

# **Technical Note**

LED Drivers for LCD Backlights

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

**BD6066GU, BD6066EKN** 

No.11040EBT26

#### Description

BD6066GU/BD6066EKN are white LED driver ICs with PWM step-up DC/DC converter that can boost max 40.5V and current driver that can drive max 30mA. The wide brightness can be adjusted to control by external PWM pulse on power control terminal. And, with extended resolution current driver, a few errors between the lines of the current driver, it is suitable for decreasing the lacking in brightness of the display. BD6066GU, CSP package type, is suited for saving space. BD6066EKN, HQFN package type, is suited for mounting on the flexible board.

#### Features

- 1) High efficiency PWM step-up DC/DC converter (fsw=1MHz)
- 2) Extended resolution current driver 4ch
- 3) Driving \*12 series × 4parallel =48 white LEDs (\*white LED Vf=3.2Vmax)
- 4) Wide input voltage range (2.7V ~ 22V)
- 5) Rich safety functions
  - Over-voltage protection (OVP)
  - Over current limit
  - External SBD open detect
  - Thermal shutdown (175 °C)
- 6) CSP small & thin package

VCSP85H2 2.6 x 2.6 x 0.85mm HQFN28V 5.2 × 5.2 × 0.95mm

#### Applications

Notebook PC, portable DVD player, car navigation systems

#### Absolute maximum ratings (Ta=25 °C)

Parameter	Symbol	Limits	Unit	Condition
Maximum applied voltage 1	VMAX1	7	V	TEST,ISET,VREG,SENSP, SENSN, SW, EN1, EN2, PWM
Maximum applied voltage 2	VMAX2	15.5	V	LED1, LED2, LED3, LED4
Maximum applied voltage 3	VMAX3	30.5	V	VBAT
Maximum applied voltage 4	VMAX4	50.5	V	VDET
Power dissipation 1 (BD6066GU)	Pd1	1100 *1	mW	
Power dissipation 2 (BD6066EKN)	Pd2	560 <sup>*2</sup>	mW	
Power dissipation 3 (BD6066EKN)	Pd3	880 <sup>*3</sup>	mW	
Power dissipation 4 (BD6066EKN)	Pd4	2650 *4	mW	
Operating temperature range	Topr	-30 ~ +85	°C	
Storage temperature range	Tstg	-55 ~ +150	°C	

(\*1) The measurement value which was mounted on the PCB by ROHM. When it's used by more than Ta=25 °C, it's reduced by 8.8mW/ °C.

(\*2) Reduced 4.5mW/ °C With Ta>25 °C when not mounted on a heat radiation Board.

(\*3) 70mm x 70mm x 1.6mm glass epoxy Board which has 1 layers (60mm x 60mm). When it's used by more than Ta=25 °C, it's reduced by 7.0mW/ °C.

(\*4) 70mm x 70mm x 1.6mm glass epoxy Board which has 2 layers (60mm x 60mm). When it's used by more than Ta=25 °C, it's reduced by 21.2mW/ °C.

#### ●Recommended operating range (Ta=-30 °C ~ +85 °C)

Parameter		Sumbol		Limits		Linit	Condition
Parameter		Symbol	Min.	Тур.	Max.	Unit	Condition
Rower oupply veltage	BD6066GU		0.7	12.0	22.0	V	
Fower supply voltage	BD6066EKN	VDAI	2.7	12.0	22.0	v	

