White LEDs Driver
for up to 2LEDs in series, 5 strings

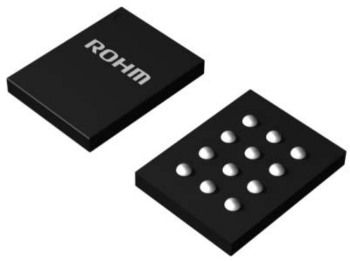
BD6079GWL

●General Description
BD6079GWL is a boost-up DC/DC type white LED driver IC with synchronous rectification that can drive up to 10 LEDs, arranged in 1-5 strings of 2LEDs in Series, with string LED Cathodes connected to GND.
With synchronous rectification (no external schottky diode required) and small package, it is possible to save mount space.
The brightness of LED can be adjusted by using PWM pulse on EN pin. (PWM Frequency :100Hz~1600Hz)
LED current is set by resistance at ISET terminal.

●Key Specification
- Power supply voltage range: 2.3V to 5.5V
- Quiescent Current: 0.4µA (Typ.)
- Switching frequency 2MHz(Typ.)
- Operating temperature range -30°C to +85°C

●Features
- Synchronous rectification Boost type DC/DC converter
- No external schottky diode required
- 1-5 strings of 2 white LEDs in series
- Boost function with 1 wire
- Brightness adjustment by external PWM pulse
- High Efficiency (87.8%(Typ.) at 115mA)
- High accuracy & good matching current driver
- Rich safety functions
  - ➢ Over-voltage protection
  - ➢ Output short protection
  - ➢ Inductor Over Current Limit
  - ➢ LED open/short protection
  - ➢ Under voltage lockout
  - ➢ Thermal shutdown

●Package
Package	W (Typ.) x D (Typ.) x H (Max.)
UCSP50L1	1.80mm x 1.40mm x 0.50mm



●Application
This LED driver IC is applicable for various fields such as Backlight for mobile phones, portable game machines, door phones, audio players, portable DVD players, printer, etc.
Torchlight and easy flash for camera of mobile phone
Portable equipment

●Typical Application Circuit

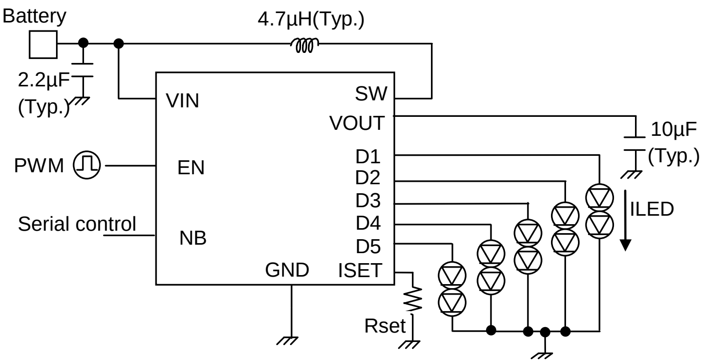
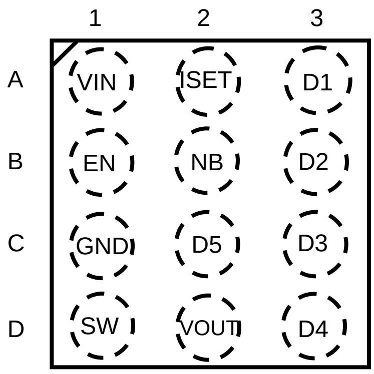


Figure 1. Typical Application Circuit

●Pin Configuration



Top View

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

●Absolute Maximum Rating(Ta=25°C)

Parameter	Symbol	Value	Unit	Condition
Maximum applied voltage 1	VMAX1	-0.3 to 7.0 *1	V	VIN, EN, NB, ISET
Maximum applied voltage 2	VMAX2	-0.3 to 10.5 *1	V	SW, VOUT, D1, D2, D3, D4, D5
Power dissipation	Pd	650 *2	mW	-
Operating temperature range	Topr	-30 to +85	°C	-
Storage temperature range	Tstg	-55 to +150	°C	-
Junction temperature	Tjnc	150	°C	-
Electrostatic protection	MM	-200 to +200	V	Machine model
	HBM	-2000 to +2000	V	Human body model
	CDM	-1000 to +1000	V	Charged device model

*1 These values are based on GND pin.
*2 50mm×58mm×1.75mm At glass epoxy board mounting. When it's used by more than Ta=25°C, it's reduced by 5.2mW/°C.

●Recommended Operating condition（Ta=25°C）

Item	Value			Unit
	Min.	Typ.	Max.	
Power supply voltage	2.3	3.7	5.5	V

●Electrical Characteristics Unless otherwise specified Ta =-30°C to +85°C, VIN=2.5 to 4.8V

Item	Symbol	Min.	Typ.	Max.	Unit	Condition
[EN, NB terminal]						
Input voltage (Low)	VthL	-	-	0.68	V	
Input voltage (High)	VthH	1.07	1.20	-	V	
Pull down resistor	PDR	-	250	-	kΩ	
[Consumption current]						
Quiescent Current	Ishut	-	0.4	2.0	µA	EN=0V, NB=0V
Operating current H	IqH	-	1.1	-	mA	EN=2.5V, NB=0V, Rset=18kΩ, No switching VOUT=7.0V, VLED*1=6.5V
[Switching regulator]						
Inductor current limit	Icoil	-	0.85	1.00	A	VIN=3.7V This parameter is tested with DC measurement.
SW NMOS on resistance	RonN	-	0.4	-	Ω	Inch=200mA
SW PMOS on resistance	RonP	-	1.0	-	Ω	Ipch=200mA, VOUT=7.0V
Switching frequency	Fsw	-	2.0	3.0	MHz	
Duty cycle limit	Duty	76.0	-	-	%	
Output voltage range	Vo	-	-	8.1	V	
Over voltage limit	Ovl	8.8	9.2	9.6	V	During Initial boost only.
VOUT ripple	VOUTpp	-	-	100	mV	COUT=10µF

1 VLED=D1~D5 voltage

●Electrical Characteristics (continued)

Unless otherwise specified Ta =-30°C to +85°C, VIN=2.5 to 4.8V

Item	Symbol	Min.	Typ.	Max.	Unit	Condition
[Switching regulator]						
Efficiency 1 *1	Eff1	78.0	83.0	-	%	VIN=3.7V, VLED*2=5.6V, PWM=100%, Iload=25mA
Efficiency 2 *1	Eff2	86.5	88.0	-	%	VIN=3.7V, VLED*2=6.3V, PWM=100%, Iload=80mA
Efficiency 3 *1	Eff3	86.8	87.8	-	%	VIN=3.7V, VLED*2=6.6V, PWM=100%, Iload=115mA
Efficiency 4 *1	Eff4	85.0	-	-	%	VIN=3.7V, VLED*2=6.8V, PWM=100%, Iload=140mA
Efficiency 5 *1	Eff5	75.5	-	-	%	VIN=3.7V,VLED*2=6.3V, PWM=1%, PWM Frequency = 1600Hz, Iload=80mA
Efficiency 6 *1	Eff6	75.5	-	-	%	VIN=3.7V,VLED*2=6.6V, PWM=1%, PWM Frequency = 1600Hz, Iload=115mA
[Current driver]						
Current setting Range	Irng	2.5	-	28.0	mA	
Current setting voltage	Vset	-	0.8	-	V	
Current driver Maximum current detection	$I_{LEDMAX.}$	32	35	38	mA	In failure case Ex) ISET terminal short to GND
Continuous output current	Iout	140	-	-	mA	VIN=2.5V, VOUT=7.5V
Current Accuracy1(27.8mA/ch)	$A_{Mat+Abs}1$	-6.5	0.0	6.5	%	at 200mV max differential between any set of drivers
Current Accuracy2(5mA/ch)	$A_{Mat+Abs}2$	-6.5	0.0	6.5	%	
Current Accuracy3(2.5mA/ch)	$A_{Mat+Abs}3$	-10.0	0.0	10.0	%	
Current matching1(27.8mA/ch)	$A_{Mat}1$	-6.5	-	6.5	%	(D1~5) / ((D_{MAX}*3. + D_{MIN}*4)/2) x 100 [%] at 200mV mad differential between any set of drivers PWM Duty=100%
Current matching2(5mA/ch)	$A_{Mat}2$	-4.0	-	4.0	%	
Current matching3(2.5mA/ch)	$A_{Mat}3$	-7.5	-	7.5	%	
Boost current	I_{BOOST}	-6.5	0.0	6.5	%	NB=2.5V
LED leak current	Iledleak	-	-	1.0	µA	EN=0V,VOUT=7.0V, VLED*2=0V
Hi-side PMOS headroom	Vhead	-	0.15	-	V	
“LED open protect” voltage	V_{LED-o}	8.0	8.2	8.4	V	“D1, D2, D3, D4 or D5” open
“LED short protect” voltage	V_{LED-s}	-	1.00	1.25	V	“D1, D2, D3, D4 or D5” is shorted by GND
Current mirror ratio	Iratio	-	625	-	-	NB=0V
[NB characteristics]						
Tinit	Tinit	120	-	-	µs	
Tlow	Tlow	2	10	25	µs	
Thigh	Thigh	2	10	25	µs	
Twindow	Twindow	-	500	-	µs	
[Others]						
UVLO voltage falling	UVLO1	1.8	-	-	V	
UVLO voltage rising	UVLO2	-	-	2.2	V	
Tshutdown	Tshut	30	33	36	ms	

*1 design guarantee, *2 VLED=D1~D5 voltage, *3 D_{MAX} : Maximum voltage of D1~D5, *4 D_{MIN} : Minimum voltage of D1~D5

●Pin Description

PIN name	In/Out	Ball number	Function
VIN	In	A1	Power supply input, (connect 2.2µF(Typ.) to GND)
ISET	Out	A2	Current setting resistor, Connect the resistor to GND. Resistance value and LED current setting detail are shown in "●LED Current setting range" on page 20.
D1	Out	A3	LED channel 1 (Connect to LED anode)
EN	In	B1	Enable control, EN=L: IC shutdown, Internal pull down When you want to control LED current according to PWM signal. Please input PWM signal from this pin. Please refer to detail setting on page 19.
NB	In	B2	Normal/Boost selectable terminal, NB=L : normal mode, NB=H : boost mode Boost mode is controlled with 1wire. See "boost function" on page 25 for details. Internal pull down
D2	Out	B3	LED channel 2 (Connect to LED anode)
GND	-	C1	Ground connection
D5	Out	C2	LED channel 5 (Connect to LED anode)
D3	Out	C3	LED channel 3 (Connect to LED anode)
SW	In	D1	Switching terminal, connect 4.7µH(Typ.) inductor to Battery
VOUT	Out	D2	Boost output, connect 10µF(Typ.) to GND
D4	Out	D3	LED channel 4 (Connect to LED anode)

●Block Diagram (Typical application)

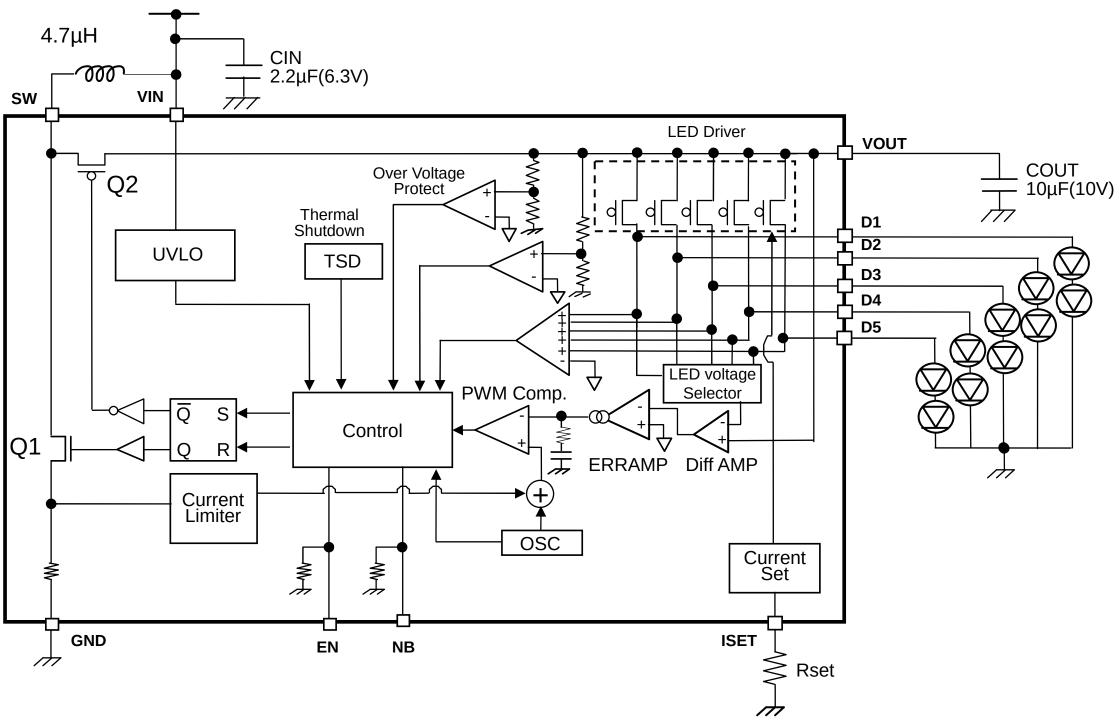


Figure 2. Block Diagram

●**Typical Performance curve (VIN= 3.7V, Ta = +25°C, unless otherwise noted.)**

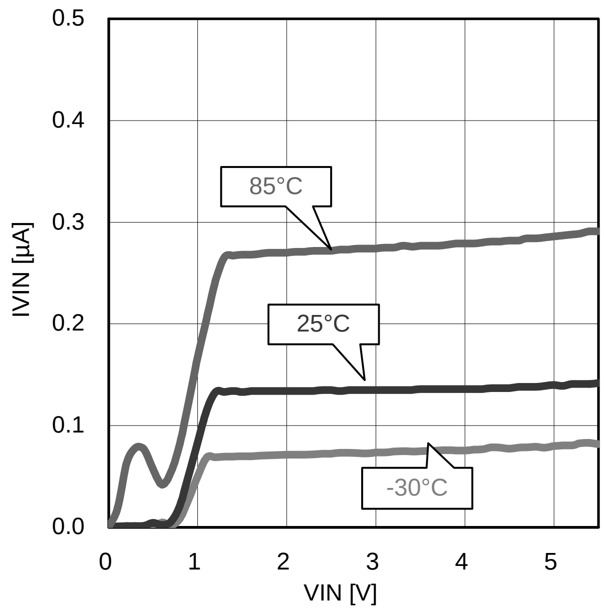


Figure 3. Quiescent Current

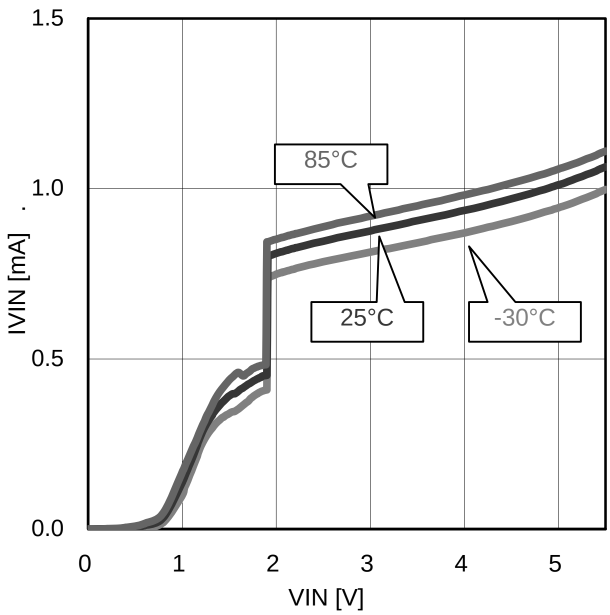


Figure 4. Device operating current

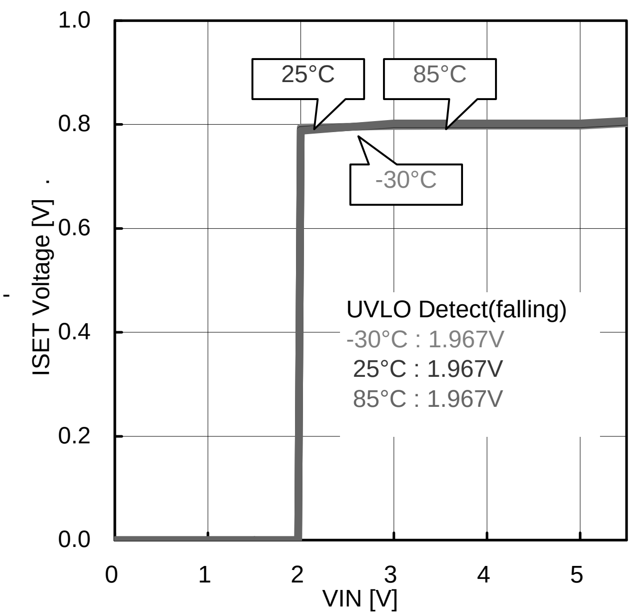


Figure 5. Current setting voltage and UVLO detect function (falling)

