250mA Dual Channel Linear Regulators with Enable Function

Features

- **Operating Voltage Range：+1.8V to +5.5V**
- **Output Voltage Range：+1.0V to +5.0V**
- **Dropout：150mV @ 100mA (Typ.) ($V_{OUT}\geqq$2.8V)**
- **Output Current：250 mA / Channel (Typ.)**
- **Low Quiescent Current：25μA (Typ.) / Channel**
- **Standby Current：0.01μA (Typ.)**
- **Highly Accurate：±2% ($V_{OUT}\geqq$2.0V)**
- **High Ripple Rejection Rate：70 dB (Typ.)**
- **Output Current Limit Protection：450mA / Channel**
- **Short Circuit Protection：100mA (Typ.)**
- **Output ON/OFF Control Function**
- **Low ESR Capacitor Compatible**
- **SOT-26, UFN-6 Packages**
- **RoHS Compliant and 100% Lead (Pb)-Free and Green (Halogen Free with Commercial Standard)**

General Description

The AC6401 series are highly accurate, dual, low noise, CMOS LDO voltage regulators with enable function. The enable function allows the output of each regulator to be turned off independently, resulting in greatly reduced power consumption. The AC6401 series have soft start function to suppress the inrush current while powering on. The current limiters' fold back circuit (it happens when over 450mA per channel) also operates as a short protection for the output current limiter. The output voltage for each regulator is set independently by metal trimming. It's also available to offer the honors other types of V_{OUT} between +1.0V ~+5.0V except the options shown on ordering information.

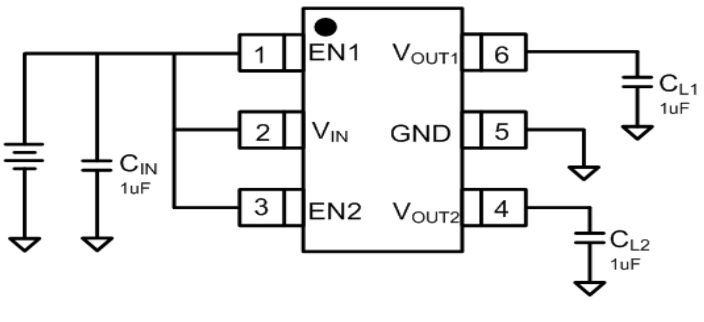
This series are fully compatible with low ESR ceramic capacitors, reducing cost and improving output stability. This high level output stability is maintained even during frequent load fluctuations, due to the excellent transient response performance and high PSRR achieved across a broad range of frequency.

AC6401 is available in SOT-26 and UFN-6 packages.

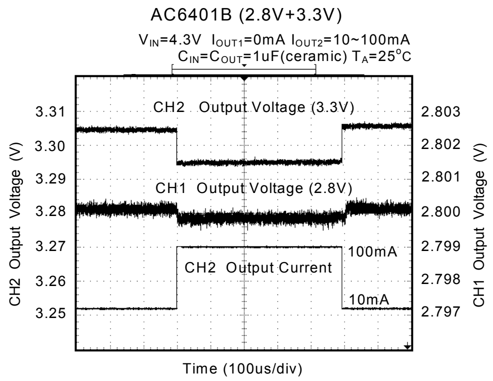
Applications

- Mobile Phones (PDC, GSM, CDMA, IMT2000 etc.) and PDAs
- Cordless Phones and Radio Communication
- Portable Audio Equipment
- Cameras, Video Recorders
- Portable Games

