Step-up DC/DC converter for White LED Backlight

NO.EA-207-091029

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), an over-voltage protection circuit (OVP), and so on.

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 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.

It is controllable the dimming of LEDs when the PWM signal (between 10kHz ~ 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.

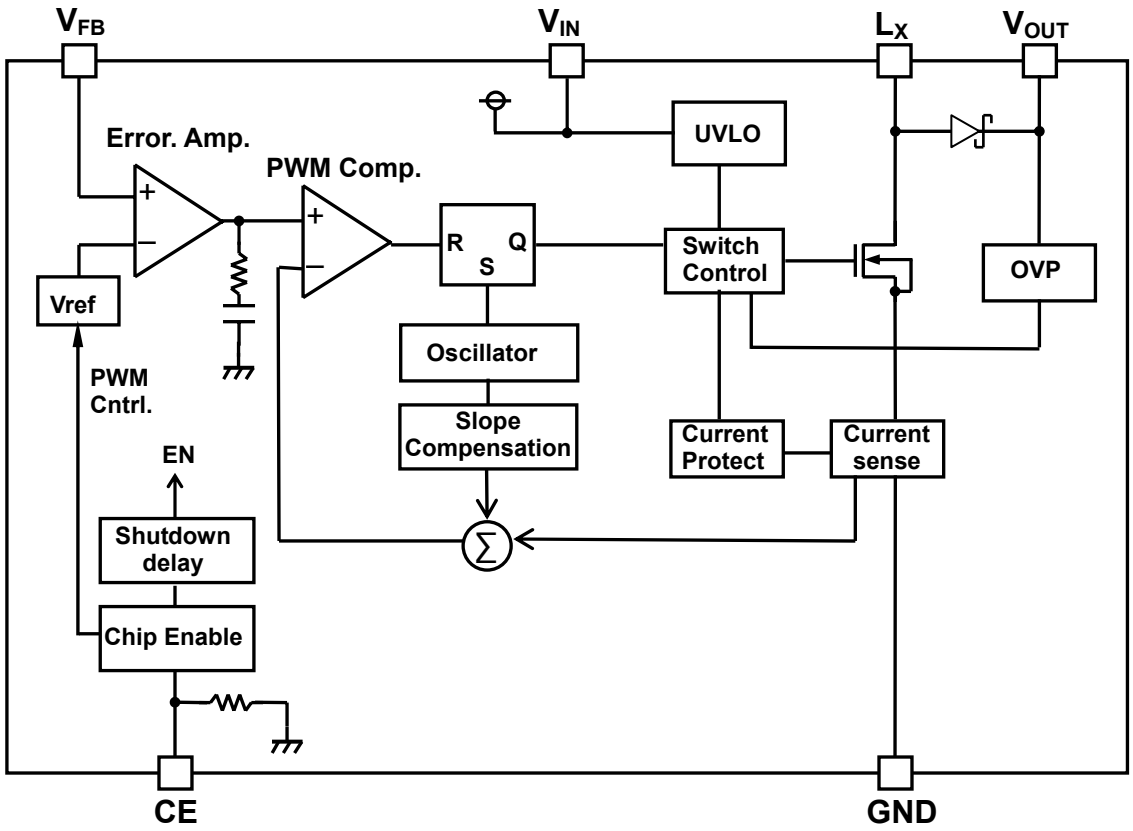
FEATURES

- Input voltage..... 1.8V to 5.5V
- Built-in 400mA, 1.5Ω, 25V Nch MOSFET and diode
- Oscillator Frequency (PWM control)..... 1.2MHz
- Maximum Duty Cycle..... Typ. 91%
- Feedback Voltage ..... Typ. 0.2V
- UVLO Threshold Voltage ..... Typ. 1.6V (Hysteresis Typ. 0.1V)
- Lx Current limit Protection..... Typ. 700mA
- Over Voltage Protection (OVP) Threshold.... Typ. 9.5V (R1201x021A)
  Typ. 14.0V (R1201x031A)
  Typ. 18.5V (R1201x041A)
  Typ. 20.6V (R1201x051A)
  Typ. 21.6V (R1201x052A)
- LED dimming control.....by external PWM signal (Frequency 10kHz to 300kHz)
- Packages SOT-23-6, DFN1616-6

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.
The selection can be available by designating the part number as shown below;

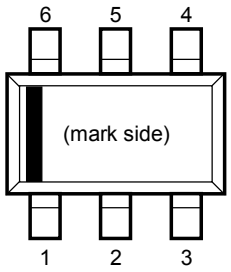
R1201x xxx A - xx-x ←Part Number
↑ ↑ ↑ ↑
a b c d