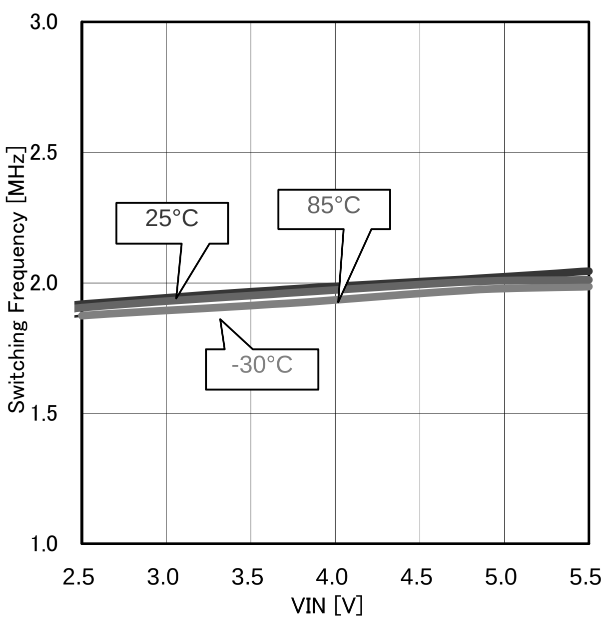


Figure 6. Switching frequency

●**Typical Performance curve - continued**

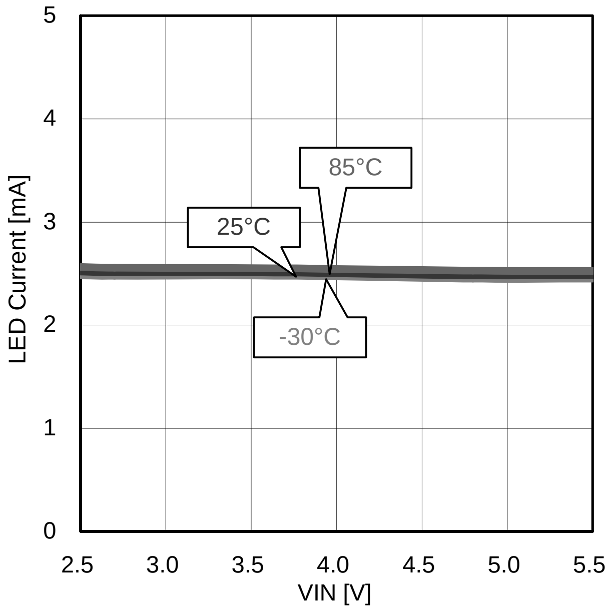


Figure 7. LED Current Stability
(2.5mA setting)

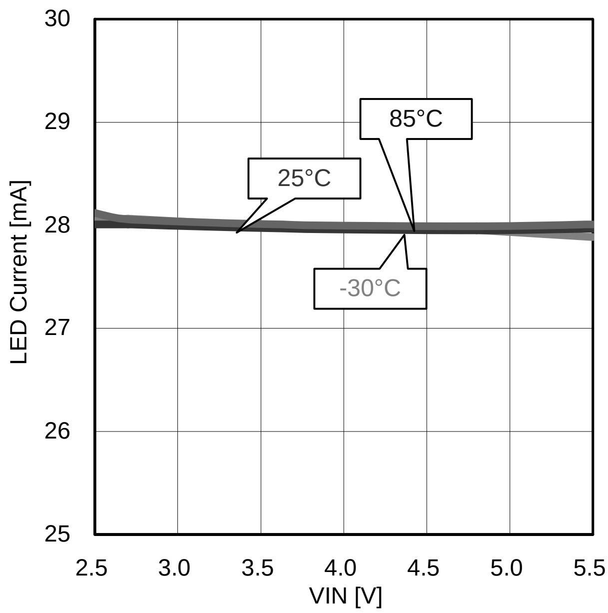


Figure 8. LED Current Stability
(28mA setting)

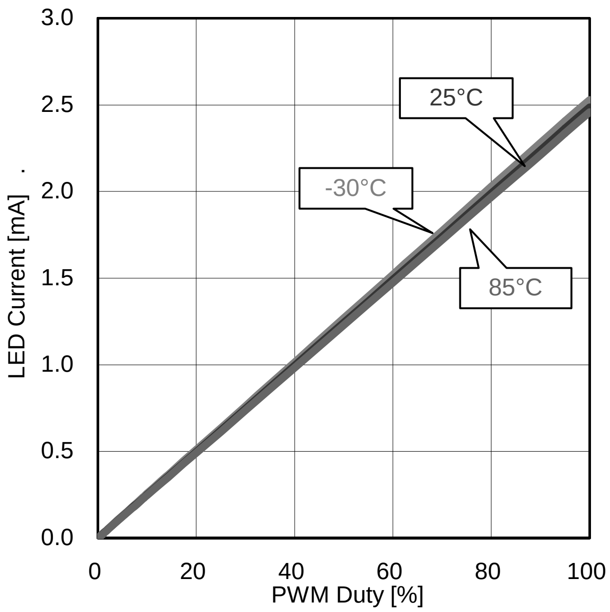


Figure 9. LED Current Linearity
(2.5mA setting, PWM Freq=1600Hz, VIN: 3.7V)

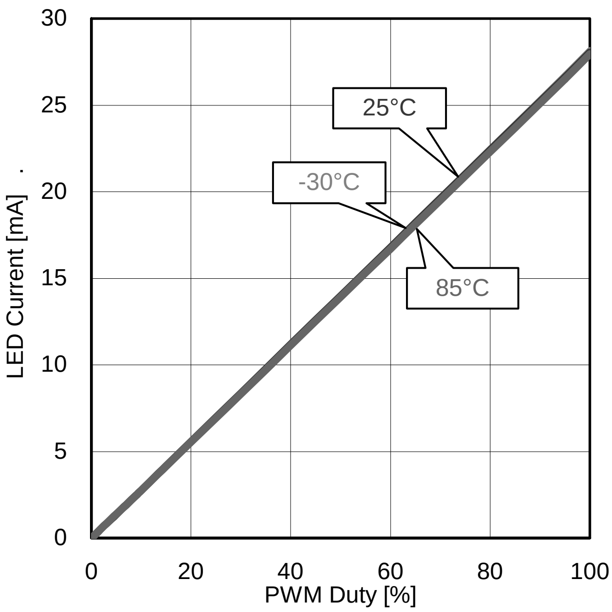


Figure 10. LED Current Linearity
(28mA setting, PWM Freq=1600Hz, VIN: 3.7V)

●**Typical Performance curve - continued**

Efficiency = (ILED1*VLED1 + ILED2*VLED2 + ILED3*VLED3+ ILED4*VLED4+ ILED5*VLED5) / (VBAT*IBAT)

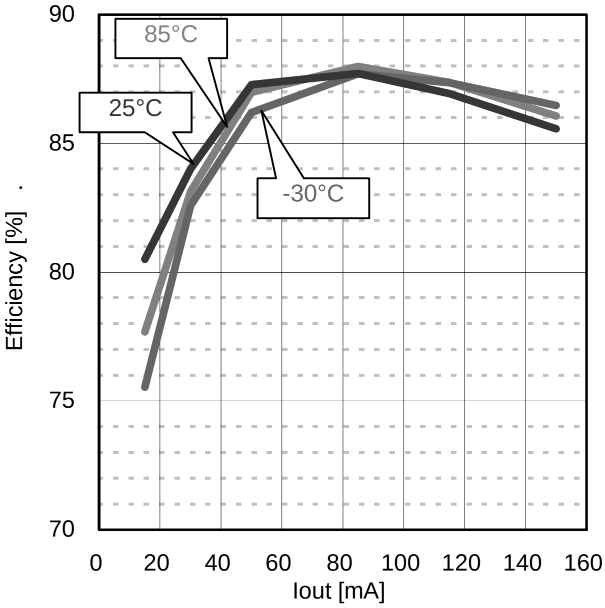


Figure 11. Efficiency vs. Iout
(VIN=3.7V)

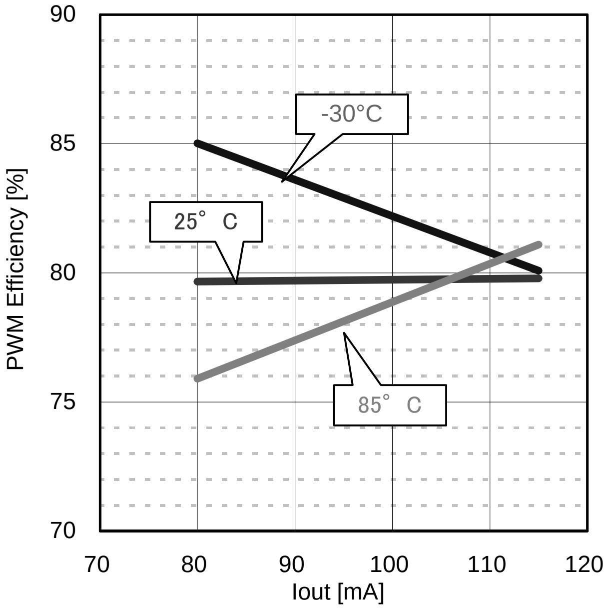


Figure 12. PWM Efficiency vs. Iout
(VIN=3.7V, PWM freq=1.6kHz, Duty=1%)

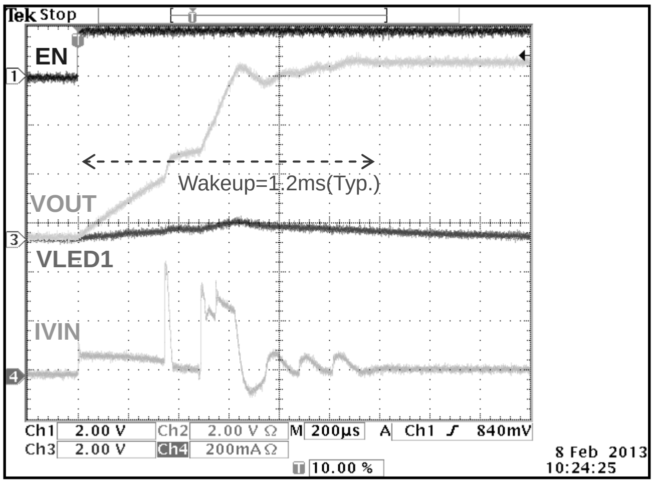


Figure 13. Startup function1 – Initial Boost
(VIN=3.7V)

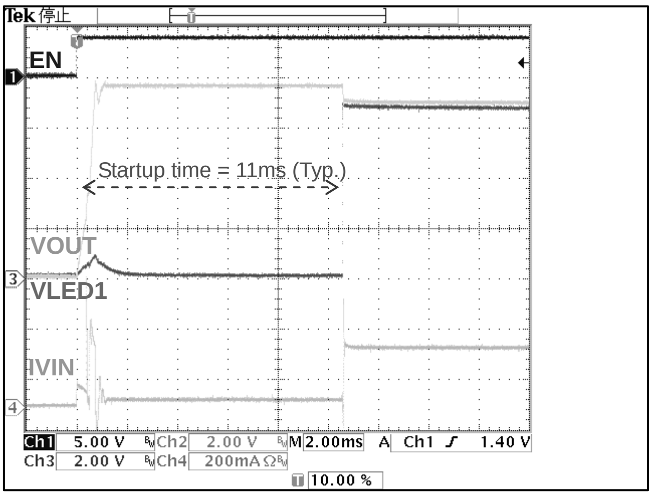


Figure 14. Startup function2 – LED ON
(VIN=3.7V)

●Typical Performance curve - continued

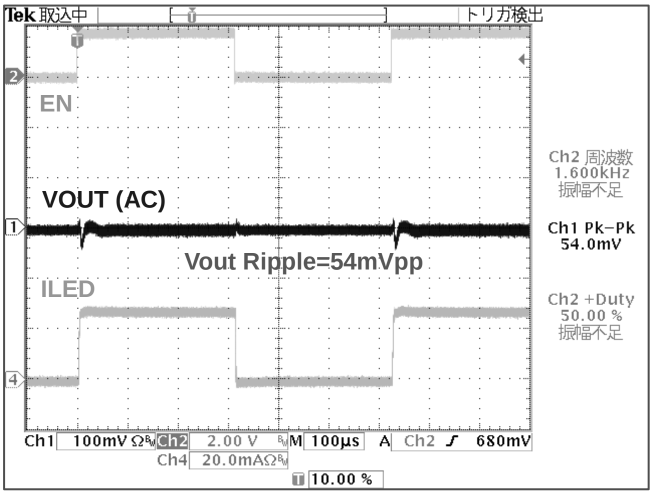


Figure 15. Vout Ripple voltage1
(28mA setting, VIN=3.7V, PWM freq=1600Hz, Duty=50%)

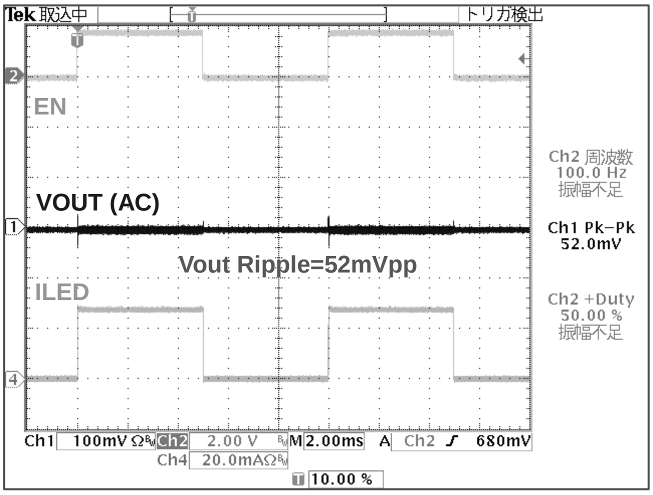


Figure 16. Vout Ripple voltage2
(28mA setting, VIN=3.7V, PWM freq=100Hz, Duty=50%)

