HIGH EFFICIENCY, SMALL PACKAGES, STEP-UP DC/DC CONVERTERS

NO.EA-193-100806

OUTLINE

RP400xxx1C Series are high efficiency, step-up DC/DC converter ICs packaged in compact 5pin SOT23 or 6pin DFN(PLP). This converter starts up of low voltage (Typ.1.2V) operation from one to two alkaline or a nickel-metal-hydride (NiMH) or one-cell Lithium-ion (Li+) battery.

This IC consists of a reference voltage unit with soft start, a chip enable circuit, an error amplifier, phase compensation circuits, a slope circuit, a PWM control circuit, a start-up circuit, a PWM/VFM mode control circuit, internal switches and a protection circuit. As a protection circuit, RP400xxx1C has a current limit circuit which limits the peak current of the inductor at each clock cycle.

A low ripple high efficiency step up DC/DC converter can be composed of RP400xxx1C Series with only an inductor, a diode and capacitors. This converter is based on a fixed frequency current mode PWM control which goes to power save mode (VFM mode) at light load automatically. RP400xxx1C Series has built-in Anti-ringing switch to prevent switching node from ringing, when the converter enters the discontinuous current mode.

The output voltage of RP400K001C can be set within 1.8~5.0V (recommended range of output voltage) by external divider resistors.

FEATURES

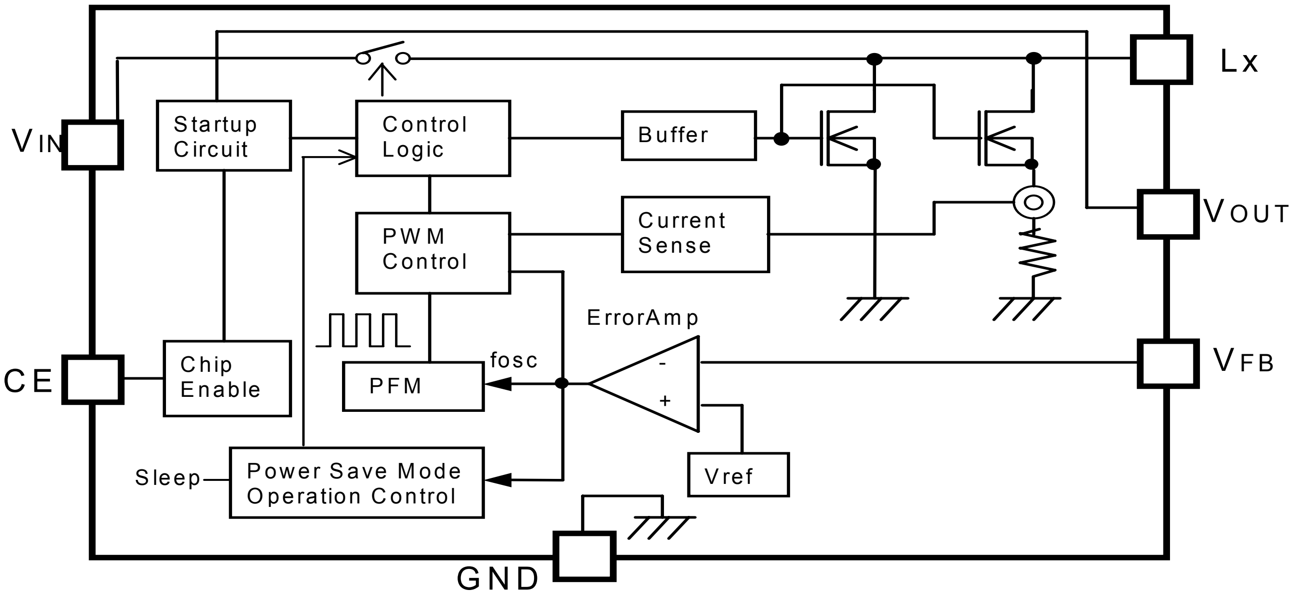
- Low Start-up Voltage guaranteed ························ 1.2V
- Input Voltage Range ·· 1.2V~5.5V
- High Efficiency ··· 85% (100mA/3.3V, V_{IN}=1.5V, 25°C)
- Output current ·· 200mA/3.3V(V_{IN}=1.5V) Typ. 100mA/2.0V(V_{IN}=1.2V)
- Internal Switch ··· NMOS=0.4Ω (V_{OUT}=3.3V, 25°C)
- Built-in Phase Compensation, Soft Start, Peak Current Limit Protection
- PWM Oscillator Frequency ································ 700kHz
- Output Voltage Range ·· Fixed: 1.8V to 5.0V with 0.1V Stepwise
  Adjustable: 1.8V~5.0V (RP400K001C only)
  (Recommended range of output voltage)
- Stable with Ceramic Capacitors
- Small Package ·· DFN(PLP)1820-6, SOT23-5
- Internal EMI suppression (Anti-ringing switch is included)

