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XC6501 Series

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 μA (in operation) to less than 0.1 μA. 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.

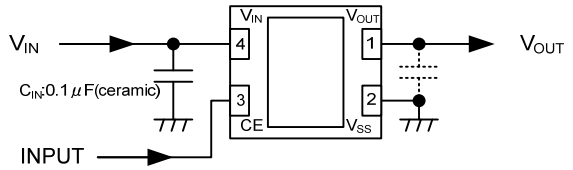
■APPLICATIONS

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

■FEATURES

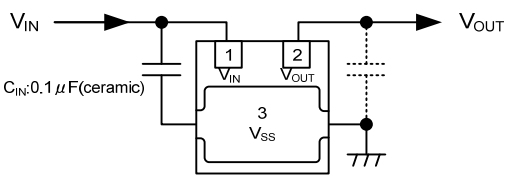
Operating Voltage Range	:	1.4～6.0V
Output Voltage Range	:	2.0～5.0V（Accuracy:±1%） 1.2～1.95V（Accuracy:±0.02V）
Dropout Voltage	:	150mV@I_{OUT}=100mA, V_{OUT}=2.8V
Low Power Supply	:	13μA@V_{OUT}=2.8V
Stand-by Current	:	Less than 0.1μA
Ripple Rejection	:	50dB@f=1kHz,V_{OUT}=2.8V
Protection Circuits	:	Current 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,USP-3
Environmentally Friendly	:	EU RoHS Compliant, Pb Free

■TYPICAL APPLICATION CIRCUIT



USP-4
(BOTTOM VIEW)

XC6501A/B/C/D Series

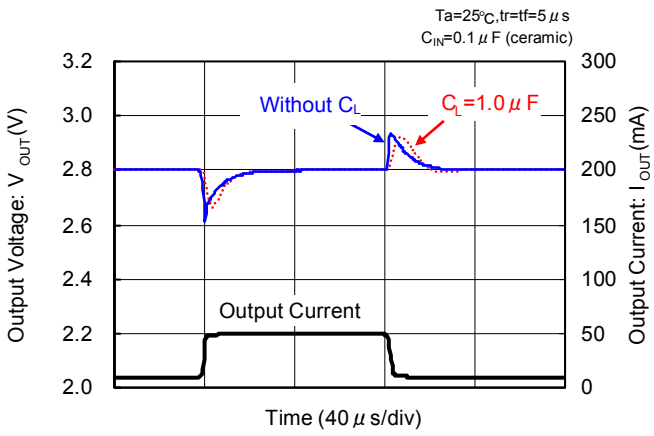


USP-3
(BOTTOM VIEW)

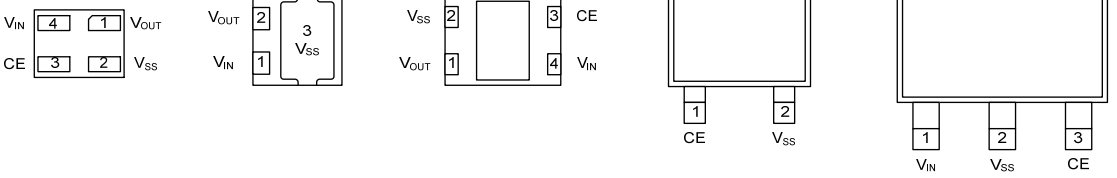
XC6501P Series

■TYPICAL PERFORMANCE CHARACTERISTICS

XC6501 Series



■PIN CONFIGURATION



USPN-4 (BOTTOM VIEW) | USP-3 (BOTTOM VIEW) | USP-4 (BOTTOM VIEW) | SSOT-24 (TOP VIEW) | SOT-25 (TOP VIEW)

*The heat dissipation pad of the USP-4 package is reference to solder as the reference 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

■PRODUCT CLASSIFICATION

●Ordering Information

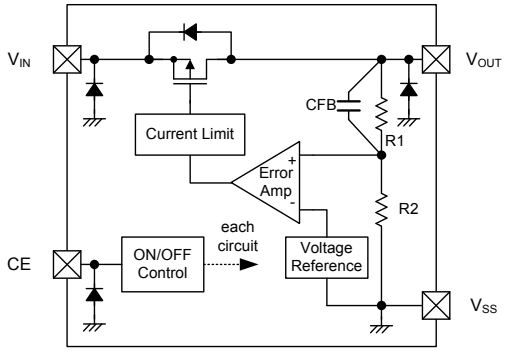
XC6501①②③④⑤⑥-⑦ (*1)

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)

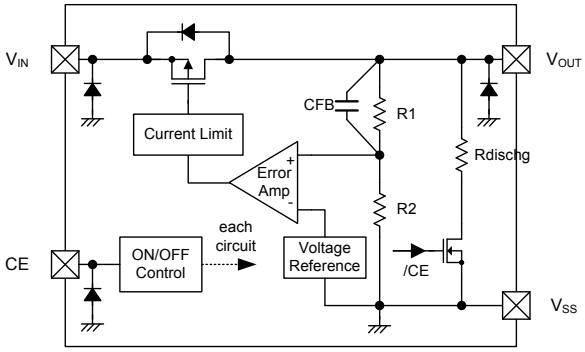
(*1) The "-G" suffix indicates that the products are Halogen and Antimony free as well as being fully RoHS compliant.

(*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

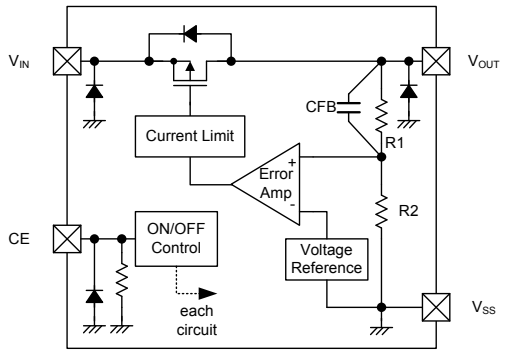
■BLOCK DIAGRAMS



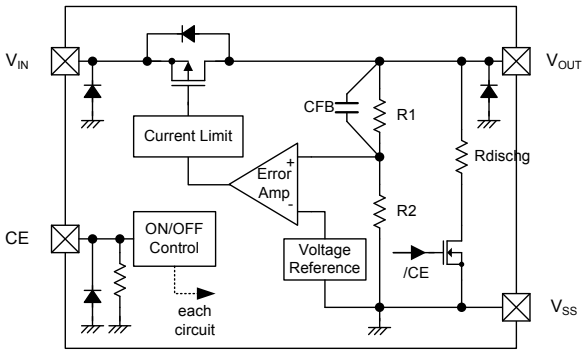
XC6501A Series



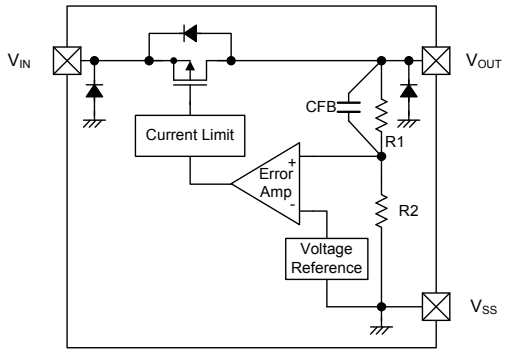
XC6501B Series



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～+6.5	V
Output Current		I_{OUT}	400 (*1)	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	USPN-4	Pd	100	mW
	USP-3		120	
	USP-4		120	
			1000 (PCB mounted)*2	
	SSOT-24		150	
			500 (PCB mounted)*2	
	SOT-25		250	
			600 (PCB mounted)*2	
Operating Temperature Range		Topr	-40～+85	℃
Storage Temperature Range		Tstg	-55～+125	℃

*1 Pd＞(V_{IN}-V_{OUT})×I_{OUT}

*2 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℃

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≦$V_{OUT(T)}$ V_{CE}=V_{IN}, I_{OUT}=10mA	×0.99 (*4)		×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≦I_{OUT}≦100mA	-	15	45	mV	①
Dropout Voltage (*5)	Vdif	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	Istby	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≦V_{IN}≦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℃≦Ta≦85℃	-	±100	-	ppm/℃	①
Ripple Rejection Rate	PSRR	$V_{OUT(T)}$≦4.75V V_{IN}={$V_{OUT(T)}$+1.0}V_{DC}+0.5Vp-p_{AC} V_{CE}=V_{IN}, I_{OUT}=30mA, f=1kHz	-	50	-	dB	③
		$V_{OUT(T)}$≧4.80V V_{IN}=5.75V_{DC}+0.5Vp-p_{AC} 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 XC6501A/B	-0.1	-	0.1	μA	①
		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: Vdif={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		
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		
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		
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		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			13	
2.45	2.4255	2.4745				
2.50	2.4750	2.5250	210	380		
2.55	2.5245	2.5755				
2.60	2.5740	2.6260				20
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		
2.85	2.8215	2.8785				
2.90	2.8710	2.9290				
2.95	2.9205	2.9795				