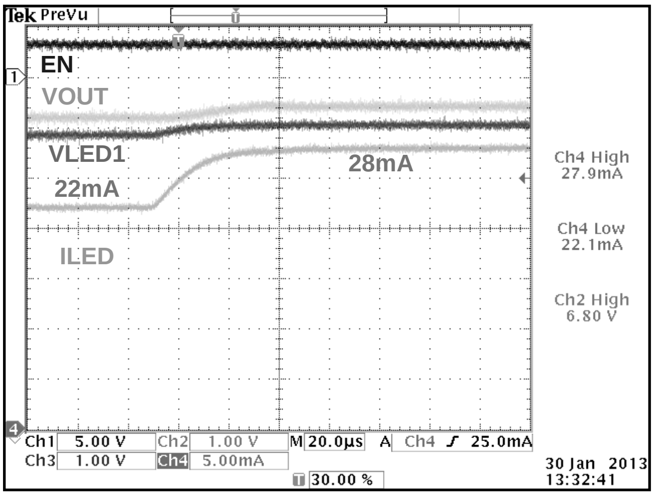


Figure 17. RSET change function
(VIN=3.7V, ILED: from 22mA to 28mA)

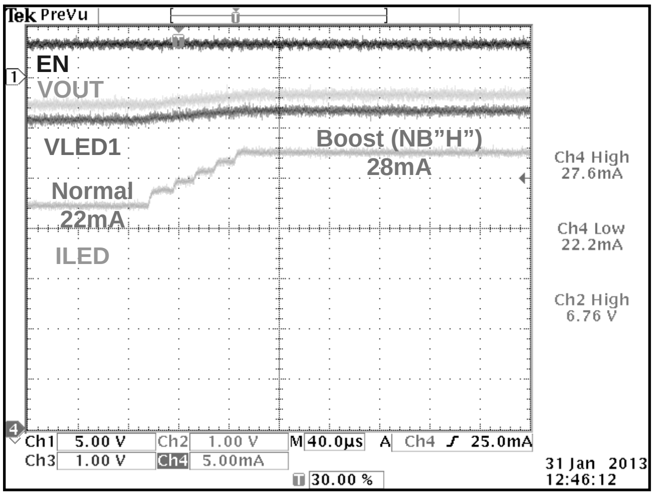


Figure 18. Normal to Boost change function
(VIN=3.7V, ILED: from Normal(22mA) to Boost(28mA))

●Operation

BD6079GWL has DC/DC converter with PWM current mode and fixed frequency. It adopts synchronous rectification architecture. The feature of PWM current mode is that input is the combination of error components from the error amplifier, and a current sensing signal that monitors the inductor current. This current sensing feedback responses is fast and is slope compensated to prevent sub-harmonic oscillation. This output controls Q1(Figure 19) and Q2(Figure 19) 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. Details of the non-overlap time slot will be specified.
In the period when Q1 is ON, energy is accumulated in the external inductor, and in the period when Q1 is OFF, energy is transferred to the capacitor of VOUT via Q2.
Furthermore, BD6079GWL has many safety functions, and stops switching operation immediately after signal input/output exceeds limits.

●Operation Description

< Soft Start-up >
BD6079GWL has soft start-up function. The soft start-up 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. Details of these functions are showed in the block diagram (Figure 15) and the timing chart (Figure 20).
-Soft start
When VOUT voltage is lower than Vth1 voltage, to decrease charge current, Q1 and Q2 are set to off (in Figure 16 “I”). And Q3 is turned on to pre-charge for COUT.
After VOUT voltage is higher than Vth1 voltage, Q1 is turned on and starts switching. In Figure 16 “II” (Vth1 < VOUT voltage < Vth2), Current Limiter is in “soft mode”.
In term Figure 20”III” (VOUT voltage > Vth2 voltage), Q2 starts switching, and Current Limiter is “soft mode”. When boost mode change “Initial boost” to “Normal boost”, Current Limiter change “Soft” to “Normal”.

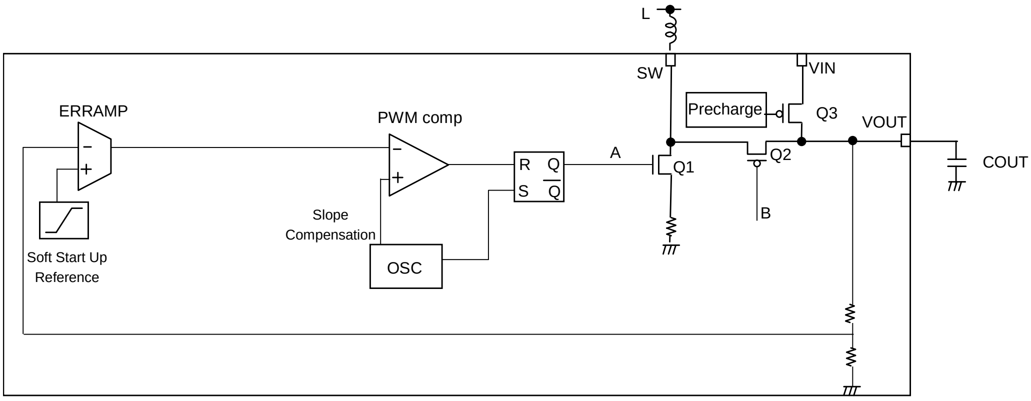


Figure 19. Block diagram of soft start and OFF status

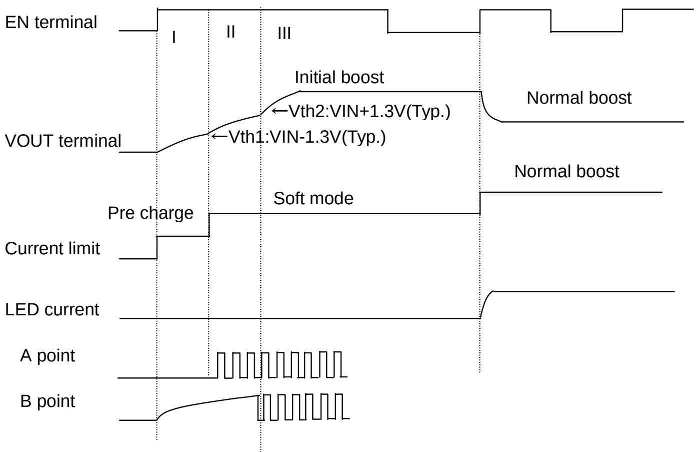


Figure 20. timing chart

●Modes of operation

BD6079GWL is turned on DC/DC by EN signal. After DC/DC turned on, BD6079GWL's current driver has 2 operation sequences that change to next EN rising edge timing.

<Case1: Startup at PWM duty 100% >

BD6079GWL's DC/DC starts up and boosts up 7.5V within 1.2ms(Typ.) at first EN signal coming.

After 11ms (Typ.), go to normal boost mode and LEDs turn on. At the first driver start-up, BD6079GWL checks LED's setting (open or short). If LED is detected to be open or short, driver will cut off current until shutdown mode. If EN signal is not asserted again and 33ms (Typ.) have elapsed after final falling edge, BD6079GWL driver goes to shutdown mode (Figure 21).

Turn on(NB=L, PWM duty = 100%)

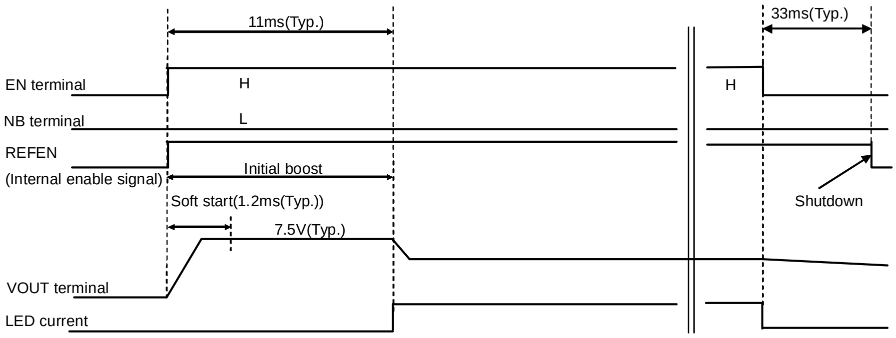


Figure 21. Turn ON (NB=L, PWM duty=100%)

<Case2: Startup with PWM dimming at PWM frequency=200Hz>

BD6079GWL's DC/DC starts up and boosts up 7.5V within 1.2ms (Typ.) at first EN signal coming.

DC/DC will be turned on regardless of H time of EN (Figure22).

If the next EN rising edge is coming within 11ms (Typ.), BD6079GWL will go to the normal boost mode and LEDs will turn on. At the first driver start-up, LED driver checks LED's setting (open or short). If LED is detected to be open or short, driver will cut off current until shutdown mode. If EN signal is not asserted again and 33ms (Typ.) have elapsed after final falling edge, LED driver goes to shutdown mode. (Figure 22, Figure 23)

Turn on(NB=L, PWM=200Hz, duty=75%)

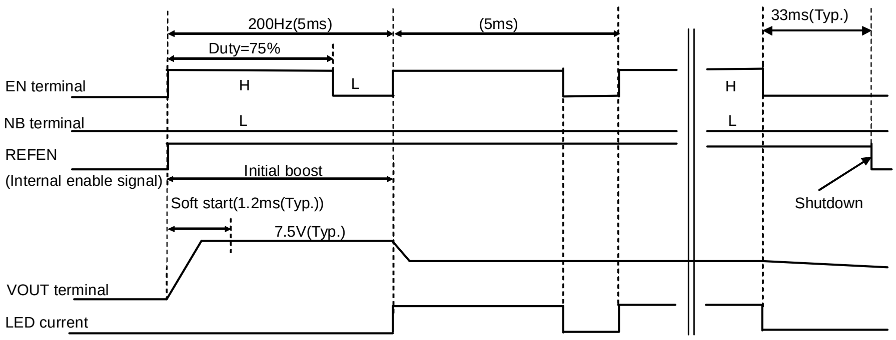


Figure 22. Turn ON (NB=L, PWM Frequency=200Hz, duty=75%)

Turn on(NB=L, PWM=200Hz, duty=0.1%(H=5μs))

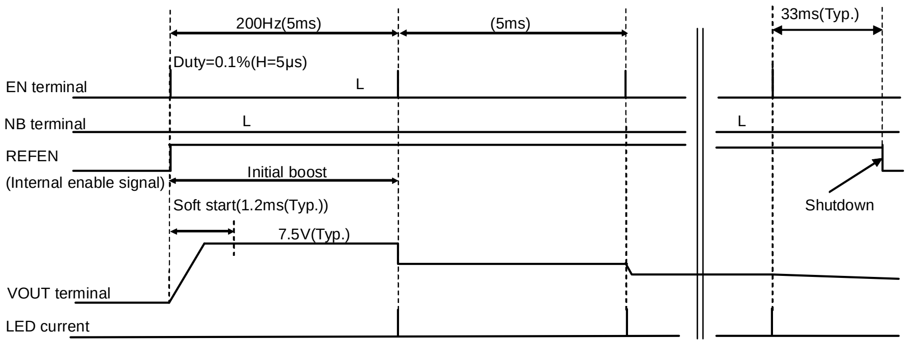


Figure 23. Turn ON (NB=L, PWM Frequency=200Hz, duty=0.1%(H=5μs))

<Case3: Startup with PWM dimming at PWM frequency=1.6kHz >
BD6079GWL's DC/DC starts up and boosts up 7.5V (Typ.) within 1.2ms (Typ.) at first EN signal coming.
DC/DC will turn on regardless of 'H' time of EN.
If the next EN rising edge is coming during "soft start" 1.2ms (Typ.), BD6079GWL will go to the normal boost mode and LEDs will turn on after "soft start". At the first driver start-up, LED driver checks LED's setting (open or short). If LED is detected to be open or short, driver will cut off current until shutdown mode. If EN signal is not asserted again and 33ms (Typ.) have elapsed after final falling edge, LED driver goes to shutdown mode. (Figure 24, Figure 25)

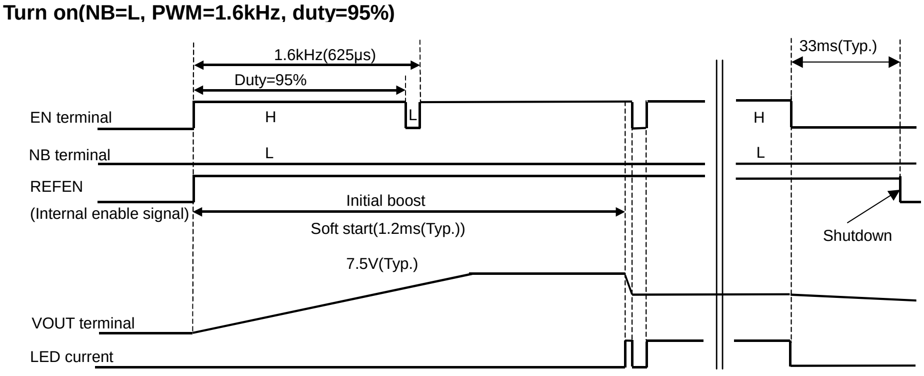


Figure 24. Turn ON (NB=L, PWM Frequency=1.6kHz, duty=95%)

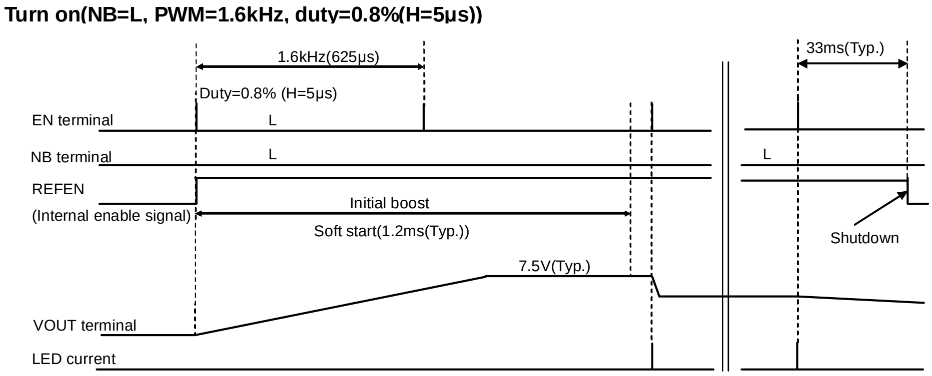


Figure 25. Turn ON (NB=L, PWM Frequency=1.6kHz, duty=0.8%(H=5µs))

<Case4: Startup with Boost mode at PWM duty 100%>
NB terminal is set for current setting (Boost mode: 25mA to 28mA).
BD6079GWL's DC/DC starts up and boosts up 7.5V (Typ.) within 1.2ms (Typ.) at first EN signal coming.
After 11ms (Typ.), go to normal boost mode and LEDs turn on. At the first driver start-up, LED driver checks LED's setting (open or short). If LED is detected to be open or short, driver will cut off current until shutdown mode. If EN signal is not asserted again and 33ms (Typ.) have elapsed after final falling edge, LED driver goes to shutdown mode. (Figure 26)

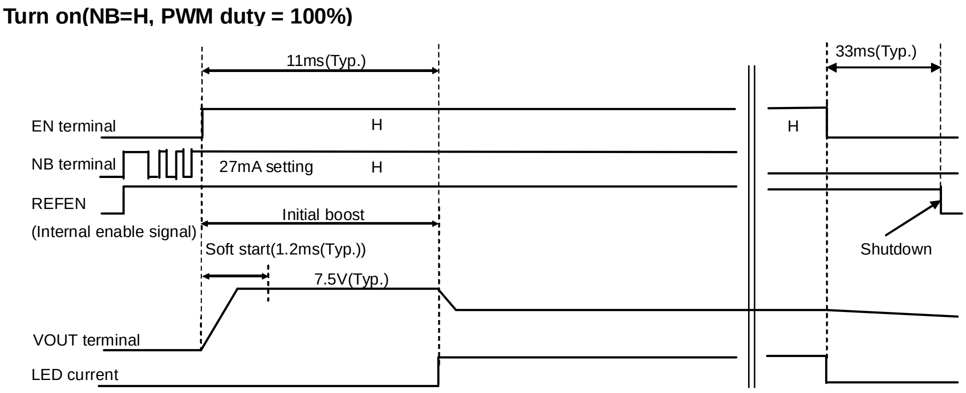


Figure 26. Turn ON (NB=H, PWM duty=100%)

●OFF status

After a falling edge of EN, if no rising edge comes in 33ms (Typ.), the DC/DC converter will be power off. (Figure 22 to 26)

●Isolation control

BD6079GWL has isolation control to prevent LED wrong lighting at power off.
The cause of the LED wrong lighting is leakage current from VIN terminal to the white LED. Therefore, when BD6079GWL is powered off (EN = 'L'), the isolation control cuts the DC path between SW terminal and VOUT terminal, and Hi-side PMOS cuts the DC Path between VOUT terminal and D1~D5 terminals and SW terminal connects the internal node to ground, so that no leakage current flows from VIN terminal to LEDs.