APPLICATIONS

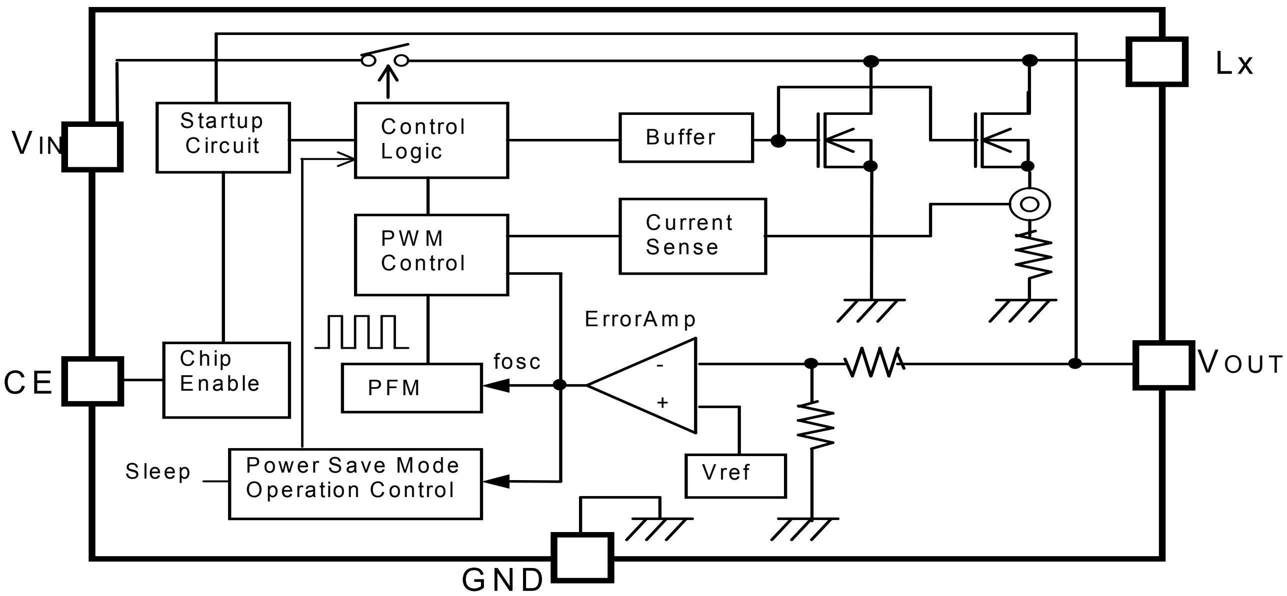
- MP3 players, PDA
- Digital Still Cameras
- LCD Bias Supplies
- Portable blood pressure meter
- Wireless Handset
- GPS

BLOCK DIAGRAMS

1. Adjustable Output with CE function RP400K001C



2. Fixed Output with CE function RP400xxx1C



SELECTION GUIDE

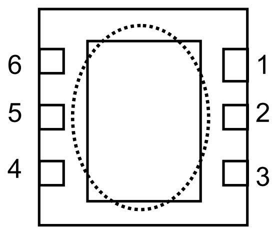
In the RP400 Series, output Voltage, Type of Output Voltage, and package for the ICs can be selected at the user's request.

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
RP400Kxx1C-TR	DFN (PLP)1820-6	5,000 pcs	Yes	Yes
RP400Nxx1C-TR-FE	SOT-23-5	3,000 pcs	Yes	Yes

xx : Designation of output voltage
00: Adjustable Version (1.8V ~ 5.0V) *** recommended range of output voltage / DFN(PLP)1820-6 only**
Fixed version is possible in the range from 1.8V to 5.0V with a step of 0.1V

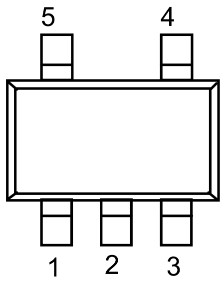
PIN CONFIGURATION

DFN(PLP)1820-6



(Bottom View)

SOT-23-5



(Top View)

PIN DESCRIPTION

RP400K001C: DFN(PLP)1820-6

Pin No	Symbol	Pin Description
1	V_{IN}	Power Supply Pin
2	CE	Chip Enable Pin (Active with "H")
3	GND	Ground Pin
4	Lx	Internal NMOS Switch Drain Pin
5	V_{FB}	Feedback Input Pin for setting output voltage
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.

RP400Kxx1C: DFN(PLP)1820-6

Pin No	Symbol	Pin Description
1	V_{IN}	Power Supply Pin
2	CE	Chip Enable Pin (Active with "H")
3	GND	Ground Pin
4	Lx	Internal NMOS Switch Drain Pin
5	NC	No Connection
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.

RP400Nxx1C: SOT-23-5

Pin No	Symbol	Pin Description
1	CE	Chip Enable Pin (Active with "H")
2	GND	Ground Pin
3	V_{IN}	Power Supply Pin
4	V_{OUT}	Output Pin
5	Lx	Internal NMOS Switch Drain Pin

ABSOLUTE MAXIMAM RATINGS

(GND=0V)

Symbol	Items	Ratings		Unit
V_{IN}	V_{IN} Supply Voltage	-0.3 ~ 6.0		V
V_{OUT}	V_{OUT} Pin Voltage	-0.3 ~ 6.0		V
V_{FB}	V_{FB} Pin Voltage	-0.3 ~ 6.0		V
V_{LX}	Pin Input Voltage	-0.3 ~ 6.0		V
V_{CE}	CE Pin Voltage	RP400K001A	-0.3 ~ 6.0	V
I_{LX}	Lx Pin Output Current	0.8		A
P_D	Power Dissipation	SOT-23-5	420	mW
		DFN(PLP)1820-6	880	
Ta	Operating Temp Range	-40 ~ + 85		°C
Tstg	Storage Temp Range	-55 ~ + 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}	Input Voltage					5.5	V
$Vstart_2$	Start-up Voltage 2	Load current = 1mA V_{CE}=1.5V			1.2	1.5	V
$Vstart_3$	Start-up Voltage 3	Load current = 1mA CE を V_{OUT} に接続時			1.2	1.5	V
$Vhold_1$	Hold-on Voltage 1 (Once started)	Load current = 1mA		0.7			V
I_{DD1}	Quiescent Current 1	Adjustable Version	V_{IN}=3V V_{OUT}=5V V_{FB}=0V		500	800	μA
		Fixed Version	V_{IN}=0.5×V_{OUT} V_{OUT}= 0.95×V_{OUT}		V_{OUT} × 100	(*3)	μA
I_{DD2}	Quiescent Current 2 (No switching)	Adjustable Version	V_{IN}=V_{OUT}=5V V_{FB}=1.0V		160	300	μA
		Fixed Version	V_{IN}=V_{OUT}=5V		160	300	μA
Istandby	Standby Current	V_{IN}=V_{OUT}=5V,V_{CE}=0V			0.15	3	μA
V_{FB}	Feedback Voltage (Adjustable Version)	V_{IN} =V_{OUT}=3.3V		0.588	0.600	0.612	V
V_{OUT}	Output-Voltage (Fixed Version)	V_{IN} = V_{CE} =1.5V		×0.98		×1.02	V
ΔV_{OUT} /ΔTa	Output-Voltage Temperature Coefficient	-40°C≤Ta≤85°C			±100		ppm/ °C
fosc	Switching Frequency	Adjustable Version	V_{IN} =V_{OUT}=3.3V	595	700	805	kHz
		Fixed Version	V_{IN}=V_{OUT}=0.95×V_{OUT}	595	700	805	kHz
Δfosc /ΔTa	Switching Frequency Temperature Coefficient	-40°C≤Ta≤85°C			±0.2		kHz /°C
R_{ONN}	NMOS On-Resistance (*1)	V_{OUT}=3.3V			0.4		Ω
I_{CEH}	CE "H" Input Current	V_{IN}=V_{OUT}=V_{CE}=5V				0.5	μA
I_{CEL}	CE "L" Input Current	V_{IN}=V_{OUT}=5V V_{CE}=0V		-0.5			μA
I_{FBH}	FB "H" Input Current (Adjustable Version)	V_{IN}=V_{OUT}=V_{FB}=5V				0.5	μA
I_{XFBL}	FB "L" Input Current (Adjustable Version)	V_{IN}=V_{OUT}=5V V_{FB}=0V		-0.5			μA
I_{LX}	Lx Leak Current	V_{IN}=V_{OUT}=VLX=5V V_{CE}=0V				5	μA
I_{Lxpeak}	Lx Leak Current limit (*2)	Adjustable Version	V_{OUT}=3.3V Detective at Duty=MaxDuty-5%	0.4	0.6		A
		Fixed Version	V_{OUT}= 0.95×V_{OUT} Detective at Duty=MaxDuty-5%	0.4	0.6		A

