White LED Driver
With PWM Brightness Control
for up to 11 LEDs in Series

BD60A00NUX **BD60A60NUX**

●General Description

This IC is boost DC/DC converter that can drive white LED with constant current. More stabled white LED lighting can be achieved by direct current connection without electric tolerance and High-speed response by current mode. Moreover, separating IC power supply (2.7V to 5.5V) and coil power supply (2.3V to 20V) makes it possible to widen input range, which will be helpful to be applied to various kinds of applications. Over voltage setting can be selected corresponding to the number of LED lightings. BD60A00NUX is for max 11 lightings, BD60A60NUX is for max 6 lightings.

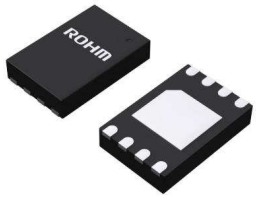
●Features

- Boost DC/DC converter
- Drive LED 11 lightings (VOUT=3.6V×11+0.7V=40.3V <VF MAX=3.7V>) BD60A00NUX
- Brightness control by outside PWM signal (PWM frequency =100Hz to 30kHz, 25kHz 1% dimming application)
- Brightness control by DC input
- Soft start function (1ms Typ.)
- Over voltage protection
  BD60A00NUX: 42V (Typ.)
  BD60A60NUX: 28V (Typ.)
- SBD open protection and output short protection
- Over current protection
- LED terminal over voltage protection
- UVLO

●Key Specifications

- Operating power supply voltage range: 2.7V to 5.5V
- LED maximum current: 30mA (Max.)
- Switching Frequency: 600kHz(Typ.)
- Quiescent Current: 0.1μA (Typ.)
- Operating temperature range: -40˚C to +85˚C

●Package W(Typ.) x D(Typ.) x H(Max.)

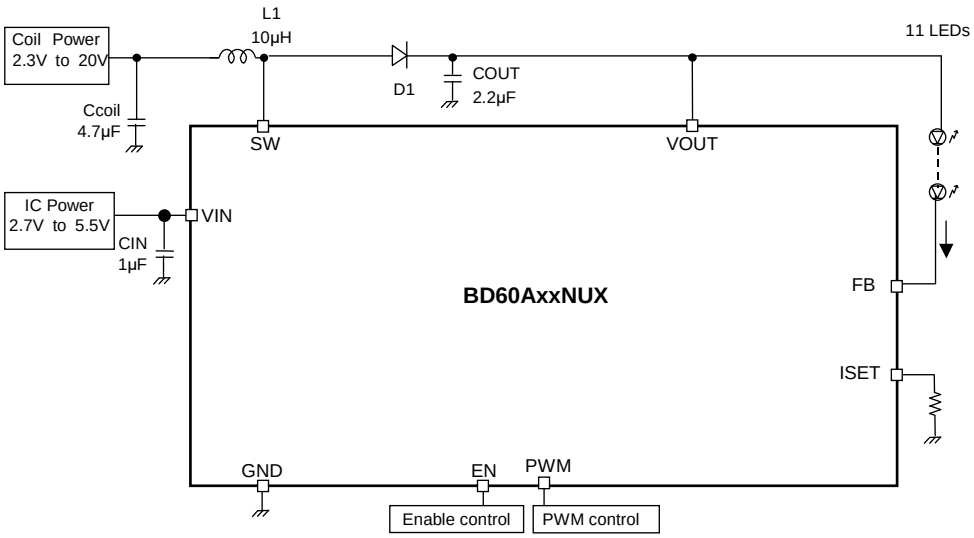


VSON008X2030
2.00mm x 3.00mm x 0.60mm

●Applications

Digital video cameras, digital single-lens reflexes, digital still cameras, digital photo frames, personal navigations (PND), mobile phones, smart phones, MID, PDA, hand-held computers, MP3 players, GPS, digital media players, etc.

●Typical Application Circuit



○Product structure：Silicon monolithic integrated circuit ○This product is not designed protection against radioactive rays

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●Absolute Maximum Ratings

Parameter	Symbol	Ratings	Unit	Condition
Maximum applied voltage 1	VMAX1	7	V	VIN, EN, PWM, ISET terminals
Maximum applied voltage 2	VMAX2	45	V	FB, SW, VOUT terminals BD60A00NUX
Maximum applied voltage 3	VMAX3	31	V	FB, SW, VOUT terminals BD60A60NUX
Operating temperature range	Topr	-40 to +85	˚C	
Storage temperature range	Tstg	-55 to +150	˚C	
Power dissipation 1	Pd1	2000	mW	*1

*1 4 layer (ROHM Standard board) has been mounted. When it's used by more than Ta=25˚C, it's reduced by 20mW/˚C.

●Recommended Operating Ratings (Ta=-40˚C to +85˚C)

Parameter	Symbol	Ratings	Unit	Conditions
Operating power supply voltage	VIN	2.7 to 5.5 *	V	VIN terminal
Operating coil voltage	Vcoil	2.3 to 20	V	Coil voltage

*When the operating supply voltage is over 4.61V for BD60A00NUX, please refer the application P.16

●Electrical Characteristics (Unless otherwise specified, Ta=25˚C, VIN=3.6V)

Parameter	Symbol	Limits			Unit	Conditions
		Min.	Typ.	Max.		
Quiescent Current	Iq	-	0.1	1.0	μA	EN=0V
Current Consumption (No Boost)	IddNB	-	1.5	3.0	mA	EN=2.8V, PWM=0V
Current Consumption (Boost)	IddB	-	2.5	5.0.	mA	EN=2.8V, PWM=2.8V
[EN, PWM Terminal]						
Low Input Voltage range	VthL	-	-	0.5	V	
High Input Voltage range	VthH	1.3	-	-	V	
Pull down register	Rcnt	65	100	135	kΩ	
[Switching Regulator]						
FB Terminal Control Voltage	FB	0.56	0.70	0.84	V	
Switching Frequency	fSW	-	600	-	kHz	
Max Duty	Duty	90	95	-	%	FB=0V
SW Transistor ON Resistor	Ronn	-	2	-	Ω	Isw=80mA
SW Transistor Leak Current	IqSW	-	0.1	2.0	μA	EN=0V
[Protection]						
Over Current Limit	Icoil	-	750	-	mA	*1
Over Voltage Limit BD60A00NUX	OVP1	40	42	44	V	Detect voltage of VOUT terminal
Over Voltage Limit BD60A60NUX	OVP2	26	28	30	V	Detect Voltage of VOUT terminal
Over Voltage Limit Hysteresis	OVPhy	-	1	-	V	
VOUT Terminal Leak Current	IqVOUT	-	0.1	1.0	μA	EN=0V
Shot key Diode Open Protection	Sop	-	0.2	-	V	Detect Voltage of VOUT terminal
LED Terminal Over Voltage Protection	LEDOVP	4.4	5.9	6.4	V	PWM=2.8V
Detect Voltage of Low Voltage	UVLO	-	2.2	-	V	VIN falling edge
[Current Driver]						
LED Maximum Current	ILMAX	-	-	30	mA	VIN=4V, COUT=1μF
LED Current Accuracy	ILACCU	-	-	±3.0	%	ILED=20mA
LED Current Limit	ILOCP	-	0	0.2	mA	Current Limit Value at ISET Resistor 1kΩ Setting
LED Leak Current	IqLED	-	0.1	2.0	μA	EN=0V
ISET Terminal Voltage	Iset	-	0.6	-	V	

*1 This parameter is tested with DC measurement.

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●Pin Description

PIN No.	PIN Name	In/Out	Function	Terminal Diagram
1	EN	In	Enable Control	B
2	VIN	In	Battery Input	C
3	PWM	In	PWM Input	B
4	ISET	In	LED Current Setting Terminal	A
5	FB	In	Feedback Voltage Input	B
6	VOUT	In	Over Voltage Protection Input	B
7	GND	-	GND	C
8	SW	Out	Switching Terminal	B

●Pin ESD Type

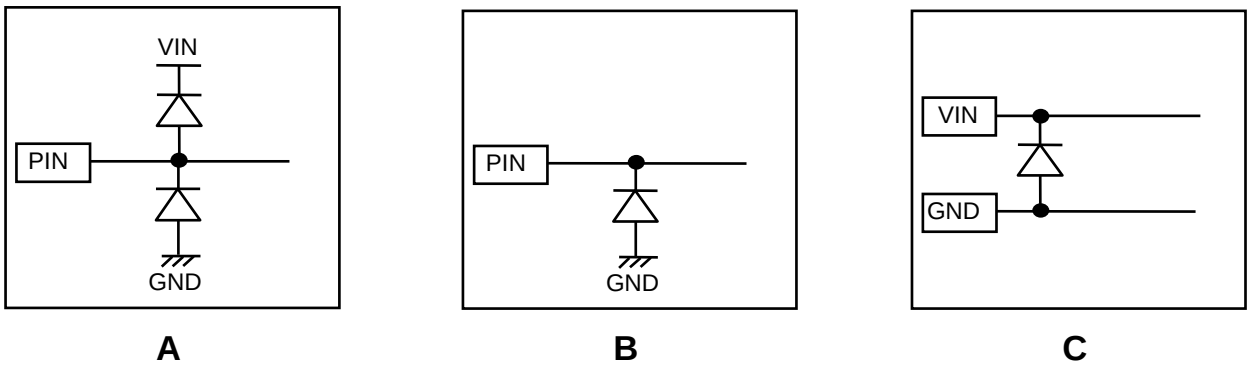
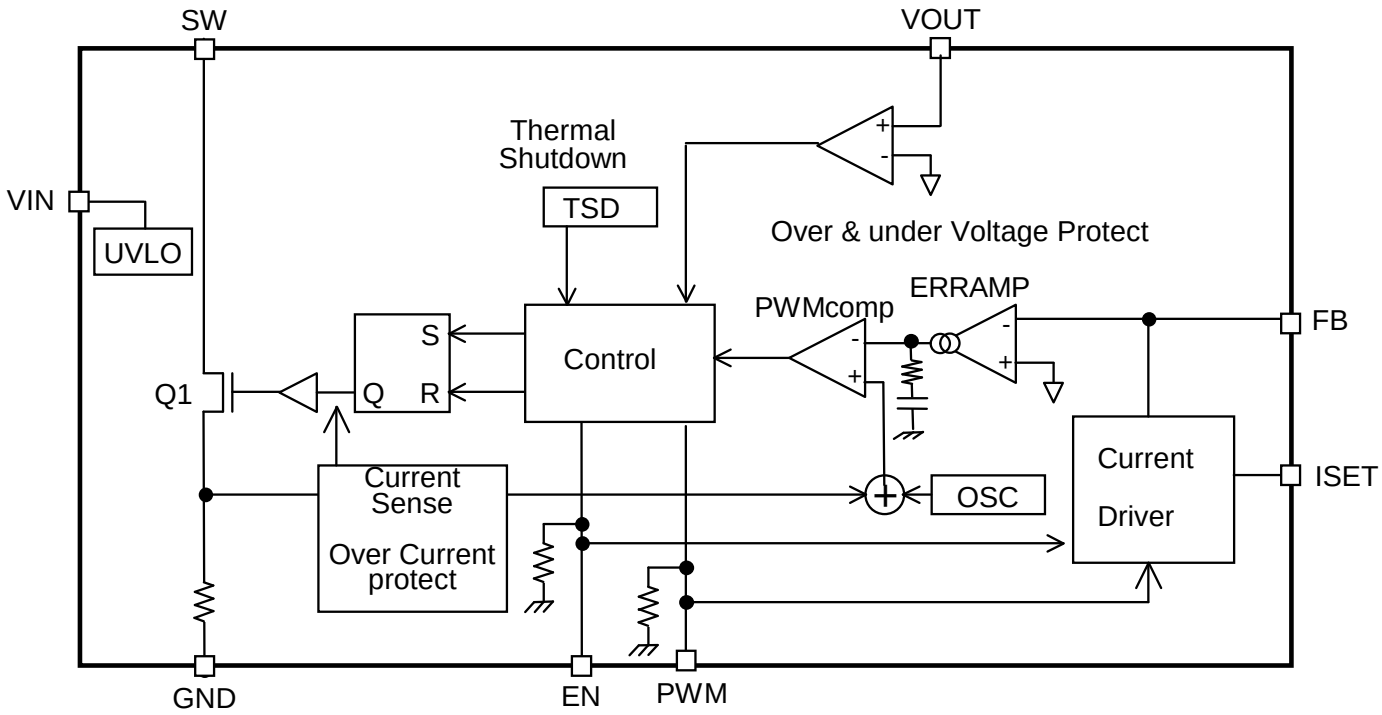


