Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

Constant Current LED Drivers

50V 500mA
1ch Source Driver for Automotive

BD8374HFP-M BD8374EFJ-M

General Description

BD8374HFP-M and BD8374EFJ-M are 50V-withstanding LED source drivers. Most suitably for Automotive LED driving, it can control light through PWM of constant current output.
Having LED open/short detective circuit and overvoltage mute functions integrated, it can deliver high reliability.
Also by utilizing our patented PBUS function, it is possible to turn OFF all LEDs in case where a row of LEDs are short/open-circuited if multiple rows of LEDs are driven through multiple number of the ICs.

Features

- AEC-Q100 Qualified
- Variable form Constant-Current Source Driver
- PWM Dimming Function
- CR Timer for PWM Dimming Function Integrated
- LED Open/Short detective Circuit Function Integrated
- Overvoltage Mute and Temperature Protection Functions Integrated
- Abnormal Output Detection and Output Functions (PBUS)

Application

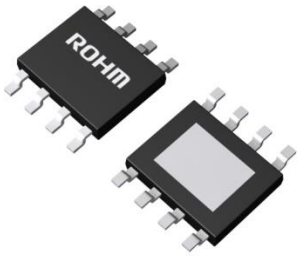
- On-board Exterior Lamp
  (Rear Lamp, Turn Lamp, DRL/Position Lamp, Fog Lamp, etc.)
- On-board Interior Lamp
  (Air Conditioner Lamp, Interior Lamp, Cluster Light, etc.)

Key Specifications

- Input Voltage Range: 4.5V to 42V
- Max Output Current: 500mA (Max)
- Output Current Accuracy: ±5% (Max)
- Operating Temperature Range: -40°C to +125°C

Packages	W(Typ) x D(Typ) x H(Max)
HRP7	9.395mm x 10.540mm x 2.005mm
HTSOP-J8	4.90mm x 6.00mm x 1.00mm

HRP7



HTSOP-J8

Basic Application Circuit

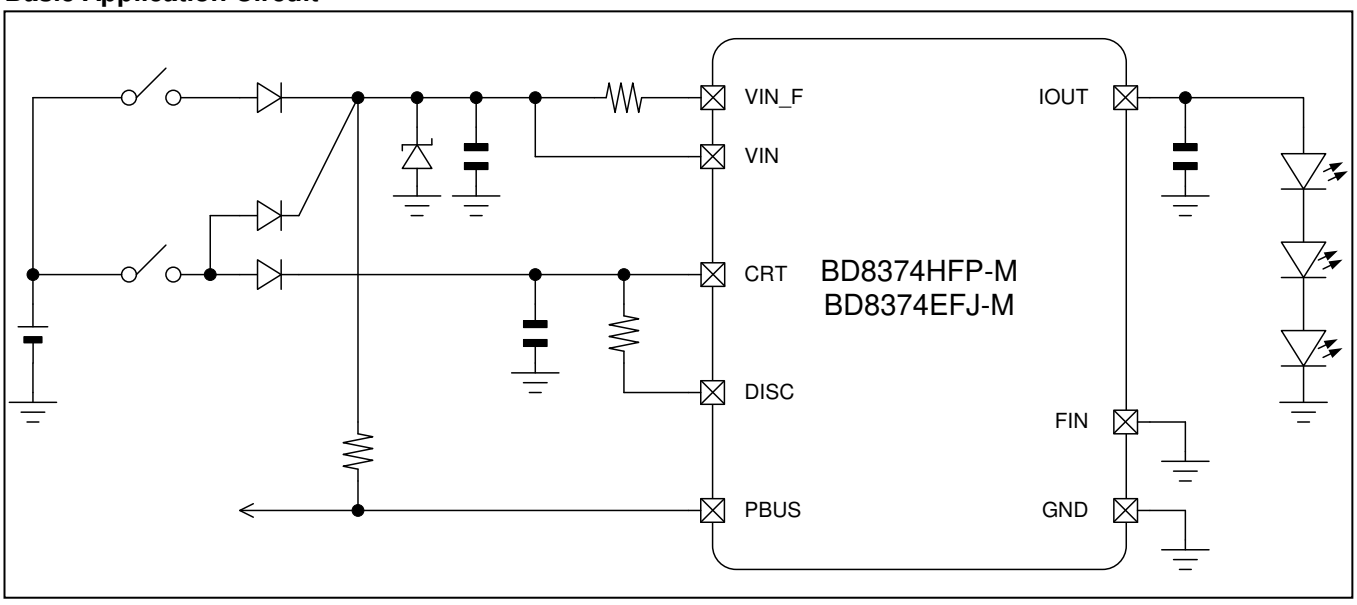


Figure 1. Typical Application Circuit

○Product configuration: Silicon monolithic integrated circuit ○ The product is not designed for radiation resistance.

Pin Configurations

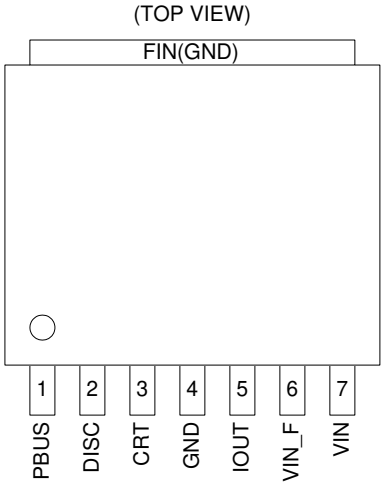


Figure 2. HRP7 Package Pin Configuration

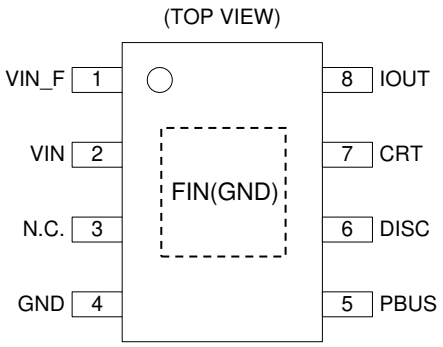


Figure 3. HTSOP-J8 Package Pin Configuration

Pin Descriptions

HRP7 Package

Pin No.	Pin Name	Function
1	PBUS	Error detection I/O
2	DISC	Discharge setting
3	CRT	PWM dimming timer setting
4	GND	GND
5	IOUT	Current output
6	VIN_F	Output current detection
7	VIN	Power supply input

HTSOP-J8 Package

Pin No.	Pin Name	Function
1	VIN_F	Output current detection
2	VIN	Power supply input
3	N.C.	N.C.
4	GND	GND
5	PBUS	Error detection I/O
6	DISC	Discharge setting
7	CRT	PWM dimming timer setting
8	IOUT	Current output

Block Diagram

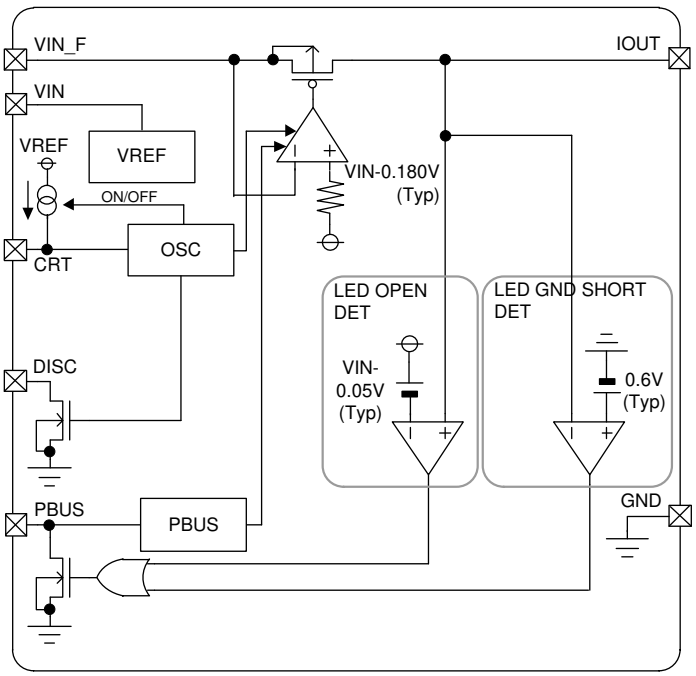


Figure 4. Block Diagram

Absolute Maximum Ratings (Ta=25°C)

Parameter	Symbol		Rating	Unit
Supply Voltage	V_{IN}		-0.3 ～ +50	V
VIN_F,CRT,DISC,IOUT,PBUS Terminal Voltage	V_{VIN_F},V_{CRT},V_{DISC},V_{IOUT},V_{PBUS}		-0.3 ～ V_{IN}+0.3	V
Power Dissipation	Pd	HRP7	2.3(Note1)	W
		HTSOP-J8	1.1(Note2)	
Operating Temperature Range	Topr		-40～125	°C
Storage Temperature Range	Tstg		-55～150	°C
Junction Temperature	Tjmax		150	°C
IOUT Output Maximum Current	I_{OUT}		500	mA

(Note1) HRP7
Derate by 18.4mW/°C when operating above Ta=25°C
(when mounted in ROHM's standard board(70mm × 70mm × 1.6mm) 2 layer copper foil(15mm × 15mm)).
(Note2) HTSOP-J8
Derate by 8.8mW/°C when operating above Ta=25°C
(when mounted in ROHM's standard board(70mm × 70mm × 1.6mm) 2 layer copper foil(15mm × 15mm)).

Caution: 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.

Recommended Operating Conditions

Parameter	Symbol	Rating	Unit
Supply Voltage(Note1)	V_{IN}	4.5～42.0	V
Operating Temperature Range	Topr	-40～125	°C
Current Setting Resistor	R_{VIN_F}	0.36～3.6	Ω
Minimum capacitor connecting IOUT terminal	C_{IOUT_MIN}	0.1	μF
CRTIMER Frequency Rage	F_{PWM}	100～5000	Hz
PWM Minimum Pulse Width	T_{MIN}	20	μs

(Note1) Pd, ASO should not be exceeded

Electrical Characteristics(Unless otherwise specified Ta=-40～125°C, V_{IN}= 13V, R_{VIN_F}=0.47Ω, R_{PBUS}=10kΩ)

Parameter	Symbol	Min	Typ	Max	UNIT	Condition
Circuit Current	I_{VIN}	-	2.1	6.0	mA	
IOUT Terminal Output Current Accuracy	I_{OUT}	373	383	393	mA	Ta=25°C
		364	383	402	mA	Ta=-40°C～125°C
VIN – IOUT Drop Voltage	V_{DR_IOUT}	-	0.45	1.0	V	I_{OUT}=383mA
IOUT Terminal OFF Current	I_{IOUT_OFF}	-	-	1	μA	V_{IOUT}=2V, V_{CRT}=0.7V Ta=25°C
IOUT Current at GND Short	I_{IOUT_SHORT}	-	-	40	μA	V_{IOUT}=0V
VIN_F Terminal Voltage	$V_{IN\_F\_REF}$	0.171	0.180	0.189	V	$V_{IN\_F\_REF}$=V_{IN}-V_{IN_F}
IOUT Voltage at LED Open Detection	V_{IOUT_OPEN}	V_{IN} -0.15	V_{IN} -0.050	V_{IN} -0.020	V	
IOUT Voltage at LED Open Detection Release	$V_{IOUT\_OPEN\_RELEASE}$	V_{IN} -0.300	V_{IN} -0.150	V_{IN} -0.060	V	
IOUT Voltage at LED Short Detection	V_{IOUT_SHORT}	0.2	0.6	1.0	V	
CRT Terminal Charge Current	I_{CRT_SO}	29.75	35.00	40.25	μA	V_{CRT}=0.9V
CRT Terminal Charge Voltage	V_{CRT_CHA}	0.990	1.10	1.21	V	
CRT Terminal Discharge Voltage 1	V_{CRT_DIS1}	2.7	3.0	3.3	V	
CRT Terminal Discharge Voltage 2	V_{CRT_DIS2}	3.6	4.0	4.4	V	$R_{D1<->}R_{D2}$(Note1)
CRT Terminal Charge Resistance	R_{CHA}	51.6	54.3	57.0	kΩ	R_{CHA}=(V_{CRT_DIS1} － V_{CRT_CHA}) / I_{CRT_SO}
DISC Terminal Discharge Resistance 1	R_{D1}	-	50.0	100	Ω	V_{CRT}=3.4V
DISC Terminal Discharge Resistance 2	R_{D2}	2.5	5.0	10	kΩ	V_{CRT}=5V
PBUS Terminal Input Voltage High	V_{IH_PBUS}	4.0	-	V_{IN} +0.20	V	
PBUS Terminal Input Voltage Low	V_{IL_PBUS}	GND -0.20	-	2.0	V	
PBUS Terminal Low Voltage	V_{OL_PBUS}	-	-	1.5	V	I_{PBUS}=2mA
PBUS Terminal Input Current	I_{IN_PBUS}	-	38.0	100	μA	V_{PBUS}=13V
Overvoltage Mute	$V_{IN\_OVPMUTE}$	27	29	33	V	V_{IOUT}=6V

