

4ch White LED Driver Built-in Current Driver Buck-Boost and Boost DC/DC Controller for Automotive

BD81A44MUV-M BD81A44EFV-M

General Description

BD81A44MUV-M/BD81A44EFV-M is a white LED driver with the capability of withstanding high input voltage (maximum 35 V). This driver has 4ch constant-current drivers in 1-chip, where each channel can draw up to 120 mA (Max), and it is suitable for high illumination LED drive. Furthermore, a buck-boost current mode DC/DC controller is also built to achieve stable operation during power voltage fluctuation. Light modulation (10,000:1@100 Hz dimming function) is possible by PWM input.

Features

- AEC-Q100 Qualified^(Note 1)
- 4ch Current Driver for LED Drive
- Buck-Boost Current Mode DC/DC Controller
- Control DC/DC Converter Oscillation Frequency by External Synchronized Signal
- 10000:1 PWM dimming @100Hz
- LSI Protection Function (UVLO, OVP, TSD, OCP, SCP)
- LED Abnormality Detection Function (Open/Short)
- VOUT Discharge Function (Buck-Boost Structure Limitation)

(Note 1) Grade 1

Application

- Automotive CID (Center Information Display) Panel
- Car Navigation
- Cluster Panel
- HUD (Head Up Display)
- Small and Medium Type LCD Panels for Automotive Use

Typical Application Circuit

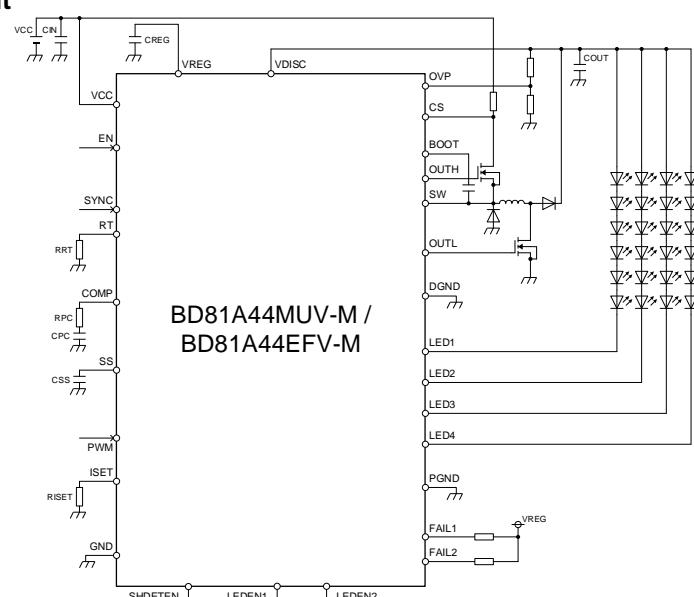


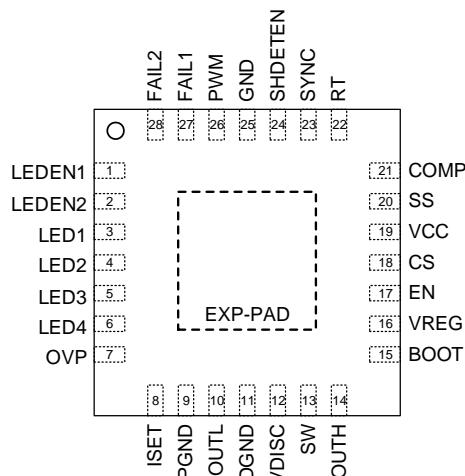
Figure 1. Buck-Boost Application Circuit

○Product structure : Silicon monolithic integrated circuit ○This product has no designed protection against radioactive rays

○This product is protected by U.S. Patent No.7,235,954, No.7,541,785, No.7,944,189.

Pin Configuration

VQFN28SV5050 (TOP VIEW)



HTSSOP-B28 (TOP VIEW)

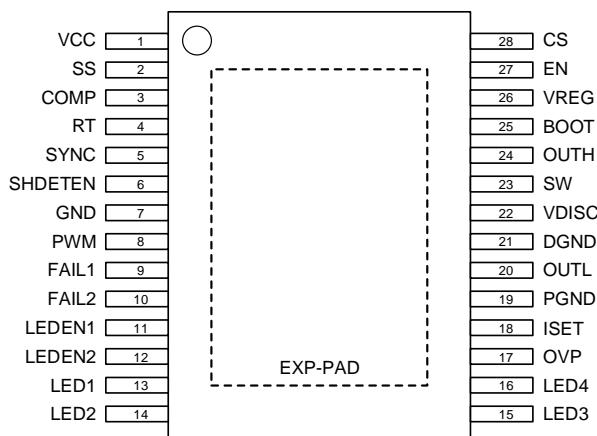


Figure 2. Pin Configuration

Pin Description

VQFN28SV5050	HTSSOP-B28	Pin Name	Function
1	11	LEDEN1	Enable pin 1 for LED output
2	12	LEDEN2	Enable pin 2 for LED output
3	13	LED1	LED output pin 1
4	14	LED2	LED output pin 2
5	15	LED3	LED output pin 3
6	16	LED4	LED output pin 4
7	17	OVP	Over voltage detection pin
8	18	ISET	LED output current setting pin
9	19	PGND	LED output GND pin
10	20	OUTL	Low side FET gate pin
11	21	DGND	DC/DC converter output GND pin
12	22	VDISC	Output voltage discharge pin
13	23	SW	High side FET source pin
14	24	OUTH	High side FET gate pin
15	25	BOOT	High side FET driver power supply pin
16	26	VREG	Internal constant voltage
17	27	EN	Enable pin
18	28	CS	DC/DC converter current sense pin
19	1	VCC	Input power supply pin
20	2	SS	“Soft Start” capacitor connection
21	3	COMP	Error Amp output
22	4	RT	Oscillation frequency setting resistor connect
23	5	SYNC	External synchronization input pin
24	6	SHDETEN	Short detection enable signal
25	7	GND	Small signal GND pin
26	8	PWM	PWM light modulation signal input pin
27	9	FAIL1	“Failure” signal output pin 1
28	10	FAIL2	“Failure” signal output pin 2
-	-	EXP-PAD	Back side thermal PAD (Connect to GND)

Block Diagram

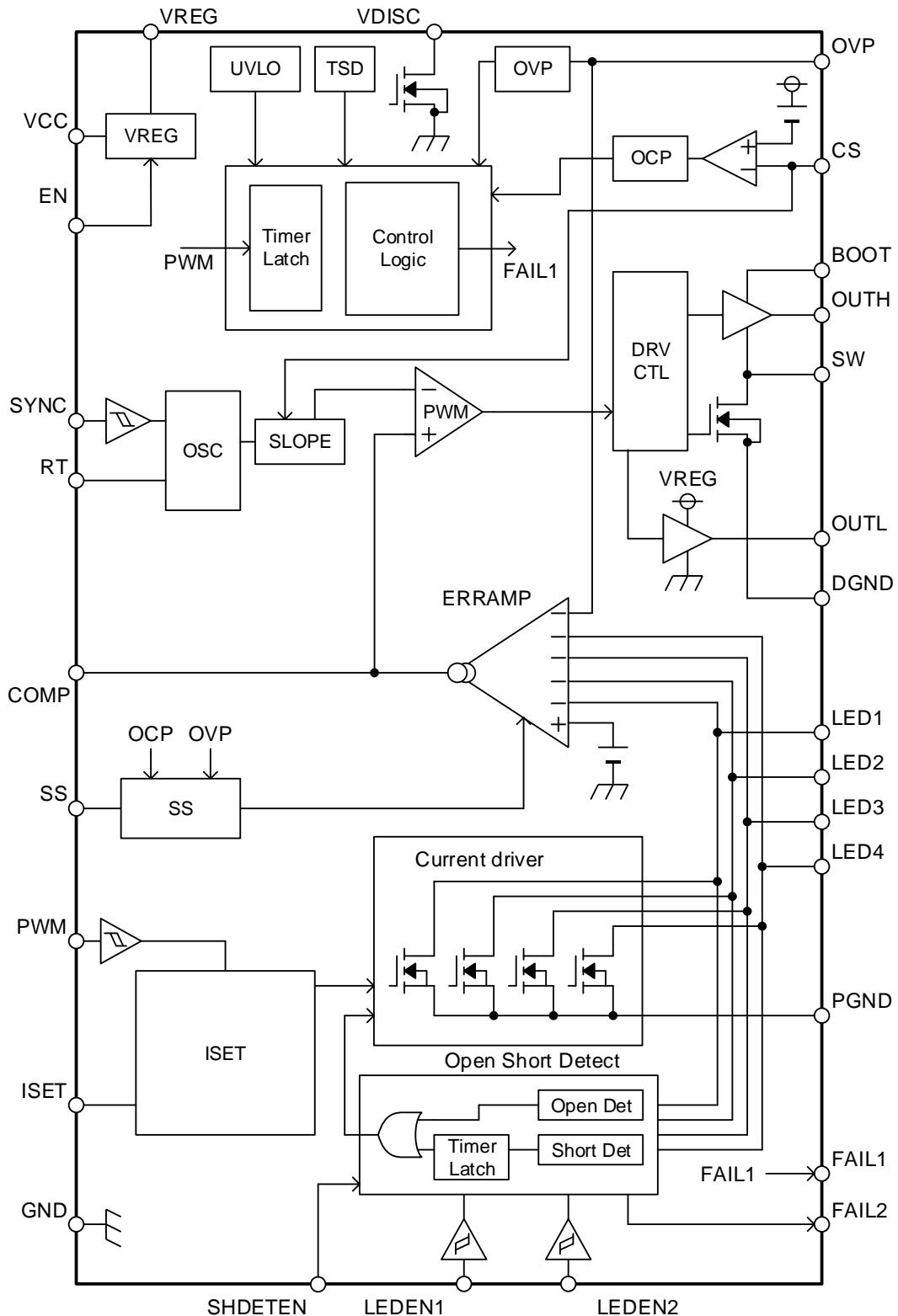


Figure 3. Block Diagram

Description of Blocks

If there is no description, the mentioned values are typical value.

1. Reference Voltage (VREG)

VREG Block generates 5 V at EN = High, and outputs to the VREG pin. This voltage (V_{VREG}) is used as power supply for internal circuit. It is also used to fix each input pin to High voltage outside IC. It cannot supply power to other parts than this IC. The VREG pin has UVLO function, and it starts operation at $VCC \geq 4.0$ V and $V_{VREG} \geq 3.5$ V and stops when at $VCC \leq 3.5$ V or $V_{VREG} \leq 2.0$ V. About the condition to release/detect VREG voltage, refer to [Table 2](#) on section 4 Protect Function. Connect a ceramic capacitor (C_{VREG}) to the VREG pin for phase margin. C_{VREG} range is 1.0 μ F to 4.7 μ F and recommended value is 2.2 μ F. If the C_{VREG} is not connected, it might occur unstable operation e.g. oscillation.

2. Current Driver

Table 1. LED Control Logic

LEDEN1	LEDEN2	LED1	LED2	LED3	LED4
Low	Low	ON	ON	ON	ON
High	Low	ON	ON	ON	OFF
Low	High	ON	ON	OFF	OFF
High	High	ON	OFF	OFF	OFF

If less than four constant-current drivers are used, please make the LED1 to LED4 pin 'open' and turn off the channel, which is not used, with the LEDEN1 and LEDEN2 pins. The truth table for these pins is shown above. If the unused constant-current driver output is set open without the process of the LEDEN1 and LEDEN2 pins, the 'open detection' will be activated. The LEDEN1 and LEDEN2 pins are pulled down internally in the IC and it is low at 'open' condition. They can be connected to the VREG pin and fixed to logic High. Logic of the LEDEN1 and LEDEN2 pins are not switchable during these in operation.

(1) Output Current Setting (R_{ISET})

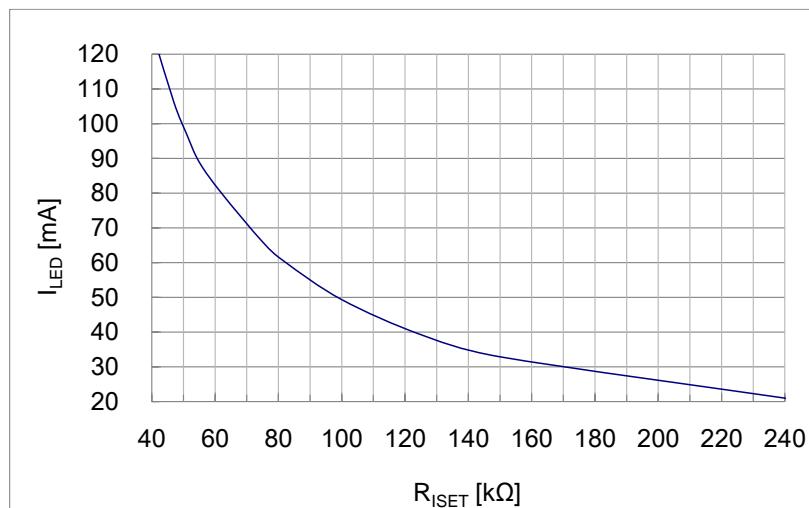


Figure 4. I_{LED} vs R_{ISET}

The Output Current I_{LED} can be obtained by the following equation:

$$I_{LED} = 5000/R_{ISET} \text{ [A]}$$

The operating range of the R_{ISET} value is from 41 kΩ to 250 kΩ. Additionally, the R_{ISET} value could not be changed during operation. In this IC, I_{SET} -GND short protection is built-in to protect an LED element from excess current when the ISET pin and GND are shorted. If the R_{ISET} value is 4.7 kΩ or lower, the IC detects ISET-GND short condition and LED current is turned off.

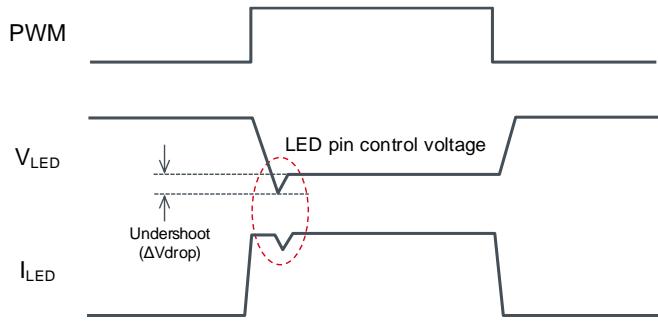
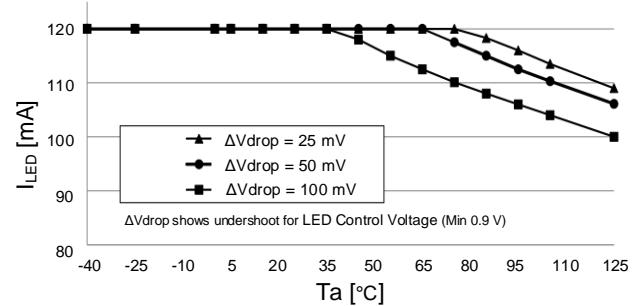
Description of Blocks – continued

<Caution of Large LED Current Setting>

During PWM dimming, the LED pin voltage (V_{LED}) rises at PWM = Low because LED current doesn't flow, and controls V_{LED} to 1 V at PWM = High. When PWM rise up, V_{LED} undershoot may occur depends on LED current setting or external parts including the output capacitor. The undershoot is large especially at high temperature and large LED current.

LED current may decrease instantly as Figure 5 (a) shows by the undershoot. The undershoot and the settable LED current are shown in Figure 5 (b).

If the LED current is decreased instantly with the undershoot, it may see as the LED flicker. Evaluate with the actual application certainly, and check at the visual perspective.

(a) Timing Chart of V_{LED} , I_{LED} at PWM Dimming(b) LED Current (I_{LED}) vs Temperature (T_a)Figure 5. Relation Between Undershoot of V_{LED} and LED Current

(2) PWM Dimming Control

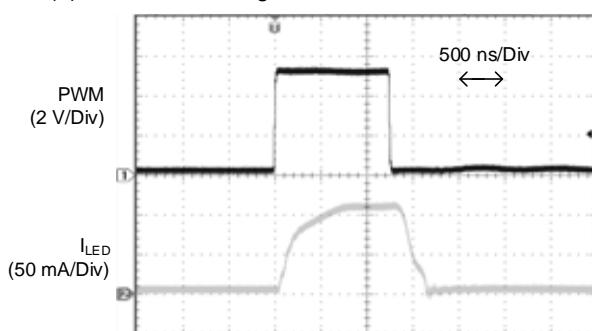
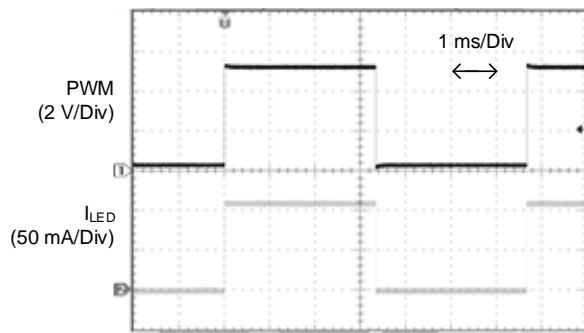
(a) PWM = 150 Hz, Duty = 0.02%, I_{LED} Waveform(b) PWM = 150 Hz, Duty = 50.0%, I_{LED} Waveform

Figure 6. PWM Dimming Waveform

The current driver ON/OFF is controlled by the PWM pin. The duty ratio of the PWM pin becomes duty ratio of I_{LED} . If PWM dimming is not totally used (i.e. 100%), fix the PWM pin to High. Output light intensity is the highest at 100%.

