National Semiconductor

December 2003

LM3500
Synchronous Step-up DC/DC Converter for White LED Applications

General Description

The LM3500 is a fixed frequency synchronous step-up DC/DC converter in a small 8-bump thin micro SMD package. The LM3500 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 LM3500 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 a pulse width modulated (PWM) signal on the shutdown pin. The LM3500 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 LM3500 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
- Input undervoltage lockout
- Output overvoltage protection, no external zener diode required
- Requires only a small 16V ceramic capacitor at the output
- Thermal Shutdown
- 0.1µA 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

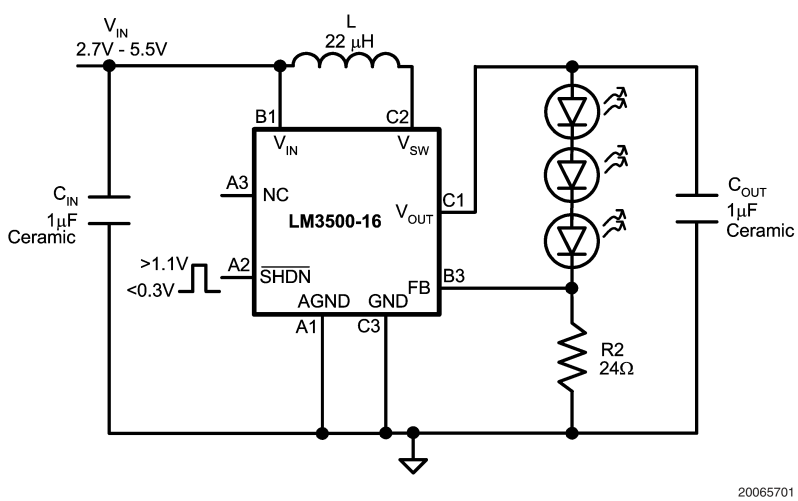
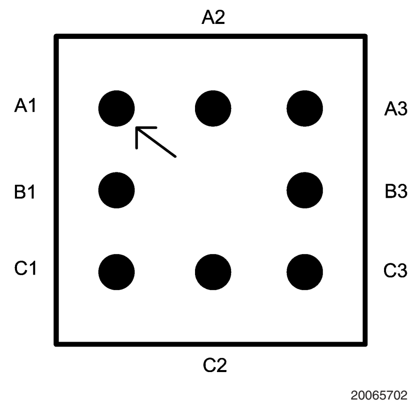


FIGURE 1. Typical 3 LED Application

Connection Diagram

Top View



8-bump micro SMD
$T_{J(MAX)}$ = 125˚C, θ_{JA} = 220˚C/W (Note 3)

Ordering Information

Order Number	Package Type	NSC Package Drawing	Top Mark	Supplied As
LM3500TL-16	micro SMD	TL08SSA	C18	250 Units, Tape and Reel
LM3500TLX-16	micro SMD	TL08SSA	C18	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	NC	No internal connection made to this pin.
A2	$\overline{SHDN}$	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.

NC(pin A3): No internal connection is made to this pin. The maximum allowable voltage that can be applied to this pin is 7.5V.

$\overline{SHDN}$(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 $\overline{SHDN}$ 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 7.5V
NC	–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 3)	–40˚C to +125˚C
Supply Voltage	2.7V to 7V

Thermal Properties

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

Electrical Characteristics

Specifications in standard type face are for T_A = 25˚C and those in **boldface type** apply over the **Operating Temperature Range of T_A = –10˚C to +85˚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		1.8	**2.5**	mA
	Shutdown	$\overline{SHDN}$ = 0V		0.1	**2**	µA
V_{FB}	FeedbackVoltage	V_{IN} = 2.7V to 7V	**0.47**	0.5	**0.53**	V
ΔV_{FB}	FeedbackVoltage Line Regulation	V_{IN} = 2.7V to 7V		0.1	**0.4**	%/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**	mA
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} = 300mA			0.43	Ω
	PMOS Switch R_{DSON}	V_{OUT} = 6V, I_{SW} = 300mA		1.1	**2.3**	Ω
D_{Limit}	Duty Cycle Limit	FB = 0V	**80**	87		%
F_{SW}	Switching Frequency		**0.85**	1.0	**1.15**	MHz
I_{SD}	$\overline{SHDN}$ Pin Current (Note 8)	$\overline{SHDN}$ = 5.5V		18	**30**	µA
		$\overline{SHDN}$ = 2.7V		9	**16**	µA
		$\overline{SHDN}$ = GND		0.1		µA
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**	V
OVP	Output Overvoltage Protection	ON Threshold	**15**	15.5	**16**	V
		OFF Threshold	**14**	14.6	**15**	V
I_{Vout}	V_{OUT} Bias Current	V_{OUT} = 15V, $\overline{SHDN}$ = V_{IN}		260	**400**	µA
I_{VL}	PMOS Switch Leakage Current	V_{OUT} = 15V, V_{SW} = 0V		0.01	**3**	µA

Electrical Characteristics (Continued)

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

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 6)	Max (Note 5)	Units
$\overline{SHDN}$ Threshold	$\overline{SHDN}$ low			0.65	**0.3**	V
	$\overline{SHDN}$ High		**1.1**	0.65		