(Note) This product is not designed for use in radioactive environments.
(Note1) Refer to Functional Description

Typical Performance Curves (Reference Data)

(Unless otherwise specified Ta=25°C, V_{IN}=V_{IN_F}=13V)

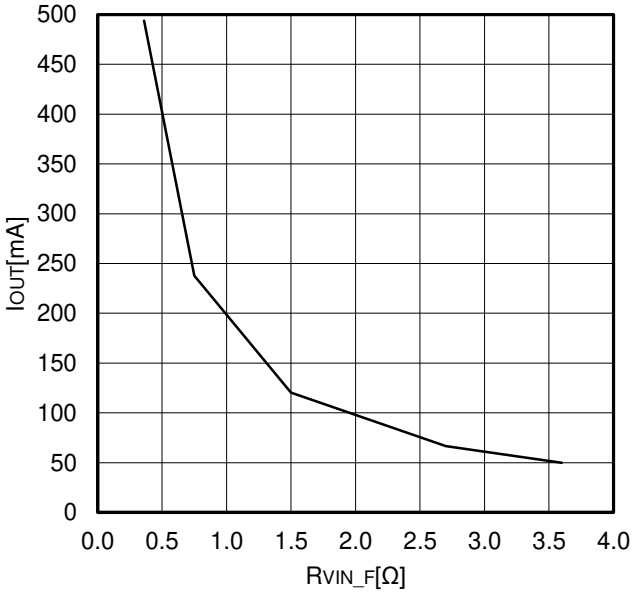


Figure 5. R_{VIN_F} vs I_{OUT}

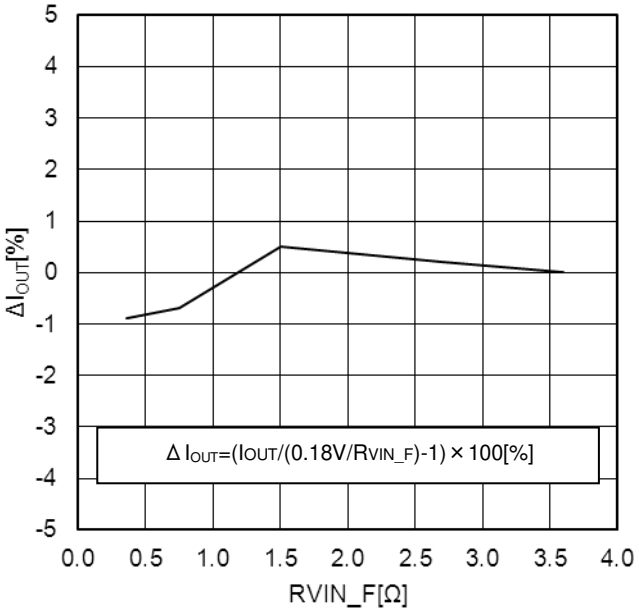


Figure 6. R_{VIN_F} vs ΔI_{OUT}

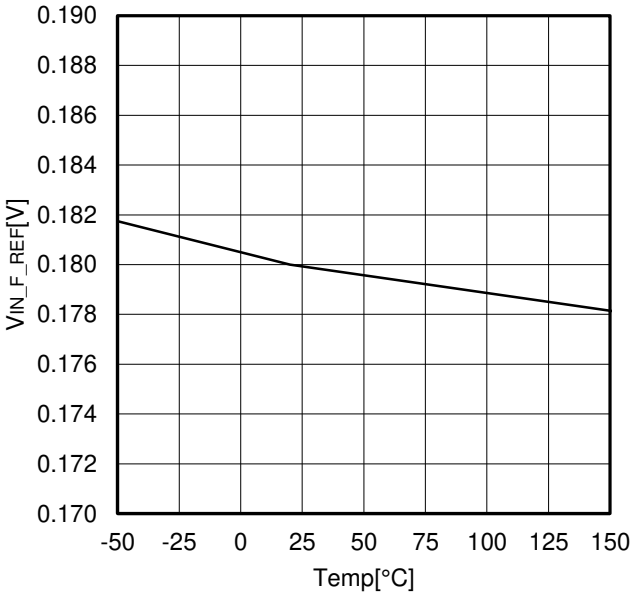


Figure 7. Temperature vs $V_{IN\_F\_REF}$

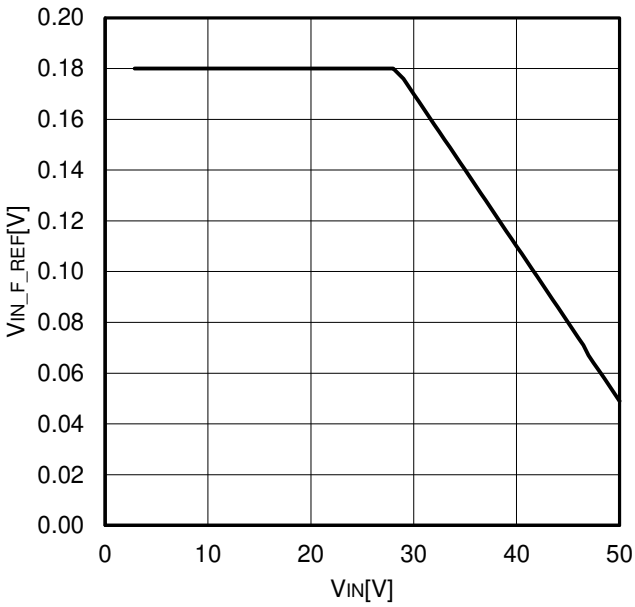


Figure 8. V_{IN} vs $V_{IN\_F\_REF}$

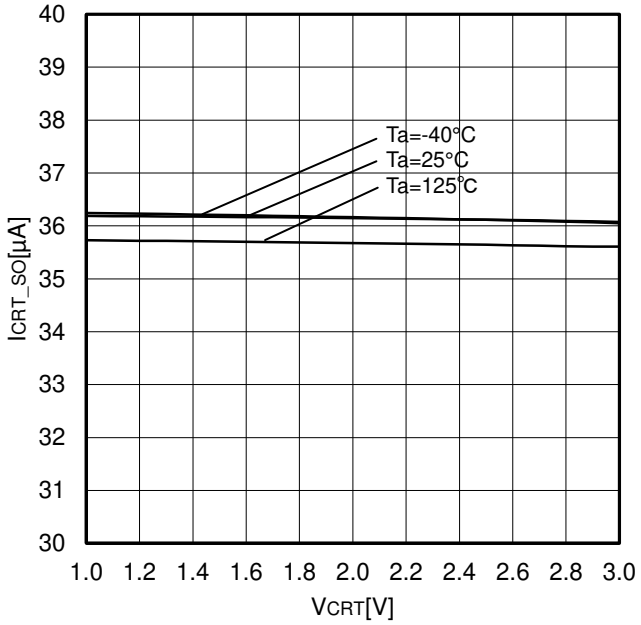


Figure 9. V_{CRT} vs I_{CRT_SO}
(V_{CRT}:CRT Terminal Voltage)

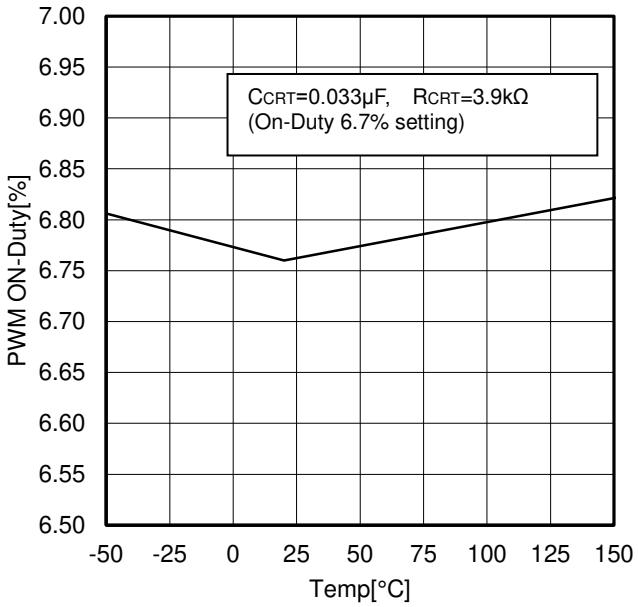


Figure 10. Temperature vs PWM ON Duty

Functional Description

(Unless otherwise specified, Ta=25°C, V_{IN}=13V, I_{OUT}=6V and R_{VIN_F}=0.47Ω. Numbers are "Typical" values.)

1. Output Current Setting

LED Current I_{OUT} can be set as below depending on values of current setting resistance R_{VIN_F}.

$$I_{OUT} = \frac{(V_{IN} - V_{IN\_F})}{R_{VIN\_F}} = \frac{V_{IN\_F\_REF}}{R_{VIN\_F}} [A]$$

where:
$V_{IN\_F\_REF}$ is 0.18V (Typ)

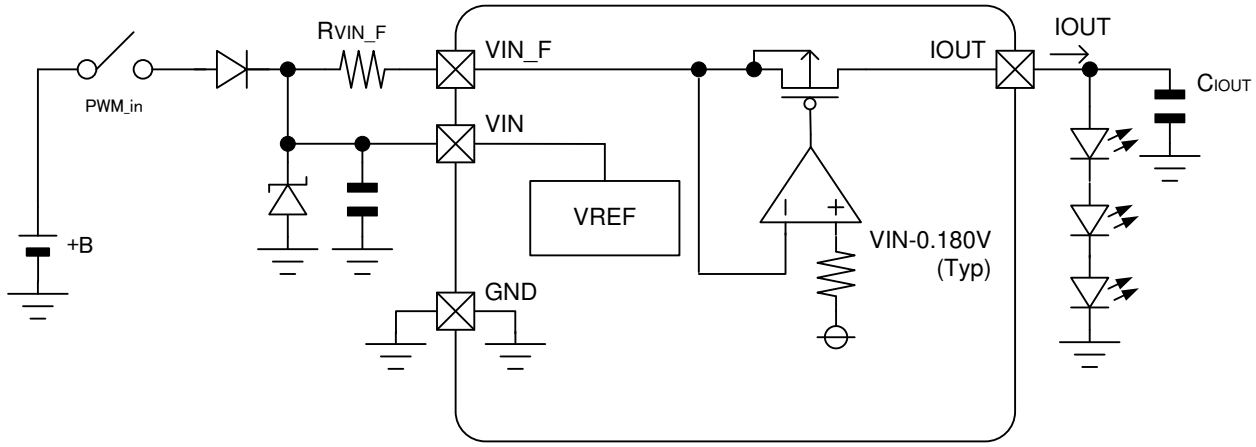


Figure 11. Output Current Setting

2. Table of Operations

PWM dimming mode switches to linear control depending on CRT terminal voltage.
When CRT terminal voltage surpasses V_{CRT_DIS2}(4.0V(Typ)), Dimming mode turns to Linear Control, and discharge resistance of DISC terminal changes from R_{D1}(50Ω(Typ)) to R_{D2}(5kΩ(Typ)).
LED open/short-circuit protection is activated depending on IOUT terminal voltage status, and output current is turned OFF.
Output current is also turned OFF when Low signal is input to PBUS terminal.