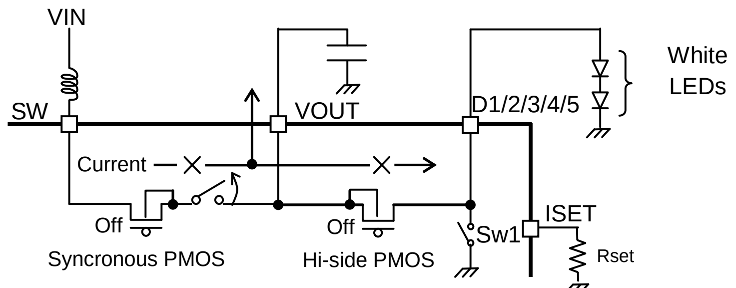


Figure 27. Isolation control

● Safety Function

CASE	FAILURE MODE	DETECTION MODE	LED Current	DC/DC Feed Back	DC/DC Action	After release Failure	Condition for releasing latch
1	LED Short (1ch LED)	LED Short Det	<Short LED> Stop <Other LED> Active	<Short LED> Feedback Cut <Other LED> Feedback Active	Normal Output	Latch	After EN terminal keeps "L" for 33ms (Typ.), latch is released
2	LED Open (1ch LED)	LED Open Det	<Open LED> Stop <Other LED> Active	<Open LED> Feedback Cut <Other LED> Feedback Active	Normal Output	Latch	After EN terminal keeps "L" for 33ms (Typ.), latch is released
3	LED Open (All LED)	LED Open Det	Stop	Feedback Cut	Stop	Latch	After EN terminal keeps "L" for 33ms (Typ.), latch is released
4	Rset Short	ISET Short Det	Clamp	Feedback Active	Normal Output	Auto Return	-
5	Rset Open	ISET Short Det or no detect	Small or Clamp	Feedback Active	Normal Output	Auto Return	-

●**Short-circuit protection, over voltage protection and over current protection**

BD6079GWL has short-circuit protection, over voltage protection and over current protection. There are detectors of the voltage of VOUT and the current of Coil.

▪ VOUT Short-circuit protection

In case of short-circuit between DC/DC outputs (VOUT) to GND, the coil or the IC may be destroyed. Therefore when VOUT voltage goes lower than “VIN-1.3V” (Typ.), the Short-Circuit Detector shown in the figure works, and turns off the output Transistor to prevent huge current in the coil and the IC. And the IC turns from operation condition into non operation condition, and current does not flow to the coil (0mA (Typ.)).

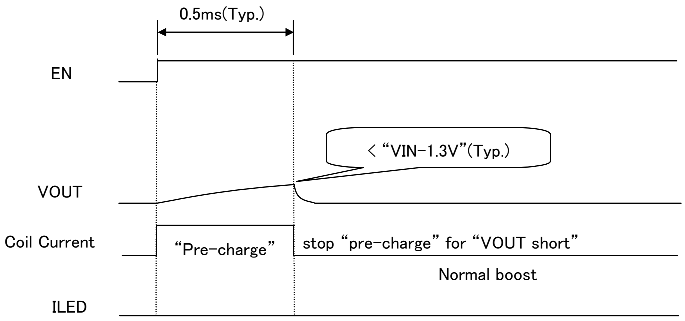


Figure 28. VOUT short at “turn on”

▪ Over Voltage Protection

In case of error as COUT (This capacitor is attached VOUT terminal.) is broken, over voltage occurs at SW terminal and VOUT terminal, exceeding the absolute maximum ratings, to protect IC, when VOUT becomes 9.2V (Typ.) or higher, the over voltage limit works, and turns off the output Transistor, and prevents the SW terminal and the VOUT terminal from exceeding the absolute maximum ratings.
At this moment, DC/DC converter turns from operation condition into non operation condition, and the output voltage goes down slowly. When the output voltage is lower than the hysteresis of over voltage limit, the output voltage goes on up to 9.2V (Typ.) once again.
But this IC has “LED open protect”, so if VOUT voltage is boosted because of LED open, this IC stops over 8.2V (Typ.) before “Over Voltage Protect” working.

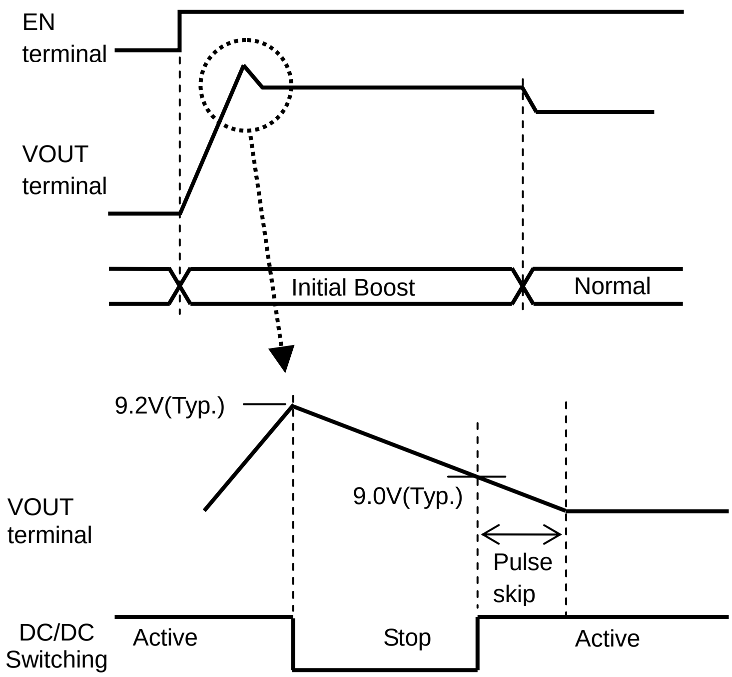


Figure 29. Over Voltage Protection function

▪ Inductor Over Current Protection

Current in Coil is monitored by Current limiter in Figure 30. If the coil's peak current exceeds coil's maximum rates, "on" duty of NMOS will be reduced to constrain the coil current.

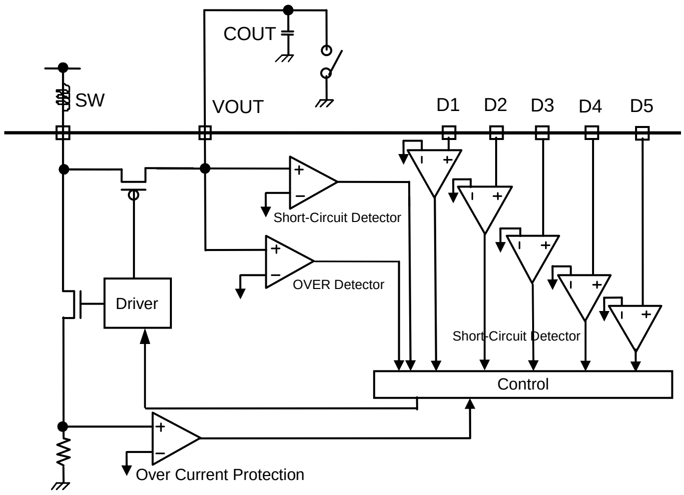


Figure 30. Block diagram of each protection

＜Estimation of peak current at normal function＞

BD6079GWL's inductor current limit is detected by peak current. So, need to estimate the peak current that is through the inductor at each use conditions.

In case of

○Switching frequency = fsw (Typ.=2.0MHz)
○Inductance's supply voltage = VIN
○Coil's inductance value = L
○Output Voltage = VOUT
○Total LED current = IOUT
○Average current of inductance = Iave
○Peak current of inductance = Ipeak
○Efficiency = eff
○On time of switching Tr = Ton

Each value is derived from below formula

$$Ipeak = (VIN / L) \times (1 / fsw) \times (1-(VIN / VOUT))$$
$$Iave=(VOUT \times IOUT / VIN) / eff$$
$$Ton=(Iave \times (1-VIN/VOUT) \times (1/fsw) \times (L/VIN) \times 2)^{1/2}$$

Since the peak current varies depending on whether DC bias current exist or not, make the following decision.

(1-VIN/VOUT) × (1/fsw) < Ton→Peak current= Ipeak /2 + Iave (Continuous mode: CCM)
(1-VIN/VOUT) × (1/fsw) > Ton→Peak current= (VIN / L)×Ton (Dis-continuous mode: DCM)

(Example)

In case of VIN=3.7V, L=4.7µH, fsw=2MHz, VOUT=6.6V, IOUT=50mA, eff=88%
Ipeak = (3.7V / 4.7µH) × (1 / 2MHz) × (1-(3.7V / 6.6V)) = 0.17A
Iave = (6.6V × 50mA / 3.7V) / 88% = 0.10A
Ton = $(0.10A \times (1-3.7V / 6.6V) \times (1 / 2MHz) \times (4.7\mu H /3.7V) \times 2)^{1/2}$ = 0.24µs
(1-VIN/VOUT) × (1/fsw) = (1-3.7V/6.6V) × (1/2MHz) = 0.22µs < Ton
Peak Current = 0.17A /2 +0.10 = 0.27A

●**LED open protection**

When Dn (1,2,3,4,5) terminal becomes higher than 8.2V (Typ.). This IC stops constant current driver (Dn) and keeps OFF state. Dn (1,2,3,4,5) terminal turn on according to EN terminal toggle. If all terminal becomes higher than 8.2V (Typ.), This IC shut down (DC/DC stop). (This function is not detected when This IC is at initial boost state)

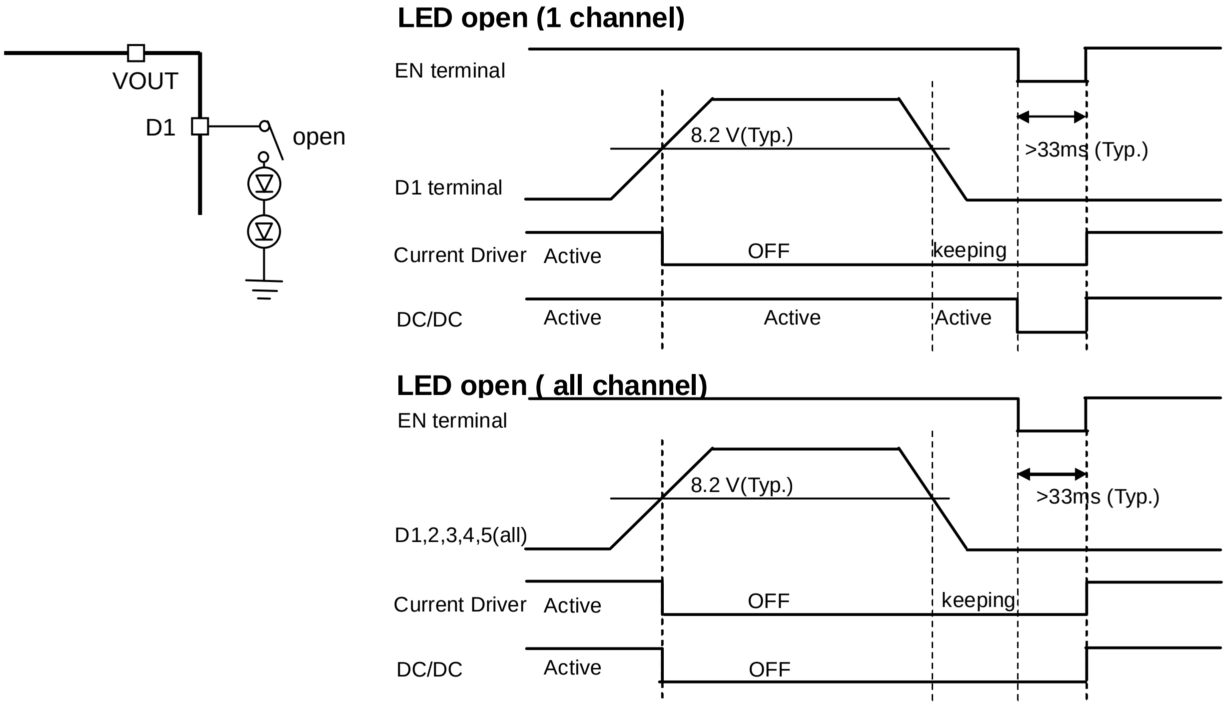


Figure 31. LED open protect

●**LED short protect**

When Dn (1,2,3,4,5) terminal becomes lower than 1.0V (Typ.). This IC stops constant current driver (Dn) and keeps OFF state. Dn terminal turn on according to EN terminal toggled. If all terminal becomes lower than 1.0V (Typ.), This IC shut down (DC/DC stop). (This function is not detected when This IC is at initial boost state)

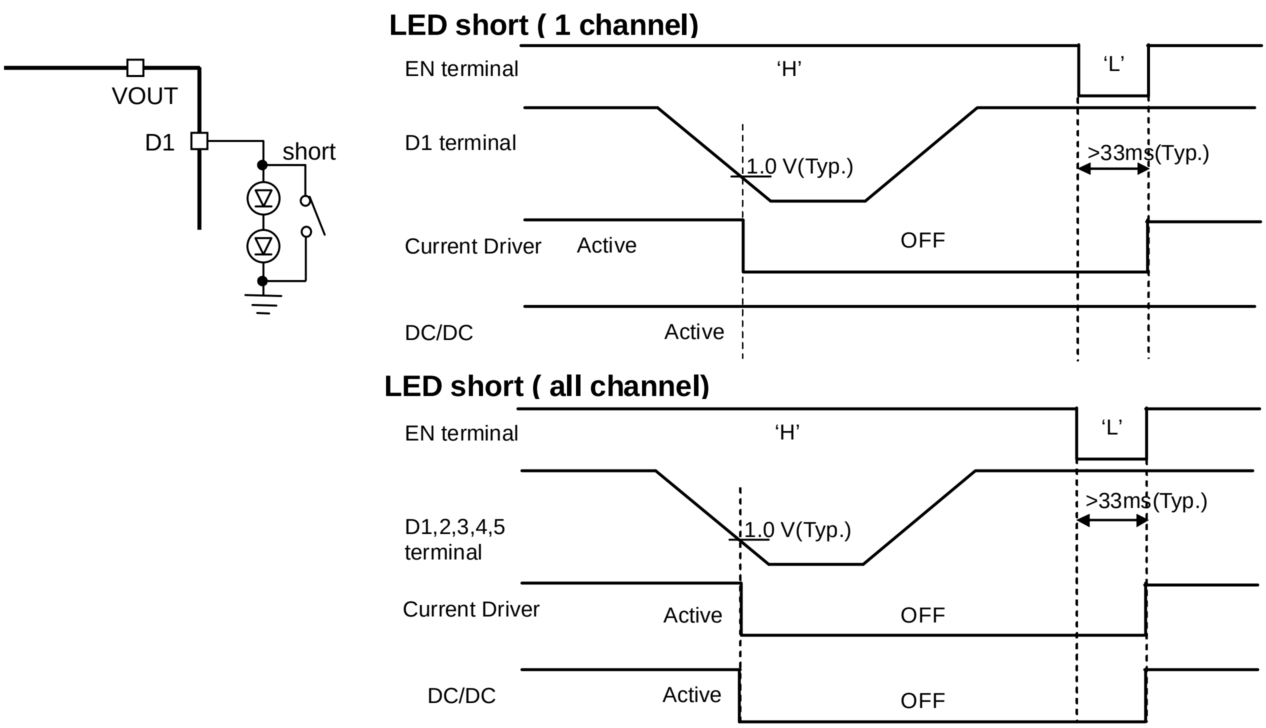


Figure 32. LED short protect

●**Thermal shut down**

BD6079GWL has thermal shut down function.
The thermal shut down starts working when temperature is 185°C or higher. While holding the setting of EN control from the outside, DC/DC converter turns from operation mode into non operation mode. When temperature drops below 165°C, the IC gets back into its normal operation.