Specifications in standard type face are for T_J = 25˚C and those in **boldface type** apply over the full **Operating Temperature Range (T_J = −40˚C to +125˚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		1.8	**2.5**	
	Shutdown	$\overline{SHDN}$ = 0V		0.1	**2**	µA
V_{FB}	FeedbackVoltage	V_{IN} = 2.7V to 7V	**0.47**	0.5	**0.53**	V
ΔV_{FB}	FeedbackVoltage Line Regulation	V_{IN} = 2.7V to 7V		0.1	**0.4**	%/V
I_{CL}	Switch Current Limit	V_{IN} = 3.0V, Duty Cycle = 70%		400		mA
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} = 300mA			0.43	Ω
	PMOS Switch R_{DSON}	V_{OUT} = 6V, I_{SW} = 300mA		1.1	**2.3**	
D_{Limit}	Duty Cycle Limit	FB = 0V		87		%
F_{SW}	Switching Frequency		**0.8**	1.0	**1.2**	MHz
I_{SD}	$\overline{SHDN}$ Pin Current (Note 8)	$\overline{SHDN}$ = 5.5V		18	**30**	µA
		$\overline{SHDN}$ = 2.7V		9	**16**	
		$\overline{SHDN}$ = GND		0.1		
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**	
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} = 15V, $\overline{SHDN}$ = V_{IN}		260	**400**	µA
I_{VL}	PMOS Switch Leakage Current	V_{OUT} = 15V, V_{SW} = 0V		0.01	**3**	µA
$\overline{SHDN}$ Threshold	$\overline{SHDN}$ low			0.65	**0.3**	V
	$\overline{SHDN}$ 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} + 0.3V 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, $T_{J(MAX)}$, the junction-to-ambient thermal resistance, θ_{JA}, and the ambient temperature, T_A. See *Thermal Properties* for the thermal resistance. The maximum allowable power dissipation at any ambient temperature is calculated using: P_D (MAX) = ($T_{J(MAX)}$ − T_A)/θ_{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 kΩ 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).

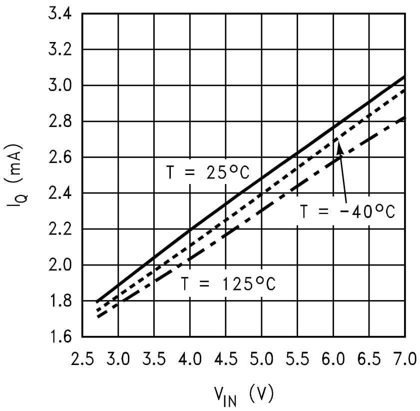
Note 6: Typical numbers are at 25˚C and represent the most likely norm.

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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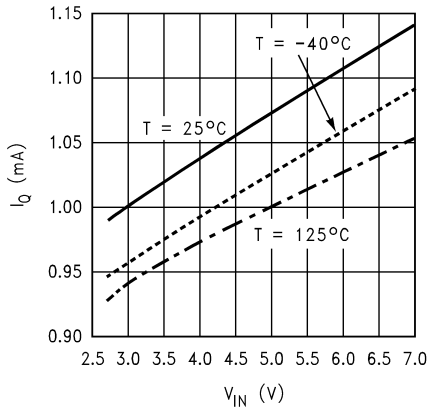
Non-Switching Quiescent Current vs V_{IN}



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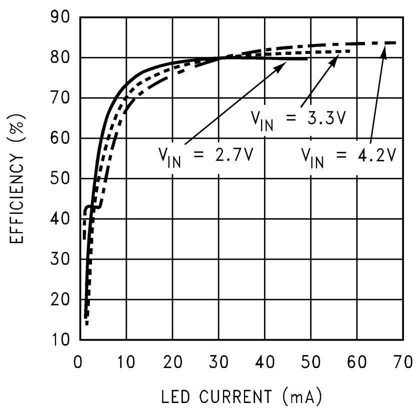
2 LED Efficiency vs LED Current
L = Coilcraft DT1608C-223,
Efficiency = 100*(P_{IN}/($2V_{LED}$*I_{LED}))



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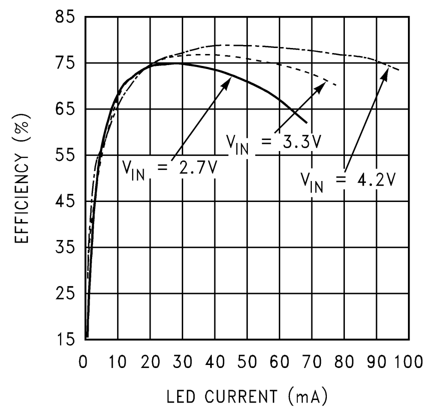
2 LED Efficiency vs LED Current
L = TDK VLP4612T-220MR34,
Efficiency = 100*(P_{IN}/($2V_{LED}$*I_{LED}))



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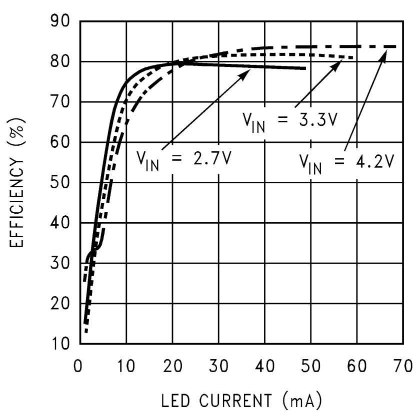
3 LED Efficiency vs LED Current
L = Coilcraft DT1608C-223,
Efficiency = 100*(P_{IN}/($3V_{LED}$*I_{LED}))



