LED Drivers for LCD Backlights

White Backlight LED Drivers for Small to Medium LCD Panels (Switching Regulator Type)

BD6067GU, BD6069GUT, BD6071HFN, BD6072HFN   No.11040ECT19

● Description

Switching Regulator type LED Driver Series for small LCD backlight are boost DC/DC converters possible to drive the white LEDs at constant. It is possible that turning on white LED steadily by a series connection which has no current variation, and by a fast transient response with current mode. And, BD6069GUT/BD6071HFN/BD6072HFN are white LED driver ICs with synchronous rectification. With synchronous rectification (no external schottky diode required) and small package, they can save mount space. BD6071HFN suited over voltage and over current limit from BD6069GUT/BD6072HFN.

● Features

1) Boost DC/DC converter
2) Adjustment of brightness by external PWM pulse
3) Possible to driving 3 LEDs (BD6071HFN)
4) Possible to driving 4 LEDs (BD6069GUT, BD6072HFN)
5) Possible to driving 8 LEDs (BD6067GU)
6) Soft start function (BD6067GU, BD6069GUT, BD6071HFN, BD6072HFN)
7) Synchronous rectification Boost DC/DC converter (BD6069GUT, BD6071HFN, BD6072HFN)
8) No external schottky diode required (BD6069GUT, BD6071HFN, BD6072HFN)
9) Output Open • Short protect (BD6069GUT, BD6071HFN, BD6072HFN)

● Applications

These drivers are applicable for various fields such as mobile phones, portable game machines, Inter-phone camera, audio player, portable DVD player, back light for printer display etc… and support light of the camera for the mobile phone, simple flash. And, these can use power supply for OEL.

● Line up matrix

Parameter	Input voltage range	Switching frequency	White LED number	Operating temperature range	Package
BD6067GU	2.7 ~ 5.5V	0.8 ~ 1.2MHz	5　~　8	-30 ~ +85℃	VCSP85H1
BD6069GUT	2.7 ~ 5.5V	0.8 ~ 1.2MHz	4	-30 ~ +85℃	VCSP60N1
BD6071HFN	2.7 ~ 5.5V	0.8 ~ 1.2MHz	3	-30 ~ +85℃	HSON8
BD6072HFN	2.7 ~ 5.5V	0.8 ~ 1.2MHz	4	-30 ~ +85℃	HSON8

►BD6067GU

●**Absolute maximum ratings** (Ta=25℃)

Parameter	Symbol	Ratings	Unit	Conditions
Power supply voltage 1	VMAX1	7 [*1]	V	Applicable to Vin, EN, Vfb and VDAC pins
Power supply voltage 2	VMAX2	40 [*1]	V	Applicable to SW and Vout pins
Operating temperature range	Topr	-30 ~ +85	℃	
Storage temperature range	Tstg	-55 ~ +150	℃	
Power dissipation	Pd	800 [*2]	mW	50mm×58mm×1.75mm Glass epoxy PCB mounting

*1   This value is based on GND.
*2   This loss decreases approximate 6.4mW/℃ when Ta is 25℃ or more.

●**Recommended Operation Range** (Ta=-30℃ to +85℃)

Parameter	Symbol	Ratings	Unit	Conditions
Operating supply voltage	VCC	2.7 ~ 5.5	V	Vin pin

●**Electrical characteristics** (Unless otherwise stated, Ta is 25℃ and Vin is 3.6V.)

Parameter	Symbol	Limits			Unit	Conditions
		Min.	Min.	Min.		
<EN pin>						
'L' level input voltage	VthL	-	-	0.4	V	
'H level input voltage	VthH	1.4	-	-	V	
'H' level input current	IIH	-	18.3	30.0	µA	EN=5.5V
'L' level input current	IIL	-2.0	-0.1	-	µA	EN=0V
<DAC control pin>						
VDAC-Vfb resistance	V_{DAR}	56	112	168	kΩ	
<Switching regulator>						
Input voltage range	Vin	3.1	-	5.5	V	
Quiescent current	Iq	-	0.1	2.0	µA	EN=0V
Operating current	Idd	-	0.9	1.4	mA	EN=3.6V, Vfb=1.0V
VFB pin control voltage	Vfb	0.18	0.20	0.22	V	
Over current limit	Icoil	450	600	750	mA	[*1]
SW transistor ON resistance	Ronn	-	0.5	1.4	Ω	Isw=200mA
Switching frequency	fSW	0.8	1.0	1.2	MHz	
Maximum duty	Duty	92.5	95.0	-	%	Vfb=0V
Output voltage range	Vo	-	-	30.0	V	
Over voltage protection	Ovp	30.0	31.0	32.0	V	Vfb=0V
Output open protection	Ovl	-	0.7	1.4	V	
Startup time	Ts	-	0.5	1.0	ms	Vout=24V

*1   The DC current is measured in this item.

►BD6067GU
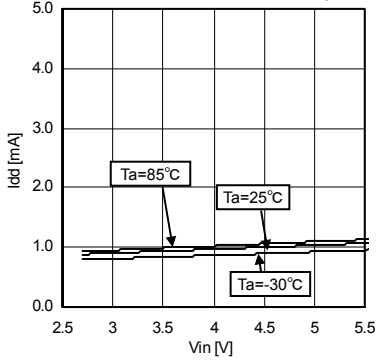●Electrical characteristic curves (Reference data)

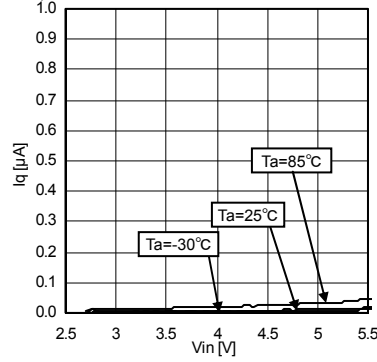Fig.1 Operating current vs. Power
Supply Voltage

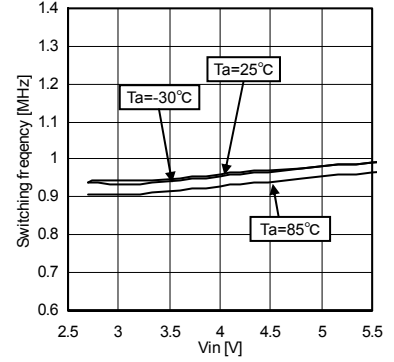Fig.2 Quiescent current vs. Power
Supply Voltage
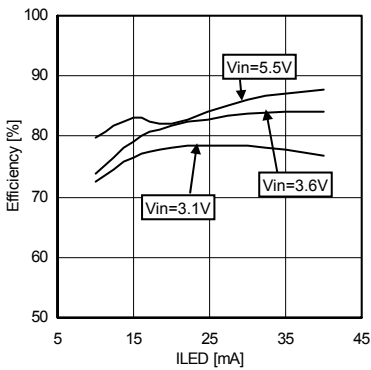

Fig.3 Oscillation Frequency vs.
Power Supply Voltage
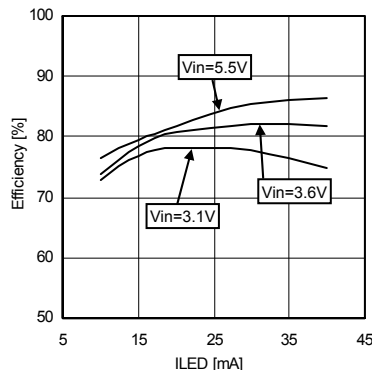

Fig.4 Efficiency vs. LED Current
(6LED) (Ta=25℃)
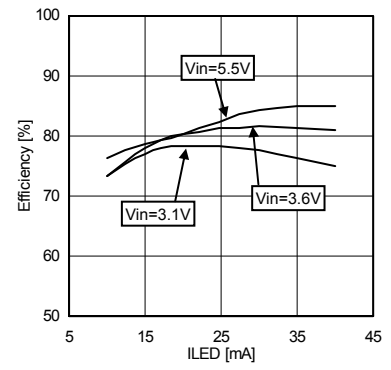

Fig.5 Efficiency vs. LED Current
(7LED) (Ta=25℃)

Fig.6 Efficiency vs. LED Current
(8LED) (Ta=25℃)
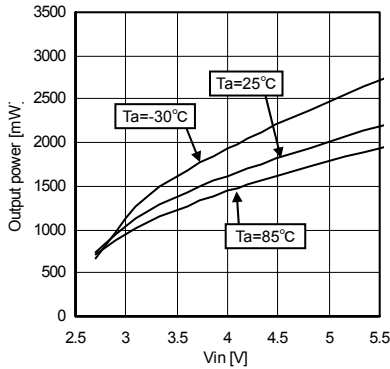

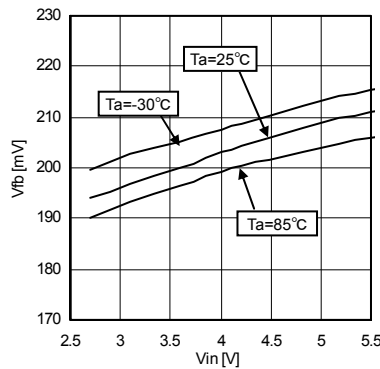Fig.7 Output Voltage vs.
Power Supply Voltage
(8LED)

Fig.8 VFB Pin Control Voltage vs.
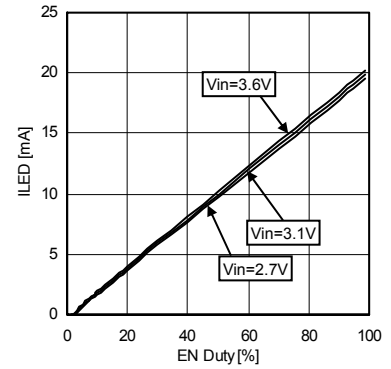Power Supply Voltage
(8LED) (ILED=20mA)

Fig.9 EN Pin
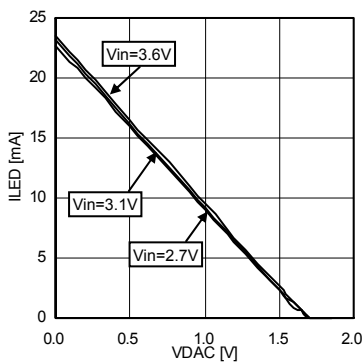PWM Brightness Control Characteristic
(f=100Hz, Ta=25℃)

Fig.10 DAC
Brightness Control Characteristic
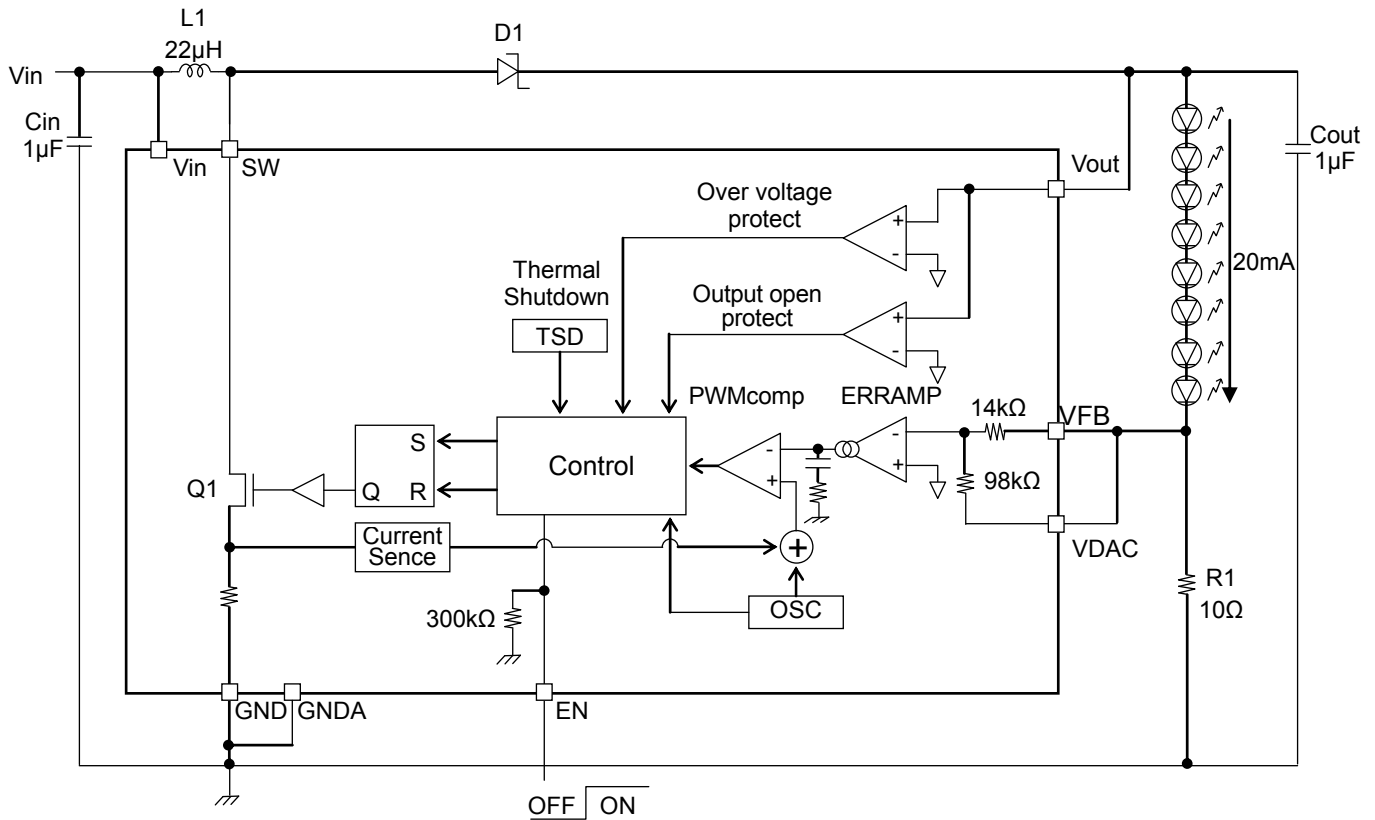
►BD6067GU
●Block Diagram and Recommended Circuit Example

