

# 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  
( $V_{OUT}=3.6V \times 11 + 0.7V = 40.3V < V_F \text{ MAX} = 3.7V >$ )  
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.)

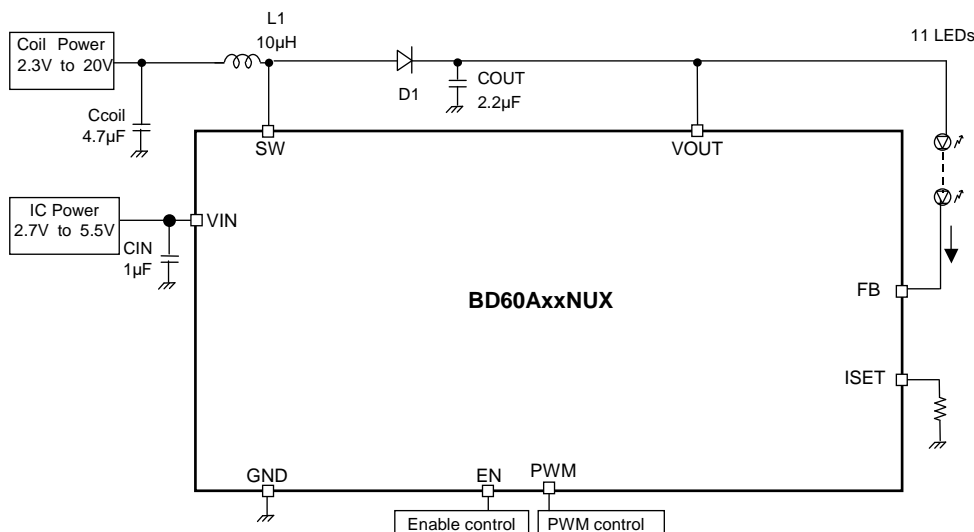

**VSON008X2030**

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



### ●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<br>BD60A00NUX |
| Maximum applied voltage 3   | VMAX3  | 31          | V    | FB, SW, VOUT terminals<br>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<br>BD60A00NUX        | OVP1   | 40     | 42   | 44   | V    | Detect voltage of VOUT terminal                     |
| Over Voltage Limit<br>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<br>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<br>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.

### ● 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       | ISSET    | 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

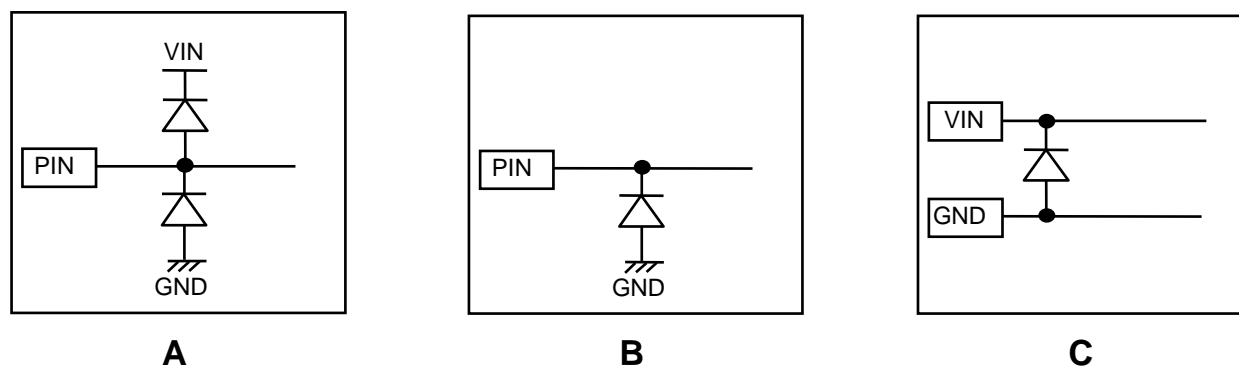
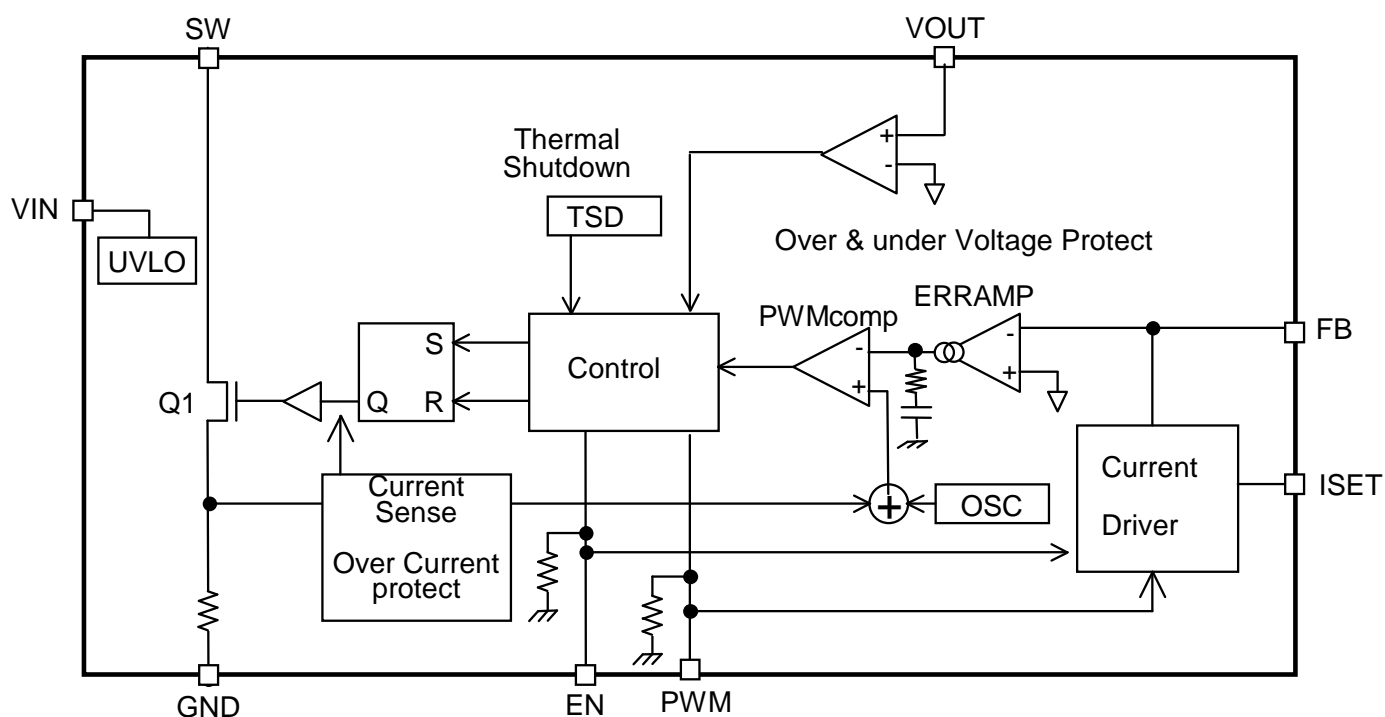


