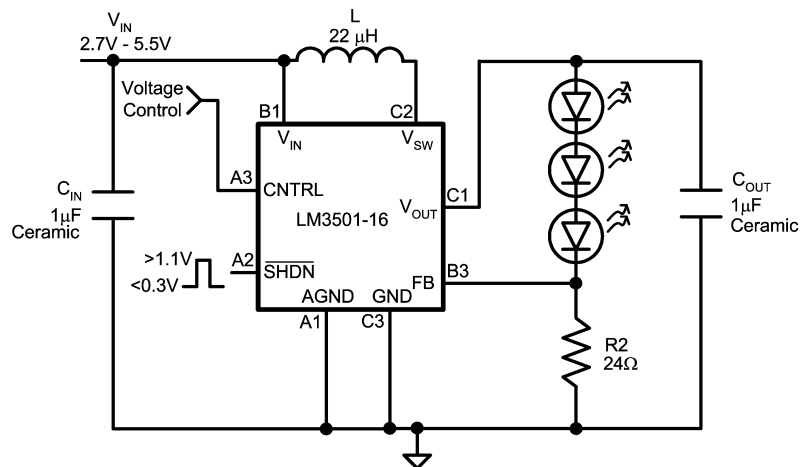
Features

- Synchronous rectification, high efficiency and no external schottky diode required
- Uses small surface mount components
- Can drive up to 3 (or 4 low V_F) white LEDs in series
- 2.7V to 7V input range
- True shutdown isolation, no LED leakage current
- DC voltage LED current control
- Input undervoltage lockout
- Output overvoltage protection, no external zener diode required
- Requires only a small 16V ceramic capacitor at the output
- Thermal Shutdown
- 0.1 μ A shutdown current
- Small 8-bump thin micro SMD package

Applications

- LCD Bias Supplies
- White LED Back-Lighting
- Handheld Devices
- Digital Cameras
- Portable Applications

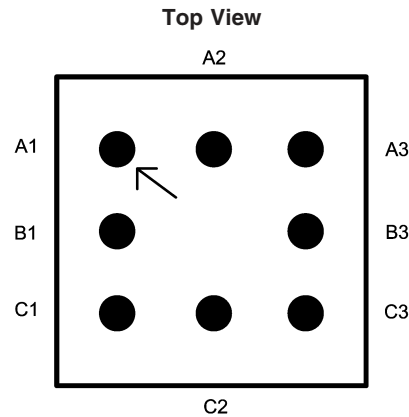
Typical Application Circuit



20065301

FIGURE 1. Typical 3 LED Application

Connection Diagram



20065302

8-bump micro SMD

$T_{J(MAX)} = 125^{\circ}\text{C}$, $\theta_{JA} = 220^{\circ}\text{C/W}$ (Note 3)

Ordering Information

Order Number	Package Type	NSC Package Drawing	Top Mark	Supplied As
LM3501TL-16	micro SMD	TL08SSA	C19	250 Units, Tape and Reel
LM3501TLX-16	micro SMD	TL08SSA	C19	3000 Units, Tape and Reel

Pin Description/Functions

Pin	Name	Function
A1	AGND	Analog ground.
B1	V_{IN}	Analog and Power supply input.
C1	V_{OUT}	PMOS source connection for synchronous rectification.
C2	V_{SW}	Switch pin. Drain connections of both NMOS and PMOS power devices.
C3	GND	Power Ground.
B3	FB	Output voltage feedback connection.
A3	CNTRL	Analog LED current control.
A2	$\overline{\text{SHDN}}$	Shutdown control pin.

AGND(pin A1): Analog ground pin. The analog ground pin should tie directly to the GND pin.

V_{IN} (pin B1): Analog and Power supply pin. Bypass this pin with a capacitor, as close to the device as possible, connected between the V_{IN} and GND pins.

V_{OUT} (pin C1): Source connection of internal PMOS power device. Connect the output capacitor between the V_{OUT} and GND pins as close as possible to the device.

V_{SW} (pin C2): Drain connection of internal NMOS and PMOS switch devices. Keep the inductor connection close to this pin to minimize EMI radiation.

GND(pin C3): Power ground pin. Tie directly to ground plane.

FB(pin B3): Output voltage feedback connection. Set the primary White LED network current with a resistor from the FB pin to GND. Keep the current setting resistor close to the device and connected between the FB and GND pins.

CNTRL(pin A3): Analog control of LED current. A voltage above 125mV will begin to regulate the LED current. Decreasing the voltage below 75mV will turn off the LEDs.

$\overline{\text{SHDN}}$ (pin A2): Shutdown control pin. Disable the device with a voltage less than 0.3V and enable the device with a voltage greater than 1.1V. The white LED current can be controlled using a PWM signal at this pin. There is an internal pull down on the $\overline{\text{SHDN}}$ pin, the device is in a normally off state.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

V_{IN}	-0.3V to 7.5V
V_{OUT} (Note 2)	-0.3V to 16V
V_{SW} (Note 2)	-0.3V to $V_{OUT}+0.3V$
FB Voltage	-0.3V to 7.5V
\overline{SHDN} Voltage	-0.3V to $V_{IN}+0.3V$
CNTRL	-0.3V to 7.5V
Maximum Junction Temperature	150°C
Lead Temperature (Soldering 10 sec.)	300°C
Vapor Phase (60 sec.)	215°C
Infrared (15 sec.)	220°C

ESD Ratings (Note 4)

Human Body Model	2kV
Machine Model	200V

Operating Conditions

Junction Temperature (Note 5)	-40°C to +125°C
Supply Voltage	2.7V to 7V
CNTRL Max.	2.7V

Thermal Properties

Junction to Ambient Thermal Resistance (θ_{JA}), 8-pin micro SMD package (Note 3)	220°C/W
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Electrical Characteristics

