



R1203x SERIES

STEP-UP DC/DC CONVERTER FOR WHITE LED BACK LIGHT

NO.EA-271-230418

OUTLINE

The R1203x Series are PWM control type step-up DC/DC converter ICs with low supply current.

The R1203x is fully dedicated to drive White LEDs with constant current. Each of these ICs consists of an NMOS FET, an oscillator, a PWM comparator, a voltage reference unit, an error amplifier, a current limit circuit, an under voltage lockout circuit (UVLO), and an over-voltage protection circuit (OVP).

The R1203x can drive white LEDs in constant current with high efficiency by using an inductor, a diode, a resistor and capacitors as external components.

The LEDs current can be set by an external resistance value and can adjust the dimming of LEDs by CE pin according to the signal of PWM. Feedback voltage is 0.2V, therefore power loss by current setting resistance is small and efficiency is good. Maximum duty cycle is internally fixed, Typ. 91%. LEDs can be driven from low voltage. Protection circuits are the current limit of Lx peak current, the over voltage limit of output, and the under voltage lockout function.

It is controllable the dimming of LEDs quickly when the PWM signal (between 200Hz to 300kHz) input to CE pin. If the CE pin input is "L" in the fixed time (Typ. 0.5ms), the IC becomes the standby mode and turns OFF LEDs.

FEATURES

- Supply Current Typ. 500 μ A
- Standby Current Max. 5 μ A
- Input Voltage Range 1.8V to 5.5V
- Feedback Voltage 0.2V
- Feedback Voltage Accuracy $\pm 1.0\%$ (± 10 mV)
- Temperature-Drift Coefficient of Feedback Voltage ... ± 150 ppm/ $^{\circ}$ C
- Oscillator Frequency Typ. 1.2MHz
- Maximum Duty Cycle Typ. 91%
- Switch ON Resistance Typ. 1.35 Ω
- UVLO Detector Threshold Typ. 1.6V
- Lx Current Limit Protection Typ. 700mA
- OVP Detector Threshold Typ. 29.5V
- Switching Control PWM
- LED dimming control by external PWM signal (Frequency 200Hz to 300kHz)
- Packages DFN1616-6B, SOT-23-6
- Ceramic capacitors are recommended 0.22 μ F

APPLICATION

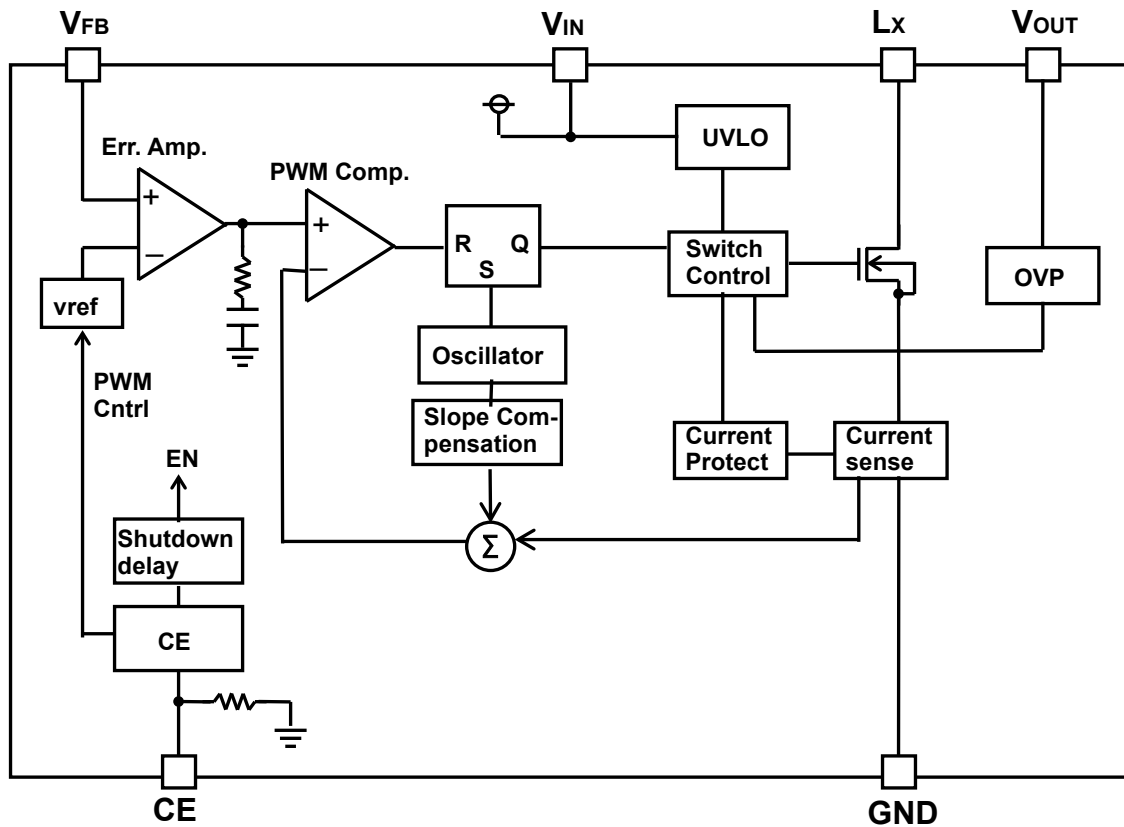
- White LED Backlight for portable equipment

SELECTION GUIDE

The package for the ICs can be selected at the user's request.

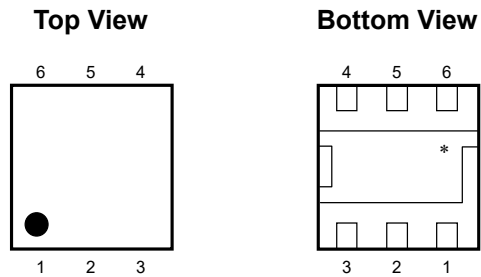
Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1203L071B-TR	DFN1616-6B	5,000 pcs	Yes	Yes
R1203N071B-TR-FE	SOT-23-6	3,000 pcs	Yes	Yes

BLOCK DIAGRAMS

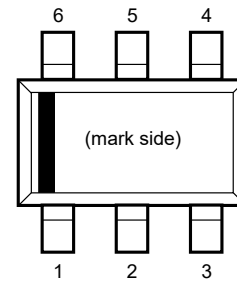


PIN DESCRIPTIONS

• DFN1616-6B



• SOT-23-6



• DFN1616-6B

Pin No	Symbol	Pin Description
1	CE	Chip Enable Pin ("H" Active)
2	V_{FB}	Feedback Pin
3	L_x	Switching Pin (Open Drain Output)
4	GND	Ground Pin
5	V_{IN}	Input Pin
6	V_{OUT}	Output Pin

*) Tab is GND level. (They are connected to the reverse side of this IC.)

The tab is better to be connected to the GND, but leaving it open is also acceptable.

