BCT3660B

White LED driver with digital pulse brightness control for up to 10 LEDs in Series

Features

- 3.0V to 5.5V Input Voltage Range
- 40V Open LED Protection for up to 10 LEDs in series
- 200mV Reference Voltage
- PWM Brightness Control
- Built-in Soft Start
- Up to 90% Efficiency
- RoHS Compliant and 100% Lead Free
- Package DFN2x2-6

Applications

Cellular Phones
Ultra Mobile Devices
Portable Media Players
PDAs, GPS Receivers
White LED Backlighting

Description

With 40V rated integrated switch FET, BCT3660B is a boost converter that drives up to 10 LEDs in series. The boost converter runs at 600kHz fixed switching frequency to reduce output ripple, improve conversion efficiency, and allows for the use of small external components. The default white LED current is set with the external sensor resistor Rset, and the feedback voltage is regulated to 200mV, as shown in the typical application. During the operation, the LED current can be controlled by pulse width modulation (PWM) signal applied to the CTRL pin through which the duty cycle determines the feedback reference voltage. BCT3660B does not burst LED current, therefore, it does not generate audible noises on the output capacitor. For maximum protection, the device integrated open LED protection that disables the BCT3660B to prevent the output from exceeding the absolute maximum ratings during open LED conditions. The BCT3660B is available in a DFN2x2 space saving package.

Pin Configurations (Top View)
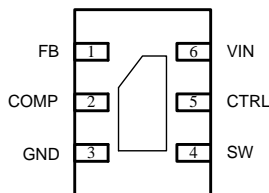
Ordering Information

Part	Pin-Package	Temp-Range	Top Mark	Supplied as:
BCT3660BELT-TR	DFN2x2-6	-40°C to +85°C	3660	3000units/Tape & Reel

Typical Application Circuit
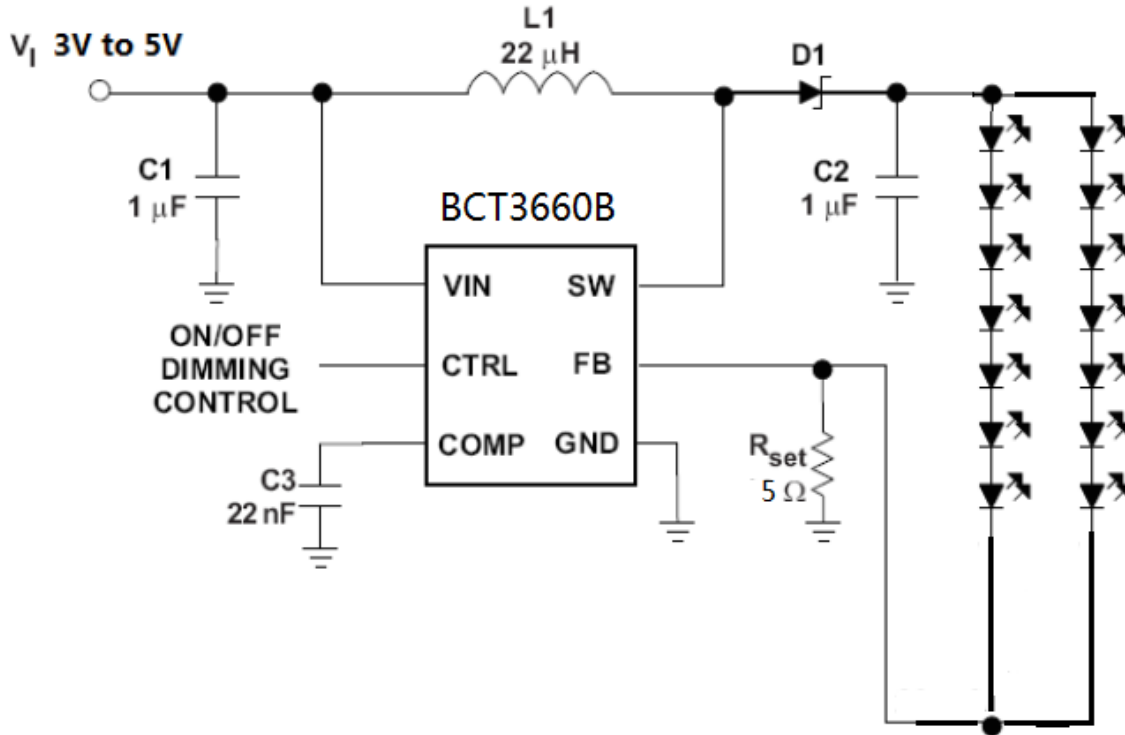
Pin Description

