

1A LDO Voltage Regulator with "GreenOperation"

☆GreenOperation-Compatible

■ GENERAL DESCRIPTION

The XC6220 series is a highly accurate, low noise, high speed, low dropout, and large current CMOS voltage regulator with GreenOperation function. The series consists of a voltage reference, an error amplifier, a current limiter, an inrush current prevention circuit and a phase compensation circuit plus a driver transistor.

With a 0.2Ω on-resistance driver transistor integrated and with output currents up to 1A, the ultra low dropout voltage performance greatly extends battery life as does the GreenOperation function which can switch between high speed and power save modes automatically. Low ESR ceramic capacitors can be used for the output stabilization capacitor (C_L).

Output voltage is selectable in 0.05V increments within the range of 0.8V~5.0V, using laser trimming technologies.

An over current protection circuit and a thermal shutdown circuit are built in. The over current protection circuit will operate when the output current reaches its limit current. The thermal shutdown circuit will operate when the junction temperature reaches its limit temperature. The inrush protection circuit works by controlling the inrush current which is charged to C_L when the IC starts up. In this way, any fluctuations to V_{IN} caused by inrush current during system start up can be minimized.

The CE function enables the output to be turned off and the IC becomes a stand-by mode resulting in greatly reduced power consumption.

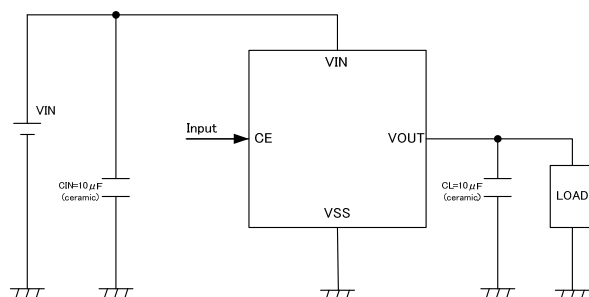
■ APPLICATIONS

- CD-ROM, CD-R/RW drives
- DVD drives
- HDD drives
- MIDs, UMPCs
- Digital still cameras, Video cameras
- Portable AV equipment

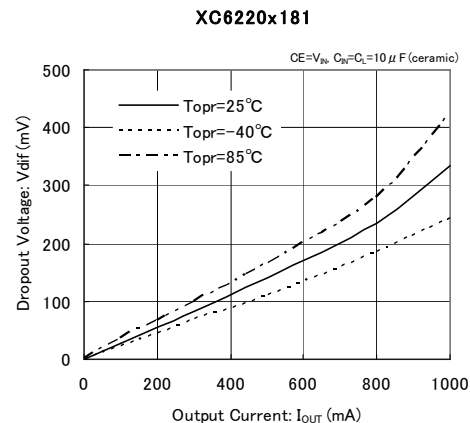
■ FEATURES

| | |
|--|--|
| Maximum Output Current | : 1000mA (TYP.:1200mA limit) ($1.2V \leq V_{OUT} \leq 5.0V$) |
| Dropout Voltage | : 20mV @ 100mA ($V_{OUT}=3.0V$) : 60mV @ 300mA ($V_{OUT}=3.0V$) |
| Operating Voltage Range | : 1.6V ~ 6.0V |
| Output Voltage Range | : 0.8V ~ 5.0V (0.05V increments) |
| Accuracy | : $\pm 1\%$ ($V_{OUT} \geq 2.0V$) : $\pm 20mV$ ($V_{OUT} < 2.0V$) |
| Low Power Consumption | : 8 μA (TYP.) in PS mode : 50 μA (TYP.) in HS mode |
| Operating Temperature | : -40°C ~ +85°C |
| Thermal Shutdown | : Detect 150°C, Release 135°C(TYP.) |
| Inrush Current Protection | : 700mA (MAX.) |
| C_L Auto Discharge | : XC6220B/D Series |
| CE Pull-Down Resistor | : XC6220C/D Series |
| Output Capacitor | : Ceramic Capacitor Compatible |
| Packages | : USP-6C, SOT-25, SOT-89-5 |
| Environmentally Friendly | : EU RoHS Compliant, Pb Free |

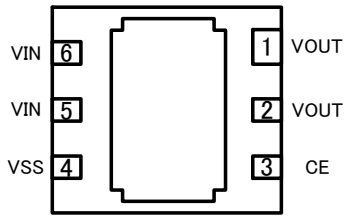
■ TYPICAL APPLICATION CIRCUIT



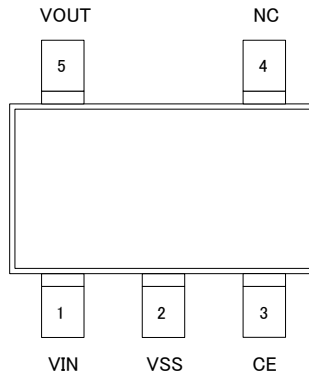
■ TYPICAL PERFORMANCE CHARACTERISTICS



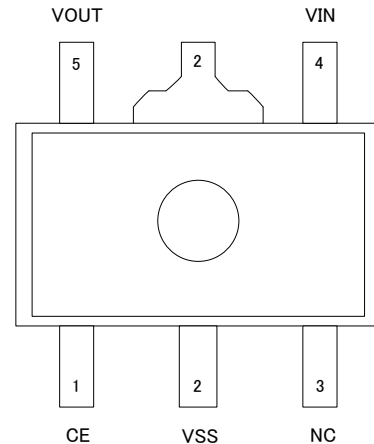
PIN CONFIGURATION



USP-6C
(BOTTOM VIEW)



SOT-25
(TOP VIEW)



SOT-89-5
(TOP VIEW)

* The No.5 and 6 V_{IN} pins should be connected. The No.1 and 2 pins V_{OUT} pins should be connected. The dissipation pad for the USP-6C package should be solder-plated in recommended mount pattern and metal masking so as to enhance mounting strength and heat release. If the pad needs to be connected to other pins, it should be connected to the V_{SS} (No. 4)

PIN ASSIGNMENT

| PIN NUMBER | | | PIN NAME | FUNCTIONS |
|------------|----------|--------|-----------|----------------|
| SOT-25 | SOT-89-5 | USP-6C | | |
| 3 | 1 | 3 | CE | ON/OFF Control |
| 1 | 4 | 6 & 5 | V_{IN} | Power Input |
| 2 | 2 | 4 | V_{SS} | Ground |
| 5 | 5 | 1 & 2 | V_{OUT} | Output |
| 4 | 3 | - | NC | No connection |

■ PRODUCT CLASSIFICATION

● Selection Guide

Please see the optional setting for C_L discharge and internal CE pull-down.

| PRODUCT NAME | CONDITIONS |
|--------------|--|
| XC6220A | without CE Pull-down resistor, without C _L auto discharge (Semi-custom) |
| XC6220B | without CE Pull-down resistor, with C _L auto discharge (Standard) |
| XC6220C | with CE Pull-down resistor, without C _L auto discharge (Semi-custom) |
| XC6220D | with CE Pull-down resistor, with C _L auto discharge (Semi-custom) |

● Ordering Information

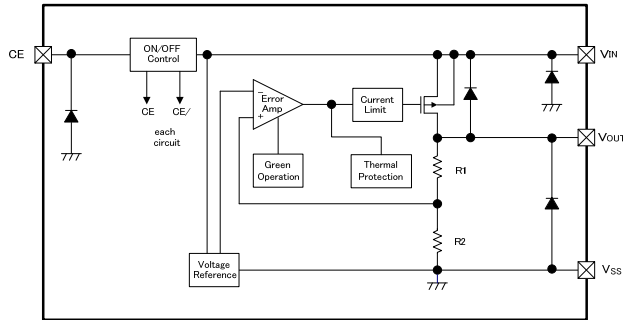
XC6220 ①②③④⑤⑥-⑦^(*)

| DESIGNATOR | DESCRIPTION | SYMBOL | DESCRIPTION |
|------------|-------------------------------------|--------|---|
| ① | Type of CE | A | without CE Pull-down resistor, without C _L discharge (Semi-custom) |
| | | B | without CE Pull-down resistor, with C _L discharge (Standard) |
| | | C | with CE Pull-down resistor, without C _L discharge (Semi-custom) |
| | | D | with CE Pull-down resistor, with C _L discharge (Semi-custom) |
| ② ③ | Output Voltage | 08~50 | e.g. 3.0V → ①=3, ②=0 |
| ④ | Output Voltage Accuracy | 1 | Output voltage {O.O0v} (the 2 nd decimal place is "0") :HS Mode Accuracy ± 1%(V _{OUT(T)} ≥ 2.1V), within 0.02V (V _{OUT(T)} ≤ 2.0V) :PS Mode Accuracy ± 2%(V _{OUT(T)} ≥ 2.1V), within 0.04V (V _{OUT(T)} ≤ 2.0V) |
| | | B | Output voltage {O.O5v} (the 2 nd decimal place is "5") :HS Mode Accuracy ± 1%(V _{OUT(T)} ≥ 2.05V), within 0.02V (V _{OUT(T)} ≤ 1.95V) :PS Mode Accuracy ± 2%(V _{OUT(T)} ≥ 2.05V), within 0.04V (V _{OUT(T)} ≤ 1.95V) |
| ⑤⑥-⑦ | Packages Taping Type ^(*) | MR | SOT-25 |
| | | MR-G | SOT-25 |
| | | PR | SOT-89-5 |
| | | PR-G | SOT-89-5 |
| | | ER | USP-6C |
| | ER-G | USP-6C | |

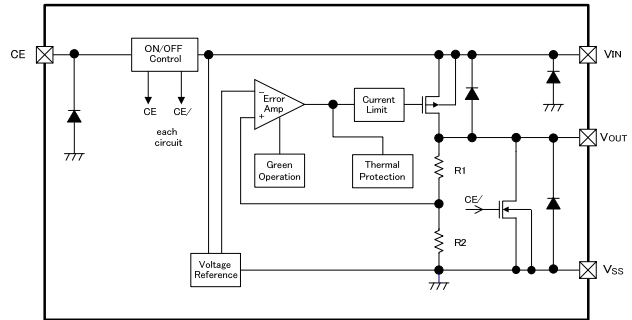
^(*) The "-G" suffix indicates that the products are Halogen and Antimony free as well as being fully RoHS compliant.

^(*) The device orientation is fixed in its embossed tape pocket. For reverse orientation, please contact your local Torex sales office or representative. (Standard orientation: ⑤R-⑦, Reverse orientation: ⑤L-⑦)

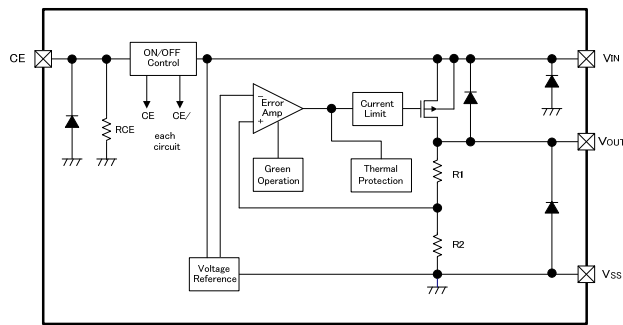
■ BLOCK DIAGRAMS



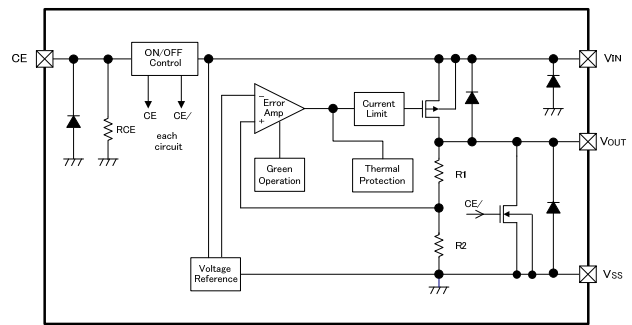
●XC6220A Series (Semi-custom)



●XC6220B Series



●XC6220C Series (Semi-custom)



●XC6220D Series (Semi-custom)

* Diodes inside the circuits are ESD protection diodes and parasitic diodes.

■ ABSOLUTE MAXIMUM RATINGS

Ta=25°C

| PARAMETER | | SYMBOL | RATINGS | UNITS |
|-------------------------------|-----------------------------------|------------------|---|-------|
| Input Voltage | | V _{IN} | 6.5 | V |
| Output Current ⁽¹⁾ | | I _{OUT} | 1400 | mA |
| Output Voltage | | V _{OUT} | V _{SS} -0.3 ~ V _{IN} +0.3 | V |
| CE Input Voltage | | V _{CE} | V _{SS} -0.3 ~ 6.5 | V |
| Power Dissipation | SOT-25 | P _d | 250 | mW |
| | | | 600 (PCB mounted) ⁽²⁾ | |
| | SOT-89-5 | | 500 | |
| | | | 1300 (PCB mounted) ⁽²⁾ | |
| USP-6C | 120 | | | |
| | 1000 (PCB mounted) ⁽²⁾ | | | |
| Operating Temperature Range | | Topr | - 40 ~ + 85 | °C |
| Storage Temperature Range | | Tstg | - 55 ~ + 125 | °C |

*1 Please use within the range of I_{OUT}=P_d / (V_{IN} - V_{OUT})

*2: The power dissipation figure shown is PCB mounted. Please refer to pages 15~17 for details.

