

## Power Management ICs for Automotive Body Control

# LED Drivers for Automotive Light



BD8381EFV-M

No.12039EBT14

### ●Description

BD8381EFV-M is a white LED driver with the capability of withstanding high input voltage (50V MAX).

A current-mode buck-boost DC/DC controller is also integrated to achieve stable operation against voltage input and also to remove the constraint of the number of LEDs in series connection.

The brightness can be controlled by either PWM or linear. The PWM brightness signal generation circuit is built into, and the control without microcomputer is also possible.

### ●Features

- 1) Input voltage range 5.0 – 30 V
- 2) Integrated buck-boost current-mode DC/DC controller
- 3) Built-in CR timer for PWM brightness
- 4) PWM linear brightness
- 5) Built-in protection functions (UVLO, OVP, TSD, OCP, SCP)
- 6) LED error status detection function (OPEN/ SHORT)
- 7) HTSSOP-B28 package

### ●Applications

Headlight and running (DRL) of night of daylight, etc.

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

Parameter	Symbol	Ratings	Unit
Power supply voltage	VCC	50	V
BOOT Voltage	VBOOT	55	V
SW,CS,OUTH Voltage	VSW, VCS, VOUTH	50	V
BOOT-SW Voltage	VBOOT-SW	7	V
VREG,OVP,OUTL,FAIL1,FAIL2,THM,SS,COMP,RT,SYNC,EN,DISC,VTH,FB,LEDR,LEDC,DRLIN, PWMOUT,CT Voltage	VVREG,V <sub>OVP</sub> ,V <sub>OUTL</sub> ,V <sub>FAIL1</sub> ,V <sub>FAIL2</sub> ,V <sub>THM</sub> ,V <sub>SS</sub> ,V <sub>COMP</sub> ,V <sub>RT</sub> ,V <sub>SYNC</sub> ,V <sub>EN</sub> ,V <sub>DISC</sub> ,V <sub>VTH</sub> ,V <sub>FB</sub> ,V <sub>LEDR</sub> ,V <sub>LEDC</sub> ,V <sub>DRLIN</sub> ,V <sub>PWMOUT</sub> V <sub>CT</sub>	-0.3~7 < VCC	V
Power Consumption	Pd	1.45 <sup>※1</sup>	W
Operating temperature range	Topr	-40~+125	°C
Storage temperature range	Tstg	-55~+150	°C
Junction temperature	Tjmax	150	°C

※1 IC mounted on glass epoxy board measuring 70mm×70mm×1.6mm, power dissipated at a rate of 11.6mW/°C at temperatures above 25°C.

※2 A radiation is not designed.

### ●Operating conditions (Ta=25°C)

Parameter	Symbol	Ratings	Unit
Power supply voltage	VCC	5.0~30	V
Oscillating frequency range	FOSC	200~600	kHz
External synchronization frequency range <sup>※3</sup> <sup>※4</sup>	F <sub>SYNC</sub>	fosc~600	kHz
External synchronization pulse duty range	FSDUTY	40~60	%

※3 Connect SYNC to GND or OPEN when not using external frequency synchronization.

※4 Do not switch between internal and external synchronization when an external synchronization signal is input to the device.

●Electrical characteristics (Unless otherwise specified, VCC=12V Ta=25°C)

Parameter	Symbol	Limits			Unit	Conditions
		Min	Typ	Max.		
Circuit current	ICC	-	4.5	7.0	mA	EN=Hi, SYNC=Hi, RT=OPEN, CIN=10μF
Standby current	IST	-	0	8	μA	EN=Low
<b>[VREG Block (VREG)]</b>						
Reference voltage	VREG	4.5	5.0	5.5	V	IREG=-5mA, CREG=10μF
<b>[OUTH Block]</b>						
OUTH high-side ON resistance	RONHH	1.5	3.5	7.0	Ω	ION=-10mA
OUTH low-side ON resistance	RONHL	1.0	2.5	5.0	Ω	ION=10mA
Over-current protection operating voltage	VOLIMIT	VCC-0.68	VCC-0.60	VCC-0.52	V	
SS charge current	ISS	3	5	7	μA	VSS=0V
<b>[OUTL Block]</b>						
OUTL high-side ON resistance	RONLH	2.0	4.0	8.0	Ω	ION=-10mA
OUTL low-side ON resistance	RONLL	1.0	2.5	5.0	Ω	ION=10mA
<b>[SW Block]</b>						
SW low-side ON resistance	RONSW	2.0	4.5	9.0	Ω	IONSW=10mA
<b>[PWMOUT Block]</b>						
PWMOUT high-side ON resistance	RONPWMH	2.0	4.0	8.0	Ω	IONPWMH=-10mA
PWMOUT low-side ON resistance	RONPWML	1.0	2.5	5.0	Ω	IONPWML=10mA
<b>[Error Amplifier Block]</b>						
Reference voltage1	VREF1	0.194	0.200	0.206	V	FB-COMP Short, 1MΩ/250kΩ
Reference voltage2	VREF2	0.190	0.200	0.210	V	FB-COMP Short, 1MΩ/250kΩ Ta=-40°C~125°C
COMP sink current	ICOMPSINK	50	75	100	μA	VFB>0.2V, Vcomp=1V
COMP source current	ICOMPSOURCE	-100	-75	-50	μA	VFB <0.2V, Vcomp=1V
Max Duty output	Dmax	83	90	-	%	FOSC=300KHz
<b>[Oscillator Block]</b>						
Oscillating frequency	FOSC	285	300	315	KHz	RT=100kΩ
<b>[OVP Block]</b>						
Over-voltage detection reference voltage	VOVP	1.9	2.0	2.1	V	VOVP=Sweep up
OVP hysteresis width	VOHYS	0.45	0.55	0.65	V	VOVP= Sweep down
<b>[UVLO Block ]</b>						
UVLO voltage	VUVLO	4.0	4.35	4.7	V	VCC : Sweep down
UVLO hysteresis width	VUHYS	50	150	250	mV	VCC : Sweep up
<b>[PWM Generation circuit Block]</b>						
VTH Threshold voltage	VTH1	3	2/3VREG	3.7	V	
VTH Threshold voltage	VTH2	1	1/3VREG	2	V	
PWM minimum ON width	TPWMON	25	-	-	μs	
LED OPEN detection function	VOPEN	30	50	70	mV	
LED SHORT detection function	VSHORT	100	200	400	mV	VSHORT ≥ VLEDR-VLEDCI
LED GND short protection timer	TSHORT	100	150	200	ms	CT=0.1μF
<b>[Logic Inputs]</b>						
Input HIGH voltage	VINH	3.0	-	-	V	
Input LOW voltage	VINL	GND	-	1.0	V	
Input current 1	IIN	20	35	50	μA	VIN=5V (SYNC/DRLIN)
Input current 2	IEN	15	30	45	μA	VEN=5V (EN)
<b>[FAIL Output (open drain) ]</b>						
FAIL LOW voltage	VOL	-	0.1	0.2	V	IOL=0.1mA

© This product is not designed for use in radioactive environments.

●Electrical characteristic curves (Reference data)

(Unless otherwise specified, Ta=25°C)

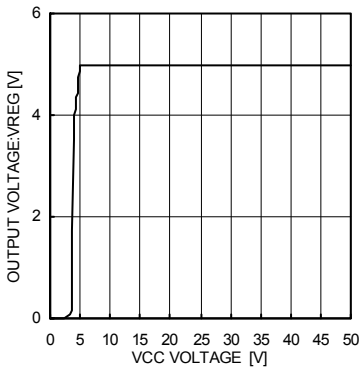


Fig.1 VREG Temperature characteristic

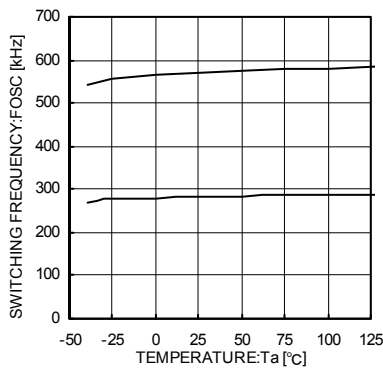


Fig.2 OSC Temperature characteristic

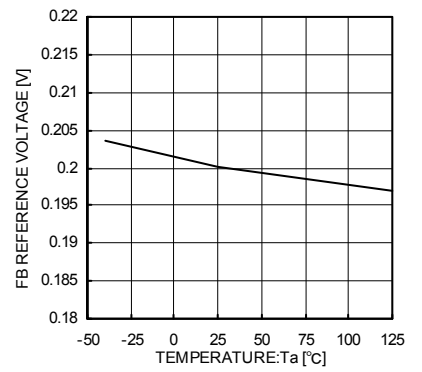


Fig.3 Standard voltage temperature characteristic

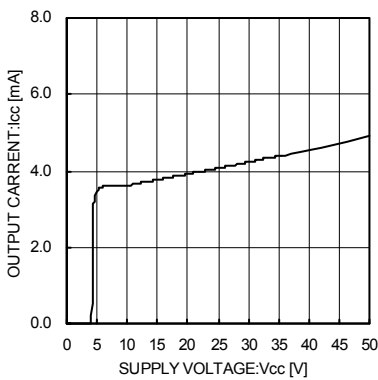


Fig.4 Circuit current (Switching OFF)