Operation Mode	CRT Terminal	IOUT Terminal Voltage (V_{IOUT})	Output Current (I_{OUT})	PBUS Terminal
Linear Control	4.0V(Typ)≤V_{CRT}	-	50mA～500mA	Hi-Z
PWM dimming	See Features Description, 3. PWM Dimming Operation	-	See Features Description, 3. PWM Dimming Operation	Hi-Z
LED Open	-	V_{IOUT} ≥ VIN - 0.050V(Typ)	1μA(Max)	Low Output
LED Short	-	V_{IOUT} ≤ 0.6V(Typ)	40μA(Max)	Low Output
PBUS Control OFF	-	-	1μA(Max)	Low Input

3. PWM Dimming Operation

PWM Dimming is performed if CRT terminal is the following circuit.
Dimming cycle and Duty width can be set through external resistance value and capacity.

CR timer function in IC is activated if DC_in OPEN. In order to perform PWM light control of LED current, triangular waveform is generated at CRT terminal. Output is controlled so that **LED current is turned OFF** while CRT voltage is ramping up, and **LED current is turned ON** while CRT voltage is ramping down.
Ramp up/down time of CRT voltage can be set by values of external components **(C_{CRT}, R_{CRT})**.

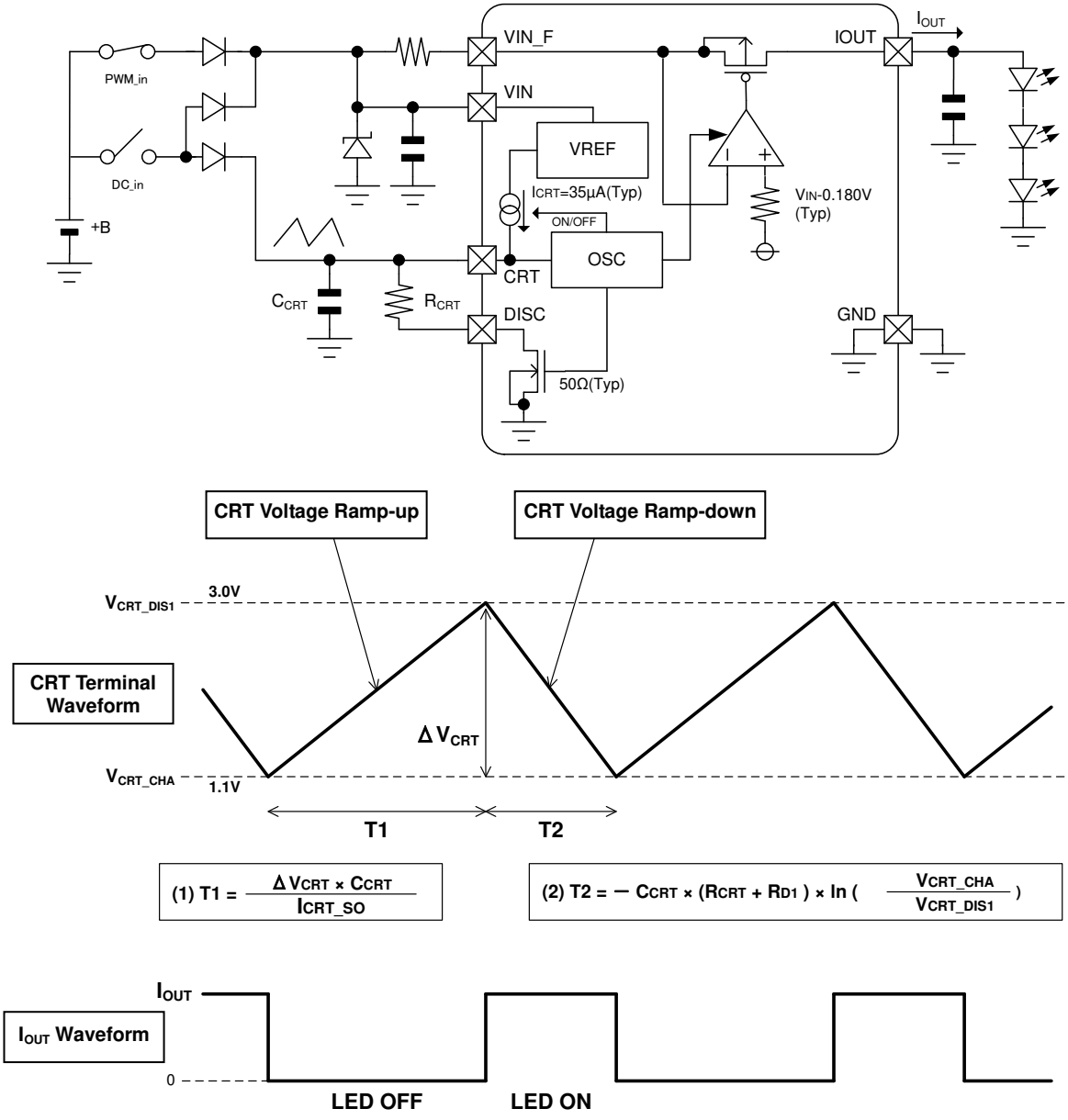


Figure 12. PWM Fimming Operation

(1) CRT Ramp up Time T1
CRT ramp up time can be obtained from the following equations:

$$T1 = \frac{\Delta V_{CRT} \times C_{CRT}}{I_{CRT\_SO}} = R_{CHA} \times C_{CRT}\,[s]$$

where:
I_{CRT_SO} is the CRT Terminal Charge Current 35μA (Typ)
R_{CHA} is the CRT Terminal Charge Resistance 54.3kΩ(Typ)

(2) CRT Ramp down Time T2

CRT ramp down time is defined by discharge period due to external capacity C_{CRT} and resistance (R_{CRT} + R_{D1}).
(CRT Terminal Charge Current is OFF at CRT ramp down)
Make sure that T2 is set at not smaller than Min. pulse width 20μs(Min).

$$T2 = -C_{CRT} \times (R_{CRT} + R_{D1}) \times \ln\left(\frac{V_{CRT\_CHA}}{V_{CRT\_DIS1}}\right) \quad [s]$$

where:
R_{D1} is the CRT Terminal Discharge Resistance 1 50Ω (Typ)
V_{CRT_CHA} is the CRT Terminal Discharge ON Voltage 1.1V (Typ)
V_{CRT_DIS1} is the CRT Terminal Discharge ON Voltage 3.0V (Typ)

(3) Dimming Frequency f_{PWM}

PWM frequency is defined by T1 and T2.

$$f_{PWM} = \frac{1}{T1 + T2} \quad [Hz]$$

(4) ON Duty (D_{ON})

Like the above, PWM ON duty is defined by T1 and T2.

$$D_{ON} = \frac{T2}{T1 + T2}$$

(Ex) In case of f_{PWM} = 518Hz and 6.7% Duty (Typ),

From f_{PWM}=518Hz; T1 + T2 = 1 / f_{PWM} = 1 / 518Hz = 1931μs
From ON Duty = 6.7%; CRT ramp up time T1 is T1 = (T1 + T2) × 0.933 = 1801.6μs
External capacity C_{CRT} is;
C_{CRT} = T1 × (I_{CRT} / ΔV_{CRT}) = 1801.6μs × 35μA / 1.9V ≒ **0.033μF**

CRT ramp down time T2 is; T2 = (T1 + T2) × 0.067 = 129μs
External resistance R_{CRT} is;
R_{CRT} = −T2 / (C_{CRT} × ln(V_{CRT_CHA} / V_{CRT_DIS})) − R_{D1} = −129μsec / (0.033μF × ln(1.1 / 3.0)) – 50Ω ≒ **3.9kΩ**

In case where PWM signal is applied from external;

It is possible to directly input PWM signal from external microcomputer for Dimming.
Input PWM signal to CRT terminal. In that case, 'High' level voltage of PWM signal should be equal to or higher than V_{CRT_DIS2}(4.4V(Max)) and 'Low' level voltage of PWM signal should be equal to or less than V_{CRT_CHA}(0.99V(Min)).

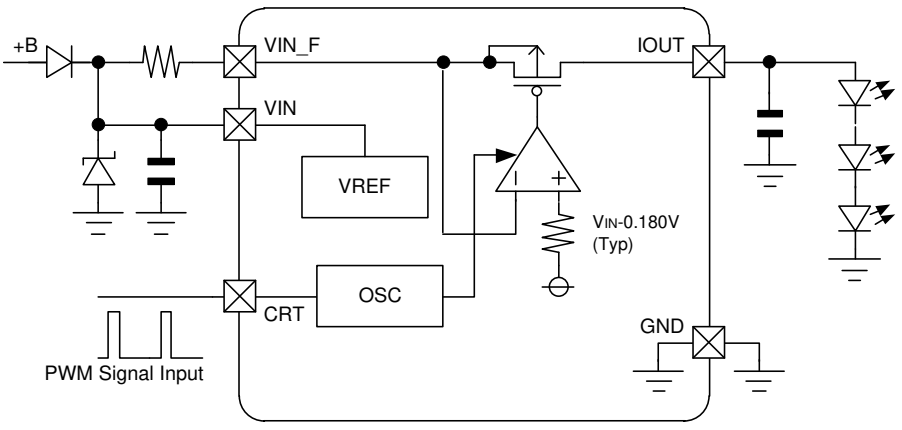


Figure 13. External Input of PWM Signal

4. LED Setting Range

Number of LED connections N should meet the following conditions:

$$V_{f\_led} \times N \leq +B - V_{f\_diode} - V_{IN\_F\_REF} - V_{DR\_IOUT}$$

where:
+B is the Battery Voltage
V_{f_diode} is the Reverse Connection Preventing Diode Vf
$V_{IN\_F\_REF}$ is the VIN_F Terminal Voltage ($V_{IN} - V_{IN\_F}$)
V_{DR_IOUT} is the IOUT Terminal Drop Voltage
V_{f_led} is the LED Vf
N is the Number of LED Levels

Ex) If you want to supply constant current to LED at 9V or higher Battery Voltage (+B) (Supposing that V_{f_diode} is 0.5V),

$V_{f\_led} \times N \leq +B - V_{f\_diode} - V_{IN\_F\_REF} - V_{DR\_IOUT}$ = 9V –0.5V –0.189V(Max) – 1.0V(Max) = 7.311V
(Sum of Vf of LED connected to IOUT terminal is set to be 7.311V Max.)