• SOT-23-6

Pin No	Symbol	Pin Description
1	CE	Chip Enable Pin ("H" Active)
2	V_{OUT}	Output Pin
3	V_{IN}	Input Pin
4	L_x	Switching Pin (Open Drain Output)
5	GND	Ground Pin
6	V_{FB}	Feedback Pin

ABSOLUTE MAXIMUM RATINGS

(GND=0V)

Symbol	Item		Rating	Unit
V_{IN}	V_{IN} Pin Voltage		-0.3 to 6.5	V
V_{CE}	CE Pin Voltage		-0.3 to $V_{IN}+0.3$	V
V_{FB}	V_{FB} Pin Voltage		-0.3 to $V_{IN}+0.3$	V
V_{OUT}	V_{OUT} Pin Voltage		-0.3 to 32	V
V_{LX}	L_X Pin Voltage		-0.3 to 32	V
I_{LX}	L_X Pin Current		1000	mA
P_D	Power Dissipation * (JEDEC STD. 51-7 Test Land Pattern)	DFN1616-6B	2400	mW
		SOT-23-6	660	
T_j	Junction Temperature Range		-40 to 125	°C
T_{stg}	Storage Temperature Range		-55 to 125	°C

*) Refer to *POWER DISSIPATION* for detailed information.

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the life time and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

RECOMMENDED OPERATING CONDITIONS

Symbol	Item	Rating	Unit
V_{IN}	Input Voltage	1.8 to 5.5	V
T_a	Operating Temperature Range	-40 to 85	°C

RECOMMENDED OPERATING CONDITIONS

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such ratings by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

ELECTRICAL CHARACTERISTICS• **R1203x**

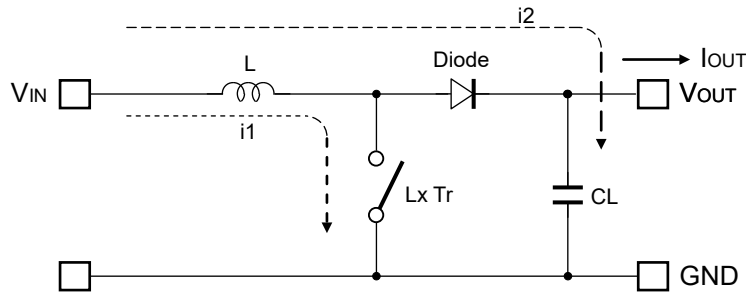
(Ta=25°C)

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
I _{DD}	Supply Current	V _{IN} =5.5V, V _{FB} =0V, Lx at no load		0.5	1.0	mA
I _{standby}	Standby Current	V _{IN} =5.5V, V _{CE} =0V		1.0	5.0	μA
V _{UVLO1}	UVLO Detector Threshold	V _{IN} falling	1.5	1.6	1.7	V
V _{UVLO2}	UVLO Released Voltage	V _{IN} rising		V _{UVLO1} +0.1	1.8	V
V _{CEH}	CE Input Voltage "H"	V _{IN} =5.5V	1.5			V
V _{CEL}	CE Input Voltage "L"	V _{IN} =1.8V			0.5	V
R _{CE}	CE Pull Down Resistance	V _{IN} =3.6V	600	1200	2200	kΩ
V _{FB}	V _{FB} Voltage Accuracy	V _{IN} =V _{CE} =3.6V	0.19	0.20	0.21	V
ΔV _{FB} / ΔT _a	V _{FB} Voltage Temperature Coefficient	V _{IN} =V _{CE} =3.6V, -40°C ≤ T _a ≤ 85°C		±150		ppm/°C
I _{FB}	V _{FB} Input Current	V _{IN} =5.5V, V _{FB} =0V or V _{IN}	-0.1		0.1	μA
R _{ON}	Switch ON Resistance	V _{IN} =3.6V, I _{LX} =100mA		1.35		Ω
I _{LXleak}	Switch Leakage Current	V _{LX} =30V		0	3.0	μA
I _{LXlim}	Switch Current Limit	V _{IN} =3.6V	400	700	1000	mA
f _{osc}	Oscillator Frequency	V _{IN} =3.6V, V _{OUT} =V _{FB} =0V	1.0	1.2	1.4	MHz
Maxduty	Maximum Duty Cycle	V _{IN} =3.6V, V _{OUT} =V _{FB} =0V	86	91		%
V _{OVP1}	OVP Detector Threshold	V _{IN} =3.6V, V _{OUT} rising	28.7	29.5	30.3	V
ΔV _{OVP1} / ΔT _a	V _{OVP1} Voltage Temperature Coefficient	V _{IN} =V _{CE} =3.6V, -40°C ≤ T _a ≤ 85°C		±150		ppm/°C
V _{OVP2}	OVP Released Voltage	V _{IN} =3.6V, V _{OUT} falling		V _{OVP1} -1.55		V

THEORY OF OPERATION

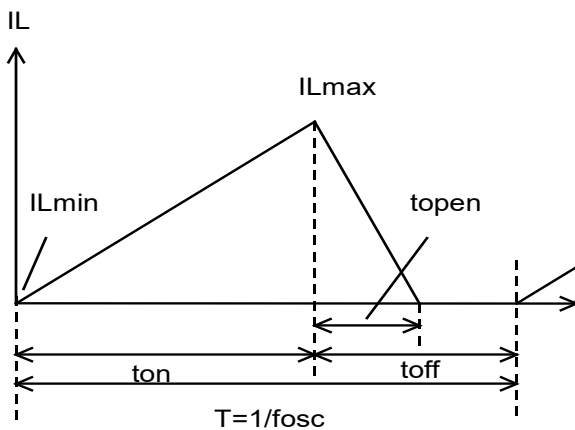
Operation of Step-Up DC/DC Converter and Output Current

<Basic Circuit>

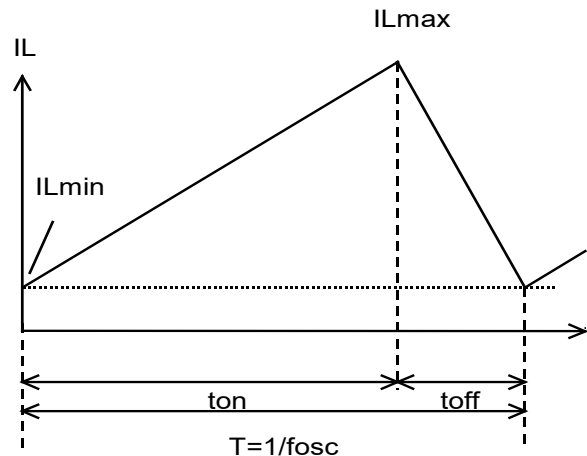


<Current through L>

Discontinuous mode



Continuous mode



There are two operation modes of the step-up PWM control-DC/DC converter. That is the continuous mode and discontinuous mode by the continuousness inductor.

When the transistor turns ON, the voltage of inductor L becomes equal to V_{IN} voltage. The increase value of inductor current ($i1$) will be

$$\Delta i1 = V_{IN} \times t_{on} / L \dots \dots \dots \text{Formula 1}$$

As the step-up circuit, during the OFF time (when the transistor turns OFF) the voltage is continually supply from the power supply. The decrease value of inductor current ($i2$) will be

$$\Delta i2 = (V_{OUT} - V_{IN}) \times t_{off} / L \dots \dots \dots \text{Formula 2}$$

At the PWM control-method, the inductor current become continuously when $t_{open}=t_{off}$, the DC/DC converter operate as the continuous mode.