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ELECTRICAL CHARACTERISTICS (cont.)

(Ta=25°C)

Symbol	Item	Conditions		MIN.	TYP.	MAX.	Unit
V_{CEH}	CE Input "H" level Voltage	Adjustable Version	V_{OUT}=3.3V	0.9			V
		Fixed Version	$V_{IN}=V_{OUT}=0.95\times V_{OUT}$	0.9			V
V_{CEL}	CE Input "L" level Voltage	Adjustable Version	$V_{IN}=V_{OUT}$=3.3V			0.4	V
	CE Input "L" level Voltage	Fixed Version	$V_{IN}=V_{OUT}= 0.95\times V_{OUT}$			0.4	V
Maxduty	Max Duty	Adjustable Version	$V_{IN}=V_{OUT}$=3.3V, V_{FB}=0V	80	88	95	%
	Max Duty	Fixed Version	$V_{IN}=V_{OUT}=0.95\times V_{OUT}$	80	88	95	%
tstart	Soft Start period	Adjustable Version	V_{IN}=1.65V V_{OUT}=3.3V V_{CE}=0V to 1.5V V_{OUT}=2.97V	0.08	0.7	3.0	ms
	Soft Start period	Fixed Version	$V_{IN}=V_{OUT}\times0.5$ (MIN:1.2V) V_{CE}=0V to 1.5V $V_{OUT}=V_{OUT}\times0.9$	0.08	0.7	3.0	ms
R_{ONA}	Anti-ringing switch On Resistance	Adjustable Version	$V_{IN}=V_{OUT}$=3.3V		110		Ω
	Anti-ringing switch On Resistance	Fixed Version	$V_{IN}=V_{OUT}=1.05\times V_{OUT}$		110		Ω

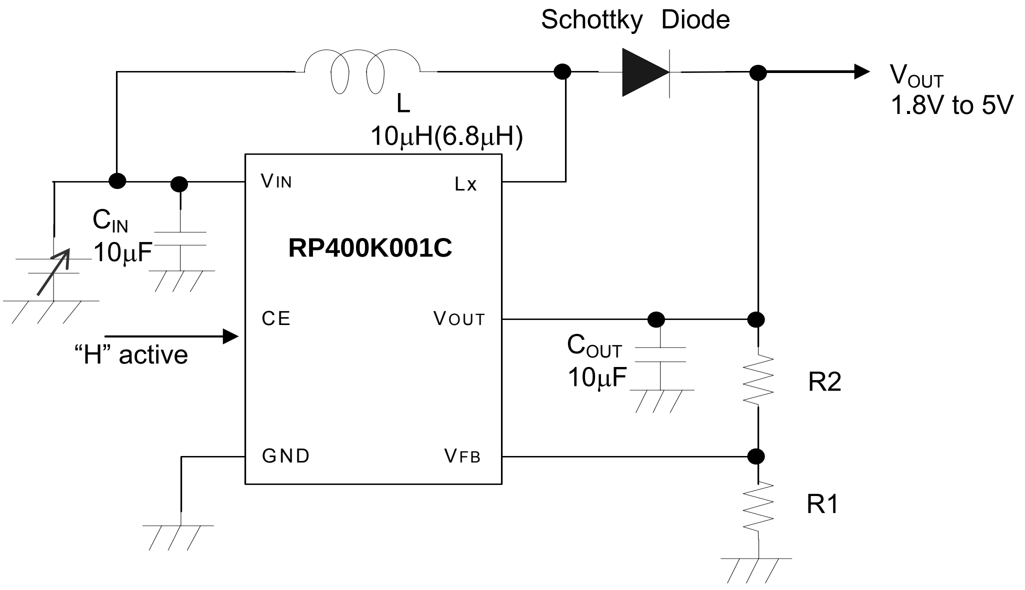
*1) Guaranteed by design engineering. NMOS On-Resistance according to the V_{OUT} voltage.
*2) Lx limit current changes by Duty.
*3) The maximum value of Operating Current 1(Fixed Version) is shown on the table below.

