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

NO.EA-207-120404

OUTLINE

The R1201x Series are PWM control type step-up DC/DC converter ICs with low supply current.

The R1201x is fully dedicated to drive White LEDs with constant current. Each of these ICs consists of an NMOS FET, a forward diode, 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 R1201x can drive white LEDs in constant current with high efficiency by using an inductor, a resistor and capacitors as external components. A diode is built-in; therefore it is possible to drive up to 5 serial white LEDs without an external diode.

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. The oscillator frequency can be selected from 1MHz or 1.2MHz.

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.

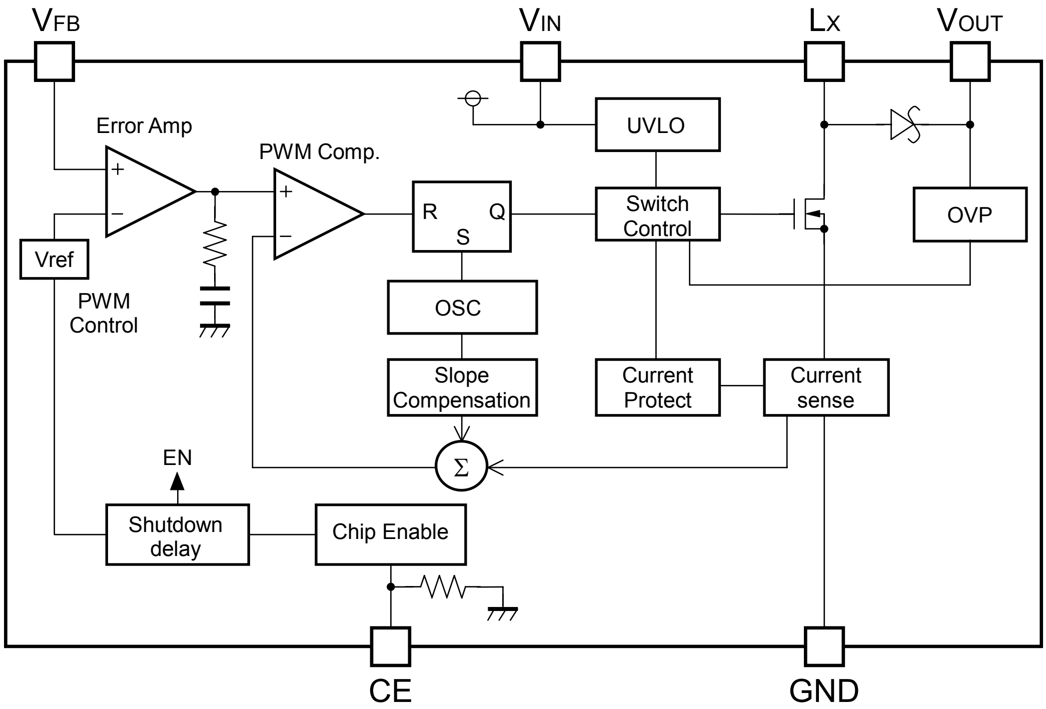
FEATURES

- Supply Current .... Typ. 450μA (R1201xxx3A/4A)
  Typ. 500μA (R1201xxx1A/2A)
- Standby Current .... Max. 5μA
- Input Voltage Range .... 1.8V to 5.5V
- Feedback Voltage 0.2V
- Feedback Voltage Accuracy.. ±10mV
- Temperature-Drift Coefficient of Feedback Voltage ... ±150ppm/°C
- Oscillator Frequency .... Typ. 1MHz, 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 .... Select from 9.5V, 14.0V, 18.5V, 20.6V, 21.6V
- Switching Control .... PWM
- LED dimming control.. by external PWM signal (Frequency 200Hz to 300kHz)
- Packages .... DFN1616-6 (Limited), SOT-23-6
- Ceramic capacitors are recommended 0.22μF (R1201x02xA/ 03xA/ 04xA)
  1μF (R1201x05xA)

APPLICATION

- White LED Backlight for portable equipment

BLOCK DIAGRAMS



SELECTION GUIDE

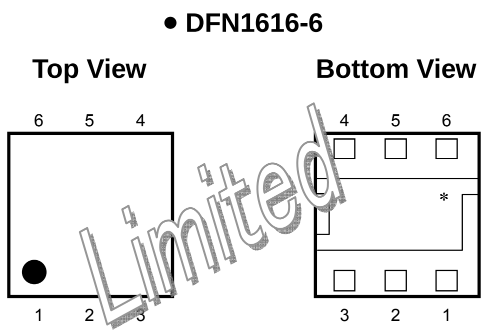
The OVP threshold voltage, and the package for the ICs can be selected at the user's request.