Description of Blocks – continued

3. Buck-Boost DC/DC Controller

(1) Number of LED in Series Connection

This IC controls output voltage to become 1.0 V by detecting LED Cathode voltage (the LED1 to LED4 pin voltage). When multiple LED outputs are operating, it controls LED pin voltage with the highest LED Vf to become 1.0 V. Thus, the output voltage of other LED pins is higher by the variations of Vf. Please set up Vf variation to meet the formula below.

LED Series Number × Vf Variation

< Short Detection Voltage (Min) – LED Control Voltage (Max)

(2) Over Voltage Protection (OVP)

The output of the DC/DC converter (VOUT) should be connected to the OVP pin via voltage divider. If the OVP pin voltage is over 2.0 V, Over Voltage Protection (OVP) is active and stop the DC/DC converter switching. Determine the setting value of OVP function by the total number of the LEDs in the series and the Vf variation. When the OVP pin voltage drops less than 1.94 V after OVP operation, the OVP will be released.

$$VOUT \geq \{(R_{OVP1} + R_{OVP2}) / R_{OVP1}\} \times 2.0$$

where:

VOUT is the Output voltage.

R_{OVP1} is the GND side OVP resistance.

R_{OVP2} is the Output voltage side OVP resistance.

For example, OVP engages when VOUT > 32 V if R_{OVP1} = 22 kΩ and R_{OVP2} = 330 kΩ.

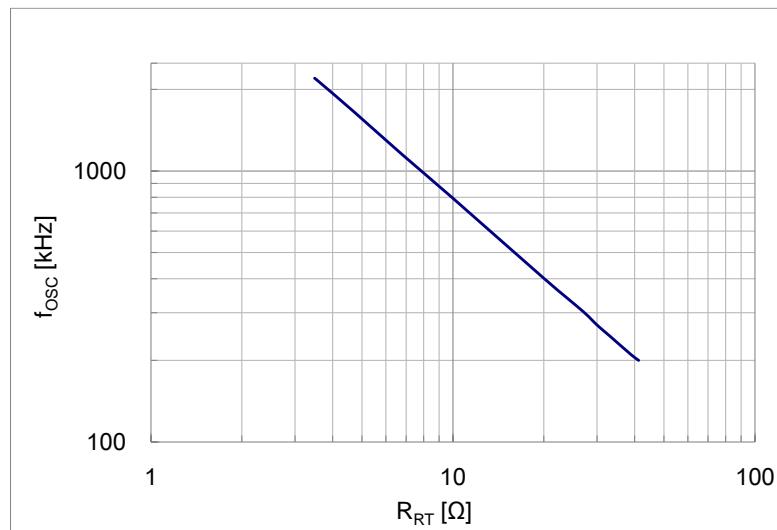
(3) Buck-Boost DC/DC Converter Oscillation Frequency (f_{osc})

Figure 7. f_{osc} vs R_{RT}

DC/DC oscillation frequency can be set via a resistor connected to the RT pin. This resistor determines the charge/discharge current to the internal capacitor, thereby changing the oscillation frequency. Please set the resistance of R_{RT} using the above data and the equation below.

$$f_{osc} = (81 \times 10^5 / R_{RT}) \text{ [kHz]}$$

81 × 10⁵ is the constant value determined in the internal circuit. Take note that operation could not be guaranteed in the case of settings other than the recommended range.

Description of Blocks - continued**(4) External Synchronization Oscillation Frequency**

By clock signal input to the SYNC pin, the internal oscillation frequency can be synchronized externally. Do not switch from external to internal oscillation if the DC/DC converter is active. The clock input to the SYNC pin is valid only in rising edge. Input the external input frequency with less than $\pm 20\%$ of internal oscillatory frequency set by the RT pin resistance.

(5) Soft Start Function (SS)

The soft-start (SS) function can start the output voltage slowly while controlling the current during the start by connecting the capacitance (C_{SS}) to the SS pin. In this way, output voltage overshoot and inrush current can be prevented. When SS function is not used, set the SS pin open. Refer to [10. Setting of the Soft Start Time](#) for the calculation of SS time.

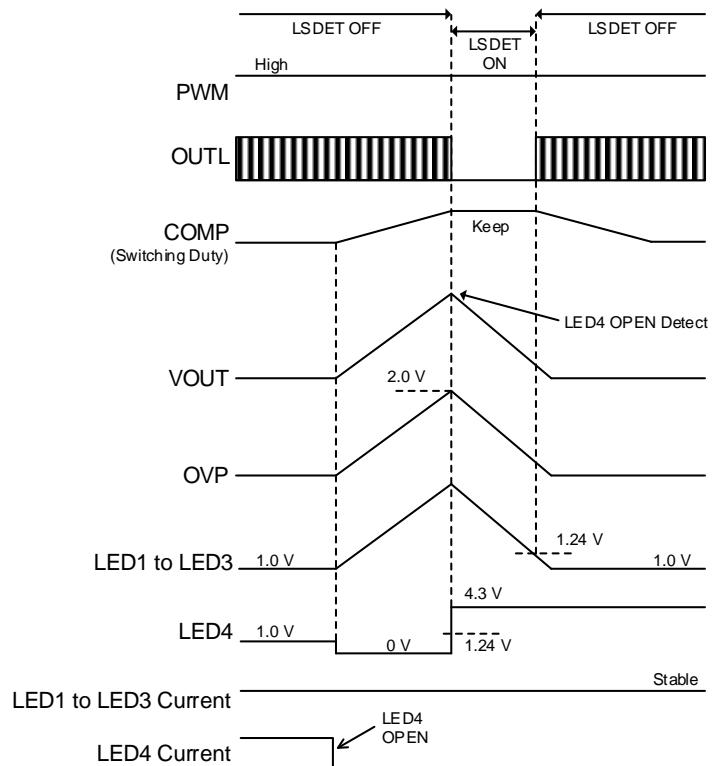
(6) Max Duty

When DC/DC switching reaches Max Duty, expected VOUT voltage could be not output, and LED lights-out might occur by the reduction of LED output current and detection of ground short protection. Set input condition and load condition such that it does not reach Max Duty.

Description of Blocks - continued

(7) DC/DC Switching Control at Over Voltage Output (LSDET)

When the lowest voltage in LED1 to LED4 pin (DC/DC feedback voltage) exceeds 1.24 V, LSDET function works and turns off the switching of the DC/DC converter and keeps the COMP voltage (switching Duty). This function reduces the VOUT voltage quickly and intended to output stable switching Duty when VOUT is over boost voltage. Below is a behavior example when LED4 open.

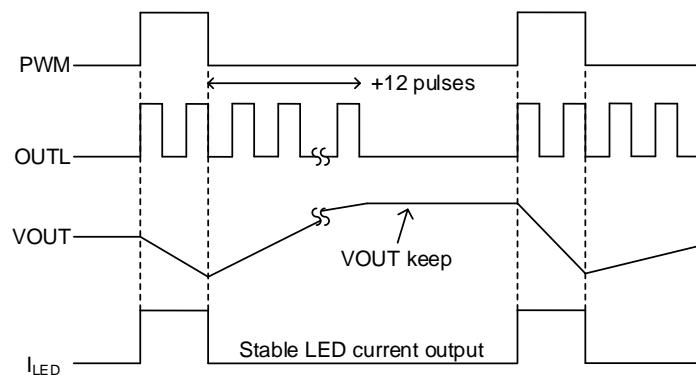


Example When LED4 Becomes OPEN

When one of LED1 to LED4 pin became 0.3 V or less and OVP pin became 2.0 V or more, it detects LED OPEN protection. (Refer to [4. Protection Feature](#)) Because all LED1 to LED4 pin become 1.24 V or more at "LSDET ON" section just after the LED4 OPEN detection, LSDET works. In this time, switching Duty is turned off and the COMP voltage is kept. Because the LED current is supplied from capacity connecting with VOUT in the LSDET ON section, the VOUT voltage decreases. The LED1 to LED3 pin voltage decreases at the same time as VOUT decreases. When it becomes less than 1.24 V, DC/DC switching is restarted again and returns to a normal control state.

(8) PWM Pulse and DC/DC Switching

After the fall of the PWM pulse, DC/DC switching is output 12 pulse and after that, turn off the DC/DC switching between PWM = Low. When PWM becomes High again, the DC/DC switching is on. Because of this, when PWM pulse width is short, it can maintain the output voltage and output the stable LED current.



Description of Blocks - continued

4. Protection Feature

Table 2. Detect Condition of Each Protection Feature and Operation during Detection

Function	Detect Condition		Operation During Detection
	[Detection]	[Release/Cancellation]	
UVLO	$V_{CC} \leq 3.5 \text{ V}$ or $V_{VREG} \leq 2.0 \text{ V}$	$V_{CC} \geq 4.0 \text{ V}$ and $V_{VREG} \geq 3.5 \text{ V}$	All blocks shut down except VREG
TSD	$T_a \geq 175 \text{ }^{\circ}\text{C}$	$T_a \leq 150 \text{ }^{\circ}\text{C}$	All blocks shut down except VREG
OVP	$V_{OVP} \geq 2.0 \text{ V}$	$V_{OVP} \leq 1.94 \text{ V}$	DC/DC switching OFF
OCP	$V_{CS} \leq V_{CC}-0.2 \text{ V}$	$V_{CS} > V_{CC}-0.2 \text{ V}$	DC/DC switching OFF
SCP	$V_{OVP} \leq 0.57 \text{ V}$ or Any of V_{LED1} to V_{LED4} is 0.3 V and below (100 ms delay @300 kHz)	EN Reset or UVLO Reset	After SCP delay time, all blocks latch OFF except VREG
LED Open Protection	Any of V_{LED1} to V_{LED4} is 0.3 V and below and $V_{OVP} \geq 2.0 \text{ V}$	EN Reset or UVLO Reset	Only detected channel latches OFF
LED Short Protection	Any of V_{LED1} to V_{LED4} is 4.5 V and more (100 ms delay @300 kHz)	EN Reset or UVLO Reset	After LED Short delay time, only detected channel latches OFF

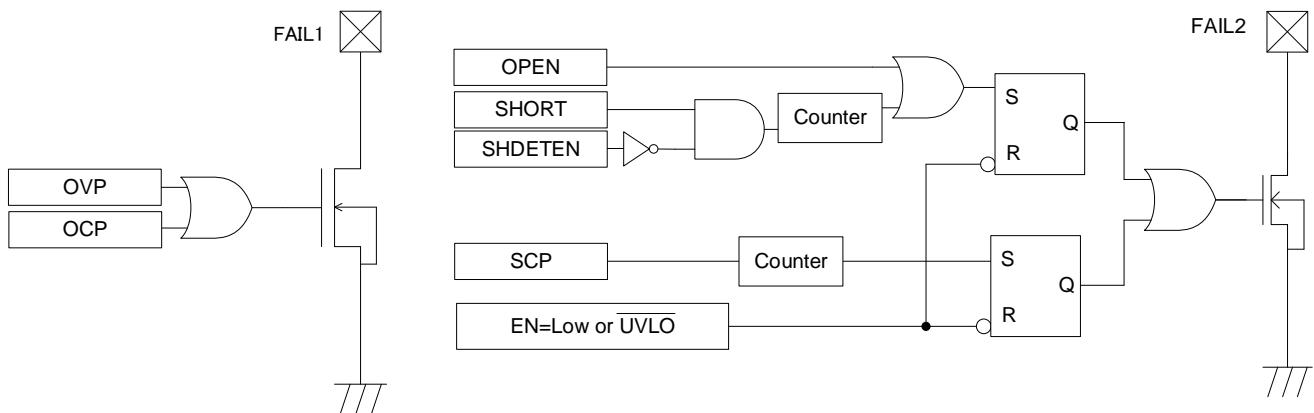


Figure 8. Protection Flag Output Block Diagram

FAIL1 becomes low when OVP or OCP protection is detected, whereas FAIL2 becomes low when SCP, LED open or LED short is detected. If the FAIL pin is not used as a flag output, set the FAIL pin open or connect it to GND. The output from the FAIL1 and FAIL2 pins are reset and return to High by starting up of EN or release of UVLO. Also, those output is unstable when EN = Low and detecting UVLO. If the FAIL pin is used as a flag output, it is recommended to pull-up the FAIL1, FAIL2 pins to the VREG pin. The recommended value of pull-up resistance is 100 kΩ.

Description of Blocks - continued

- (1) Under-Voltage Lock Out (UVLO)
The UVLO shuts down DC/DC converter and Current Driver when $V_{CC} \leq 3.5$ V or $V_{VREG} \leq 2.0$ V. And UVLO is released by $V_{CC} \geq 4.0$ V and $V_{VREG} \geq 3.5$ V.
- (2) Thermal Shutdown (TSD)
The TSD shuts down DC/DC converter and Current Driver when the T_j reaches 175 °C, and releases when the T_j becomes below 150 °C.
- (3) Over Voltage Protection (OVP)
The output voltage of DC/DC converter is detected from the OVP pin voltage, and the over voltage protection will activate if the OVP pin voltage becomes ≥ 2.0 V. When OVP is activated, the switching operation of the DC/DC converter turns off. And the OVP pin voltage becomes ≤ 1.94 V, OVP is released and the switching operation of the DC/DC converter turns on.
- (4) Over Current Protection (OCP)
The OCP detects the coil current by monitoring the voltage of the high side resistor, and activates when $V_{CS} \leq V_{CC}-0.2$ V. When the OCP is activated, the switching operation of the DC/DC converter turns off. And $V_{CS} > V_{CC}-0.2$ V, OCP is released and the switching operation of the DC/DC converter turns on.
- (5) Short Circuit Protection (SCP)
The SCP can be operated when the SS pin voltage reaches 3.3 V while start-up. When any of the LED1 to LED4 pin voltage becomes 0.3 V and below or $V_{OVP} \leq 0.57$ V, the built-in counter operation starts. The clock frequency of counter is the oscillation frequency (f_{osc}), which is determined by R_{RT} . After it counts 32770, the DC/DC converter and the current driver are latched off. When $f_{osc} = 300$ kHz, the count time is approximately 100 ms and SCP operates after this count time. If all of the LED pin voltage becomes over 0.3 V or $V_{OVP} \geq 1.0$ V before 32770th count, the counter resets and SCP is not detected.
- (6) LED Open Protection
When any of the LED pins voltage is 0.3 V and below and $V_{OVP} \geq 2.0$ V, LED open is detected and latches off the open channel.
- (7) LED Short Protection
If any of V_{LED1} to V_{LED4} is 4.5 V and more, the built-in counter operation starts. The clock frequency of counter is the oscillation frequency (f_{osc}), which is determined by R_{RT} . After it counts 32770, the DC/DC converter and the current driver are latched off. When $f_{osc} = 300$ kHz, the count time is approximately 100 ms and SCP operates after this count time.
During PWM dimming, the LED Short Protection is carried out only when PWM = High. If the condition of LED Short is reset while working the counter, the counter resets and LED Short is not detected.
- (8) PWM Low Interval Detect
The low interval of PWM input is counted by built-in counter during EN = High. The clock frequency of counter is the oscillation frequency (f_{osc}), which is determined by R_{RT} . It stops the operation of circuits except VREG at 32768 counts. When $f_{osc} = 300$ kHz, the count time is approximately 100 ms and the Low interval of PWM is detected after this count time.

Description of Blocks - continued

(9) Output Voltage Discharge Circuit (VOUT Discharge Function)

If start up with a charge remaining at VOUT, LED might occur flicker. To prevent this, it is necessary to discharge of VOUT when starting-up. If use only resistance for setting OVP to discharge, it takes a lot time for discharging VOUT. Therefore, this product has functionality of circuit for VOUT discharge. VOUT discharge function is available at Buck-Boost application and Buck application. For this case, be sure to connect VOUT and the VDISC pin. It discharge the residual electric charge of VOUT when DC/DC circuit is OFF; changing EN High to Low or operating protect function. The discharge time (t_{DISC}) is expressed in the following equations.

$$t_{DISC} = \frac{3 \times VOUT \times C_{OUT}}{4 \times I_{DISC}} \quad [s]$$

where:

t_{DISC} is the DC/DC converter output discharge time.