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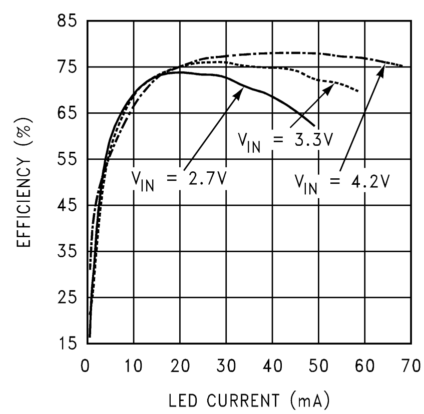
3 LED Efficiency vs LED Current
L = TDK VLP4612T-220MR34,
Efficiency = 100*(P_{IN}/($3V_{LED}$*I_{LED}))



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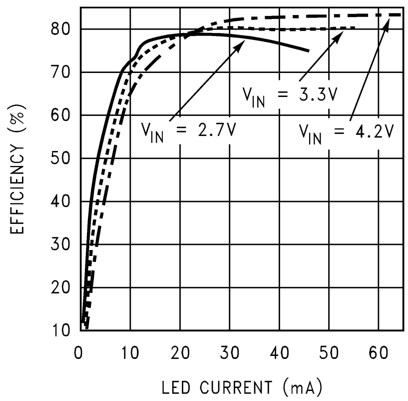
Typical Performance Characteristics (Continued)

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



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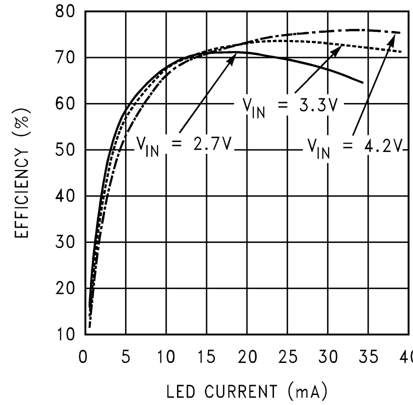
4 LED Efficiency vs LED Current
L = TDK VLP4612T-220MR34,
Efficiency = 100*(P_{IN}/(4V_{LED}*I_{LED}))



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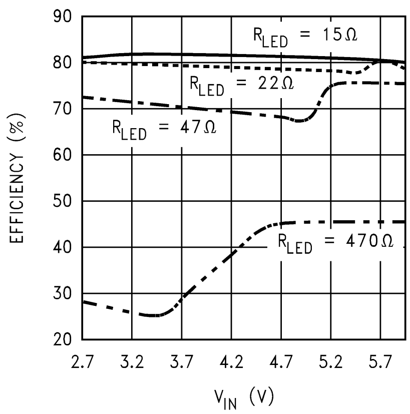
2 LED Efficiency vs V_{IN}
L = Coilcraft DT1608C-223,
Efficiency = 100*(P_{IN}/(2V_{LED}*I_{LED}))



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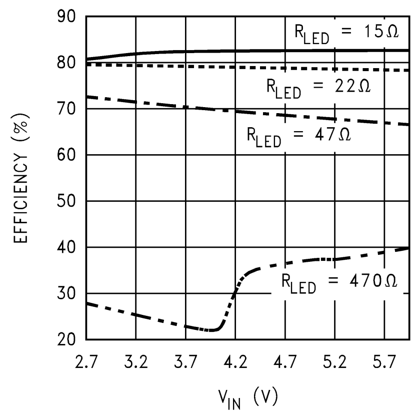
3 LED Efficiency vs V_{IN}
L = Coilcraft DT1608C-223,
Efficiency = 100*(P_{IN}/(3V_{LED}*I_{LED}))



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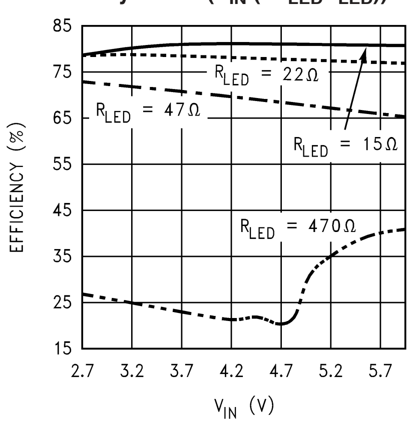
4 LED Efficiency vs V_{IN}
L = Coilcraft DT1608C-223,
Efficiency = 100*(P_{IN}/(4V_{LED}*I_{LED}))



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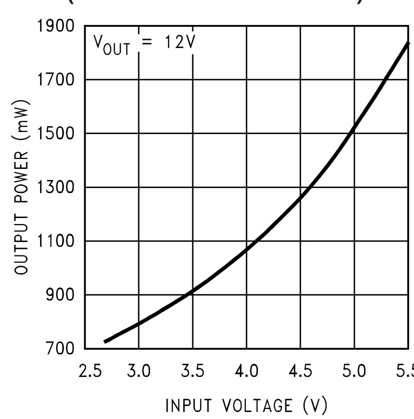
Output Power vs V_{IN}
(L = Coilcraft DT1608C-223)