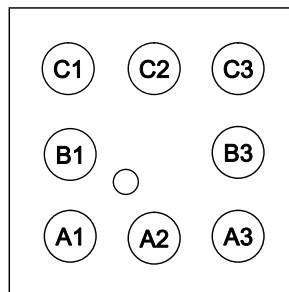Fig.11 Block Diagram and Recommended Circuit Example

Fig.12 Pin location diagram VCSP85H1 (Bottom view)

●Pin assignment table

Pin number	Pin name	In/Out	Function
A1	GNDA	-	Analog GND
A2	EN	In	Enable control (pull-down by internal resistance)
A3	VDAC	In	Analog signal input for current adjustment
B1	Vin	-	Supply voltage input
B3	VFB	In	Feedback voltage input
C1	VOUT	In	Over voltage protection input SBD open protection input
C2	SW	In	Switching pin
C3	GND	-	Power GND

►BD6067GU
● Release Circuit Protection
1) Operation

BD6067GU is a constant frequency PWM current mode DC/DC converter. It is shown in the block diagram of Fig.11. In a PWM comparator forming one of the PWM current mode features, one is an error element from the error amplifier and another is an element produced by superimposing the inductor current on a slope waveform that prevents sub-harmonic oscillation. This output controls Q1 via the RS latch. Energy is stored in an external inductor whileQ1 is ON and then it is moved to the COUT capacitor via D1 while Q1 is OFF. In this way, voltage Vout higher than input voltage Vin can be obtained. Because the above operation is performed in a way that the VFB pin voltage equals the Vfb voltage, the boost voltage is dominantly determined by the expression "Vf × number of LEDs."

Vout voltage = (Vf × number of LEDs) + Vfb

2) LED current control

The LED current is determined depending on the VFB pin voltage "Vfb" and the resistance connected to VFB. I_{LED} is given below.

I_{LED} =200mV/ R1

I_{LED} [mA]	BD6067GU R1 [Ω]
5	39
10	20
12	16
15	13
20	10

3) Dimming control

▪ Control by PWM signal

The startup condition of BD6067GU is controlled via the SHDNB/EN pin. It is powered OFF at 0.4V or less and powered ON at 1.4V or more.

As shown in Fig.13, brightness is controlled in the BD6067GU via the PWM signal input the SHDNB/EN pin. In this way, the LED current is controlled in a range from 0 to the maximum current. The average LED current increases in proportion to the Duty cycle of the PWM signal. In the PWM off cycle, no current dissipation takes place in IC and LEDs, resulting in high efficiency. Duties below 5% and above 95% must no be used for brightness control because they significantly affects the leading and trailing edges. BD6067GU standard PWM frequency ranges from 100Hz to 300Hz.
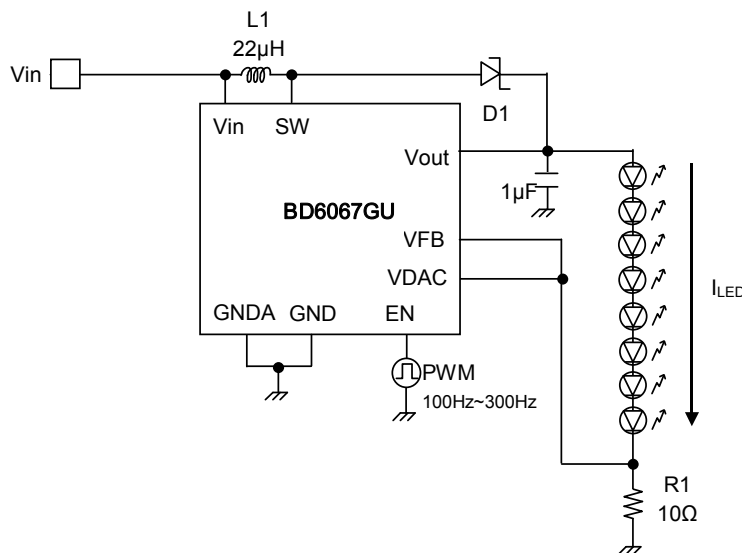

Fig.13 Example of Brightness Control by PWM signal at the EN Pin

►BD6067GU

▪ Control by DC Voltage
  BD067GU has a built-in function for LED current control by DC voltage and can control the current by VDAC pin control voltage.
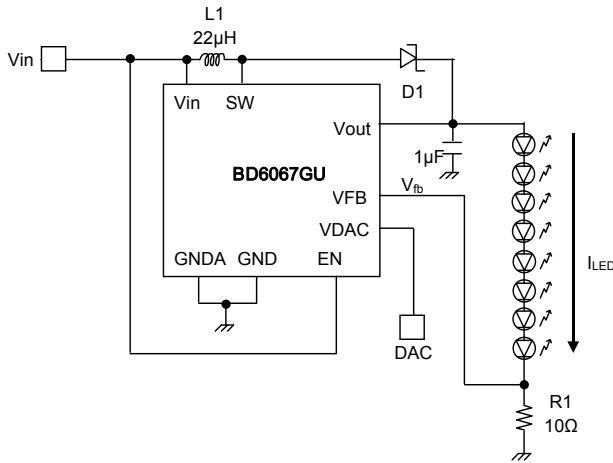

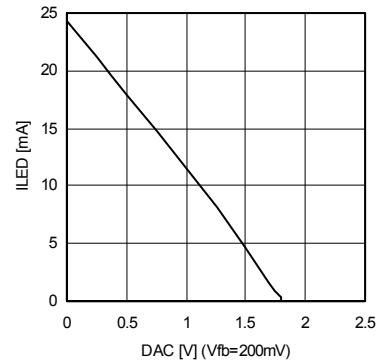Fig.14 Brightness Control by BD6067GU DAC

Fig.15 DAC Constant Current Characteristics by DAC Control

●Over voltage Protection
  BD6067GU has an over voltage protection feature. When a fault occurs, for example, IC is disconnected from LED, an excessive voltage rise may cause the SW pin and VOUT pin to exceed the absolute maximum ratings respectively, resulting in IC damage. For this reason, when VOUT is 30V or more, over voltage protection is activated to turn Q1 off so that the SW pin and VOUT pin don't exceed the absolute maximum ratings.
  At this time, the IC state changes from active to inactive and the output voltage drops slowly. Then, when the output voltage falls below the over voltage protection hysteresis level, the output voltage continues to rise up to 30V again.
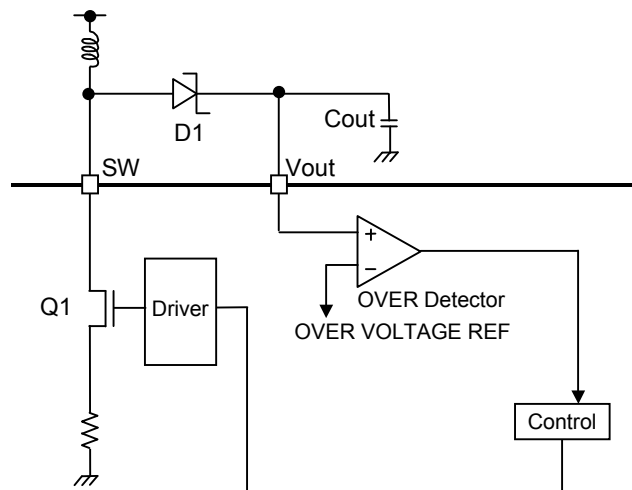 This protection circuit is shown in Fig.16.

Fig.16 Block Diagram for Short-circuit Protection and over voltage Protection

►BD6067GU
●Startup and Rush Current
   BD6067GU has a built-in soft start function. This function prevents the rush current from being generated at startup time.
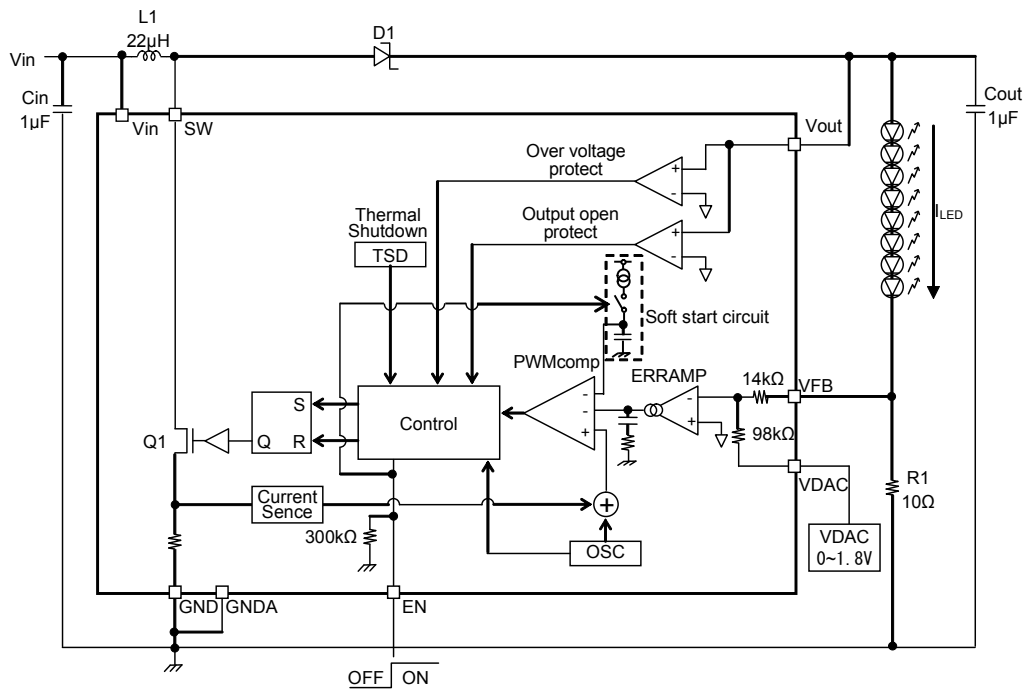

Fig.17 Soft Start Circuit

●Application Circuit Example
   The output maximum voltage range of BD6067GU is 30V.
   *** When LED has 8 lights, special care should be taken to prevent output voltage (VOUT) from exceeding 30V.

   VOUT = (LED vf × number of LED lights) + Vfb
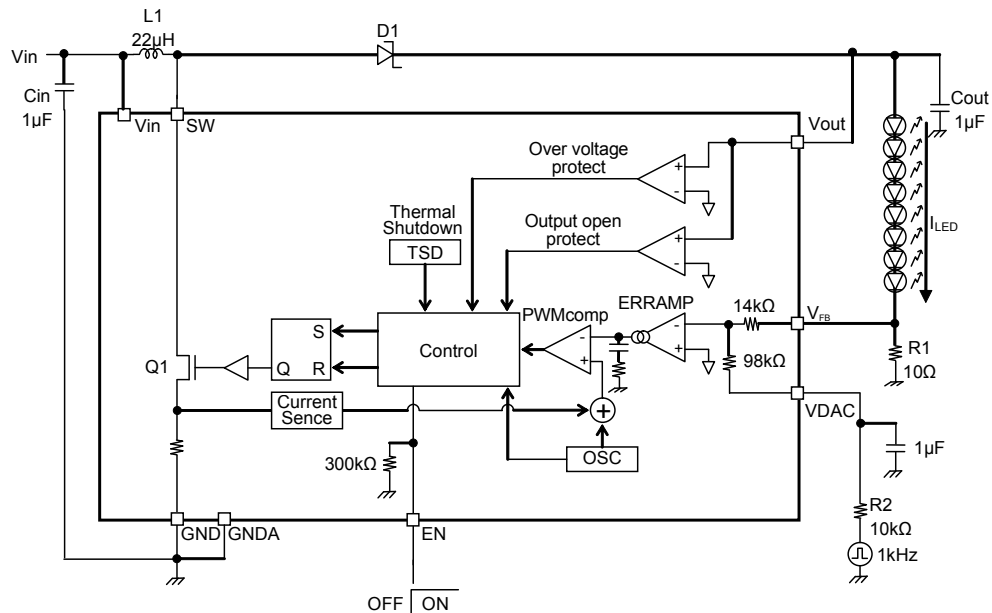

Fig.18 Example of Dimming Circuit Subject to PWM Control at the VDAC Pin

▶BD6067GU
●External components Selection Method
<<Constants in the standard circuit example>>
R1: Determines the LED current I_{LED} at power ON.
<Recommended parts>

I_{LED} (mA)	R1[Ω]
5	39
15	13
20	10

L1: Coil for boost. The recommended value is 22μH. be sure to use a sufficient DC current permissible value and a sufficient low DC resistance coil.
<Recommended parts>

Inductance value	Model number/manufacturer
22μH	NR3015T220M / TAIYO YUDEN

Cin: Power supplie bypass capacitor. This capacitor must be provided to remove an instantaneous power supply noise for stable voltage supply to this IC. To obtain good characteristics, the low ESR parts like the ceramics capacitor must be used. The recommended capacitance is 1μF or more.
<Recommended parts>

Capacitance value	Model number/manufacturer
1.0μF	GRM188B11A105KA61B / MURATA

C0: Output smoothing capacitor. The capacitance recommended for BD6067GU is 1.0μF.
<Recommended parts>

Capacitance value	Model number/manufacturer
1.0μF	UMK107C105KA-B / TAIYO YUDEN

When selecting capacitors for Cin and C0, special care should be taken for rated voltage. The desirable rated voltage is about double the voltage actually applied to the capacitor. When the margin for rated voltage is not sufficient, the capacitance may be a half or less of the nominal value.