#### ●Electrical characteristic (Unless otherwise specified, VBAT=12V, Ta = +25 °C)

Parameter	Symbol		Limits		Lloit	Condition
Falameter	Symbol	Min.	Тур.	Max.	Unit	Condition
[EN Terminal]	1		1	T		T
EN threshold voltage (Low)	VthL	0	-	0.2	V	
EN threshold voltage (High) 1	VthH1	1.4	-	5.0	V	VBAT > 5.0V
EN threshold voltage (High) 2	VthH2	1.4	-	VBAT	V	VBAT < 5.0V
EN terminal input current	lin	-	8.3	14.0	μA	EN=2.5V
EN terminal output current	lout	-2.0	-0.1	-	μA	EN=0V
[PWM Terminal]						
Low Input Voltage range	PWML	0	-	0.2	V	
High Input Voltage range1	PWMH1	1.4	-	5.0	V	VBAT > 5.0V
High Input Voltage range2	PWMH2	1.4	-	VBAT	V	VBAT < 5.0V
PWM pull down resistor	PWMR	300	500	700	kΩ	
[Regulator]						-
VREG Voltage	VREG	4.0	5.0	6.0	V	
Under Voltage Lock Out	UVLO	2.05	2.35	2.65	V	
[Switching Regulator]					1	-
Input voltage range	Vin	3.1	12.0	22.0	V	*1
Quiescent Current 1	lq1	-	0.6	3.4	μA	EN=0V, VBAT=12V
Quiescent Current 2	lq2	-	4.6	10	μA	EN=0V, VBAT=22V
Current Consumption	ldd	-	3.4	5.1	mA	EN=3.6V, VDET=0V,ISET=24kΩ
LED Control voltage	VLED	0.4	0.5	0.6	V	
Over Current Limit voltage	Оср	70	100	130	mV	*2
SBD Open Protect	Sop	-	0.2	1.4	V	
Switching frequency	fSW	0.8	1.0	1.2	MHz	
Duty cycle limit	Duty	92.5	95.0	99.0	%	LED1=LED2=LED3=LED4=0V
Over Voltage Limit	Ovl	40.5	42.0	43.5	V	LED1=LED2=LED3=LED4=0V
Start up time	Ts	-	0.5	1.0	ms	Output voltage=24V
[Current driver]						
LED maximum current	ILMAX	-	-	30	mA	
LED current accuracy	ILACCU	-	-	±5	%	ILED=20mA
LED current matching	ILMAT	-	-	±3	%	- Each LED current / Average (LED1,2,3,4) - ILED=20mA
ISET voltage	lset	0.5	0.6	0.7	V	
LED current limiter	ILOCP	35	60	90	mA	
LED Terminal Over Voltage Protect	LEDOVP	12.5	13.5	14.5	V	

\*1 Electrical characteristics are guaranteed from 3.1V to 22V and operating is guaranteed from 2.7V to 3.1V.
\*2 This parameter is tested with dc measurement.

#### Reference data



Current Consumption - power source voltage



#### Over Voltage Limit - power source voltage



Fig.7





Fig.2 Quiescent current - power source voltage





1.3

Oscillation frequency - power source voltage



Fig.6 LED terminal Over Voltage Protect vs power source voltage



Fig.9 Over Current Limit Voltage - Temperature





VREG - power source voltage



Ta[⁰C]

Fig.8

UVLO - Temperature



0.4

2.5

2

1.5

1

0.5

0

-50 -25 0 25 50 75 100

Fig.5

SBD Open Protect Limit - power source voltage

20

100

30



Fig.22 LED Open Voltage

#### Block diagram, I/O equivalent circuit diagram



#### Pin assignment table

DIN Nomo	In/Out	PIN n	umber	Function	Terminal equivalent
	m/Out	BD6066GU	BD6066EKN	Function	circuit diagram
SENSN	In	A1	1	- Side Current sense terminal	A
GND	-	A2	2	GND	В
VDET	In	C3	3	Detect input for SBD open and OVP	С
N.C.	-	-	4	No connect pin	-
N.C.	-	-	5	No connect pin	-
ISET	In	A3	6	Resistor connection for LED current setting	A
TEST	In	A4	7	TEST input (Pull down 100kΩ to GND)	G
N.C.	-	-	8	No connect pin	-
LED4	In	A5	9	Current sink for LED4	С
LED3	In	B5	10	Current sink for LED3	С
N.C.	-	-	11	No connect pin	-
LED2	In	C5	12	Current sink for LED2	С
LED1	In	D5	13	Current sink for LED1	С
N.C.	-	-	14	No connect pin	-
EN1	In	E5	15	Enable input 1	E
N.C.	-	-	16	No connect pin	-
EN2	In	E3	17	Enable input 2	E
N.C.	-	-	18	No connect pin	-
VBAT	In	E4	19	Battery input	С
VREG	Out	E2	20	Regulator output / Internal power-supply	D
PWM	In	E1	21	PWM input	F
N.C.	-	-	22	No connect pin	-
GND	-	D1	23	GND	В
N.C.	-	-	24	No connect pin	-
VREG	Out	-	25	Regulator output / Internal power-supply	D
SW	Out	C1	26	Switching Tr drive terminal	G
SENSP	In	B1	27	+ Side Current sense terminal	G
GND	-	-	28	GND	В

