RICOH

R1203x SERIES

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

NO.EA-271-180703

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. 500μA
- Standby Current .... Max. 5μA
- Input Voltage Range .... 1.8V to 5.5V
- Feedback Voltage 0.2V
- Feedback Voltage Accuracy .... ±1.0% (±10mV)
- Temperature-Drift Coefficient of Feedback Voltage ... ±150ppm/°C
- Oscillator Frequency .... Typ. 1.2MHz
- Maximum Duty Cycle .... Typ. 91%
- Switch ON Resistance... Typ. 1.35Ω
- 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..................... 0.22μF

APPLICATION

- White LED Backlight for portable equipment

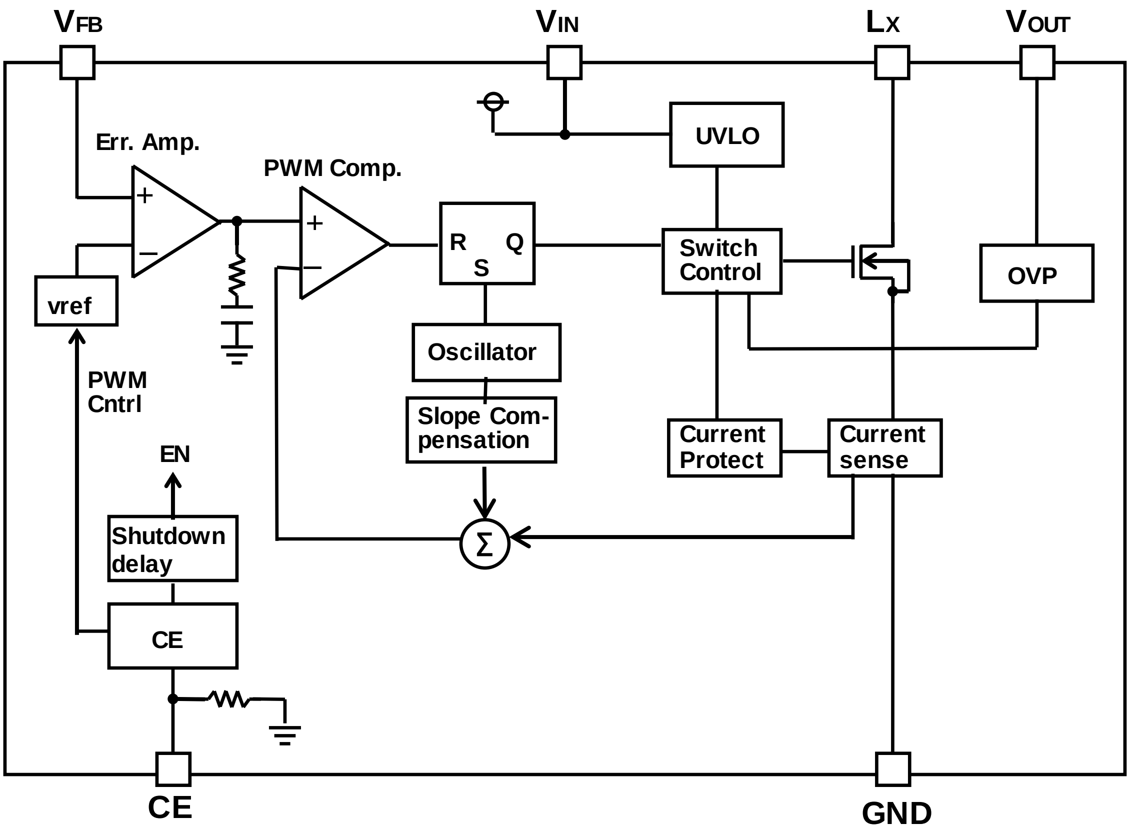
*R1203L(DFN1616-6B) is the non-promotional product of as February 2021.

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



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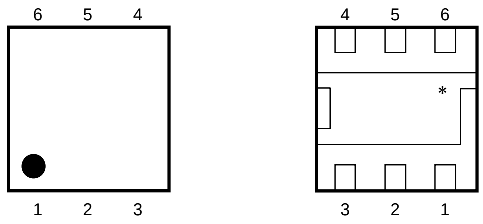
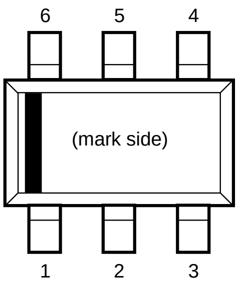
PIN DESCRIPTIONS

- **DFN1616-6B**

Top View **Bottom View**



- **SOT-23-6**



- **DFN1616-6B**

Pin No	Symbol	Pin Description
1	CE	Chip Enable Pin ("H" Active)
2	V_{FB}	Feedback Pin
3	Lx	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	Lx	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	
Tj	Junction Temperature Range		−40 to 125	°C
Tstg	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
Ta	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**

