

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

NO.EA-297-170905

#### OUTLINE

The R1206N071B is PWM control type step-up DC/DC converter IC with low supply current.

The R1206N071B 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 R1206N071B 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 $\mu$ A
- Standby Current..... Max. 5 $\mu$ A
- Input Voltage Range ..... 1.8V to 5.5V
- Feedback Voltage ..... 0.2V
- Feedback Voltage Accuracy..... $\pm 1.0\%$  ( $\pm 10$ mV)
- Temperature-Drift Coefficient of Feedback Voltage ... $\pm 150$ ppm/ $^{\circ}$ C
- Oscillator Frequency ..... Typ. 1.2MHz
- Maximum Duty Cycle ..... Typ. 91%
- Switch ON Resistance ..... Typ. 1.35 $\Omega$
- 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 ..... SOT-23-6
- Ceramic capacitors are recommended..... 0.22 $\mu$ F

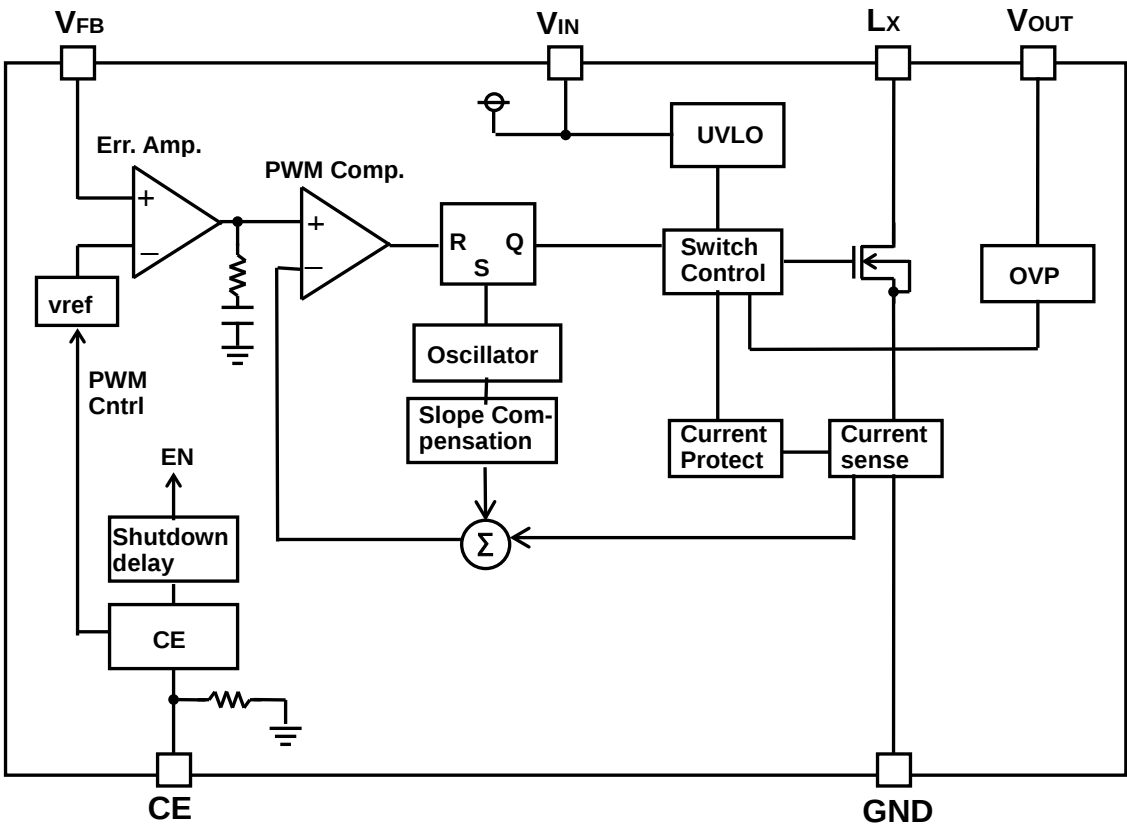
#### APPLICATIONS

- White LED Backlight for portable equipment

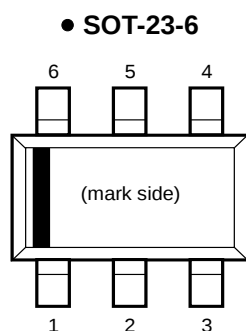
SELECTION GUIDE

| Product Name     | Package  | Quantity per Reel | Pb Free | Halogen Free |
|------------------|----------|-------------------|---------|--------------|
| R1206N071B-TR-FE | SOT-23-6 | 3,000 pcs         | Yes     | Yes          |