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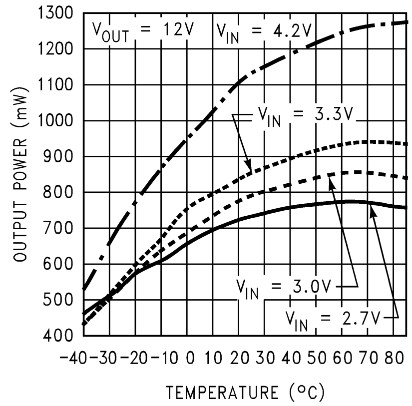
Typical Performance Characteristics (Continued)

Output Power vs Temperature (L = Coilcraft DT1608C-223)



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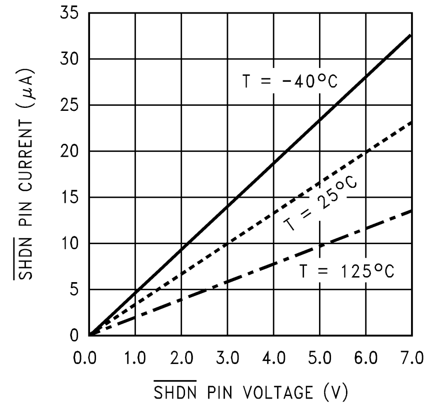
$\overline{SHDN}$ Pin Current vs $\overline{SHDN}$ Pin Voltage



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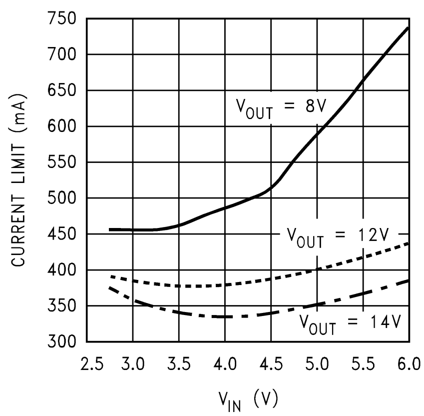
Switch Current Limit vs V_{IN}



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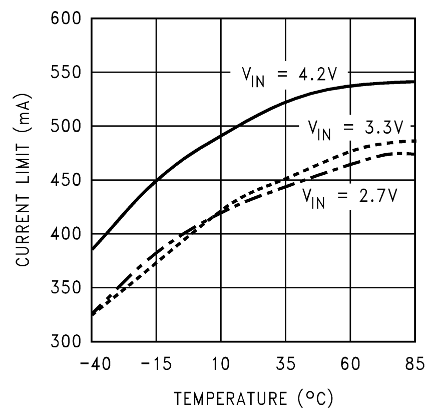
Switch Current Limit vs Temperature (V_{OUT}=8V)



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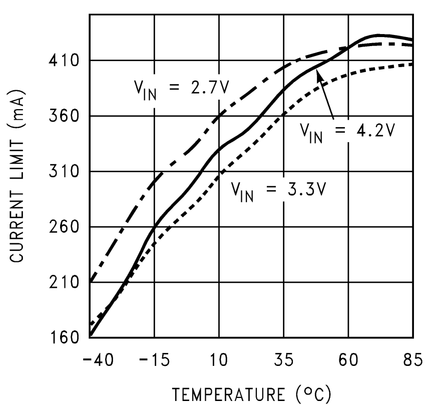
Switch Current Limit vs Temperature (V_{OUT}=12V)



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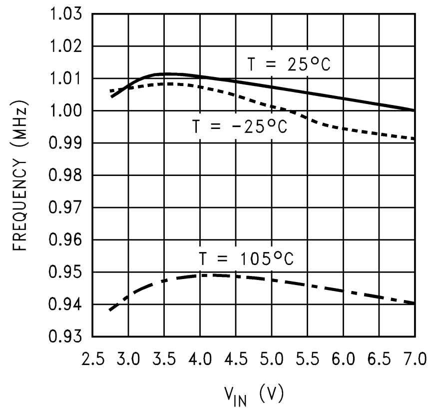
Oscillator Frequency vs V_{IN}



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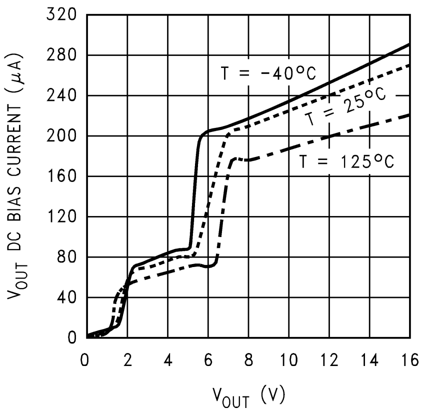
Typical Performance Characteristics (Continued)

V_{OUT} DC Bias vs V_{OUT} Voltage



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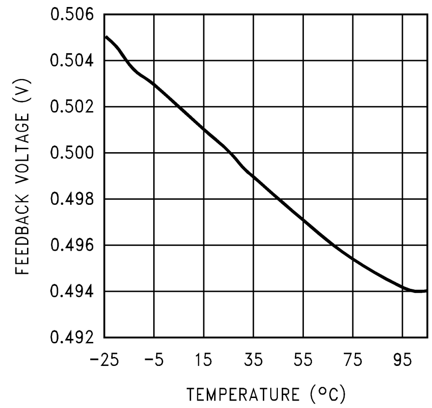
FB Voltage vs Temperature



