# STEP-UP DC/DC CONVERTER

NO.EA-298-141208

## OUTLINE

The R1207N Series are CMOS-based PWM control type step-up DC/DC converter ICs with low supply current. Each of these ICs consists of an NMOS FET, a diode, an oscillator, a PWM comparator, a voltage reference unit, an error amplifier, a current limit circuit, an under voltage lockout circuit (UVLO), an over-voltage protection circuit (OVP), a soft-start circuit, a Maxduty limit circuit, and a thermal shutdown protection circuit. This step-up DC/DC converter can be easily built with a few external components such as a coil, a resistor, and a capacitor. As the protection functions, the R1207N Series have a Lx peak current limit function, an over voltage protection (OVP) function, an under voltage lock out (UVLO) function and a thermal shutdown function.

The R1207N Series present the R1207N8xxA version that is optimized for the constant voltage power source, and the R1207N8xxB/C version that is optimized for driving the white LED with the constant current. The R1207N8xxB/C is an adjustable version that can change the LED brightness dynamically by using a 200Hz to 300kHz PWM signal toward the CE pin.

The R1207N Series are available in TSOT-23-6 package.

## FEATURES

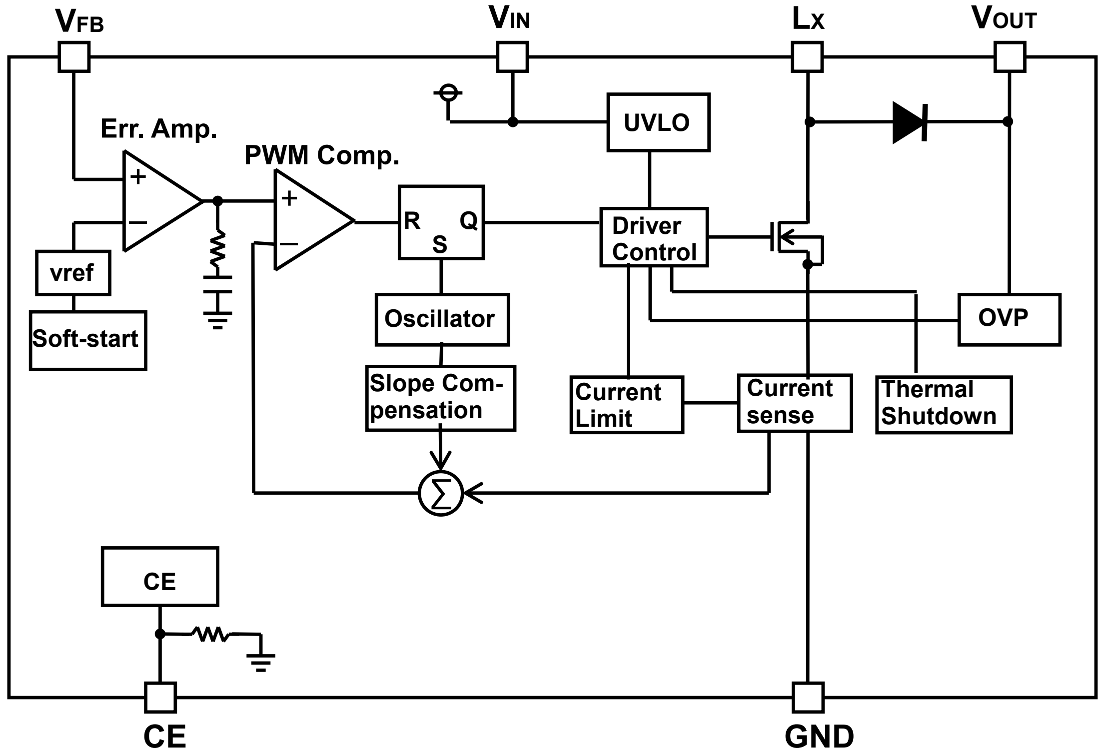
- Input Voltage Range .................................................2.3V to 5.5V (R1207N8xxA)
  1.8V to 5.5V (R1207N8xxB/C)
- Supply Current ..........................................................Typ. 800μA
- Standby Current.........................................................Max. 5μA
- Feedback Voltage ......................................................1.0V±1.5% (R1207N8xxA)
  0.2V±10mV (R1207N8xxB)
  0.4V±10mV (R1207N8xxC)
- Oscillator Frequency ..................................................Typ. 1.2MHz
- Maximum Duty Cycle .................................................Typ. 91%
- UVLO Function ············································ Typ.2.0V (Hys.Typ.0.2V) (R1207N8xxA)
  Typ.1.6V (Hys.Typ.0.1V) (R1207N8xxB/C)
- Lx Current Limit Function...........................................Select from 350mA, 700mA
- Over Voltage Protection .............................................Typ. 25V
- LED dimming control (R1207N8xxB/C) ...................by external PWM signal (Frequency 200Hz to 300kHz)
- Thermal Protection Function......................................Typ.150ºC(Hys.Typ.50ºC)
- Switch ON Resistance ...............................................Typ. 1.35Ω
- Package .....................................................................TSOT-23-6
- Ceramic capacitors are recommended

## APPLICATION

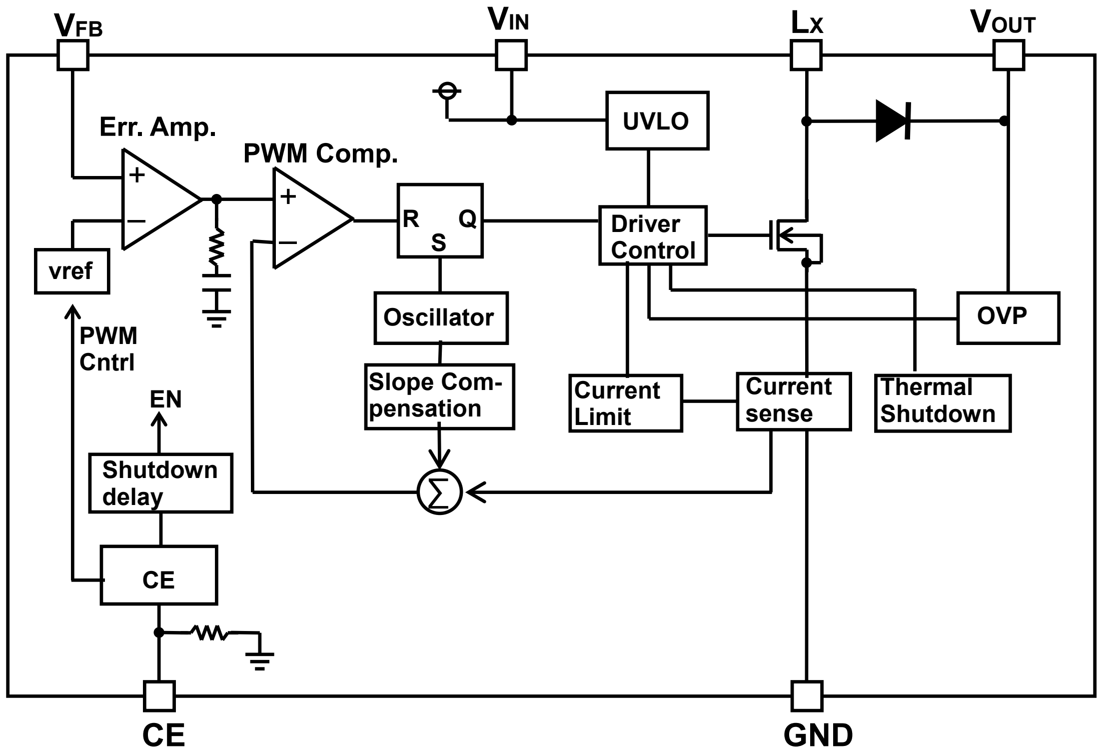
- Constant Voltage Power Source for portable equipment
- OLED power supply for portable equipment
- White LED Backlight for portable equipment

# BLOCK DIAGRAMS

●R1207N8xxA




●R1207N8xxB/C



## SELECTION GUIDE

The OVP threshold voltage, current limit and $V_{FB}$/Auto discharge are user-selectable options.

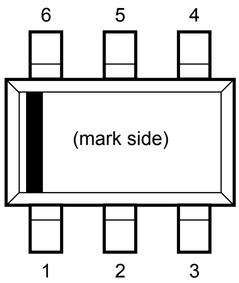
| Product Name | Package | Quantity per Reel | Pb Free | Halogen Free |
|---|---|---|---|---|
| R1207N8x3∗-TR-FE | TSOT-23-6 | 3,000 pcs | Yes | Yes |

x : Designation of current limit.
(1) 350mA
(2) 700mA

∗ : Designation of VFB.
(A) 1.0V
(B) 0.2V
(C) 0.4V

# PIN CONFIGURATIONS

- TSOT-23-6




# PIN DESCRIPTIONS

- **TSOT-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 |
|---|---|---|---|
| $V_{IN}$ | $V_{IN}$ Pin Voltage | –0.3 to 6.5 | V |
| $V_{CE}$ | CE Pin Voltage | –0.3 to 6.5 | V |
| $V_{FB}$ | $V_{FB}$ Pin Voltage | –0.3 to 6.5 | V |
| $V_{OUT}$ | $V_{OUT}$ Pin Voltage | –0.3 to 28 | V |
| $V_{LX}$ | $L_X$ Pin Voltage | –0.3 to 28 | V |
| $I_{LX}$ | $L_X$ Pin Current | 1000 | mA |
| $P_D$ | Power Dissipation (TSOT-23-6)* | 460 | mW |
| Ta | Operating Temperature Range | –40 to 85 | °C |
| Tstg | Storage Temperature Range | –55 to 125 | °C |

∗) For details regarding Power Dissipation and Standard Test Land Pattern, please refer to PACKAGE 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 (ELECTRICAL CHARACTERISTICS)**

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.