D1: Schottky barrier diode (SBD) for output rectification. To achieve high conversion efficiency, use a diode characterized by of low Vf, low reverse leak and high current capacity.
<Recommended parts>

Model number/manufacturer
RB160M-40 / ROHM

●Recommended PCB layout
When a PCB designed, the power supply line should be wired in a way that the board impedance can be minimized. If necessary, the bypass capacitor must be connected. In particular, pins around the DC/DC converter must be wired in such a way that the wiring impedance can be minimized. In addition, when a DC/DC converter using a coil is used, it is necessary to place the output capacitor Cout, coil L1, rectification diode D1 and bypass capacitor CIN near this IC and keep the GND impedance low.
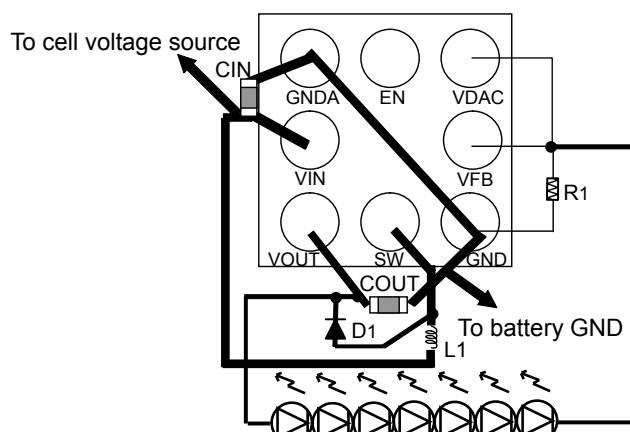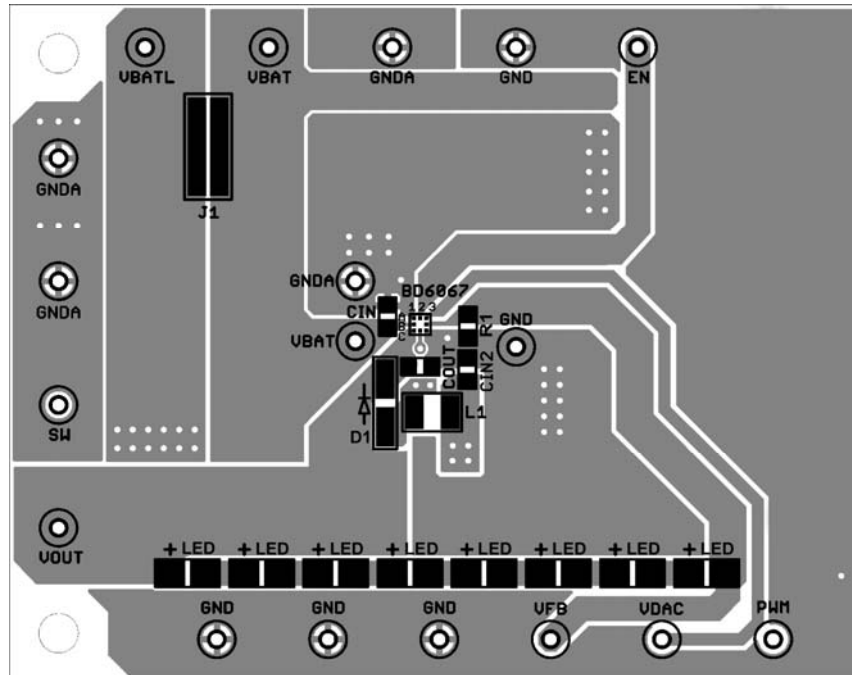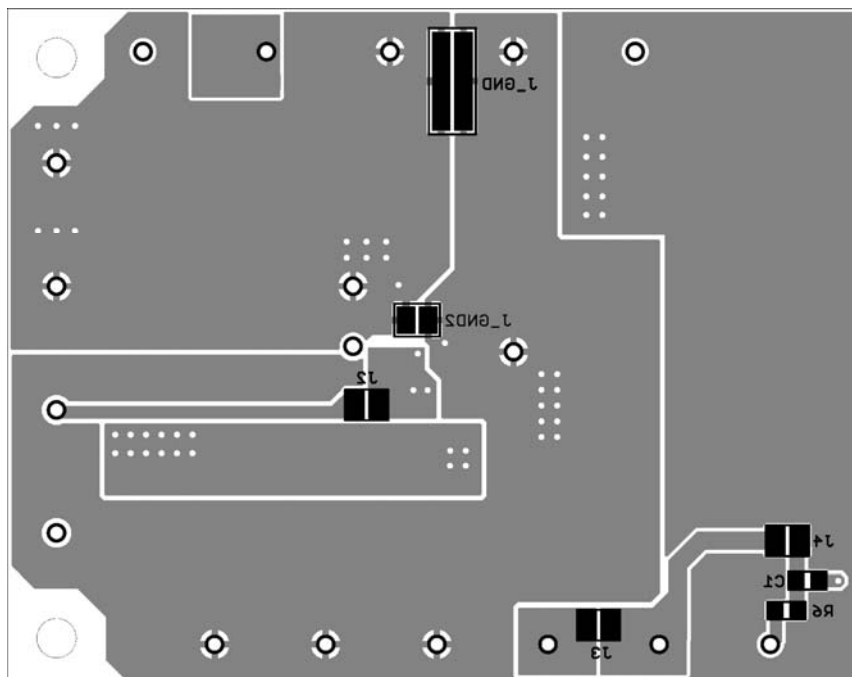

Fig.19   PCB Layout Image

►BD6067GU

Top surface (Top view)

Bottom surface (Top view)
Fig. 20   PCB Layout

***Bypass capacitor and GND
It is necessary to place bypass capacitor CIN, coil L1 and power ground GND near this IC (CIN2 of Fig.20).
To obtain good characteristics, as the need arises power supply, bypass capacitor CIN between analog GNDA must be added. (at LED8 lights).
When LED has 8 lights, full assessment is required for characteristics prior to usage.

►BD6071HFN
●Absolute maximum ratings (Ta=25℃)

Parameter	Symbol	Ratings	Unit	Conditions
Power supply voltage 1	VMAX1	7 *1	V	Applicable to Vin,EN,VFB, TEST pins
Power supply voltage 2	VMAX2	20 *1	V	Applicable to SW,Vout pins
Power dissipation	Pd	630 *2	mW	70mm×70mm×1.6mm at glass epoxy board mounting
Operating temperature range	Topr	-30 ~ +85	℃	
Storage temperature rang	Tstg	-55 ~ +150	℃	

*1   These values are based on GND and GNDA pins.
*2   When it's used by more than Ta=25℃, it's reduced by 5.04mW/℃.

●Recommended operating range (Ta=-30℃ ~+85℃)

Parameter	Symbol	Ratings			Unit	Conditions
		Min.	Typ.	Max.		
Operating supply voltage	Vin	2.7	3.6	5.5	V	

●Electrical characteristic (Unless otherwise specified Ta = +25℃, Vin=3.6V)

Parameter	Symbol	Limits			Unit	Conditions
		Min.	Typ.	Max.		
<EN Terminal>						
EN threshold voltage (Low)	VthL	-	-	0.4	V	
EN threshold voltage (High)	VthH	1.4	-	-	V	
EN terminal input current	Iin	-	18.3	30.0	μA	EN=5.5V
EN terminal output current	Iout	-2.0	-0.1	-	μA	EN=0
<Switching regulator>						
Input voltage range	Vin	3.1	-	5.5	V	
Quiescent Current	Iq	-	0.1	2.0	μA	EN=0V
Current Consumption	Idd	-	1.1	1.5	mA	EN=2.6V,VFB=1.0V,VIN=3.6V
Feedback voltage	Vfb	0.47	0.50	0.53	V	
Inductor current limit	Icoil	200	265	330	mA	Vin=3.6V *1
SW saturation voltage	Vsat	-	0.14	0.28	V	Isw=200mA, Vout=13V
SW on resistance P	Ronp	-	2.1	3.2	Ω	Ipch=200mA,Vout=13V
Switching frequency	fSW	0.8	1.0	1.2	MHz	
Duty cycle limit	Duty	82.7	85.0	-	%	VFB=0V
Output voltage range	Vo	-	-	14.0	V	
Over voltage limit	Ovl	14.0	14.5	15.0	V	VFB=0V
Start up time	Ts	-	0.5	1.0	ms	

*1   This parameter is tested with dc measurement.

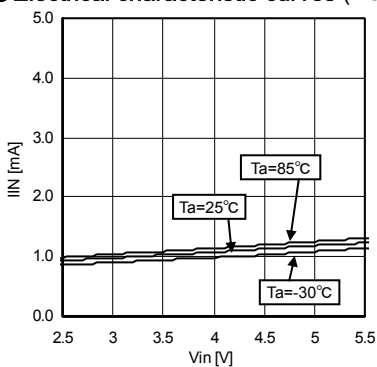●Electrical characteristic curves (Reference data)

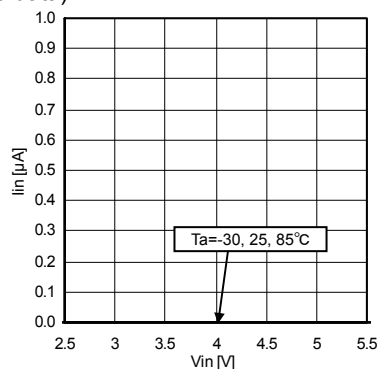Fig.21 Current Consumption vs. power source voltage

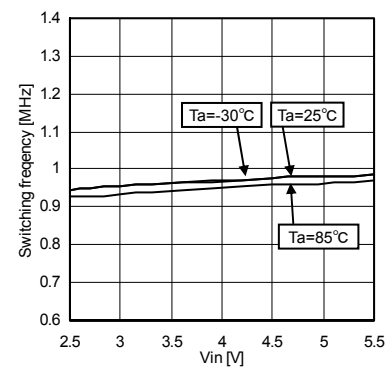Fig.22 Quiescent current vs. power source voltage

Fig.23 Oscillation frequency vs. power source voltage

►BD6071HFN

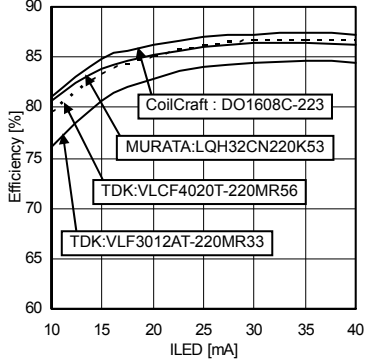●Electrical characteristic curves (Reference data)

Fig.24 Efficiency vs. LED current in each coil
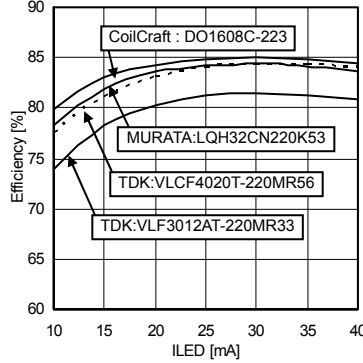< 2LED > (VOUT=7.5V, VIN=3.6V, Ta=25℃)

Fig.25 Efficiency vs. LED current in each coil
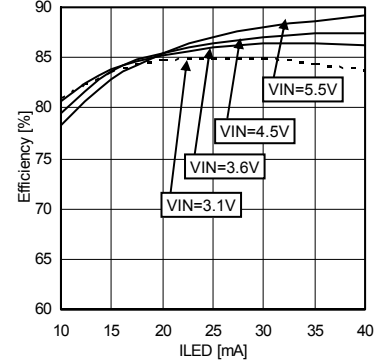< 3LED > (VOUT=10.5V, VIN=3.6V, Ta=25℃)

Fig.26 Efficiency vs. LED current
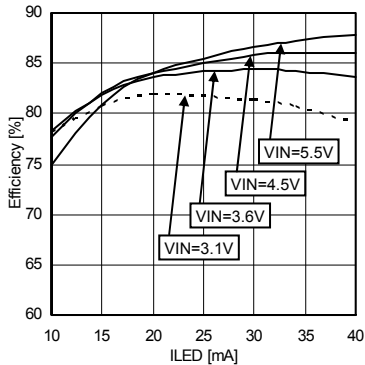< 2LED > (VOUT=7.5V, Ta=25℃)

Fig.27 Efficiency vs. LED current
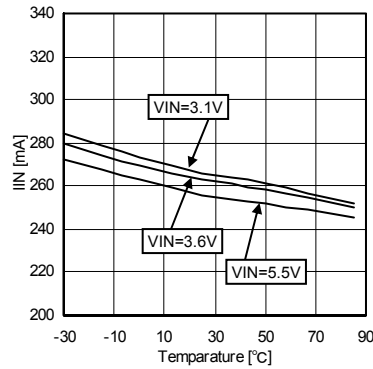< 3LED > (VOUT=10.5V, VIN=3.6V, Ta=25℃)