V_{OUT} (V)	MAX (μA)
1.8 V	290
1.9 V	310
2.0 V	320
2.1 V	340
2.2 V	360
2.3 V	370
2.4 V	390
2.5 V	400
2.6 V	420
2.7 V	440
2.8 V	450
2.9 V	470
3.0 V	480
3.1 V	500
3.2 V	520
3.3 V	530
3.4 V	550

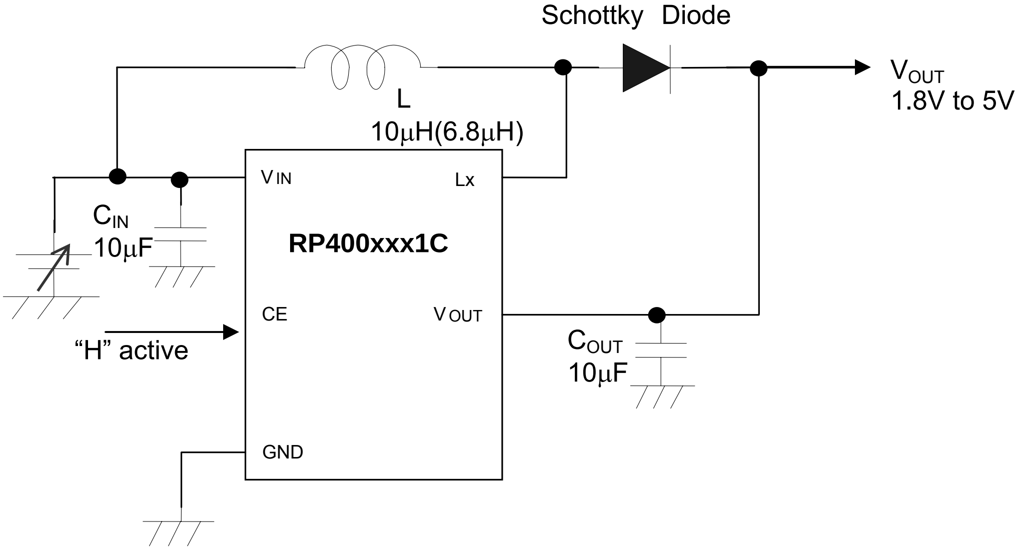
V_{OUT} (V)	MAX (μA)
3.5 V	560
3.6 V	580
3.7 V	600
3.8 V	610
3.9 V	630
4.0 V	640
4.1 V	660
4.2 V	680
4.3 V	690
4.4 V	710
4.5 V	720
4.6 V	740
4.7 V	760
4.8 V	770
4.9 V	790
5.0 V	800

APPLICATION NOTES

Adjastable Output Voltage Type (Version:C)



Fixed Output Voltage Type (Version:C)



External components

Capacitor	:C2012JB1C106M (TDK)
Diode	:CRS02 (TOSHIBA)
Inductor	:TDK SLF7045T-100M1R3-PF(TDK)

●Setting of output voltage

Output voltage(1.8V to 5.0V recommended range of voltage) can be set with divider resistors for voltage setting, R1 and R2 as shown in the typical application. Refer to the next formula.

Output Voltage＝ $V_{FB}\times(R1+R2)/R1$ (V_{FB}=0.6V)
Recommended value of resistors(R1+R2) is lower than 100kΩ.
Make sufficient power supply and ground and reinforce supplying. The large switching current could flow through the connection of power supply, inductor, ground, diode and the connection of VOUT. If the impedance of the connection of power supply and ground is high, the voltage level of power supply of the IC fluctuates with the switching current. We recommend you to use output capacitor and diode with an allowable voltage at least 1.5 times as much as setting output voltage. This is because there may be case where a spike-shaped high voltage is generated by an inductor when built-in transistor is on and off.

Use a diode of a Schottky type with high switching speed, low reverse current and also pay attention to its current capacity.

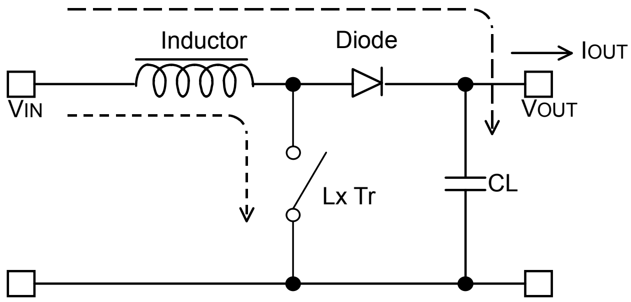
Set external components as close as possible to the IC and minimize the connection between the components and the IC. In particular, output capacitor should be connected to V_{OUT} pin with IC ground by the minimum connection, because this IC uses the V_{OUT} voltage as the main power supply, after start-up. Use capacitors with a capacity of 10µF or more for V_{OUT} pin. We recommend you to set a ceramic capacitor (10µF) between VIN and ground.
The divider resistors should be placed as close as possible to the IC ground pin. V_{FB} line is recommended to use short line as well to avoid the influence of noise.

Please select the inductor value 10µH in the case of $V_{OUT}\geqq 2.5V$ and 6.8µH in the case of $V_{OUT}<2.5V$. Choose an inductor that has sufficiently small D.C. resistance and large allowable current and is hard to reach magnetic saturation. And if the value of inductance of an inductor is extremely small, the ILX may exceed the absolute maximum rating at the maximum loading. Use an inductor with appropriate inductance. (Refer to next Output Current of Step-up Circuit and External Components)

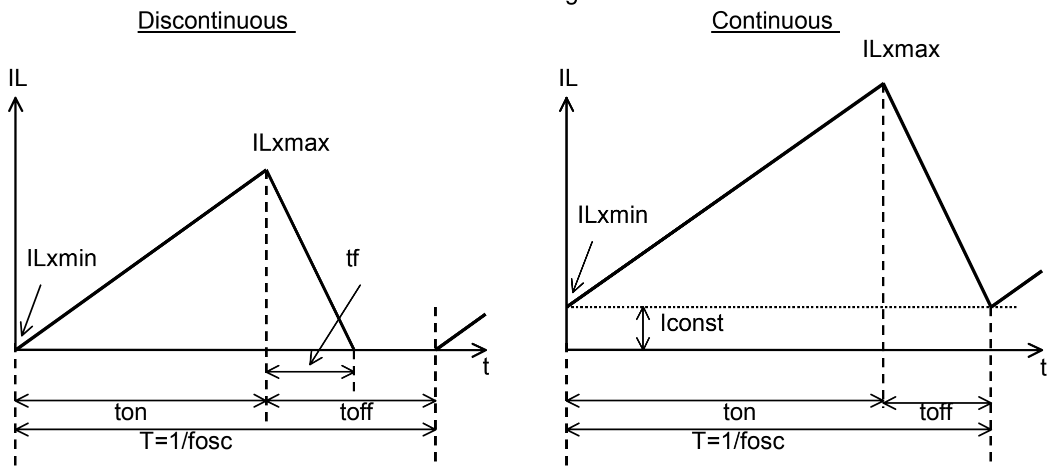
*****The performance of power circuit using those ICs extremely depends upon the peripheral circuits. Pay attention in the selection of the peripheral circuits. In particular, design the peripheral circuits in a way that the values such as voltage, current, and power of each component, PCB patterns and the IC do not exceed their respected rated values. (such as the voltage, current , and power)