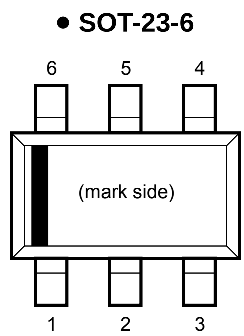
Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1201LxxxA-TR	DFN1616-6 (Limited)	5,000 pcs	Yes	Yes
R1201NxxxA-TR-FE	SOT-23-6	3,000 pcs	Yes	Yes

xxx : Designation of OVP detector threshold
(021) 9.5V threshold of OVP, Frequency 1.2MHz
(031) 14.0V threshold of OVP, Frequency 1.2MHz
(041) 18.5V threshold of OVP, Frequency 1.2MHz
(051) 20.6V threshold of OVP, Frequency 1.2MHz
(052) 21.6V threshold of OVP, Frequency 1.2MHz
(023) 9.5V threshold of OVP, Frequency 1MHz
(033) 14.0V threshold of OVP, Frequency 1MHz
(043) 18.5V threshold of OVP, Frequency 1MHz
(053) 20.6V threshold of OVP, Frequency 1MHz
(054) 21.6V threshold of OVP, Frequency 1MHz
*As for R1201x052A/ 054A version, input voltage range is 1.8V to 4.5V.

The products scheduled to be discontinued (be sold to limited customer) : "Limited"
These products will be discontinued in the future. You can not select these products newly. We will provide these products to the customer who has been using or has ordered them before. But we recommend changing to other products as soon as possible.

PIN CONFIGURATIONS





PIN DESCRIPTIONS

• DFN1616-6 (Limited)

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 25.0	V
V_{LX}	L_X Pin Voltage	−0.3 to 25.0	V
I_{LX}	L_X Pin Current	1000	mA
P_D	Power Dissipation (DFN1616-6) (Limited)*	640	mW
	Power Dissipation (SOT-23-6)*	420	
Topt	Operating Temperature Range	−40 to 85	°C
Tstg	Storage Temperature Range	−55 to 125	°C

∗) For Power Dissipation, 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.

ELECTRICAL CHARACTERISTICS

- **R1201x**

Topt=25°C

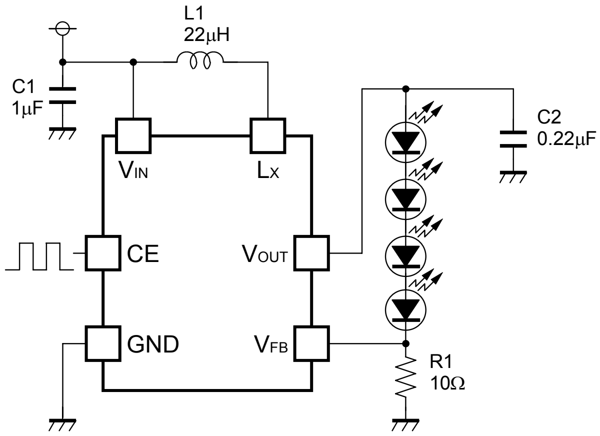
Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
V_{IN}	Operating Input Voltage	R1201xxx1A, R1201xxx3A		1.8		5.5	V
		R1201x052A, R1201x054A		1.8		4.5	
I_{DD}	Supply Current	V_{IN}=Input voltage Max, V_{FB}=0V, Lx at no load	R1201xxx1A/2A		0.5	1.0	mA
			R1201xxx3A/4A		0.45	0.9	
$I_{standby}$	Standby Current	V_{IN}=Input voltage Max, 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}=Input voltage Max		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
$\Delta V_{FB}/\Delta Topt$	V_{FB} Voltage Temperature Coefficient	V_{IN}=V_{CE}=3.6V, −40°C ≤ Topt ≤ 85°C			±150		ppm /°C
I_{FB}	V_{FB} Input Current	V_{IN}=Input voltage Max, 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}=24V			0	3.0	μA
I_{LXlim}	Switch Current Limit	V_{IN}=3.6V		400	700	1000	mA
Vf	Diode Forward Voltage	I_{DIODE}=100mA			0.8		V
$I_{DIODEleak}$	Diode Leakage Current	V_{OUT}=24V, V_{LX}=0V				10	μA
fosc	Oscillator Frequency	V_{IN}=3.6V, V_{OUT}=V_{FB}=0V	R1201xxx1A/2A	1.0	1.2	1.4	MHz
			R1201xxx3A/4A	0.83	1.0	1.17	
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	R1201x021A/023A	8.9	9.5	10.1	V
			R1201x031A/033A	13.4	14.0	14.6	
			R1201x041A/043A	17.9	18.5	19.1	
			R1201x051A/053A	20.0	20.6	21.2	
			R1201x052A/054A	21.0	21.6	22.2	
$\Delta V_{OVP1}/\Delta Topt$	V_{OVP1} Voltage Temperature Coefficient	V_{IN}=V_{CE}=3.6V, −40°C ≤ Topt ≤ 85°C			±150		ppm /°C

Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
V_{OVP2}	OVP Released Voltage	V_{IN}=3.6V, V_{OUT} falling	R1201x021A/023A		V_{OVP1} −0.5		V
			R1201x031A/033A		V_{OVP1} −0.75		
			R1201x041A/043A		V_{OVP1} −1.0		
			R1201x051A/053A		V_{OVP1} −1.1		
			R1201x052A/054A		V_{OVP1} −1.15		

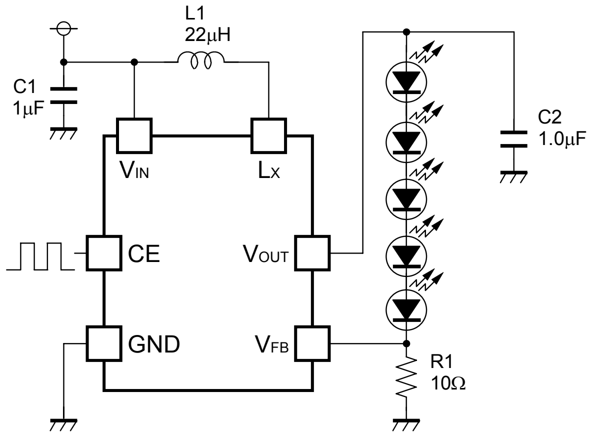
RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

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.

