

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.

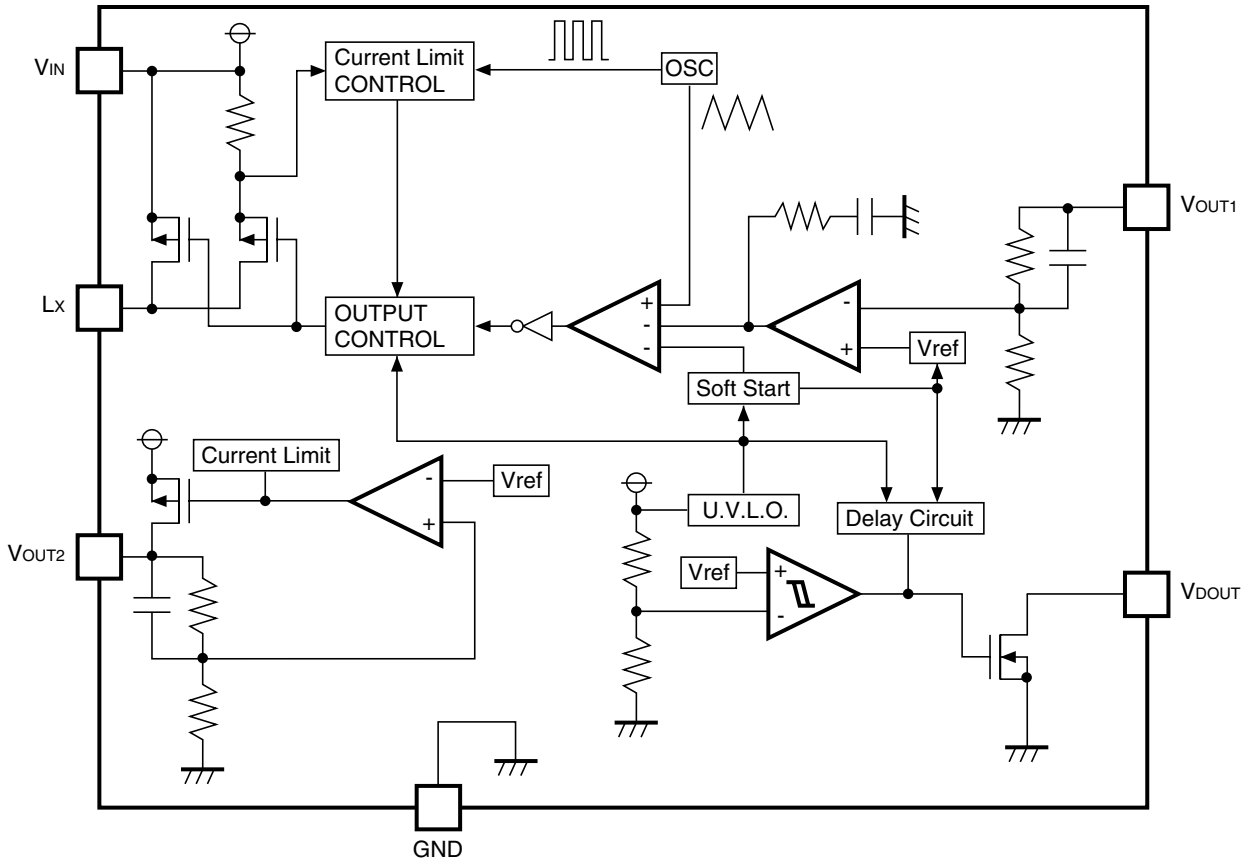
FEATURES

- 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 Current500mA (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 HSON-6 (thickness: Max. 0.9mm)

APPLICATIONS

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

BLOCK DIAGRAM



SELECTION GUIDE

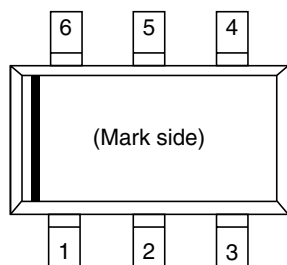
In the R5210x Series, the output voltage combination for the ICs can be selected at the user's request. The selection can be made with designating the part number as shown below;