C_{OUT} is the VOUT capacity.

$VOUT$ is the DC/DC converter output voltage.

I_{DISC} is the discharge current.

From the graph below, find the I_{DISC} value in 25% VOUT voltage, and substitute it in the above equation. For example, substitute I_{DISC} value in $VOUT = 5$ V (approximately 76 mA) in the above equation when using in $VOUT = 20$ V, and calculate the discharge time.

In order to suppress the flickering of the LED, the time of restarting EN = Low should be secured t_{DISC} or more long.

Always check with actual machine because the t_{DISC} found here is a reference level.

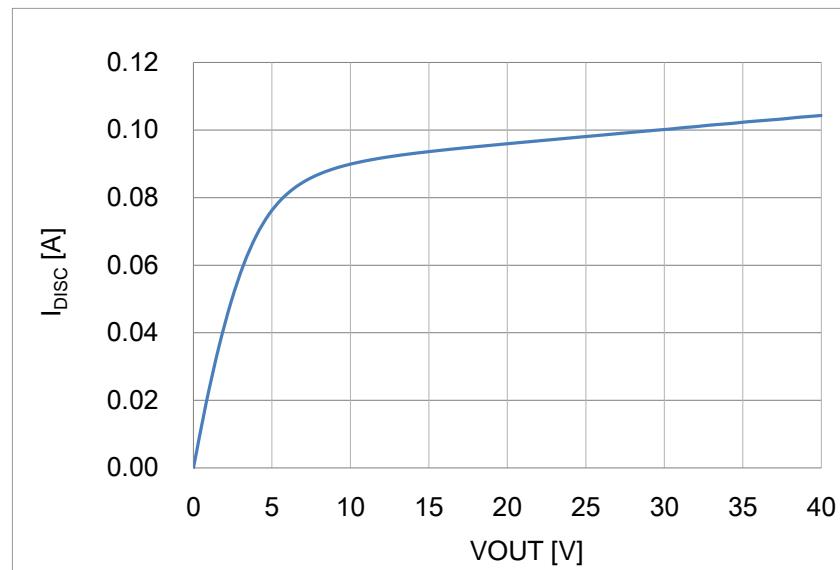


Figure 9. I_{DISC} vs $VOUT$

Absolute Maximum Ratings (Ta = 25 °C)

Parameter	Symbol	Rating	Unit
Power Supply Voltage	VCC	40	V
BOOT, OUTH Pin Voltage	V _{BOOT} , V _{OUTH}	45	V
SW, CS, OUTL Pin Voltage	V _{SW} , V _{CS}	40	V
BOOT-SW Pin Voltage	V _{BOOT-SW}	7	V
LED1 to LED4, VDISC Pin Voltage	V _{LED1} , V _{LED2} , V _{LED3} , V _{LED4} , V _{VDISC}	40	V
PWM, SYNC, EN Pin Voltage	V _{PWM} , V _{SYNC} , V _{EN}	-0.3 to +7	V
VREG, OVP, FAIL1, FAIL2, SS, RT Pin Voltage	V _{VREG} , V _{OVP} , V _{FAIL1} , V _{FAIL2} , V _{SS} , V _{RT}	-0.3 to +7 < VCC	V
LEDEN1, LEDEN2, ISET, OUTL, COMP, SHDETEN Pin Voltage	V _{LEDEN1} , V _{LEDEN2} , V _{ISET} , V _{OUTL} , V _{COMP} , V _{SHDETEN}	-0.3 to +7 < V _{VREG}	V
Maximum Junction Temperature	T _{jmax}	150	°C
Storage Temperature Range	T _{stg}	-55 to +150	°C
LED Maximum Output Current	I _{LED}	120 ^(Note 1)	mA

Caution 1: Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

Caution 2: Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, design a PCB board with thermal resistance taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.

(Note 1) Current level per channel. Please set LED current that does not over Junction Temperature Range (T_j) maximum.

Thermal Resistance^(Note 2)

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s ^(Note 4)	2s2p ^(Note 5)	
VQFN28SV5050				
Junction to Ambient	θ _{JA}	128.5	31.5	°C/W
Junction to Top Characterization Parameter ^(Note 3)	Ψ _{JT}	12	9	°C/W
HTSSOP-B28				
Junction to Ambient	θ _{JA}	107.0	25.1	°C/W
Junction to Top Characterization Parameter ^(Note 3)	Ψ _{JT}	6	3	°C/W

(Note 2) Based on JESD51-2A(Still-Air).

(Note 3) The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.

(Note 4) Using a PCB board based on JESD51-3.

(Note 5) Using a PCB board based on JESD51-5, 7.

Layer Number of Measurement Board	Material	Board Size
Single	FR-4	114.3 mm x 76.2 mm x 1.57 mm

Top	
Copper Pattern	Thickness
Footprints and Traces	70 µm

Layer Number of Measurement Board	Material	Board Size	Thermal Via ^(Note 6)	
			Pitch	Diameter
4 Layers	FR-4	114.3 mm x 76.2 mm x 1.6 mm	1.20 mm	Φ0.30 mm

Top	2 Internal Layers		Bottom		
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70 µm	74.2 mm x 74.2 mm	35 µm	74.2 mm x 74.2 mm	70 µm

(Note 6) This thermal via connects with the copper pattern of all layers.

Recommended Operating Conditions

Parameter	Symbol	Min	Max	Unit
Power Supply Voltage ^(Note 1)	VCC	4.5	35	V
Operating Temperature	Topr	-40	+125	°C
DC/DC Oscillation Frequency	f _{OSC}	200	2200	kHz
External Synchronized Frequency (<i>Note 2</i>)(<i>Note 3</i>)	f _{SYNC}	200 or higher of f _{OSC} x 0.8	2200 or lower of f _{OSC} x 1.2	kHz
External Synchronized Pulse Duty	D _{SYNC}	40	60	%

(Note 1) This indicates the voltage near the VCC pin. Be careful of voltage drop by the impedance of power line.

(Note 2) When external synchronization frequency is not used, connect the SYNC pin to open or GND.

(Note 3) When external synchronization frequency is used, do not change to internal oscillation frequency along the way.

Operating Conditions (External Constant Range)

Parameter	Symbol	Min	Max	Unit
VREG Capacity	C _{VREG}	1.0	4.7	μF
LED Current Setting Resistance	R _{ISET}	41	250	kΩ
Oscillation Frequency Setting Resistance	R _{RT}	3.6	41	kΩ
Soft Start Capacity Setting	C _{SS}	0.047	0.47	μF

Electrical Characteristics

(Unless otherwise specified, VCC = 12 V, Ta = -40 °C to +125 °C)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Circuit Current	I _{CC}	-	-	10	mA	EN = High, SYNC = High, RT = OPEN, PWM = Low, ISET = OPEN, CIN = 10 µF
Standby Current	I _{ST}	-	-	10	µA	EN = Low, VDISC = OPEN
[VREG]						
Reference Voltage	V _{VREG}	4.5	5.0	5.5	V	I _{REG} = -5 mA, C _{VREG} = 2.2 µF
[OUTH]						
OUTH High Side ON-Resistor	R _{ONHH}	1.5	3.5	7.0	Ω	I _{OUTH} = -10 mA
OUTH Low Side ON-Resistor	R _{ONHL}	0.8	2.5	5.5	Ω	I _{OUTH} = 10 mA
OCP Detection Voltage	V _{OLIMIT}	VCC-0.22	VCC-0.20	VCC-0.18	V	
[OUTL]						
OUTL High Side ON-Resistor	R _{ONLH}	1.5	3.5	10.0	Ω	I _{OUTL} = -10 mA
OUTL Low Side ON-Resistor	R _{ONLL}	0.8	2.5	5.5	Ω	I _{OUTL} = 10 mA
[SW]						
SW ON-Resistor	R _{ON_SW}	4.0	10.0	25.0	Ω	I _{SW} = 10 mA
[ERRAMP]						
LED Control Voltage	V _{LED}	0.9	1.0	1.1	V	
COMP Sink Current	I _{COMPSINK}	35	80	145	µA	V _{LEDn} = 2 V (n = 1, 2, 3, 4), V _{COMP} = 1 V
COMP Source Current	I _{COMPSOURCE}	-145	-80	-35	µA	V _{LEDn} = 0.5 V (n = 1, 2, 3, 4), V _{COMP} = 1 V
[Oscillator]						
Oscillation Frequency 1	f _{OSC1}	285	300	315	kHz	R _{RT} = 27 kΩ
Oscillation Frequency 2	f _{OSC2}	1800	2000	2200	kHz	R _{RT} = 3.9 kΩ
[OVP]						
OVP Detection Voltage	V _{OVP1}	1.9	2.0	2.1	V	V _{OVP} : Sweep up
OVP Hysteresis Width	V _{OVPHYS1}	0.02	0.06	0.10	V	V _{OVP} : Sweep down

Electrical Characteristics - continued

(Unless otherwise specified, VCC = 12 V, Ta = -40 °C to +125 °C)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
[UVLO]						
UVLO Detection Voltage	V _{UVLO}	3.2	3.5	3.8	V	VCC: Sweep down
UVLO Hysteresis Width	V _{UHYS}	0.25	0.50	0.75	V	VCC: Sweep up, V _{VREG} > 3.5 V
[LED Output]						
LED Current Relative Dispersion	I _{LEDrel}	-3	-	+3	%	I _{LED} = 50 mA, Ta = 25 °C ΔI _{LEDrel} = (I _{LEDn} /I _{LEDn_AVG} -1) × 100 (n = 1,2,3,4)
		-5	-	+5	%	I _{LED} = 50 mA, Ta = -40 °C to +125 °C ΔI _{LEDrel} = (I _{LEDn} /I _{LEDn_AVG} -1) × 100 (n = 1,2,3,4)
LED Current Absolute Dispersion	I _{LEDab}	-3	-	+3	%	I _{LED} = 50 mA, Ta = 25 °C ΔI _{LEDab} = (I _{LEDn} /50mA-1) × 100 (n = 1,2,3,4)
		-5	-	+5	%	I _{LED} = 50 mA, Ta = -40 °C to +125 °C ΔI _{LEDab} = (I _{LEDn} /50mA-1) × 100 (n = 1,2,3,4)
ISET Voltage	V _{ISET}	0.9	1.0	1.1	V	R _{ISET} = 100 kΩ
PWM Minimum Pulse Width	t _{MIN}	1	-	-	μs	f _{PWM} = 100 Hz to 20 kHz, I _{LED} = 20 mA to 100 mA
PWM Frequency	f _{PWM}	0.1	-	20	kHz	
[Protection Circuit]						
LED Open Detection Voltage	V _{OPEN}	0.2	0.3	0.4	V	V _{LED1} , V _{LED2} , V _{LED3} , V _{LED4} : Sweep down
LED Short Detection Voltage	V _{SHORT}	4.2	4.5	4.8	V	V _{LED1} , V _{LED2} , V _{LED3} , V _{LED4} : Sweep up
LED Short Detection Latch OFF Delay Time	t _{SHORT}	70	100	130	ms	R _{RT} = 27 kΩ
SCP Latch OFF Delay Time	t _{SCP}	70	100	130	ms	R _{RT} = 27 kΩ
PWM Latch OFF Delay Time	t _{PWM}	70	100	130	ms	R _{RT} = 27 kΩ
ISET-GND Short Protection Impedance	I _{ISETPROT}	-	-	4.7	kΩ	
[Logic Input Voltage]						
Input High Voltage	V _{INH}	2.1	-	V _{VREG}	V	EN, SYNC, PWM, LEDEN1, LEDEN2
Input Low Voltage	V _{INL}	GND	-	0.8	V	EN, SYNC, PWM, LEDEN1, LEDEN2
Input Current	I _{IN}	15	50	100	μA	V _{IN} = 5 V (EN, SYNC, PWM, LEDEN1, LEDEN2)
[FAIL Output (Open Drain)]						
FAIL Low Voltage	V _{OL}	-	0.1	0.2	V	I _{FAIL} = 0.1 mA

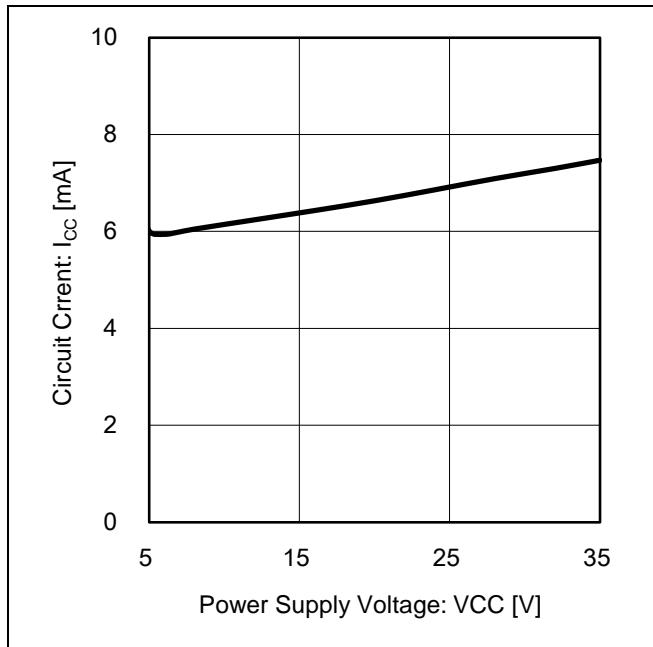
Typical Performance Curves(Reference Data. Unless otherwise specified, $T_a = -40$ °C to +125 °C)

Figure 10. Circuit Current vs Power Supply Voltage
($T_a = 25$ °C, $VCC = 4.5$ V to 35 V,
 $V_{EN} = 3.3$ V, $V_{PWM} = 0$ V)

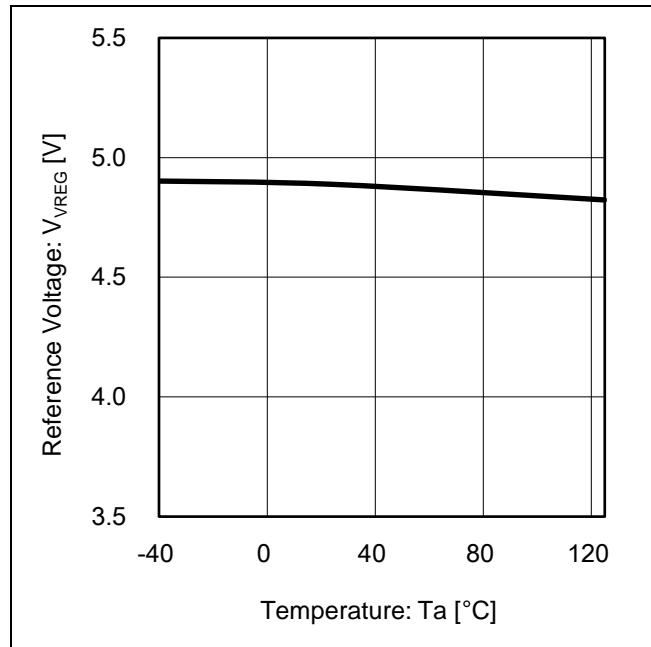


Figure 11. Reference Voltage vs Temperature
($VCC = 12$ V, $V_{EN} = 3.3$ V, $V_{PWM} = 0$ V)

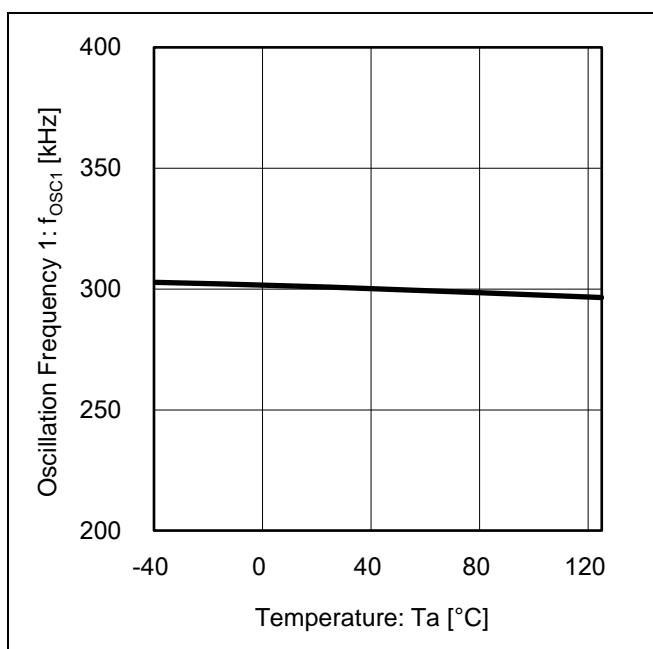


Figure 12. Oscillation Frequency 1 vs Temperature
(@300 kHz, $VCC = 12$ V, $V_{EN} = 3.3$ V, $R_{RT} = 27$ kΩ)