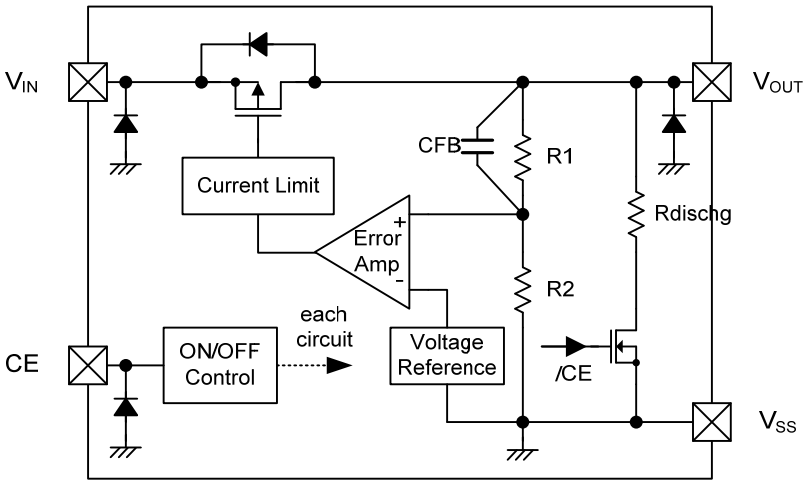
■ELECTRICAL CHARACTERISTICS (Continued)

●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				
3.10	3.0690	3.1310				21
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	
3.65	3.6135	3.6865				
3.70	3.6630	3.7370				
3.75	3.7125	3.7875				
3.80	3.7620	3.8380				22
3.85	3.8115	3.8885				
3.90	3.8610	3.9390				
3.95	3.9105	3.9895				
4.00	3.9600	4.0400				
4.05	4.0095	4.0905				
4.10	4.0590	4.1410				
4.15	4.1085	4.1915				
4.20	4.1580	4.2420	120	330	16	
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				23
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 (τ=C x Rdischg), the output voltage after discharge via the N-channel transistor is calculated by the following formulas.

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

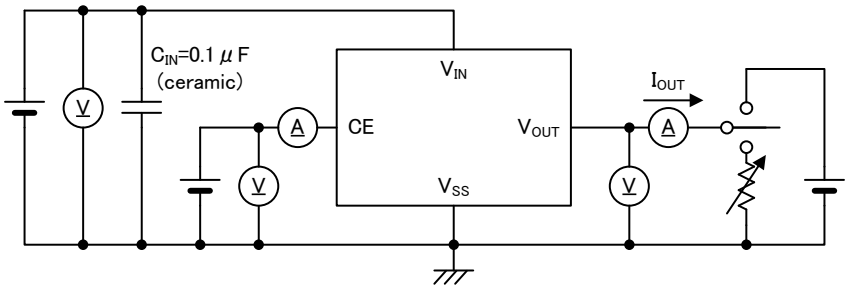
The IC's internal circuitry can be shutdown via the signal from the CE pin with the XC6501 series. In shutdown mode output at the V_{OUT} pin will be pulled down to the V_{SS} level via R1 & R2. However, as for the XC6501B/D series, the C_L auto-discharge resistor is connected in parallel to R1 and R2 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

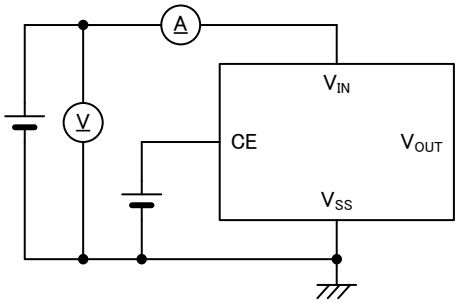
1. Please use this IC within the stated absolute maximum ratings. The IC is liable to malfunction should the ratings be exceeded.
2. This IC achieves stable operation without an output capacitor C_L by internal phase compensation. However, wiring impedance is high, operations may become unstable due 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

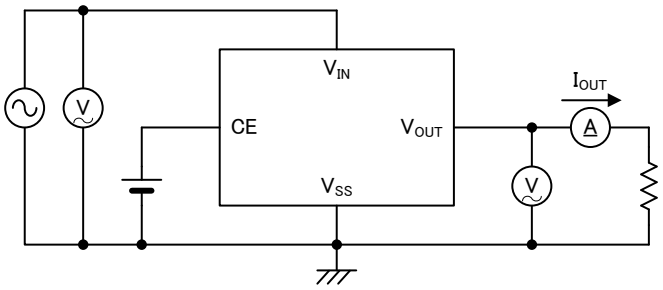
●Circuit ①



●Circuit ②



●Circuit ③

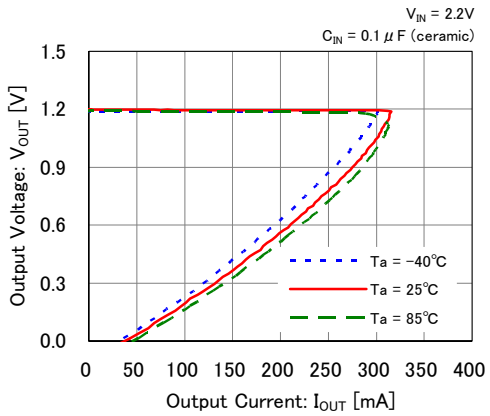


■TYPICAL PERFORMANCE CHARACTERISTICS

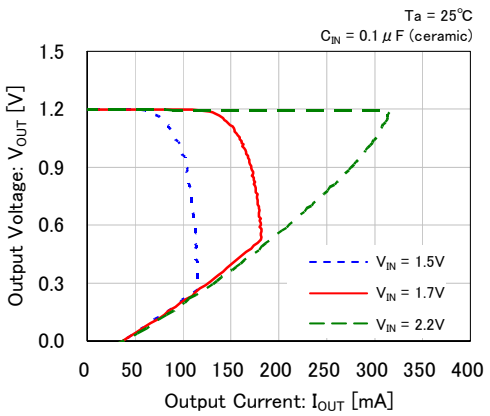
*CE Voltage condition: Unless otherwise stated, V_{CE} =V_{IN}

(1) Output Voltage vs. Output Current

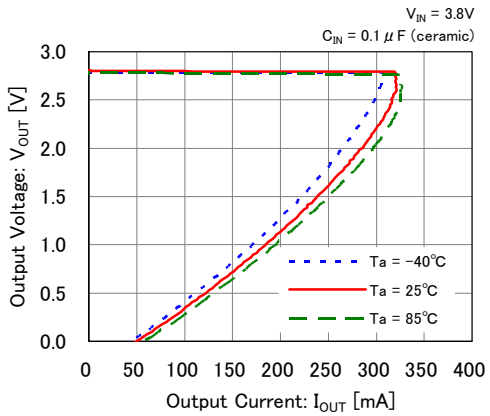
XC6501x121



XC6501x121



XC6501x281



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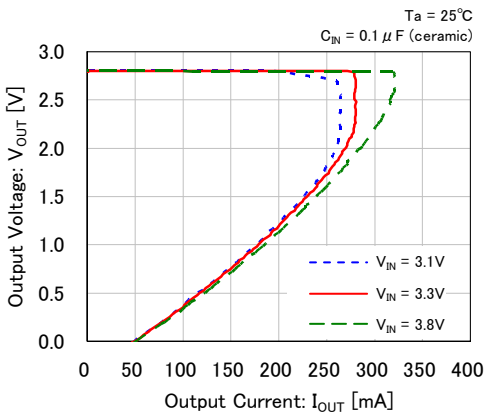