NO.	NAME	I/O	DESCRIPTION
1	FB	I	Feedback pin for current. Connect the sense resistor from FB to GND.
2	COMP	O	Output of the trans conductance error amplifier. Connect an external capacitor to this pin to compensate the regulator.
3	GND	G	Ground.
4	SW	I	This is the switching node of the IC. Connect the inductor between the VIN and LX pin. This pin is also used to sense the output voltage for open LED protection.
5	CTRL	I	Control pin of the boost regulator. It is a multi-functional pin which can be used for enable control and digital dimming.
6	VIN	I	The input supply pin for the IC. Connect VIN to a supply voltage between 3.0V and 5.5V.
-	Thermal Pad	-	The thermal pad should be soldered to the analog ground plane. If possible, use thermal via to connect to ground plane for ideal power dissipation.

Absolute Maximum Ratings[1]

Symbol	Description	Value	Unit
V_{IN}	Supply Voltages on VIN [2]	−0.3 to 6	V
V_{CTRL}	Voltages on CTRL [2]	−0.3 to 6	V
	Voltages on FB and COMP [2]	−0.3 to 6	V
V_{LX}	Voltage on SW [2]	−0.3 to 40	V
P_D	Continuous Power Dissipation	See Dissipation Rating Table	
T_J	Operating Junction Temperature Range	−40 to 150	°C
T_{STG}	Storage Temperature Range	−65 to 150	°C

(1) 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 under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground terminal.

Recommended Operating Conditions

Symbol	Description	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage range, VIN	3.0		5.5	V
L	Inductor[1]	10		22	µH
C_{IN}	Input capacitor	1		10	µF
C_O	Output capacitor[1]	0.47		10	uF
T_A	Operating ambient temperature	-40		85	°C
T_J	Operating junction temperature	-40		125	°C

(1) These values are recommended values that have been successfully tested in several applications. Other values may be acceptable in other applications but should be fully tested by the user.

Dissipation Ratings

RqJC	RqJA	DERATING FACTOR ABOVE TA = 25°C	T_A < 25°C	T_A = 70°C	T_A = 85°C
20°C/W	140°C/W	7.1 mW/°C	715 mW	395 mW	285 mW

Electrical Characteristics

V_{IN} = 3.6 V, CTRL = V_{IN}, T_A = −40°C to 85°C, typical values are at T_A = 25°C (unless otherwise noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
SUPPLY CURRENT						
Input voltage range	V_{IN}		3.0		5.5	V
Quiescent supply current	I_Q	V_{CTRL}= high			2.0	mA
Input shutdown current	I_{SHDN}	V_{CTRL}= low, V_{IN}=4.2V			2.0	µA
ENABLE AND REFERENCE CONTROL						
Logic threshold: Low	V_{IL}	CTRL pin			0.4	V
Logic threshold: High	V_{IH}	CTRL pin	1.2			V
CTRL pin internal pull-down resistance	$R_{PULL-DOWN}$			800		KΩ
CTRL pulse width to shutdown	t_{OFF}	CTRL high to low	2.5			ms
VOLTAGE AND CURRENT CONTROL						
Voltage feedback regulation voltage	VREF			200		mV
Voltage feedback regulation voltage under brightness control	V(REF_PWM)	VFB=50mV	47	50	53	mV
		VFB=20mV	17	20	23	
Voltage feedback input bias current	IFB	VFB=200mV			2	uA
Oscillator frequency	f_{OSC}	T_A = 25 °C	500	600	700	KHz
Maximum duty cycle	DMAX	VFB=100mV		93		%
PWM Input Frequency Range	f_{PWM}		10		100	kHz
POWER SWITCH						
N-channel MOSFET on-resistance	$R_{DS(ON)}$	VIN=3.6V		0.3	0.6	Ω
		VIN=3.0V			0.7	
N-channel leakage current	I_{LN_NFET}	VSW=35V, TA = 25 °C			1	uA
OC and OLP						
N-Channel MOSFET Current Limit	ILIM	D=DMAX		0.8		A
Open LED protection threshold	V_{OVP}	Measured on the SW pin		40		V
THERMAL SHUTDOWN						
Thermal shutdown threshold	$t_{SHUTOWN}$			160		°C
Thermal shutdown threshold hysteresis	t_{HYS}			15		°C