Code	Contents
a	Designation of Package Type: N: SOT-23-6 L: DFN1616-6
b	Designation of OVP threshold and with/without of built-in diode 021: 9.5V 031: 14.0V 041: 18.5V 051: 20.6V 052: 21.6V (Note1)
c	Designation of Taping Type: Ex. TR (Refer to Taping Specifications; for SOT-23-6 and DFN1616-6)
d	Designation of composition of plating: -F : Lead free plating (SOT-23-6) None : Au plating (DFN1616-6)

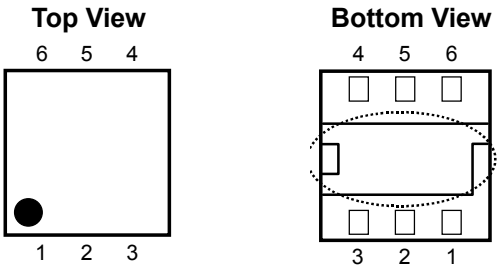
Note1: As for R1201x052A version, input voltage range is 1.8V~4.5V.

PIN CONFIGURATIONS

● **SOT-23-6**



● **DFN1616-6**



PIN DESCRIPTIONS

R1201N: SOT-23-6

Pin No.	Symbol	Description
1	CE	Chip Enable Pin
2	V_{OUT}	Output Pin
3	V_{IN}	Power Supply Input Pin
4	L_X	Switching Pin (Open Drain Output)
5	GND	Ground Pin
6	V_{FB}	Feedback Pin

R1201L: DFN1616-6

Pin No.	Symbol	Description
1	CE	Chip Enable Pin
2	V_{FB}	Feedback Pin
3	L_X	Switching Pin (Open Drain Output)
4	GND	Ground Pin
5	V_{IN}	Power Supply Input Pin
6	V_{OUT}	Output Pin

* Tab is GND level. (They are connected to the back side of this IC.)
Do not connect to other wires or land patterns.

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		V
V_{LX}	L_X Pin Voltage	-0.3 to 25		V
I_{LX}	L_X Pin Current	1000		mA
P_D	Power Dissipation *	SOT-23-6	420	mW
		DFN1616-6	640	
Ta	Ambient Temperature Range	-40 to 85		°C
Tstg	Storage Temperature Range	-55 to 125		°C

*) For Power Dissipation, please refer to PACKAGE INFORMATION to be described.

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.

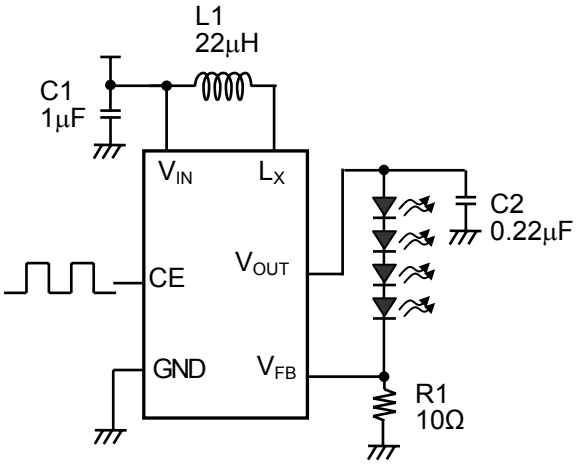
ELECTRICAL CHARACTERISTICS

(Ta=25°C)