In the continuous mode, the variation of current of i_1 and i_2 is same at regular condition.

$$V_{IN} \times t_{on} / L = (V_{OUT} - V_{IN}) \times t_{off} / L \dots\dots\dots \text{Formula 3}$$

The duty at continuous mode will be

$$\text{duty (\%)} = t_{on} / (t_{on} + t_{off}) = (V_{OUT} - V_{IN}) / V_{OUT} \dots\dots\dots \text{Formula 4}$$

The average of inductor current at $t_f = t_{off}$ will be

$$I_L(\text{Ave.}) = V_{IN} \times t_{on} / (2 \times L) \dots\dots\dots \text{Formula 5}$$

If the input voltage = output voltage, the I_{OUT} will be

$$I_{OUT} = V_{IN}^2 \times t_{on} / (2 \times L \times V_{OUT}) \dots\dots\dots \text{Formula 6}$$

If the I_{OUT} value is large than above the calculated value (Formula 6), it will become the continuous mode, at this status, the peak current (I_{Lmax}) of inductor will be

$$I_{Lmax} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times t_{on} / (2 \times L) \dots\dots\dots \text{Formula 7}$$

$$I_{Lmax} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times T \times (V_{OUT} - V_{IN}) / (2 \times L \times V_{OUT}) \dots\dots\dots \text{Formula 8}$$

The peak current value is larger than the I_{OUT} value. In case of this, selecting the condition of the input and the output and the external components by considering of I_{Lmax} value.

The explanation above is based on the ideal calculation, and the loss caused by L_x switch and the external components are not included.

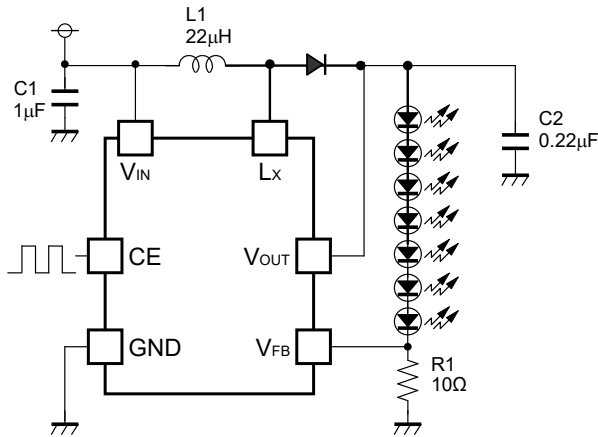
The actual maximum output current will be between 50% and 80% by the above calculations. Especially, when the I_L is large or V_{IN} is low, the loss of V_{IN} is generated with on resistance of the switch. Moreover, it is necessary to consider V_f of the diode (approximately 0.8V) about V_{OUT} .

● Soft-Start

The output of the error amplifier starts from 0V and the inrush current is suppressed when starting by the CE pin "H" input. Moreover, the inrush current can be suppressed by gradually enlarging Duty of the PWM signal to the CE pin.

APPLICATION INFORMATION

• Typical Applications



• Selection of Inductors

The peak current of the inductor at normal mode can be estimated as the next formula when the efficiency is 80%.

$$I_{Lmax} = 1.25 \times I_{OUT} \times V_{OUT} / V_{IN} + 0.5 \times V_{IN} \times (V_{OUT} - V_{IN}) / (L \times V_{OUT} \times f_{osc})$$

In the case of start-up or dimming control by CE pin, inductor transient current flows, and the peak current of it must be equal or less than the current limit of the IC. The peak current should not beyond the rated current of the inductor. The recommended inductance value is 10-22μH.

Table 1 Peak current value in each condition

Condition				
V _{IN} (V)	V _{OUT} (V)	I _{OUT} (mA)	L (μH)	I _{Lmax} (mA)
3	14	20	10	215
3	14	20	22	160
3	21	20	10	280
3	21	20	22	225

Table 2 Recommended inductors

L (μH)	Part No.	Rated Current (mA)	Size (mm)
10	LQH32CN100K53	450	3.2x2.5x1.55
10	LQH2MC100K02	225	2.0x1.6x0.9
10	VLF3010A-100	490	2.8x2.6x0.9
10	VLS252010-100	520	2.5x2.0x1.0
22	LQH32CN220K53	250	3.2x2.5x1.55
22	LQH2MC220K02	185	2.0x1.6x0.9
22	VLF3010A-220	330	2.8x2.6x0.9

• Selection of Capacitors

Set 1 μ F or more value bypass capacitor C1 between V_{IN} pin and GND pin as close as possible.

Set 0.22 μ F or more capacitor C2 between V_{OUT} and GND pin.

Note the V_{OUT} that depends on LED used, and select the rating of V_{OUT} or more.

• Selection of SBD (Schottky Barrier Diode)

Select the diode with low V_F such as Schottky type with low reverse current I_R, and with low capacitance.

Table 3 Recommended components

	Rated voltage (V)	Part No.
C1	6.3	CM105B105K06
C2	25	GRM21BR11E224
	50	GRM21BR71H224
D1	30	CRS10I30A
	30	RSX051VA-30

• LED Current Setting

When CE pin input is "H" (Duty=100%), LED current can be set with feedback resistor (R1)

$$I_{LED} = V_{FB} / R1$$

• LED Dimming Control

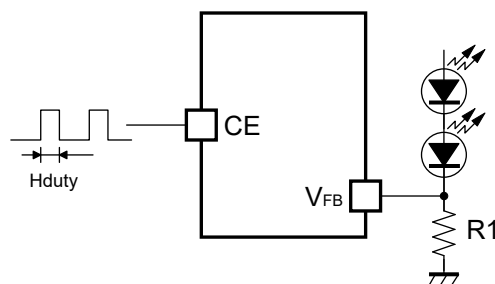
The LED brightness can be controlled by inputting the PWM signal to the CE pin. If the CE pin input is "L" in the fixed time (Typ.0.5ms), the IC becomes the standby mode and turns OFF LEDs.

The current of LEDs when the CE pin is "H" input (Duty=100%) is shown by the above expression. The current of LEDs can be controlled by Duty of the PWM signal of the input CE pin. The current of LEDs when High-Duty of the CE input is Hduty reaches the value as calculatable following formula.

$$I_{LED} = Hduty \times V_{FB} / R1$$

The frequency of the PWM signal is using the range between 200Hz to 300kHz.

When controlling the LED brightness by the PWM signal of 20kHz or less; The increasing or decreasing of the inductor current might be make a sounds in the hearable sound wave area. In that case, please use the PWM signal in the high frequency area.



Dimming control by CE pin input

TECHNICAL NOTES

● Current Path on PCB

The current paths in an application circuit are shown in Fig. 1 and 2.

A current flows through the paths shown in Fig. 1 at the time of MOSFET-ON, and shown in Fig. 2 at the time of MOSFET-OFF. In the paths pointed with red arrows in Fig. 2, current flows just in MOSFET-ON period or just in MOSFET-OFF period. Parasitic impedance/inductance and the capacitance of these paths influence stability of the system and cause noise outbreak. So please minimize this side effect. In addition, please shorten the wiring of other current paths shown in Fig. 1 and 2 except for the paths of LED load.

● Layout Guide for PCB

- Please shorten the wiring of the input capacitor (C1) between V_{IN} pin and GND pin of IC. The GND pin should be connected to the strong GND plane.
- The area of L_x land pattern should be smaller.
- The wiring between L_x pin and inductor and diode should be short and please put output capacitor (C2) close to the cathode of diode.
- Please make the GND side of output capacitor (C2) close to the GND pin of IC.