Specifications in standard type face are for $T_A = 25^\circ\text{C}$ and those in **boldface type** apply over the **Operating Temperature Range of $T_A = -10^\circ\text{C}$ to $+85^\circ\text{C}$** . Unless otherwise specified $V_{IN} = 2.7V$.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 6)	Max (Note 5)	Units
I_Q	Quiescent Current, Device Not Switching	FB > 0.54V		0.95	1.2	mA
	Quiescent Current, Device Switching	FB = 0V		2	2.5	
	Shutdown	SHDN = 0V		0.1	2	μA
V_{FB}	Feedback Voltage	CNTRL = 2.7V, $V_{IN} = 2.7V$ to 7V	0.485	0.515	0.545	V
		CNTRL = 1V, $V_{IN} = 2.7V$ to 7V	0.14	0.19	0.24	
ΔV_{FB}	Feedback Voltage Line Regulation	$V_{IN} = 2.7V$ to 7V		0.1	0.5	%/V
I_{CL}	Switch Current Limit	$V_{IN} = 2.7V$, Duty Cycle = 80%	275	400	480	mA
		$V_{IN} = 3.0V$, Duty Cycle = 70%	255	400	530	
I_B	FB Pin Bias Current	FB = 0.5V (Note 7)		45	200	nA
V_{IN}	Input Voltage Range		2.7		7.0	V
R_{DSON}	NMOS Switch R_{DSON}	$V_{IN} = 2.7V$, $I_{SW} = 300\text{mA}$			0.43	Ω
	PMOS Switch R_{DSON}	$V_{OUT} = 6V$, $I_{SW} = 300\text{mA}$		1.3	2.3	
D_{Limit}	Duty Cycle Limit	FB = 0V	80	87		%
F_{SW}	Switching Frequency		0.85	1.0	1.15	MHz
I_{SD}	SHDN Pin Current (Note 8)	SHDN = 5.5V		1.8	4	μA
		SHDN = 2.7V		1	2.5	
		SHDN = GND		0.1		
I_{CNTRL}	CNTRL Pin Current (Note 8)	$V_{CNTRL} = 2.7V$		10	20	μA
		$V_{CNTRL} = 1V$		4	15	
I_L	Switch Leakage Current	$V_{SW} = 15V$		0.01	0.5	μA
UVP	Input Undervoltage Lockout	ON Threshold	2.4	2.5	2.6	V
		OFF Threshold	2.3	2.4	2.5	

Electrical Characteristics (Continued)

Specifications in standard type face are for $T_A = 25^\circ\text{C}$ and those in **boldface type** apply over the **Operating Temperature Range of $T_A = -10^\circ\text{C}$ to $+85^\circ\text{C}$** . Unless otherwise specified $V_{IN} = 2.7\text{V}$.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 6)	Max (Note 5)	Units
OVP	Output Overvoltage Protection	ON Threshold	15	15.5	16	V
		OFF Threshold	14	14.6	15	
I_{Vout}	V_{OUT} Bias Current	$V_{OUT} = 15\text{V}$, $\overline{\text{SHDN}} = V_{IN}$		260	400	μA
I_{VL}	PMOS Switch Leakage Current	$V_{OUT} = 15\text{V}$, $V_{SW} = 0\text{V}$		0.01	3	μA
CNTRL Threshold		LED power off		75		mV
		LED power on		125		
SHDN Threshold	$\overline{\text{SHDN}}$ low			0.65	0.3	V
	$\overline{\text{SHDN}}$ High		1.1	0.65		

Specifications in standard type face are for $T_J = 25^\circ\text{C}$ and those in **boldface type** apply over the full **Operating Temperature Range ($T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$)**. Unless otherwise specified $V_{IN} = 2.7\text{V}$.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 6)	Max (Note 5)	Units
I_Q	Quiescent Current, Device Not Switching	$\text{FB} > 0.54\text{V}$		0.95	1.2	mA
	Quiescent Current, Device Switching	$\text{FB} = 0\text{V}$		2	2.5	
	Shutdown	$\overline{\text{SHDN}} = 0\text{V}$		0.1	2	μA
V_{FB}	Feedback Voltage	$\text{CNTRL} = 2.7\text{V}$, $V_{IN} = 2.7\text{V}$ to 7V	0.485	0.515	0.545	V
		$\text{CNTRL} = 1\text{V}$, $V_{IN} = 2.7\text{V}$ to 7V	0.14	0.19	0.24	
ΔV_{FB}	Feedback Voltage Line Regulation	$V_{IN} = 2.7\text{V}$ to 7V		0.1	0.5	$\%/V$
I_{CL}	Switch Current Limit	$V_{IN} = 3.0\text{V}$, Duty Cycle = 70%		400		mA
I_B	FB Pin Bias Current	$\text{FB} = 0.5\text{V}$ (Note 7)		45	200	nA
V_{IN}	Input Voltage Range		2.7		7.0	V
R_{DSON}	NMOS Switch R_{DSON}	$V_{IN} = 2.7\text{V}$, $I_{SW} = 300\text{mA}$			0.43	Ω
	PMOS Switch R_{DSON}	$V_{OUT} = 6\text{V}$, $I_{SW} = 300\text{mA}$		1.3	2.3	
D_{Limit}	Duty Cycle Limit	$\text{FB} = 0\text{V}$		87		%
F_{SW}	Switching Frequency		0.8	1.0	1.2	MHz
I_{SD}	$\overline{\text{SHDN}}$ Pin Current (Note 8)	$\overline{\text{SHDN}} = 5.5\text{V}$		1.8	4	μA
		$\overline{\text{SHDN}} = 2.7\text{V}$		1	2.5	
		$\overline{\text{SHDN}} = \text{GND}$		0.1		
I_{CNTRL}	CNTRL Pin Current (Note 8)	$V_{CNTRL} = 2.7\text{V}$		10	20	μA
		$V_{CNTRL} = 1\text{V}$		4	15	
I_L	Switch Leakage Current	$V_{SW} = 15\text{V}$		0.01	0.5	μA
UVP	Input Undervoltage Lockout	ON Threshold	2.4	2.5	2.6	V
		OFF Threshold	2.3	2.4	2.5	
OVP	Output Overvoltage Protection	ON Threshold	15	15.5	16	V
		OFF Threshold	14	14.6	15	
I_{Vout}	V_{OUT} Leakage Current	$V_{OUT} = 15\text{V}$, $\overline{\text{SHDN}} = V_{IN}$		260	400	μA
I_{VL}	PMOS Switch Leakage Current	$V_{OUT} = 15\text{V}$, $V_{SW} = 0\text{V}$		0.01	3	μA
CNTRL Threshold		LED power off		75		mV
		LED power on		125		

Electrical Characteristics (Continued)

Specifications in standard type face are for $T_J = 25^\circ\text{C}$ and those in **boldface type** apply over the full **Operating Temperature Range** ($T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$). Unless otherwise specified $V_{IN} = 2.7\text{V}$.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 6)	Max (Note 5)	Units
SHDN Threshold	SHDN low			0.65	0.3	V
	SHDN High		1.1	0.65		

Note 1: Absolute maximum ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions for which the device is intended to be functional, but device parameter specifications may not be guaranteed. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Note 2: This condition applies if $V_{IN} < V_{OUT}$. If $V_{IN} > V_{OUT}$, a voltage greater than $V_{IN} + 0.3\text{V}$ should not be applied to the V_{OUT} or V_{SW} pins.