TYPICAL APPLICATIONS



R1201x02xA/ 03xA/ 04xA



R1201x05xA

(External Components) C2: R1201x02xA/ 03xA/ 04xA 0.22μF
C2: R1201x05xA 1.0μF

- **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**

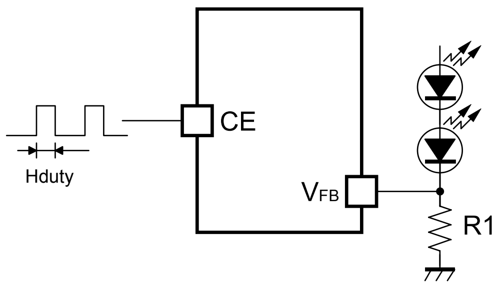
The LED brightness can be controlled by inputting the PWM signal to the CE pin. If the CE pin input is "L" in the fixed time (Typ.0.5ms), the IC becomes the standby mode and turns OFF LEDs.

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

• 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.

• Selection of Inductors

The peak current of the inductor at normal mode can be calculated as next formula:

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

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 4LEDs are driven with V_{IN}=3.6V, the recommended inductance value is 22μH or more.

• Selection of Capacitors

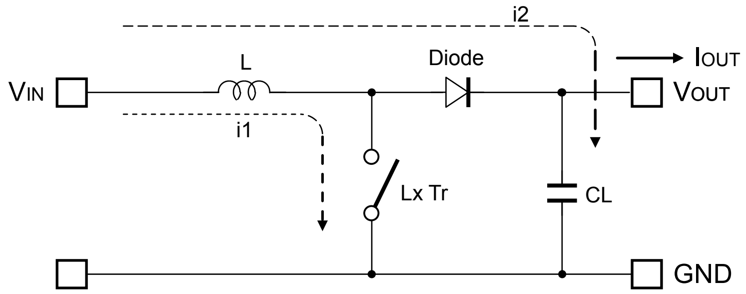
Set 1μF or more value bypass capacitor C1 between V_{IN} pin and GND pin as close as possible.

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

As for R1201x05xA version, set 1μF or more capacitor C2 between V_{OUT} pin and GND pin.

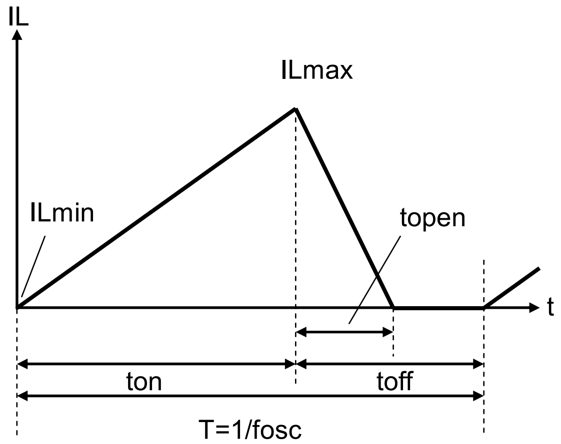
OPERATION OF STEP-UP DC/DC CONVERTER AND OUTPUT CURRENT

<Basic Circuit>

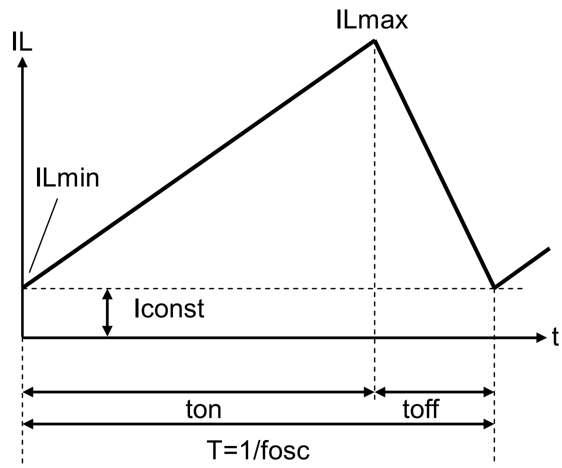


<Current through L>

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

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

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

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

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.

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

$IL1(Ave.) = V_{IN} \times t_{on} / (2 \times L)$ .... 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_{xmax}) of inductor will be

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

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

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 ILmax value.