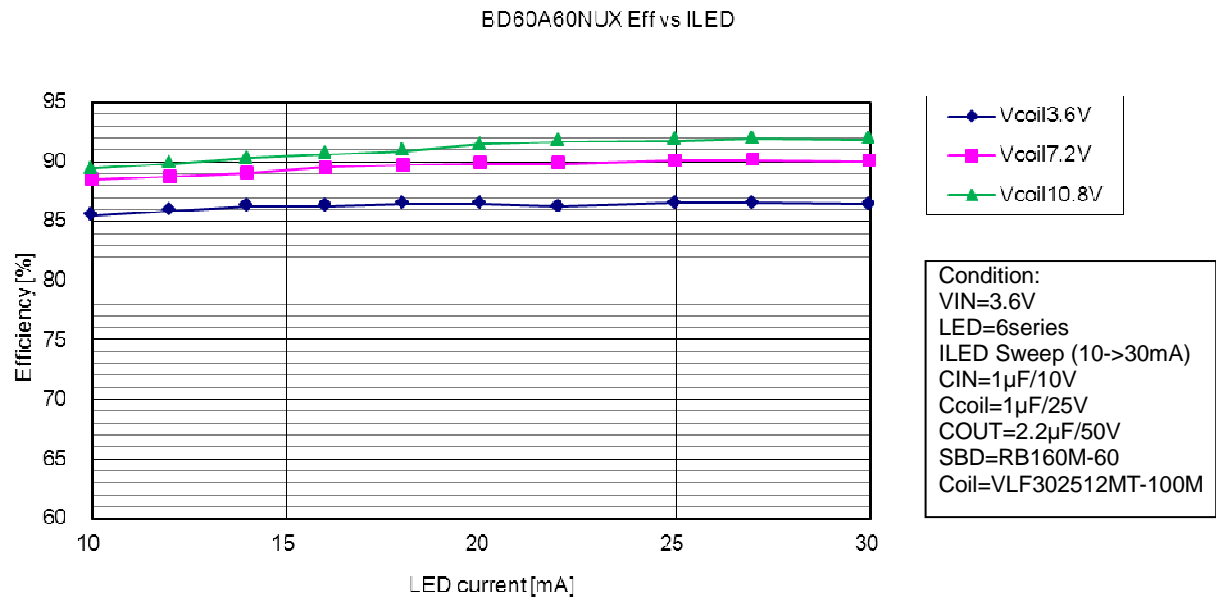
Figure 1. Pin ESD Type

### ●Block Diagram

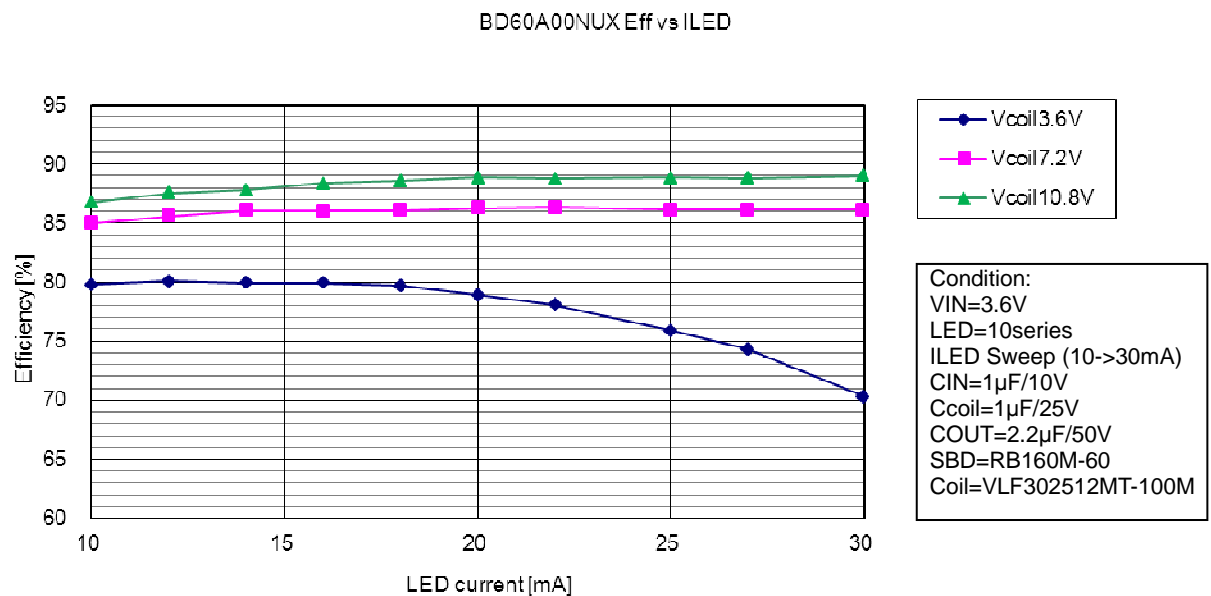


# Main characteristics examples

LED 6series, coil: VLF302512MT-100M



LED 10series, coil: VLF302512MT-100M

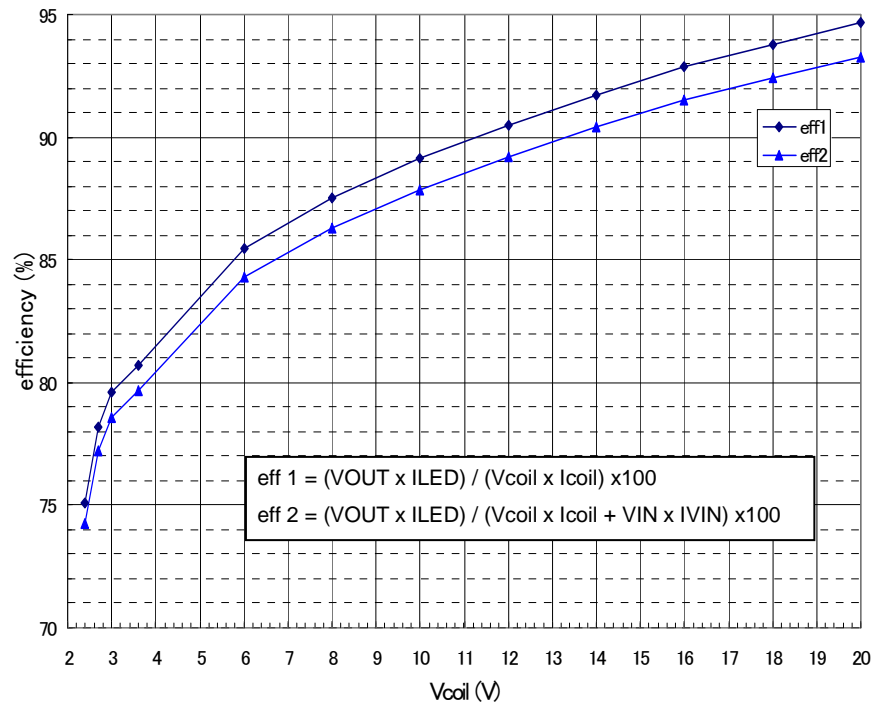


# Main characteristics examples- continued

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