#### Application example









Battery





#### 4.7µH 12| FD g RB160M-60 J 10µF (25V) Ż 2.2µF (100V) **≥**270kΩ Ţ SW VDET SENSP $\overset{\cdot}{\boxtimes}$ 39mΩ ~ $\bigotimes$ SENSN Ţ LED1 Power ON/OFF EN1 LED2 EN2 Ж PWM LED3 200Hz LED4 A VBAT Each 20mA VREG 2 1µF(10V) GND GND TEST ISET **≩** 24kΩ

Fig.28 Over voltage 48.1V(typ) by external resistor, LED current 20mA setting example (12 series (V<sub>F</sub>3.6Vmax) × 4parallel)

#### Terminal processing

TEST pin = Connect to GND

- N.C. = Nothing specified in particular. Open is recommended.
- VREG = When IC is driving from the outside of 3.1~5.5V, short VBAT and VREG, and put the voltage to VREG
- EN1, 2 = Connect to GND in case of fixing at L level
- LED1, 2 = When each LED driver are not used at EN setting, connect to VREG terminal or the power supply of more than 1V.
- GND = Each GND is connecting inside IC. Connect to GND of all PCB

#### Description of Functions

1) PWM current mode DC/DC converter

While BD6066GU/EKN is power ON, the lowest voltage of LED1, 2, 3, 4 is detected, PWM duty is decided to be 0.5V and output voltage is kept invariably. 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 external Nch Tr via the RS latch. In the period where external Nch Tr gate is ON, energy is accumulated in the external inductor, and in the period where external Nch Tr gate is OFF, energy is transferred to the output capacitor via external SBD. BD6066GU/EKN has many safety functions, and their detection signals stop switching operation at once.

#### 2) Soft start and off status

BD6066GU/EKN has soft start function and off status function.

The soft start function and the off status function prevent large coil current.

Rush current at turning on is prevented by the soft start function, and invalid current at turning off is prevented by the off status function.

#### 3) External SBD open detect and over voltage protection

BD6066GU/EKN has over boost protection by external SBD open and over voltage protection. This function will stop the switching. Details are as shown below.

External SBD open detect

In the case of external SBD is not connected to IC, the coil or external Tr may be destructed. Therefore, at such an error as VOUT becoming 0.2V 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 activation into non-activation, and current does not flow to the coil (0mA).

#### 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 will boost too much and the VDET terminal exceed the absolute maximum ratings, and may destruct the IC. Therefore, when VDET becomes sensing voltage or higher, the over voltage limit works, and turns off the output Tr, and the pressure up made stop. At this moment, the IC changes from activation into non-activation, 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 pressure up to sensing voltage once again and unless the application error is recovered, this operation is repeated.

This protection action is shown in Fig.29.



Fig.29 Block diagram of external SBD open detect and over voltage

#### 4) Thermal shut down

BD6066GU/EKN has thermal shut down function.

The thermal shut down works at 175°C or higher, and while holding the setting of EN control from the outside, the IC changes from activation into non-activation. And at 175°C or below, the IC gets back to its normal action.

5) Over Current Limit

Over current flows the current detection resistor that is connected to switching transistor source and between GND, SENSP pin 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 BD6066GU/EKN is detected peak current, current more than over current setting value does not flow.

And, over current value can decide freely by changing over current detection voltage.

<Derivation sequence of detection resistor>

Detection resistor =Over current detection voltage / Over current setting value

TYP value of over current detection voltage is 100mV, MIN = 70mV and MAX = 130mV and after the current value which was necessary for the normal operation was decided, detection resistor is derived by using MIN value of over current detection value.

For example, detection resistor when necessary current value was set at 1A is given as shown below.

Detection resistor =70mV / 1A = 70m $\Omega$ 

MAX current dispersion of this detection resistor value is

MAX current =  $130mV / 70m\Omega = 1.86A$ 

<The estimate of the current value which need for the normal operation >

As over current detector of BD6066GU/EKN is detected the peak current, it have to estimate peak current to flow to the coil by operating condition.

In case of, Supply voltage of coil = VIN Reactance value of coil = L Switching frequency = fsw Output voltage = VOUT Total LED current = IOUT Average current of coil = lave Peak current of coil = lpeak Efficiency = eff ON time of switching transistor = Ton

 $\begin{aligned} & |\text{peak} = (\text{VIN} / \text{L}) \times (1 / \text{fsw}) \times (1 - (\text{VIN} / \text{VOUT})) \\ & |\text{lave} = (\text{VOUT} \times |\text{OUT} / \text{VIN}) / \text{eff} \\ & \text{Ton} = (\text{lave} \times (1 - \text{VIN}/\text{VOUT}) \times (1 / \text{fsw}) \times (\text{L}/\text{VIN}) \times 2)^{1/2} \end{aligned}$ 

Each current is calculated.