Note 3: The maximum allowable power dissipation is a function of the maximum operating junction temperature, $T_{J(\text{MAX})}$, the junction-to-ambient thermal resistance, θ_{JA} , and the ambient temperature, T_A . See the *Thermal Properties* section for the thermal resistance. The maximum allowable power dissipation at any ambient temperature is calculated using: $P_D(\text{MAX}) = (T_{J(\text{MAX})} - T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature.

Note 4: The human body model is a 100 pF capacitor discharged through a 1.5 k Ω resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.

Note 5: All limits guaranteed at room temperature (standard typeface) and at temperature extremes (bold typeface). All room temperature limits are production tested, guaranteed through statistical analysis or guaranteed by design. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

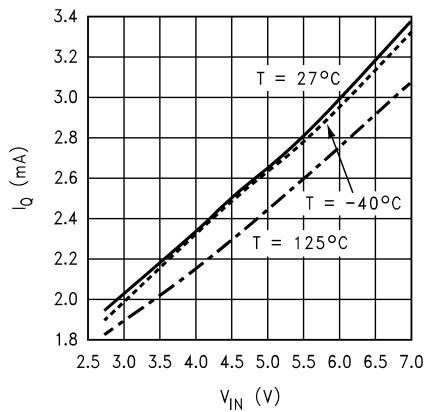
Note 6: Typical numbers are at 25°C and represent the most likely norm.

Note 7: Feedback current flows out of the pin.

Note 8: Current flows into the pin.

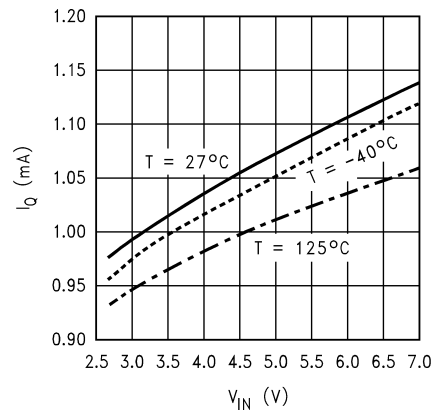
Typical Performance Characteristics

Switching Quiescent Current vs V_{IN}



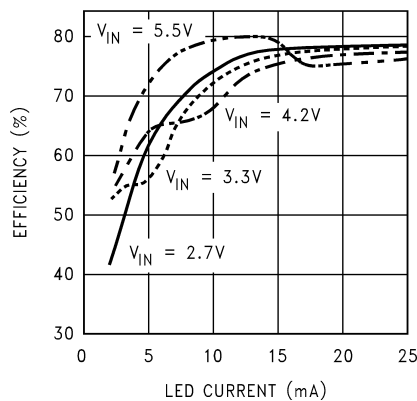
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Non-Switching Quiescent Current vs V_{IN}



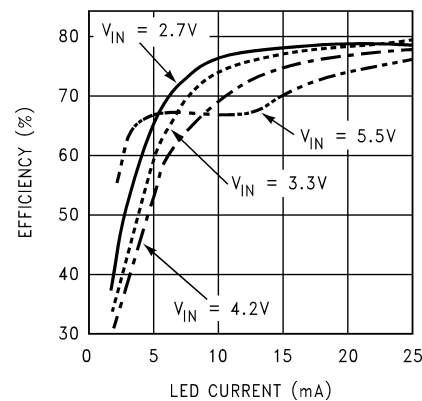
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2 LED Efficiency vs Load Current
L = Coilcraft DT1608C-223,
Efficiency = $100 \cdot (P_{IN} / (2V_{LED} \cdot I_{LED}))$



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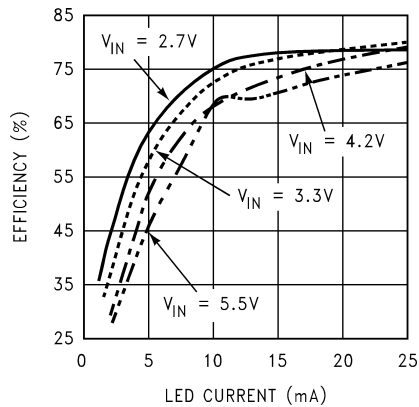
3 LED Efficiency vs Load Current
L = Coilcraft DT1608C-223,
Efficiency = $100 \cdot (P_{IN} / (3V_{LED} \cdot I_{LED}))$



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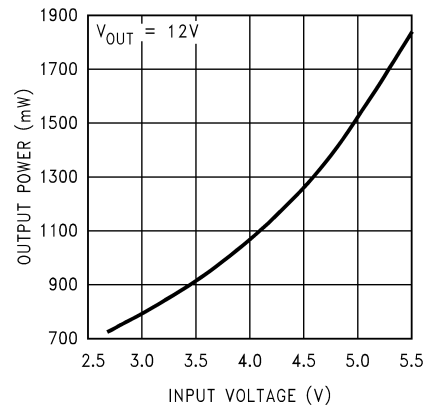
Typical Performance Characteristics (Continued)

4 LED Efficiency vs Load Current
 L = Coilcraft DT1608C-223,
 Efficiency = $100 * (P_{IN} / (4V_{LED} * I_{LED}))$



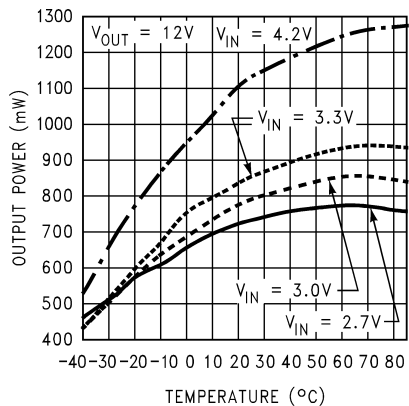
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Output Power vs V_{IN}
 L = Coilcraft DT1608C-223