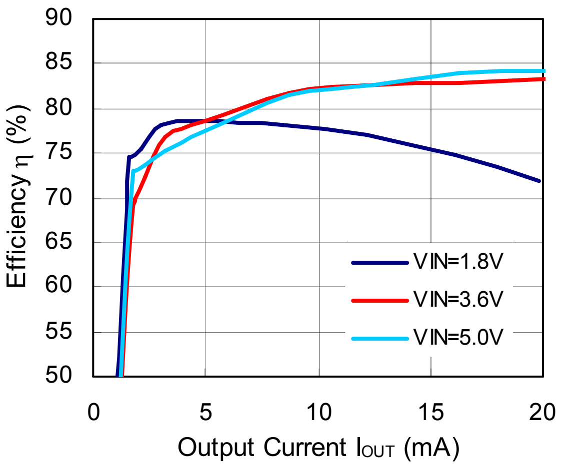
The explanation above is based on the ideal calculation, and the loss caused by L_X switch and the external components are not included.

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}.

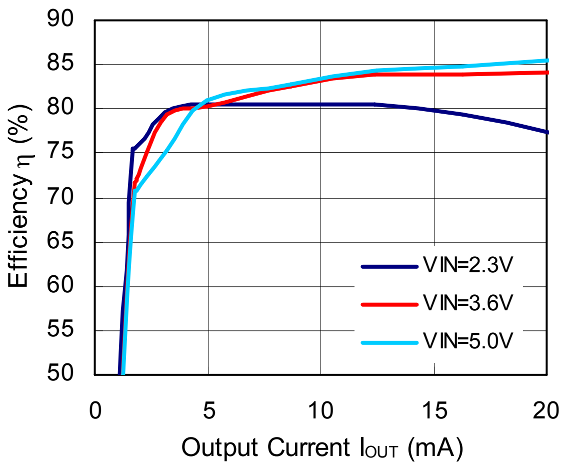
TYPICAL CHARACTERISTICS

1) Efficiency vs. Output Current Characteristics (f_{OSC}=1.2MHz)