BLOCK DIAGRAM



## PIN DESCRIPTIONS



● SOT-23-6

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

**ABSOLUTE MAXIMUM RATINGS**

(GND=0V)

| Symbol           | Item                         |                                                 | Rating                       | Unit |
|------------------|------------------------------|-------------------------------------------------|------------------------------|------|
| V <sub>IN</sub>  | V <sub>IN</sub> Pin Voltage  |                                                 | −0.3 to 6.5                  | V    |
| V <sub>CE</sub>  | CE Pin Voltage               |                                                 | −0.3 to V <sub>IN</sub> +0.3 | V    |
| V <sub>FB</sub>  | V <sub>FB</sub> Pin Voltage  |                                                 | −0.3 to V <sub>IN</sub> +0.3 | V    |
| V <sub>OUT</sub> | V <sub>OUT</sub> Pin Voltage |                                                 | −0.3 to 32                   | V    |
| V <sub>LX</sub>  | L <sub>x</sub> Pin Voltage   |                                                 | −0.3 to 32                   | V    |
| I <sub>LX</sub>  | L <sub>x</sub> Pin Current   |                                                 | 1000                         | mA   |
| P <sub>D</sub>   | Power Dissipation *          | SOT-23-6<br>(JEDEC STD. 51-7 Test Land Pattern) | 660                          | mW   |
| T <sub>j</sub>   | Junction Temperature Range   |                                                 | −40 to 125                   | °C   |
| T <sub>stg</sub> | 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 <sub>IN</sub> | Operating Input Voltage     | 1.8 to 5.5 | V    |
| T <sub>a</sub>  | 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 conditions 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

## • R1206N071B

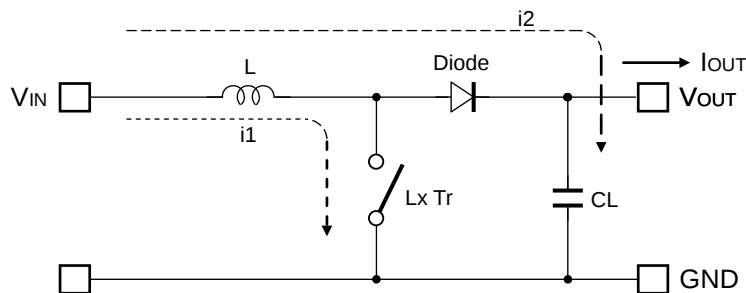
(Ta=25°C)

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

## THEORY OF OPERATION

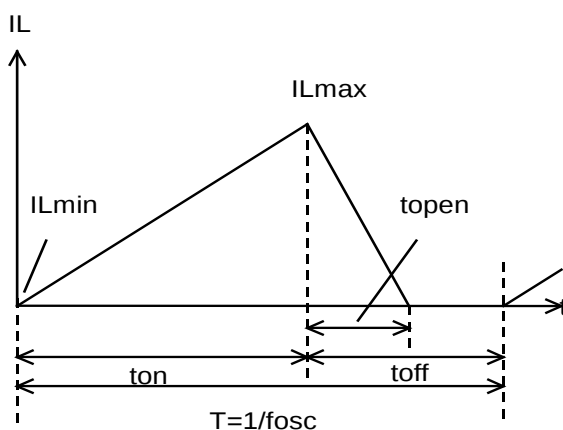
### Operation of Step-Up DC/DC Converter and Output Current

<Basic Circuit>

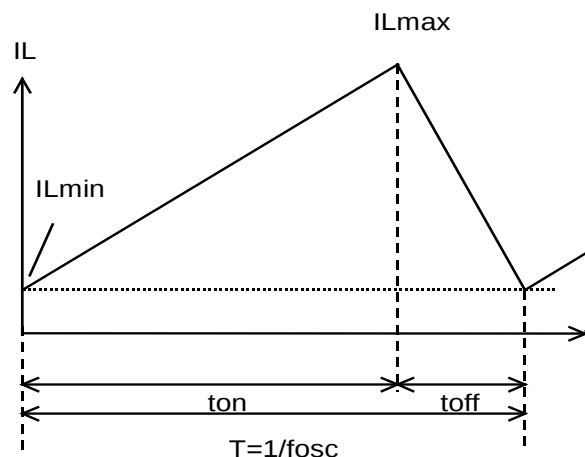


<Current through L>

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

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

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 i1 and i2 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  $V_{OUT}$ .