■ ELECTRICAL CHARACTERISTICS

● XC6220A/B/C/D Series

Ta=25°C

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|--|--|---|-----------------------|---------------------|-----------------------|---------|---------|
| Output Voltage | $V_{OUT(E)}$ (2) | High Speed Mode (HS) $2.0V \leq V_{OUT(T)} \leq 5.0V$ $V_{CE}=V_{IN}, I_{OUT}=30mA$ | ×0.99 | $V_{OUT(T)}$ (3) | ×1.01 | V | ① |
| | | High Speed Mode (HS) $0.8V \leq V_{OUT(T)} \leq 1.95V$ $V_{CE}=V_{IN}, I_{OUT}=30mA$ | -0.02 | | +0.02 | | |
| | | Power Save Mode (PS) $2.0V \leq V_{OUT(T)} \leq 5.0V$ $V_{CE}=V_{IN}, I_{OUT}=0.1mA$ | ×0.98 | | ×1.02 | | |
| | | Power Save Mode (PS) $0.8V \leq V_{OUT(T)} \leq 1.95V$ $V_{CE}=V_{IN}, I_{OUT}=0.1mA$ | -0.04 | | +0.04 | | |
| Output Current | I_{OUTMAX} | High Speed Mode(HS), $V_{CE}=V_{IN}$ $V_{IN}=V_{OUT(T)}+1.0V$ $0.8V \leq V_{OUT(T)} \leq 1.15V$ | 700 | 1200 | - | mA | ① |
| | | High Speed Mode(HS), $V_{CE}=V_{IN}$ $V_{IN}=V_{OUT(T)}+1.0V$ $1.2V \leq V_{OUT(T)} \leq 5.0V$ | 1000 | 1200 | - | | |
| Load Regulation | ΔV_{OUT} | High Speed Mode (HS), $V_{CE}=V_{IN}$ $10mA \leq I_{OUT} \leq 300mA$ | - | 10 | 45 | mV | ① |
| Dropout Voltage1 ^(*) | Vdif | High Speed Mode (HS) $I_{OUT}=300mA, V_{CE}=V_{IN}$ | see the Voltage Chart | | | mV | ① |
| Dropout Voltage2 ^(*) | Vdif | High Speed Mode(HS) $I_{OUT}=1000mA, V_{CE}=V_{IN}$ | see the Voltage Chart | | | mV | ① |
| Supply Current 1 | I_{SS1} | High Speed Mode(HS) $V_{IN}=V_{CE}=V_{OUT(T)}+1.0V$ $I_{OUT}=10mA$ (A/B Series) | - | 50 | 108 | μA | ② |
| | | High Speed Mode(HS) $V_{IN}=V_{CE}=V_{OUT(T)}+1.0V$ $I_{OUT}=10mA$ (C/D Series) | - | 50 | see the Voltage Chart | | |
| Supply Current 2 | I_{SS2} | Power Save Mode(PS) $V_{IN}=V_{CE}=V_{OUT(T)}+1.0V$ $I_{OUT}=0.1mA$ | - | 8 | 18 | μA | ② |
| | | Power Save Mode(PS) $V_{IN}=V_{CE}=V_{OUT(T)}+1.0V$ $I_{OUT}=0.1mA$ | - | 8 | see the Voltage Chart | | |
| Stand-by Current | I_{STBY} | $V_{IN}=6.0V, V_{CE}=V_{SS}$ | -0.1 | 0.01 | 0.1 | μA | ② |
| Line Regulation | $\frac{\Delta V_{OUT}}{(\Delta V_{IN} \cdot V_{OUT})}$ | $V_{OUT(T)}+0.5V \leq V_{IN} \leq 6.0V$: $1.1V \leq V_{OUT(T)} \leq 5.0V$ High Speed Mode (HS), $V_{CE}=V_{IN}$ $I_{OUT}=100mA$ | - | 0.01 | 0.20 | %V | ① |
| | | $1.6V \leq V_{IN} \leq 6.0V$: $0.8V \leq V_{OUT(T)} \leq 1.05V$ High Speed Mode (HS), $V_{CE}=V_{IN}$ $I_{OUT}=100mA$ | | | | | |
| Input Voltage | V_{IN} | | 1.6 | - | 6.0 | V | |
| Output Voltage Temperature Characteristics | $\frac{\Delta V_{OUT}}{(\Delta Ta \cdot V_{OUT})}$ | High Speed Mode (HS), $V_{CE}=V_{IN}$ $I_{OUT}=30mA$ $-40^\circ C \leq Ta \leq 85^\circ C$ | - | ±100 | - | ppm/°C | ① |

ELECTRICAL CHARACTERISTICS (Continued)

| PARAMETER | SYMBOL | CONDITIONS | MIN. | TYP. | MAX. | UNITS | CIRCUIT |
|--|-------------|--|-----------------------|------|------|-------------|---------|
| Ripple Rejection Rate | PSRR | $V_{IN}=5.75V_{DC}+0.5V_{p-pAC}$: $4.75V \leq V_{OUT(T)} \leq 5.0V$ High Speed Mode (HS), $V_{CE}=V_{IN}$ $I_{OUT}=30mA, f=1kHz$ | | | | | |
| | | $V_{IN}=\{V_{OUT(T)}+1.0\}$ $V_{DC}+0.5V_{p-pAC}$: $0.85V \leq V_{OUT(T)} \leq 4.7V$ High Speed Mode (HS), $V_{CE}=V_{IN}$ $I_{OUT}=30mA, f=1kHz$ | - | 50 | - | dB | ③ |
| | | $V_{IN}=1.85V_{DC}+0.5V_{p-pAC}$: $V_{OUT(T)}=0.8V$ High Speed Mode (HS), $V_{CE}=V_{IN}$ $I_{OUT}=30mA, f=1kHz$ | | | | | |
| Limit Current | I_{LIM} | $V_{CE}=V_{IN}=V_{OUT(T)}+1.0V$ $0.8V \leq V_{OUT(T)} \leq 1.15V$ | 705 | 1200 | - | mA | ① |
| | | $V_{CE}=V_{IN}$ $V_{IN}=V_{OUT(T)}+1.0V$ $1.2V \leq V_{OUT(T)} \leq 5.0V$ | 1005 | 1200 | - | | |
| Short Current | I_{SHORT} | $V_{CE}=V_{IN}$ Short V_{OUT} to V_{SS} level | - | 180 | - | mA | ① |
| PS Switching Current | I_{GOR} | : $1.45V \leq V_{OUT(T)} \leq 5.0V$ $V_{IN}=V_{OUT(T)}+1.0V, V_{CE}="H" Level$: $0.8V \leq V_{OUT(T)} \leq 1.4V$ $V_{IN}=1.6V, V_{CE}="H" Level$ $I_{OUT}=\text{heavy to light load}$ | 1.0 | 2.0 | - | mA | ⑤ |
| HS Switching Current | I_{GO} | : $1.45V \leq V_{OUT(T)} \leq 5.0V$ $V_{IN}=V_{OUT(T)}+1.0V, V_{CE}="H" Level$: $0.8V \leq V_{OUT(T)} \leq 1.4V$ $V_{IN}=1.6V, V_{CE}="H" Level$ $I_{OUT}=\text{light to heavy load}$ | - | 5.0 | 10 | mA | ⑤ |
| Switch Current Hysteresis Range | I_{GOhys} | $I_{GOhys}=I_{GO}-I_{GOR}$ | - | 3.0 | - | mA | ⑤ |
| PS Switching Delay Time | t_{DPS} | $V_{CE}=V_{IN}=V_{OUT(T)}+1.0V,$ (HS/PS Auto-Switching) Time until HS mode is changed-over to PS mode by I_{GOR} . | see the Voltage Chart | | | μs | ⑤ |
| CE High Level Voltage | V_{CEH} | $V_{CE}=V_{IN}$ | 1.2 | - | 6.0 | V | ④ |
| CE Low Level Voltage | V_{CEL} | $V_{CE}=V_{SS}$ | - | - | 0.4 | V | ④ |
| CE High Level Current | I_{CEH} | $V_{CE}=V_{IN}$ (A/B series) | -0.1 | - | 0.1 | μA | ④ |
| | | $V_{CE}=V_{IN}=6.0V$ (C/D series) | - | 9 | 15 | μA | |
| CE Low Level Current | I_{CEL} | $V_{CE}=V_{SS}$ | -0.1 | - | 0.1 | μA | ④ |
| CL Discharge Resistance ⁽⁷⁾ | R_{DCHG} | $V_{IN}=6.0V, V_{OUT}=5.0V, V_{CE}=V_{SS}$ | - | 460 | - | Ω | ① |
| Thermal Shutdown Detect Temperature | T_{TSD} | Junction Temperature | - | 150 | - | $^{\circ}C$ | |
| Thermal Shutdown Release Temperature | T_{TSR} | Junction Temperature | - | 135 | - | $^{\circ}C$ | |
| Inrush Current | I_{RUSH} | $V_{IN}=V_{OUT(T)}+1.0V, C_L=22\mu F$ $V_{CE}=0V \rightarrow V_{OUT(T)}+1.0V$ (Only when rising and within 1ms) | - | - | 700 | mA | ⑥ |

NOTE:

*1: Unless otherwise stated, $V_{IN}=V_{OUT(T)}+1.0V$.

*2: $V_{OUT(E)}$ = Effective output voltage (see the voltage chart)

(ie. The output voltage when " $V_{OUT(T)}+1.0V$ " is provided at the V_{IN} pin while maintaining a certain I_{OUT} value.

*3: $V_{OUT(T)}$: Nominal output voltage

*4: $V_{dif}=\{V_{IN1}^{(6)} - V_{OUT1}^{(5)}\}$

*5: V_{OUT1} =A voltage equal to 98% of the $V_{OUT(T)}$ when an amply stabilized I_{OUT} ($V_{OUT(T)}+1.0V$) is input in the HS mode.

*6: V_{IN1} =The input voltage when V_{OUT1} appears as input voltage is gradually decreased.

*7: For the XC6220B/D series only. The XC6220A/C series (semi-custom) discharges by resistors R1 and R2 only as shown in the block diagrams.

*8: For the XC6220A/C series, output voltage rises when the IC is in the high temperature stand-by mode.

■ ELECTRICAL CHARACTERISTICS (Continued)

● Voltage Chart 1

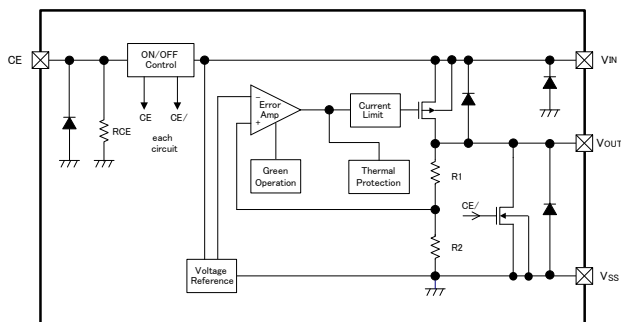
| NOMINAL OUTPUT VOLTAGE (V) | OUTPUT VOLTAGE 1 (HS Mode) (V) | | OUTPUT VOLTAGE 2 (PS Mode) (V) | | DROPOUT VOLTAGE 1 Vdif 1 (mV) I _{OUT} =300mA | | DROPOUT VOLTAGE 2 Vdif 2 (mV) I _{OUT} =1000mA | | SUPPLY CURRENT 1 (XC6220C/D) (μA) | SUPPLY CURRENT 2 (XC6220C/D) (μA) | PS SWITCH DELAY TIME (μs) |
|-------------------------------------|---|--------|---|--------|--|--------|---|------------------|--|--|---------------------------------------|
| | V _{OUT} | | V _{OUT} | | Vdif | | Vdif | I _{SS1} | I _{SS2} | t _{DPS} | |
| | V _{OUT(T)} | MIN. | MAX. | MIN. | MAX. | TYP. | MAX. | MAX. | MAX. | MAX. | |
| 0.80 | 0.7800 | 0.8200 | 0.7600 | 0.8400 | 400 | 575 | - | 112.500 | 22.500 | 650 | |
| 0.85 | 0.8300 | 0.8700 | 0.8100 | 0.8900 | | | | 112.625 | 22.625 | | |
| 0.90 | 0.8800 | 0.9200 | 0.8600 | 0.9400 | | | | 112.750 | 22.750 | | |
| 0.95 | 0.9300 | 0.9700 | 0.9100 | 0.9900 | | | | 112.875 | 22.875 | | |
| 1.00 | 0.9800 | 1.0200 | 0.9600 | 1.0400 | 240 | 405 | 113.000 | 23.000 | | | |
| 1.05 | 1.0300 | 1.0700 | 1.0100 | 1.0900 | | | 113.125 | 23.125 | | | |
| 1.10 | 1.0800 | 1.1200 | 1.0600 | 1.1400 | 180 | 305 | 113.250 | 23.250 | | | |
| 1.15 | 1.1300 | 1.1700 | 1.1100 | 1.1900 | | | 113.375 | 23.375 | | | |
| 1.20 | 1.1800 | 1.2200 | 1.1600 | 1.2400 | 150 | 215 | 460 | 113.500 | 23.500 | | |
| 1.25 | 1.2300 | 1.2700 | 1.2100 | 1.2900 | | | | 113.625 | 23.625 | | |
| 1.30 | 1.2800 | 1.3200 | 1.2600 | 1.3400 | | | | 113.750 | 23.750 | | |
| 1.35 | 1.3300 | 1.3700 | 1.3100 | 1.3900 | | | | 113.875 | 23.875 | | |
| 1.40 | 1.3800 | 1.4200 | 1.3600 | 1.4400 | | | | 114.000 | 24.000 | | |
| 1.45 | 1.4300 | 1.4700 | 1.4200 | 1.4800 | | | | 114.125 | 24.125 | | |
| 1.50 | 1.4800 | 1.5200 | 1.4700 | 1.5300 | 100 | 150 | 114.250 | 24.250 | | | |
| 1.55 | 1.5300 | 1.5700 | 1.5100 | 1.5900 | | | 114.375 | 24.375 | | | |
| 1.60 | 1.5800 | 1.6200 | 1.5600 | 1.6400 | | | 114.500 | 24.500 | | | |
| 1.65 | 1.6300 | 1.6700 | 1.6100 | 1.6900 | | | 114.625 | 24.625 | | | |
| 1.70 | 1.6800 | 1.7200 | 1.6600 | 1.7400 | | | 114.750 | 24.750 | | | |
| 1.75 | 1.7300 | 1.7700 | 1.7100 | 1.7900 | | | 114.875 | 24.875 | | | |
| 1.80 | 1.7800 | 1.8200 | 1.7600 | 1.8400 | | | 85 | 130 | 115.000 | 25.000 | |
| 1.85 | 1.8300 | 1.8700 | 1.8100 | 1.8900 | | | | | 115.125 | 25.125 | |
| 1.90 | 1.8800 | 1.9200 | 1.8600 | 1.9400 | | | | | 115.250 | 25.250 | |
| 1.95 | 1.9300 | 1.9700 | 1.9100 | 1.9900 | | | | | 115.375 | 25.375 | |
| 2.00 | 1.9800 | 2.0200 | 1.9600 | 2.0400 | 115.500 | 25.500 | | | | | |
| 2.05 | 2.0295 | 2.0705 | 2.0090 | 2.0910 | 115.625 | 25.625 | | | | | |
| 2.10 | 2.0790 | 2.1210 | 2.0580 | 2.1420 | 115.750 | 25.750 | | | | | |
| 2.15 | 2.1285 | 2.1715 | 2.1070 | 2.1930 | 115.875 | 25.875 | | | | | |
| 2.20 | 2.1780 | 2.2220 | 2.1560 | 2.2440 | 655 | 655 | | | 116.000 | 26.000 | |
| 2.25 | 2.2275 | 2.2725 | 2.2050 | 2.2950 | | | | | 116.125 | 26.125 | |
| 2.30 | 2.2770 | 2.3230 | 2.2540 | 2.3460 | | | 116.250 | 26.250 | | | |
| 2.35 | 2.3265 | 2.3735 | 2.3030 | 2.3970 | | | 116.375 | 26.375 | | | |
| 2.40 | 2.3760 | 2.4240 | 2.3520 | 2.4480 | | | 116.500 | 26.500 | | | |
| 2.45 | 2.4255 | 2.4745 | 2.4010 | 2.4990 | | | 116.625 | 26.625 | | | |
| 2.50 | 2.4750 | 2.5250 | 2.4500 | 2.5500 | | | 116.750 | 26.750 | | | |
| 2.55 | 2.5245 | 2.5755 | 2.4990 | 2.6010 | | | 116.875 | 26.875 | | | |
| 2.60 | 2.5740 | 2.6260 | 2.5480 | 2.6520 | | | 117.000 | 27.000 | | | |
| 2.65 | 2.6235 | 2.6765 | 2.5970 | 2.7030 | | | 117.125 | 27.125 | | | |
| 2.70 | 2.6730 | 2.7270 | 2.6460 | 2.7540 | 65 | 110 | 117.250 | 27.250 | | | |
| 2.75 | 2.7225 | 2.7775 | 2.6950 | 2.8050 | | | 117.375 | 27.375 | | | |
| 2.80 | 2.7720 | 2.8280 | 2.7440 | 2.8560 | | | 117.500 | 27.500 | | | |
| 2.85 | 2.8215 | 2.8785 | 2.7930 | 2.9070 | | | 117.625 | 27.625 | | | |
| 2.90 | 2.8710 | 2.9290 | 2.8420 | 2.9580 | | | 117.750 | 27.750 | | | |
| 2.95 | 2.9205 | 2.9795 | 2.8910 | 3.0090 | | | 117.875 | 27.875 | | | |

