

## OUTLINE

The R5210x is CMOS-based PWM step-down DC/DC converter combined with a voltage regulator (VR) and a voltage detector (VD), with low supply current.

Each of these ICs consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a soft-start circuit, a current limit circuit, a phase compensation circuit, a resistor net for voltage detect circuit, an output driver transistor, and so on. A low ripple, high efficiency step-down DC/DC converter can be easily composed of this IC with some external components, or an inductor, a diode, and capacitors.

The oscillator frequency is 800kHz, therefore small inductor and capacitor can be used with this IC. Further, this IC equips the under voltage lockout function (UVLO). If the input voltage becomes 2.35V (Typ.) or less, the output of DC/DC converter is turned off. However, embedded voltage regulator and the detector continue to operate.

The voltage regulator consists of a reference voltage unit, a resistor net for voltage detect circuit, an error amplifier, an output driver transistor, and so on.

The built-in voltage detector supervises the input voltage and the output is N-channel open drain type. Power-on reset delay time is also included and internally set typically at 10ms

## FEATURES

- Wide Range of Input Voltage ..... 2.7V~5.5V
- Built-in Soft-start Function (Typ. 2ms) and built-in power-on reset delay (Typ. 10ms)
- Maximum Output Current.....500mA (DC/DC), 200mA (VR)
- High Accuracy Output Voltage .....  $\pm 2.0\%$  (DC/DC and Voltage Regulator Output)
- Accuracy of voltage detector.....  $\pm 2.5\%$
- Output Voltage (VR) ..... Stepwise Setting with a step of 0.1V in the range of 2.5V to 3.6V
- Output Voltage (DC/DC) ..... Stepwise Setting with a step of 0.1V in the range of 1.5V to 3.3V
- Output Voltage (VD) ..... Stepwise Setting with a step of 0.1V in the range of 3.0V to 4.5V
- Packages ..... SOT-23-6W (thickness: Max. 1.3mm) or  
HSO6-6 (thickness: Max. 0.9mm)

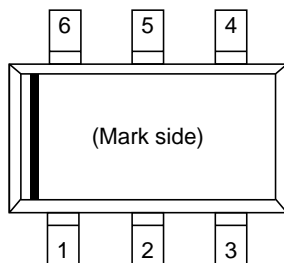
## APPLICATIONS

- Power source for hand-held communication equipment, CD or DVD drives.
- Power source for battery-powered equipment.



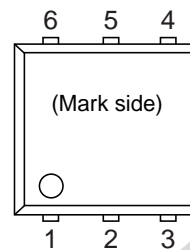
## PIN CONFIGURATION

**SOT-23-6W**



**R5210Nxxxx**

**HSON-6**



**R5210Dxxxx**

## PIN DESCRIPTIONS

Pin No		Symbol	Pin Description
R5210N	R5210D		
1	5	$V_{OUT2}$	Output Pin of Voltage Regulator
2	4	$V_{DOUT}$	Output Pin of Voltage Detector (N-channel open-drain output type)
3	3	$V_{OUT1}$	DC/DC converter Step-down Output monitoring Pin
4	1	$L_x$	Switching Pin (P-channel open-drain output type)
5	2	GND	Ground Pin
6	6	$V_{IN}$	Voltage Supply Pin

## ABSOLUTE MAXIMUM RATINGS

(GND=0V)

Symbol	Item	Rating	Unit
$V_{IN}$	$V_{IN}$ Pin Voltage	6.5	V
$V_{LX}$	$L_x$ Pin Voltage	$-0.3 \sim V_{IN}+0.3$	V
$V_{OUT1}$	$V_{OUT1}$ Pin Voltage	$-0.3 \sim V_{IN}+0.3$	V
$V_{OUT2}$	$V_{OUT2}$ Pin Voltage	$-0.3 \sim V_{IN}+0.3$	V
$V_{DOUT}$	$V_{DOUT}$ Pin Voltage	$-0.3 \sim V_{IN}+0.3$	V
$I_{LX}$	$L_x$ Pin Output Current	800	mA
$I_{OUT2}$	$V_{OUT2}$ Pin Output Current	250	mA
$P_D$	Power Dissipation (SOT-23-6W)	250	mW
	Power Dissipation (HSON-6)	400	
$T_{opt}$	Operating Temperature Range	$-40 \sim +85$	$^{\circ}\text{C}$
$T_{stg}$	Storage Temperature Range	$-55 \sim +125$	$^{\circ}\text{C}$

**R5210x****Discontinued****ELECTRICAL CHARACTERISTICS****• R5210N001C**T<sub>opt</sub>=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V <sub>IN</sub>	Operating Input Voltage		2.7		5.5	V
I <sub>DD</sub>	Supply Current	V <sub>IN</sub> =5.0V, V <sub>OUT1</sub> =5.0V		150	300	μA
V <sub>UVLO1</sub>	UVLO Detector Threshold Voltage		2.15	V <sub>UVLO2</sub> -0.15		V
V <sub>UVLO2</sub>	UVLO Release Voltage		2.35	2.50	2.65	V