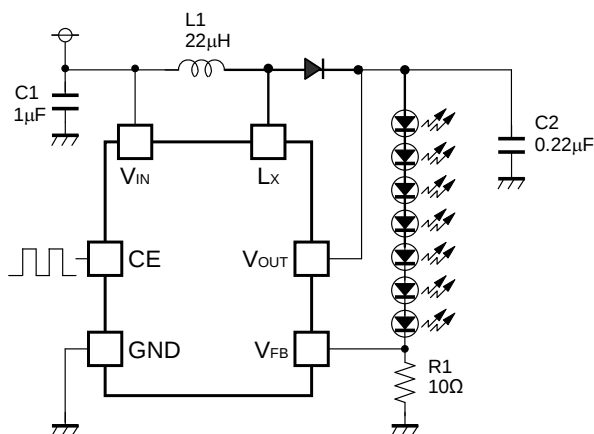
- **Soft-Start**

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 Application Circuit



|    |               |
|----|---------------|
| C1 | CM105B105K06  |
| C2 | GRM21BR71H224 |
| L1 | LQH32CN220K53 |

- Selection of Inductors

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

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

When the start-up or dimming control by CE pin, transient current flows, the peak current must be equal or less than the current limit of the IC. The peak current should not beyond the rating current of the inductor.

When 4-7 LEDs are driven with  $V_{IN}=3.6V$ , the recommended inductance value is 10μH -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 VIN pin and GND pin as close as possible.

Set 0.22μF or more capacitor C2 between VOUT pin and GND pin.

Note the V<sub>OUT</sub> that depends on LED used, and select the rating of V<sub>OUT</sub> or more.

### ● Selection of SBD (Schottky Barrier Diode )

Select the diode with low V<sub>F</sub> such as Schottky type with low reverse current I<sub>R</sub>, and with low capacitance.

**Table 3 Recommended components for R1206**

|    | 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

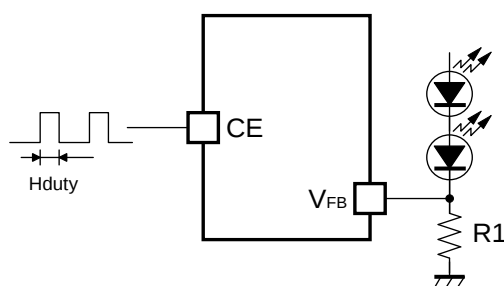
The LED brightness can be controlled by inputting the PWM signal to the CE pin. If the CE pin input is "L" in the fixed time (Typ.0.5ms), the IC becomes the standby mode and turns OFF LEDs.

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.

