# RICOH

# R5220x SERIES

## PWM Step-down DC/DC Converter with switch function

NO.EA-121-120113

## OUTLINE

The R5220x Series are CMOS-based PWM step-down DC/DC Converters with synchronous rectifier, low supply current and LDO mode.

DC/DC converter of the R5220x consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a soft-start circuit, protection circuits, a protection against miss operation under low voltage (UVLO), PWM-DC to DC converter / LDO alternative circuit, a chip enable circuit, and a driver transistor. A high efficiency step-down DC/DC converter can be easily composed of this IC with only a few kinds of external components, or an inductor and capacitors.

LDO of the R5220x consists of a vortage reference unit, an error amplifier, resistors for voltage setting, output current limit circuit, a driver transistor, and so on. The output voltage is fixed internally in the R5220x. The output voltage of the DC/DC converter and the LDO can be set independently.

PWM step-down DC/DC converter / LDO alternative circuit is active with Mode Pin of the R5220x Series. Thus, when the load current is small, the operation can be switching into the LDO operation from PWM operation by the logic of MODE pin and the consumption current of the IC itself will be small at light load current. As protection circuits, the current limit circuit which limits peak current of Lx at each clock cycle, and the latch type protection circuit which works if the term of the over-current condition keeps on a certain time in PWM mode. Latch-type protection circuit works to latch an internal driver with keeping it disable. To release the protection, after disable this IC with a chip enable circuit, enable it again, or restart this IC with power-on or make the supply voltage at UVLO detector threshold level or lower than UVLO.

## FEATURES

- Supply Current ............................................................. Typ. 350$\mu$A (DC/DC), Typ. 5$\mu$A (VR)
- Standby Current ........................................................... Typ. 0.1$\mu$A
- Built-in Driver ON Resistance ........................................ P-channel 0.5$\Omega$, N-channel 0.5$\Omega$ (at $V_{IN}$=3.6V)
- Output Current ............................................................. Min. 400mA (DC/DC), Min. 50mA (VR)
- Input Voltage ................................................................ 2.8V to 5.5V (Absolute Input Maximum: 6.5V)
- Output Voltage ............................................................. 1.0V to 3.3V (0.1V steps)

  (For other voltages, please refer to MARK INFORMATIONS.)

- Output Voltage Accuracy................................................ $\pm$2.0% ($V_{OUT} \geqq 1.5$), $\pm$30mV ($V_{OUT}$ <1.5V)
- Oscillator Frequency (DC/DC) ...................................... Typ. 1.2MHz
- Package ....................................................................... SON-6, DFN(PLP)2514-6
- Built-in Soft-start Function............................................. Typ. 0.2ms
- Latch-type Protection Function (Delay Time).................. Typ. 3.0ms
- Built-in fold-back protection circuit (DC/DC, VR)
- Ceramic Capacitor is recommended.

## APPLICATIONS

- Power source for portable equipment such as DSC, DVC, and communication equipment.
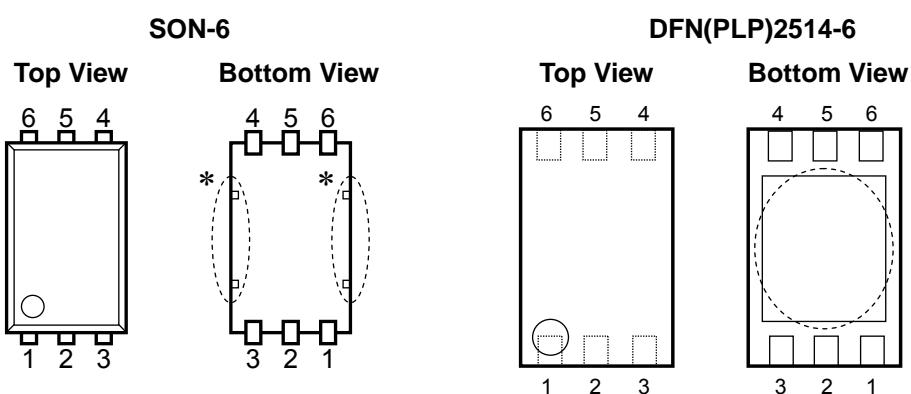
1

# BLOCK DIAGRAM
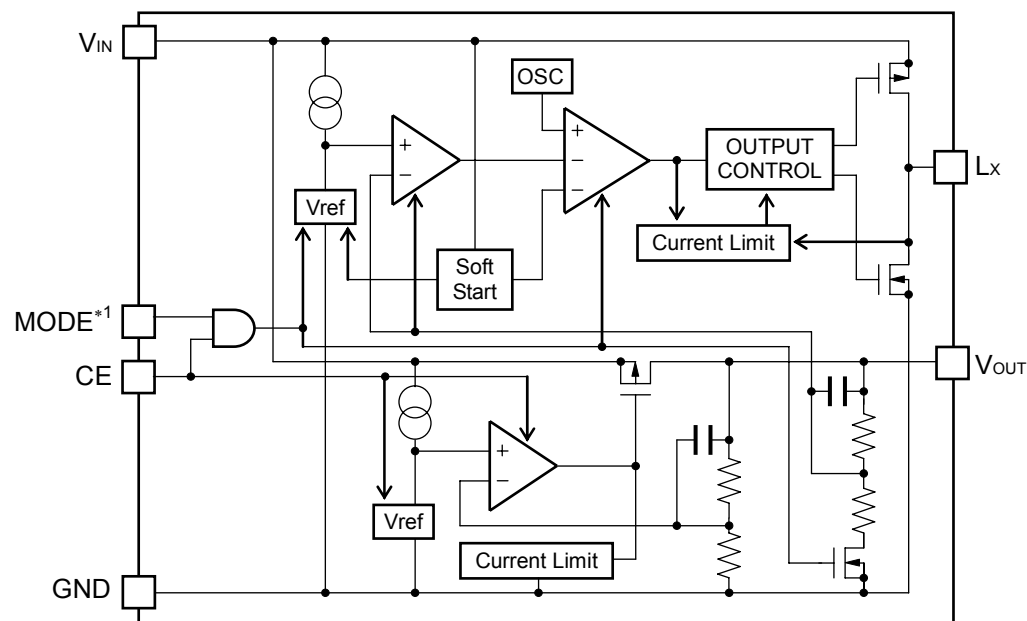


*1) R5220xxxxA: DC/DC mode: Mode pin= "H", VR mode: Mode pin= "L"
  R5220xxxxB: DC/DC mode: Mode pin= "L", VR mode: Mode pin= "H"

# SELECTION GUIDE

In the R5220x Series, the output voltage, the version and the pin polalities for the ICs can be selected at the user's request.

| Product Name | package | Quantity per Reel | Pb Free | Halogen Free |
|---|---|---|---|---|
| R5220Kxx∗$-TR | DFN(PLP)2514-6 | 5,000 pcs | ○ | ○ |
| R5220Dxx∗$-TR-FE | SON-6 | 3,000 pcs | ○ | ○ |

xx : Output Voltage (V_OUT) or serial number.
  The output voltage can be designed in the range from 1.0V(10) to 3.3V(33) in 0.1V steps.
  ( If selected the custum-made product)The output voltage can be designed by Serial numbers.
  Please refer to the attached Mark Informations.

∗  : （1）Standard (DC/DC output voltage = LDO output voltage)
    （2）Custom-made (DC/DC output voltage ≠ LDO output voltage)

$  : Designation of chip enable and Mode pin polarities
   （A）Mode pin; "H"=DC/DC converter mode, "L"=LDO Mode
   （B）Mode pin; "L"=DC/DC converter mode, "H"=LDO Mode

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## PIN CONFIGURATIONS

**SON-6**

Top View    Bottom View



**DFN(PLP)2514-6**

Top View    Bottom View



## PIN DESCRIPTIONS

| Pin No | Symbol | Description |
|--------|--------|-------------|
| 1 | Lx | $L_X$ Pin Voltage Supply Pin |
| 2 | GND | Ground Pin |
| 3 | MODE | Mode changer Pin (Refer to the Selection Guide) |
| 4 | CE | Chip Enable Pin (active with "H") |
| 5 | $V_{OUT}$ | Output Pin |
| 6 | $V_{IN}$ | Voltage Supply Pin |

∗1) 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.

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## ABSOLUTE MAXIMUM RATINGS

| Symbol | Item | Rating | Unit |
|---|---|---|---|
| $V_{IN}$ | $V_{IN}$ Supply Voltage | 6.5 | V |
| $V_{LX}$ | $L_X$ Pin Voltage | $-0.3$ to $V_{IN}+0.3$ | V |
| $V_{CE}$ | CE Pin Input Voltage | $-0.3$ to 6.5 | V |
| $V_{MODE}$ | MODE Pin Input Voltage | $-0.3$ to 6.5 | V |
| $V_{OUT}$ | $V_{OUT}$ Pin Voltage | $-0.3$ to $V_{IN}+0.3$ | V |
| $I_{LX}$ | $L_X$ Pin Output Current | 600 | mA |
| $I_{OUT}$ | $V_{OUT}$ Pin Output Current | 200 | mA |
| $P_D$ | Power Dissipation (SON-6)* | 500 | mW |
| | Power Dissipation (DFN(PLP)2514-6)* | 730 | |
| 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.

| 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.