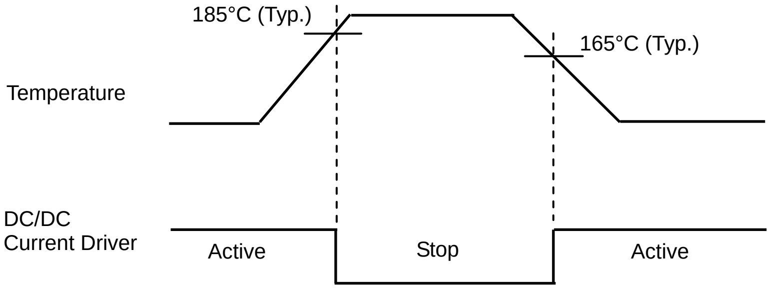


Figure 33. TSD protection function

●**Under Voltage Lockout (UVLO)**

When Battery voltage (VIN) goes to under UVLO detection voltage (Min. : 1.8V), BD6079GWL will be stop to DC/DC and Current Driver. Also, Battery voltage up to un-detection voltage (Max. : 2.2V) from UVLO detection point, this detection function will be released.

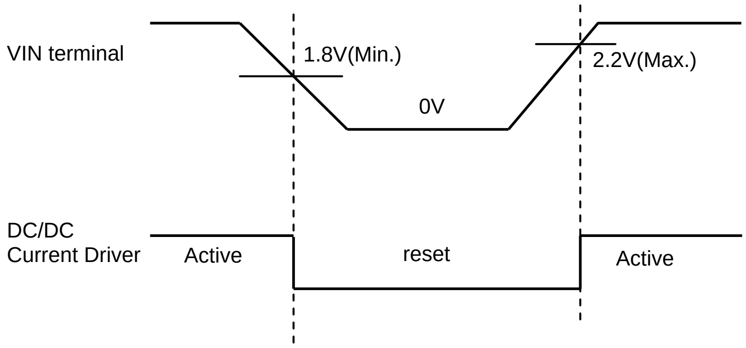


Figure 34. UVLO protection function

Action by TSD / UVLO

	TSD	UVLO
DC/DC	Stop Goes to shutdown mode	Stop Goes to shutdown mode
Current Driver	Stop	Stop
LED Open/Short Information	Reset	Reset
N/B Information	Hold	Reset
“11ms Counter” (LED connection check)	Reset	Reset
“33ms Counter” (Shut down counter)	Reset	Reset
Soft Start	Reset	Reset

●**Operating of the application deficiency**

1) When 1 LED or 1string open during the operating
Since D1 terminal is set to VOUT when set to OPEN, Output boosts up to "LED open voltage (8.2V Typ.)". When "LED open protect" is detected, the boosting operation stops and then output voltage goes down slowly.

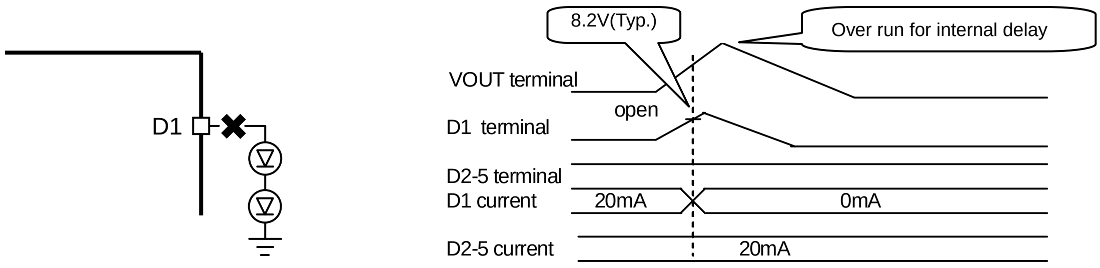


Figure 35. LED open detect

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

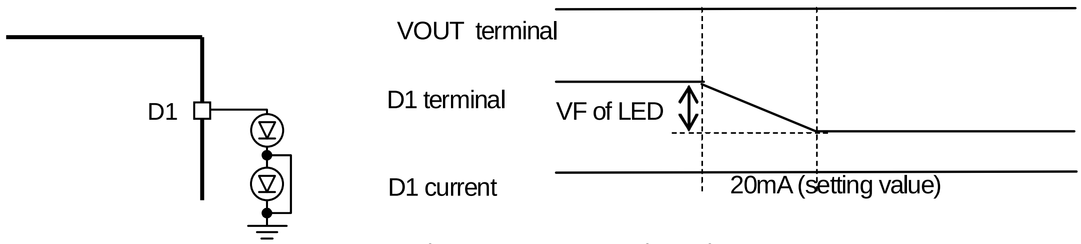


Figure 36. One LED shorted

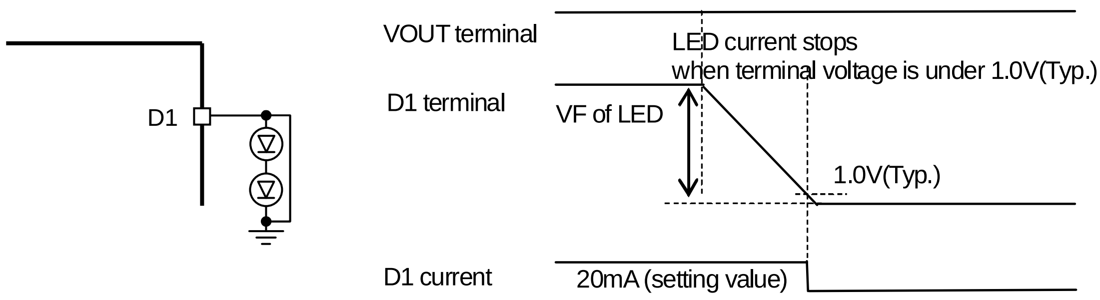


Figure 37. two LED shorted

3) When VOUT terminal is shorted to GND.
In the situation that VOUT terminal is shorted and also DC/DC is activated, SW terminal voltage becomes more than rated voltage due to a lack of parts that can accept the current accumulated inside the coil. Consequently IC might be destroyed. To prevent the IC destruction, "Output short protection" is functioned. SW terminal is never destroyed as boosting operation is stopped after VOUT terminal detects less than "VIN-1.3V"(Typ.).

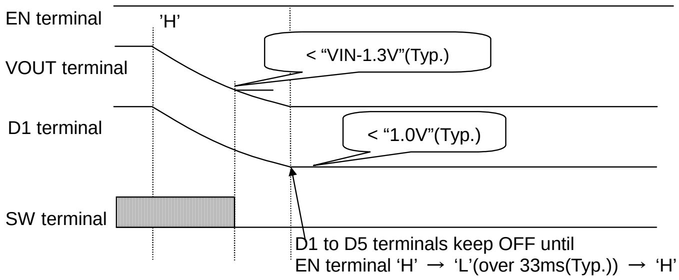


Figure 38. VOUT short during "normal boost"

4) When resistance linked to an ISET terminal short-circuits
Since Resistor connected to ISET terminal becomes 0Ω, LED current setting value change to "Boost mode" setting.

●Start and PWM control (EN) and select LED current setting (NB)

This IC can control the IC system by EN terminal and also turns off compulsorily by setting "L" level input voltage 0.68V (Max.) or below. It also powers on when EN becomes more than "H" level input voltage 1.07V (Typ.). In the case of EN=H, LED current fixed by ISET resistor with NB=L flows. When NB=H, LED current is set by Boost operating mode.

EN	NB	IC	LED current
L	L	Off	Off
H	L	On	Current fixed by ISET (normal mode)
L	H	Off	Off
H	H	On	Current fixed by Boost operating mode

●Power on control and brightness control

BD6079GWL controls the start conditions by its EN terminal. It is powered off when "EN" is below 0.68V (Max.) and powered on when "EN" is 1.07V (Min.). And by changing the duty cycle of PWM control, the LED brightness can be adjusted.

PWM brightness adjustment is done by connecting PWM signal to EN as shown in Figure 39.
The BD6079GWL is powered on/off by the PWM signal. By this method, LED current is controlled from 0 to the Maximum current. Average LED current increases with proportion to the duty cycle of PWM signal. The recommended PWM frequency is 100Hz ~ 1600Hz. Minimum Hi-pulse width and Minimum Low-plus width is shown in Figure 40.

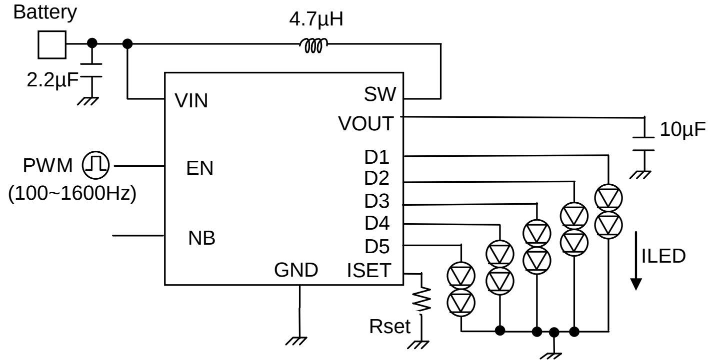


Figure 39. The example of brightness adjustment by PWM input signal to EN terminal

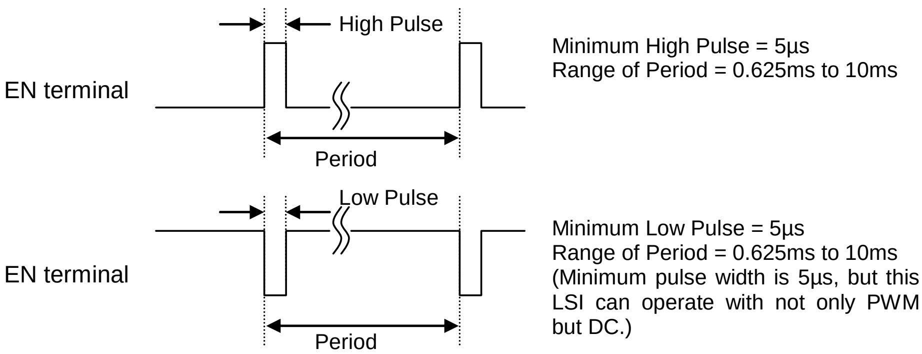


Figure 40. The Rule of PWM input signal to "EN" terminal

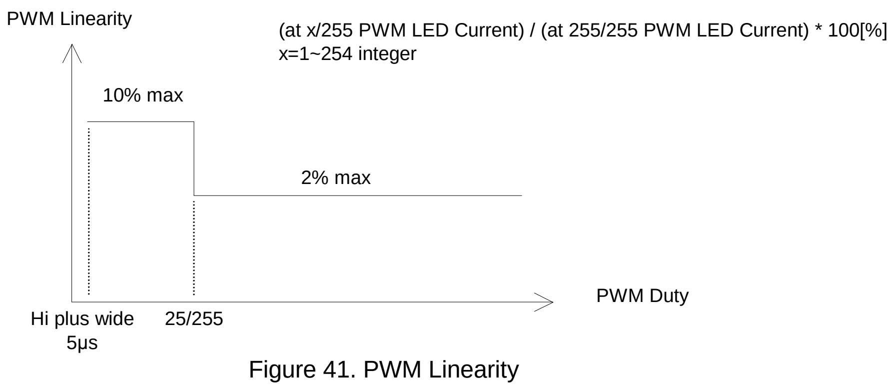


Figure 41. PWM Linearity

●**Current characteristic of PWM dimming function and linearity**

BD6079GWL constantly controls the rising time to keep the accuracy of the LED current at PWM function.
And, BD6079GWL has delay time of EN rise edge to LED turn on and EN falling edge to LED turn off. LED current linearity at PWM dimming control depends on these delays.

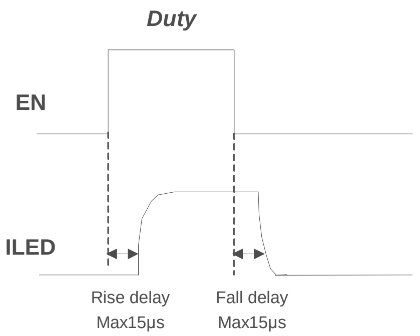


Figure 42. LED Current at PWM (delay function)

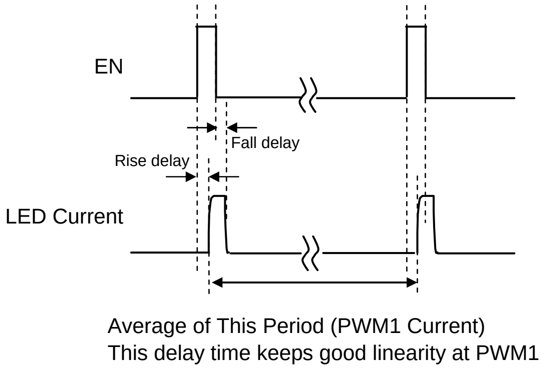


Figure 43. LED Current Line Regulation (PWM1)

●**LED Current setting range**

LED current is determined by the voltage of ISET and the resistor connected to ISET terminal.
ILED is given as shown below.

ILED=ISET voltage/Rset x ratio

The current in the standard application is as shown below.