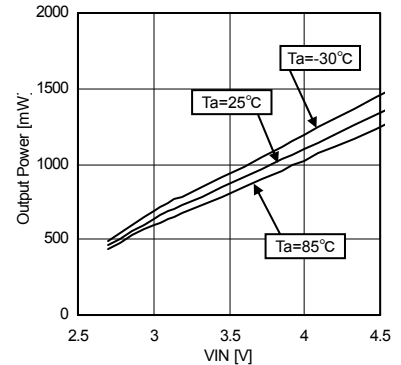Fig.28 Inductor current limits vs.
Temperature

Fig.29 Output power vs. power
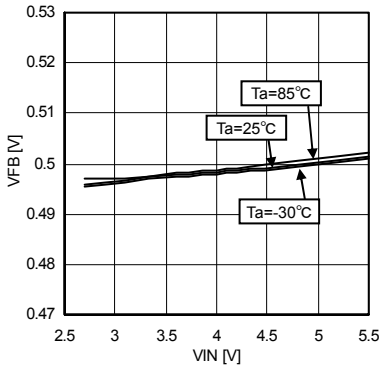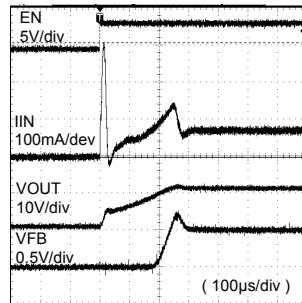source voltage

Fig.30 Feedback voltage vs.
Power source voltage

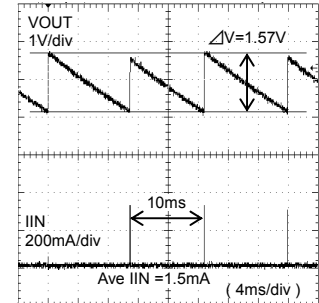

Fig.31 Soft Start
(VIN = 3.6V, Ta = 25℃, 3LED, 20mA Load)
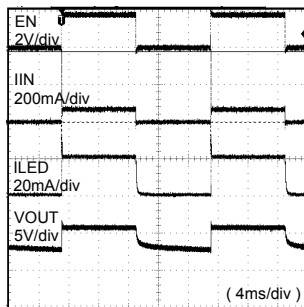

Fig.32 LED Open output voltage

Fig.33 LED luminance adjustment
(VIN = 3.6V, Ta = 25℃, 3LED, 20mA Load)

►BD6071HFN
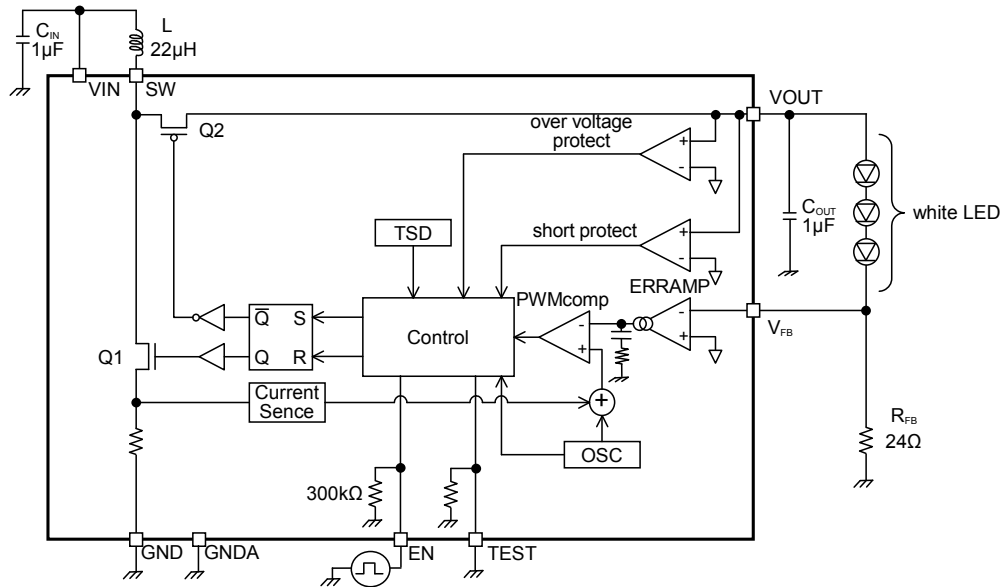●Block diagram, recommended circuit example, pin location diagram

Fig.34 Block diagram and recommended circuit diagram
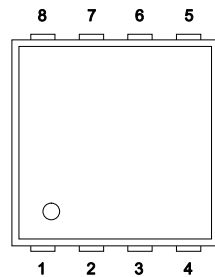
Fig.35 Pin location diagram HSON8 (Top view)

●Pin assignment table

PIN Name	In/Out	Pin number	Function
GNDA	-	1	Analog GND
EN	In	2	Enable control(pull down is integrated on resistance)
TEST	In	3	TEST input (pull down is integrated on resistance)
VIN	In	8	Power supply input
VFB	In	4	Feedback input voltage
VOUT	Out	7	Output
SW	In	6	Switching terminal
GND	-	5	Power GND

●Operation

BD6071HFN is a fixed frequency PWM current mode DC/DC converter, and adopts synchronous rectification architecture. 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 for sub harmonic oscillation prevention. This output controls Q1 and Q2 via the RS latch.

Timing of Q1 and Q2 is precisely adjusted so that they will not turn ON at the same time, thus putting them into non-overlapped relation.

In the period where Q1 is ON, energy is accumulated in the external inductor, and in the period where Q1 is OFF, energy is transferred to the capacitor of VOUT via Q2.

Further, BD6071HFN has many safety functions, and their detection signals stop switching operation at once.

►BD6071HFN
●Description of Functions
1) Soft starts and off status
   BD6071HFN has soft start function and off status function.
   The soft start function and the off status function prevent large current from flowing to the IC via coil.
   Occurrence of rush current at turning on is prevented by the soft start function, and occurrence of invalid current at turning off is prevented by the off status function.

2) Isolation control
   BD6071HFN has isolation control to prevent LED wrong lighting at power off.
   The cause of the LED wrong lighting is leak current from VIN to the white LED.
   Therefore, when BD6071HFN gets in power off (EN = L), the isolation control cuts the DC path between SW and Vout, thereby the leak current from VIN to LED is prevented.
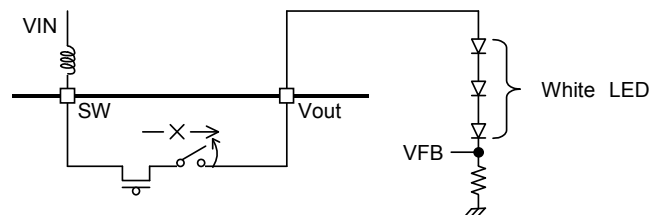

Fig.36 Isolation control

3) Short-circuit protection and over voltage protection
   BD6071HFN has short-circuit protection and over voltage protection. These detect the voltage of VOUT, and at error, they stop the output Tr. Details are as shown below.
   ・Short-circuit protection
   In the case of short-circuit of the DC/DC output (VOUT) to GND, the coil or the IC may be destructed.
   Therefore, at such an error as VOUT becoming 0.7V or below, the Under Detector shown in the figure works, and turns off the output Tr, and prevents the coil and the IC from being destructed.
   And the IC changes from its action condition into its non-action condition, and current does not flow to the coil (0mA).
   ・Over voltage protection
   At such an error as the IC and the LED being cut off, over voltage causes the SW terminal and the VOUT terminal exceed the absolute maximum ratings, and may destruct the IC. Therefore, when VOUT becomes 14.5V or higher, the over voltage limit works, and turns off the output Tr, and prevents the SW terminal and the VOUT terminal from exceeding the absolute maximum ratings.
   At this moment, the IC changes from its action condition into its non action condition, and the output voltage goes down slowly. And, when the output voltage becomes the hysteresis of the over voltage limit or below, the output voltage goes on up to 14.5V once again.
   This protection action is shown in Fig.37.
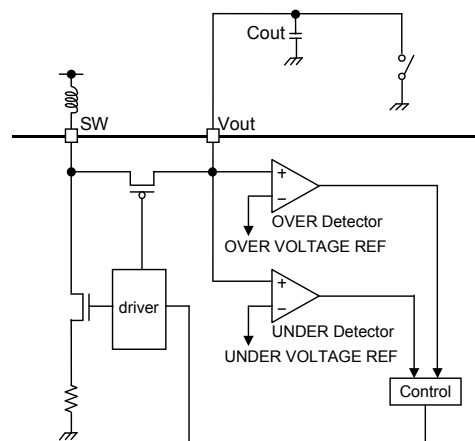

Fig.37 Block diagram of short-circuit protection and over voltage

4) Thermal shut down
   BD6071HFN has thermal shut down function.
   The thermal shut down works at 175℃ or higher, and while holding the setting of EN control from the outside, the IC changes from its action condition into its non action condition. And at 175℃ or below, the IC gets back to its normal action.

►BD6071HFN
●Start control and brightness control

BD6071HFN can control the start conditions by its EN terminal, and power off at 0.4V or below, and power on at 1.4V or higher. And by changing the duty of power on and off by PWM control, the LED brightness can be adjusted.

Two techniques are available for the brightness adjustment. One is discrete time (PWM) adjustment, and the other is continuous time adjustment.

1) PWM brightness adjustment is made by giving PWM signal to EN as shown in Fig.38.

The BD6068GU/BD6071HFN T power on/off are according to the PWM signal. By this method, LED current is controlled from 0 to the maximum current. The average LED current increases in proportion with the duty cycle of PWM signal. While in PWM off-cycle mode, the IC and LED both consume no currents, thus providing a high-efficiency operation. And please don't use duty less than 5% or more than 95% of current setting for the brightness adjustment because of the influence of turning on and off operating is large. The recommended PWM frequency is 100Hz ~ 300Hz.
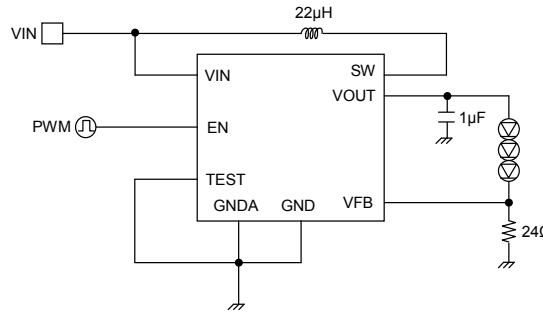

Fig.38 The brightness adjustment example of EN terminal by PWM (f_{PWM} = 100Hz ~ 300Hz)

2-1) The continuous time the brightness adjustment is made by giving DC control voltage to VFB pin of BD6068GUT / BD6071HFN via a series resistor as shown in Fig.39. 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 Fig.41. The advantage of this approach is that the PWM signal to be used to control the LED brightness can be set to a high frequency (1kHz or higher). And please don't use duty less than 5% or more than 95% of current setting for the brightness adjustment.

LED current (I_{LED}) is approximated by the following equation.

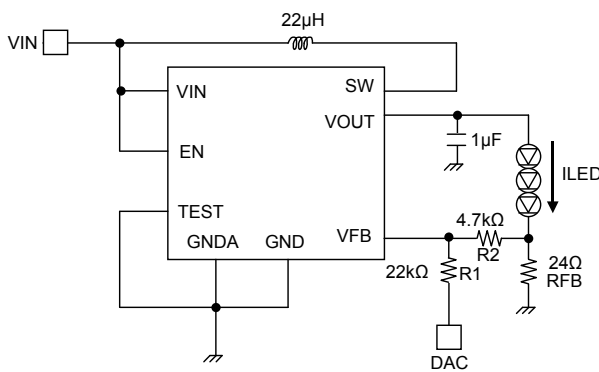$$I_{LED} = [\{(VFB-DAC) / R1\} \times R2 + VFB] / RFB$$

Fig.39 The brightness adjustment example by DAC
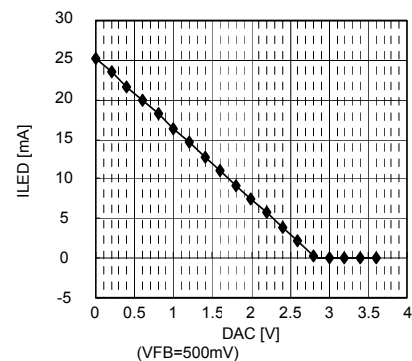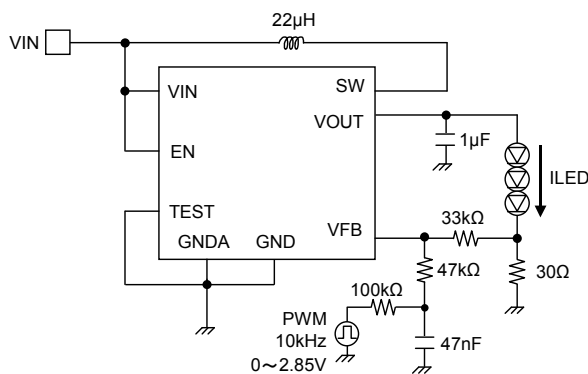

Fig.40 DAC adjustment

Fig.41 The brightness adjustment example of
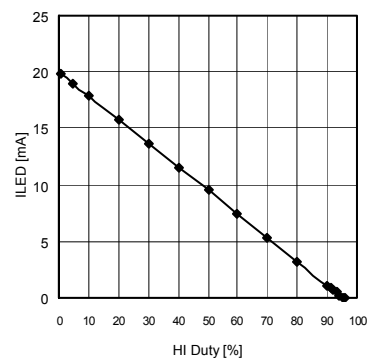VFB terminal by PWM (f_{PWM}=10kHz)

Fig.42 VFB PWM Control

►BD6071HFN

2-2) The brightness adjustment of below is done in adjusting of R2 ON time by R1 and Duty cycle of PWM.
The minimum value of the LED current is decided by VFB / R1 at the PWM 0%, the maximum value of the LED current is decided by VFB / R2 at the PWM 100%.
I_{LED} is given as shown below.