Figure 1. Pin ESD Type

●Block Diagram

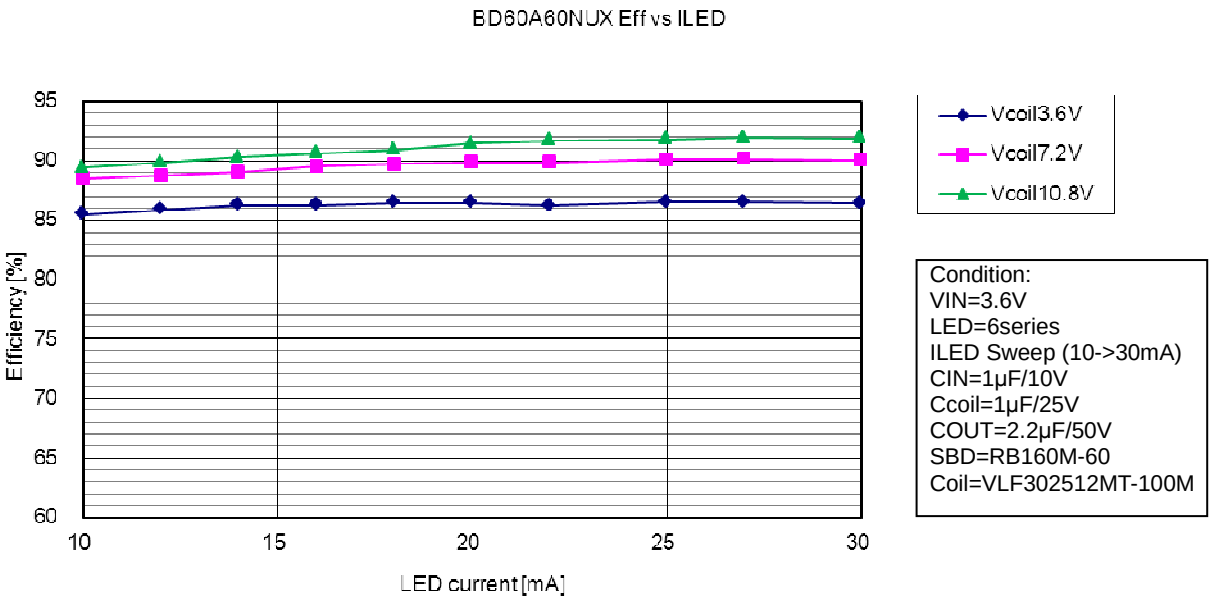


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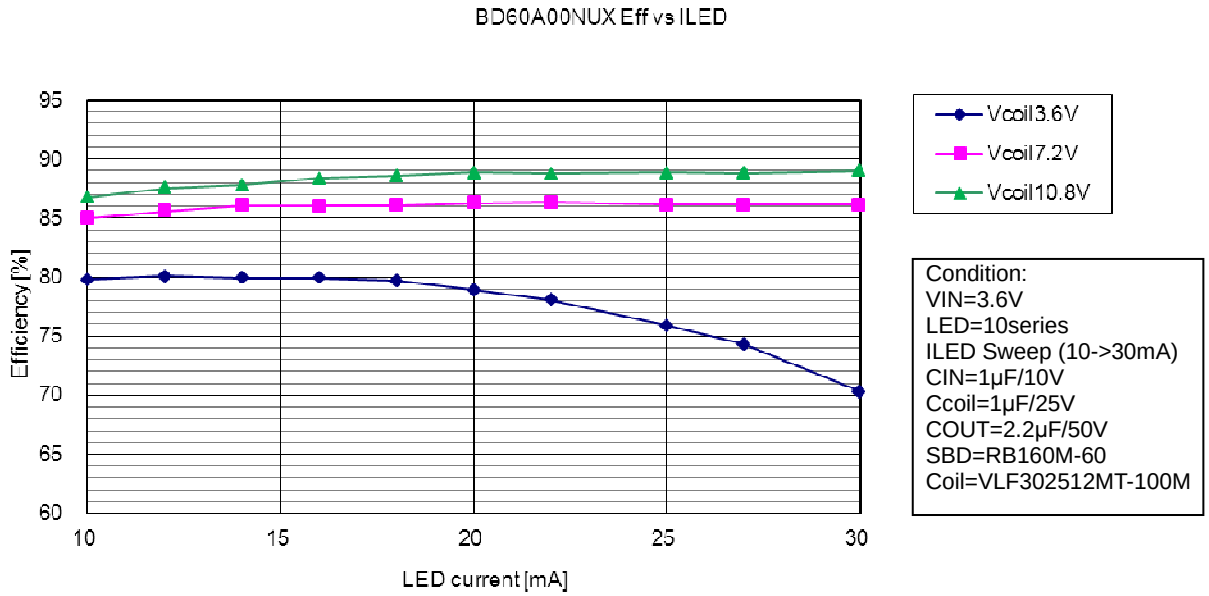
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●Main characteristics examples

LED 6series, coil: VLF302512MT-100M



LED 10series, coil: VLF302512MT-100M



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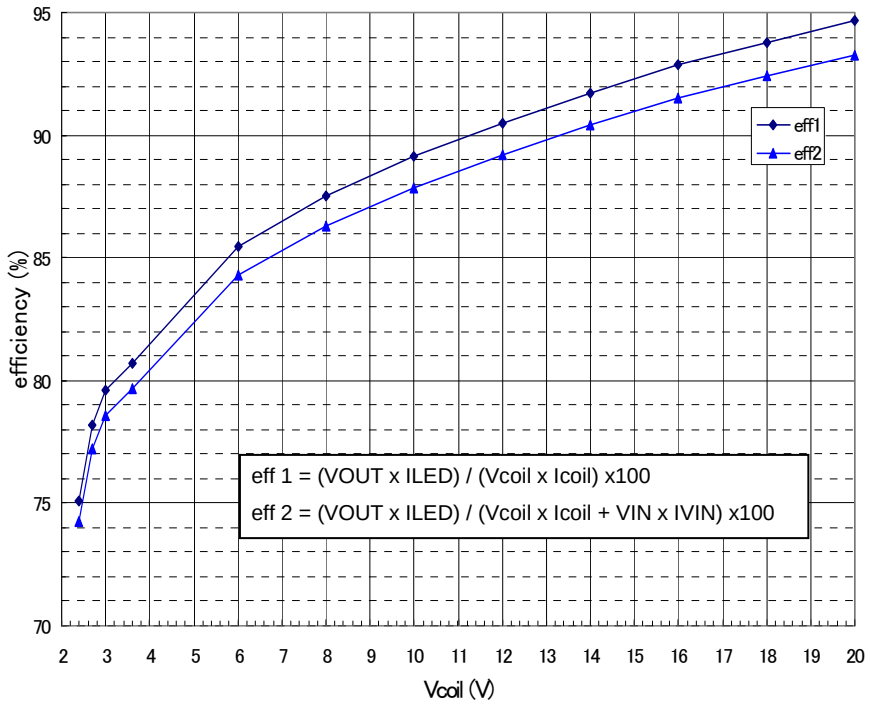
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●Main characteristics examples- continued