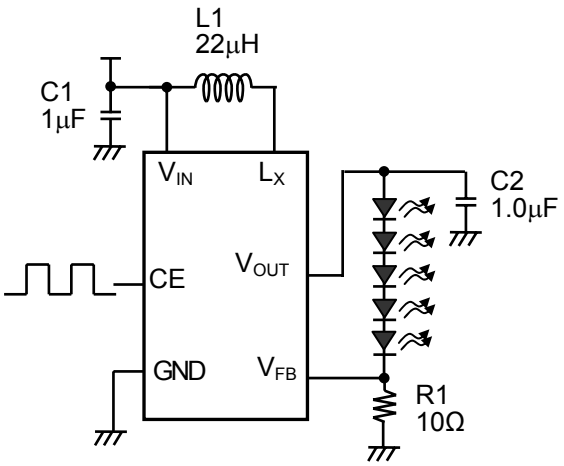
Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
■V_{IN} SECTION							
V_{IN}	Input Voltage			1.8		5.5	V
		R1201x052A		1.8		4.5	V
I_{IN}	Supply Current	V_{IN}= Input Voltage MAX, V_{FB}=0V, Lx No-Load			0.5	1	mA
$I_{standby}$	Standby Current	V_{IN}= Input Voltage MAX, V_{CE}=0V			1.0	5.0	μA
V_{UVLO1}	UVLO 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
■CE SECTION							
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
■FB SECTION							
V_{FB}	V_{FB} Voltage	V_{IN}=V_{CE}=3.6V		0.19	0.2	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}= Input Voltage MAX. , V_{FB}=0V or V_{IN}		-0.1		0.1	μA
■Nch-SWITCH & DIODE SECTION							
R_{ON}	Switch On Resistance	V_{IN}=3.6V, I_{LX}=100mA			1.35		Ω
I_{OFF}	Switch Leakage Current	V_{LX}=24V			0	3.0	μA
I_{LIM}	Switch Current Limit	V_{IN}=3.6V		400	700	1000	mA
R1201xxx1A							
V_F	Diode Forward Voltage	I_{DIODE}=100mA			0.8		V
$I_{DIODEleak}$	Diode Leakage Current	V_{OUT}=24V, V_{LX}=0V				10	μA
■OSCILLATOR & PWM SECTION							
fosc	Oscillator Frequency	V_{IN}=3.6V, V_{OUT}=V_{FB}=0V		1000	1200	1400	kHz
Maxduty	Maximum Duty Cycle	V_{IN}=3.6V, V_{OUT}=V_{FB}=0V		86	91		%
■OUTPUT SECTION							
V_{OVP1}	OVP Detector Threshold	V_{IN}=3.6V V_{OUT} rising	R1201x021A	8.9	9.5	10.1	V
			R1201x031A	13.4	14.0	14.6	V
			R1201x041A	17.9	18.5	19.1	V
			R1201x051A	20.0	20.6	21.2	V
			R1201x052A	21.0	21.6	22.2	V
$\Delta V_{OVP1}/\Delta T$	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	R1201x021A		V_{OVP1} -0.5		V
			R1201x031A		V_{OVP1} -0.75		V
			R1201x041A		V_{OVP1} -1.0		V
			R1201x051A		V_{OVP1} -1.1		V
			R1201x052A		V_{OVP1} -1.15		V

TYPICAL APPLICATION

R1201X021A / 031A / 041A



R1201X051A / 052A



- **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 x V_{FB} / R1

The frequency of the PWM signal is using the range between 10kHz 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.

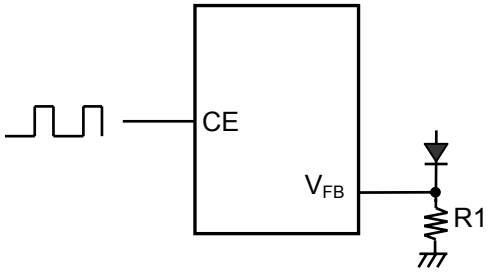


Fig.2 Dimming control by CE pin input

- **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:

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

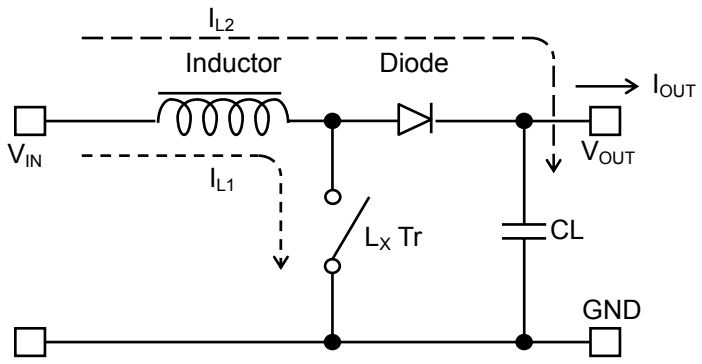
When the start-up or dimming control by CE pin, transient current flows, the peak current must be equal or less than the current limit of the IC. The peak current should not beyond the rating current of the inductor. When 4LEDs are driven with V_{IN}=3.6V, the recommended inductance value is 22uH.

- **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.
As for R1201X051A、R1201X052A version , set 1uF or more capacitor C2 between V_{OUT} and GND pin.