As peak current varies according to whether there is the direct current superposed, the next is decided. (1-VIN/VOUT) × (1/fsw) < Ton $\rightarrow$  peak current = Ipeak /2 + Iave (1-VIN/VOUT) × (1/fsw) > Ton $\rightarrow$  peak current = Ipeak

(Example 1) In case of, VIN=6.5V, L=4.7 $\mu$ H, fsw=1MHz, VOUT=39V, IOUT=80mA, Efficiency=85% Ipeak = (6.5V / 4.7 $\mu$ H) × (1 / 1MHz) × (1-(6.5V / 39V)) =1.08A Iave = (39V × 80mA / 6.0V) / 85% = 0.61A Ton = (0.61A × (1-6.0V / 39V) × (1 / 1MHz) × (4.7 $\mu$ H /6.0V) × 2)<sup>1/2</sup> = 0.90 $\mu$ s (1-VIN/VOUT) × (1/fsw)=0.85 $\mu$ s < Ton Peak current = 1.08A/2+0.61A = 1.15A

(Example 2) In case of, VIN=12.0V, L=4.7 $\mu$ H, fsw=1MHz, VOUT=39V, IOUT=80mA, Efficiency=85% Ipeak = (12.0V / 4.7 $\mu$ H) × (1 / 1MHz) × (1-(12V / 39V)) =1.77A Iave = (39V × 80mA / 12.0V) / 85% = 0.31A Ton = (0.31A × (1-12 V / 39V) × (1 / 1MHz) × (4.7 $\mu$ H /12 V) × 2)<sup>1/2</sup> = 0.41 $\mu$ s (1-VIN/VOUT) × (1/fsw)=0.69 $\mu$ s > Ton Peak current = 12V/4.7 $\mu$ H × 0.41 $\mu$ s = 1.05A

#### Start control and select constant current driver

BD6066GU/EKN can control the start conditions by EN1, 2 terminal and PWM terminal, and sets 0.2V or below EN1, 2 terminal or sets 0.2 or below PWM terminal and IC can power off by being 0V LED terminal selected EN1, 2. PWM, EN power on at more than 1.4V, constant current can select ON/OFF by the combination of EN as shown below table. When there is unused constant current driver, connect unused LED terminal to VREG terminal or connect to fixed voltage of more than 1V. And, EN1, 2 are changed with PWM=H and it is prohibited to change a constant current driver.

	Enable		Constant current driver				
EN1	EN2	PWM	LED1	LED2	LED3	LED4	
Н	Н	Н	OFF	OFF	ON	ON	
L	Н	Н	OFF	ON	ON	ON	
Н	L	Н	ON	ON	ON	ON	
L	L	Н					
Н	Н	L	]				
L	Н	L		Ur A a far thaga actu	-F	<b>`</b>	
Н	L	L	(As for these setups, power-off IC.)				
L	L	L					

#### Off sequence

Off sequence controls power off timing of each block, LED terminal may not exceed the pressure.

After EN or PWM terminal set  $H\rightarrow L$ , it continues electric current by the current value decided with ISET terminal until all the LED terminals selected with EN are less than 40mV and output voltage reduces. On that occasion, the DC/DC power-off is given and it doesn't have a charge to the output capacitor. After that, LED driver is turned off, built-in REG is turned off, and power-off is completed. If the VF tolerance of the LED is large, it doesn't need to examine VF not to exceed pressure of the LED terminal by this sequence.



Fig.30 Block diagram of off sequence

LED current

20.0mA

18.8mA

17.8mA

17.1mA

16.0mA 14.5mA

ISET setting example

RISET

24.0 kΩ (E24)

(E96)

(E12)

(E96)

(E24)

(E6)

25.5 kΩ

27.0 kΩ

28.0 kΩ

30.0 kΩ

33.0 kΩ

#### Setting of LED current and current range

LED current can set up resistance value (RISET) connecting to ISET, LED current setting range is 4mA~30mA.