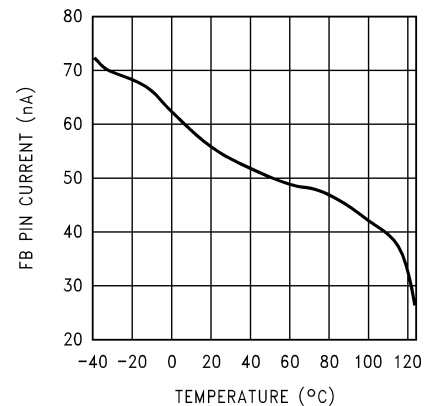
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Output Power vs Temperature
 L = Coilcraft DT1608C-223



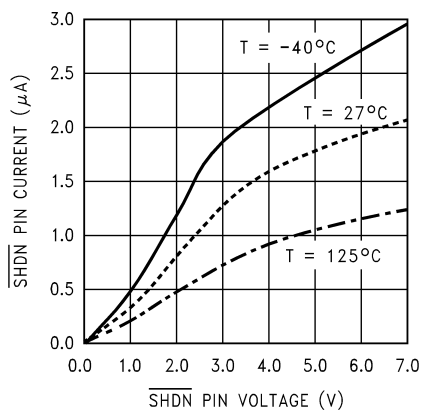
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FB Pin Current vs Temperature



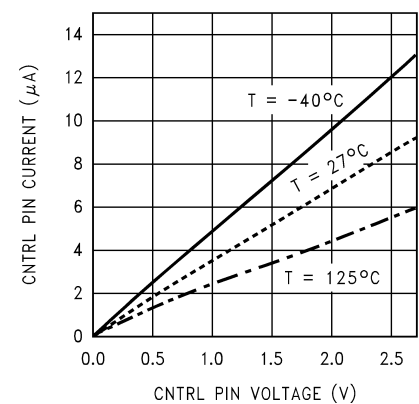
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SHDN Pin Current vs SHDN Pin Voltage



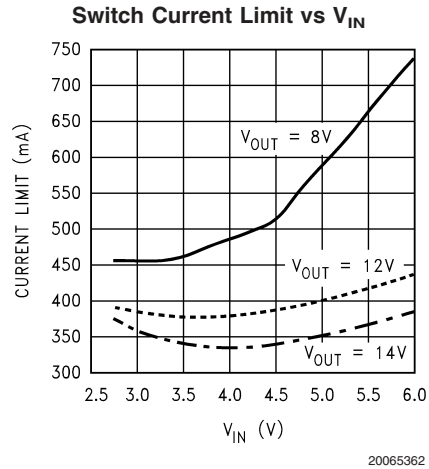
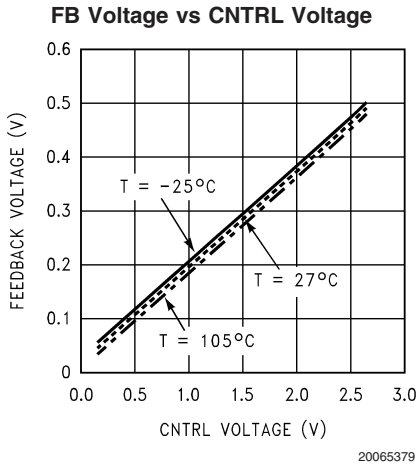
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CNTRL Pin Current vs CNTRL Pin Voltage

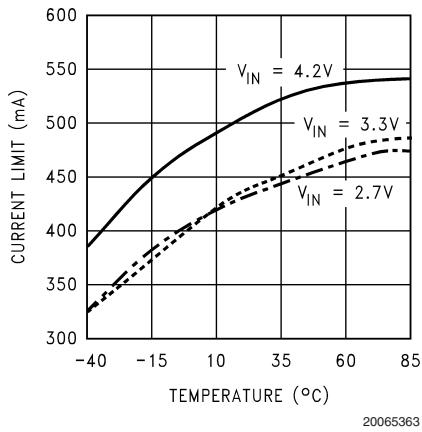


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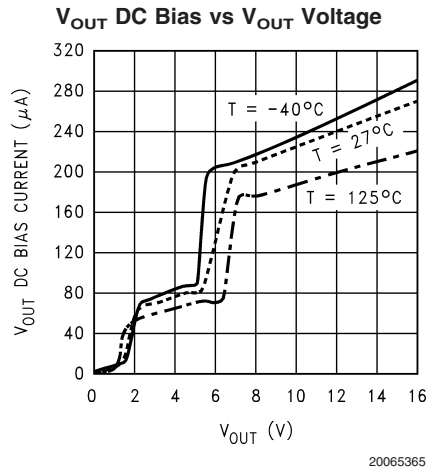
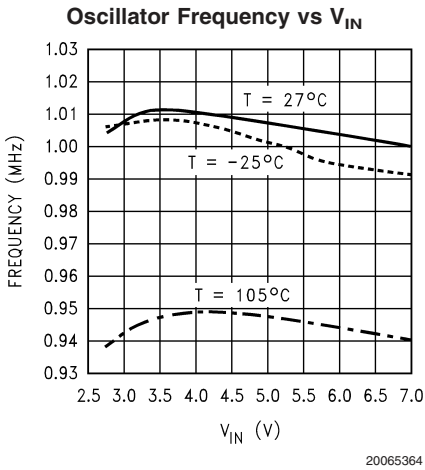
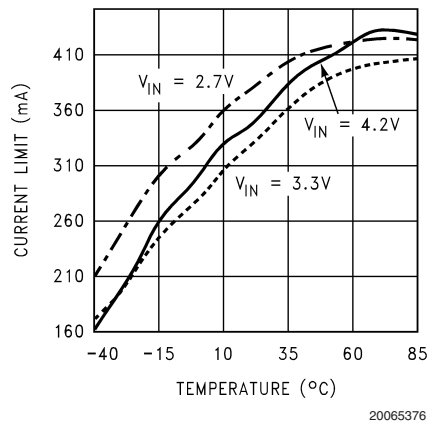
Typical Performance Characteristics (Continued)