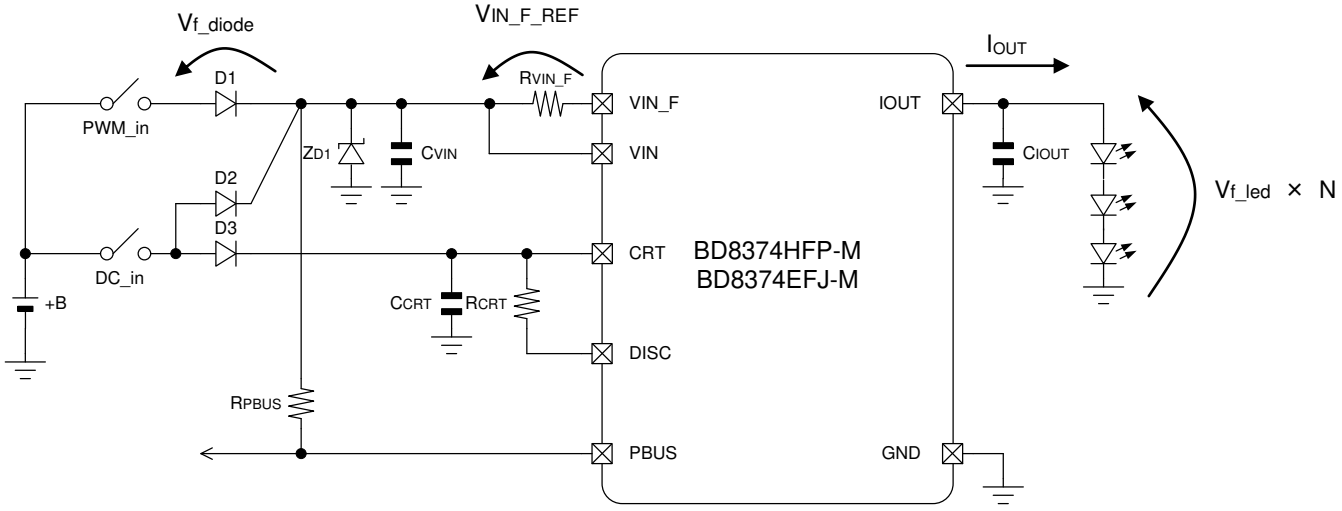


Figure 14. LED Setting Range Schematic

5. Overvoltage Mute

If 29V (Typ) ≤ V_{IN}, Overvoltage Mute is activated to restrict output current in order to suppress heat generated from IC. I_{OUT} attenuates by 3.2%/V(Typ).

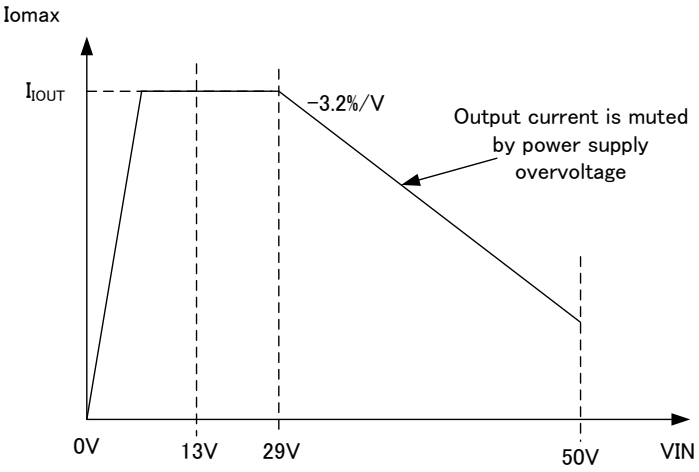


Figure 15. Overvoltage Mute Performance

6. Protective Function

In this IC integrated is a function for protection from short/open-circuit of external component, and it is possible to detect abnormal condition at PBUS terminal.

(1) LED Open Detective Function

In case where LED connected to IOUT terminal is open-circuited, it is detected due to overvoltage of IOUT terminal. During the detection, PBUS terminal is switched to Low to notify the trouble.

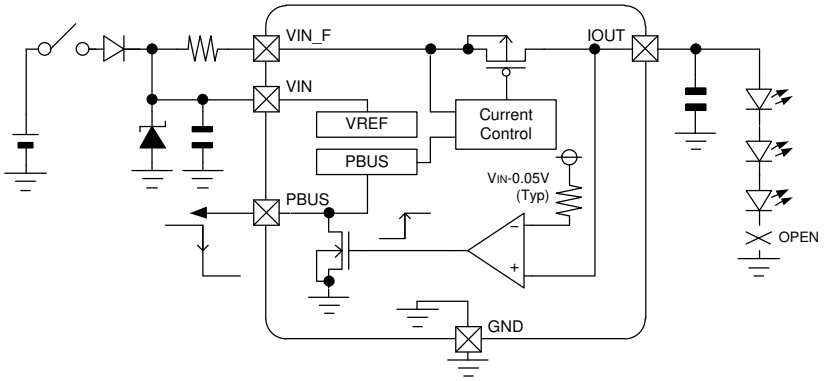


Figure 16. LED Open Detection

(2) LED Short-circuit Detective Function

In case where LED connected to IOUT terminal is short-circuited, it is detected due to low voltage of IOUT terminal. During the detection, output current is turned OFF to prevent thermal destruction of IC, and PBUS terminal is switched to Low to notify the trouble.

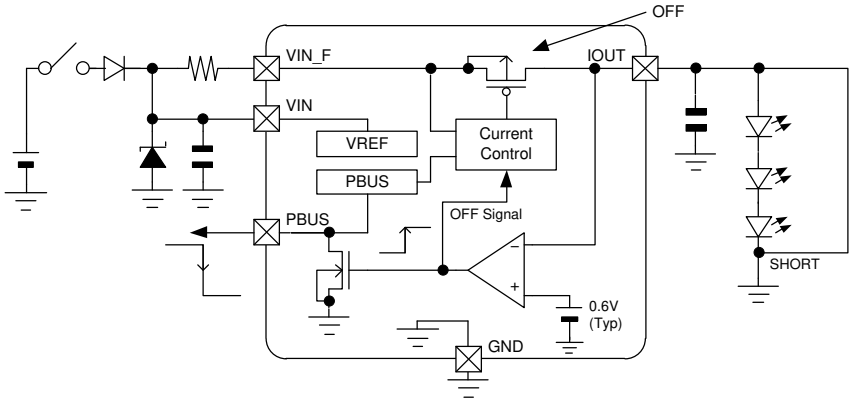


Figure 17. LED Short-circuit Detection

(3) IOUT Current at GND Short (I_{IOUT_SHORT})

When V_{IOUT} is less than 1.4V(Typ), IOUT Current at GND Short(I_{IOUT_SHORT}) flows from IOUT terminal. It is varied due to IOUT terminal Voltage.

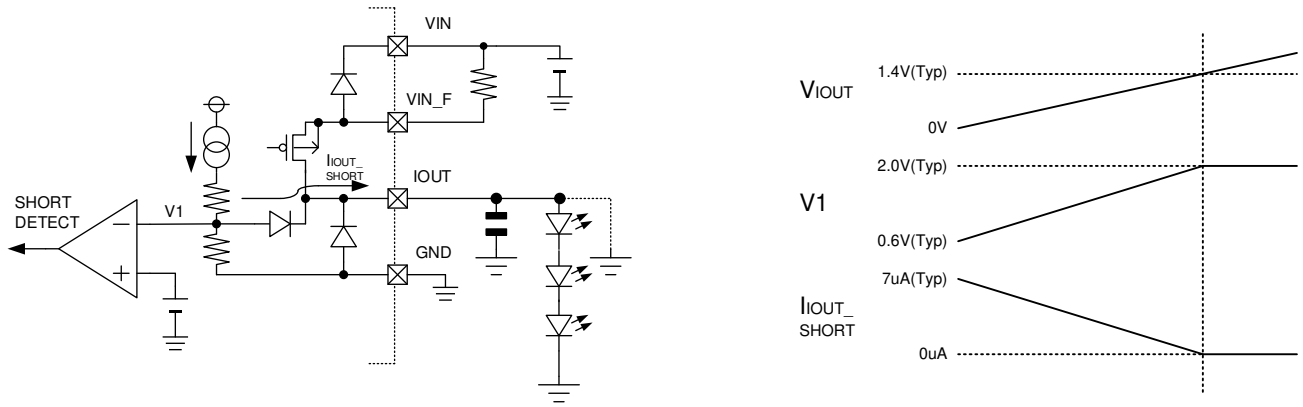


Figure 18. About IOUT Current at GND Short

(4) About Active zone of LED Open Detective & LED Short Detective Function and IOUT Terminal Hi-Z zone

Active zone of LED Open Detective & LED Short Circuit Detective Function is different from Linear Control Mode and PWM dimming Mode.(Refer to Figure19.)

Linear Control Mode : Each function is active at All zone.
PWM dimming Mode : LED Open Detective Fucntion is active only Fall time of V_{CRT}.
LED Short Circuit Detective Function is active at All zone.

There is **IOUT Terminal Hi-Z zone at PWM dimming Mode**.
To prevent Malfunction of LED Short Detective Function by noise(Note1),
It is necessary to connect Capacitor(more than 0.1uF(Note2))
between IOUT terminal and GND terminal nearby terminal
(ROHM Recommended Value : C_{IOUT}=0.1µF GCM188R11H104KA42 murata)

(Note1) Conducted noise, Radiated noise, Interference of connecter and PCB pattern etc…
(Note2) If connect more than 0.1uF, please evaluate the time of V_{IN} on to I_{IOUT} on.

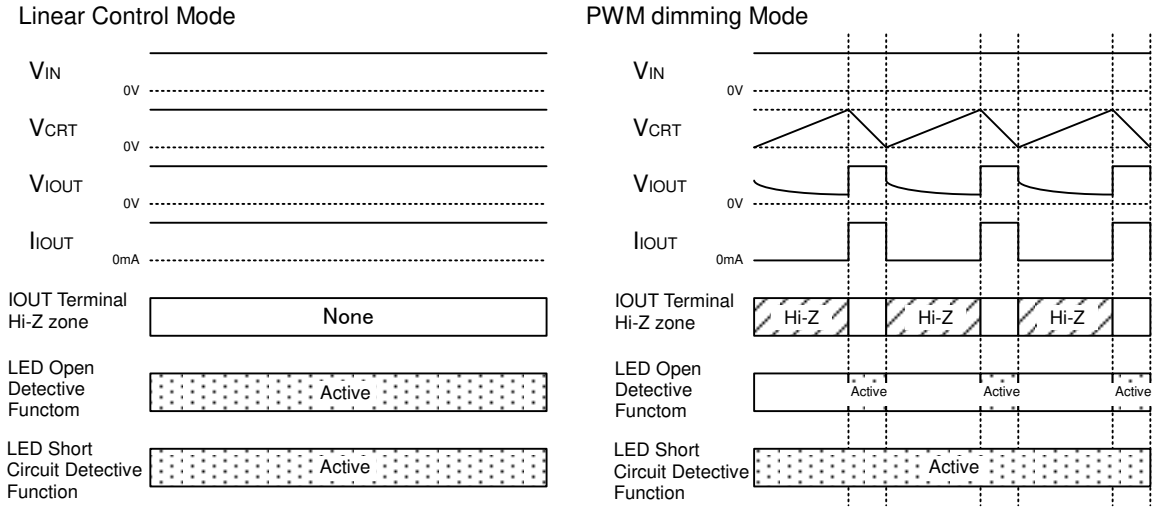


Figure 19. About Active zone of LED Open Detective & LED Short Detective Function and IOUT Terminal Hi-Z zone

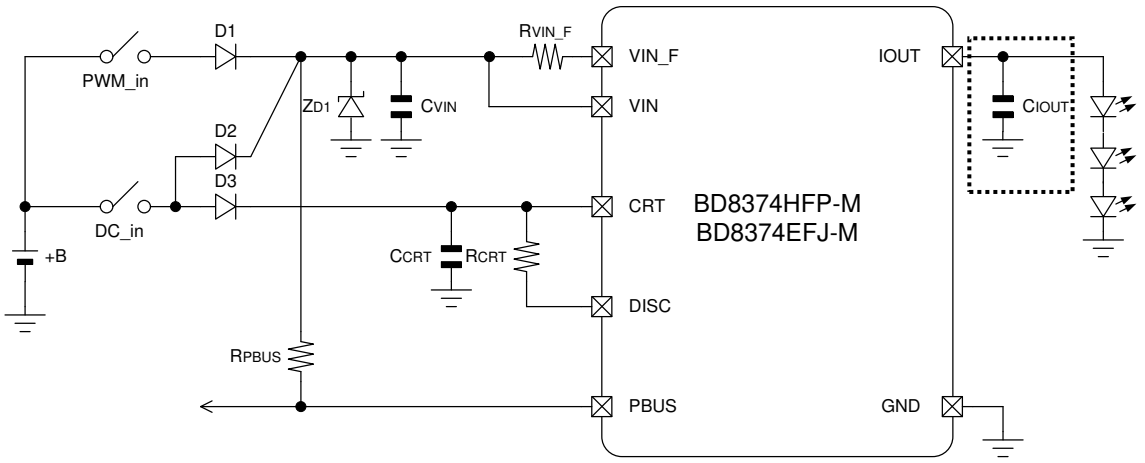
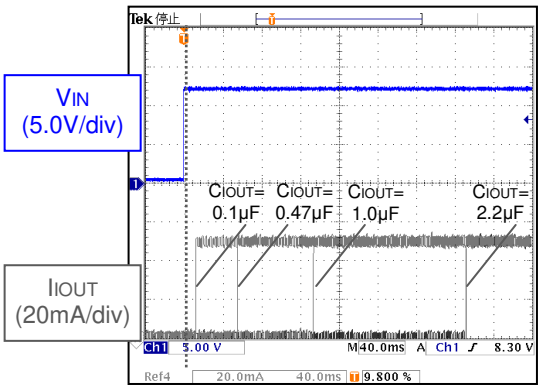