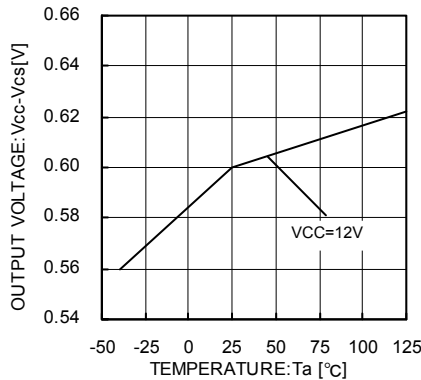


Fig.5 Overcurrent detection voltage temperature characteristic

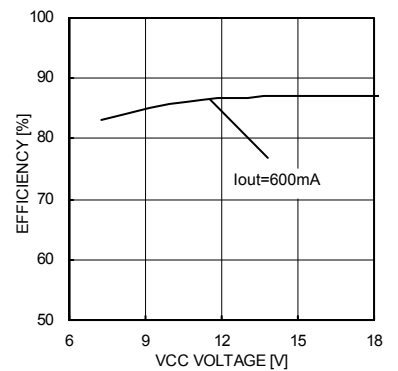


Fig.6 Efficiency (Input voltage dependence)

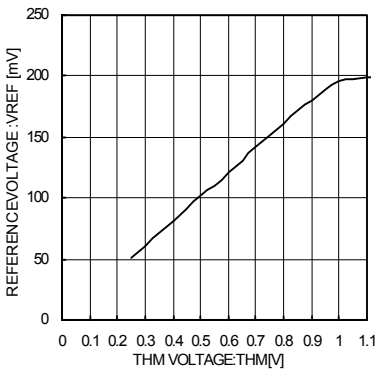


Fig.7 THM Gain

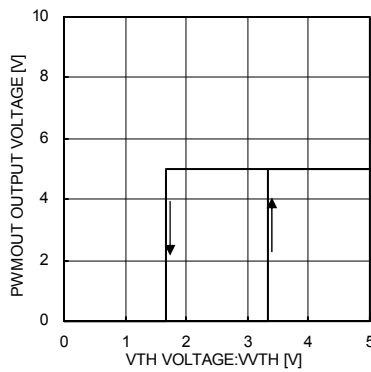


Fig.8 VTH Threshold voltage

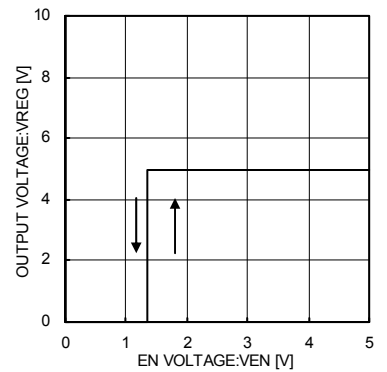


Fig.9 EN Threshold voltage

●Block diagram and pin configuration

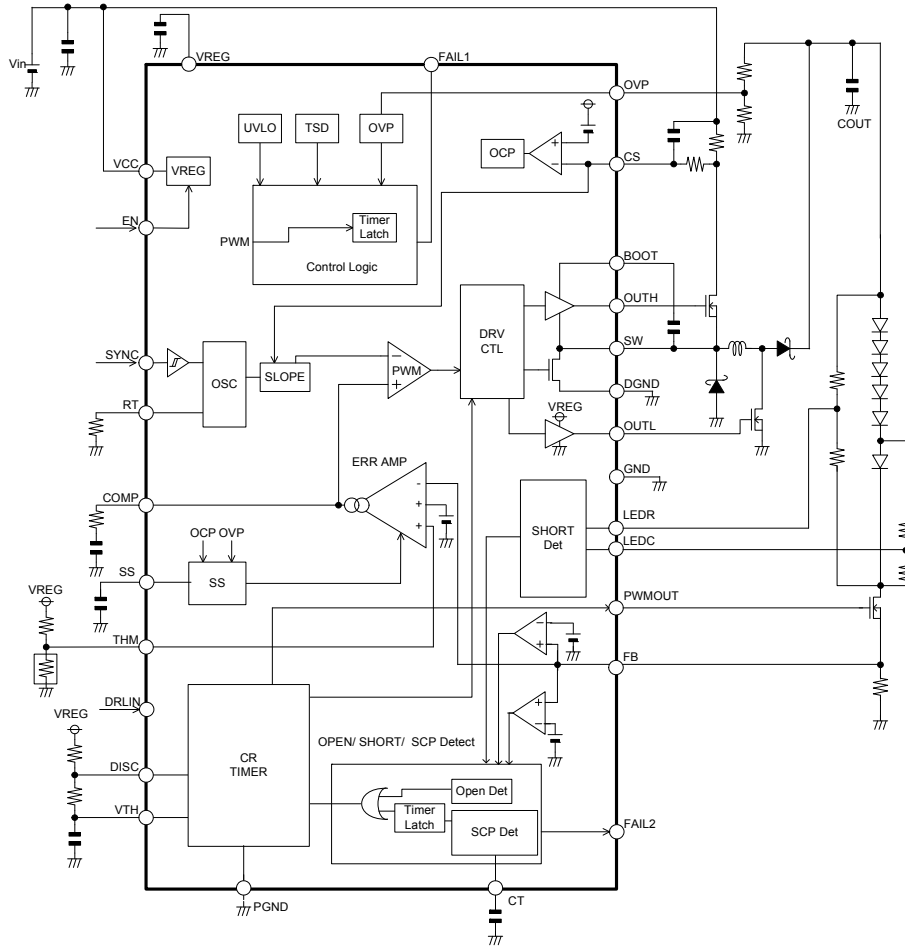


Fig.10 Buck-boost application composition

●Pin layout

BD8381EFV-M(HTSSOP-B28)

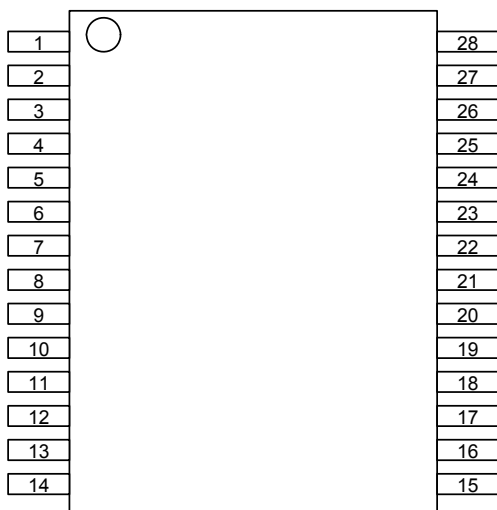


Fig.11

●Pin function table

Pin	Symbol	Function
1	COMP	Error amplifier output
2	SS	Soft start
3	VCC	Input power supply
4	EN	Enable input
5	RT	Oscillation frequency-setting resistance input
6	SYNC	External synchronization signal input
7	GND	Small-signal GND
8	THM	Thermally sensitive resistor connection pin
9	FB	ERRAMP FB signal input pin
10	DISC	CR Timer discharge pin
11	VTH	CR Timer threshold pin
12	DRLIN	DRL switch terminal (Pulse output setting terminal)
13	FAIL1	Failure signal output
14	FAIL2	LED open/short detection signal output
15	OVP	Over-voltage detection input
16	LEDC	LED short detection pin (LED detection side)
17	LEDR	LED short detection pin (Resistor detection side)
18	N.C.	-
19	PGND	PWM brightness source pin
20	PWMOUT	PWM brightness signal output pin
21	CT	GND short protection timer setting pin
22	OUTL	Low-side external FET Gate Drive out put
23	DGND	Low-side FET driver source pin
24	SW	High-side FET Source pin
25	OUTH	High-side external FET Gate Drive out put
26	CS	DC/DC output current detection pin
27	BOOT	High-side FET driver source pin
28	VREG	Internal reference voltage output

●5V voltage reference (VREG)

5V (Typ.) is generated from the VCC input voltage when the enable pin is set high. This voltage is used to power internal circuitry, as well as the voltage source for device pins that need to be fixed to a logical HIGH. UVLO protection is integrated into the VREG pin. The voltage regulation circuitry operates uninterrupted for output voltages higher than 4.5 V (Typ.), but if output voltage drops to 4.3 V (Typ.) or lower, UVLO engages and turns the IC off. Connect a capacitor (Creg = 10µF Typ.) to the VREG terminal for phase compensation. Operation may become unstable if Creg is not connected.

●About the method of setting the output current

$I_{LED} = \min[THM / 5V, 0.2V] / R_{ISET} [A]$   
 As for  $\min[THM / 5V, 0.2V]$ , small one is selected from among THM and VFB=0.2V.  
 Please input within the range of 0.25-5.0V when controlling the output current with THM. Please connect with VREG when not using THM. There is a possibility that the LED GND short detection malfunctions when  $THM \leq 0.25V$ .

●About the method of setting the CR Timer

Built-in CR timer function enables PWM On Duty and frequency setting by external resistors and capacitors. (Refer to equation below) Dimming range by the CR timer function are controllable to Dimming ratio 2%~45% and frequency range 1Hz~20kHz. (However, min pulse width are  $\geq 25\mu s$ )  
 Moreover PWM dimming is also feasible by external signal input to VTH pin to synchronize PWM control to external signal. When using external signal, controllable range will be Dimming ratio 0%~100% and frequency 100Hz~20kHz. (In case of using external PWM dimming, SCP(short circuit protection) will activate simultaneously to EN input. Therefore it will detect SCP status in case duration between EN input time and PWM input time > SCP detection setting time.)

