

PWM STEP-UP DC/DC CONTROLLER

NO.EA-088-100617

OUTLINE

The R1211x Series are CMOS-based PWM step-up DC/DC converter controllers with low supply current.

Each of the R1211x Series consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a reference current unit, a protection circuit, and an under voltage lockout (UVLO) circuit. A low ripple, high efficiency step-up DC/DC converter can be composed of this IC with some external components, or an inductor, a diode, a power MOSFET, divider resistors, and capacitors.

Phase compensation has been made internally in the R1211x002B/D Series, while phase compensation can be made externally as for R1211x002A/C Series. B/D version has stand-by mode.

Max duty cycle is internally fixed typically at 90%. Soft start function is built-in, and Soft-starting time is set typically at 9ms(A/B, 700kHz version) or 10.5ms(C/D, 300kHz version). As for the protection circuit, after the soft-starting time, if the maximum duty cycle is continued for a certain period, the R1211x Series latch the external driver with its off state, or Latch-type protection circuit works.

The delay time for latch the state can be set with an external capacitor.

To release the protection circuit, restart with power-on (Voltage supplier is equal or less than UVLO detector threshold level), or once after making the circuit be stand-by with chip enable pin and enable the circuit again.

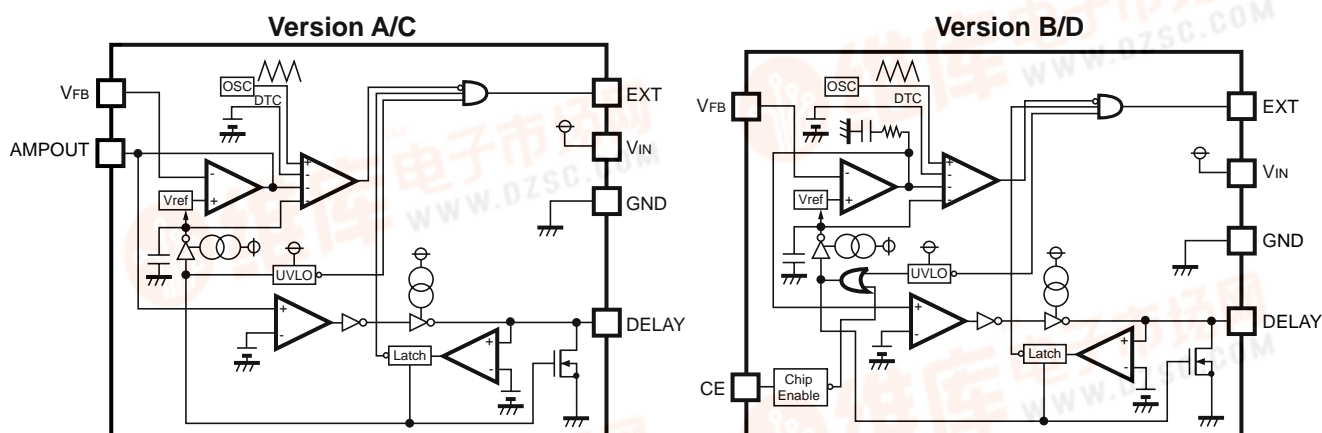
FEATURES

- Input Voltage Range2.5V to 6.0V
- Oscillator Frequency (PWM control)300kHz, 700kHz
- Maximum Duty CycleTyp. 90%
- Standby CurrentTyp. 0 μ A (for B/D version)
- Feedback Voltage1.0V
- Feedback Voltage Accuracy $\pm 1.5\%$
- UVLO Threshold levelTyp. 2.2V (Hysteresis Typ. 0.13V)
- Feedback Voltage Temperature Coefficient $\pm 150\text{ppm}/^\circ\text{C}$
- Built-in Latch-type Protection CircuitProtction Delay Time can be set with an external capacitor
- PackagesSON-6, SOT-23-6W

APPLICATIONS

- Constant Voltage Power Source for portable equipment.
- Constant Voltage Power Source for LCD and CCD.

BLOCK DIAGRAMS



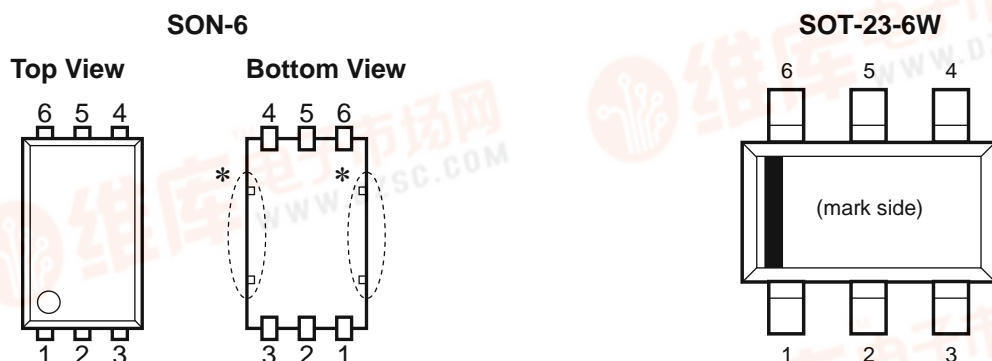
SELECTION GUIDE

In the R1211x Series, the oscillator frequency, the optional function, and the package type for the ICs can be selected at the user's request.

| Product Name | Package | Quantity per Reel | Pb Free | Halogen Free |
|------------------|-----------|-------------------|---------|--------------|
| R1211D002x-TR-FE | SON-6 | 3,000 pcs | Yes | Yes |
| R1211N002x-TR-FE | SOT-23-6W | 3,000 pcs | Yes | Yes |

x : Designation of Oscillator Frequency and Optional Function
 (A) 700kHz, with AMPOUT pin (External Phase Compensation Type)
 (B) 700kHz, with CE pin (Internal Phase Compensation Type, with Stand-by)
 (C) 300kHz, with AMPOUT pin (External Phase Compensation Type)
 (D) 300kHz, with CE pin (Internal Phase Compensation Type, with Stand-by)

PIN CONFIGURATIONS



PIN DESCRIPTIONS

| Symbol | Pin No | | | | Pin Description |
|-----------------|--------------|-----------|--------------|-----------|---|
| | R1211x002A/C | | R1211x002B/D | | |
| | SON-6 | SOT-23-6W | SON-6 | SOT-23-6W | |
| DELAY | 1 | 1 | 1 | 1 | Pin for External Capacitor (for Setting Output Delay Time of Protection) |
| GND | 2 | 5 | 2 | 5 | Ground Pin |
| EXT | 3 | 6 | 3 | 6 | External FET Drive Pin (CMOS Output) |
| V _{IN} | 4 | 4 | 4 | 4 | Power Supply Pin |
| V _{FB} | 5 | 3 | 5 | 3 | Feedback Pin for monitoring Output Voltage |
| AMPOUT | 6 | 2 | - | - | Amplifier Output Pin |
| CE | - | - | 6 | 2 | Chip Enable Pin ("H" Active) |

*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.

ABSOLUTE MAXIMUM RATINGS

| Symbol | Item | Rating | Unit |
|-----------|---------------------------------------|------------------------|--------------------|
| V_{IN} | V_{IN} Pin Voltage | 6.5 | V |
| V_{EXT} | EXT Pin Output Voltage | $-0.3 \sim V_{IN}+0.3$ | V |
| V_{DLY} | DELAY Pin Voltage | $-0.3 \sim V_{IN}+0.3$ | V |
| V_{AMP} | AMPOUT Pin Voltage | $-0.3 \sim V_{IN}+0.3$ | V |
| V_{CE} | CE Pin Input Voltage | $-0.3 \sim V_{IN}+0.3$ | V |
| V_{FB} | V_{FB} Pin Voltage | $-0.3 \sim V_{IN}+0.3$ | V |
| I_{AMP} | AMPOUT Pin Current | ± 10 | mA |
| I_{EXT} | EXT Pin Inductor Drive Output Current | ± 50 | mA |
| P_D | Power Dissipation (SOT-23-6W)* | 430 | |
| | Power Dissipation (SON-6)* | 500 | mW |
| T_{opt} | Operating Temperature Range | $-40 \sim +85$ | $^{\circ}\text{C}$ |
| T_{stg} | Storage Temperature Range | $-55 \sim +125$ | $^{\circ}\text{C}$ |

*) 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.

ELECTRICAL CHARACTERISTICS

• R1211x002A

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|--------------------------------------|---|--|-------|-------|-------|--------|
| V _{IN} | Operating Input Voltage | | 2.5 | | 6.0 | V |
| V _{FB} | Feedback Voltage | V _{IN} =3.3V | 0.985 | 1.000 | 1.015 | V |
| ΔV _{FB} /ΔT _{opt} | V _{FB} Voltage Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±150 | | ppm/°C |
| I _{FB} | V _{FB} Input Current | V _{IN} =6V, V _{FB} =0V or 6V | -0.1 | | 0.1 | μA |
| f _{osc} | Oscillator Frequency | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 595 | 700 | 805 | kHz |
| Δf _{osc} /ΔT _{opt} | Oscillator Frequency Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±1.4 | | kHz/°C |
| I _{DD1} | Supply Current 1 | V _{IN} =6V, V _{DLY} =V _{FB} =0V, EXT at no load | | 600 | 900 | μA |
| maxdty | Maximum Duty Cycle | V _{IN} =3.3V, EXT "H" side | 82 | 90 | 94 | % |
| R _{EXTH} | EXT "H" ON Resistance | V _{IN} =3.3V, I _{EXT} =-20mA | | 5 | 10 | Ω |
| R _{EXTL} | EXT "L" ON Resistance | V _{IN} =3.3V, I _{EXT} =20mA | | 3 | 6 | Ω |
| I _{DLY1} | Delay Pin Charge Current | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 2.5 | 5.0 | 7.5 | μA |
| I _{DLY2} | Delay Pin Discharge Current | V _{IN} =V _{FB} =2.5V, V _{DLY} =0.1V | 2.5 | 5.5 | 9.0 | mA |
| V _{DLY} | Delay Pin Detector Threshold | V _{IN} =3.3V, V _{FB} =0V, V _{DLY} =0V→2V | 0.95 | 1.00 | 1.05 | V |
| T _{START} | Soft-start Time | V _{IN} =3.3V at 90% of rising edge | 4.5 | 9.0 | 13.5 | ms |
| V _{UVLO1} | UVLO Detector Threshold | V _{IN} =3.3V→0V, V _{DLY} =V _{FB} =0V | 2.1 | 2.2 | 2.3 | V |
| V _{UVLO2} | UVLO Detector Hysteresis | V _{IN} =0V→3.3V, V _{DLY} =V _{FB} =0V | 0.08 | 0.13 | 0.18 | V |
| I _{AMP1} | AMP "H" Output Current | V _{IN} =3.3V, V _{AMP} =1V, V _{FB} =0.9V | 0.45 | 0.90 | 1.50 | mA |
| I _{AMP2} | AMP "L" Output Current | V _{IN} =3.3V, V _{AMP} =1V, V _{FB} =1.1V | 30 | 60 | 90 | μA |

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.

R1211x

• R1211x002B

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|--------------------------------------|---|--|-------|-------|-------|--------|
| V _{IN} | Operating Input Voltage | | 2.5 | | 6.0 | V |
| V _{FB} | Feedback Voltage | V _{IN} =3.3V | 0.985 | 1.000 | 1.015 | V |
| ΔV _{FB} /ΔT _{opt} | V _{FB} Voltage Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±150 | | ppm/°C |
| I _{FB} | VFB Input Current | V _{IN} =6V, V _{FB} =0V or 6V | -0.1 | | 0.1 | μA |
| f _{OSC} | Oscillator Frequency | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 595 | 700 | 805 | kHz |
| Δf _{OSC} /ΔT _{opt} | Oscillator Frequency Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±1.4 | | kHz/°C |
| I _{DD1} | Supply Current 1 | V _{IN} =6V, V _{DLY} =V _{FB} =0V, EXT at no load | | 600 | 900 | μA |
| maxdty | Maximum Duty Cycle | V _{IN} =3.3V, EXT "H" side | 82 | 90 | 94 | % |
| R _{EXTH} | EXT "H" ON Resistance | V _{IN} =3.3V, I _{EXT} =-20mA | | 5 | 10 | Ω |
| R _{EXTL} | EXT "L" ON Resistance | V _{IN} =3.3V, I _{EXT} =20mA | | 3 | 6 | Ω |
| I _{DLY1} | Delay Pin Charge Current | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 2.5 | 5.0 | 7.5 | μA |
| I _{DLY2} | Delay Pin Discharge Current | V _{IN} =V _{FB} =2.5V, V _{DLY} =0.1V | 2.5 | 5.5 | 9.0 | mA |
| V _{DLY} | Delay Pin Detector Threshold | V _{IN} =3.3V, V _{FB} =0V, V _{DLY} =0V→2V | 0.95 | 1.00 | 1.05 | V |
| T _{START} | Soft-start Time | V _{IN} =3.3V | 4.5 | 9.0 | 13.5 | ms |
| V _{UVLO1} | UVLO Detector Threshold | V _{IN} =3.3V→0V, V _{DLY} =V _{FB} =0V | 2.1 | 2.2 | 2.3 | V |
| V _{UVLO2} | UVLO Detector Hysteresis | V _{IN} =0V→3.3V, V _{DLY} =V _{FB} =0V | 0.08 | 0.13 | 0.18 | V |
| I _{STB} | Standby Current | V _{IN} =6V, V _{CE} =0V | | 0 | 1 | μA |
| I _{CEH} | CE "H" Input Current | V _{IN} =6V, V _{CE} =6V | -0.5 | | 0.5 | μA |
| I _{CEL} | CE "L" Input Current | V _{IN} =6V, V _{CE} =0V | -0.5 | | 0.5 | μA |
| V _{CEH} | CE "H" Input Voltage | V _{IN} =6V, V _{CE} =0V→6V | 1.5 | | | V |
| V _{CEL} | CE "L" Input Voltage | V _{IN} =2.5V, V _{CE} =2V→0V | | | 0.3 | V |

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

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• R1211x002C

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---------------------------------|---|--|-------|-------|-------|--------|
| V _{IN} | Operating Input Voltage | | 2.5 | | 6.0 | V |
| V _{FB} | V _{FB} Voltage Tolerance | V _{IN} =3.3V | 0.985 | 1.000 | 1.015 | V |
| $\Delta V_{FB}/\Delta T_{opt}$ | V _{FB} Voltage Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±150 | | ppm/°C |
| I _{FB} | V _{FB} Input Current | V _{IN} =6V, V _{FB} =0V or 6V | -0.1 | | 0.1 | μA |
| f _{osc} | Oscillator Frequency | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 240 | 300 | 360 | kHz |
| $\Delta f_{osc}/\Delta T_{opt}$ | Oscillator Frequency Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±0.6 | | kHz/°C |
| I _{DD1} | Supply Current 1 | V _{IN} =6V, V _{DLY} =V _{FB} =0V, EXT at no load | | 300 | 500 | μA |
| maxdty | Maximum Duty Cycle | V _{IN} =3.3V, EXT "H" side | 82 | 90 | 94 | % |
| R _{EXTH} | EXT "H" ON Resistance | V _{IN} =3.3V, I _{EXT} =-20mA | | 5 | 10 | Ω |
| R _{EXTL} | EXT "L" ON Resistance | V _{IN} =3.3V, I _{EXT} =20mA | | 3 | 6 | Ω |
| I _{DLY1} | Delay Pin Charge Current | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 2.0 | 4.5 | 7.0 | μA |
| I _{DLY2} | Delay Pin Discharge Current | V _{IN} =V _{FB} =2.5V, V _{DLY} =0.1V | 2.5 | 5.5 | 9.0 | mA |
| V _{DLY} | Delay Pin Detector Threshold | V _{IN} =3.3V, V _{FB} =0V, V _{DLY} =0V→2V | 0.95 | 1.00 | 1.05 | V |
| T _{START} | Soft-start Time | V _{IN} =3.3V | 5.0 | 10.5 | 16.0 | ms |
| V _{UVLO1} | UVLO Detector Threshold | V _{IN} =3.3V→0V, V _{DLY} =V _{FB} =0V | 2.1 | 2.2 | 2.3 | V |
| V _{UVLO2} | UVLO Detector Hysteresis | V _{IN} =0V→3.3V, V _{DLY} =V _{FB} =0V | 0.08 | 0.13 | 0.18 | V |
| I _{AMP1} | AMP "H" Output Current | V _{IN} =3.3V, V _{AMP} =1V, V _{FB} =0.9V | 0.45 | 0.90 | 1.50 | mA |
| I _{AMP2} | AMP "L" Output Current | V _{IN} =3.3V, V _{AMP} =1V, V _{FB} =1.1V | 25 | 50 | 75 | μA |

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.