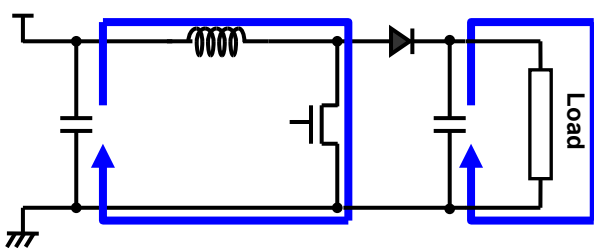


Fig. 1 MOSFET-ON

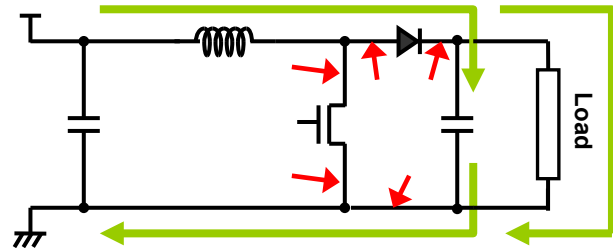
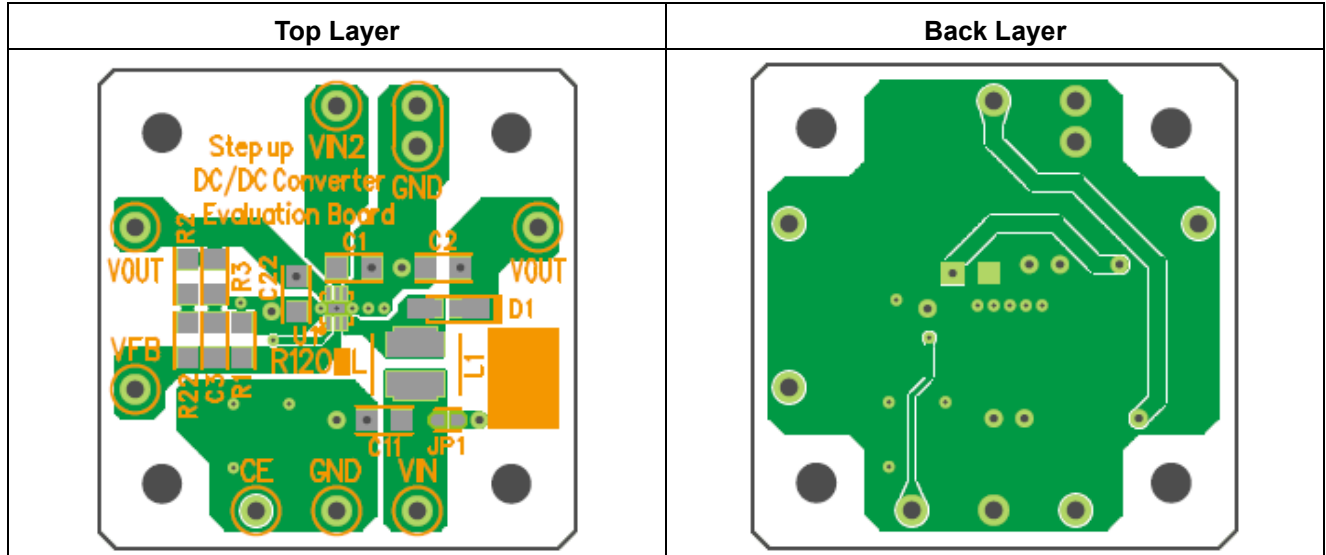


Fig. 2 MOSFET-OFF

● PCB Layout

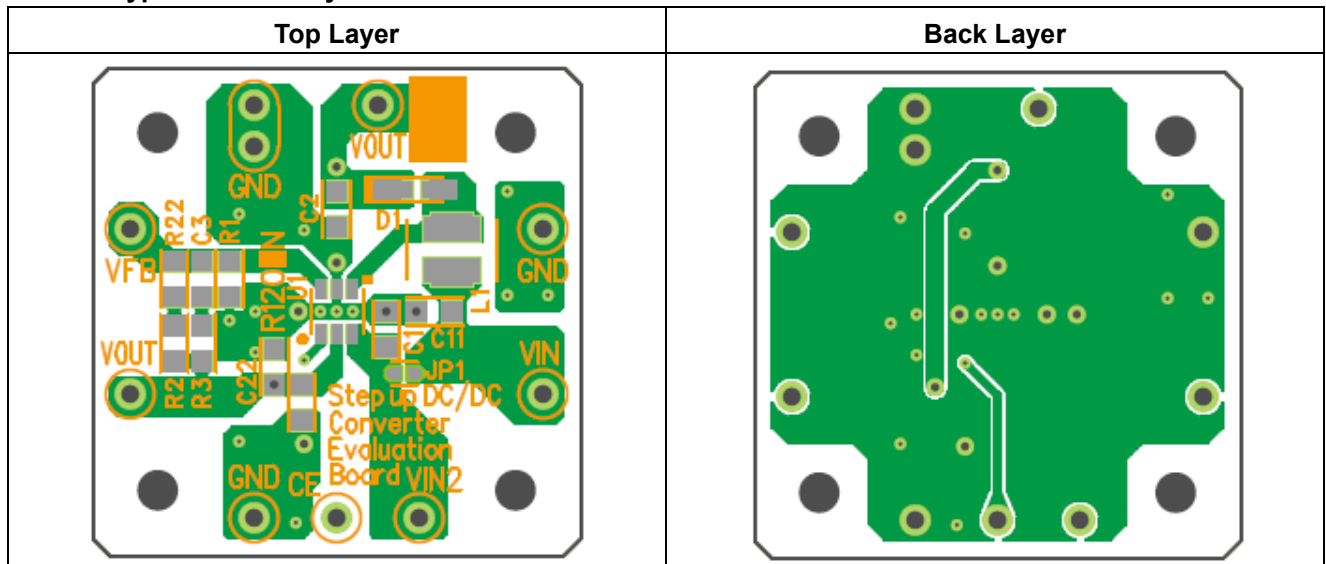
- PKG: DFN1616-6B pin

R1203L Typical Board Layout



- PKG: SOT-23-6pin

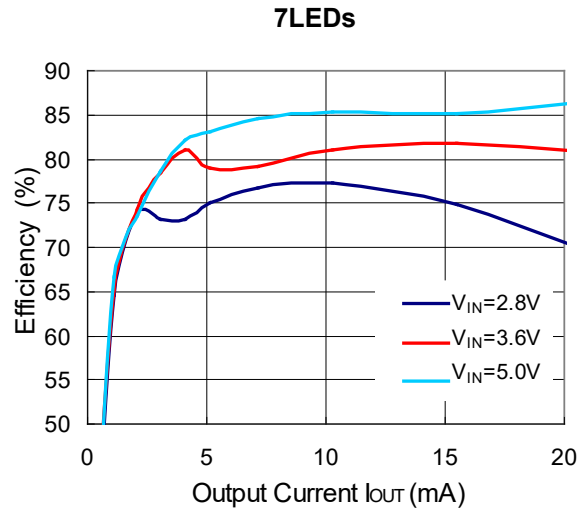
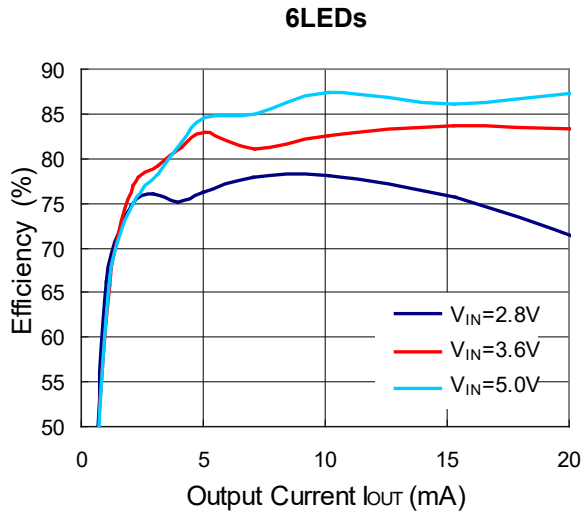
R1203N Typical Board Layout