R5210xxxx-TR ←Part Number
 ↑ ↑ ↑ ↑
 a b c d

| Code | Contents |
|------|--|
| a | Designating the Package type: N: SOT-23-6W D: HSON-6 (Under Development) |
| b | Output Voltage Combination Code Number |
| c | Designation of Optional Function C (Standard) |
| d | Designation of Taping Type: Refer to Taping specification. |

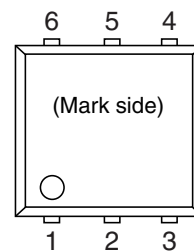
PIN CONFIGURATIONS

- SOT-23-6W



R5210Nxxxx

- HSON-6



R5210Dxxxx

PIN DESCRIPTION

| Pin No. | | Symbol | 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~V _{IN} +0.3 | V |
| V _{OUT1} | V _{OUT1} Pin Voltage | -0.3~V _{IN} +0.3 | V |
| V _{OUT2} | V _{OUT2} Pin Voltage | -0.3~V _{IN} +0.3 | V |
| V _{DOUT} | V _{DOUT} Pin Voltage | -0.3~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 |
| P _D | Power Dissipation (HSON-6/Under Development) | 400 | mW |
| T _{opt} | Operating Temperature Range | -40~+85 | °C |
| T _{stg} | Storage Temperature Range | -55~+125 | °C |

ELECTRICAL CHARACTERISTICS

• R5210N001C

T_{opt}=25°C

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

DC/DC Part

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

VR part

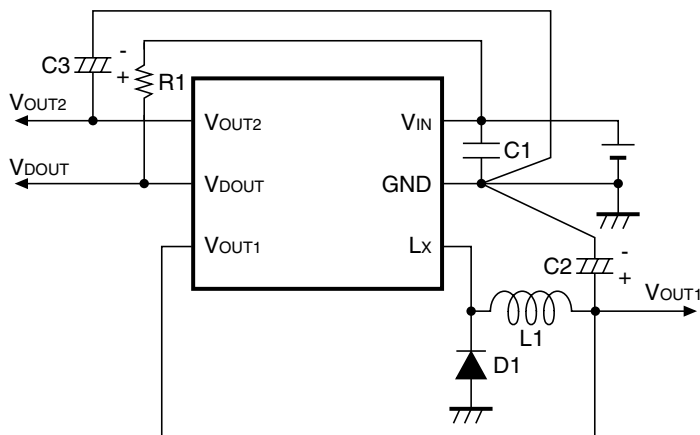
| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---------------------------|---|--|-------|-------|-------|------------|
| V _{OUT2} | VR Output Voltage | V _{IN} =5.0V, I _{OUT2} =10mA | 3.332 | 3.400 | 3.468 | V |
| I _{OUT2} | Maximum Output Current of VR | V _{IN} =5.0V | 200 | | | mA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

VD part

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---------------------------|---|--|-------|------------------------|-------|-------------------------|
| $-V_{DET}$ | VD Detector Threshold | | 4.095 | 4.200 | 4.305 | V |
| $\Delta-V_{DET}/\Delta T$ | VD Detector Threshold Temperature Coefficient | $-40^{\circ}\text{C} \leq T_{opt} \leq 85^{\circ}\text{C}$ | | ± 100 | | ppm/ $^{\circ}\text{C}$ |
| V_{HYS} | Hysteresis Range | | | $-V_{DET} \times 0.05$ | | V |
| tPLH | VD Output Delay Time for Release | | 5 | 10 | 20 | ms |
| I _{DOUTL} | V _{DOUT} "L" Output Current | $V_{IN}=2.0\text{V}, V_{DOUT}=0.1\text{V}$ | 2 | 7 | 15 | mA |

TYPICAL APPLICATION AND APPLICATION HINTS

• R5210NxxxC



Examples of Components

Inductor L1 : LQH4C (Murata, 10 μH) or LDR655312T (TDK)