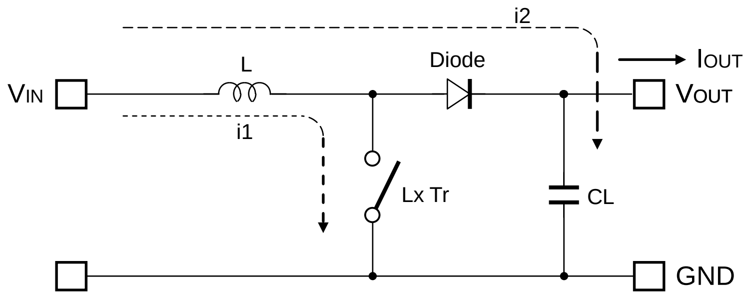
(Ta=25°C)

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
Istandby	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
$\Delta V_{FB}/\Delta Ta$	V_{FB} Voltage Temperature Coefficient	V_{IN}=V_{CE}=3.6V, -40°C ≤ Ta ≤ 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
fosc	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
$\Delta V_{OVP1}/\Delta Ta$	V_{OVP1} Voltage Temperature Coefficient	V_{IN}=V_{CE}=3.6V, −40°C ≤ Ta ≤ 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

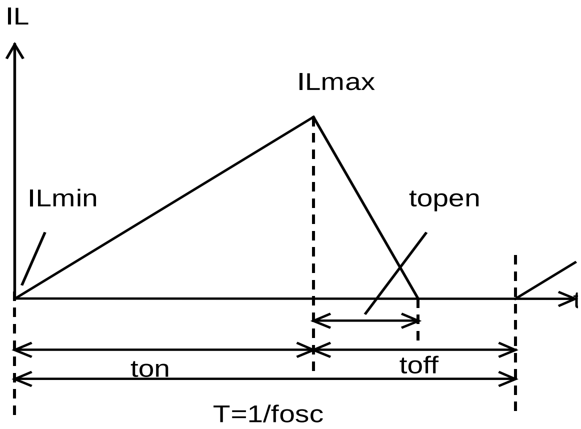
Operation of Step-Up DC/DC Converter and Output Current

<Basic Circuit>

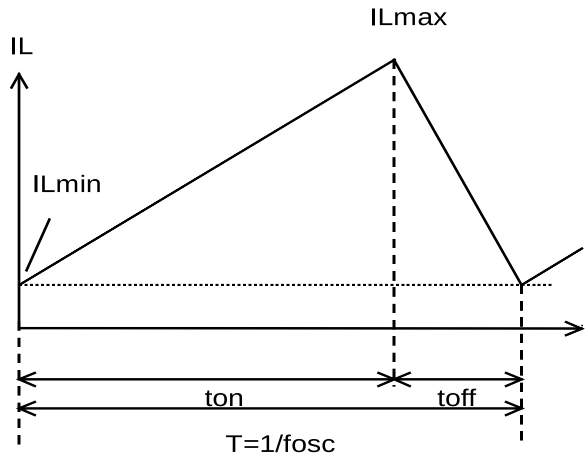


<Current through L>

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

$$\Delta i1 = V_{IN} \times ton / L \quad \text{......... Formula 1}$$

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

$$\Delta i2 = (V_{OUT} - V_{IN}) \times topen / L \quad \text{......... Formula 2}$$

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 i1 and i2 is same at regular condition.

$V_{IN} \times ton / L = (V_{OUT} - V_{IN}) \times toff / L$ ....Formula 3

The duty at continuous mode will be

$duty (\%) = ton / (ton + toff) = (V_{OUT} - V_{IN}) / V_{OUT}$..........Formula 4

The average of inductor current at tf = toff will be

$IL(Ave.) = V_{IN} \times ton / (2 \times L)$..........Formula 5

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

$I_{OUT} = V_{IN}^2 \times ton / (2 \times L \times V_{OUT})$..........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 (IL_{max}) of inductor will be

$IL_{max} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times ton / (2 \times L)$..........Formula 7

$IL_{max} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times T \times (V_{OUT} - V_{IN}) / (2 \times L \times V_{OUT})$..........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 IL_{max} 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 IL 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 Vf 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.

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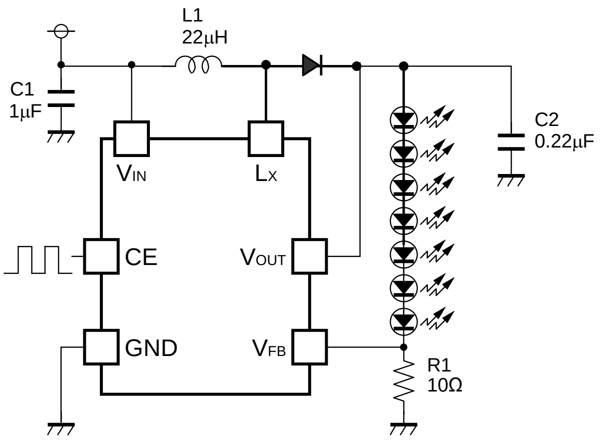
APPLICATION INFORMATION

● 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%.