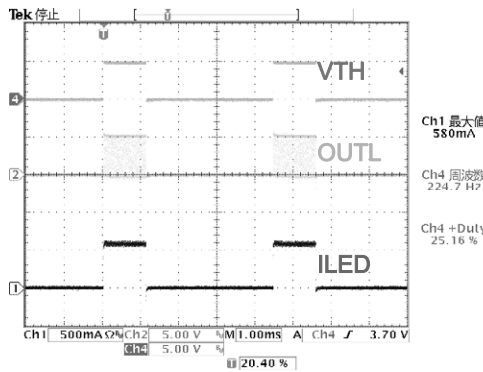


Fig. 12

Rcr1	20	kΩ
Rcr2	10	kΩ
Ccr	100000	pF

$$FPWM = \frac{1.44}{(R_{CR1} + 2R_{CR2})C_{CR}}$$

$$TON\_PWM = \frac{R_{CR2}}{(R_{CR1} + 2R_{CR2})} \times 100$$

●About time from EN turning on to PWM turning on and the start from PWM low Duty

※The GND short protection detecting function (hereafter, SCP) starts with EN=Low→Hi, and after the time of the timer set with the external capacitor connected with CT, it becomes latch off. (Above figure ① and ②)

The charge with SS begins synchronizing with turning on EN. The PWM latch off function is built into when there is not PWM turning on, and when the PWM latch off is detected, (② of SS and the SCP counter) is reset. (The time of the timer at latch OFF is calculated by oscillatory frequency × 32770 counts of DC/DC.) Therefore, the following relations exist at time until PWM is turned on, time of PWM latch timer and SCP detection time after EN is turned on at external brightness.

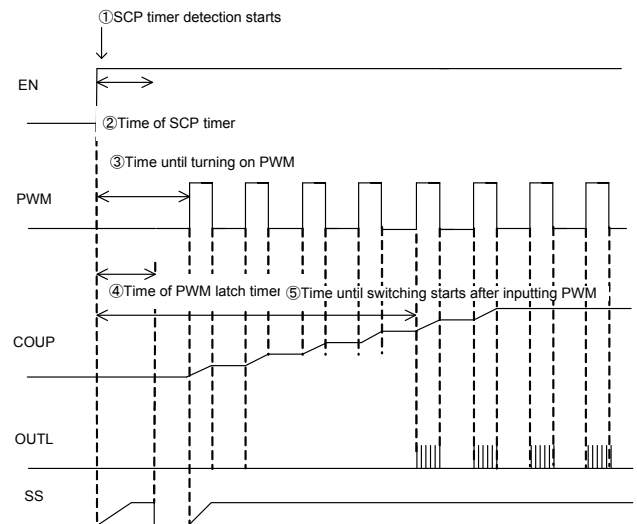
(However, after ③ is turned on, ③ < ④ is deleted from the sequence because ④ doesn't operate.)

Each sequence

② < ④ < ③ ⇒ SCP is detected and No LED light.

④ < ② < ③ ⇒ LED lighting

④ < ③ < ② ⇒ LED lighting



●About Dirating of the LED current that uses THM

It is an ability to set the Dirating curve of the LED current to the temperature as one of the functions to use THM. As for LED, because deterioration at the high temperature is fast, the maximum allowance LED currents and the curve of temperatures is given to the data sheet of LED. The voltage with a negative temperature characteristic in THM the Thermistor resistance is used is input, and the LED current is controlled when the LED current is controlled according to the temperature characteristic. Moreover, external Tr is used, and two input composition is also possible.

### ● Buck-Boost DC/DC controller

#### ▪ Over-voltage protection circuit (OVP)

The output of the DCDC converter should be connected to the OVP pin via a voltage divider. In determining an appropriate trigger voltage of for OVP function, consider the total number of LEDs in series and the maximum variation in VF. Also, bear in mind that over-current protection (OCP) is triggered at 0.85 x OVP trigger voltage. If the OVP function engages, it will not release unless the DCDC voltage drops to 72.5% of the OVP trigger voltage. For example, if ROVP1 (out put voltage side), ROVP2 (GND side), and DCDC voltage VOUT are conditions for OVP, then:

$$V_{OUT} \geq (ROVP1 + ROVP2) / ROVP2 \times 2.0 \text{ V.}$$

OVP will engage when  $V_{OUT} \geq 32 \text{ V}$  if  $ROVP1 = 330 \text{ k}\Omega$  and  $ROVP2 = 22 \text{ k}\Omega$ .

#### ▪ Buck-boost DC/DC converter oscillation frequency (FOSC)

The regulator's internal triangular wave oscillation frequency can be set via a resistor connected to the RT pin (pin 5). This resistor determines the charge/discharge current to the internal capacitor, thereby changing the oscillating frequency. Refer to the following theoretical formula when setting RT:

$$f_{osc} = \frac{60 \times 10^6}{RT [\Omega]} \times \alpha \text{ [kHz]}$$

$60 \times 10^6 \text{ (V/A/S)}$  is a constant ( $\pm 5\%$ ) determined by the internal circuitry, and  $\alpha$  is a correction factor that varies in relation to RT:  
 { RT:  $\alpha = 100\text{k}\Omega: 1.0, 150\text{k}\Omega: 0.99, 200\text{k}\Omega: 0.98, 280\text{k}\Omega: 0.97$  }

A resistor in the range of  $100\text{k}\Omega \sim 280\text{k}\Omega$  is recommended. Settings that deviate from the frequency range shown below may cause switching to stop, and proper operation cannot be guaranteed.

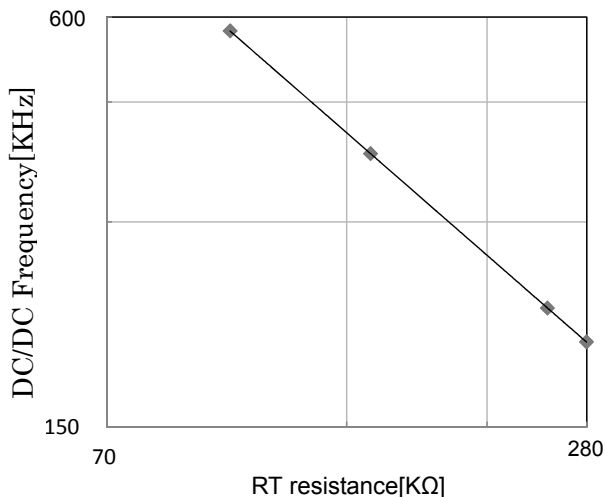


Fig.13 RT versus switching frequency

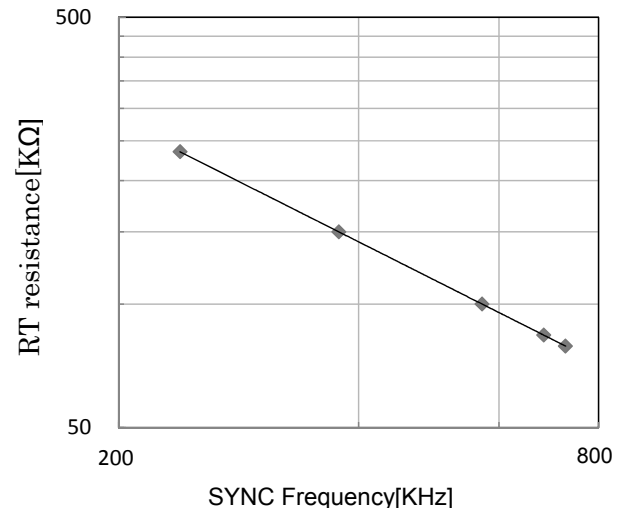


Fig.14 RT versus SYNC frequency

#### ▪ External DC/DC converter oscillating frequency synchronization (FSYNC)

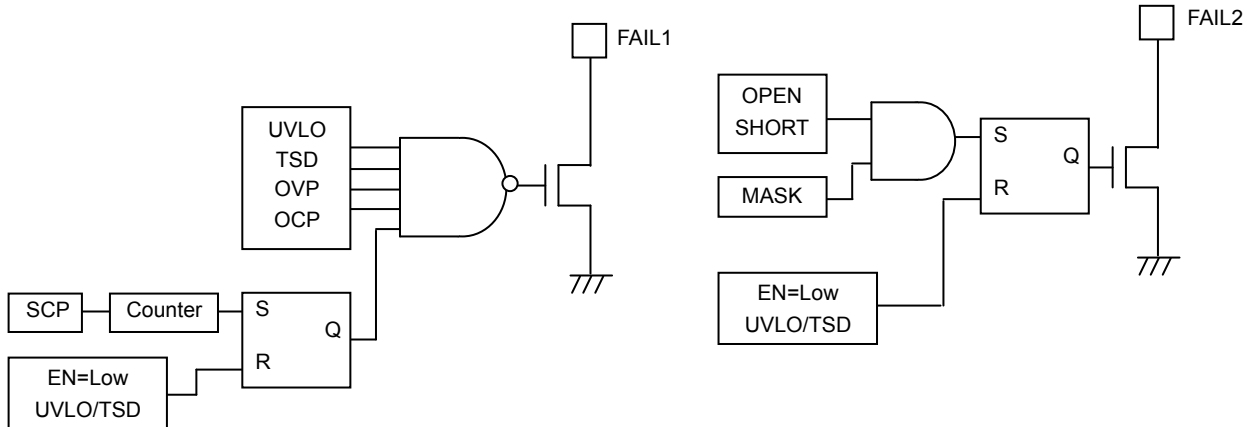
Do not switch from external to internal oscillation of the DC/DC converter if an external synchronization signal is present on the SYNC pin. When the signal on the SYNC terminal is switched from high to low, a delay of about  $30 \mu\text{s}$  (typ.) occurs before the internal oscillation circuitry starts to operate (only the rising edge of the input clock signal on the SYNC terminal is recognized). Moreover, the external synchronizing signal is given to priority when an external input frequency is used. And in the case of using external input frequency, follow the Fig.14.

#### ▪ Soft Start Function

The soft-start (SS) limits the current and slows the rise-time of the output voltage during the start-up, and hence leads to prevention of the overshoot of the output voltage and the inrush current. The SS voltage is made Low when OVP of the overcurrent and the excess voltage is detected, and the switching is stopped. Resume operation is begun.

### • Self-diagnostic functions

The operating status of the built-in protection circuitry is propagated to FAIL1 and FAIL2 pins (open-drain outputs). FAIL1 becomes low when UVLO, TSD, OVP, or SCP protection is engaged, whereas FAIL2 becomes low when open or short LED is detected.