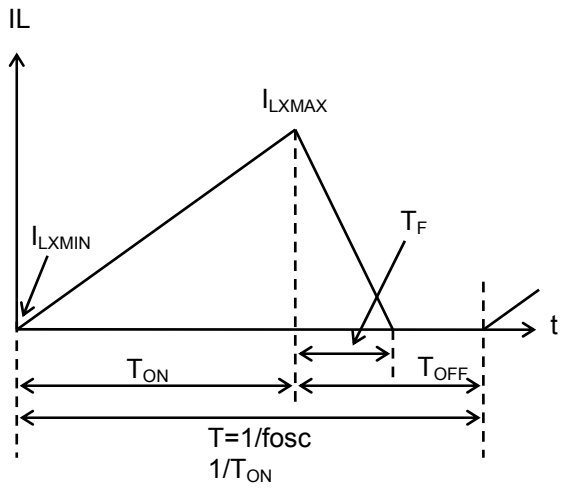
OPERATION OF STEP-UP DC/DC CONVERTER AND OUTPUT CURRENT

<Basic Circuit>

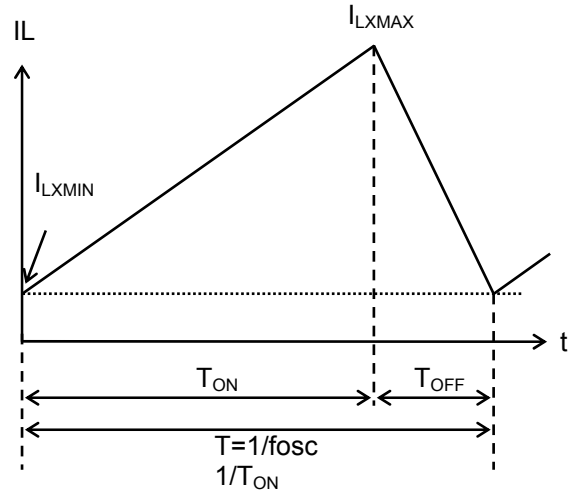


<Current through L>

Discontinuous Mode



Continuous Mode



There are two operation modes of the step-up PWM control-switching regulator. 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 (I_{L1}) will be

$$\Delta I_{L1} = V_{IN} \times T_{ON} / L \quad \text{.....Formula 1}$$

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 (I_{L2}) will be

$$\Delta I_{L2} = (V_{OUT}-V_{IN}) \times T_F / L \quad \text{.....Formula 2}$$

At the PWM control-method, the inductor current become continuously when $T_F=T_{OFF}$, the switching regulator operate as the continuous mode.

In the continuous mode, the variation of current of I_{L1} and I_{L2} is same at regular condition.

$$V_{IN} \times T_{ON} / L = (V_{OUT}-V_{IN}) \times T_{OFF} / L \quad \text{.....Formula 3}$$

The duty at continuous mode will be

$$DUTY = T_{ON} / (T_{ON} + T_{OFF}) = (V_{OUT}-V_{IN}) / V_{OUT} \quad \text{.....Formula 4}$$

If the input voltage is equal to the output voltage, it becomes the continuous mode if the I_{OUT} value is larger than the value will be calculated by following formula.

$$I_{OUT} = V_{IN}^2 \times T_{ON} / (2 \times L \times V_{OUT}) \text{.....Formula 5}$$

The peak current (I_{LXMAX}) of inductor will be

$$I_{LXMAX} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times T_{ON} / (2 \times L) \quad \text{.....Formula 6}$$

$$I_{LXMAX} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times t \times (V_{OUT}-V_{IN}) / (2 \times L \times V_{OUT}) \quad \text{.....Formula 7}$$

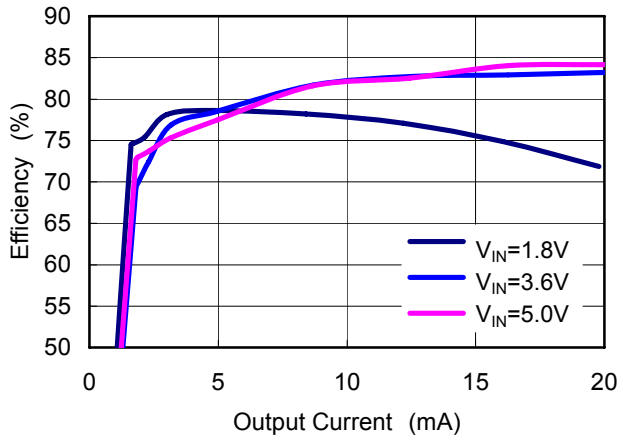
The peak current value is larger than the I_{OUT} value. In case of this, selecting the condition of the input and the output and the external components by considering of I_{LXMAX} value.

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

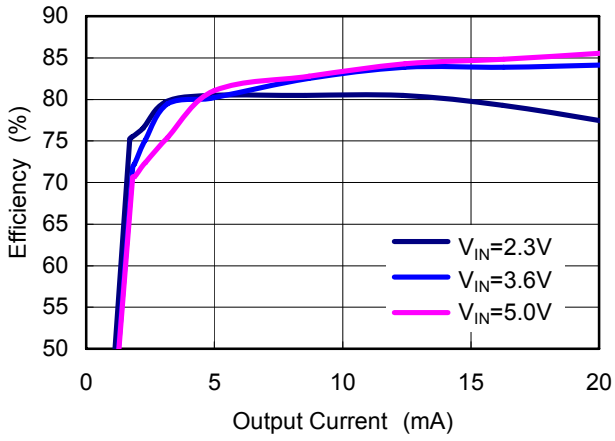
The actual maximum output current will be between 50% and 80% by the above calculations. Especially, when the I_L is large or V_{IN} is low, the loss of V_{IN} is generated with on resistance of the switch. Moreover, it is necessary to consider V_F of the diode (approximately 0.8V) about V_{OUT}.