OUTPUT CURRENT OF STEP-UP CIRCUIT AND EXTERNAL COMPONENTS

<Basic Circuit>



<Current through L>



There are two modes, or discontinuous mode and continuous mode for the PWM step-up switching regulator depending on the continuous characteristic of inductor current. During on time of the transistor, when the voltage added on to the inductor is described as V_{IN}, the current is $V_{IN} \times t/L$.
Therefore, the electric power, P_{ON}, which is supplied with input side, can be described as in next formula.

$$P_{ON} = \int_0^{ton} V_{IN}^2 \times t/L \, dt \quad \cdots\cdots \text{Formula 1}$$

With the step-up circuit, electric power is supplied from power source also during off time. In this case, input current is described as$(V_{OUT} - V_{IN}) \times t/L$, therefore electric power, P_{OFF} is described as in next formula.

$$P_{OFF} = \int_0^{tf} V_{IN} \times (V_{OUT} - V_{IN}) t/L \, dt \quad \cdots\cdots \text{Formula 2}$$

In this formula, tf means the time of which the energy saved in the inductance is being emitted. Thus average electric power, P_{AV} is described as in the next formula.

$$P_{AV} = 1/(ton + toff) \times \{\int_0^{ton} V_{IN}^2 \times t/L \, dt + \int_0^{tf} V_{IN} \times (V_{OUT} - V_{IN}) t/L \, dt\} \quad \cdots\cdots \text{Formula 3}$$

In PWM control, when tf=toff is true, the inductor current becomes continuous, then the operation of switching regulator becomes continuous mode. In the continuous mode, the deviation of the current is equal between on time and off time.

$V_{IN}\times ton/L = (V_{OUT} - V_{IN})\times toff/L$ ········· Formula 4

Further, the electric power, PAV is equal to output electric power, $V_{OUT} \times I_{OUT}$, thus,

$I_{OUT} = fosc\times V_{IN}^2\times ton^2/\{2\times L (V_{OUT} - V_{IN})\} = V_{IN}^2\times ton/(2\times L\times V_{OUT})$ ········· Formula 5

When I_{OUT} becomes more than $V_{IN}\times ton\times toff/(2\times L\times (ton+toff))$,the current flows through the inductor, then the mode becomes continuous. The continuous current through the inductor is described as Iconst, then,

$I_{OUT} = fosc\times V_{IN}^2\times ton^2 / (2\times L\times (V_{OUT} - V_{IN})) + V_{IN}\times Iconst / V_{OUT}$ ········· Formula 6

In this moment, the peak current, Ilxmax flowing through the inductor and the driver Tr. is described as follows:

$ILxmax = Iconst + V_{IN}\times ton / L$ ········· Formula 7

With the formula 4 , 6 and Ilxmax is

$ILxmax = V_{OUT} / V_{IN} \times I_{OUT} + V_{IN}\times ton/(2\times L)$ ········· Formula 8

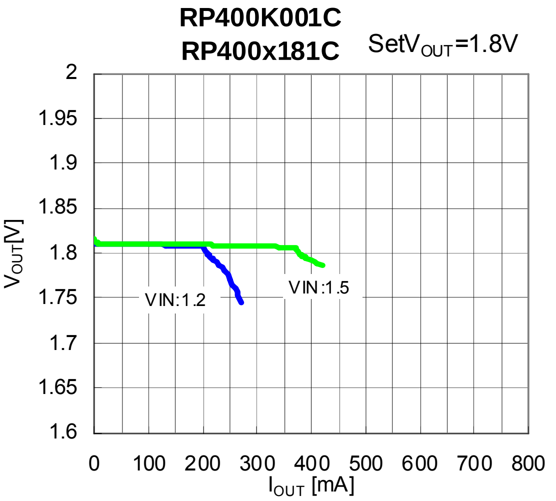
However, $ton=(1-V_{IN}/V_{OUT})/fosc$

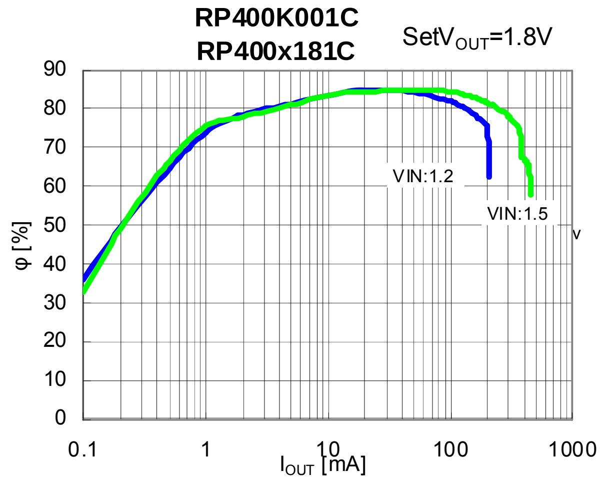
Therefore, peak current is more than I_{OUT}. Considering the value of ILxmax, the condition of input and output, and external components should be selected.
In the formula 7, peak current ILxmax at discontinuous mode can be calculated. Put Iconst＝0 in the formula.
The explanation above is based on the ideal calculation, and the loss caused by Lx switch and external components is not included. Please select the inductor and the diode with current peak to the standard(Formula 8).