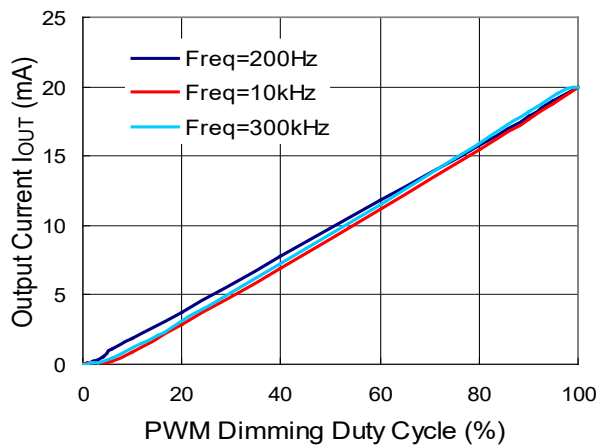
U1-● indicates the position of No.1 pin.

TYPICAL CHARACTERISTICS

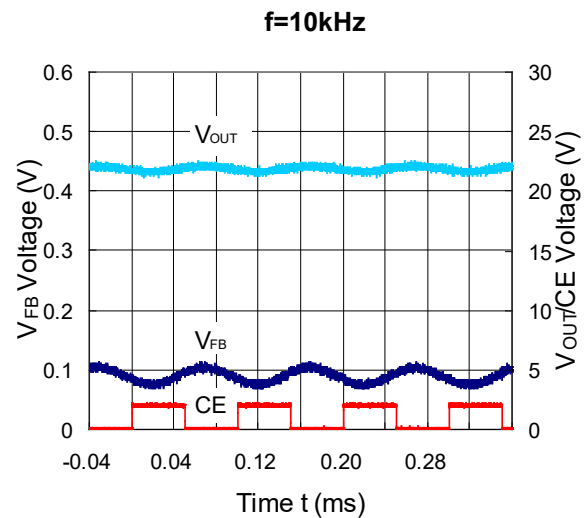
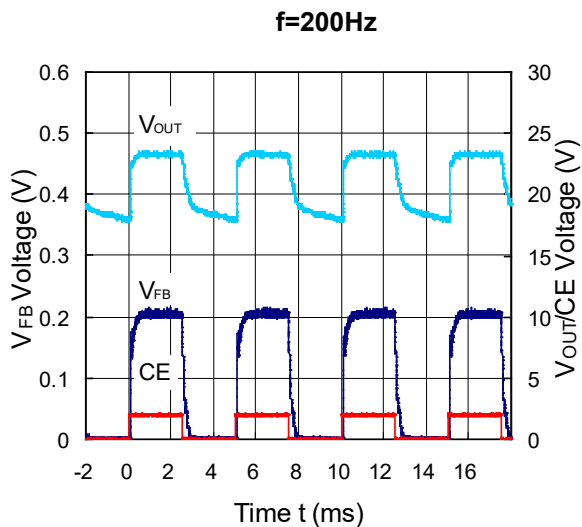
1) Efficiency vs. Output Current Characteristics

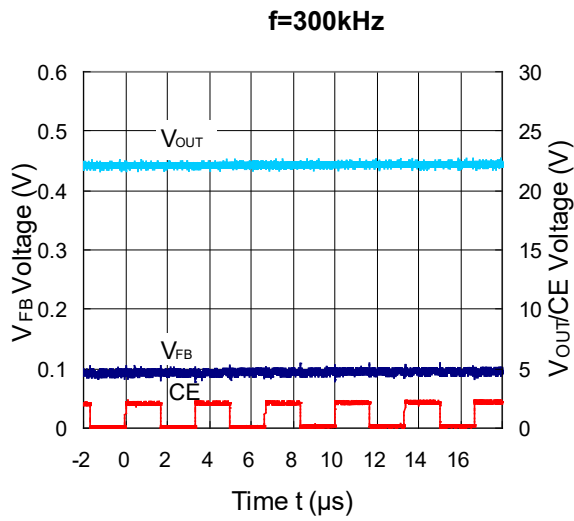


2) PWM Dimming Duty Cycle vs. Output Current ($R1=10\Omega$)