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# ELECTRICAL CHARACTERISTICS

● **R5220xxxxA**                                                                 Topt=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{IN}$ | Input Voltage | | 2.8 | | 5.5 | V |
| $I_{SS1}$ | Supply Current 1 (Standby mode) | $V_{IN}=V_{OUT1}+1.0V$, $V_{CE}$=GND, $V_{MODE}$=GND or $V_{IN}$ $V_{OUT1}$:DC/DC Set $V_{OUT}$ | | 0.1 | 1.0 | μA |
| $I_{SS2}$ | Supply Current 2 (Power Save mode) | $V_{IN}=V_{CE}=V_{OUT2}+1.0V$, $V_{MODE}$=GND $V_{OUT2}$:VR Set $V_{OUT}$, $I_{OUT}$=0mA | | 5 | 10 | μA |
| $I_{SS3}$ | Supply Current 3 | $V_{IN}=V_{CE}=V_{MODE}$=3.6V | | 350 | 450 | μA |

**DC/DC Part**                                                                   Topt=25°C

| Symbol | Item | Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $V_{OUT1}$ | Output Voltage | $V_{IN}$=3.6V $I_{OUT}$=50mA | $V_{OUT1} \geqq 1.5$ | ×0.98 | | ×1.02 | V |
| | | | $V_{OUT1} < 1.5$ | −0.03 | | +0.03 | |
| fosc | Oscillator Frequency | $V_{IN}$=3.6V | | 0.96 | 1.20 | 1.44 | MHz |
| $T_{START}$ | Soft-start Time | $V_{IN}$=3.6V | $V_{OUT1} < 1.5$ | | 0.15 | 0.30 | ms |
| | | | $V_{OUT1} \geqq 1.5$ | | 0.20 | 0.35 | |
| $R_{ONP}$ | ON Resistance of Pch Transistor | $V_{IN}$=3.6V, $I_{LX}$=−100mA | | | 0.5 | | Ω |
| $R_{ONN}$ | ON Resistance of Nch Transistor | $V_{IN}$=3.6V, $I_{LX}$=−100mA | | | 0.5 | | Ω |
| $I_{LXLEAK}$ | Lx Leakage Current | $V_{IN}$=5.5V, $V_{CE}$=0V, Lx=5.5V/0V | | −1.0 | | 1.0 | μA |
| $\Delta V_{OUT}/\Delta T_{opt}$ | Output Voltage Temperature Coefficient | $-40°C \leqq T_{opt} \leqq 85°C$ | | | ±150 | | ppm/°C |
| Maxduty | Oscillator Maximum Duty Cycle | $V_{OUT}$=0V | | 100 | | | % |
| $I_{LXlim}$ | Lx Current Limit | $V_{IN}$=3.6V | | 500 | 800 | | mA |
| $T_{prot}$ | Protection Delay Circuit | $V_{IN}$=3.6V | | 1.0 | 3.0 | 7.0 | ms |
| $V_{UVLO1}$ | UVLO Threshold Voltage | $V_{IN}=V_{CE}=V_{MODE}$, $V_{OUT}$=0V | | 2.00 | 2.35 | 2.75 | V |
| $V_{UVLO2}$ | UVLO Released Voltage | $V_{IN}=V_{CE}=V_{MODE}$, $V_{OUT}$=0V | | 2.05 | 2.45 | 2.80 | V |
| $V_{MODEH}$ | MODE "H" Input Voltage | | | 1.0 | | | V |
| $V_{MODEL}$ | MODE "L" Input Voltage | | | 0 | | 0.3 | V |

**VR Part**                                                                      Topt=25°C

| Symbol | Item | Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $V_{OUT2}$ | Output Voltage | $V_{IN}=V_{OUT2}+1.0V$ $I_{OUT}$=10mA | $V_{OUT2} \geqq 1.5$ | ×0.98 | | ×1.02 | V |
| | | | $V_{OUT2} < 1.5$ | −0.03 | | +0.03 | |
| $I_{OUT}$ | Output Current | $V_{IN}=V_{OUT2}+1.0V$ | | 50 | | | mA |
| $\Delta V_{OUT2}/\Delta I_{OUT}$ | Load Regulation | $V_{IN}=V_{OUT2}+1.0V$ $10μA \leqq I_{OUT} \leqq 25mA$ | $V_{OUT2} < 2.3$ | | 15 | 40 | mV |
| | | | $2.3 \leqq V_{OUT2} < 3.0$ | | 25 | 50 | |
| | | | $V_{OUT2} \geqq 3.0$ | | 35 | 65 | |
| $V_{DIF}$ | Dropout Voltage | $I_{OUT}$=50mA | $V_{OUT2} < 1.8$ | | 0.7 | | V |
| | | | $V_{OUT2} \geqq 1.8$ | | 0.3 | | |
| $\Delta V_{OUT2}/\Delta V_{IN}$ | Line Regulation | $2.8V \leqq V_{IN} \leqq 5.5V$ $I_{OUT}$=25mA | $V_{OUT2} < 2.3$ | | | 0.2 | %/V |
| | | $V_{OUT2}+0.5V \leqq V_{IN} \leqq 5.5V$ $I_{OUT}$=25mA | $V_{OUT2} \geqq 2.3$ | | | | |
| RR | Ripple Rejection | Refer to Typical Characteristics | | | | | dB |
| $\Delta V_{OUT}/\Delta T_{opt}$ | Output Voltage Temperature Coefficient | $I_{OUT}$=30mA, $-40°C \leqq T_{opt} \leqq 85°C$ | | | ±100 | | ppm/°C |
| $I_{lim}$ | Short Current Limit | $V_{OUT}$=0V | | | 60 | | mA |
| $I_{PDC}$ | CE pull-down current | | | 0.12 | 0.40 | 0.70 | μA |
| $V_{CEH}$ | CE "H" Input Voltage | | | 1.0 | | | V |
| $V_{CEL}$ | CE "L" Input Voltage | | | 0 | | 0.3 | V |

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● **R5220xxxxB**
<div align="right">Topt=25°C</div>

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{IN}$ | Input Voltage | | 2.8 | | 5.5 | V |
| $I_{SS1}$ | Supply Current 1 (Standby mode) | $V_{IN}=V_{OUT1}+1.0V$, $V_{CE}=GND$, $V_{MODE}=GND$ or $V_{IN}$ $V_{OUT1}$:DC/DC Set $V_{OUT}$ | | 0.1 | 1.0 | μA |
| $I_{SS2}$ | Supply Current 2 (Power Save mode) | $V_{IN}=V_{CE}=V_{MODE}=V_{OUT2}+1.0V$, $V_{OUT2}$:VR Set $V_{OUT}$, $I_{OUT}=0mA$ | | 5 | 10 | μA |
| $I_{SS3}$ | Supply Current 3 | $V_{IN}=V_{CE}=3.6V$, $V_{MODE}=GND$ | | 350 | 450 | μA |

**DC/DC Part**
<div align="right">Topt=25°C</div>

| Symbol | Item | Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $V_{OUT1}$ | Output Voltage | $V_{IN}=3.6V$ $I_{OUT}=50mA$ | $V_{OUT1} \geqq 1.5$ | ×0.98 | | ×1.02 | V |
| | | | $V_{OUT1}<1.5$ | −0.03 | | +0.03 | |
| fosc | Oscillator Frequency | $V_{IN}=V_{SET1}+1.5V$ | | 0.96 | 1.20 | 1.44 | MHz |
| $T_{START}$ | Soft-start Time | $V_{IN}=3.6V$ | $V_{OUT1}<1.5$ | | 0.15 | 0.30 | ms |
| | | | $V_{OUT1} \geqq 1.5$ | | 0.20 | 0.35 | |
| $R_{ONP}$ | ON Resistance of Pch Transistor | $V_{IN}=3.6V$, $I_{LX}=−100mA$ | | | 0.5 | | Ω |
| $R_{ONN}$ | ON Resistance of Nch Transistor | $V_{IN}=3.6V$, $I_{LX}=−100mA$ | | | 0.5 | | Ω |
| $I_{LXLEAK}$ | Lx Leakage Current | $V_{IN}=5.5V$, $V_{CE}=0V$, $L_x=5.5V/0V$ | | −1.0 | | 1.0 | μA |
| $\Delta V_{OUT}/\Delta T_{opt}$ | Output Voltage Temperature Coefficient | $−40°C \leqq T_{opt} \leqq 85°C$ | | | ±150 | | ppm/°C |
| Maxduty | Oscillator Maximum Duty Cycle | $V_{OUT}=0V$ | | 100 | | | % |
| $I_{LXlim}$ | Lx Current Limit | $V_{IN}=3.6V$ | | 500 | 800 | | mA |
| $T_{prot}$ | Protection Delay Circuit | $V_{IN}=3.6V$ | | 1.0 | 3.0 | 7.0 | ms |
| $V_{UVLO1}$ | UVLO Threshold Voltage | $V_{CE}=V_{IN}$, $V_{MODE}=GND$, $V_{OUT}=0V$ | | 2.00 | 2.35 | 2.75 | V |
| $V_{UVLO2}$ | UVLO Released Voltage | $V_{CE}=V_{IN}$, $V_{MODE}=GND$, $V_{OUT}=0V$ | | 2.05 | 2.45 | 2.80 | V |
| $V_{MODEH}$ | MODE "H" Input Voltage | | | 1.0 | | | V |
| $V_{MODEL}$ | MODE "L" Input Voltage | | | 0 | | 0.3 | V |