ILED=VFB / R1 + VFB / R2 × HI Duty

Standard PWM frequency is 100Hz~1kHz. And please don't use duty less than 5% or more than 95% of current setting for the brightness adjustment.
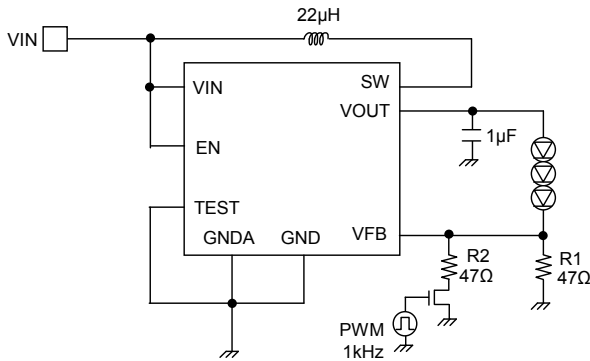
Fig.43 The brightness adjustment example of VFB terminal by PWM
(f_{PWM}=100Hz ~ 1kHz)
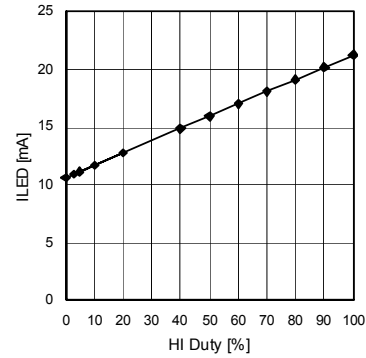
Fig.44 VFB PWM Control

●Setting range of LED current
LED current is determined by the voltage of VFB and the resistor connected to VFB terminal.
I_{LED} is given as shown below.
$I_{LED}=V_{FB}/R_{FB}$
The current in the standard application is as shown below.
V_{FB}=0.5V, R_{FB}=24Ω
I_{LED}=20.8mA
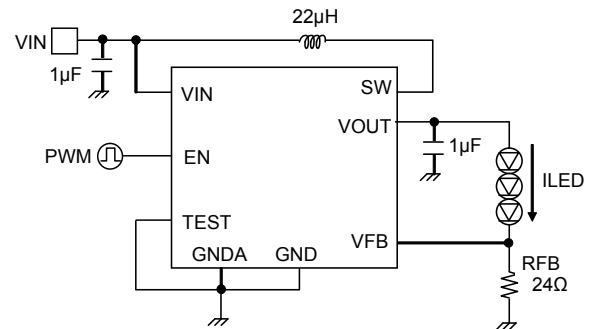
Fig.45 Recommended circuit diagram

The shaded portion in the figure below is the setting range of LED current to become the standard. In case of using 2LED, LED current might increase due to over boosting when VOUT is less than 5.5V. Therefore some ICs may not be used at desired currents. Consequently, for the proper setting of LED current, thoroughly check it for the suitability under use conditions including applicable power supply voltage and temperature.

Fig.46 LED Setting range of LED current

►BD6071HFN

●Selection of external parts

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

・Coil

Value	Tolerance	Manufacturer	Product number	Size (mm)			DCR(Ω)
				W	L	H	
22μH	±10%	MURATA	LQH32CN220K53	2.5	3.2	1.55	0.71
22μH	±20%	TDK	VLF3012AT220MR33	2.6	2.8	1.2	0.66
22μH	±20%	Coil Craft	DO1608	4.45	6.6	2.92	0.37
22μH	±20%	TDK	VLF3010AT220MR33	2.6	2.8	1.0	1.30

Please refer to the reference data of p.11 for the change in the efficiency when the coil is changed.

・Capacitor

Value	Manufacturer	Product number	Size (mm)			Temperature range
			L	W	H	
<CIN>						
1μF	MURATA	GRM188B11A105K	1.6	0.8	0.8	-25deg~+85deg
<COUT>						
1μF	MURATA	GRM188B31E105K	1.6	0.8	0.8	-25deg~+85deg

・Resistor

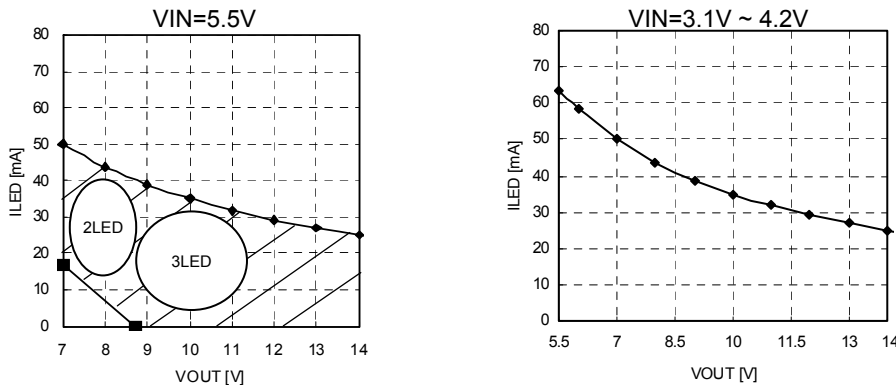| Value	Tolerance	Manufacturer	Product number	Size (mm)		
				L	W	H
<R_FB>						
24Ω	±1%	ROHM	MCR006YZPF24R0	0.6	0.3	0.23

The coil is the part that is most influential to efficiency. Select the coil whose direct current resistor (DCR) and current - inductance characteristic is excellent. The BD6068GUT/BD6071HFN is designed for the inductance value of 22μH. Do not use other inductance value. Select a capacitor of ceramic type with excellent frequency and temperature characteristics. Further, select Capacitor to be used for CIN/COUT with small direct current resistance, and pay sufficient attention to the PCB layout shown in the next page.
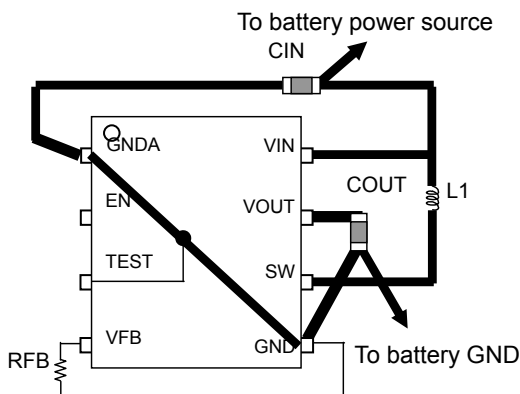
●PCB Layout

Fig.47 PCB Layout Image

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 layout, which please note carefully.
Connect the input bypath capacitor CIN nearest to between VIN and GNDA pin, as shown in the upper diagram. Thereby, the input voltage ripple of the IC can be reduced. And, connect the output capacitor COUT nearest to between VOUT and GND pin. Thereby, the output voltage ripple of the IC can be reduced. Connect the current setting RFB nearest to VFB pin. Connect the GND connection side of RFB directly to GND pin. Connect the GNDA pin directly to GND pin. When those pins are not connected directly near the chip, influence is given to the performance of BD6068/BD6071HFN 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. And keep the pins that are subject to the influence like VFB pin away from the wire to SW. The PCB layout in consideration of these is shown in the Fig.49.

►BD6071HFN
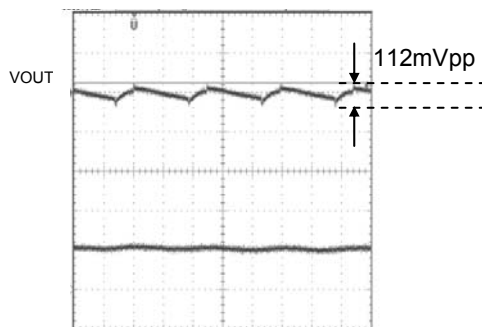
(VBAT=3.6V, Ta=25℃, VOUT=14V, 20mA Load)
Fig.48 Output noise

●Recommended PCB layout

Front surface (Top view)

Bottom surface (Top view)
Fig.49 PCB Layout
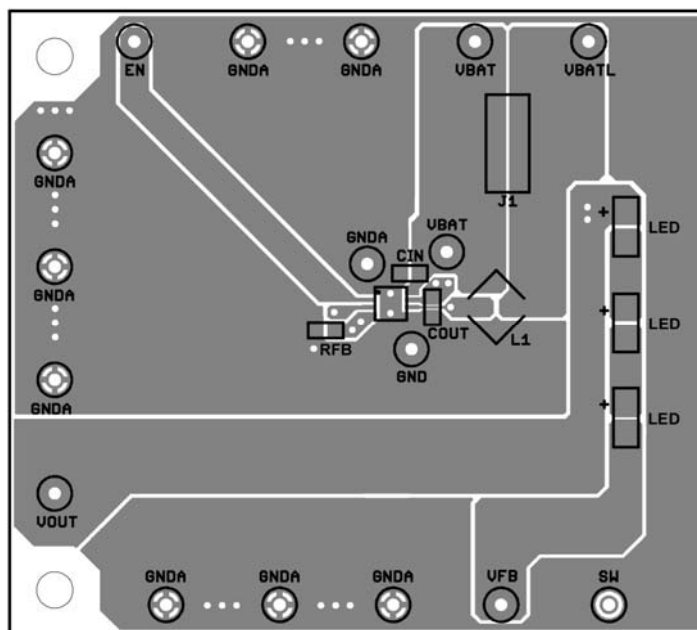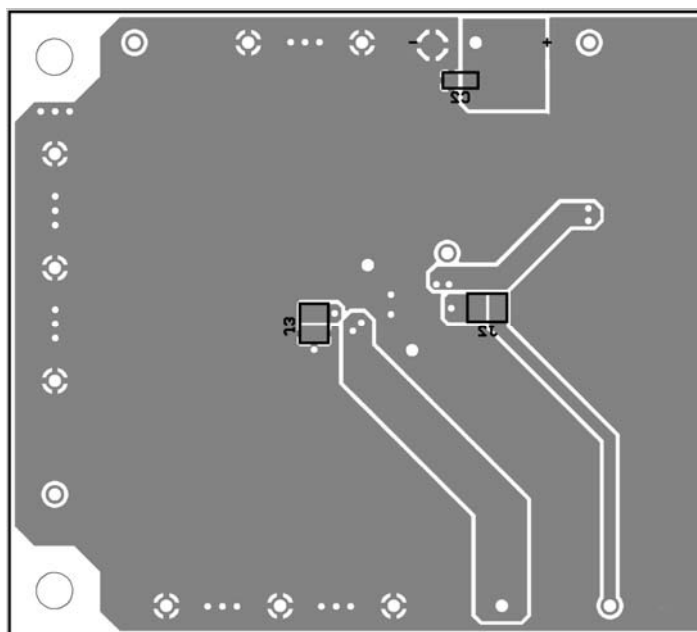
►BD6069GUT, BD6072HFN
●Absolute maximum ratings (Ta=25℃)

Parameter		Symbol	Ratings	Unit	Conditions
Power supply voltage 1		VMAX1	7 *[1]	V	Vin,EN,VFB,TEST
Power supply voltage 2		VMAX2	20 *[1]	V	SW,Vout
Power dissipation	BD6069GUT	Pd	800 *[2]	mW	50mm×58mm×1.75mm At glass epoxy board mounting.
	BD6072HFN		630 *[3]	mW	70mm×70mm×1.6mm At glass epoxy board mounting.
Operating temperature range		Topr	-30 ~ +85	℃	
Storage temperature range		Tstg	-55 ~ +150	℃	

*1   These values are based on GND and GNDA pins.
*2   When it's used by more than Ta=25℃, it's reduced by 6.4mW/℃.
*3   When it's used by more than Ta=25℃, it's reduced by 5.04mW/℃.

●Recommended operating range (Ta=-30℃ ~ +85℃)

Parameter		Symbol	Ratings			Unit	Conditions
			Min.	Typ.	Max.		
Operating supply voltage	BD6069GUT	Vin	2.7	3.6	5.5	V	
	BD6072HFN						

●Electrical characteristics (Unless otherwise specified Ta = +25℃, Vin=3.6V)

Parameter	Symbol	Limits			Unit	Conditions
		Min.	Typ.	Max.		
<EN terminal>						
EN threshold voltage (Low)	VthL	-	-	0.4	V	
EN threshold voltage (High)	VthH	1.4	-	-	V	
EN terminal input current	Iin	-	18.3	30.0	µA	EN=5.5V
EN terminal output current	Iout	-2.0	-0.1	-	µA	EN=0
<Switching regulator>						
Input voltage range	Vin	3.1	-	5.5	V	
Quiescent Current	Iq	-	0.1	2.0	µA	EN=0V
Current Consumption	Idd	-	1.1	1.5	mA	EN=2.6V,VFB=1.0V,VIN=3.6V
Feedback voltage	Vfb	0.47	0.50	0.53	V	
Inductor current limit	Icoil	270	350	430	mA	Vin=3.6V *[1]
SW saturation voltage	Vsat	-	0.14	0.28	V	Isw=200mA, Vout=13V
SW on resistance P	Ronp	-	2.1	3.2	Ω	Ipch=200mA,Vout=13V
Switching frequency	fSW	0.8	1.0	1.2	MHz	
Duty cycle limit	Duty	82.7	85.0	-	%	VFB=0V
Output voltage range	Vo	-	-	18.0	V	
Over voltage limit	Ovl	18.0	18.5	19.0	V	VFB=0V
Start up time	Ts	-	0.5	1.0	ms	

*1   This parameter is tested with dc measurement.