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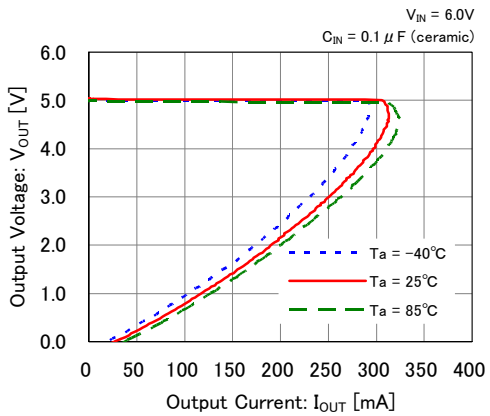

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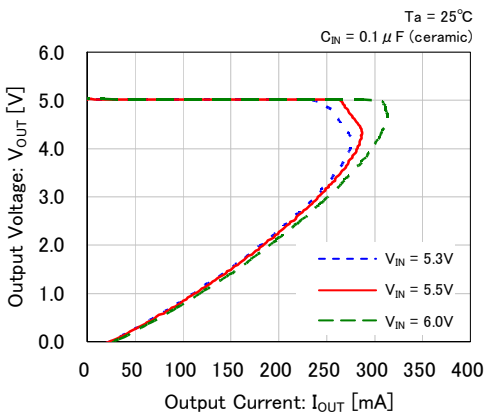
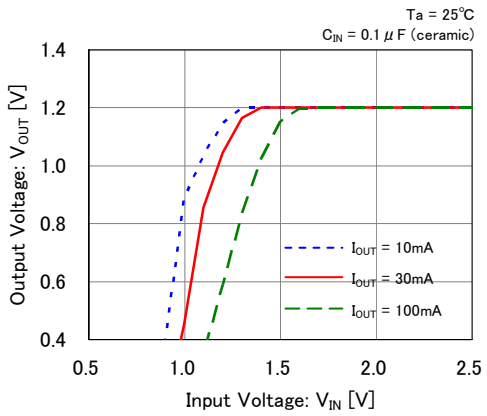


■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(2) Output Voltage vs. Input Voltage

XC6501x121



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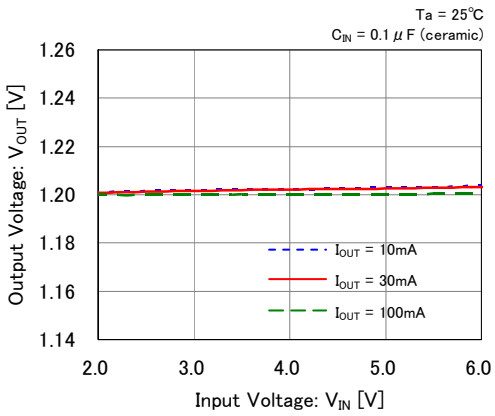

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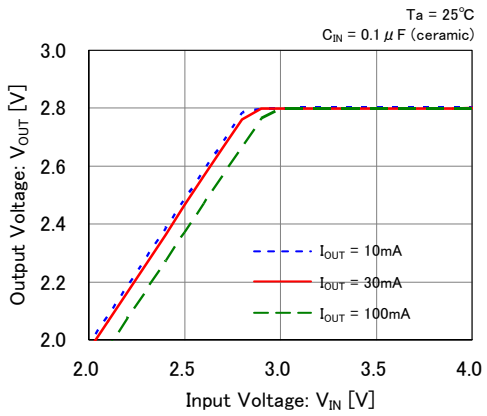

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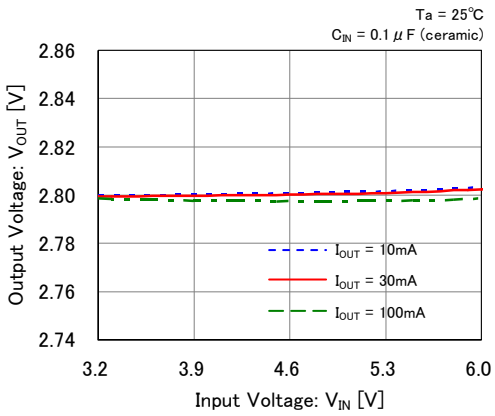

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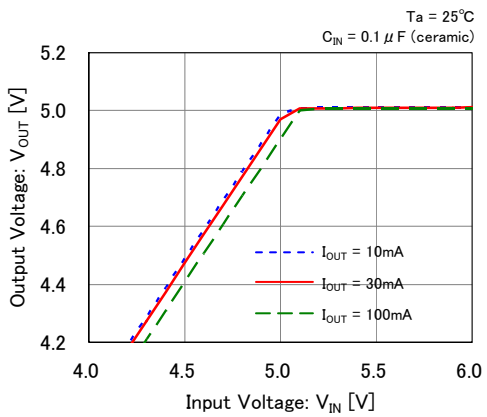

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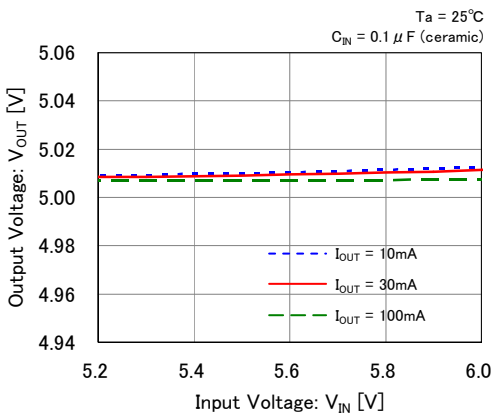

■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(3) Dropout Voltage vs. Output Current

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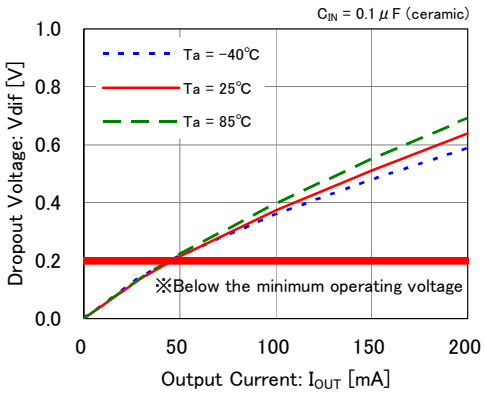

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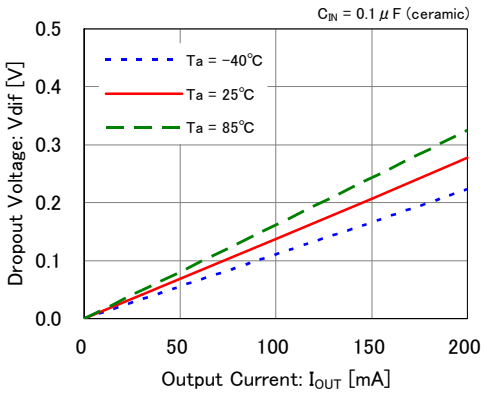

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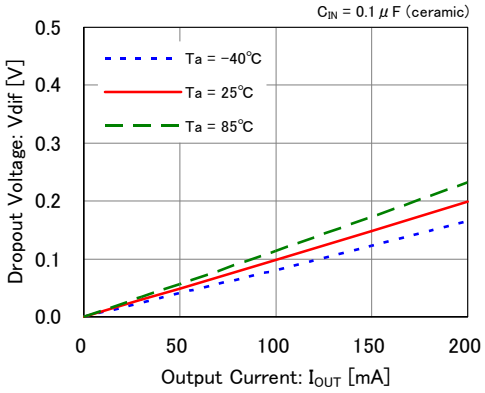
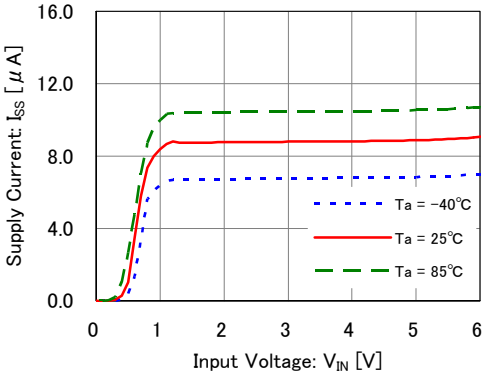


(4) Supply Current vs. Input Voltage

XC6501x121



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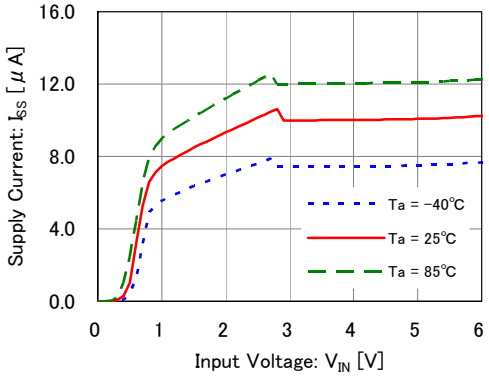