Efficiency vs Output Current Characteristics

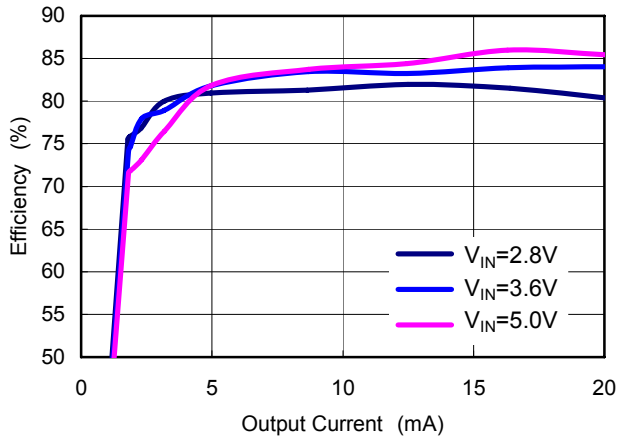
2 LEDs



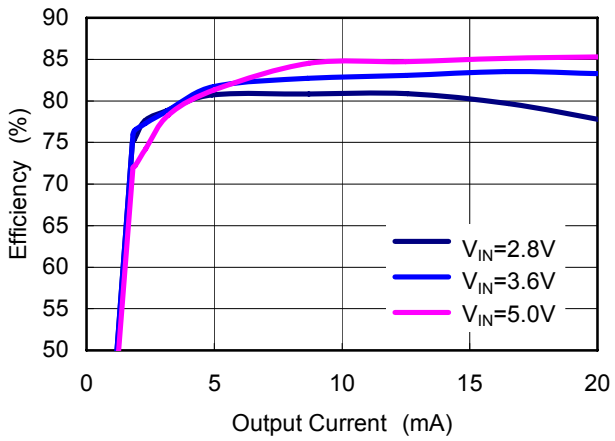
3 LEDs



4 LEDs

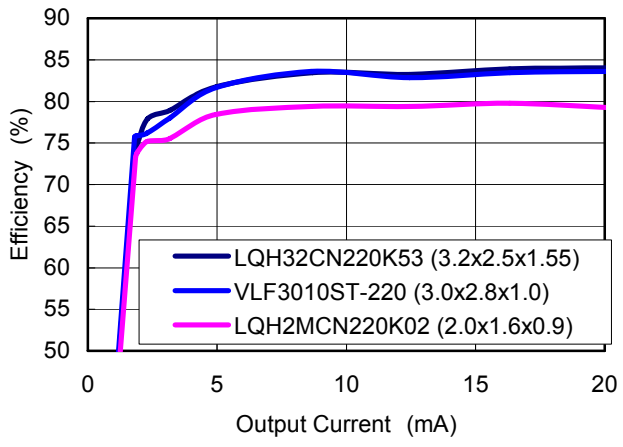


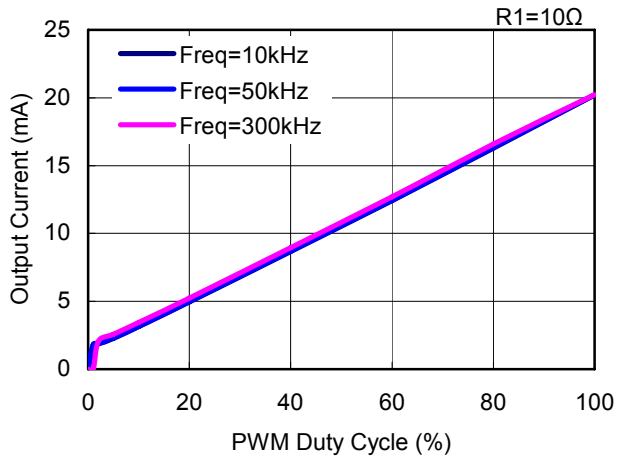
5 LEDs



PWM Dimming Duty Cycle vs Output Current