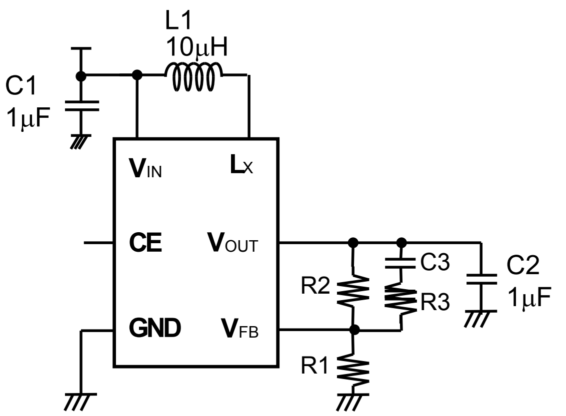
# ELECTRICAL CHARACTERISTICS

**• R1207N** (Ta=25°C)

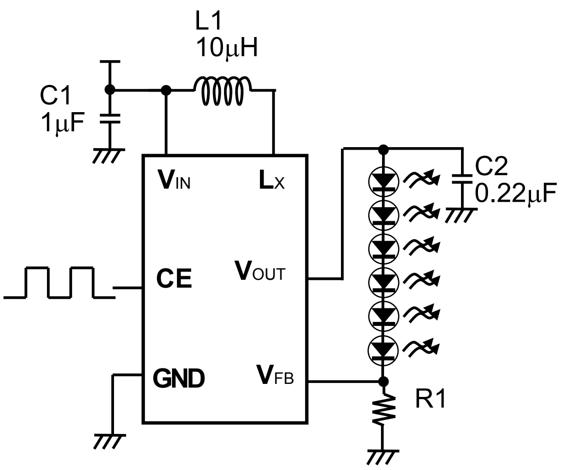
| Symbol | Item | Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $V_{IN}$ | Operating Input Voltage | | R1207N8xxA | 2.3 | | 5.5 | V |
| | | | R1207N8xxB/C | 1.8 | | 5.5 | |
| $I_{DD}$ | Supply Current | $V_{IN}$=5.5V, $V_{FB}$=0V , $L_X$ at no load | | | 0.8 | 1.2 | mA |
| $I_{standby}$ | Standby Current | $V_{IN}$=5.5V, $V_{CE}$=0V | | | 1.0 | 5.0 | μA |
| $V_{UVLO1}$ | UVLO Detector Threshold | $V_{IN}$ falling | R1207N8xxA | 1.9 | 2.0 | 2.1 | V |
| | | | R1207N8xxB/C | 1.5 | 1.6 | 1.7 | |
| $V_{UVLO2}$ | UVLO Released Voltage | $V_{IN}$ rising | R1207N8xxA | | $V_{UVLO1}$ +0.2 | 2.3 | V |
| | | | R1207N8xxB/C | | $V_{UVLO1}$ +0.1 | 1.8 | |
| $V_{CEH}$ | 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 | | | | 1200 | | kΩ |
| $V_{FB}$ | $V_{FB}$ Voltage Accuracy | $V_{IN}$=3.6V | R1207N8xxA | 0.985 | 1.000 | 1.015 | V |
| | | | R1207N8xxB | 0.19 | 0.2 | 0.21 | |
| | | | R1207N8xxC | 0.39 | 0.4 | 0.41 | |
| $\Delta V_{FB}/\Delta Ta$ | $V_{FB}$ Voltage Temperature Coefficient | $V_{IN}$=3.6V, $-40°C \leq Ta \leq 85°C$ | | | ±150 | | ppm /°C |
| $I_{FB}$ | $V_{FB}$ Input Current | $V_{IN}$=5.5V, $V_{FB}$=0V or 5.5V | | -0.1 | | 0.1 | μA |
| $t_{start}$ | Soft-start Time | | R1207N8xxB/C | | 2.0 | 3.0 | ms |
| $R_{ON}$ | FET ON Resistance | $I_{LX}$=100mA | | | 1.35 | | Ω |
| $I_{OFF}$ | FET Leakage Current | $V_{LX}$=24V | | | | 3.0 | μA |
| $I_{LIM}$ | FET Current Limit | | R1207N81xx | 250 | 350 | 450 | mA |
| | | | R1207N82xx | 500 | 700 | 900 | |
| $V_F$ | Diode Forward Voltage | $I_{SW}$=100mA | | | 0.8 | | V |
| $I_{DIODEleak}$ | Diode Leakage Current | $V_{OUT}$=24V, $V_{LX}$=0V | | | | 10 | μA |
| $f_{osc}$ | Oscillator Frequency | $V_{IN}$=3.6V, $V_{FB}$=0V | | 1000 | 1200 | 1400 | kHz |
| Maxduty | Maximum Duty Cycle | $V_{IN}$=3.6V, $V_{FB}$=0V | | 86 | 91 | | % |
| $V_{OVP1}$ | OVP Detect Voltage | $V_{IN}$=3.6V, $V_{OUT}$ rising | | 24.2 | 25 | 25.8 | V |
| $V_{OVP2}$ | OVP Release Voltage | $V_{IN}$=3.6V, $V_{OUT}$ falling | | | $V_{OVP1}$ -1.8 | | V |
| $T_{TSD}$ | Thermal Shutdown Detect Temperature | $V_{IN}$=3.6V | | | 150 | | °C |
| $T_{TSR}$ | Thermal Shutdown Release Temperature | $V_{IN}$=3.6V | | | 100 | | °C |

# TYPICAL APPLICATIONS

●R1207N8xxA




●R1207N8xxB/C




**Recommended external Inductor**

| L1 (µH) | Parts No | Rated Current(mA) | Size(mm) |
|---|---|---|---|
| 10 | LQH32CN100K53 | 450 | 3.2×2.5×1.55 |
| 10 | LQH2MC100K02 | 225 | 2.0×1.6×0.9 |
| 10 | VLF3010A-100 | 490 | 2.8×2.6×0.9 |
| 20 | LQH32CN220K53 | 250 | 3.2×2.5×1.55 |
| 20 | LQH2MC220K02 | 185 | 2.0×1.6×0.9 |
| 20 | VLF3010A-220 | 330 | 2.8×2.6×0.9 |

**R1207N8xxA Recommended external components**

| | Rated voltage(V) | Part No. |
|---|---|---|
| C1 | 6.3 | CM105B105K06 |
| C2 | 25 | GRM21BR11E105K |
| C3 | 25 | 220pF |
| R1 | | For $V_{OUT}$ Setting |
| R2 | | For $V_{OUT}$ Setting |
| R3 | | 2kΩ |

**R1207N8xxB/C Recommended external components**

| | R1207x | Rated voltage(V) | Part No. |
|---|---|---|---|
| C1 | R1207N8xxB/C | 6.3 | CM105B105K06 |
| C2 | R1207N8xxB | 25 | GRM21BR11E224 |
| | R1207N8xxC | 25 | C2012X7R1E474K |
| R1 | R1207N8xxB | - | (10/ LED Arrays*1 (Ω)) |
| | R1207N8xxC | - | (20/ LED Arrays*1 (Ω)) |

*1 LED Arrays indicate the number of parallel LEDs in series.

## ● The Method of Output Voltage Setting (R1207N8xxA)

The output voltage ($V_{OUT}$) can be calculated with divider resistors (R1 and R2) values as the following formula:

Output Voltage ($V_{OUT}$) = $V_{FB}$ × (R1 + R2) / R1

The total value of R1 and R2 should be equal or less than 300kΩ. Make the $V_{IN}$ and GND line sufficient. The large current flows through the $V_{IN}$ and GND line due to the switching. If this impedance ($V_{IN}$ and GND line) is high, the internal voltage of the IC may shift by the switching current, and the operating may become unstable. Moreover, when the built-in $L_X$ switch is turn OFF, the spike noise caused by the inductor may be generated. As a result of this, recommendation voltage rating of capacitor (C2) value is equal 1.5 times larger or more than the setting output voltage.

## ● LED Current setting (R1207N8xxB/C)

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 (R1207N8xxB/C)

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.

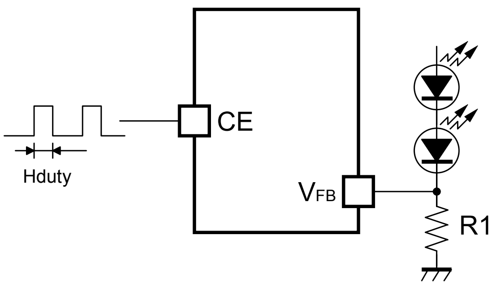
The current of LEDs can be controlled by Duty of the PWM signal of the input CE pin. The current of LEDs when High-Duty of the CE input is ”Hduty” reaches the value as calculatable following formula.

$I_{LED}$ = Hduty × $V_{FB}$ / 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 5kHz or less, R1207N8xxB/C are recomended to avoide discharge function during dimming control.