**• DC/DC Part**T<sub>opt</sub>=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V <sub>OUT1</sub>	DC/DC Output Voltage	V <sub>IN</sub> =5.0V, at no load	2.646	2.700	2.754	V
ΔV <sub>OUT1</sub> /ΔT	DC/DC Output Voltage Temperature Coefficient	40°C ≤ T <sub>opt</sub> ≤ 85°C		±100		ppm/°C
f <sub>osc</sub>	Oscillator Frequency	V <sub>IN</sub> =5.0V	640	800	960	kHz
Δf <sub>osc</sub> /ΔT	Oscillator Frequency Temperature Coefficient	40°C ≤ T <sub>opt</sub> ≤ 85°C		1.5		KHz/°C
R <sub>LX</sub>	Lx on Resistance	V <sub>IN</sub> =5.0V, I <sub>LX</sub> =100mA		0.4	0.8	Ω
I <sub>LXleak</sub>	Lx Leakage Current	V <sub>IN</sub> =V <sub>OUT1</sub> =5.0V, V <sub>LX</sub> =0V		0.01	5.00	μA
I <sub>LXLIM</sub>	Lx Current Limit	V <sub>IN</sub> =5.0V	600	750		mA
Maxduty	Maximum duty cycle		100			%
T <sub>start</sub>	Soft-start Time	V <sub>IN</sub> =5.0V	0.7	2.0	5.0	ms

**• VR part**T<sub>opt</sub>=25°C

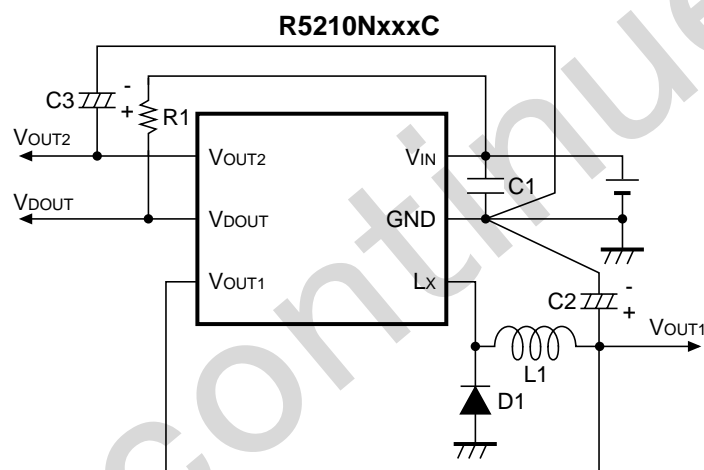
Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V <sub>OUT2</sub>	VR Output Voltage	V <sub>IN</sub> =5.0V, I <sub>OUT2</sub> =10mA	3.332	3.400	3.468	V
I <sub>OUT2</sub>	Maximum Output Current of VR	V <sub>IN</sub> =5.0V	200			mA
V <sub>REG2</sub>	VR Load Regulation	V <sub>IN</sub> =5.0V, 1mA ≤ I <sub>OUT2</sub> ≤ 80mA		30	70	mV
V <sub>DIF2</sub>	Dropout Voltage	I <sub>OUT2</sub> =100mA		0.2	0.3	V
I <sub>LIM2</sub>	Short Current Limit	V <sub>OUT2</sub> =0V		50		mA
ΔV <sub>OUT2</sub> /ΔT	VR Output Voltage Temperature Coefficient	40°C ≤ T <sub>opt</sub> ≤ 85°C		±100		ppm/°C

• **VD part**

T<sub>opt</sub>=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
-V <sub>DET</sub>	VD Detector Threshold		4.095	4.200	4.305	V
Δ-V <sub>DET</sub> /ΔT	VD Detector Threshold Temperature Coefficient	40°C ≤ T <sub>opt</sub> ≤ 85°C		±100		ppm /°C
V <sub>HYS</sub>	Hysteresis Range			-V <sub>DET</sub> × 0.05		V
t <sub>PLH</sub>	VD Output Delay Time for Release		5	10	20	ms
I <sub>DOUTL</sub>	V <sub>DOUT</sub> "L" Output Current	V <sub>IN</sub> =2.0V, V <sub>DOUT</sub> =0.1V	2	7	15	mA

## TYPICAL APPLICATION AND APPLICATION HINTS



### Examples of Components

- Inductor L1 :LQH4C (Murata, 10μH) or LDR655312T (TDK)
- Shottky Diode D1 :RB491D (Rohm) or EP05Q03L (Nihon Inter)
- Pull-up Resistor R1 :50KΩ
- Capacitors :C1:10μF (Ceramic Capacitor)  
C2:22μF (Tantalum Capacitor)  
C3:10μF (Tantalum Capacitor)

When you use these ICs, consider the following issues;

- Set external components as close as possible to the IC and minimize the connection between the components and the IC. In particular, a capacitor should be connected to between V<sub>IN</sub> and GND with the minimum connection. Make sufficient grounding, and reinforce supplying. A large switching current flows through the connection of power supply, an inductor and the connection of V<sub>OUT1</sub>. If the impedance of the connection of power supply or ground is high, the voltage level of power supply of the IC fluctuates with the switching current. This may cause unstable operation of the IC.