►BD6069GUT, BD6072HFN
●Electrical characteristic curves (Reference data)
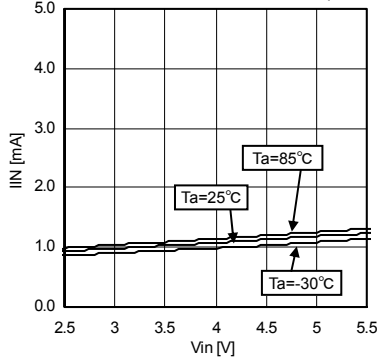

Fig.50 Current Consumption vs
Power source voltage
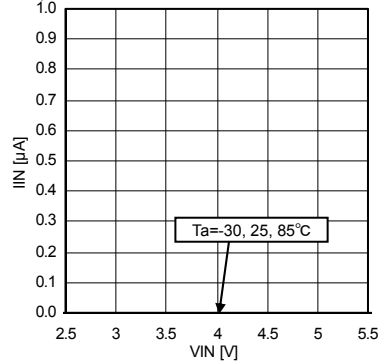
Fig.51 Quiescent current vs
power source voltage
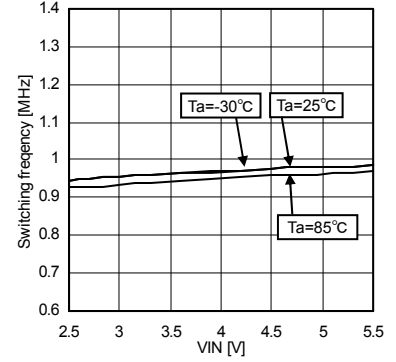
Fig.52 Oscillation frequency vs.
power source voltage
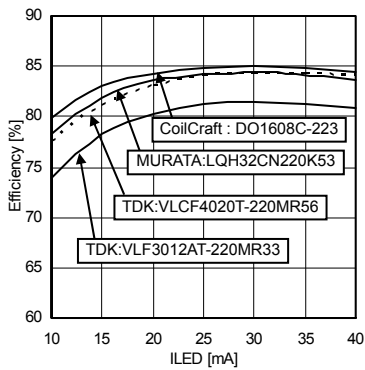
Fig.53 Efficiency vs.
LED current in each coil
< 3LED > (VOUT=10.5V, VIN=3.6V, Ta=25℃)
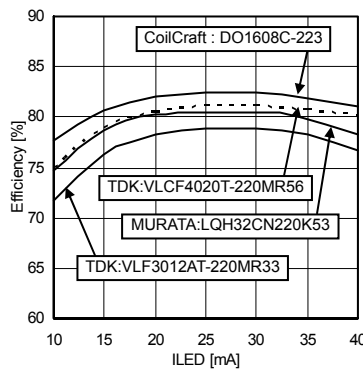
Fig.54 Efficiency vs.
LED current in each coil
< 4LED > (VOUT=14V, VIN=3.6V, Ta=25℃)
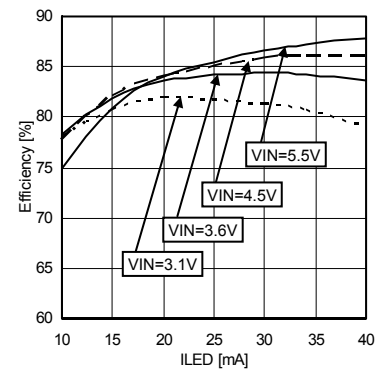
Fig.55 Efficiency vs. LED
current in each coil
< 3LED > (VOUT=10.5V, VIN=3.6V, Ta=25℃)

Fig.56 Efficiency vs.
LED current in each coil
< 4LED > (VOUT=14V, VIN=3.6V, Ta=25℃)

Fig.57 Inductor current limits vs.
Temperature

Fig.58 Output power vs.
Power source voltage
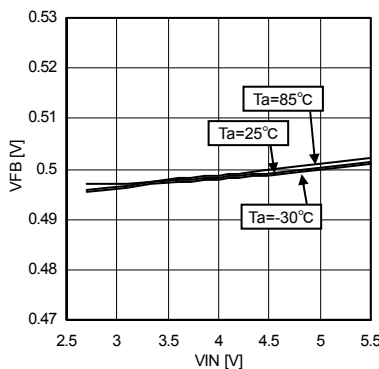
Fig.59 Feedback voltage vs.
Power source voltage
(ILED=20mA)
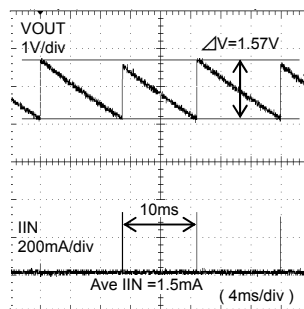
Fig.60 LED Open output voltage
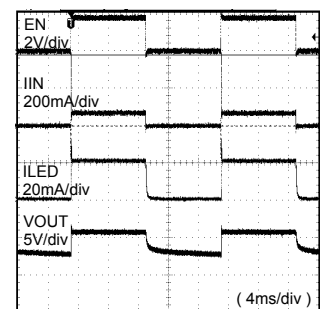
Fig.61 LED luminance adjustment
(VIN = 3.6V, Ta = 25℃, 3LED, 20mA Load)

►BD6069GUT, BD6072HFN
●Block diagram, recommended circuit example, pin location diagram
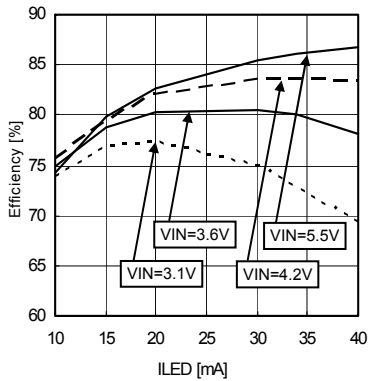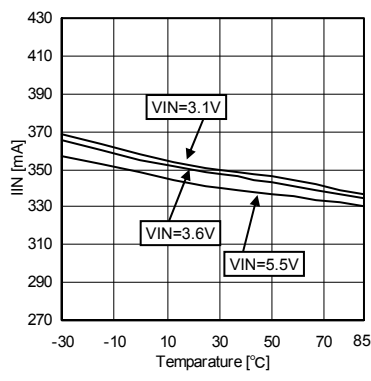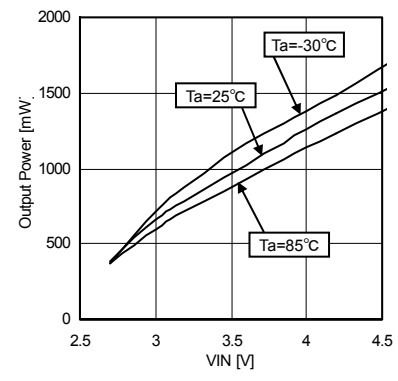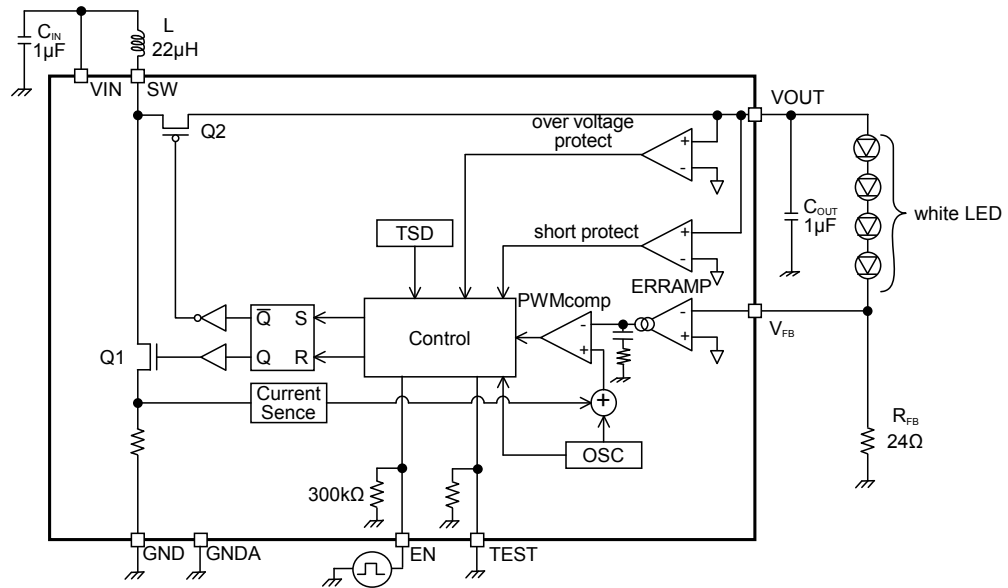

Fig.62 Block diagram and recommended circuit diagram

<BD6069GUT>
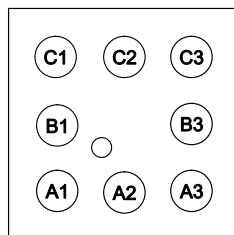
Fig.63 Pin location diagram VCSP60N1 (Bottom view)

<BD6072HFN>
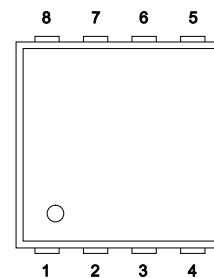
Fig.64 Pin location diagram HSON8 (Top view)

●Pin assignment table

PIN Name	In/Out	Ball number		Function
		BD6069GUT	BD6072HFN	
GNDA	-	A1	1	Analog GND
EN	In	A2	2	Enable control (pull down is integrated on resistance)
TEST	In	A3	3	TEST input (pull down is integrated on resistance)
VIN	In	B1	8	Power supply input
VFB	In	B3	4	Feedback input voltage
VOUT	Out	C1	7	Output
SW	In	C2	6	Switching terminal
GND	-	C3	5	Power GND

●Operation
   BD6069GUT is a fixed frequency PWM current mode DC/DC converter, and adopts synchronous rectification architecture. 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 for sub harmonic oscillation prevention. This output controls Q1 and Q2 via the RS latch.
   Timing of Q1 and Q2 is precisely adjusted so that they will not turn ON at the same time, thus putting them into non-overlapped relation. In the period where Q1 is ON, energy is accumulated in the external inductor, and in the period where Q1 is OFF, energy is transferred to the capacitor of VOUT via Q2. Further, BD6069GUT/BD6072HFN has many safety functions, and their detection signals stop switching operation at once.

►BD6069GUT, BD6072HFN
●Description of Functions
1) Soft starts and off status
   BD6069GUT/BD6072HFN has soft start function and off status function.
   The soft start function and the off status function prevent large current from flowing to the IC via coil.
   Occurrence of rush current at turning on is prevented by the soft start function, and occurrence of invalid current at turning off is prevented by the off status function.

2) Isolation control
   BD6069GU/BD6072HFN T has isolation control to prevent LED wrong lighting at power off.
   The cause of the LED wrong lighting is leak current from VIN to the white LED.
   Therefore, when BD6069GUT/BD6072HFN gets in power off (EN = L), the isolation control cuts the DC path between SW and Vout, thereby the leak current from VIN to LED is prevented.
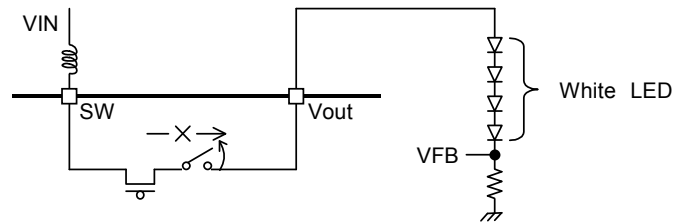
Fig.65 Isolation control

3) Short-circuit protection and over voltage protection
   BD6069GUT/BD6072HFN has short-circuit protection and over voltage protection. These detect the voltage of VOUT, and at error, they stop the output Tr. Details are as shown below.
   ・Short-circuit protection
   In the case of short-circuit of the DC/DC output (VOUT) to GND, the coil or the IC may be destructed.
   Therefore, at such an error as VOUT becoming 0.7V or below, the Under Detector shown in the figure works, and turns off the output Tr, and prevents the coil and the IC from being destructed.
   And the IC changes from its action condition into its non action condition, and current does not flow to the coil (0mA).
   ・Over voltage protection
   At such an error as the IC and the LED being cut off, over voltage causes the SW terminal and the VOUT terminal exceed the absolute maximum ratings, and may destruct the IC. Therefore, when VOUT becomes 18.5V or higher, the over voltage limit works, and turns off the output Tr, and prevents the SW terminal and the VOUT terminal from exceeding the absolute maximum ratings.
   At this moment, the IC changes from its action condition into its non action condition, and the output voltage goes down slowly. And, when the output voltage becomes the hysteresis of the over voltage limit or below, the output voltage goes on up to 18.5V once again.
   This protection action is shown in Fig.66.
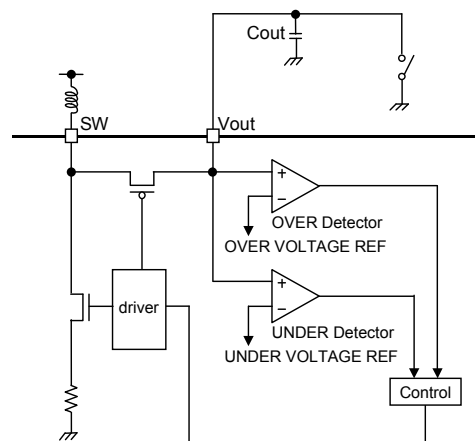
Fig.66 Block diagram of short-circuit protection and over voltage

4) Thermal shut down
   BD6069GUT/BD6072HFN has thermal shut down function.
   The thermal shut down works at 175℃ or higher, and while holding the setting of EN control from the outside, the IC changes from its action condition into its non action condition. And at 175℃ or below, the IC gets back to its normal action.