ELECTRICAL CHARACTERISTICS (Continued)

Voltage Chart 2

| NOMINAL OUTPUT VOLTAGE (V) | OUTPUT VOLTAGE (HS Mode) (V) | | OUTPUT VOLTAGE (PS Mode) (V) | | DROPOUT VOLTAGE 1 Vdif 1 (mV) I _{OUT} =300mA | | DROPOUT VOLTAGE 2 Vdif 2 (mV) I _{OUT} =1000mA | | SUPPLY CURRENT 1 (XC6220C/D) (μA) | SUPPLY CURRENT 2 (XC6220C/D) (μA) | PS SWITCH DELAY TIME (μs) |
|-------------------------------------|---------------------------------------|--------|---------------------------------------|--------|--|--------|---|------|--|--|---------------------------------------|
| | V _{OUT} | | V _{OUT} | | Vdif | | Vdif | | I _{SS1} | I _{SS2} | t _{DPS} |
| | V _{OUT(T)} | MIN. | MAX. | MIN. | MAX. | TYP. | MAX. | MAX. | MAX. | MAX. | MAX. |
| 3.00 | 2.9700 | 3.0300 | 2.9400 | 3.0600 | 60 | 95 | | | 118.000 | 28.000 | 1200 |
| 3.05 | 3.0195 | 3.0805 | 2.9890 | 3.1110 | | | | | 118.125 | 28.125 | |
| 3.10 | 3.0690 | 3.1310 | 3.0380 | 3.1620 | | | | | 118.250 | 28.250 | |
| 3.15 | 3.1185 | 3.1815 | 3.0870 | 3.2130 | | | | | 118.375 | 28.375 | |
| 3.20 | 3.1680 | 3.2320 | 3.1360 | 3.2640 | | | | | 118.500 | 28.500 | |
| 3.25 | 3.2175 | 3.2825 | 3.1850 | 3.3150 | | | | | 118.625 | 28.625 | |
| 3.30 | 3.2670 | 3.3330 | 3.2340 | 3.3660 | | | | | 118.750 | 28.750 | |
| 3.35 | 3.3165 | 3.3835 | 3.2830 | 3.4170 | | | | | 118.875 | 28.875 | |
| 3.40 | 3.3660 | 3.4340 | 3.3320 | 3.4680 | | | | | 119.000 | 29.000 | |
| 3.45 | 3.4155 | 3.4845 | 3.3810 | 3.5190 | | | | | 119.125 | 29.125 | |
| 3.50 | 3.4650 | 3.5350 | 3.4300 | 3.5700 | | | | | 119.250 | 29.250 | |
| 3.55 | 3.5145 | 3.5855 | 3.4790 | 3.6210 | | | | | 119.375 | 29.375 | |
| 3.60 | 3.5640 | 3.6360 | 3.5280 | 3.6720 | | | | | 119.500 | 29.500 | |
| 3.65 | 3.6135 | 3.6865 | 3.5770 | 3.7230 | | | | | 119.625 | 29.625 | |
| 3.70 | 3.6630 | 3.7370 | 3.6260 | 3.7740 | | | | | 119.750 | 29.750 | |
| 3.75 | 3.7125 | 3.7875 | 3.6750 | 3.8250 | | | | | 119.875 | 29.875 | |
| 3.80 | 3.7620 | 3.8380 | 3.7240 | 3.8760 | | | | | 120.000 | 30.000 | |
| 3.85 | 3.8115 | 3.8885 | 3.7730 | 3.9270 | | | | | 120.125 | 30.125 | |
| 3.90 | 3.8610 | 3.9390 | 3.8220 | 3.9780 | | | | | 120.250 | 30.250 | |
| 3.95 | 3.9105 | 3.9895 | 3.8710 | 4.0290 | | | | | 120.375 | 30.375 | |
| 4.00 | 3.9600 | 4.0400 | 3.9200 | 4.0800 | 120.500 | 30.500 | | | | | |
| 4.05 | 4.0095 | 4.0905 | 3.9690 | 4.1310 | 120.625 | 30.625 | | | | | |
| 4.10 | 4.0590 | 4.1410 | 4.0180 | 4.1820 | 120.750 | 30.750 | | | | | |
| 4.15 | 4.1085 | 4.1915 | 4.0670 | 4.2330 | 120.875 | 30.875 | | | | | |
| 4.20 | 4.1580 | 4.2420 | 4.1160 | 4.2840 | 121.000 | 31.000 | | | | | |
| 4.25 | 4.2075 | 4.2925 | 4.1650 | 4.3350 | 121.125 | 31.125 | | | | | |
| 4.30 | 4.2570 | 4.3430 | 4.2140 | 4.3860 | 121.250 | 31.250 | | | | | |
| 4.35 | 4.3065 | 4.3935 | 4.2630 | 4.4370 | 121.375 | 31.375 | | | | | |
| 4.40 | 4.3560 | 4.4440 | 4.3120 | 4.4880 | 121.500 | 31.500 | | | | | |
| 4.45 | 4.4055 | 4.4945 | 4.3610 | 4.5390 | 121.625 | 31.625 | | | | | |
| 4.50 | 4.4550 | 4.5450 | 4.4100 | 4.5900 | 121.750 | 31.750 | | | | | |
| 4.55 | 4.5045 | 4.5955 | 4.4590 | 4.6410 | 121.875 | 31.875 | | | | | |
| 4.60 | 4.5540 | 4.6460 | 4.5080 | 4.6920 | 122.000 | 32.000 | | | | | |
| 4.65 | 4.6035 | 4.6965 | 4.5570 | 4.7430 | 122.125 | 32.125 | | | | | |
| 4.70 | 4.6530 | 4.7470 | 4.6060 | 4.7940 | 122.250 | 32.250 | | | | | |
| 4.75 | 4.7025 | 4.7975 | 4.6550 | 4.8450 | 122.375 | 32.375 | | | | | |
| 4.80 | 4.7520 | 4.8480 | 4.7040 | 4.8960 | 122.500 | 32.500 | | | | | |
| 4.85 | 4.8015 | 4.8985 | 4.7530 | 4.9470 | 122.625 | 32.625 | | | | | |
| 4.90 | 4.8510 | 4.9490 | 4.8020 | 4.9980 | 122.750 | 32.750 | | | | | |
| 4.95 | 4.9005 | 4.9995 | 4.8510 | 5.0490 | 122.875 | 32.875 | | | | | |
| 5.00 | 4.9500 | 5.0500 | 4.9000 | 5.1000 | 123.000 | 33.000 | | | | | |
| | | | | | 53 | 85 | | | | | 1450 |

OPERATIONAL EXPLANATION



The voltage divided by resistors R1 & R2 is compared with the internal reference voltage by the error amplifier. The P-channel MOSFET which is connected to the V_{OUT} pin is then driven by the subsequent output signal. The output voltage at the V_{OUT} pin is controlled & stabilized by a system of negative feedback. The current limit circuit and short protect circuit operate in relation to the level of output current. The GO function monitors the output current and switches the IC between two operating modes according to the level of output current. Further, the IC's internal circuitry can be shutdown via the CE pin's signal.

<GreenOperation>

The XC6220 series always operates in a green operation (GO) mode. The GO mode enables the IC to switch automatically between the high speed (HS) mode or the power save (PS) mode according to the level of output current. The switching point of the HS mode and the PS mode is fixed inside the IC. When the output current becomes $I_{GOR}=1.0\text{mA}$ (MIN.) or below, the mode changes automatically to the PS mode after a delay time of hundreds of microseconds. Supply current in light load is greatly reduced. Also when the output current becomes I_{GO} 10mA (MAX.) or more, the mode changes automatically to the HS mode and the IC returns to high speed operation.

<Low ESR capacitor>

The XC6220 series has a built-in phase compensation circuit which means that a stable output voltage is achieved even if the IC is used with low ESR capacitors. In order to ensure stable phase compensation it is recommended that a C_L capacitor is connected as close as possible to the V_{OUT} pin and V_{SS} pin. For a stable power supply, please connect an input capacitor (C_{IN}) between the V_{IN} pin and the V_{SS} pin. Values required for the phase compensation are shown in the chart below. If a loss of the capacitance happens, the stable phase compensation may not be obtained. Please ensure to use a capacitor which does not depend on bias or temperature too much.

Recommended output capacitor (C_L) Values corresponding to input capacitor (C_{IN})

| OUTPUT VOLTAGE (V) | INPUT CAPACITOR VALUE | | |
|--------------------|-----------------------|-------------------|-------------------|
| | 4.7 μF | 10 μF | 22 μF |
| 0.80V~0.95V | × | × | 22 μF |
| 1.00V~1.45V | 47 μF | 47 μF | 22 μF |
| 1.50V~1.75V | 47 μF | 22 μF | 10 μF |
| 1.80V~2.95V | 47 μF | 6.8 μF | 6.8 μF |
| 3.00V~3.50V | 47 μF | 4.7 μF | 4.7 μF |
| 3.55V~5.00V | 47 μF | 10 μF | 6.8 μF |

× No option

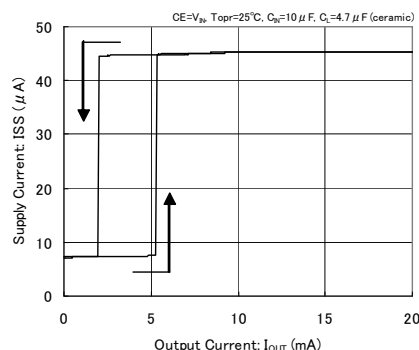
<Current Limiter, Short-Circuit Protection>

The XC6220 series includes a fold-back circuit, which aids the operation of the current limiter and circuit protection. When the load current reaches the current limit level, the fold-back circuit operates and output voltage drops. As a result of this drop in output voltage, output current also decreases. When the output pin is shorted, a current of about 180mA flows.

<CE Pin>

The IC's internal circuitry can be shutdown via the signal from the CE pin with the XC6220 series. With the XC6220B/D series, output at the V_{OUT} pin will be pulled down to the V_{SS} level. However, with XC6220A/B series, the C_L auto-discharge resistor is connected in parallel to R1 and R2 while the power supply is applied to the V_{IN} pin. Therefore, the time until the V_{OUT} pin reaches the V_{SS} level is shortened. The output voltage becomes unstable, when the CE pin is open. If this IC is used with the correct output voltage for the CE pin, the logic is fixed and the IC will operate normally. However, with the XC6220C/D series, supply current may increase as a result of through current in the IC's internal circuitry when medium voltage is input.

XC6220x301



OPERATIONAL EXPLANATION (Continued)

<CL High Speed Auto-Discharge Function>

The XC6220B/D series can quickly discharge the electric charge at the output capacitor (C_L), when a low signal to the CE pin, which enables the whole IC circuit put into an OFF state, is inputted to the CE pin via the N-channel transistor located between the V_{OUT} pin and the V_{SS} pin (cf. BLOCK DIAGRAM). The C_L auto-discharge resistance value is fixed to $460\ \Omega$ ($V_{IN}=6.0V$, $V_{OUT}=5.0V$ at TYP.). The discharge time of the output capacitor (C_L) is set by the C_L auto-discharge resistance (R_{DCHG}) and the output capacitor (C_L). By setting a time constant of the C_L auto-discharge resistance value [R_{DCHG}] and an output capacitor value (C_L) as τ ($\tau = C \times R_{DCHG}$), the output voltage after discharge via the N channel transistor is calculated by the following formulas.

$$V = V_{OUT} \times e^{-t/\tau}, \text{ or } t = \tau \ln(V_{OUT(E)} / V)$$

where

V : Output voltage after discharge

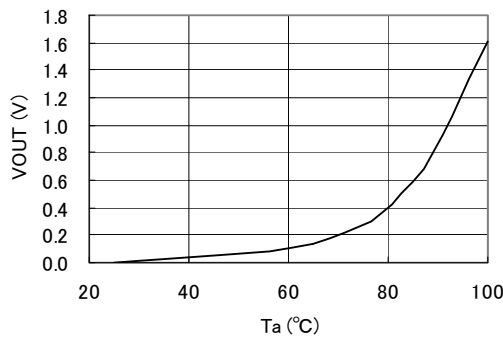
$V_{OUT(E)}$: Output voltage

t : Discharge time

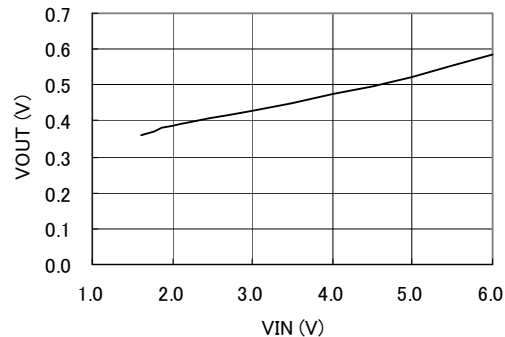
τ : C_L auto-discharge resistance R_{DCHG} \times Output capacitor (C_L) value C

For the XC6220A/C series, output voltage may rises when in the high stand-by mode. Please note that in that case, the typical characteristics may worse. When the XC6220A/C series is used, please be noted the characteristics shown below.

XC6220A501xx



Output Voltage vs. Input Voltage



<Thermal Shutdown>

When the junction temperature of the built-in driver transistor reaches the temperature limit level ($150^{\circ}C$ TYP.), the thermal shutdown circuit operates and the driver transistor will be turned OFF. The IC resumes its operation when the thermal shutdown function is released and the IC's operation is automatically restored because the junction temperature drops to the level of the thermal shutdown release voltage.

<Inrush Current Protection>

The XC6220 series includes an inrush current protection circuit.

The inrush current protection circuit suppresses inrush current charged to C_L when the IC starts up to 700 mA (MAX.) for approximately 1 ms.

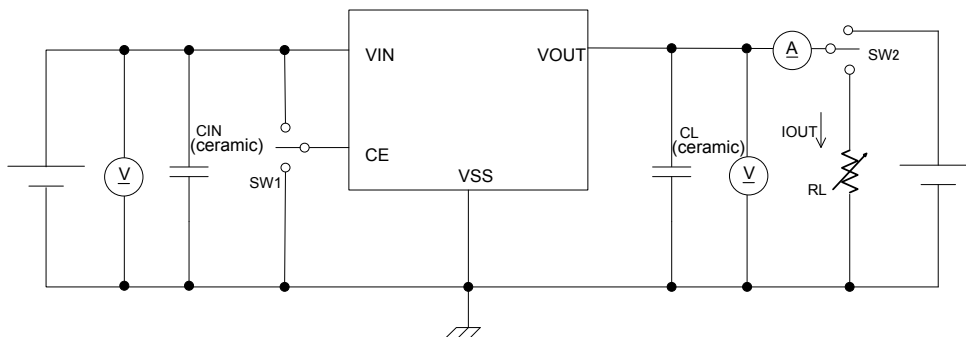
* Please note that the device can not provide the output current beyond 700 mA for a period of approximately 1 ms after the CE pin goes high.