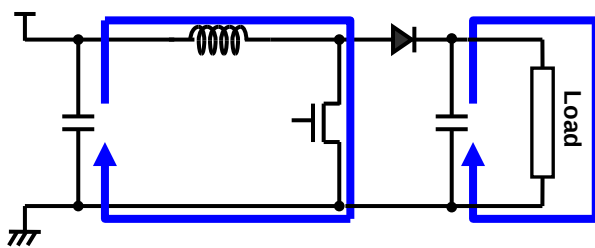


Fig. 1 MOSFET-ON

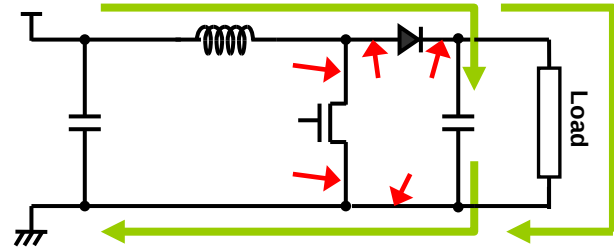
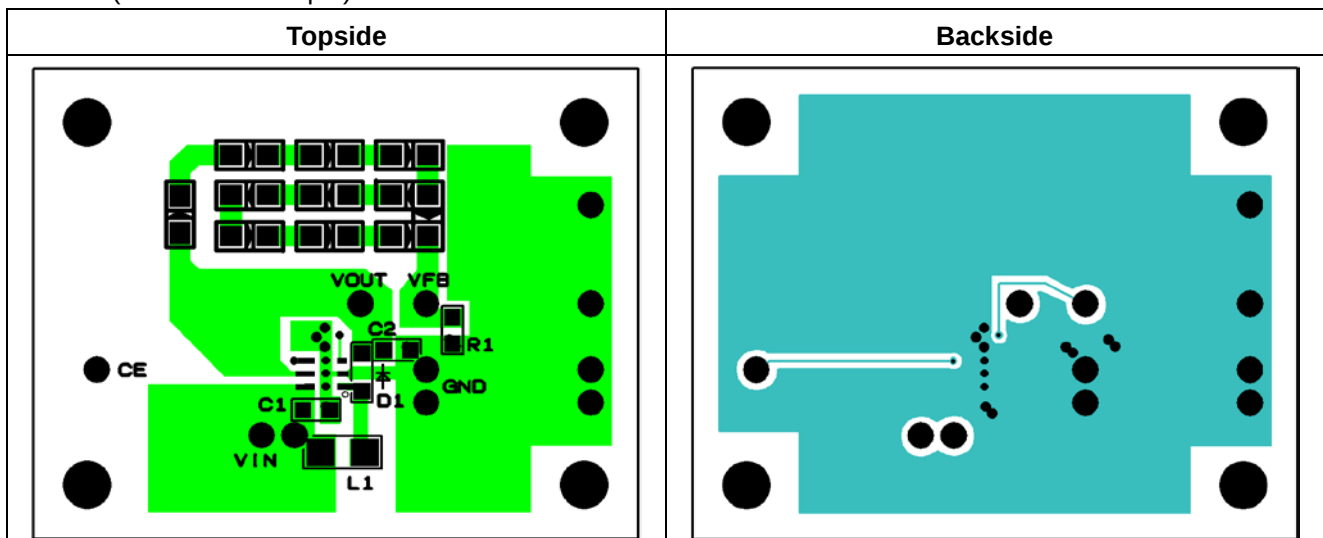


Fig. 2 MOSFET-OFF

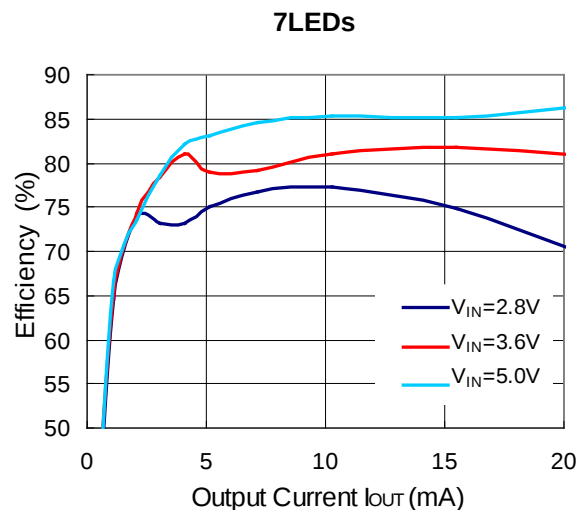
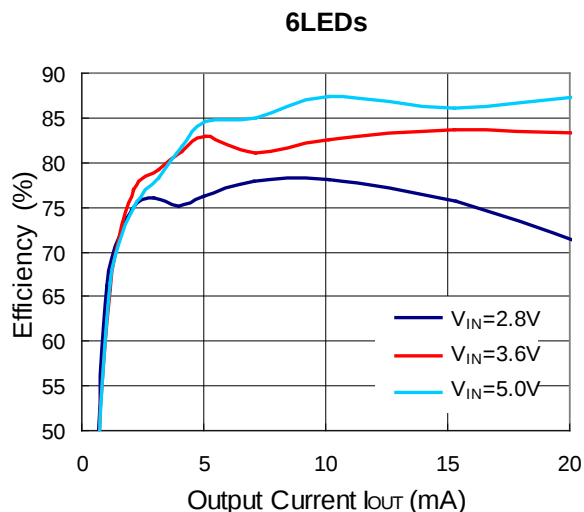
### ● PCB Layout

R1206N (PKG: SOT-23-6pin)

