

Output Capacitor-Less, Low Power Consumption, High Speed LDO Regulator

■ GENERAL DESCRIPTION

The XC6501 series is a 6.0V high speed, low noise CMOS LDO regulator that can provide stable output voltages within a range of 1.2V to 5.0V (0.05V increments) even without a load capacitor C_L . This is possible because phase compensation is carried out internally unlike other LDOs where it is done externally. The series consists of a reference voltage source, driver transistor, error amplifier, current limit circuit, and phase compensation circuit.

The CE function enables the circuit to be put into stand-by mode by inputting a low level signal to the CE pin thereby reducing current consumption from an already low 13 μ A (in operation) to less than 0.1 μ A. In the stand-by mode, if a C_L cap is used, the electric charge stored at C_L can be discharged via the internal auto-discharge switch and as a result, the V_{OUT} pin quickly returns to the V_{SS} level.

The current limit fold-back circuit operates as a short circuit protection and a current limiter function for the output pin.

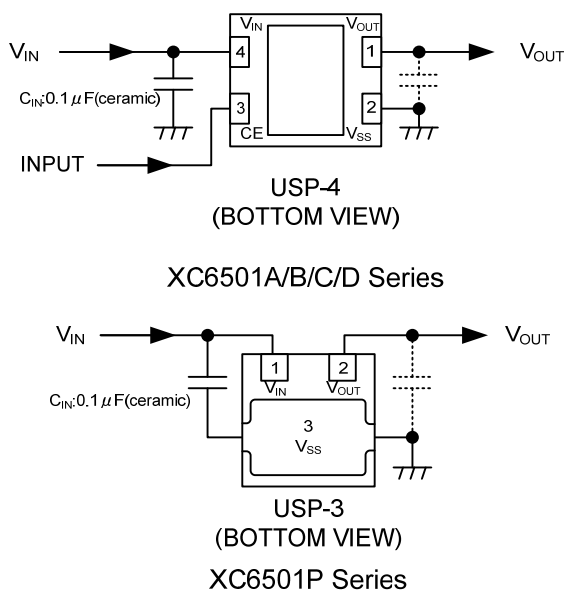
■ APPLICATIONS

- Mobile phones (RF, Digital cash, I/O etc.)
- Portable games
- Camera modules
- Wireless LAN modules
- LCD modules
- Bluetooth
- Digital-TV tuners

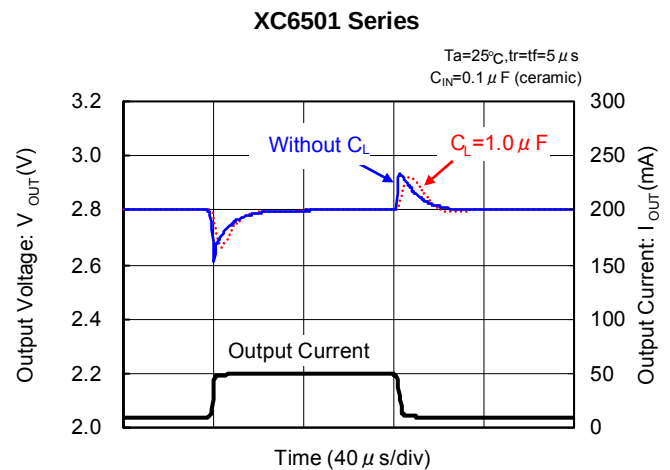
■ FEATURES

Operating Voltage Range	: 1.4~6.0V
Output Voltage Range	: 2.0~5.0V (Accuracy: $\pm 1\%$) 1.2~1.95V (Accuracy: $\pm 0.02V$)
Dropout Voltage	: 150mV@ $I_{OUT}=100mA$, $V_{OUT}=2.8V$
Low Power Supply	: 13 μ A@ $V_{OUT}=2.8V$
Stand-by Current	: Less than 0.1 μ A
Ripple Rejection	: 50dB@ $f=1kHz$, $V_{OUT}=2.8V$
Protection Circuits	: Current limit (300mA, TYP.) : Short circuit protection
Output capacitor is not required	: Internal phase compensation
CL High Speed Auto Discharge	
Packages	SOT-25, SSOT-24, USP-4, USPN-4 (under development) USP-3

■ TYPICAL APPLICATION CIRCUIT

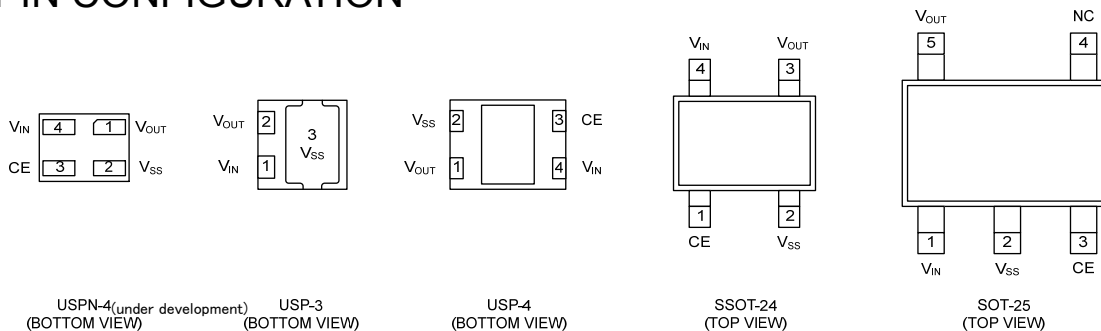


■ TYPICAL PERFORMANCE CHARACTERISTICS



XC6501 Series

PIN CONFIGURATION



*The heat dissipation pad of the USP-4 package is recommended to solder as the recommended mount pattern and metal mask pattern for mounting strength. The mount pattern should be electrically opened or connected to the V_{SS} (No.2) pin.

PIN ASSIGNMENT

PIN NUMBER					PIN NAME	FUNCTION
USP-3	USP-4	SSOT-24	SOT-25	USPN-4*		
1	4	4	1	4	V _{IN}	Power Supply
2	1	3	5	1	V _{OUT}	Output
3	2	2	2	2	V _{SS}	Ground
-	3	1	3	3	CE	ON/OFFControl
-	-	-	4	-	NC	No Connection

* USP-4 is under development

PRODUCT CLASSIFICATION

● Ordering Information

XC6501①②③④⑤⑥-⑦ (*1)

DESIGNATOR	DESCRIPTION	SYMBOL	DESCRIPTION
①	Regulator Type	A	CE High Active, Without CE Pull-down, Without CL discharge
		B	CE High Active, Without CE Pull-down, With CL discharge
		C	CE High Active, With CE Pull-down, Without CL discharge
		D	CE High Active, With CE Pull-down, With CL discharge
		P	3 pin, without CE pin (USP-3)
②③	Output Voltage	12~50	ex.)28V → ②=2, ③=8
④	Output Voltage Accuracy	1	0.1V increments ex.)1.80V → ②=1, ③=8, ④=1 Accuracy= ±0.02V @ 1.2V~1.9V Accuracy= ±1% @ 2.0~5.0V
		A	0.05V increments ex.)1.85V → ②=1, ③=8, ④=A Accuracy= ±0.02V @ 1.25V~1.95V Accuracy= ±1% @ 2.05~4.95V
⑤⑥-⑦	Packages Taping Type (*2)	HR	USP-3 (Only XC6501P)
		HR-G	USP-3 (Halogen & Antimony free)
		GR	USP-4
		GR-G	USP-4 (Halogen & Antimony free)
		NR	SSOT-24
		NR-G	SSOT-24 (Halogen & Antimony free)
		MR	SOT-25
		MR-G	SOT-25 (Halogen & Antimony free)
		7R-G	USPN-4 (Halogen & Antimony free) (*3)

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

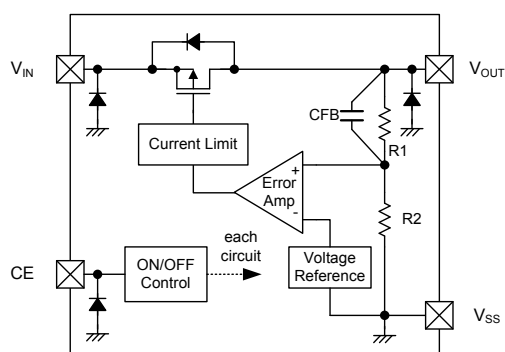
(*2) The device orientation is fixed in its embossed tape pocket.

For reverse orientation, please contact your local Torex sales office or representative.

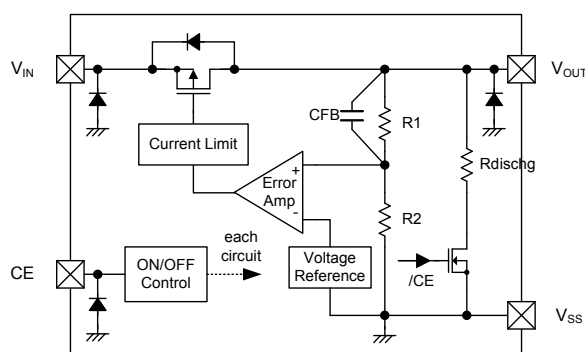
(Standard orientation: ⑤R-⑦, Reverse orientation: ⑤L-⑦)

(*3) USPN-4 (Halogen & Antimony free) is under development.