## R5210x

### Discontinued

· Use a capacitor with a capacity of  $10\mu\text{F}$  or more for  $V_{\text{IN}}$  and GND, and with low ESR ceramic type. In terms of  $V_{\text{OUT1}}$ , use a capacitor with a capacity of  $22\mu\text{F}$  or more, and with good high frequency characteristics such as tantalum capacitors.

· Choose an inductor that has sufficiently small D.C. resistance and large allowable current and which is hard to reach magnetic saturation. If the value of inductance of an inductor is extremely small, the  $I_{\text{Lx}}$ , which flows through Lx transistor and an inductor, may exceed the absolute maximum rating at the maximum loading. Use an inductor with appropriate inductance.

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

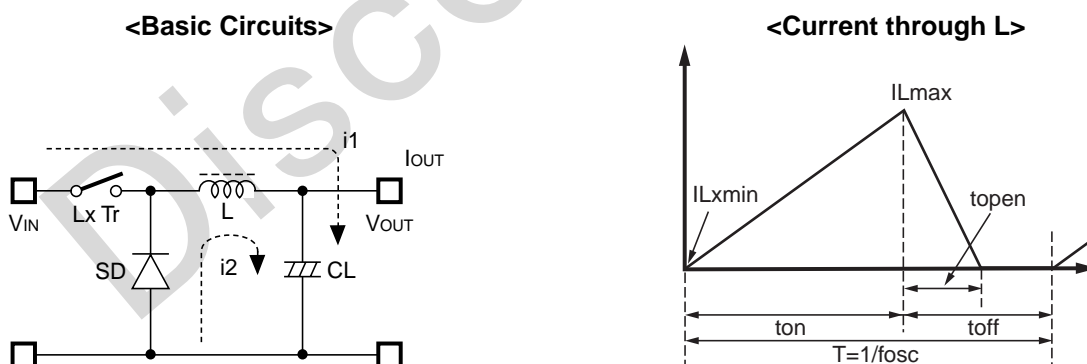
· If the spike noise of Lx pin is too large, make snub circuit (such as serial connection of CR) between Lx and GND, then the noise will be reduced. The time constant of the CR depends on the actual PCB, so evaluate it on the actual PCB.

· If the load current of the voltage regulator is small, because of the switching noise of DC/DC converter, the output voltage of  $V_{\text{OUT2}}$  may be large. To avoid this, use the voltage regulator with a load current at least 1mA.

☆The performance of power source circuits using these 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.

## OPERATION of step-down DC/DC converter and Output Current

The step-down DC/DC converter charges energy in the inductor when Lx transistor is ON, and discharges the energy from the inductor when Lx transistor is OFF and controls with less energy loss, so that a lower output voltage than the input voltage is obtained. The operation will be explained with reference to the following diagrams:



Step 1 : Lx Tr. turns on and current  $I_{\text{L}}$  ( $=i_1$ ) flows, and energy is charged into CL. At this moment,  $I_{\text{L}}$  increases from  $I_{\text{Lmin}}$  ( $=0$ ) to reach  $I_{\text{Lmax}}$  in proportion to the on-time period ( $t_{\text{on}}$ ) of Lx Tr.

Step 2 : When Lx Tr. turns off, Schottky diode (SD) turns on in order that L maintains  $I_{\text{L}}$  at  $I_{\text{Lmax}}$ , and current  $I_{\text{L}}$  ( $=i_2$ ) flows.

Step 3 :  $I_{\text{L}}$  decreases gradually and reaches  $I_{\text{Lmin}}$  after a time period of  $t_{\text{open}}$ , and SD turns off, provided that in the continuous mode, next cycle starts before  $I_{\text{L}}$  becomes to 0 because  $t_{\text{off}}$  time is not enough. In this case,  $I_{\text{L}}$  value is from this  $I_{\text{Lmin}}$  ( $>0$ ).

In the case of PWM control system, the output voltage is maintained by controlling the on-time period ( $t_{\text{on}}$ ), with the oscillator frequency ( $f_{\text{osc}}$ ) being maintained constant.

· **Discontinuous Conduction Mode and Continuous Conduction Mode**

The maximum value (ILmax) and the minimum value (ILmin) current which flow through the inductor is the same as those when Lx Tr. turns on and when it turns off.

The difference between ILmax and ILmin, which is represented by ΔI;

$$\Delta I = I_{Lmax} - I_{Lmin} = V_{OUT} \times t_{open} / L = (V_{IN} - V_{OUT}) \times t_{on} / L \dots \dots \dots \text{Equation 1}$$

Where,  $T = 1 / f_{osc} = t_{on} + t_{off}$   
 duty (%) =  $t_{on} / T \times 100 = t_{on} \times f_{osc} \times 100$   
 $t_{open} \leq t_{off}$

In Equation 1,  $V_{OUT} \times t_{open} / L$  and  $(V_{IN} - V_{OUT}) \times t_{on} / L$  are respectively shown the change of the current at ON, and the change of the current at OFF.