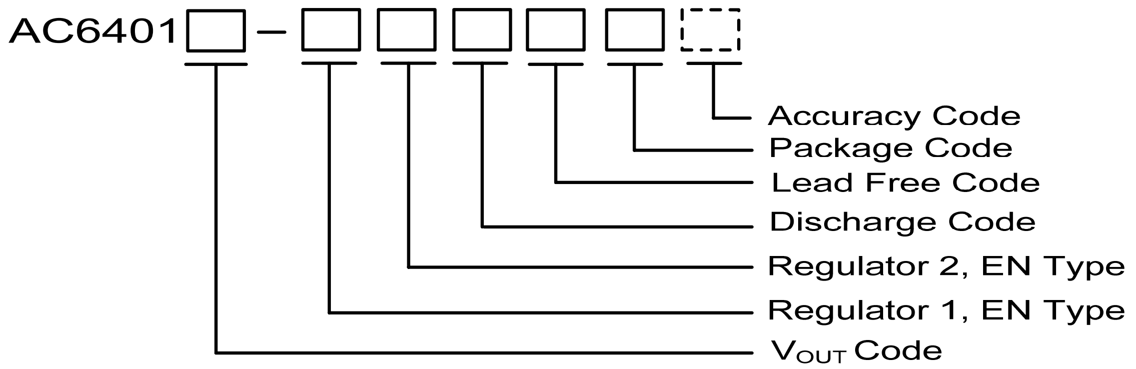
Simplified Application Circuit



Cross Talk



Ordering Information



Vout Code：$V_{OUT}1 + V_{OUT}2$

A：3.3V+3.3V	**J**：1.8V+2.8V	**S**：1.5V+1.8V	**2**：1.8V+3.0V
B：2.8V+3.3V	**K**：1.5V+2.8V	**T**：1.2V+1.8V	**3**：3.0V+3.0V
C：2.5V+3.3V	**L**：1.2V+2.8V	**U**：1.5V+1.5V	**4**：1.3V+2.8V
D：1.8V+3.3V	**M**：2.5V+2.5V	**V**：1.2V+1.5V	**5**：1.5V+3.0V
E：1.5V+3.3V	**N**：1.8V+2.5V	**W**：2.85V+2.85V	**6**：1.3V+3.3V
F：1.2V+3.3V	**P**：1.5V+2.5V	**X**：2.8V+1.8V	**7**：2.7V+2.7V
G：2.8V+2.8V	**Q**：1.2V+2.5V	**Y**：3.3V+2.8V	
H：2.5V+2.8V	**R**：1.8V+1.8V	**1**：3.0V+3.3V	

Regulator 1, EN Type：

E：High Active with Pull-down Resistor
G：Low Active with Pull-up Resistor
F：High Active with no Pull-down Resistor
H：Low Active with no Pull-up Resistor

Regulator 2, EN Type：

E：High Active with Pull-down Resistor
G：Low Active with Pull-up Resistor
F：High Active with no Pull-down Resistor
H：Low Active with no Pull-up Resistor

Discharge Code：

N：Normal Discharge
F：Fast Discharge

Lead Free Code：

P：Commercial Standard, Lead (Pb) Free and Phosphorous (P) Free Package

G：Green (Halogen Free with Commercial Standard)

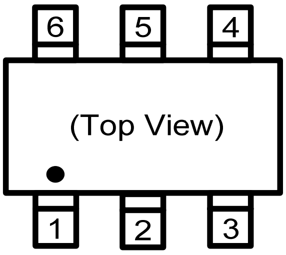
Package Code：

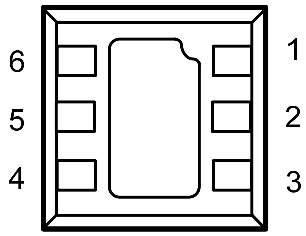
V：SOT-26*
U：UFN-6

Accuracy Code：

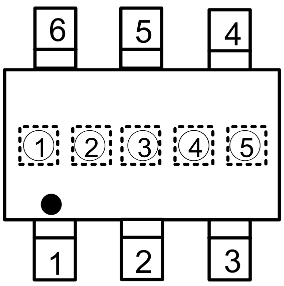
Default = None Digit = 2% Accuracy
1 = 1% Accuracy