IC Power=5.0V, Coil Power=4V to 16V

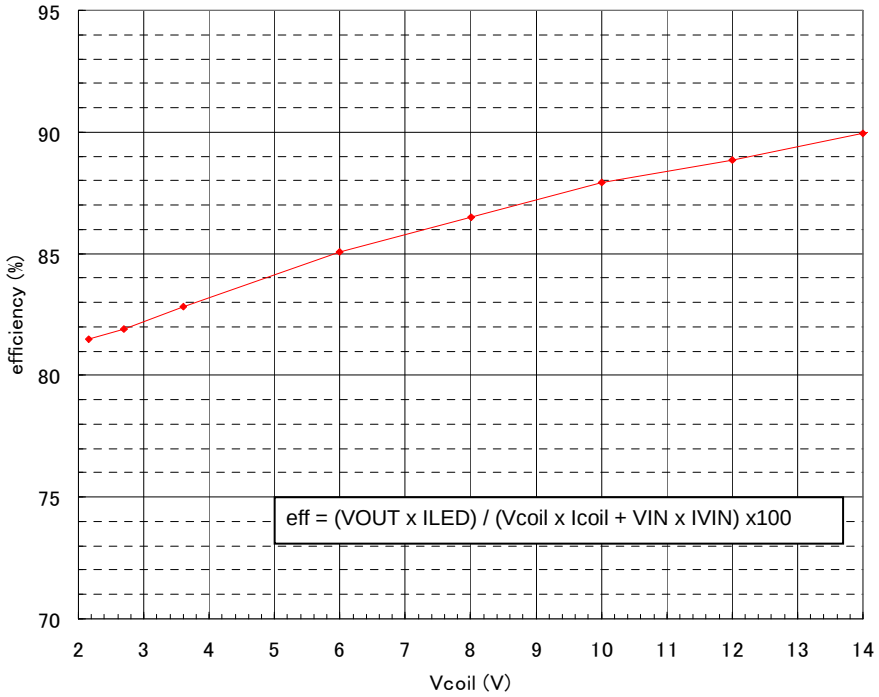
・BD60A00NUX

IC Power=5.0V, Coil Power=2.7V to 20V, LED 8serial, LED current =25mA,
coil 1094AS-10M (TOKO), SBD RB060M-60TR (ROHM)



・BD60A60NUX

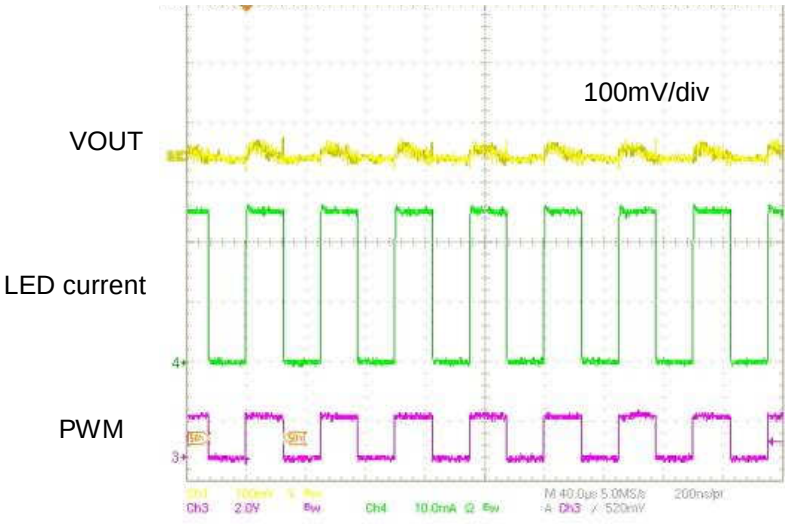
IC Power=5.0V, Coil Power=2.7V to 20V, LED 6serial, LED current =25mA,
coil 1094AS-10M (TOKO), SBD RB521A-40TR (ROHM)



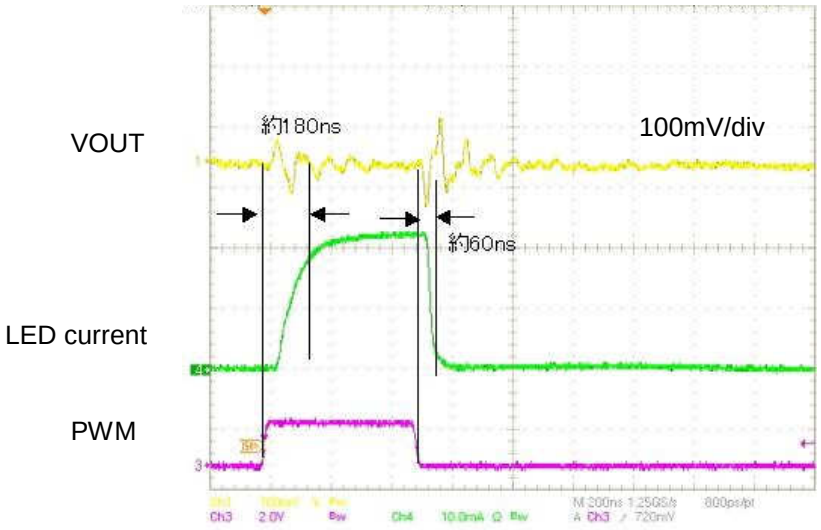
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●**Main characteristics examples- continued**



PWM 20kHz Duty 50%



PWM 20kHz Duty 1%

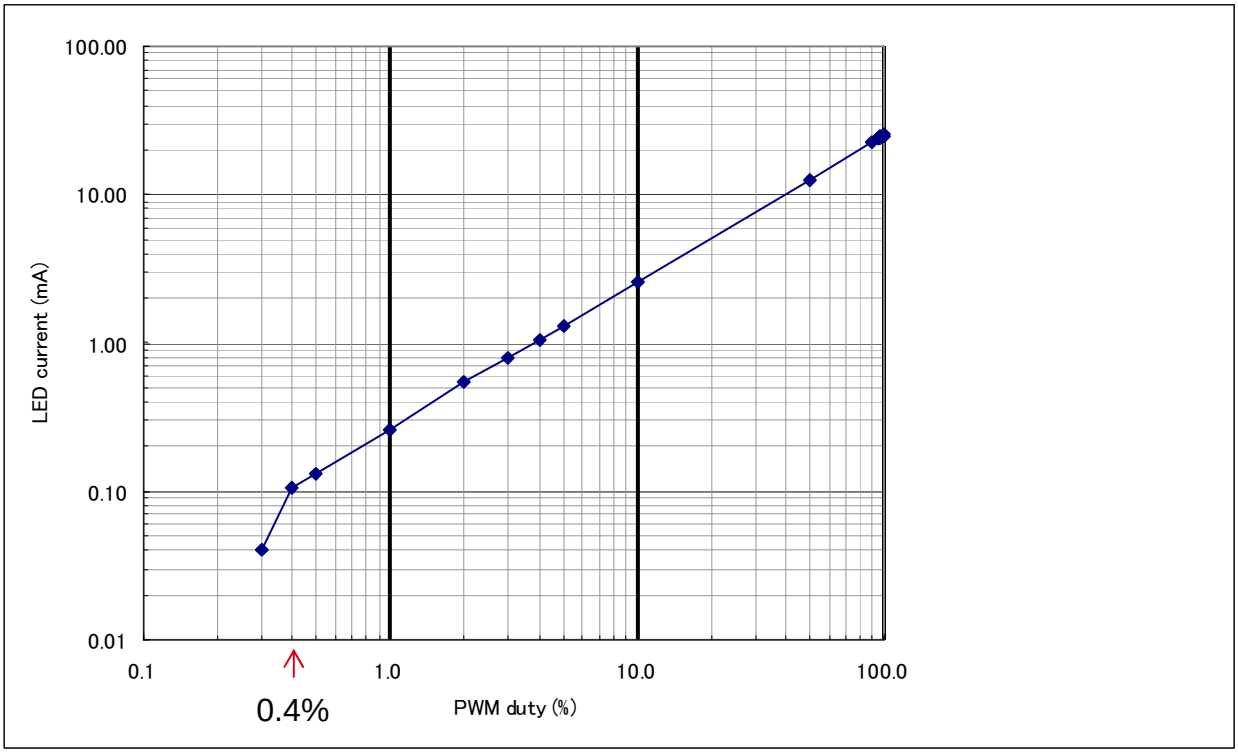
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●Main characteristics examples - continued

・BD60A00NUX PWM duty – LED current

IC Power=5.0V, LED 8serial, LED current =25mA, PWM frequency = 20 kHz, Ta=25deg
coil 1094AS-10M (TOKO), SBD RB060M-60TR (ROHM)



Possible to Duty 0.4% at PWM=20 kHz

●Functional Descriptions

1) PWM current mode DC/DC converter

This IC keeps output voltage invariably by setting PWM duty to make FB terminal 0.7V when the power is on. As for the inputs of the PWM comparator as the feature of the PWM current mode, one is overlapped with error components from the error amplifier, and the other is overlapped with a current sense signal that controls the inductor current into Slope waveform to prevent sub harmonic oscillation. This output controls internal Nch Tr via the RS latch. In the period where internal Nch Tr gate is ON, energy is accumulated in the external inductor, and in the period where internal Nch Tr gate is OFF, energy is transferred to the output capacitor via external SBD.
This IC has many safety functions, and their detection signals stop switching operation at once.

2) Soft Start

This IC has soft start function, which prevents rush current at turning on.
After EN and PWM are changed L→ H, soft start becomes effective within 1ms. Soft start become effective even if Enable is changed H→ L→ H, after that. By changing EN and PWM L→ H, soft start can become effective.

Since a soft start function stops working at the time of following PWM=H when EN=H is held with PWM=L
After EN=H should input a PWM signal within 10ms.

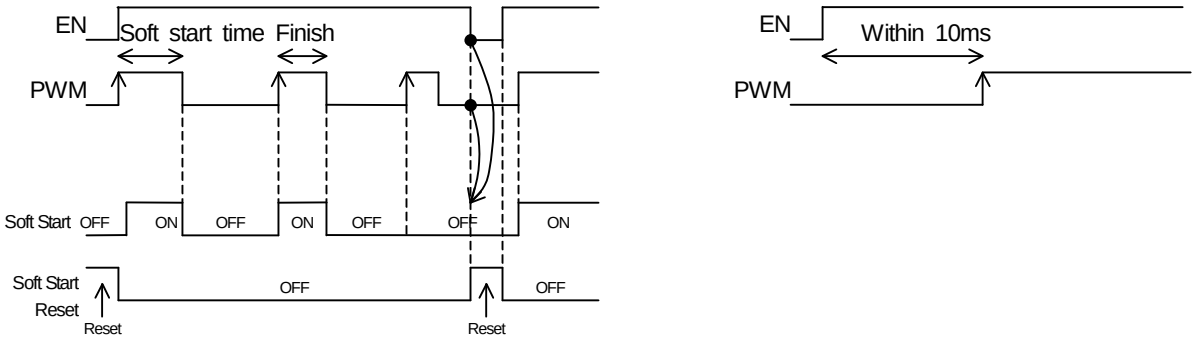


Figure 2. Soft start

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●Protection

▪ Over voltage protection

At such an error of output open as the output DC/DC and the LED is not connected to IC, the DC/DC boosts too much and the VOUT terminal exceeds the absolute maximum ratings, and may destruct the IC. Therefore, when the VOUT becomes sensing voltage or higher, the over voltage limit protection works, turns off the switching Tr, DC/DC will be stopped, and the output voltage goes down slowly. When output voltage becomes below the hysteresis voltage of Over voltage protection, A boost function works and output voltage reaches detection voltage again.
This operation is repeated unless the abnormalities in application are recovered.