**VR Part**
<div align="right">Topt=25°C</div>

| Symbol | Item | Conditions | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $V_{OUT2}$ | Output Voltage | $V_{IN}=V_{OUT2}+1.0V$ $I_{OUT}=10mA$ | $V_{OUT2} \geqq 1.5$ | ×0.98 | | ×1.02 | V |
| | | | $V_{OUT2}<1.5$ | −0.03 | | +0.03 | |
| $I_{OUT}$ | Output Current | $V_{IN}=V_{OUT2}+1.0V$ | | 50 | | | mA |
| $\Delta V_{OUT2}/\Delta I_{OUT}$ | Load Regulation | $V_{IN}=V_{OUT2}+1.0V$ $10μA \leqq I_{OUT} \leqq 25mA$ | $V_{OUT2}<2.3$ | | 15 | 40 | mV |
| | | | $2.3 \leqq V_{OUT2}<3.0$ | | 25 | 50 | |
| | | | $V_{OUT2} \geqq 3.0$ | | 35 | 65 | |
| $V_{DIF}$ | Dropout Voltage | $I_{OUT}=50mA$ | $V_{OUT2}<1.8V$ | | 0.7 | | V |
| | | | $V_{OUT2} \geqq 1.8V$ | | 0.3 | | |
| $\Delta V_{OUT2}/\Delta V_{IN}$ | Line Regulation | $2.8V \leqq V_{IN} \leqq 5.5V$ $I_{OUT}=25mA$ | $V_{OUT2}<2.3V$ | | | 0.2 | %/V |
| | | $V_{OUT2}+0.5V \leqq V_{IN} \leqq 5.5V$ $I_{OUT}=25mA$ | $V_{OUT2} \geqq 2.3V$ | | | | |
| RR | Ripple Rejection | Refer to Typical Characteristics | | | | | dB |
| $\Delta V_{OUT}/\Delta T_{opt}$ | Output Voltage Temperature Coefficient | $I_{OUT}=30mA$, $−40°C \leqq T_{opt} \leqq 85°C$ | | | ±100 | | ppm/°C |
| $I_{lim}$ | Short Current Limit | $V_{OUT}=0V$ | | | 60 | | mA |
| $I_{PDC}$ | CE pull-down current | | | 0.12 | 0.40 | 0.70 | μA |
| $V_{CEH}$ | CE "H" Input Voltage | | | 1.0 | | | V |
| $V_{CEL}$ | CE "L" Input Voltage | | | 0 | | 0.3 | V |

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## TYPICAL APPLICATION



**Parts Recommendation**

| $C_{IN}$ | 10μF Ceramic Capacitor C2012JB0J106K (TDK) |
|---|---|
| $C_{OUT}$ | 10μF Ceramic Capacitor C2012JB0J106K (TDK) |
| L | 4.7μH VLP5610T-4R7MR90 (TDK) |

## External Components

- Set external components such as an inductor, $C_{IN}$, $C_{OUT}$ as close as possible to the IC, in particular, minimize the wiring to $V_{IN}$ pin and GND pin. If $V_{DD}$ line or GND line's impedance is high, the internal voltage level of the IC may fluctuate and the operation may be unstable. Make GND line and $V_{DD}$ line sufficient. Through the $V_{DD}$ line, the GND line, the inductor, Lx pin, and $V_{OUT}$ line, a large current caused by switching may flow, therefore, those lines should be sufficient and avoid the cross talk with other sensitive lines. Use the individual line from the $V_{OUT}$ pin of the IC for the inductor and the capacitor and load.

- Use a low ESR ceramic capacitor $C_{OUT}/C_{IN}$ with a capacity of 10μF or more.

- Select an inductor with an inductance range from 4.7μH to 10μH. The internal phase compensation is secured with these inductance values and $C_{OUT}$ value. Choose the inductor with a low DC resistance and enough permissible current and hard to reach magnetic saturation. In terms of inductance value, choose the appropriate value with considering the conditions of the input voltage range and the output voltage, and load current. If the inductance value is too small and the load current is large, the peak current of Lx may reach the Lx current limit, and the protection against over-current may work.

- The protection circuit against over-current is affected by the self-heating and the heat radiation environment. Therefore evaluate under the considerable environment of the application.

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 $L_x$ transistor is ON, and discharges the energy from the inductor when $L_x$ 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:

**<Basic Circuits>**                                        **<Current through L>**
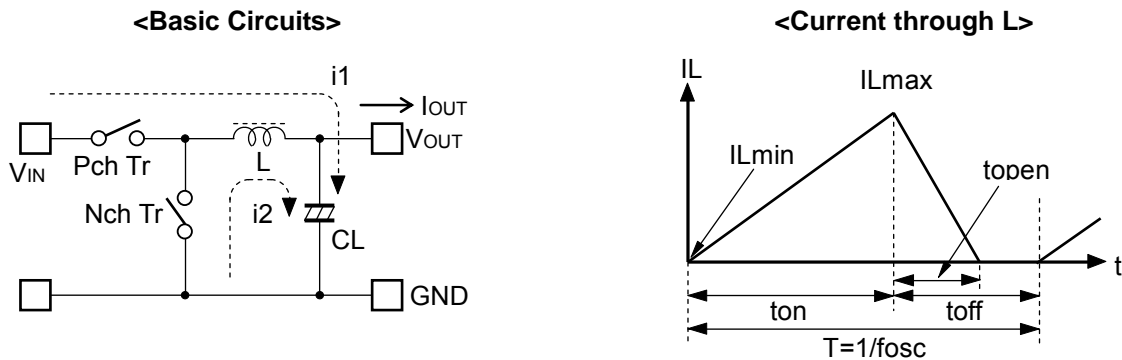


Step 1:  P-channel Tr. turns on and current IL (=i1) flows, and energy is charged into CL. At this moment, IL increases from ILmin (=0) to reach ILmax in proportion to the on-time period (ton) of P-channel Tr.

Step 2:  When P-channel Tr. turns off, Synchronous rectifier N-channel Tr. turns on in order that L maintains IL at ILmax, and current IL (=i2) flows.

Step 3:  IL (=i2) decreases gradually and reaches IL=ILmin=0 after a time period of topen, and N-channel Tr. Turns off. Provided that in the continuous mode, next cycle starts before IL becomes to 0 because toff time is not enough. In this case, IL value increases from this ILmin (>0).

In the case of PWM control system, the output voltage is maintained by controlling the on-time period (ton), with the oscillator frequency (fosc) being maintained constant.

The maximum value (ILmax) and the minimum value (ILmin) of the current flowing through the inductor are the same as those when P-channel Tr. turns on and off.

The difference between ILmax and ILmin, which is represented by $\Delta I$;

$$\Delta I = ILmax - Ilmin = V_{OUT} \times topen / L = (V_{IN} - V_{OUT}) \times ton / L \dots\dots\dots\dots\dots\dots\text{Equation 1}$$

wherein,  $T = 1 / fosc = ton + toff$
         $duty (\%) = ton / T \times 100 = ton \times fosc \times 100$
         $topen \leq toff$

In Equation 1, $V_{OUT} \times topen / L$ and $(V_{IN} - V_{OUT}) \times ton / L$ respectively show the change of the current at "ON", and the change of the current at "OFF".

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# OUTPUT CURRENT AND SELECTION OF EXTERNAL COMPONENTS

When P-channel Tr. of $L_X$ is ON:

(Wherein, Ripple Current P-P value is described as $I_{RP}$, ON resistance of P-channel Tr. and N-channel Tr. of $L_X$ are respectively described as $R_{ONP}$ and $R_{ONN}$, and the DC resistor of the inductor is described as $R_L$.)

$$V_{IN} = V_{OUT} + (R_{ONP} + R_L) \times I_{OUT} + L \times I_{RP} / ton \text{.............................................................. Equation 2}$$

When P-channel Tr. of $L_X$ is "OFF" (N-channel Tr. is "ON"):

$$L \times I_{RP} / toff = R_{ONN} \times I_{OUT} + V_{OUT} + R_L \times I_{OUT} \text{................................................... Equation 3}$$

Put Equation 3 to Equation 2 and solve for ON duty of P-channel transistor, ton / (toff + ton) = $D_{ON}$,

$$D_{ON} = (V_{OUT} - R_{ONN} \times I_{OUT} + R_L \times I_{OUT}) / (V_{IN} + R_{ONN} \times I_{OUT} - R_{ONP} \times I_{OUT}) \text{........................... Equation 4}$$

Ripple Current is as follows;

$$I_{RP} = (V_{IN} - V_{OUT} - R_{ONP} \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / fosc / L \text{............................................... Equation 5}$$

wherein, peak current that flows through L, and $L_X$ Tr. is as follows;

$$ILmax = I_{OUT} + I_{RP} / 2 \text{..................................................................................................... Equation 6}$$

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

## 1) IC start-up

The timing chart as shown in the next describes the operation starting the IC is enabled with CE. When the CE pin voltage becomes higher than the threshold voltage, the IC's operations starts. At first, only the voltage regulator (VR) starts. The threshold level of the CE pin is between CE "H" input voltage and CE "L" input voltage. After starting the operation, the output capacitor ($C_{OUT}$) is charged with the output current of the VR, and the output level becomes the set VR output voltage. At this moment, the output of Lx is "off", ("Hi-Z"), the pin voltage, $V_{LX}=V_{OUT}$ through the external inductor L.