Pin Description

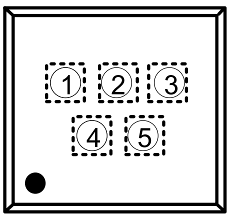
Part NO.	Pin V	Symbol	Pin Description
 SOT-23-6	1	EN1	Regulator 1 Enable Pin
	2	V_{IN}	Chip Input Pin
	3	EN2	Regulator 2 Enable Pin
	4	V_{OUT2}	Regulator 2 Output Pin
	5	GND	Ground Pin
	6	V_{OUT1}	Regulator 1 Output Pin

Part NO.	Pin	Symbol	Pin Description
 UFN-6 (Bottom View)	1	EN2	Regulator 2 Enable Pin
	2	V_{IN}	Chip Input Pin
	3	EN1	Regulator 1 Enable Pin
	4	GND	Ground Pin
	5	V_{OUT1}	Regulator 1 Output Pin
	6	V_{OUT2}	Regulator 2 Output Pin

Package Marking Information



SOT-23-6
(Top View)



UFN-6
(Top View)

① 、② Represents Products Series

Mark	Products Series
See Note 1	See Note 1

③ Represents Type of Output Voltage

Mark	Products Series
See Note 2	See Note 2

④ 、⑤ Represents Production Date Code

Note：

* There is a under-line on 2nd digit for N type package.
* There is a upper-line on 2nd digit for 1% accuracy.
* There are two under-lines on 4th & 5th digit for Green
* There are no under-lines on 4th & 5th digit for Pb-Free package.

Note 1：

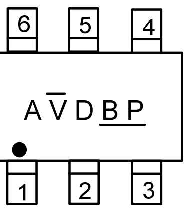
Product*	Mark	Product*	Mark	Product*	Mark
AC6401X-EEN	**AA**	AC6401X-HEN	**AM**	AC6401X-GEF	**AY**
AC6401X-EFN	**AB**	AC6401X-HFN	**AN**	AC6401X-GFF	**AZ**
AC6401X-EGN	**AC**	AC6401X-HGN	**AO**	AC6401X-GGF	**A1**
AC6401X-EHN	**AD**	AC6401X-HHN	**AP**	AC6401X-GHF	**A2**
AC6401X-FEN	**AE**	AC6401X-EEF	**AQ**	AC6401X-HEF	**A3**
AC6401X-FFN	**AF**	AC6401X-EFF	**AR**	AC6401X-HFF	**A4**
AC6401X-FGN	**AG**	AC6401X-EGF	**AS**	AC6401X-HGF	**A5**
AC6401X-FHN	**AH**	AC6401X-EHF	**AT**	AC6401X-HHF	**A6**
AC6401X-GEN	**AI**	AC6401X-FEF	**AU**		
AC6401X-GFN	**AJ**	AC6401X-FFF	**AV**		
AC6401X-GGN	**AK**	AC6401X-FGF	**AW**		
AC6401X-GHN	**AL**	AC6401X-FHF	**AX**		

* X represents the voltage mark and please refers to Note 2.

Note 2：

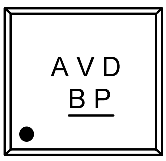
Mark	Voltage	Mark	Voltage	Mark	Voltage
A	3.3V+3.3V	**L**	1.2V+2.8V	**X**	2.8V+1.8V
B	2.8V+3.3V	**M**	2.5V+2.5V	**Y**	3.3V+2.8V
C	2.5V+3.3V	**N**	1.8V+2.5V	**W**	2.85V+2.85V
D	1.8V+3.3V	**P**	1.5V+2.5V	**1**	3.0V+3.3V
E	1.5V+3.3V	**Q**	1.2V+2.5V	**2**	1.8V+3.0V
F	1.2V+3.3V	**R**	1.8V+1.8V	**3**	3.0V+3.0V
G	2.8V+2.8V	**S**	1.5V+1.8V	**4**	1.3V+2.8V
H	2.5V+2.8V	**T**	1.2V+1.8V	**5**	1.5V+3.0V
J	1.8V+2.8V	**U**	1.5V+1.5V	**6**	1.3V+3.3V
K	1.5V+2.8V	**V**	1.2V+1.5V		