・Schottky Diode open protection

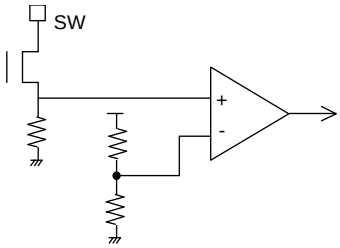
In the case of external SBD is not connected to IC, or VOUT is shorted to GND, the coil or internal Tr may be destructed. Therefore, at such an error as VOUT becoming 0.2V or below, turns off the output Tr, and prevents the coil and the IC from being destructed.
And the IC changes from activation into non-activation, and current does not flow to the coil (0mA).

・Thermal shut down

This IC has thermal shut down function.
The thermal shut down works at 175˚C or higher, and the IC changes from activation into non-activation.

・Over Current Protection

Over current flows the current detection resistor that is connected to between internal switching transistor source and GND. Current sense voltage turns more than detection voltage, over current protection is operating and it is prevented from flowing more than detection current by reducing ON duty of switching Tr without stopping boost.
As over current detector of This IC is detected peak current, current more than over current setting value does not flow.



< The estimate of the current value which need for the normal operation>
As over current detector of This IC is detected the peak current, it has to estimate peak current to flow to the coil by operating condition.

In case of, ○ Switching frequency = fsw Typ.=0.6MHz
○ Supply voltage of coil = VIN ○ Inductance value of coil = L
○ Output voltage = VOUT ○ Total LED current = IOUT
○ Average current of coil = Iave ○ Peak current of coil = Ipeak
○ Efficiency = eff
○ ON time of switching transistor = Ton

Ipeak = (VIN / L) × (1 / fsw) × (1-(VIN / VOUT))
Iave=(VOUT × IOUT / VIN) / eff
Ton=(Iave × (1-VIN/VOUT) × (1/fsw) × (L/VIN) × 2)$^{1/2}$
As peak current varies according to whether there is the direct current superposed, the next is decided.
(1-VIN/VOUT) × (1/fsw) < Ton→ peak current = Ipeak /2 + Iave (continuous mode CCM)
(1-VIN/VOUT) × (1/fsw) > Ton→ peak current = (VIN / L)×Ton (discontinuous mode DCM)

(Example 1)
In case of, VIN=6.0V, L=10µH, fsw=0.6MHz, VOUT=32.5V, IOUT=25mA, current =85%
Ipeak = (6.0V / 10µH) × (1 / 0.6MHz) × (1-(6.0V / 32.5V)) =0.82 A
Iave = (32.5V × 25mA / 6.0V) / 85% = 0.16A
Ton = (0.16A × (1-6.0V / 32.5V) × (1 / 0.75MHz) × (10µH /6.0V) × 2)$^{1/2}$ = 0.85µs
(1-VIN/VOUT) × (1/fsw)=1.36µs > Ton
peak current = (6.0V / 10µH)×0.85µs =0.51A

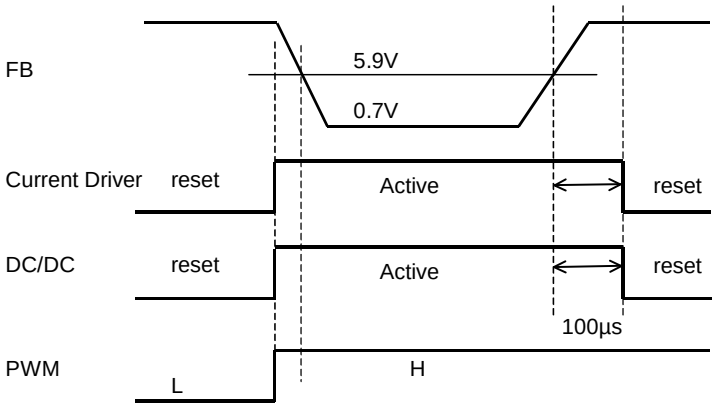
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●Protection - continued

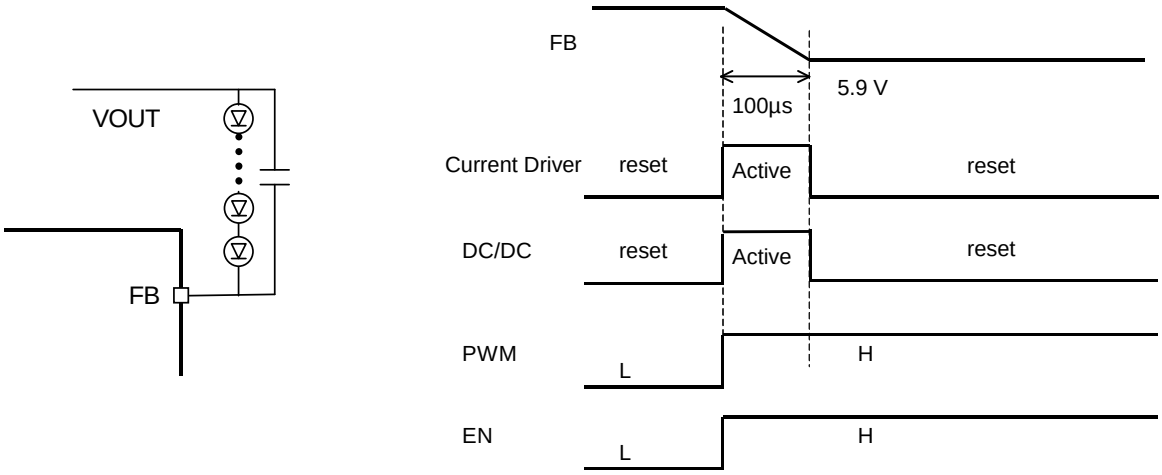
・LED terminal over voltage protection

When FB terminal becomes higher than 5.9V (Typ.), IC senses the situation trouble after 100µs and then stops constant current driver and DC/DC. Therefore IC becomes never heated, even if output and FB are both shorted. Moreover, if FB terminal becomes lower than 5.9V (Typ.), IC senses normal condition and activates constant current driver.



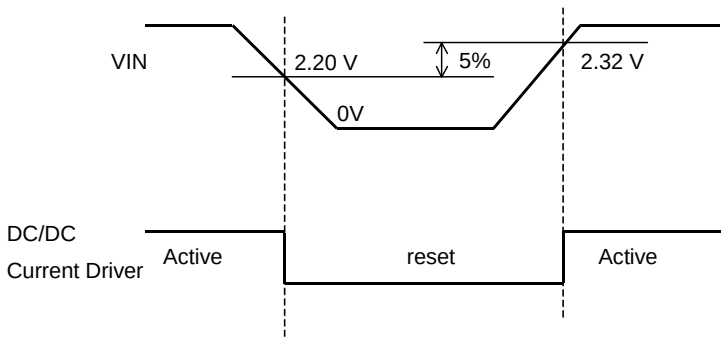
・Prevention of LED terminal over voltage protection malfunction

As the below diagrams show, voltage drop of FB terminal becomes slow when PWM operates by connecting capacitor on a parallel with LED and decreasing LED current. At that time, LED terminal voltage protection works after condition of FB terminal > 5.9V keeps more than 100µs. LED terminal voltage protection might stop current driver and DC/DC and also turns off LEDs, so that please set up coil selection and LED current setting less than 100µs until FB terminal < 5.9V.



・Low voltage detect protection (UVLO)

Supply voltage(VIN) becomes lower than low voltage detect voltage 2.2V(Typ.), IC stops DC/DC and constant current driver. Moreover, this function can be off by boosting supply voltage up to more than hysteresis voltage.



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●**Operating of the application deficiency**

1) When 1 LED or 1string OPEN during the operating
Since FB terminal is set to 0V when set to OPEN, Output boosts up to the over voltage protection voltage. When over voltage is detected, the boosting operation stops and then output voltage goes down slowly. Later, if output voltage becomes less than hysteresis of over current protection, output voltage keeps boosting up to over voltage protection voltage again.

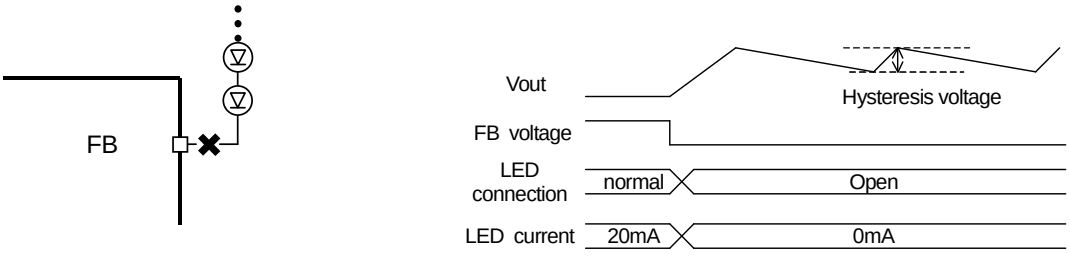


Figure 3. LED open detect

2) When LED short-circuited in the plural
Even if one LED short-circuits during boost operation, it usually passes along LED and it is turned on. By making LED shorted, FB terminal voltage increases by LED VF. Therefore output voltage becomes lower by LED VF, and the condition turns to be normal.