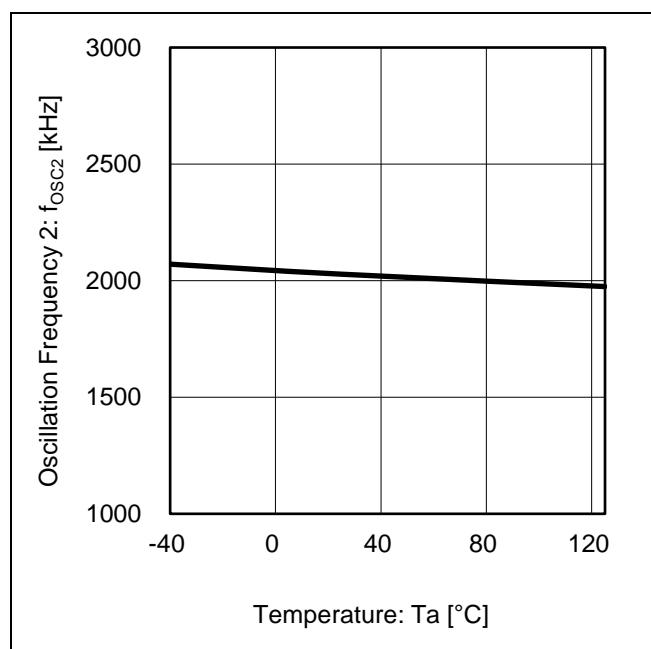


Figure 13. Oscillation Frequency 2 vs Temperature
(@2000 kHz, $VCC = 12$ V, $V_{EN} = 3.3$ V, $R_{RT} = 3.6$ kΩ)

Typical Performance Curves - continued

(Reference Data)

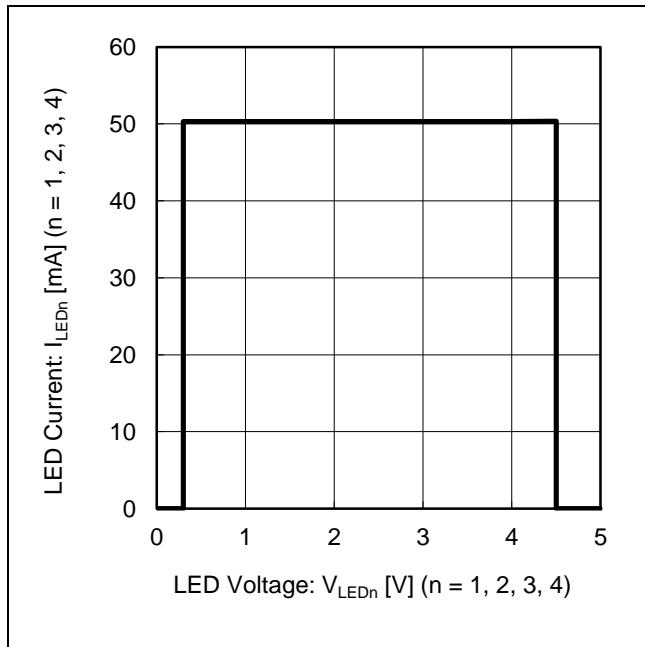


Figure 14. LED Current vs LED Voltage
(Ta = 25°C, VCC = 12 V, V_{EN} = 3.3 V, V_{LEDn} = sweep)

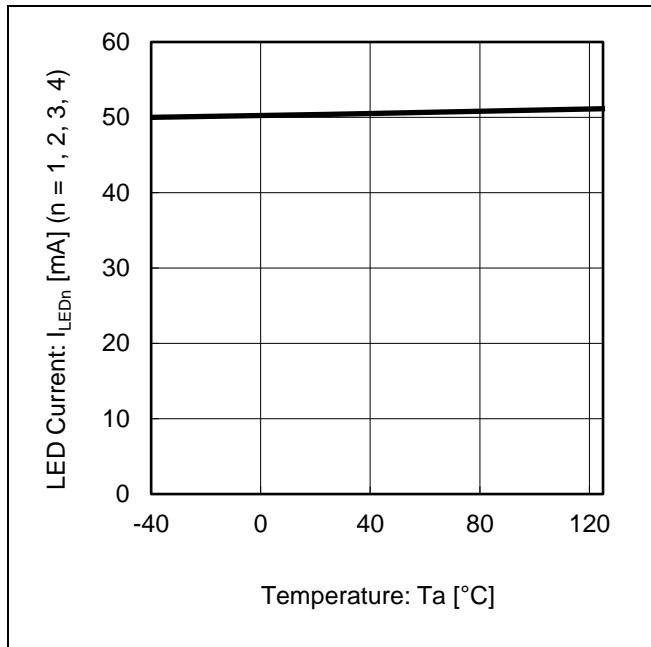


Figure 15. LED Current vs Temperature
(VCC = 12 V, V_{EN} = 3.3 V,
V_{LEDn} = 2 V (n = 1, 2, 3, 4), V_{PWM} = V_{VREG})

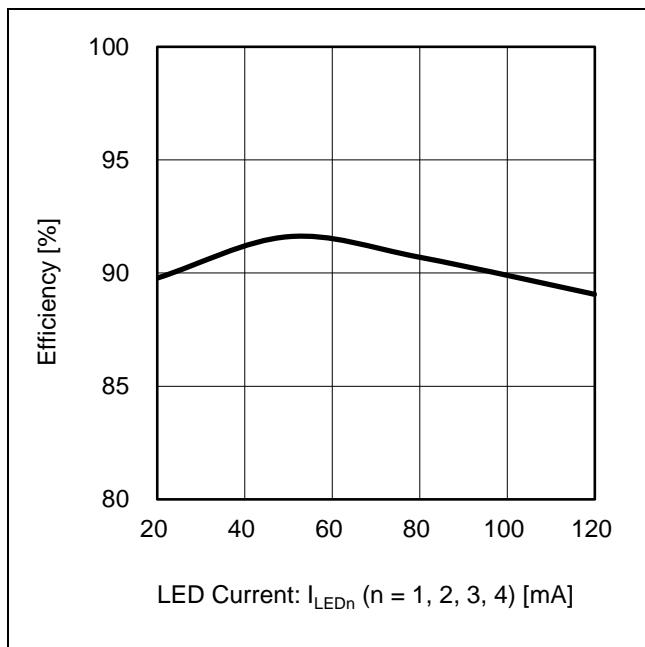


Figure 16. Efficiency vs LED Current
(Buck-Boost Application)
(Ta = 25 °C, VCC = 12 V,
V_{EN} = 3.3 V, V_{PWM} = V_{VREG}, LED4 Series 4ch)

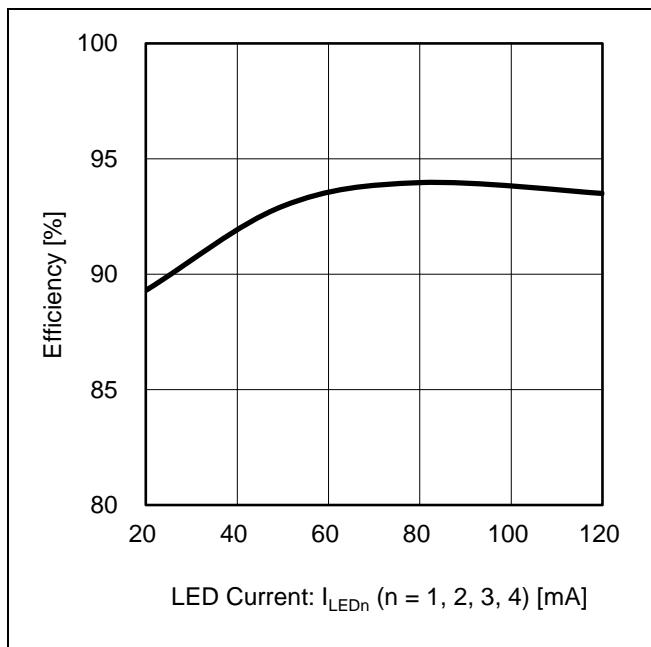


Figure 17. Efficiency vs LED Current
(Boost Application)
(Ta = 25 °C, VCC = 12 V,
V_{EN} = 3.3 V, V_{PWM} = V_{VREG}, LED8 Series 4ch)

Timing Chart (Start up and Protection)

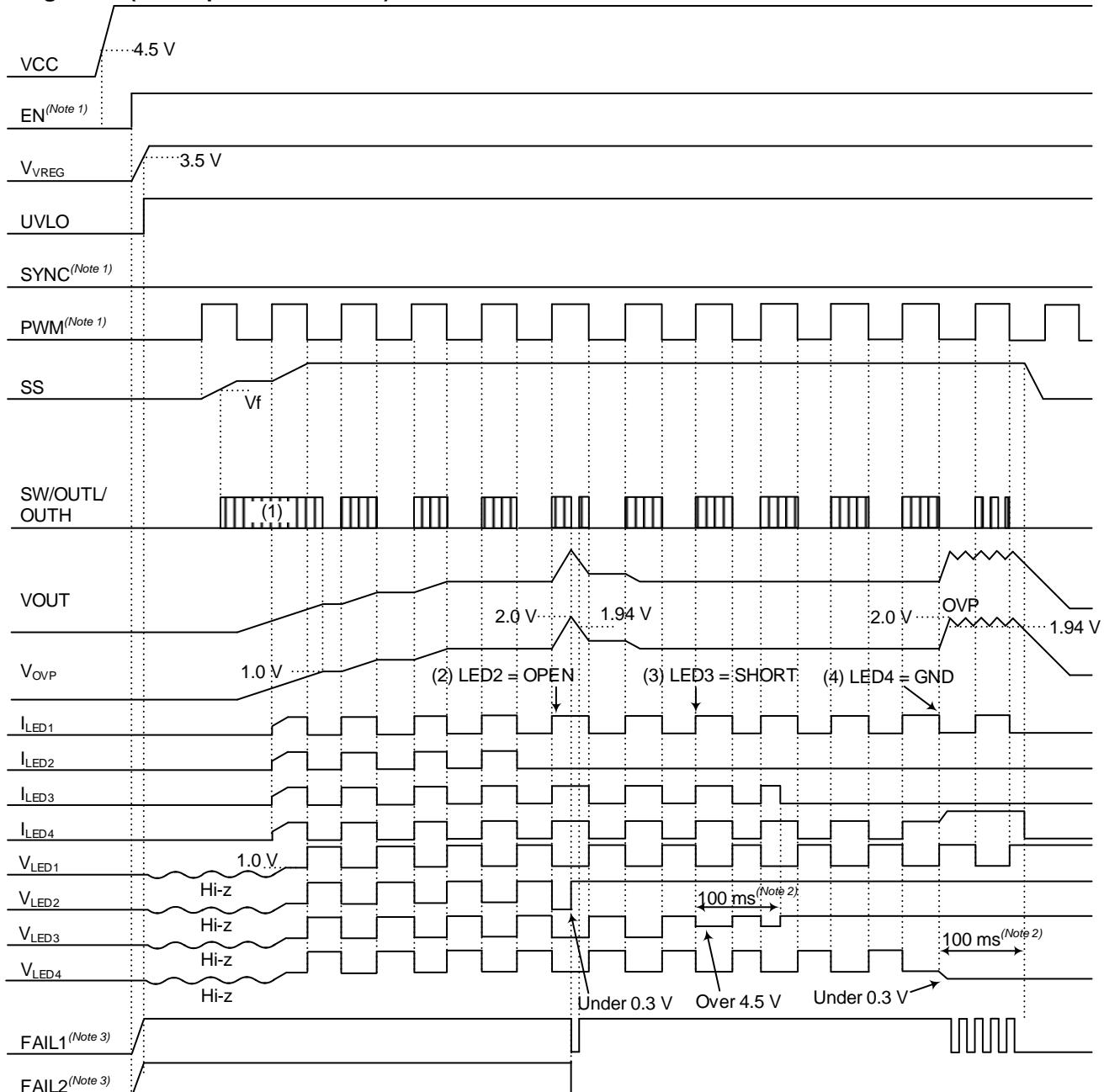


Figure 18. Startup and Protect Function Timing Chart

(Note 1) EN is input after input VCC in the timing chart above, but there is no problem to input EN, PWM, and SYNC before input VCC. EN is judged as Low at V_{EN} is below 0.8 V and as High at V_{EN} is more than 2.1 V. Do not use this IC in the condition of V_{EN} is between 0.8 V and 2.1 V.

(Note 2) The count time of $32770\text{clk} \times 1/\text{fosc}$. In case of $\text{fosc} = 300\text{ kHz}$, the count time is approximately 100 ms.

(Note 3) The above timing chart is when the FAIL1 and FAIL2 pin are pulled up to the VREG pin.

1. When V_{OVP} is less than 1.0 V, regardless of PWM input, the DC/DC switching operation will be active (Pre-Boost function). And if V_{OVP} reaches 1.0 V, the pre-boost is finished. When V_{OVP} at the time of the start is 0.57 V or less, pre-boost function is effective.
2. When V_{LED2} is less than 0.3 V and V_{OVP} is more than 2.0 V, LED Open Protect is active and LED2 is turned OFF. Then FAIL2 becomes Low.
3. If the condition of V_{LED3} is more than 4.5 V and passes 100 ms ($@f_{osc} = 300$ kHz), LED3 is turned OFF. Then FAIL2 becomes Low.
4. When V_{LED4} is shorted to GND, increase the V_{OUT} voltage. Then V_{OVP} rises over 2.0 V and detect OVP. FAIL1 becomes Low. If OVP occurs, DC/DC switching is OFF and decrease the V_{OUT} voltage, then OVP repeats ON/OFF. And DC/DC switching and LED current of each channel is turned OFF after approximately 100 ms by detecting ground short protection. (In case of $f_{osc} = 300$ kHz).

Timing Chart (Start up and Restart)

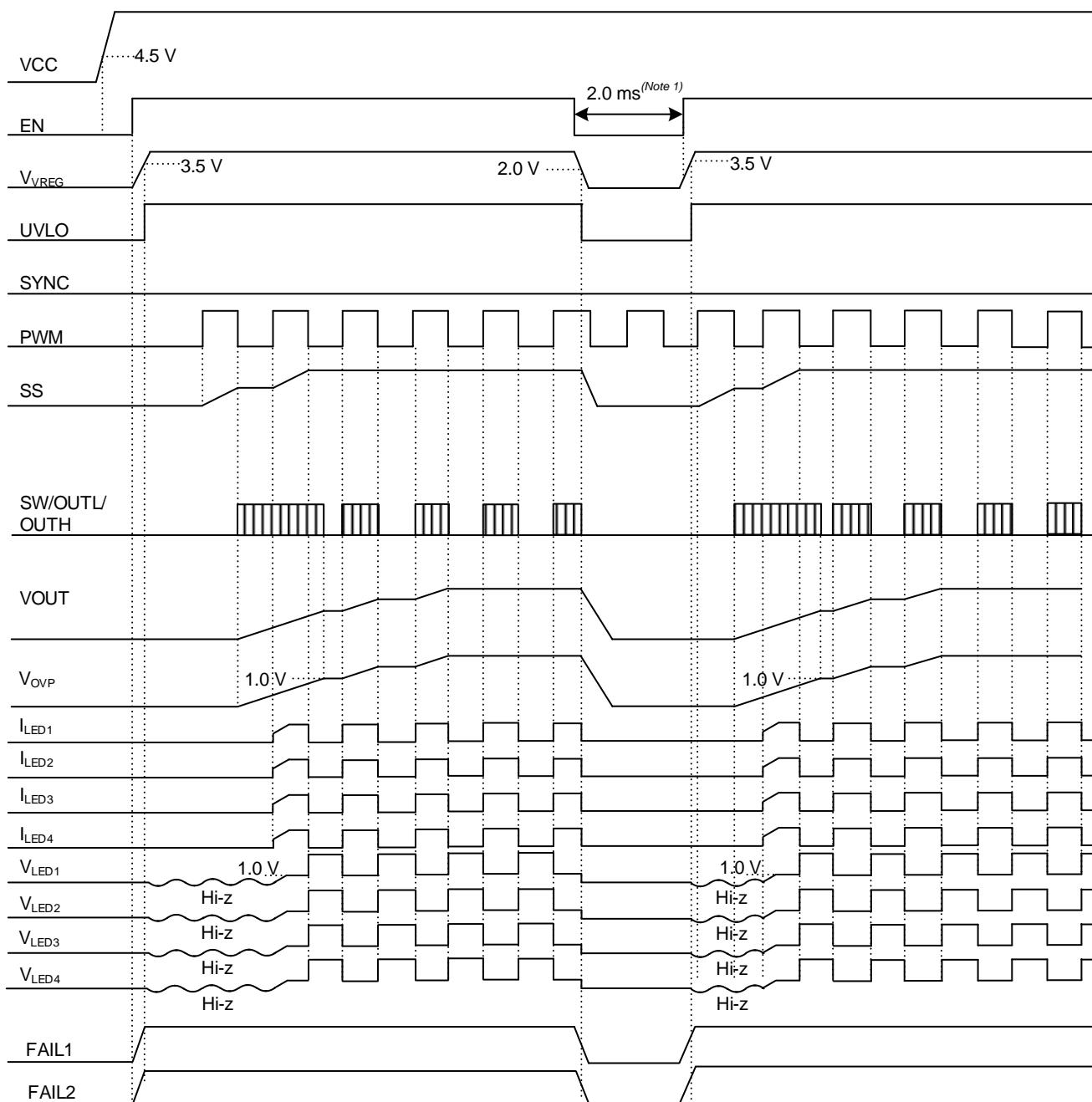


Figure 19. Start up and EN Restart Timing Chart

(Note 1) The Low section during EN restart requires 2.0 ms or more.