R1211x

• R1211x002D

T_{opt}=25°C

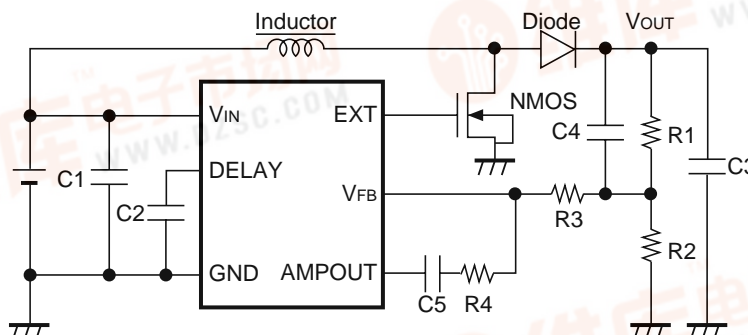
| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---------------------------------|---|--|-------|-------|-------|--------|
| V _{IN} | Operating Input Voltage | | 2.5 | | 6.0 | V |
| V _{FB} | V _{FB} Voltage Tolerance | V _{IN} =3.3V | 0.985 | 1.000 | 1.015 | V |
| $\Delta V_{FB}/\Delta T_{opt}$ | V _{FB} Voltage Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±150 | | ppm/°C |
| I _{FB} | V _{FB} Input Current | V _{IN} =6V, V _{FB} =0V or 6V | -0.1 | | 0.1 | μA |
| f _{OSC} | Oscillator Frequency | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 240 | 300 | 360 | kHz |
| $\Delta f_{OSC}/\Delta T_{opt}$ | Oscillator Frequency Temperature Coefficient | -40°C ≤ T _{opt} ≤ 85°C | | ±0.6 | | kHz/°C |
| I _{DD1} | Supply Current 1 | V _{IN} =6V, V _{DLY} =V _{FB} =0V, EXT at no load | | 300 | 500 | μA |
| maxdty | Maximum Duty Cycle | V _{IN} =3.3V, EXT "H" side | 82 | 90 | 94 | % |
| R _{EXTH} | EXT "H" ON Resistance | V _{IN} =3.3V, I _{EXT} =-20mA | | 5 | 10 | Ω |
| R _{EXTL} | EXT "L" ON Resistance | V _{IN} =3.3V, I _{EXT} =20mA | | 3 | 6 | Ω |
| I _{DLY1} | Delay Pin Charge Current | V _{IN} =3.3V, V _{DLY} =V _{FB} =0V | 2.0 | 4.5 | 7.0 | μA |
| I _{DLY2} | Delay Pin Discharge Current | V _{IN} =V _{FB} =2.5V, V _{DLY} =0.1V | 2.5 | 5.5 | 9.0 | mA |
| V _{DLY} | Delay Pin Detector Threshold | V _{IN} =3.3V, V _{FB} =0V, V _{DLY} =0V→2V | 0.95 | 1.00 | 1.05 | V |
| T _{START} | Soft-start Time | V _{IN} =3.3V | 5.0 | 10.5 | 16.0 | ms |
| V _{UVLO1} | UVLO Detector Threshold | V _{IN} =3.3V→0V, V _{DLY} =V _{FB} =0V | 2.1 | 2.2 | 2.3 | V |
| V _{UVLO2} | UVLO Detector Hysteresis | V _{IN} =0V→3.3V, V _{DLY} =V _{FB} =0V | 0.08 | 0.13 | 0.18 | V |
| I _{STB} | Standby Current | V _{IN} =6V, V _{CE} =0V | | 0 | 1 | μA |
| I _{CEH} | CE "H" Input Current | V _{IN} =6V, V _{CE} =6V | -0.5 | | 0.5 | μA |
| I _{CEL} | CE "L" Input Current | V _{IN} =6V, V _{CE} =0V | -0.5 | | 0.5 | μA |
| V _{CEH} | CE "H" Input Voltage | V _{IN} =6V, V _{CE} =0V→6V | 1.5 | | | V |
| V _{CEL} | CE "L" Input Voltage | V _{IN} =2.5V, V _{CE} =2V→0V | | | 0.3 | V |

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

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TYPICAL APPLICATIONS AND TECHNICAL NOTES

<R1211x002A/R1211x002C>



NMOS : IRF7601 (International Rectifier)

Inductor : LDR655312T-100 10 μ H (TDK) for R1211x002A

: LDR655312T-220 22 μ H (TDK) for R1211x002C

Diode : CRS02 (Toshiba)

C1 : 4.7 μ F (Ceramic)

C2 : 0.22 μ F (Ceramic)

C3 : 10 μ F (Ceramic)

C4 : 680pF (Ceramic)

C5 : 2200pF (Ceramic)

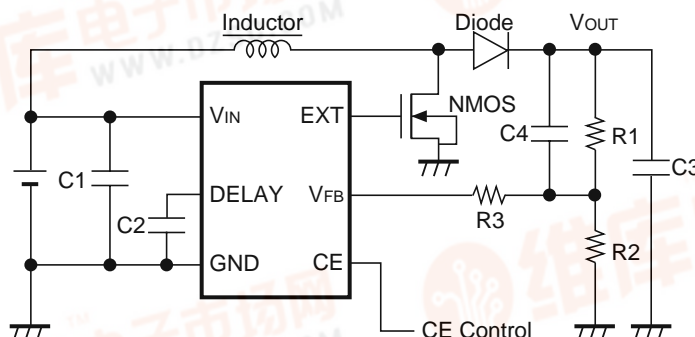
R1 : Output Voltage Setting Resistor 1

R2 : Output Voltage Setting Resistor 2

R3 : 30k Ω

R4 : 30k Ω

<R1211x002B/R1211x002D>



NMOS : IRF7601 (International Rectifier)

Inductor : LDR655312T-100 10 μ H (TDK) for R1211x002B

: LDR655312T-220 22 μ H (TDK) for R1211x002D

Diode : CRS02 (Toshiba)

C1 : 4.7 μ F (Ceramic)

C2 : 0.22 μ F (Ceramic)

C3 : 10 μ F (Ceramic)

C4 : 680pF (Ceramic)

R1 : Setting Output Voltage Resistor 1

R2 : Setting Output Voltage Resistor 2

R3 : 30k Ω

[Note]

These example circuits may be applied to the output voltage requirement is 15V or less. If the output voltage requirement is 15V or more, ratings of NMOS and diode as shown above is over the limit, therefore, choose other external components.

Use a 1μF or more capacitance value of bypass capacitor between V_{IN} pin and GND, C1 as shown in the typical applications above.

- In terms of the capacitor for setting delay time of the latch protection, C2 as shown in typical applications of the previous page, connect between Delay pin and GND pin of the IC with the minimum wiring distance.
- Connect a 1μF or more value of capacitor between V_{OUT} and GND, C3 as shown in typical applications of the previous page. (Recommended value is from 10μF to 22μF.) If the operation of the composed DC/DC converter may be unstable, use a tantalum type capacitor instead of ceramic type.
- Connect a capacitor between V_{OUT} and the dividing point, C4 as shown in typical applications of the previous page. The capacitance value of C4 depends on divider resistors for output voltage setting. Typical value is between 100pF and 1000pF.

- Output Voltage can be set with divider resistors for voltage setting, R1 and R2 as shown in typical applications of the previous page. Refer to the next formula.

$$\text{Output Voltage} = V_{FB} \times (R1+R2)/R2$$

R1+R2=100kΩ is recommended range of resistances.

- The operation of Latch protection circuit is as follows: When the IC detects maximum duty cycle, charge to an external capacitor, C2 of DELAY pin starts. And maximum duty cycle continues and the voltage of DELAY pin reaches delay voltage detector threshold, V_{DLY}, outputs "L" to EXT pin and turns off the external power MOSFET.

To release the latch protection operation, make the IC be standby mode with CE pin and make it active in terms of B/D version. Otherwise, restart with power on.

The delay time of latch protection can be calculated with C2, V_{DLY}, and Delay Pin Charge Current, I_{DLY1}, as in the next formula.

$$t = C2 \times V_{DLY} / I_{DLY1}$$

Once after the maximum duty is detected and released before delay time, charge to the capacitor is halt and delay pin outputs "L".

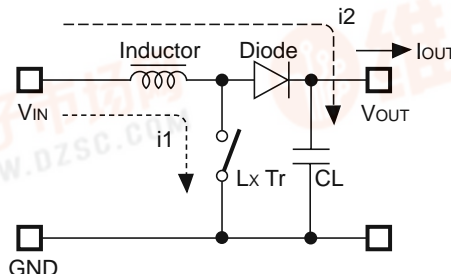
- As for R1211x002A/C version, the values and positioning of C4, C5, R3, and R4 shown in the above diagram are just an example combination. These are for making phase compensation. If the spike noise of V_{OUT} may be large, the spike noise may be picked into V_{FB} pin and make the operation unstable. In this case, a resistor R3, shown in typical applications of the previous page. The recommended resistance value of R3 is in the range from 10kΩ to 50kΩ. Then, noise level will be decreased.

- As for R1211x002B/D version, EXT pin outputs GND level at standby mode.
- Select the Power MOSFET, the diode, and the inductor within ratings (Voltage, Current, Power) of this IC. Choose the power MOSFET with low threshold voltage depending on Input Voltage to be able to turn on the FET completely. Choose the diode with low V_F such as Schottky type with low reverse current I_R, and with fast switching speed. When an external transistor is switching, spike voltage may be generated caused by an inductor, therefore recommended voltage tolerance of capacitor connected to V_{OUT} is three times of setting voltage or more.

* The performance of power circuit with using this IC depends on external components. Choose the most suitable components for your application.

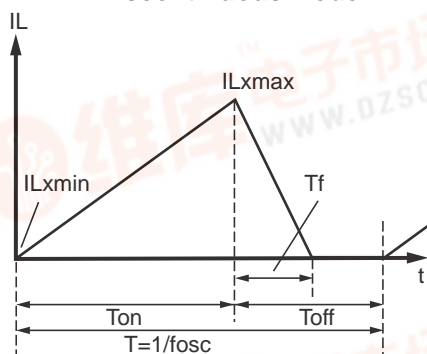
Output Current and Selection of External Components

<Basic Circuit>

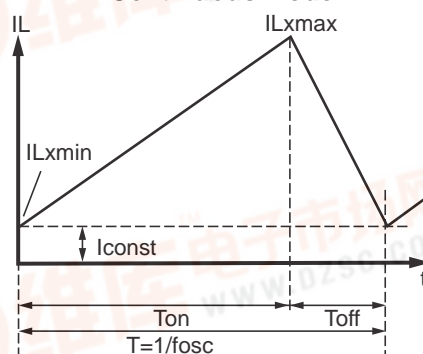


<Circuit through L>

Discontinuous Mode



Continuous Mode



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.

$$P_{ON} = \int_0^{T_{on}} V_{IN}^2 \times t / L \, dt \dots\dots\dots \text{Formula 1}$$

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.

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

In this formula, T_f 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.

$$P_{AV} = 1 / (T_{ON} + T_{OFF}) \times \left\{ \int_0^{T_{on}} V_{IN}^2 \times t / L \, dt + \int_0^{T_f} V_{IN} \times (V_{OUT} - V_{IN}) \times t / L \, dt \right\} \dots\dots\dots \text{Formula 3}$$

In PWM control, when $T_f = T_{off}$ 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.

$$V_{IN} \times T_{ON} / L = (V_{OUT} - V_{IN}) \times T_{OFF} / L \dots\dots\dots \text{Formula 4}$$

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

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

When I_{OUT} becomes more than formula 5, the current flows through the inductor, then the mode becomes continuous. The continuous current through the inductor is described as I_{CONST} , then,

$$I_{OUT} = f_{OSC} \times V_{IN}^2 \times T_{ON}^2 / \{2 \times L \times (V_{OUT} - V_{IN})\} + V_{IN} \times I_{CONST} / V_{OUT} \dots\dots\dots \text{Formula 6}$$

In this moment, the peak current, I_{LXMAX} flowing through the inductor and the driver Tr , is described as follows:

$$I_{LXMAX} = I_{CONST} + V_{IN} \times T_{ON} / L \dots\dots\dots \text{Formula 7}$$

With the formula 4,6, and I_{LXMAX} is,

$$I_{LXMAX} = V_{OUT} / V_{IN} \times I_{OUT} + V_{IN} \times T_{ON} / (2 \times L) \dots\dots\dots \text{Formula 8}$$

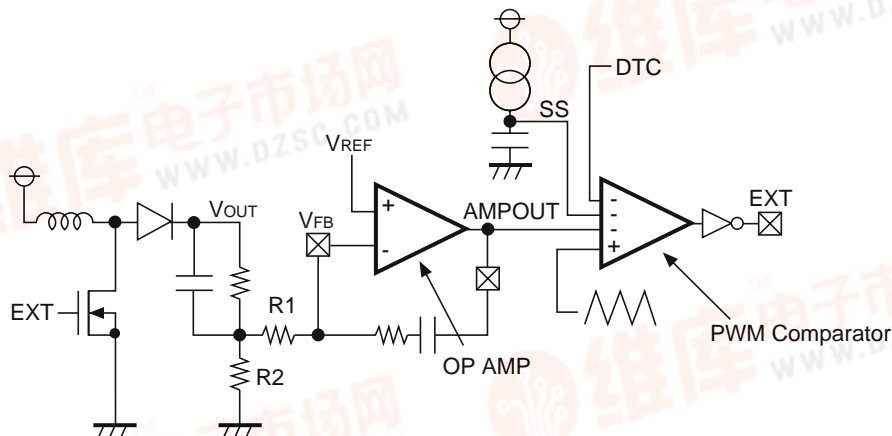
Therefore, peak current is more than I_{OUT} . Considering the value of I_{LXMAX} , the condition of input and output, and external components should be selected.

In the formula 7, peak current I_{LXMAX} at discontinuous mode can be calculated. Put $I_{CONST}=0$ in the formula.