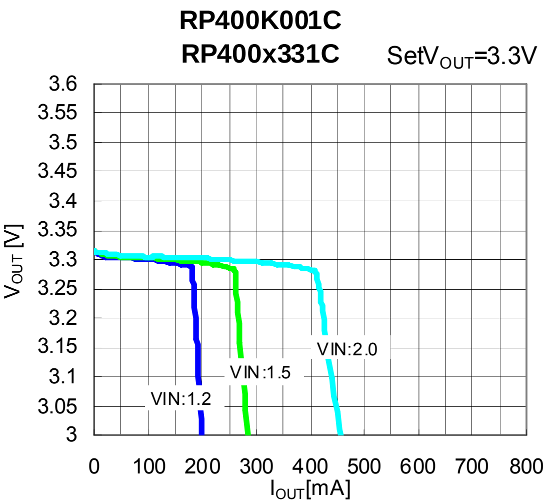
■ TYPICAL CHALACTERISTI(

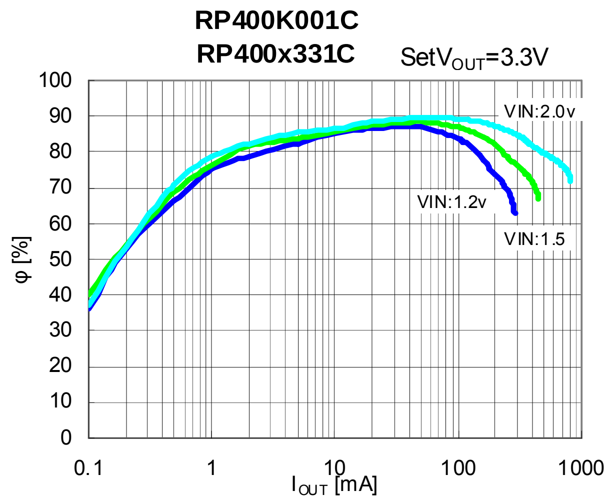
1) Output Voltage vs. Output Current

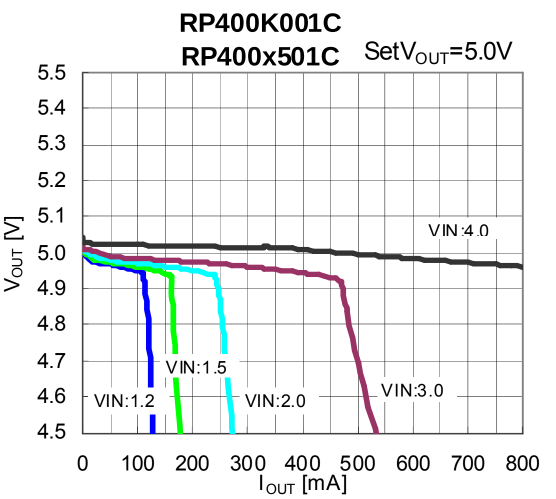
2) Efficiency vs. Output Current

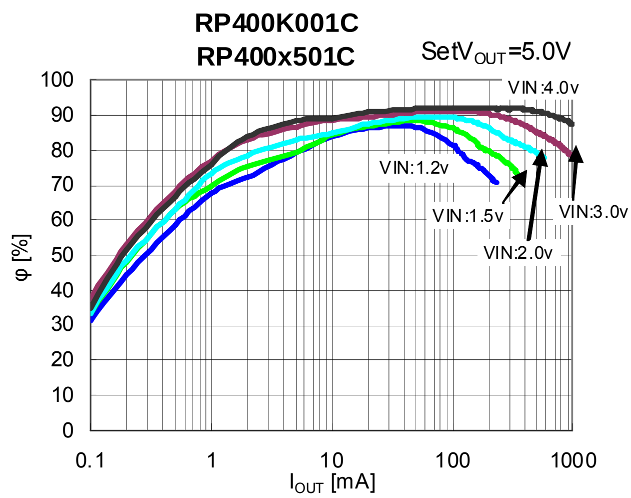






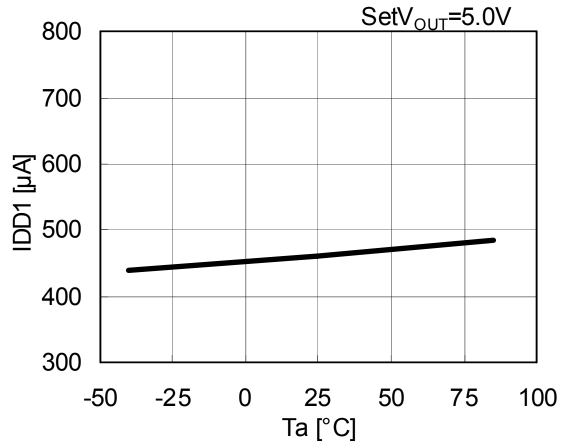






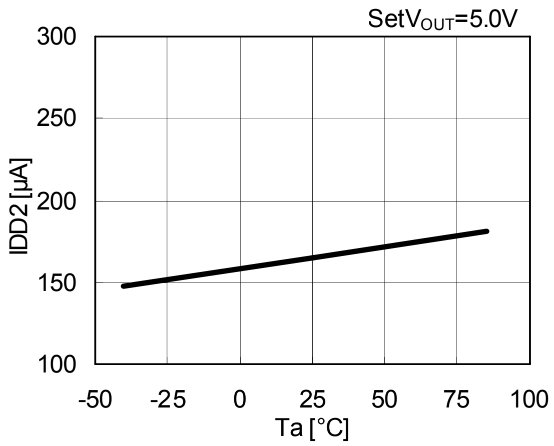
3) Quiescent Current 1 vs.Temperature

RP400K001C
RP400x501C



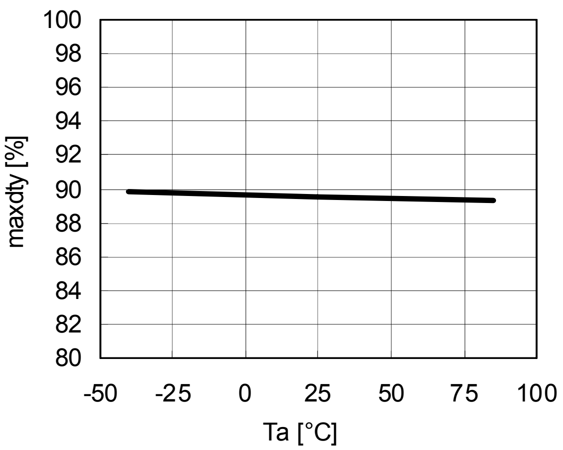
4) Quiescent Current 2 vs.Temperature

RP400K001C
RP400x501C



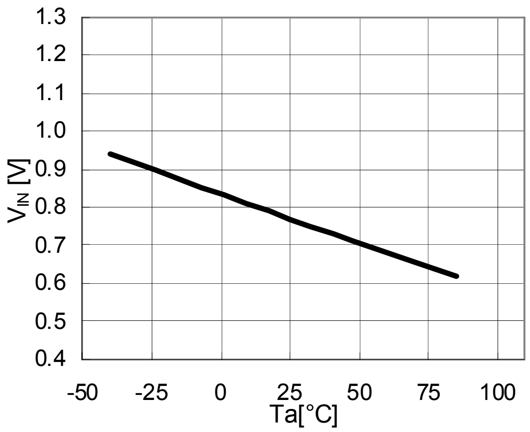
5) Maxduty vs. Temperature

RP400K001C
RP400xxx1C



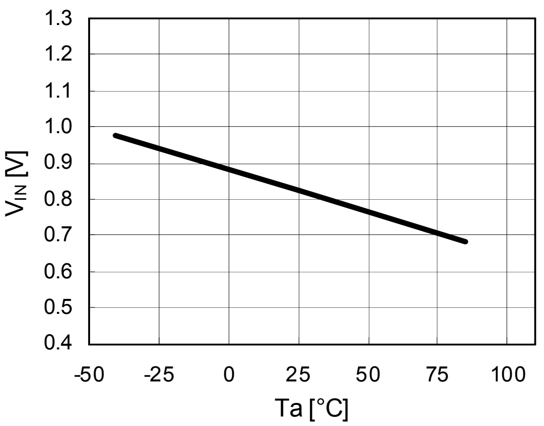
6) Start-up Voltage 2 vs. Temperature

RP400K001C
RP400xxx1C



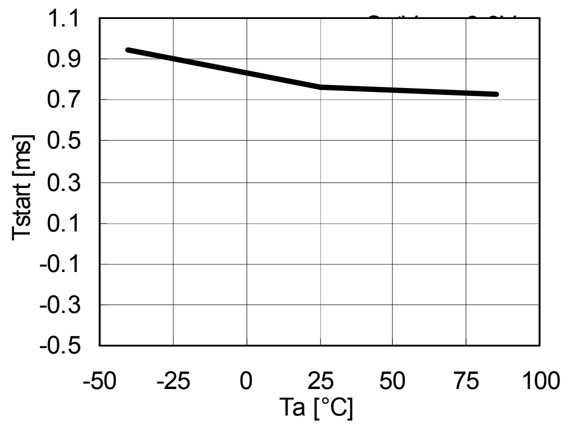
7) Start-up Voltage 3 vs.Temperature

RP400K001C
RP400xxx1C