Restart after V_{OUT} voltage is discharged. [V_{OUT} discharge function](#) or external discharge switch is recommended. If EN is restarted with remaining V_{OUT} voltage, LED flickering might occur.

Application Examples

When using as Boost DC/DC converter

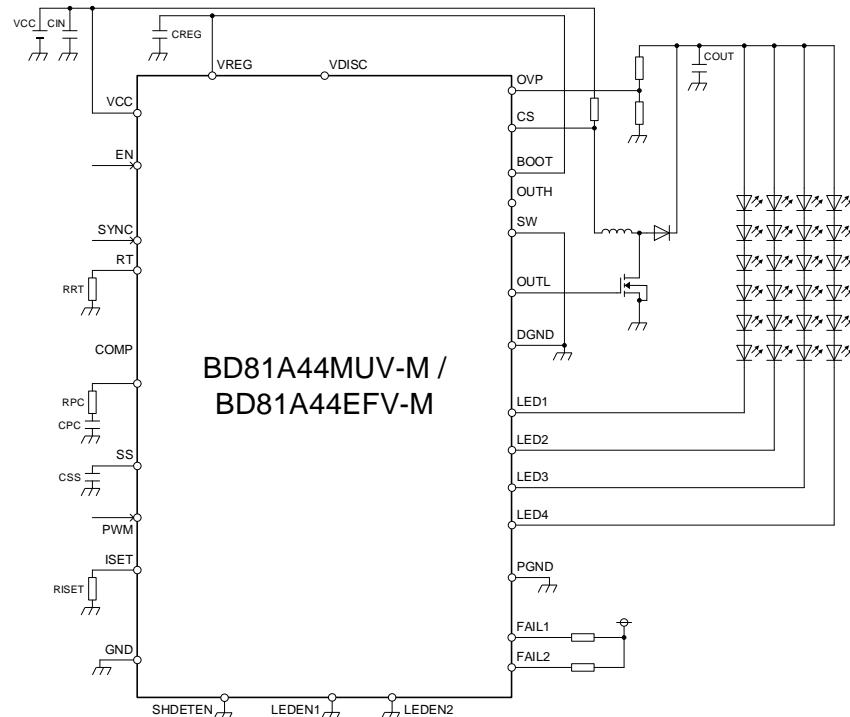


Figure 20. Boost application Circuit

If the VOUT and LED pin are shorted in this case, the overcurrent from V_{IN} cannot be prevented. To prevent overcurrent, carry out measure such as inserting fuse of which value is OCP setting value or more and is part's rating current or less in between VCC and R_{CS} .

When using as Buck DC/DC Converter

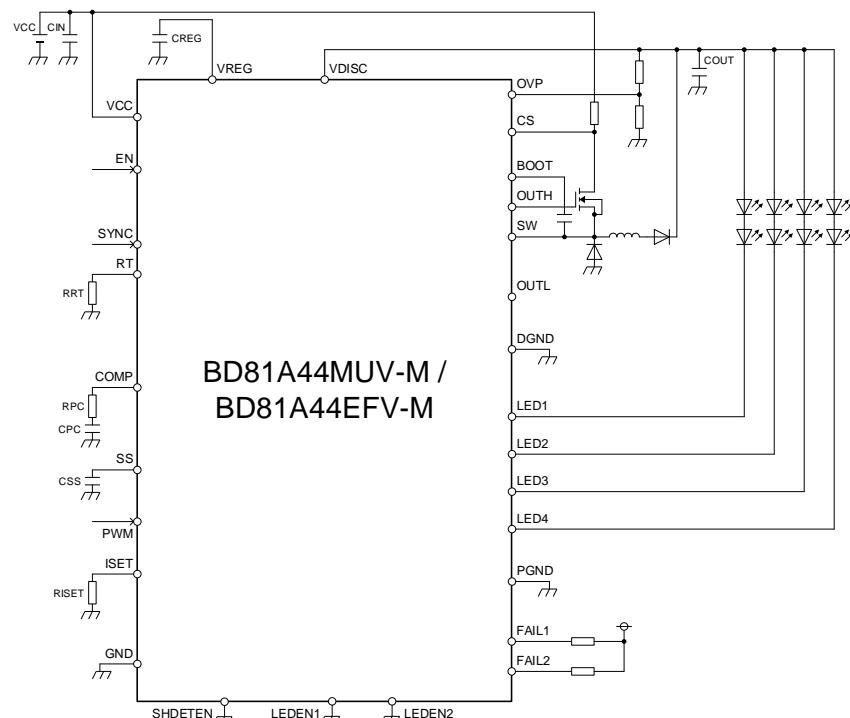


Figure 21. Buck Application Circuit

PCB Application Circuit

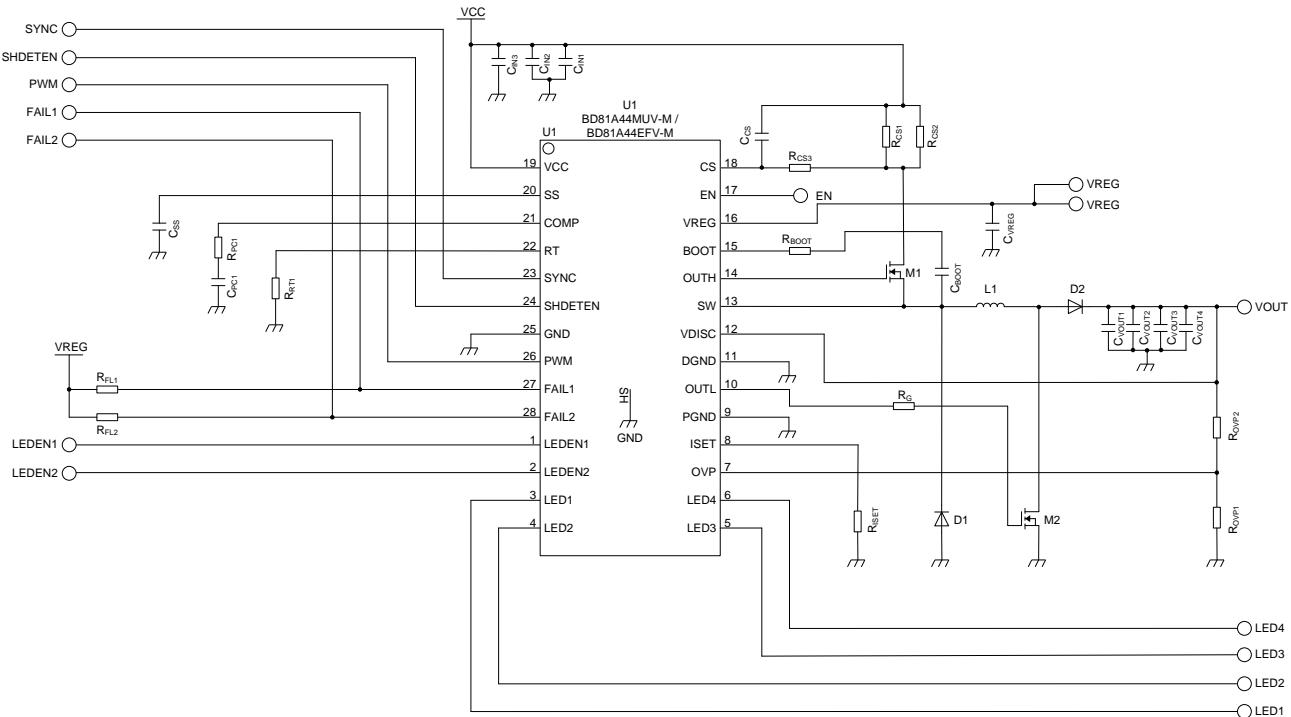


Figure 22. PCB Application Circuit

- Arrange R_{RT} resistor near the RT pin and do not attach capacitor.
- Arrange R_{ISET} resistor near the ISET pin and do not attach capacitor.
- Attach the decoupling capacitor of C_{IN} and C_{VREG} to IC pin as close as possible.
- Keep the impedance low because large current might flow into DGND and PGND.
- Be careful not to occur noise in the ISET, RT, and COMP pins.
- Since PWM, OUTH, OUTL, SW, SYNC and LED1 to LED4 have switching, avoid affecting the surrounding patterns.
- There is thermal PAD at the back of package. Solder the board for thermal PAD.
- Set the gate resistor of step-down FET (M1) to $0\ \Omega$. If resistor is connected, M1 OFF timing is delayed in M1 parasitic capacity and gate resistor, and the penetrating current flows to the internal transistor of M1 and SW. The penetrating current might worsen the efficiency or detect OCP.
- To reduce noise, consider the board layout in the shortest minimum impedance for Boost loop ($D2 \rightarrow C_{VOUT} \rightarrow DGND \rightarrow M2 \rightarrow D2$) and Buck loop ($VCC \rightarrow R_{CS} \rightarrow M1 \rightarrow D1 \rightarrow DGND \rightarrow GND \rightarrow C_{IN} \rightarrow VCC$).
- The ringing of Low-side FET can be suppressed by R_G , but there is a concern that efficiency might worsen when R_G increases. When using R_G , decide the resistance value after full evaluation.

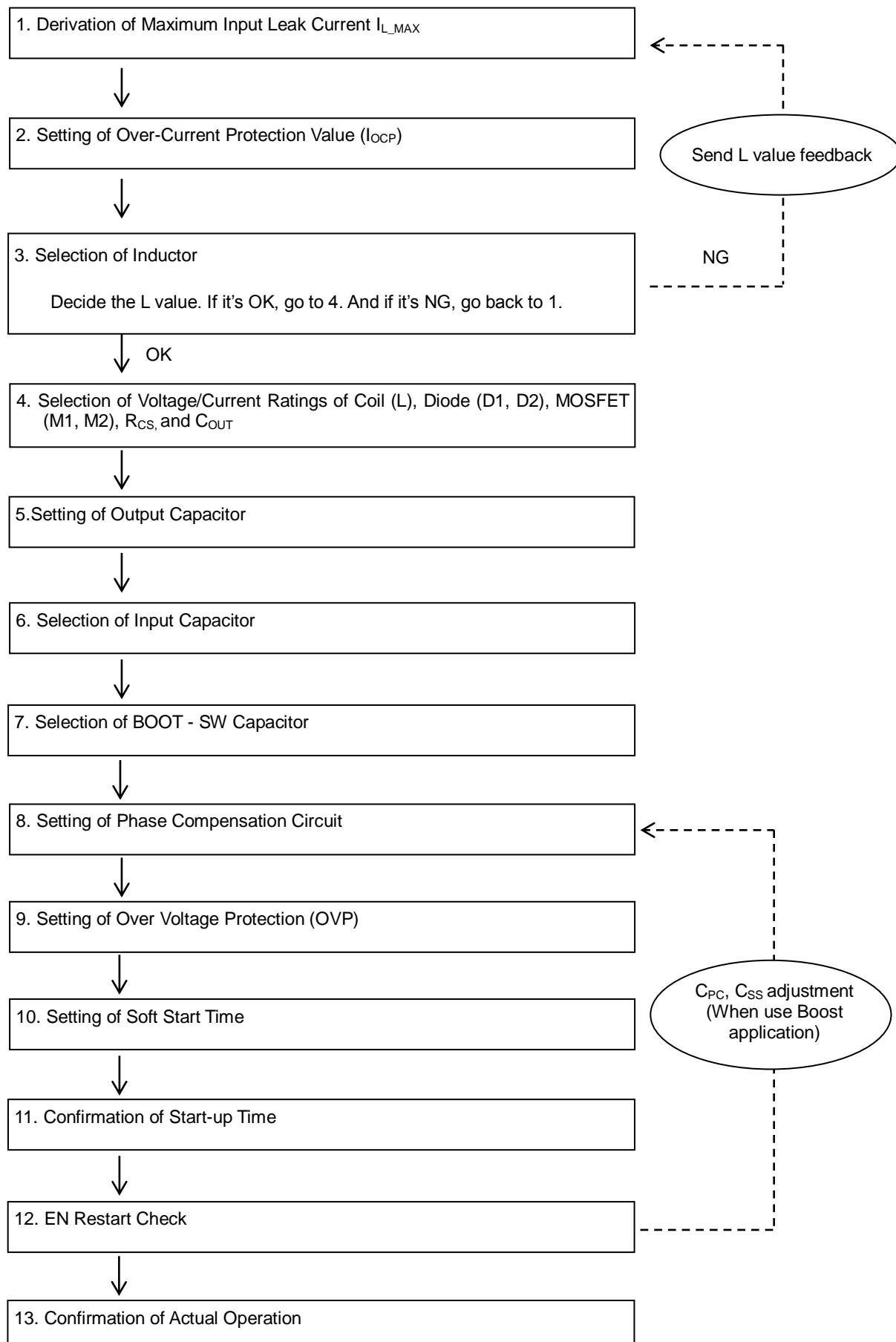
PCB Board External Components List (Buck Boost Application)

Serial No.	Component Name	Component Value	Product Name	Manufacturer
1	C _{IN1}	10 μ F	GCM32EC71H106KA03	Murata
2	C _{IN2}	-	-	-
3	C _{IN3}	-	-	-
4	R _{CS1}	150 m Ω	MCR100JZHFL0R15	Rohm
5	R _{CS2}	150 m Ω	MCR100JZHFL0R15	Rohm
6	R _{CS3}	Short	-	-
7	C _{CS}	-	-	-
8	C _{SS}	0.1 μ F	GCM188R11C104JA01	Murata
9	C _{PC1}	0.01 μ F	GCM188R71H103JA01	Murata
10	R _{PC1}	5.1 k Ω	MCR03EZPJ512	Rohm
11	R _{RT1}	27 k Ω	MCR03EZPD2702	Rohm
12	R _{FL1}	100 k Ω	MCR03EZPJ104	Rohm
13	R _{FL2}	100 k Ω	MCR03EZPJ104	Rohm
14	C _{VREG}	2.2 μ F	GCM188C71A225KE01	Murata
15	C _{BOOT}	0.1 μ F	GCM188R11C104JA01	Murata
16	R _{BOOT}	Short	-	-
17	L1	22 μ H	CLF10060NIT-220M-D	TDK
18	M1	-	RSS070N05FRA	Rohm
19	M2	-	RSS070N05FRA	Rohm
20	D1	-	RB050L-40DD	Rohm
21	D2	-	RB050L-40DD	Rohm
22	C _{VOUT1}	10 μ F	GCM32EC71H106KA03	Murata
23	C _{VOUT2}	10 μ F	GCM32EC71H106KA03	Murata
24	C _{VOUT3}	10 μ F	GCM32EC71H106KA03	Murata
25	C _{VOUT4}	10 μ F	GCM32EC71H106KA03	Murata
26	R _{OVP1}	20 k Ω	MCR03EZPD2002	Rohm
27	R _{OVP2}	360 k Ω	MCR03EZPD3603	Rohm
28	R _{ISET}	100 k Ω	MCR03EZPJ104	Rohm
29	R _G	0 Ω	-	-

* The above components are modified according to operating conditions and load to be used.

Selection of Components Externally Connected

Select the external components following the steps below.