Typical Function Diagram
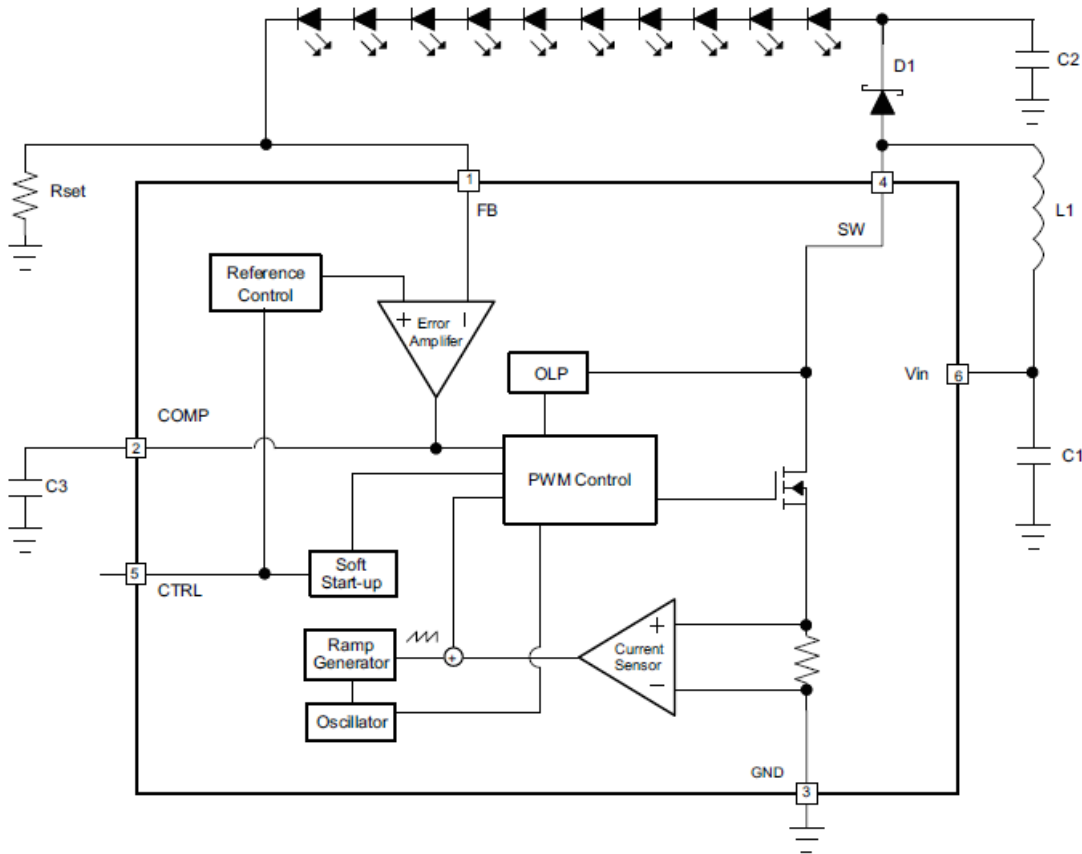
Detailed Description

OPERATION

The BCT3660B is a high efficiency, high output voltage boost converter in small package size, The device is ideal for driving up to 10 white LED in series. The serial LED connection provides even illumination by sourcing the same output current through all LEDs, eliminating the need for expensive factory calibration. The device integrates 40V/0.7A switch FET and operates in pulse width modulation (PWM) with 600kHz fixed switching frequency. For operation see the block diagram. The duty cycle of the converter is set by the error amplifier output and the current signal applied to the PWM control comparator. The control architecture is based on traditional current-mode control; therefore, a slope compensation is added to the current signal to allow stable operation for duty cycles larger than 50%. The feedback loop regulates the FB pin to a low reference voltage (200mV typical), reducing the power dissipation in the current sense resistor.

SOFT START-UP

Soft-start circuitry is integrated into the IC to avoid a high inrush current during start-up. After the device is enabled, the voltage at FB pin ramps up to the reference voltage in 32 steps, each step takes 213ms. This

ensures that the output voltage rises slowly to reduce the input current. Additionally, for the first 5msec after the COMP voltage ramps, the current limit of the switch is set to half of the normal current limit spec. During this period, the input current is kept below 400mA (typical).