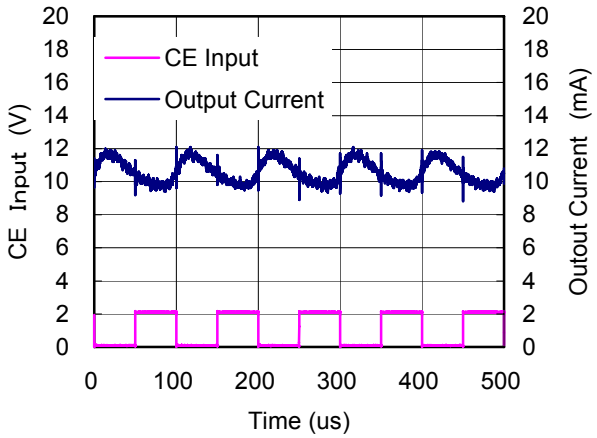
4 LEDs



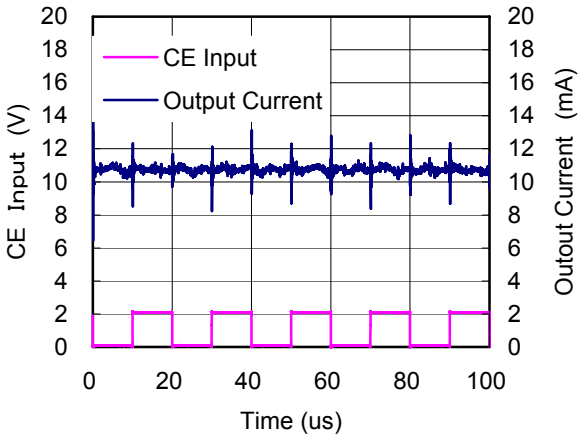


Output Current during PWM Dimming

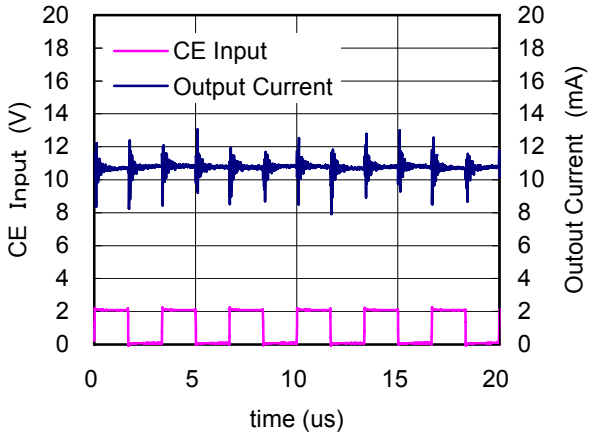
Freq=10kHz



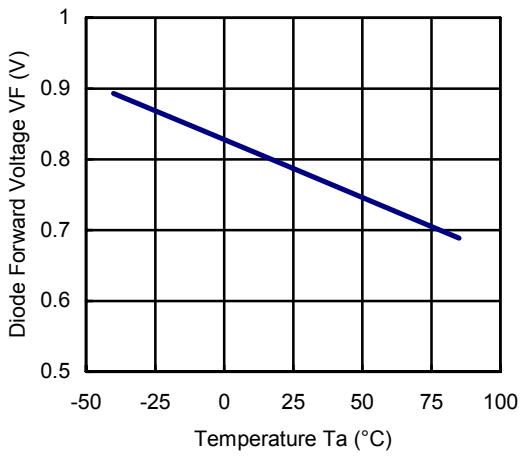
Freq=50kHz



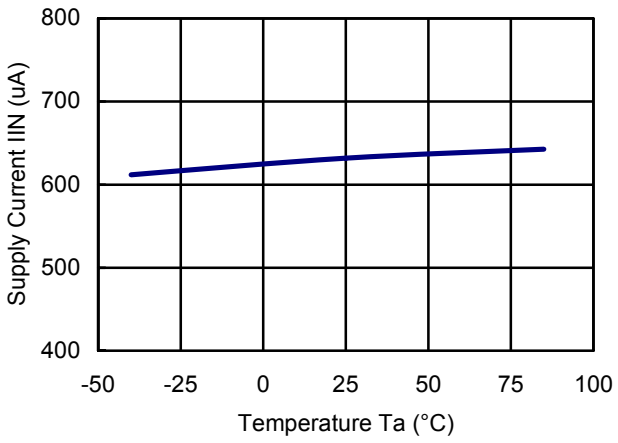
Freq=300kHz