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

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 1µF or more value bypass capacitor C1 between V_{IN} pin and GND pin as close as possible.
Set 0.22µF 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)

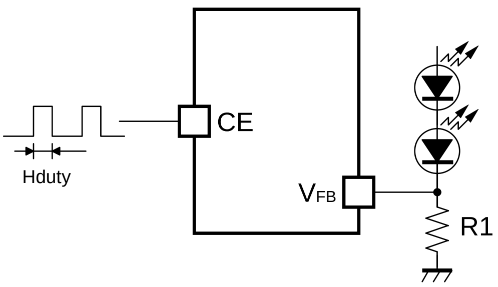
$$I_{LED}=V_{FB} / R1$$

- **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.

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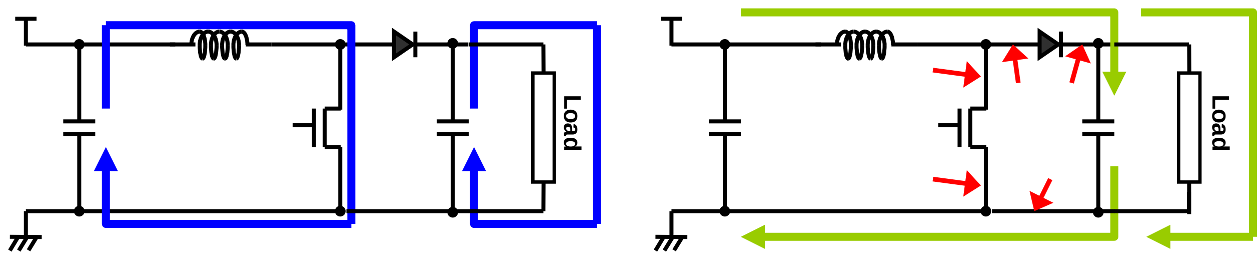


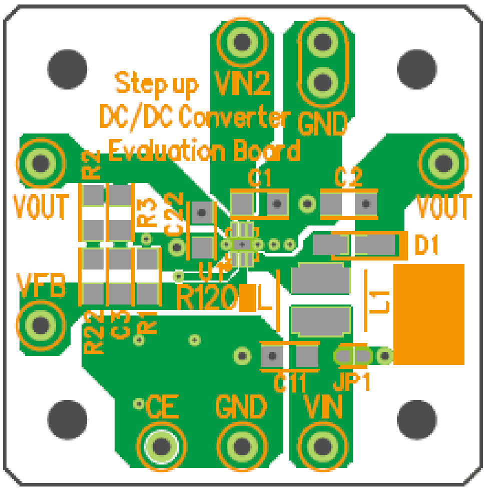
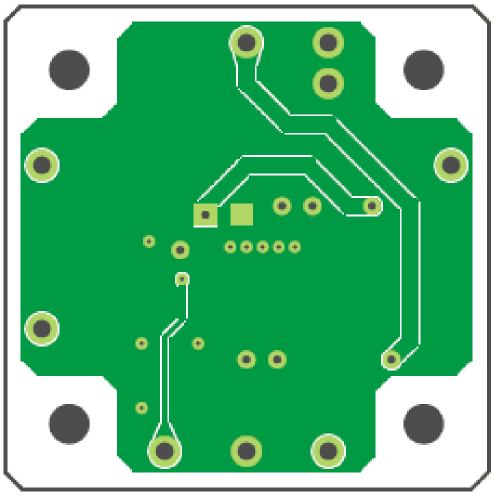
Fig. 1 MOSFET-ON

Fig. 2 MOSFET-OFF

● PCB Layout

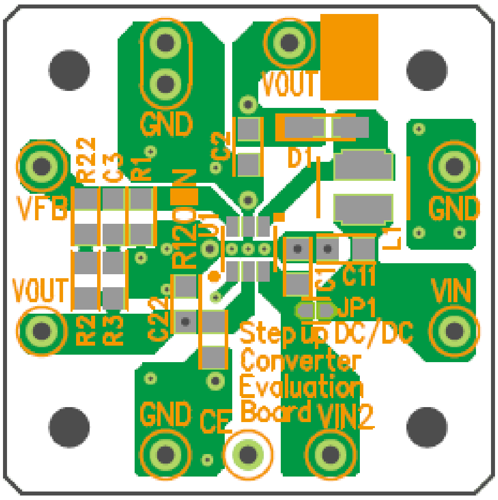
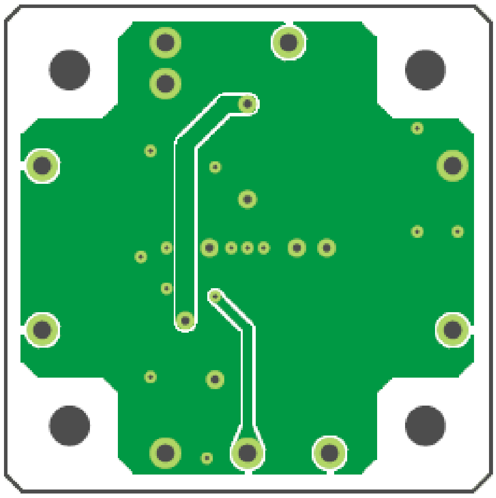
・PKG: DFN1616-6B pin