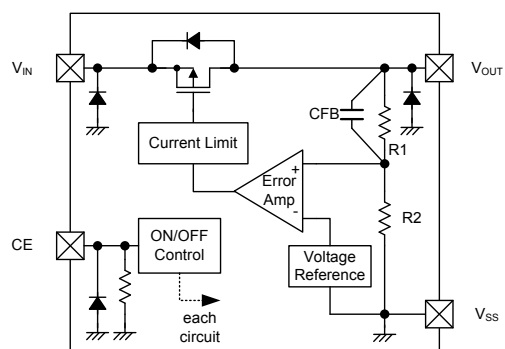
BLOCK DIAGRAMS



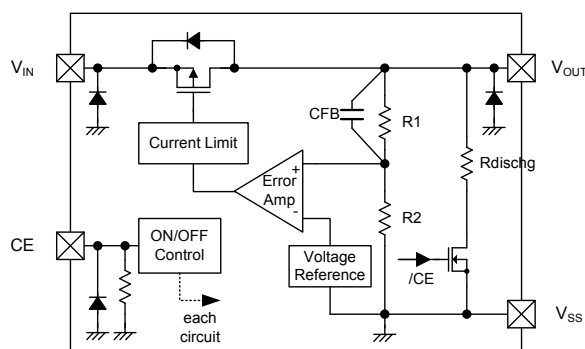
XC6501A Series



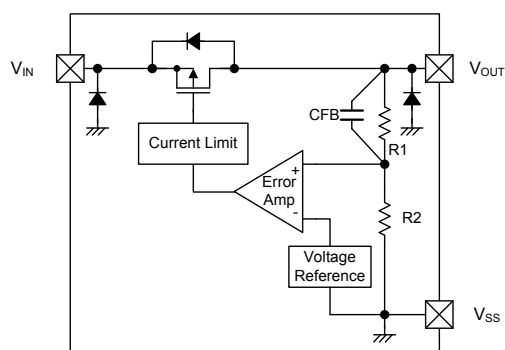
XC6501B Series



XC6501C Series



XC6501D Series



XC6501P Series

*Diodes inside the circuit are an ESD protection diode and a parasitic diode.

ABSOLUTE MAXIMUM RATINGS

PARAMETER		SYMBOL	RATINGS	UNITS
Input Voltage		V_{IN}	$V_{SS}-0.3 \sim +6.5$	V
Output Current		I_{OUT}	400 ^{(*)1}	mA
Output Voltage		V_{OUT}	$V_{SS}-0.3 \sim V_{IN}+0.3$	V
CE Input Voltage		V_{CE}	$V_{SS}-0.3 \sim +6.5$	V
Power Dissipation	USPN-4 ^{(*)2}	P_d	100	mW
	USP-3		120	
	USP-4		120	
	SSOT-24		150	
	SOT-25		250	
			600 (PCB mounted) ^{(*)3}	
Operating Temperature Range		T_{opr}	$-40 \sim +85$	$^{\circ}\text{C}$
Storage Temperature Range		T_{stg}	$-55 \sim +125$	$^{\circ}\text{C}$

*1 $P_d > (V_{IN} - V_{OUT}) \times I_{OUT}$

*2 USPN-4 is under development.

*3 The power dissipation figure shown is PCB mounted and is for reference only. Please refer to page 20 for details.

ELECTRICAL CHARACTERISTICS

●XC6501 Series

Ta=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	CIRCUIT
Output Voltage	$V_{OUT(E)}^{(*)2}$	$2.0V > V_{OUT(T)}^{(*)3}$ $V_{CE}=V_{IN}, I_{OUT}=10mA$	-0.02 (*)4	$V_{OUT(T)}$	+0.02 (*)4	V	①
		$2.0V \leq V_{OUT(T)}$ $V_{CE}=V_{IN}, I_{OUT}=10mA$	$\times 0.99$ (*)4		$\times 1.01$ (*)4		
Maximum Output Current	I_{OUTMAX}	$V_{CE}=V_{IN}$	200	-	-	mA	①
Load Regulation	ΔV_{OUT}	$V_{CE}=V_{IN}, 0.1mA \leq I_{OUT} \leq 100mA$	-	15	45	mV	①
Dropout Voltage ^{(*)5}	V_{dif}	$V_{CE}=V_{IN}, I_{OUT}=100mA$	E-1			mV	①
Supply Current	I_{DD}	$V_{IN}=V_{CE}=6.0V, I_{OUT}=0mA$	E-2			μA	②
Stand-by Current	I_{stby}	$V_{IN}=6.0V, V_{CE}=V_{SS}$	-	0.01	0.1	μA	②
Line Regulation	$\frac{\Delta V_{OUT}}{\Delta V_{IN} \cdot V_{OUT}}$	$V_{OUT(T)}+0.5V \leq V_{IN} \leq 6.0V$, $V_{CE}=V_{IN}, I_{OUT}=30mA$	-	0.10	0.20	%/V	①
Input Voltage	V_{IN}		1.4	-	6.0	V	①
Output Voltage Temperature Characteristics	$\frac{\Delta V_{OUT}}{\Delta Ta \cdot V_{OUT}}$	$V_{CE}=V_{IN}, I_{OUT}=30mA$ $-40^\circ C \leq Ta \leq 85^\circ C$	-	± 100	-	ppm/°C	①
Ripple Rejection Rate	PSRR	$V_{OUT(T)} \leq 4.75V$ $V_{IN} = \{V_{OUT(T)} + 1.0\} V_{DC} + 0.5V_{p-pAC}$ $V_{CE}=V_{IN}, I_{OUT}=30mA, f=1kHz$	-	50	-	dB	③
		$V_{OUT(T)} \geq 4.80V$ $V_{IN} = 5.75V_{DC} + 0.5V_{p-pAC}$ $V_{CE}=V_{IN}, I_{OUT}=30mA, f=1kHz$					
Current Limit	I_{LIM}	$V_{CE}=V_{IN}$	210	300	-	mA	①
Short Circuit Current	I_{SHORT}	$V_{CE}=V_{IN}$, V_{OUT} is short-circuited at the V_{SS} level	-	25	-	mA	①
CE High Level Voltage	V_{CEH}		1.0	-	6.0	V	①
CE Low Level Voltage	V_{CEL}		V_{SS}	-	0.25	V	①
CE High Level Current	I_{CEH}	$V_{IN}=V_{CE}=6.0V$	-0.1	-	0.1	μA	①
		XC6501A/B/P XC6501C/D	3.5	6.0	10		
CE Low Level Current	I_{CEL}	$V_{CE}=V_{SS}$	-0.1	-	0.1	μA	①
CL Auto-Discharge Resistance ^{(*)8}	R_{DCHG}	$V_{IN}=6.0V, V_{OUT}=1.2V, V_{CE}=V_{SS}$	-	250	300	Ω	①
		$V_{IN}=6.0V, V_{OUT}=5.0V, V_{CE}=V_{SS}$	-	400	480	Ω	

Notes:

1: Unless otherwise stated regarding input voltage conditions, $V_{IN}=V_{OUT(T)}^{()3}+1.0V$.

*2: $V_{OUT(E)}$: An actual output voltage when an amply stabilized I_{OUT} ($V_{OUT(T)}+1.0V$) is input..

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

*4: $V_{OUT(E)}$: Effective output voltage value

5: $V_{dif}=\{V_{IN1}^{()7} - V_{OUT1}^{(*)6}\}$

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

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

*8: This function is built in the XC6501B/D series only.

The XC6501A/C series discharges by resistors R1+ R2 only as shown in the block diagrams.

■ ELECTRICAL CHARACTERISTICS (Continued)

● Voltage Chart

	E-0		E-1		E-2					
NOMINAL VOLTAGE (V)	OUTPUT VOLTAGE (V)		DROPOUT VOLTAGE (mV)		SUPPLY CURRENT (μ A)					
V _{OUT(T)}	V _{OUT(E)}		V _{dif}		I _{SS}					
	MIN.	MAX.	TYP.	MAX.	TYP.	MAX.				
1.20	1.1800	1.2200	440	690	11	17				
1.25	1.2300	1.2700								
1.30	1.2800	1.3200								
1.35	1.3300	1.3700								
1.40	1.3800	1.4200	300	610			11	17		
1.45	1.4300	1.4700								
1.50	1.4800	1.5200								
1.55	1.5300	1.5700								
1.60	1.5800	1.6200	260	530					11	17
1.65	1.6300	1.6700								
1.70	1.6800	1.7200								
1.75	1.7300	1.7700								
1.80	1.7800	1.8200	230	470	12	18				
1.85	1.8300	1.8700								
1.90	1.8800	1.9200								
1.95	1.9300	1.9700								
2.00	1.9800	2.0200	200	430			12	18		
2.05	2.0295	2.0705								
2.10	2.0790	2.1210								
2.15	2.1285	2.1715								
2.20	2.1780	2.2220	190	410					13	19
2.25	2.2275	2.2725								
2.30	2.2770	2.3230								
2.35	2.3265	2.3735								
2.40	2.3760	2.4240	210	380	13	19				
2.45	2.4255	2.4745								
2.50	2.4750	2.5250								
2.55	2.5245	2.5755								
2.60	2.5740	2.6260	210	380			13	19		
2.65	2.6235	2.6765								
2.70	2.6730	2.7270								
2.75	2.7225	2.7775								
2.80	2.7720	2.8280	150	360	13	20				
2.85	2.8215	2.8785								
2.90	2.8710	2.9290								
2.95	2.9205	2.9795								