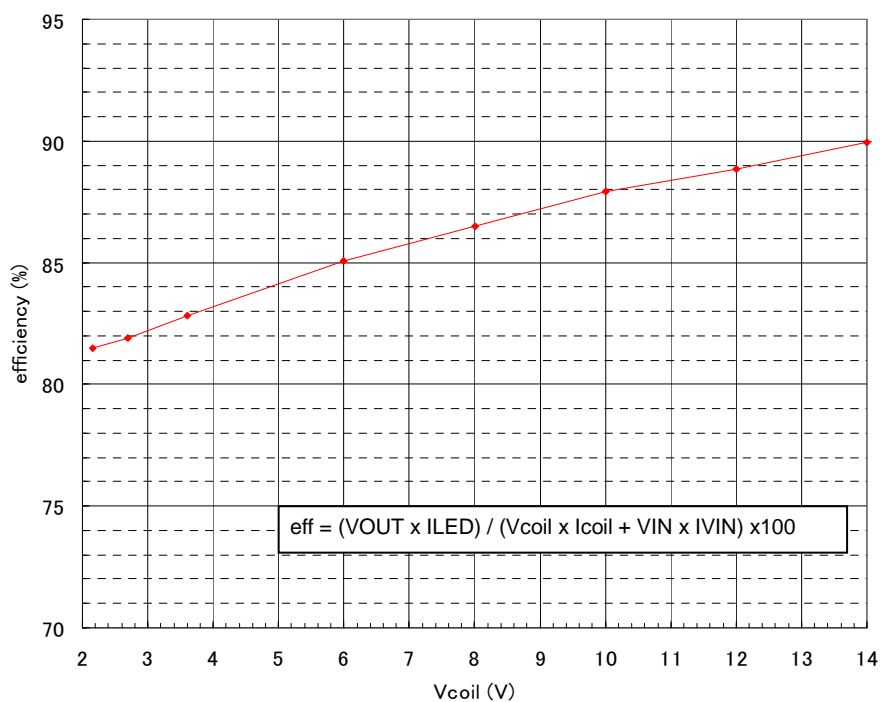
## BD60A00NUX

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

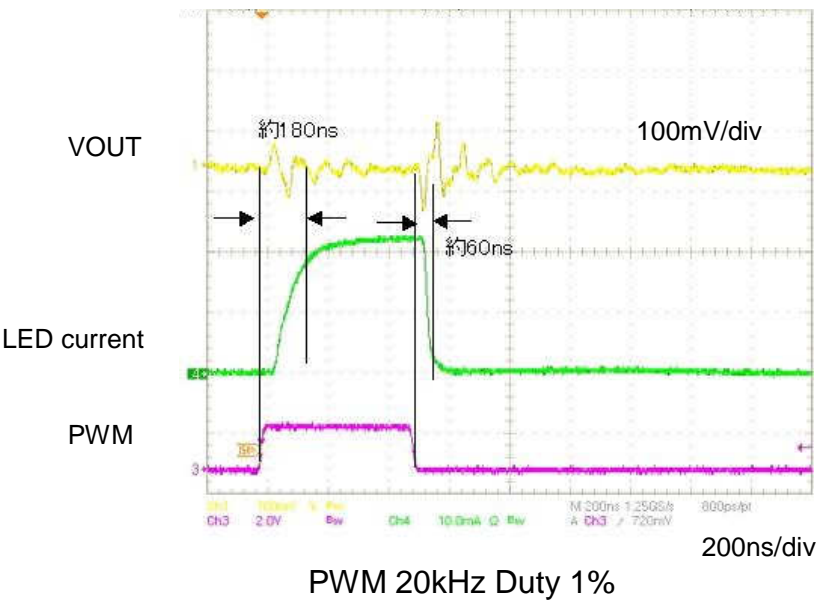
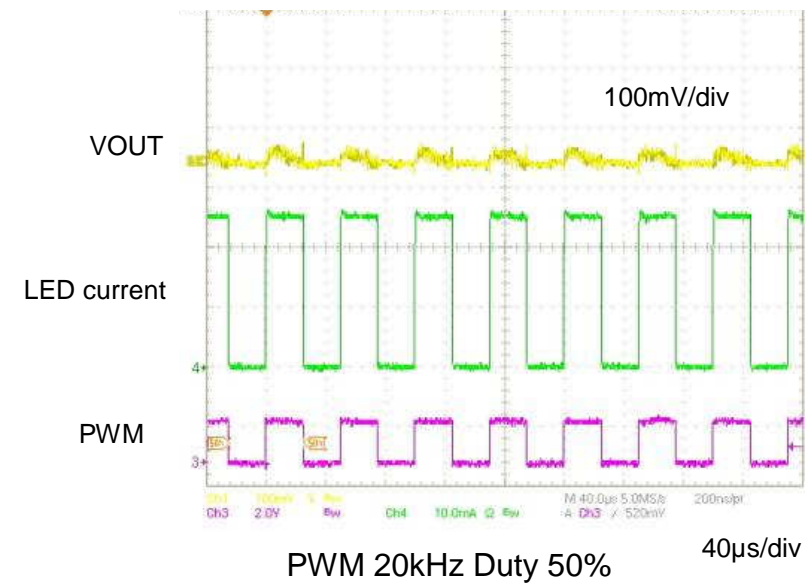


## BD60A60NUX

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



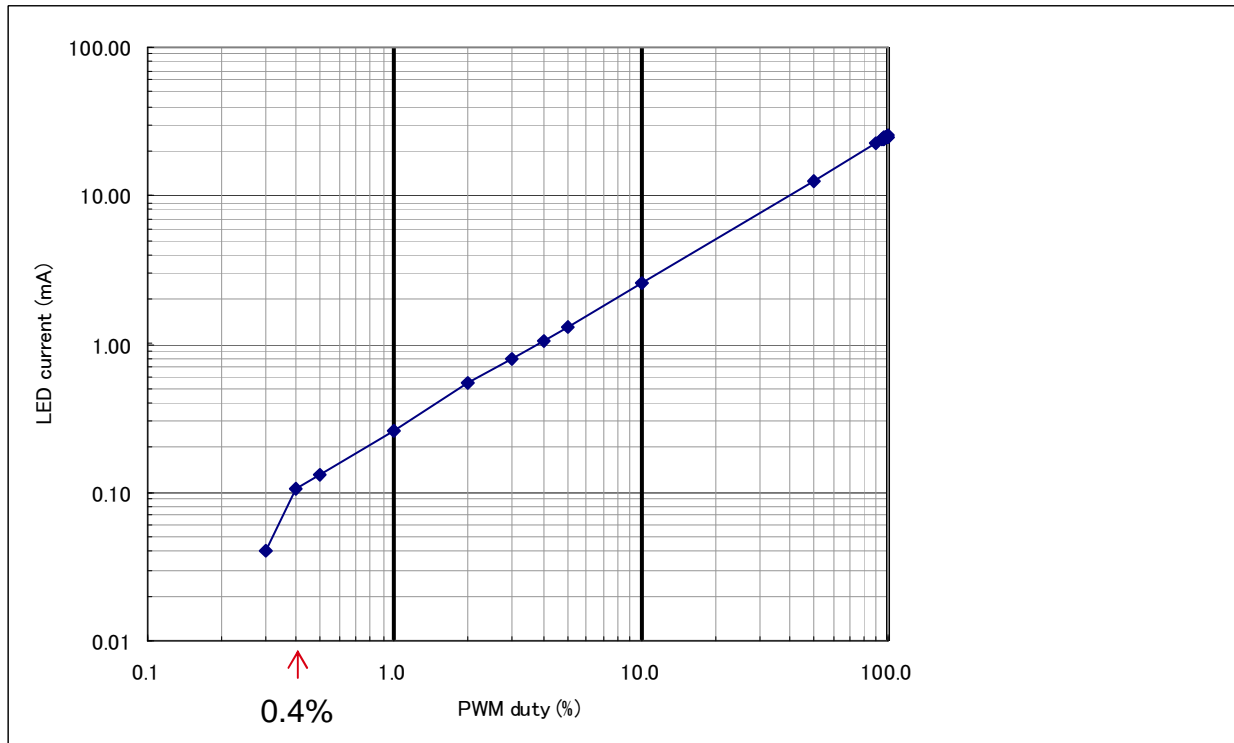
●Main characteristics examples- continued