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**

## • Low luminance Dimming Accuracy (R1207N8xxC)

Low luminance Dimming filtered $V_{FB}$ voltage tolerance depends on the offset voltage of the internal DC/DC converter. By this offset voltage, some voltage difference may be generated between VREF voltage and $V_{FB}$ voltage. Low luminance Dimming Accuracy is shown in Table.4

Table 4. Low luminance Dimming Accuracy for R1207N8xxC (R1=20ohm)

| The duty of a PWM signal for the CE pin | $I_{LED}$ Min. | $I_{LED}$ Max. |
|---|---|---|
| 3.5% (Frequency = 20kHz ~ 300kHz) | 0.01mA*2 | 2.1mA*2 |

*2 guaranteed by design engineering (Ta=25 ºC)

- **Soft-Start (R1207N8xxB/C)**

The output and referrence of the error amplifier start from 0V and the referrence gradually rises up to 1.0V. After the softstart time ($T_{SS}$), output voltage rise up to the setting voltage.

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.

- **Current Limit Function**

Current limit function monitors the over current and if it reaches the peak current, it will turn off the driver. When the over current decreases, it will restart oscillation and will restart the monitoring.

- **Inductor Selection**

The peak current of the inductor under the stationary operation can be calculated by the following formula.

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

In the case of adjusting the brightness at the start-up or by the CE pin, the peak current can be transiently more than the above. Select the inductor that can limit the peak current within the current limit of the ICs.

Also, select the inductor of which peak current will not exceed the rated inductor value. The recommended inductance value is between 10μH to22μH.

- **Capacitor Selection**

The recommended capacitor value for C1 is in the range from 1.0μF to 4.7μF. Connect C1 between $V_{IN}$ and GND pin as close as possible to the pins.

Connect a output capacitor in the range from 1.0μF to 4.7μF between $V_{OUT}$ and GND pins. (R1207N8xxA)
Connect a output capacitor in the range from 0.22μF to 1.0μF between $V_{OUT}$ and GND pins. (R1207N8xxB)
Connect a output capacitor in the range from 0.47μF to 2.2μF between $V_{OUT}$ and GND pins. (R1207N8xxC)

- **External Components Setting**

If the $V_{OUT}$ spike noise is high, it may influence on the $V_{FB}$ pin to cause the operation of R1205x8xxA unstable. To reduce the noise coming into $V_{FB}$ pin, please place a 1kΩ to 5kΩ resistor in R3 in Fig 1.

- **Application of Using 5.5V or more Power Supply**

Other than the IC power supply, if there is a power supply greater than 5.5V, the high power output can be achieved by using the power supply as an inductor power supply. In this case, please place a capacitor between an inductor power supply and GND (shown in Fig 2.) aside from a bypass capacitor between the $V_{IN}$ pin and GND of the IC.

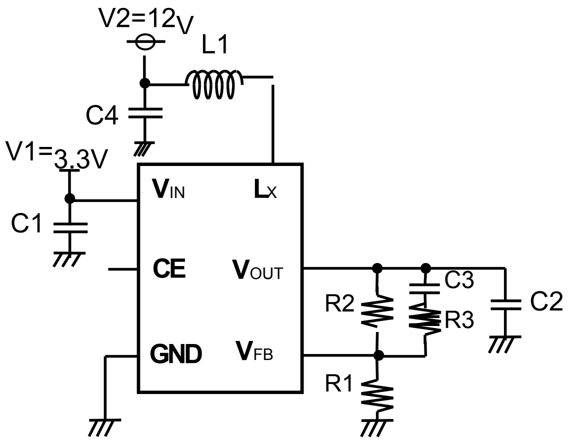



**Fig 1. R1207N8xxA**

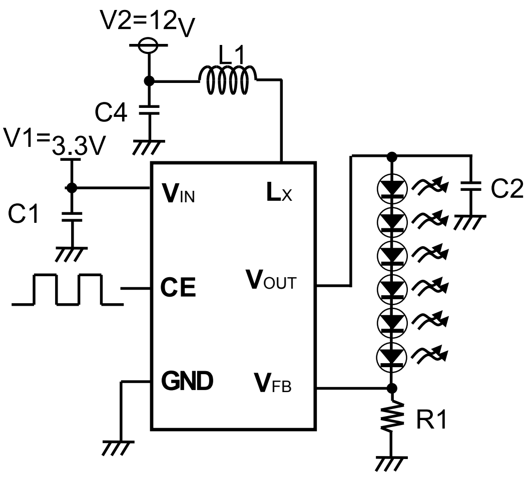
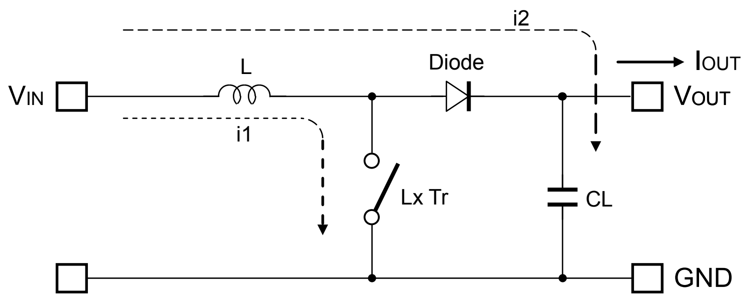


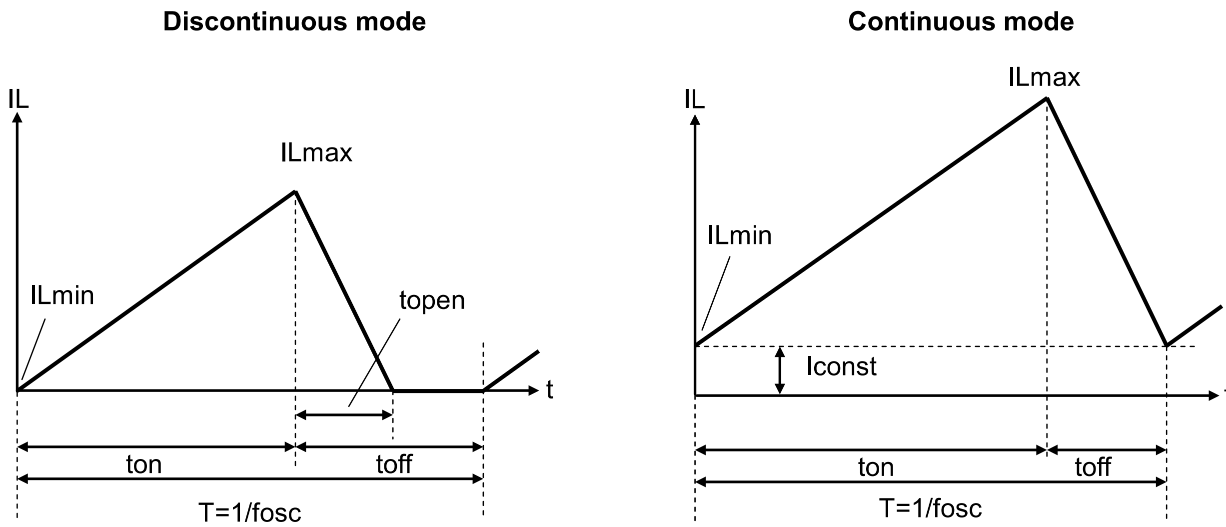

**Fig 2. R1207N8xxB/C**

# OPERATION OF STEP-UP DC/DC CONVERTER AND OUTPUT CURRENT

**<Basic Circuit>**




**<Current through L>**




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

$\Delta i1 = V_{IN} \times t_{on} / L$ .......................................................................................... 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

$\Delta i2 = (V_{OUT} - V_{IN}) \times t_{open} / L$ ................................................................................ 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.

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

The duty at continuous mode will be

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

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

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

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

$I_{OUT} = V_{IN}^2 \times t_{on} / (2 \times L \times V_{OUT})$ ........ 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

$IL_{max} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times t_{on} / (2 \times L)$ ........ 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.

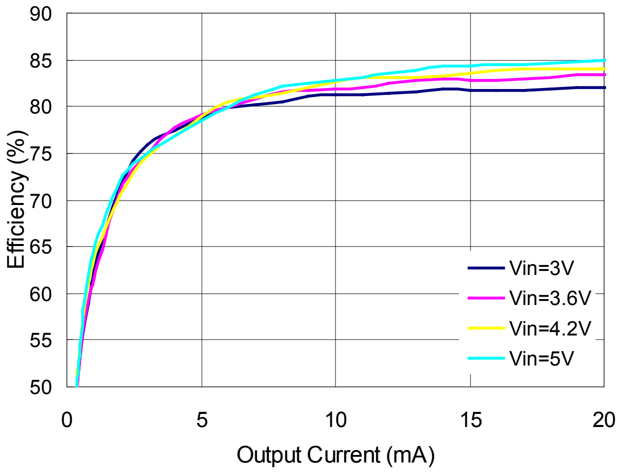
The explanation above is based on the ideal calculation, and the loss caused by $L_X$ switch and the external components are not included.

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 $V_f$ of the diode (approximately 0.8V) about $V_{OUT}$.