R1203L Typical Board Layout

Top Layer	Back Layer
	

・PKG: SOT-23-6pin

R1203N Typical Board Layout

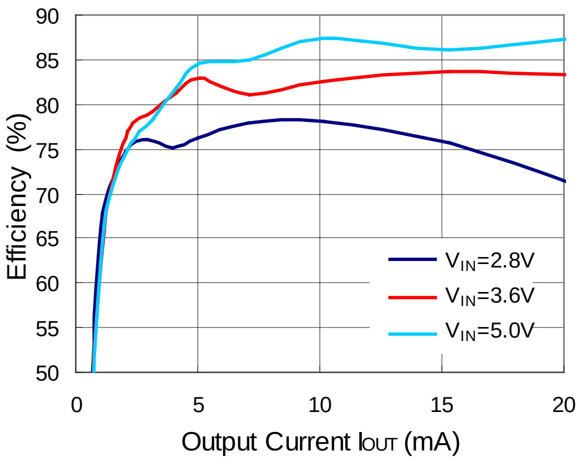
Top Layer	Back Layer
	

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

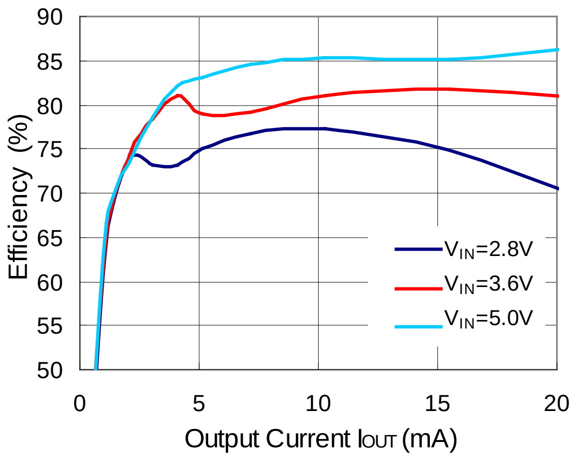
TYPICAL CHARACTERISTICS

1) Efficiency vs. Output Current Characteristics

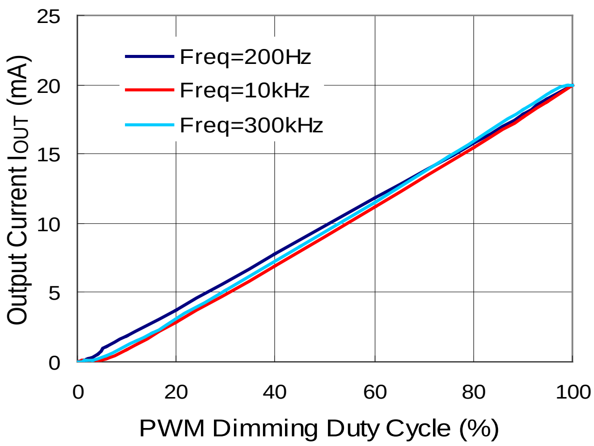
6LEDs



7LEDs

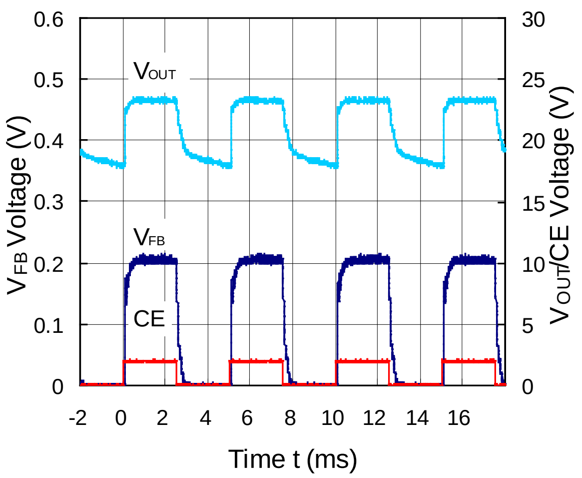


2) PWM Dimming Duty Cycle vs. Output Current (R1=10Ω)