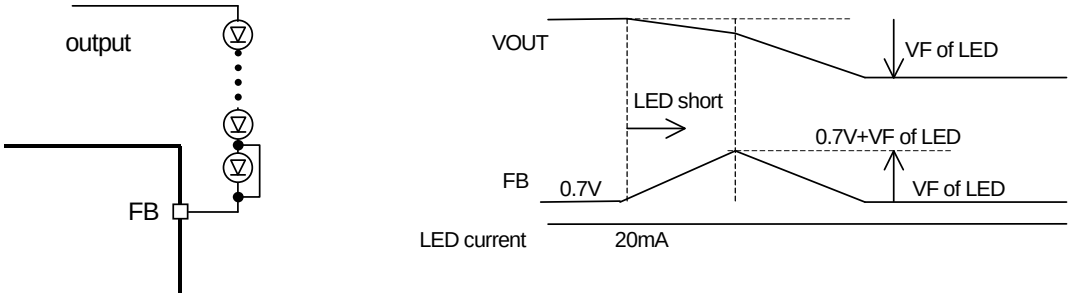


Figure 4. One LED shorted

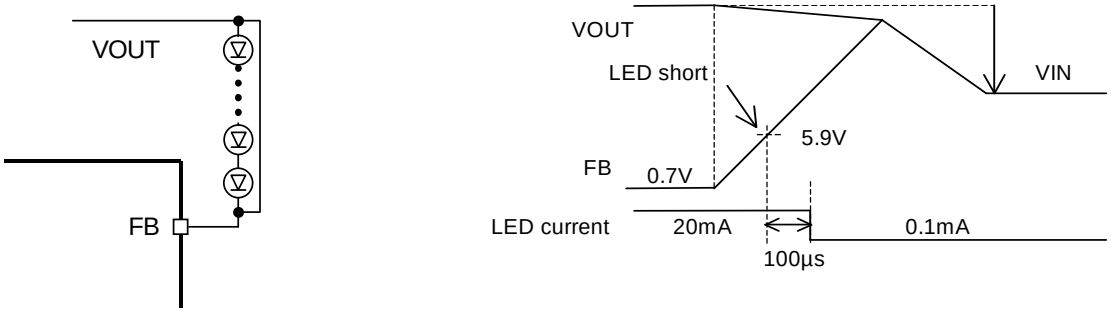


Figure 5. FB terminal – VOUT terminal shorted

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●**Operating of the application deficiency - continued**

3) When Schottky diode (SBD) remove
In the situation that connection is opened and also DC/DC is activated, SW terminal voltage becomes more than rated voltage due to a lack of parts that can accept the current accumulated inside the coil. Consequently IC might be destroyed. To prevent the IC destruction, SBD open protection is functioned. SW terminal is never destroyed as boosting operation is stopped after VOUT terminal detects less than 0.2V.

4) When resistance linked to an ISET terminal short-circuits
Since Resistor connected to ISET terminal becomes 0Ω, LED current setting value becomes more than rating. In order to avoid this trouble, this IC has LED current limit protection. By using this function, setting current of rating current driver becomes 0mA, and the current flow of LED is almost same as leak current.

●**Control signal input timing**

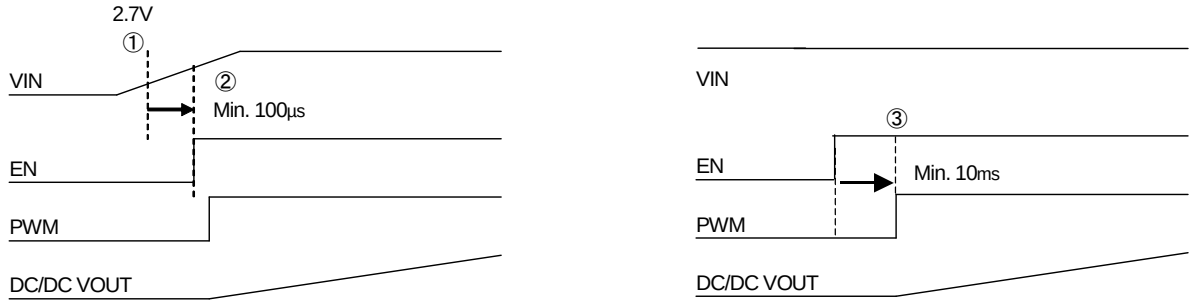


Figure 6. Control signal input timing

When input control signals such as Enable and PWM without completing the standup of supply voltage (VIN), be careful of the following points.
① Input each control signal after VIN exceeds 2.7V and UVLO is off.
② When input Enable and PWM, the standup time should be placed as Min.100µs from 2.7V to stable voltage for VIN.
③ Since a soft start function stops working at the time of following PWM=H when EN=H is held with PWM=L.
After EN=H should input a PWM signal within 10ms.

●**Start control (EN) and select LED current driver (PWM)**

This IC can control the IC system by EN terminal and also turns off compulsorily by setting “L” level input voltage 0.4V or below. It also powers on when EN becomes more than “H” level input voltage 1.3V. In the case of EN=H, LED current fixed by ISET resistor with PWM=H flows. When it is selected at PWM=L, LED current stop to flow.

EN	PWM	IC	LED current
L	L	Off	Off
H	L	On	Off
L	H	Off	Off
H	H	On	Current fixed by ISET

●**LED current setting range**

LED current sets up normal current by resister (RISET) connected to ISET voltage.
Each setting current is shown as below.
Normal current = 600/RISET [A]
Normal current setting range is 10mA to 30mA, and also LED current at off setting is MAX 2µA of leak current.

ISET Normal current setting example

RISET	LED current
20.0kΩ (E96)	30.0mA
24.0kΩ (E24)	25.0mA
30.0kΩ (E24)	20.0mA
56.0kΩ (E24)	10.7mA

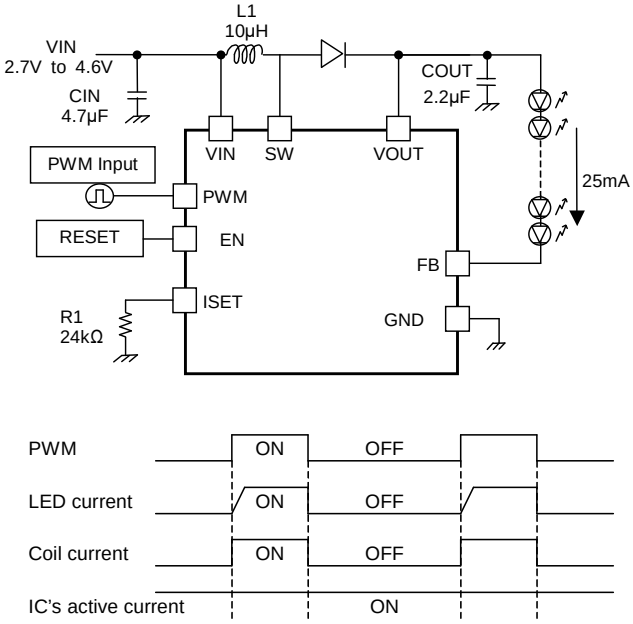
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●Brightness control

There are two dimming method available; the first method is analog dimming that applies analog voltage to ISET terminal, and the second method is digital dimming that inputs PWM to PWM terminal. Since each method has the different merits, please choose a suitable method for the application of use.

1) Current driver PWM control is controlled by providing PWM signal to PWM, as it is shown Figure 7.
The current set up with ISET is chosen as the H section of PWM and the current is off as the L section. Therefore, the average LED current increases in proportion to duty cycle of PWM signal. This method that internal circuit and DC/DC work, because it becomes to switch the driver, the current tolerance is a few when the PWM brightness is adjusted, so it makes it possible to brightness control until 0.4µs (MIN1% at 25kHz). And, don't use for the brightness control, because effect of ISET changeover is big under 0.4µs ON time and under 3µs OFF time. Typical PWM frequency is 100Hz to 25kHz.



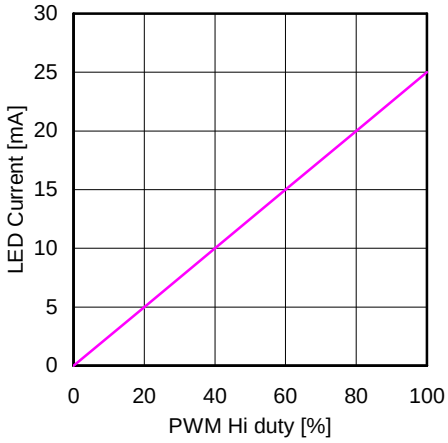
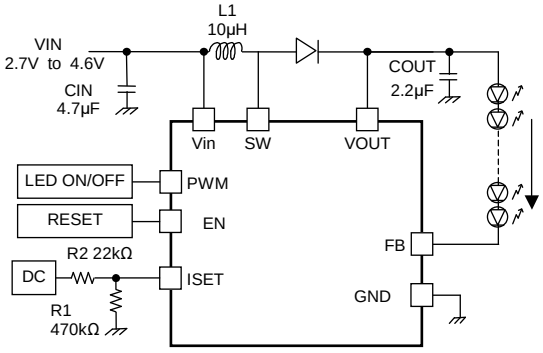
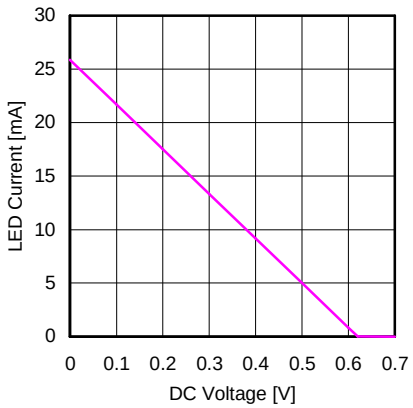


Figure 7. PWM sequence

2) Analog dimming can be operated by applying voltage to ISET terminal via resistor as the below figure shows. ISET terminal voltage works to become 0.6V regardless of the connected resistor. LED current increases ISET terminal current 600 times, so that LED current can be minimized by decreasing flow current into ISET terminal using external DC input



$$\text{LED current} = \frac{1000 \times 0.6V}{470k\Omega} + \frac{1000}{22k\Omega}\left(0.6V - \text{DAC output}\right)$$