Setting of LED current is given as shown below. LED current =  $20\text{mA} \times (24\text{k}\Omega / \text{RISET})$ 

The current in the standard application is as shown below. RISET=24k $\Omega$ , LED current=20mA

#### Brightness control

PWM brightness adjustment is made by inputting PWM pulse to PWM pin.

The electric current select setting with ISET in the Hi section, and the Lo section turns off the electric current. Lo. The average current increases in proportion with the duty cycle of PWM signal. By this method, IC can power off at the OFF time, the IC and LED both consume no currents, thus providing a high-efficiency operation. The recommended PWM frequency is 100Hz ~ 300Hz.

<ON time limit>

On time is necessary more than 750µs (at the time of 200Hz, 15%) to require the start up-time of 750µs.

#### < OFF time limit >

OFF time is approximated by the following parameter.

External output capacitor	: Cvout	
LED current setting	: ILED	(worst = +5%)
LED sequence number	: NPLED	
LED series number	: NSLED	
VF tolerance of LED terminal	:ΔVF	
Reaction time of internal circuit	: 10µs	(worst = 15µs)

Necessary time for OFF (typ) = Cvout × (( $\Delta$ VF × NSLED) + 0.5V)/(ILED × NPLED)+10µs

#### (example)

Necessary time for OFF (typ) =  $2\mu$ F × ((0.2V × 10 lights) + 0.5V)/(20mA × 4)+10 $\mu$ s = 72.5 $\mu$ s

<PWM=200Hz, duty1.5% equivalent>

<PWM=200Hz. dutv2.3% equivalent >

Please use worst value of each parameter when you calculate the worst time.

(example) Necessary time for OFF (worst) = (2μF × 1.3) × ((0.26V × 10 lights) + 0.7V)/((20mA × 1.05) × 4)+15μs =117μs

And please don't use ON time under 750µs or under OFF time calculated in the above of current setting for the brightness control, because power-on/off has very influential.

#### •Noise of ceramic capacitor by PWM brightness control

In order to use a ceramic capacitor as the output capacitor, noise of capacitor occurs by the kind of the circuit board and mounted method, the mounting place.

As for the noise cause, the resonant of ceramic capacitor and the board give cause by output voltage fluctuation. Measures of this trouble are shown.

(1) Ceramic capacitor is changed to tantalum capacitor.

By changing to tantalum capacitor, noise is stopped because of changing ceramic capacitor itself bringing about the noise. But, as the output ripple increases by ESR that is characteristic of the tantalum, it needs to select tantalum with low ESR.

Also, it recommends connecting parallel capacitor for the noise measure of  $0.1 \mu \text{F}$ 

Recommended capacitor is shown next page.

(2) Ceramic capacitor is floated from the top of the circuit board.

Reducing the contact surface of the ceramic capacitor and the circuit board can reduce the noise.

Capacitor that can float a capacitor from the circuit board are as shown below. This capacitor is connected the metal cap both electrodes of the capacitor, so It can have the effect which be floated because the metal cap is connected to the circuit board. Recommended capacitor is shown next page.



Fig.31 The metal cap capacitor

#### 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 Manufacturar	Product number		Size		DC current	DCR	Use power	
value	Manufacturer	FIGUELIUMBEI	Vertical	Horizontal	Height	(mA)	(Ω)	voltage range
4.7µH	ТОКО	B1015AS-4R7N	8.4	8.3	4.0	3300	0.038	2.7 ~ 22V
4.7µH	TAIYO YUDEN	NR4012T4R7M	4.0	4.0	1.2	960	0.14	2.7 ~ 22V
4.7µH	TAIYO YUDEN	NR4018T4R7M	4.0	4.0	1.8	1200	0.11	2.7 ~ 22V
6.8µH	TAIYO YUDEN	NR4012T6R8M	4.0	4.0	1.2	840	0.18	7.0 ~ 22V