NOTES ON USE

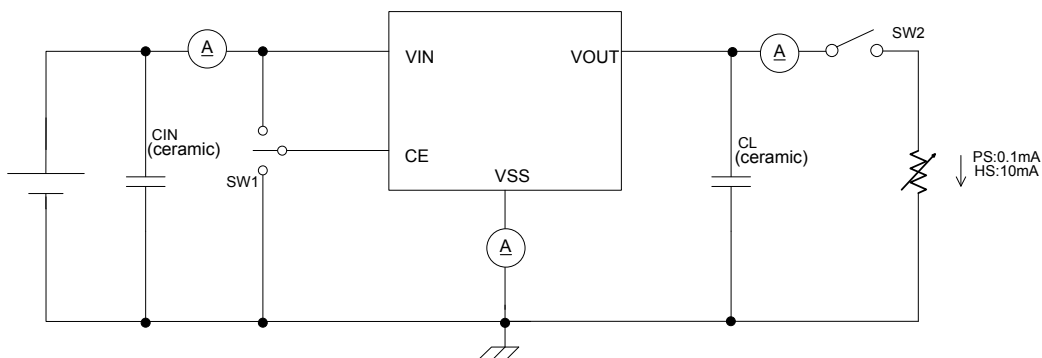
1. Please use this IC within the stated absolute maximum ratings. The IC is liable to malfunction should the ratings be exceeded.
2. Where wiring impedance is high, operations may become unstable due to noise and/or phase lag depending on output current. Please strengthen V_{IN} and V_{SS} wiring in particular.
3. Please wire the input capacitor (C_{IN}) and the output capacitor (C_L) as close to the IC as possible.

TEST CIRCUITS

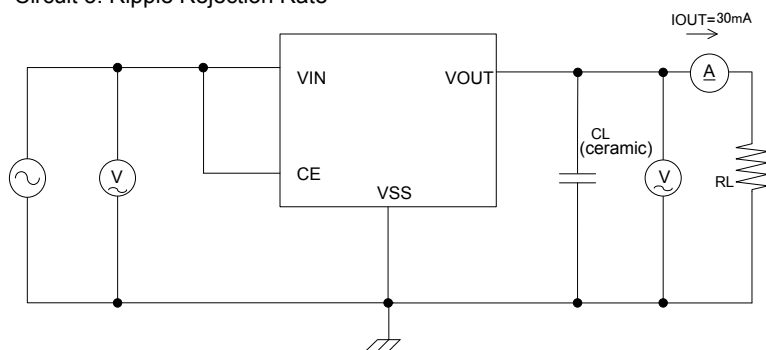
Circuit 1: Output Voltage, Output Current, Dropout Voltage, Input/Operating Voltage, Line Regulation, Load Regulation, Current Limit, Short Current, CL Discharge Resistance



Circuit 2: Supply Current, Stand-by Current

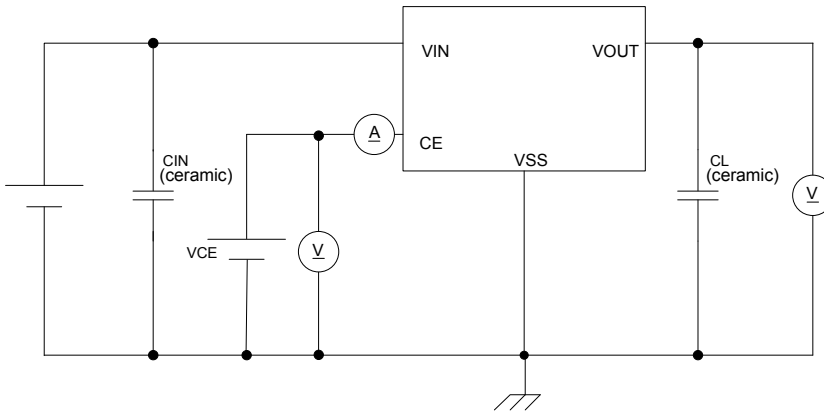


Circuit 3: Ripple Rejection Rate

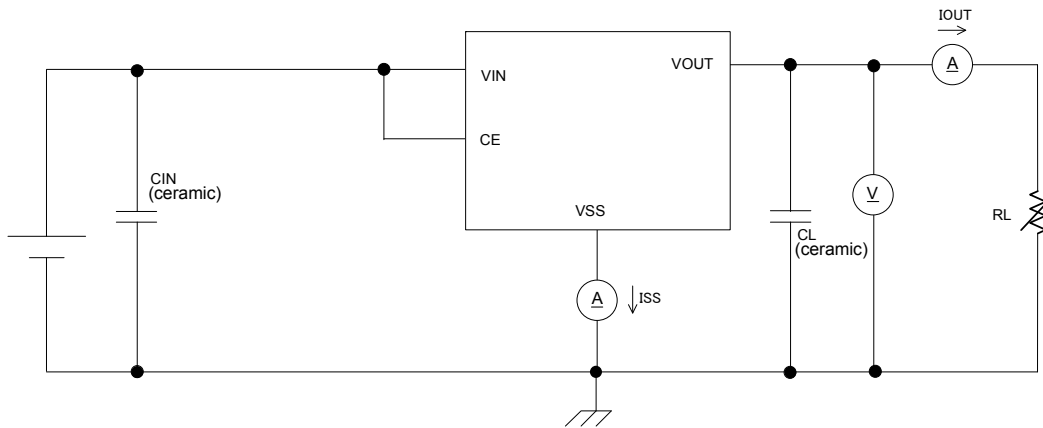


TEST CIRCUITS (Continued)

Circuit 4: CE "H" "L" Level Voltage, CE "H" "L" Level Current

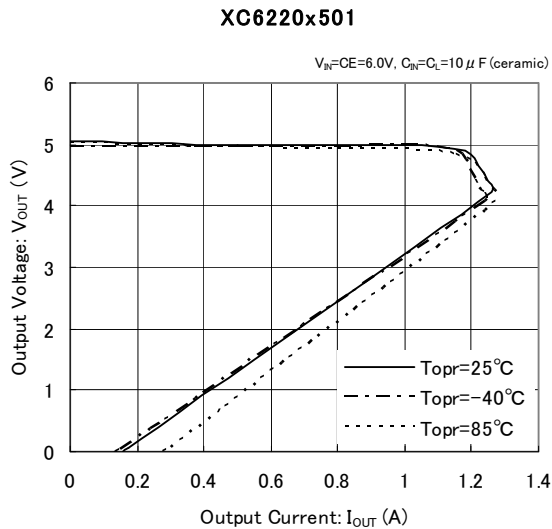
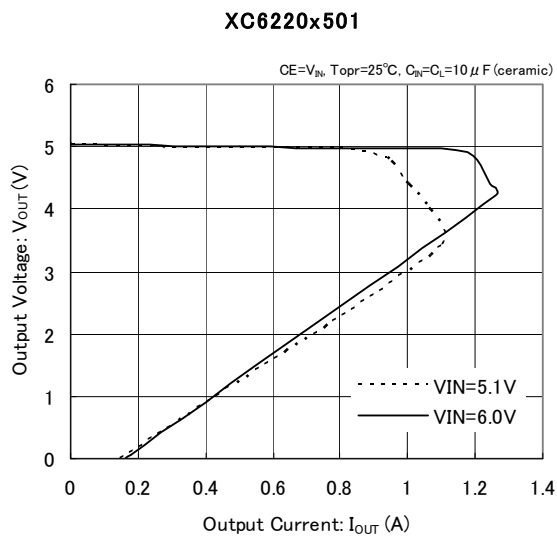
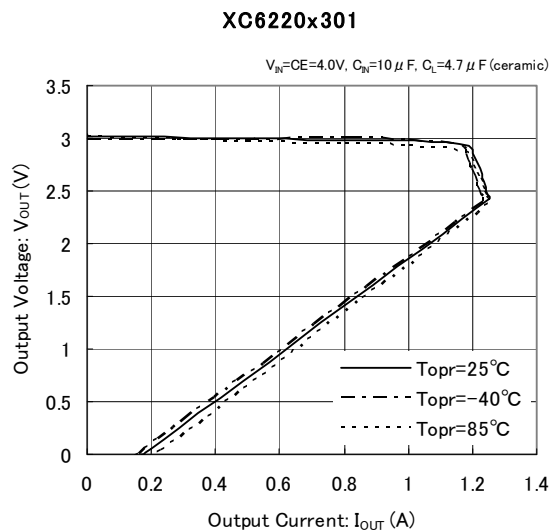
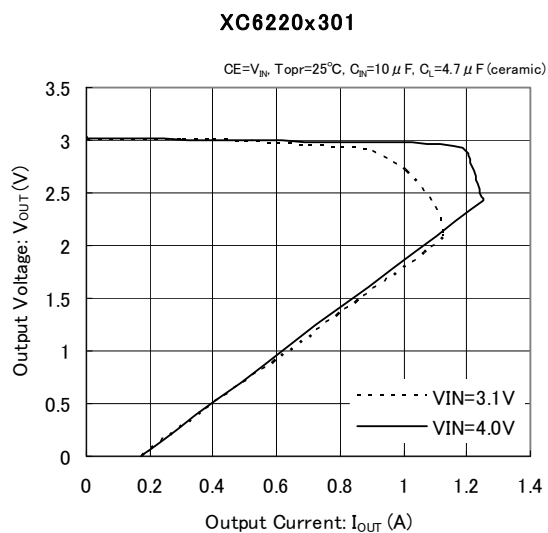
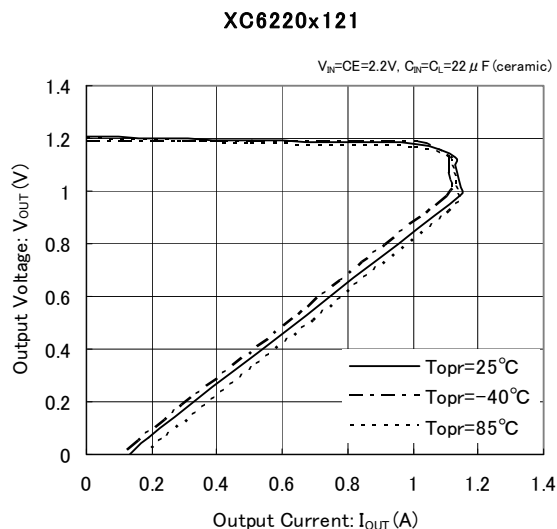
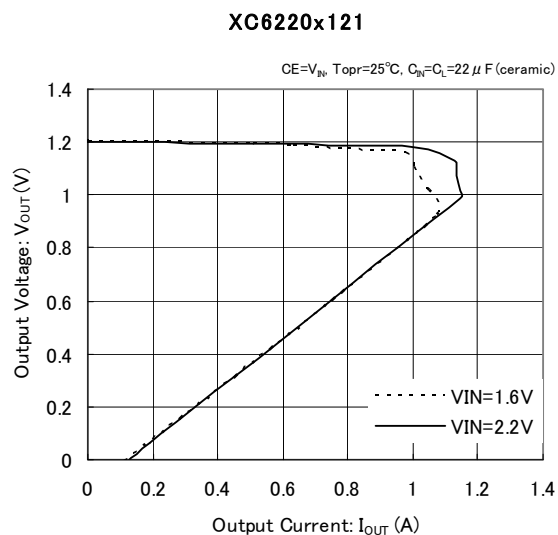


Circuit 5: HS Switching Current, PS Switching Current, Switch Current Hysteresis Range, PS Switching Delay Time



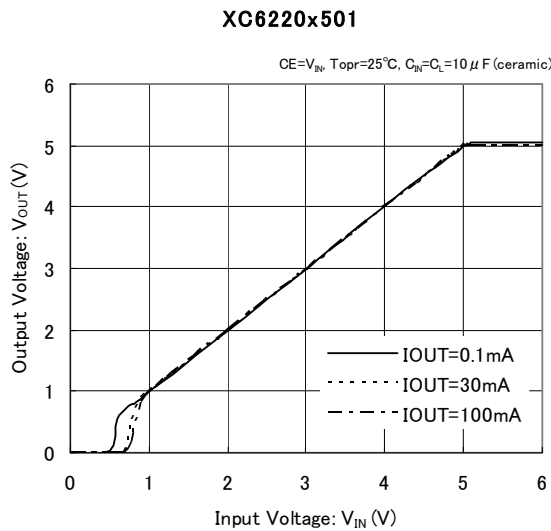
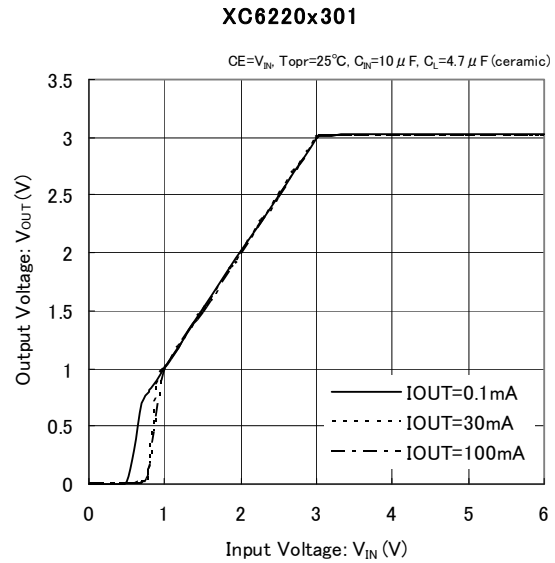
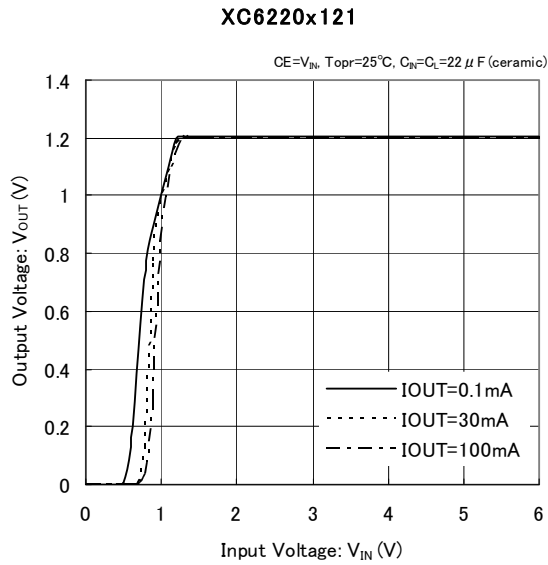
TYPICAL PERFORMANCE CHARACTERISTICS

(1) Output Voltage vs. Output Current

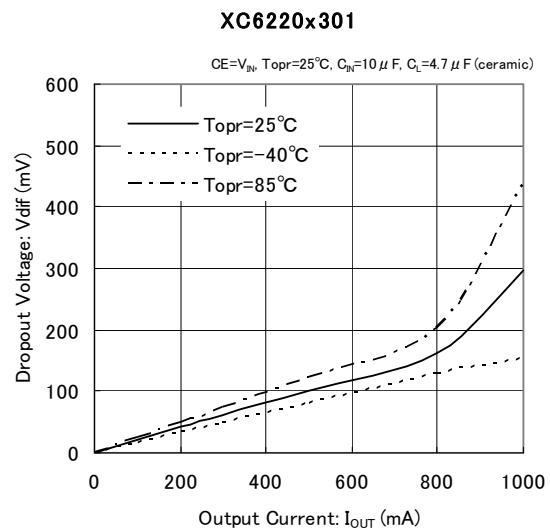
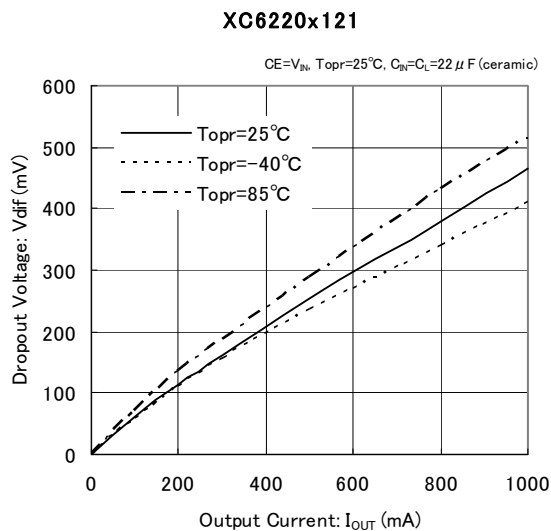