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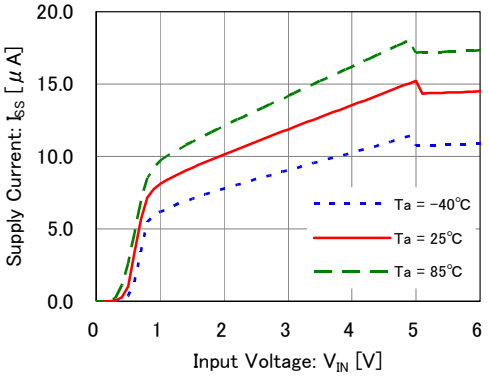
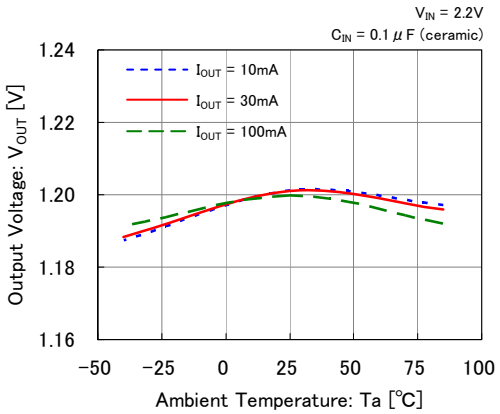


■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(5) Output Voltage vs. Ambient Temperature

XC6501x121



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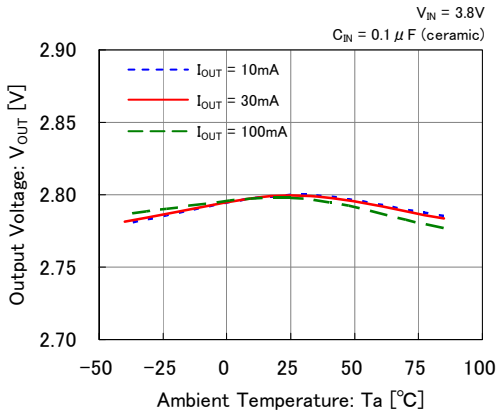

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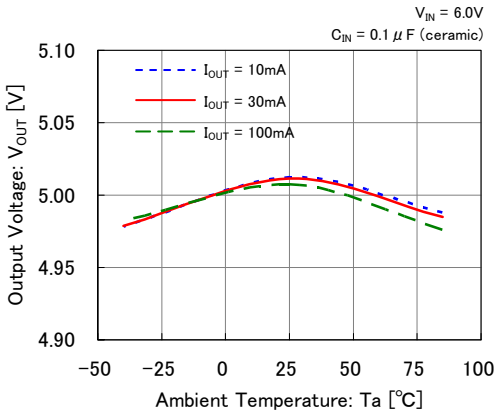
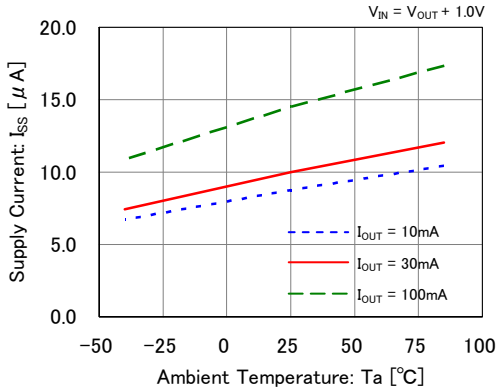


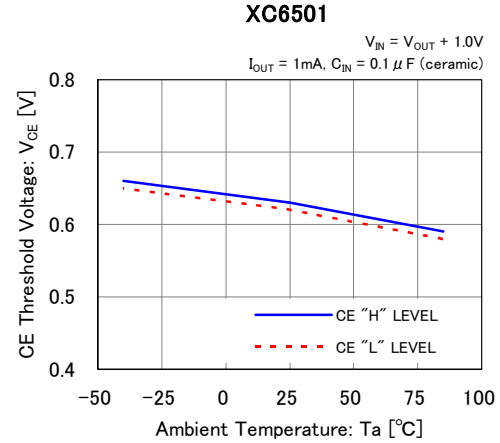
(6) Supply Current vs. Ambient Temperature

XC6501



(7) CE Threshold Voltage vs. Ambient Temperature

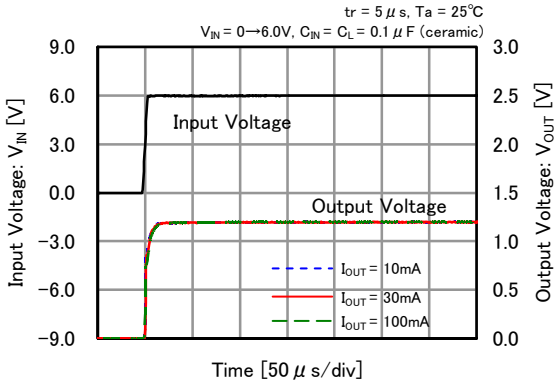
XC6501



■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(8) Rising Response Time

XC6501x121



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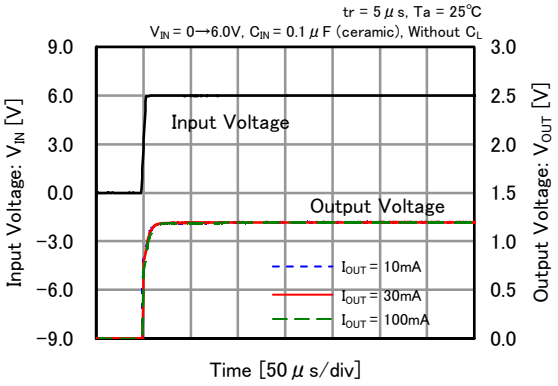

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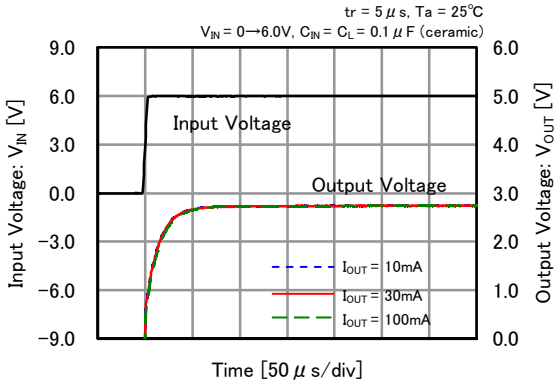

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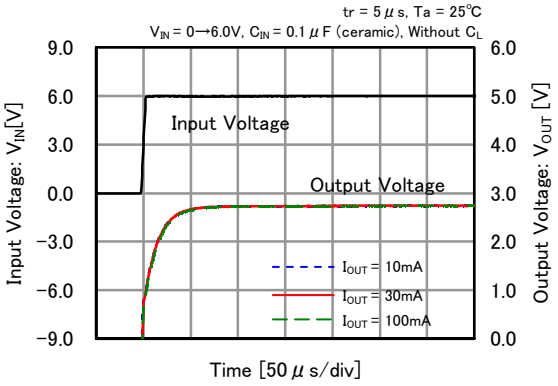

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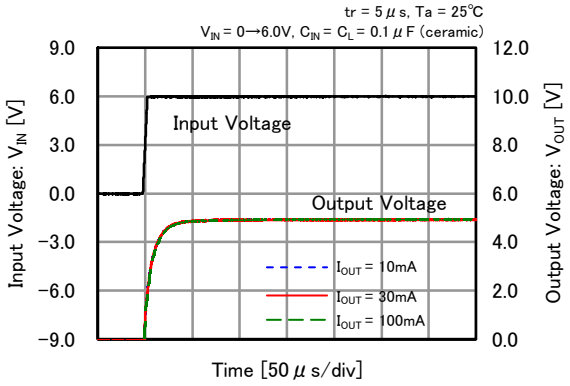