### ●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.

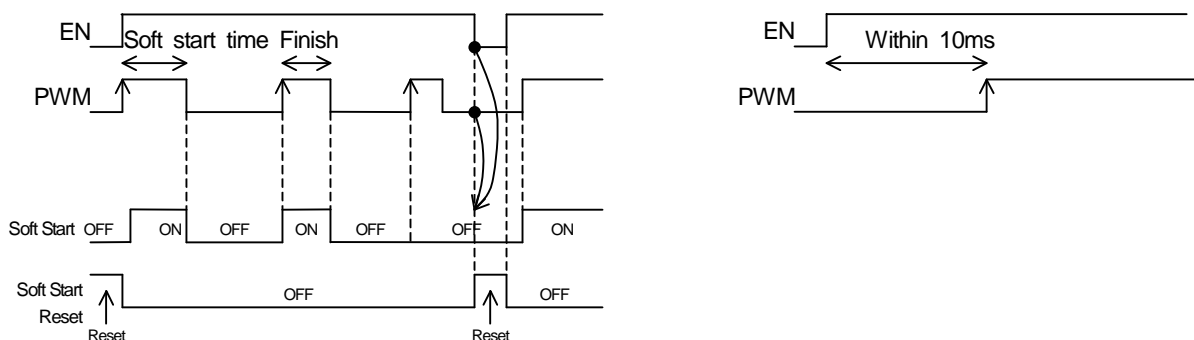


Figure 2. Soft start

## ●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

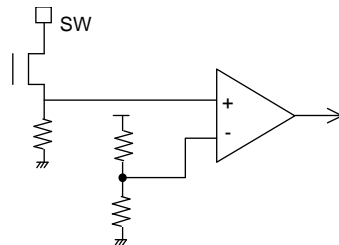
This IC has thermal shut down function.

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 = IOU
  - Average current of coil = Iave      ○ Peak current of coil = Ipeak
  - Efficiency = eff
  - ON time of switching transistor = Ton

$$I_{peak} = (VIN / L) \times (1 / fsw) \times (1 - (VIN / VOUT))$$

$$I_{ave} = (VOUT \times IOU / VIN) / eff$$

$$Ton = (I_{ave} \times (1 - VIN/VOUT) \times (1/fsw) \times (L/VIN) \times 2)^{1/2}$$

As peak current varies according to whether there is the direct current superposed, the next is decided.

$$(1 - VIN/VOUT) \times (1/fsw) < Ton \rightarrow \text{peak current} = I_{peak} / 2 + I_{ave} \text{ (continuous mode CCM)}$$

$$(1 - VIN/VOUT) \times (1/fsw) > Ton \rightarrow \text{peak current} = (VIN / L) \times Ton \text{ (discontinuous mode DCM)}$$

(Example 1)

In case of, VIN=6.0V, L=10μH, fsw=0.6MHz, VOUT=32.5V, IOU=25mA, current =85%

$$I_{peak} = (6.0V / 10\mu H) \times (1 / 0.6MHz) \times (1 - (6.0V / 32.5V)) = 0.82 \text{ A}$$

$$I_{ave} = (32.5V \times 25mA / 6.0V) / 85\% = 0.16A$$

$$Ton = (0.16A \times (1 - 6.0V / 32.5V) \times (1 / 0.75MHz) \times (10\mu H / 6.0V) \times 2)^{1/2} = 0.85\mu s$$

$$(1 - VIN/VOUT) \times (1/fsw) = 1.36\mu s > Ton$$

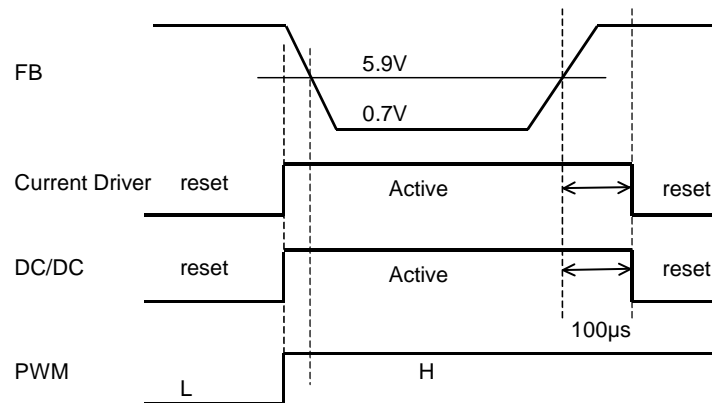
$$\text{peak current} = (6.0V / 10\mu H) \times 0.85\mu s = 0.51A$$



### ●Protection - continued

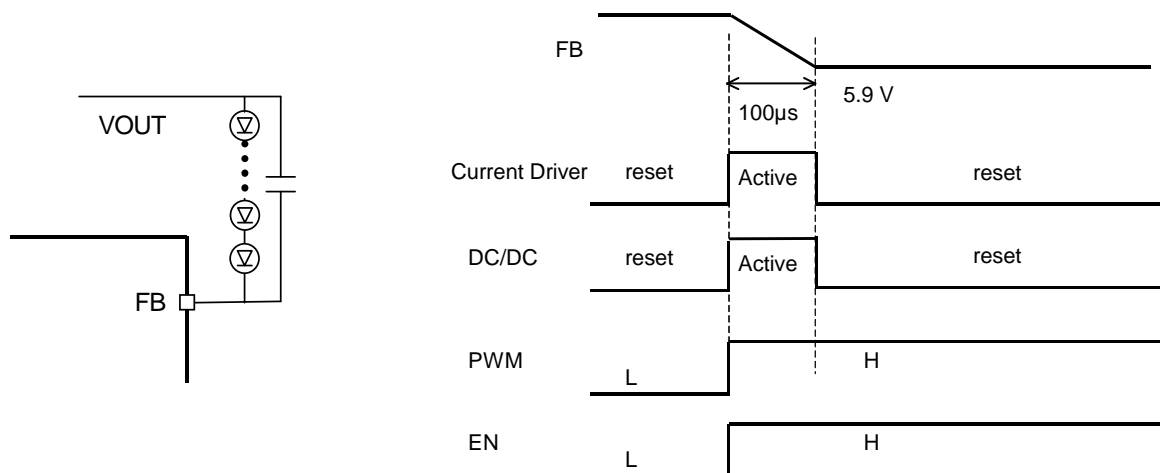
#### • LED terminal over voltage protection

When FB terminal becomes higher than 5.9V (Typ.), IC senses the situation trouble after 100 $\mu$ s 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.



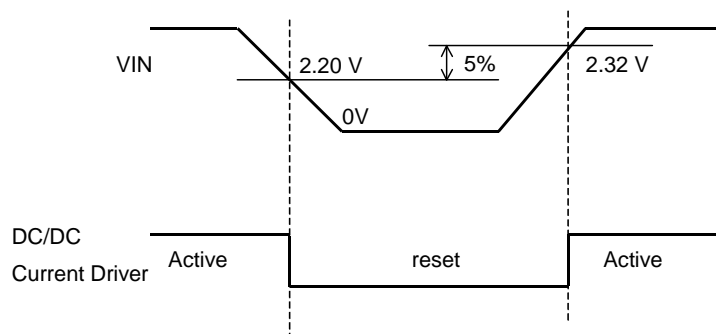
#### • Prevention of LED terminal over voltage protection malfunction

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 100 $\mu$ s. 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 100 $\mu$ s 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.