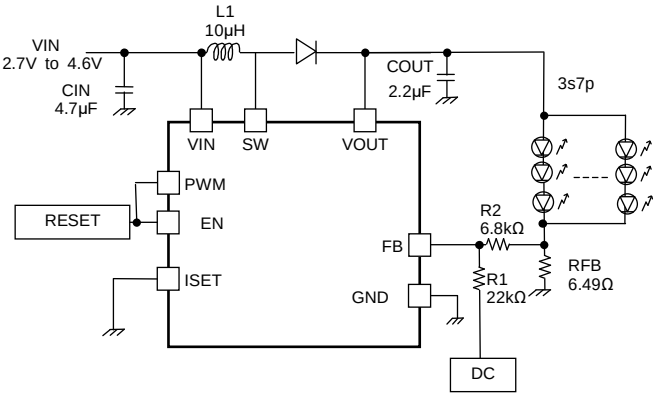
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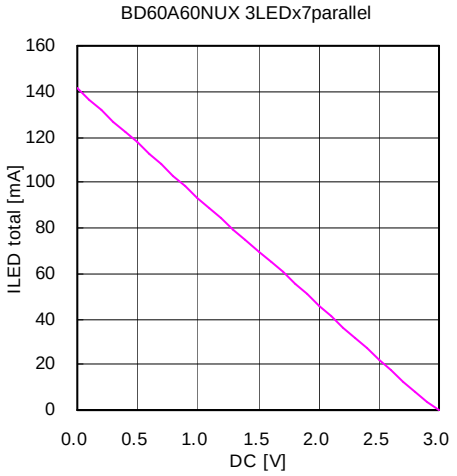
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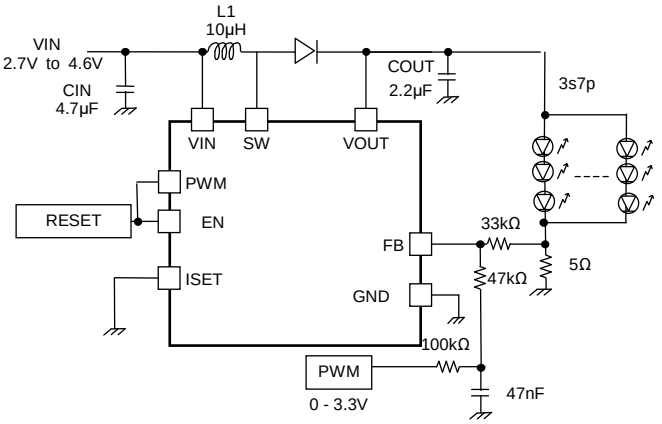
●Brightness control - continued

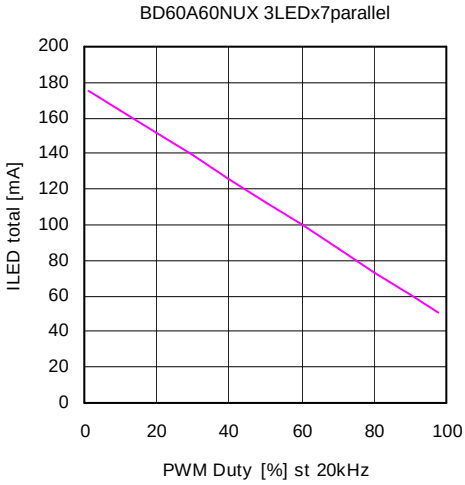
3) The brightness control to set large current over IC max setting current is made by giving DC control voltage to VFB pin of IC via a series resistor as shown in under figure. LED luminance (current) changed by giving DC voltage to VFB directly. DC voltage is given from filtered one of DAC signal, or PWM signal shown in under figure.

LED current (ILED) is next expression.
ILED = [[(FB-DC) / R1] * R2 + FB] / RFB









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●The coil selection

The DC/DC is designed by more than 4.7µH. When L value sets to a lower value, it is possibility that the specific sub-harmonic oscillation of current mode DC / DC will be happened.
Please do not let L value to 3.3µH or below.
And, L value increases, the phase margin of DC / DC becomes to zero. Please enlarge the output capacitor value when you increase L value.

●Output capacitor selection

Output Capacitor smoothly keeps output voltage and supplies LED current.
If LED current is set more than 20mA with Vcoil=2.3V to 5.5V, please make output capacitor more than 2.2µF. Otherwise phase margin of DC/DC decreases and might oscillate.
Output Voltage consists of Charge (FET ON) and Discharge (LED current). So Output voltage has Output ripple Voltage every FET switching.
Output ripple voltage is calculated as following.

Output ripple Voltage

- Switching cycle = T
- Switching ON duty = D
- Output Capacitor = COUT
- Decreasing ratio of Capacitor = C_{error}
- Total LED current = ILED
- Output ripple Voltage = V_{ripple}
- Output Capacitor (real value) = C_{real}

$C_{real} = COUT \times C_{error}$ (Capacitor value is decreased by Bias, so)

$C_{real} = ILED \times (1-D) \times T / V_{ripple}$

$COUT = ILED \times (1-D) \times T / V_{ripple} / C_{error}$

(Example 1)

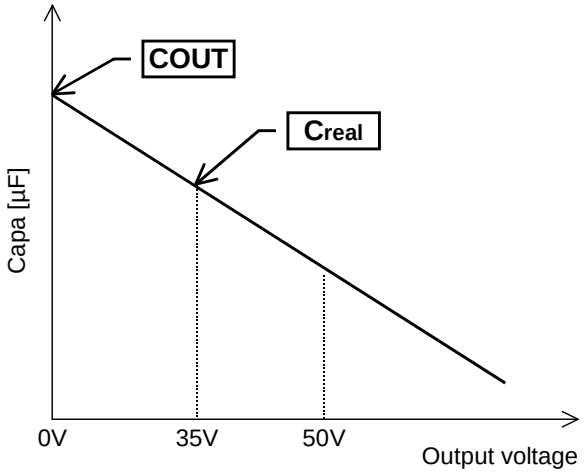
In case of, VIN=5.0V, fsw = 0.6MHz, VOUT =32.5V, ILED =20mA, COUT = 2.2µF, C_{error} = 50%

$T = 1 / 0.6MHz$

$D = 1 – VIN / VOUT = 1 – 5/32.5$

$V_{ripple} = ILED \times (1-D) \times T / (COUT \times C_{error}) = 20mA \times (5/32.5) \times (1 / 0.6MHz) / (2.2\mu F \times 0.5)$

$= 4.7mV$



●LED selection

Please select LED VF that input voltage is smaller than output voltage (VOUT).

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●The separation of the IC power supply and coil power supply

This IC can work in separating the power source in both IC power supply and coil power supply. With this application, it can obtain that decrease of IC power consumption, and the applied voltage exceeds IC rating 5.5V.

That application is shown in below Figure 8. The coil power supply is connected to high voltage source applied from adapters. Then the IC power supply is connected to the power supply that should be different from the coil power supply.

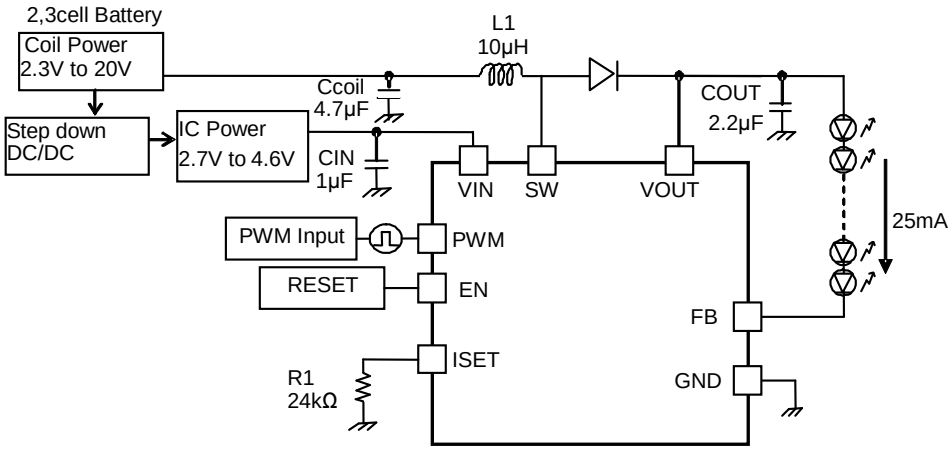


Figure 8. Application at the time of power supply separation

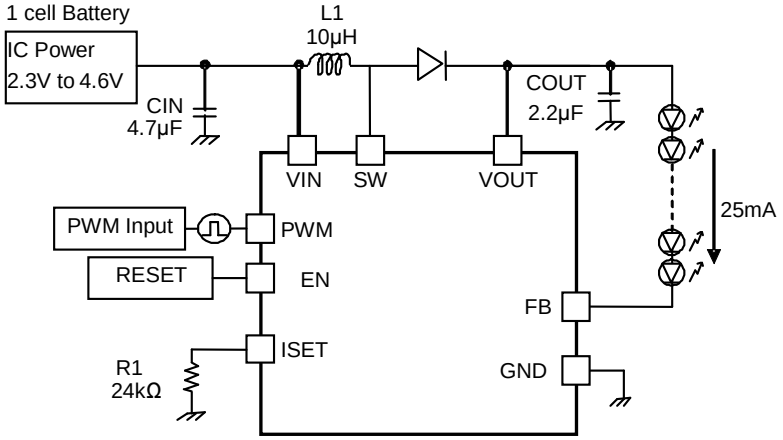


Figure 9. Application at the time of power supply common

The number of available LEDs by each power supply voltage condition

PWM dimming(LED current setting=25mA)

	1セル				2セル			3セル										
VIN / LEDs	2.7V	3V	4V	5V	6V	7V	8V	9V	10V	11V	12V	13V	14V	15V	16V	17V	18V	19V	20V
2	C、S	C、S	C、S	C、S	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
3	C、S	C、S	C、S	C、S	S	S	×	×	×	×	×	×	×	×	×	×	×	×	×
4	C、S	C、S	C、S	C、S	S	S	S	S	S	×	×	×	×	×	×	×	×	×	×
5	C、S	C、S	C、S	C、S	S	S	S	S	S	S	S	×	×	×	×	×	×	×	×
6	C、S	C、S	C、S	C、S	S	S	S	S	S	S	S	S	S	×	×	×	×	×	×
7	C、S	C、S	C、S	C、S	S	S	S	S	S	S	S	S	S	S	S	×	×	×	×
8	C、S	C、S	C、S	C、S	S	S	S	S	S	S	S	S	S	S	S	S	×	×	×
9	C、S	C、S	C、S	C、S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	×
10	C、S	C、S	C、S	C、S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

※ C・・・Vcoil-Vin common power supply
S・・・Vcoil-Vin separated power supply
×・・・No use due to LED terminal over voltage protection

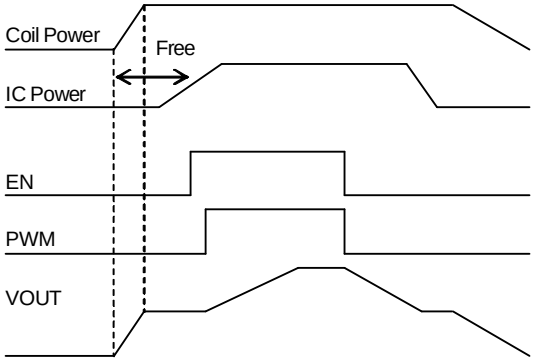
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●About the order of a power supply injection at the time of power supply separation

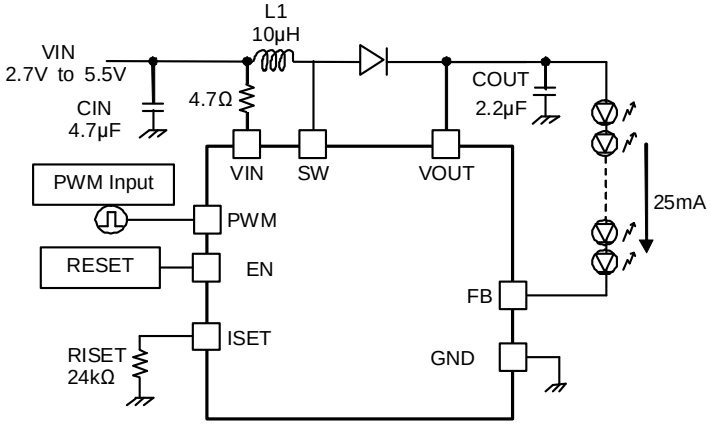
Even if the IC power supply is 0V, leak channel is blocked as pull down resistor for power off is placed inside the IC. The resistor intercepts leak channel from coil power supply. Additionally, there is no order for standing up and down of coil and IC power supply.