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(2) Output Voltage vs. Input Voltage



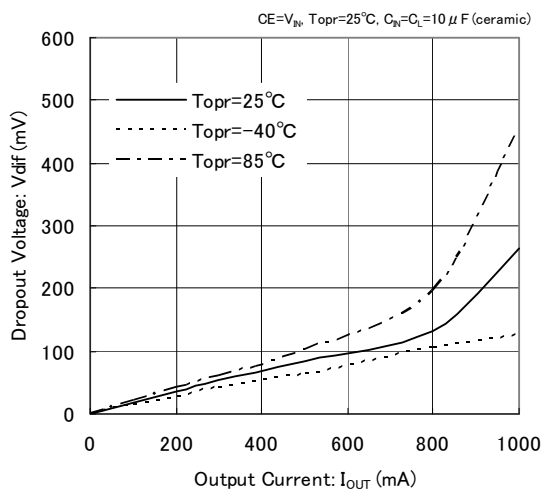
(3) Dropout Voltage vs. Output Current



■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

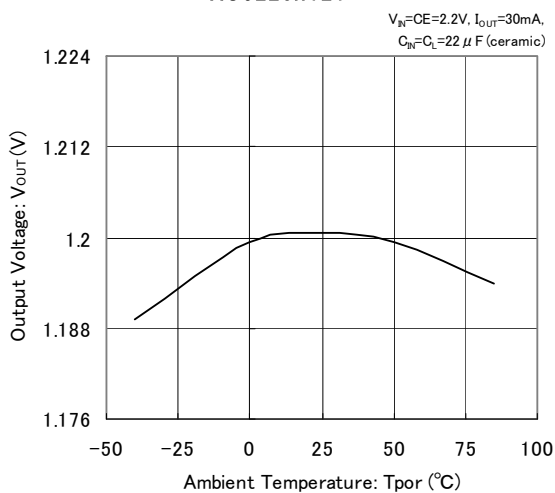
(3) Dropout Voltage vs. Output Current

XC6220x501

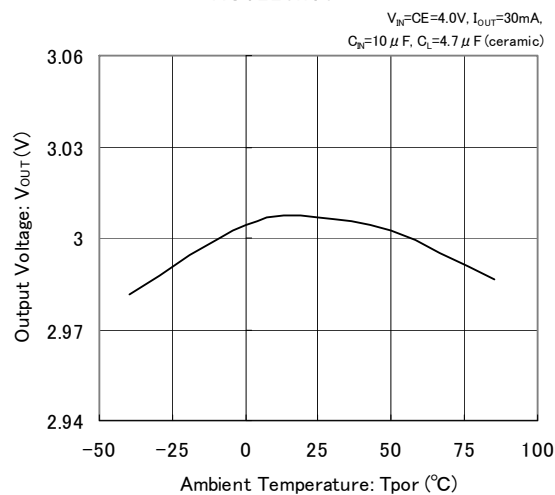


(4) Output Voltage vs. Ambient Temperature

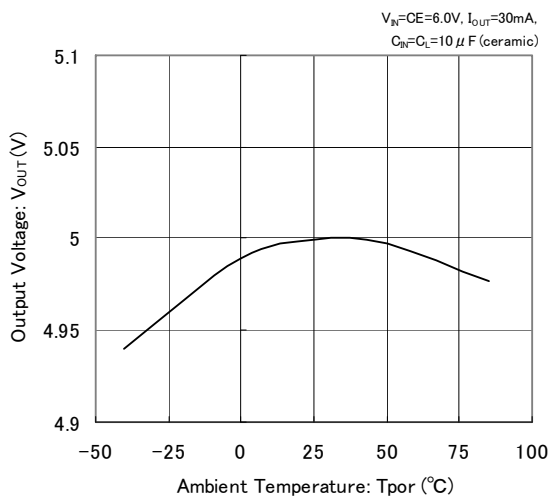
XC6220x121



XC6220x301

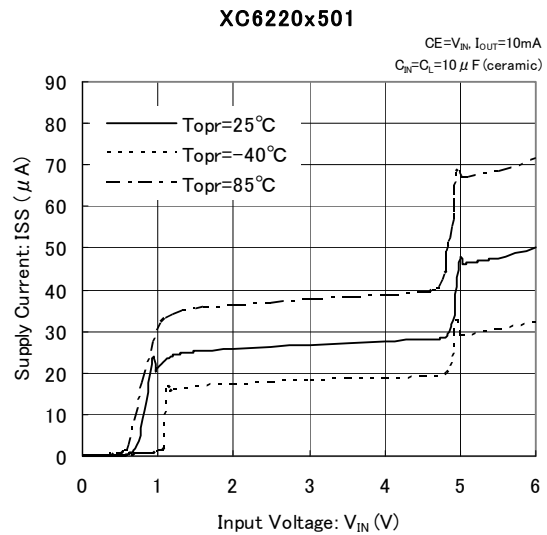
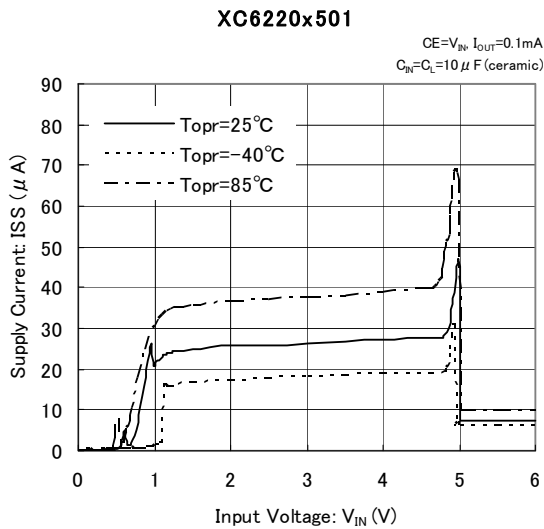
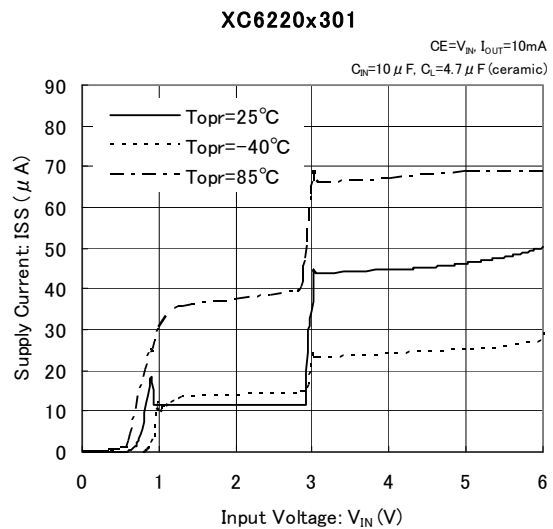
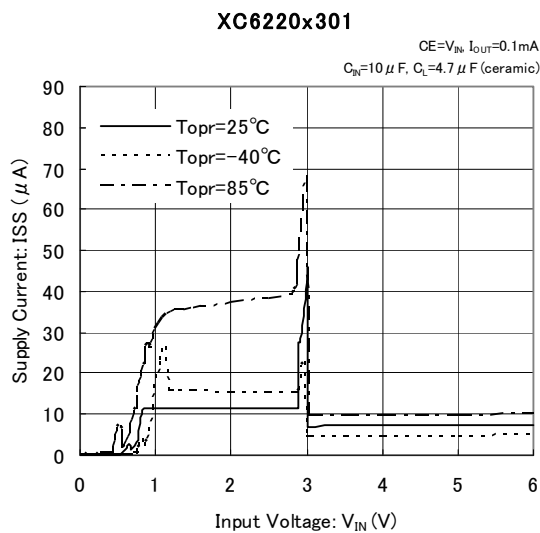
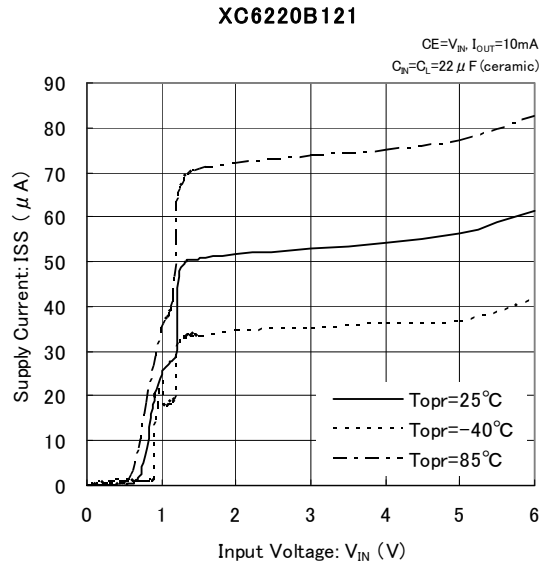
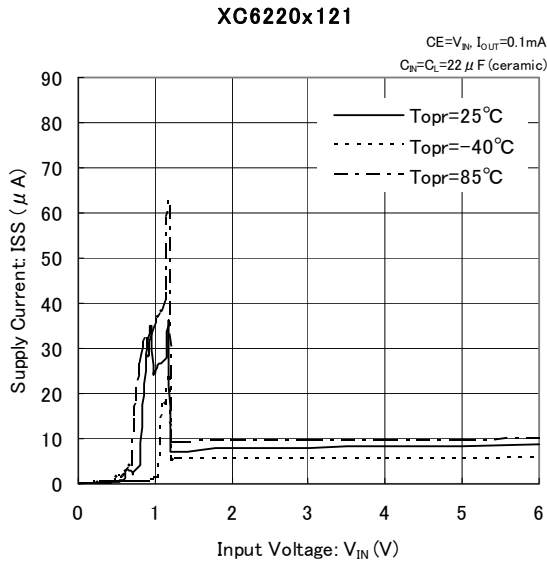


XC6220x501



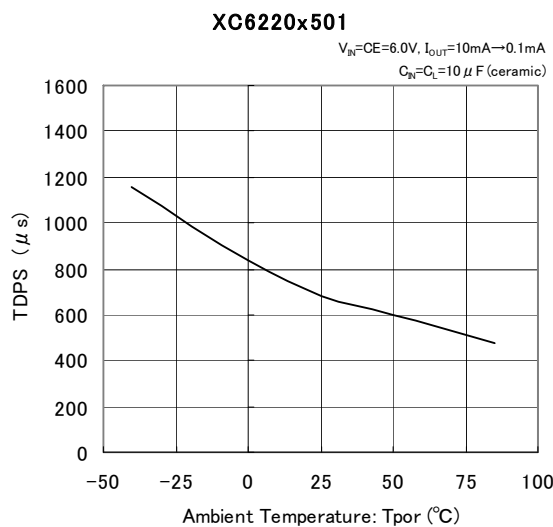
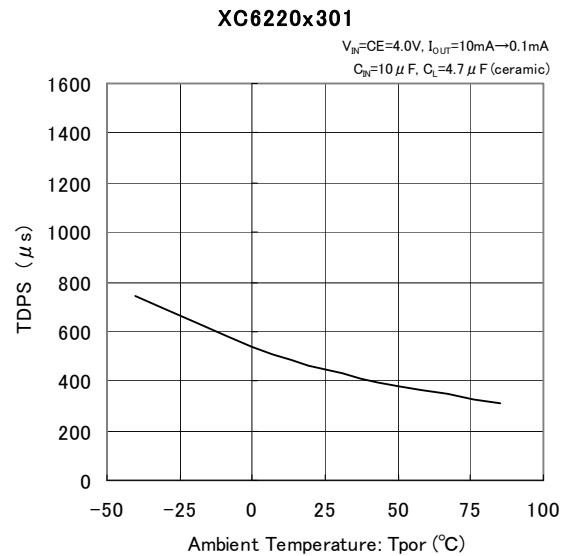
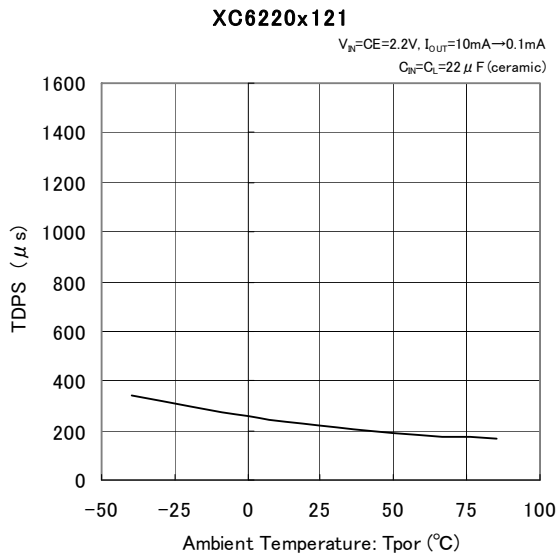
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(5) Supply Current vs. Input Voltage

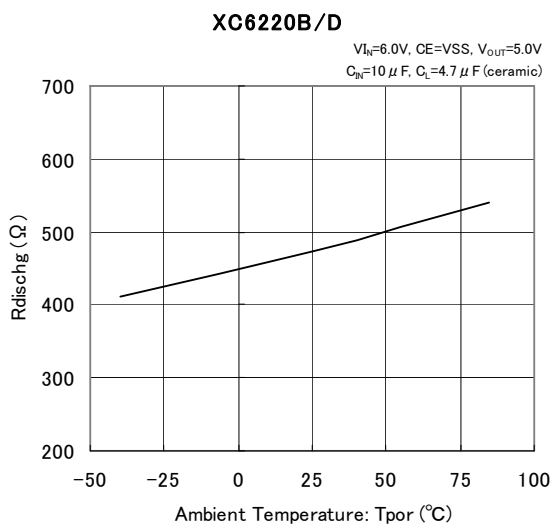


■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

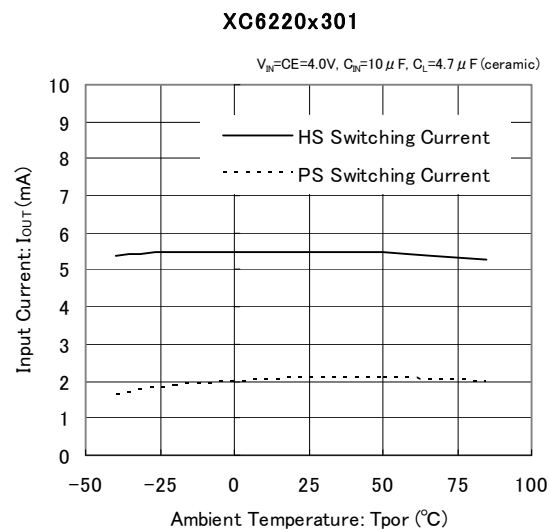
(6) PS Switching Delay Time vs. Ambient Temperature