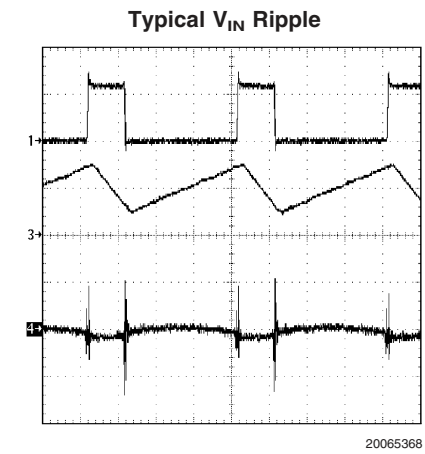
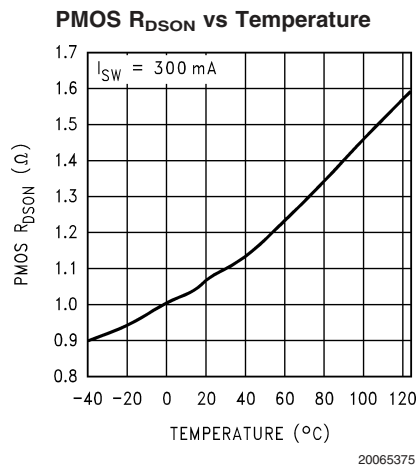
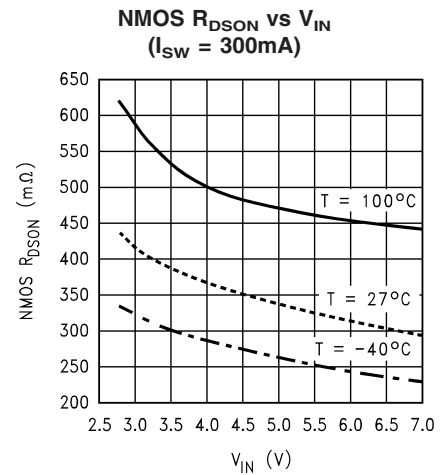
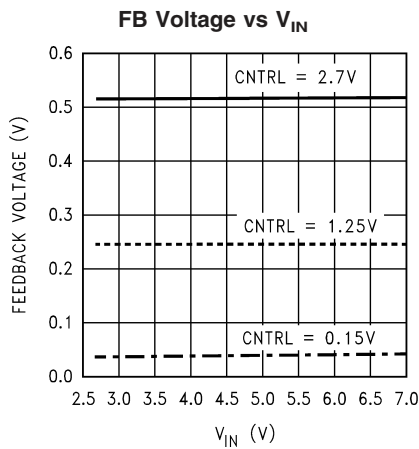
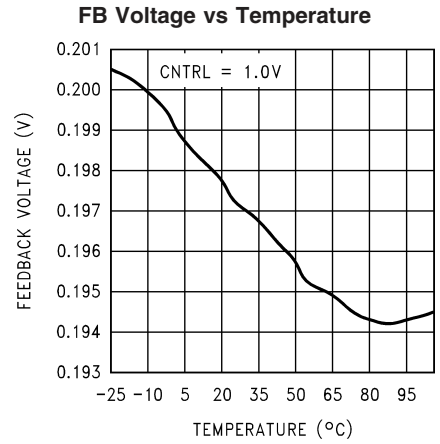
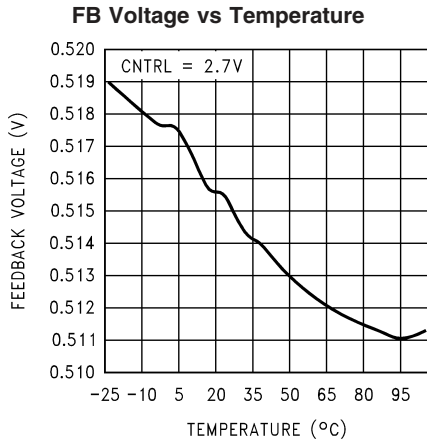
Switch Current Limit vs Temperature ($V_{OUT}=8\text{V}$)



Switch Current Limit vs Temperature ($V_{OUT}=12\text{V}$)



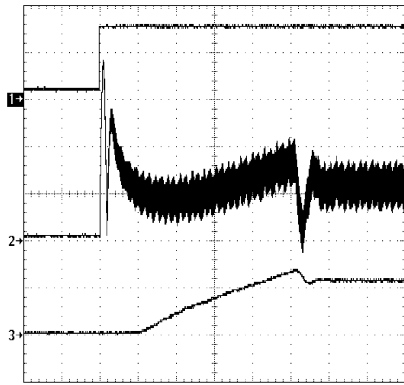
Typical Performance Characteristics (Continued)



3 LEDs, R_{LED} = 22Ω, V_{IN} = 3.0V, CNTRL = 2.7V
 1) SW, 10V/div, DC
 3) I_L, 100mA/div, DC
 4) V_{IN}, 100mV/div, AC
 T = 250ns/div

Typical Performance Characteristics (Continued)

Start-Up

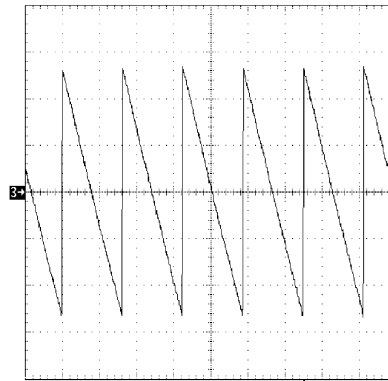


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3 LEDs, $R_{LED} = 22\Omega$, $V_{IN} = 3.0V$, $CNTRL = 2.7V$

- 1) \overline{SHDN} , 1V/div, DC
 - 2) I_L , 100mA/div, DC
 - 3) I_{LED} , 20mA/div, DC
- $T = 100\mu s/div$