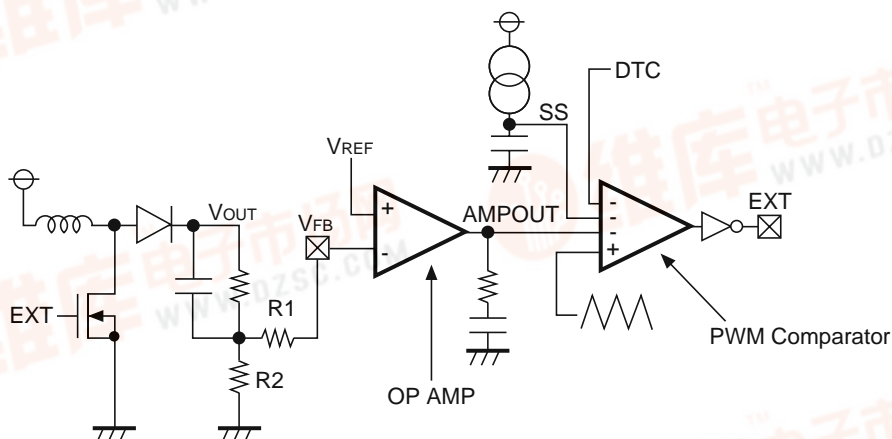
The explanation above is based on the ideal calculation, and the loss caused by Lx switch and external components is not included. The actual maximum output current is between 50% and 80% of the calculation. Especially, when the I_{LX} is large, or V_{IN} is low, the loss of V_{IN} is generated with the on resistance of the switch. As for V_{OUT} , V_f (as much as 0.3V) of the diode should be considered.

TIMING CHART

• R1211x002A/R1211x002C



• R1211x002B/R1211x002D



<Soft-start Operation>

Soft-start operation is starting from power-on as follows:

(Step1)

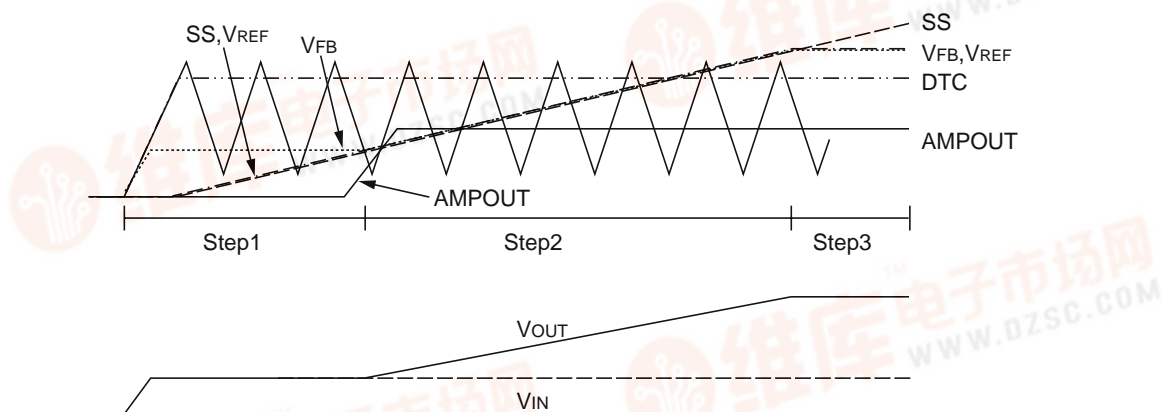
The voltage level of SS is rising gradually by constant current circuit of the IC and a capacitor. V_{REF} level which is input to OP AMP is also gradually rising. V_{OUT} is rising up to input voltage level just after the power-on, therefore, V_{FB} voltage is rising up to the setting voltage with input voltage and the ration of R1 and R2. AMPOUT is at "L", and switching does not start.

(Step2)

When the voltage level of SS becomes the setting voltage with the ration of R1 and R2 or more, switching operation starts. V_{REF} level gradually increases together with SS level. V_{OUT} is also rising with balancing V_{REF} and V_{FB} . Duty cycle depends on the lowest level among AMPOUT, SS, and DTC of the 4 input terminals in the PWM comparator.

(Step3)

When SS reaches 1V, soft-start operation finishes. V_{REF} becomes constant voltage ($=1V$). Then the switching operation becomes normal mode.



<Latch Protection Operation>

The operation of Latch protection circuit is as follows: When AMPOUT becomes "H" and the IC detects maximum duty cycle, charge to an external capacitor, C2 of DELAY pin starts. And maximum duty cycle continues and the voltage of DELAY pin reaches delay voltage detector threshold, V_{DLY} , outputs "L" to EXT pin and turns off the external power MOSFET.

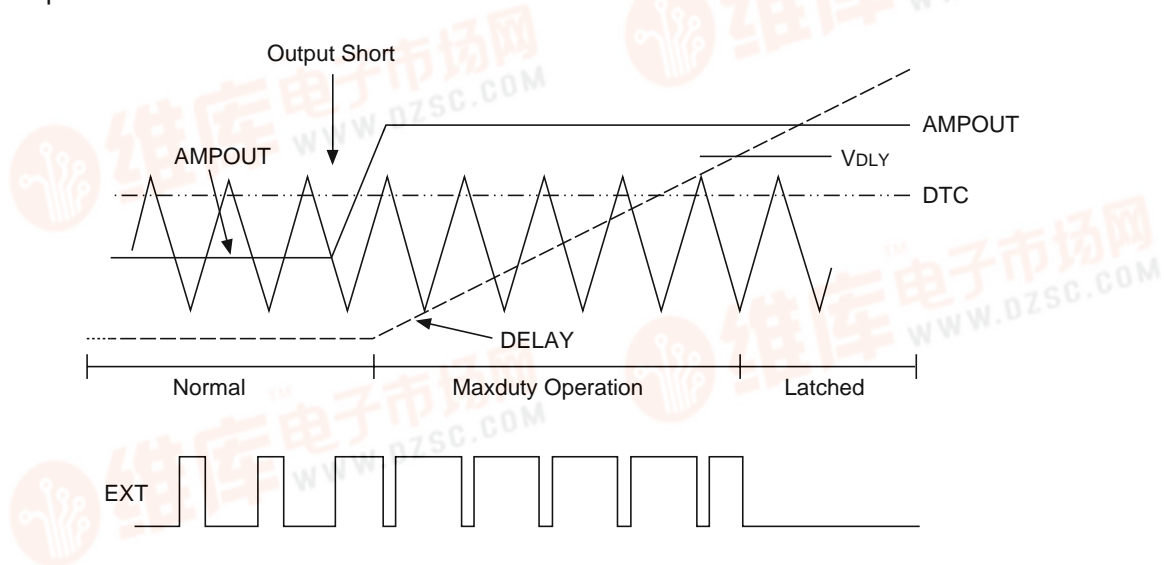
To release the latch protection operation, make the IC be standby mode with CE pin and make it active in terms of R1211x002B/D version. Otherwise, make supply voltage down to UVLO detector threshold or lower, and make it rise up to the normal input voltage.

During the soft-start time, if the duty cycle may be the maximum, protection circuit does not work and DELAY pin is fixed at GND level.

The delay time of latch protection can be calculated with C2, V_{DLY} , and Delay Pin Charge Current, I_{DLY1} , as in the next formula.

$$t = C2 \times V_{DLY} / I_{DLY1}$$

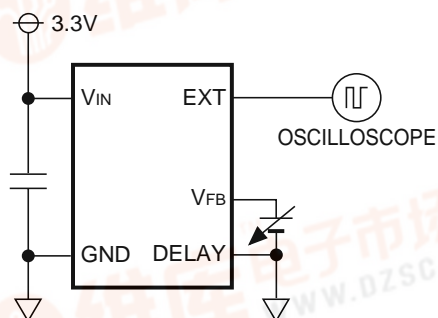
Once after the maximum duty is detected and released before delay time, charge to the capacitor is halt and delay pin outputs "L".



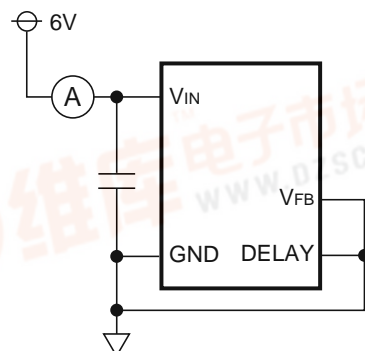
TEST CIRCUITS

• R1211x002A/R1211x002C

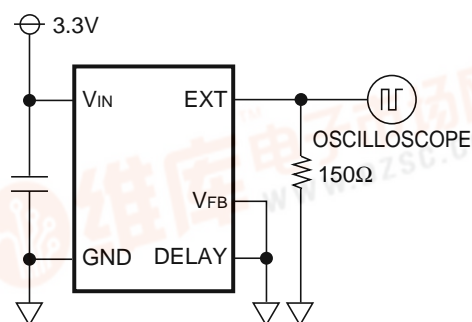
*Oscillator Frequency, Maximum Duty Cycle, V_{FB} Voltage Test



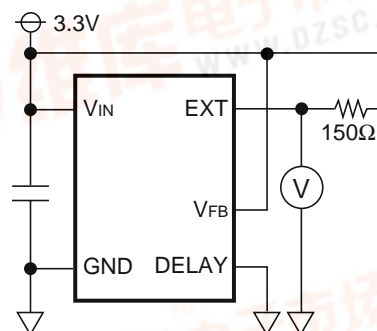
*Consumption Current Test



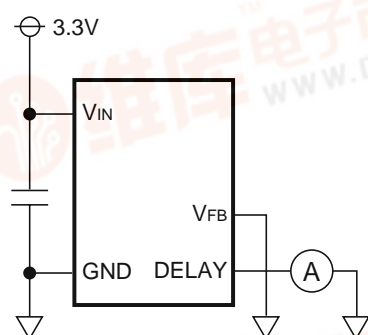
*EXT "H" ON Resistance



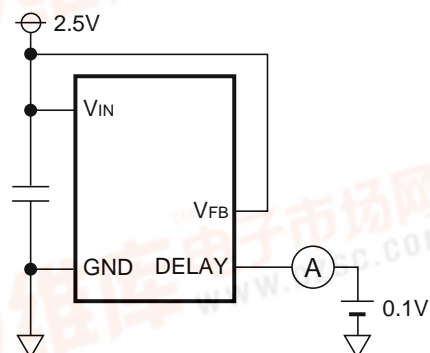
*EXT "L" ON Resistance



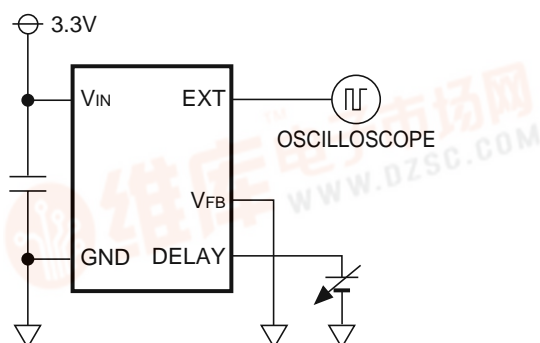
*DELAY Pin Charge Current



*DELAY Pin Discharge Current

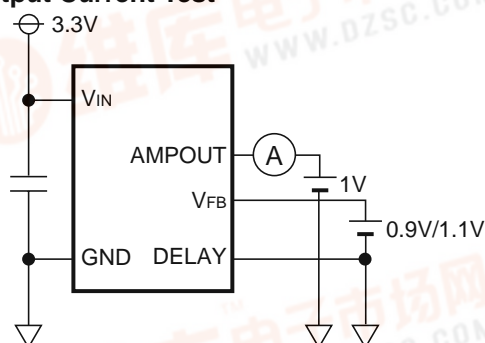


***DELAY Pin Detector Threshold Voltage Test**

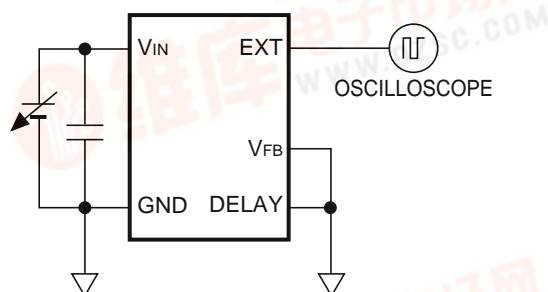


***AMP "H" Output Current/"L"**

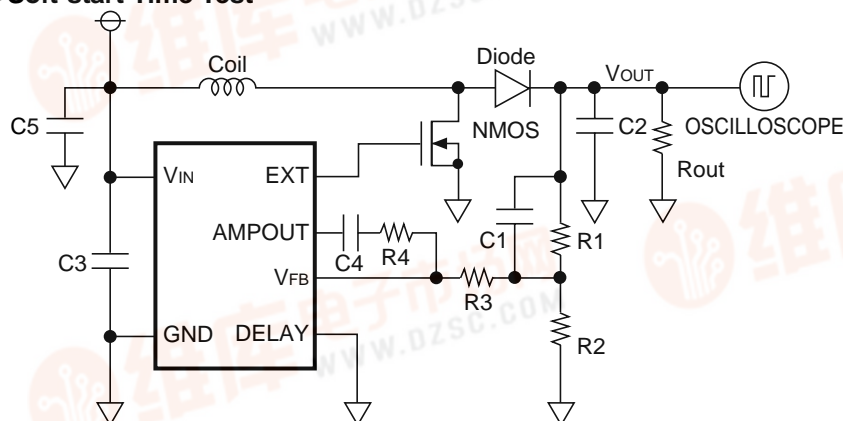
Output Current Test



***UVLO Detector Threshold/Hysteresis Range Test**



***Soft-start Time Test**

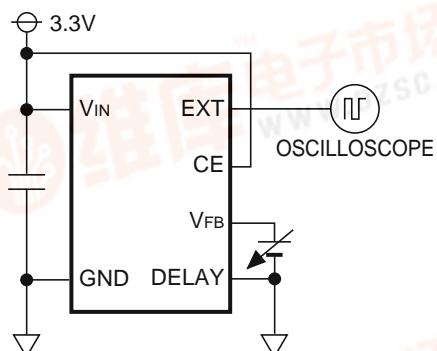


<Components>

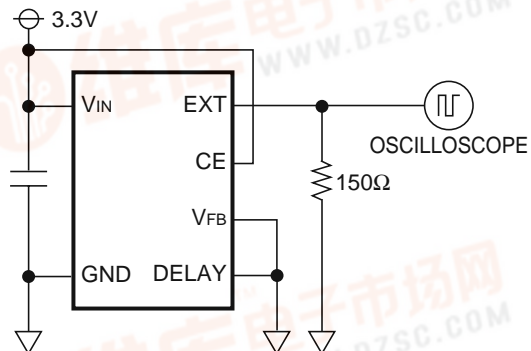
| | |
|-----------------|---|
| Inductor (L) | : 22μH (TDK LDR655312T-220) |
| Diode (SD) | : CRS02 (Toshiba) |
| Capacitors | C1:680pF(Ceramic), C2:22μF (Tantalum)+2.2μF (Ceramic), C3:68μF (Tantalum)+2.2μF (Ceramic), C4:2200pF(Ceramic), C5:22μF(Tantalum) |
| NMOS Transistor | : IRF7601 (International Rectifier) |
| Resistors | : R1: 90kΩ, R2:10kΩ, R3:30kΩ, R4:30kΩ, Rout:1kΩ/330Ω |

• R1211x002B/R1211x002D

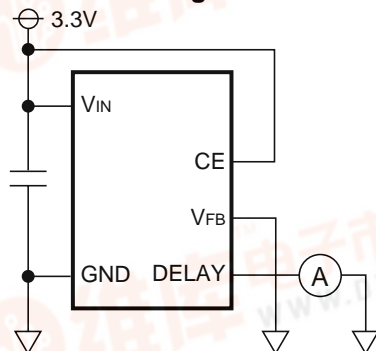
***Oscillator Frequency,
Maximum Duty Cycle, V_{FB} Voltage Test**