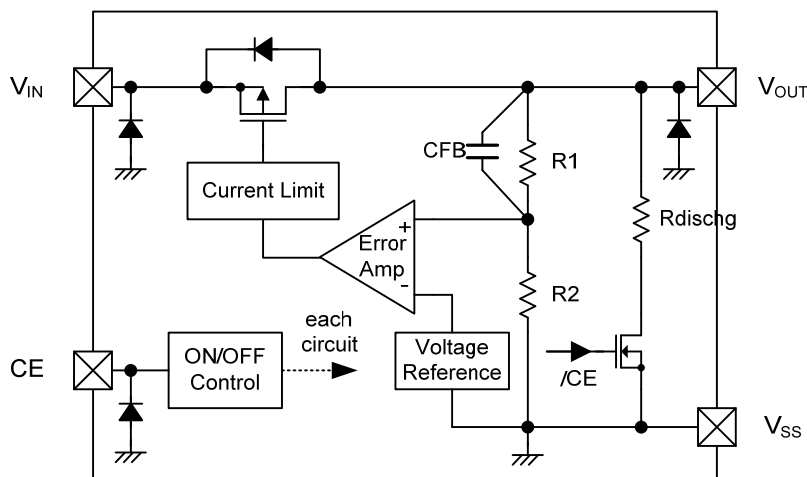
ELECTRICAL CHARACTERISTICS (Continued)

● Voltage Table (continued)

	E-0		E-1		E-2			
NOMINAL VOLTAGE (V)	OUTPUT VOLTAGE (V)		DROPOUT VOLTAGE (mV)		SUPPLY CURRENT (μ A)			
V _{OUT(T)}	V _{OUT(E)}		V _{dif}		I _{ss}			
	MIN.	MAX.	TYP.	MAX.	TYP.	MAX.		
3.00	2.9700	3.0300	150	360	14	20		
3.05	3.0195	3.0805				21		
3.10	3.0690	3.1310						
3.15	3.1185	3.1815						
3.20	3.1680	3.2320	140	350				
3.25	3.2175	3.2825						
3.30	3.2670	3.3330						
3.35	3.3165	3.3835						
3.40	3.3660	3.4340						
3.45	3.4155	3.4845						
3.50	3.4650	3.5350						
3.55	3.5145	3.5855						
3.60	3.5640	3.6360	130	340	15	22		
3.65	3.6135	3.6865						
3.70	3.6630	3.7370						
3.75	3.7125	3.7875						
3.80	3.7620	3.8380						
3.85	3.8115	3.8885						
3.90	3.8610	3.9390						
3.95	3.9105	3.9895						
4.00	3.9600	4.0400	120	330	16			
4.05	4.0095	4.0905						
4.10	4.0590	4.1410					23	
4.15	4.1085	4.1915						
4.20	4.1580	4.2420						
4.25	4.2075	4.2925						
4.30	4.2570	4.3430						
4.35	4.3065	4.3935						
4.40	4.3560	4.4440						
4.45	4.4055	4.4945						
4.50	4.4550	4.5450						
4.55	4.5045	4.5955						
4.60	4.5540	4.6460						
4.65	4.6035	4.6965						
4.70	4.6530	4.7470						
4.75	4.7025	4.7975						
4.80	4.7520	4.8480						
4.85	4.8015	4.8985						
4.90	4.8510	4.9490						
4.95	4.9005	4.9995						
5.00	4.9500	5.0500						

■ 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. Further, the IC's internal circuitry can be shutdown via the CE pin's signal.



XC6501B Series

<C_L High Speed Auto-Discharge Function>

The XC6501B/D series can discharge the electric charge in the output capacitor C_L, when a low signal to the CE pin, which enables a whole IC circuit turn off, is inputted via the N-channel transistor located between the V_{OUT} pin and the V_{SS} pin as shown in the BLOCK DIAGRAM. The C_L auto-discharge resistance value is set at 400Ω (V_{OUT}=5.0V @ V_{IN}=6.0V at typical). The discharge time of the output capacitor C_L is set by the C_L auto-discharge resistance R and the output capacitor C_L. By setting time constant of a C_L auto-discharge resistance value Rdischg and an output capacitor value C_L as τ ($\tau = C \times R$), the output voltage after discharge via the N-channel transistor is calculated by the following formulas.

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

where V : Output voltage after discharge, V_{OUT(E)} : Output voltage, t : Discharge time,

τ : C_L auto-discharge resistance Rdischg x Output capacitor C_L

<Current Limiter, Short-Circuit Protection>

The XC6501 series' fold-back circuit operates as an output current limiter and a short protection of the output pin. When the load current reaches the current limit level, the fixed current limiter circuit operates and output voltage drops. When the output voltage is shorted to the V_{SS}, its current flow reached and minimized to about 25mA.

<CE Pin>

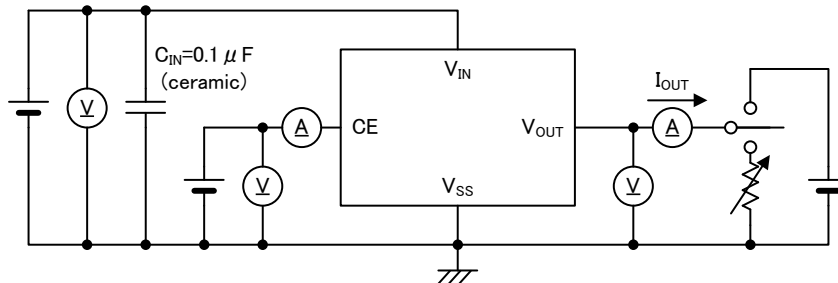
The IC's internal circuitry can be shutdown via the signal from the CE pin with the XC6501 series. In shutdown mode output at the V_{OUT} pin will be pulled down to the V_{SS} level via R1 & R2. However, as for the XC6501B/D series, the C_L auto-discharge resistor is connected in parallel to R1 and R2 while the power supply is applied to the V_{IN} pin. Therefore, time until the V_{OUT} pin reaches the V_{SS} level becomes short. 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, supply current may increase as a result of through current in the IC's internal circuitry when medium voltage is input.

■ NOTES ON USE

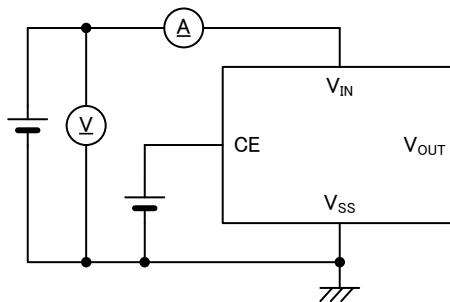
1. Please use this IC within the stated absolute maximum ratings. The IC is liable to malfunction should the ratings be exceeded.
2. This IC achieves stable operation without an output capacitor C_L by internal phase compensation. However, wiring impedance is high, operations may become unstable due to noise and/or phase lag depending on output current. Please wire the input capacitor C_{IN} and the output capacitor C_L as close to the IC as possible.

TEST CIRCUITS

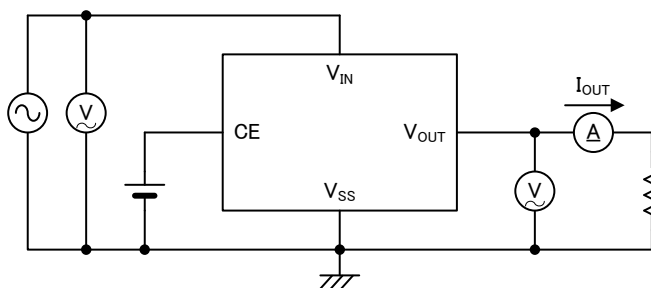
● Circuit ①



● Circuit ②



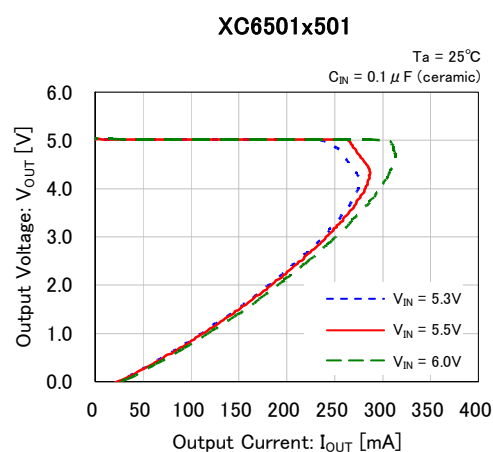
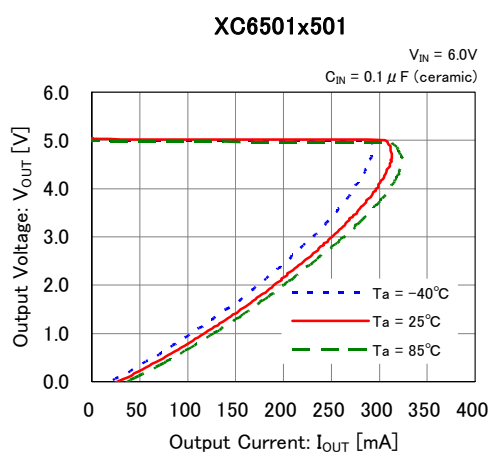
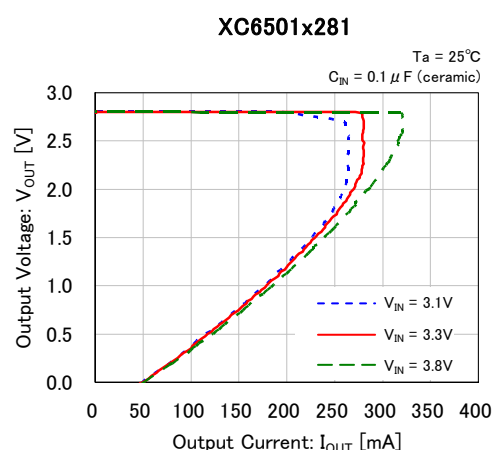
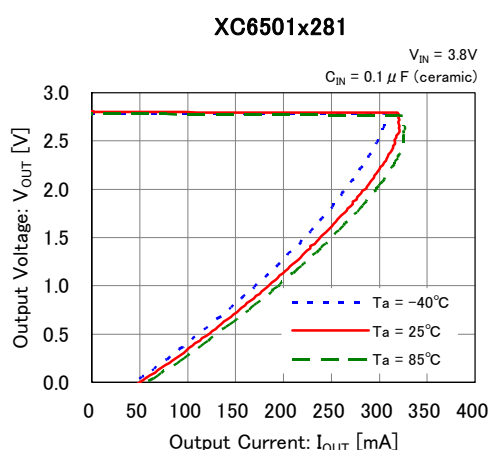
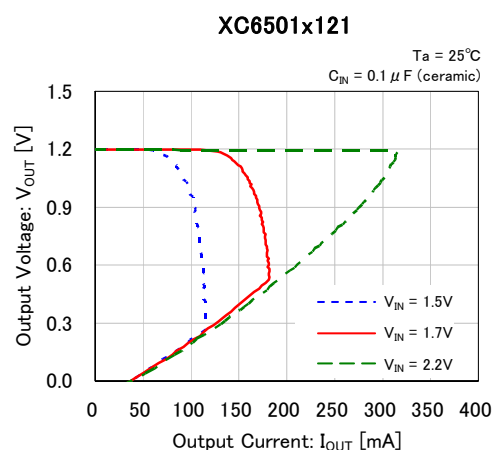
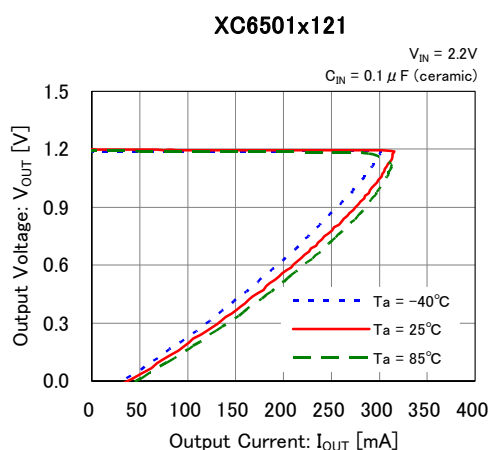
● Circuit ③