Secondly, the Mode pin voltage is higher than the threshold voltage, internal operation of DC/DC starts. The threshold level is between Mode "H" input voltage and Mode "L" input voltage. The soft-start circuit inside the DC/DC converter's operation is as follows:

(Case 1) DC/DC output voltage < VR output voltage

After the soft-start time, while the output voltage level is down from the VR output voltage to DC/DC output voltage, the circuit is waiting for the start of DC/DC operation. When the output voltage reaches so set DC/DC output voltage level, the actual DC/DC operation starts.

(Case 2) DC/DC output voltage> VR output voltage

The soft-start circuit of DC/DC converter makes the voltage reference unit of the IC rise gradually and be constant. After the voltage reference unit reaches the constant level which the output voltage of DC/DC converter can balance becomes the output voltage of VR, the set output voltage of DC/DC converter may be realized.

Therefore, the soft-start time means the time range of starting to the time when the voltage reference unit reaches the constant level, and the soft-start time is different from turning on speed in some cases. The operation starting time depends on the ability of the power supply, the load current, the inductance value, the capacitance value, and the voltage difference between the set VR output and the set DC/DC output.

If CE and Mode are on at once, the same operation as above is happened except the VR start-up and Soft-start operation start at the same time.

If Mode signal is forced earlier than CE signal, this IC is stand-by until CE signal comes. Therefore when the CE signal is set, the IC operation starts as above.

● **$V_{OUT}$ voltage rising speed at start-up with power supply is affected by the next conditions:**

1. The turning on speed of $V_{IN}$ voltage limited by the power supply to the IC and the input capacitor $C_{IN}$.
2. The output capacitor, $C_{OUT}$ value and load current.

● **DC/DC operation starting time**

1. If the VR output $\geq$ DC/DC output, the operation starting time of the DC/DC converter is approximately equal to the next formula.

   $T_{DC/DC\_ACT} = T_{SS} + (V_{OUT\_VR} - V_{OUT\_DC/DC} + 15mV) \times C_{OUT}$ / (load current at mode change + $1\mu A$)

   $T_{SS}$: Soft-start time

   $V_{OUT\_VR}$: VR output voltage

   $V_{OUT\_DC/DC}$: DC/DC Output Voltage

   *$1\mu A$ is the supply current of the IC itself for the output.

2. If the VR output < DC/DC output, the operation starting time is the soft-start time + starting operation time which depends on the power supply, the load current, and the external components.

**RICOH**

VCEH

CE pin input signal

VCEL        VMODEH

MODE pin input signal

VMODEL

Soft start time

IC DC/DC Voltage Reference Unit

A.VR Output=DC/DC Output voltage

VOUT

Effect from Power Supply, Load Current, External Components

Lx voltage

DC/DC Operation

B.VR voltage > DC/DC Output

VOUT

DC/DC does not operate if VR output is larger than DC/DC

Lx voltage

DC/DC Operation

C. VR voltage < DC/DC voltage

VOUT

Lx voltage

DC/DC Operating

If CE pin input signal is forced earlier than the supply voltage, the voltage difference between the input and the output which is according to the input voltage to $V_{IN}$, is maintained and the $V_{OUT}$ is rising up.

# TEST CIRCUITS
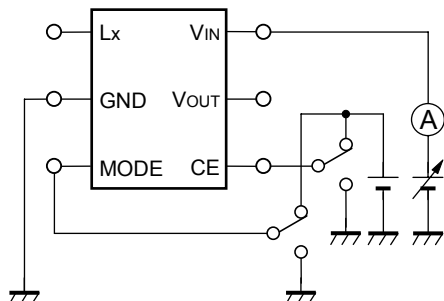


**Supply Current 1,2,3**
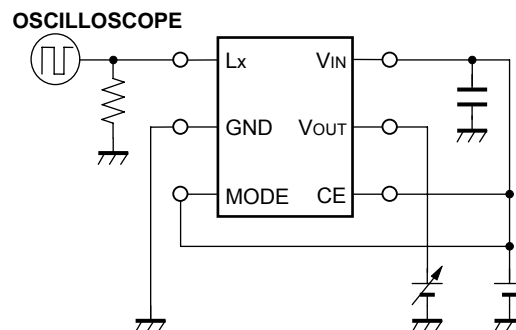


**Output Voltage(DC/DC)**
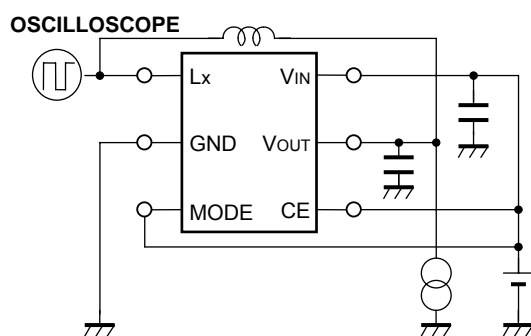


**Oscillator Frequency**
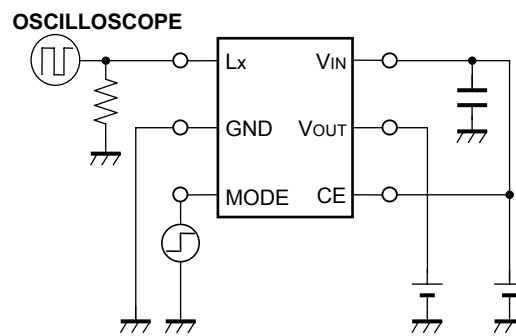


**Soft-start Time**
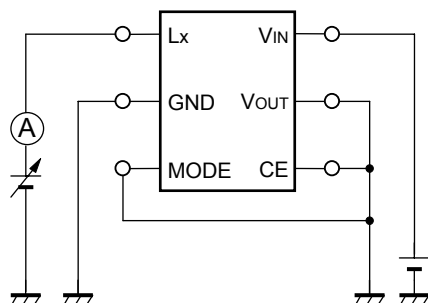


**Lx Leakage Current**
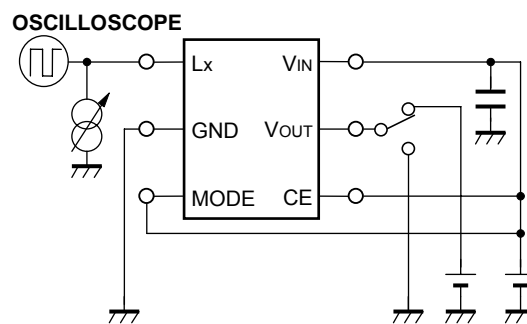


**Lx Current Limit, Output Delay for Protection**
**Lx Pch transistor ON resistance**
**Nch transistor ON resistance**

**RICOH**
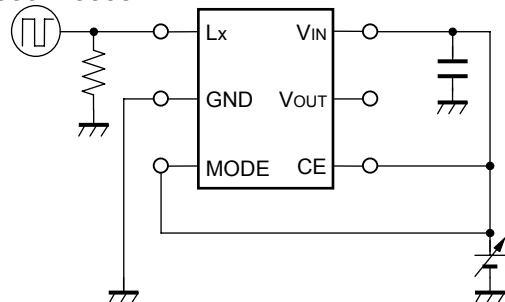
**UVLO Detector Threshold UVLO Release Voltage**
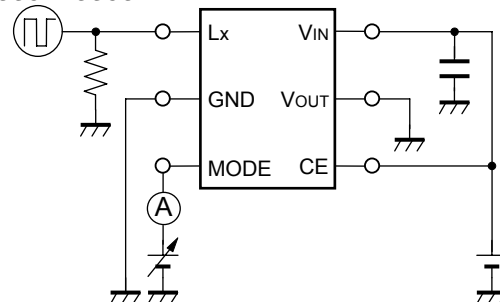