Selection of Components Externally Connected - continued

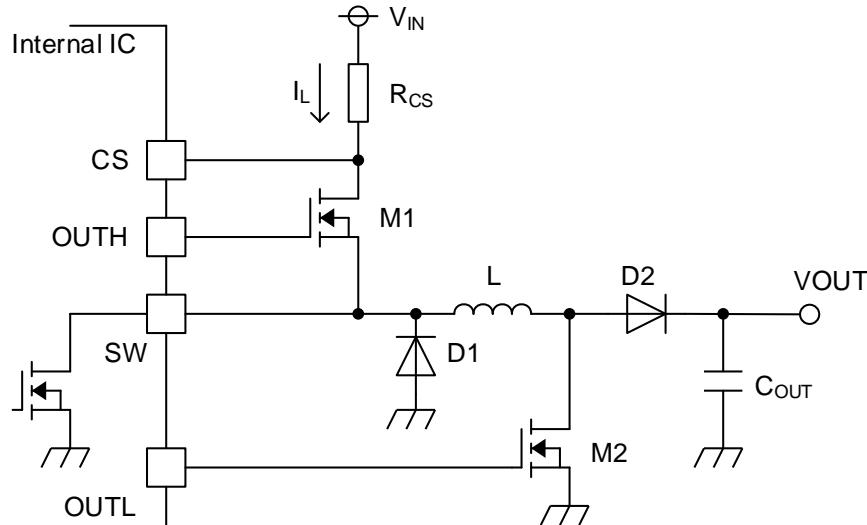
1. Derivation of Maximum Input Leak Current I_{L_MAX} 

Figure 23. Output Application Circuit Diagram (Buck-Boost Application)

(1) Max Output Voltage ($VOUT_MAX$) ComputationConsider the V_f variation and number of LED connection in series for $VOUT_MAX$ derivation

$$VOUT_MAX = (V_f + \Delta V_f) \times N + 1.1$$

where:

 $VOUT_MAX$ is the Max output voltage. V_f is the LED V_f voltage. ΔV_f is the LED V_f voltage variation. N is the LED series number.(2) Max Output Current I_{OUT_MAX} Computation

$$I_{OUT_MAX} = I_{LED} \times 1.05 \times M$$

where:

 I_{OUT_MAX} is the Max output current. I_{LED} is the Output current per channel. M is the LED parallel number.(3) Max Input Peak Current I_{L_MAX} Computation

$$I_{L_MAX} = I_{L_AVG} + \frac{1}{2} \Delta I_L$$

where:

 I_{L_MAX} is the Max input current. I_{L_AVG} is the Max Input average current. ΔI_L is the coil current amplification.

(In case of Boost Application)

$$I_{L_AVG} = VOUT_MAX \times \frac{I_{OUT_MAX}}{\eta \times VCC}$$

$$\Delta I_L = \frac{VCC}{L} \times \frac{1}{f_{osc}} \times \frac{VOUT_MAX - VCC}{VOUT_MAX}$$

Selection of Components Externally Connected - continued

(In case of Buck-Boost application)

$$I_{L_AVG} = (VCC + VOUT_MAX) \times \frac{I_{OUT_MAX}}{\eta \times VCC}$$

$$\Delta I_L = \frac{VCC}{L} \times \frac{1}{fosc} \times \frac{VOUT_MAX}{VCC + VOUT_MAX}$$

(In case of Buck application)

$$I_{L_AVG} = I_{OUT_MAX} / \eta$$

$$\Delta I_L = \frac{VOUT}{L} \times \frac{1}{fosc} \times \frac{VCC - VOUT_MAX}{VCC}$$

where:

 VCC is the supply voltage. η is the efficiency. $fosc$ is the DC/DC oscillation frequency. L is the coil value.

- The worst case for VIN is minimum, so the minimum value should be applied in the equation.
- BD81A44MUV-M/ BD81A44EFV-M adopts the current mode DC/DC converter control and is appropriately designed for coil value. The abovementioned value is recommended according to efficiency and stability. If choose the L values outside this recommended range, it not to be guaranteed the stable continuous operation. For example, it may cause irregular switching waveform.
- η (efficiency) is around 80%.

2. Setting of Over-Current Protection Value (I_{OCP})

$$I_{OCP} = \frac{V_{OCP_MIN}}{R_{CS}} > I_{L_MAX} \quad [\text{A}]$$

where:

 I_{OCP_MIN} is the over current protection detect voltage. V_{OCP_MIN} is the over current protection detect voltage (0.17 V). R_{CS} is the current detect resistance. I_{L_MAX} is the max input peak current. R_{CS} should be selected by the above equation.

3. Selection of Inductor

In order to achieve stable operation of the current mode DC/DC converter, it is recommended adjusting the L value within the range indicated below.

$$0.05 < \frac{VOUT \times R_{CS}}{L} < 0.63 \times fosc$$

where:

 $VOUT$ is the DC/DC converter output voltage. R_{CS} is the current detect resistance. L is the coil value. $fosc$ is the DC/DC oscillation frequency.

Consider the deviation of L value and set with enough margins.

It is more stable by reducing the value of $\frac{VOUT \times R_{CS}}{L}$, however it slows down the response time.

Selection of Components Externally Connected - continued

Also, the following equation should be satisfied during coil selection in case it is used in VCC = 5 V or less.

$$L < \frac{12 \times VCC \times VCC \times \eta}{VOUT \times I_{LED} \times f_{osc}}$$

where:

L is the coil value.

VCC is the supply voltage.

η is the efficiency.

$VOUT$ is the DC/DC converter output voltage.

I_{LED} is the LED current per channel.

f_{osc} is the DC/DC oscillation frequency.

LED intensity may drop when a coil which does not satisfy the above is chosen.

4. Selection of Voltage/Current Ratings of Coil (L), Diode (D1, D2), MOSFET (M1, M2), R_{cs} , and C_{out}

	Current Rating	Voltage Rating	Heat Loss
Coil L	$> I_{L_MAX}$	-	-
Diode D1	$> I_{OCP}$	$> VCC_MAX$	-
Diode D2	$> I_{OCP}$	$> V_{OVP_MAX}$	-
MOSFET M1	$> I_{OCP}$	$> VCC_MAX$	-
MOSFET M2	$> I_{OCP}$	$> V_{OVP_MAX}$	-
R_{cs}	-	-	$> I_{OCP}^2 \times R_{cs}$
C_{out}	-	$> V_{OVP_MAX}$	-

(Note 1) Consider deviation of external parts and set with enough margins.

(Note 2) In order to achieve fast switching, choose the MOSFET's with smaller gate-capacitance.

5. Setting of Output Capacitor

Select the output capacitor C_{out} based on the requirements of the ripple voltage $VOUTpp$.

$$VOUTpp = \frac{20 \times I_{LED} \times M}{f_{osc} \times C_{VOUT} \times \eta} + \Delta I_L \times R_{ESR} \quad [V]$$

where:

$VOUTpp$ is the VOUT ripple voltage.

I_{LED} is the LED current per channel.

M is the LED parallel number.

f_{osc} is the DC/DC oscillation frequency.

C_{VOUT} is the VOUT capacity.

η is the efficiency.

ΔI_L is the coil current amplification.

R_{ESR} is the equivalent series resistance of output capacitor C_{out} .

The actual VOUT ripple voltage is sensitive to PCB layout and external components characteristics. Therefore, check with the actual machine, and design a capacity with enough margins to fit in allowable ripple voltage.

The maximum value of C_{out} that can be set is 500 μ F.

6. Selection of Input Capacitor

An input capacitor which is 10 μ F or more with low ESR ceramic capacitor is recommended. An input capacitor which is not recommended may cause large ripple voltage at the input and hence lead to malfunction of the IC.

7. Selection of BOOT - SW Capacitor

When using the Buck-Boost application or Buck application, insert 0.1 μ F capacitor between BOOT and SW.

Selection of Components Externally Connected - continued

8. Setting of Phase Compensation Circuit

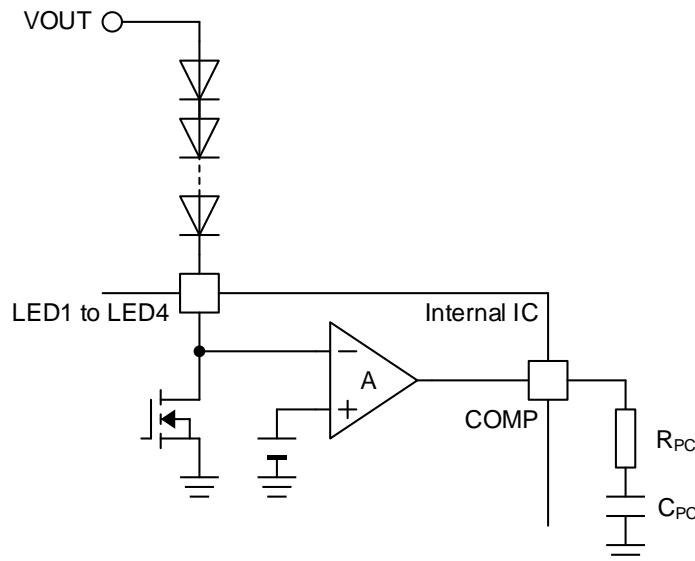


Figure 24. COMP Pin Application Schematic

Stability Condition of Application

The stability in LED voltage feedback system is achieved when the following conditions are met.

- (1) The phase delay when gain is 1 (0 dB) is 150° or less (or simply, phase margin is 30° or more).
- (2) The frequency (Unity Gain Frequency) when gain is 1 (0 dB) is 1/10 or less of switching frequency.

One way to assure stability based on phase margin adjustment is setting the Phase-lead f_z close to unity gain frequency. In addition, the Phase-lag f_{p1} shall be decided based on C_{OUT} and output impedance R_L . The respective formulas are as follows.

$$\text{Phase-lead} \quad f_z = 1/(2\pi R_{PC} C_{PC}) \quad [\text{Hz}]$$

$$\text{Phase-lag} \quad f_{p1} = 1/(2\pi R_L C_{OUT}) \quad [\text{Hz}]$$

* The output impedance that was calculated in $R_L = V_{OUT}/I_{OUT}$

To make a good result, set f_z between 1 kHz to 10 kHz. Substitute the value in the maximum load for R_L . Further, this setting is easily obtained, and the adjustment with the actual machine may be necessary because it is not strictly calculated. In case of mass production design, thorough confirmation with the actual machine is necessary because these characteristics can change based on board layout, load condition and etc.

Selection of Components Externally Connected - continued

9. Setting of Over Voltage Protection (OVP)

Over voltage protection (OVP) is set from the external resistance R_{OVP1} , R_{OVP2} .

The setting described below is important in the either boost, buck and buck-boost applications.

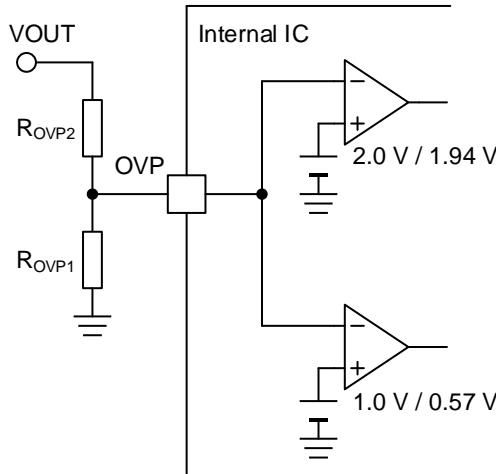


Figure 25. OVP Application Circuit

The OVP pin detects the over voltage when at 2.0 V (Typ) or more and stops the DC/DC switching. In addition, it detects the open condition when the OVP pin is at 2.0 V (Typ) or more and LED1 to LED4 pin voltage is at 0.3 V (Typ) or less, and the circuit is latched to OFF ([Protection Feature](#)). In preventing error in detection of OPEN, it is necessary that the resistor divide voltage of the maximum value of output voltage shall be less than the minimum value of OPEN detection voltage.

Set the R_{OVP1} , R_{OVP2} in such a way the formula shown below can be met.

$$VOUT(\text{Max}) \times \frac{R_{OVP1}}{(R_{OVP1} + R_{OVP2})} < V_{OVPopen}(\text{Min}) \dots (1)$$

where:

$VOUT$ is the DC/DC output voltage.

$V_{OVPopen}$ is the OVP pin open detection voltage.

Example 1: When $V_f = 3.2 V \pm 0.3 V$ LED is used in 8 series

$$VOUT(\text{Max}) = 1.1(\text{LED control voltage Max}) + (3.2 + 0.3) \times 8 = 29.1 \text{ [V]}$$

$$\text{Open Detection OVP Pin Voltage } V_{OVPopen}(\text{Min}) = 1.9 \text{ [V]}$$

If $R_{OVP1} = 20 \text{ k}\Omega$, set by $R_{OVP2} > 286.3 \text{ k}\Omega$ from (1).

Example 2: When $V_f = 3.2 V \pm 0.3 V$ LED is used in 3series

$$VOUT(\text{Max}) = 1.1(\text{LED control voltage Max}) + (3.2 + 0.3) \times 3 = 11.6 \text{ [V]}$$

$$\text{Open Detection OVP Pin Voltage } V_{OVPopen}(\text{Min}) = 1.9 \text{ [V]}$$

If $R_{OVP1} = 20 \text{ k}\Omega$, set by $R_{OVP2} > 102.1 \text{ k}\Omega$ from (1).

Setting of Over Voltage Protection (OVP) - continued

<Attention at the OVP Voltage Setting>

At the boost application, it is decided whether pre-boost works by initial value of the OVP pin voltage. When it does not perform pre-boost, be careful because startup time may become long.

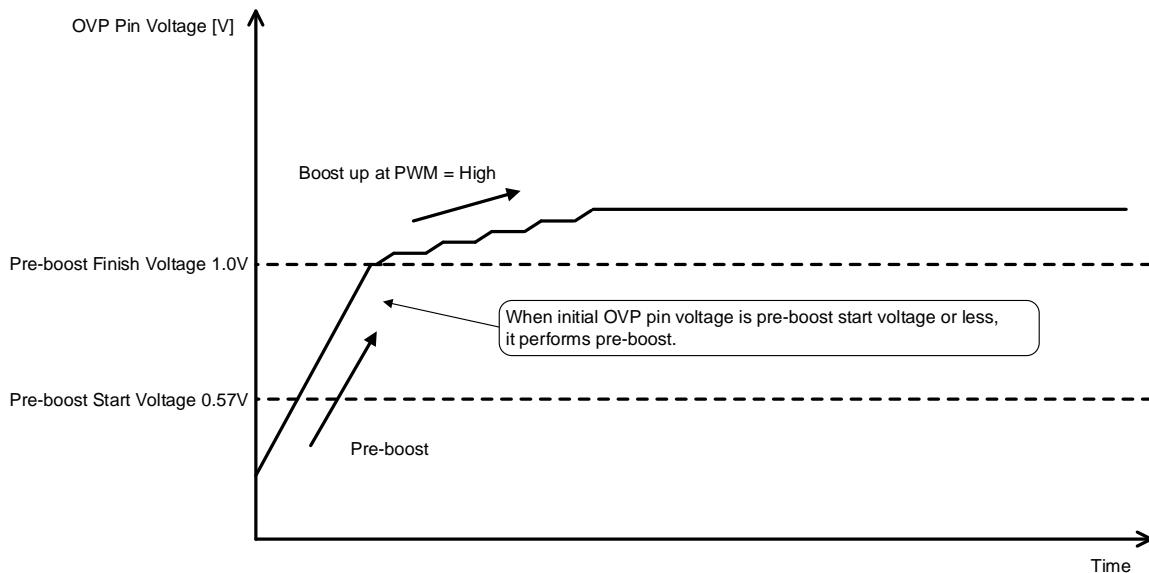


Figure 26. With Pre-boost

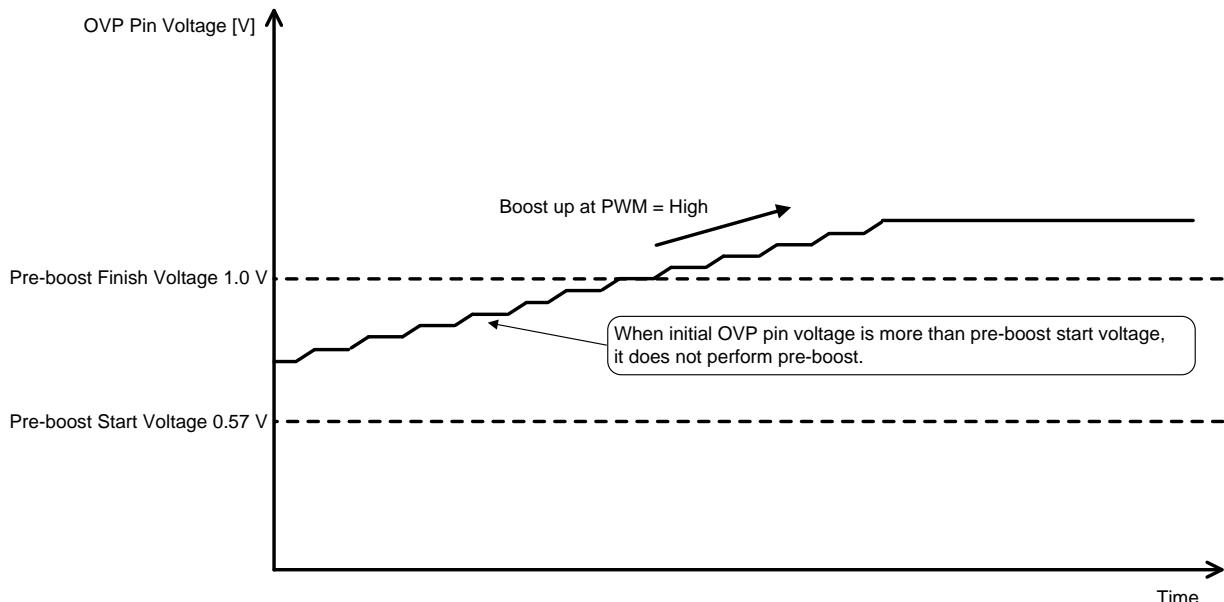


Figure 27. Without Pre-boost

At the buckboost or buck application, initial OVP voltage is less than pre-boost start voltage by VDISC function, it always performs pre-boost.