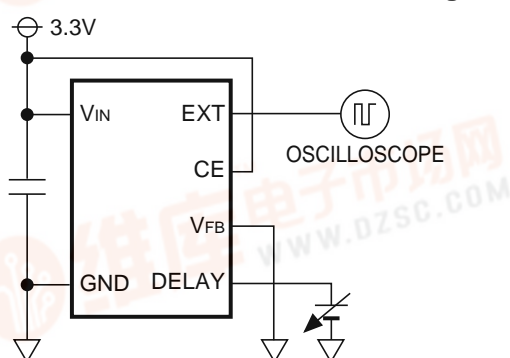
***EXT "H" ON Resistance**



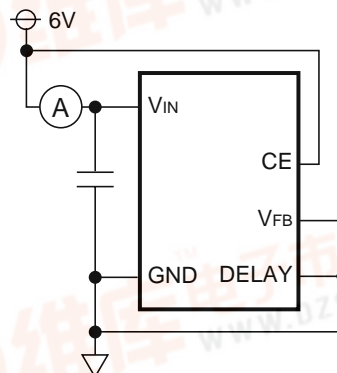
***DELAY Pin Charge Current**



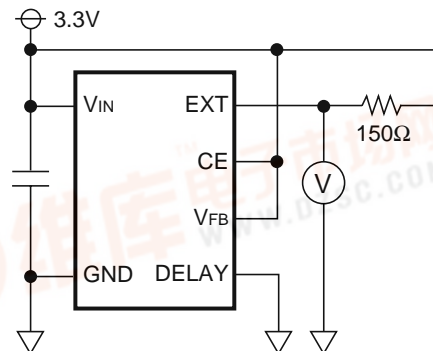
***DELAY Pin Detector Threshold Voltage Test**



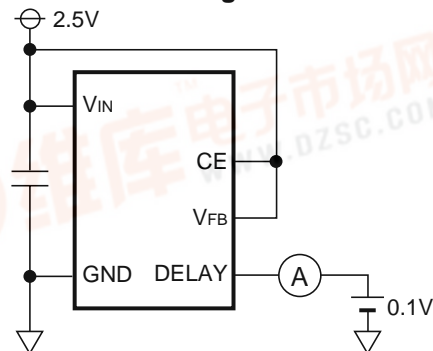
***Consumption Current Test**



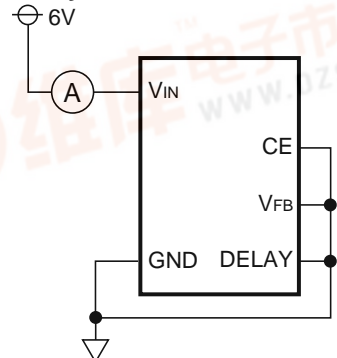
***EXT "L" ON Resistance**



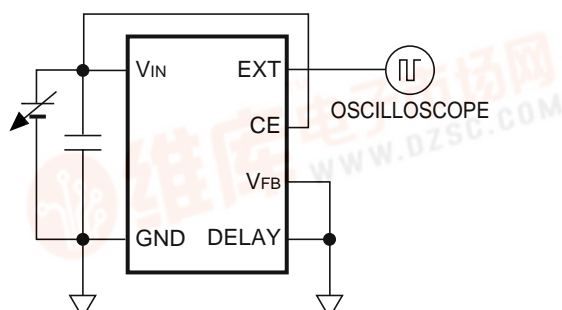
***DELAY Pin Discharge Current**



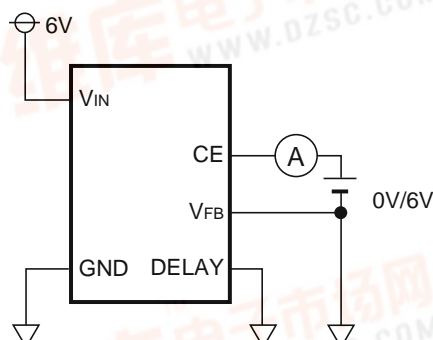
***Standby Current Test**



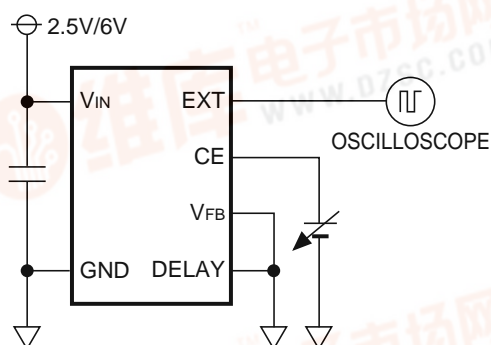
***UVLO Detector Threshold/
Hysteresis Range Test**



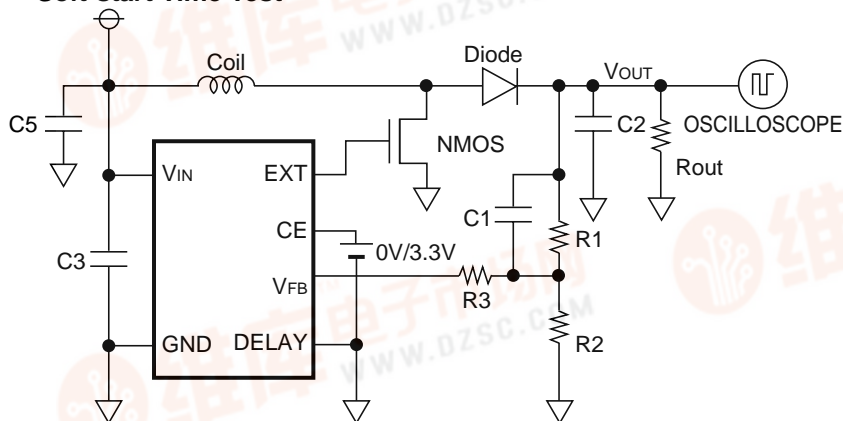
*** CE "L" Input Current/"H" Input Current Test**



***CE "L" Input Voltage/"H" Input Voltage Test**



***Soft-start Time Test**



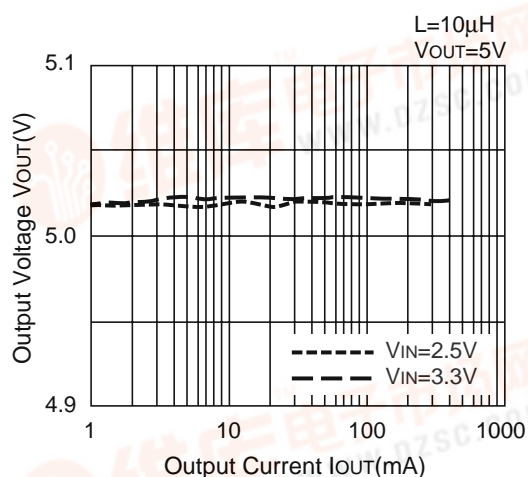
<Components>

- Inductor (L) : 22 μ H (TDK LDR655312T-220)
- Diode (SD) : CRS02 (Toshiba)
- Capacitors : C1 : 680pF (Ceramic), C2: 22 μ F (Tantalum)+2.2 μ F (Ceramic),
C3 : 68 μ F (Tantalum)+2.2 μ F (Ceramic), C5: 22 μ F (Tantalum)
- NMOS Transistor : IRF7601 (International Rectifier)
- Resistors : R1: 90k Ω , R2: 10k Ω , R3: 30k Ω

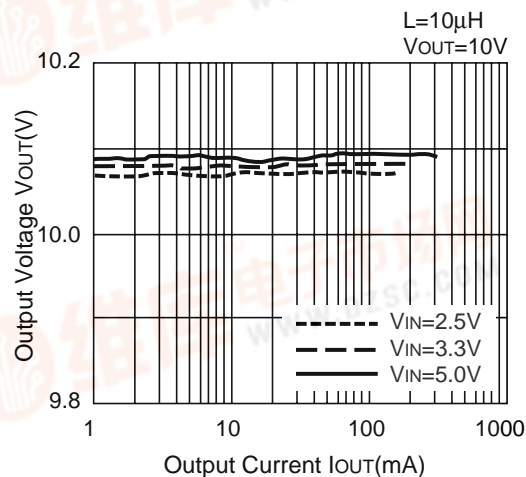
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

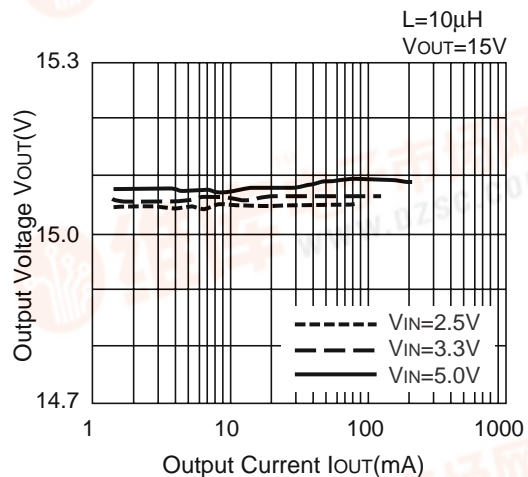
R1211x002A



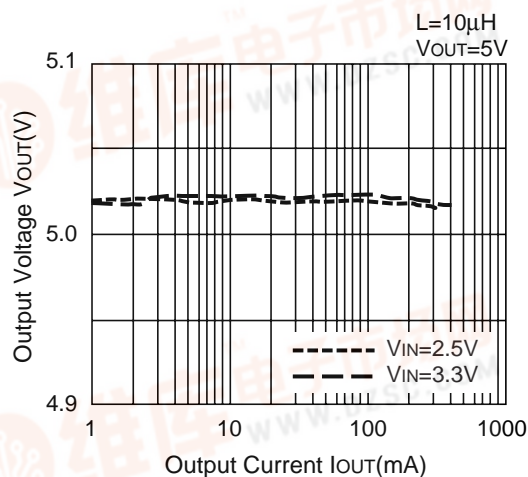
R1211x002A



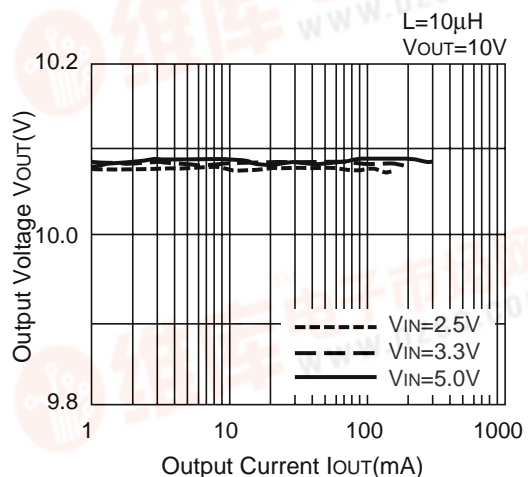
R1211x002A



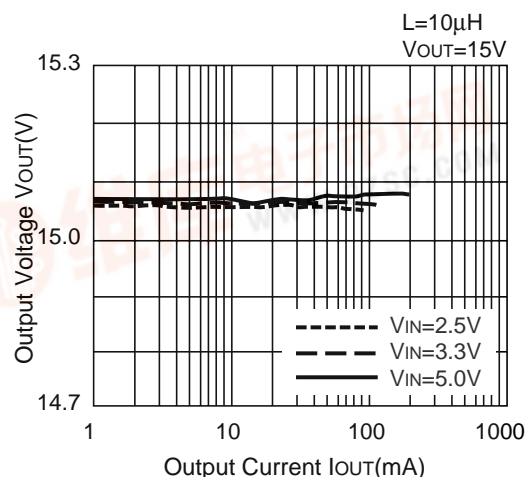
R1211x002B

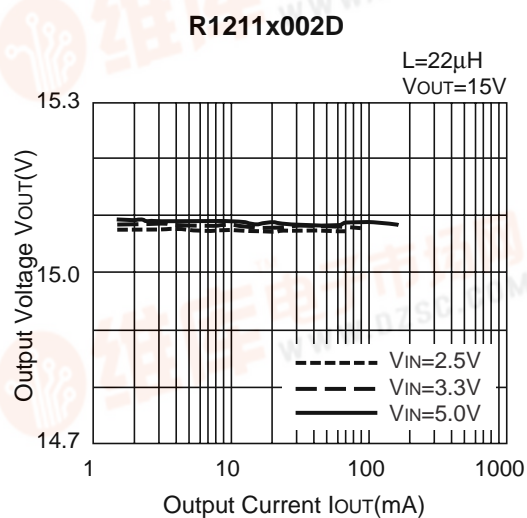
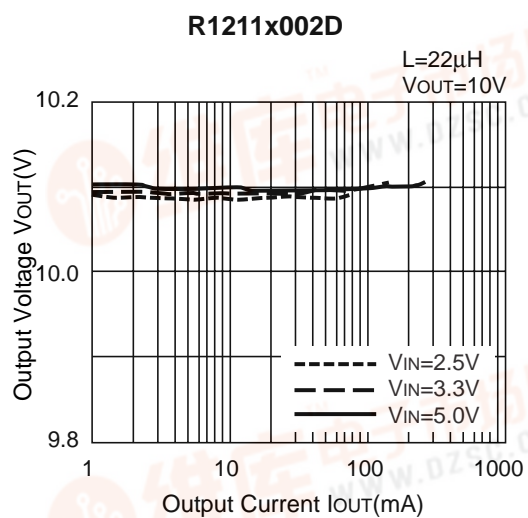
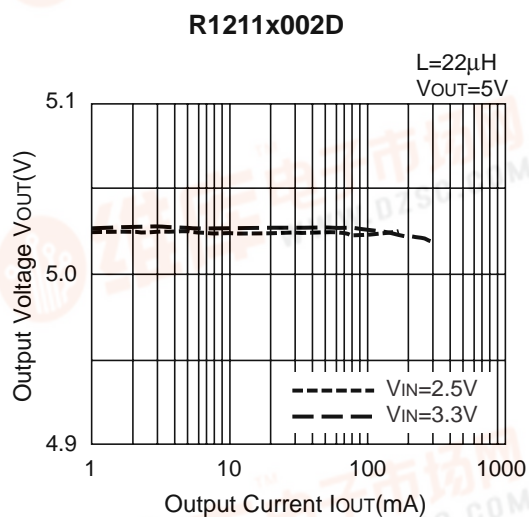
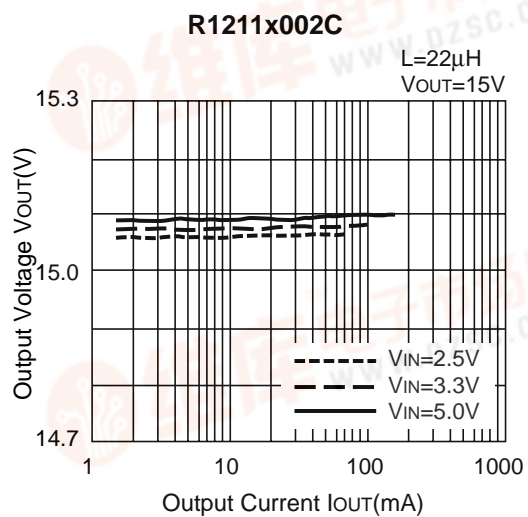
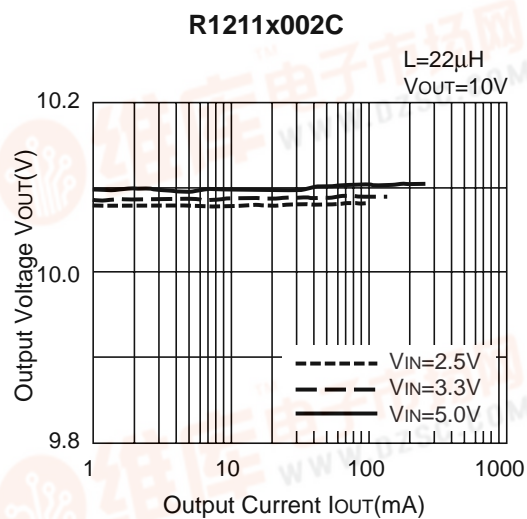
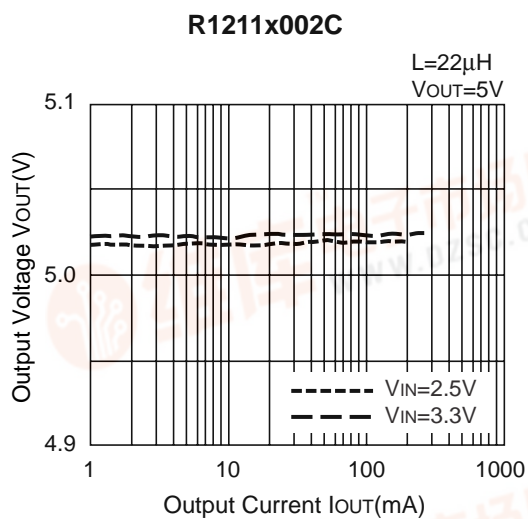