### • Operation of the Protection Circuitry

#### • Under-Voltage Lock Out (UVLO)

The UVLO shuts down all the circuits other than REG when  $V_{REG} \leq 4.3V$  (TYP).

#### • Thermal Shut Down (TSD)

The TSD shuts down all the circuits other than REG when the  $T_j$  reaches  $175^\circ C$  (TYP), and releases when the  $T_j$  becomes below  $150^\circ C$  (TYP).

#### • Over Current Protection (OCP)

The OCP detects the current through the power-FET by monitoring the voltage of the high-side resistor, and activates when the CS voltage becomes less than  $V_{CC}-0.6V$  (TYP).

When the OCP is activated, the external capacitor of the SS pin becomes discharged and the switching operation of the DCDC turns off.

#### • Over Voltage Protection (OVP)

The output voltage of the DCDC is detected with the OVP-pin voltage, and the protection activates when the OVP-pin voltage becomes greater than  $2.0V$  (TYP).

When the OVP is activated, the external capacitor of the SS pin becomes discharged and the switching operation of the DCDC turns off.

### • Short Circuit Protection (SCP)

When the FB-pin voltage becomes less than  $0.05V$  (TYP), the internal counter starts operating and latches off the circuit approximately after 150ms (when  $C_T = 0.1\mu F$ ). If the FB-pin voltage becomes over  $0.05V$  before 150ms, then the counter resets. When the LED anode (i.e. DCDC output voltage) is shorted to ground, then the LED current becomes off and the FB-pin voltage becomes low. Furthermore, the LED current also becomes off when the LED cathode is shorted to ground. Hence in summary, the SCP works with both cases of the LED anode and the cathode being shorted.

### • LED Open Detection

When the LED-pin voltage  $\leq 0.05V$  (TYP) as well as OVP-pin voltage  $\geq 1.7V$  (TYP) simultaneously, the device detects as LED open and latches off that particular channel.

• LED Short Detection

When the voltage between LEDR-pin and LEDC-pin  $\geq 0.2$  (TYP), the internal counter starts operating, and approximately after 100ms (when FOSC = 300kHz) the operation latches off. With the PWM brightness control, the detecting operation is processed only when PWMOUT-pin = High. If the condition of the detection operation is released before 100ms (when FOSC = 300kHz), then the internal counter resets.

There is a possibility that the LED short detection malfunctions when the difference of Vf is large. Therefore, please adjust external resistance for connected Vf. It is recommended 2V-3V to the input range of LEDR and LEDC.

※The counter frequency is the DCDC switching frequency determined by the RT. The latch proceeds at the count of 32770.

○High luminance LED (multichip) with built-in LED of X piece in 1 chip when using Y piece

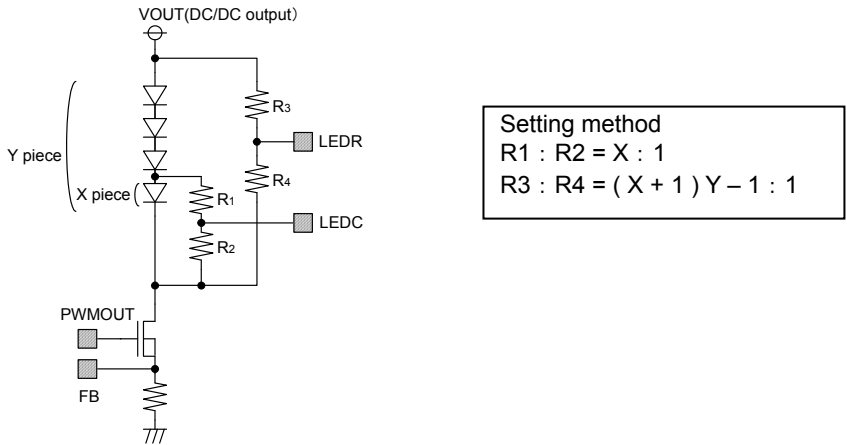


Fig. 15

○When using the single chip

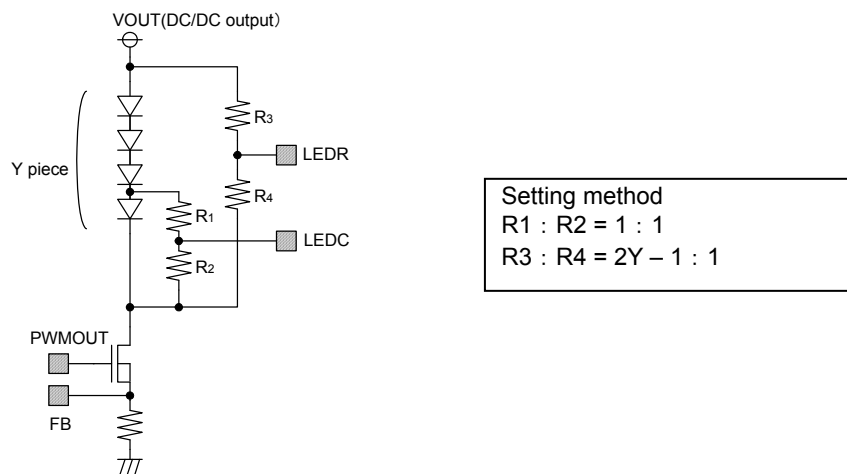


Fig. 16

●Error all condition

Protection	Detecting Condition		Operation after detect
	[Detect]	[Release]	
UVLO	$V_{CC} < 4.3V$	$V_{REG} > 4.45V$	All blocks (but except REG) shut down
TSD	$T_j > 175^{\circ}C$	$T_j < 150^{\circ}C$	All blocks (but except REG) shut down
OVP	$VOVP > 2.0V$	$VOVP < 1.45V$	SS discharged
OCP	$V_{CS} \leq V_{CC} - 0.6V$	$V_{CS} > V_{CC} - 0.6V$	SS discharged
SCP	$V_{FB} < 0.05V$ (150ms delay when $C_T = 0.1\mu F$ )	EN or UVLO	Counter starts and then latches off all blocks (but except REG)
LED open	$V_{FB} < 0.05V$ & $VOVP > 1.7V$	EN or UVLO	Counter starts and then latches off all blocks (but except REG)
LED short	$ V_{LEDR} - V_{LEDCL}  > 0.2V$ (100ms delay when $F_{OSC} = 300kHz$ )	EN or UVLO	Counter starts and then latches off all blocks (but except REG)

●Protection sequence

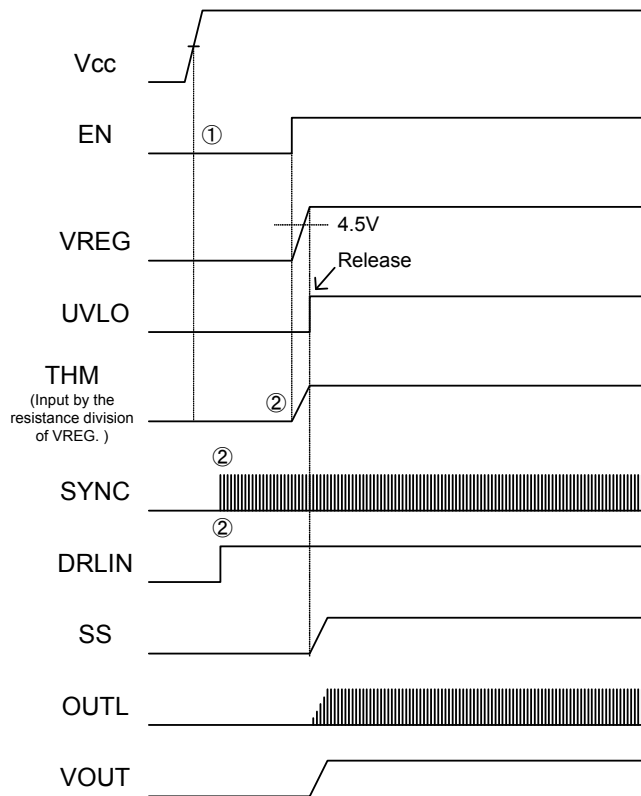


Fig.17

Power supply turning on sequence

- ① Please turn on EN with  $V_{CC} \geq 4.5V$  or more after impressing  $V_{CC}$ .
- ② Please fix the potential of DRLIN and THM before turning on EN.
- ③ A soft start operates at the same time as turning on EN, and the switching is output.
- ④ After turning on  $V_{CC}$ , the order is not related to other input when inputting external PWM from VTH.)

※It leads to the destruction of IC and external parts because it doesn't error output according to an external constant of adjacent pin 24pin SW terminal, 25pin OUTH terminal, 26pin CS terminal and 27pin BOOT terminal.