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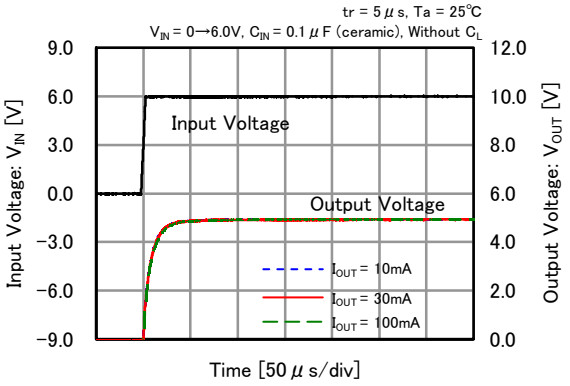

■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(9) Input Transient Response

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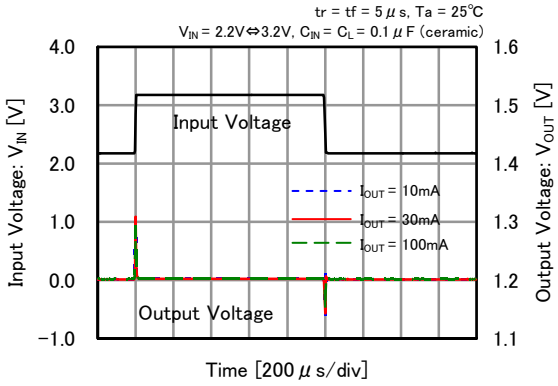

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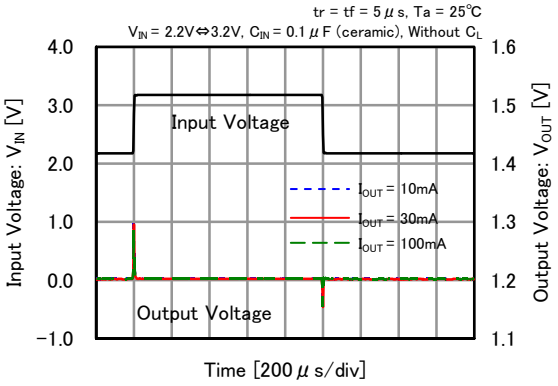

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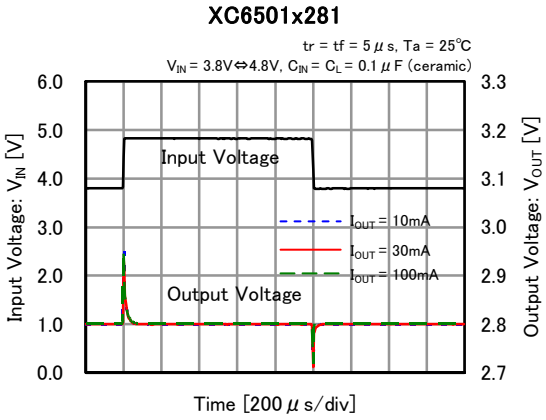

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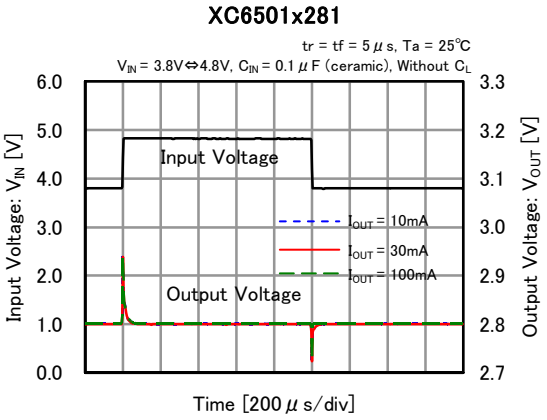

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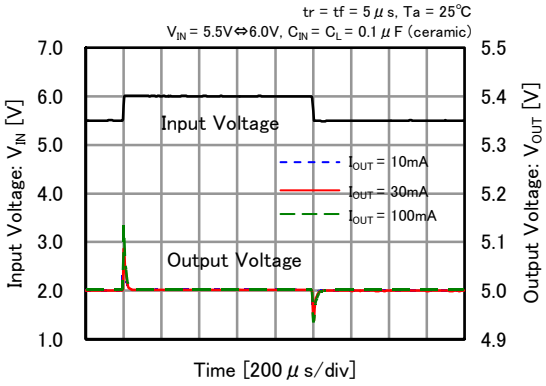

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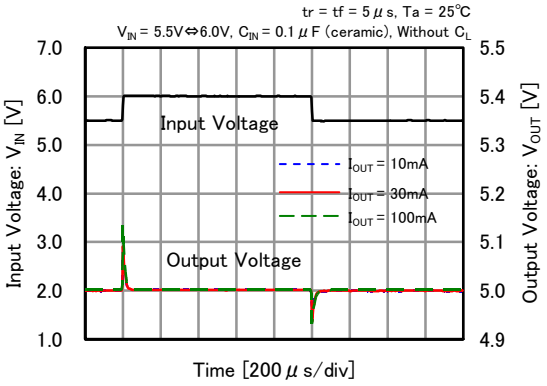

■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(10) Load Transient Response

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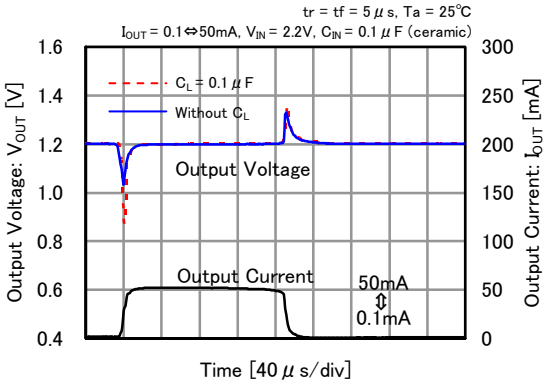

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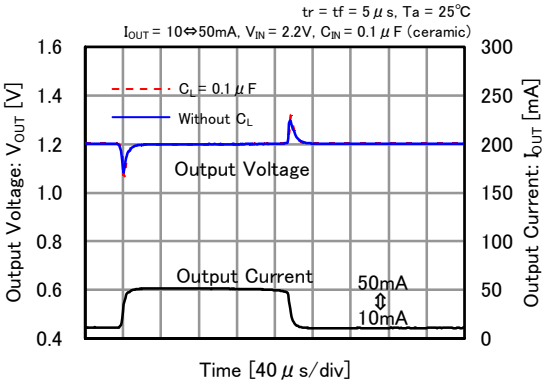

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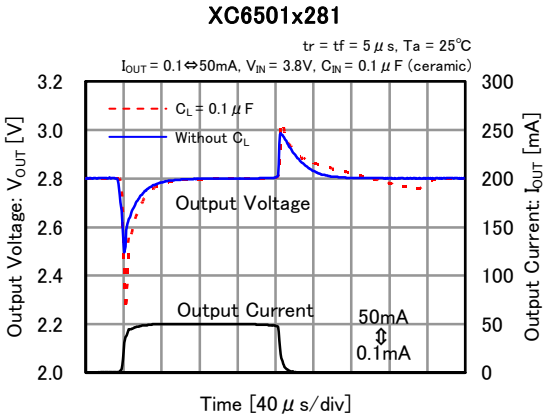

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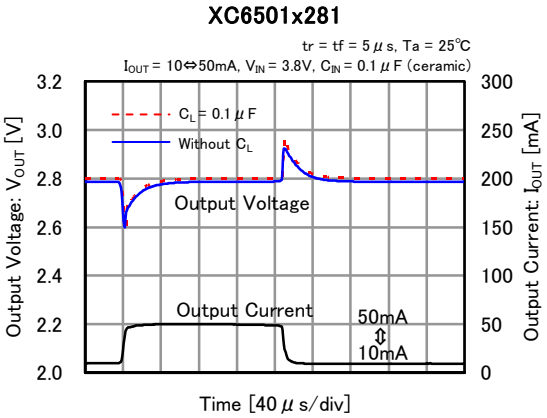

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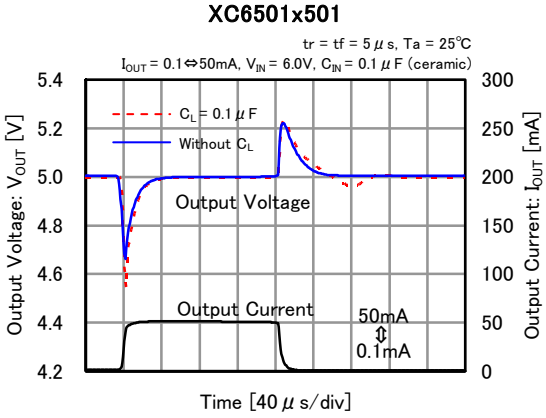