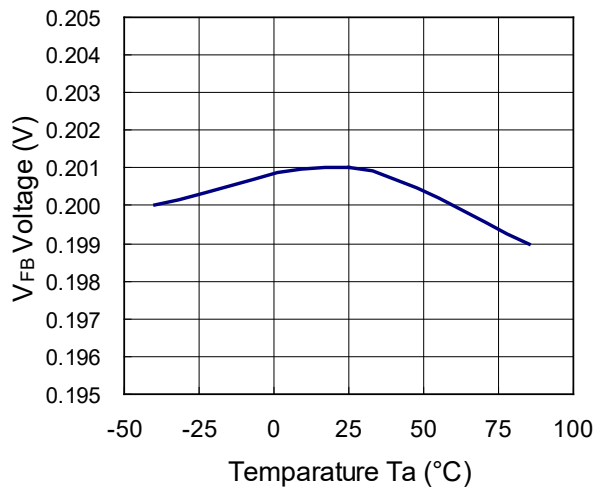


3) Output Current Ripple during PWM Dimming

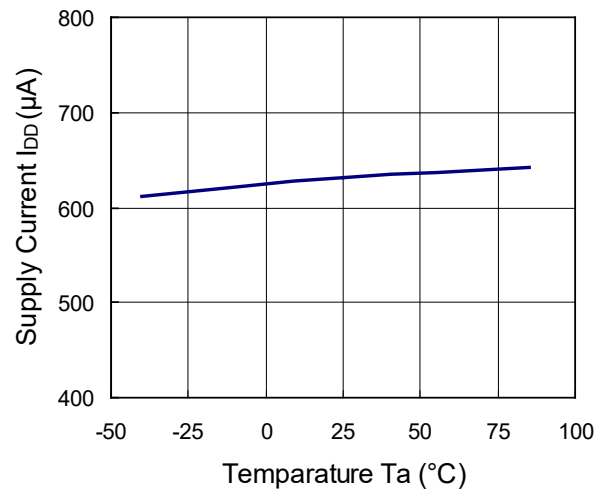




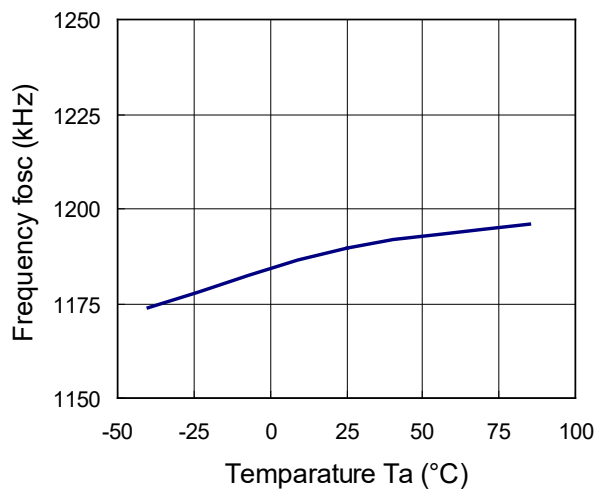
4) VFB Voltage vs. Temperature



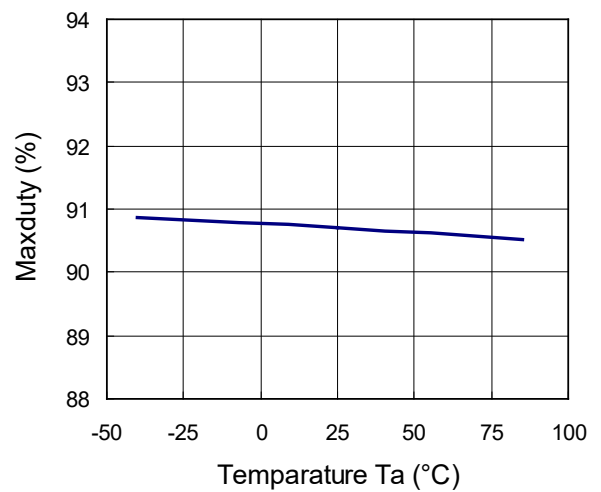
5) Supply Current vs. Temperature



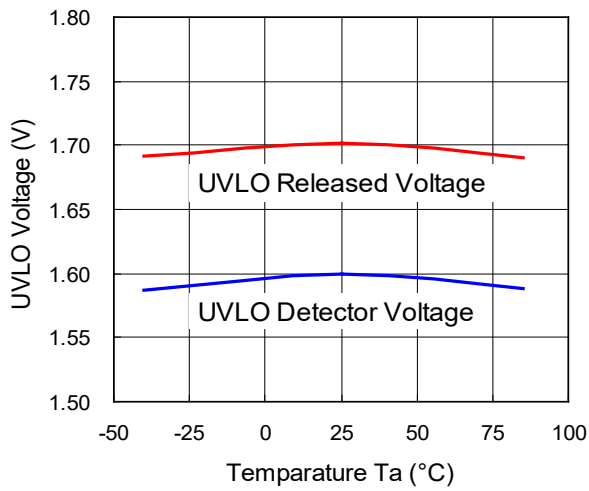
6) Oscillator Frequency vs. Temperature



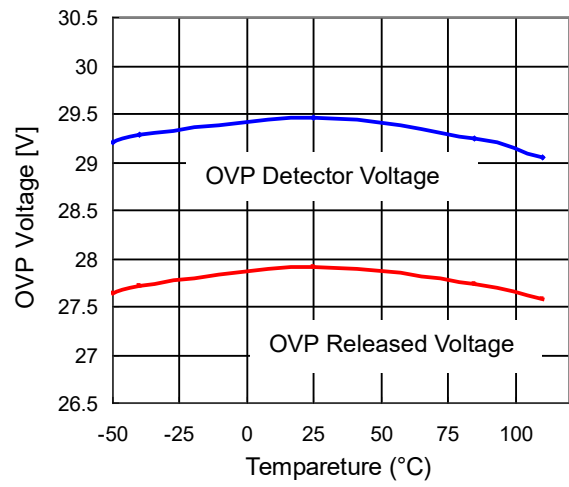
7) Maxduty vs. Temperature



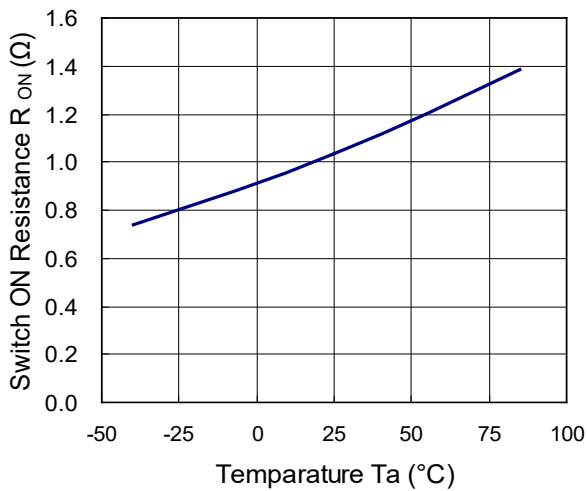
8) UVLO Output Voltage vs. Temperature



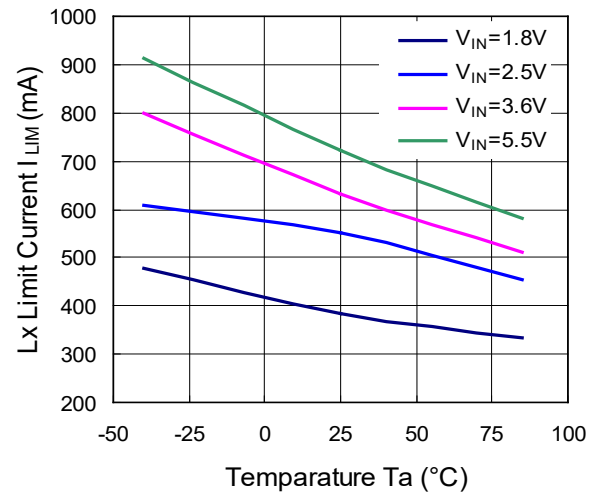
9) OVP Voltage vs. Temperature



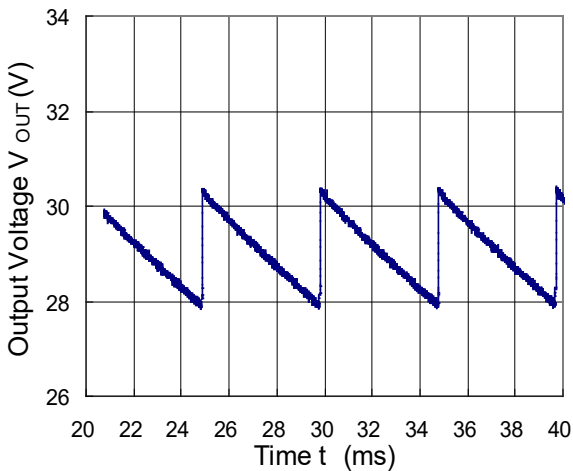
10) Switch ON Resistance vs. Temperature



11) Lx Current Limit vs. Temperature



12) OVP Operating Output Voltage Waveform



POWER DISSIPATION

DFN1616-6B

Ver. A

The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following conditions are used in this measurement.