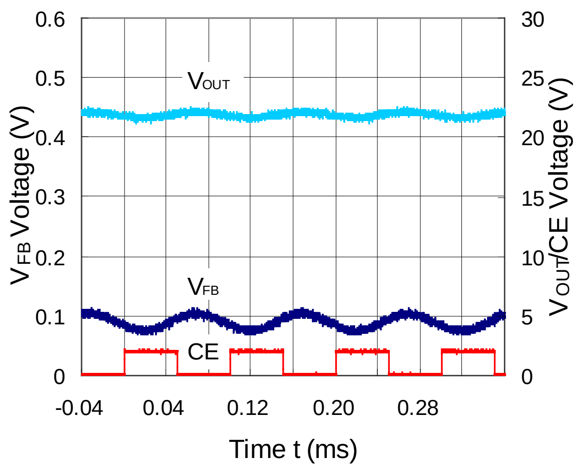


3) Output Current Ripple during PWM Dimming

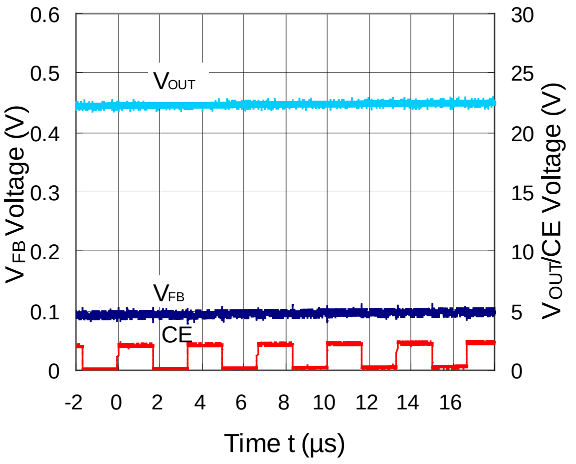
f=200Hz



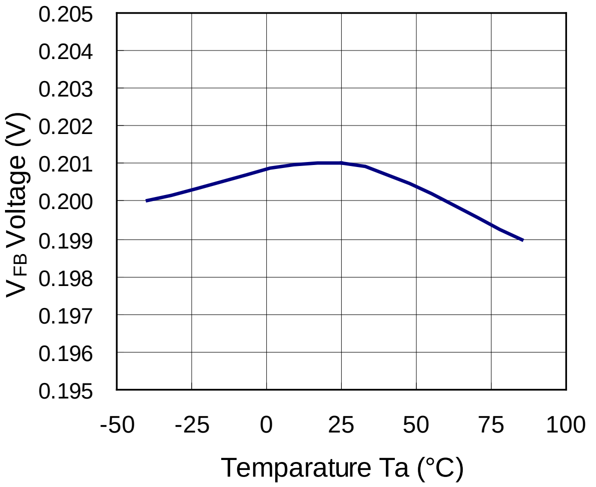
f=10kHz



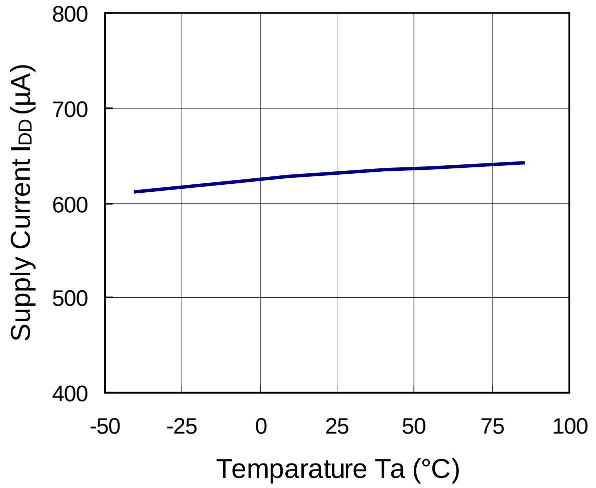
f=300kHz



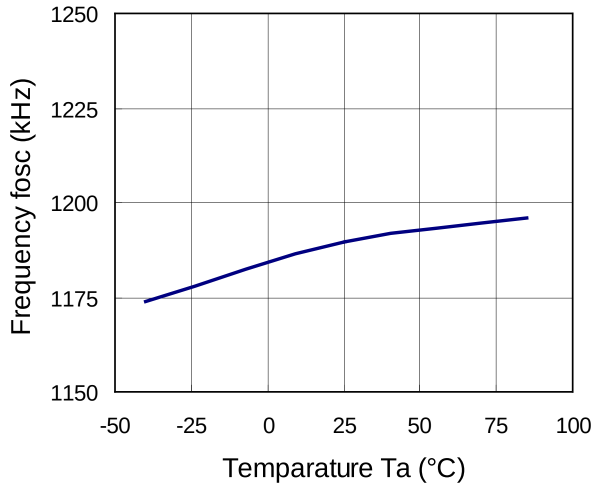
4) VFB Voltage vs. Temperature



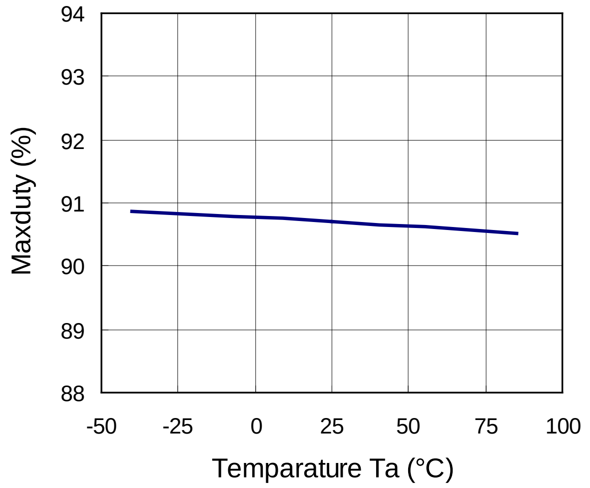
5) Supply Current vs. Temperature