When the output current (I<sub>OUT</sub>) is relatively small,  $t_{open} < t_{off}$  as illustrated in the above diagram. In this case, the energy is charged in the inductor during the time period of  $t_{on}$  and is discharged in its entirely during the time period of  $t_{off}$ , therefore ILmin becomes to zero (ILmin=0). When I<sub>OUT</sub> is gradually increased, eventually,  $t_{open}$  becomes to  $t_{off}$  ( $t_{open} = t_{off}$ ), and when I<sub>OUT</sub> is further increased, ILmin becomes larger than zero (ILmin>0). The former mode is referred to as the discontinuous mode and the latter mode is referred to as continuous mode.

In the continuous mode, when Equation 1 is solved for  $t_{on}$  and assumed that the solution is  $t_{onc}$

$$t_{onc} = T \times V_{OUT} / V_{IN} \dots \dots \dots \text{Equation 2}$$

When  $t_{on} < t_{onc}$ , the mode is the discontinuous mode, and when  $t_{on} = t_{onc}$ , the mode is the continuous mode.

**OUTPUT CURRENT AND SELECTION OF EXTERNAL COMPONENTS**

When Lx Tr. is “ON”:

(Wherein, Ripple Current P-P value is described as I<sub>RP</sub>, ON resistance of Lx Tr. is described as R<sub>P</sub> the direct current of the inductor is described as R<sub>L</sub>.)

$$V_{IN} = V_{OUT} + (R_P + R_L) \times I_{OUT} + L \times I_{RP} / t_{on} \dots \dots \dots \text{Equation 3}$$

When Lx Tr. is “OFF”:

$$L \times I_{RP} / t_{off} = V_F + V_{OUT} + R_L \times I_{OUT} \dots \dots \dots \text{Equation 4}$$

Put Equation 4 to Equation 3 and solve for ON duty,  $t_{on} / (t_{off} + t_{on}) = D_{ON}$ ,

$$D_{ON} = (V_{OUT} + V_F + R_L \times I_{OUT}) / (V_{IN} + V_F - R_P \times I_{OUT}) \dots \dots \dots \text{Equation 5}$$

Ripple Current is as follows;

$$I_{RP} = (V_{IN} - V_{OUT} - R_P \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / f / L \dots \dots \dots \text{Equation 6}$$

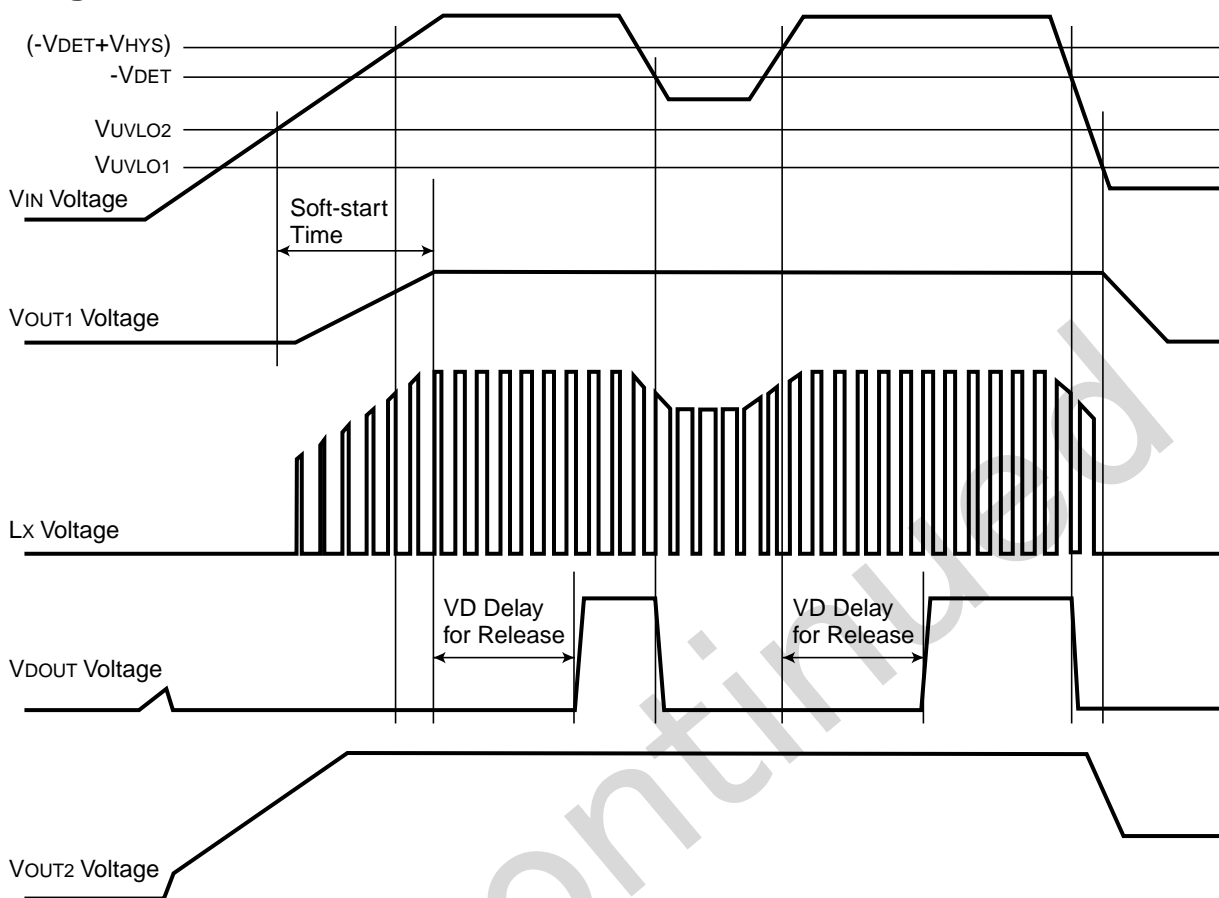
Wherein, peak current that flows through L, Lx Tr., and SD is as follows;