Shottky Diode D1 : RB491D (Rohm) or EP05Q03L (Nihon Inter)

Pull-up Resistor R1 : 50k Ω

Capacitors : C1=10 μF (Ceramic Capacitor) C2: 22 μF (Tantalum Capacitor) C3: 10 μF (Tantalum Capacitor)

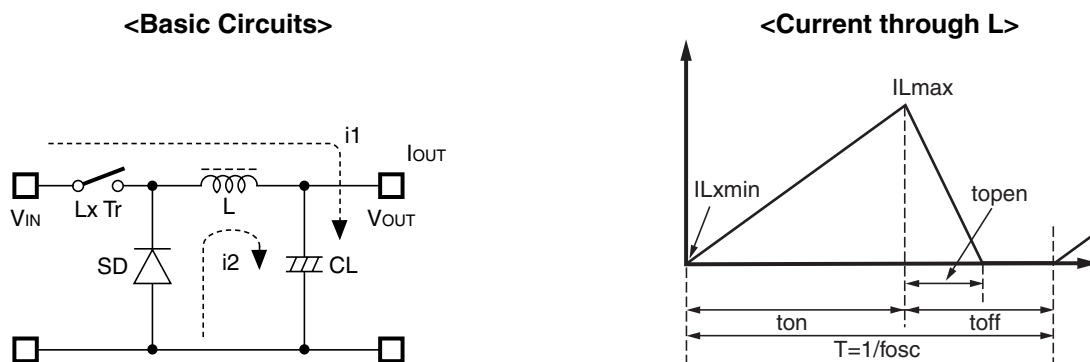
When you use these ICs, consider the following issues;

- 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_{IN} 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_{OUT1} . 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.

- Use a capacitor with a capacity of $10\mu\text{F}$ or more for V_{IN} and GND, and with low ESR ceramic type. In terms of V_{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_{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_{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 $I_L (=i_1)$ flows, and energy is charged into CL. At this moment, I_L increases from $I_{Lmin} (=0)$ to reach I_{Lmax} in proportion to the on-time period (t_{on}) of LX Tr.
- Step 2 : When Lx Tr. turns off, Schottky diode (SD) turns on in order that L maintains I_L at I_{Lmax} , and current $I_L (=i_2)$ flows.
- Step 3 : I_L decreases gradually and reaches I_{Lmin} after a time period of t_{open} , and SD turns off, provided that in the continuous mode, next cycle starts before I_L becomes to 0 because t_{off} time is not enough. In this case, I_L value is from this $I_{Lmin} (>0)$.

In the case of PWM control system, the output voltage is maintained by controlling the on-time period (t_{on}), with the oscillator frequency (f_{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;

ΔI=ILmax-ILmin=VOUT×topen/L=(VIN-VOUT)×ton/L..... Equation 1

Where, T=1/fosc=ton+toff

duty (%)=ton/T×100=ton×fosc×100

topen≤toff

In Equation 1, VOUT×topen/L and (VIN-VOUT)×ton/L are respectively shown the change of the current at ON, and the change of the current at OFF.

When the output current (IOUT) is relatively small, topen < toff as illustrated in the above diagram. In this case, the energy is charged in the inductor during the time period of ton and is discharged in its entirety during the time period of toff, therefore ILmin becomes to zero (ILmin=0). When IOUT is gradually increased, eventually, topen becomes to toff (topen=toff), and when IOUT 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 ton and assumed that the solution is tonc,

tonc=T×VOUT/VIN..... Equation 2

When ton < tonc, the mode is the discontinuous mode, and when ton = tonc, 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 IRP, ON resistance of Lx Tr. is described as RP the direct current of the inductor is described as RL.)