Figure 20. About the capacitor of connecting IOUT terminal

Evaluation example(The time of VIN on to IIOUT on)

Condition : +B=13V
Ta=25°C
LED 3Strings
VCRT=VIN
DC Mode

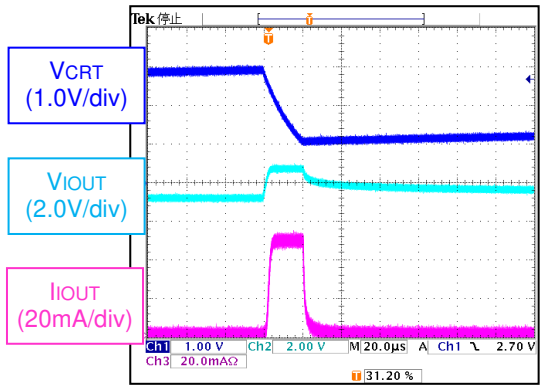
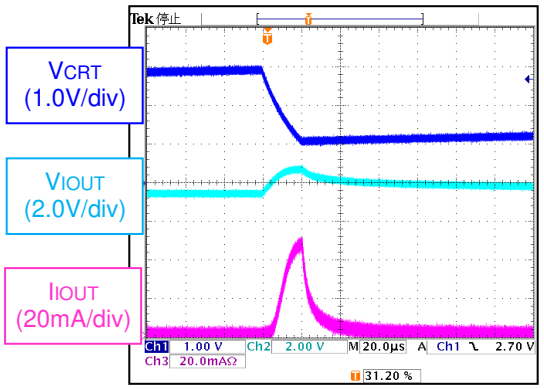
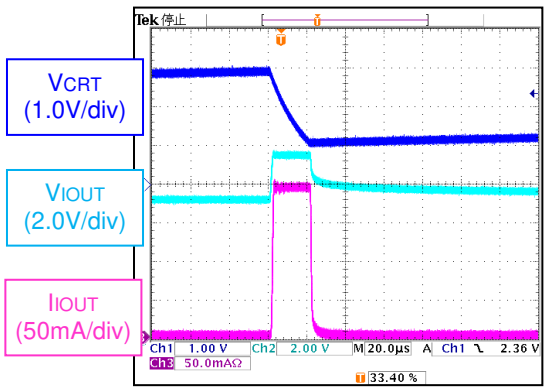
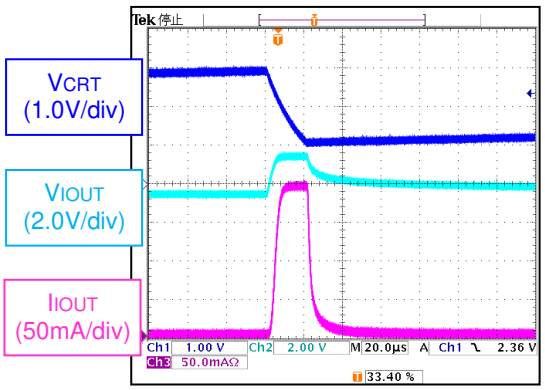


The time of VIN on to IIOUT on

CIOUT=0.1μF	:	11ms
CIOUT=0.47μF	:	51ms
CIOUT=1.0μF	:	130ms
CIOUT=2.2μF	:	290ms

Evaluation example(IIOUT pulse width at PWM Dimming operation)

Condition : +B=13V
Ta=25°C
LED 3Strings
RCRT=560Ω
CCRT=0.033μF
PWM Dimming Mode

	CIOUT=0.1μF	CIOUT=0.47μF
RVIN_F=3.6Ω (IIOUT=50mA)		
RVIN_F=0.91Ω (IIOUT=198mA)		

7. PBUS Function

PBUS terminal is an input/output terminal for outputting trouble and inputting trouble detection.
In case where a trouble occurred due to open/short-circuit of external component, it is possible to notify the trouble outside by switching PBUS terminal output from High (Note1) to Low.
It is possible to turn OFF output current by externally controlling PBUS from High→Low.

(Note1) PBUS terminal is an open drain terminal. Even when used separately, please be pulled up(10kΩ) to power supply voltage.

In case where you use multiple number of this LSI to drive multiple LEDs, as shown in the drawing below, it is possible to turn off all rows of LEDs even if some LEDs are short/open-circuited by connecting PBUS terminal of each CH.

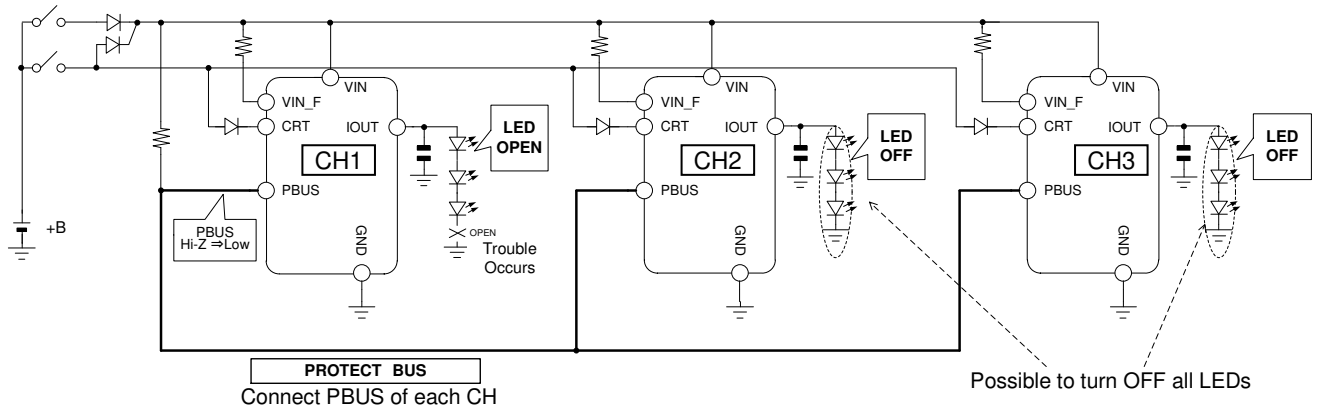


Figure 21. PBUS Function

▼Example of Protective Operation by LED Open

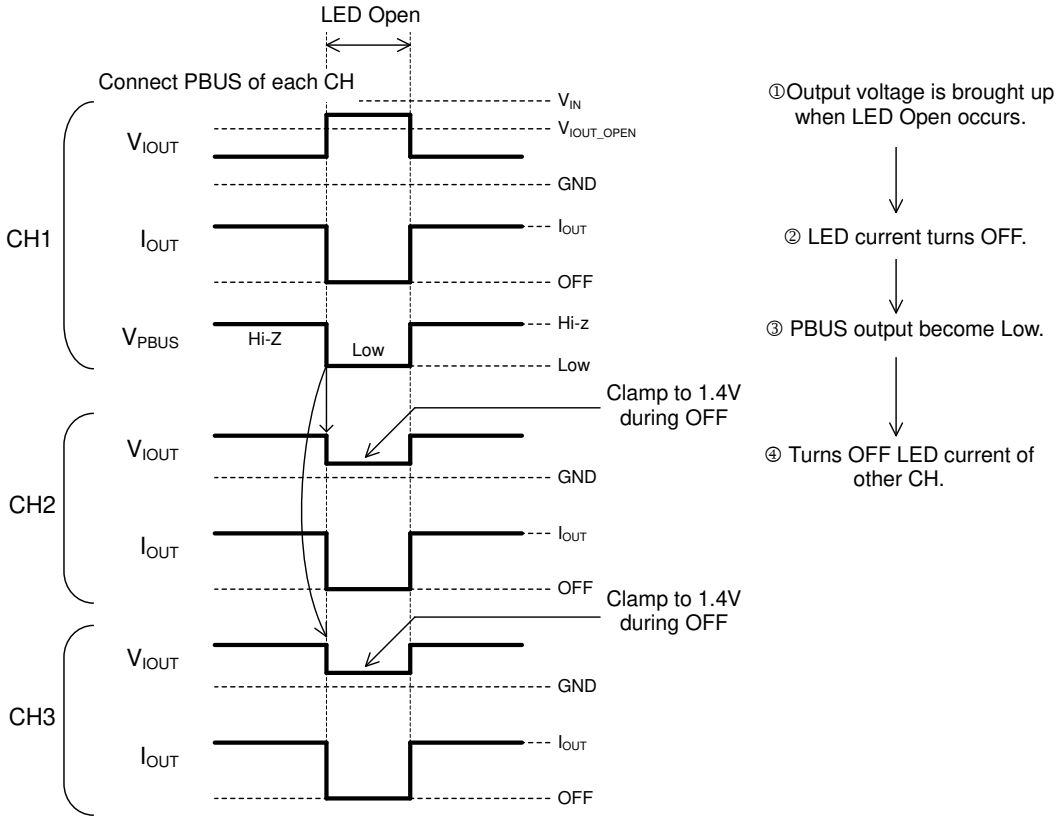


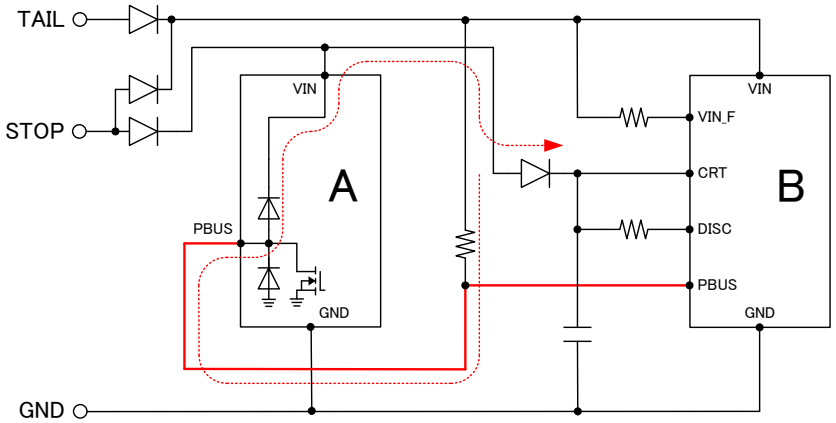
Figure 22. Example of Protective Operation

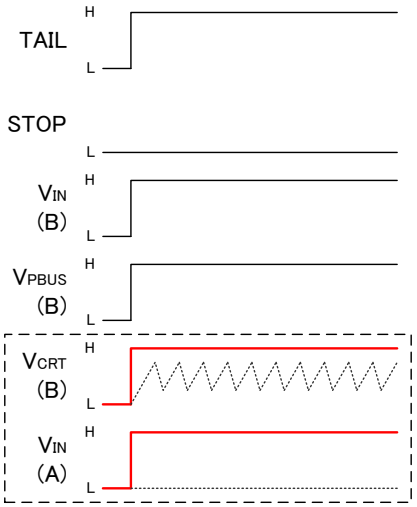
If LED OPEN occurs, PBUS of CH1 is switched from Hi-z to Low output. As PBUS becomes Low, LED drivers of other CH detect the trouble and turns OFF their own LEDs. VIOUT clamps to 1.4V (Typ) during the OFF period, in order to prohibit ground fault detection.