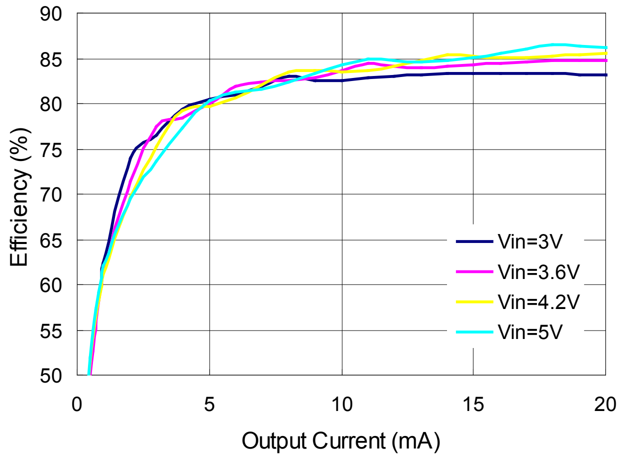
# TYIPICAL CHARACTERISTICS

## 1) Efficiency vs. Output Current Characteristics (R1207N823A)

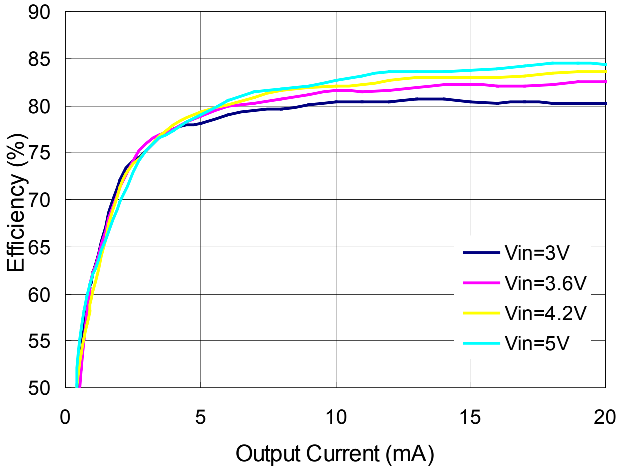
### $V_{OUT}$=10V, L=10µH (LQH32CN100K53)