VIN=VOUT+(RP+RL)×IOUT+L×IRP/ton..... Equation 3

When Lx Tr. is “OFF”:

L×IRP/toff=VF+VOUT+RL×IOUT..... Equation 4

Put Equation 4 to Equation 3 and solve for ON duty, ton/(toff+ton)=DON,

DON=(VOUT+VF+RL×IOUT)/(VIN+VF-RP×IOUT)..... Equation 5

Ripple Current is as follows;

IRP=(VIN-VOUT-RP×IOUT-RL×IOUT)×DON/f/L..... Equation 6

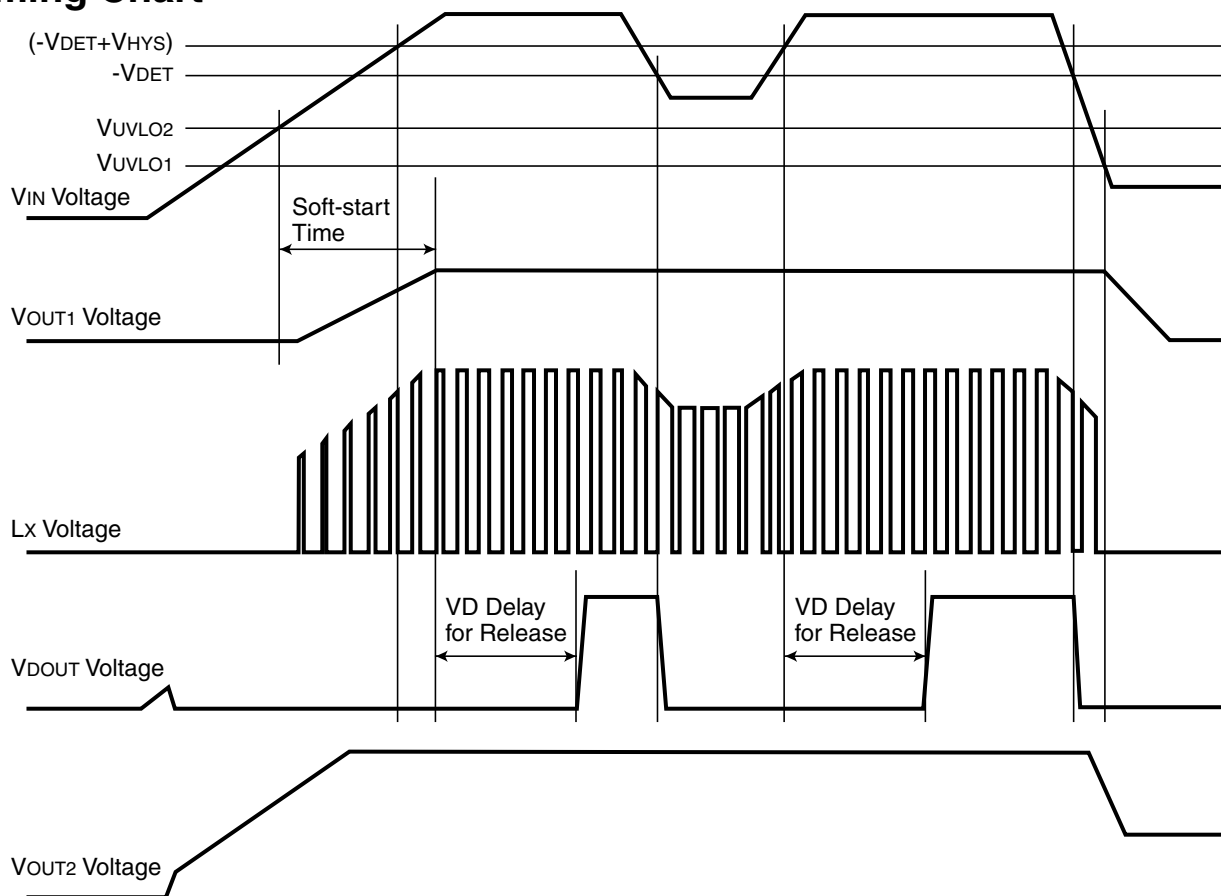
Wherein, peak current that flows through L, Lx Tr., and SD is as follows;

ILmax=IOUT+IRP/2..... 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 release 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