ISET voltage=0.8V, ratio=625

Rset is 200kΩ to 18kΩ

Rset	ILED
200kΩ	2.5mA
20kΩ	25mA
18kΩ	27.8mA

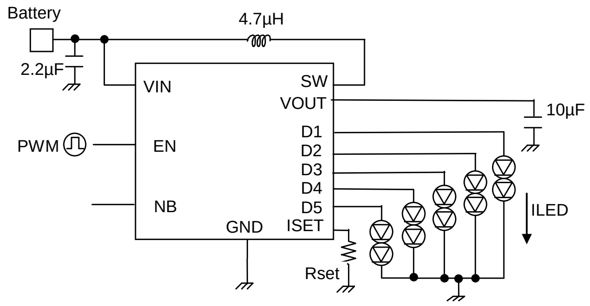


Figure 44. Standard Application

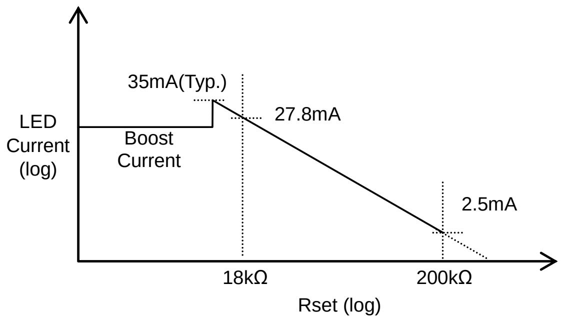


Figure 45. ILED vs Rset

●"Driver Accuracy"

Regarding "Normal mode"

	"Driver Accuracy"
[Rset setting]	
100kΩ to 18kΩ	±6.5%
200kΩ to 100kΩ	±10%
other	no specification
[Rset setting x PWM Duty setting]	
over 5mA	±6.5%
2.5mA to 5mA	±10%
other	no specification

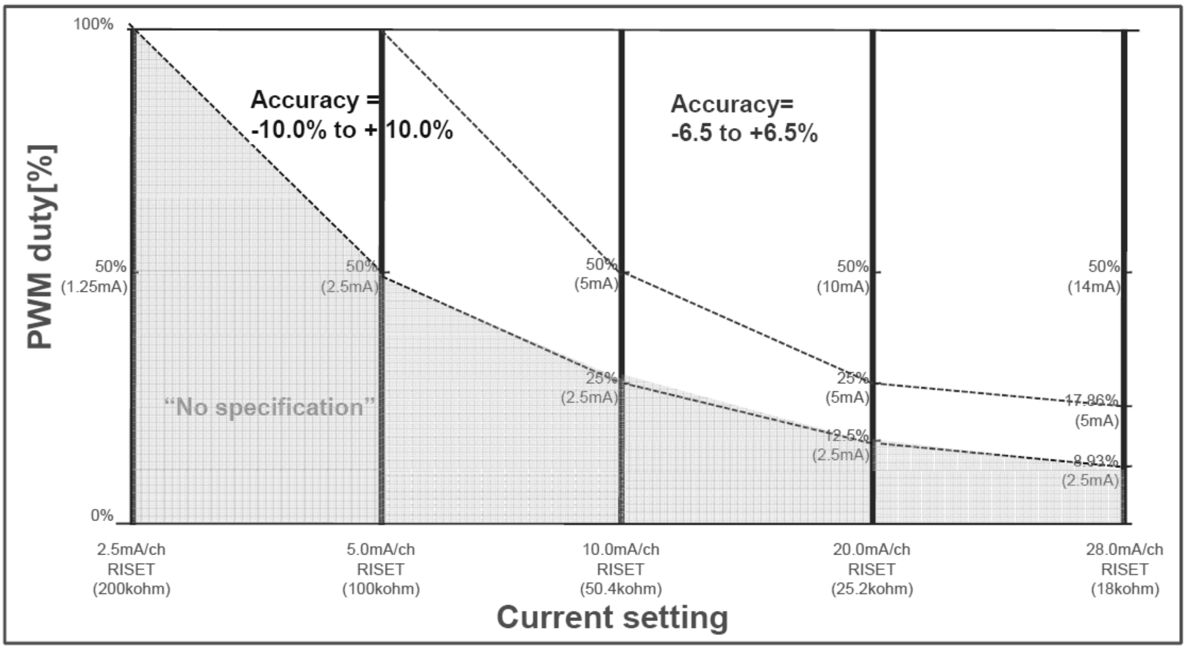


Figure 46. Current setting vs. PWM duty 1

Formula : Accuracy = 1 – "measured data" / "Ideal current"

Ex.) condition : 28mA setting, duty 25% measured data = 13.8mA
Accuracy = 1- 13.8mA /(28Max. 50%) = 1.43%

Regarding "Boost mode"

	"Driver Accuracy"
[Boost setting]	
25mA to 28mA (all setting)	±6.5%
[Boost setting x PWM Duty setting]	
over 5mA	±6.5%
2.5mA to 5mA	±10%
other	no specification

●"LED current Matching"

Regarding "Normal mode"

	"LED current Matching"
[Rset setting]	
18kΩ (28mA)	±6.5%
100kΩ (5mA)	±4%
200kΩ (2.5mA)	±7.5%
other	no specification
[PWM Duty setting]	
100%	Same as [Rset setting] specification
0% to 99.95%	no specification

Regarding "Boost mode"

	"LED current Matching"
[Boost setting]	
25mA to 28mA (all setting)	±4.0%
[PWM Duty setting]	
100%	Same as [Boost setting] specification
0% to 99.95%	no specification

Formula

"Average" = ("Max current "+ "Min current")/2
"Max. Matching" = ("Max current" - "Average") / "Average"
"Min. Matching" = ("Average" - "Min current") / "Average"

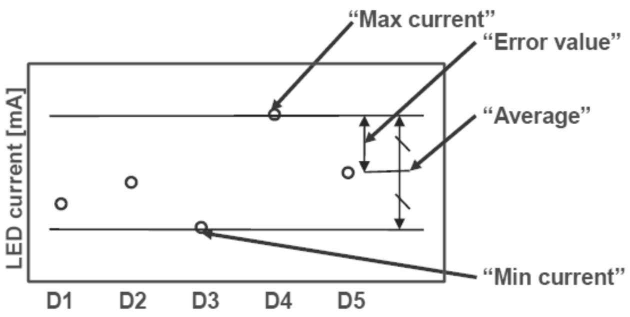


Figure 47. Concept of LED current Matching

●"Driver Linearity"

Regarding "Normal mode"

[Rset setting]	[PWM Duty setting]	"Driver Linearity"
18kΩ	25/255 to 255/255	±2%
	2/255 to 25/255	±10%
	1/255	no specification
other	ALL	no specification

Regarding "Boost mode"

[Boost setting]	[PWM Duty setting]	"Driver Linearity"
28mA	25/255 to 255/255	±2%
	2/255 to 25/255	±10%
	1/255	no specification
other	ALL	no specification

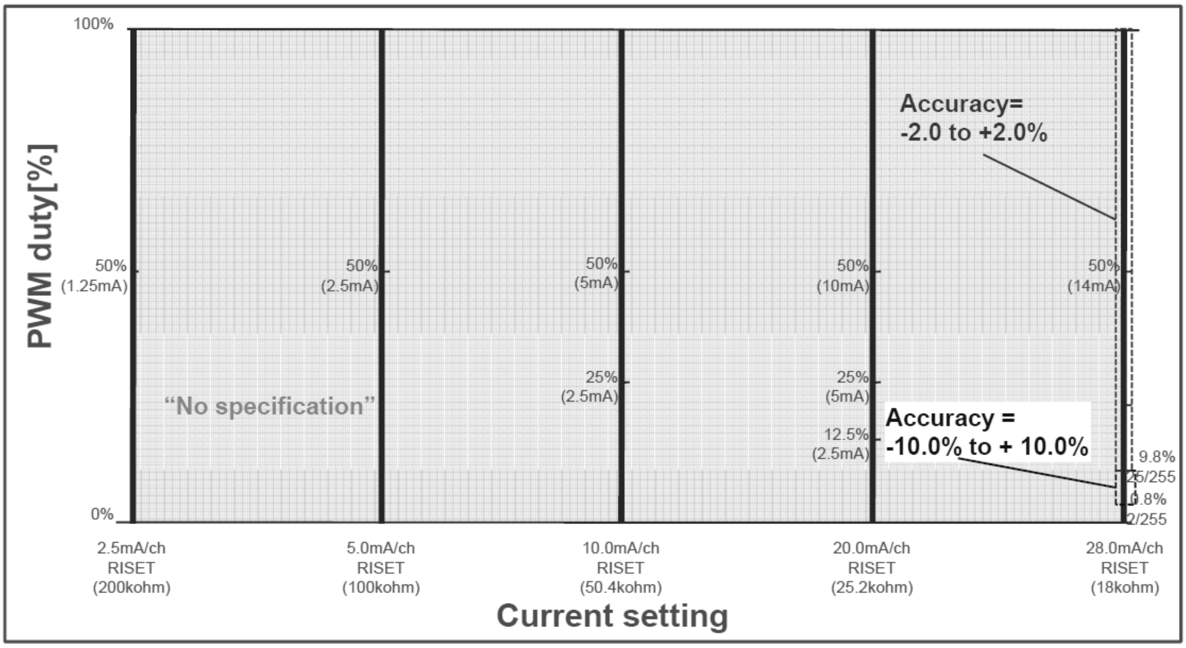


Figure 48. Current setting vs. PWM duty 2

Formula : "Linearity" = 1 – "measured data(each duty)" / ("measured data(100%) x duty)"

Ex.) condition : 28mA setting, measured data(100%) = 27.8mA, measured data(25%) = 13.8mA,
Accuracy = 1- 13.8mA / (27.8Max. 50%) = +0.72%

●LED current setting resistor (Rset) value change application function

BD6079GWL allowed current setting resistor value to change during operation (100% PWM & PWM dimming).
When Rset value changes, LED current change as shown in Figure 50.

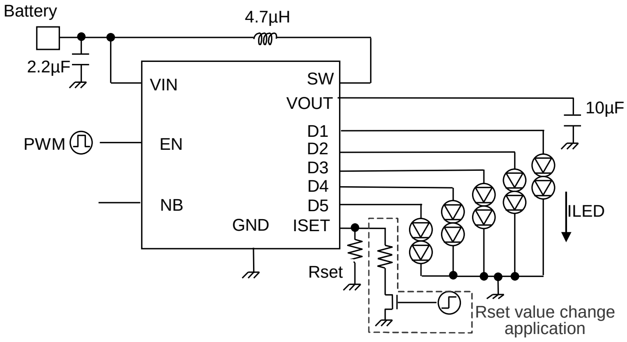


Figure 49. Rset change Application

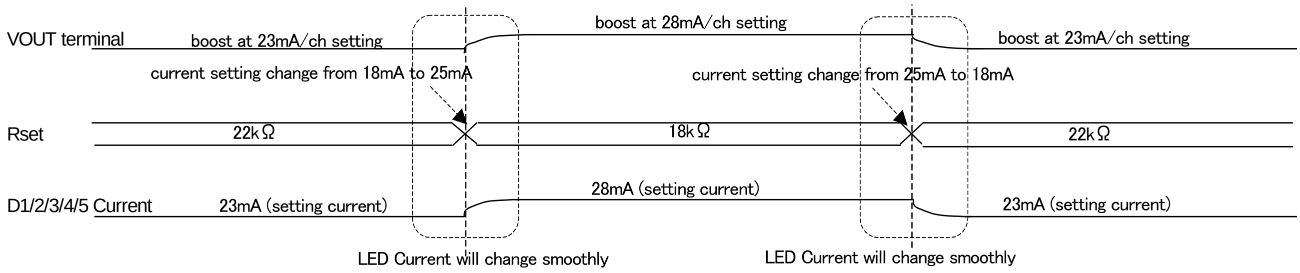
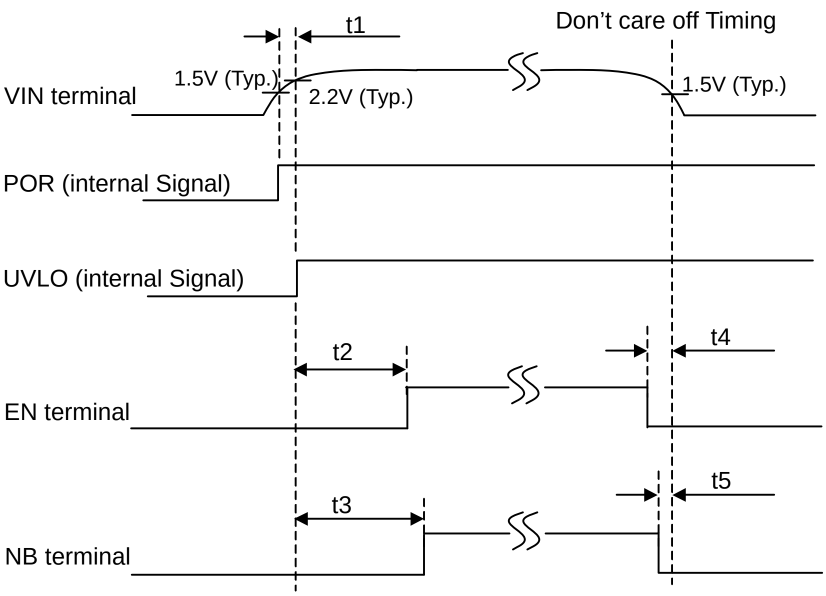


Figure 50. Rset change Function

●Power charge sequence

EN terminal must keep "L" voltage from Power Charge to "t1+t2" time.
If EN and VIN terminal are rising at same timing, LED may not light.
Regarding the timing sequence of EN and NB terminal, please refer to Figure 52 and Figure 53.



t1=100ns(Min.), t2=0µs(Min.), t3=0µs(Min.), t4=0µs(Min.), t5=0µs(Min.)

Figure 51. Power Charge Timing

●Boost function

When setting NB terminal = 'H', LED current becomes 28mA (Typ.) regardless of Rset value.
LED current moves to Boost current that is set after "Tinit＋Twindow" by NB='H'.
Boost current can be changed as below by the number of NB Rising edge in "Twindow".
Boost current is reset by UVLO only.

Rising Edge times	Boost Current
1	25mA
2	26mA
3	27mA
4	28mA

	Min.	Typ.	Max.	Unit
Tinit	120	-	-	µs
Tlow	2	10	25	µs
Thigh	2	10	25	µs
Twindow	-	500	-	µs

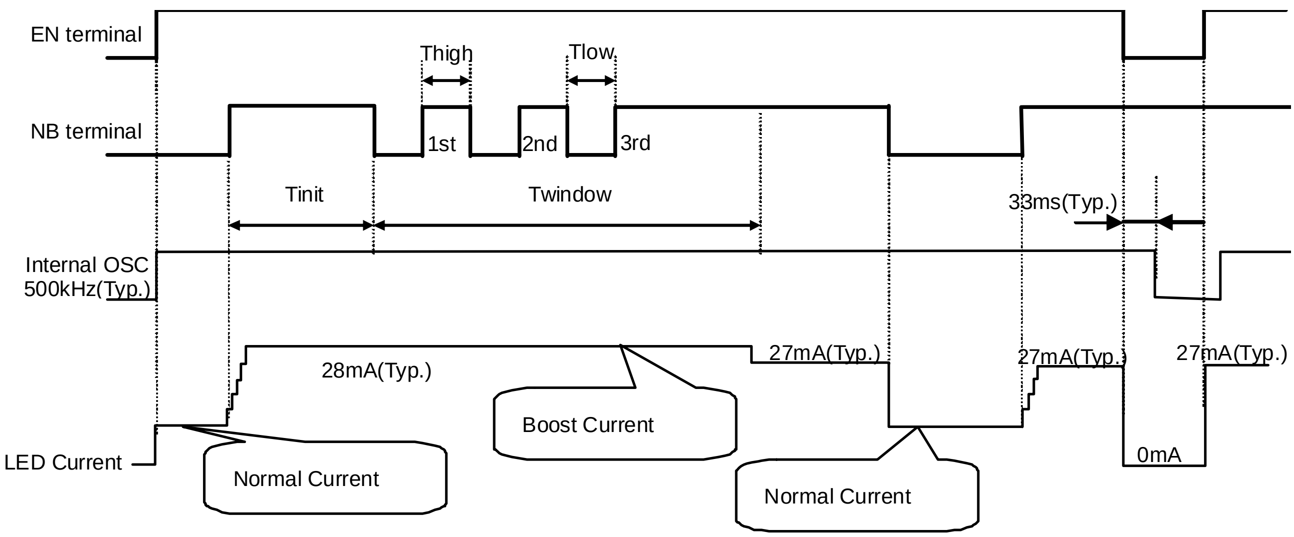


Figure 52. Boost Timing chart (setting on EN=H)