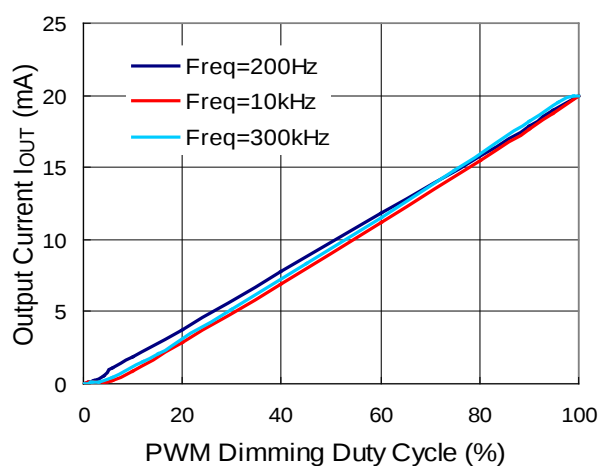


## TYPICAL CHARACTERISTICS

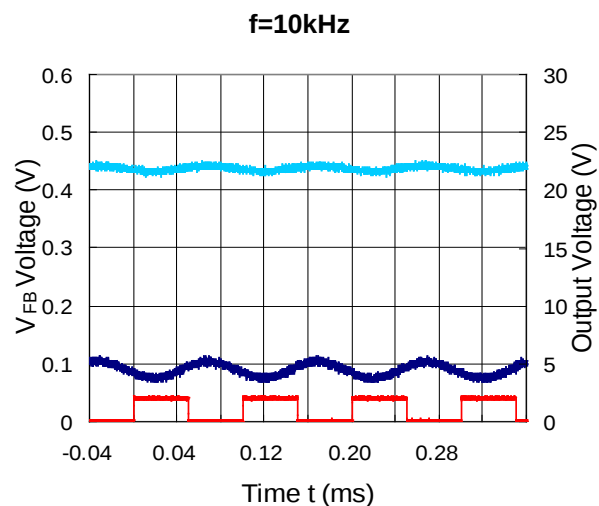
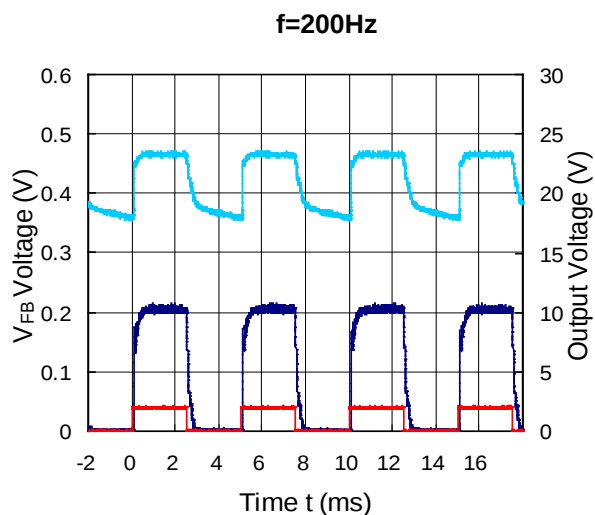
### 1) Efficiency vs. Output Current Characteristics