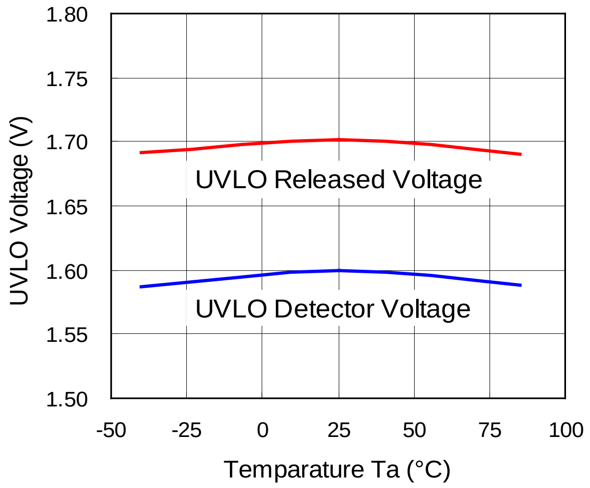
6) Oscillator Frequency vs. Temperature



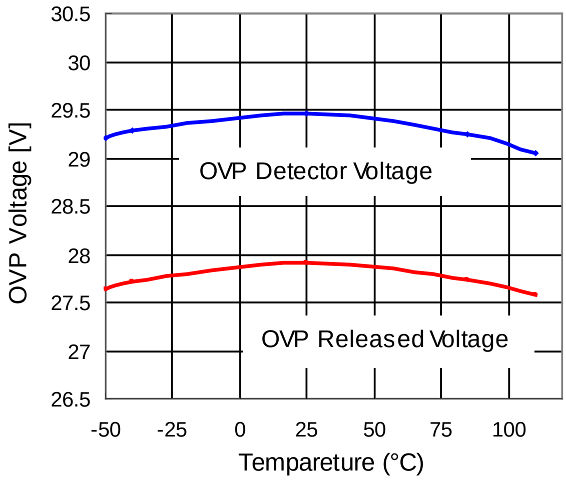
7) Maxduty vs. Temperature



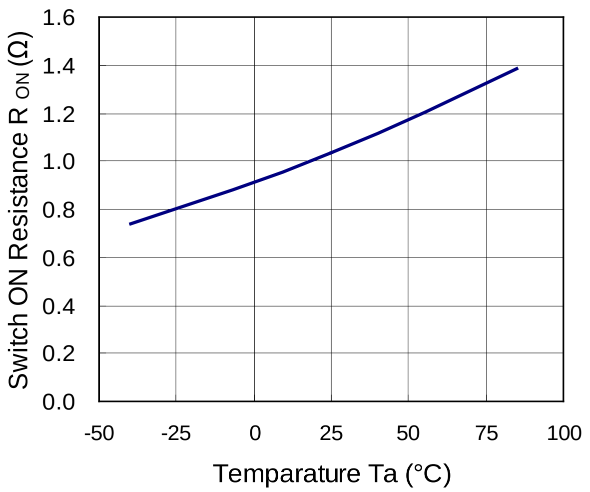
8) UVLO Output Voltage vs. Temperature



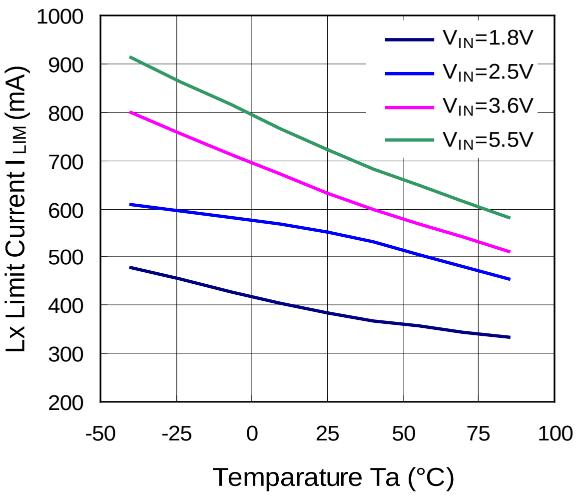
9) OVP Voltage vs. Temperature



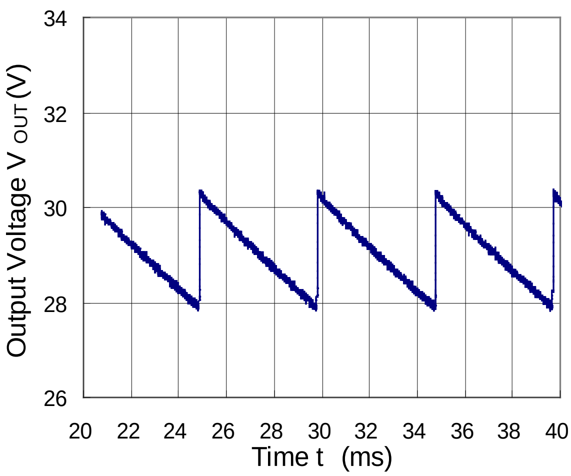
10) Switch ON Resistance vs. Temperature