**MODEInput Voltage "H","L" Input Current**
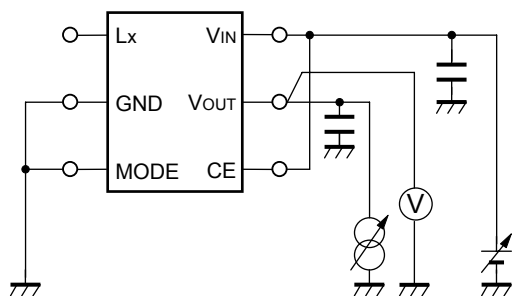


**Output Voltage (VR), Load Regulation
Line Regulation, Dropout Voltage**
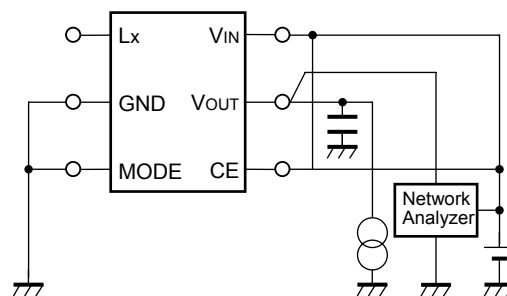


**(J) RippleRejection**
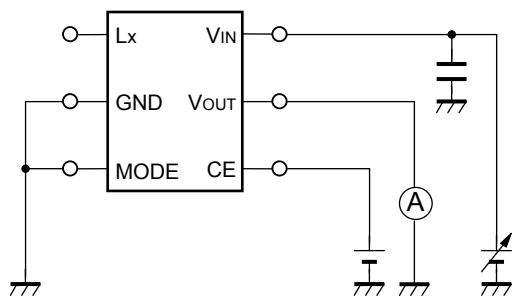


**Short Current Limit**
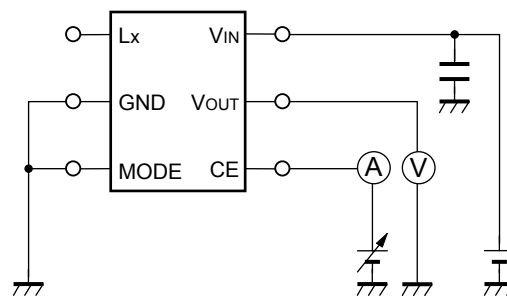


**CE="H"/"L" Input Voltage/ Input Current**

# TYPICAL CHARACTERISTICS

## 1) DC/DC Converter

1-1) DC/DC Output Voltage vs. Output Current

**R5220x181A**
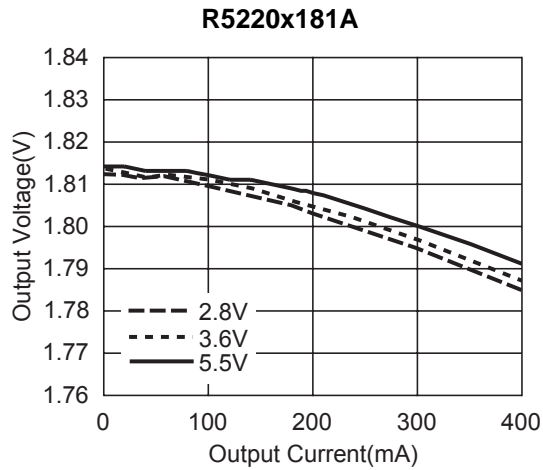
1-2) DC/DC Output Voltage vs. Input Voltage

**R5220x181A**
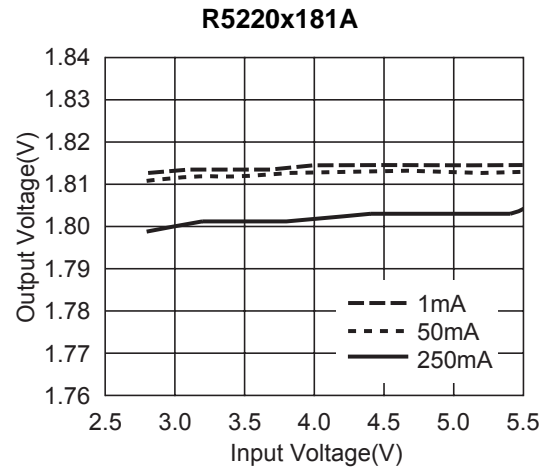
1-3) DC/DC Efficiency vs. Output Current

**R5220x181A**
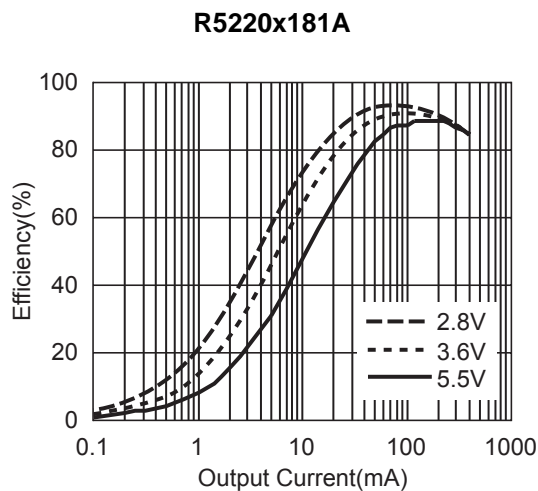
1-4) DC/DC Supply Current vs. Temperature
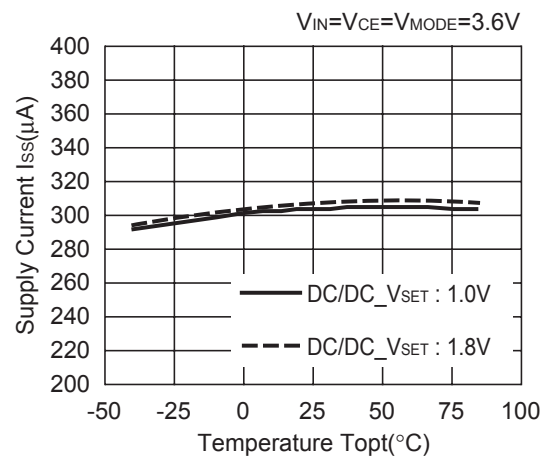
1-5) DC/DC Supply Current vs. Input Voltage

1-6) DC/DC Output Waveform

**R5220x121A**

**RICOH**

**R5220x181A**
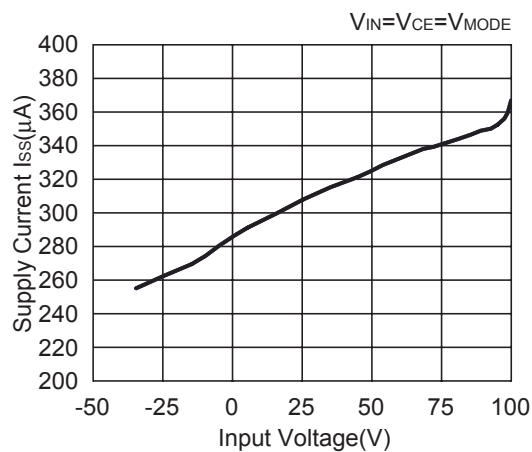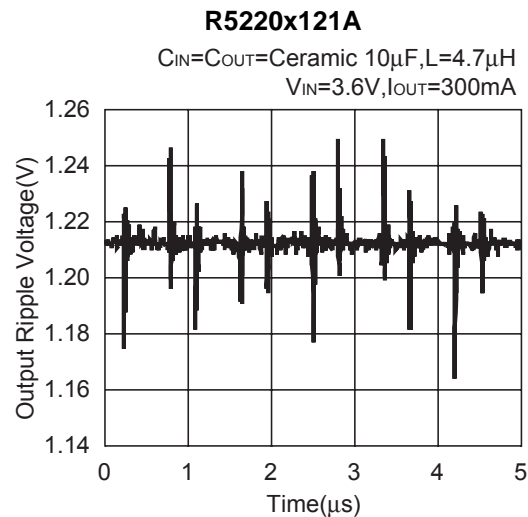


1-7) DC/DC Output Voltage vs. Temperature
**R5220x181A**

$I_{OUT}$=50mA
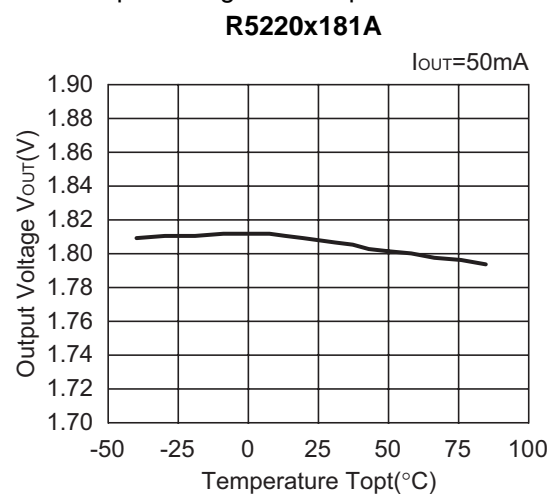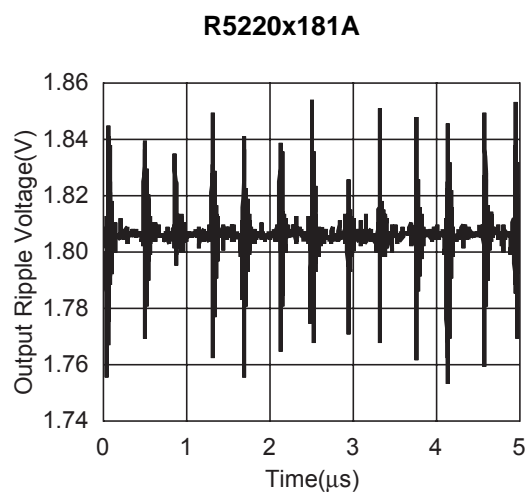