### ●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.

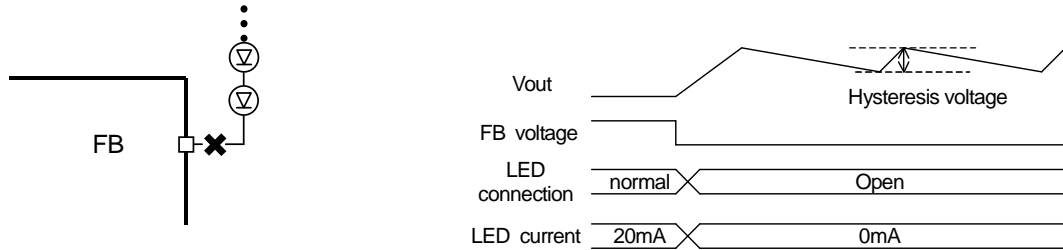


Figure 3. LED open detect

#### 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.

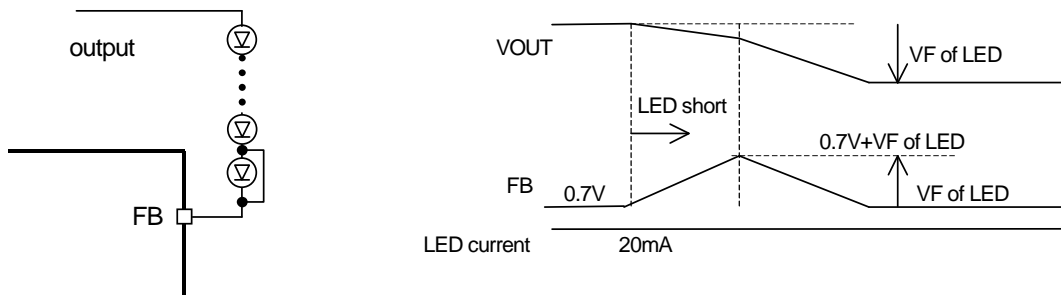


Figure 4. One LED shorted

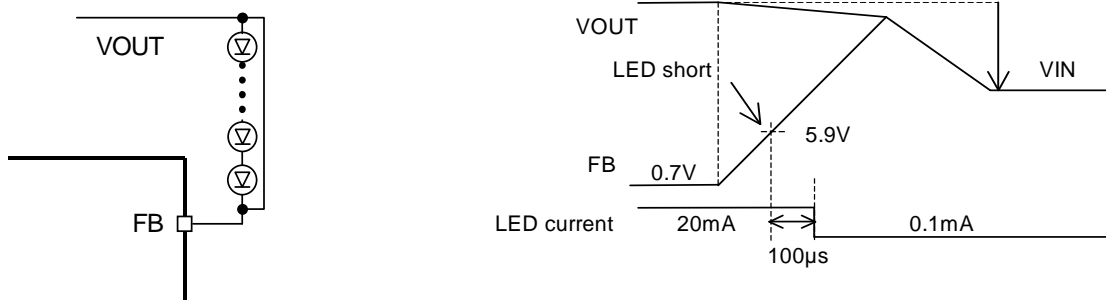


Figure 5. FB terminal – VOUT terminal shorted

### ●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

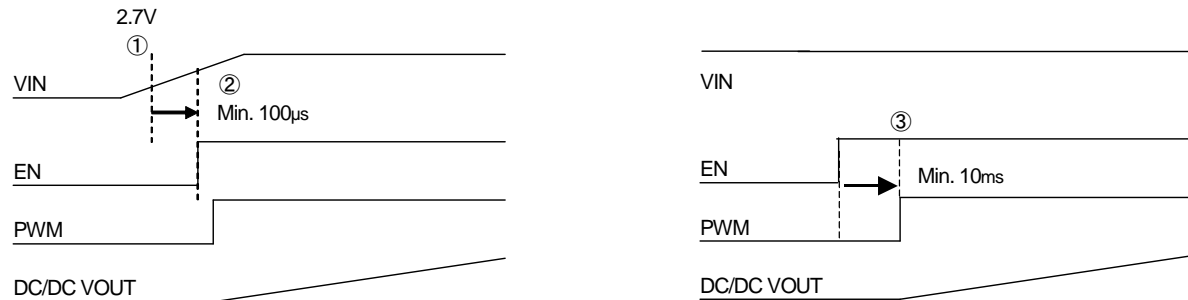


Figure 6. Control signal input timing

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 resistor (RISET) connected to ISET voltage.

Each setting current is shown as below.

Normal current =  $600/\text{RISET}$  [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      |

## ●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.

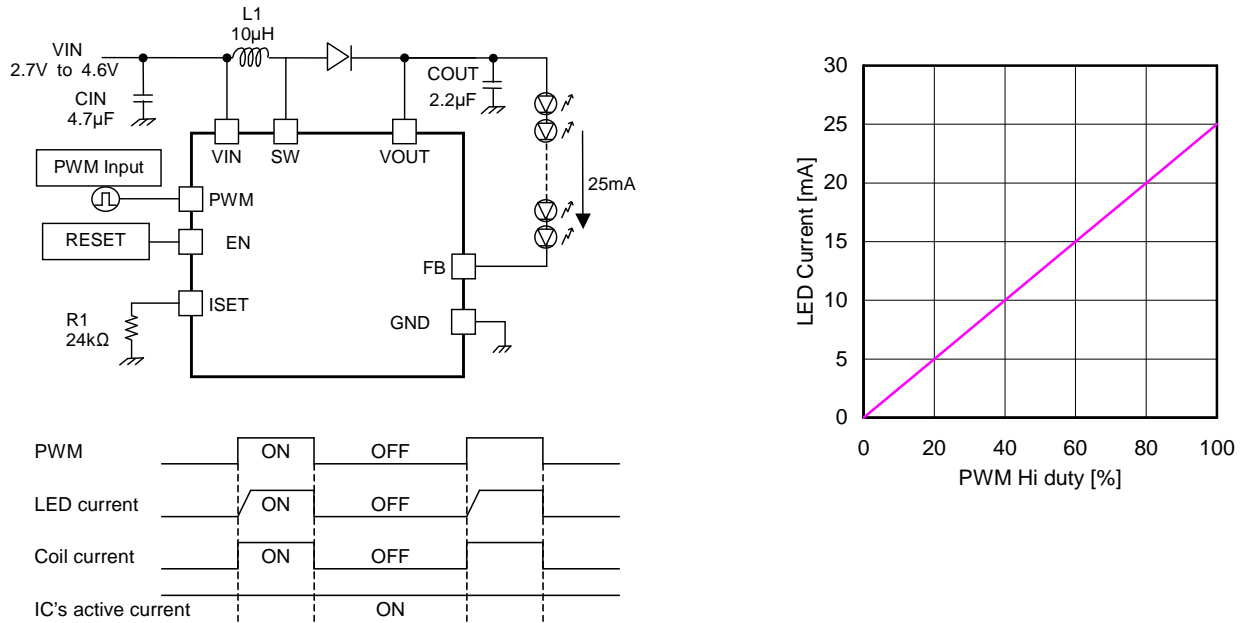
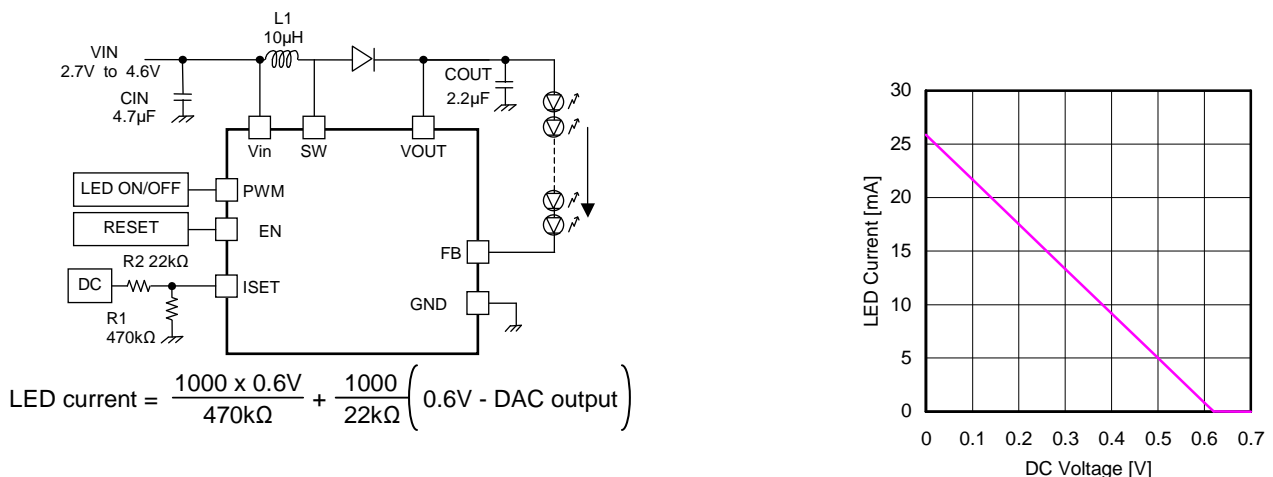