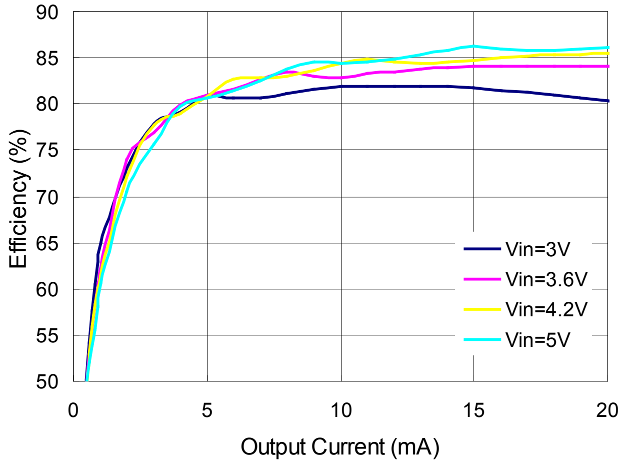

### $V_{OUT}$=10V, L=22µH (LQH32CN220K53)



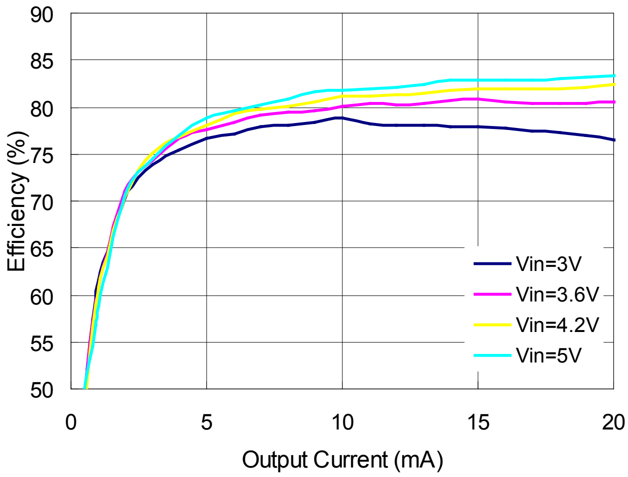

### $V_{OUT}$=15V, L=10µH (LQH32CN100K53)



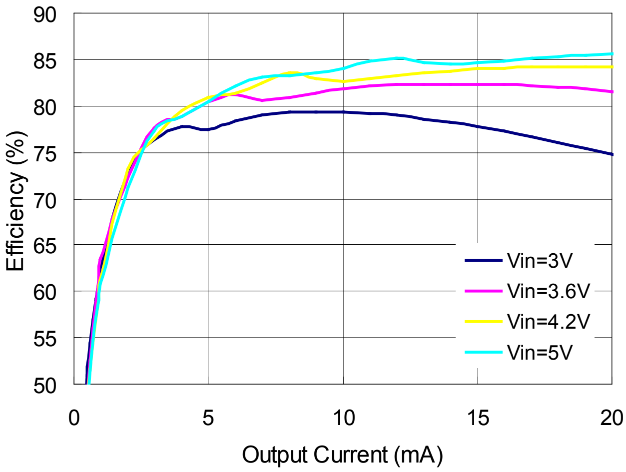

### $V_{OUT}$=15V, L=22µH (LQH32CN220K53)



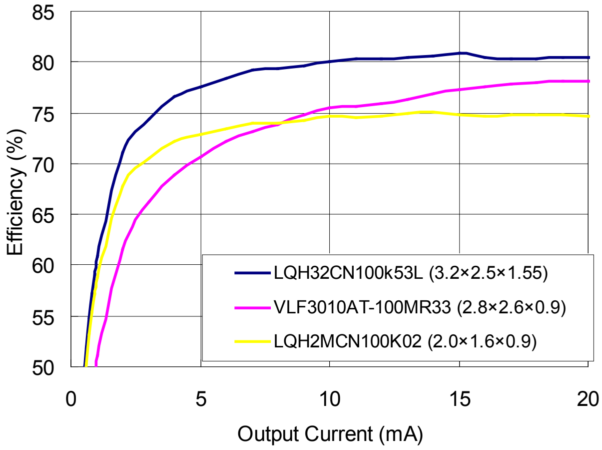

### $V_{OUT}$=20V, L=10µH (LQH32CN100K53)




### $V_{OUT}$=20V, L=22µH (LQH32CN220K53)

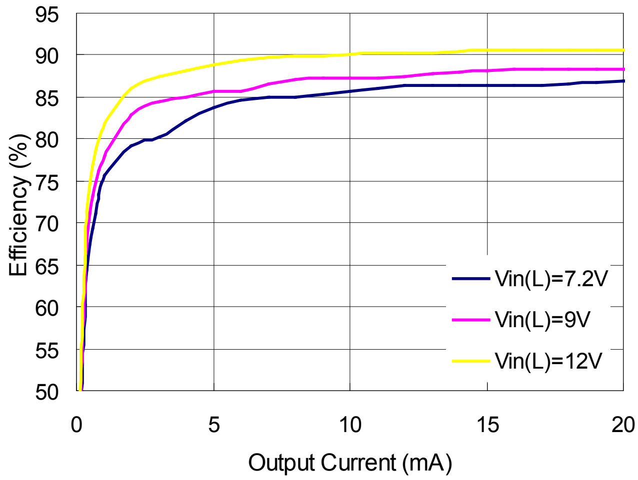


**VOUT=20V, VIN=3.6V**

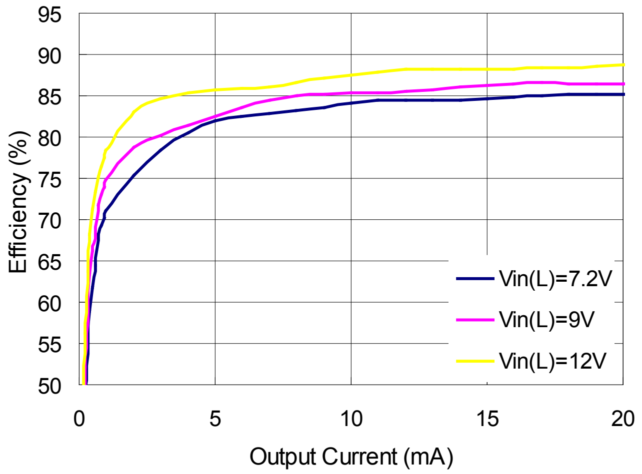



## ■Typical Applications with Using 5.5V or Greater

**VOUT=15V, L=10µH (LQH32CN100K53)**

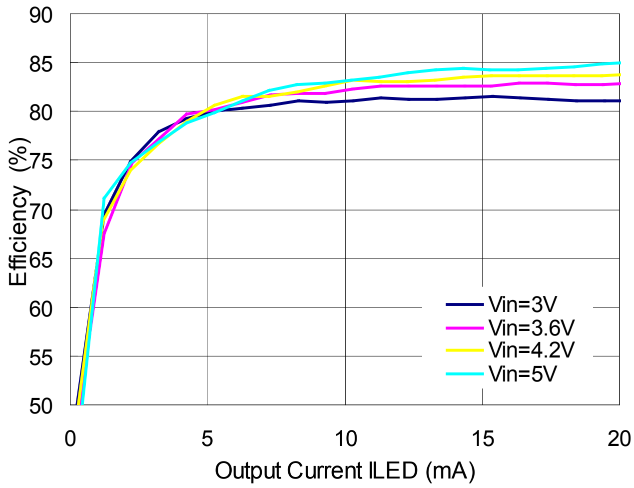



**VOUT=20V, L=10µH (LQH32CN100K53)**

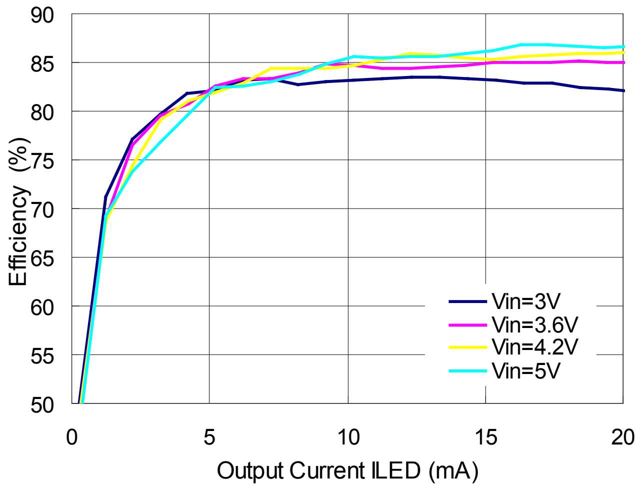


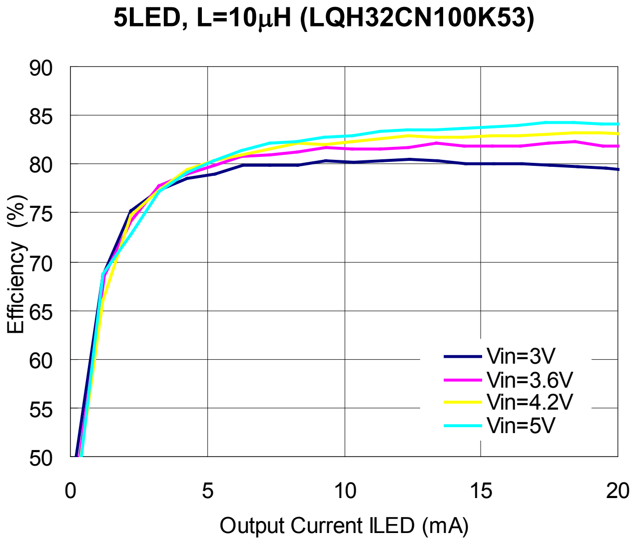

## 2) Efficiency vs. Output Current Characteristics (R1207N823B/C)

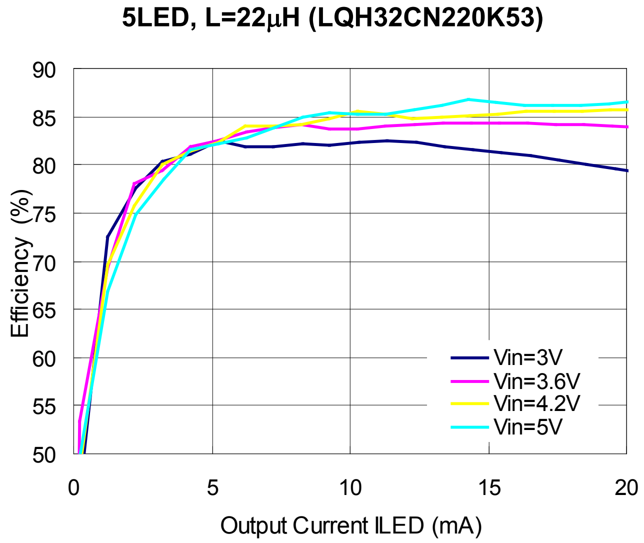
**4LED, L=10µH (LQH32CN100K53)**

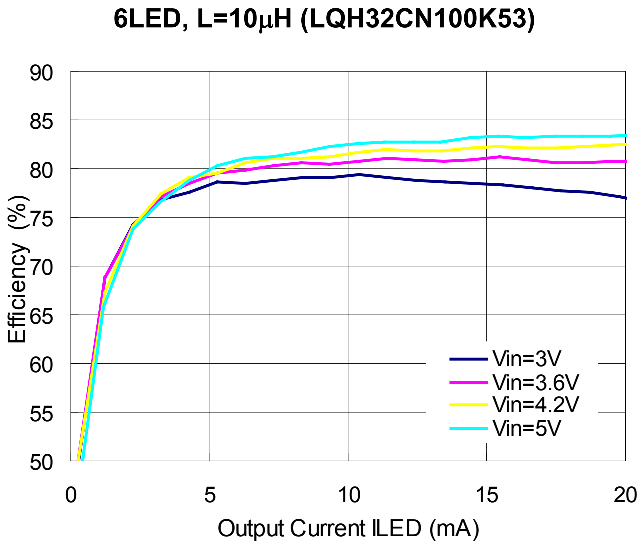


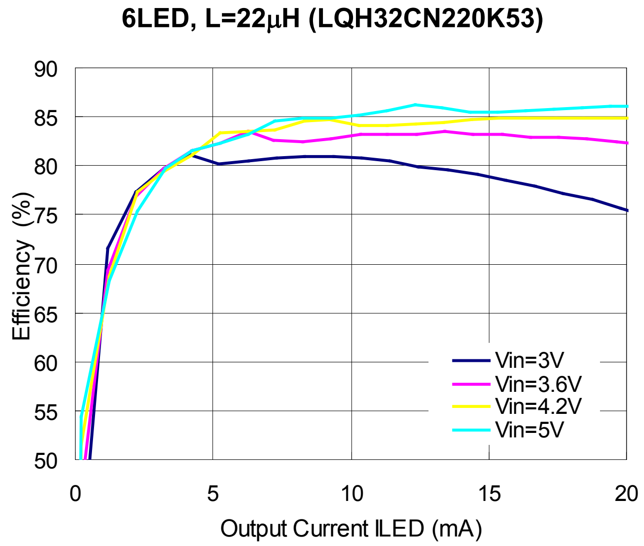

**4LED, L=22µH (LQH32CN220K53)**

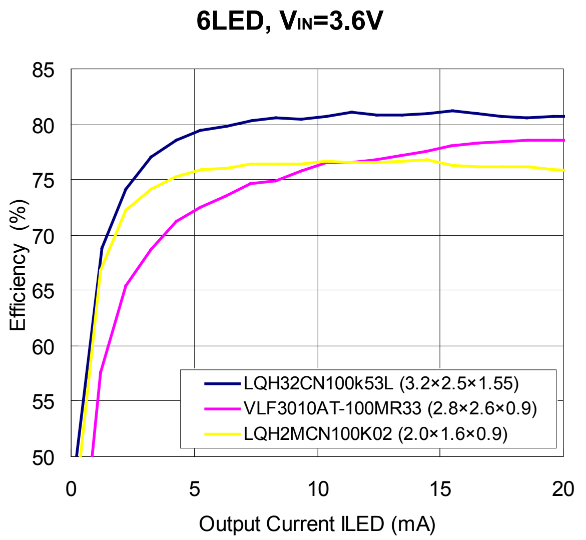



5LED, L=10µH (LQH32CN100K53)
Efficiency (%)
Output Current ILED (mA)
Vin=3V
Vin=3.6V
Vin=4.2V
Vin=5V


5LED, L=22µH (LQH32CN220K53)
Efficiency (%)
Output Current ILED (mA)
Vin=3V
Vin=3.6V
Vin=4.2V
Vin=5V

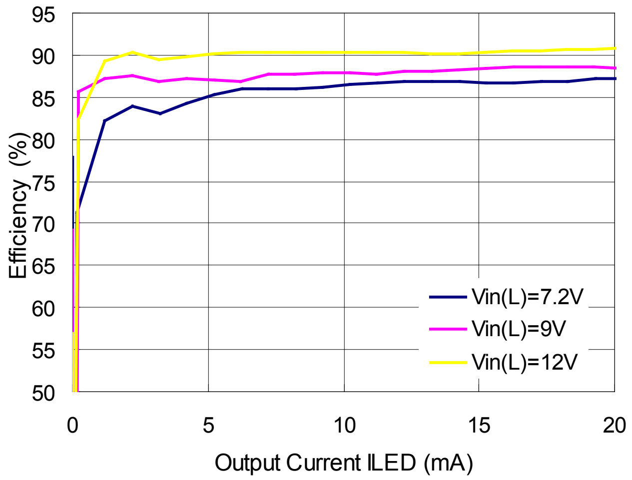

6LED, L=10µH (LQH32CN100K53)
Efficiency (%)
Output Current ILED (mA)
Vin=3V
Vin=3.6V
Vin=4.2V
Vin=5V


6LED, L=22µH (LQH32CN220K53)
Efficiency (%)
Output Current ILED (mA)
Vin=3V
Vin=3.6V
Vin=4.2V
Vin=5V

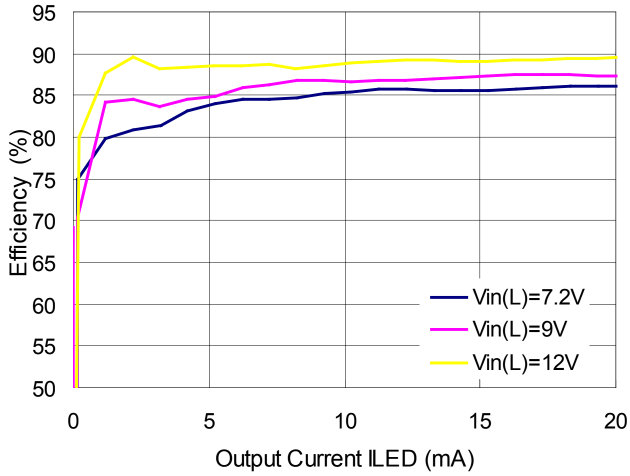

6LED, VIN=3.6V
Efficiency (%)
Output Current ILED (mA)
LQH32CN100k53L (3.2×2.5×1.55)
VLF3010AT-100MR33 (2.8×2.6×0.9)
LQH2MCN100K02 (2.0×1.6×0.9)