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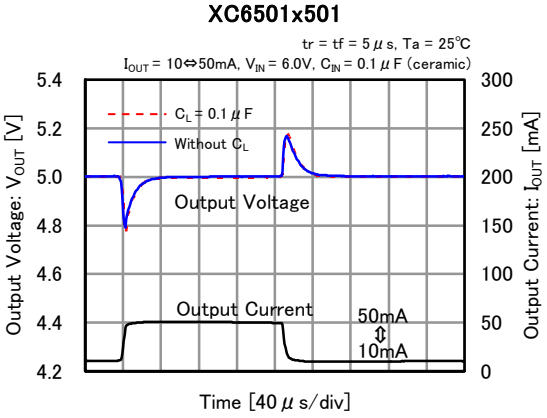

■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(11) CE Rising Respose Time

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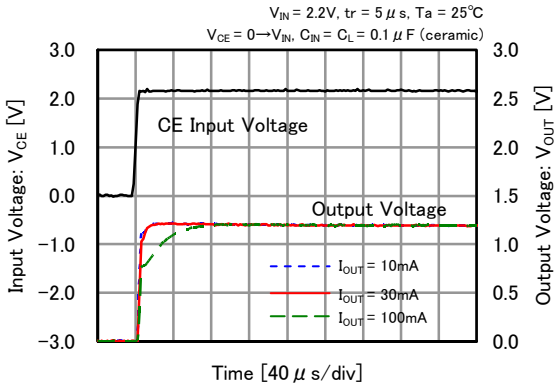

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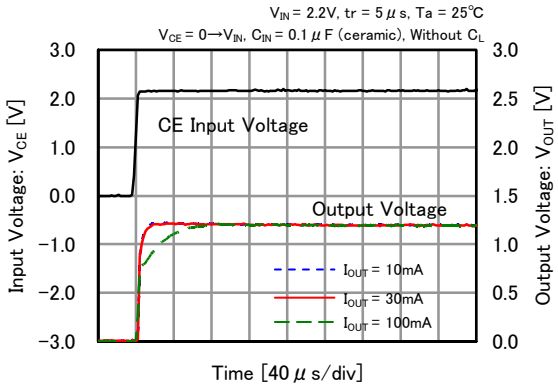

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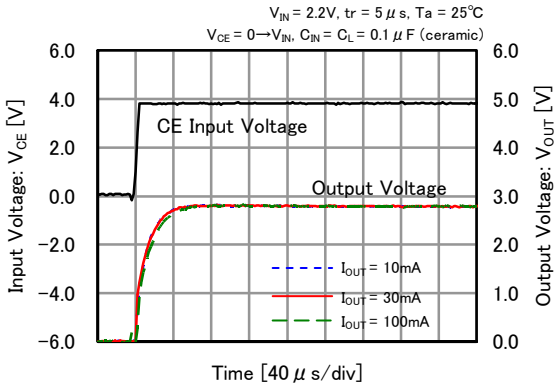

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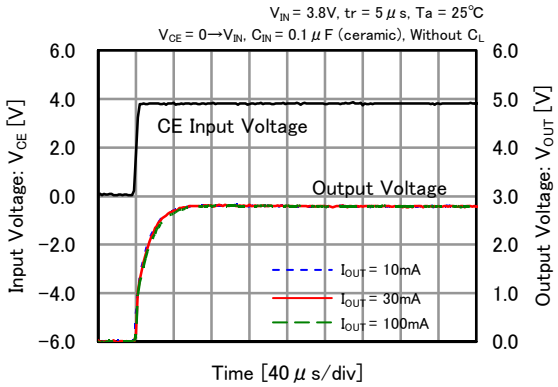

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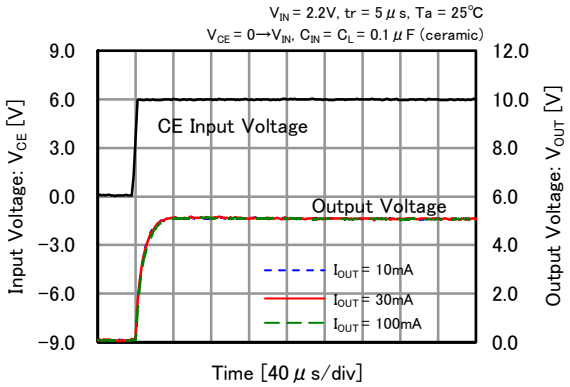

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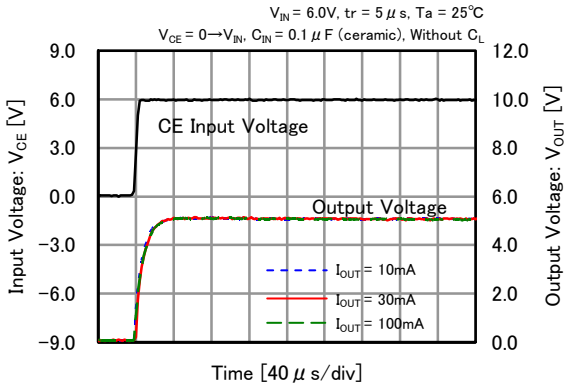
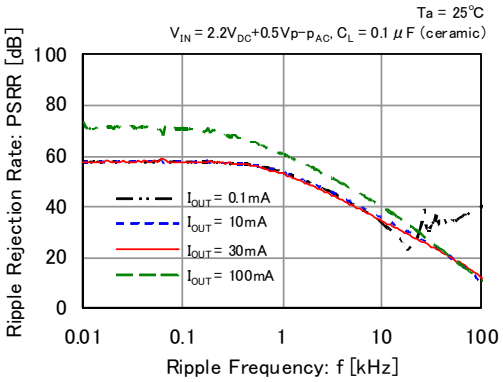


■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

(12) Ripple Rejection Rate

XC6501x121



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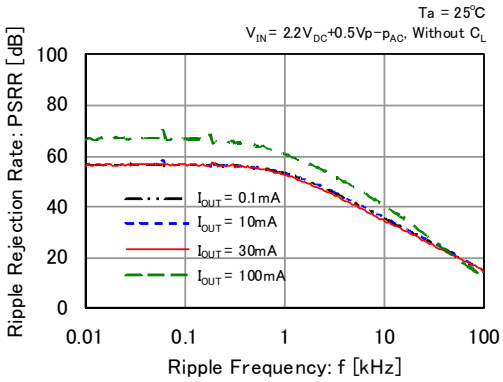

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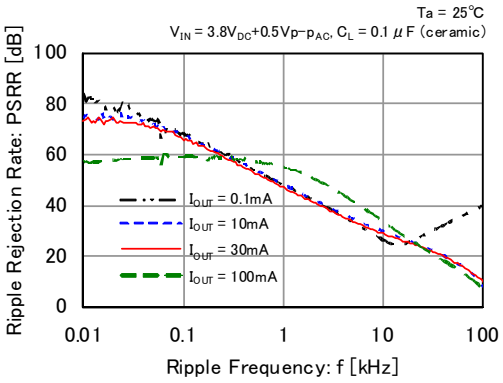

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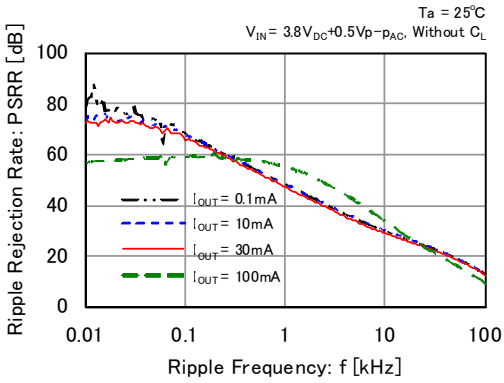

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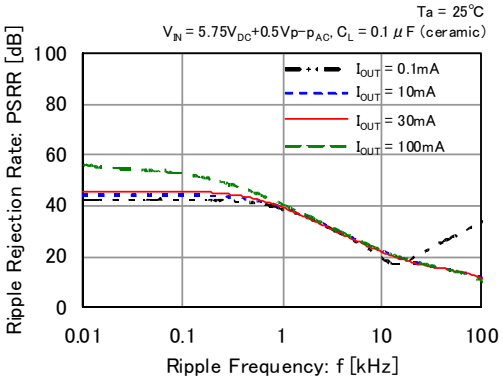