8. Caution of driving IC used multi-power supply

Each Input terminal is built- in ESD protection diodes. (Refer to I/O equivalence circuits)
If VIN terminal is not supplied voltage and Input terminal (without VIN) is supplied voltage, IC may occur malfunction(abnormal operation mode, abnormal LED lighting) due to arise VIN terminal voltage .

The Application Example of accidental operation is below.





⇒Due to Voltage arises VIN(A), CRT(B) is not triangle wave output

Figure 23. Application Example

(Operational Explanation)
Only input Tail : Arise VIN terminal voltage of IC A from ESD protection Diode between VIN terminal and PBUS terminal of IC A.
Due to connect VIN terminal of IC A and CRT terminal of IC B across Diode, DC voltage inputs CRT terminal of IC B, so it is possible to operate ICB DC mode.

Timing Chart

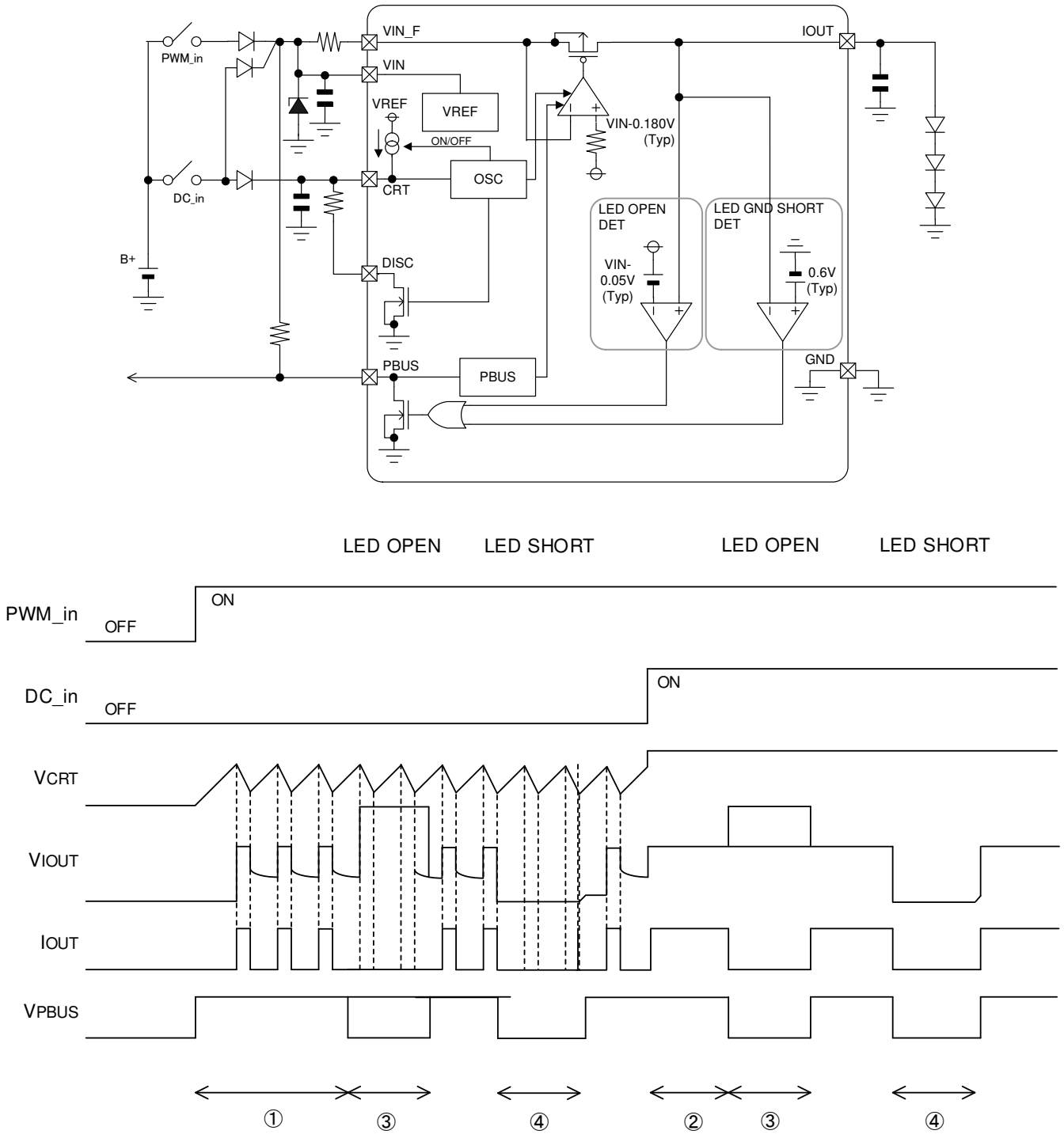


Figure 24. Timing Chart

① If PWM_in is switched ON, V_{CRT} will start oscillation, and according to its waveform LED current I_{OUT} is output. (PWM light control mode)

② If DC_in is switched ON, V_{CRT} will be fixed at High (V_{IN}-Vf). LED current I_{OUT} will be continuously output. (Linear control mode)

③ If LED becomes OPEN, LED current I_{OUT} will stop. At the same time, V_{PBUS} falls to Low.

④ If LED is short-circuited to GND, LED current I_{OUT} will stop. At the same time, V_{PBUS} falls to Low.

Guaranteed Range of Current Accuracy and LED Open Detection Range

Guaranteed range of current accuracy and LED open detection range can be obtained from the following equation:

PBUS output becomes Low if IOUT terminal output (V_{IOUT}) is higher than the LED open detection range at the time of reduced VIN terminal voltage.
Therefore, pay attention to respective setting range during power ON/OFF, and consider operating voltage range of the set.

Guaranteed Range of Current Accuracy
$V_{IN} \geq V_{f\_led} \times N + V_{IN\_F\_REF} + V_{DR\_IOUT}$ [V]

Where:
V_{IN} is the VIN Terminal Voltage
V_{f_led} is the LED Vf
N is the: Number of LED Levels
$V_{IN\_F\_REF}$ is the VIN_F Terminal Voltage (V_{IN} - V_{IN_F})
V_{DR_IOUT} is the IOUT Terminal Drop Voltage

LED Open Detection Voltage
$V_{IOUT} = V_{IN}$ - 50mV(Typ)

LED Open Detection Release Voltage
$V_{IOUT} = V_{IN}$ - 150mV(Typ)

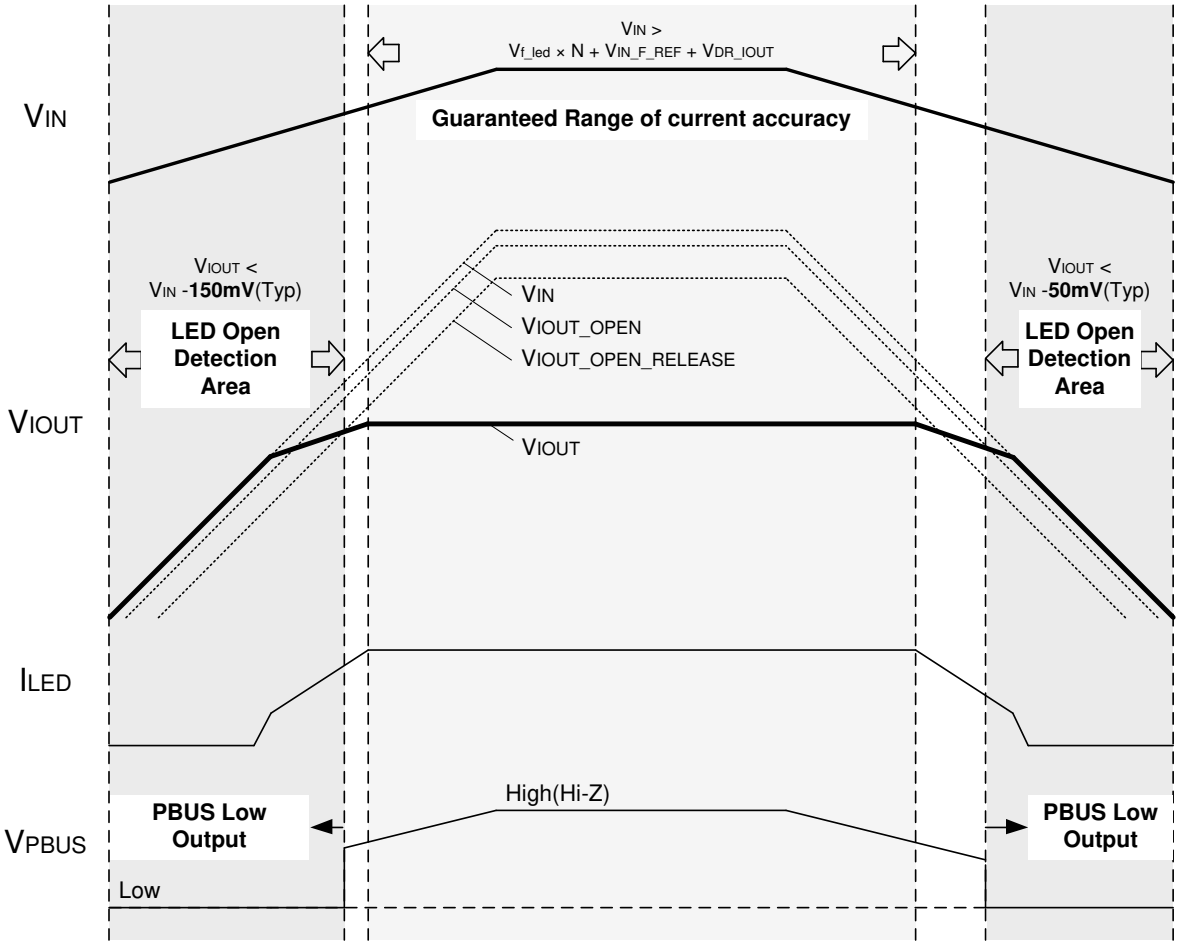


Figure 25. Guaranteed Range of Current Accuracy and LED Open Detection Range

How to Connect LED

In case of connected LED to IOUT terminal as shown in the following, note that protective detection becomes possible/impossible depending on connection patterns.

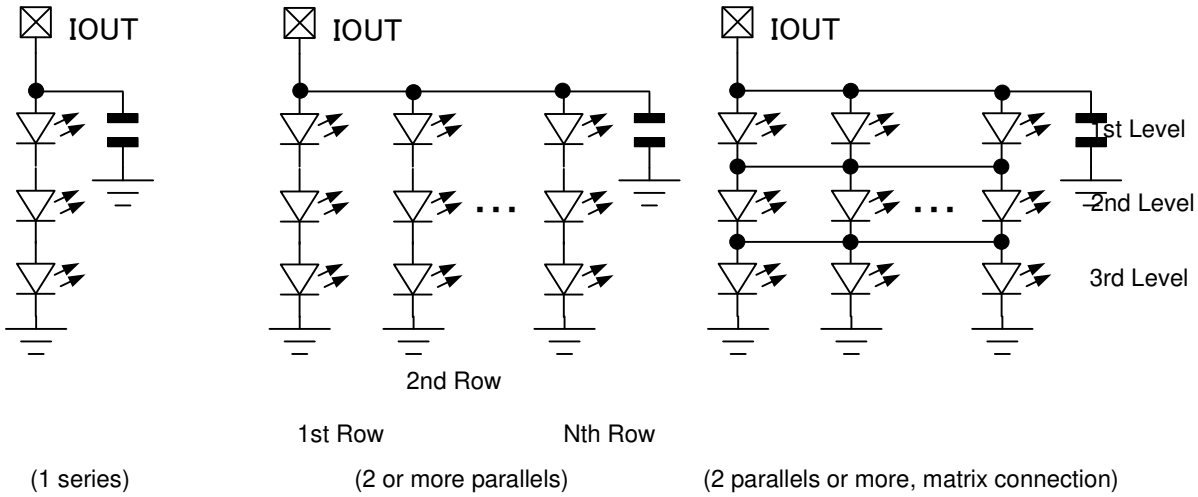


Figure 26. LED Connection Patterns

Connection Pattern	LED Short-circuit Detection (GND short of IOUT terminal)	LED OPEN detection
1 Series	Detectable	Detectable-
2 parallels or more	Detectable	Non-detectable (Note 1)
2 parallels or more (Matrix Connection)	Detectable	Non-detectable (Note 2)

(Note1) : Detectable only when one or more LEDs become open in all rows.
(Note2) : Detectable only when all LEDs on the same level become open.