TYPICAL PERFORMANCE CHARACTERISTICS

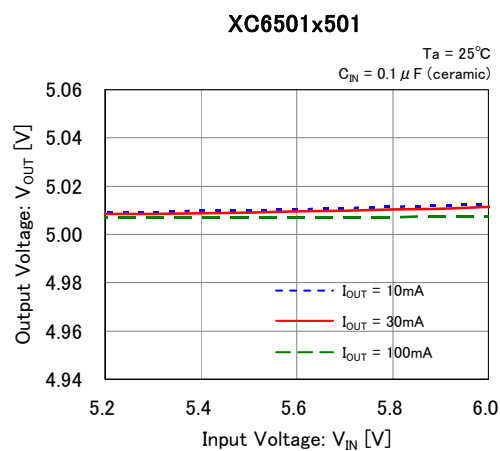
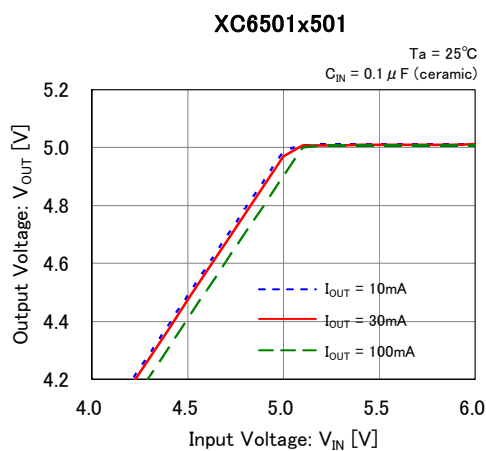
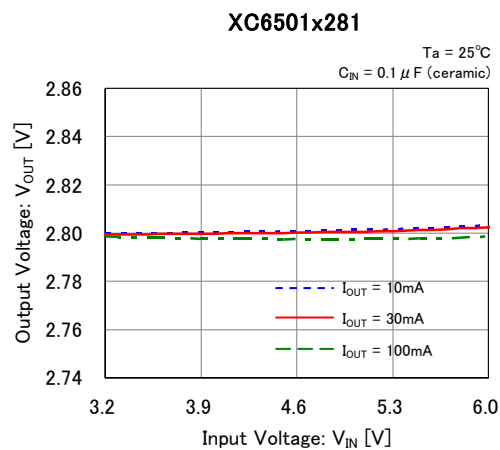
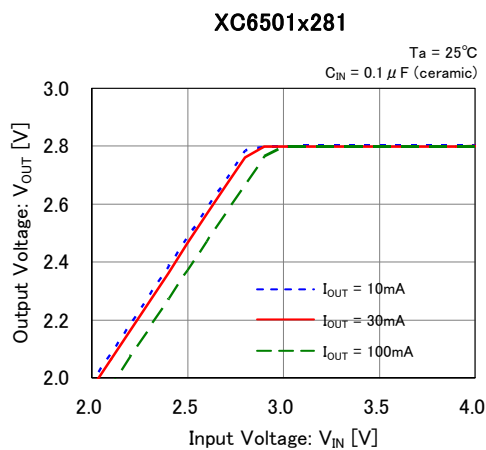
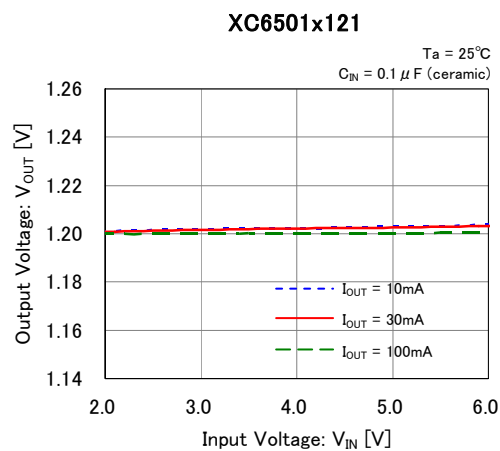
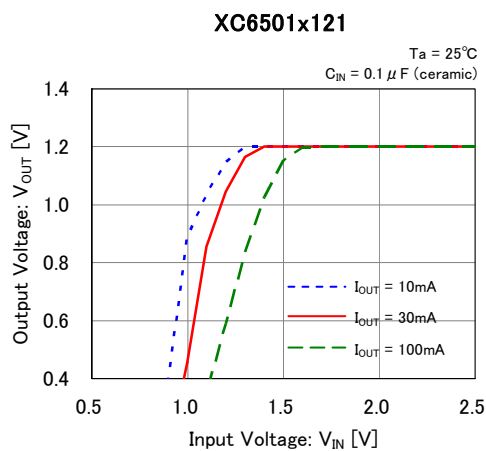
*CE Voltage condition: Unless otherwise stated, $V_{CE} = V_{IN}$

(1) Output Voltage vs. Output Current



TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

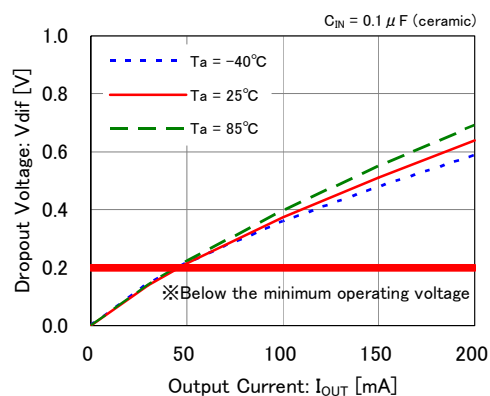
(2) Output Voltage vs. Input Voltage



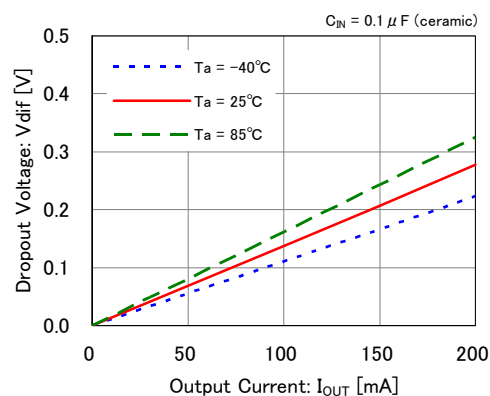
■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(3) Dropout Voltage vs. Output Current

XC6501x121

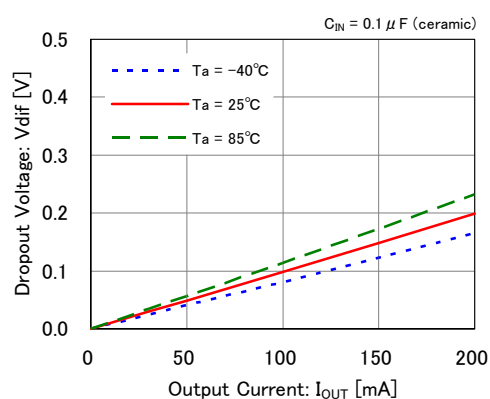


XC6501x281

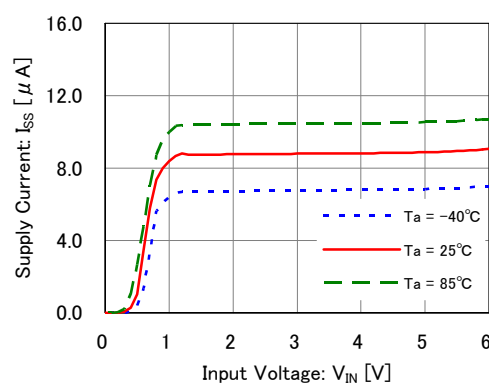


(4) Supply Current vs. Input Voltage

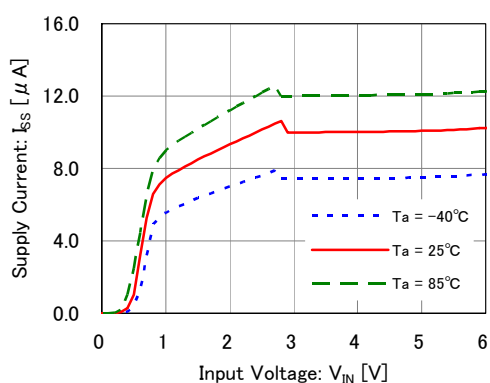
XC6501x501



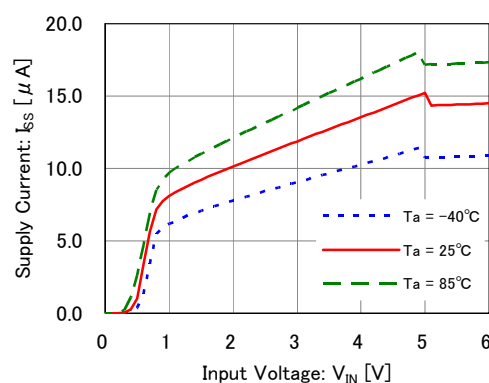
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XC6501x281