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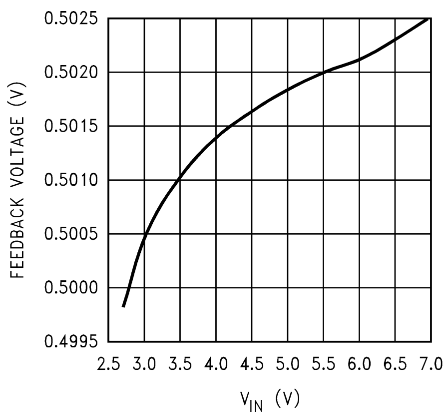
FB Voltage vs V_{IN}



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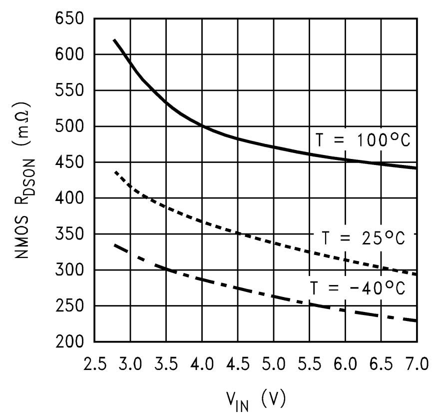
NMOS R_{DSON} vs V_{IN} (I_{SW} = 300mA)



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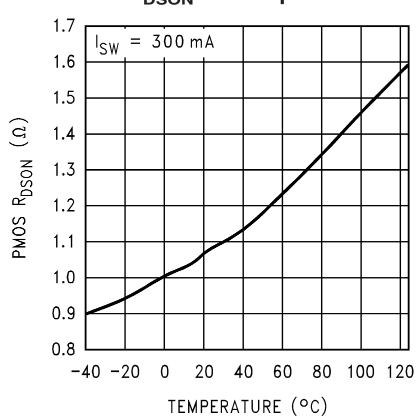
PMOS R_{DSON} vs Temperature



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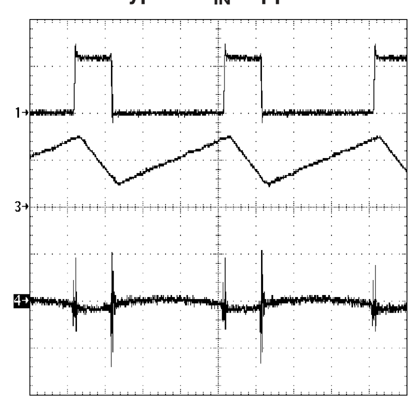
Typical V_{IN} Ripple



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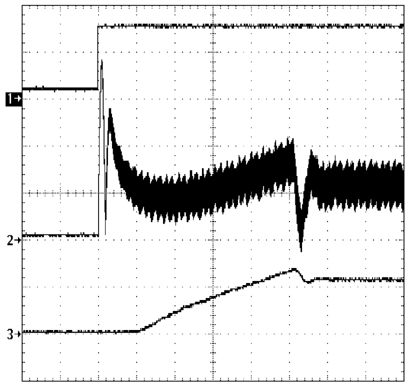
3 LEDs, R_{LED} = 22Ω, V_{IN} = 3.0V
1) SW, 10V/div, DC
3) I_L, 100mA/div, DC
4) V_{IN}, 100mV/div, AC
T = 250ns/div

Typical Performance Characteristics (Continued)

Start-Up



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3 LEDs, R_{LED} = 22Ω, V_{IN} = 3.0V

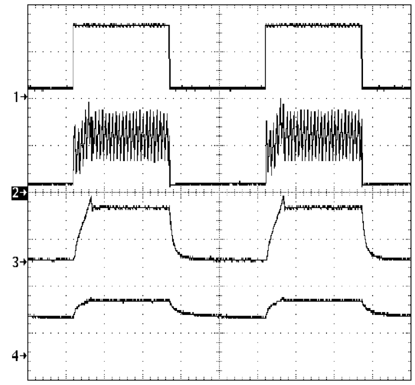
1) $\overline{SHDN}$, 1V/div, DC

2) I_L, 100mA/div, DC

3) I_{LED}, 20mA/div, DC

T = 100µS/div

$\overline{SHDN}$ Pin Duty Cycle Control Waveforms



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3 LEDs, R_{LED} = 22Ω, V_{IN} = 3.0V, $\overline{SHDN}$ frequency = 200Hz