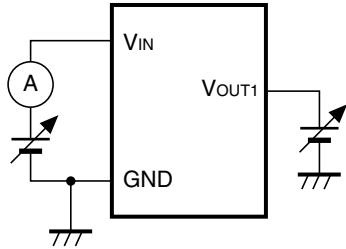
If the V_{IN} voltage is at VD detector threshold level or less, the N-channel transistor of V_{DOUT} pin turns on and outputs "L" to V_{DOUT} pin. Then, when the V_{IN} voltage becomes VD detector threshold level + its hysteresis range ($-V_{DET} + V_{HYS}$) or more, after VD delay for release ($tpLH$) 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

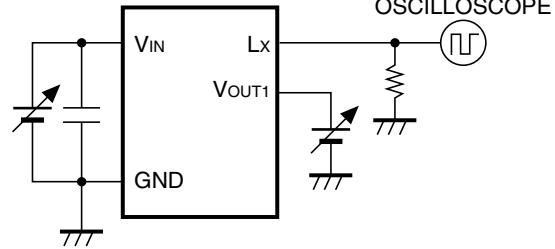
The voltage regulator always operates even if UVLO function would work. Therefore, V_{OUT2} voltage is nearly equal to V_{IN} voltage. Actual value depends on the load current. When the V_{IN} voltage becomes set V_{OUT2} voltage or more, V_{OUT2} voltage will be the set output voltage.

TEST CIRCUITS

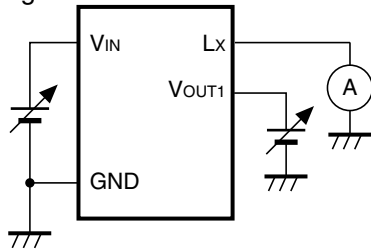
A) Supply Current



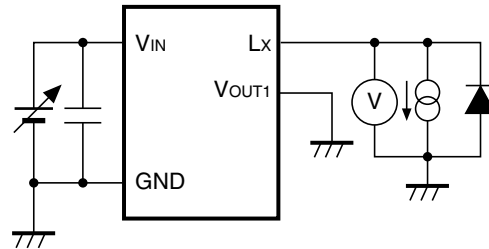
B) UVLO Detector Threshold/ Released Voltage
OSCILLOSCOPE