Example：



SOT-23-6
(Top View)

Part No.: AC6401D-FFFGV1
Type: EN1 & EN2 High Active
with no Pull-down Resistor
& Fast Discharge & 1% Accuracy
Date Code: BP
2007/49th week
Green Package



UFN-6
(Top View)

Part No.: AC6401D-FFFGV
Type: EN1 & EN2 High Active
with no Pull-down Resistor
& Fast Discharge
Date Code: BP
2007/49th week
Green Package

Absolute Maximum Ratings

Parameter		Symbol	Ratings	Units
Input Voltage V_{IN} to GND		V_{IN}	6.0	V
Output Current Limit, $I_{(LIMIT)}$		I_{OUT}	500	mA
Junction Temperature		T_J	+155	°C
Thermal Resistance	SOT-26	θ_{JA}	250	°C/W
	UFN-6		165	
Power Dissipation	SOT-26	P_D	400	mW
	UFN-6		500	
Operating Ambient Temperature		T_{OPR}	-40 ~ +125	°C
Storage Temperature		T_{STG}	-55 ~ +150	°C
Lead Temperature (soldering, 10sec)			+260	°C

Note：
* The power dissipation values are based on the condition that junction temperature T_J and ambient temperature T_A difference is 100°C.
* Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and function operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum -rated conditions for extended periods may affect device reliability.

Electrical Characteristics

(T_A=25℃, unless otherwise noted.)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{IN}	Input Voltage		1.8		5.5	V
V_{OUT}	Output Voltage	$V_{IN}=V_{OUT}+1.0V$, I_{OUT}=30mA, $V_{OUT}>2.0V$	-2%	V_{OUT}	+2%	V
		$V_{IN}=V_{OUT}+1.0V$, I_{OUT}=30mA, $V_{OUT}\leqq 2.0V$	-0.04	V_{OUT}	+0.04	V
I_{MAX}	Output Current	$V_{OUT}+1.0V \leq V_{IN} \leqq 5.5V$ (see note *1)	250			mA
V_{DROP}	Dropout Voltage	I_{OUT}=100mA		150	250	mV
		I_{OUT}=200mA		300	450	
I_{SS}	Supply Current	$V_{IN}=V_{EN1}=V_{EN2}=V_{OUT}+1.0V$, I_{OUT}=0mA		25	55	μA
I_{STB}	Standby Current	$V_{IN}=V_{OUT}+1.0V$, $V_{EN1}=V_{EN2}=V_{SS}$		0.01	1	μA
ΔV_{LINE}	Line Regulation	$V_{OUT}+1.0V \leq V_{IN} \leq 5.5V$, I_{OUT}=0mA		0.2	0.3	%/V
ΔV_{LOAD}	Load Regulation	$V_{IN}=V_{OUT}+1.0V$, 1mA ≤ I_{OUT} ≤ 100mA		0.02	0.03	%/mA
T_C	Temperature Characteristics	I_{OUT}=30mA, -25°C ≤ T_{OPR} ≤ +85°C		±100		ppm/°C
I_{LIM}	Current Limiter	$V_{IN}=V_{OUT}+1.0V$, $V_{IN}=V_{EN1}$, V_{EN2}=0V		450		mA
I_{SHORT}	Short-Circuit Current	$V_{IN}=V_{OUT}+1.0V$, $V_{IN}=V_{EN1}$, V_{EN2}=0V		100		mA
PSRR	Ripple Rejection Rate	I_{OUT}=30mA, F=1KHz		70		dB
V_{IH}	EN Pin Input Voltage "H"	(see note *2)	1.6			V
V_{IL}	EN Pin Input Voltage "L"	(see note *2)			0.3	V
T_{TST}	Thermal Shutdown Temperature			150		°C
T_{TSH}	Thermal Shutdown Hysteresis			40		°C