$$I_{Lmax} = I_{OUT} + I_{RP} / 2 \dots \dots \dots \text{Equation 7}$$

Consider ILmax, condition of input and output and select external components.

★The above explanation is directed to the calculation in an ideal case in continuous mode.

## Timing Chart



The timing chart which is shown in the previous page describes the relation of supply voltage changes with time and each output of DC/DC converter, voltage detector, and voltage regulator.

### (1) DC/DC converter

When the power turns on and in the case of rising the  $V_{IN}$  voltage, while the  $V_{IN}$  voltage is at UVLO level ( $V_{UVLO2}$ ) or less, the operation of the DC/DC converter stops and does not make switching, therefore  $V_{OUT1}$  voltage does not rise.

When the  $V_{IN}$  voltage becomes UVLO release level or more, the DC/DC converter starts soft-start operation, and start switching, then  $V_{OUT1}$  will rise. After the soft-start time, if  $V_{IN}$  voltage becomes set  $V_{OUT1}$  level or more,  $V_{OUT1}$  will be settled at  $V_{OUT1}$  set output voltage. If  $V_{IN}$  voltage becomes UVLO detector threshold level ( $V_{UVLO1}$ ) or less, the DC/DC converter stops switching then Lx transistor in the IC turns off.

### (2) Voltage Detector

If the  $V_{IN}$  voltage is at VD detector threshold level or less, the N-channel transistor of  $V_{DOUT}$  pin turns on and outputs "L" to  $V_{DOUT}$  pin. Then, when the  $V_{IN}$  voltage becomes VD detector threshold level + its hysteresis range ( $-V_{DET}+V_{HYS}$ ) or more, after VD delay for release ( $t_{PLH}$ ) passing, the N-channel transistor inside the IC turns off,  $V_{DOUT}$  pin voltage reaches to the pull-up voltage. Besides, the release circuit for VD starts after soft-start time and under this condition,  $V_{IN}$  voltage should be ( $-V_{DET}+V_{HYS}$ ) or more.

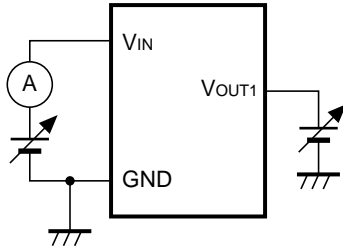
### (3) Voltage Regulator

The voltage regulator always operates even if UVLO function would work. Therefore,  $V_{OUT2}$  voltage is nearly equal to  $V_{IN}$  voltage. Actual value depends on the load current. When the  $V_{IN}$  voltage becomes set  $V_{OUT2}$  voltage or more,  $V_{OUT2}$  voltage will be the set output voltage.

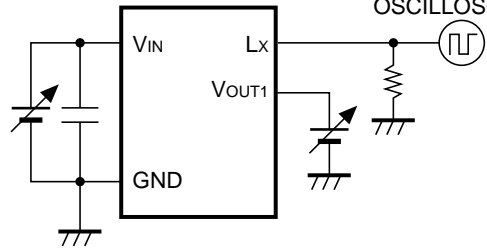


## TEST CIRCUITS

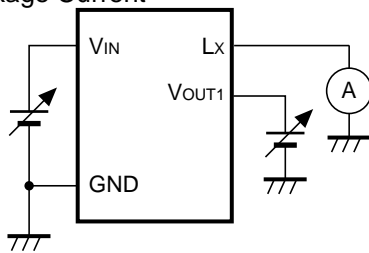
A) Supply Current



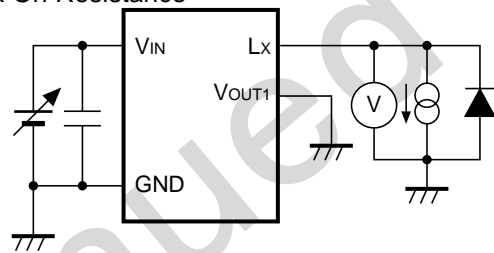
B) UVLO Detector Threshold/ Released Voltage  
OSCILLOSCOPE