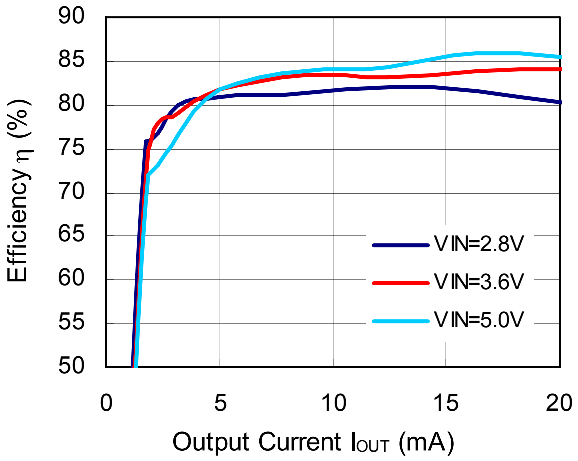
2LEDs



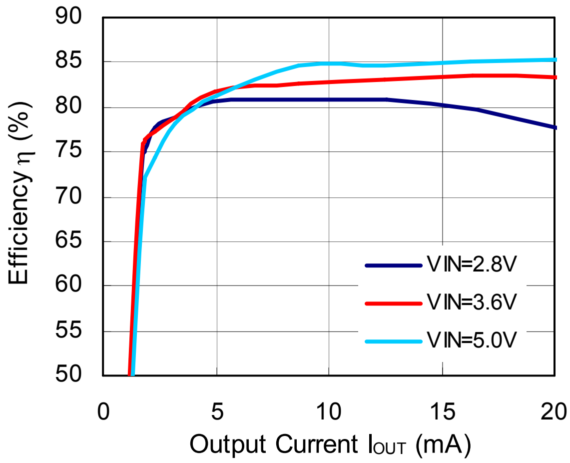
3LEDs



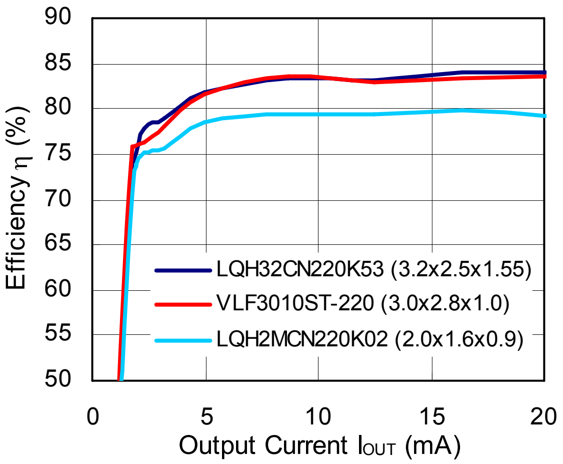
4LEDs



5LEDs

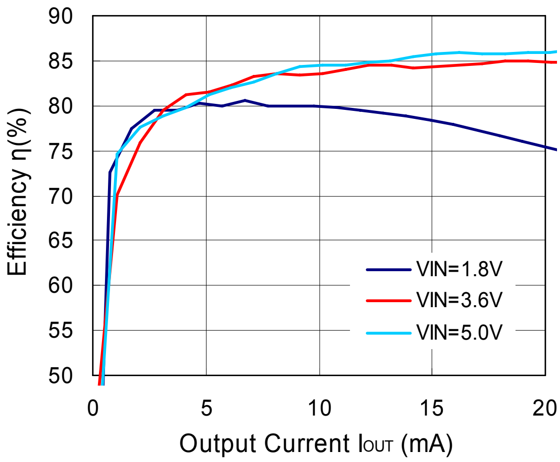


4LEDs（V_{IN} =3.6V）

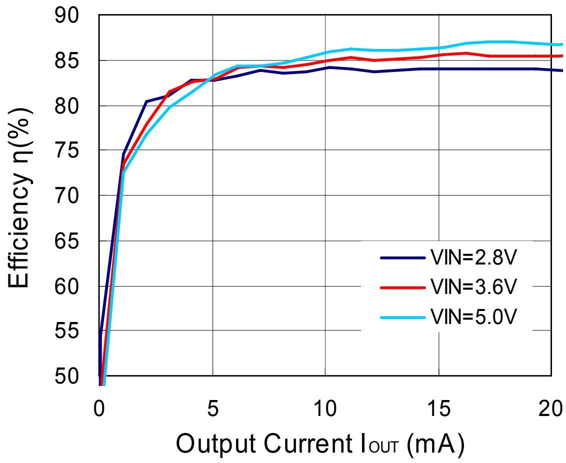


2) Efficiency vs. Output Current Characteristics (fosc=1.0MHz)

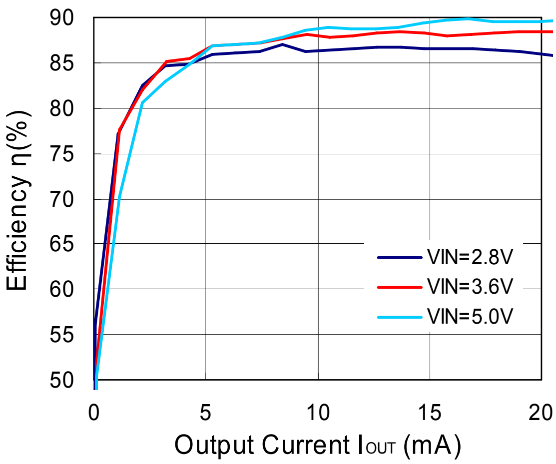
2LEDs



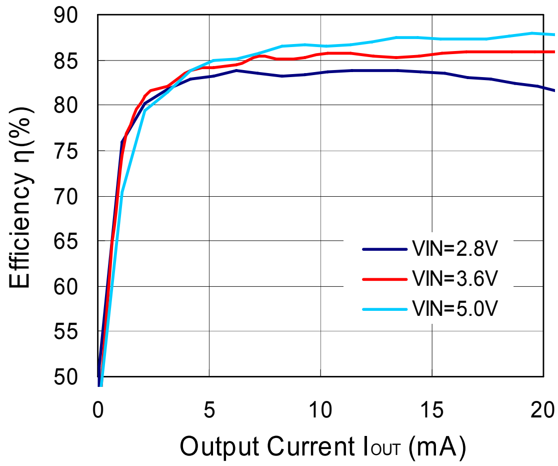
3LEDs



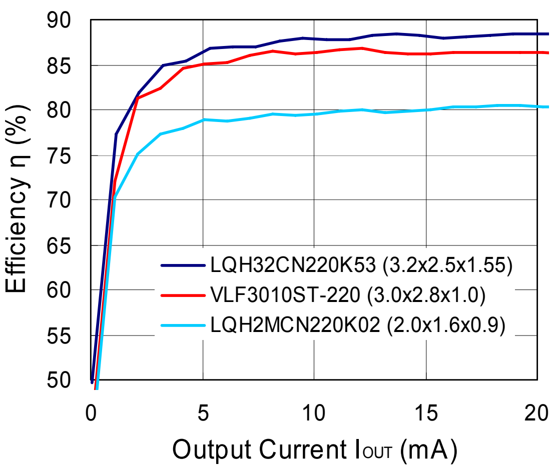
4LEDs



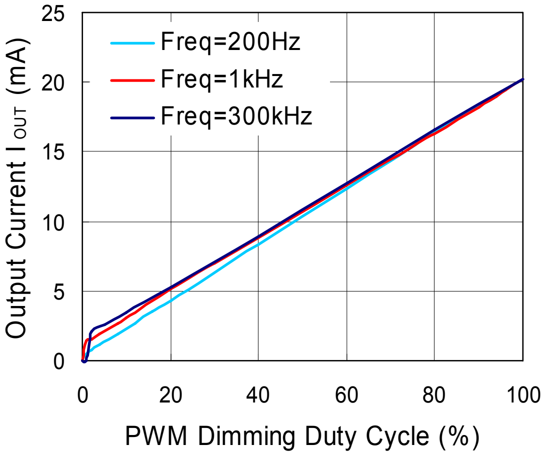
5LEDs



4LEDs（V_{IN}=3.6V）

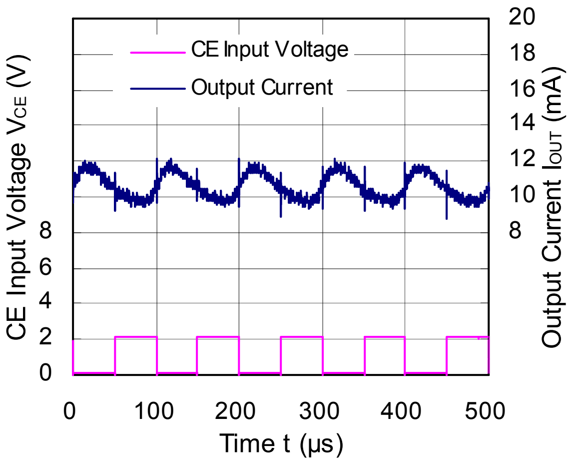


3) PWM Dimming Duty Cycle vs. Output Current (R1=10Ω)