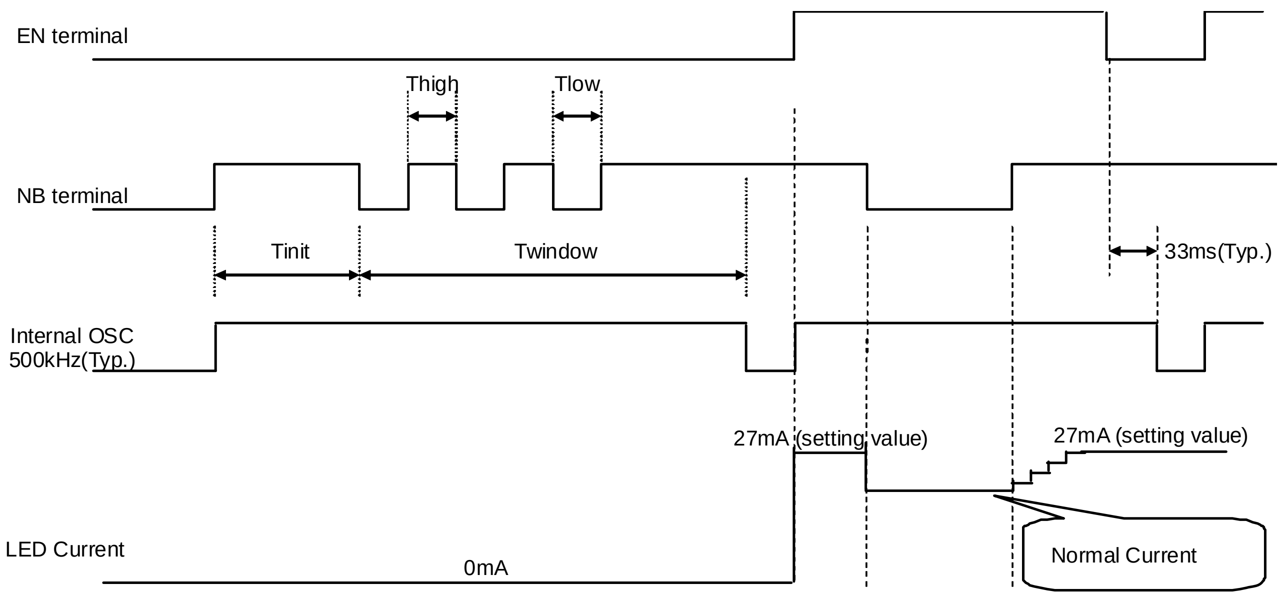


Figure 53. Boost Timing chart (setting on EN=L)

●**Capacitor for D1~5 terminals**

Please be aware that linearity of LED current may be influenced when connecting/adding Capacitor to the D1~5 terminals.

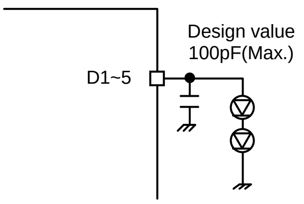


Figure 54. D1~5 terminal

●**Line transient response**

The influence on LED current by the change of VIN is suppressed to 10% (Max.).
Furthermore, after 20ms from the change, it suppresses it to 1% (Max.).

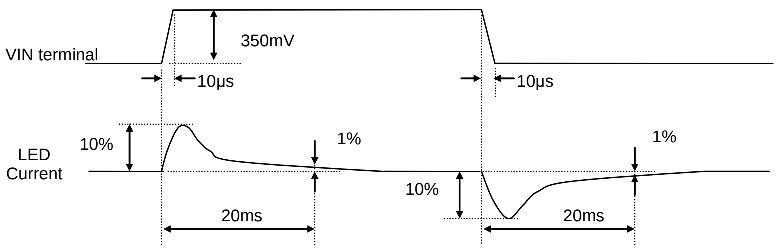


Figure 55. Line transient response

●**VOUT ripple**

The ripple of VOUT is suppressed to 100mV (Max.).
(Not contain changing of VOUT by changing IOUT for select NB or select Rset value.)

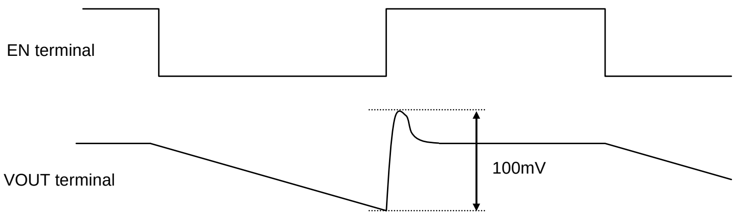


Figure 56. VOUT ripple

●**LED current DC ripple (Duty = 100%)**

The LED ripple is suppressed to 2% (Max.) on the following condition.

Condition

- Rset=18kΩ
- Output capacitor = 10µF
- Bandwidth filter = 500kHz

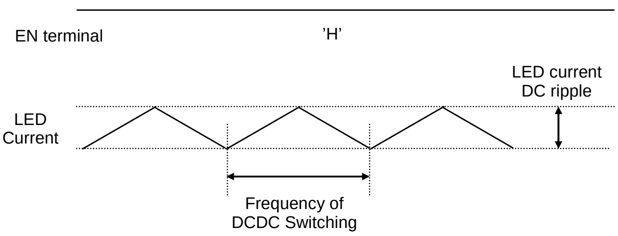


Figure 57. LED current DC ripple

●**Current ability of DC/DC**

The current output of DC/DC receives the limitation by Inductor current limit as shown in the figure below.

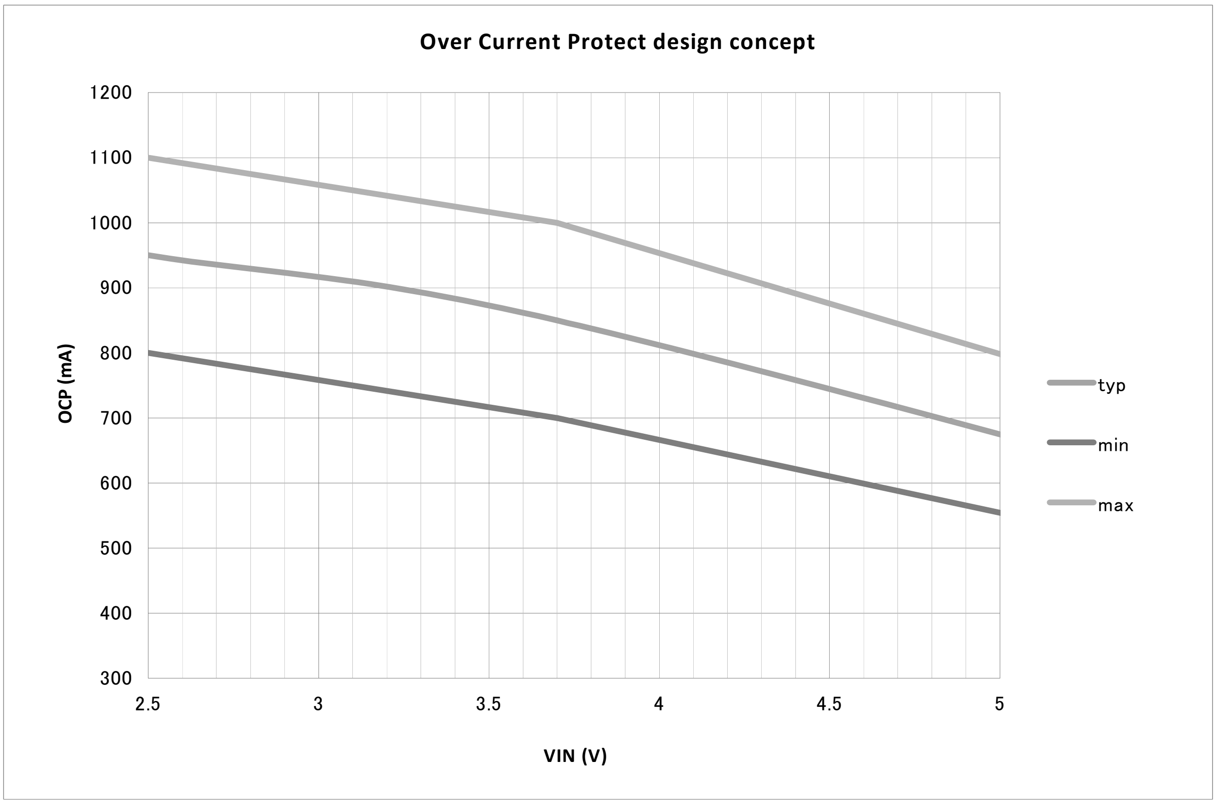


Figure 58. Over Current Protect design target

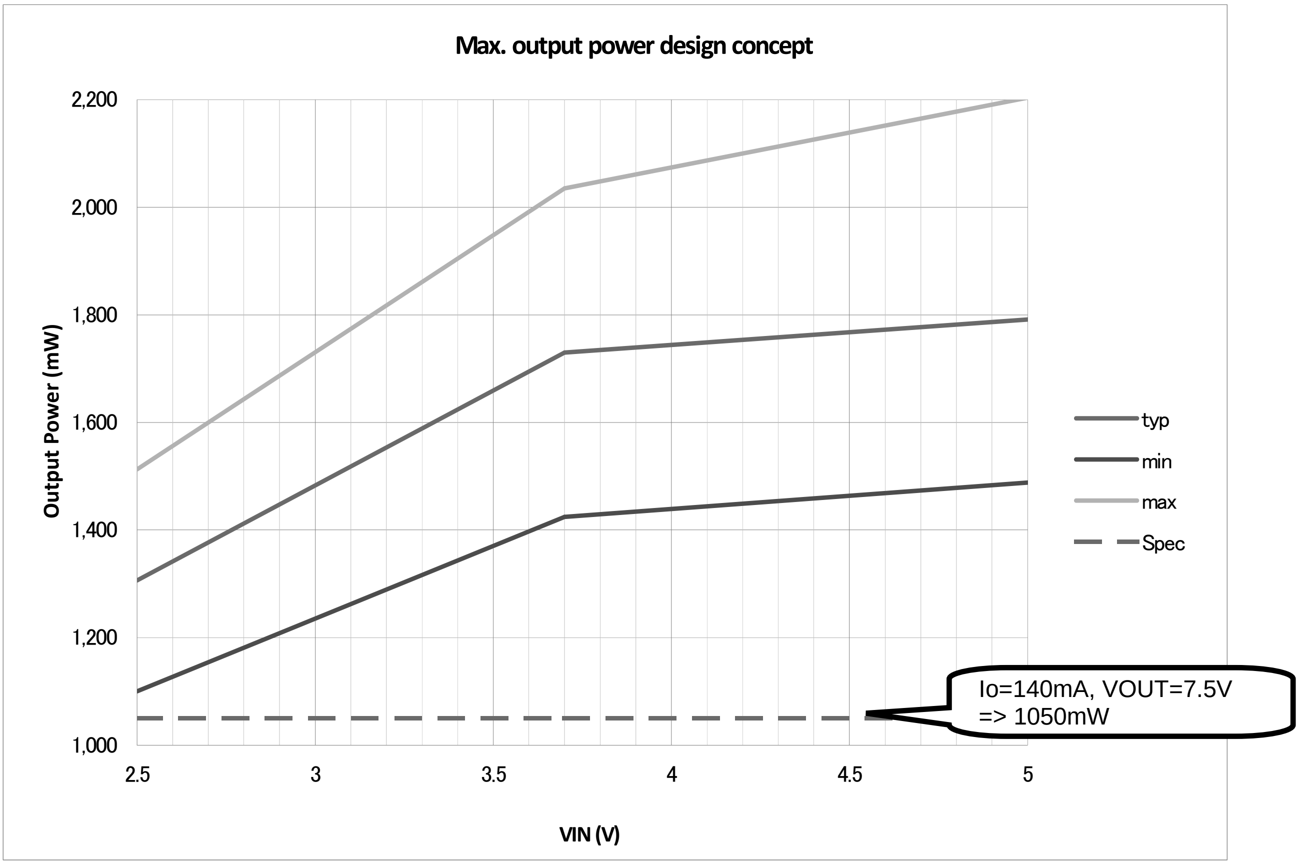


Figure 59. Max. output power design target

●How to set Non-used terminal

Setting it as follows is recommended with the pin that isn't used.
Set up pin referring to the "●Block Diagram on page 4" so that there may not be a problem under the actual use.

Terminal name	How to set Non-used terminal.
NB	Connect to GND (Normal Mode)
	Connect to VIN (Boost Mode)
Non-used Dn Pin (n=1,2,3,4,5)	Connect to GND (wire impedance is under 20Ω)
	Open (When this IC turn on, VOUT terminal voltage is over 8V.)

The "start up sequence" figure when the Dn(n=1,2,3,4,5) terminal is 'opened' is as follows. 'Open' processing the Dn (n=1,2,3,4,5) terminal which are not used or in case of VOUT short, those detection cannot be done under "Tset" < 5µs.
In one PWM cycle, there is case where LED open condition will not be detected. In this case, it will be detected either at next or following EN = H cycle.

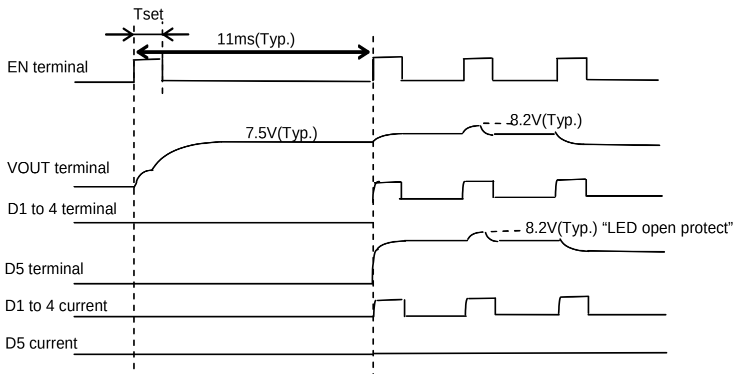


Figure 60. D5: Not used (open or VOUT short) PWM control

If you want to turn off D5 under Tset<5µs as Figure 61, please have unused output terminal to be GND short.

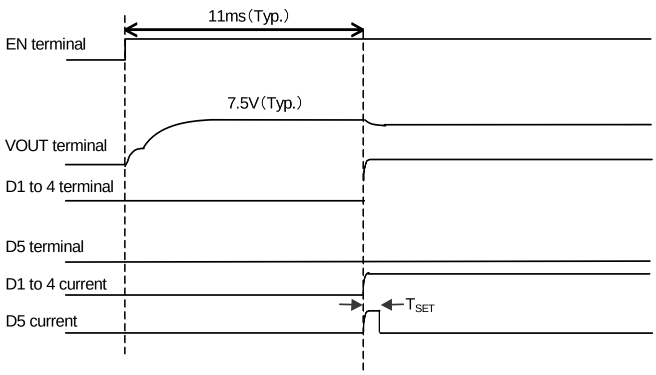


Figure 61. D5: Not used (GND short) PWM control

●**The coil selection**

The DC/DC is designed by more than 4.7µH. When “L value” sets to a lower value, it is possibility that the specific sub-harmonic oscillation of current mode DC / DC will be happened.
Please do not let “L value” to 2.4µH or below (“L value” is decreased when big current flow. Please select parts according to checking this characteristics.)
And, when L value increases, the phase margin of DC / DC decrease. Please enlarge the output capacitor value when you increase L value.