R1211x002B



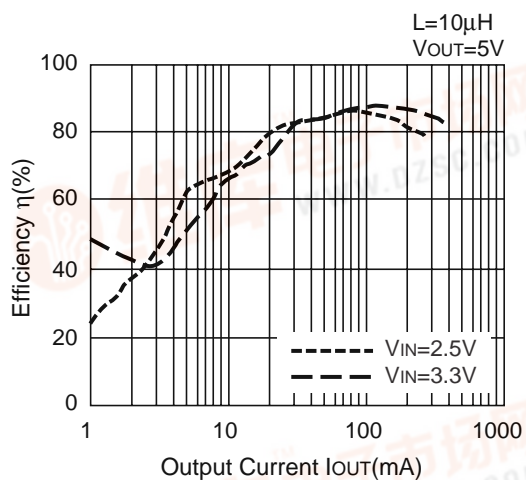
R1211x002B



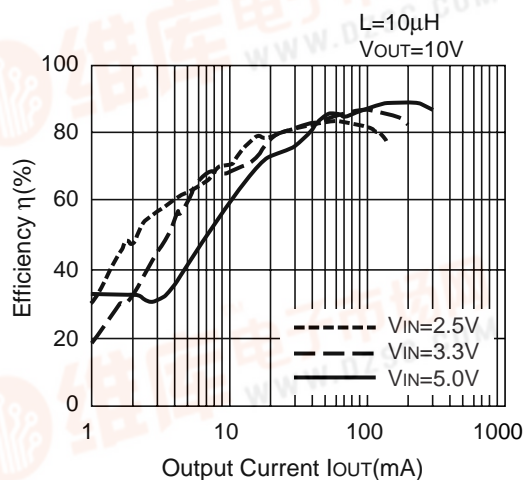


2) Efficiency vs. Output Current

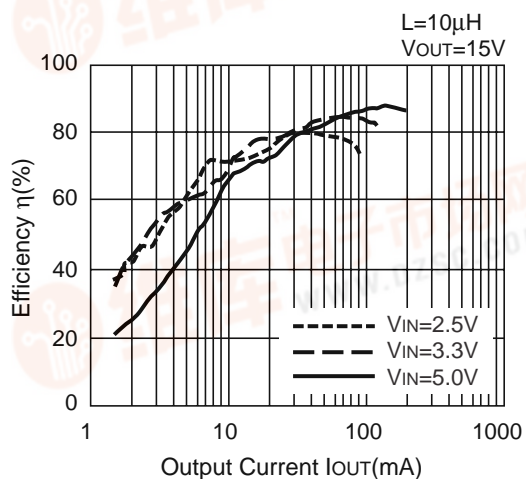
R1211x002A



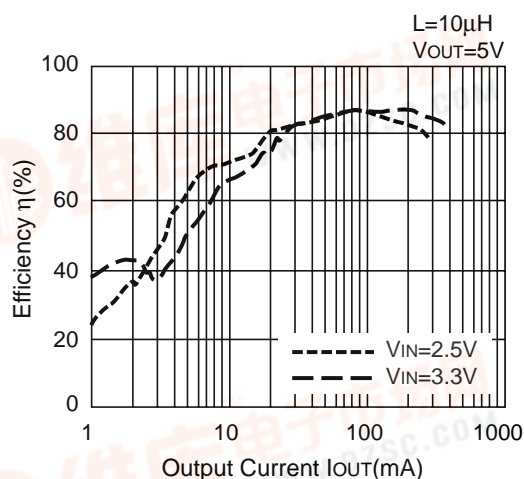
R1211x002A



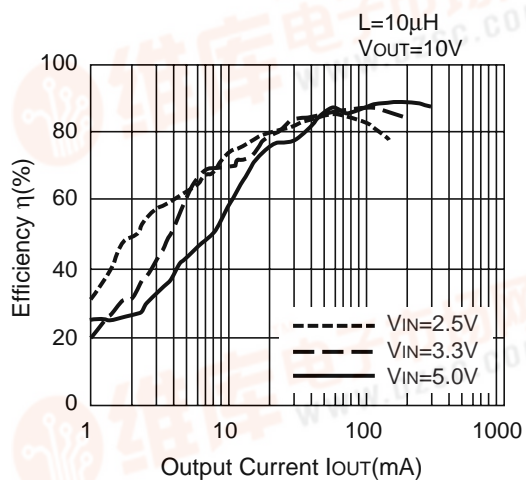
R1211x002A



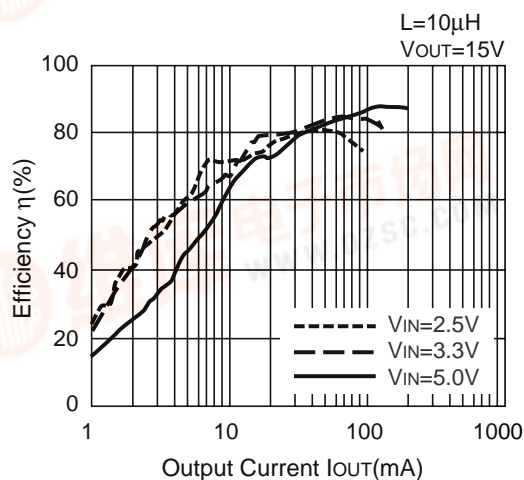
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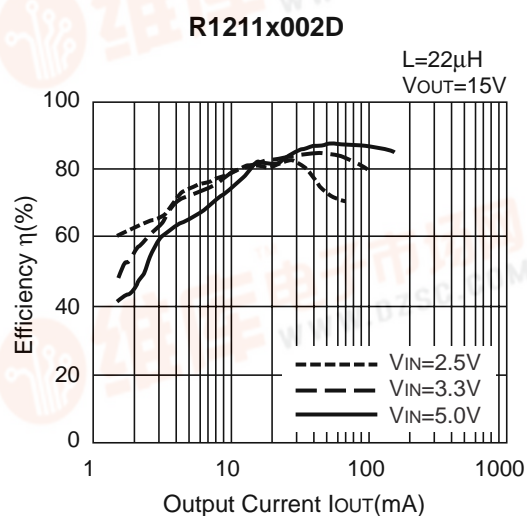
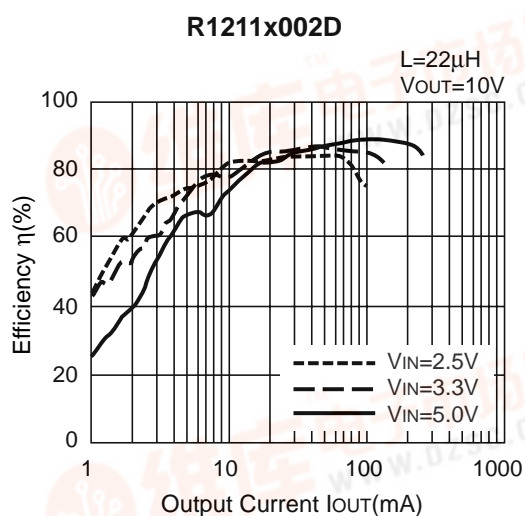
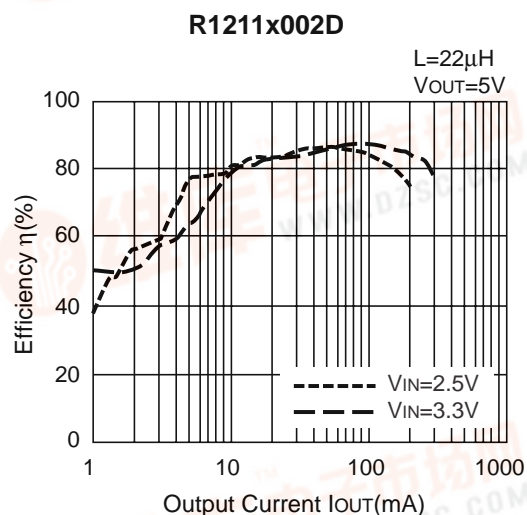
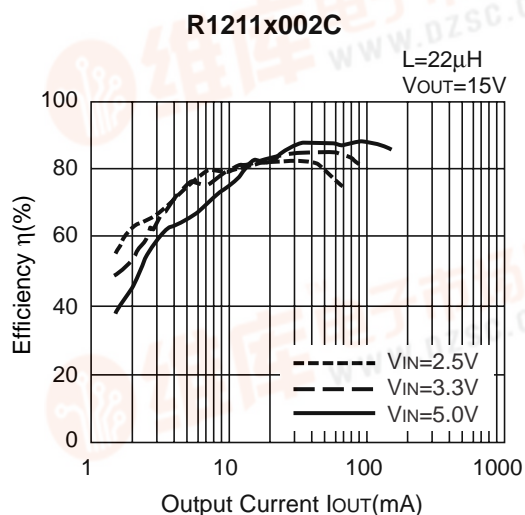
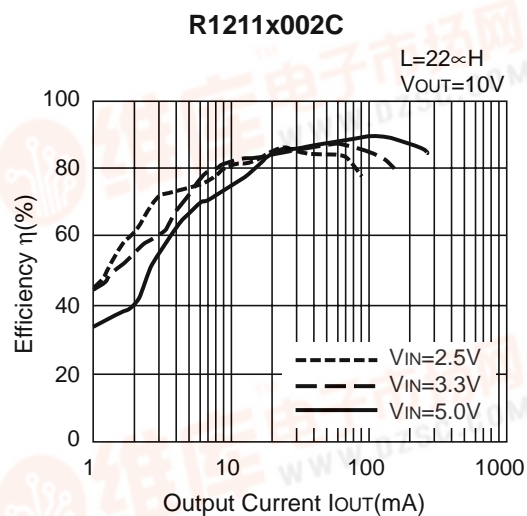
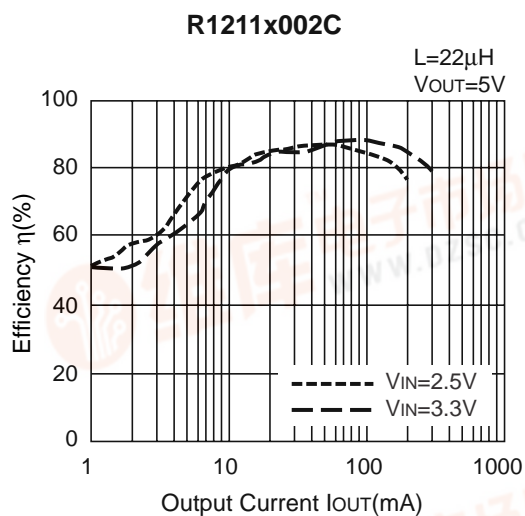


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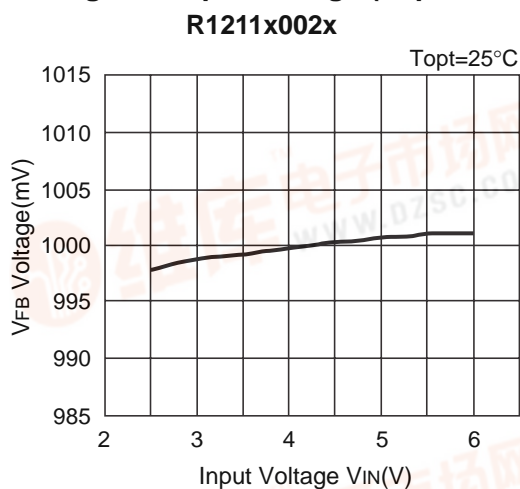


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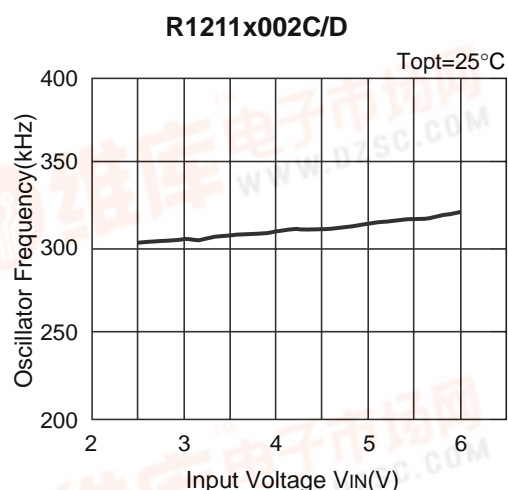
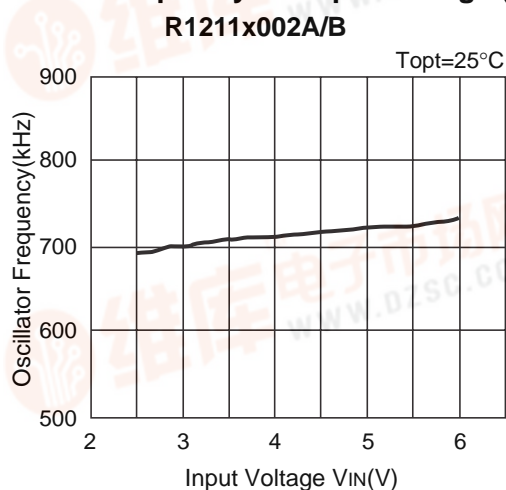




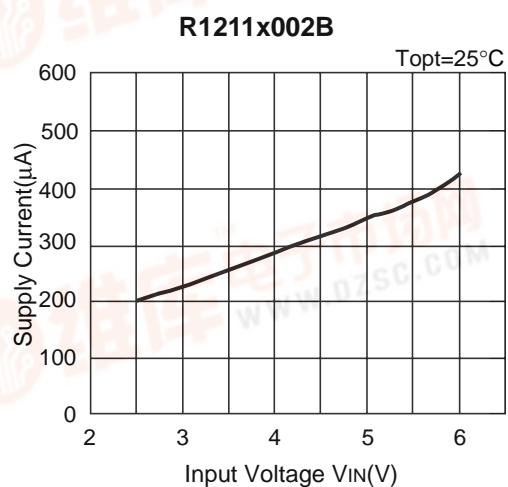
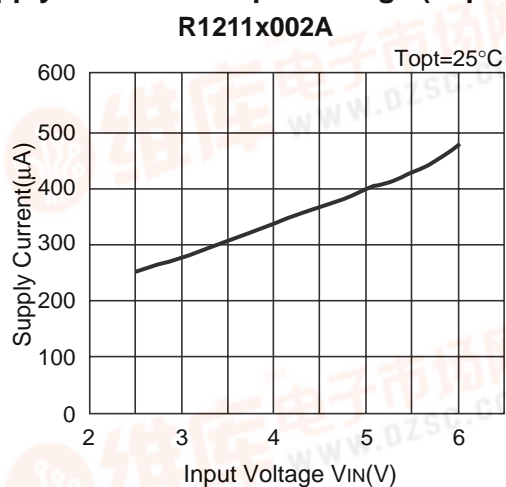
3) V_{FB} Voltage vs. Input Voltage ($T_{opt}=25^{\circ}\text{C}$)