Typical V_{OUT} Ripple, OVP Functioning

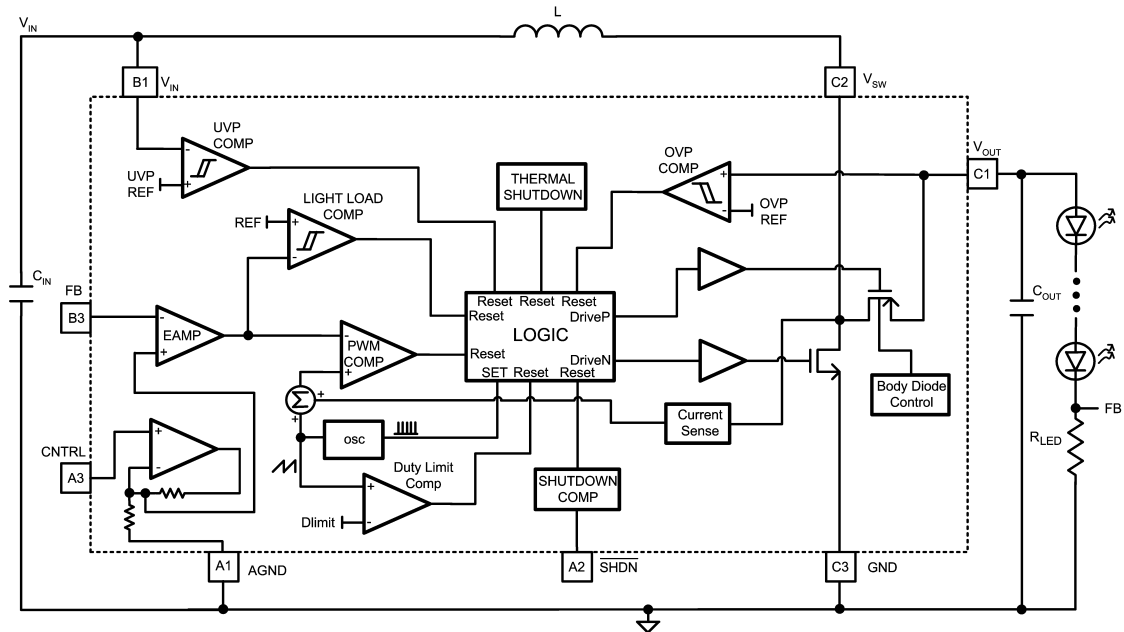


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V_{OUT} open circuit and equals approx. 15V DC, $V_{IN} = 3.0V$

- 3) V_{OUT} , 200mV/div, AC
- $T = 1ms/div$

Operation



20065304

FIGURE 2. LM3501 Block Diagram

The LM3501 utilizes a synchronous Current Mode PWM control scheme to regulate the feedback voltage over almost all load conditions. The DC/DC controller acts as a controlled current source ideal for white LED applications. The LM3501 is internally compensated preventing the use of any external compensation components providing a compact overall solution. The operation can best be understood referring to the block diagram in *Figure 2*. At the start of each cycle, the oscillator sets the driver logic and turns on the NMOS power device conducting current through the inductor and turns off the PMOS power device isolating the output from the V_{SW} pin. The LED current is supplied by the output capacitor when the NMOS power device is active. During this cycle, the output voltage of the EAMP controls the current through the inductor. This voltage will increase for larger loads and decrease for smaller loads limiting the peak current in the inductor minimizing EMI radiation. The EAMP voltage is compared with a voltage ramp and the sensed switch voltage. Once this voltage reaches the EAMP output voltage, the PWM COMP will then reset the logic turning off the NMOS power device and turning on the PMOS power device. The inductor current then flows through the PMOS power device to the white LED load and output capacitor. The inductor current recharges the output capacitor and supplies the current for the white LED branches. The oscil-

lator then sets the driver logic again repeating the process. The Duty Limit Comp is always operational preventing the NMOS power switch from being on more than one cycle and conducting large amounts of current.

The LM3501 has dedicated protection circuitry active during normal operation to protect the IC and the external components. The Thermal Shutdown circuitry turns off both the NMOS and PMOS power devices when the die temperature reaches excessive levels. The LM3501 has a UVP Comp that disables both the NMOS and PMOS power devices when battery voltages are too low preventing an on state of the power devices which could conduct large amounts of current. The OVP Comp prevents the output voltage from increasing beyond 15.5V when the primary white LED network is removed or if there is an LED failure, allowing the use of small 16V ceramic capacitors at the output. This comparator has a 0.9V hysteresis that will regulate the output voltage between 15.5V and 14.6V typically. The LM3501 features a shutdown mode that reduces the supply current to 0.1uA and isolates the input and output of the converter. The CNTRL pin can be used to change the white LED current. A CNTRL voltage above 125mV will enable power to the LEDs and a voltage lower than 75mV will turn off the power to the LEDs.

Application Information

ADJUSTING LED CURRENT

The maximum White LED current is set using the following equation:

$$I_{LED} = V_{FB(MAX)} / R_{LED}$$

The LED current can be controlled using an external DC voltage. The maximum feedback voltage is achieved when CNTRL is 2.7V, typically FB = 0.515V. The CNTRL to FB voltage relationship is:

$$FB = 0.191 * CNTRL$$

The LED current can be controlled using a PWM signal on the SHDN pin with frequencies in the range of 100Hz (greater than visible frequency spectrum) to 1kHz. For controlling LED currents down to the μ A levels, it is best to use a PWM signal frequency between 200-500Hz. The LM3501 LED current can be controlled with PWM signal frequencies above 1kHz but the controllable current decreases with higher frequency. The maximum LED current would be achieved using the equation above with 100% duty cycle, ie. the SHDN pin always high.

Applying a voltage greater than 125mV to the CNTRL pin will begin regulating current to the LEDs. A voltage below 75mV will prevent application or regulation of the LED current.

The minimum number of LEDs the LM3501 can drive is 2 in series and the maximum is 4. The LM3501 can also drive multiple strings of white LEDs. When driving 4 LEDs in series the application should use lower forward voltage drop white LEDs to prevent the OVP function from activating during normal operation.

OUTPUT OVERVOLTAGE PROTECTION

The LM3501 contains dedicated circuitry for monitoring the output voltage. In the event that the primary LED network is disconnected the output will increase and be limited to 15.5V. There is a 900mV hysteresis associated with this circuitry which will cause the output to fluctuate between 15.5V and 14.6V if the primary network is disconnected. In the event that the network is reconnected regulation will begin at the appropriate output voltage. The 15.5V limit allows the use of 16V 1 μ F ceramic output capacitors creating an overall small solution for white LED applications.