## ■Typical Applications with Using 5.5V or Greater

**5LED, $V_{IN}$(IC)=3.6V**

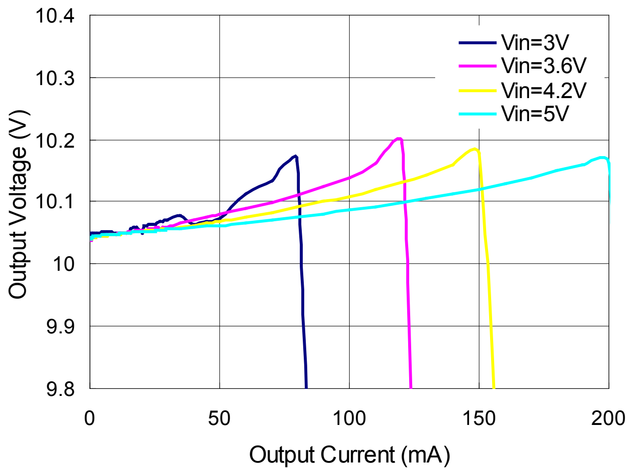



**6LED, $V_{IN}$(IC)=3.6V**

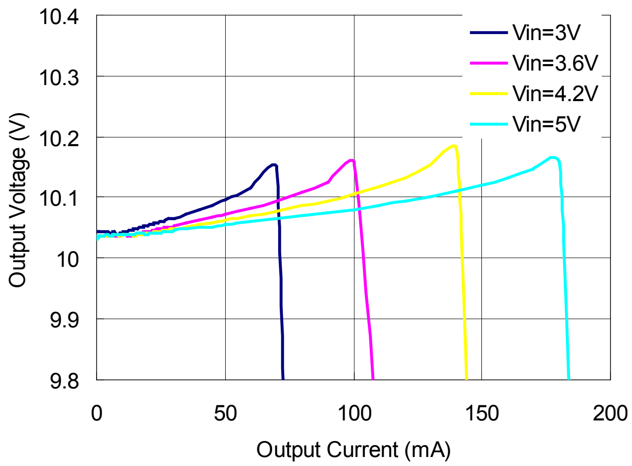



### 3) Output Voltage vs. Output Current (R1207N823A)

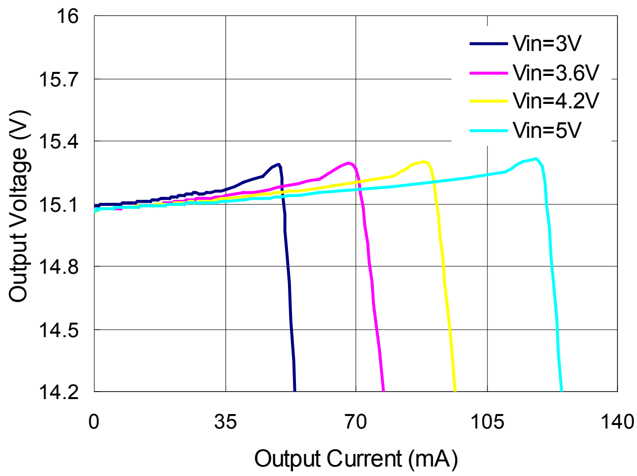
**$V_{OUT}$=10V, L=10µH (LQH32CN100K53)**



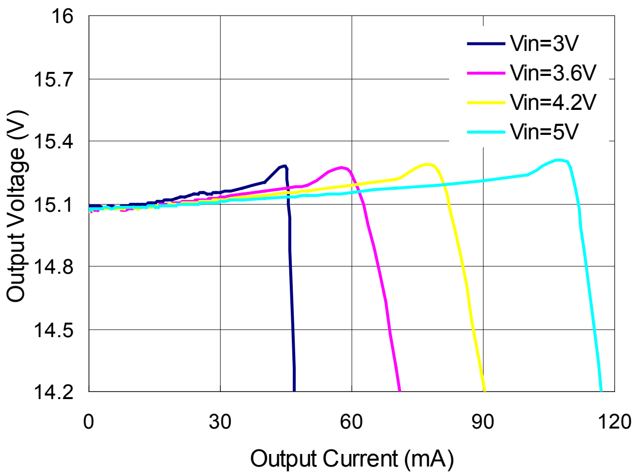

**$V_{OUT}$=10V, L=22µH (LQH32CN220K53)**



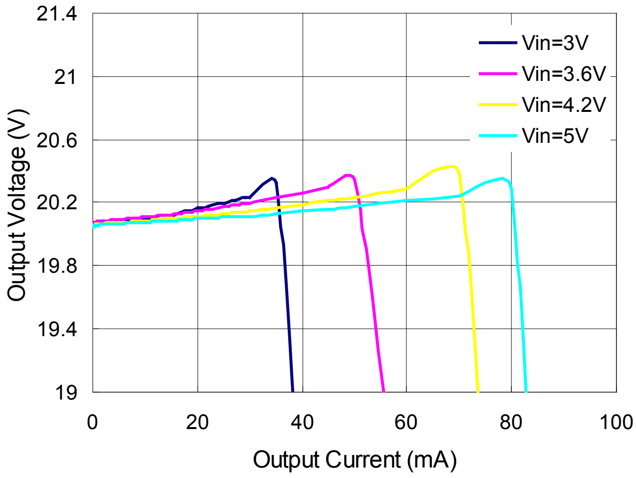

**$V_{OUT}$=15V, L=10µH (LQH32CN100K53)**



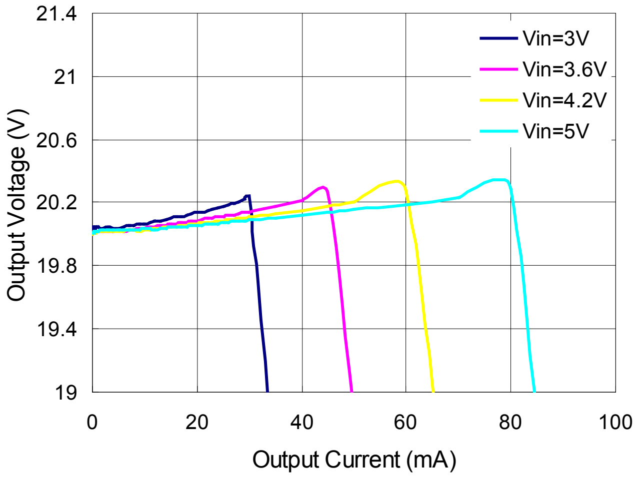

**$V_{OUT}$=15V, L=22µH (LQH32CN220K53)**



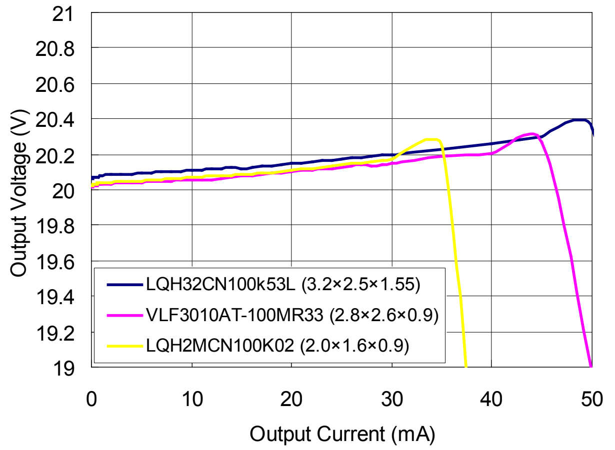
$V_{OUT}$=20V, L=10µH (LQH32CN100K53)




$V_{OUT}$=20V, L=22µH (LQH32CN220K53)

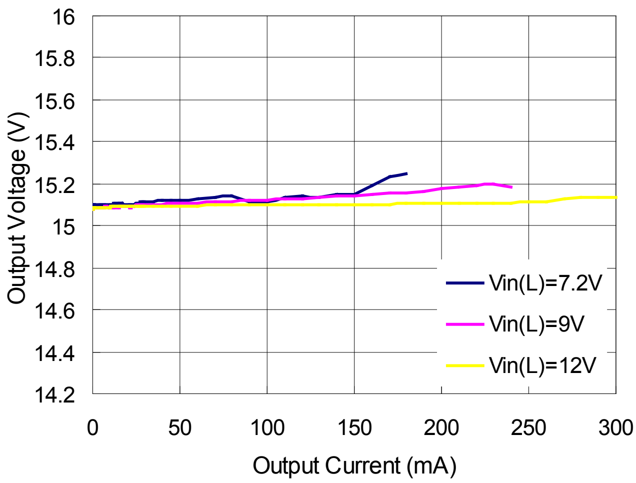



$V_{OUT}$=20V, $V_{IN}$=3.6V

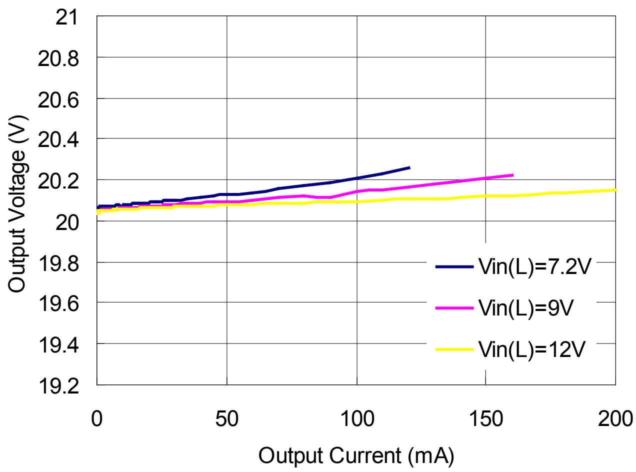



## ■Typical Applications with Using 5.5V or Greater

$V_{OUT}$=15V, L=10µH (LQH32CN100K53)