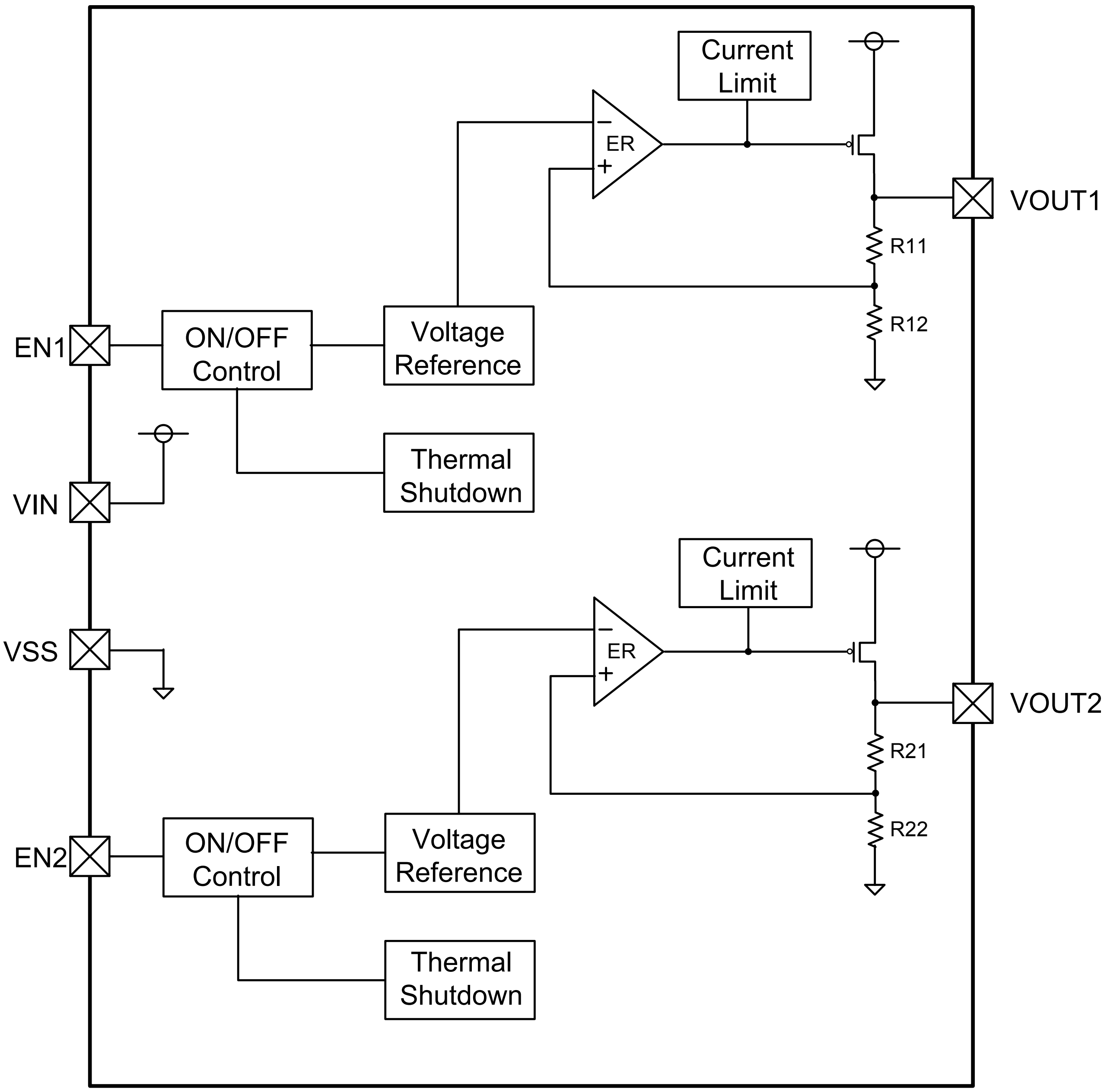
Note：

*1) Measured using a double sided board with 1" x 2" square inches of copper area connected to the GND pins for "heat spreading".