#### Capacitor

Value	Value Pressure Manufacturer		Draduat number		Size		Tomporatura rango
value	Pressure	Manufacturer	Product number	Vertical	Horizontal	Height	remperature range
[ Power	supply capa	acitor ]					
10µF	25V	MURATA	GRM31CB31E106KA75	3.2	1.6	1.6	-25deg ~ +85deg
[ Smooth	hing capacit	tor for built-in reg	gulator]				
1µF	10V	MURATA	GRM188B10J105KA01	1.6	0.8	0.8	-25deg ~ +85deg
[Output	capacitor ]						
1µF	50V	MURATA	GRM31MB31H105KA87	3.2	1.6	1.15	-25deg ~ +85deg
2.2µF	50V	MURATA	GRM31CB31H225KA87	3.2	1.6	1.6	-25deg ~ +85deg
[Output	capacitor ]	Noise measure	1 of ceramic capacitor (tant	alum capao	citor +0.1µF	)	
0.1µF	50V	MURATA	GRM188B31H104KA92	1.6	0.8	0.8	-25deg ~ +85deg
1.0µF	50V	KYOCERA	TAJW105M050	6.0	3.2	1.5	-55deg ~ +125deg
2.2µF	50V	KYOCERA	TAJC225M050	6.0	3.2	2.6	-55deg ~ +125deg
[ Output	capacitor ]	Noise measure	2 of ceramic capacitor (cap	acitor with	the metal ca	ıp)	
2.2µF	100V	TDK	CKG45NX7R2A225N	5.5	4.0	5.5	-55deg ~ +125deg

#### Resistor

Value	Toloronoo	Manufacturor	Product number	Size			
value	TOIETATICE	Manulacturer	FIGURELING	Vertical	Horizontal	Height	
[Resist	or for LED o	current decision	<iset pin="">]</iset>				
24kΩ	±0.5%	ROHM	MCR006YZPD243	0.6	0.3	0.23	
[Resist	or for over o	current decision	<sensp pin="">]</sensp>				
47mΩ	±1%	ROHM	MCR10EZHFLR047	2.0	1.25	0.55	

#### SBD

Proceuro	Manufacturor	Product number		Size	
Flessule	Manulacturer	Product number	Vertical	Horizontal	Height
60V	ROHM	RB160M-60	3.5	1.6	0.8

#### MOS FET Nch

Prossure	Manufacturor	Product number		Size	Current	Driving	
Flessule	Manufacturer	FIGURELITUINDEL	Vertical	Horizontal	Height	ability	voltage
45V	ROHM	RTR020N05	3.5	1.6	0.8	2A	2.5V
60V	ROHM	2SK2503	9.5	6.5	2.3	5A	4.0V
60V	FAIR CHILD	NDT3055L	6.5	7.0	1.8	4A	2.0V

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. BD6066GU/EKN are designed for the inductance value of  $4.7\mu$ H or  $6.8\mu$ H. Do not use other inductance value. Select a capacitor of ceramic type with excellent frequency and temperature characteristics. Further, select Capacitor to be used 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 layout patterns, which please note carefully.



#### Fig.32 PCB Layout

Connect the input bypath capacitor CIN(10µF) nearest to coil L, as shown in the upper diagram.

Wire the power supply line by the low resistance from CIN to VBAT pin.

And, when it can't be wired by the low resistance, connect the input capacitor  $CBAT(1\mu F)$  nearest to between VBAT and GND pin, as shown in the upper diagram. Thereby, the input voltage ripple of the IC can be reduced.

Connect smoothing capacitor CREG of the regulator nearest to between VREG and GND pin, as shown in the upper diagram.

Connect schottky barrier diode SBD of the regulator nearest to between coil L and switching transistor Tr.

And connect output capacitor COUT nearest to between CIN and GND pin. Thereby, the output voltage ripple of the IC can be reduced.

Connect switching transistor Tr nearest to SW pin. Wire coil L and switching transistor Tr, current sensing resistor  $R_{SENSE}$  by the low resistance. Wiring to the SENSP pin isn't Tr side, but connect it from  $R_{SENSE}$  side.

Over current value may become low when wiring from Tr side.

Connect  $R_{SENSE}$  of GND side isolated to SENS pin. Don't wire between  $R_{SENSE}$  and SNESN pin wiring from SNESN pin to GND pin. After via SENSN pin, connect GND pin, as shown in the upper diagram.

Connect LED current setting resistor RISET nearest to ISET pin. There is possibility to oscillate when capacity is added to ISET terminal, so pay attention that capacity isn't added. And, connect RISET of GND side directly to GND pin.

When those pins are not connected directly near the chip, influence is given to the performance of BD6066GU/EKN, 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



Fig.33 BD6066EKN Component side (Top view)

Fig.34 BD6066EKN Back side (Top view)

#### •Attention point of PCB layout

In PCB layout 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°C
- 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

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°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 part number



#### VCSP85H2 (BD6066GU)



#### HQFN28V



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