RELIABILITY AND THERMAL SHUTDOWN

The maximum continuous pin current for the 8 pin thin micro SMD package is 535mA. When driving the device near its power output limits the V_{SW} pin can see a higher DC current than 535mA (see *INDUCTOR SELECTION* section for average switch current). To preserve the long term reliability of the device the average switch current should not exceed 535mA.

The LM3501 has an internal thermal shutdown function to protect the die from excessive temperatures. The thermal shutdown trip point is typically 150°C. There is a hysteresis of typically 35°C so the die temperature must decrease to approximately 115°C before the LM3501 will return to normal operation.

INDUCTOR SELECTION

The inductor used with the LM3501 must have a saturation current greater than the cycle by cycle peak inductor current. Choosing inductors with low DCR decreases power losses and increases efficiency.

The minimum inductor value required for the LM3501 can be calculated using the following equation:

$$L > \frac{V_{IN} R_{DSON}}{0.29} \left(\frac{D}{D'} - 1 \right)$$

where L is in μ H, V_{IN} is the input supply of the chip in Volts, R_{DSON} is the ON resistance of the NMOS power switch found in the *Typical Performance Characteristics* section in ohms and D is the duty cycle of the switching regulator. The above equation is only valid for D greater than 0.5. An inductor value in the range of 4.7 μ H to 22 μ H is good for most applications, however the value must meet the requirements of the above equation. The duty cycle, D, is given by the following equation:

$$D' = \frac{V_{IN}}{V_{OUT}} = 1 - D$$

where V_{OUT} is the voltage at pin C1. The typical cycle-by-cycle peak inductor current can be calculated from the following equation:

$$I_{PK} \approx \frac{I_{OUT}}{\eta D'} + \frac{V_{IN} D}{2 L F_{SW}}$$

where I_{OUT} is the total load current, F_{SW} is the switching frequency, L is the inductance and η is the converter efficiency of the total driven load. A good typical number to use for η is 0.8. The value of η can vary with load and duty cycle. The average inductor current, which is also the average V_{SW} pin current, is given by the following equation:

$$I_{L(AVE)} \approx \frac{I_{OUT}}{\eta D'}$$

The maximum output current capability of the LM3501 can be estimated with the following equation:

$$I_{OUT} \approx \eta D' \left(I_{CL} - \frac{V_{IN} D}{2 L F_{SW}} \right)$$

where I_{CL} is the current limit. Some recommended inductors include but are not limited to:

Coilcraft DT1608C series

Coilcraft DO1608C series

TDK VLP4612 series

TDK VLP5610 series

TDK VLF4012A series

Application Information (Continued)

CAPACITOR SELECTION

Choose low ESR ceramic capacitors for the output to minimize output voltage ripple. Multilayer X7R or X5R type ceramic capacitors are the best choice. For most applications, a 1 μ F ceramic output capacitor is sufficient.

Local bypassing for the input is needed on the LM3501. Multilayer X7R or X5R ceramic capacitors with low ESR are a good choice for this as well. A 1 μ F ceramic capacitor is sufficient for most applications. However, for some applications at least a 4.7 μ F ceramic capacitor may be required for proper startup of the LM3501. Using capacitors with low ESR decreases input voltage ripple. For additional bypassing, a 100nF ceramic capacitor can be used to shunt high frequency ripple on the input. Some recommended capacitors include but are not limited to:

TDK C2012X7R1C105K

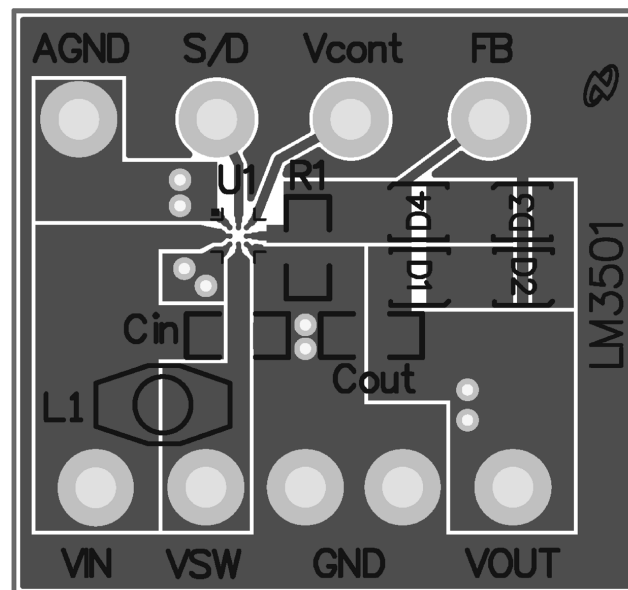
Taiyo-Yuden EMK212BJ105 G

Vishay Vitramon VJ1206S105KXJ

LAYOUT CONSIDERATIONS

The input bypass capacitor C_{IN} , as shown in *Figure 2*, must be placed close to the device and connect between the V_{IN} and GND pins. This will reduce copper trace resistance

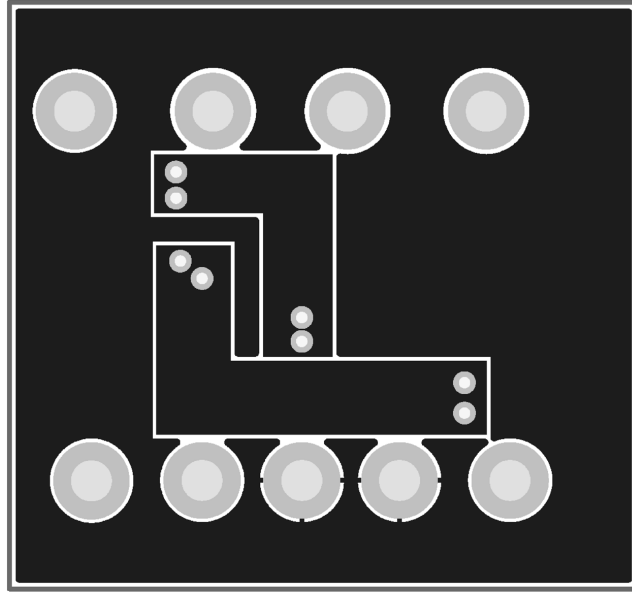
which effects the input voltage ripple of the IC. For additional input voltage filtering, a 100nF bypass capacitor can be placed in parallel with C_{IN} to shunt any high frequency noise to ground. The output capacitor, C_{OUT} , should also be placed close to the LM3501 and connected directly between the V_{OUT} and GND pins. Any copper trace connections for the C_{OUT} capacitor can increase the series resistance, which directly effects output voltage ripple and efficiency. The current setting resistor, R_{LED} , 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 current setting resistor should connect directly to the GND pin. The AGND pin should connect directly to the GND pin. Not connecting the AGND pin directly, as close to the chip as possible, may affect the performance of the LM3501 and limit its current driving capability. Trace connections made to the inductor should be minimized to reduce power dissipation, EMI radiation and increase overall efficiency. It is good practice to keep the V_{SW} routing away from sensitive pins such as the FB pin. Failure to do so may inject noise into the FB pin and affect the regulation of the device. See *Figure 3* and *Figure 4* for an example of a good layout as used for the LM3501 evaluation board.