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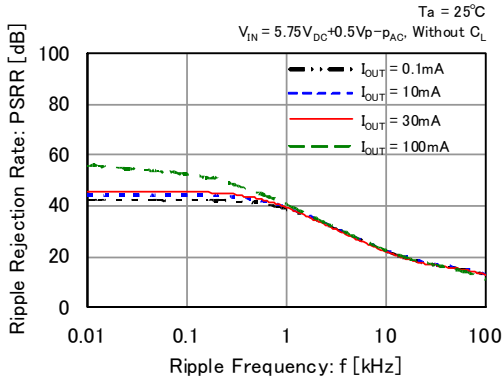
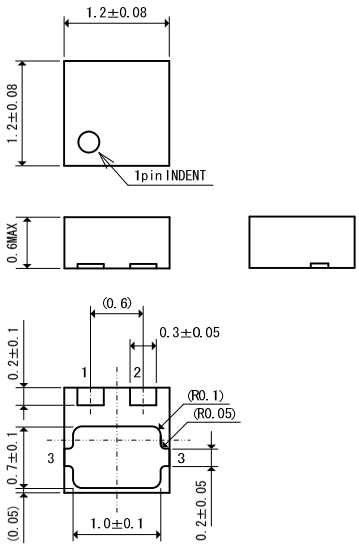
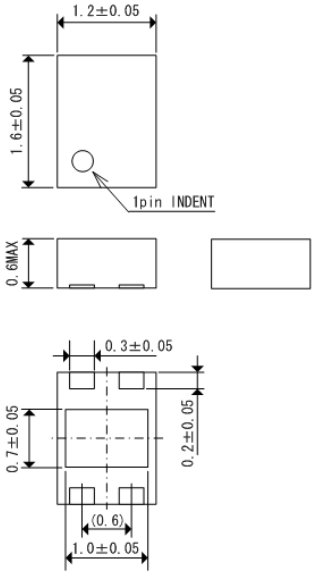


■PACKAGING INFORMATION

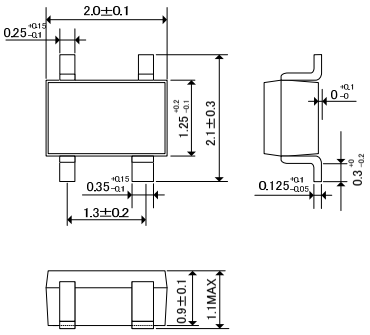
● USP-3



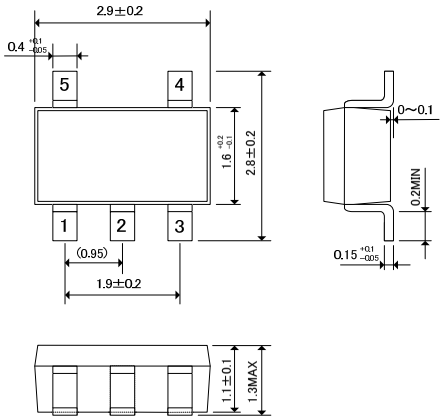
● USP-4



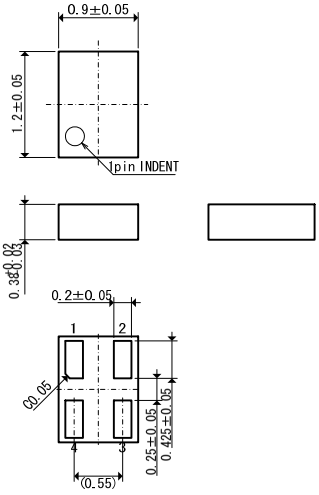
● SSOT-24



● SOT-25

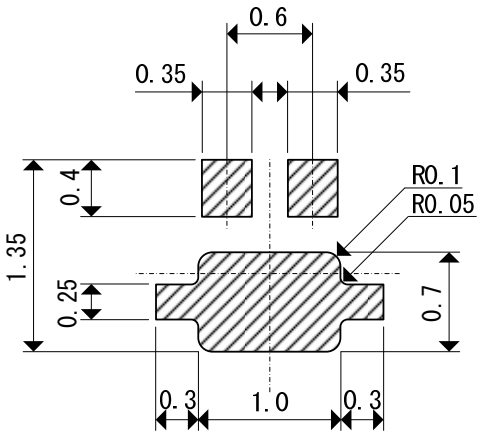


● USPN-4

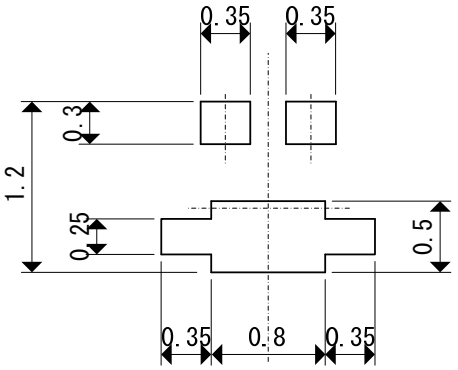


■PACKAGING INFORMATION (Continued)

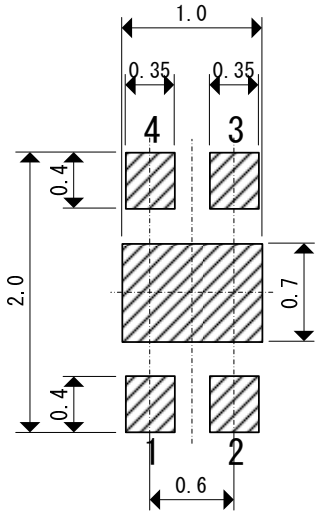
●USP-3 Reference Pattern Layout



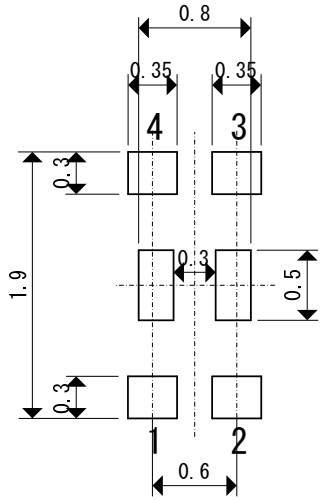
●USP-3 Reference Metal Mask Design



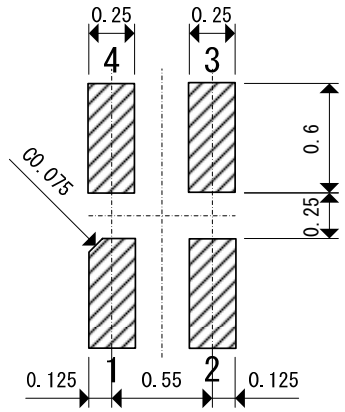
●USP-4 Reference Pattern Layout



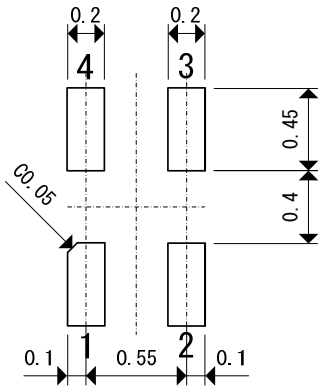
●USP-4 Reference Metal Mask Design



●USPN-4 Reference Pattern Layout



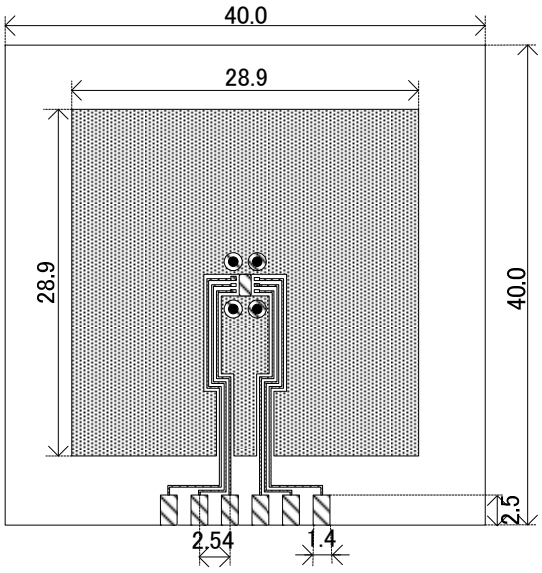
●USPN-4 Reference Metal Mask Design



■PACKAGING INFORMATION (Continued)

● USP-4 Power Dissipation

Power dissipation data for the USP-4 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.