● Operation in error circumstances of LED

① LED open detection

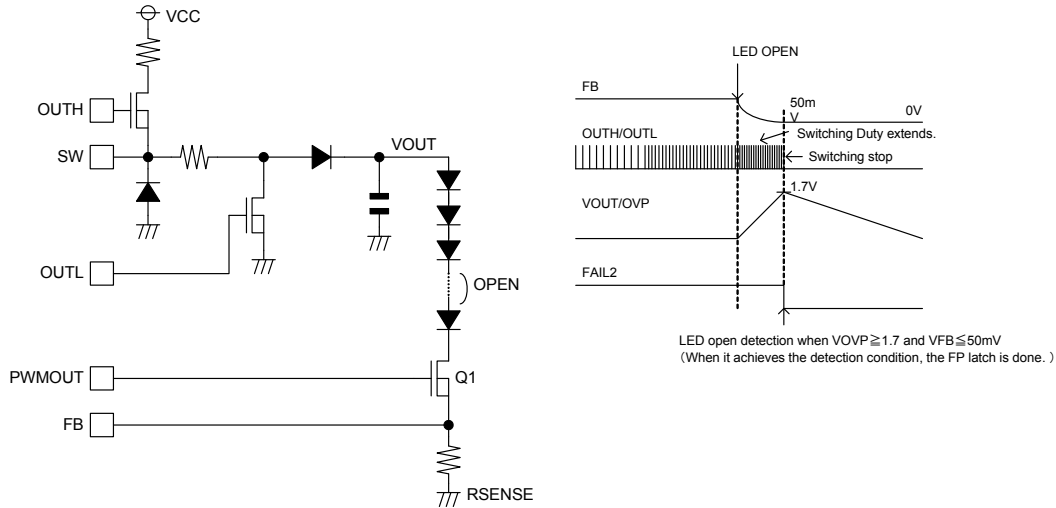


Fig.18

② LED short detection

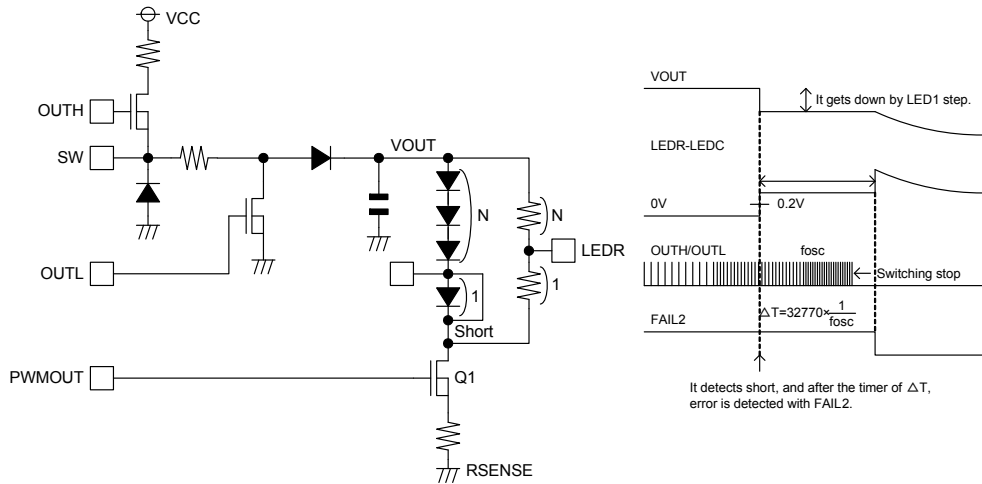


Fig.19

③ LED anode/cathode land GND short detection

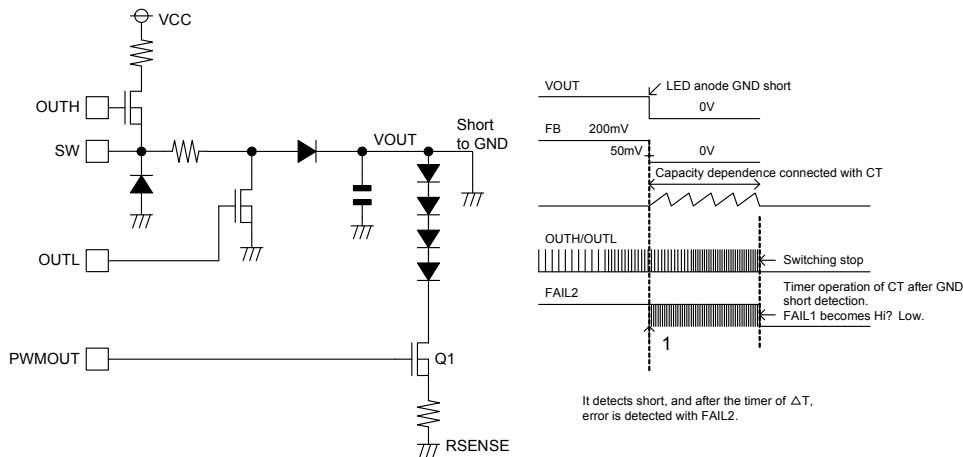
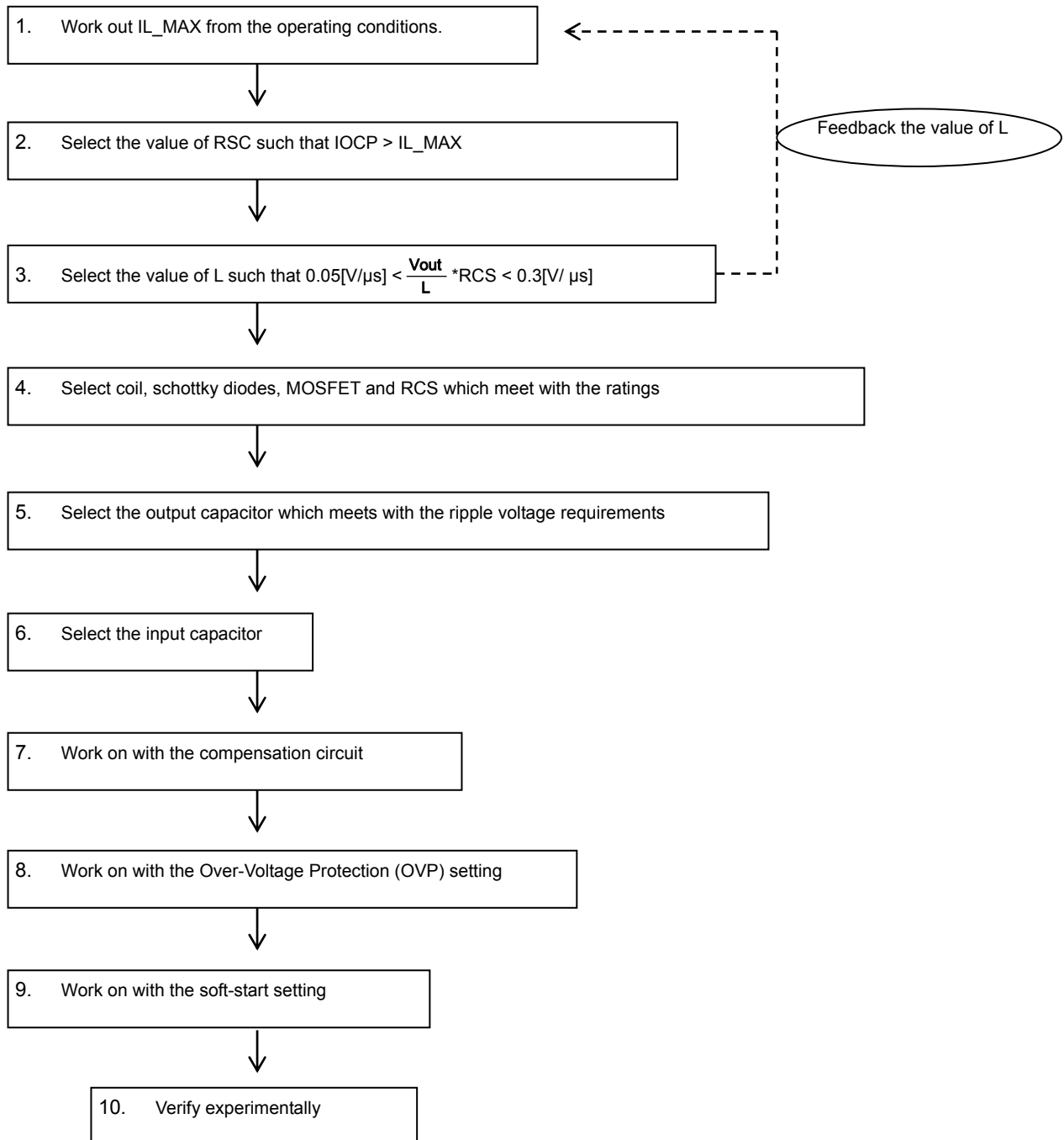


Fig.20

● Procedure for external components selection

Follow the steps as shown below for selecting the external components



1. Computation of the Input Peak Current and IL\_MAX

① Calculation of the maximum output voltage (Vout\_max)

To calculate the Vout\_max, it is necessary to take into account of the VF variation and the number of LED connection in series.

$$V_{out\_max} = (VF + \Delta VF) \times N + 0.2 + RPWMON \times I_{out}$$

ΔVF: VF Variation    N: Number of LED connection in series  
RPWMON: PWMOUT FET Ron

② Calculation of the output current Iout

$$I_{out} = \frac{0.2V \times D}{RISET}$$

D: FB standard voltage variation  
M: Output current resistance variation

③ Calculation of the input peak current IL\_MAX

$$I_{L\_MAX} = I_{L\_AVG} + 1/2 \Delta I_L$$

$$I_{L\_AVG} = (V_{IN} + V_{out}) \times I_{out} / (n \times V_{IN})$$

$$\Delta I_L = \frac{V_{IN}}{L} \times \frac{1}{F_{osc}} \times \frac{V_{out}}{V_{IN} + V_{out}}$$

n: efficiency    Fosc: switching frequency

- The worst case scenario for VIN is when it is at the minimum, and thus the minimum value should be applied in the equation.
- The L value of 6.8μH ~ 33μH is recommended. The current-mode type of DC/DC conversion is adopted for BD8381EFV-M, which is optimized with the use of the recommended L value in the design stage. This recommendation is based upon the efficiency as well as the stability. The L values outside this recommended range may cause irregular switching waveform and hence deteriorate stable operation.
- n (efficiency) is approximately 80%

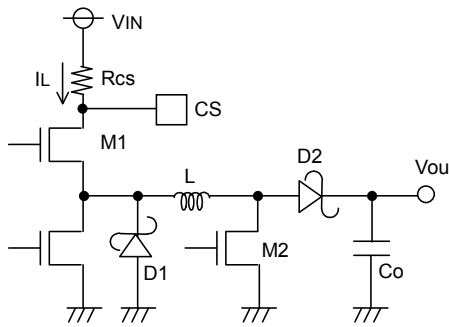


Fig.21 External Application Circuit

2. The setting of over-current protection

Choose Rcs with the use of the equation  $V_{ocp\_min} (=0.52V) / R_{cs} > I_{L\_MAX}$

When investigating the margin, it is worth noting that the L value may vary by approximately ±30%.