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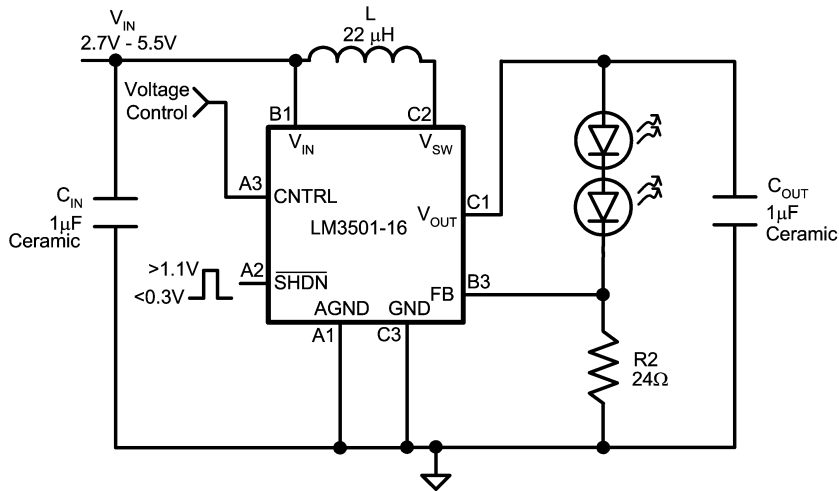
FIGURE 3. Evaluation Board Layout (2X Magnification)
Top Layer

Application Information (Continued)



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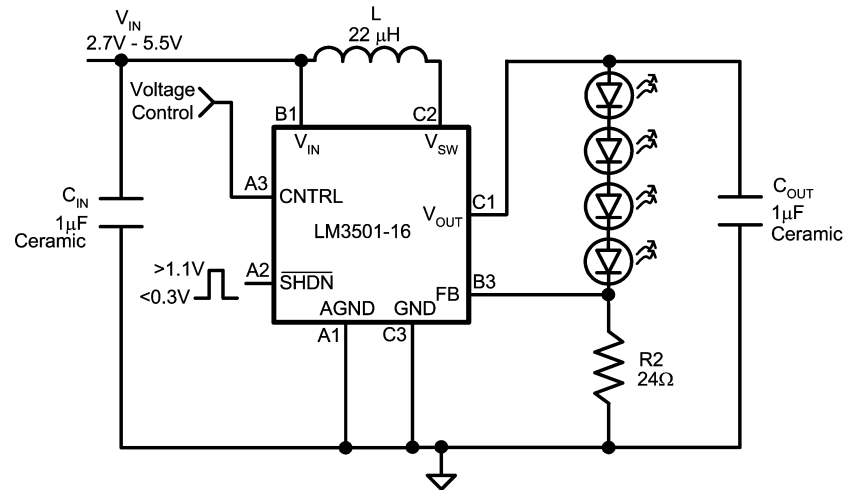
FIGURE 4. Evaluation Board Layout (2X Magnification) Bottom Layer (as viewed from the top)



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FIGURE 5. 2 White LED Application

Application Information (Continued)

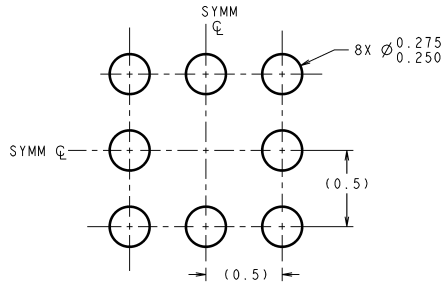


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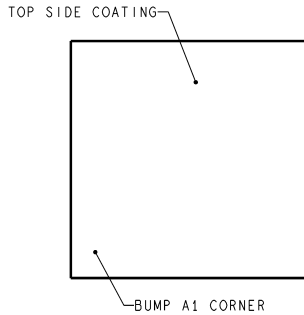
FIGURE 6. 4 White LED Application

Physical Dimensions inches (millimeters)

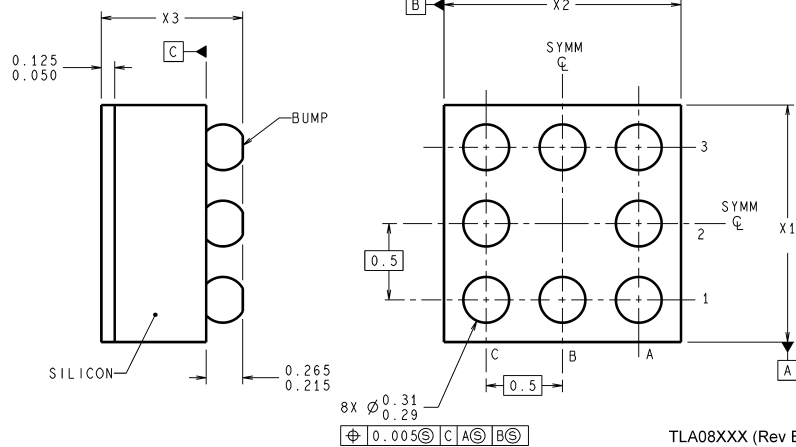
unless otherwise noted



LAND PATTERN RECOMMENDATION



DIMENSIONS ARE IN MILLIMETERS



8-Bump Micro SMD Package (TL)

For Ordering, Refer to Ordering Information Table

NS Package Number TLA08A

X1 = 1.92mm (±0.03mm), X2 = 1.92mm (±0.03mm), X3 = 0.6mm (±0.075mm)

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