1) $\overline{SHDN}$, 1V/div, DC

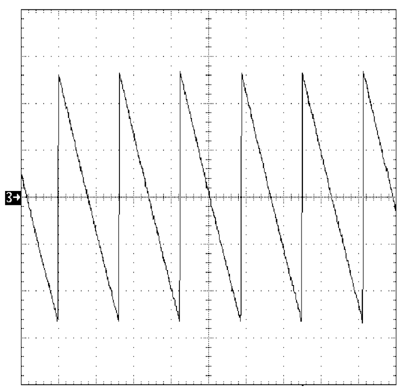
2) I_L, 100mA/div, DC

3) I_{LED}, 20mA/div, DC

4) V_{OUT}, 10V/div, DC

T = 1mS/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

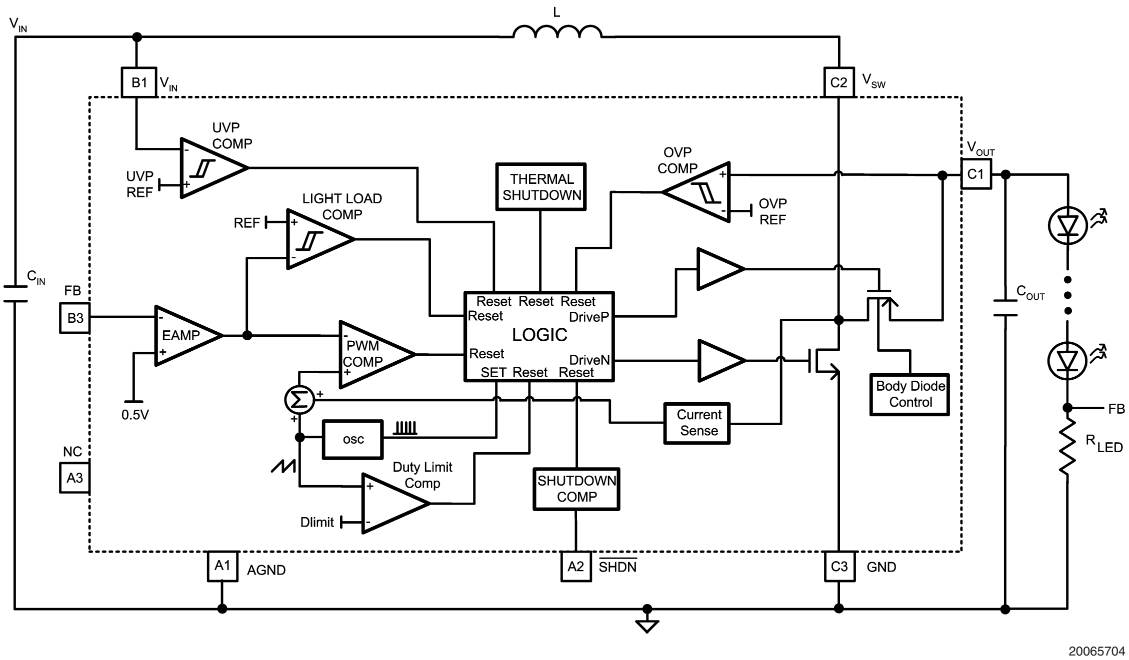


FIGURE 2. LM3500 Block Diagram

The LM3500 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 LM3500 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 oscillator 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 LM3500 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 LM3500 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 LM3500 features a shutdown mode that reduces the supply current to 0.1uA and isolates the input and output of the converter.

Application Information

ADJUSTING LED CURRENT

The White LED current is set using the following equation:

$$I_{LED} = V_{FB}/R_{LED}$$

The LED current can be controlled using a PWM signal on the $\overline{SHDN}$ pin with frequencies in the range of 100Hz (greater than visible frequency spectrum) to 1kHz. For controlling LED currents down to the µA levels, it is best to use a PWM signal frequency between 200-500Hz. The LM3500 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 $\overline{SHDN}$ pin always high.

The minimum number of LEDs the LM3500 can drive is 2 in series and the maximum is 4. The LM3500 can also drive multiple strings of white LEDs, see typical applications for suggestions. 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 LM3500 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 1µF 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 LM3500 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 LM3500 will return to normal operation.

INDUCTOR SELECTION

The inductor used with the LM3500 must have a saturation current greater than the cycle by cycle peak inductor current (see *Typical Peak Inductor Currents* table below). Choosing inductors with low DCR decreases power losses and increases efficiency.

The minimum inductor value required for the LM3500 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 µH, 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. For applications where the minimum duty cycle is less than or equal to 0.5, use 0.51 for the inductor equation above. 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.

Typical Peak Inductor Currents (mA)

V_{IN} (V)	# LEDs (in series)	LED Current 15 mA	20 mA	30 mA	40 mA	50 mA	60 mA
2.7	2	82	100	134	160	204	234
	3	118	138	190	244	294	352
	4	142	174	244	322	X	X
3.3	2	76	90	116	136	172	198
	3	110	126	168	210	250	290
	4	132	158	212	270	320	X
4.2	2	64	76	96	116	142	162
	3	102	116	148	180	210	246
	4	122	146	186	232	272	318

$C_{IN} = C_{OUT} = 1$ µF
L = 22 µH, 160 mΩ DCR max. Coilcraft DT1608C-223
LED V_F = 3.77V at 20mA and room temperature for the 2 and 3 LED applications.
LED V_F = 3.41V at 20mA and room temperature for the 4 LED application.

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:

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

Application Information (Continued)

The maximum output current capability of the LM3500 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

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 1µF ceramic output capacitor is sufficient.

Local bypassing for the input is needed on the LM3500. Multilayer X7R or X5R ceramic capacitors with low ESR are a good choice for this as well. A 1µF ceramic capacitor is sufficient for most applications. However, for some applications at least a 4.7µF ceramic capacitor may be required for proper startup of the LM3500. 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

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 LM3500 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 LM3500 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 LM3500 evaluation board.