1-8) DC/DC Oscillator Frequency vs. Temperature

$V_{IN}$=3.6V
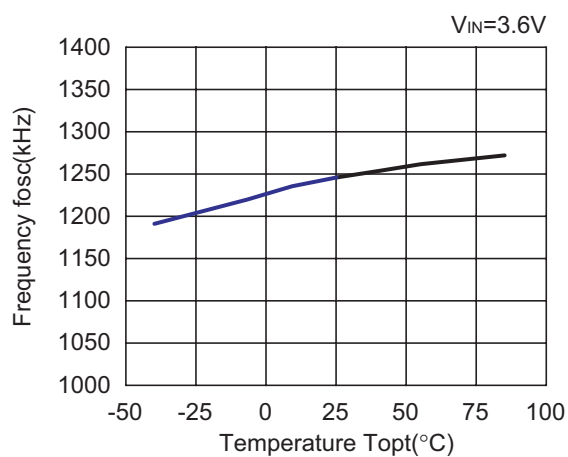


1-9) DC/DC Oscillator Frequency vs. Input Voltage
**R5220x181A**
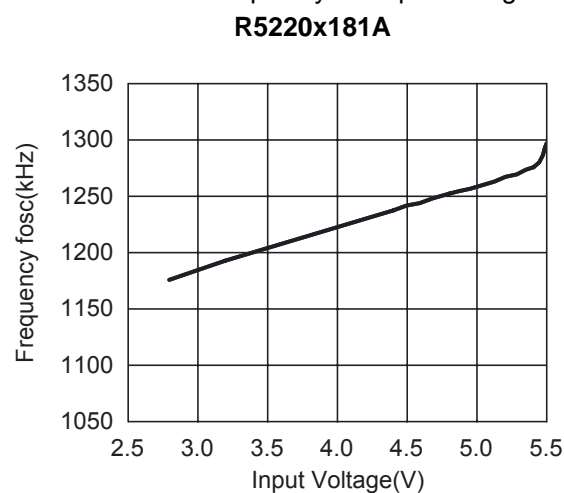


1-10) Soft-start time vs. Temperature
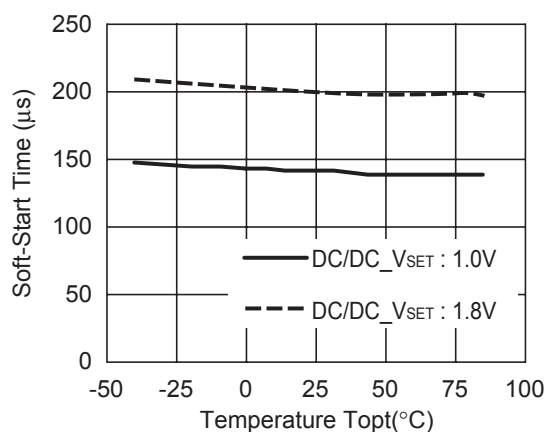


1-11) UVLO Detector Threshold/ Released Voltage vs. Temperature
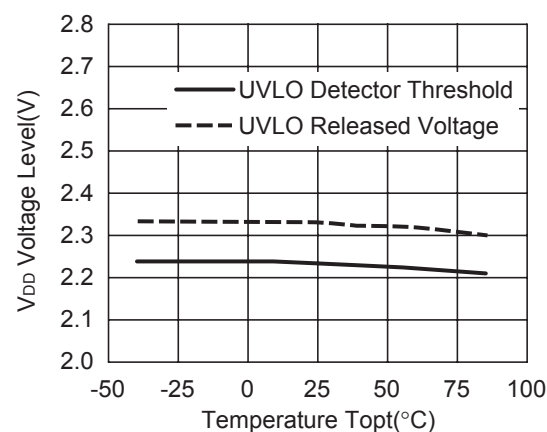
1-12) MODE Input Voltage vs. temperature
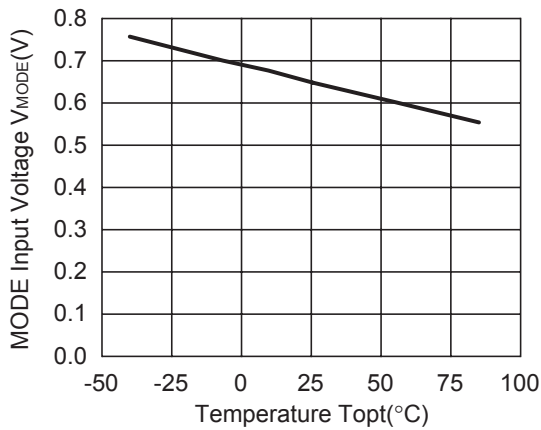


1-13) Pch Transistor On Resistance vs. Temperature
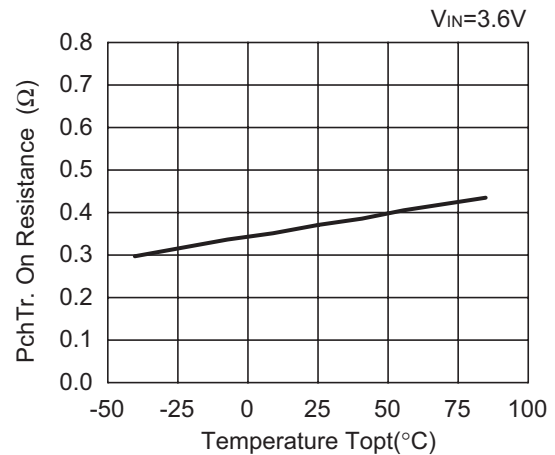


1-14) Nch Transistor On Resistance vs. Temperature
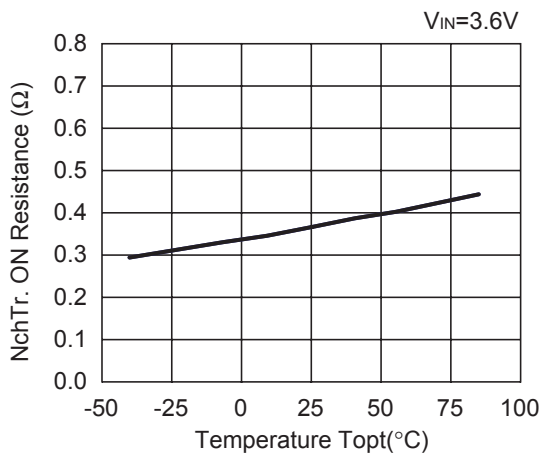


1-15) DC/DC Lx Current Limit vs. Temperature
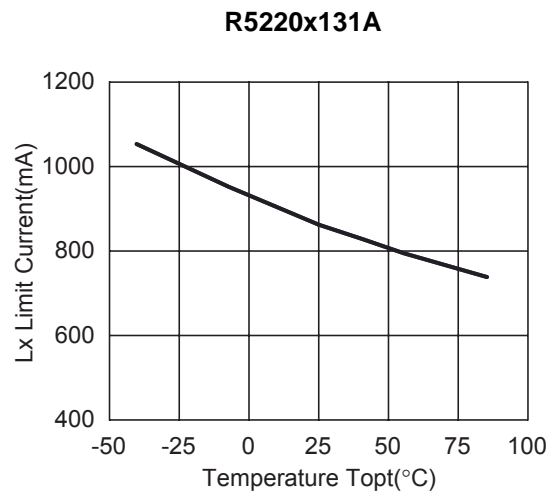
**R5220x131A**



**2) VR**

2-1) VR Output Voltage vs. Output Current
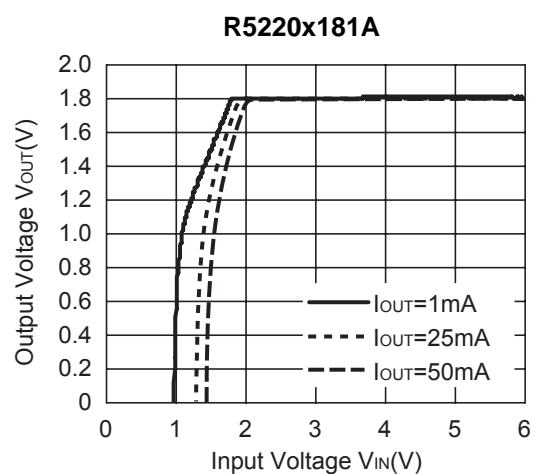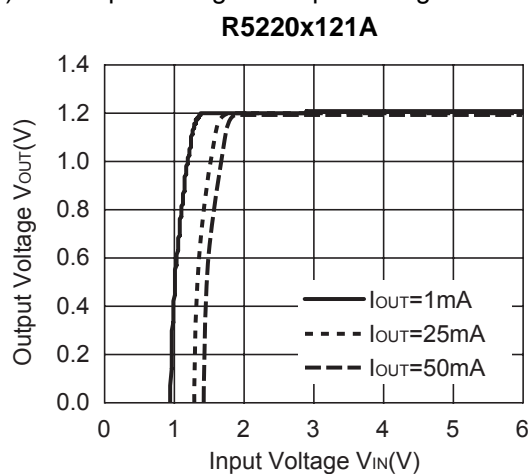
**R5220x121A**