- At the time of starting
  It doesn't matter whether coil Power or IC Power becomes activated first.
- At the time of power supply OFF
  Please turn off after make EN terminal "L". If power supply voltage of coil power becomes low, coil current increases due to high boosting, which leads to over current limit. In order to avoid this state, before turning off a power supply it is necessary to surely set EN to L.



●Input voltage 5V（BD60A00NUX）

The GND noise become big by impedance of PCB boards, so that wake up characteristics might become unstable. To select input voltage to 5V(input voltage 4.61V over), we recommend under application to insert 4.7Ω between input voltage line and Vin terminal

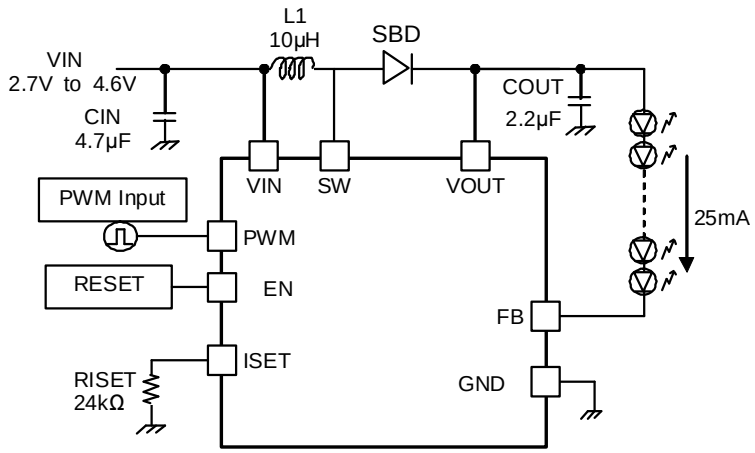


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●PCB Layout

In order to make the most of the performance of this IC, its PCB layout is very important. Characteristics such as efficiency and ripple and the likes change greatly with PCB layout, which please note carefully



<Input capacitor CIN for coil>

Connect input capacitor CIN as close as possible between coil L1 and GND.

<Schottky barrier diode SBD>

Connect schottky barrier diode SBD as close as possible between coils L1and SW pin.

<Output capacitor COUT>

Connect output capacitor COUT between cathode of SBD and GND.
Make both GND sides of CIN and COUT as close as possible.

<LED current setting resistor RISET(24kΩ)>>

Connect LED current setting resistor RISET(24kΩ) as close as possible between ISET pin and GND.
There is possibility to oscillate when capacity is added to ISET terminal, So pay attention that capacity isn't added.

<Heat radiation of back side PAD>

PAD is used for improving the efficiency of IC heat radiation. Solder PAD to GND pin.
Moreover, connect ground plane of board using via as shown in the patterns of next page.
The efficiency of heat radiation improves according to the area of ground plane.

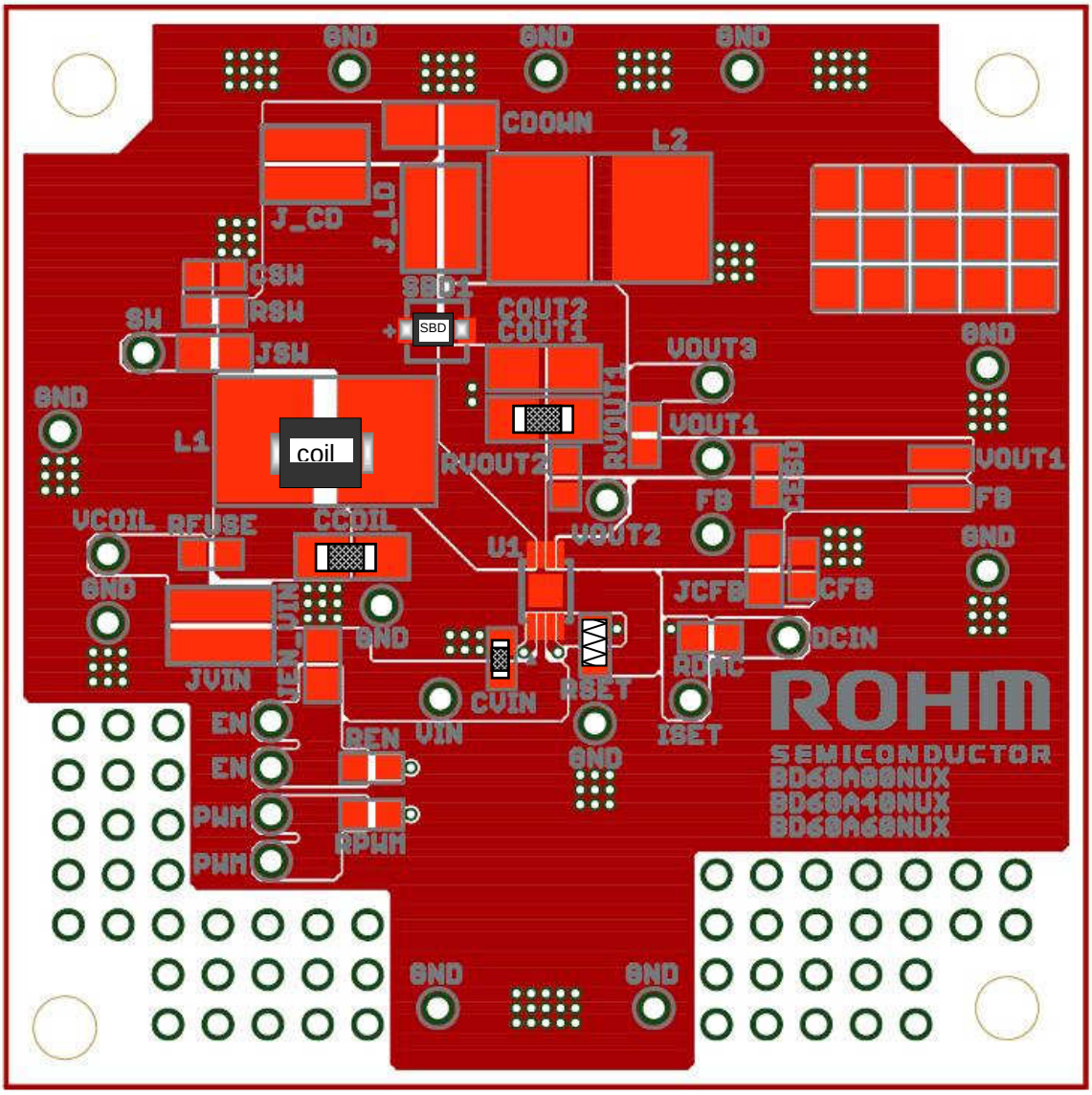
<Others>

When those pins are not connected directly near the chip, influence is give to the performance of BD60A00NUX, and may limit the current drive performance. As for the wire to the inductor, make its resistance component small so as to reduce electric power consumption and increase the entire efficiency.
The PCB layout in consideration of these is shown in the next page.

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●Recommended PCB layout



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●Selection of external parts

Recommended external parts are as shown below.
When to use other parts than these, select the following equivalent parts.

L1: This coil is for boosting. Recommended capacity value is 10uH. Please use the coil with adequate direct current capacity and also low direct current resistor.

Value	Manufacturer	Product number	Size			DC current (mA)	DCR (Ω)
			Vertical	Horizontal	Height		
10µH	TDK	VLF4012AT-100MR79	4.0	3.8	1.2	800	0.30
10µH	TDK	VLF302512MT-100M	3.0	2.5	1.2	690	0.25
10µH	TOKO	1094AS-100M	3.5	3.7	1.2	760	0.18
10µH	TOKO	1229AS-H-100M	3.5	3.7	1.2	750	0.24

CIN: This is bypath capacitor for power supply, which removes power supply noise occurred instantly and provides stable power supply for IC. In order to obtain better quality, please use low ESR products such as ceramic capacitors. Recommended capacity value is more than 1µF.
COUT: This is output smoothing capacitor. Recommended capacity value is 2.2µF.
When choosing capacitors such as CIN and COUT, please be careful of pressure. The base line of pressure is about 2 times of actual applying voltage. If pressure margin decreases, it might be happened that capacity value becomes almost a half of nominal value.

Value	Pressure	Manufacture	Product number	Size		
				Vertical	Horizontal	Height
[CIN : Power supply voltage capacitor]						
1.0µF	10V.	MURATA	GRM185B31A105	1.6.	0.8.	0.5.
[COUT : Output capacitor]						
1.0µF	50V	MURATA	GRM31MB31H105	3.2	1.6	1.15
2.2µF	50V	MURATA	GRM31CB31H225	3.2	1.6	1.6

RISET: LED current ILED should be decided when activated.

Value	Tolerance	Manufacturer	Product number	Size			I_{LED} (mA)
				Vertical	Horizontal	Height	
[RISET : Resistor used for deciding LED current]							
20kΩ	±0.5%	ROHM	MCR03PZPZD2002	1.6	0.8	0.45	30
24kΩ	±0.5%	ROHM	MCR03PZPZD2402	1.6	0.8	0.45	25
30kΩ	±0.5%	ROHM	MCR03PZPZD3002	1.6	0.8	0.45	20
56kΩ	±0.5%	ROHM	MCR03PZPZD5602	1.6	0.8	0.45	10.7

SBD: This schottky diode (SBD) is for output rectification. In order to obtain higher switching efficiency, please use low VF low reverse leak, and high current capacity.