(7) CL Discharge Resistance vs. Ambient Temperature

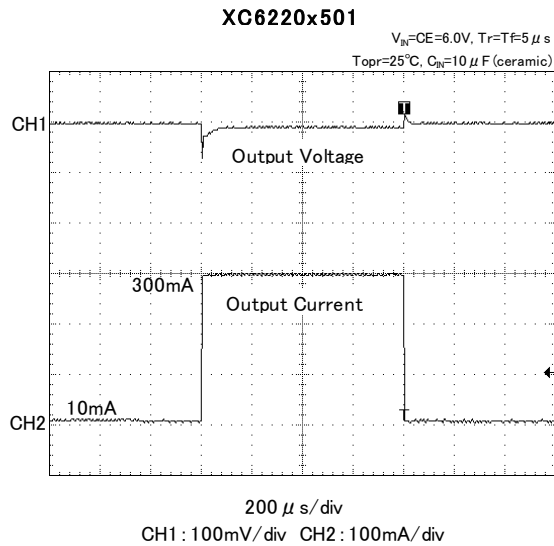
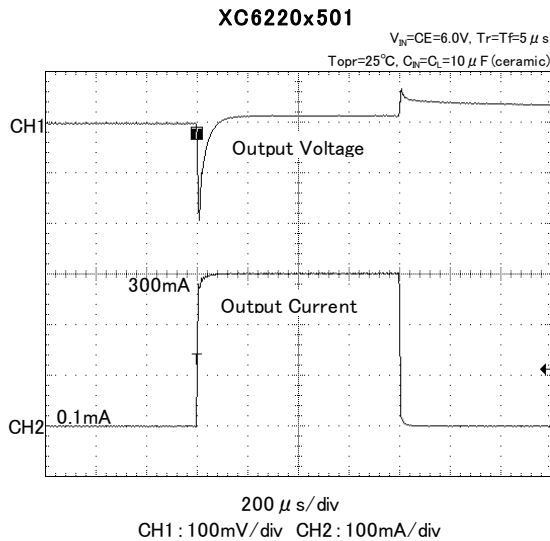
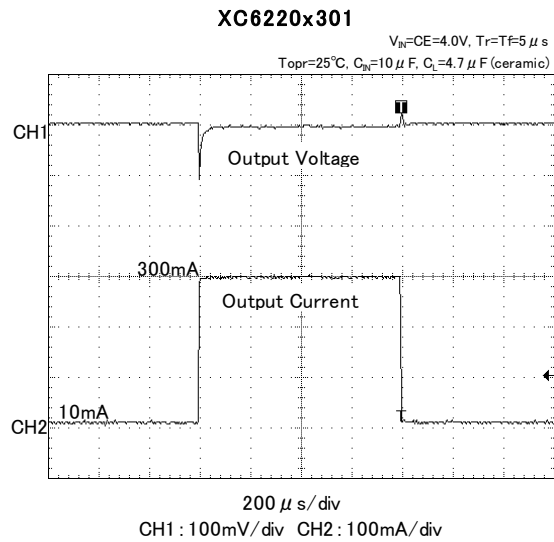
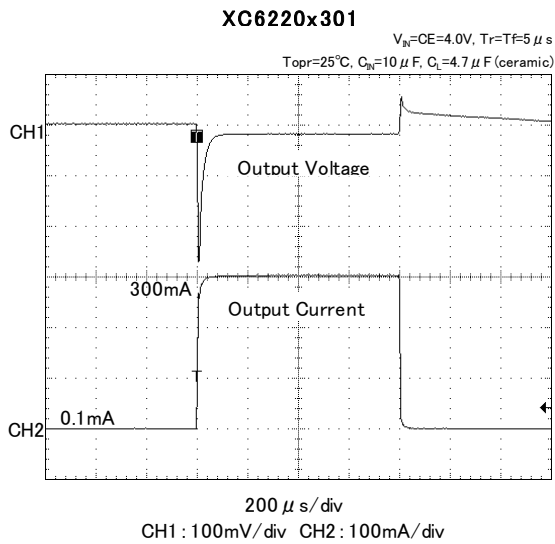
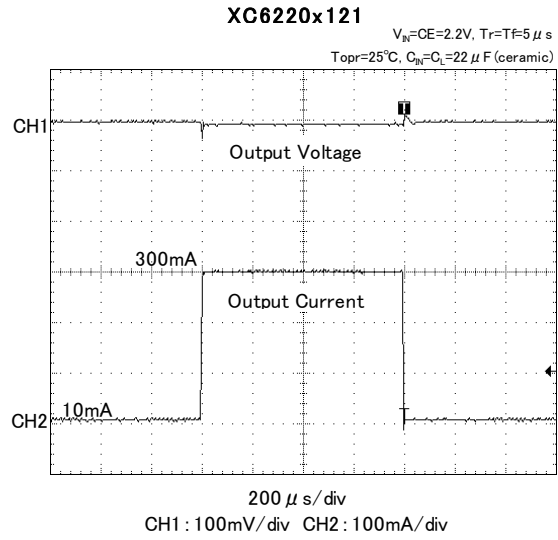
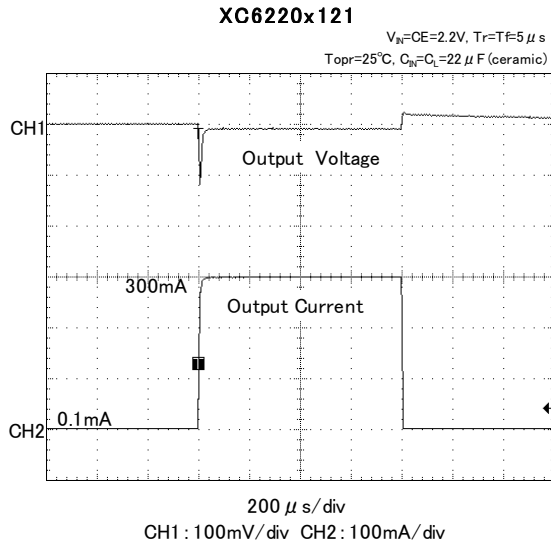


(8) PS/HS Switch Current vs. Ambient Temperature



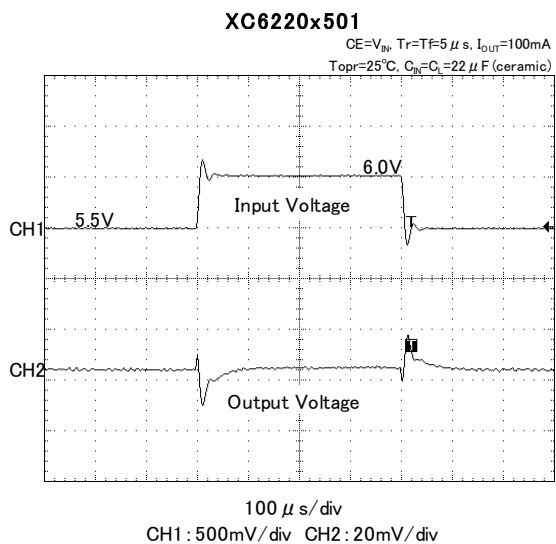
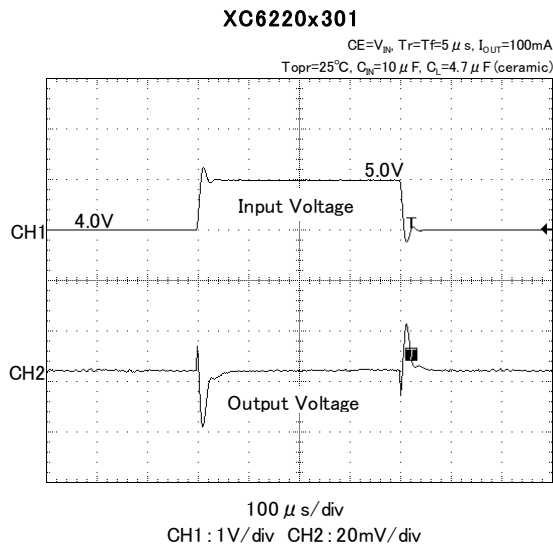
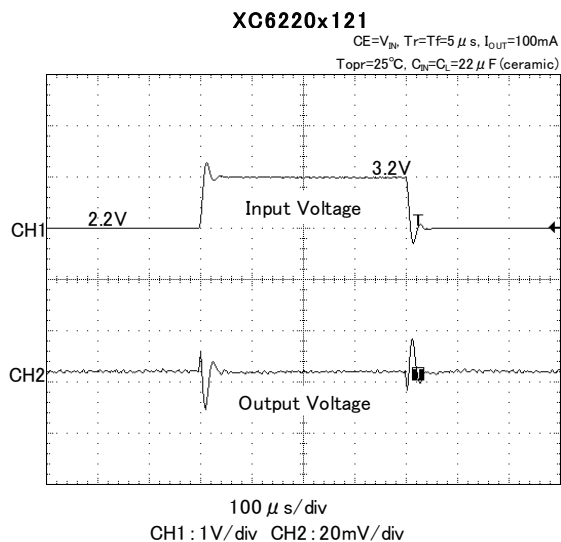
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(9) Load Transient Response

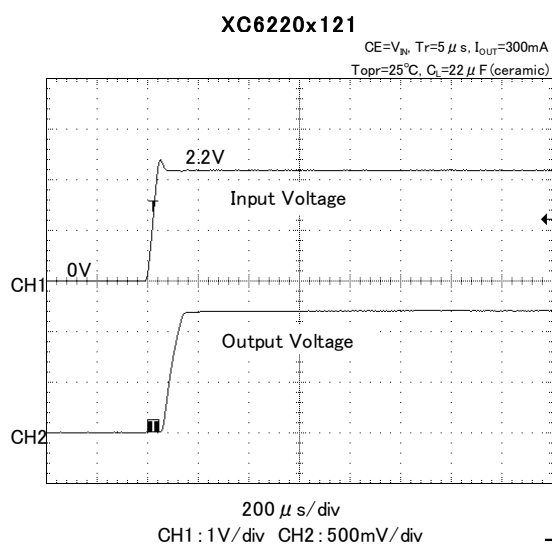
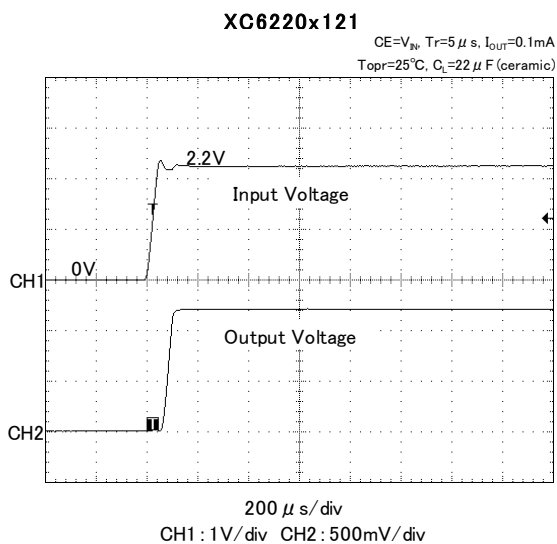


■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(10) Line Transient Response

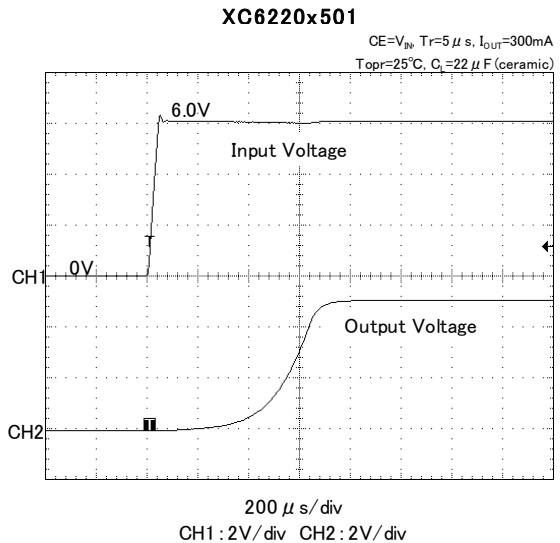
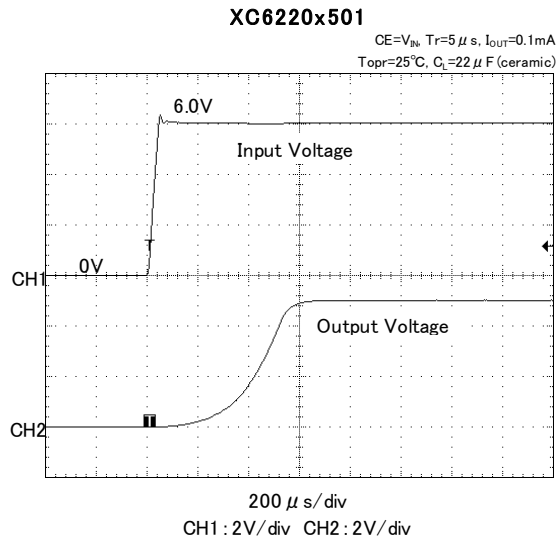
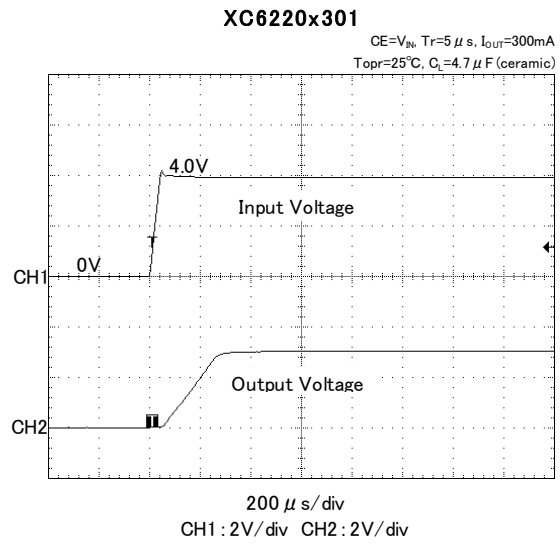
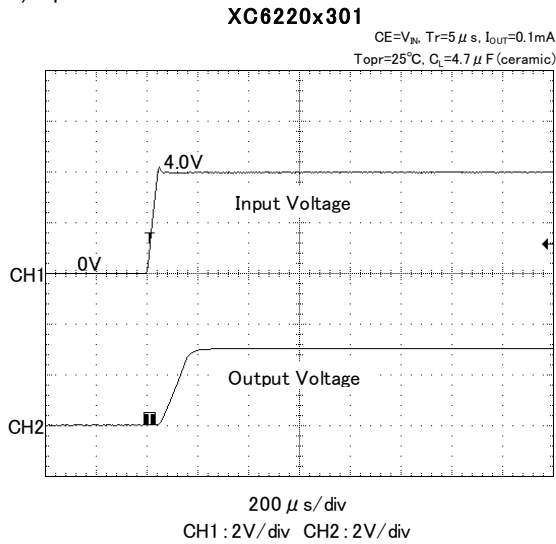