**R5220x181A**

**RICOH**

2-2) VR Output Voltage vs. Input Voltage

**R5220x121A**



**R5220x181A**



2-3) VR Supply Current vs. Input Voltage

**R5220x121A**



**R5220x181A**



2-4) VR Output Voltage vs. Temperature

**R5220x121A**



**R5220x181A**



**RICOH**
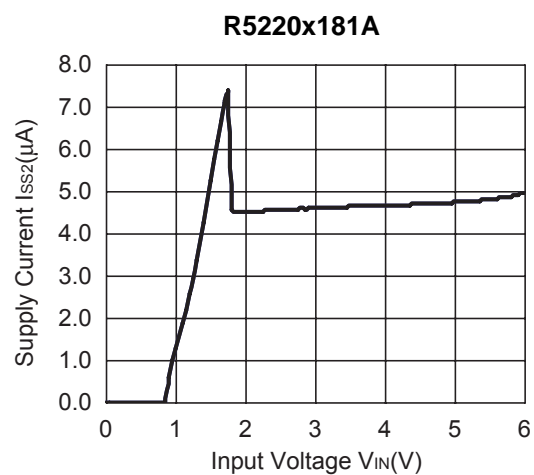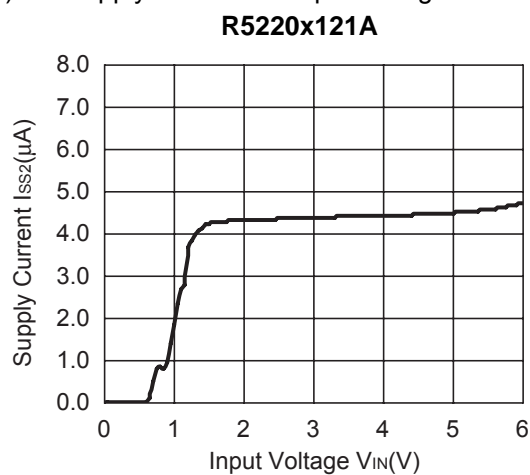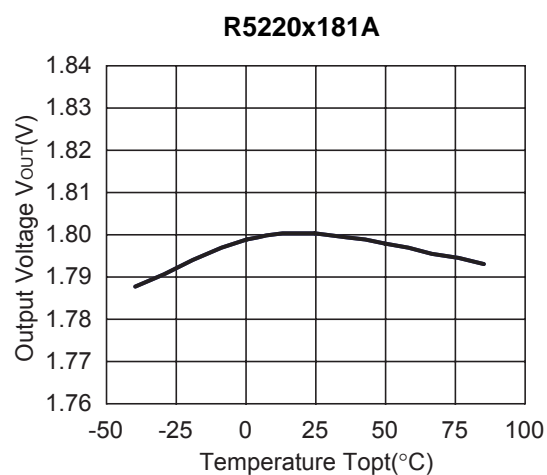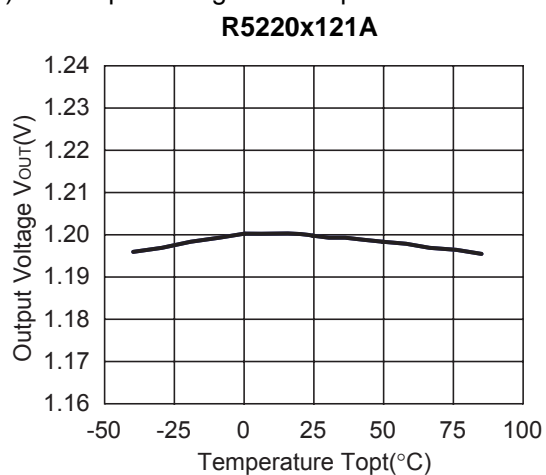
2-5) VR Supply Current vs. Temperature
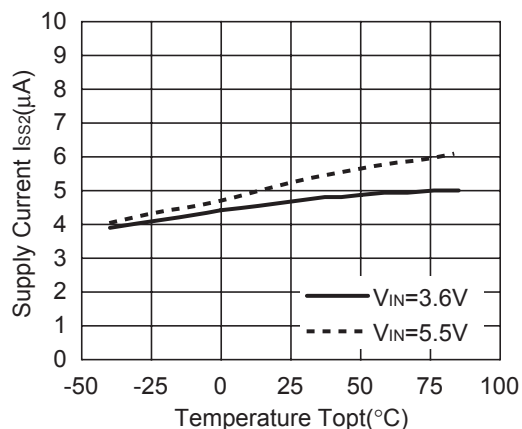
**R5220x121A**
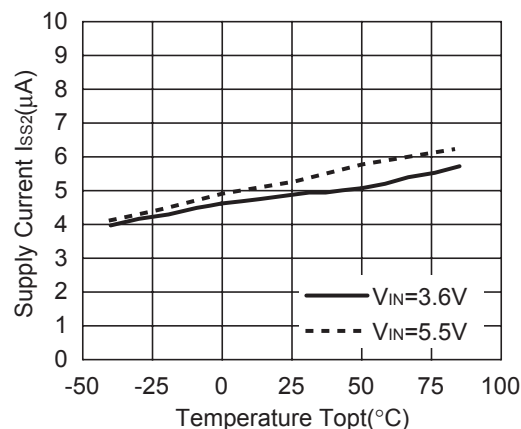


**R5220x181A**



2-6) Dropout Voltage vs. Output Current
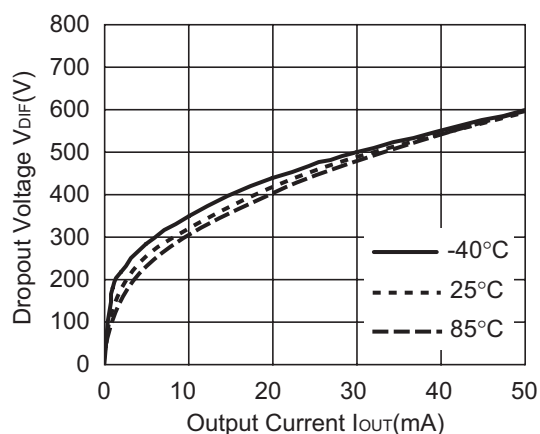
**R5220x121A**
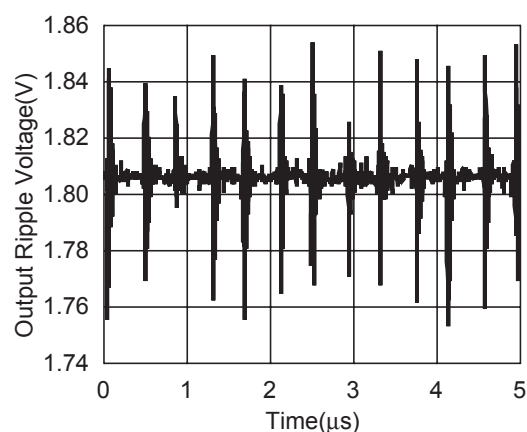


**R5220x181A**



2-7) Ripple Rejection vs. Input Voltage

**R5220x121A**

Ripple 0.2Vp-p,$I_{OUT}$=25mA,
$C_{IN}$=none,$C_{OUT}$=Ceramic10μF
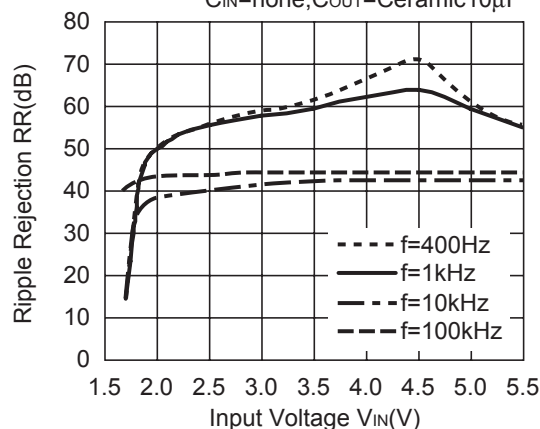


**R5220x181A**

Ripple 0.2Vp-p,$I_{OUT}$=25mA,
$C_{IN}$=none,$C_{OUT}$=Ceramic10μF

**RICOH**
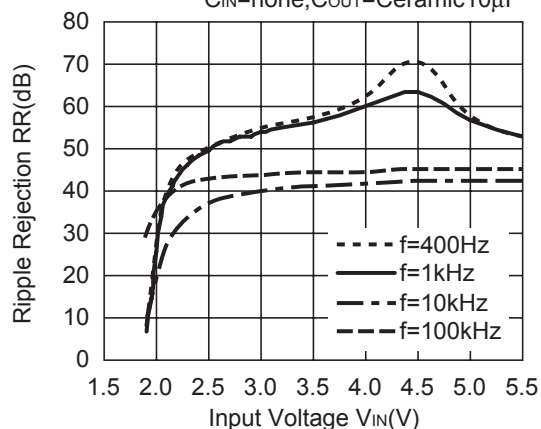
2-8) VR Ripple Rejection vs. Frequency

**R5220x121A**

$V_{IN}$=2.2V+0.2Vp-p
$C_{IN}$=none $C_{OUT}$=Ceramic10μF



**R5220x181A**

$V_{IN}$=2.8V+0.2Vp-p
$C_{IN}$=none $C_{OUT}$=Ceramic10μF
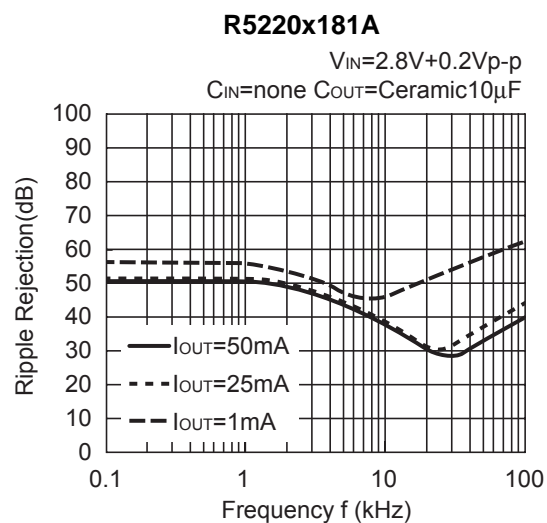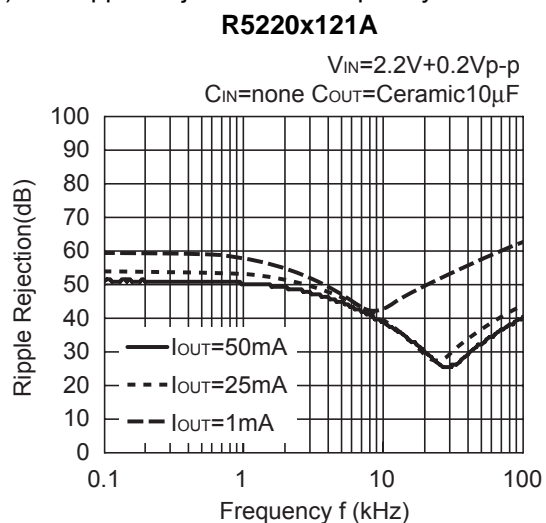