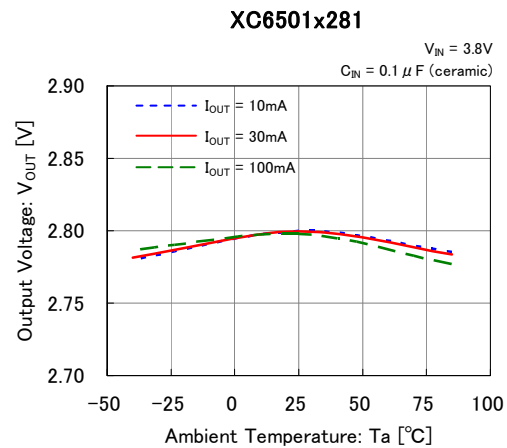
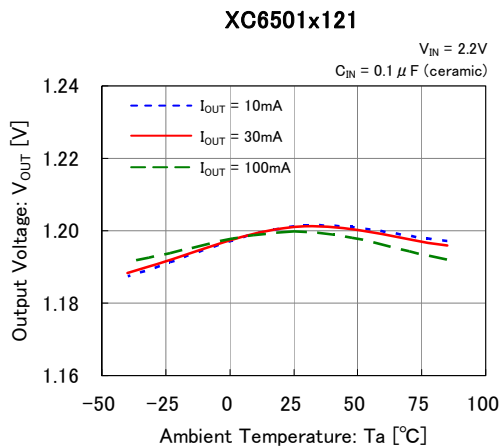


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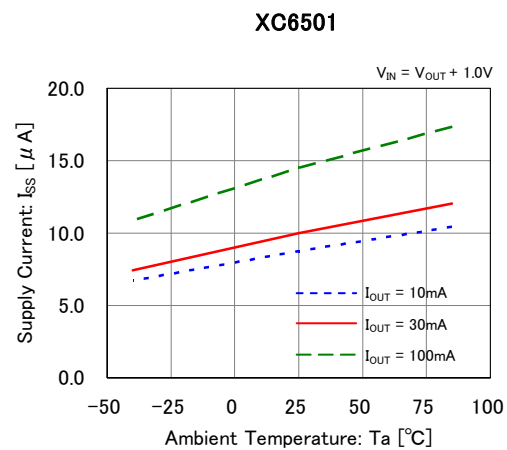
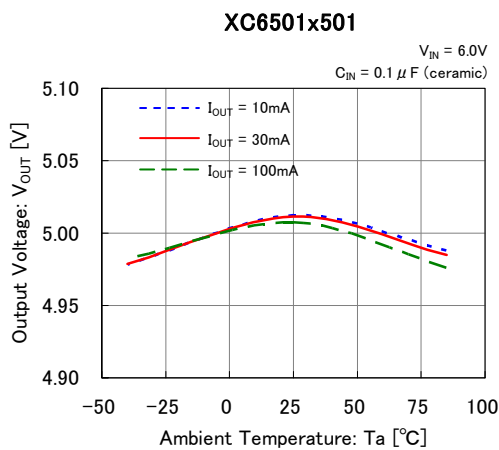


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

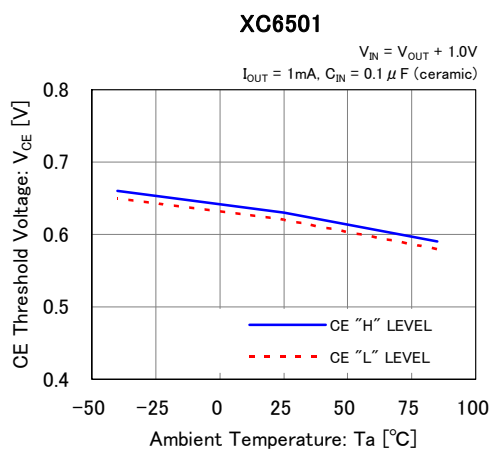
(5) Output Voltage vs. Ambient Temperature



(6) Supply Current vs. Ambient Temperature

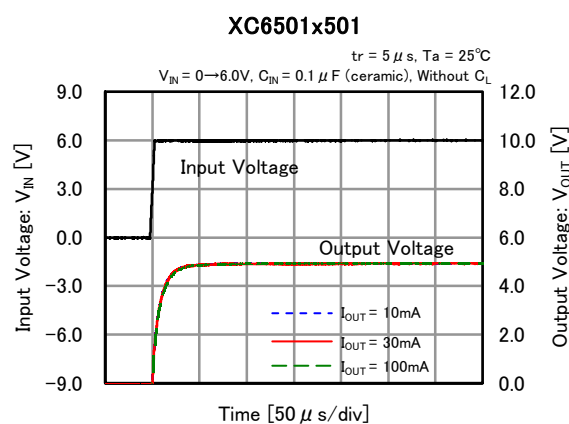
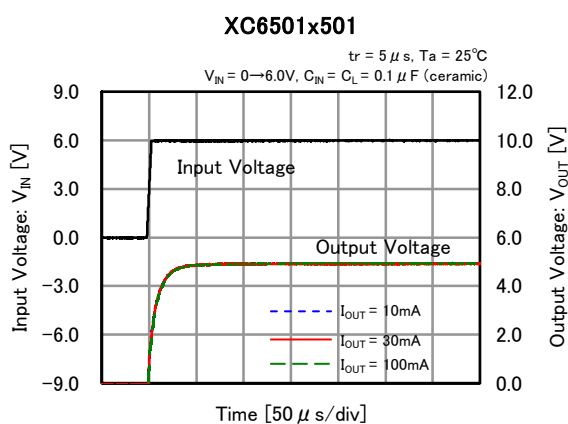
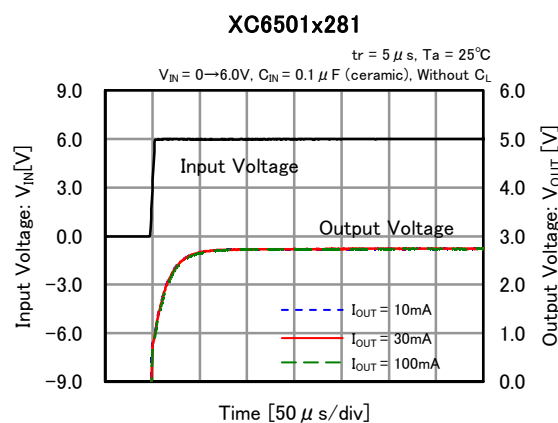
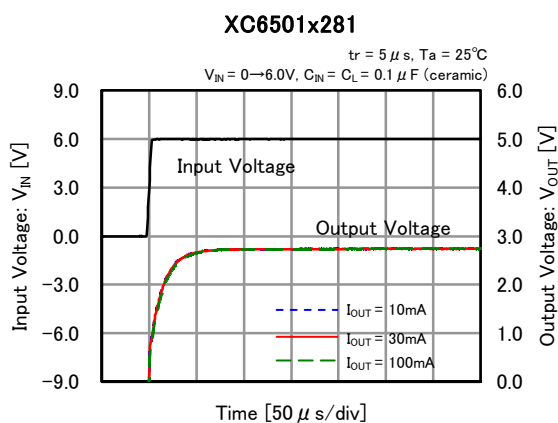
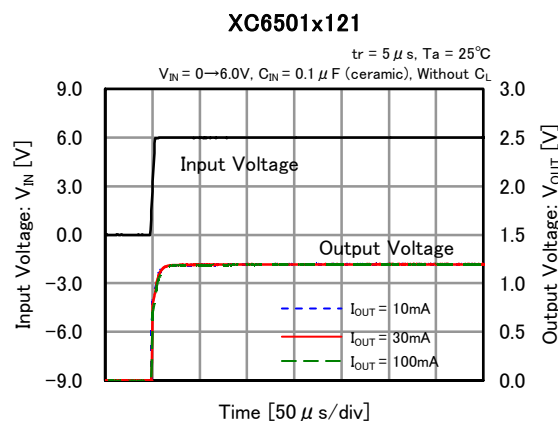
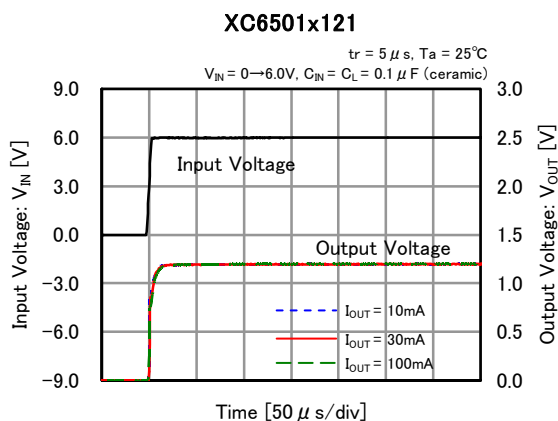