Measurement Conditions

Item	Measurement Conditions (JEDEC STD. 51-7)
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 0.8 mm
Copper Ratio	1st Layer: Less than 95% of 50 mm Square 2nd, 3rd, 4th Layers: Approx. 100% of 50 mm Square
Through-holes	φ 0.2 mm × 15 pcs

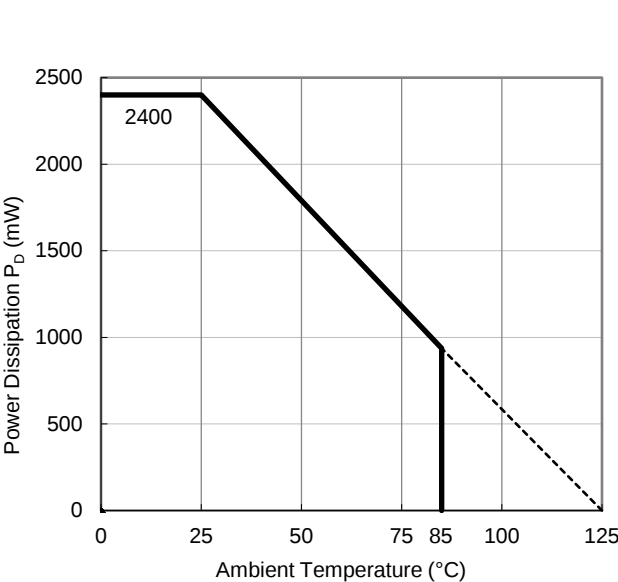
Measurement Result

(Ta = 25°C, Tjmax = 125°C)

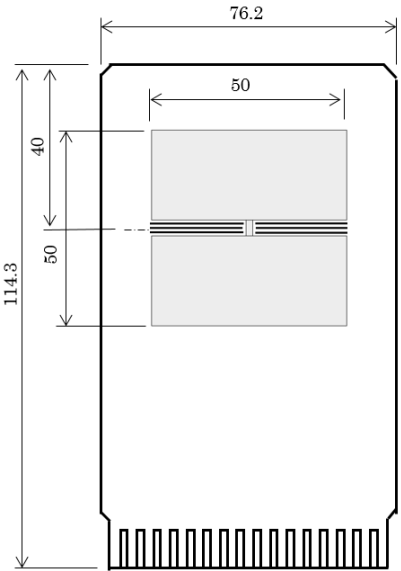
Item	Measurement Result
Power Dissipation	2400 mW
Thermal Resistance (θja)	θja = 41°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 11°C/W

θja: Junction-to–ambient thermal resistance.

ψjt: Junction–to–top of package thermal characterization parameter.



Power Dissipation vs. Ambient Temperature

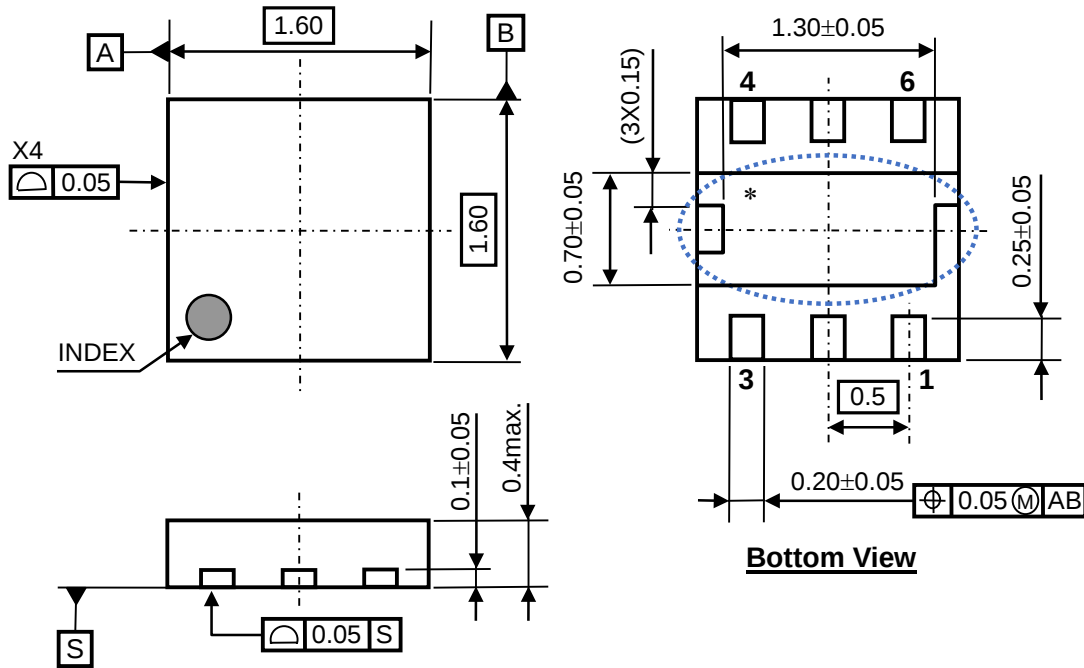


Measurement Board Pattern

PACKAGE DIMENSIONS

DFN1616-6B

Ver. A



DFN1616-6B Package Dimensions (Unit: mm)

* The tab on the bottom of the package shown by blue circle is a substrate potential (GND). It is recommended that this tab be connected to the ground plane pin on the board but it is possible to leave the tab floating.

POWER DISSIPATION

SOT-23-6

Ver. A

The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following conditions are used in this measurement.

Measurement Conditions

Item	Measurement Conditions (JEDEC STD. 51-7)
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 0.8 mm
Copper Ratio	1st Layer : Less than 95% of 50 mm Square 2nd, 3rd, 4th Layers: Approx. 100% of 50 mm Square
Through-holes	φ 0.3 mm × 7 pcs

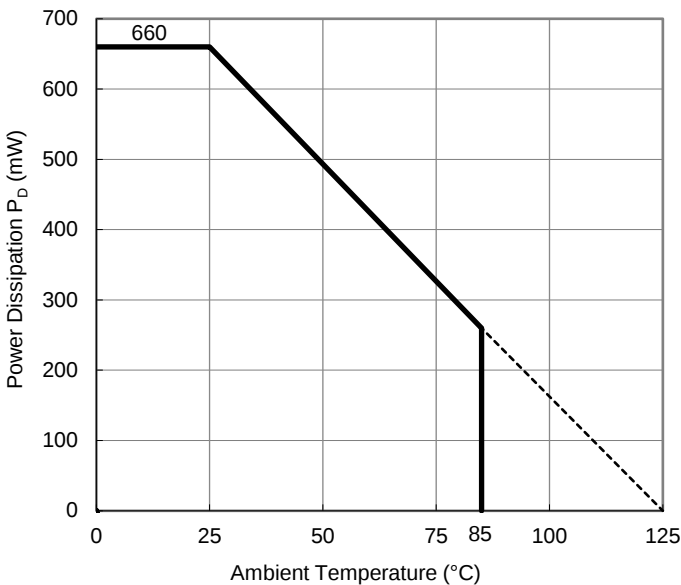
Measurement Result

(Ta = 25°C, Tjmax = 125°C)

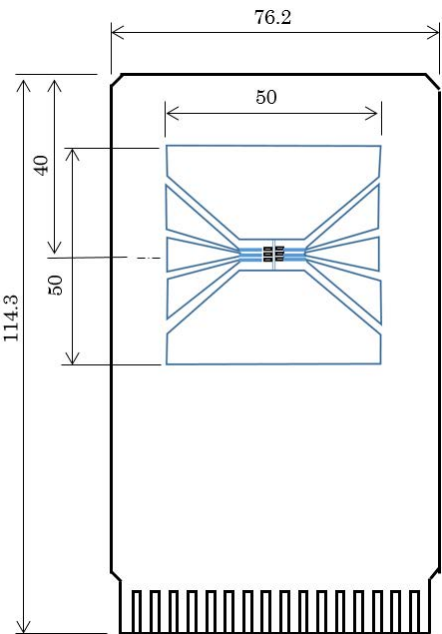
Item	Measurement Result
Power Dissipation	660 mW
Thermal Resistance (θja)	θja = 150°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 51°C/W

θja: Junction-to-ambient thermal resistance.