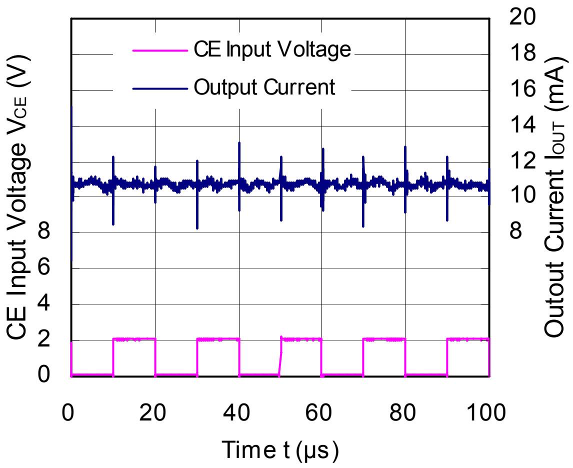


4) Output Current Ripple during PWM Dimming

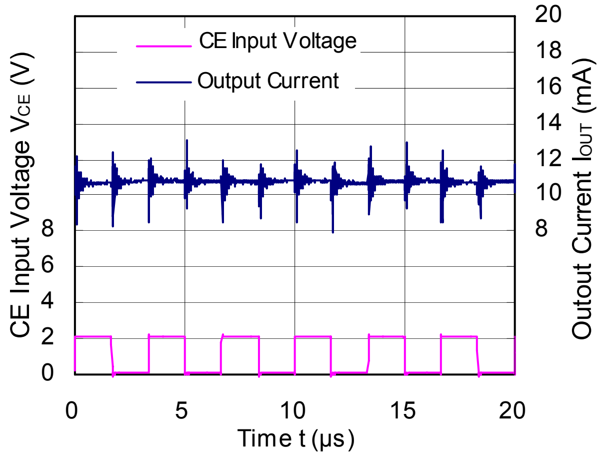
f=10kHz



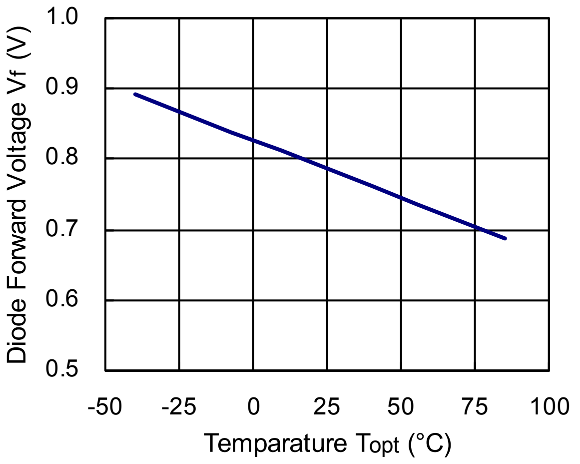
f=50kHz



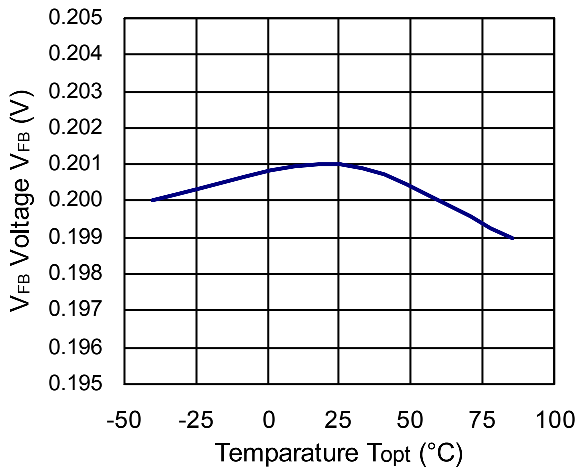
f=300kHz



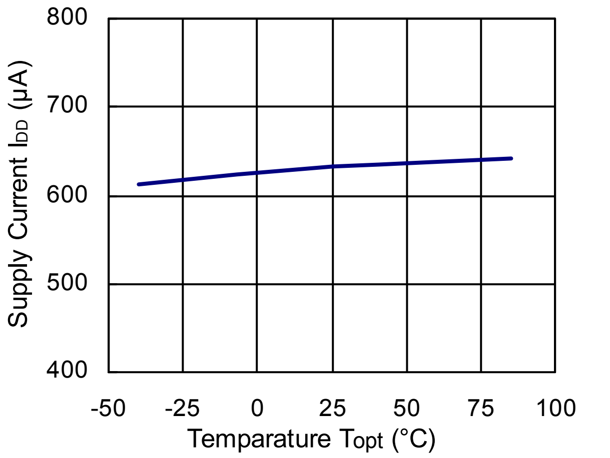
5) Diode Forward Voltage vs. Temperature