11) Lx Current Limit vs. Temperature



12) OVP Operating Output Voltage Waveform



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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

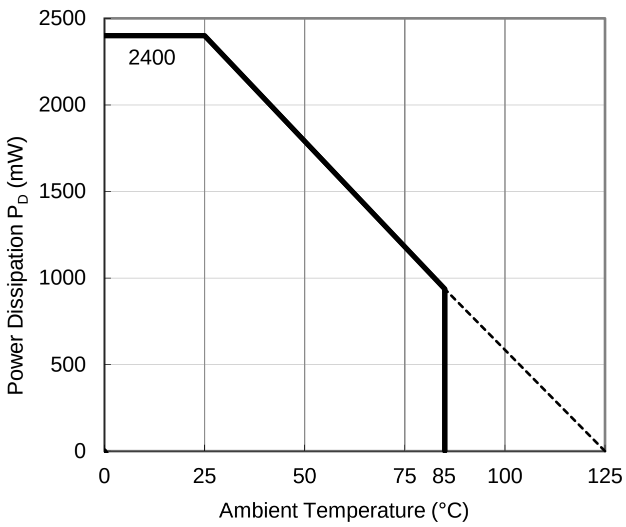
Item	Measurement Conditions (JEDEC STD. 51-7)
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 0.8 mm
Copper Ratio	1st Layer: Less than 95% of 50 mm Square 2nd, 3rd, 4th Layers: Approx. 100% of 50 mm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

Measurement Result (Ta = 25°C, Tjmax = 125°C)

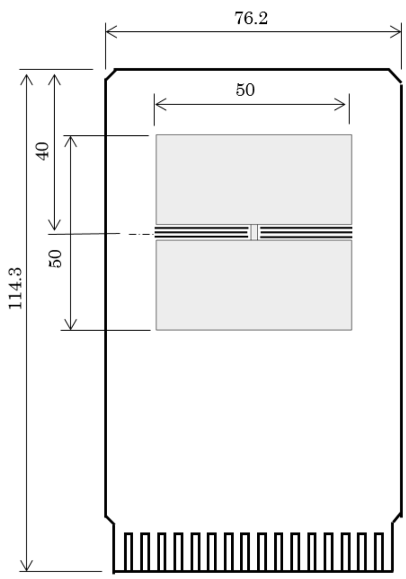
Item	Measurement Result
Power Dissipation	2400 mW
Thermal Resistance (θja)	θja = 41°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 11°C/W

θja: Junction-to–ambient thermal resistance.

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



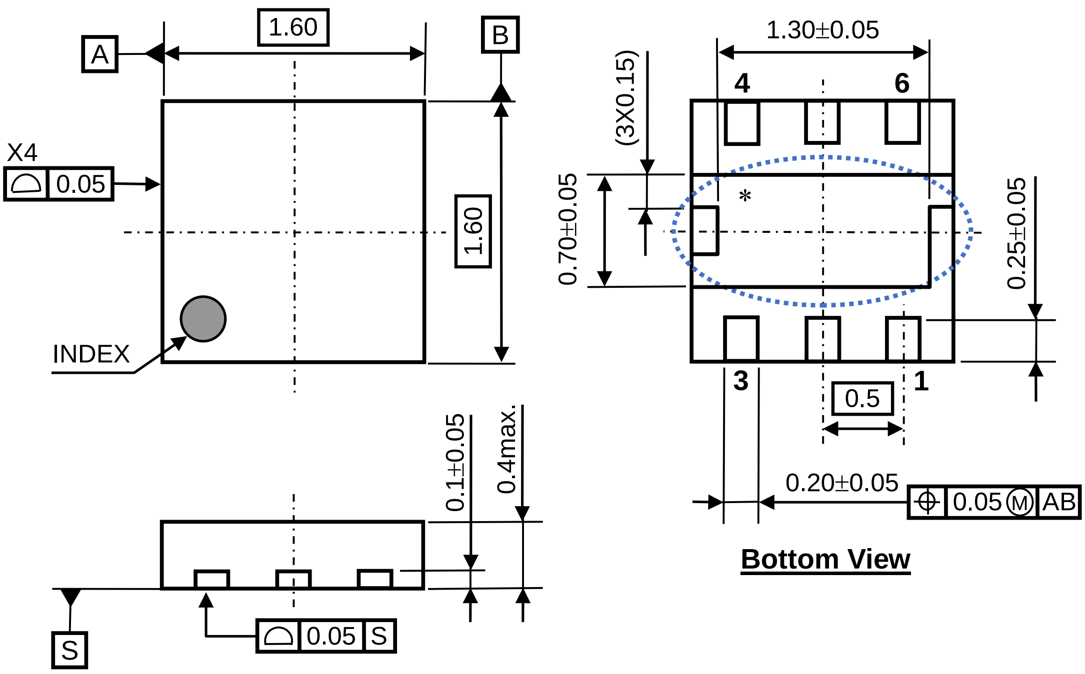
Power Dissipation vs. Ambient Temperature



Measurement Board Pattern

*R1203L(DFN1616-6B) is the non-promotional product of as February 2021.