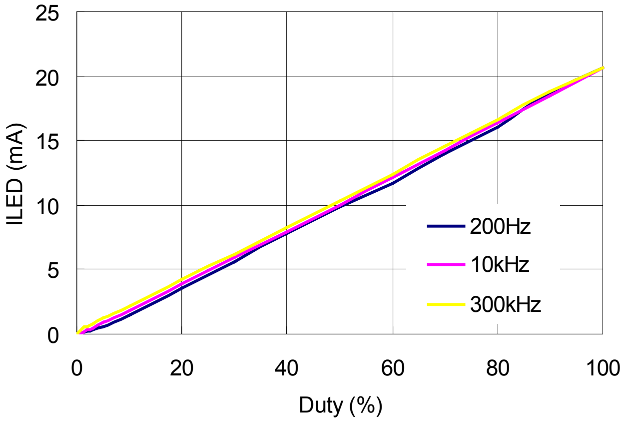



$V_{OUT}$=20V, L=10µH (LQH32CN100K53)



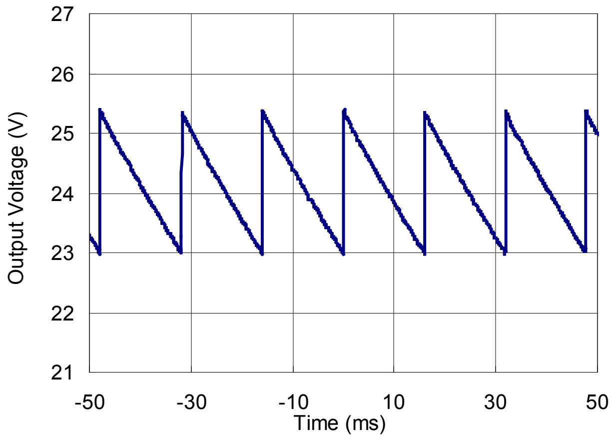
### 4) Maxduty vs. ILED

R1207N823B/C



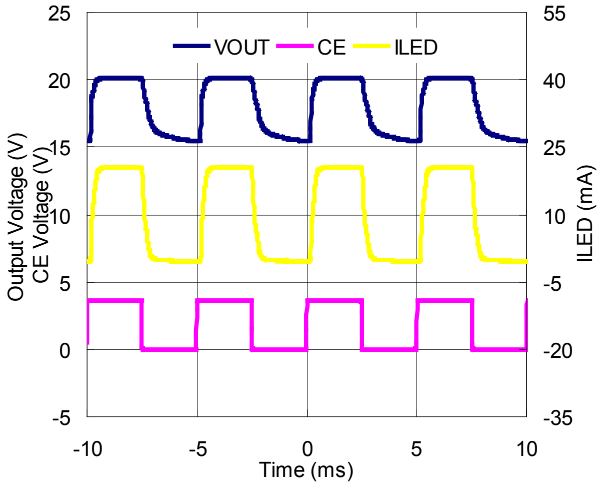

### 5) OVP Output Waveform

R1207N823B/C

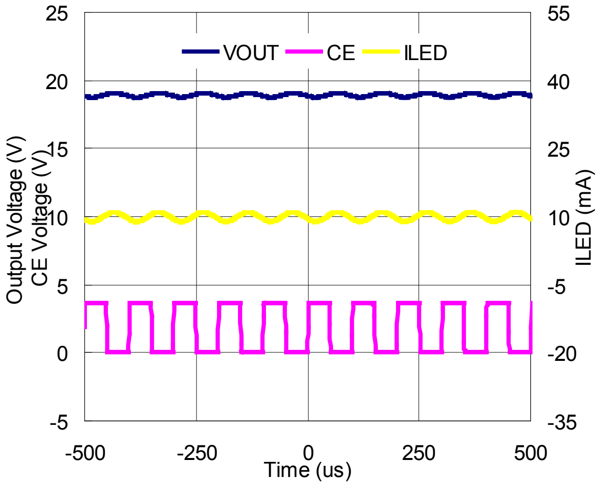



### 6) Waveform (6LED)

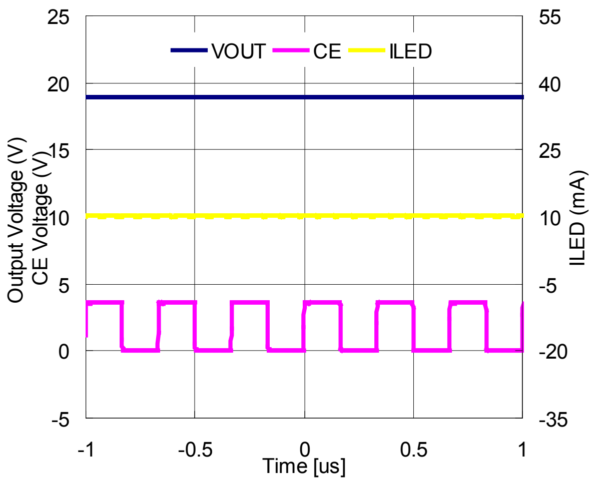
R1207N823B/C (CE Freq=200Hz)



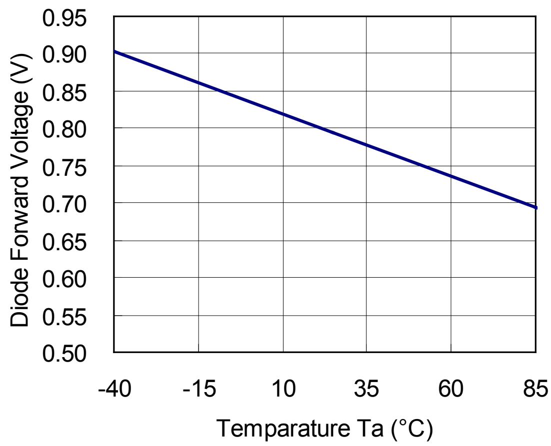

R1207N823B/C (CE Freq=10KHz)



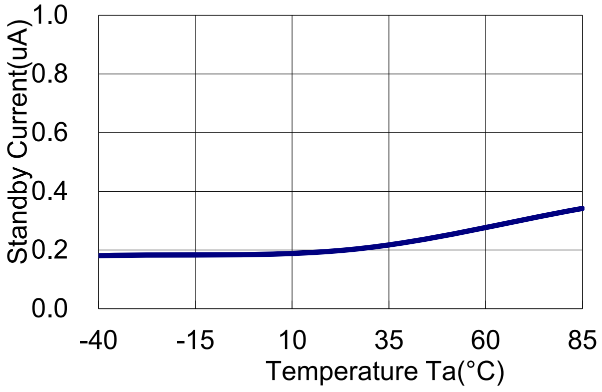

R1207N823B/C (CE Freq=300KHz)