►BD6069GUT, BD6072HFN
●Start control and brightness control

BD6069GUT/BD6072HFN can control the start conditions by its EN terminal, and power off at 0.4V or below, and power on at 1.4V or higher. And by changing the duty of power on and off by PWM control, the LED brightness can be adjusted.

Two techniques are available for the brightness adjustment. One is discrete time (PWM) adjustment, and the other is continuous time adjustment.

1) PWM brightness adjustment is made by giving PWM signal to EN as shown in Fig.67.
The BD6069GUT/BD6072HFN power on/off is according to the PWM signal. By this method, LED current is controlled from 0 to the maximum current. The average LED current increases in proportion with the duty cycle of PWM signal. While in PWM off-cycle mode, the IC and LED both consume no currents, thus providing a high-efficiency operation. And please don't use duty less than 5% or more than 95% of current setting for the brightness adjustment because of the influence of turning on and off operating is large. The recommended PWM frequency is 100Hz ~ 300Hz.
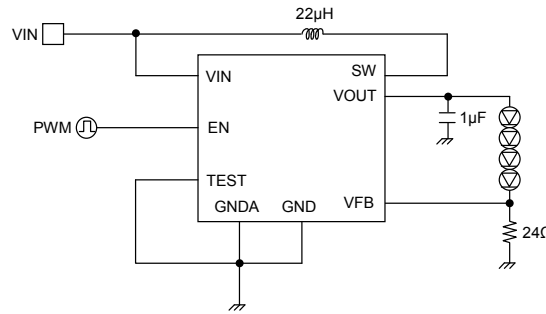
Fig.67 The brightness adjustment example of EN terminal by PWM (fPWM = 100Hz ~ 300Hz)

2-1) The continuous time the brightness adjustment is made by giving DC control voltage to VFB pin of BD6069GUT / BD6072HFN via a series resistor as shown in Fig.68. 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 Fig.70. The advantage of this approach is that the PWM signal to be used to control the LED brightness can be set to a high frequency (1kHz or higher). And please don't use duty less than 5% or more than 95% of current setting for the brightness adjustment.

LED current (ILED) is approximated by the following equation.

$$ILED = [\{(VFB-DAC) / R1\} \times R2 + VFB] / RFB$$
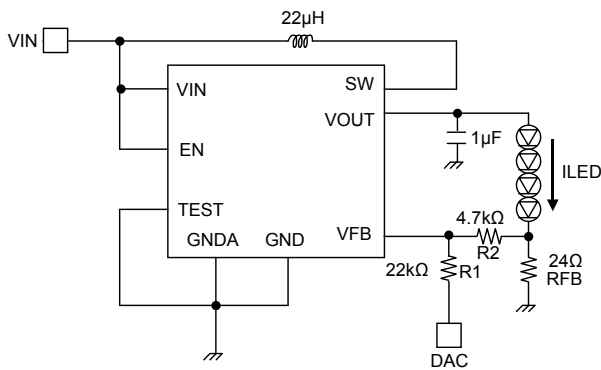
Fig.68 The brightness adjustment example by DAC
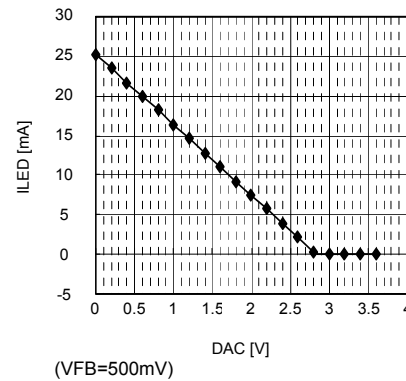
Fig.69 DAC adjustment
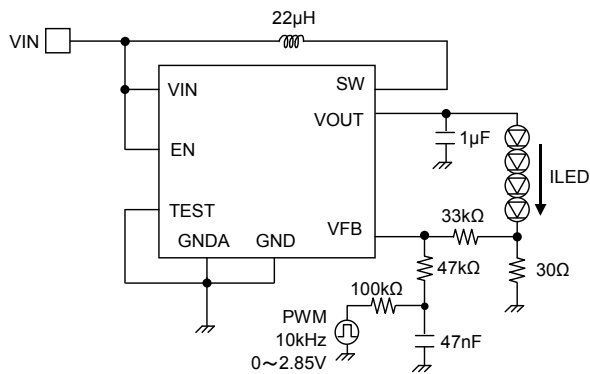
Fig.70 The brightness adjustment example of VFB terminal by PWM (fPWM=10kHz)
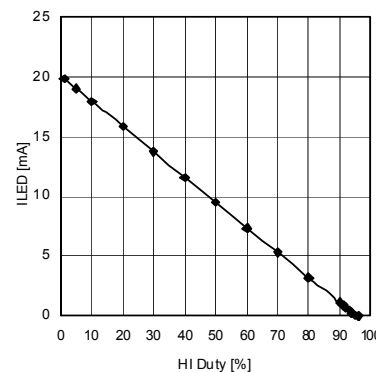
Fig.71 VFB PWM Control

►BD6069GUT, BD6072HFN

2-2) The brightness adjustment of below is done in adjusting of R2 ON time by R1 and Duty cycle of PWM.
The minimum value of the LED current is decided by VFB / R1 at the PWM 0%, the maximum value of the LED current is decided by VFB / R2 at the PWM 100%.
I_{LED} is given as shown below.

ILED=VFB / R1 + VFB / R2 × HI Duty

Standard PWM frequency is 100Hz~1kHz. And please don't use duty less than 5% or more than 95% of current setting for the brightness adjustment.
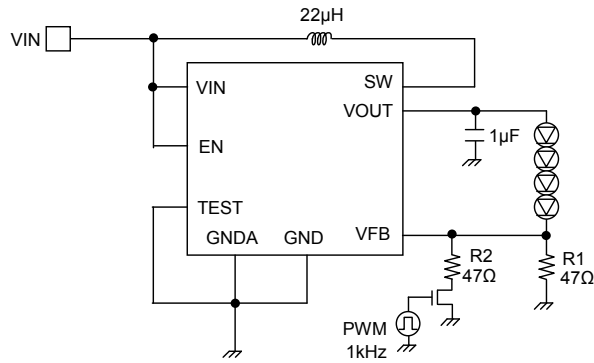
Fig.72 he brightness adjustment example of VFB terminal by PWM (f_{PWM}=100Hz~1kHz)
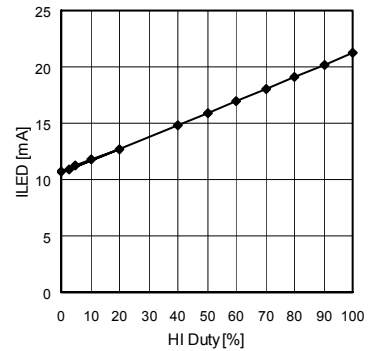
Fig.73 VFB PWM Control

●Setting range of LED current

LED current is determined by the voltage of VFB and the resistor connected to VFB terminal.
I_{LED} is given as shown below.

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

The current in the standard application is as shown below.

V_{FB}=0.5V, R_{FB}=24Ω
I_{LED}=20.8mA
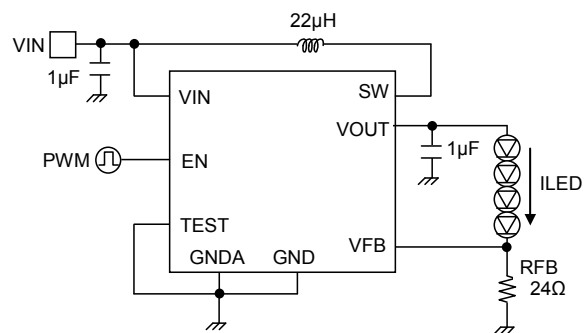
Fig.74 Recommended circuit diagram

The shaded portion in the figure below is the setting range of LED current to become the standard. Depending on coils and white LEDs to be used, however, some ICs may not be used at desired currents. Consequently, for the proper setting of LED current, thoroughly check it for the suitability under use conditions including applicable power supply voltage and temperature.
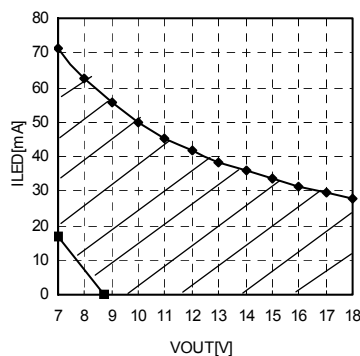
Fig.75 Setting range of LED current

▶BD6069GUT, BD6072HFN
●Selection of external parts
Recommended external parts are as shown below.
When to use other parts than these, select the following equivalent parts.

・Coil

Value	Tolerance	Manufacturer	Product number	Size (mm)			DCR (Ω)
				W	L	H	
22μH	±10%	MURATA	LQH32CN220K53	2.5	3.2	1.55	0.71
22μH	±20%	TDK	VLF3012AT220MR33	2.6	2.8	1.2	0.66
22μH	±20%	Coil Craft	DO1608	4.45	6.6	2.92	0.37
22μH	±20%	TDK	VLF3010AT220MR33	2.6	2.8	1.0	1.30

Please refer to the reference data of p.20 for the change in the efficiency when the coil is changed.

・Capacitor

Value	Manufacturer	Product number	Size (mm)			Temperature range
			L	W	H	
<CIN>						
1μF	MURATA	GRM188B11A105K	1.6	0.8	0.8	-25deg~+85deg
<COUT>						
1μF	MURATA	GRM188B31E105K	1.6	0.8	0.8	-25deg~+85deg

・Resistor

Value	Tolerance	Manufacturer	Product number	Size (mm)		
				L	W	H
<R$_{FB}$>						
24Ω	±1%	ROHM	MCR006YZPF24R0	0.6	0.3	0.23

The coil is the part that is most influential to efficiency. Select the coil whose direct current resistor (DCR) and current - inductance characteristic is excellent. The BD6069GUTT/BD6072HFN is designed for the inductance value of 22μH. Do not use other inductance value. Select a capacitor of ceramic type with excellent frequency and temperature characteristics. Further, select Capacitor to be used for CIN/COUT with small direct current resistance, and pay sufficient attention to the PCB layout shown in the next page.

●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.
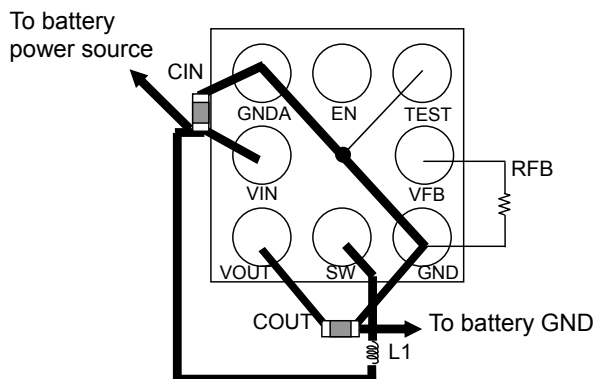
Fig.76 BD6069GUT PCB Layout Image
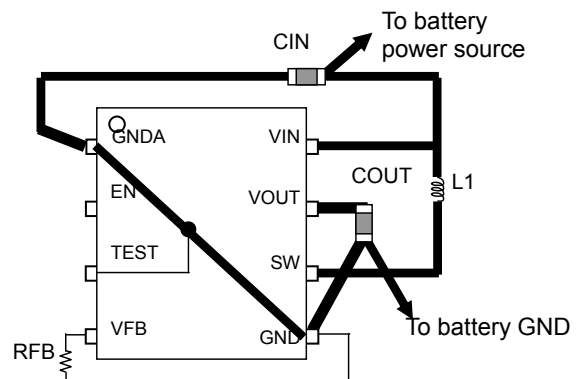
Fig.77 BD6072HFN PCB Layout Image

►BD6069GUT, BD6072HFN

Connect the input bypath capacitor CIN nearest to between VIN and GNDA pin, as shown in the upper diagram. Thereby, the input voltage ripple of the IC can be reduced. And, connect the output capacitor COUT nearest to between VOUT and GND pin. Thereby, the output voltage ripple of the IC can be reduced. Connect the current setting RFB nearest to VFB pin. Connect the GND connection side of RFB directly to GND pin. Connect the GNDA pin directly to GND pin. When those pins are not connected directly near the chip, influence is given to the performance of BD6069GUT /BD6072HFN, 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. And keep the pins that are subject to the influence like VFB pin away from the wire to SW.
The PCB layout in consideration of these is shown in the Fig.79 to 82.
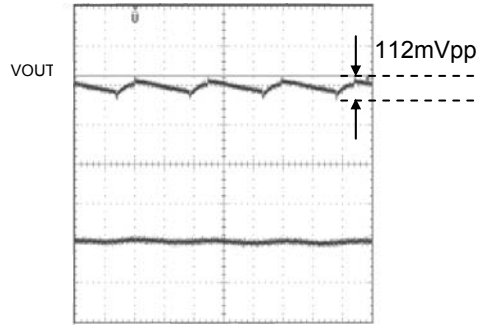
(VBAT=3.6V, Ta=25℃, VOUT=14V, 20mA Load)
Fig.78 Output noise