Recommended Application Circuit

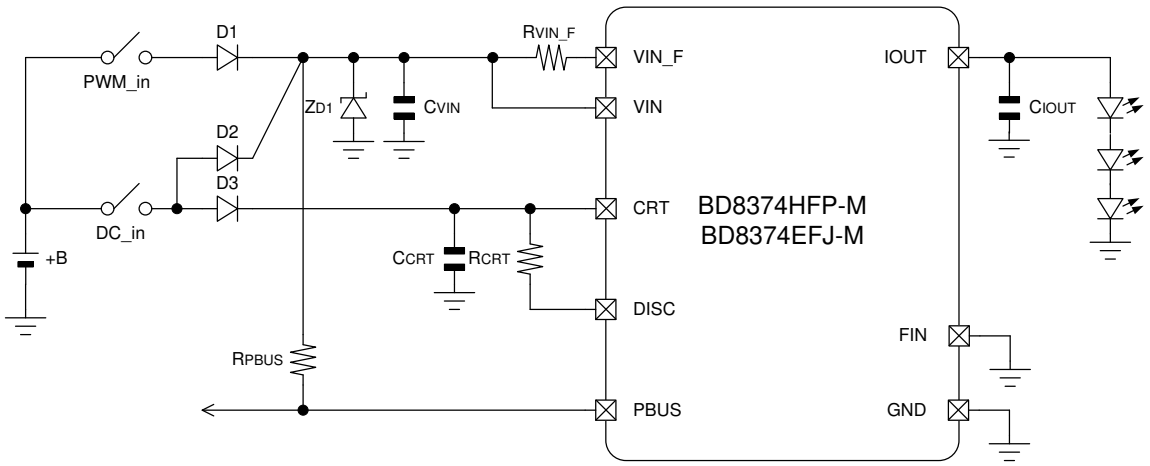


Figure 27. Recommended Application Circuit

▼Corresponding EMC Test Items

- ISO11425-2
- ISO11452-4
- ISO7637-2

(pulse1, pulse 2a,2b, pulse 3a,3b)

No.	Component Name	Component Value	Product Name	Company
1	D1	-	RFN1L6S	ROHM
2	D2	-	RFN1L6S	ROHM
3	D3	-	RFN1L6S	ROHM
4	Z_{D1}	-	TNR12H-220K	NIPPON CHEMICON
5	C_{VIN}	4.7µF	GCM32ER71H475KA40	murata
6	R_{VIN_F}	0.91Ω	MCR10 Series	ROHM
7	R_{PBUS}	10kΩ	MCR03 Series	ROHM
8	C_{CRT}	0.033µF	GCM188R11H333KA40	murata
9	R_{CRT}	3.9kΩ	MCR03 Series	ROHM
10	C_{IOUT}	0.1µF	GCM188R11H104KA42	murata

Table 1. BOM List

PWM_in	DC_in	Mode
Low	Low	OFF
High	Low	PWM Dimming Mode (Note1,Note2) (13.25mA 6.7% ON duty@518Hz)
Low	High	Linear Control Mode (Note2) (197.8mA 100% ON duty)
High	High	Linear Control Mode (Note2) (197.8mA 100% ON duty)

(Note1) See Functional Description "3. PWM Dimming Operation."
(Note2) See Functional Description "2. Table of Operations."

Table 2. Table of Operations

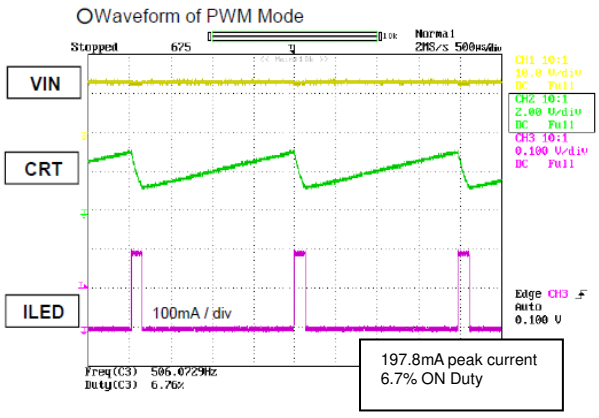


Figure 28. Example of Waveform Measurement

Thermal Loss

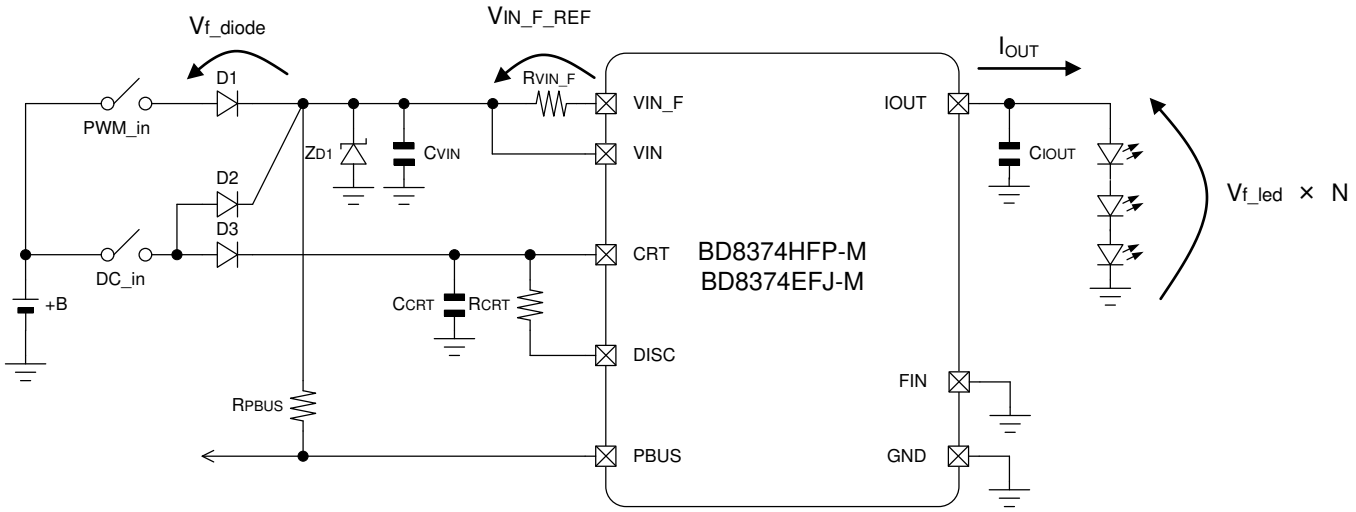


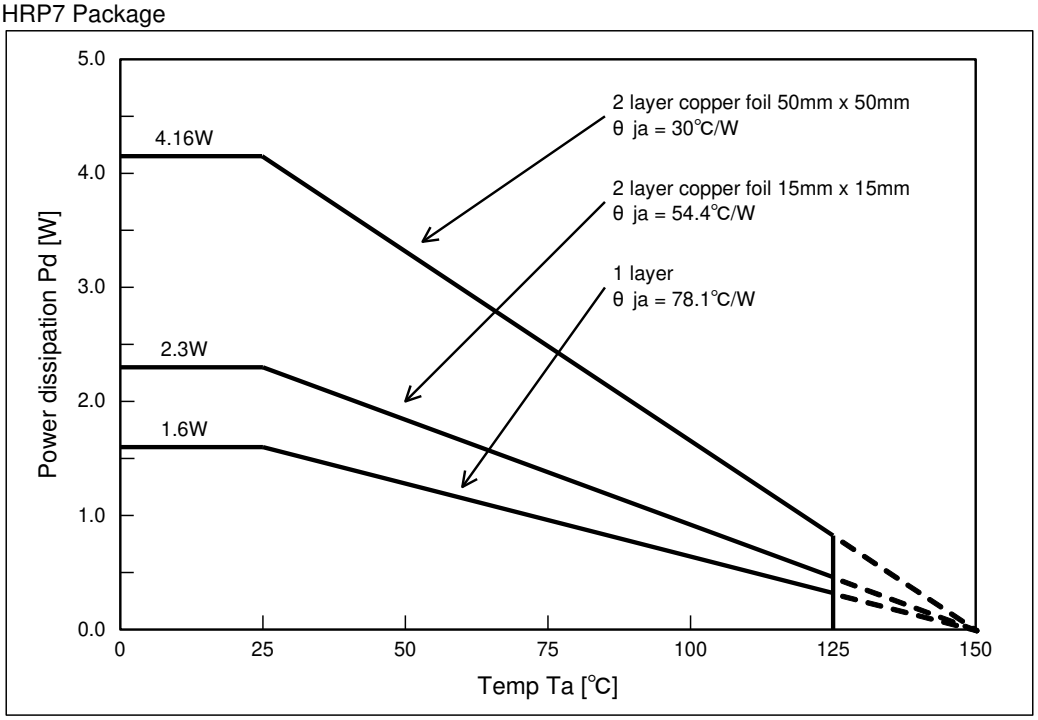
Figure 29. Application Circuit Diagram for Thermal Description

Thermal design should meet the following equation:

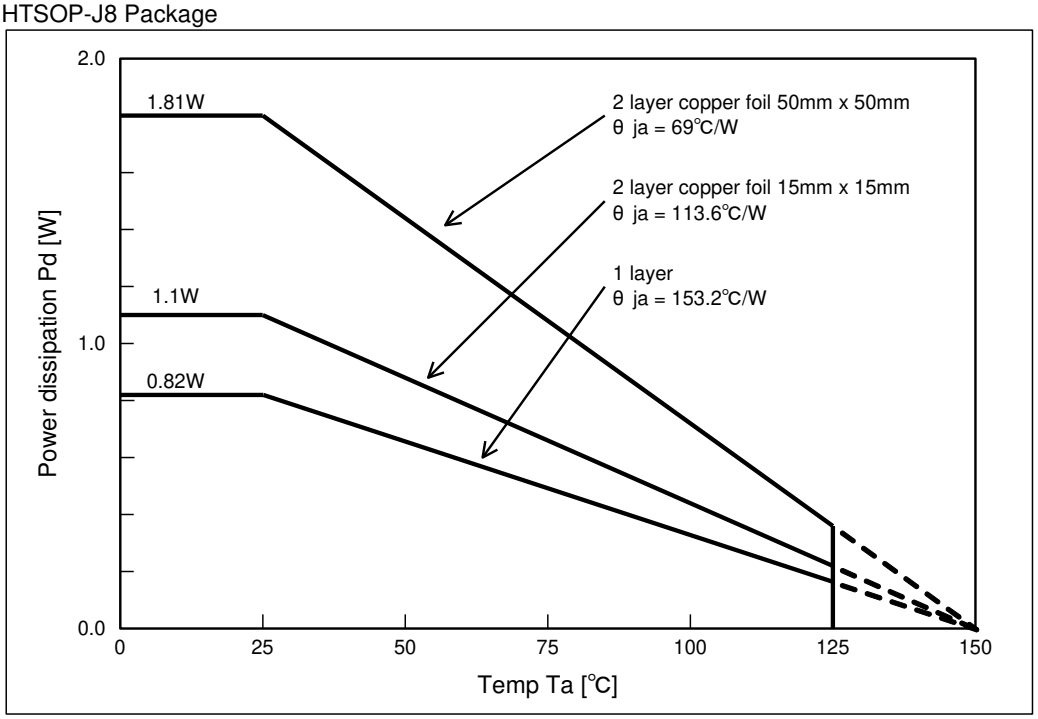
$Pd > Pc = (+B - V_{f\_diode} - V_{IN\_F\_REF} - V_{f\_led} \times N) \times I_{OUT} + I_{VIN} \times V_{IN}$
$Pd = (1/\theta ja) \times (Tjmax - Ta)$ or $(1/\theta jc) \times (Tjmax - Tc)$

where:
Pd is the Power Dissipation
Pc is the Power Consumption
+B is the Battery Voltage
V_{f_diode} is the Reverse Connection Preventing Diode Vf
$V_{IN\_F\_REF}$ is the VIN_F Terminal Voltage (V_{IN}-V_{IN_F})
V_{f_led} is the LED Vf
N is the Number of LED Levels
I_{OUT} is the Output Current
I_{VIN} is the Circuit Current
V_{IN} is the Power Supply Voltage
θja is the Thermal Resistance between Tj and Ta
θjc is the Thermal Resistance between Tj and Tc
Tjmax is the Max Joint Temperature (150°C)
Ta is the Ambient Temperature
Tc is the Case Surface Temperature

HRP7 Package



HTSOP-J8 Package



(Caution1) When mounted with 70.0mm X 70.0mm X 1.6mm glass epoxy substrate.
(Caution2) Above copper foil area indicates backside copper foil area.
(Caution3) Value changes according to number of substrate layers and copper foil area. Note that this value is a measured value, not a guaranteed value.