(11) Input Rise Characteristics

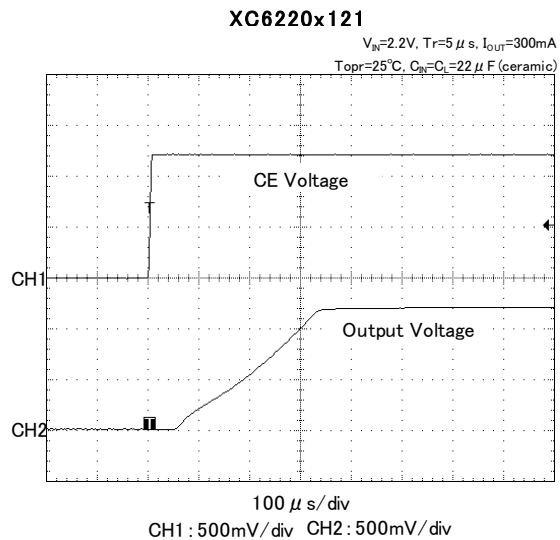
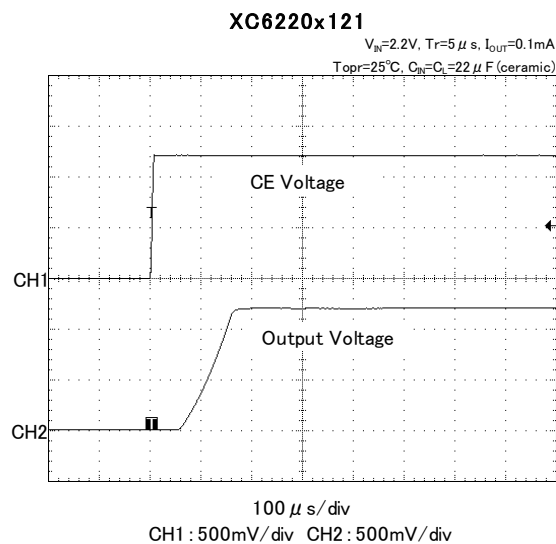


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(11) Input Rise Characteristics

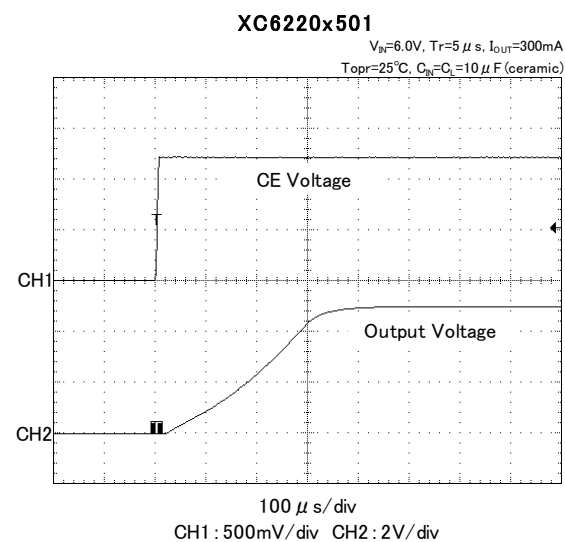
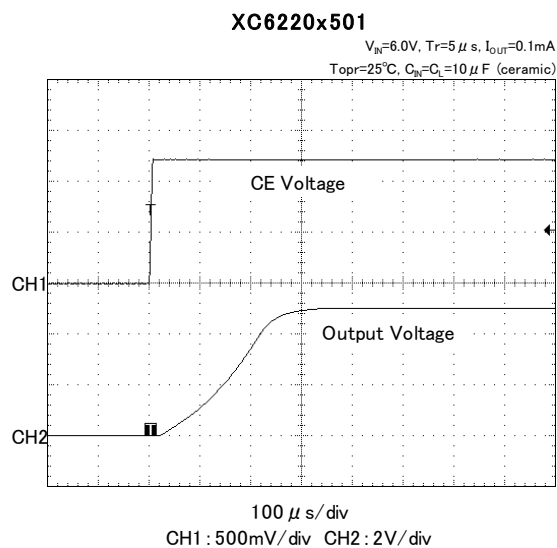
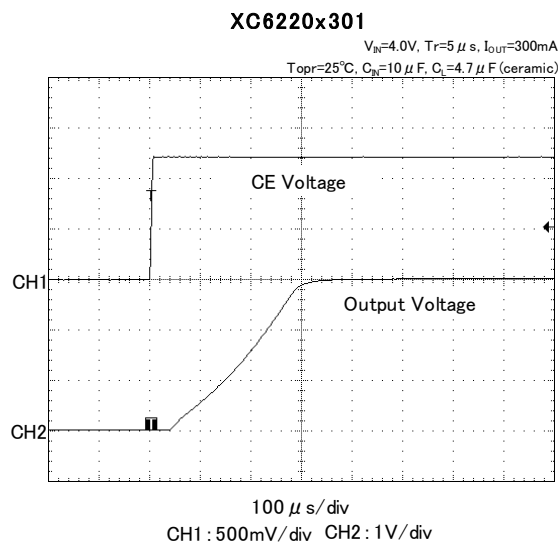
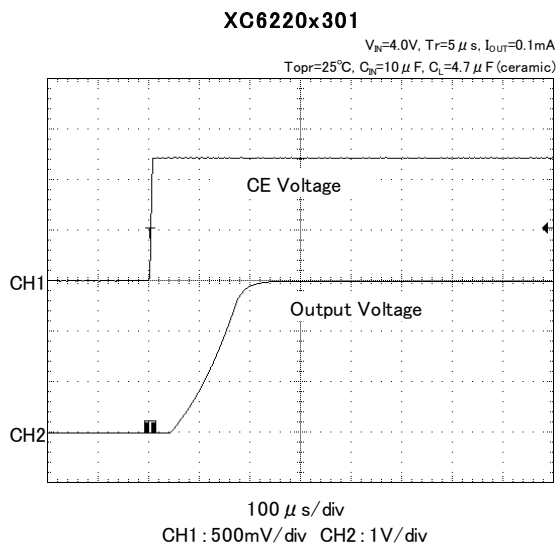


(12) CE Rise Characteristics

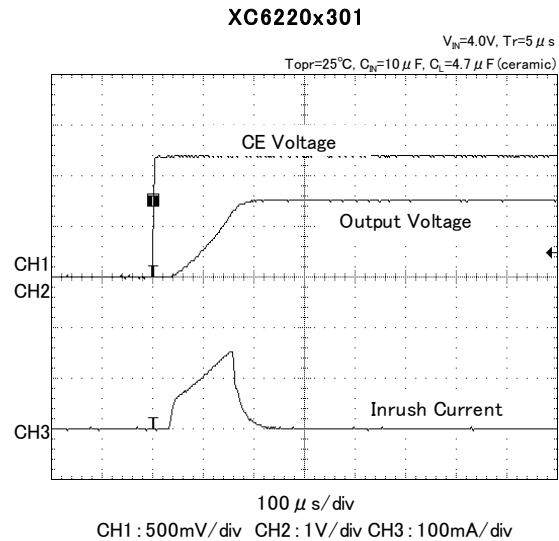
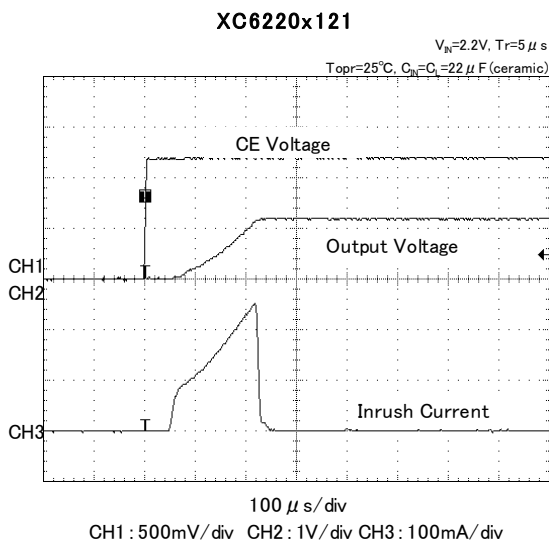


■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(12) CE Rise Characteristics



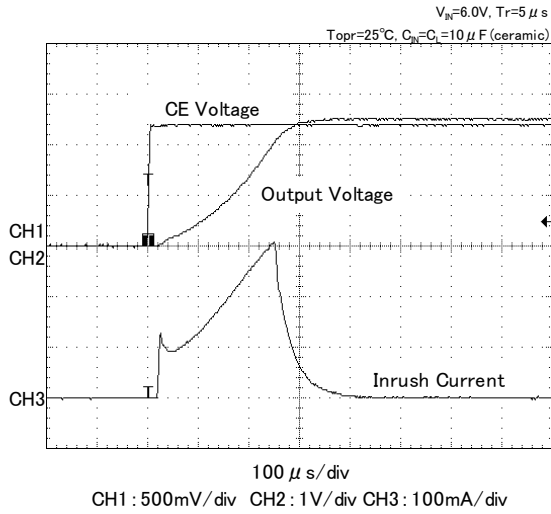
(13) Inrush Current



TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

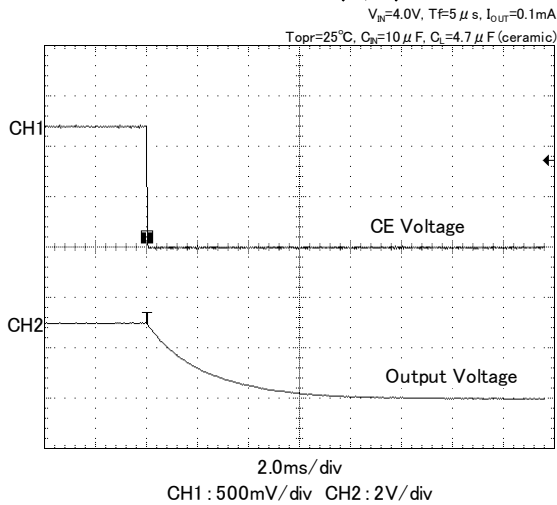
(13) Inrush Current

XC6220x501

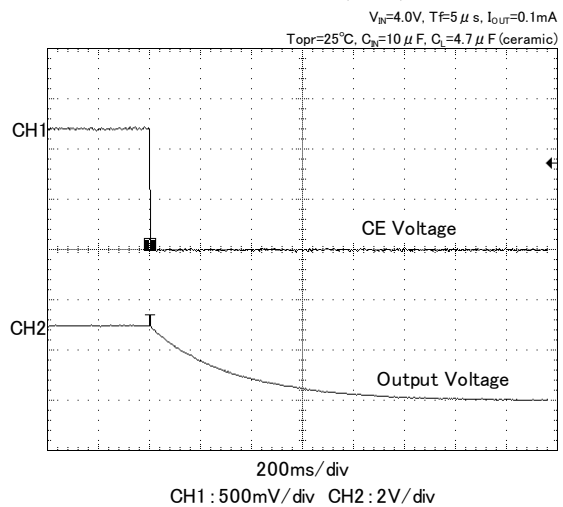


(14) CL Discharge Time

XC6220x301 (B/D)

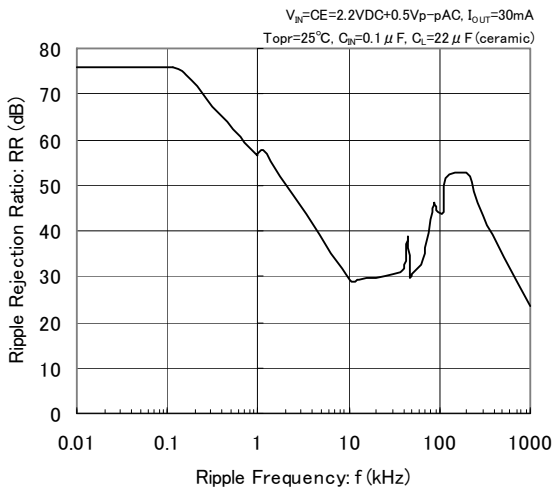


XC6220x301 (A/C)

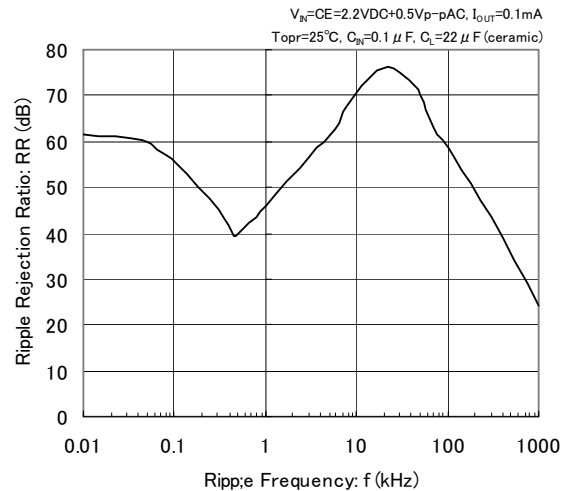


(15) Ripple Rejection Rate

XC6220x121 (HighSpeed mode)

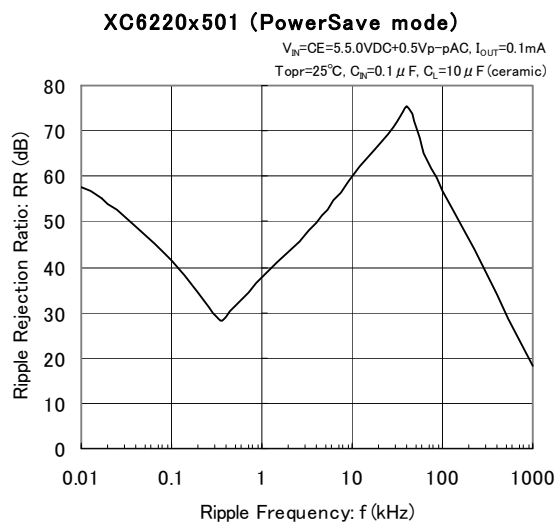
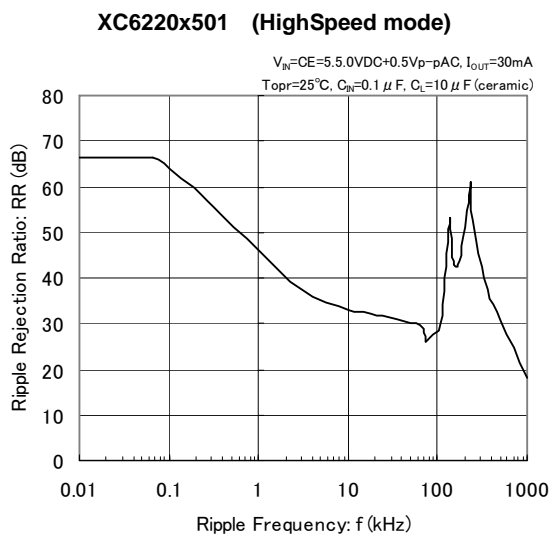
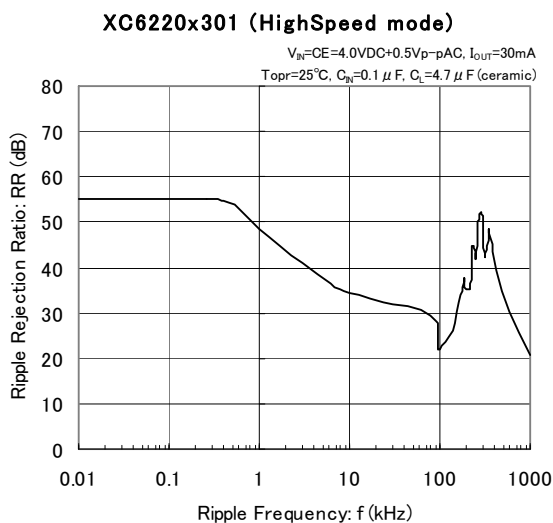


XC6220x121 (PowerSave mode)



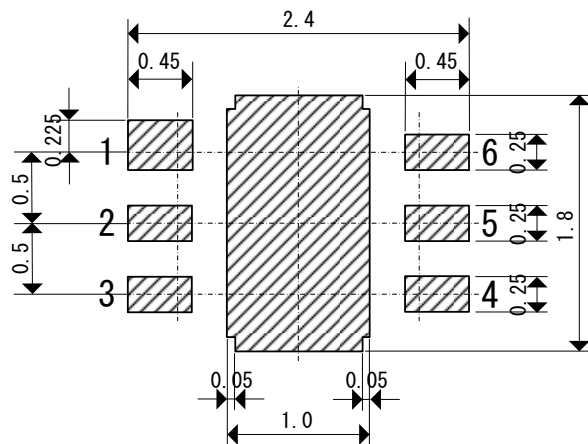
■ **TYPICAL PERFORMANCE CHARACTERISTICS (Continued)**