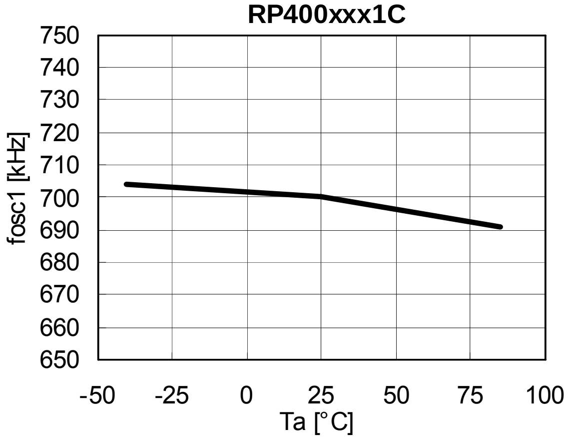
8) Soft-Start Period vs. Temperature

RP400K001C
RP400x331C



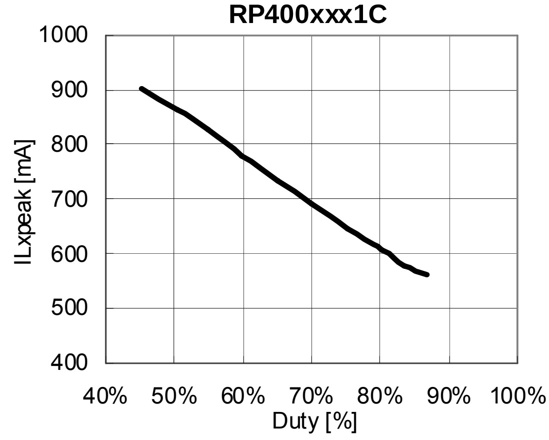
9) Switching Frequency vs. Temperature

RP400K001C
RP400xxx1C



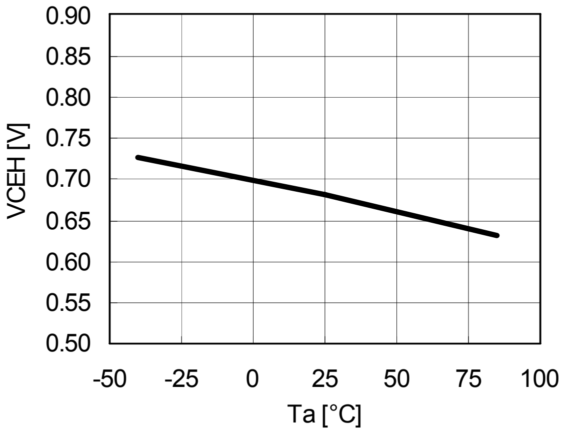
10) Lx Peak Current Limit vs. Duty

RP400K001C
RP400xxx1C



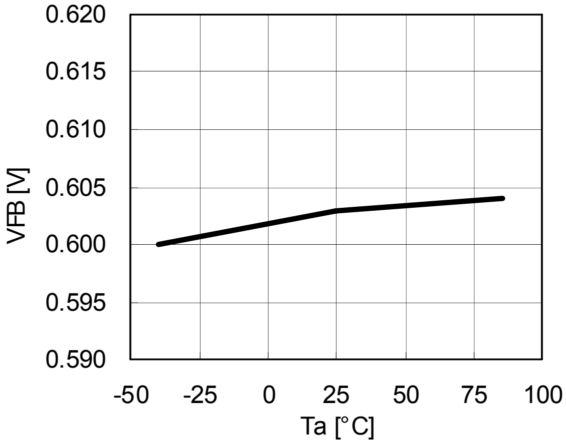
11) CE Input Voltage vs. Temperature

RP400K001C
RP400xxx1C



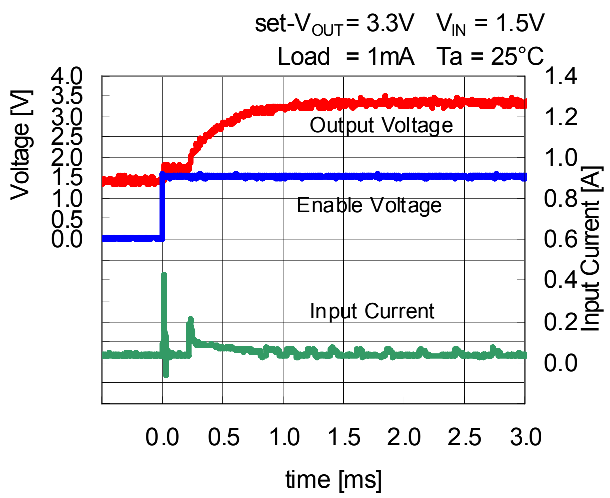
12) Feedback Voltage vs. Temperature

RP400x001C



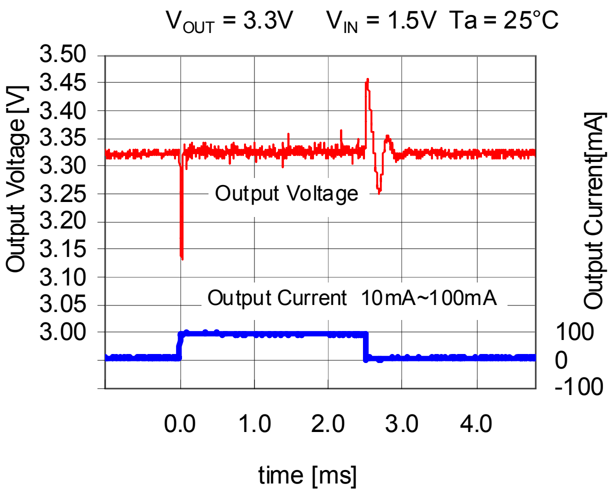
13) Start-up Waveform

RP400K001C
RP400x331C



14) Load Response

RP400K001C
RP400x331C



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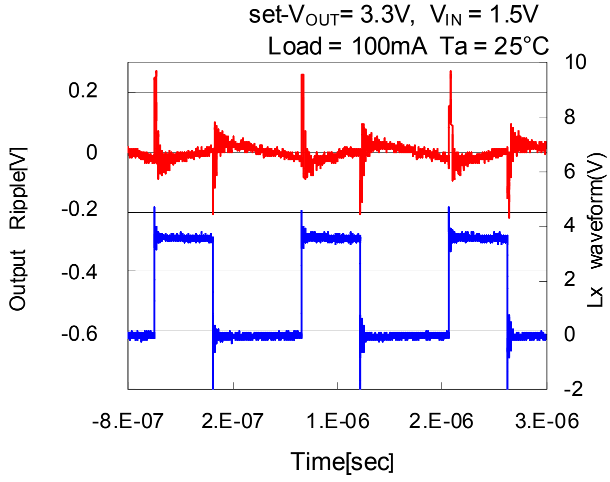
15) Output Voltage Waveform

RP400K001C
RP400x331C