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.

*R1203L(DFN1616-6B) is the non-promotional product of as February 2021.

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

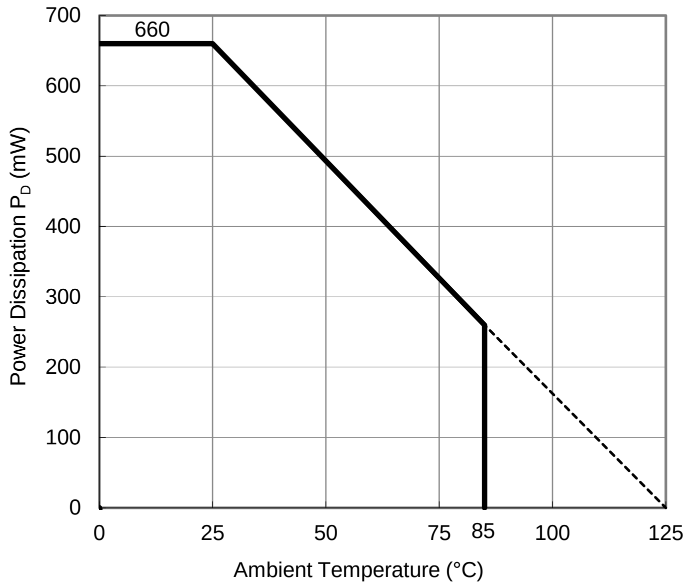
Item	Measurement Conditions (JEDEC STD. 51-7)
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 0.8 mm
Copper Ratio	1st Layer : Less than 95% of 50 mm Square 2nd, 3rd, 4th Layers: Approx. 100% of 50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

Measurement Result (Ta = 25°C, Tjmax = 125°C)

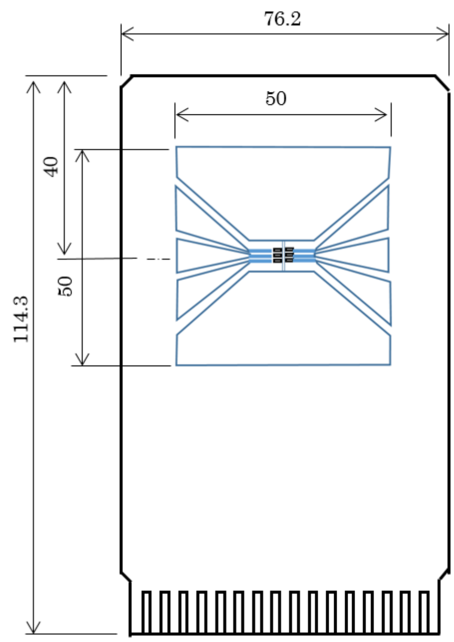
Item	Measurement Result
Power Dissipation	660 mW
Thermal Resistance (θja)	θja = 150°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 51°C/W

θja: Junction-to–ambient thermal resistance.

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



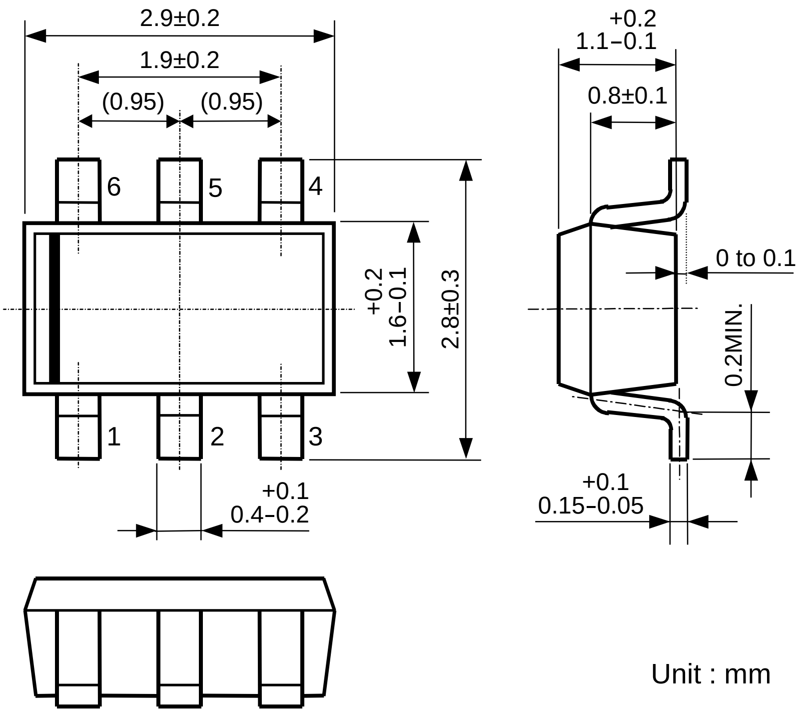
Power Dissipation vs. Ambient Temperature



Measurement Board Pattern

PACKAGE DIMENSIONS SOT-23-6

Ver. A



SOT-23-6 Package Dimensions

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