3. The selection of the L

In order to achieve stable operation of the current-mode DC/DC converter, we recommend selecting the L value in the range indicated below:

$$0.05 [V/\mu s] < \frac{V_{out} \times R_{cs}}{L} < 0.3 [V/\mu s]$$

The smaller  $\frac{V_{out} \times R_{cs}}{L}$  allows stability improvement but slows down the response time.

4. Selection of coil L, diode D1 and D2, MOSFET M1 and M2, and Rcs

	Current rating	Voltage rating	Heat loss
Coil L	> IL_MAX	—	
Diode D1	> Iocp	> VIN_MAX	
Diode D2	> Iocp	> Vout	
MOSFET M1	> Iocp	> VIN_MAX	
MOSFET M2	> Iocp	> Vout	
Rcs	—	—	> Iocp <sup>2</sup> × Rcs

- ※ Allow some margin, such as the tolerance of the external components, when selecting.
- ※ In order to achieve fast switching, choose the MOSFETs with the smaller gate-capacitance.

### 5. Selection of the output capacitor

Select the output capacitor  $C_{out}$  based on the requirement of the ripple voltage  $V_{pp}$ .

$$V_{pp} = \frac{I_{out}}{C_{out}} \times \frac{V_{out}}{V_{out}+V_{IN}} \times \frac{1}{F_{osc}} + I_{L\_MIN} \times RESR$$

Choose  $C_{out}$  that allows the  $V_{pp}$  to settle within the requirement. Allow some margin also, such as the tolerance of the external components.

### 6. Selection of the input capacitor

A capacitor at the input is also required as the peak current flows between the input and the output in DC/DC conversion. We recommend an input capacitor greater than  $10\mu\text{F}$  with the ESR smaller than  $100\text{m}\Omega$ . The input capacitor outside of our recommendation may cause large ripple voltage at the input and hence lead to malfunction.

### 7. Phase Compensation Guidelines

In general, the negative feedback loop is stable when the following condition is met:

- Overall gain of 1 (0dB) with a phase lag of less than  $150^\circ$  (i.e., a phase margin of  $30^\circ$  or more)

However, as the DC/DC converter constantly samples the switching frequency, the gain-bandwidth (GBW) product of the entire series should be set to 1/10 the switching frequency of the system. Therefore, the overall stability characteristics of the application are as follows:

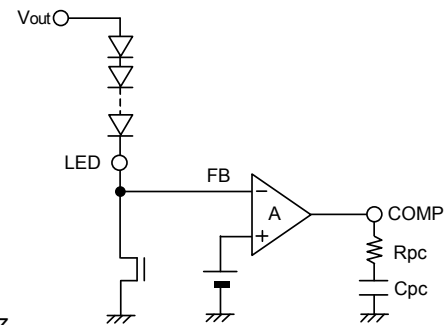
- Overall gain of 1 (0dB) with a phase lag of less than  $150^\circ$  (i.e., a phase margin of  $30^\circ$  or more)
- GBW (frequency at gain 0dB) of 1/10 the switching frequency

Thus, to improve response within the GBW product limits, the switching frequency must be increased.

The key for achieving stability is to place  $f_z$  near to the GBW. GBW is decided by phase delay  $f_{p1}$  by  $C_{OUT}$  and output impedance  $R_L$ . Of each becomes like the next expression.

$$\text{Phase-lead } f_z = \frac{1}{2\pi C_{pc}R_{pc}} \text{ [Hz]}$$

$$\text{Phase-lag } f_{p1} = \frac{1}{2\pi R_L C_{out}} \text{ [Hz]}$$



Good stability would be obtained when the  $f_z$  is set between  $1\text{kHz} \sim 10\text{kHz}$ .

Please substitute the value at the maximum load for  $R_L$ .

In buck-boost applications, Right-Hand-Plane (RHP) Zero exists. This Zero has no gain but a pole characteristic in terms of phase. As this Zero would cause instability when it is in the control loop, so it is necessary to bring this zero before the GBW.

$$f_{RHP} = \frac{V_{out}+V_{IN}/(V_{out}+V_{IN})}{2\pi I_{LOAD}L} \text{ [Hz]} \quad I_{LOAD}: \text{ MAXIMUM LOAD CURRENT}$$

It is important to keep in mind that these are very loose guidelines, and adjustments may have to be made to ensure stability in the actual circuitry. It is also important to note that stability characteristics can change greatly depending on factors such as substrate layout and load conditions. Therefore, when designing for mass-production, stability should be thoroughly investigated and confirmed in the actual physical design.

#### 8. Setting of the soft-start

The soft-start allows minimization of the coil current as well as the overshoot of the output voltage at the start-up.

For the capacitance we recommend in the range of 0.001 ~ 0.1 $\mu$ F. For the capacitance less than 0.001 $\mu$ F may cause overshoot of the output voltage. For the capacitance greater than 0.1 $\mu$ F may cause massive reverse current through the parasitic elements of the IC and damage the whole device. In case it is necessary to use the capacitance greater than 0.1 $\mu$ F, ensure to have a reverse current protection diode at the Vcc or a bypass diode placed between the SS-pin and the Vcc.

Soft-start time TSS

$$TSS = CSS \times 0.7V / 5\mu A [s]$$

CSS: The capacitance at the SS-pin

#### 9. Verification of the operation by taking measurements

The overall characteristic may change by load current, input voltage, output voltage, inductance, load capacitance, switching frequency, and the PCB layout. We strongly recommend verifying your design by taking the actual measurements.

●Power consumption calculation

$$Pc(N) = ICC \cdot VCC + \frac{1}{2} \cdot Ciss \cdot VREG \cdot Fsw \cdot VREG \times 2 \times 2 + \frac{1}{2} \times Ciss \times VREG \times F_{PWM} \times VREG \times 2$$

- ICC : Current of the maximum circuit
- VCC : Power-supply voltage
- Ciss : External FET capacity
- Vsw : SW gate voltage
- Fsw : SW frequency
- FPWM : PWM frequency

<Calculation example>

When assuming

$$Pc(4) = 7mA \times 30V + 500pF \times 5V \times 300kHz \times 5V \times 2 \times 2 + \frac{1}{2} \times 1500pF \times 5 \times 200 \times 5 \times 2,$$

it becomes

Pc = about 210mW.

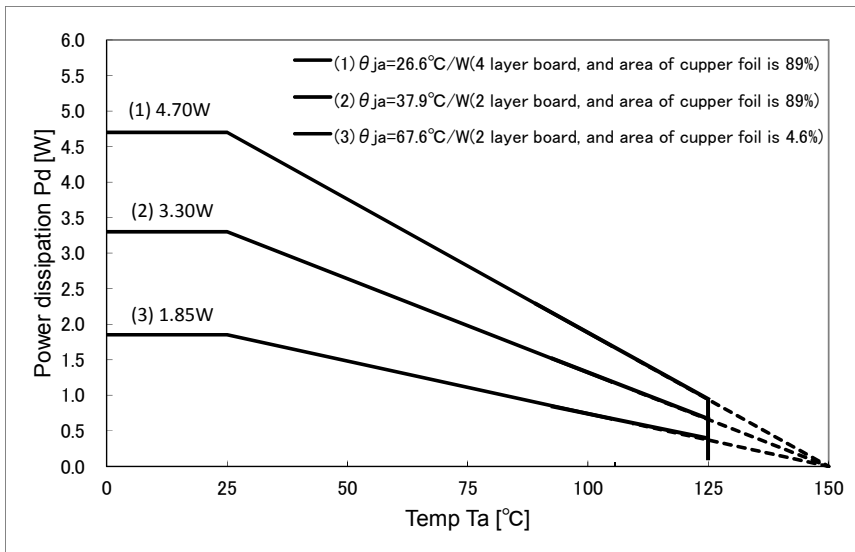


Fig.22

Note1: The value of Power consumption : on glass epoxy board measuring 70mm×70mm×1.6mm (1 layer board/Copper foil thickness 18μm)

Note2: The value changes depending on the density of the board copper foil. However, this value is an actual measurement value and no guarantee value.

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Pd=1.85W (0.37W): Board copper foil area 225m<sup>2</sup>

Pd=3.30W (0.66W): Board copper foil area 4900m<sup>2</sup>

Pd=4.70W (0.94W): Board copper foil area 4900m<sup>2</sup>

●Application circuit 1

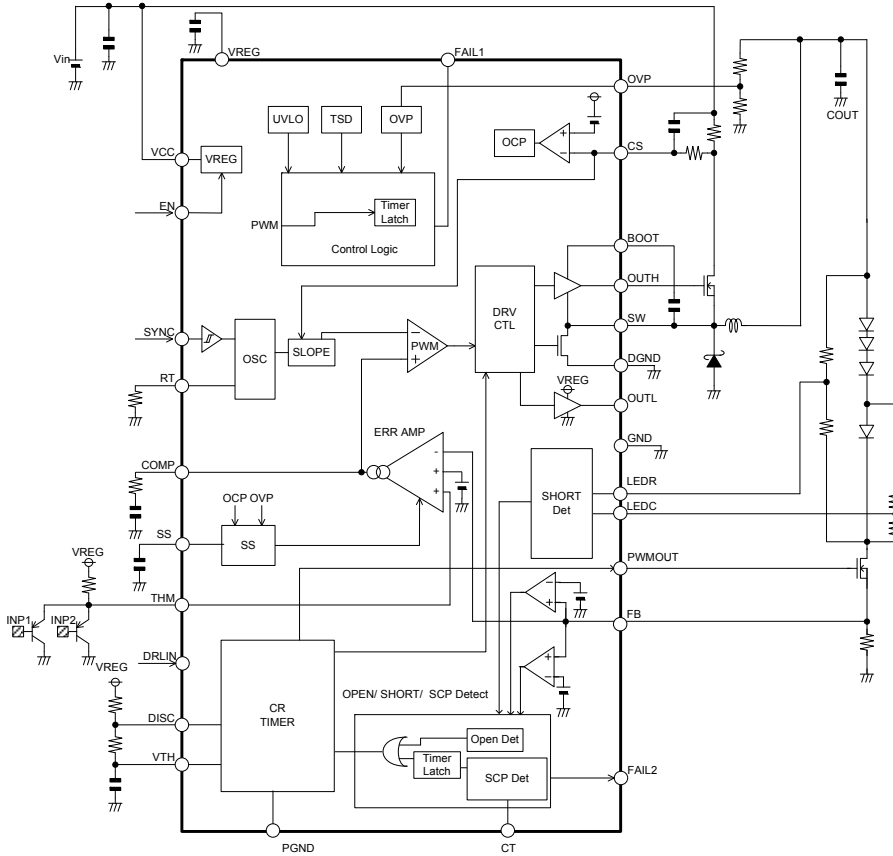


Fig. 23

Buck application composition (It is INP1, INP2, and two input selector function.)