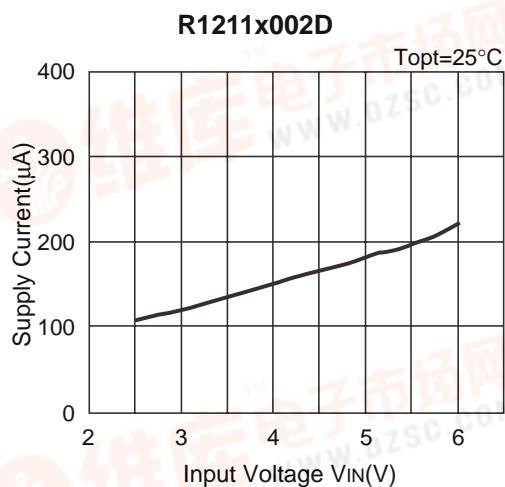
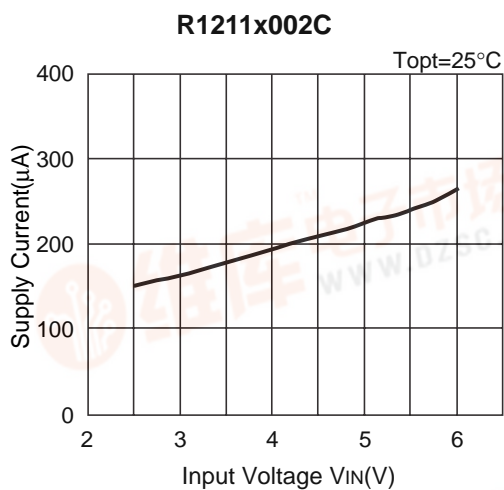
4) Oscillator Frequency vs. Input Voltage ($T_{opt}=25^{\circ}\text{C}$)



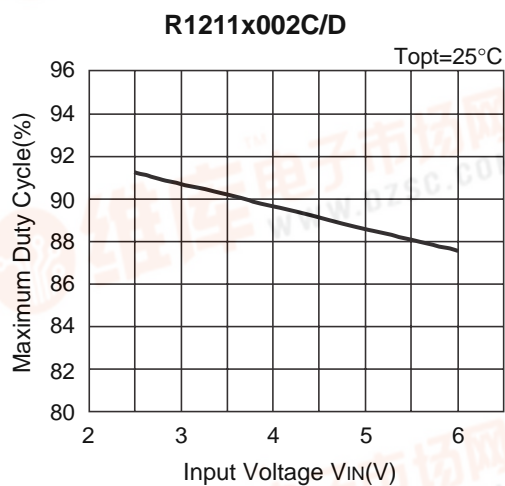
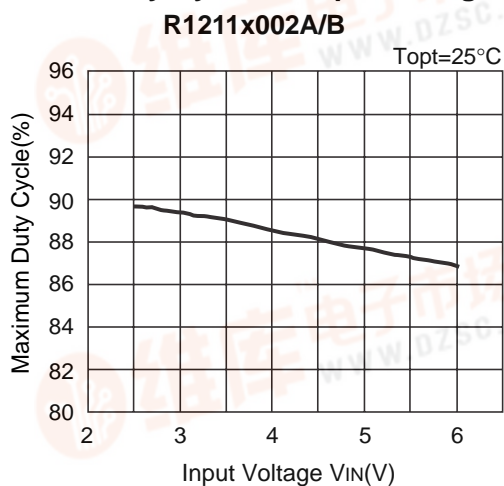
5) Supply Current vs. Input Voltage ($T_{opt}=25^{\circ}\text{C}$)



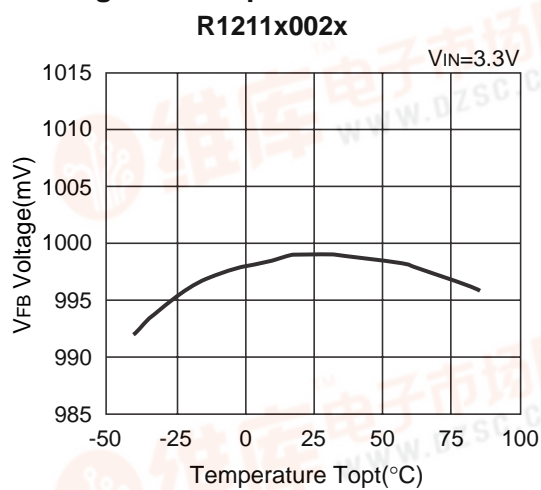
R1211x



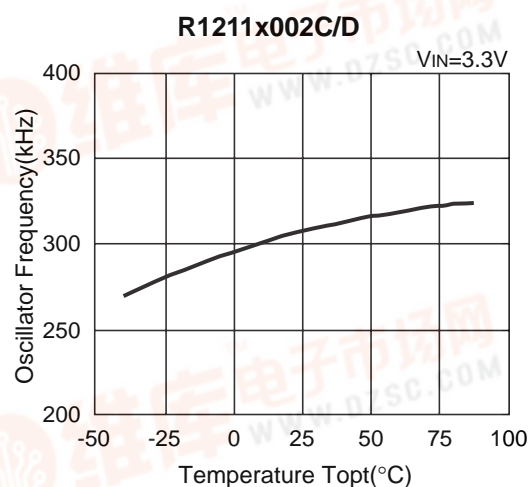
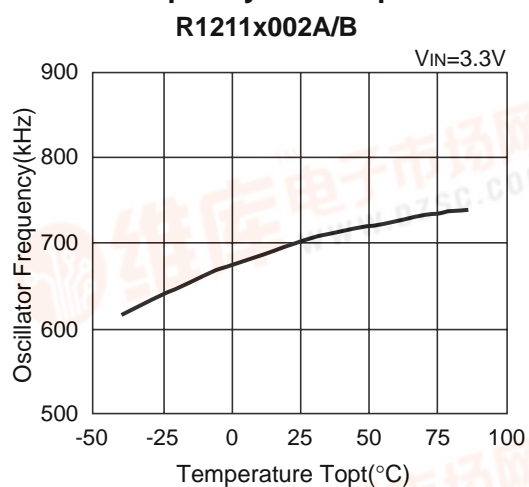
6) Maximum Duty Cycle vs. Input Voltage ($T_{opt}=25^{\circ}\text{C}$)



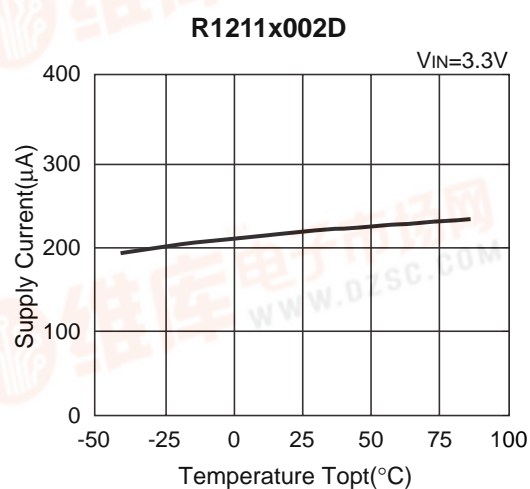
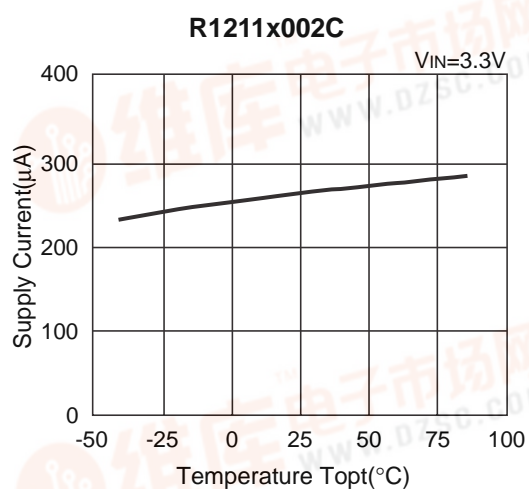
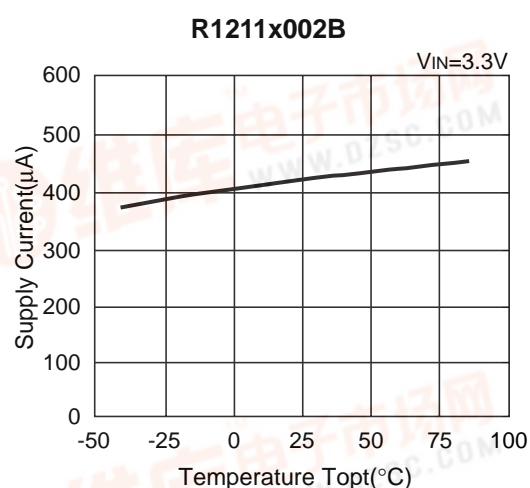
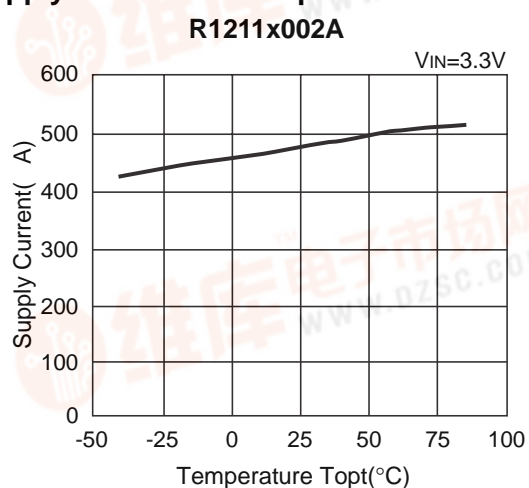
7) V_{FB} Voltage vs. Temperature



8) Oscillator Frequency vs. Temperature

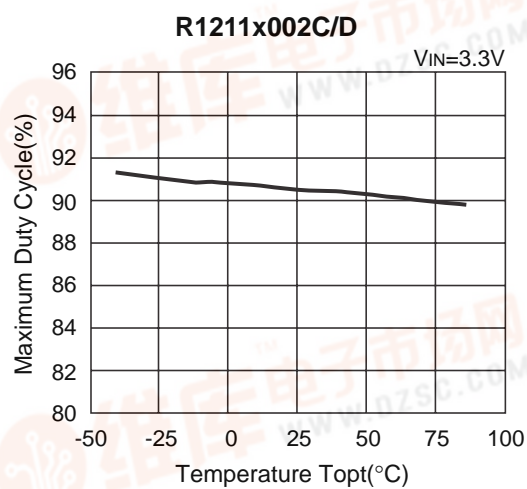
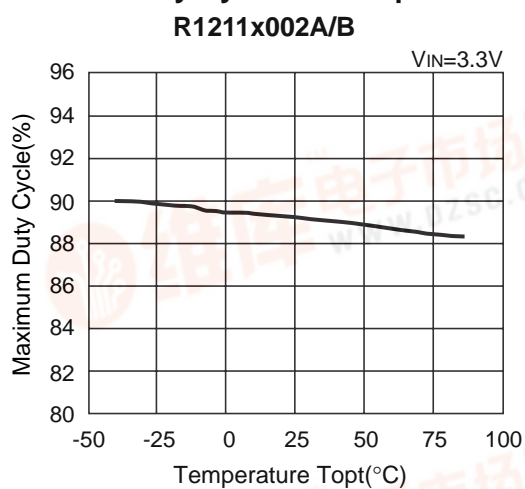


9) Supply Current vs. Temperature

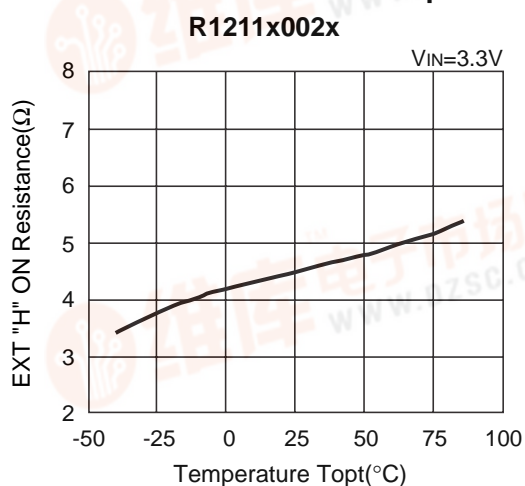


R1211x

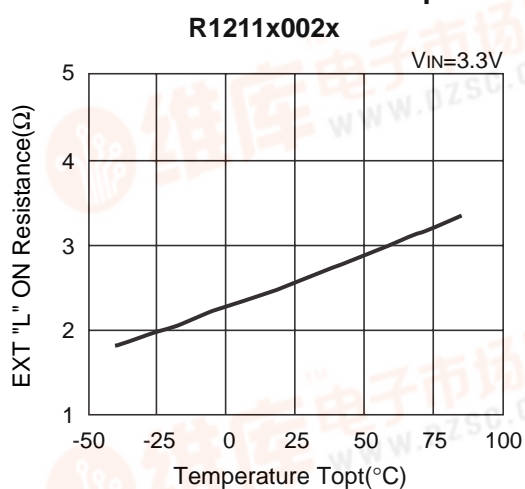
10) Maximum Duty Cycle vs. Temperature



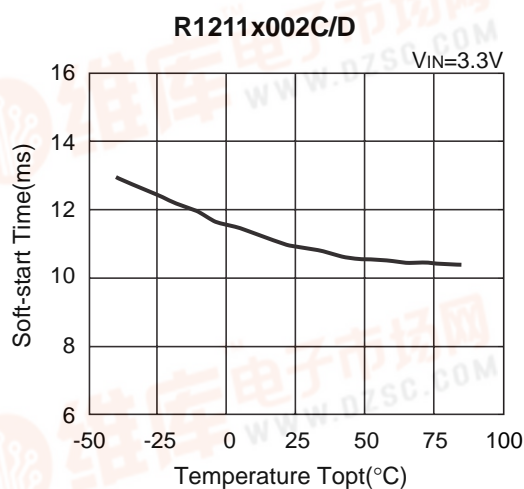
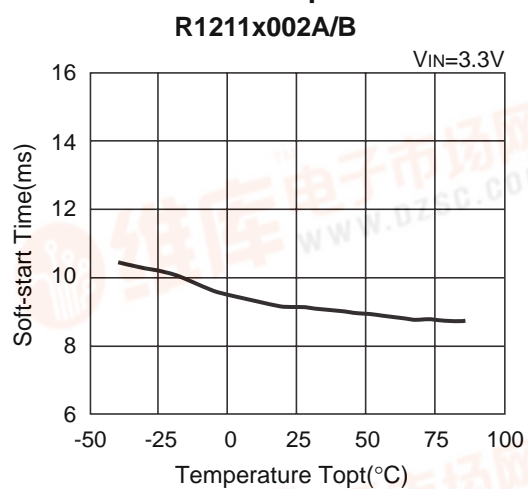
11) EXT "H" On Resistance vs. Temperature



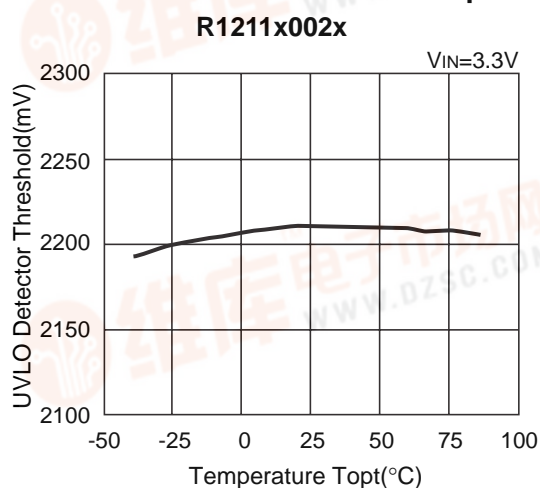
12) EXT "L" On Resistance vs. Temperature