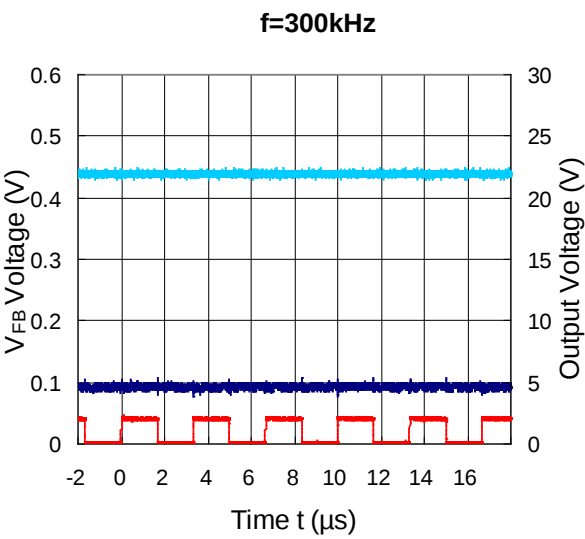


### 2) PWM Dimming Duty Cycle vs. Output Current( $R1=10\Omega$ )

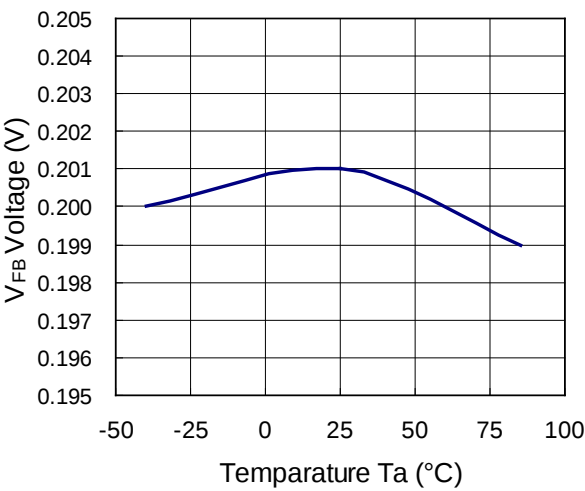


### 3) Output Current Ripple during PWM Dimming

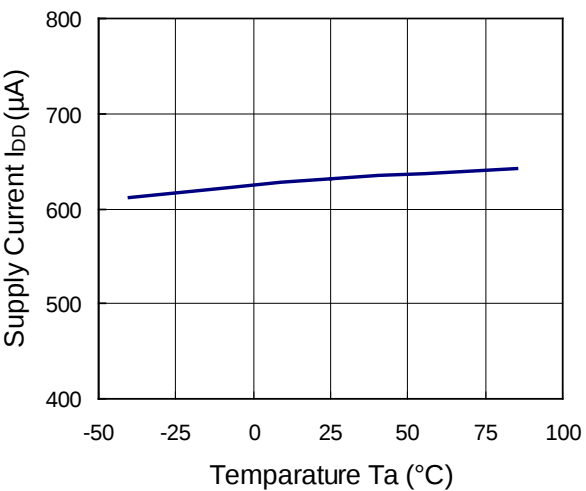




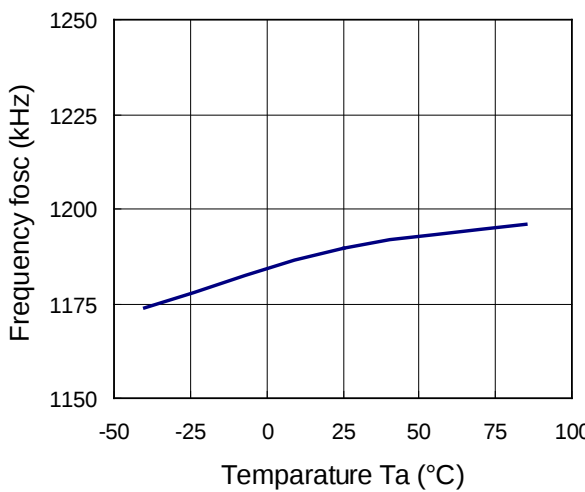
4) VFB Voltage vs. Temperature



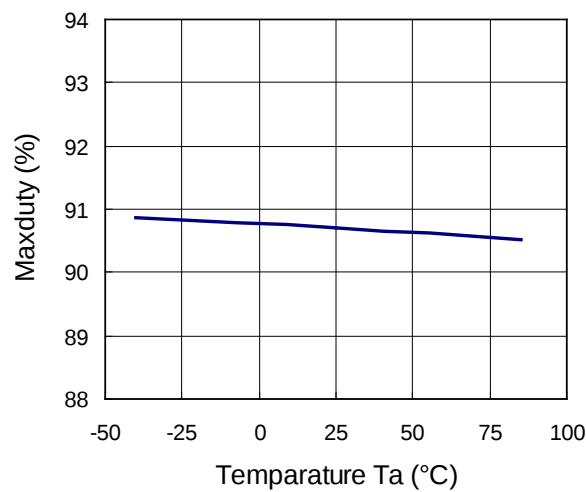
5) Supply Current vs. Temperature



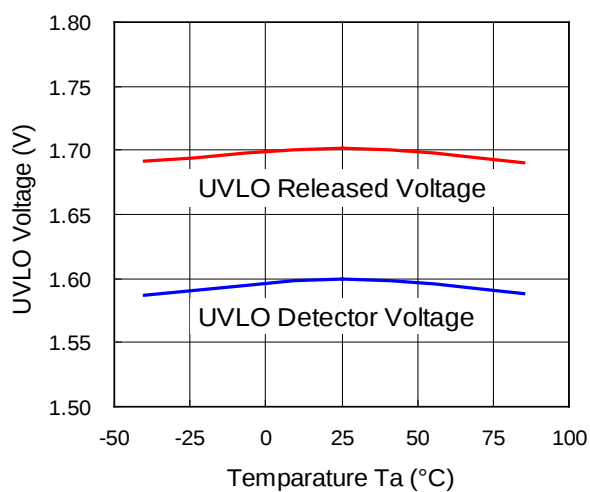
6) Oscillator Frequency vs. Temperature



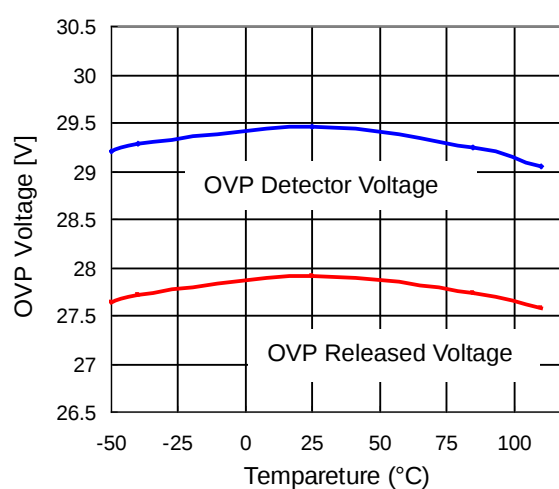
7) Maxduty vs. Temperature