2-9) Input Transient Response

**R5220x121A**

$I_{OUT}$=10mA
$C_{IN}$=none, $C_{OUT}$=Ceramic10μF



**R5220x181A**

$I_{OUT}$=10mA
$C_{IN}$=none, $C_{OUT}$=Ceramic10μF
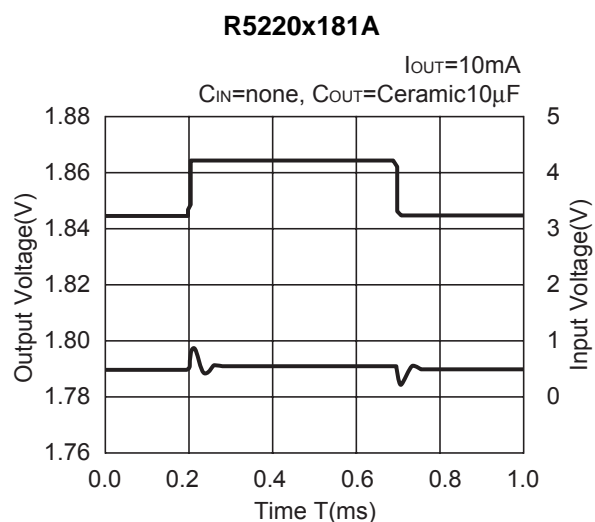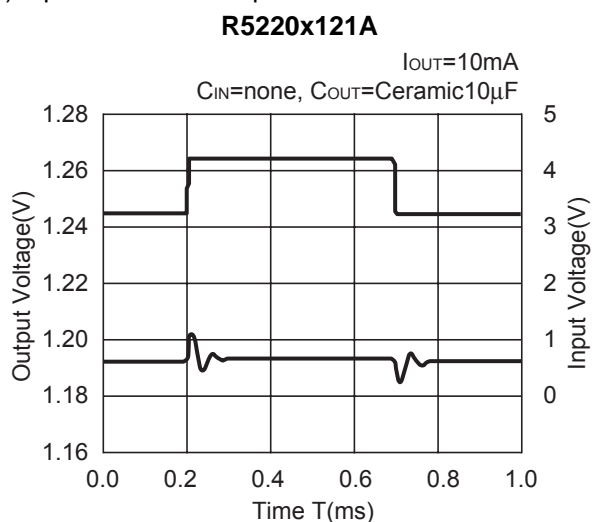


2-10) Load Transient Response

**R5220x121A**

$V_{IN}$=3.6V,$C_{IN}$=$C_{OUT}$=Ceramic10μF



**R5220x121A**

$V_{IN}$=3.6V,$C_{IN}$=$C_{OUT}$=Ceramic10μF



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**R5220x181A**

$V_{IN}$=3.6V,$C_{IN}$=$C_{OUT}$=Ceramic10μF



**R5220x181A**

$V_{IN}$=3.6V,$C_{IN}$=$C_{OUT}$=Ceramic10μF
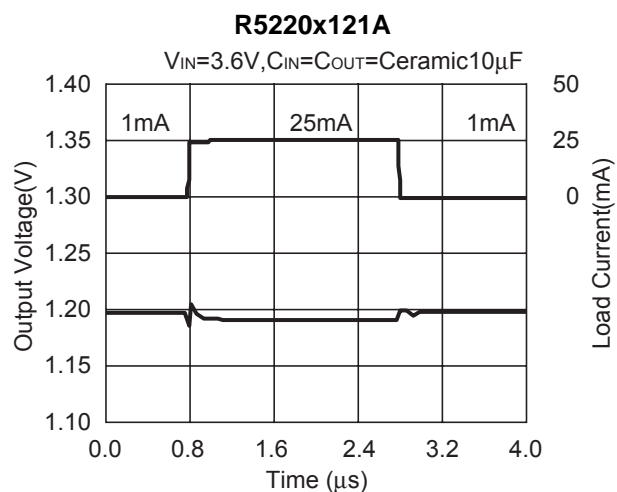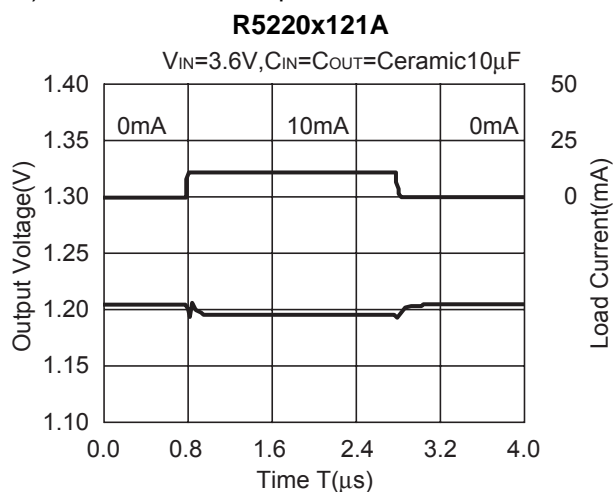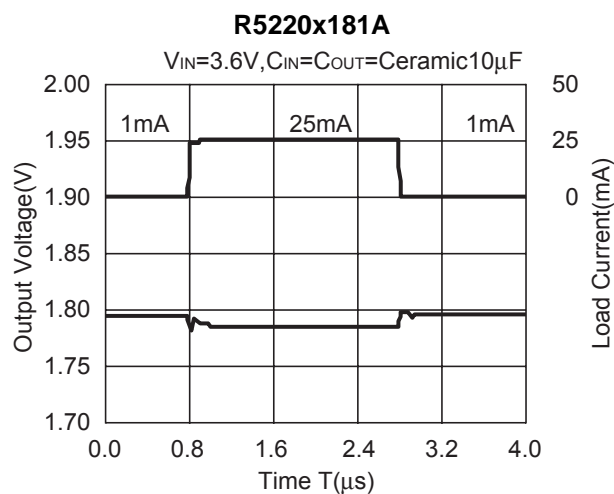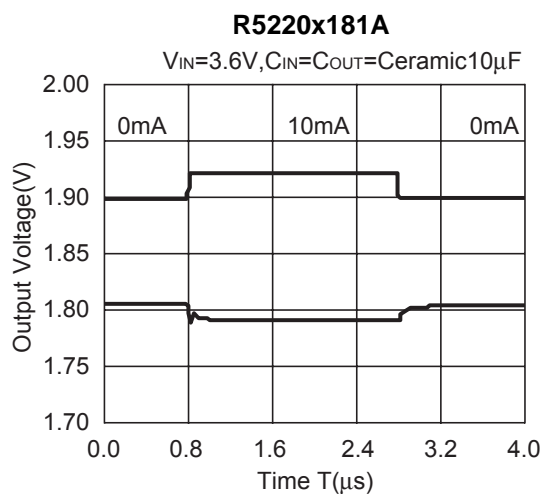


## 3) Mode Transient Response between VR and DC/DC

3-1) VR to DC/DC Mode Transient Response

**R5220x151A**

$V_{IN}$=3.6V,$I_{OUT}$=0.5mA
$C_{IN}$=$C_{OUT}$=Ceramic10μF
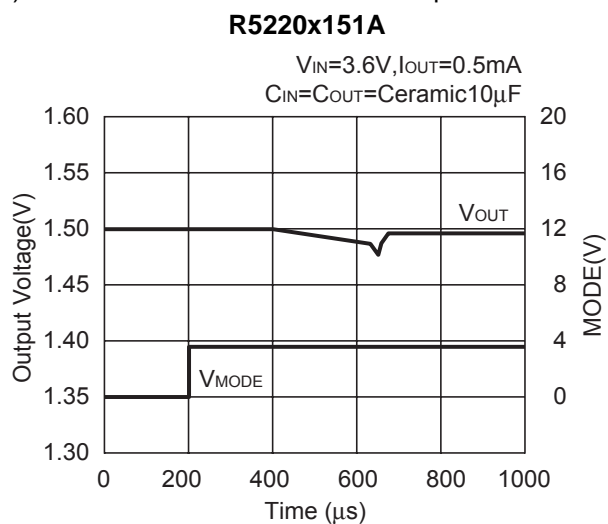


3-2) DC/DC to VR Mode Transient Response

**R5220x151A**

$V_{IN}$=3.6V,$I_{OUT}$=0.5mA
$C_{IN}$=$C_{OUT}$=Ceramic10μF

**RICOH**

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