ψjt: Junction-to-top of package thermal characterization parameter



Power Dissipation vs. Ambient Temperature

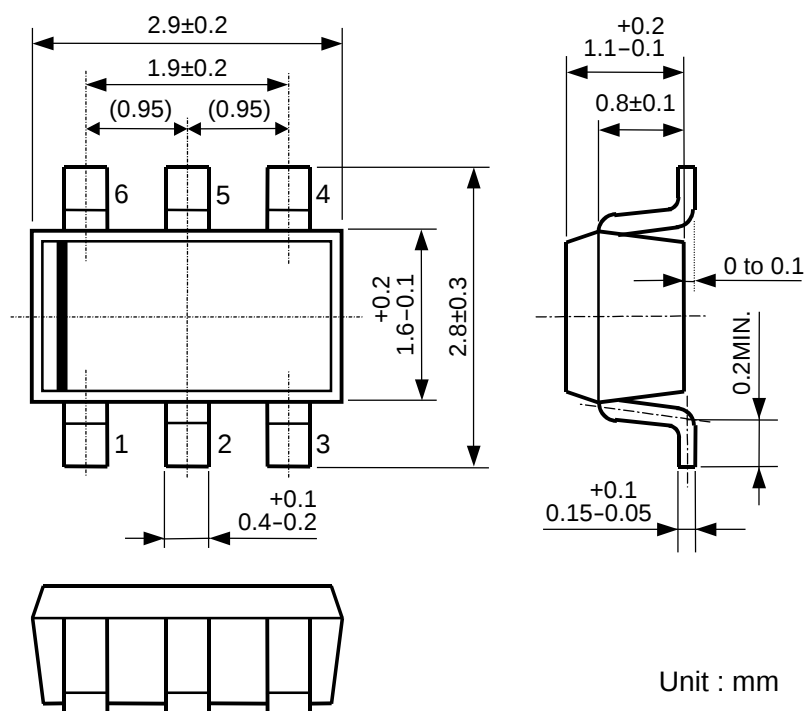


Measurement Board Pattern

PACKAGE DIMENSIONS

SOT-23-6

Ver. A



SOT-23-6 Package Dimensions

1. The products and the product specifications described in this document are subject to change or discontinuation of production without notice for reasons such as improvement. Therefore, before deciding to use the products, please refer to our sales representatives for the latest information thereon.
2. The materials in this document may not be copied or otherwise reproduced in whole or in part without the prior written consent of us.
3. This product and any technical information relating thereto are subject to complementary export controls (so-called KNOW controls) under the Foreign Exchange and Foreign Trade Law, and related politics ministerial ordinance of the law. (Note that the complementary export controls are inapplicable to any application-specific products, except rockets and pilotless aircraft, that are insusceptible to design or program changes.) Accordingly, when exporting or carrying abroad this product, follow the Foreign Exchange and Foreign Trade Control Law and its related regulations with respect to the complementary export controls.
4. The technical information described in this document shows typical characteristics and example application circuits for the products. The release of such information is not to be construed as a warranty of or a grant of license under our or any third party's intellectual property rights or any other rights.
5. The products listed in this document are intended and designed for use as general electronic components in standard applications (office equipment, telecommunication equipment, measuring instruments, consumer electronic products, amusement equipment etc.). Those customers intending to use a product in an application requiring extreme quality and reliability, for example, in a highly specific application where the failure or misoperation of the product could result in human injury or death should first contact us.
 - Aerospace Equipment
 - Equipment Used in the Deep Sea
 - Power Generator Control Equipment (nuclear, steam, hydraulic, etc.)
 - Life Maintenance Medical Equipment
 - Fire Alarms / Intruder Detectors
 - Vehicle Control Equipment (automotive, airplane, railroad, ship, etc.)
 - Various Safety Devices
 - Traffic control system
 - Combustion equipment

In case your company desires to use this product for any applications other than general electronic equipment mentioned above, make sure to contact our company in advance. Note that the important requirements mentioned in this section are not applicable to cases where operation requirements such as application conditions are confirmed by our company in writing after consultation with your company.

6. We are making our continuous effort to improve the quality and reliability of our products, but semiconductor products are likely to fail with certain probability. In order to prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design, such as redundancy feature, fire containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.
7. The products have been designed and tested to function within controlled environmental conditions. Do not use products under conditions that deviate from methods or applications specified in this datasheet. Failure to employ the products in the proper applications can lead to deterioration, destruction or failure of the products. We shall not be responsible for any bodily injury, fires or accident, property damage or any consequential damages resulting from misuse or misapplication of the products.
8. **Quality Warranty**
 - 8-1. **Quality Warranty Period**
In the case of a product purchased through an authorized distributor or directly from us, the warranty period for this product shall be one (1) year after delivery to your company. For defective products that occurred during this period, we will take the quality warranty measures described in section 8-2. However, if there is an agreement on the warranty period in the basic transaction agreement, quality assurance agreement, delivery specifications, etc., it shall be followed.
 - 8-2. **Quality Warranty Remedies**
When it has been proved defective due to manufacturing factors as a result of defect analysis by us, we will either deliver a substitute for the defective product or refund the purchase price of the defective product.
Note that such delivery or refund is sole and exclusive remedies to your company for the defective product.
 - 8-3. **Remedies after Quality Warranty Period**
With respect to any defect of this product found after the quality warranty period, the defect will be analyzed by us. On the basis of the defect analysis results, the scope and amounts of damage shall be determined by mutual agreement of both parties. Then we will deal with upper limit in Section 8-2. This provision is not intended to limit any legal rights of your company.
9. Anti-radiation design is not implemented in the products described in this document.
10. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
11. WLCSP products should be used in light shielded environments. The light exposure can influence functions and characteristics of the products under operation or storage.
12. Warning for handling Gallium and Arsenic (GaAs) products (Applying to GaAs MMIC, Photo Reflector). These products use Gallium (Ga) and Arsenic (As) which are specified as poisonous chemicals by law. For the prevention of a hazard, do not burn, destroy, or process chemically to make them as gas or power. When the product is disposed of, please follow the related regulation and do not mix this with general industrial waste or household waste.
13. Please contact our sales representatives should you have any questions or comments concerning the products or the technical information.



Nisshinbo Micro Devices Inc.

Official website

<https://www.nisshinbo-microdevices.co.jp/en/>

Purchase information

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