(7) CE Threshold Voltage vs. Ambient Temperature



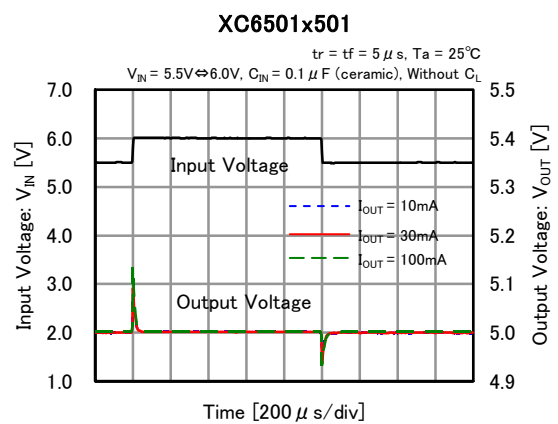
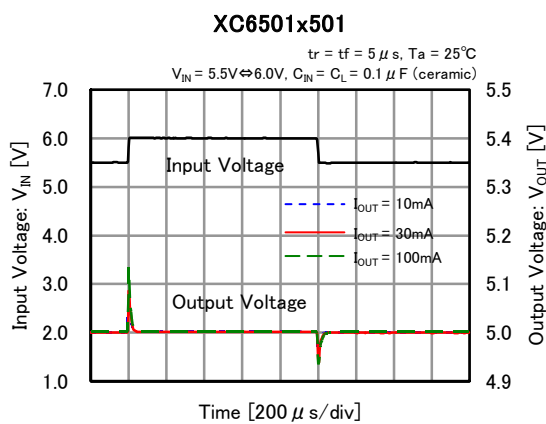
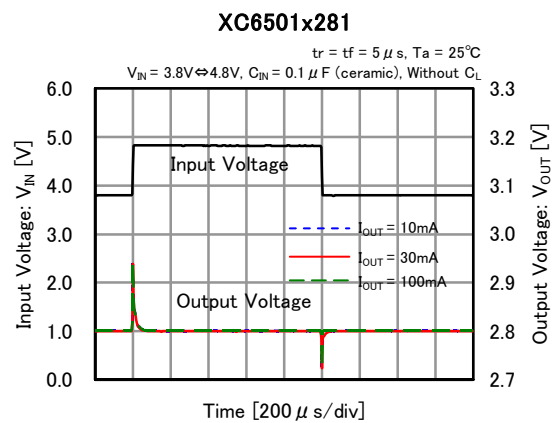
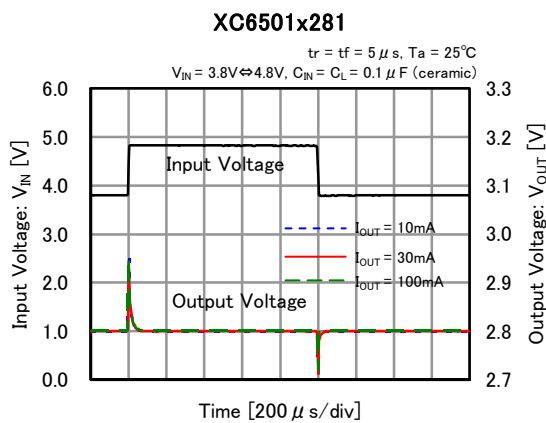
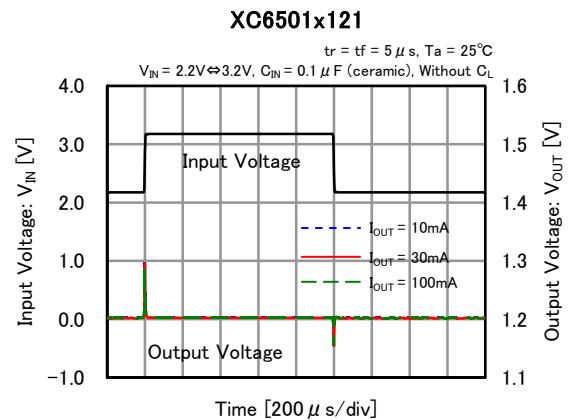
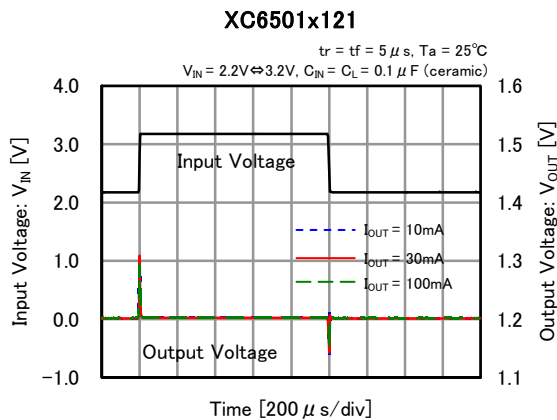
■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(8) Rising Response Time



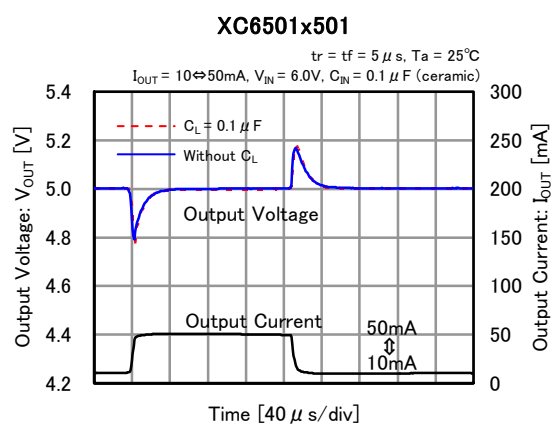
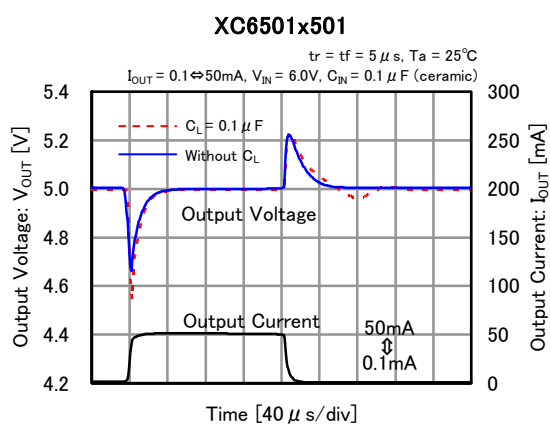
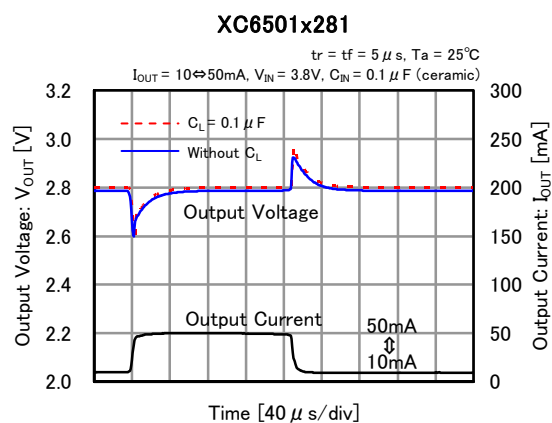
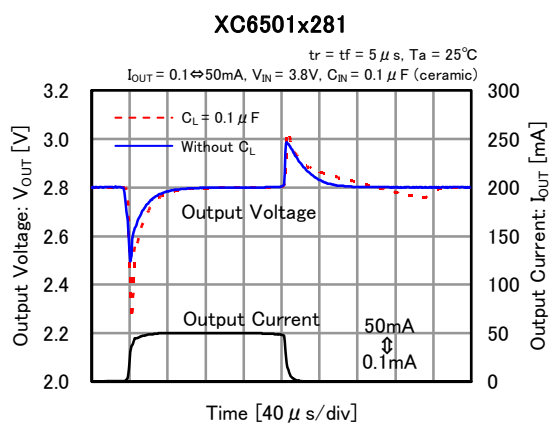
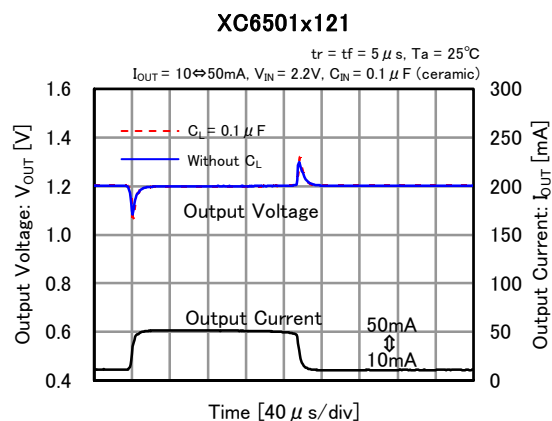
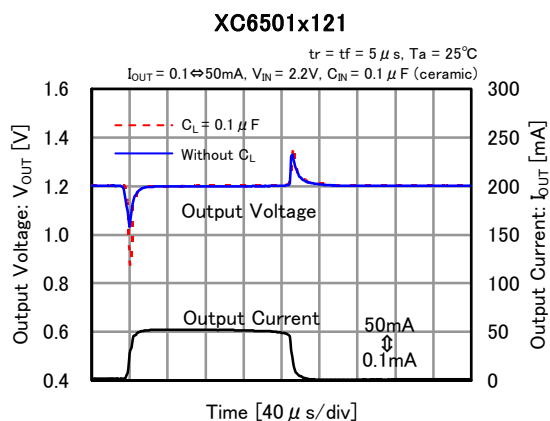
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(9) Input Transient Response