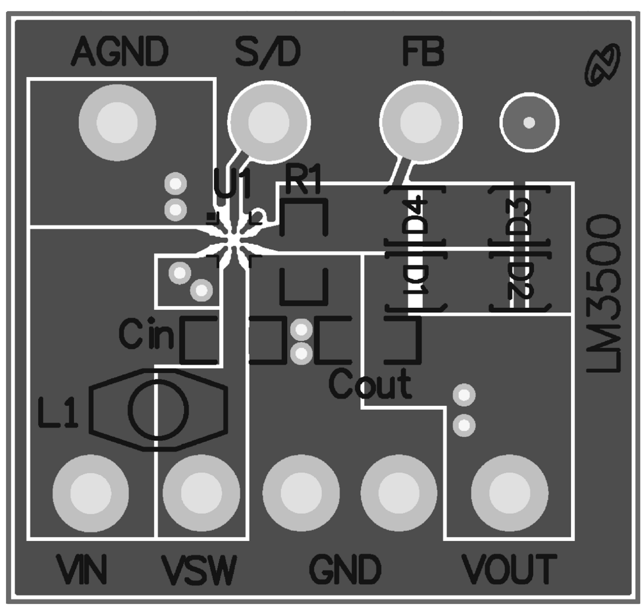


FIGURE 3. Evaluation Board Layout (2X Magnification) Top Layer

Application Information (Continued)

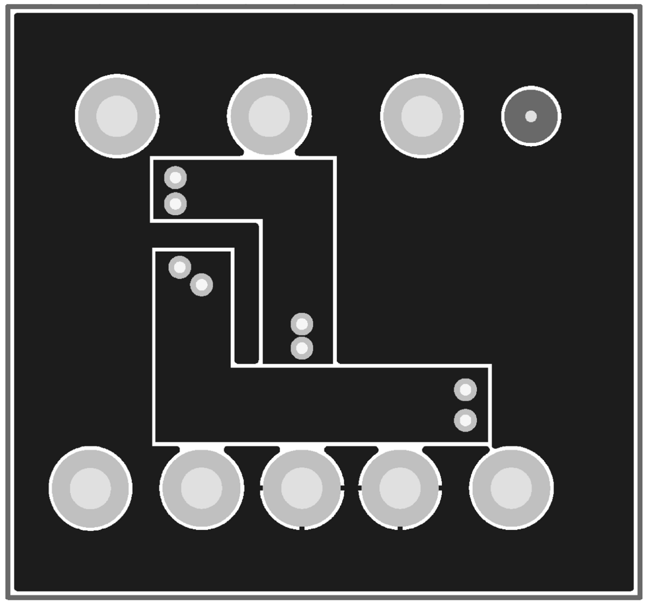


FIGURE 4. Evaluation Board Layout (2X Magnification) Bottom Layer (as viewed from the top)

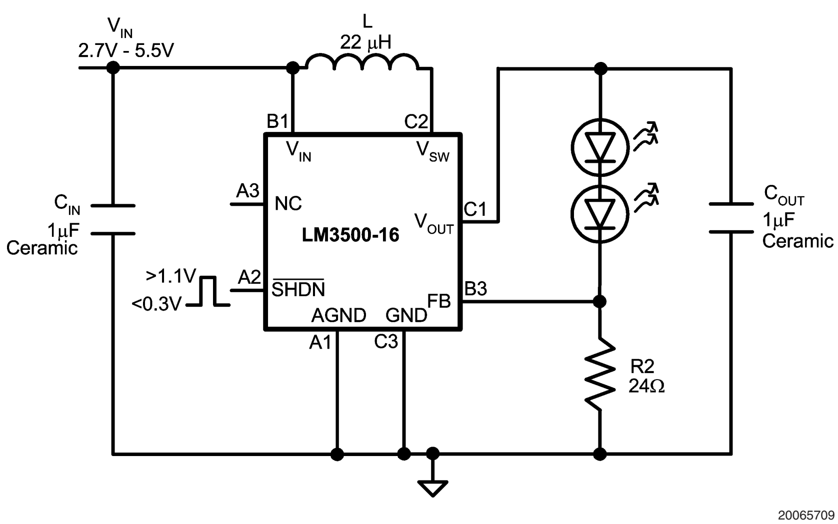


FIGURE 5. 2 White LED Application

Application Information (Continued)