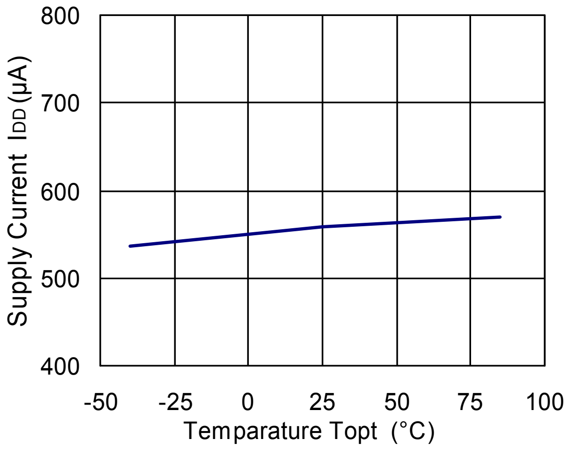
6) V_{FB} Voltage vs. Temperature



7) Supply Current vs. Temperature (f_{osc}=1.2MHz)

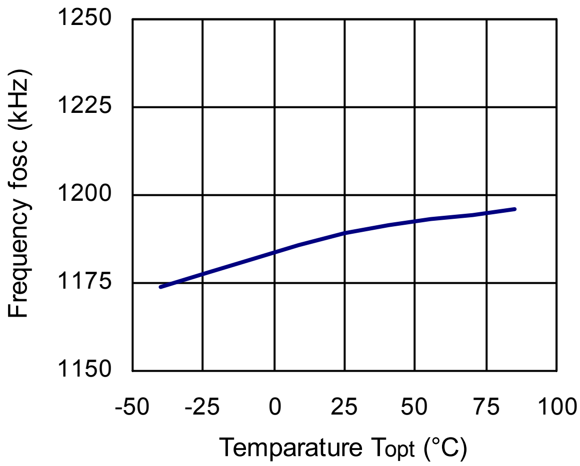


8) Supply Current vs. Temperature(f_{osc}=1.0MHz)



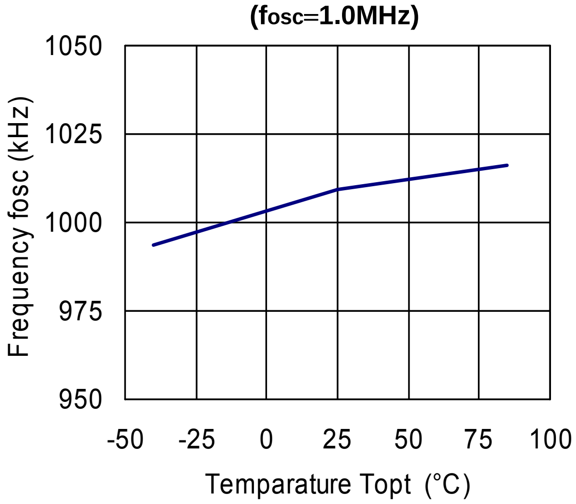
9) Oscillator Frequency vs. Temperature

(f_{osc}=1.2MHz)

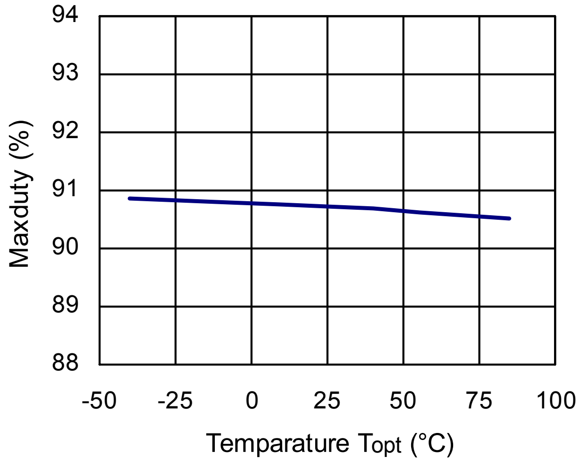


10） Oscillator Frequency vs. Temperature

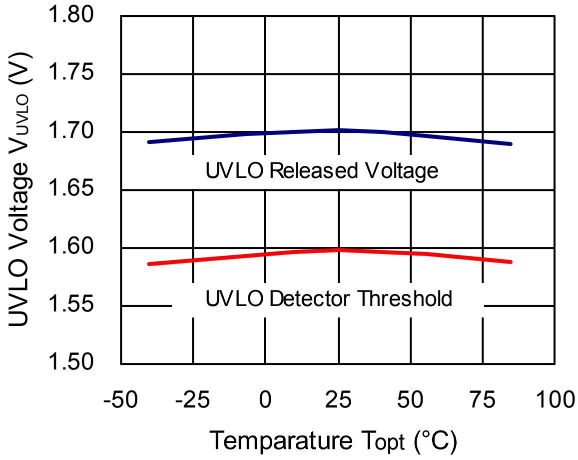
(f_{osc}=1.0MHz)