OPEN LED PROTECTION

Open LED protection circuitry prevents IC damage as the result of white LED disconnection. The BCT3660B monitors the voltage at the SW pin and FB pin during each switching cycle. The circuitry turns off the switch FET and shuts down the IC as soon as the SW voltage exceeds the Vovp threshold and the FB voltage is less than half of regulation voltage for 8 clock cycles. As a result, the output voltage falls to the level of the input supply. The device remains in shutdown mode until it is enabled by toggling the CTRL pin logic. To allow the use of inexpensive low-voltage output capacitor, the BCT3660B has different open lamp protection thresholds to prevent the internal 42V FET from breaking down. The threshold is set at 40V for the BCT3660B. The devices can be selected according to the number of external LEDs and their maximum forward voltage.

SHUTDOWN

The BCT3660B enters shutdown mode when the CTRL voltage is logic low for more than 1 ms. During shutdown, the input supply current for the device is less than 2uA (max). Although the internal FET does not switch in shutdown, there is still a DC current path between the input and the LEDs through the inductor and Schottky diode. The minimum forward voltage of the LED array must exceed the maximum input voltage to ensure that the LEDs remain off in shutdown. However, in the typical application with two or more LEDs, the forward voltage is large enough to reverse bias the Schottky and keep leakage current low.

CURRENT PROGRAM

The loop of Boost structure will keep the FB pin voltage equal to the reference voltage V_{REF}. Therefore, when R_{SET} connects FB pin and GND, the current flows from VOUT through LED and R_{SET} to GND will be decided by the current on R_{SET}, which is equal to following equation:

$$I_{LED} = V_{FB}/ R_{SET} \qquad (1)$$

Where
I_{LED}=output current of LEDs
V_{FB}=regulated voltage of FB
R_{SET}=current sense resistor
The output current tolerance depends on the FB accuracy and the current sensor resistor accuracy.
The CTRL pin is used for PWM dimming. When the CTRL pin is constantly high, the FB voltage is regulated to 200mV typically. However, the CTRL pin allows a PWM signal to reduce this regulation voltage, therefore, it achieves LED brightness dimming. The relationship between the duty cycle and FB voltage is given by Equation 2.

$$V_{FB} = Duty \times 200mV \qquad (2)$$

Where:
    Duty = duty cycle of the PWM signal

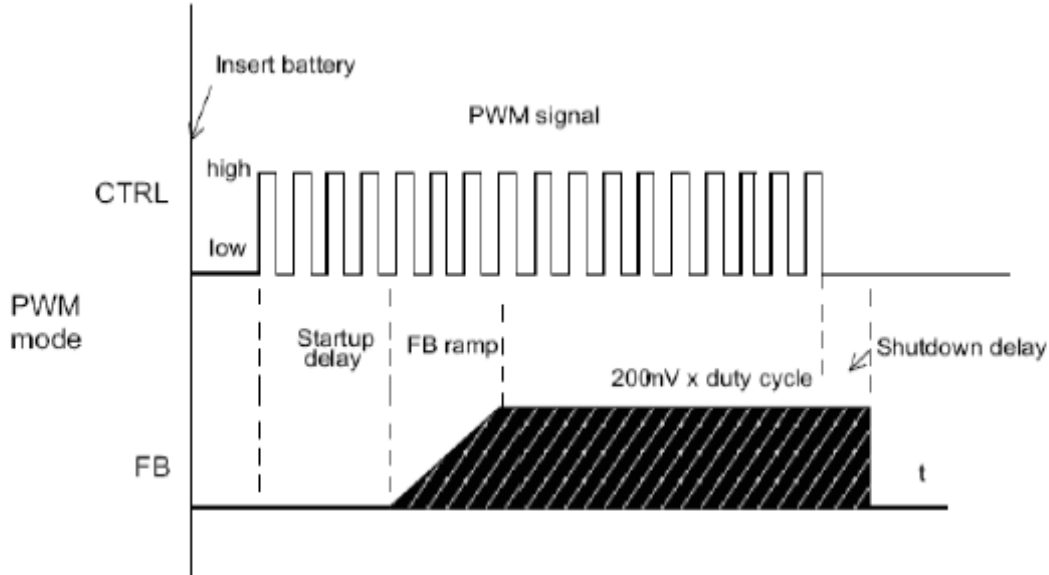For optimum performance, use the PWM dimming frequency in the range of 10kHz to 100kHz.

Figure 1. Soft Start PWM Brightness Dimming

For the BCT3660B, the PWM dimming minimum duty cycle changes with the PWM dimming frequency.