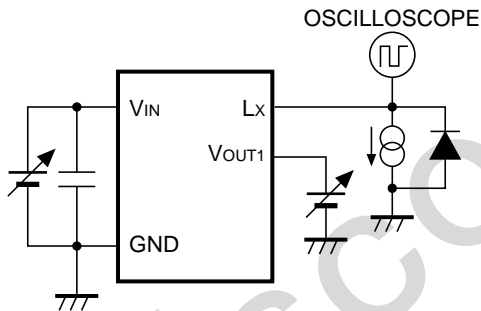
C) Lx Leakage Current



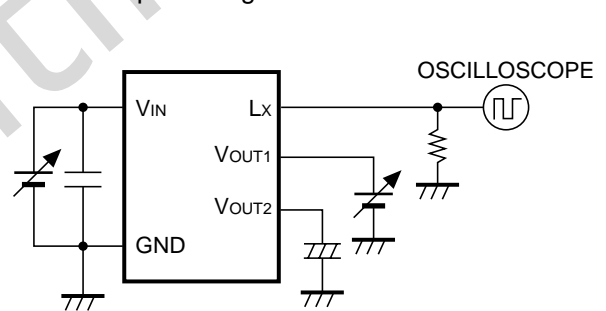
D) Lx On Resistance



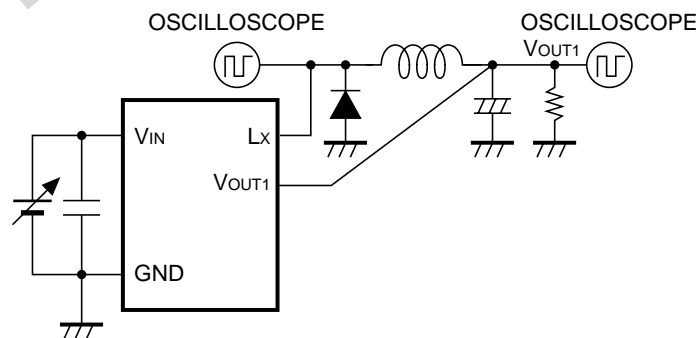
E) Lx Current Limit



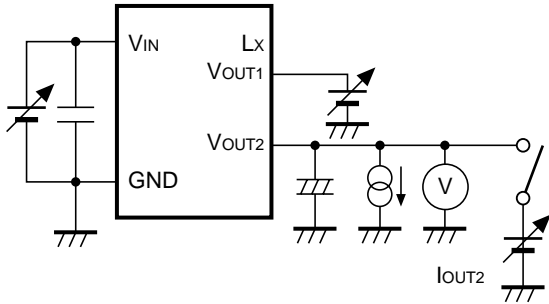
F) VOUT1 Output Voltage



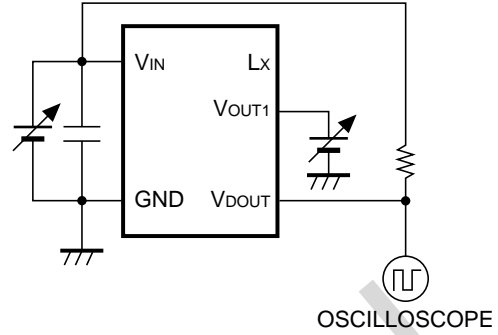
G) Oscillator Frequency, Soft-start Time



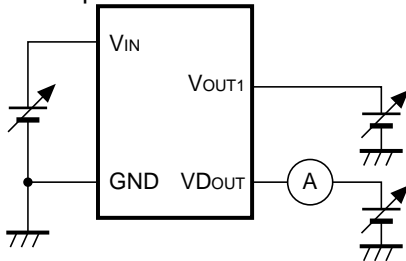
H)  $V_{OUT2}$  Output Voltage, Load Regulation, Dropout Voltage, Current Limit, Short Current Limit



I)  $V_{DOUT}$  Detector Threshold, Hysteresis Range, VD Output Delay Time for Release



J)  $V_{DOUT}$  "L" Output Current

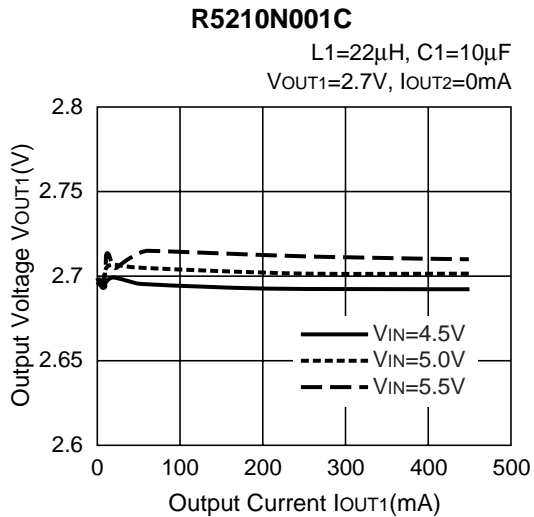


Typical Characteristics were obtained with using the test circuits as follows;