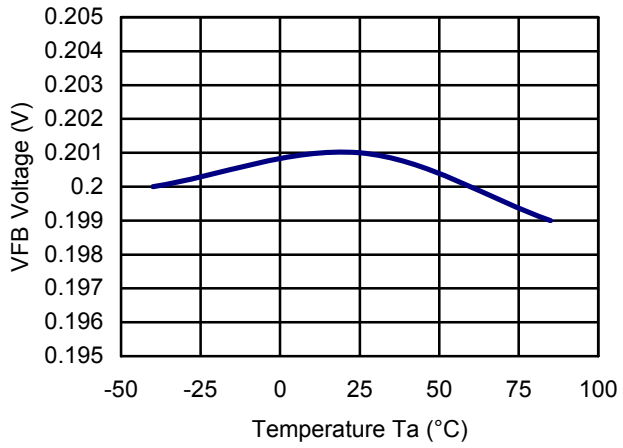
Diode Forward Voltage vs Temperatures



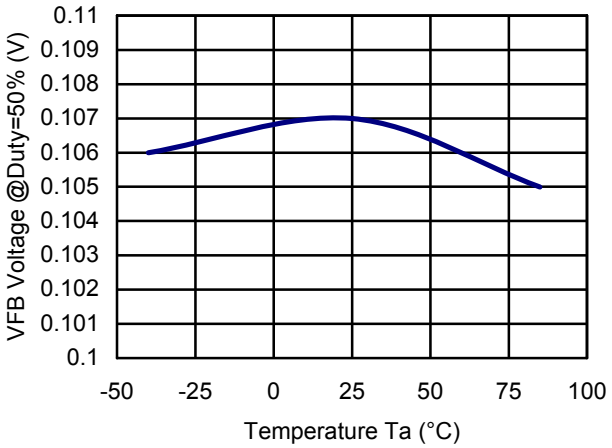
Supply Current vs Temperatures



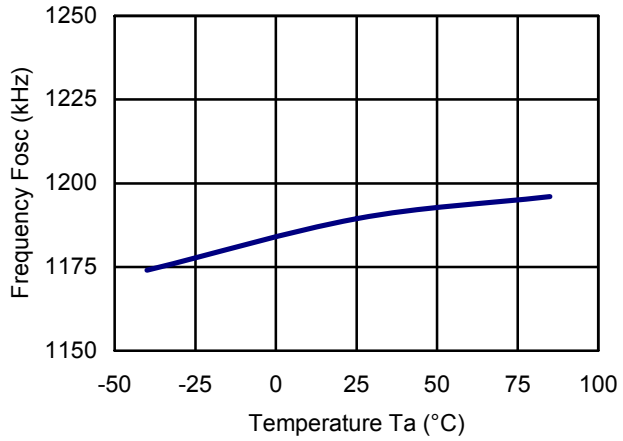
VFB Voltage vs Temperatures



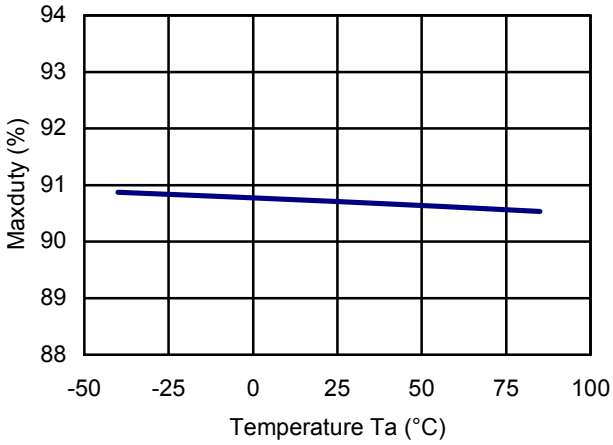
VFB Voltage(PWM Dimming Duty=50%) vs Temperatures