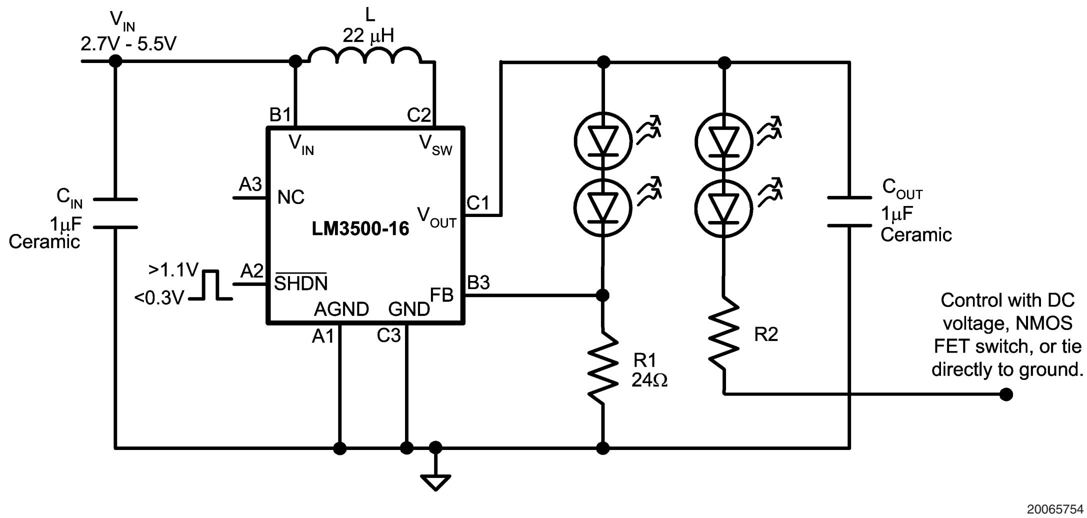


FIGURE 6. Multiple 2 LED String Application

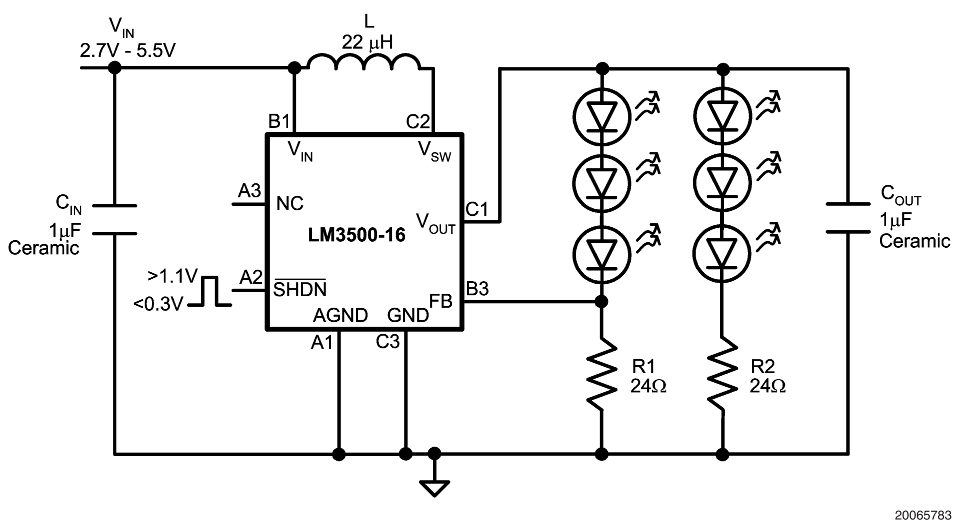
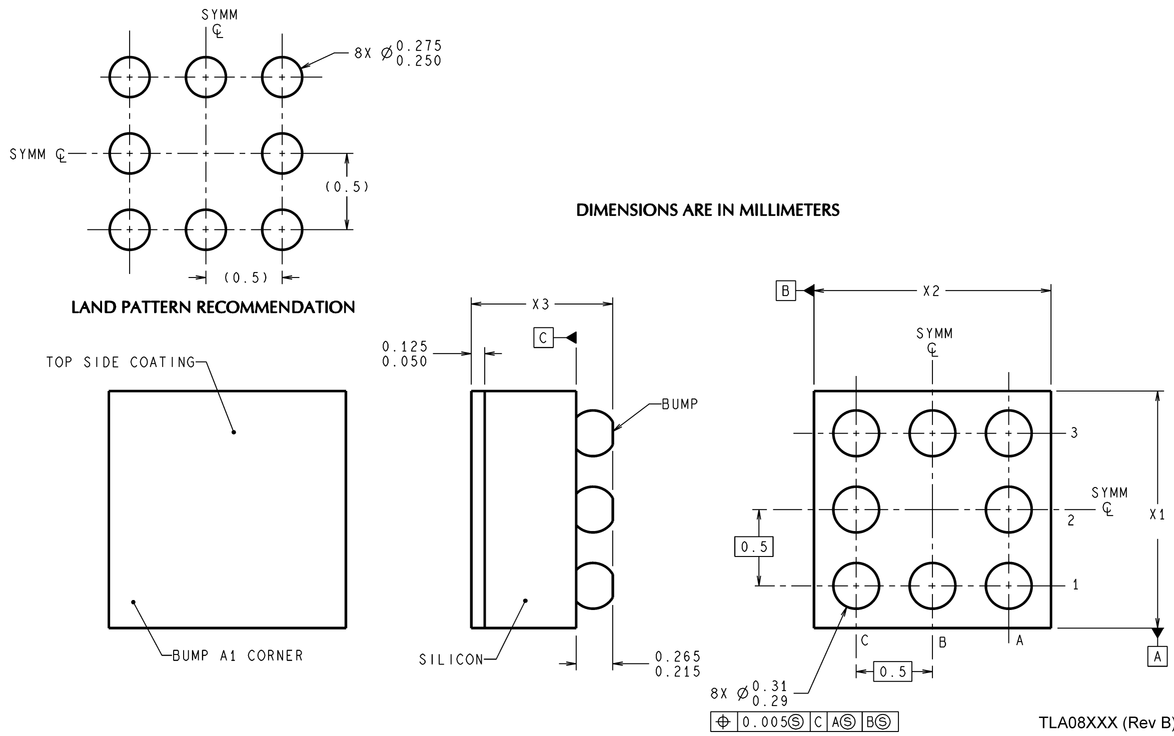


FIGURE 7. Multiple 3 LED String Application

Physical Dimensions inches (millimeters) unless otherwise noted



8-Bump Micro SMD Package (TL)
For Ordering, Refer to Ordering Information Table
NS Package Number TLA08SSA
X1 = 1.92mm (±0.03mm), X2 = 1.92mm (±0.03mm), X3 = 0.6mm (±0.075mm)

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