●Application circuit 2

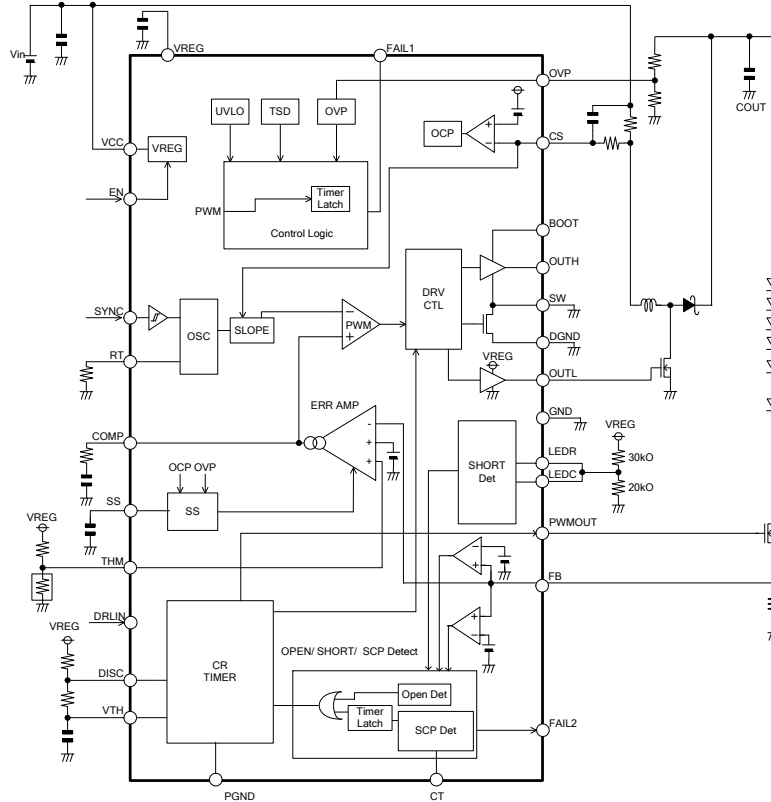
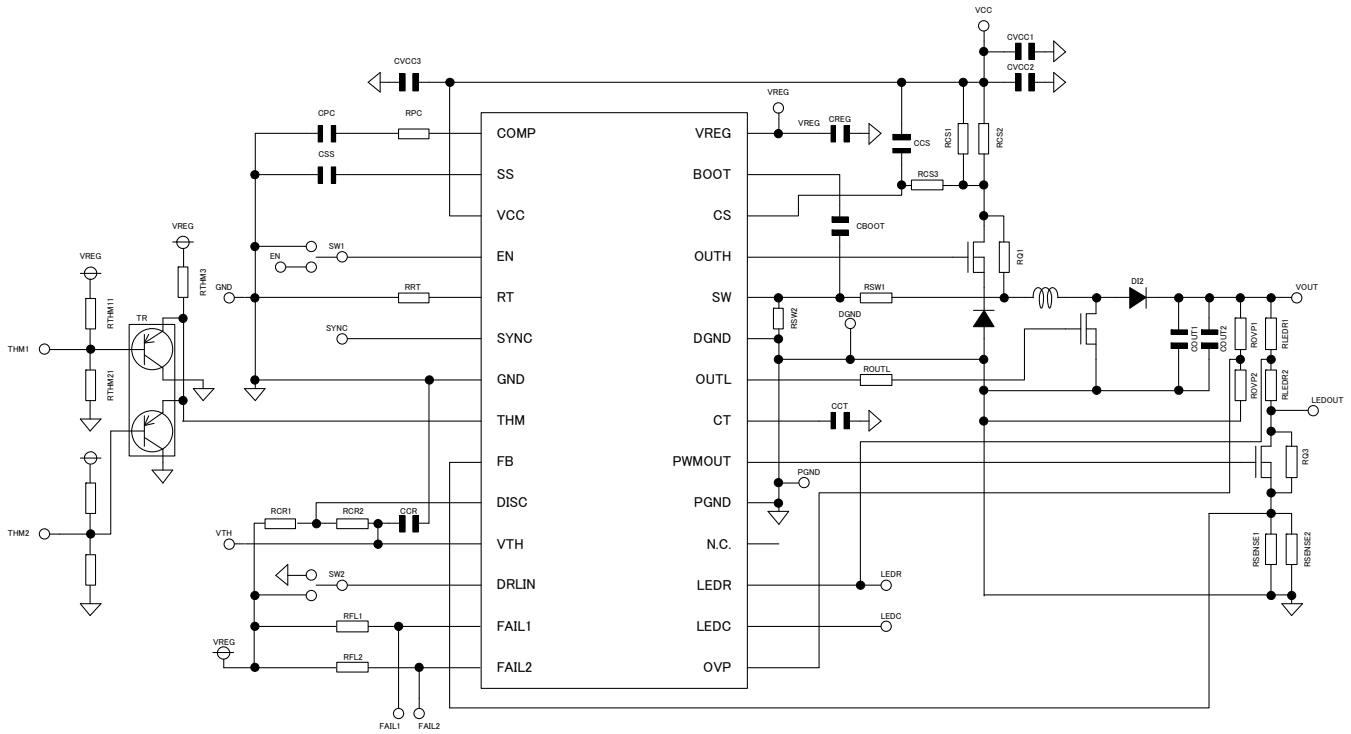


Fig. 24

Boost application composition (When invalidating short detection.)

●Reference PCB Setting



No.	Component Name	Component Value	Product Name	No.	Component Name	Component Value	Product Name
1	CVCC1	10uF	GCM32ER71E106KA42	23	CCS	N.M	-
2	CVCC2	10uF	GCM32ER71E106KA42	24	CBOOT	0.1uF	GCM188R11H104KA42
3	CVCC3	0.1uF	GRM31CB31E104KA75B	25	Q1	RSS070N05	-
4	CPC	0.1uF	GCM188R11H104KA42	26	DI1	RB050L-40	-
5	RPC	820ohm	MCR03 Series	27	RSW1	0ohm	-
6	CSS	0.1uF	GCM188R11H104KA42	28	RSW2	N.M	-
7	RRT	200kohm	MCR03 Series	29	RQ1	N.M	-
8	RTHM11	100kohm	MCR03 Series	30	L	10uH	SLF12575T100M5R4-H
9	RTHM12	100kohm	MCR03 Series	31	ROUTL	0ohm	MCR03 Series
10	RTHM21	100kohm	MCR03 Series	32	Q2	RSS070N05	-
11	RTHM22	100kohm	MCR03 Series	33	DI2	RF201L2S	-
12	RTHM3	0ohm	-	34	COU1	10uF	GCM32ER71E106KA42
13	TR	-	-	35	COU2	10uF	GCM32ER71E106KA42
14	RCR1	30kohm	MCR03 Series	36	CCT	0.1uF	GCM188R11H104KA42
15	RCR2	10kohm	MCR03 Series	37	ROVP1	270kohm	MCR03 Series
16	CCR	0.22uF	GCM21BR11H224KA01	38	ROVP2	30kohm	MCR03 Series
17	FRL1	100kohm	MCR03 Series	39	RLED1	90kohm	MCR03 Series
18	FRL2	100kohm	MCR03 Series	39	RLED2	30kohm	MCR03 Series
19	CREG	10uF	GCM32ER71E106KA42	40	Q3	RSS070N05	-
20	RCS1	110mohm	MCR100JZHFSR110	41	RQ3	N.M	-
21	RCS2	N.M	-	42	RSENSE1	200mohm	MCR100JZHFSR510
22	RCS3	0ohm	-	43	RSENSE2	N.M	-

※When no PWM dimming, DI2 should be schottky diode instead of Fast Recovery diode to improve efficiency. Remove Q3, change RQ3=0Ω then short to DS.