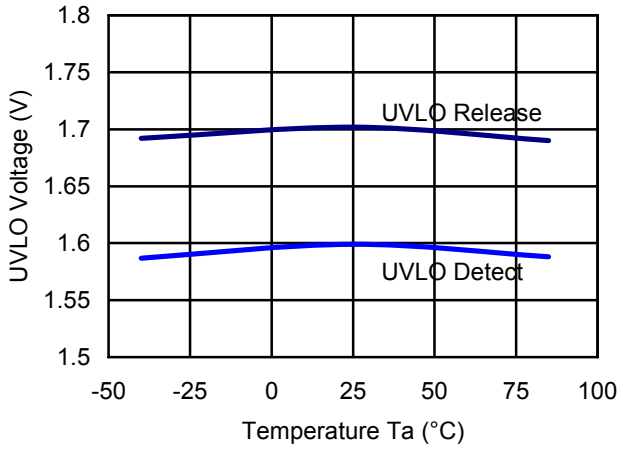
Oscillator Frequency vs Temperatures



Maxduty vs Temperatures

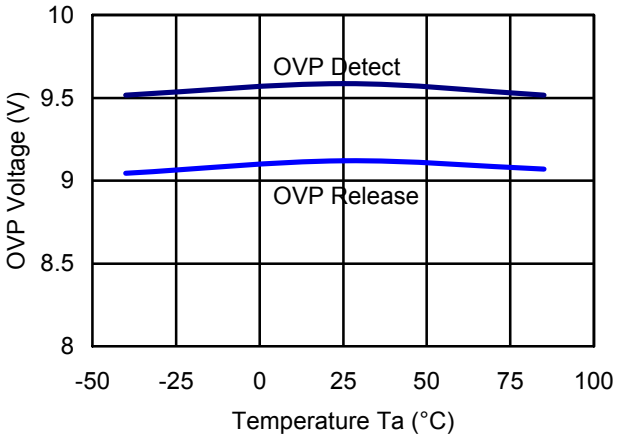


UVLO Output Voltage vs Temperatures

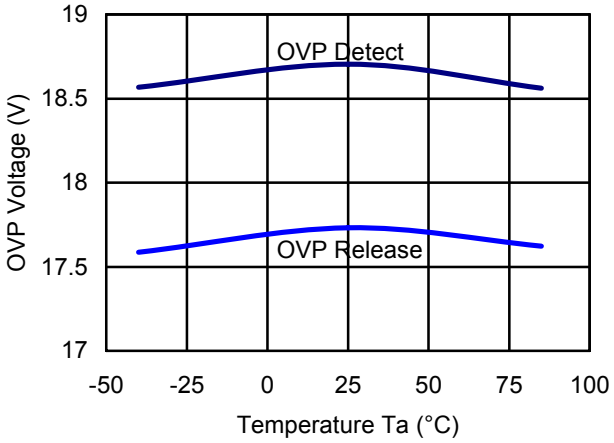


OVP Voltage vs Temperatures

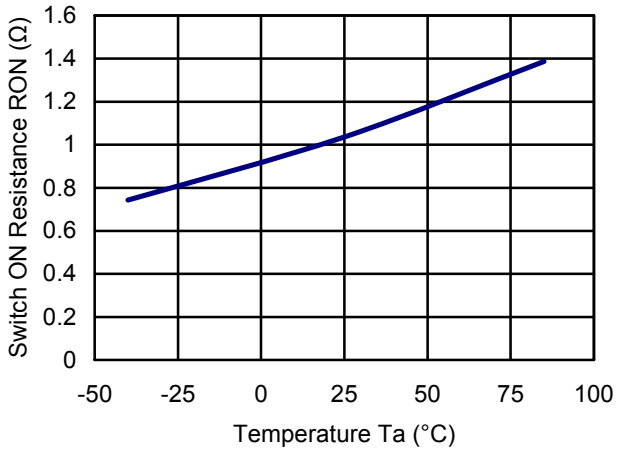
R1201x021A



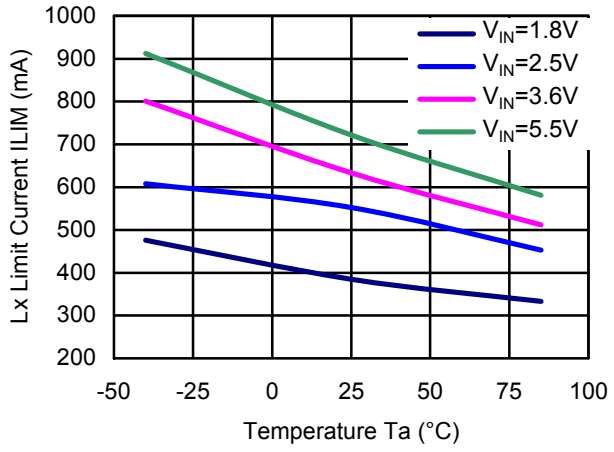
R1201x041A



Switch ON Resistance vs Temperatures

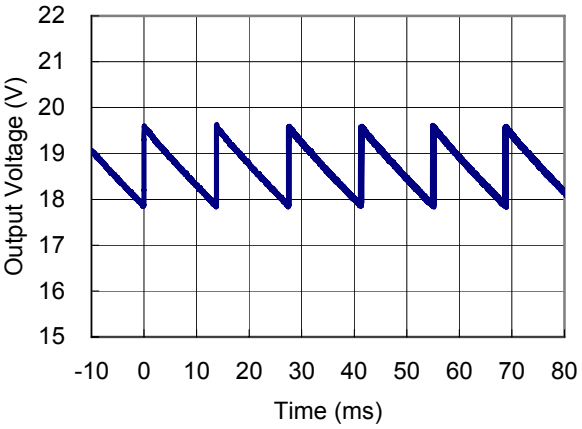


LX Current Limit vs Temeperatures



OVP Operating Output Voltage Waveform

R1201x041A



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■Ricoh awarded ISO 14001 certification.
The Ricoh Group was awarded ISO 14001 certification, which is an international standard for environmental management systems, at both its domestic and overseas production facilities. Our current aim is to obtain ISO 14001 certification for all of our business offices.

RoHS Compliant
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