Figure 30. Thermal Dissipation Curve

Thermal Design for Few Number of LED Lamps

If there are few LED lamps, insert resistance between IOUT terminal and LED to reduce heat generation from IC and dissipate heat.
(This does not apply where amperage is low.)
In that case, note that guaranteed range of current accuracy will be as shown in the following equation:

$$+B \geq V_{f\_diode} + V_{f\_led} \times N + V_{IN\_F\_REF} + V_{DR\_IOUT} + I_{OUT} \times R1$$

V_{f_diode} is the Reverse Connection Preventing Diode Vf
V_{f_led} is the LED Vf
N is the Number of LED Levels
$V_{IN\_F\_REF}$ is the VIN_F Terminal Voltage (V_{IN} - V_{IN_F})
V_{DR_IOUT} is the IOUT Terminal Drop Voltage
I_{OUT} is the Output Current
R1 is the Thermal Dissipation Resistance

Thermal design should meet the following equation when inserting thermal dissipation resistance:

$$Pd > Pc = (+B - V_{f\_diode} - V_{IN\_F\_REF} - V_{f\_led} \times N) \times I_{OUT} + I_{VIN} \times V_{IN}$$
$$Pd = (1/\theta ja) \times (Tjmax - Ta) \text{ or } (1/\theta jc) \times (Tjmax - Tc)$$

Pd is the Power Dissipation
Pc is the Power Consumption
+B is the Battery Voltage
V_{f_diode} is the Reverse Connection Preventing Diode Vf
$V_{IN\_F\_REF}$ is the VIN_F Terminal Voltage (V_{IN} - V_{IN_F})
V_{f_led} is the LED Vf
N is the Number of LED Levels
I_{OUT} is the Output Current
R1 is the Thermal Dissipation Resistance
I_{VIN} is the Circuit Current
V_{IN} is the Power Supply Voltage
θja is the Thermal Resistance between Tj and Ta
θjc is the Thermal Resistance between Tj and Tc
Tjmax is the Max Joint Temperature (150°C)
Ta is the Ambient Temperature
Tc is the Case Surface Temperature

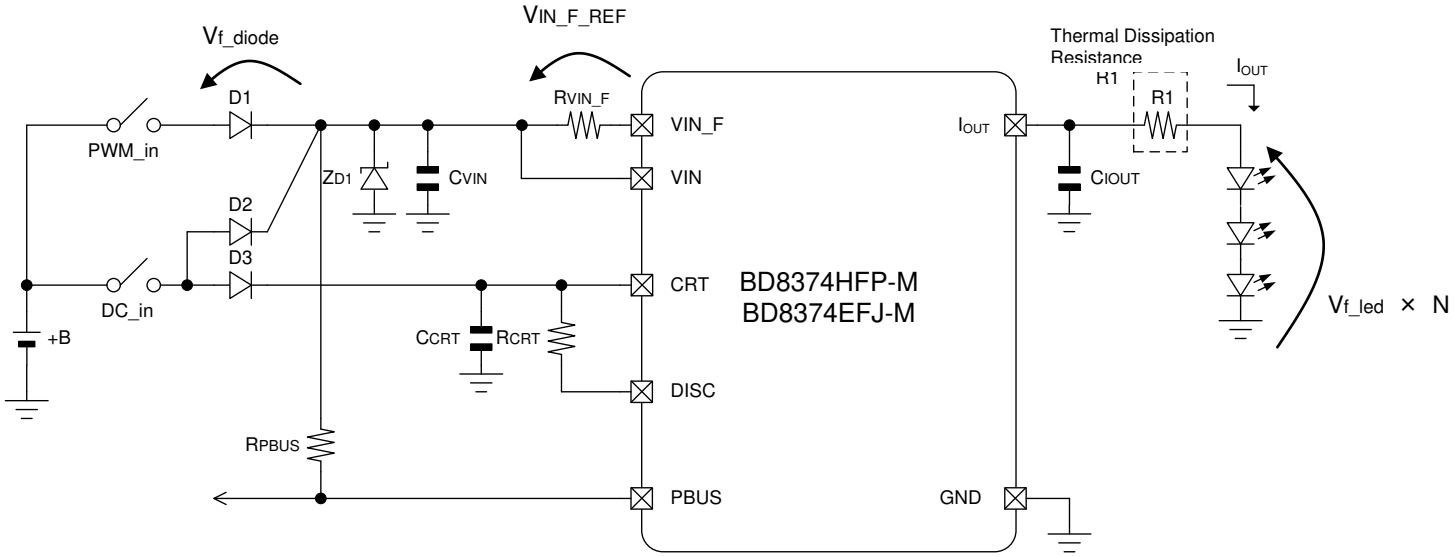
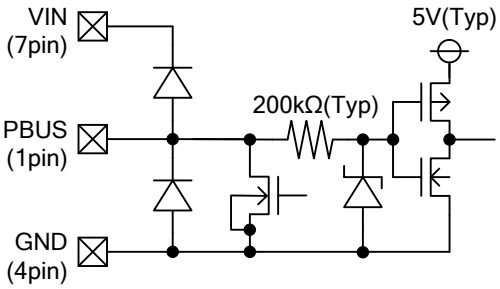
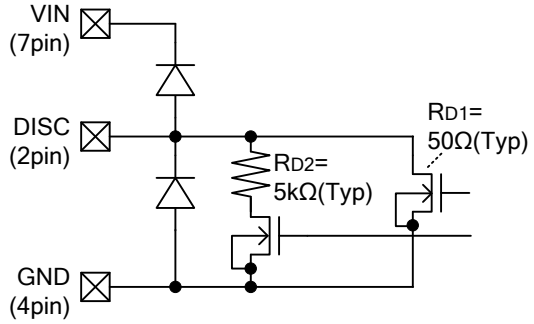
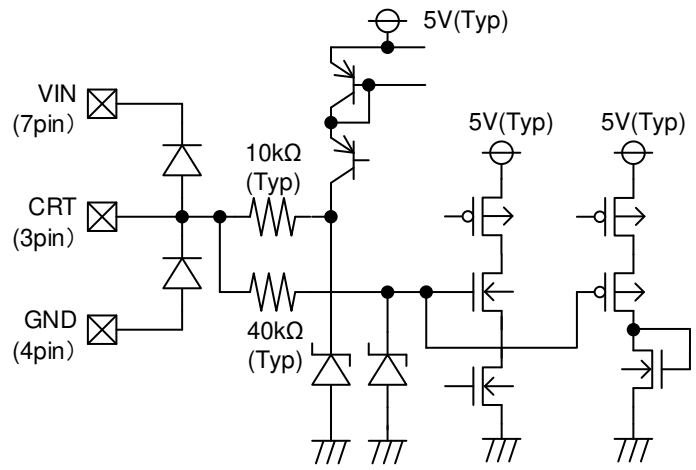
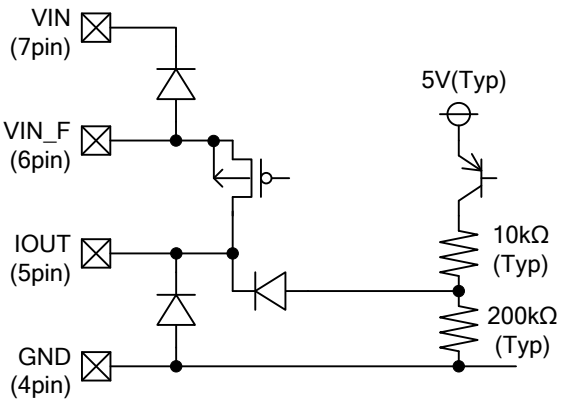


Figure 31. Example of How to Connect Thermal Dissipation Resistance

I/O equivalence circuits (HRP7 Package)

Number	Terminal Name	Equivalence Circuit
1	PBUS	
2	DISC	
3	CRT	
4	GND	-
5	IOUT	
6	VIN_F	
7	VIN	-

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 terminals.

2. **Power Supply Lines**
   Design the PCB layout pattern to provide low impedance supply lines. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. 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**
   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. **Thermal Consideration**
   Should by any chance the power dissipation rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. The absolute maximum rating of the Pd stated in this specification is when the IC is mounted on a 70mm x 70mm x 1.6mm glass epoxy board. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the Pd rating.

6. **Recommended Operating Conditions**
   These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.

7. **Rush 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.

8. **Operation Under Strong Electromagnetic Field**
   Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

9. **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.

10. **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.

Operational Notes – continued

11. Unused Input Terminals

Input terminals 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 terminals should be connected to the power supply or ground line.

12. 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.

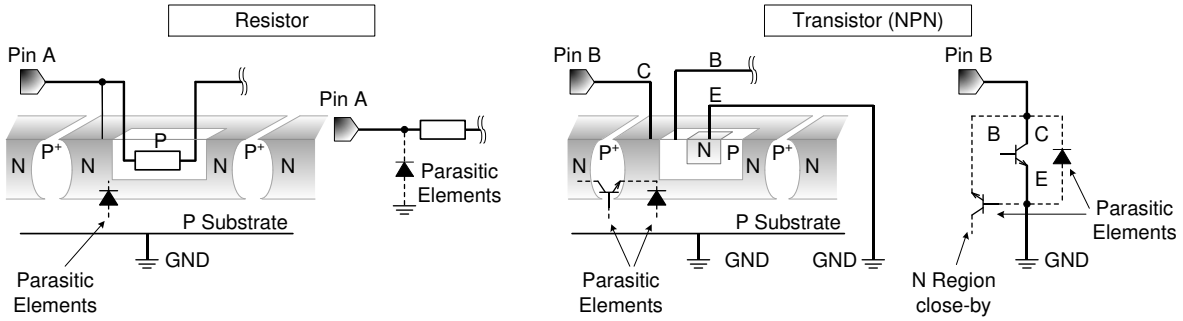


Figure 32. Example of monolithic IC structure

13. Ceramic Capacitor

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

14. Area of Safe Operation (ASO)

Operate the IC such that the output voltage, output current, and power dissipation are all within the Area of Safe Operation (ASO).

15. 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 power dissipation rating. If however the rating is exceeded for a continued period, the junction temperature (Tj) will rise which will activate the TSD circuit that will turn OFF all output pins. When the Tj 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.