●Recommended PCB layout
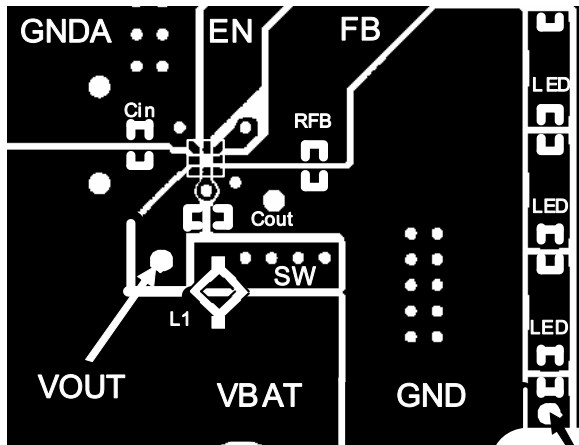
Fig.79 BD6069GUT
Front surface (Top view)
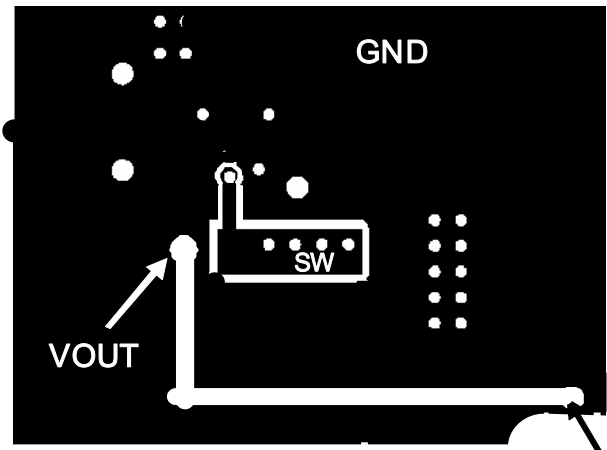
Fig.80 BD6069GUT
Bottom surface (Top view)

►BD6069GUT, BD6072HFN
●Recommended PCB layout
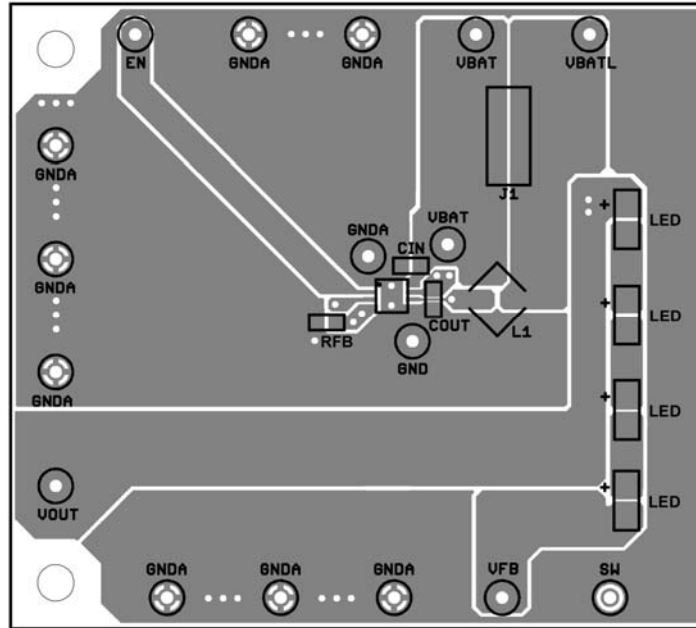
Fig.81 BD6072HFN
Front surface (Top view)
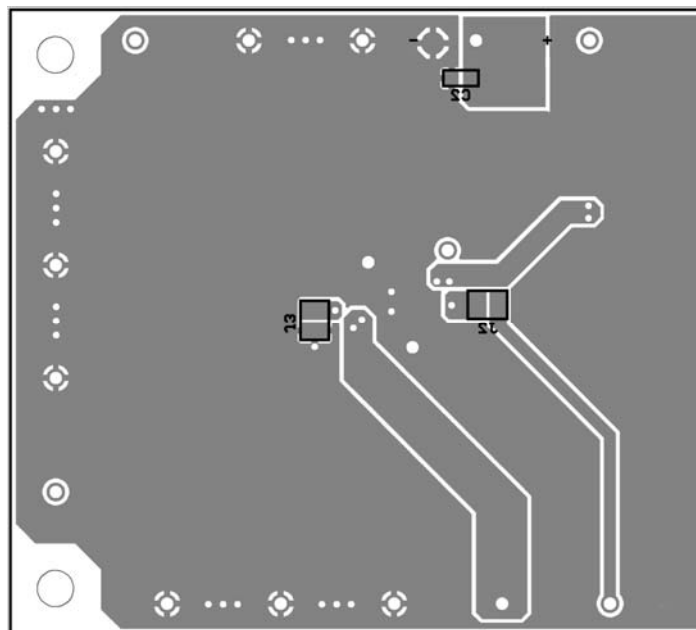
Fig.82 BD6072HFN
Bottom surface (Top view)

●Attention point of PCB layout
In PCB design, the wiring of power supply line should be low Impedance, and put the bypass capacitor if necessary. Especially the wiring impedance must be lower around the DC/DC converter.

●About heat loss
In heat design, operate the DC/DC converter in the following condition.
(The following temperature is a guarantee temperature, so consider the margin.)

1. Periphery temperature Ta must be less than 85℃.
2. The loss of IC must be less than dissipation Pd.

●Notes for use

1) Absolute Maximum Ratings
An excess in the absolute maximum ratings, such as supply voltage, temperature range of operating conditions, 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. In this regard, for the digital block power supply and the analog block power supply, even though these power supplies has the same level of potential, separate the power supply pattern for the digital block from that for the analog block, thus suppressing the diffraction of digital noises to the analog block power supply resulting from impedance common to the wiring patterns. For the GND line, give consideration to design the patterns in a similar manner. 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
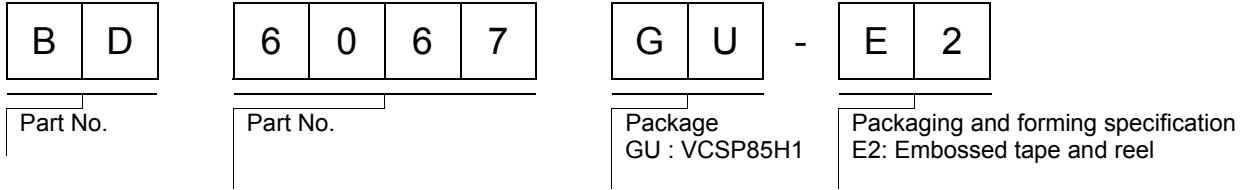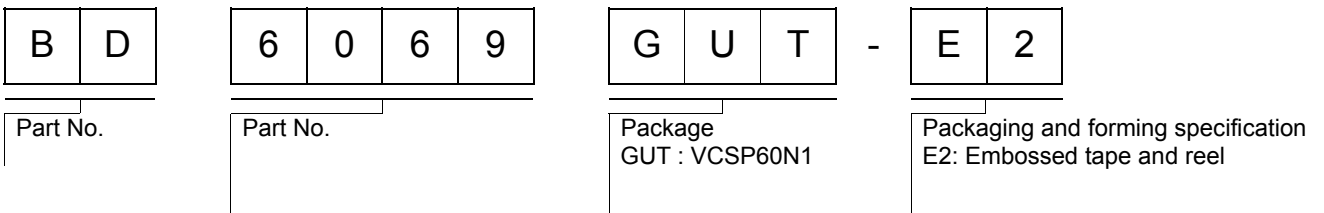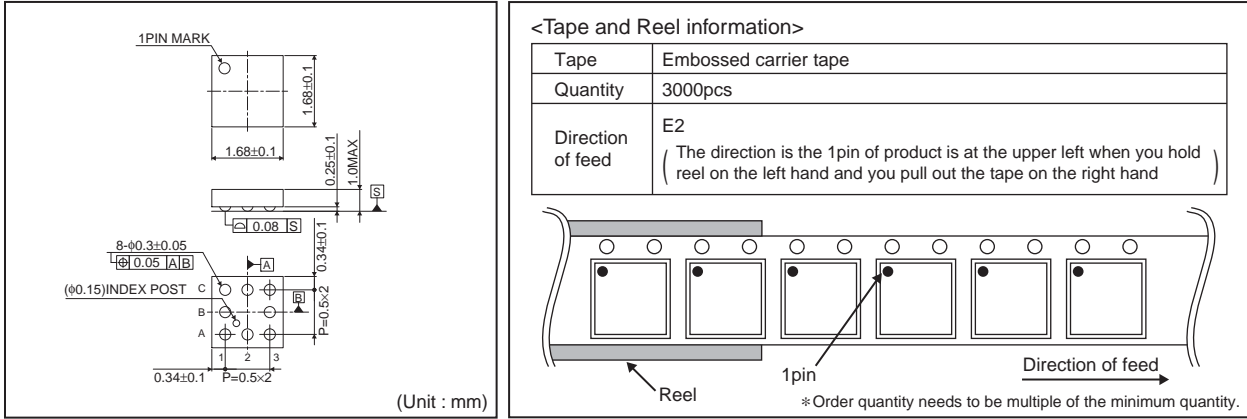In order to mount ICs on a set PCB, pay thorough attention to the direction and offset of the ICs. Erroneous mounting can break down the ICs. Furthermore, if a short circuit occurs due to foreign matters entering between terminals or between the terminal and the power supply or the GND terminal, the 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℃ (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 part number

B	D		6	0	6	7		G	U	-	E	2

Part No.   Part No.   Package   Packaging and forming specification
              GU : VCSP85H1 E2: Embossed tape and reel

VCSP85H1 (BD6067GU)

<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	3000pcs
Direction of feed	E2 (The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand)

(Unit : mm)

※Order quantity needs to be multiple of the minimum quantity.

B	D		6	0	6	9		G	U	T	-	E	2

Part No.   Part No.   Package   Packaging and forming specification
              GUT : VCSP60N1 E2: Embossed tape and reel

VCSP60N1 (BD6069GUT)

<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	3000pcs
Direction of feed	E2 (The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand)

(Unit : mm)

※Order quantity needs to be multiple of the minimum quantity.

| B | D | | 6 | 0 | 7 | 1 | | H | F | N | - | T | R |

Part No.   Part No.   Package   Packaging and forming specification
            6071   6072   HFN : HSON8   TR: Embossed tape and reel

HSON8

2.9±0.1
(MAX 3.1 include. BURR)
0.475
3.0±0.2
2.8±0.1
1PIN MARK
(2.2) (0.05)
(0.2)
(1.8)
(0.45)
(0.3)
(0.15)
(0.2)
0.13 +0.1 −0.05
0.6MAX
+0.03
0.02 −0.02
0.65
0.32±0.1
0.1 S
0.08 M

(Unit : mm)

<Tape and Reel information>

Tape	Embossed carrier tape
Quantity	3000pcs
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)

1pin

Reel   Direction of feed

*Order quantity needs to be multiple of the minimum quantity.

N o t e s

No copying or reproduction of this document, in part or in whole, is permitted without the consent of ROHM Co.,Ltd.

The content specified herein is subject to change for improvement without notice.

The content specified herein is for the purpose of introducing ROHM's products (hereinafter "Products"). If you wish to use any such Product, please be sure to refer to the specifications, which can be obtained from ROHM upon request.

Examples of application circuits, circuit constants and any other information contained herein illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

Great care was taken in ensuring the accuracy of the information specified in this document. However, should you incur any damage arising from any inaccuracy or misprint of such information, ROHM shall bear no responsibility for such damage.

The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM and other parties. ROHM shall bear no responsibility whatsoever for any dispute arising from the use of such technical information.

The Products specified in this document are intended to be used with general-use electronic equipment or devices (such as audio visual equipment, office-automation equipment, communication devices, electronic appliances and amusement devices).

The Products specified in this document are not designed to be radiation tolerant.

While ROHM always makes efforts to enhance the quality and reliability of its Products, a Product may fail or malfunction for a variety of reasons.

Please be sure to implement in your equipment using the Products safety measures to guard against the possibility of physical injury, fire or any other damage caused in the event of the failure of any Product, such as derating, redundancy, fire control and fail-safe designs. ROHM shall bear no responsibility whatsoever for your use of any Product outside of the prescribed scope or not in accordance with the instruction manual.

The Products are not designed or manufactured to be used with any equipment, device or system which requires an extremely high level of reliability the failure or malfunction of which may result in a direct threat to human life or create a risk of human injury (such as a medical instrument, transportation equipment, aerospace machinery, nuclear-reactor controller, fuel-controller or other safety device). ROHM shall bear no responsibility in any way for use of any of the Products for the above special purposes. If a Product is intended to be used for any such special purpose, please contact a ROHM sales representative before purchasing.

If you intend to export or ship overseas any Product or technology specified herein that may be controlled under the Foreign Exchange and the Foreign Trade Law, you will be required to obtain a license or permit under the Law.

Thank you for your accessing to ROHM product informations.
More detail product informations and catalogs are available, please contact us.

ROHM Customer Support System

http://www.rohm.com/contact/