10. Setting of Soft Start Time

The soft start circuit is necessary to prevent increase of the coil current and overshoot of the output during the start-up. A capacitance in the range of 0.047 μ F to 0.47 μ F is recommended. A capacitance of 0.047 μ F or less may cause overshoot at the output voltage. On the other hand, a capacitance 0.47 μ F or more may cause massive reverse current through the parasitic elements when power supply is OFF and may damage the IC.

Soft start time t_{SS} (Typ).

$$t_{SS} = C_{SS} \times 3.3 / (5 \times 10^{-6}) \text{ [s]}$$

where:

C_{SS} is the Capacitance at SS pin.

Selection of Components Externally Connected - continued

11. Confirmation of Start-up Time

The smaller is PWM duty at start-up, the longer is the start-up time becomes. It is effective to reduce the C_{PC} value to shorten start-up time, however, confirmation of the phase margin is necessary. PWM duty and data of start-up time in typical 2 conditions are shown below.

Condition 1 (Boost)

$V_{CC} = 12\text{ V}$, $V_{OUT} = 30\text{ V}$ (assume LED8 series), $R_{RT} = 27\text{ k}\Omega$ ($f_{osc} = 300\text{ kHz}$), $C_{PC} = 0.01\text{ }\mu\text{F}$, $R_{PC} = 5.1\text{ k}\Omega$, $C_{SS} = 0.1\text{ }\mu\text{F}$, $R_{OVP1} = 20\text{ k}\Omega$, $R_{OVP2} = 360\text{ k}\Omega$

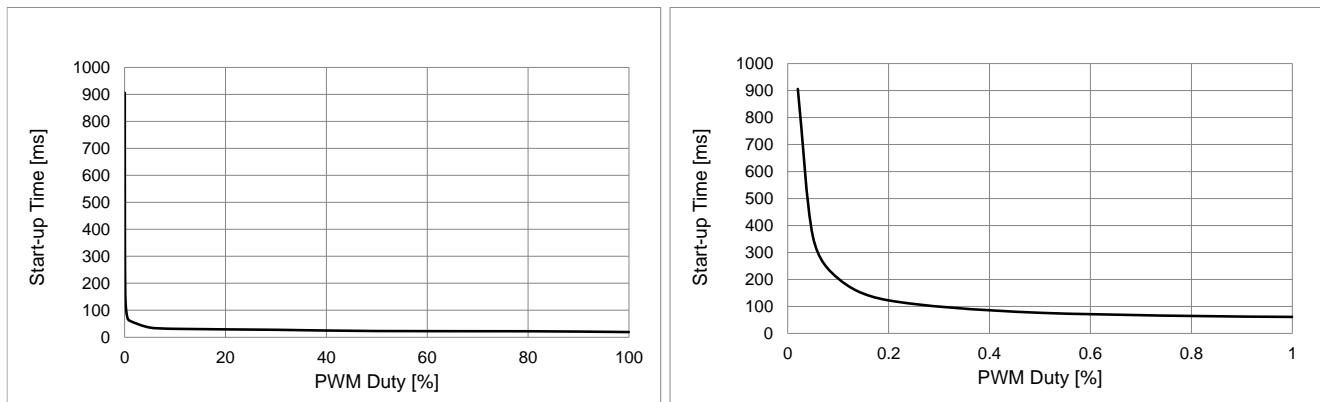


Figure 28. Start-up Time vs PWM Duty (Boost)

Condition 2 (Buck-Boost)

$V_{CC} = 12\text{ V}$, $V_{OUT} = 20\text{ V}$ (assume LED5 series), $R_{RT} = 27\text{ k}\Omega$ ($f_{osc} = 300\text{ kHz}$), $C_{PC} = 0.01\text{ }\mu\text{F}$, $R_{PC} = 5.1\text{ k}\Omega$, $C_{SS} = 0.1\text{ }\mu\text{F}$, $R_{OVP1} = 30\text{ k}\Omega$, $R_{OVP2} = 360\text{ k}\Omega$

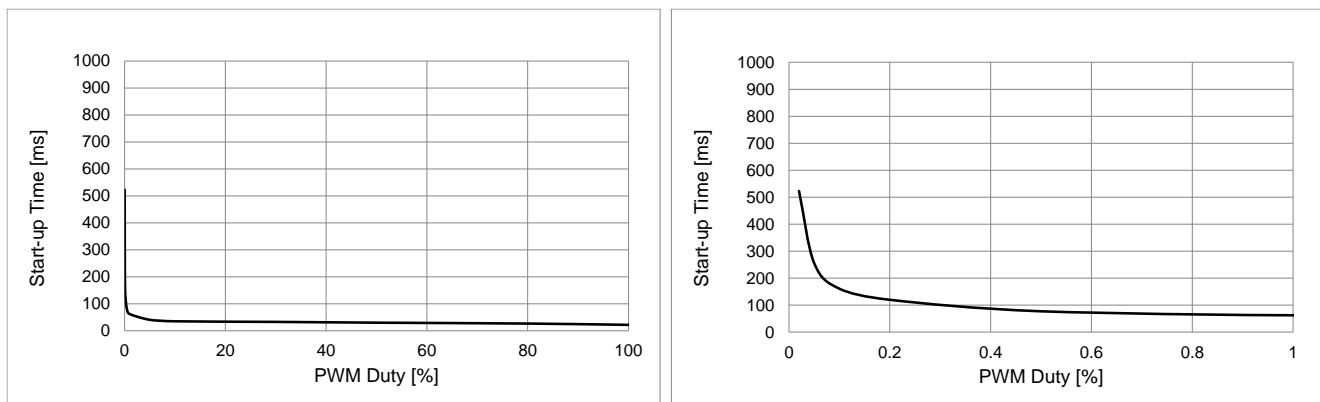


Figure 29. Start-up Time vs PWM Duty (Buck-Boost)

The above are reference data. Always confirm by machine operation because the actual start-up time depends on layout pattern, component constant, and component characteristics.

Selection of Components Externally Connected – continued

12. EN Restart Check

When it starts in the state that an electric charge remains in Vout including the case of the EN restart, It may become the SCP detection condition. Set the condition according to applications.

When use the BuckBoost or Buck application.

Connect the VOUT and VDISC pin and set EN = Low time to satisfy the below equation.

$$t_{DISC}[s] = \frac{3 \times VOUT[V] \times C_{OUT}[F]}{4 \times I_{DISC}[A]} < EN \text{ Low Time } [s]$$

Regarding t_{DISC} details, please refer [\(9\) Output Voltage Discharge Circuit \(VOUT Discharge Function\)](#).

When use the Boost application.

Adjust C_{SS} and C_{PC} value to satisfy the below equation. If C_{PC} value is changed, phase margin will change, and if C_{SS} value is changed, start up time is changed. Please verifying by actual measurements.

$$t1[s] = \left(\frac{0.4 + 2.7 \times n - VCC[V]}{0.4 + 2.7 \times n} \times \frac{1}{fosc[kHz] \times R_{RT}[k\Omega] \times 1.38 \times 10^{-4}} + 1.56 \right) \times \frac{C_{PC}[\mu F]}{(0.46 \times \text{Duty}[\%])}$$

$$t2[s] = C_{SS}[\mu F] \times 0.61 + 29.8/fosc[kHz]$$

Adjust C_{SS} and C_{PC} value with $t1[s] < t2[s]$

n: LED series number

VCC [V]: Power supply

f_{osc} [kHz] : DCDC Frequency

R_{RT} [kΩ]: RT resistance

C_{PC} [μF]: COMP capacitor

Duty [%]: PWM Duty

C_{SS} [μF]: SS capacitor

(Example) n = 7, VCC = 7 V, f_{osc} = 300 kHz, R_{RT} = 27 kΩ, C_{PC} = 0.01 μF, C_{SS} = 0.1 μF, PWM Duty = 1%

$$t1[s] = \left(\frac{0.4 + 2.7 \times 7 - 7}{0.4 + 2.7 \times 7} \times \frac{1}{300 \times 27 \times 138\mu} + 1.56 \right) \times 0.01 / (0.46 \times 1) = 46.3ms$$

$$t2[s] = 0.1 \times 0.61 + \frac{29.8}{300} = 160.3ms$$

In the case of this condition, it is no problem because “ $t1[s] < t2[s]$ ” is met.

Selection of Components Externally Connected - continued

13. Confirmation of Actual Operation

Set up the application circuit and external components value by procedures and attentions mentioned above. However, those settings above are not guaranteed because these are theoretically calculated and it does not include the external parts' variation or characteristics changing. The overall characteristics may change depend on load current, input voltage, output voltage, inductance, load capacitance, switching frequency, and PCB layout. We strongly recommend verifying your design by taking the actual measurements.

Additional parts for EMC

The example of EMC countermeasure components is shown in the chart below.

1. The resistance for adjusting Slew Rate of high side FET
2. The capacitor for reducing current loop noise of high side FET.
3. The capacitor for reducing noise of high frequency on power line.
4. The low pass filter for reducing noise of power line.
5. The common mode filter for reducing noise of power line.
6. The snubber circuit for reducing noise of high frequency of low side FET.
7. The snubber circuit for reducing ringing of low side FET switching.

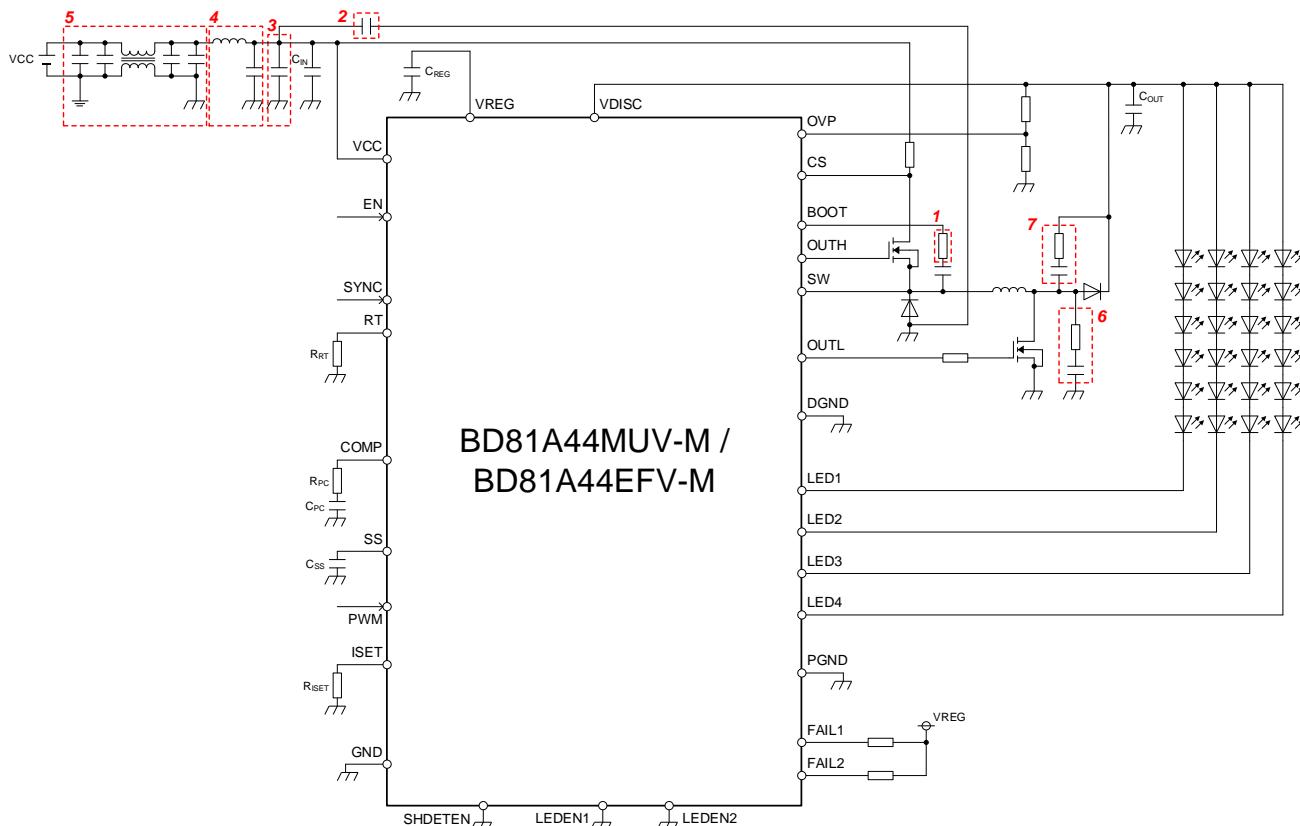


Figure 30. Application Circuit Reference Example (Including EMC Countermeasure Components)

Precautions on PCB Layout

The layout pattern greatly affects the efficiency and ripple characteristics. Therefore, it is necessary to examine carefully when designing. As shown in the figure on the right, Buck-Boost DC/DC converter has two loops; "Loop1" and "Loop2". The parts in each loop have to be set as near as possible to each other. (For example, GND of C_{OUT} and DGND should be very near, GND of C_{IN} and GND of $D1$ should be very near and so on.)

Moreover, the wirings of each loop should be as low impedance as possible.