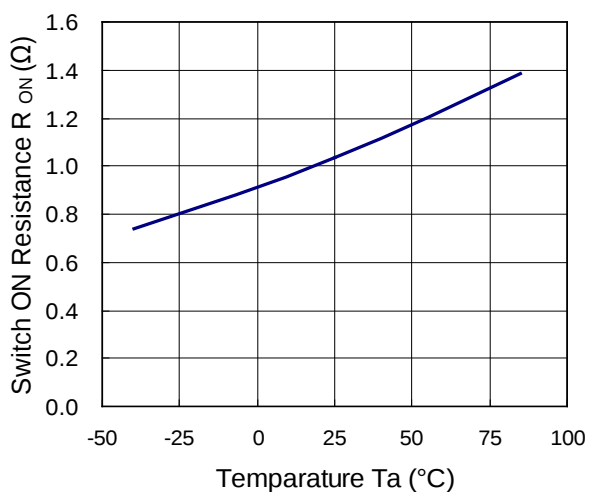
**8) UVLO Output Voltage vs. Temperature**



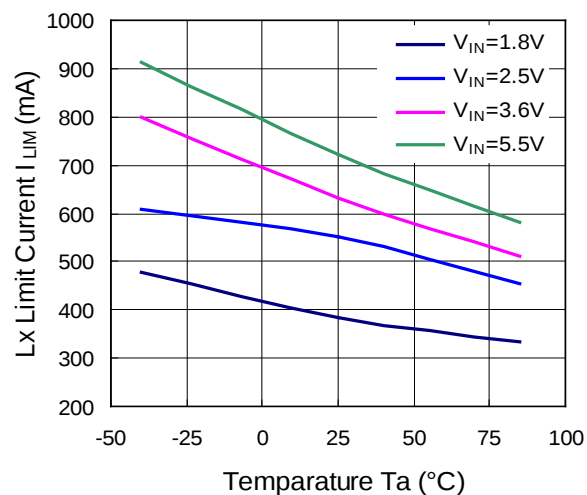
**9) OVP Voltage vs. Temperature**



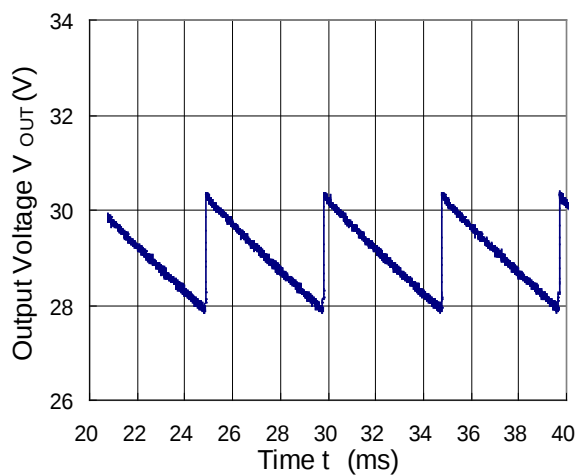
**10) Switch ON Resistance vs. Temperature**



**11) Lx Current Limit vs. Temperature**



**12) OVP Operating Output Voltage Waveform**



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<br>2nd, 3rd, 4th Layers: Approx. 100% of 50 mm Square |
| Through-holes    | φ 0.3 mm × 7 pcs                                                                                |