Pressure	Manufacturer	Product Number	Size		
			Vertical	Horizontal	Height
60V	ROHM	RB160M-60	3.5	1.6	0.8
40V	ROHM	RB521S-40	1.6	0.8	0.6
60V	ROHM	RB060M-60	3.5	1.6	0.8

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●Operational Notes

(1) Absolute Maximum Ratings
An excess in the absolute maximum ratings, such as supply voltage (VIN), temperature range of operating conditions (Topr), etc., can break down devices, thus making impossible to identify breaking mode such as a short circuit or an open circuit. If any special mode exceeding the absolute maximum ratings is assumed, consideration should be given to take physical safety measures including the use of fuses, etc.

(2) Operating conditions
These conditions represent a range within which characteristics can be provided approximately as expected. The electrical characteristics are guaranteed under the conditions of each parameter.

(3) Reverse connection of power supply connector
The reverse connection of power supply connector can break down ICs. Take protective measures against the breakdown due to the reverse connection, such as mounting an external diode between the power supply and the IC's power supply terminal.

(4) Power supply line
Design PCB pattern to provide low impedance for the wiring between the power supply and the GND lines. Furthermore, for all power supply terminals to ICs, mount a capacitor between the power supply and the GND terminal. At the same time, in order to use an electrolytic capacitor, thoroughly check to be sure the characteristics of the capacitor to be used present no problem including the occurrence of capacity dropout at a low temperature, thus determining the constant.

(5) GND voltage
Make setting of the potential of the GND terminal so that it will be maintained at the minimum in any operating state. Furthermore, check to be sure no terminals are at a potential lower than the GND voltage including an actual electric transient.

(6) Short circuit between terminals and erroneous mounting
In order to mount ICs on a set PCB, pay thorough attention to the direction and offset of the ICs. Erroneous mounting can break down the ICs. Furthermore, if a short circuit occurs due to foreign matters entering between terminals or between the terminal and the power supply or the GND terminal, the ICs can break down.

(7) Operation in strong electromagnetic field
Be noted that using ICs in the strong electromagnetic field can malfunction them.

(8) Inspection with set PCB
On the inspection with the set PCB, if a capacitor is connected to a low-impedance IC terminal, the IC can suffer stress. Therefore, be sure to discharge from the set PCB by each process. Furthermore, in order to mount or dismount the set PCB to/from the jig for the inspection process, be sure to turn OFF the power supply and then mount the set PCB to the jig. After the completion of the inspection, be sure to turn OFF the power supply and then dismount it from the jig. In addition, for protection against static electricity, establish a ground for the assembly process and pay thorough attention to the transportation and the storage of the set PCB.

(9) Input terminals
In terms of the construction of IC, parasitic elements are inevitably formed in relation to potential. The operation of the parasitic element can cause interference with circuit operation, thus resulting in a malfunction and then breakdown of the input terminal. Therefore, pay thorough attention not to handle the input terminals, such as to apply to the input terminals a voltage lower than the GND respectively, so that any parasitic element will operate. Furthermore, do not apply a voltage to the input terminals when no power supply voltage is applied to the IC. In addition, even if the power supply voltage is applied, apply to the input terminals a voltage lower than the power supply voltage or within the guaranteed value of electrical characteristics.

(10) Ground wiring pattern
If small-signal GND and large-current GND are provided, It will be recommended to separate the large-current GND pattern from the small-signal GND pattern and establish a single ground at the reference point of the set PCB so that resistance to the wiring pattern and voltage fluctuations due to a large current will cause no fluctuations in voltages of the small-signal GND. Pay attention not to cause fluctuations in the GND wiring pattern of external parts as well.

(11) External capacitor
In order to use a ceramic capacitor as the external capacitor, determine the constant with consideration given to a degradation in the nominal capacitance due to DC bias and changes in the capacitance due to temperature, etc.

(12) Thermal shutdown circuit (TSD)
When junction temperatures become 175˚C (Typ.) or higher, the thermal shutdown circuit operates and turns a switch OFF. The thermal shutdown circuit, which is aimed at isolating the LSI from thermal runaway as much as possible, is not aimed at the protection or guarantee of the LSI. Therefore, do not continuously use the LSI with this circuit operating or use the LSI assuming its operation.

(13) Thermal design
Perform thermal design in which there are adequate margins by taking into account the permissible dissipation (Pd) in actual states of use.

(14) Selection of coil
Select the low DCR inductors to decrease power loss for DC/DC converter.

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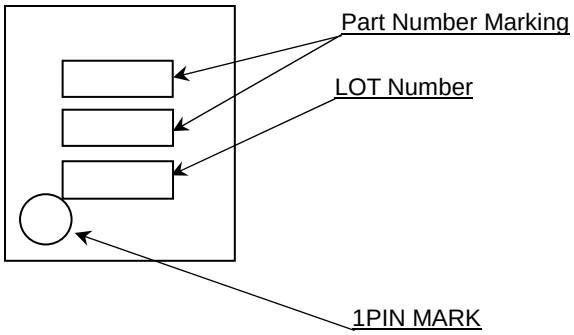
●Ordering Information

B	D	6	0	A	x	0	N	U	X	-	T R

Part Number	0: BD60A00NUX 6: BD60A60NUX	Package NUX: VSON008X2030	Packaging and forming specification TR: Embossed tape and reel

●Marking Diagram

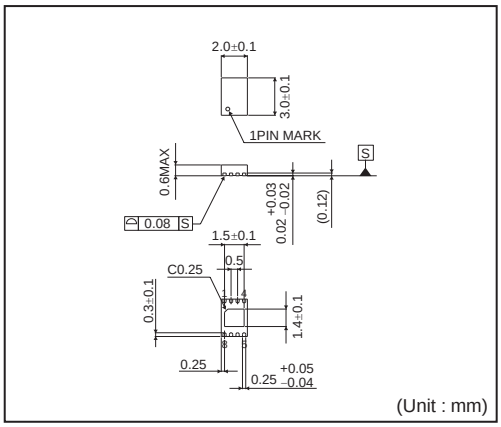
VSON008X2030 (TOP VIEW)



Marking	Part Number
D 6 0 A 0 0	BD60A00NUX
D 6 0 A 6 0	BD60A60NUX

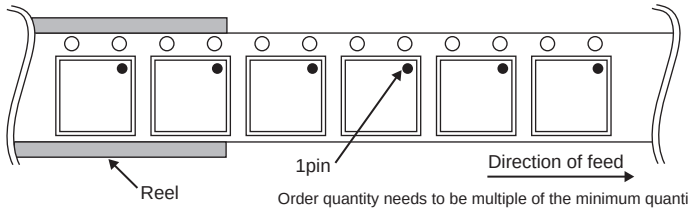
●Physical Dimension Tape and Reel Information

VSON008X2030



<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	4000pcs
Direction of feed	TR (The direction is the 1pin of product is at the upper right when you hold reel on the left hand and you pull out the tape on the right hand)



Order quantity needs to be multiple of the minimum quantity.

Status of this document
The Japanese version of this document is formal specification. A customer may use this translation version only for a reference to help reading the formal version.
If there are any differences in translation version of this document formal version takes priority.

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●**Revision History**

Date	Revision	Changes
27.Sep.2012	001	New Release
07.Feb.2013	002	P.2 Modify “High Input Voltage Range” Min.1.4V to 1.3V of [EN,PWM Terminal] of Electrical Characteristics P.11 Modify “High Input Voltage Range” Min.1.4V to 1.3V of Start control (EN) and select LED current driver (PWM)
07.Nov.2016	003	P.2 Electrical Characteristics SW Transistor ON Resistor change the Typ. value 1Ω to 2Ω. LED Current Limit change the Typ. value 0.1mA to 0.2mA. P.7 2) Soft Start 3rd line Before ; Soft start doesn't become effective even if Enable is changed L→ H, after that. After ; Soft start become effective even if Enable is changed H→ L→ H, after that. P.11 Figure6. Control signal input timing, change the voltage 2.2V to 2.7V. P.11 Before : ① … VIN exceeds 2.2V and UVLO is off. After : ① … VIN exceeds 2.7V and UVLO is off. P.11 Before : ② … Min.100µs from 2.2V to stable voltage for … After : ② … Min.100µs from 2.7V to stable voltage for … P.21 Ordering Information Add “ 0: BD60A00NUX 6: BD60A60NUX ”

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Notice

Precaution on using ROHM Products

1. Our Products are designed and manufactured for application in ordinary electronic equipments (such as AV equipment, OA equipment, telecommunication equipment, home electronic appliances, amusement equipment, etc.). If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), transport equipment, traffic equipment, aircraft/spacecraft, nuclear power controllers, fuel controllers, car equipment including car accessories, safety devices, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property ("Specific Applications"), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM's Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

2. ROHM designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:
   [a] Installation of protection circuits or other protective devices to improve system safety
   [b] Installation of redundant circuits to reduce the impact of single or multiple circuit failure

3. Our Products are designed and manufactured for use under standard conditions and not under any special or extraordinary environments or conditions, as exemplified below. Accordingly, ROHM shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any ROHM's Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc, prior to use, must be necessary:
   [a] Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
   [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
   [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
   [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
   [f] Sealing or coating our Products with resin or other coating materials
   [g] Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   [h] Use of the Products in places subject to dew condensation

4. The Products are not subject to radiation-proof design.

5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse. is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

Precaution for Mounting / Circuit board design

1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.

2. In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

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Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.

2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
   - [a] the Products are exposed to sea winds or corrosive gases, including Cl2, H2S, NH3, SO2, and NO2
   - [b] the temperature or humidity exceeds those recommended by ROHM
   - [c] the Products are exposed to direct sunshine or condensation
   - [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

Precaution for Product Label

A two-dimensional barcode printed on ROHM Products label is for ROHM's internal use only.

Precaution for Disposition

When disposing Products please dispose them properly using an authorized industry waste company.

Precaution for Foreign Exchange and Foreign Trade act

Since concerned goods might be fallen under listed items of export control prescribed by Foreign exchange and Foreign trade act, please consult with ROHM in case of export.

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General Precaution

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