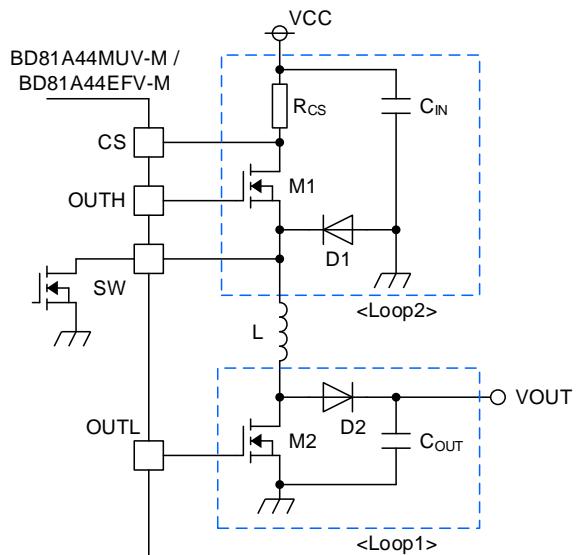


Figure 31. Circuit of DC/DC Block

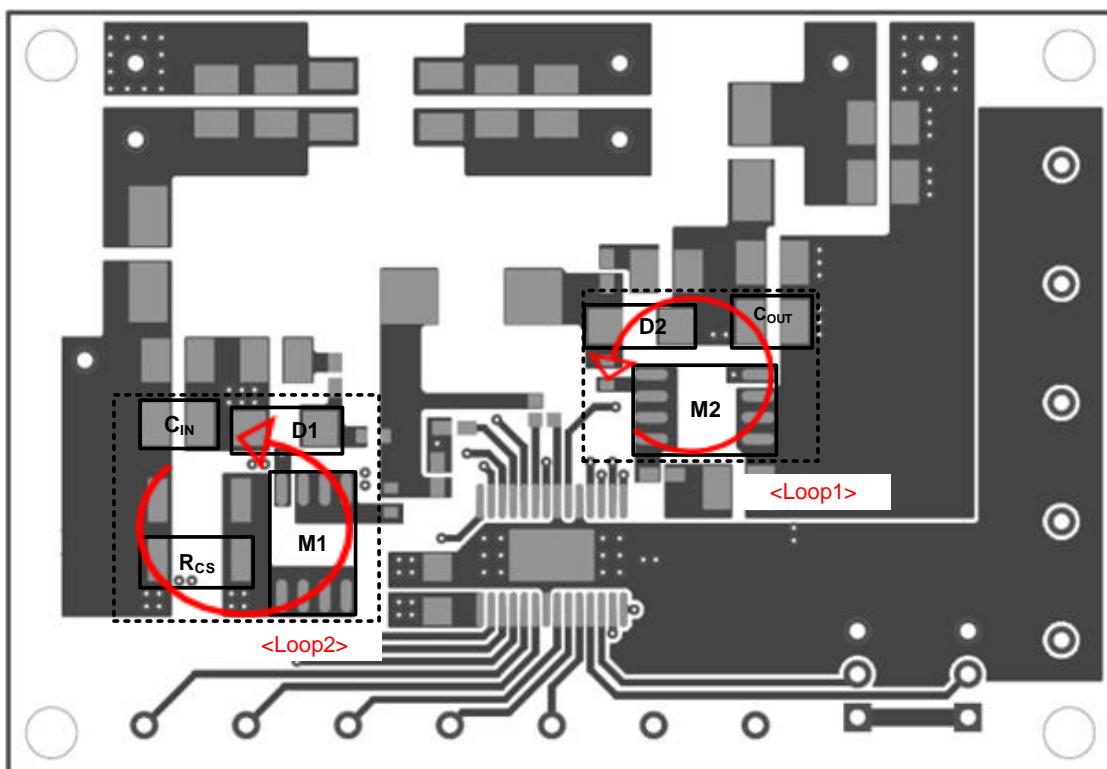


Figure 32. BD81A44EFV-M PCB TOP-layer

Calculation Example of Power Consumption

$$\begin{aligned}
 P_C &= I_{CC} \times V_{CC} && \cdots (1) \text{ Circuit Power} \\
 &+ C_{ISS1} \times V_{VREG} \times f_{OSC} \times V_{VREG} && \cdots (2) \text{ Boost FET Power} \\
 &+ C_{ISS2} \times V_{VREG} \times f_{OSC} \times V_{VREG} && \cdots (3) \text{ Buck FET Power} \\
 &+ \{V_{LED} \times M + \Delta Vf \times (M - 1)\} \times I_{LED} && \cdots (4) \text{ Current Driver Power}
 \end{aligned}$$

where:

P_C is the IC power consumption.
 I_{CC} is the circuit current.
 V_{CC} is the supply voltage.
 C_{ISS1} is the boost FET gate capacity.
 C_{ISS2} is the buck FET gate capacity.
 V_{REG} is the VREG voltage.
 f_{OSC} is the switching frequency.
 V_{LED} is the LED control voltage.
 I_{LED} is the LED output current.
 M is the number of LED parallel.
 ΔVf is the LED Vf tolerance.

<Sample Calculation>

$I_{CC} = 10 \text{ mA}$, $V_{CC} = 12 \text{ V}$, $C_{ISS1} = 2000 \text{ pF}$, $C_{ISS2} = 2000 \text{ pF}$, $V_{VREG} = 5 \text{ V}$, $f_{OSC} = 2200 \text{ kHz}$, $V_{LED} = 1 \text{ V}$, $I_{LED} = 50 \text{ mA}$, $N = 7$, $M = 4$, $Vf = 3.5 \text{ V}$, $\Delta Vf = 0.5 \text{ V}$, $\eta = 80\%$

$$P_C(4) = 10 \times 12 + 2000 \times 5 \times 2200 \times 5 + 2000 \times 5 \times 2200 \times 5 + \{1.0 \times 4 + 0.5 \times (4 - 1)\} \times 50 = 0.615 \text{ [W]}$$

The above is a simple calculation and the value may differ from the actual value.

I/O Equivalence Circuit

SS	COMP	RT
SYNC, PWM	SHDEDETEN, LEDEN1, LEDEN2	FAIL1, FAIL2
LED1, LED2, LED3, LED4	OVP	ISET
OUTL	VDISC	SW
OUTH	BOOT	VREG
EN	CS	

*All values are Typ value

Operational Notes

1. Reverse Connection of Power Supply

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. Power Supply Lines

Design the PCB layout pattern to provide low impedance supply lines. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. Ground Voltage

Except for pins the output and the input of which were designed to go below ground, ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

4. Ground Wiring Pattern

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. Recommended Operating Conditions

The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

6. Inrush Current

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

7. Operation Under Strong Electromagnetic Field

Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

8. Testing on Application Boards

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

9. Inter-pin Short and Mounting Errors

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

10. Unused Input Pins

Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

Operational Notes - continued

11. Regarding the Input Pin of the IC

This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.

When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

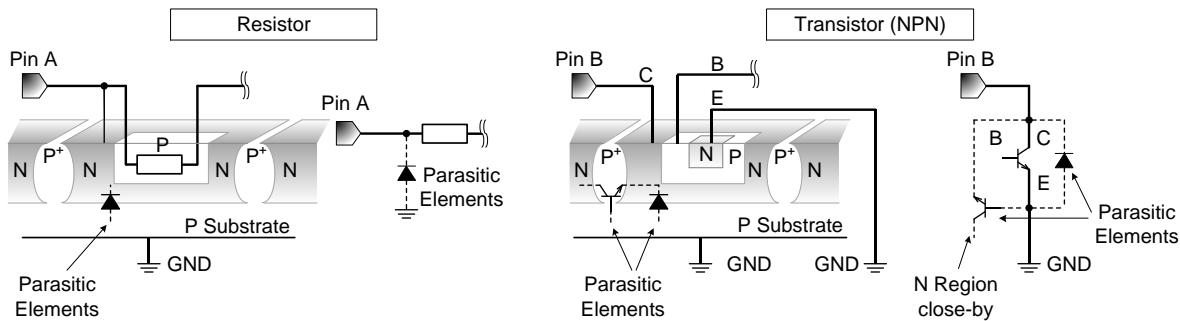


Figure 33. Example of monolithic IC structure

12. Ceramic Capacitor

When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

13. Area of Safe Operation (ASO)

Operate the IC such that the output voltage, output current, and the maximum junction temperature rating are all within the Area of Safe Operation (ASO).

14. Thermal Shutdown Circuit (TSD)

This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature (T_j) will rise which will activate the TSD circuit that will turn OFF power output pins. When the T_j falls below the TSD threshold, the circuits are automatically restored to normal operation.

Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

15. Over Current Protection Circuit (OCP)

This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.

16. Disturbance Light

In a device where a portion of silicon is exposed to light such as in a WL-CSP and chip products, IC characteristics may be affected due to photoelectric effect. For this reason, it is recommended to come up with countermeasures that will prevent the chip from being exposed to light.

Ordering Information

B	D	8	1	A	4	4	M	U	V	-	M E 2
---	---	---	---	---	---	---	---	---	---	---	-------

Product name

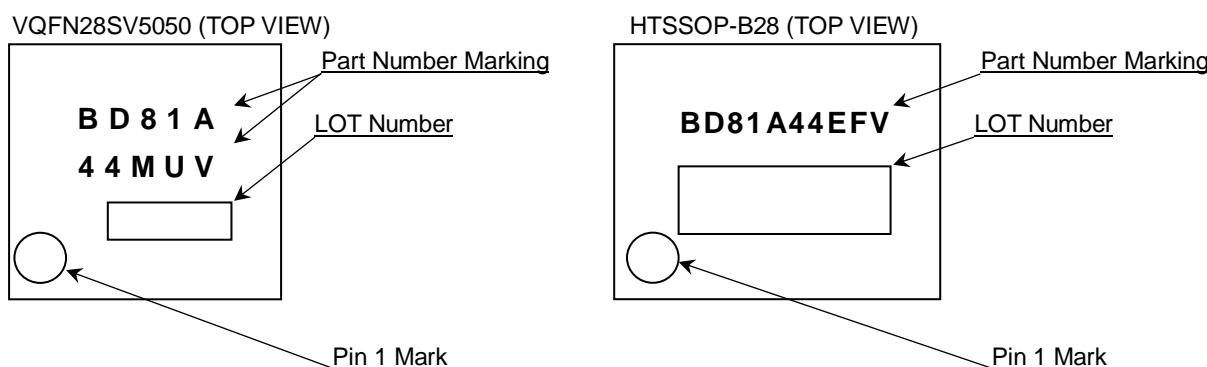
Package
MUV:VQFN28SV5050Packing & foaming specification
M: for Automotive
E2: reel shape embossed taping

B	D	8	1	A	4	4	E	F	V	-	M E 2
---	---	---	---	---	---	---	---	---	---	---	-------

Product name

Package
EFV:HTSSOP-B28Packing & foaming specification
M: for Automotive
E2: reel shape embossed taping

Marking Diagram



Part Number Marking	Package	Orderable Part Number
BD81A44MUV	VQFN28SV5050	BD81A44MUV-ME2
BD81A44EFV	HTSSOP-B28	BD81A44EFV-ME2

Physical Dimension and Packing Information

Package Name	VQFN28SV5050
--------------	--------------

The figure contains three main parts: 1) A top view of the package with a pin mark circle and a dimension of 5.0 ± 0.1 . 2) A side view of the tape showing the lead spacing and a dimension of 0.2 ± 0.02 . 3) A detailed view of the tape layout with pins numbered 1 through 28. Pin 1 is at the top left. The layout includes a central square cavity and a row of 14 pins on each side. Pin 1 dimensions are 0.4 ± 0.1 , and the overall width is 2.7 ± 0.1 . Pin 1 spacing is 1.0 ± 0.1 . Pin 1 height is 1.0 ± 0.1 . Pin 1 lead length is 0.25 ± 0.35 . The drawing is labeled '(UNIT : mm)'.

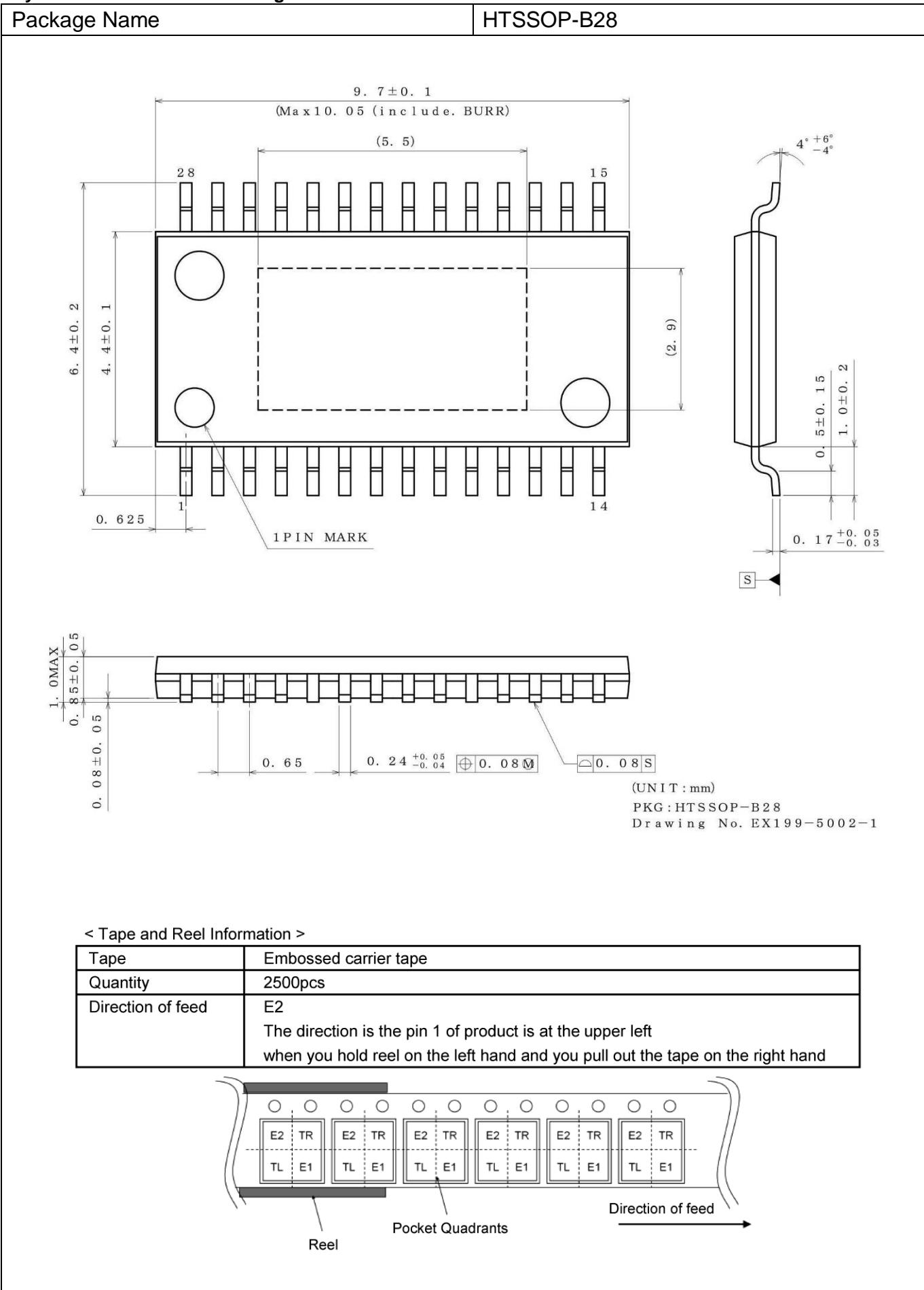
PKG : VQFN28SV5050
Drawing No. EX384-5001

< Tape and Reel Information >	
Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	E2 The direction is the pin 1 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

Reel Layout Diagram:

The diagram shows a reel with six pockets, each containing a tape segment. The pockets are labeled E2, TR, TL, and E1. Arrows indicate the direction of feed from right to left. The diagram is labeled 'Direction of feed' with an arrow pointing left.

Physical Dimension and Packing Information - continued



Revision History

Date	Revision	Details
13.Jan.2016	001	New
26.Apr.2016	002	<p>P.9 Absolute Maximum Ratings PWM, SYNC and EN terminal. Before : -0.3 to +7 < VCC After : -0.3 to +7</p> <p>P.10 Thermal Resistance 2 internal layers / Copper Pattern, Bottom / Copper Pattern Before : 74.2mm²(Square) After : 74.2mm x 74.2mm</p> <p>P.29 I/O Equivalence Circuit Change RT, OUTL, OUTH and EN terminal.</p>
19.Oct.2016	003	P.12 Change the PWM Frequency Limit Max value 15kHz to 20kHz.
25.Oct.2017	004	<p>P.1 General Description Change to "Light modulation (10,000:1@100Hz dimming function) is possible by PWM input."</p> <p>P.1 Features Change to "10,000:1 PWM dimming @100Hz".</p> <p>P.12 PWM Minimum Pulse Width, Conditions Change to "f_{PWM}=100Hz to 20kHz".</p> <p>P.12 PWM Frequency, Min Change to "0.1kHz".</p>
29.Aug.2019	005	<p>P.1 Add ○This product is protected by U.S. Patent No.7,235,954, No.7,541,785, No.7,944,189.</p> <p>P.5 Add <Caution of Large LED Current Setting></p> <p>P.8 Add "(7) DC/DC Switching Control at Over Voltage Output (LSDET)"</p> <p>P.8 Add "(8) PWM Pulse and DC/DC Switching"</p> <p>P.18 1. Add sentence, "When VOVP at the time of the start is 0.57V or less, pre-boost function is effective."</p> <p>P.29 Add "<Attention at the OVP Voltage Setting>".</p> <p>All pages change the format to BD81A74MUV-M, BD81A74EFV-M.</p>
17.Oct.2019	006	P.1 Features Change "Spread Spectrum Function" to "10,000:1 PWM dimming @100Hz".

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

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 - [f] Sealing or coating our Products with resin or other coating materials
 - [g] Use of our Products without cleaning residue of flux (Exclude cases where no-clean type fluxes is used. However, recommend sufficiently about the residue.); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
 - [h] Use of the Products in places subject to dew condensation
4. The Products are not subject to radiation-proof design.
5. Please verify and confirm characteristics of the final or mounted products in using the Products.
6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse, is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.
7. De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.
8. Confirm that operation temperature is within the specified range described in the product specification.
9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

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

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 - [c] the Products are exposed to direct sunshine or condensation
 - [d] the Products are exposed to high Electrostatic
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4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

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