Figure 7. PWM sequence

- 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

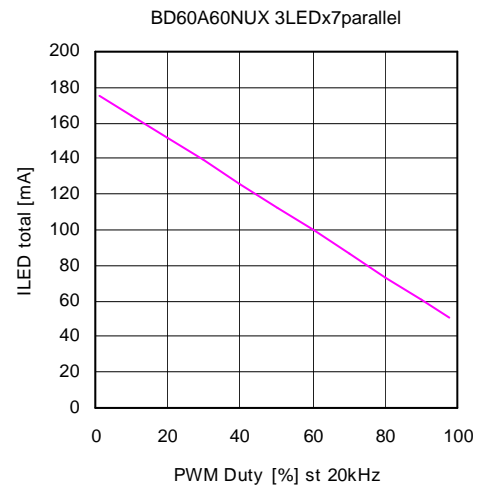
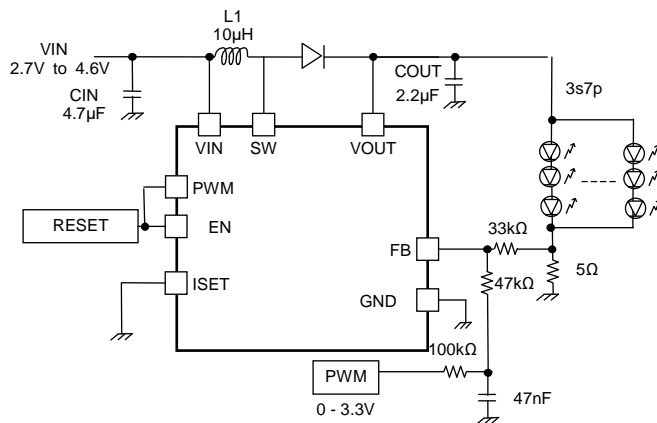
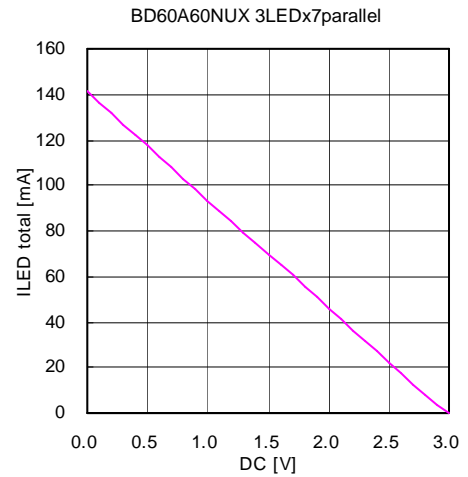
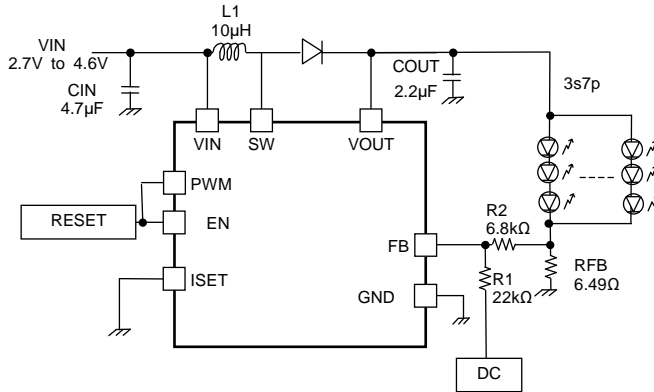


### ●Brightness control - continued

- 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.

$$I_{LED} = [((V_{FB} - DC) / R_1) * R_2 + I_{SET}] / R_{FB}$$



### ●The coil selection

The DC/DC is designed by more than  $4.7\mu\text{H}$ . 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  $3.3\mu\text{H}$  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  $V_{\text{coil}}=2.3\text{V}$  to 5.5V, please make output capacitor more than  $2.2\mu\text{F}$ . 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 = Cerror
- Total LED current = ILED
- Output ripple Voltage = V<sub>ripple</sub>
- Output Capacitor (real value) = C<sub>real</sub>

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

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

$C_{\text{OUT}} = I_{\text{LED}} \times (1-D) \times T / V_{\text{ripple}} / C_{\text{error}}$

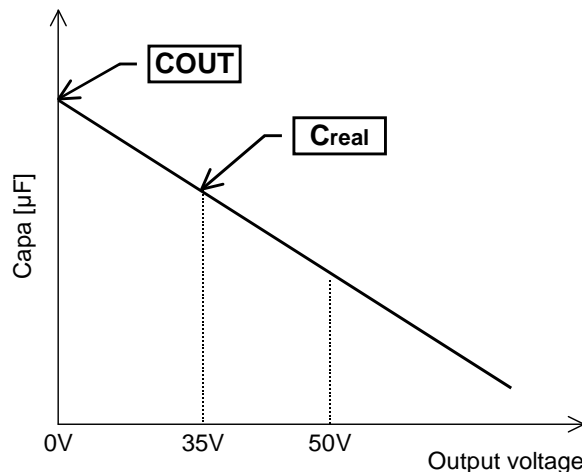
(Example 1)

In case of,  $V_{\text{IN}}=5.0\text{V}$ ,  $f_{\text{sw}} = 0.6\text{MHz}$ ,  $V_{\text{OUT}} = 32.5\text{V}$ ,  $I_{\text{LED}} = 20\text{mA}$ ,  $C_{\text{OUT}} = 2.2\mu\text{F}$ ,  $C_{\text{error}} = 50\%$

$T = 1 / 0.6\text{MHz}$

$D = 1 - V_{\text{IN}} / V_{\text{OUT}} = 1 - 5/32.5$

$V_{\text{ripple}} = I_{\text{LED}} \times (1-D) \times T / (C_{\text{OUT}} \times C_{\text{error}}) = 20\text{mA} \times (5/32.5) \times (1 / 0.6\text{MHz}) / (2.2\mu\text{F} \times 0.5)$   
 $= 4.7\text{mV}$



### ●LED selection

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

●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.