Table 1. Dimming frequency and minimum duty cycle

Dimming Frequency	Minimum Duty(VIN=3V)	Minimum Duty(VIN=4.5V)
10K	0.15%	0.1%
20K	0.3%	0.2%
40K	0.5%	0.4%
80K	1%	0.7%
100K	1.3%	0.9%

Application Information

External component and layout are critical and should be considered carefully.

Inductor Selection

Inductor value, saturation current, and Direct Current Resistance (DCR) are the most important parameters used to select an inductor for the BCT3660B.

The suitable inductance range for this device is 10 uH to 22uH. Higher inductance lowers the value of the RMS current of the step-up converter. Together with a lower DCR value of the inductor, the total inductor power loss becomes much lower. Considering inductor size and cost, 10 uH inductance is recommended. The below table lists some recommended inductors for the BCT3660B.

Table1. Recommend Inductors

Part Number	L(uH)	DCR MAX (Ω)	Saturation Current (mA)	Size(L x W x H mm)	Vendor
LQH3NPN100NM0	10	0.3	750	3×3×1.5	Murata
VLCF5020T-220MR75-1	22	0.4	750	5×5×2.0	TDK

| CDH3809/SLD | 10 | 0.3 | 570 | 4×4×1.0 | Sumida |
| A997AS-220M | 22 | 0.4 | 510 | 4×4×1.8 | TOKO |

Schottky Diode Selection

The high switching frequency of the BCT3660B demands a high-speed rectification for optimum efficiency. Ensure that the diode average and peak current rating exceeds the average output current and peak inductor current. In addition, the diode's reverse breakdown voltage must exceed the open LED protection voltage. To achieve better efficiency, a low VF Schottky diode is recommended. ONSemi MBR0540 and ZETEX ZHCS400 are recommended for the BCT3660B.

Output Capacitor Selection

The output capacitor is mainly selected to meet the requirements for the output ripple and loop stability.
The output voltage of the BCT3660B could reach up to 40V. X7R type output capacitor rated of 50 V is suggested. To reduce power loss, a ceramic capacitor with a low Effective Series Resistance (ESR) is better. The capacitor in the range of 0.47uF to 10uF is recommended for input side. The recommended output capacitor value is 1uF.

PCB Layout Consideration

For best performance of the BCT3660B, the following guidelines must be followed.
1. Input /Output capacitors should be placed close to the IC and connected to ground to reduce noise coupling.
2. The Exposed Pad should be connected to a strong ground plane for heat sinking and noise protection.
3. Keep the main current traces as possible as short and wide.
4. Vin will be connected with Vbattery with wide track, to avoid the interference of RF PA and Audio PA.
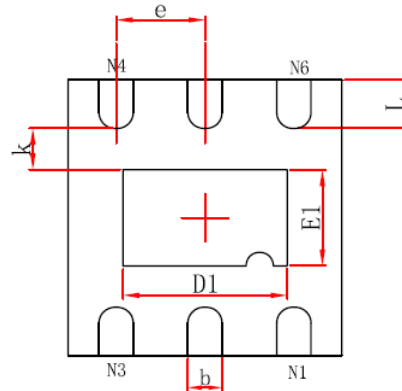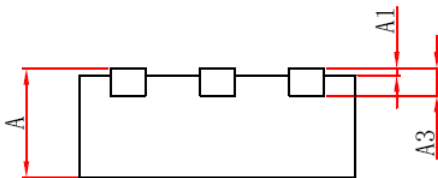
Package Information

DFN2x2-6
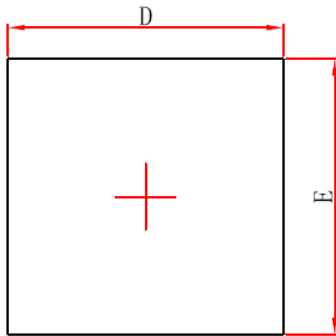
Top View

Bottom View

Side View

Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.7	0.75	0.8	0.028	0.0295	0.031
A1	0	0.025	0.05	0	0.001	0.002
A3	0.203REF.			0.008REF.		
D	1.924	2.0	2.076	0.076	0.079	0.082
E	1.924	2.0	2.076	0.076	0.079	0.082
D1	1.1	1.2	1.3	0.043	0.047	0.051
E1	0.6	0.7	0.8	0.024	0.027	0.031
k	0.2TYP.			0.008TYP.		
b	0.2	0.25	0.3	0.007	0.01	0.012
e	0.65TYP.			0.026TYP.		
L	0.274	0.35	0.426	0.011	0.014	0.017