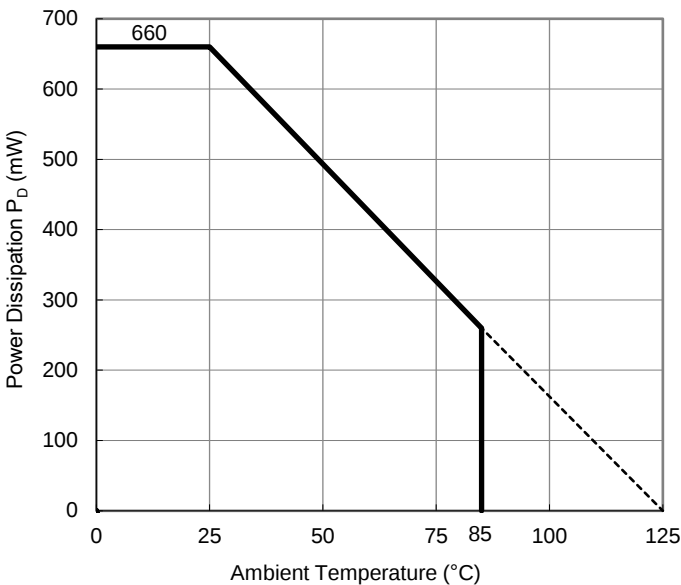
Measurement Result

(Ta = 25°C, Tjmax = 125°C)

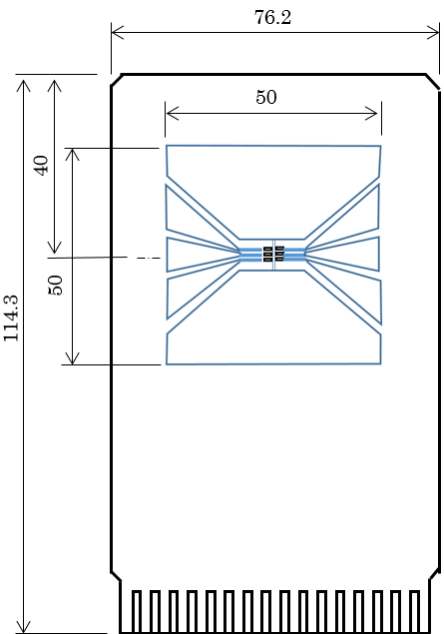
|                                          |                    |
|------------------------------------------|--------------------|
| Item                                     | Measurement Result |
| Power Dissipation                        | 660 mW             |
| Thermal Resistance (θja)          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

θja: Junction-to-ambient thermal resistance.

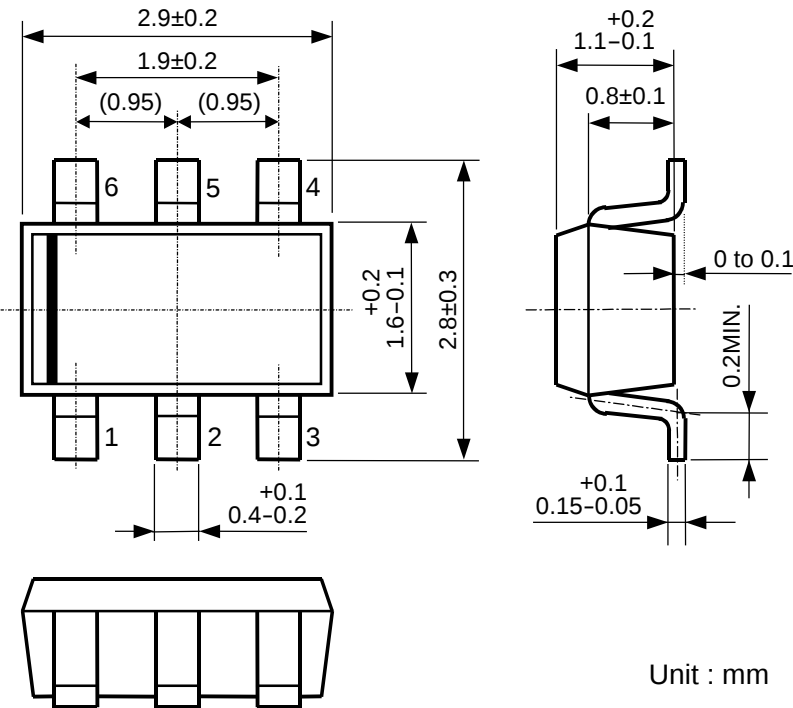
ψjt: Junction-to-top of package thermal characterization parameter



Power Dissipation vs. Ambient Temperature



Measurement Board Pattern



SOT-23-6 Package Dimensions



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**Ricoh is committed to reducing the environmental loading materials in electrical devices with a view to contributing to the protection of human health and the environment.**

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