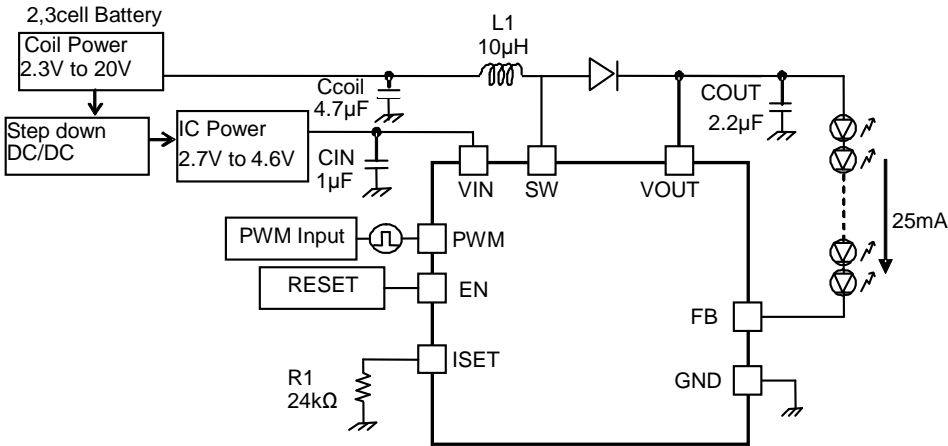


Figure 8. Application at the time of power supply separation

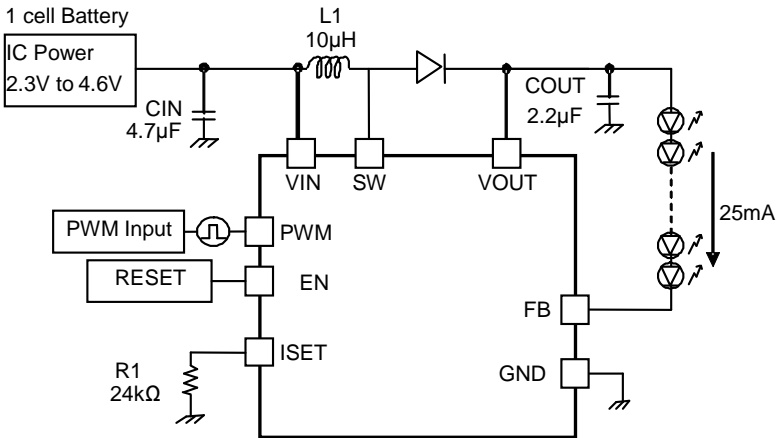


Figure 9. Application at the time of power supply common

The number of available LEDs by each power supply voltage condition

PWM dimming(LED current setting=25mA)

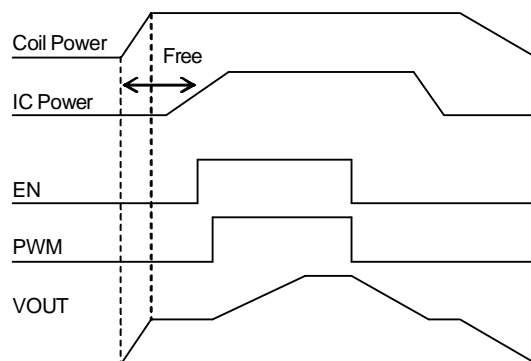
| 1セル  |    |      |    |    | 2セル |    |    |    |    |     |     |     | 3セル |     |     |     |     |     |     |     |
|------|----|------|----|----|-----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| VIN  |    | 2.7V | 3V | 4V | 5V  | 6V | 7V | 8V | 9V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

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

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

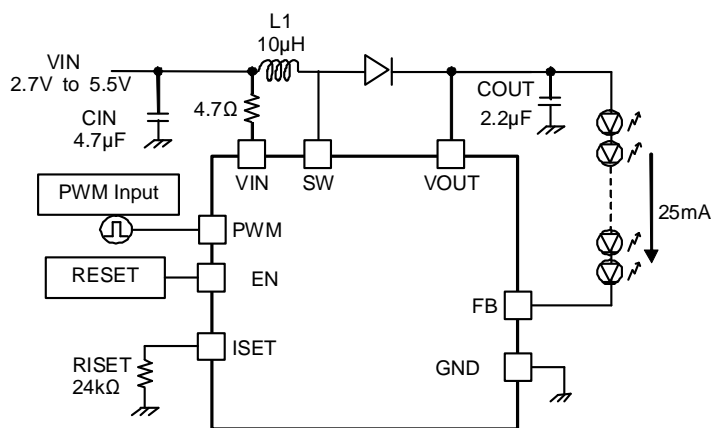
Even if the IC power supply is 0V, leak channel is blocked as pull down resistor for power off is placed inside the IC. The resistor intercepts leak channel from coil power supply. Additionally, there is no order for standing up and down of coil and IC power supply.

- 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)

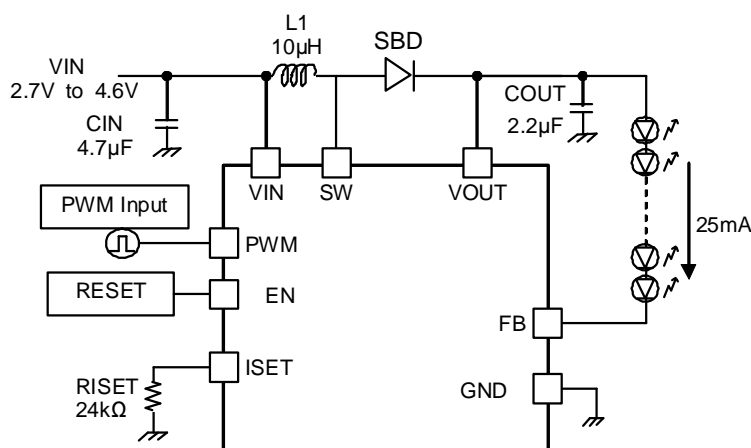
The GND noise become big by impedance of PCB boards, so that wake up characteristics might become unstable. To select input voltage to 5V(input voltage 4.61V over), we recommend under application to insert 4.7Ω between input voltage line and Vin terminal