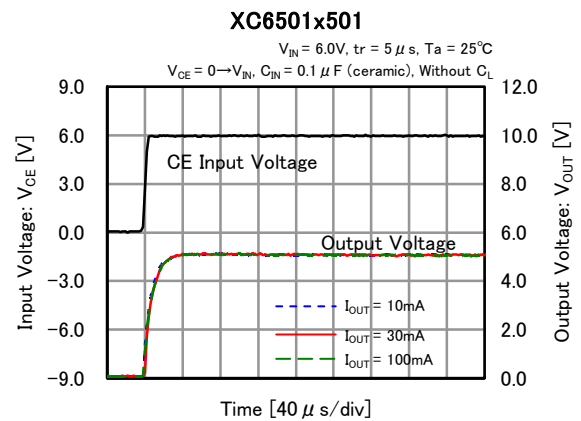
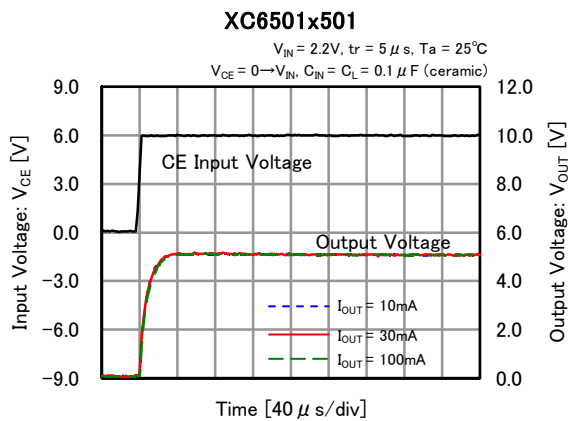
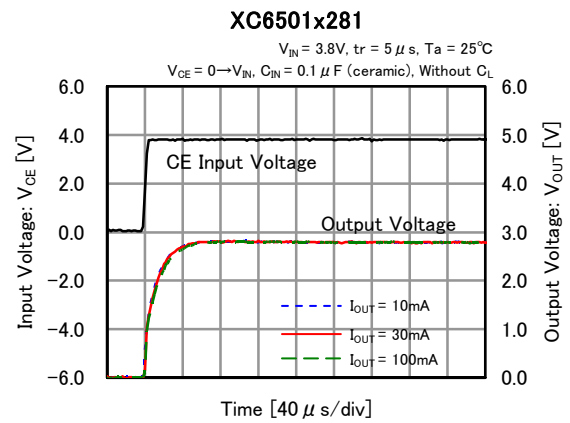
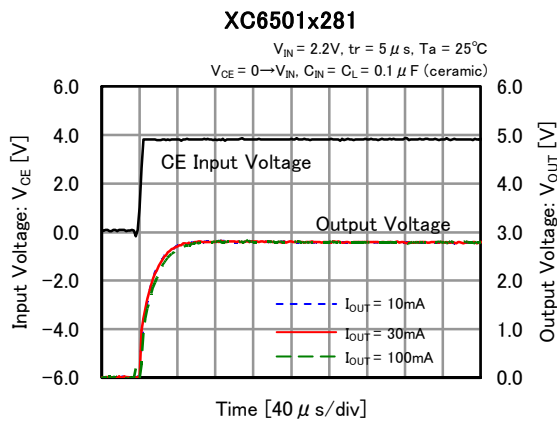
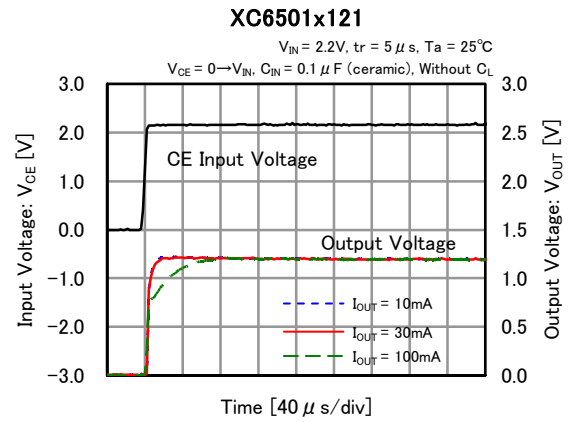
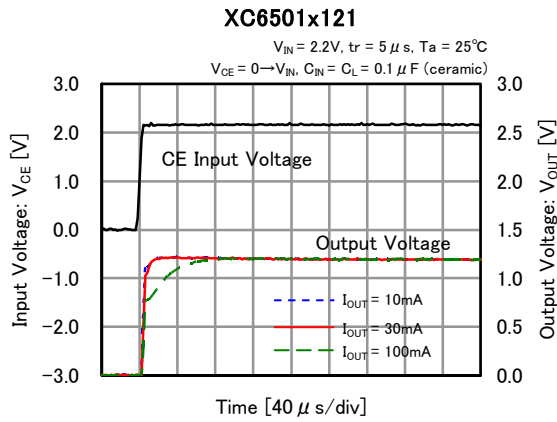
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(10) Load Transient Response



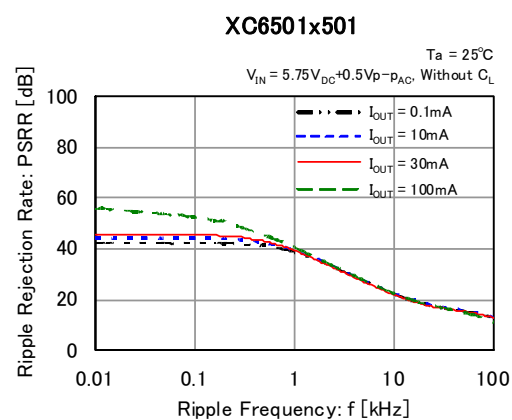
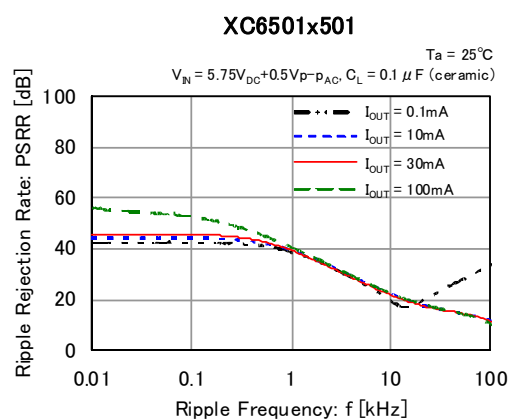
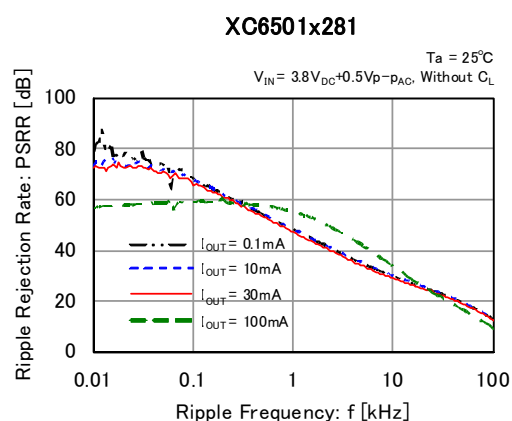
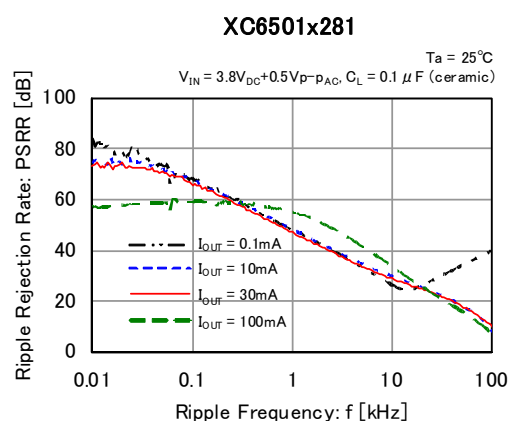
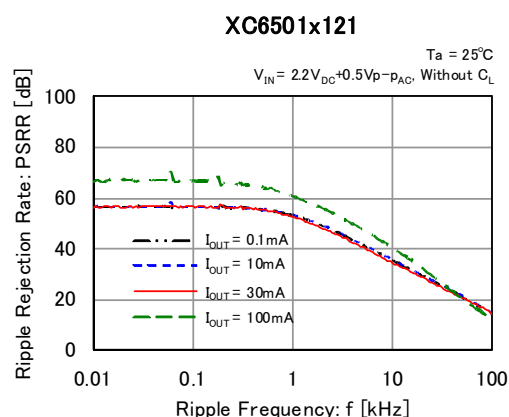
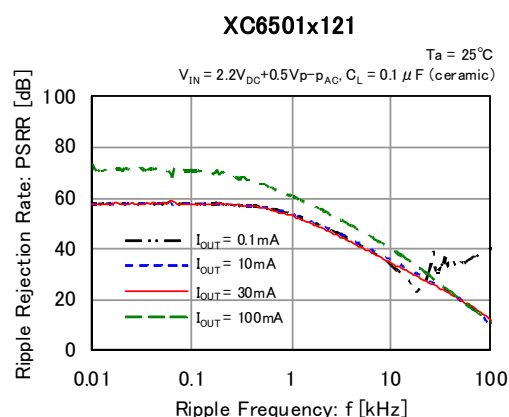
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(11) CE Rising Respose Time