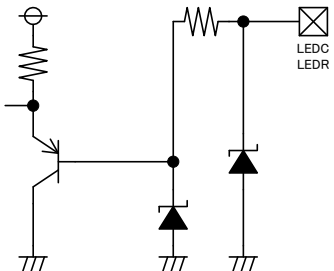
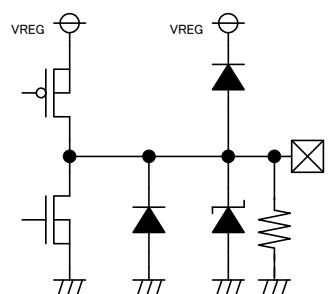
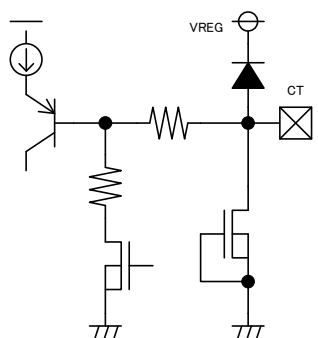
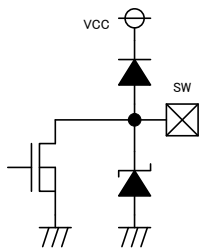
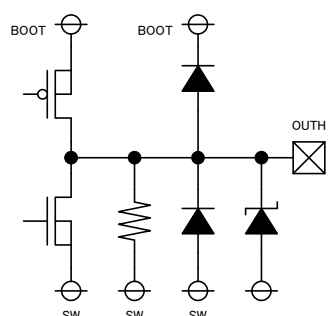
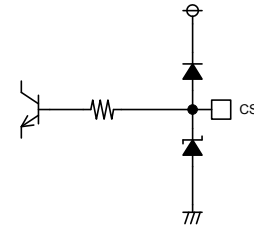
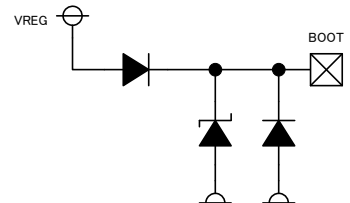
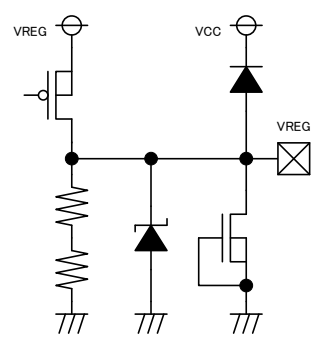
When dimming with External PWM signal, DISC should be pulled up to VREG with 10KΩ, then input PWM signal to VTH. (when no PWM dimming, remove Q3, change RQ3=0Ω and short to DS)

●Input/output Equivalent Circuits

<p>1. COMP</p>	<p>2. SS</p>	<p>4. EN</p>
<p>5. RT</p>	<p>6. SYNC</p>	<p>8. THM</p>
<p>9. FB</p>	<p>10. DISC</p>	<p>11. VTH</p>
<p>12. DRLIN</p>	<p>13,14. FAIL1,FAIL2</p>	<p>15. OVP</p>

※The values are all Typ. value.

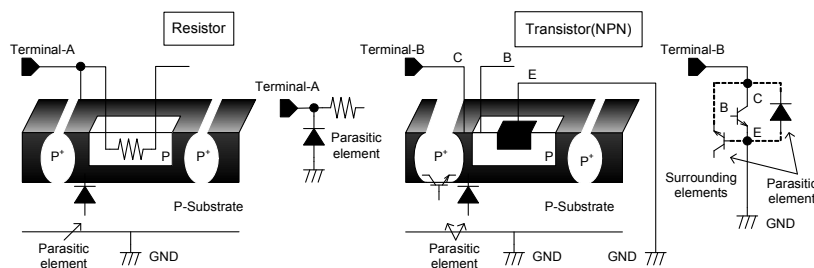
●Input/output Equivalent Circuits(Continuation)

<p>16,17. LEDC, LEDR</p> 	<p>19,22. PWMOUT, OUTL</p> 	<p>20. CT</p> 
<p>24. SW</p> 	<p>25. OUTH</p> 	<p>26. CS</p> 
<p>27. BOOT</p> 	<p>28. VREG</p> 	

※The values are all Typ. value.

### ●Notes for use

1. Absolute maximum ratings  
We are careful enough for quality control about this IC. So, there is no problem under normal operation, excluding that it exceeds the absolute maximum ratings. However, this IC might be destroyed when the absolute maximum ratings, such as impressed voltages or the operating temperature range( $T_{opr}$ ), is exceeded, and whether the destruction is short circuit mode or open circuit mode cannot be specified. Please take into consideration the physical countermeasures for safety, such as fusing, if a particular mode that exceeds the absolute maximum rating is assumed.
2. Reverse polarity connection  
Connecting the power line to the IC in reverse polarity (from that recommended) will damage the part. Please utilize the direction protection device as a diode in the supply line.
3. Power supply line  
Due to return of regenerative current by reverse electromotive force, using electrolytic and ceramic suppress filter capacitors (0.1 $\mu$ F) close to the IC power input terminals ( $V_{cc}$  and GND) are recommended. Please note the electrolytic capacitor value decreases at lower temperatures and examine to dispense physical measures for safety. And, for ICs with more than one power supply, it is possible that rush current may flow instantaneously due to the internal powering sequence and delays. Therefore, give special consideration to power coupling capacitance, width of power wiring, GND wiring, and routing of wiring. Please make the power supply lines (where large current flow) wide enough to reduce the resistance of the power supply patterns, because the resistance of power supply pattern might influence the usual operation.
4. GND line  
The ground line is where the lowest potential and transient voltages are connected to the IC.
5. Thermal design  
Do not exceed the power dissipation ( $P_d$ ) of the package specification rating under actual operation, and please design enough temperature margins.
6. Short circuit mode between terminals and wrong mounting  
Do not mount the IC in the wrong direction and be careful about the reverse-connection of the power connector. Moreover, this IC might be destroyed when the dust short the terminals between them or power supply, GND.
7. Radiation  
Strong electromagnetic radiation can cause operation failures.
8. ASO(Area of Safety Operation.)  
Do not exceed the maximum ASO and the absolute maximum ratings of the output driver.
9. TSD(Thermal shut-down)  
The TSD is activated when the junction temperature ( $T_j$ ) reaches 175°C(with 25°C hysteresis), and the output terminal is switched to Hi-z. The TSD circuit aims to intercept IC from high temperature. The guarantee and protection of IC are not purpose. Therefore, please do not use this IC after TSD circuit operates, nor use it for assumption that operates the TSD circuit.
10. Inspection by the set circuit board  
The stress might hang to IC by connecting the capacitor to the terminal with low impedance. Then, please discharge electricity in each and all process. Moreover, in the inspection process, please turn off the power before mounting the IC, and turn on after mounting the IC. In addition, please take into consideration the countermeasures for electrostatic damage, such as giving the earth in assembly process, transportation or preservation.
11. IC terminal input  
This IC is a monolithic IC, and has  $P^+$  isolation and P substrate for the element separation. Therefore, a parasitic PN junction is formed in this P-layer and N-layer of each element. For instance, the resistor or the transistor is connected to the terminal as shown in the figure below. When the GND voltage potential is greater than the voltage potential at Terminals A or B, the PN junction operates as a parasitic diode. In addition, the parasitic NPN transistor is formed in said parasitic diode and the N layer of surrounding elements close to said parasitic diode. These parasitic elements are formed in the IC because of the voltage relation. The parasitic element operating causes the wrong operation and destruction. Therefore, please be careful so as not to operate the parasitic elements by impressing to input terminals lower voltage than GND(P substrate). Please do not apply the voltage to the input terminal when the power-supply voltage is not impressed. Moreover, please impress each input terminal lower than the power-supply voltage or equal to the specified range in the guaranteed voltage when the power-supply voltage is impressing.

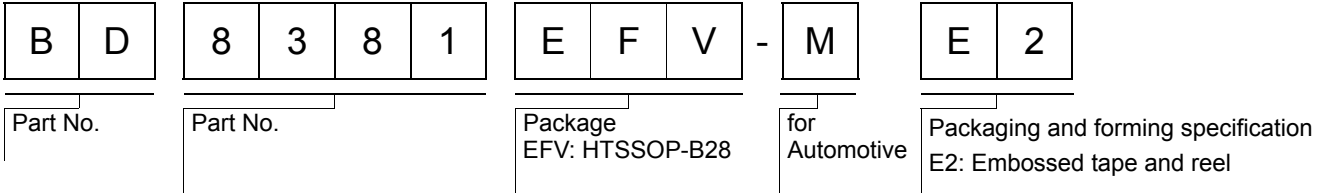


structure of IC

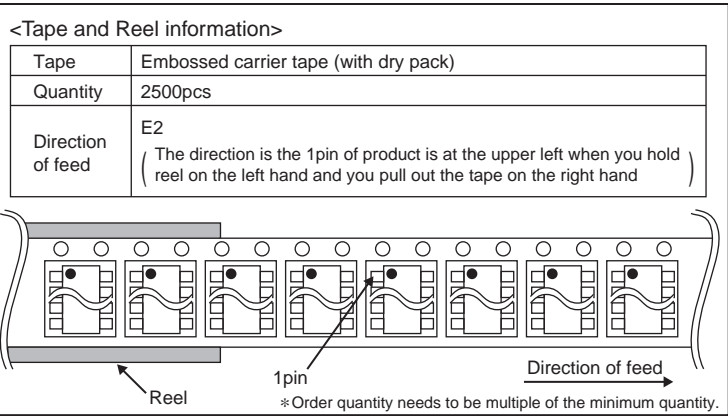
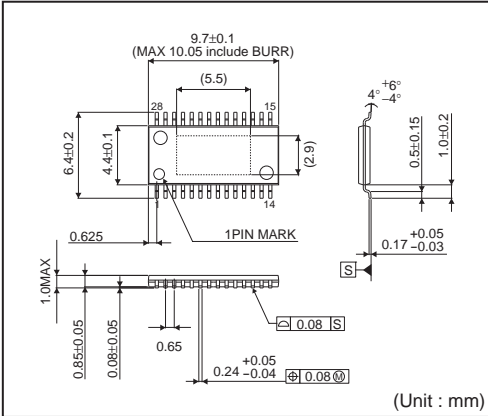
### 12. Earth wiring pattern

Use separate ground lines for control signals and high current power driver outputs. Because these high current outputs that flows to the wire impedance changes the GND voltage for control signal. Therefore, each ground terminal of IC must be connected at the one point on the set circuit board. As for GND of external parts, it is similar to the above-mentioned

●Ordering part number



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