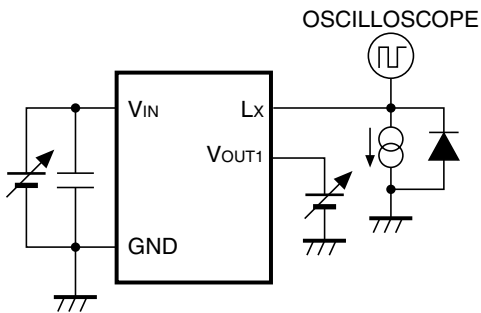
C) Lx Leakage Current



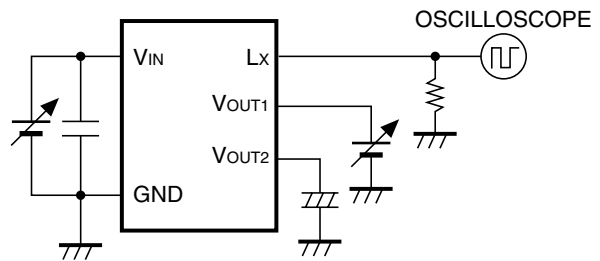
D) Lx On Resistance



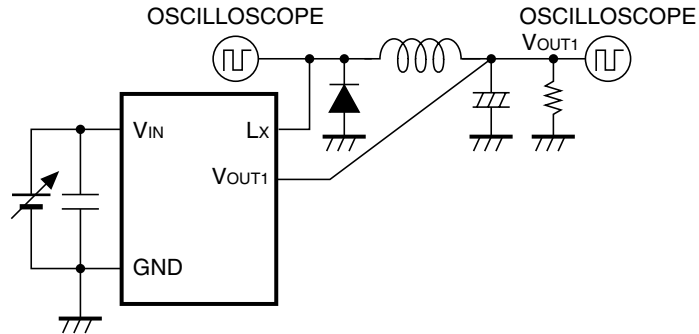
E) Lx Current Limit



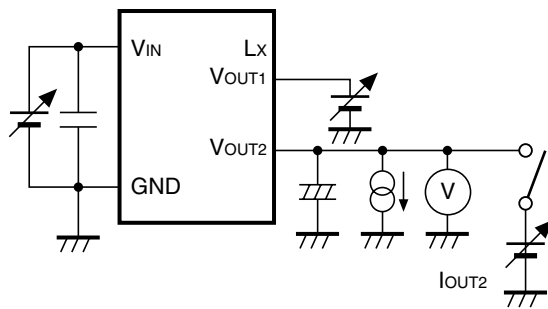
F) V_{OUT1} Output Voltage



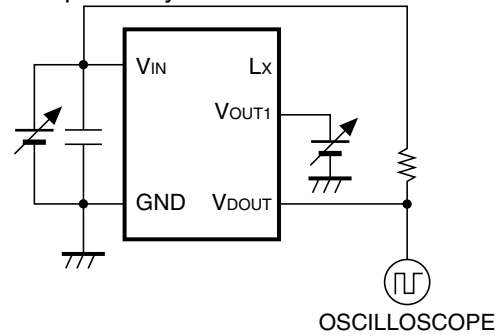
G) Oscillator Frequency, Soft-start Time



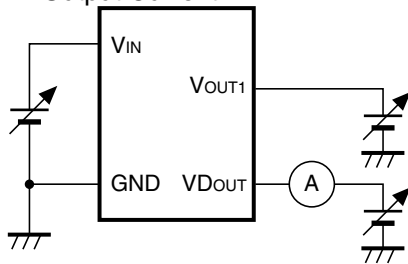
H) V_{OUT2} Output Voltage, Load Regulation, Dropout Voltage, Current Limit, Short Current Limit



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)

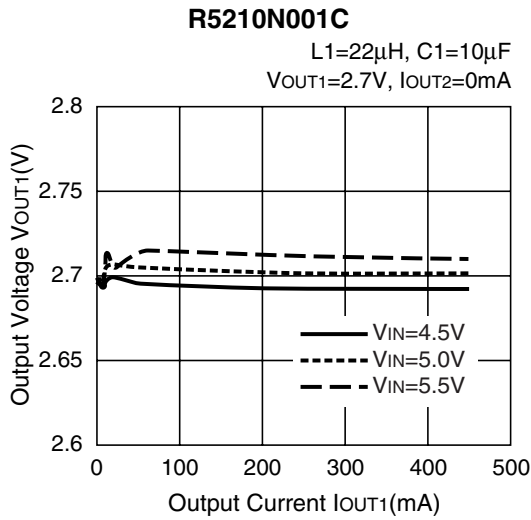
Test Circuit G : Typical Characteristics 6) 7)

Test Circuit H : Typical Characteristics 4) 9) 10)

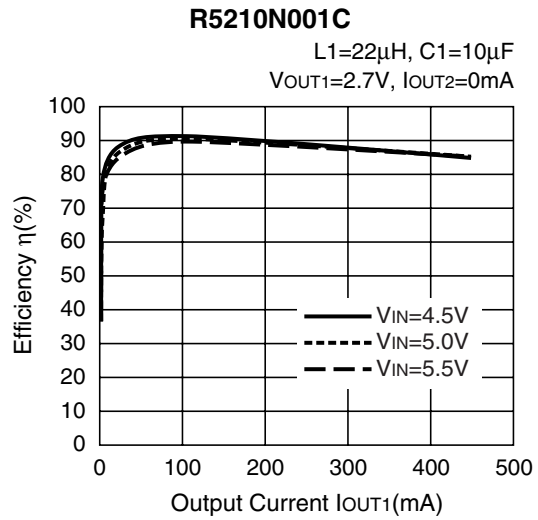
Test Circuit I : Typical Characteristics 5) 8)