11) Maxduty vs. Temperature

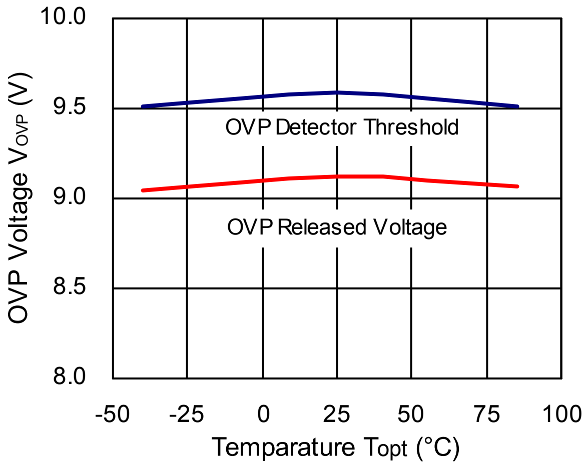


12) UVLO Output Voltage vs. Temperature

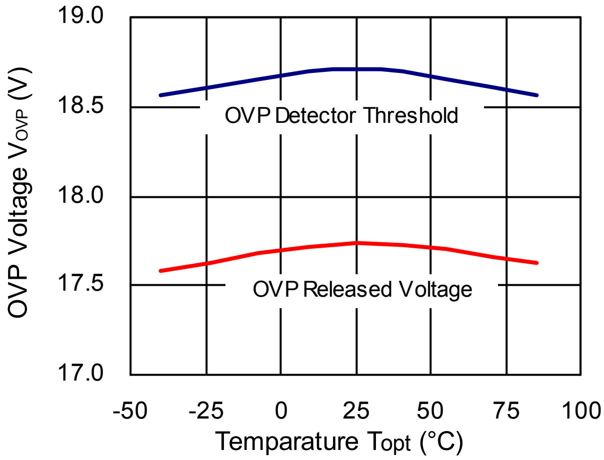


13) OVP Voltage vs. Temperature

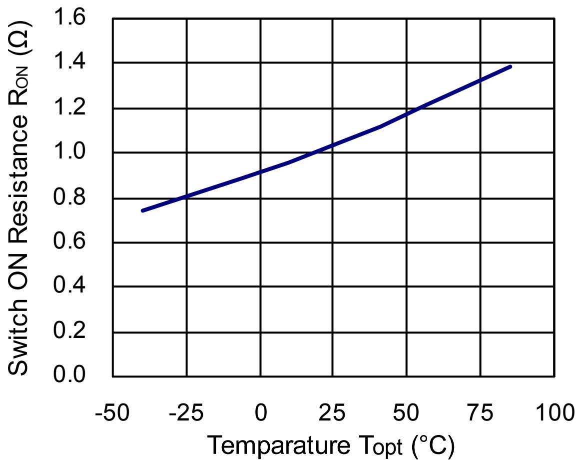
R1201x02xA



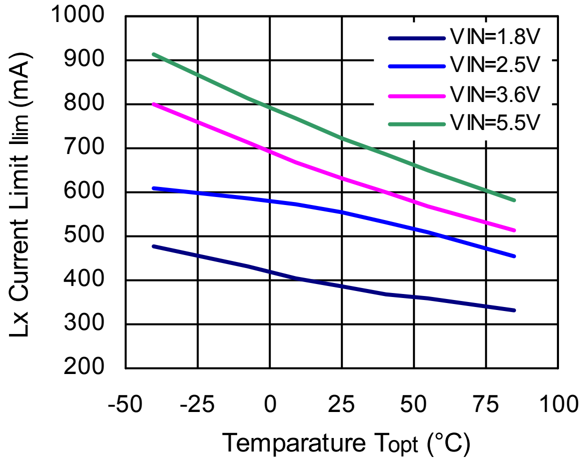
R1201x04xA



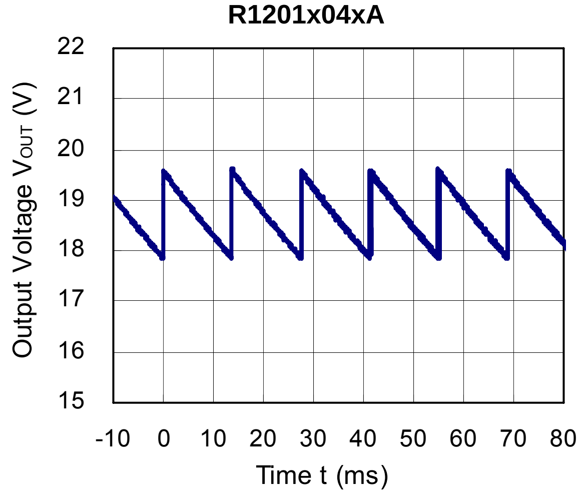
14) Switch ON Resistance vs. Temperature



15) Lx Current Limit vs. Temperature



16) OVP Operating Output Voltage Waveform



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日本経営品質賞 1999年度受賞

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