## ●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 L1 and 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.

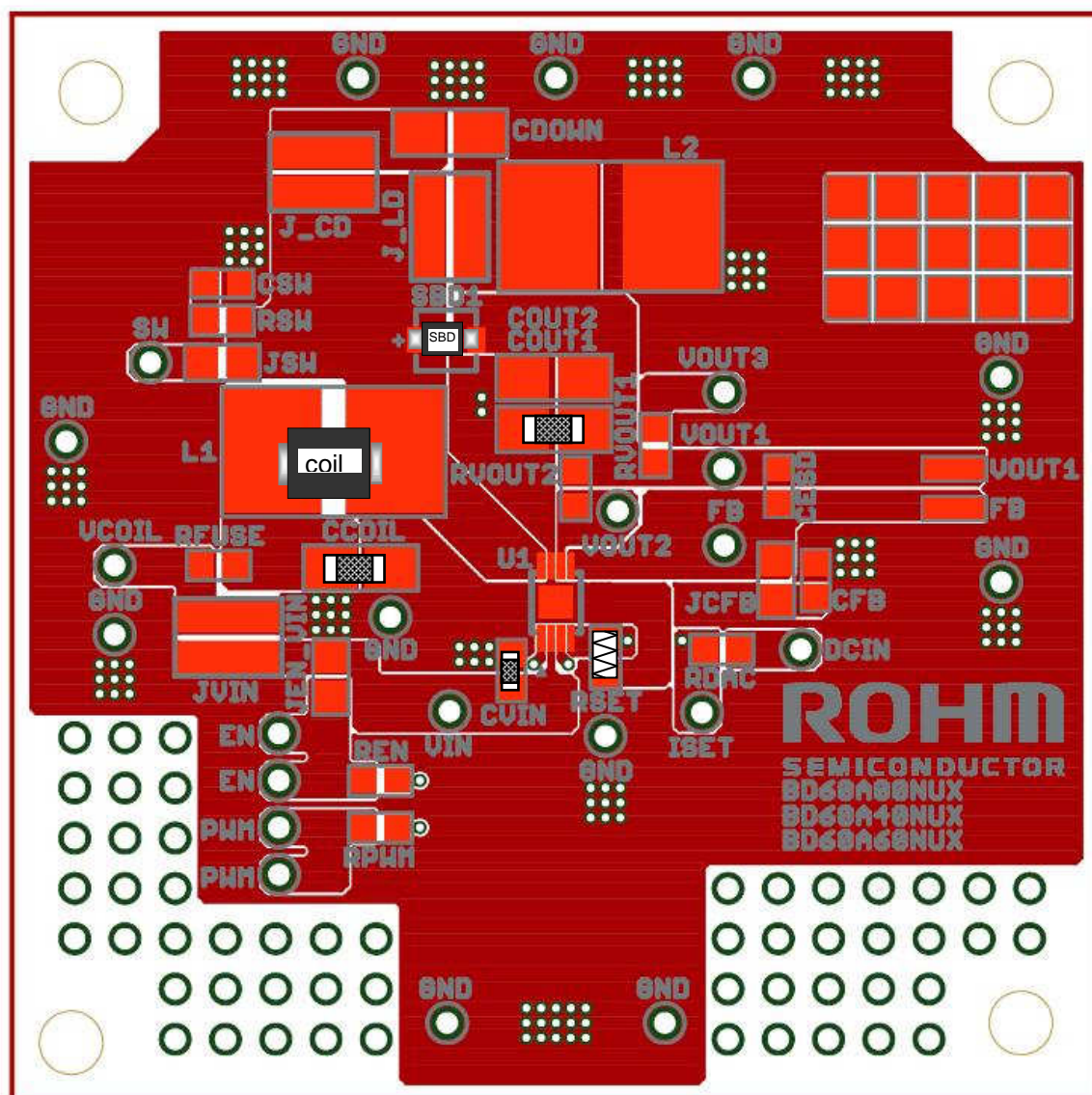
### <Heat radiation of back side PAD>

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.

### ●Recommended PCB layout



### ● 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<br>(mA) | DCR<br>(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 bypass 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                                   | Pressur<br>e | Manufactur<br>e | 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.

| [RSET : Resistor used for deciding LED current] |           |              |                |          |            |        |           |
|---|-----------|--------------|----------------|----------|------------|--------|-----------|
| Value   | Tolerance | Manufacturer | Product number | Size     |            |        | ILED (mA) |
|   |           |              |                | Vertical | Horizontal | Height |           |
| 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    |

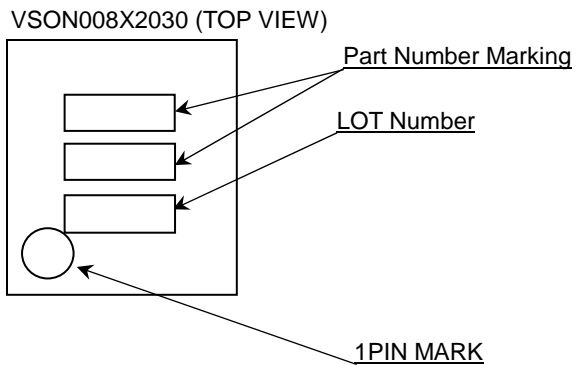
**●Operational Notes**

- (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.

●Ordering Information

|                     |  |  |                                |  |  |                              |  |  |  |   |     |  |
|---------------------|--|--|--------------------------------|--|--|------------------------------|--|--|--|---|-----|--|
| B D 6 0 A x 0 N U X |  |  |                                |  |  |                              |  |  |  | - | T R |  |
| Part Number         |  |  | 0: BD60A00NUX<br>6: BD60A60NUX |  |  | Package<br>NUX: VSON008X2030 |  |  | Packaging and forming<br>specification<br>TR: Embossed tape and reel |   |     |  |

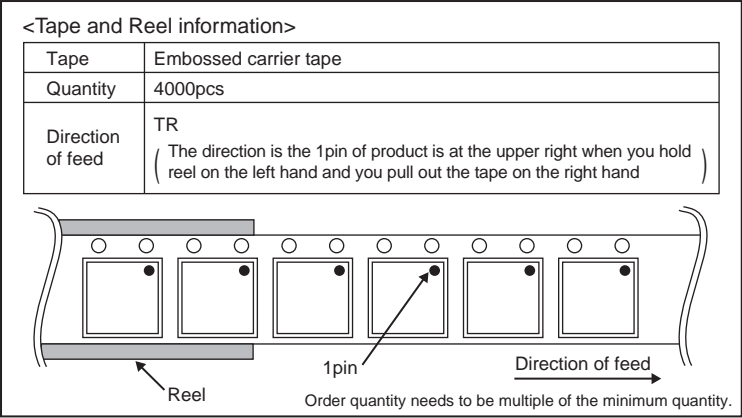
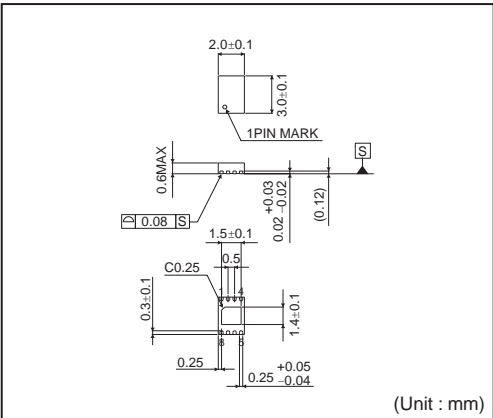
●Marking Diagram



| Marking        | Part Number |
|----------------|-------------|
| D 6 0<br>A 0 0 | BD60A00NUX  |
| D 6 0<br>A 6 0 | BD60A60NUX  |

●Physical Dimension Tape and Reel Information

VSON008X2030



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.

## ●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<br>of [EN,PWM Terminal] of Electrical Characteristics<br>P.11 Modify "High Input Voltage Range" Min.1.4V to 1.3V<br>of Start control (EN) and select LED current driver (PWM)   |
| 07.Nov.2016 | 003      | P.2 Electrical Characteristics<br>SW Transistor ON Resistor change the Typ. value $1\Omega$ to $2\Omega$ .<br>LED Current Limit change the Typ. value 0.1mA to 0.2mA.<br><br>P.7 2) Soft Start 3rd line<br>Before ; Soft start doesn't become effective even if Enable is changed L→H, after that.<br>After ; Soft start become effective even if Enable is changed H→L→H, after that.<br><br>P.11 Figure6. Control signal input timing, change the voltage 2.2V to 2.7V.<br><br>P.11<br>Before : ① ... VIN exceeds 2.2V and UVLO is off.<br>After : ① ... VIN exceeds 2.7V and UVLO is off.<br><br>P.11<br>Before : ② ... Min.100μs from 2.2V to stable voltage for ...<br>After : ② ... Min.100μs from 2.7V to stable voltage for ...<br><br>P.21 Ordering Information<br>Add "0: BD60A00NUX 6: BD60A60NUX " |

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(Note1) Medical Equipment Classification of the Specific Applications

| JAPAN     | USA       | EU         | CHINA     |
|-----------|-----------|------------|-----------|
| CLASS III | CLASS III | CLASS II b | CLASS III |
| CLASS IV  |           | CLASS III  |           |

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  - Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
  - Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
  - Sealing or coating our Products with resin or other coating materials
  - 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
  - Use of the Products in places subject to dew condensation
- The Products are not subject to radiation-proof design.
- Please verify and confirm characteristics of the final or mounted products in using the Products.
- 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.
- 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.
- Confirm that operation temperature is within the specified range described in the product specification.
- ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

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- 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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  - [a] the Products are exposed to sea winds or corrosive gases, including Cl<sub>2</sub>, H<sub>2</sub>S, NH<sub>3</sub>, SO<sub>2</sub>, and NO<sub>2</sub>
  - [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
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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.
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