TYPICAL CHARACTERISTICS

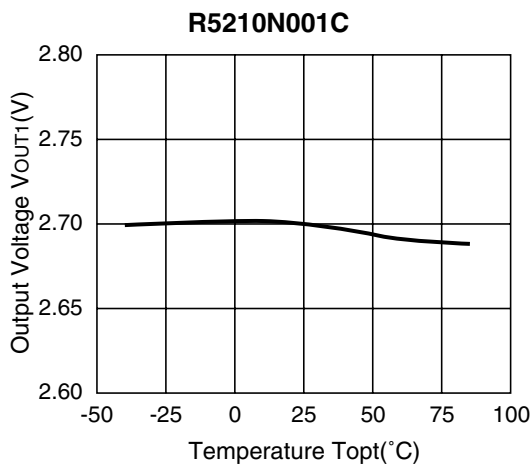
1) Output Voltage vs. Output Current



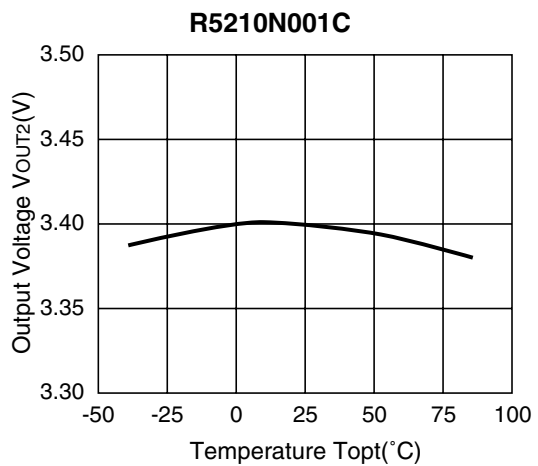
2) Efficiency vs. Output Current



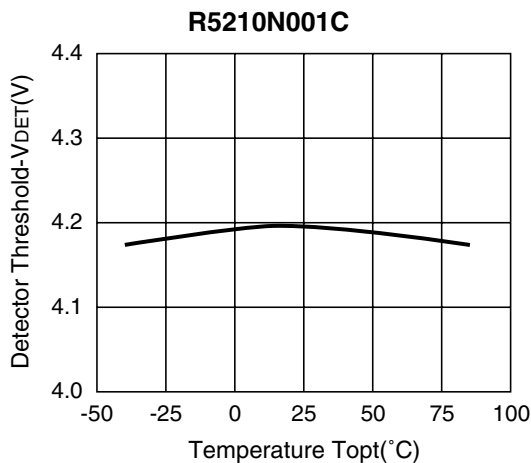
3) DC/DC Output Voltage vs. Temperature



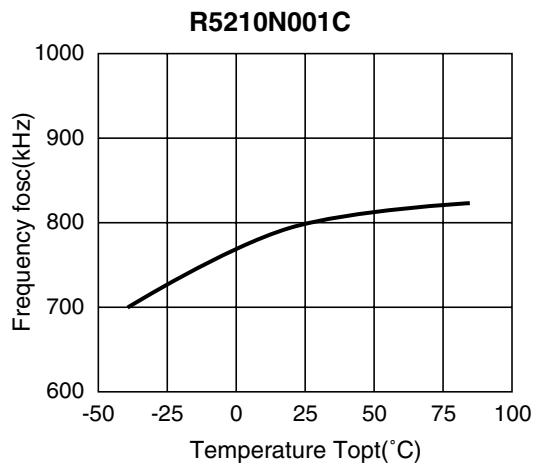
4) VR Output Voltage vs. Temperature



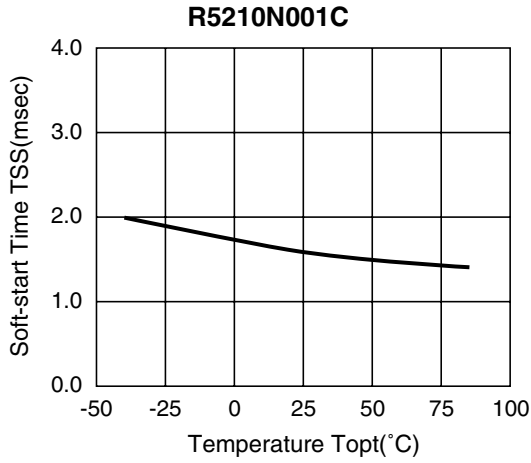
5) Detector Threshold vs. Temperature



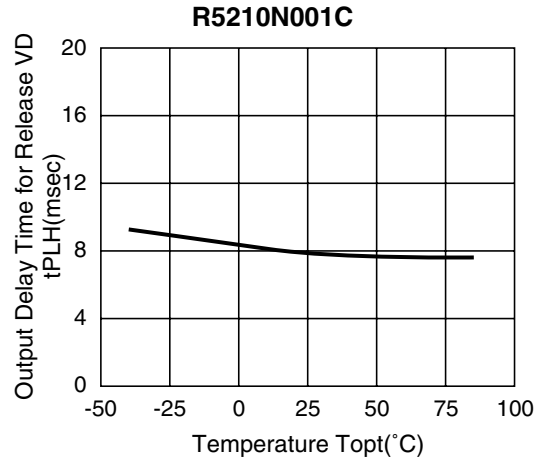