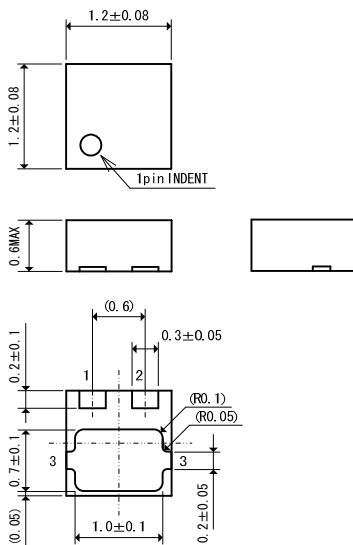
TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(12) Ripple Rejection Rate

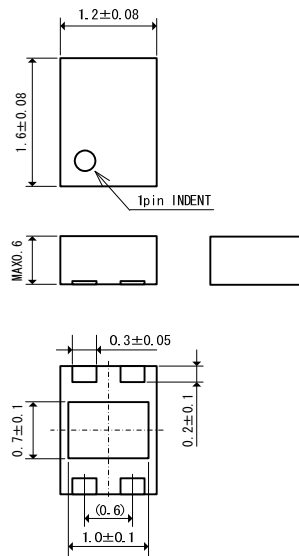


PACKAGING INFORMATION

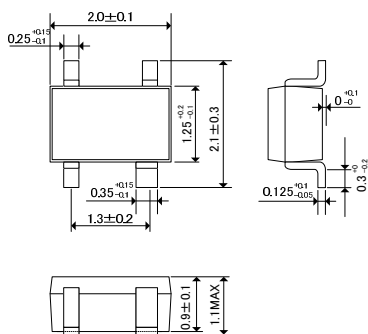
● USP-3



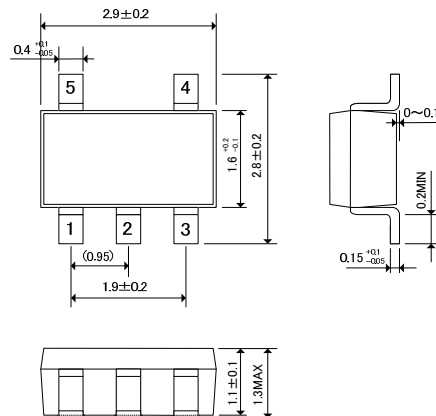
● USP-4



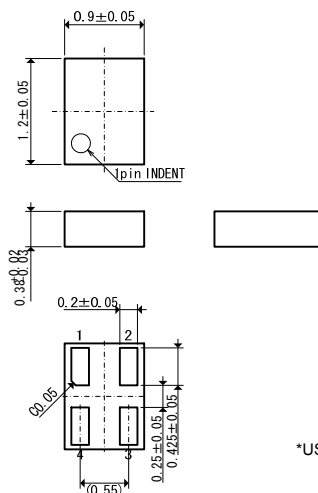
● SSOT-24



● SOT-25



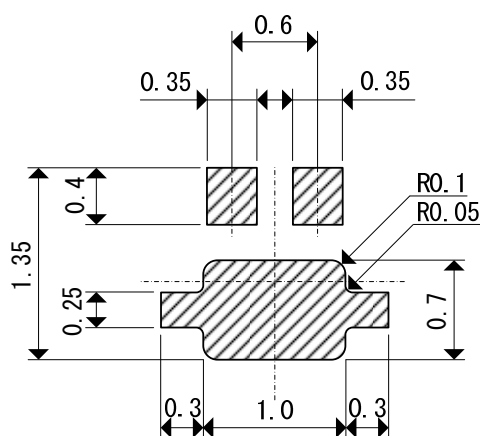
● USPN-4



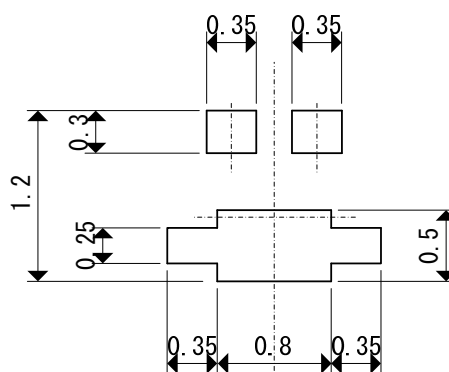
*USPN-4 is under development.

■ PACKAGING INFORMATION (Continued)

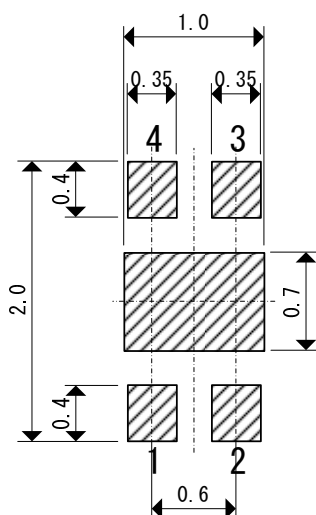
● USP-3 Reference Pattern Layout



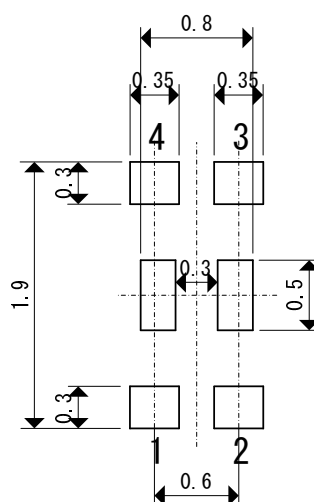
● USP-3 Reference Metal Mask Design



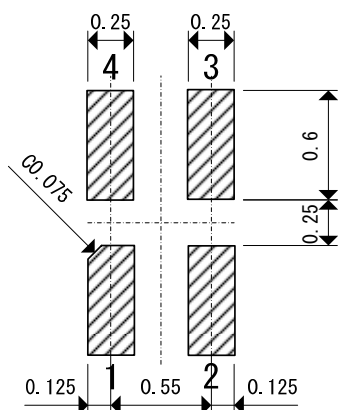
● USP-4 Reference Pattern Layout



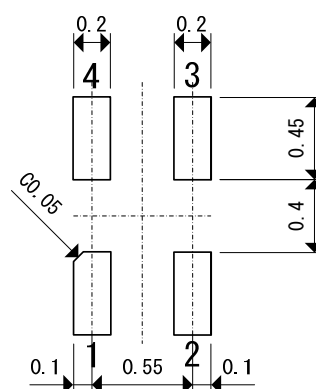
● USP-4 Reference Metal Mask Design



● USPN-4 Reference Pattern Layout



● USPN-4 Reference Metal Mask Design



*USPN-4 is under development.

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

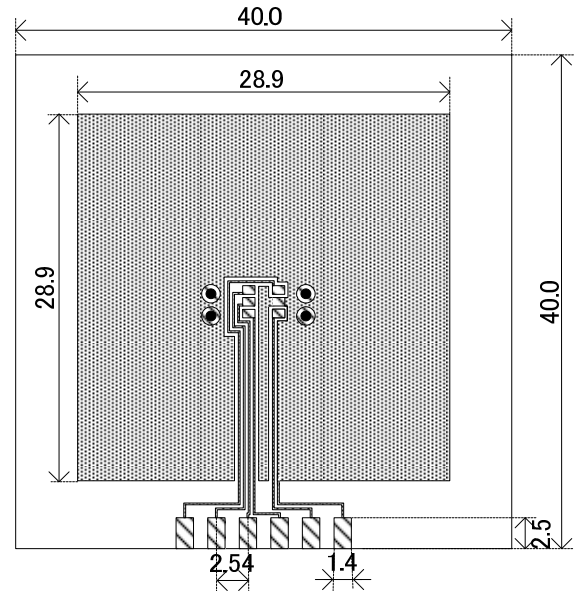
Package heat-sink is tied to the copper traces

(Board of SOT-26 is used.)

Material: Glass Epoxy (FR-4)

Thickness: 1.6 mm

Through-hole: 4 x 0.8 Diameter

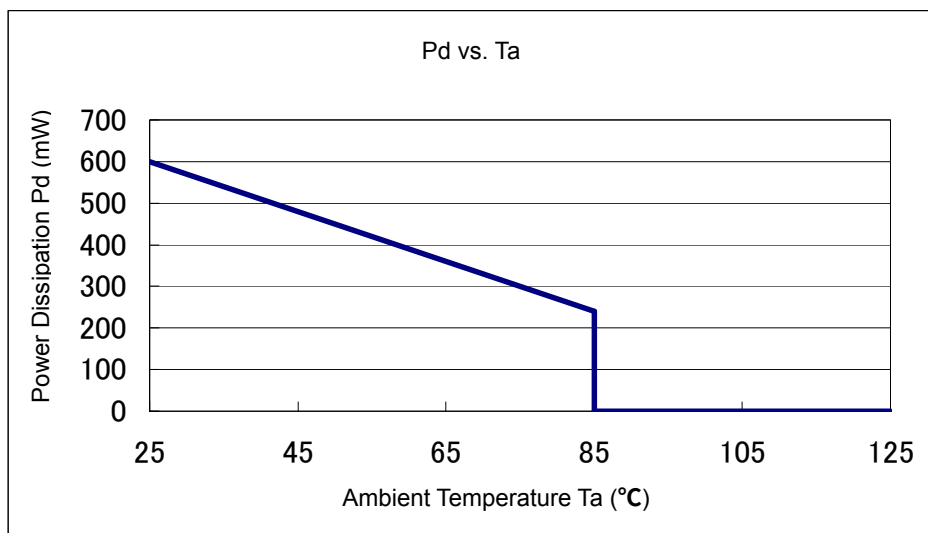


Evaluation Board (Unit: mm)

2. Power Dissipation vs. Operating temperature

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

Ambient Temperature ($^\circ\text{C}$)	Power Dissipation P_d (mW)	Thermal Resistance ($^\circ\text{C/W}$)
25	600	166.67
85	240	



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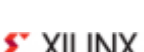
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