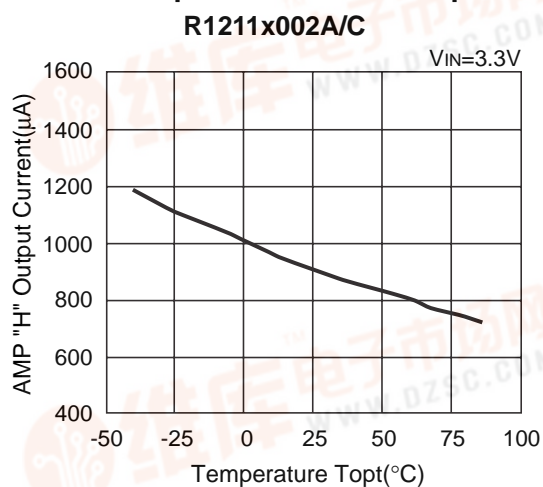
13) Soft-start Time vs. Temperature



14) UVLO Detector Threshold vs. Temperature

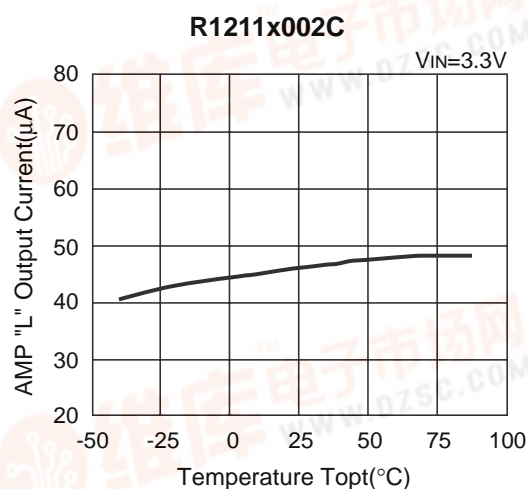
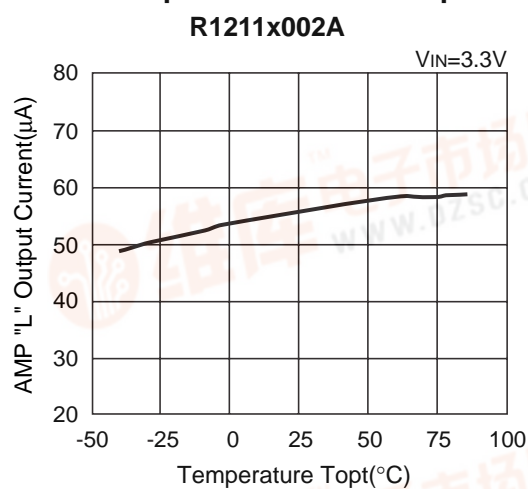


15) AMP "H" Output Current vs. Temperature

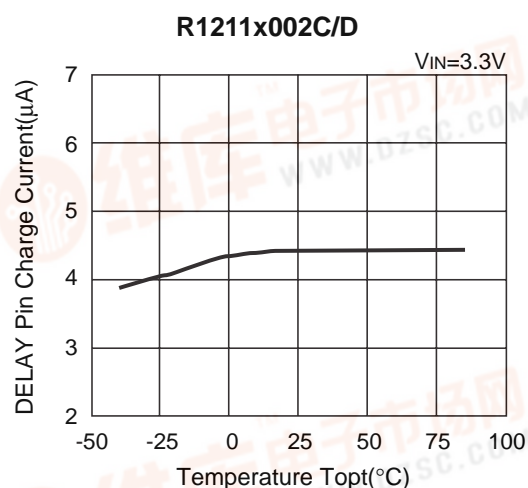
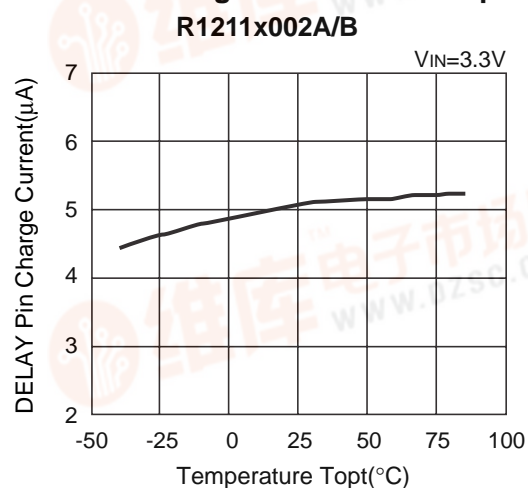


R1211x

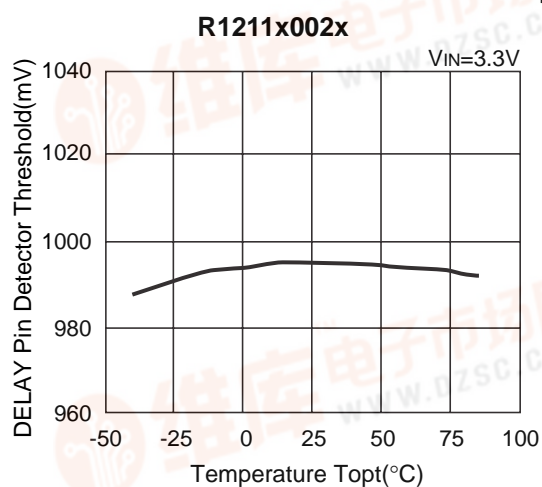
16) AMP "L" Output Current vs. Temperature



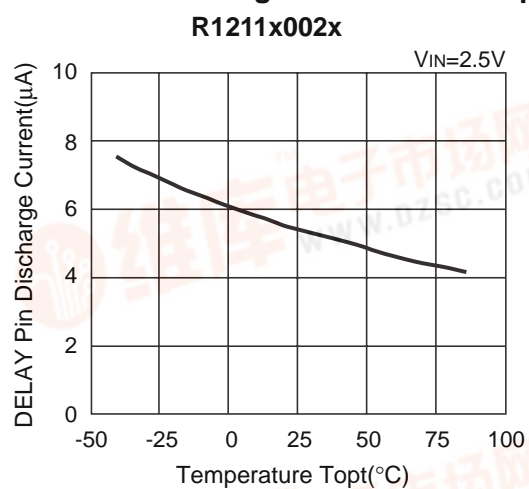
17) DELAY Pin Charge Current vs. Temperature



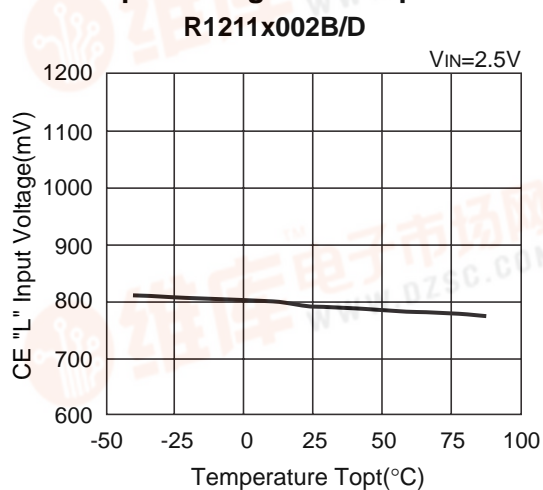
18) DELAY Pin Detector Threshold vs. Temperature



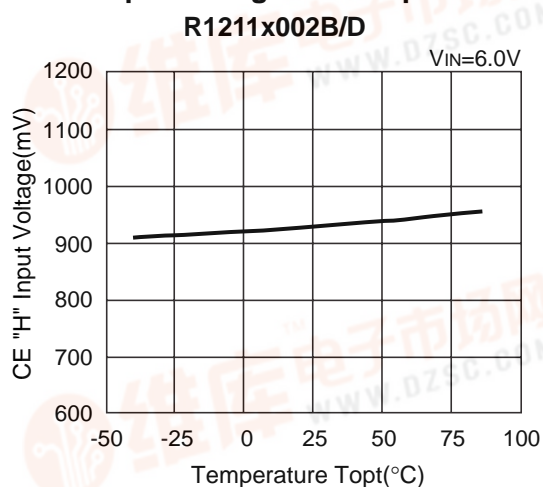
19) DELAY Pin Discharge Current vs. Temperature



20) CE "L" Input Voltage vs. Temperature



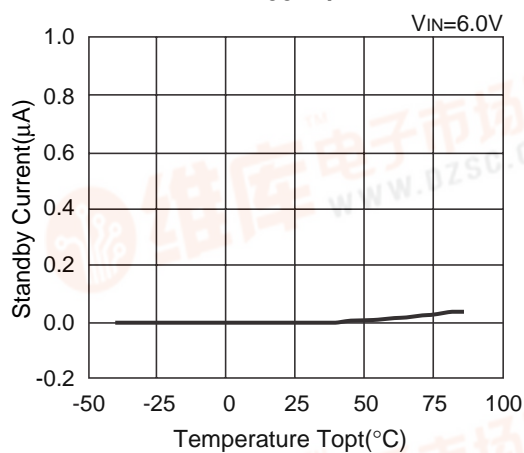
21) CE "H" Input Voltage vs. Temperature



R1211x

22) Standby Current vs. Temperature

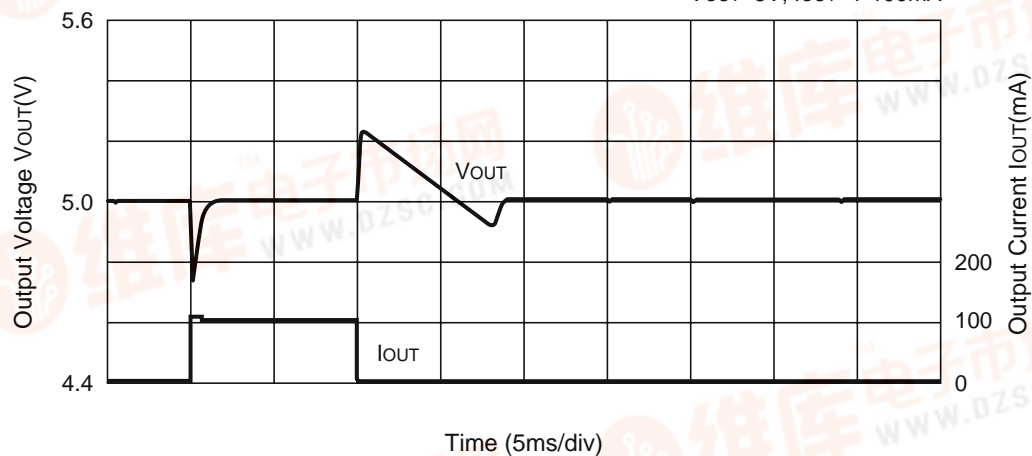
R1211x002B/D



23) Load Transient Response

R1211x002A

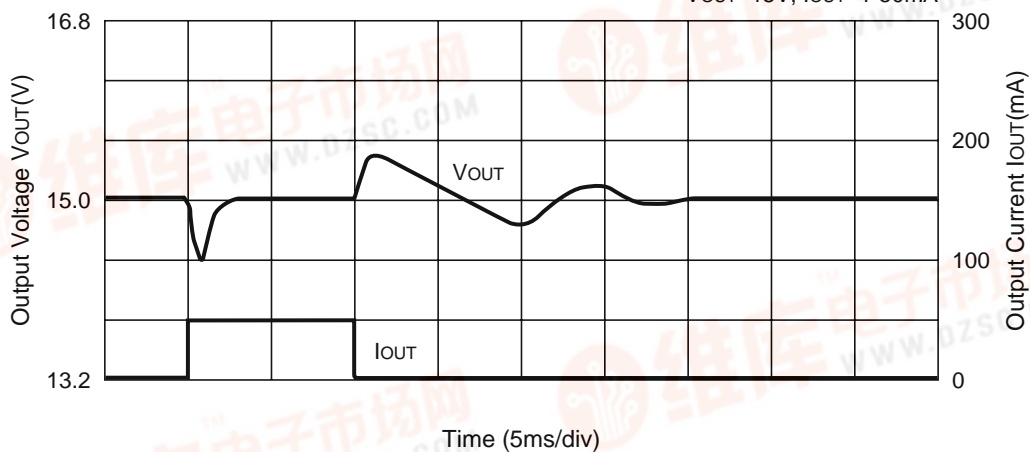
$L=10\mu H$
 $V_{IN}=3.3V$, $C3=22\mu F$
 $V_{OUT}=5V$, $I_{OUT}=1-100mA$



R1211x002A

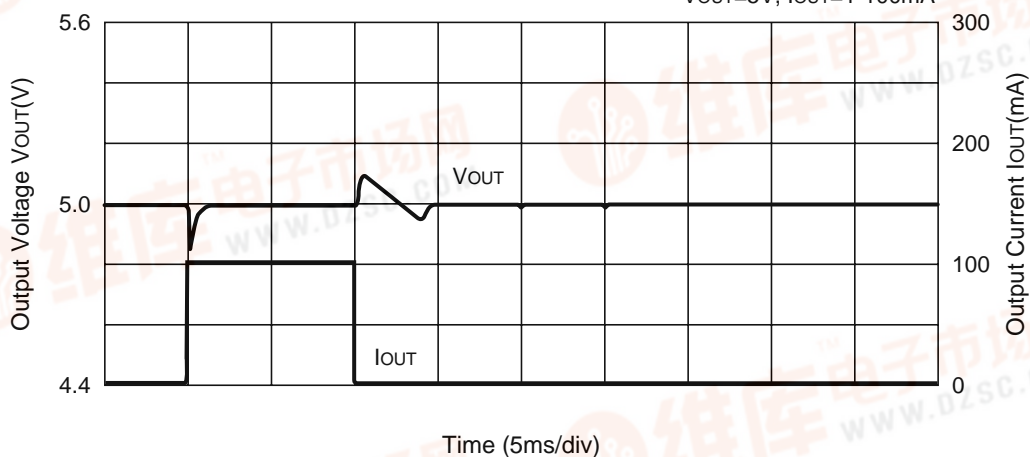
R1211x002A

L=10 μ H
V_{IN}=3.3V, C3=22 μ F
V_{OUT}=15V, I_{OUT}=1-50mA



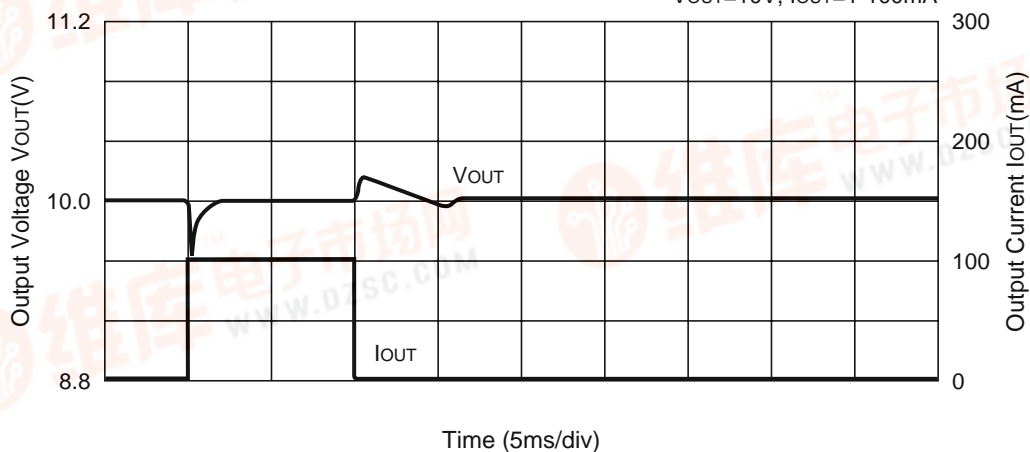
R1211x002B

L=10 μ H
V_{IN}=3.3V, C3=22 μ F
V_{OUT}=5V, I_{OUT}=1-100mA



R1211x002B

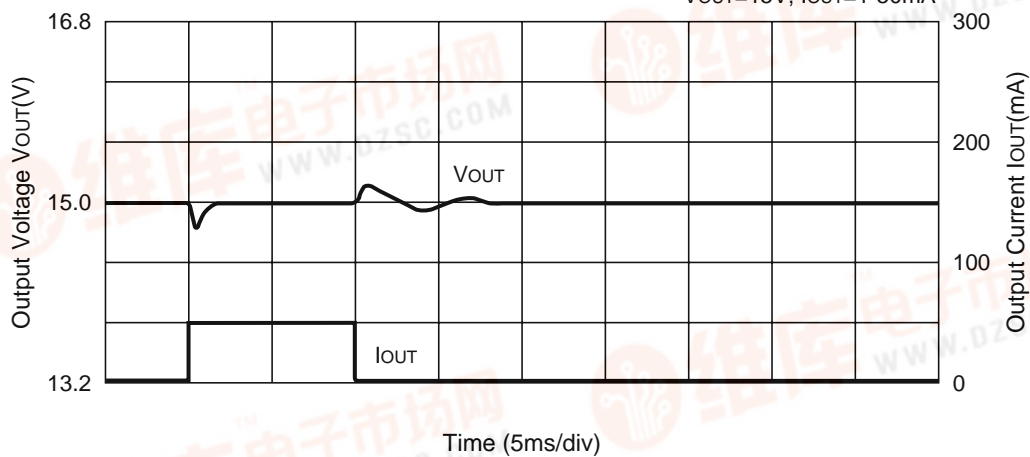
L=10 μ H
V_{IN}=3.3V, C3=22 μ F
V_{OUT}=10V, I_{OUT}=1-100mA