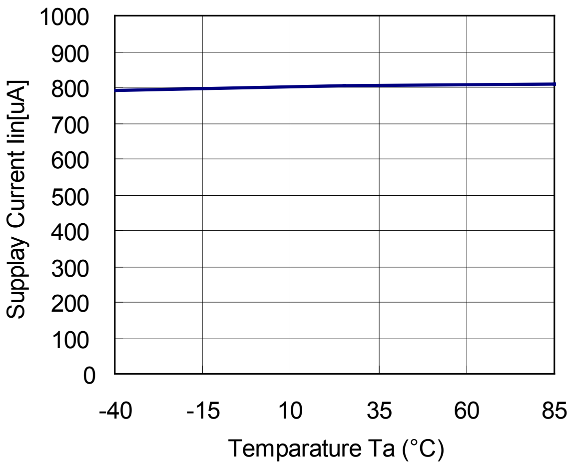

### 7) Diode Forward Voltage vs. Temperature



### 8) Standby Current vs. Temperature

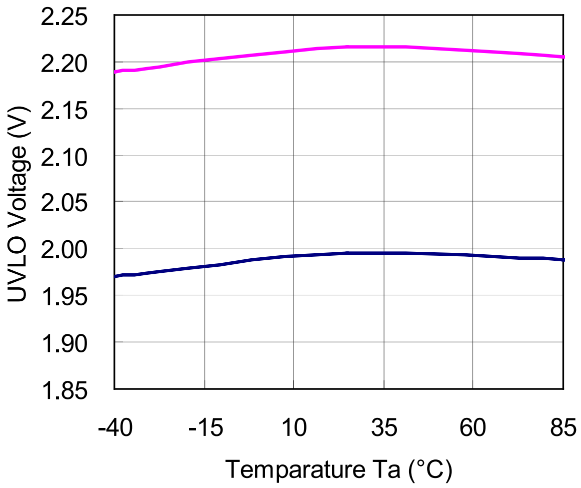



### 9) Supply Current vs. Temperature

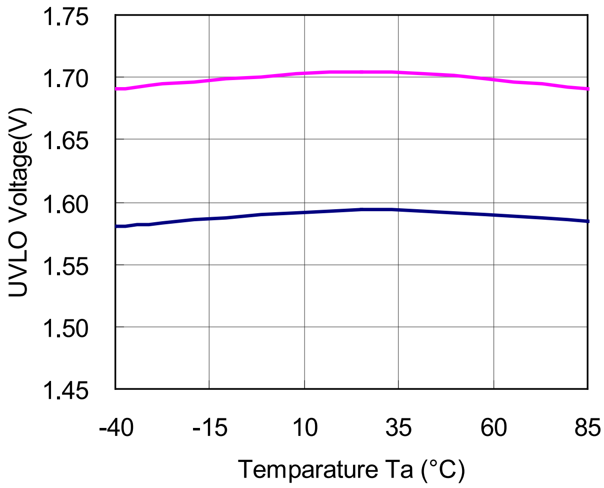



### 10) UVLO Output Voltage vs. Temperature

**R1207N8xxA**

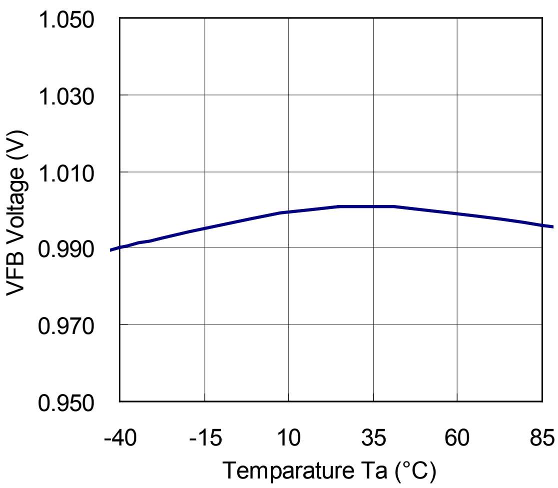



**R1207N8xxB**

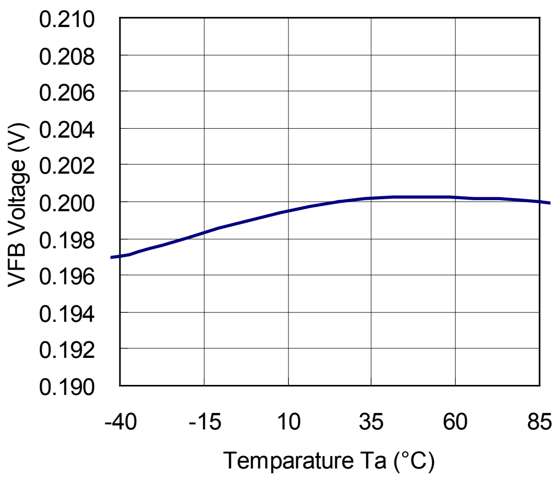



### 11) VFB Voltage vs. Temperature

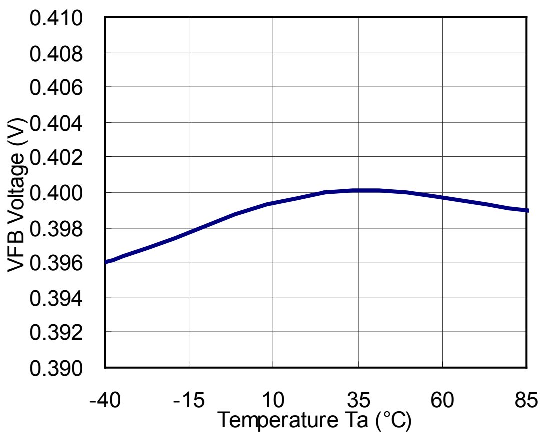
**R1207N8xxA**



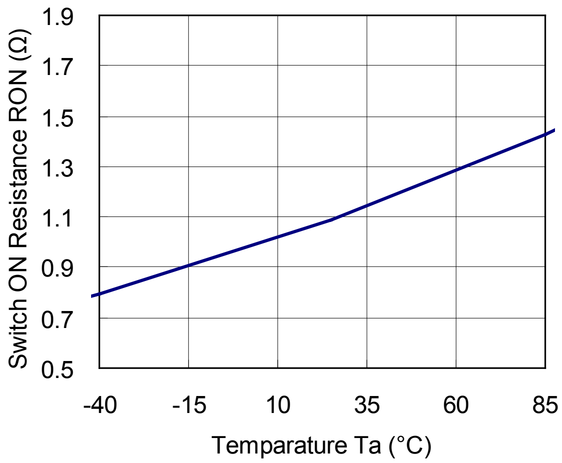

**R1207N8xxB**



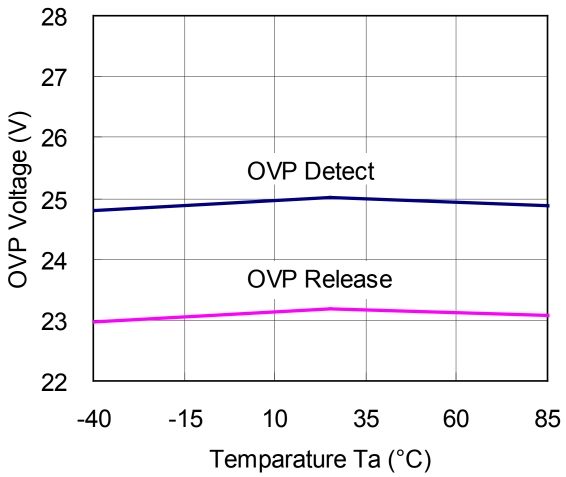
R1207N8xxC




## 12）Switch ON Resistance RON vs. Temperature

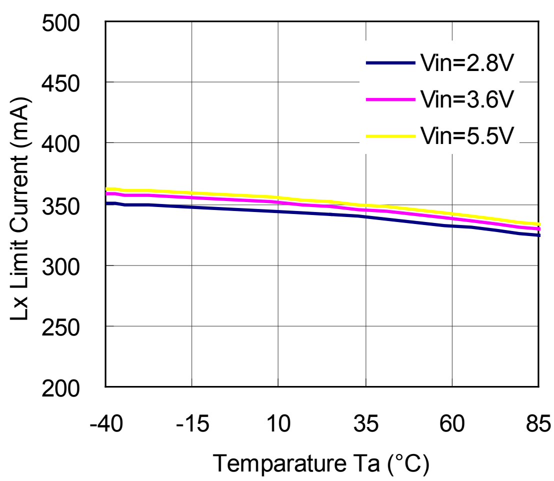



## 13）OVP Voltage vs. Temperature

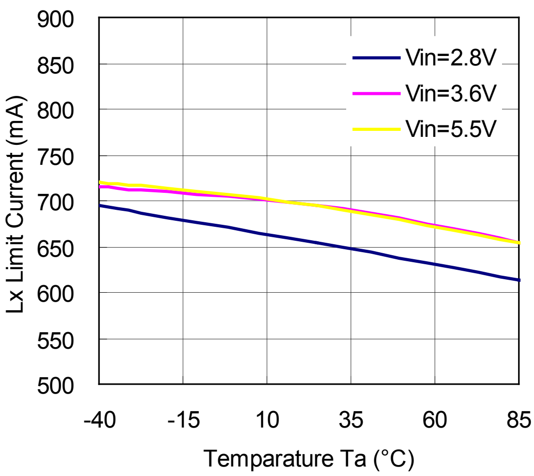



## 14）Lx Current Limit vs. Temperature

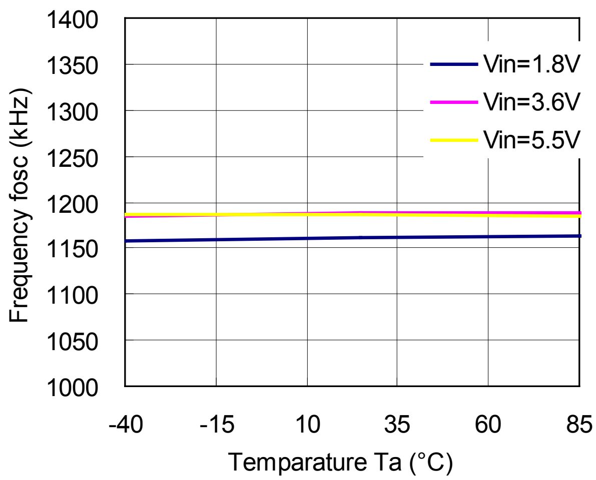
R1207N81xx



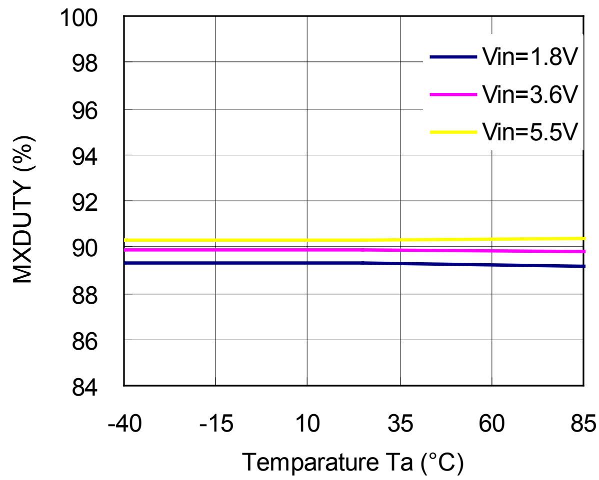

R1207N82xx



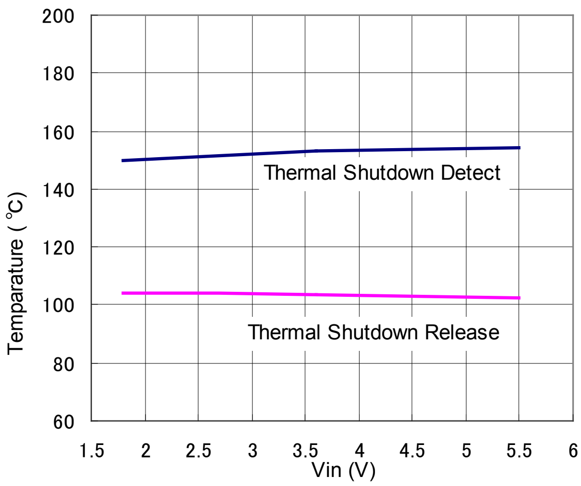
**15) Oscillator Frequency vs. Temperature**




**16) Maxduty vs. Temperature**




**17) Thermal Shutdown Detect / Release Temperature vs. Input Voltage**



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