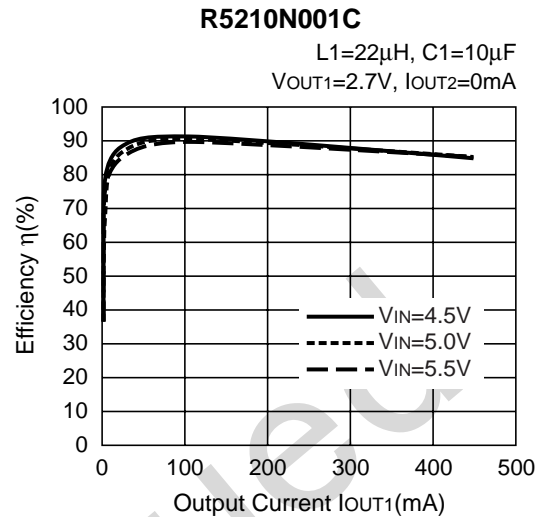
- Typical Application Circuit: Typical Characteristics 1) 2) 11) 12)
- Test Circuit F : Typical Characteristics 3)
- Test Circuit G : Typical Characteristics 6) 7)
- Test Circuit H : Typical Characteristics 4) 9) 10)
- Test Circuit I : Typical Characteristics 5) 8)

## TYPICAL CHARACTERISTICS

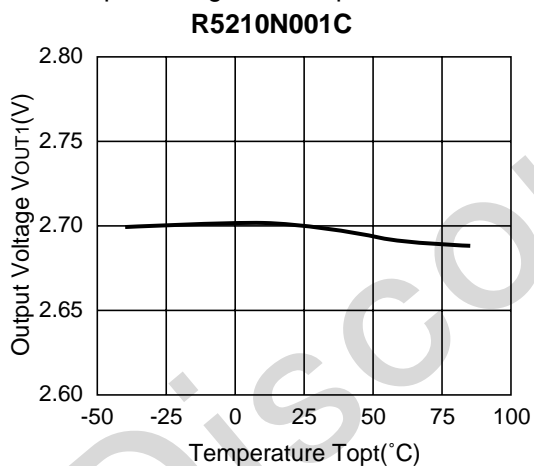
1) Output Voltage vs. Output Current



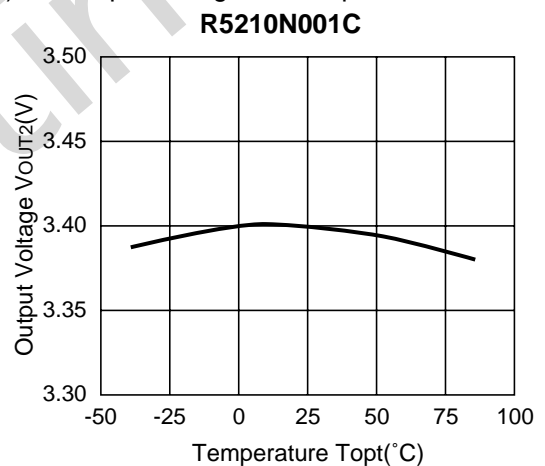
2) Efficiency vs. Output Current



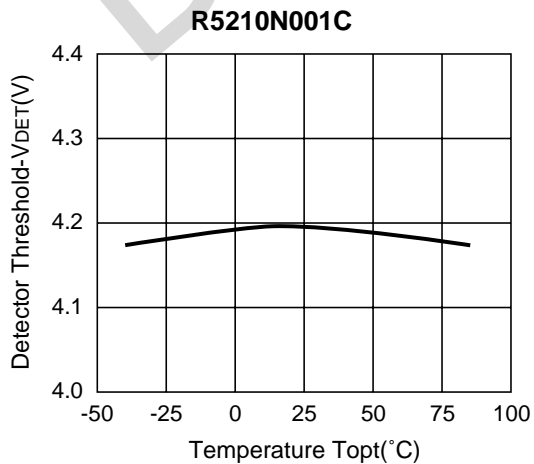
3) DC/DC Output Voltage vs. Temperature



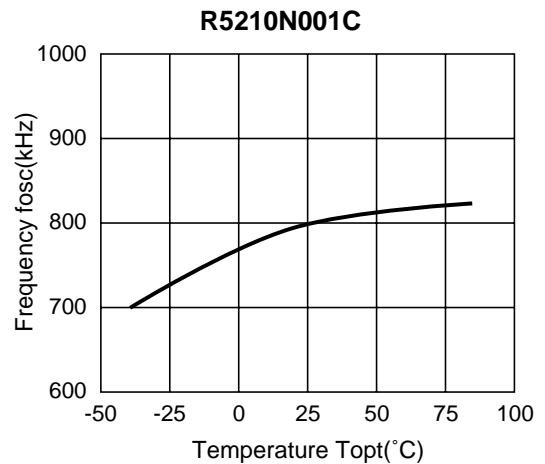
4) VR Output Voltage vs. Temperature



5) Detector Threshold vs. Temperature

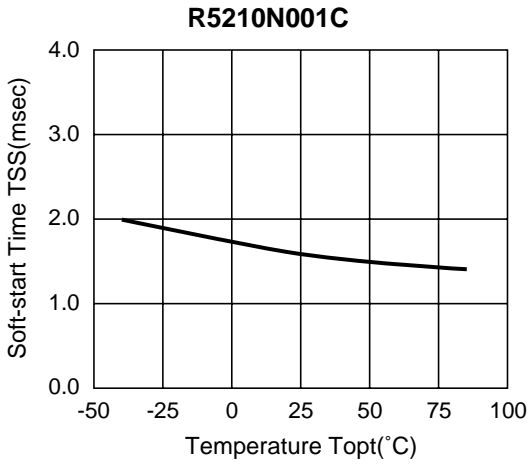


6) Oscillator Frequency vs. Temperature

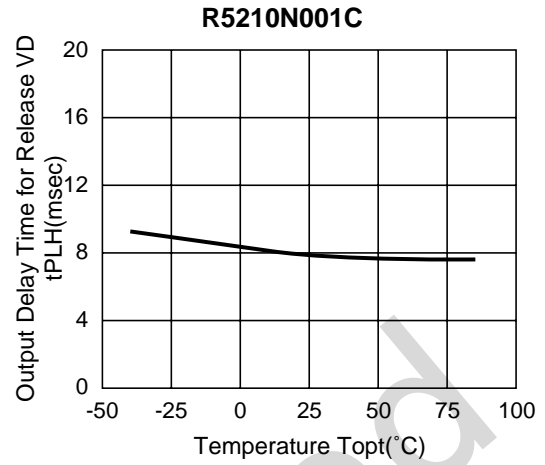


**R5210x**  
**Discontinued**

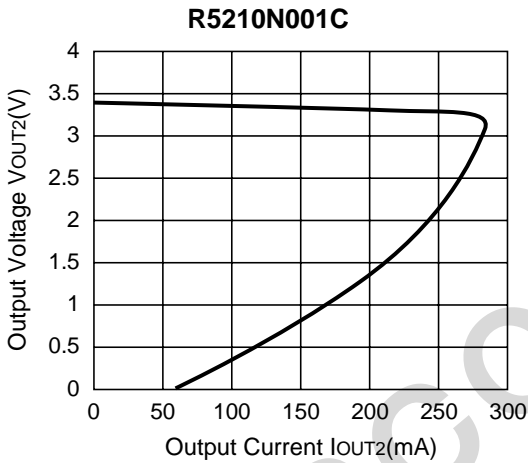
7) Soft-start time vs. Temperature



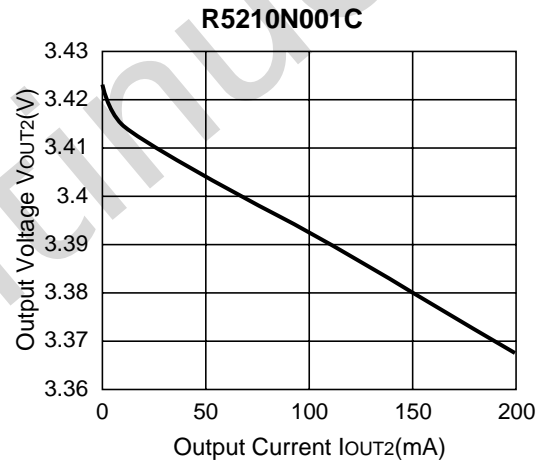
8) Output Delay Time for Release VD vs. Temperature



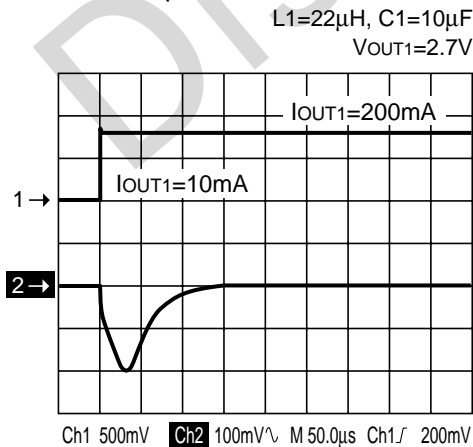
9) VR Output Voltage vs. Output Current



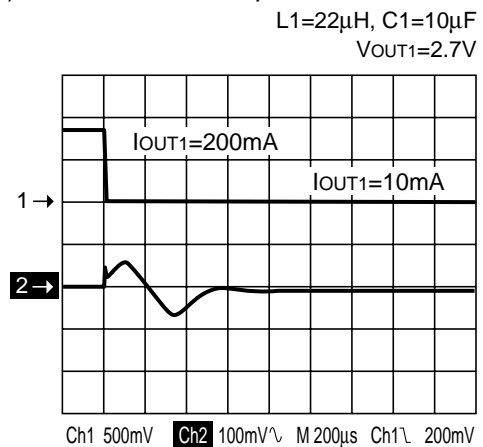
10) VR Output Voltage vs. Output Current (zoomed)



11) Load Transient Response 1



12) Load Transient Response 2





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6. We are making our continuous effort to improve the quality and reliability of our products, but semiconductor products are likely to fail with certain probability. In order to prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design, such as redundancy feature, fire containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.
7. Anti-radiation design is not implemented in the products described in this document.
8. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
9. WLCSP products should be used in light shielded environments. The light exposure can influence functions and characteristics of the products under operation or storage.
10. There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact Ricoh sales or our distributor before attempting to use AOI.
11. Please contact Ricoh sales representatives should you have any questions or comments concerning the products or the technical information.



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

Ricoh has been providing RoHS compliant products since April 1, 2006 and Halogen-free products since April 1, 2012.

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