R1211x

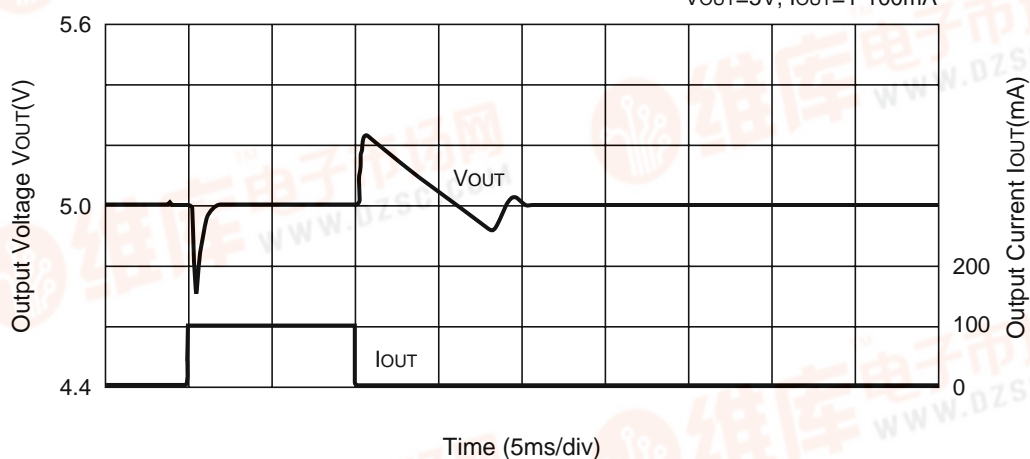
R1211x002B

L=10 μ H
VIN=3.3V, C3=22 μ F
VOUT=15V, IOUT=1-50mA



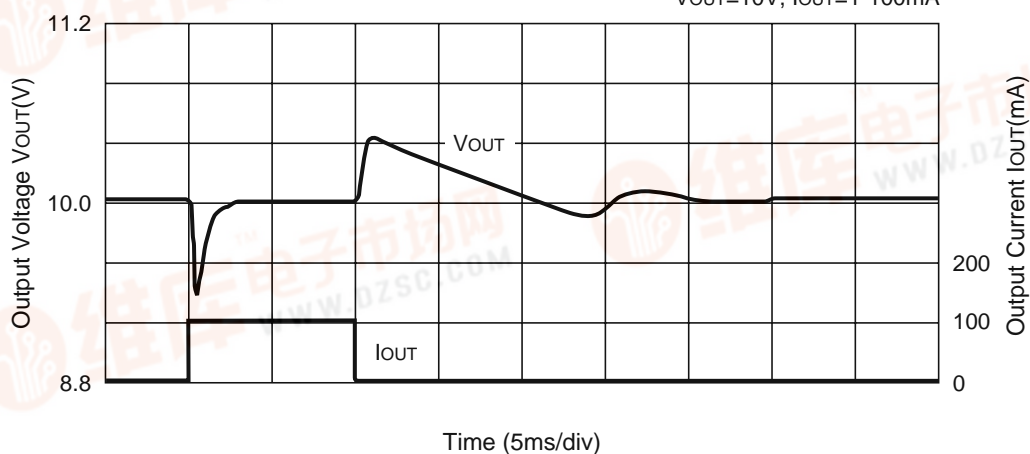
R1211x002C

L=22 μ H
VIN=3.3V, C3=22 μ F
VOUT=5V, IOUT=1-100mA



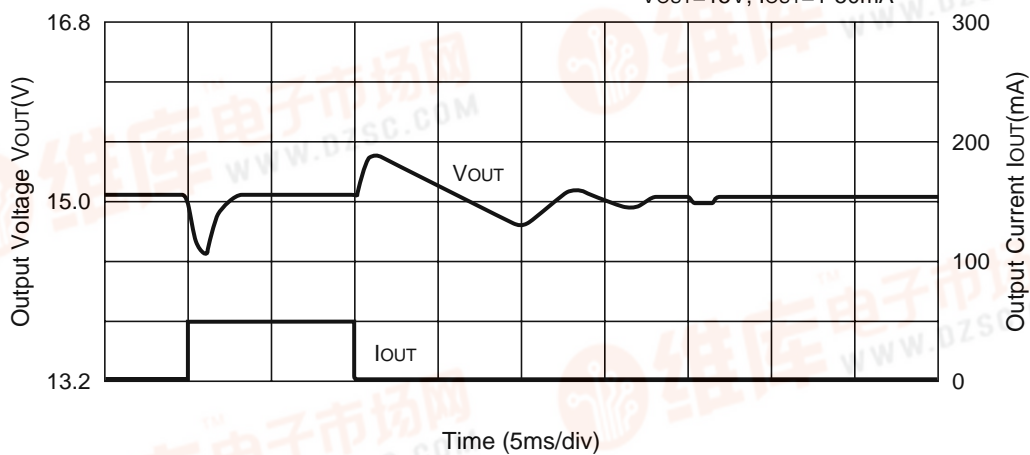
R1211x002C

L=22 μ H
VIN=3.3V, C3=22 μ F
VOUT=10V, IOUT=1-100mA



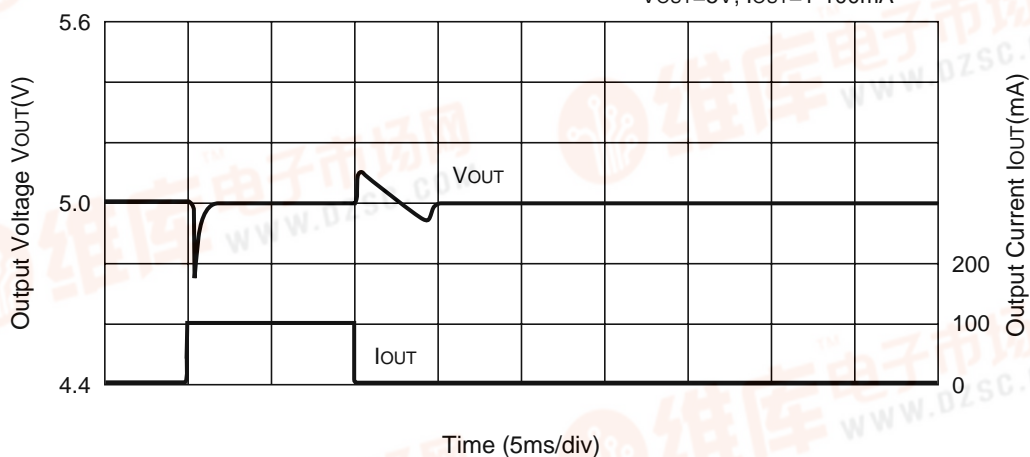
R1211x002C

$L=22\mu\text{H}$
 $V_{\text{IN}}=3.3\text{V}$, $C3=22\mu\text{F}$
 $V_{\text{OUT}}=15\text{V}$, $I_{\text{OUT}}=1\text{-}50\text{mA}$



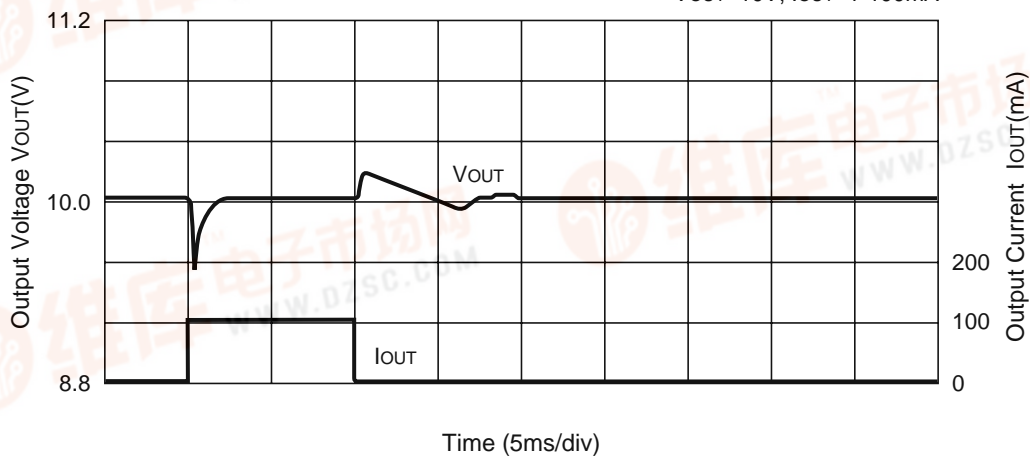
R1211x002D

$L=22\mu\text{H}$
 $V_{\text{IN}}=3.3\text{V}$, $C3=22\mu\text{F}$
 $V_{\text{OUT}}=5\text{V}$, $I_{\text{OUT}}=1\text{-}100\text{mA}$

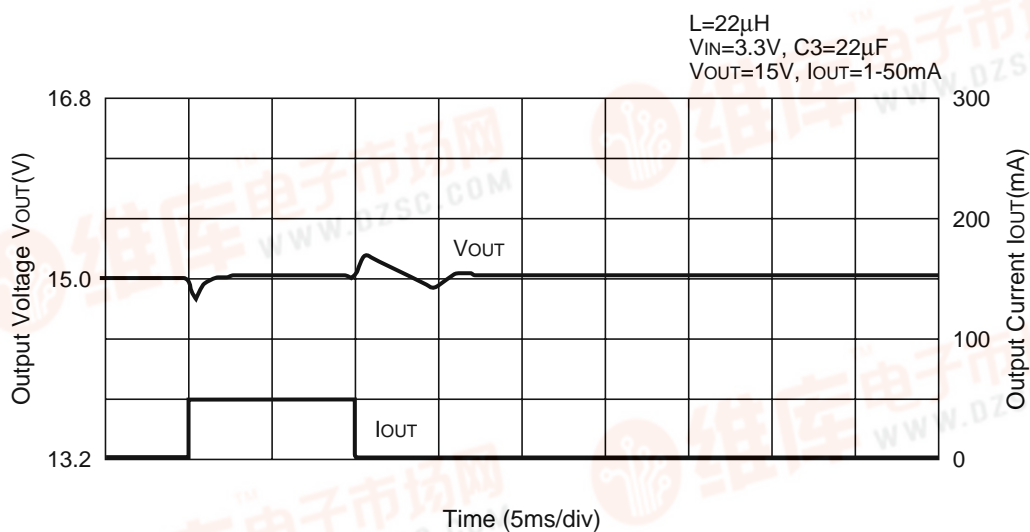


R1211x002D

$L=22\mu\text{H}$
 $V_{\text{IN}}=3.3\text{V}$, $C3=22\mu\text{F}$
 $V_{\text{OUT}}=10\text{V}$, $I_{\text{OUT}}=1\text{-}100\text{mA}$

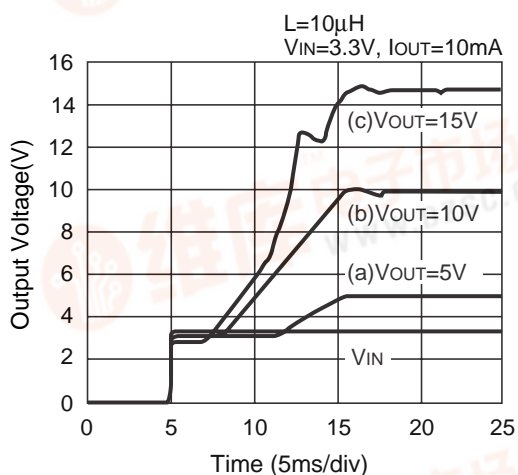


R1211x002D

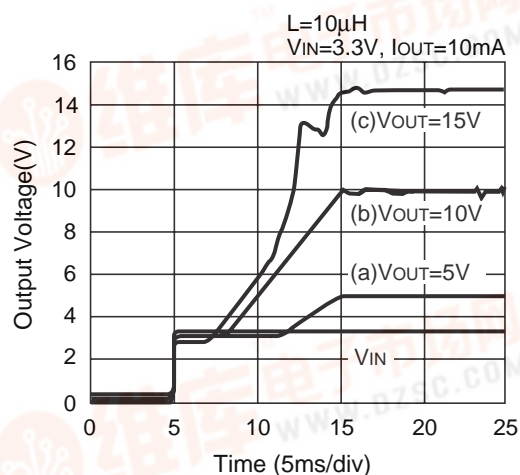


24) Power-on Response

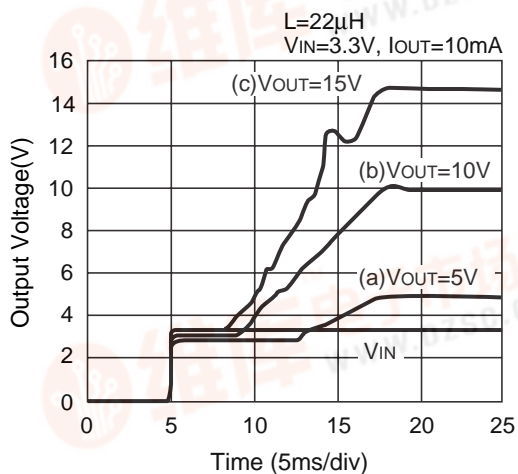
R1211x002A



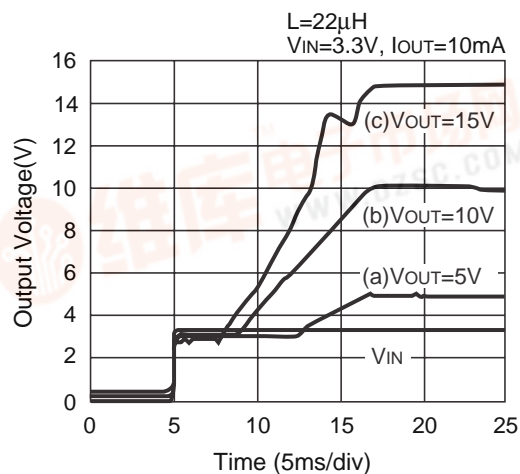
R1211x002B



R1211x002C



R1211x002D





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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.