6) Oscillator Frequency vs. Temperature



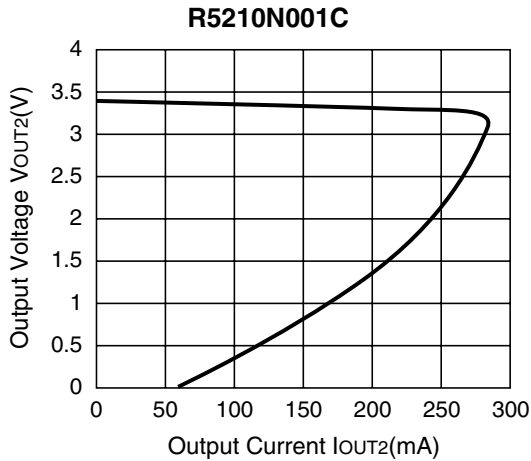
7) Soft-start time vs. Temperature



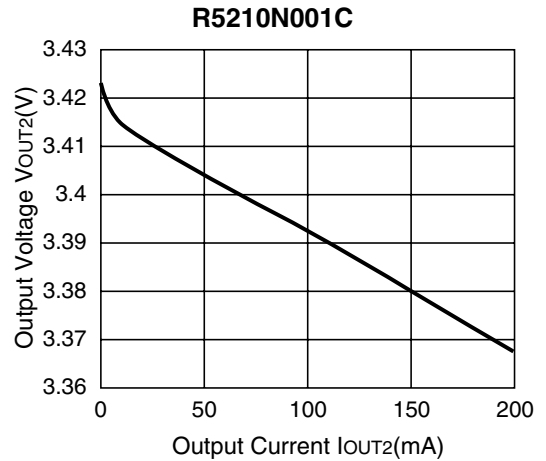
8) Output Delay Time for Release VD vs. Temperature



9) VR Output Voltage vs. Output Current

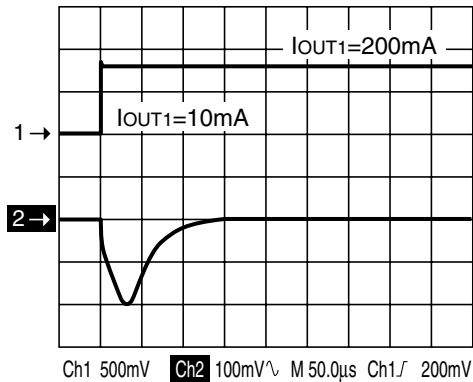


10) VR Output Voltage vs. Output Current (zoomed)



11) Load Transient Response 1

L1=22μH, C1=10μF
VOUT1=2.7V



12) Load Transient Response 2

L1=22μH, C1=10μF
VOUT1=2.7V