(15) Ripple Rejection Rate

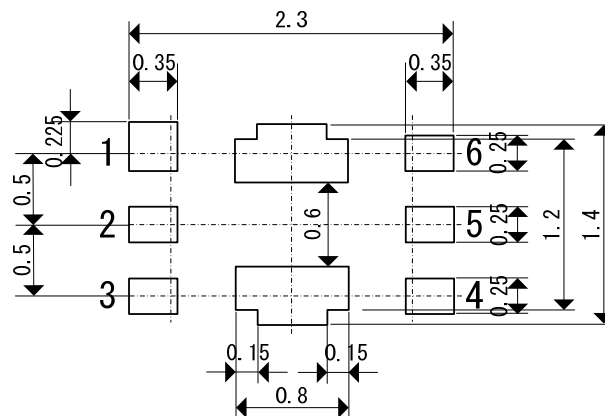


PACKAGING INFORMATION (Continued)

● USP-6C Reference Pattern Layout



● USP-6C Reference Metal Mask Design



PACKAGING INFORMATION (Continued)

- SOT-25 Power Dissipation

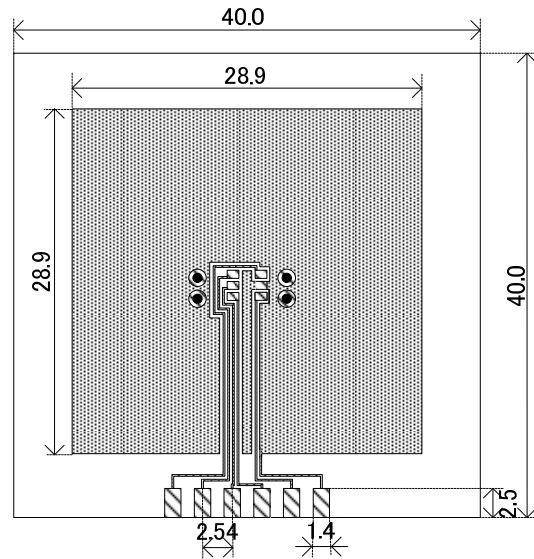
Power dissipation data for the SOT-25 is shown in this page.

The value of power dissipation varies with the mount board conditions.

Please use this data as one of reference data taken in the described condition.

1. Measurement Condition (Reference data)

- Condition: Mount on a board
- Ambient: Natural convection
- Soldering: Lead (Pb) free
- Board: Dimensions 40 x 40 mm (1600 mm² in one side)
Copper (Cu) traces occupy 50% of the board area
In top and back faces
Package heat-sink is tied to the copper traces
(Board of SOT-26 is used.)
- Material: Glass Epoxy (FR-4)
- Thickness: 1.6 mm
- Through-hole: 4 x 0.8 Diameter

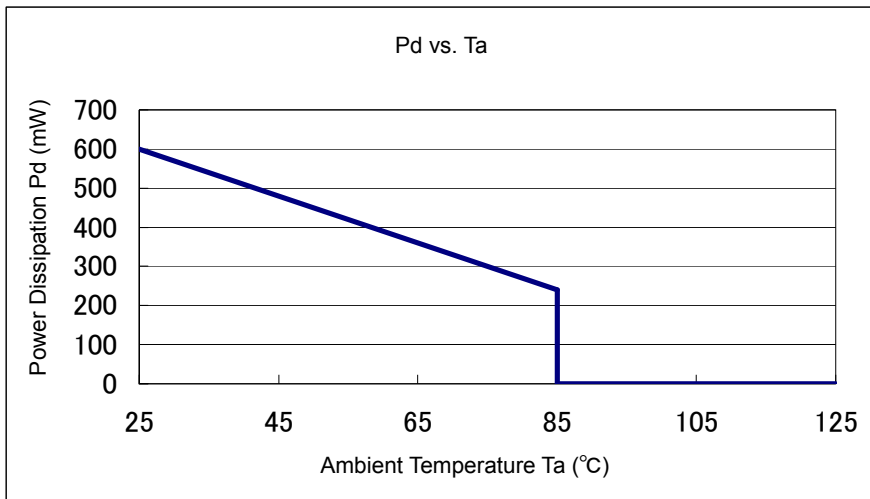


2. Power Dissipation vs. Ambient temperature

Evaluation Board (Unit: mm)

Board Mount (T_j max = 125°C)

| Ambient Temperature (°C) | Power Dissipation Pd (mW) | Thermal Resistance (°C/W) |
|--------------------------|---------------------------|---------------------------|
| 25 | 600 | 166.67 |
| 85 | 240 | |



■ PACKAGING INFORMATION (Continued)

● SOT-89-5 Power Dissipation

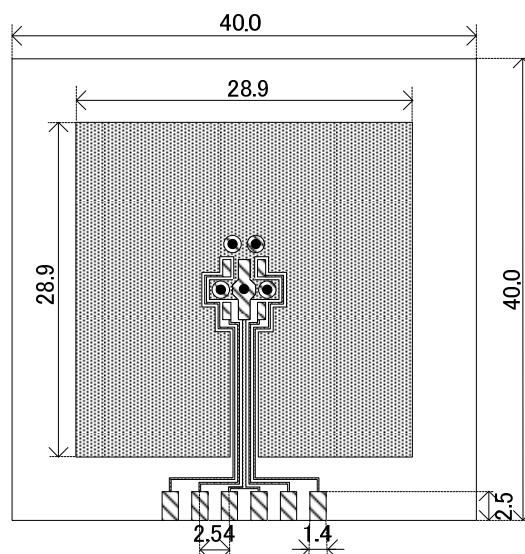
Power dissipation data for the SOT-89-5 is shown in this page.

The value of power dissipation varies with the mount board conditions.

Please use this data as one of reference data taken in the described condition.

2. Measurement Condition (Reference data)

- Condition: Mount on a board
- Ambient: Natural convection
- Soldering: Lead (Pb) free
- Board: Dimensions 40 x 40 mm (1600 mm² in one side)
Copper (Cu) traces occupy 50% of the board area
In top and back faces
Package heat-sink is tied to the copper traces
- Material: Glass Epoxy (FR-4)
- Thickness: 1.6 mm
- Through-hole: 5 x 0.8 Diameter

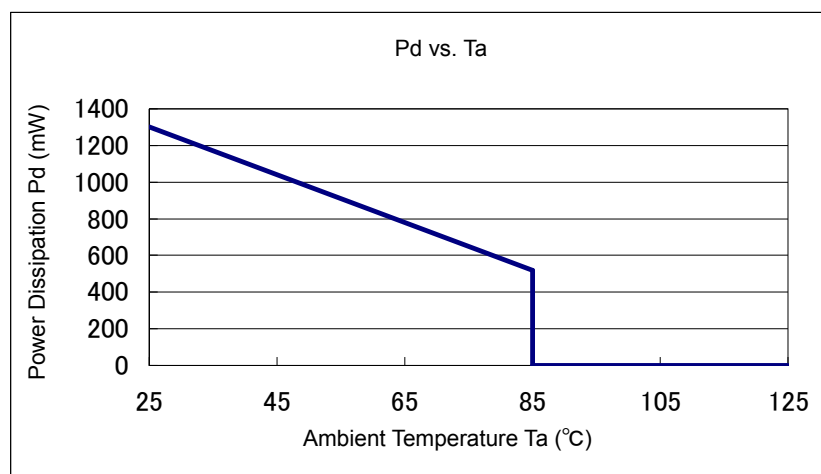


Evaluation Board (Unit: mm)

2. Power Dissipation vs. Ambient temperature

Board Mount (T_j max = 125°C)

| Ambient Temperature (°C) | Power Dissipation Pd (mW) | Thermal Resistance (°C/W) |
|--------------------------|---------------------------|---------------------------|
| 25 | 1300 | 76.92 |
| 85 | 520 | |



PACKAGING INFORMATION (Continued)

- USP-6C Power Dissipation

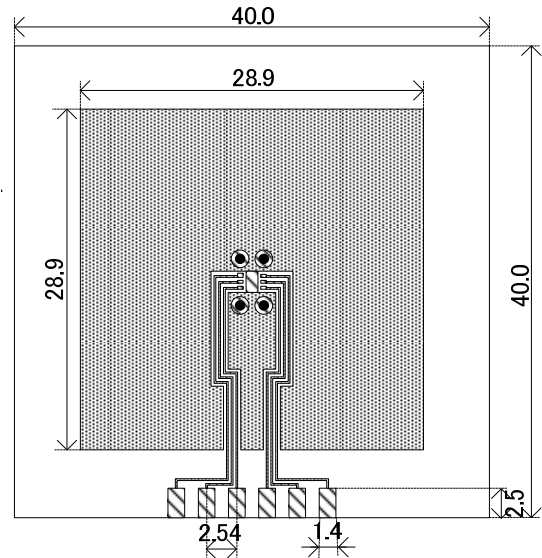
Power dissipation data for the USP-6C is shown in this page.

The value of power dissipation varies with the mount board conditions.

Please use this data as one of reference data taken in the described condition.

3. Measurement Condition (Reference data)

- Condition: Mount on a board
- Ambient: Natural convection
- Soldering: Lead (Pb) free
- Board: Dimensions 40 x 40 mm (1600 mm² in one side)
Copper (Cu) traces occupy 50% of the board area
In top and back faces
Package heat-sink is tied to the copper traces
- Material: Glass Epoxy (FR-4)
- Thickness: 1.6 mm
- Through-hole: 4 x 0.8 Diameter

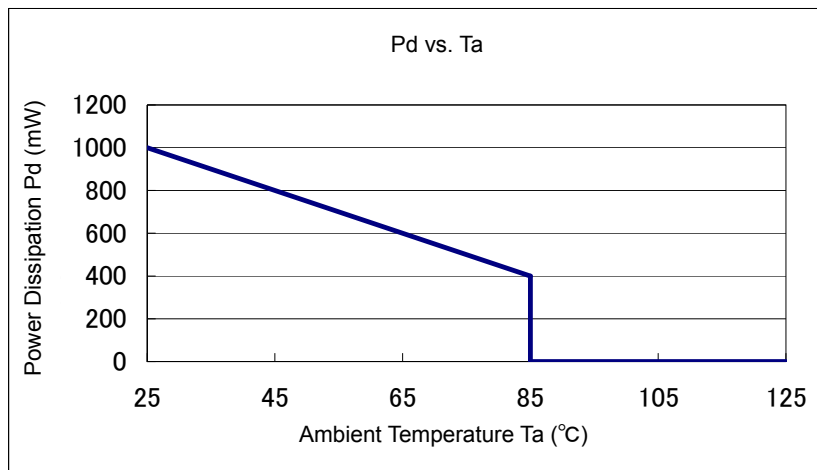


Evaluation Board (Unit: mm)

2. Power Dissipation vs. Ambient temperature

Board Mount ($T_j \text{ max} = 125^\circ\text{C}$)

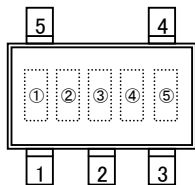
| Ambient Temperature ($^\circ\text{C}$) | Power Dissipation Pd (mW) | Thermal Resistance ($^\circ\text{C}/\text{W}$) |
|--|---------------------------|--|
| 25 | 1000 | 100.00 |
| 85 | 400 | |



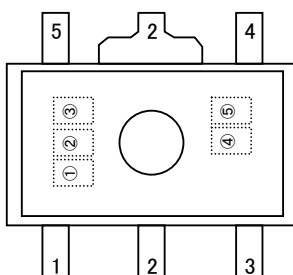
MARKING RULE

● SOT-25, SOT-89-5

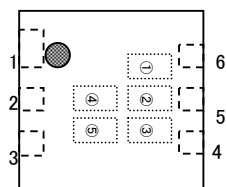
SOT25



SOT89-5



USP6C



① represents product series

| MARK | PRODUCT SERIES |
|------|----------------|
| H | XC6220***** |

② represents type of CE, voltage range, and accuracy

| MARK | CE | OUTPUT VOLTAGE RANGE | OUTPUT VOLTAGE ACCURACY | PRODUCT SERIES |
|------|----|----------------------|-------------------------|-----------------------------|
| 0 | A | 0.8~2.9 | 1 | XC6220A081** ~ XC6220A291** |
| 1 | A | 0.8~2.9 | B | XC6220A08B** ~ XC6220A29B** |
| 2 | A | 3.0~5.0 | 1 | XC6220A301** ~ XC6220A501** |
| 3 | A | 3.0~4.9 | B | XC6220A30B** ~ XC6220A49B** |
| 4 | B | 0.8~2.9 | 1 | XC6220B081** ~ XC6220B291** |
| 5 | B | 0.8~2.9 | B | XC6220B08B** ~ XC6220B29B** |
| 6 | B | 3.0~5.0 | 1 | XC6220B301** ~ XC6220B501** |
| 7 | B | 3.0~4.9 | B | XC6220B30B** ~ XC6220B49B** |
| 8 | C | 0.8~2.9 | 1 | XC6220C081** ~ XC6220C291** |
| 9 | C | 0.8~2.9 | B | XC6220C08B** ~ XC6220C29B** |
| A | C | 3.0~5.0 | 1 | XC6220C301** ~ XC6220C501** |
| B | C | 3.0~4.9 | B | XC6220C30B** ~ XC6220C49B** |
| C | D | 0.8~2.9 | 1 | XC6220D081** ~ XC6220D291** |
| D | D | 0.8~2.9 | B | XC6220D08B** ~ XC6220D29B** |
| E | D | 3.0~5.0 | 1 | XC6220D301** ~ XC6220D501** |
| F | D | 3.0~4.9 | B | XC6220D30B** ~ XC6220D49B** |

* Accuracy "1"...0.1V increments, Accuracy "B"...0.05V increments

③ represents output voltage

| MARK | OUTPUT VOLTAGE (V) | | MARK | OUTPUT VOLTAGE (V) | | MARK | OUTPUT VOLTAGE (V) | |
|------|--------------------|------|------|--------------------|------|------|--------------------|------|
| 0 | — | 3.0x | A | 1.0x | 4.0x | N | 2.0x | 5.0x |
| 1 | — | 3.1x | B | 1.1x | 4.1x | P | 2.1x | — |
| 2 | — | 3.2x | C | 1.2x | 4.2x | R | 2.2x | — |
| 3 | — | 3.3x | D | 1.3x | 4.3x | S | 2.3x | — |
| 4 | — | 3.4x | E | 1.4x | 4.4x | T | 2.4x | — |
| 5 | — | 3.5x | F | 1.5x | 4.5x | U | 2.5x | — |
| 6 | — | 3.6x | H | 1.6x | 4.6x | V | 2.6x | — |
| 7 | — | 3.7x | K | 1.7x | 4.7x | X | 2.7x | — |
| 8 | 0.8x | 3.8x | L | 1.8x | 4.8x | Y | 2.8x | — |
| 9 | 0.9x | 3.9x | M | 1.9x | 4.9x | Z | 2.9x | — |

④,⑤ represents production lot number
01~09, 0A~0Z, 11~9Z, A1~A9, AA~Z9, ZA~ZZ repeated
(G, I, J, O, Q, W excluded)

*No character inversion used.

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