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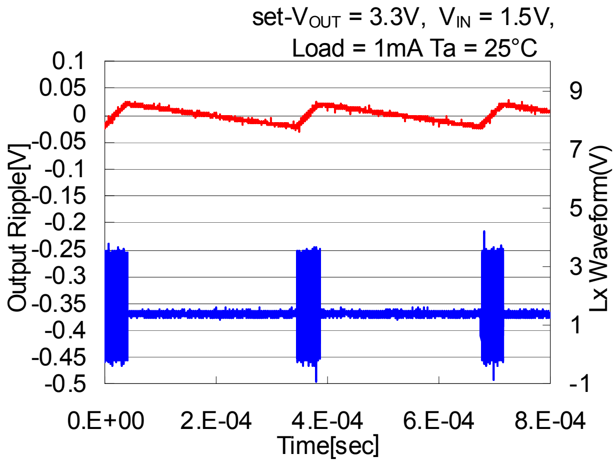
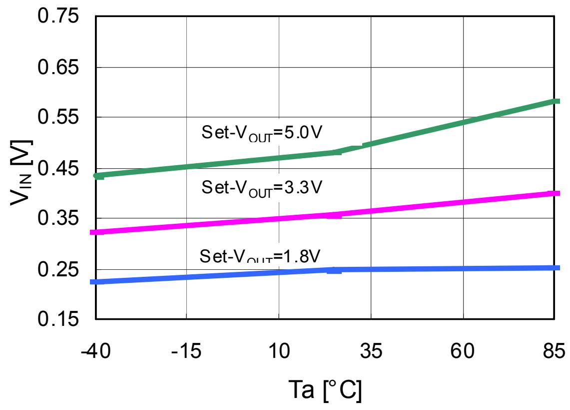


16) Hold-on Voltage 1

RP400K001C
RP400xxx1C



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RICOH COMPANY., LTD. Electronic Devices Company

日本経営品質賞
1999年度受賞

■Ricoh presented with the Japan Management Quality Award for 1999.
Ricoh continually strives to promote customer satisfaction, and shares the achievements of its management quality improvement program with people and society.

■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

Ricoh completed the organization of the Lead-free production for all of our products. After Apr. 1, 2006, we will ship out the lead free products only. Thus, all products that will be shipped from now on comply with RoHS Directive.

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