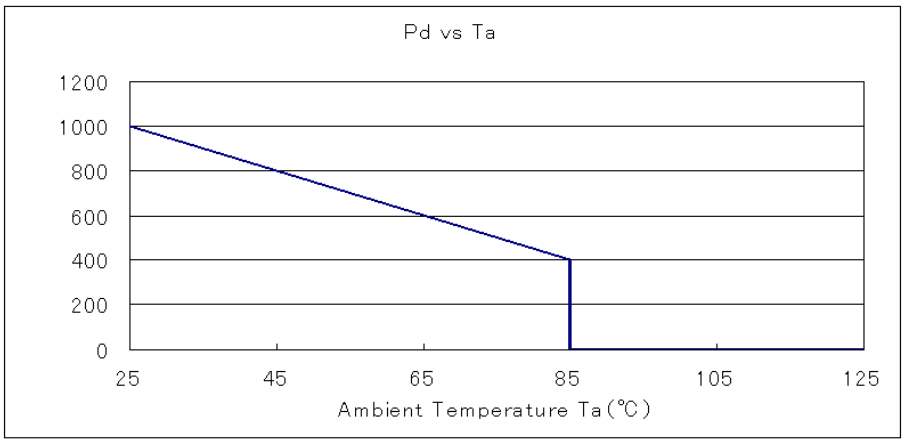
Evaluation Board (Unit: mm)

1. Measurement Condition (Reference data)
   Condition: Mount on a board
   Ambient: Natural convection
   Soldering: Lead (Pb) free
   Board: Dimensions 40 x 40 mm (1600 mm^2 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

2. Power Dissipation vs. Ambient temperature

Board Mount (Tj max = 125℃)

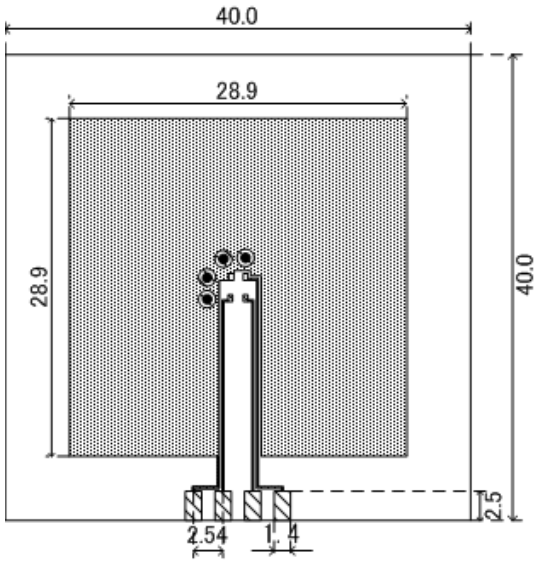
Ambient Temperature(℃)	Power Dissipation Pd(mW)	Thermal Resistance (℃/W)
25	1000	100.00
85	400	



■PACKAGING INFORMATION (Continued)

● SSOT-24 Power Dissipation

Power dissipation data for the SSOT-24 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.



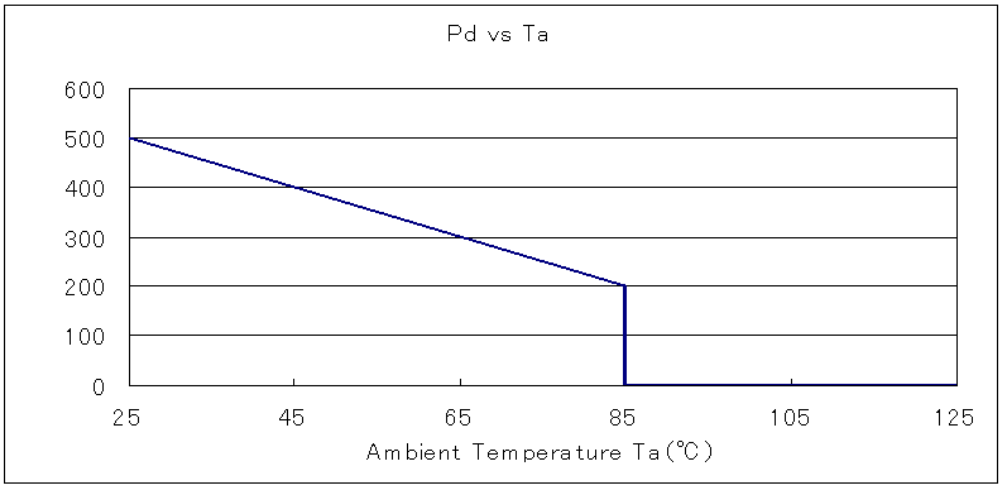
Evaluation Board (Unit: mm)

2. Measurement Condition (Reference data)
Condition: Mount on a board
Ambient: Natural convection
Soldering: Lead (Pb) free
Board: Dimensions 40 x 40 mm (1600 mm^2 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

2. Power Dissipation vs. Ambient temperature

Board Mount (Tj max = 125℃)

Ambient Temperature (℃)	Power Dissipation Pd (mW)	Thermal Resistance (℃/W)
25	500	200.00
85	200	

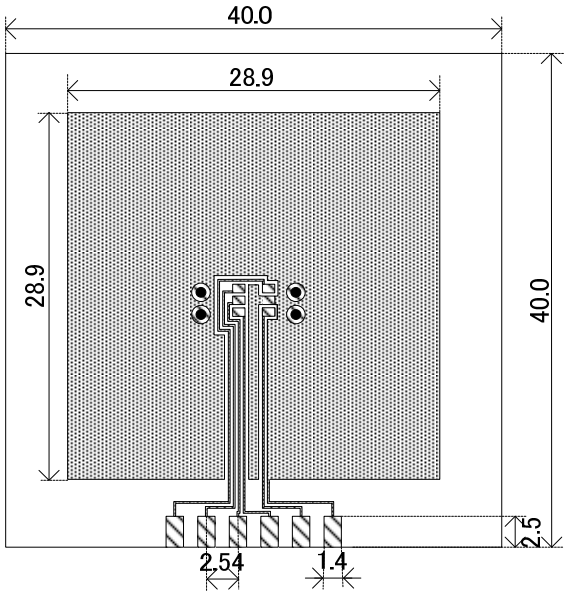


■PACKAGING INFORMATION (Continued)

● 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.

3. Measurement Condition (Reference data)
   Condition: Mount on a board
   Ambient: Natural convection
   Soldering: Lead (Pb) free
   Board: Dimensions 40 x 40 mm (1600 mm^2 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

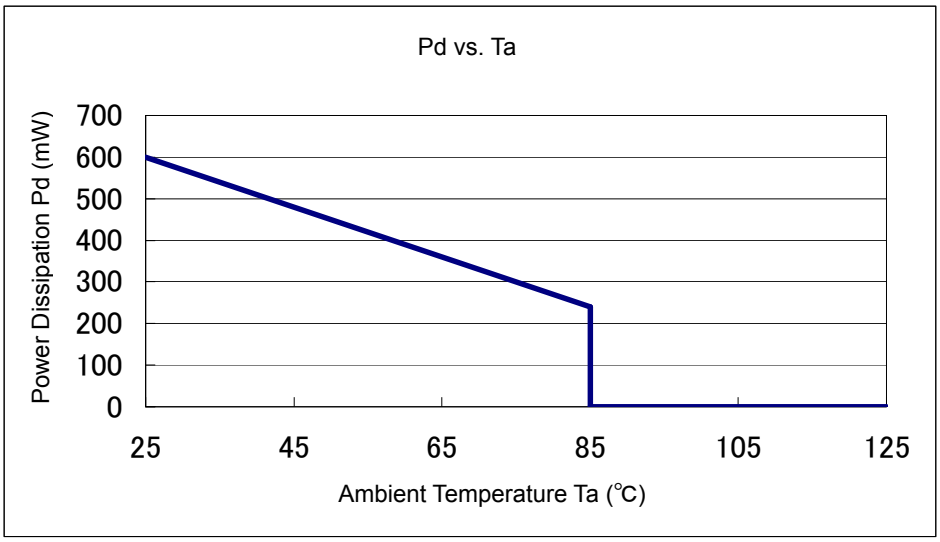


Evaluation Board (Unit: mm)

2. Power Dissipation vs. Ambient temperature

Board Mount (Tj max = 125℃)

Ambient Temperature (℃)	Power Dissipation Pd (mW)	Thermal Resistance (℃/W)
25	600	166.67
85	240	



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