●**Output capacitor selection**

Output Capacitor smoothly keeps output voltage and supplies LED current. If LED current is set more than 28mA with Vcoil=2.5V to 4.8V, please make output capacitor more than 10µF. Otherwise phase margin of DC/DC decreases and might oscillate.
Output Voltage consists of Charge (FET ON) and Discharge (LED current). So Output voltage has Output ripple Voltage every FET switching. Output ripple voltage is calculated as following (Continuous Current Mode).

Output ripple Voltage

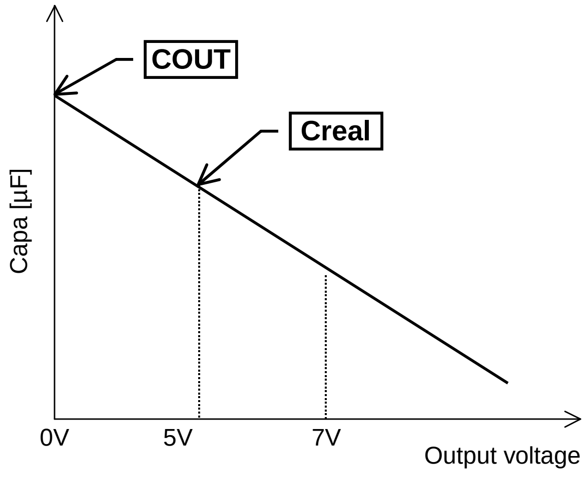
- Switching cycle = T
- Switching ON duty = D
- Output Capacitor = COUT
- Decreasing ratio of Capacitor = Cerror
- Total LED current = ILED
- Output ripple Voltage = Vripple
- Output Capacitor (real value) = Creal

Creal = COUT × Cerror (Capacitor value is decreased by Bias, so)
Creal = ILED × D × T / Vripple
COUT = ILED × D × T / Vripple / Cerror

(Example 1)
In case of, VIN=2.5V, fsw = 2.0MHz, VOUT =6.5V, ILED =28Max. 5ch, COUT = 10µF, Cerror = 50%

T = 1 / 2.0MHz
D = 1 – VIN / VOUT = 1 – 3.6/6.5

Vripple = ILED × D × T / (COUT×Cerror) = 28mA × 5 x (1-2.5/6.5) ×(1 / 2.0MHz) / (10µF×0.5)
= 8.62mV



●**LED selection**

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

●Selection of external parts

Recommended external parts are listed as below.
When to use other parts than these, it is suggested select equivalent components in following table.

▪ Coil

Value	Tolerance	Manufacturer	Product number	Size (Unit:[mm])			DCR (Ω)
				Vertical size	Horizontal size	Height	
4.7µH	±20%	TaiyoYuden	CKP3225N4R7M-T	3.2	2.5	1.0	0.15

▪ Capacitor

Value	Manufacturer	Product number	Size (Unit:[mm])			Temperature range
			Vertical size	Horizontal size	Height	
[CIN]						
2.2µF	MURATA	GRM188R61A225K	1.6	0.8	0.9	-55°C to +85°C
[COUT]						
10µF	TAIYO YUDEN	LDK212ABJ106MDNT	2	1.25	0.95	-55°C to +85°C

▪ Resistor

Value	Tolerance	Manufacturer	Product number	Size (Unit:[mm])		
				Vertical size	Horizontal size	Height
[Rset]						
18kΩ-200kΩ	±0.5%	ROHM	MCR006YZPD□□□□	0.6	0.3	0.23

Value	□□□□
22kΩ	2202
27kΩ	2702
33kΩ	3302

The coil is the most influential component to efficiency. Select coil which has excellent DC resistance (DCR) and current characteristic. Select a capacitor of ceramic Type with excellent frequency and temperature characteristics. Further, select Capacitor to be used for CIN/COUT with small DC resistance, and pay lots of attention to the layout pattern

●Notice for PCB Board Layout

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

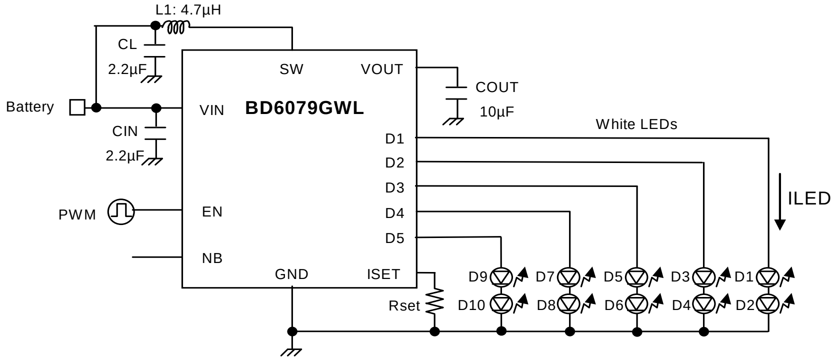


Figure 62. PCB circuit

< Priority 1 : Output capacitor COUT (10µF)>
Put output capacitor COUT (10µF) as close as possible between VOUT and GND pin.
< Priority 2 : Coil L1 (4.7µH)>
Put coil as close as possible between coil (L1) and SW pin.
SW terminal pattern is as small as possible.
< Priority 3 : Battery & Coil's input bypass capacitor CL (2.2µF)>
Put input bypass capacitor CL (2.2µF) as close as possible between coil (L1) and GND pin.
< Priority 4 : Input capacitor CIN (2.2µF)>
Put input bypass capacitor CIN (2.2µF) as close as possible between VIN pin and GND pin.
Put this capacitor if Battery noise is big.
< Priority 5 : LED current setting resistor Rset (setting value as shown in "●LED Current setting range")>
Connect LED current setting resistor Rset as independent as possible between GND of Rset and GND of CIN.
There is possibility to oscillate when capacity is added to ISET terminal, so pay attention that capacity isn't added.

●Recommended layout pattern

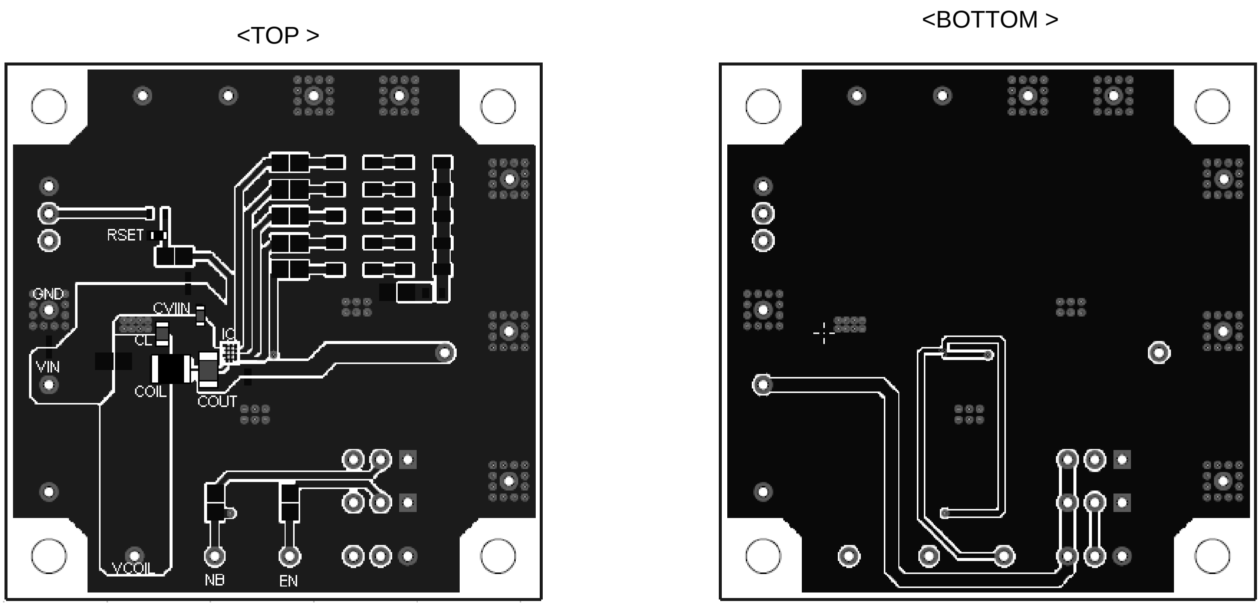


Figure 63. PCB Layout

●Application Example

< 10LED Setting >

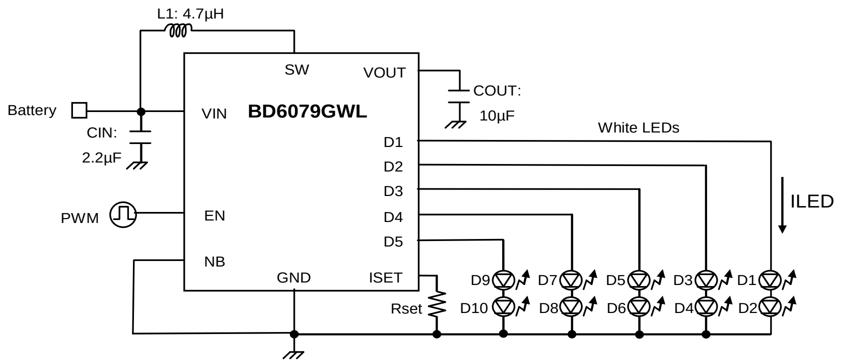


Figure 64. 10LEDs application setting

< 8LED Setting1 >

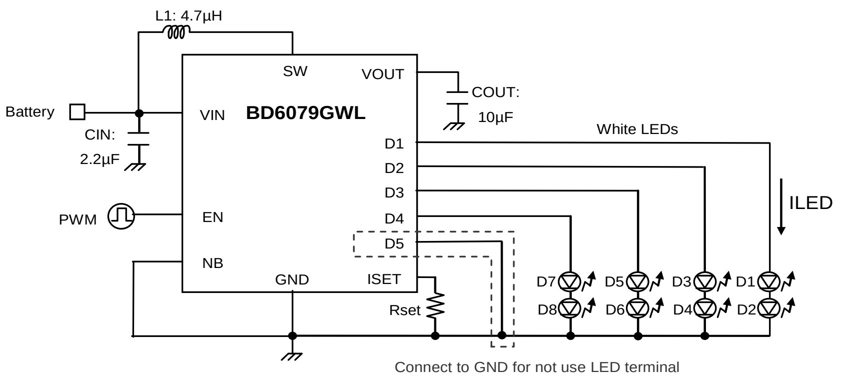


Figure 65. 8LEDs application setting 1

< 8LED Setting2 >

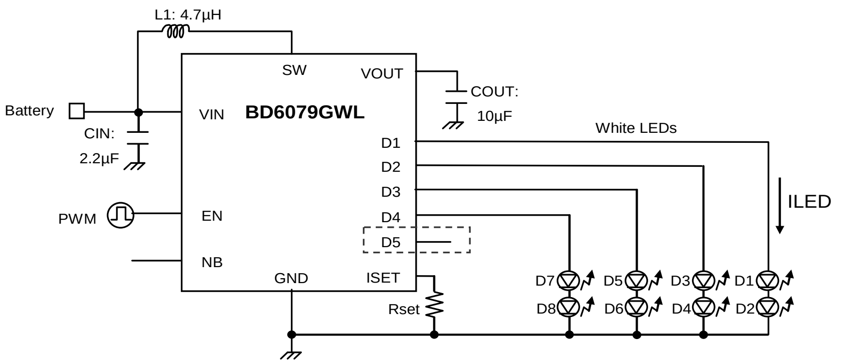


Figure 66. 8LEDs application setting 2

●Thermal Reduction Characteristic

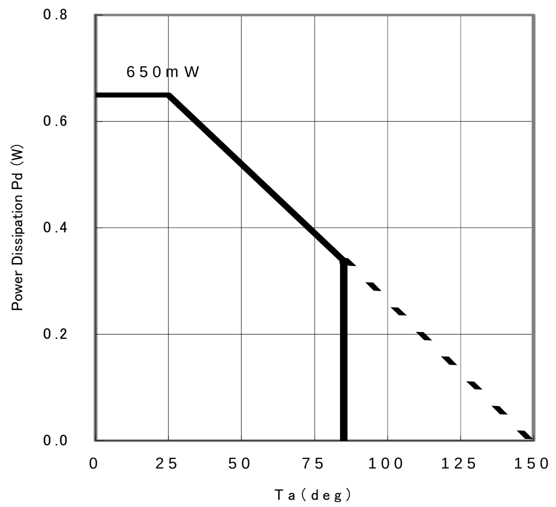


Figure 67. Power Dissipation

●Operational Notes

(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. 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 185deg (Typ.) or higher, the thermal shutdown circuit operates and turns a switch OFF. The thermal shutdown circuit, which is aimed at isolating the LSI from thermal runaway as much as possible, is not aimed at the protection or guarantee of the LSI. Therefore, do not continuously use the LSI with this circuit operating or use the LSI assuming its operation.

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

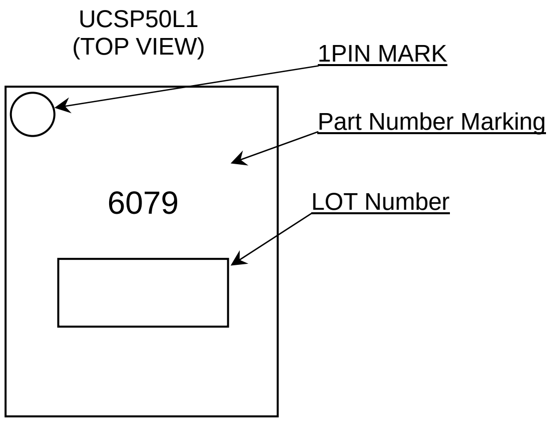
(14) Selection of coil
Select the low DCR inductors to decrease power loss for DC/DC converter.

●Ordering information

B	D	6	0	7	9	G	W	L	-	E 2

- Part Number
- Package: GWL:UCSP50L1
- Packaging and forming specification: E2: Embossed tape and reel

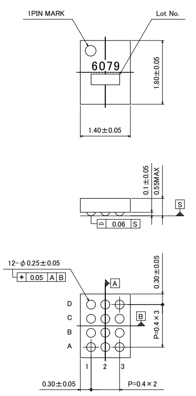
●Marking Diagram



●Physical Dimension Tape and Reel Information

UCSP50L1

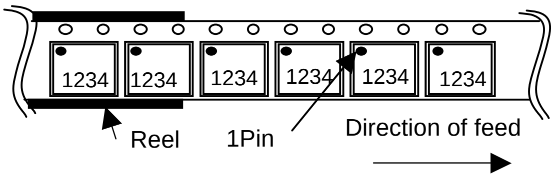
<Dimension>



(Unit:mm)

<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)



※When you order , please order in times the amount of package quantity.

●**Revision History**

Date	Revision	Changes
14.Mar.2013	001	New Release

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JAPAN	USA	EU	CHINA
CLASSⅢ	CLASSⅢ	CLASSⅡb	CLASSⅢ
CLASSⅣ		CLASSⅢ	

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   [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
   [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including Cl_2, H_2S, NH_3, SO_2, and NO_2
   [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
   [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
   [f] Sealing or coating our Products with resin or other coating materials
   [g] Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   [h] Use of the Products in places subject to dew condensation

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

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

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

7. De-rate Power Dissipation (Pd) depending on Ambient temperature (Ta). When used in sealed area, confirm the actual ambient temperature.

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

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

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BD6079GWL - Web Page

Distribution Inventory

Part Number	BD6079GWL
Package	UCSP50L1
Unit Quantity	3000
Minimum Package Quantity	3000
Packing Type	Taping
Constitution Materials List	inquiry
RoHS	Yes