*2) EN pin input voltage must be always less than or equal to input voltage.

*3) The pull-up and pull-down resistance are around 3MΩ~6MΩ.

AC6401 Function Block Diagram



Detail Description

The AC6401 series are highly accurate, dual, low noise, CMOS LDO voltage regulators with enable function. The output voltage for each regulator is set independently by metal trimming. It's also available to offer other types of V_{OUT} between +1.0V~+5.0V except the options shown on ordering information. As illustrated in function block diagram, it consists of a bandgap reference, error amplifier, a P-channel pass transistor, an ON/OFF control logic , a current limiter and an internal feedback voltage divider.

The bandgap reference is connected to the error amplifier, which compares the reference with the feedback voltage and amplifies the voltage difference. If the feedback voltage is lower than the reference voltage, the pass-transistor's gate is pulled lower, which allows more current to pass to the V_{OUT} pin and increases the output voltage. If the feedback voltage is too high, the pass transistor's gate is pulled up to decrease the output voltage.

The output voltage is feed back through an internal resistive divider connected to V_{OUT} pin. Additional blocks include an output current limiter, thermal sensor, and shutdown logic.

Internal P-channel Pass Transistor

Each channel of AC6401 features a P-channel MOSFET pass transistor. Unlike similar designs using PNP pass transistors, P-channel MOSFETs require no base drive, which reduces quiescent current. PNP-based regulators also waste considerable current in dropout when the pass transistor saturates, and use high base-drive currents under large loads. The AC6401 does not suffer from these problems and consumes only 25μA (Typ.) per channel of current consumption under heavy loads as well as in dropout conditions.

Enable Function

EN1 and EN2 pins start and stop the correspponding outputs independently. When the EN pin is switched to the power off level, the operation of all internal circuit stops, the build-in P-channel MOSFET output transistor between pins V_{IN} and V_{OUT} is switched off, allowing current consumption to be drastically reduced.

Current Limit

Each channel of AC6401 includes a foldback current limiter. It monitors and controls the pass transistor's gate voltage, estimates the output current, and limits the output current under 450mA.

Thermal Overload Protection

Thermal overload protection limits total power dissipation of AC6401. When the junction temperature exceeds T_J = +150°C, a thermal sensor turns off the pass transistor, allowing the IC to cool down. The thermal sensor turns the pass transistor on again after the junction temperature cools down by 40°C, resulting from a pulsed output during continuous thermal overload conditions.

Thermal overload protection is designed to protect the AC6401 in the event of fault conditions. For continuous operation, the absolute maximum operating junction temperature rating of T_J = +125°C should not be exceeded.

Operating Region and Power Dissipation

Maximum power dissipation of the AC6401 depends on the thermal resistance of the case and printed circuit board, the temperature difference between the die junction and ambient air, and the rate of airflow. The power dissipation across the devices is P = I_{OUT} x (V_{IN}-V_{OUT}). The resulting maximum power dissipation is:

$$P_{MAX} = \frac{(T_J - T_A)}{\theta_{JC} + \theta_{CA}} = \frac{(T_J - T_A)}{\theta_{JA}}$$

Where (T_J-T_A) is the temperature difference between the AC6401 die junction and the surrounding air, θ_{JC} is the thermal resistance of the package chosen, and θ_{CA} is the thermal resistance through the printed circuit board, copper traces and other materials to the surrounding air. For better heatsinking, the copper area should be equally shared between the V_{IN}, V_{OUT}, and GND pins.

The thermal resistance θ_{JA} of SOT-23-6 package of AC6401 is 250°C/W. Based on a maximum operating junction temperature 125°C with an ambient of 25°C, the maximum power dissipation will be:

$$P_{MAX} = \frac{(T_J - T_A)}{\theta_{JC} + \theta_{CA}} = \frac{(125 - 25)}{250} = 0.40W$$

Thermal characteristics were measured using a double sided board with 1" x 2" square inches of copper area connected to to GND pin.

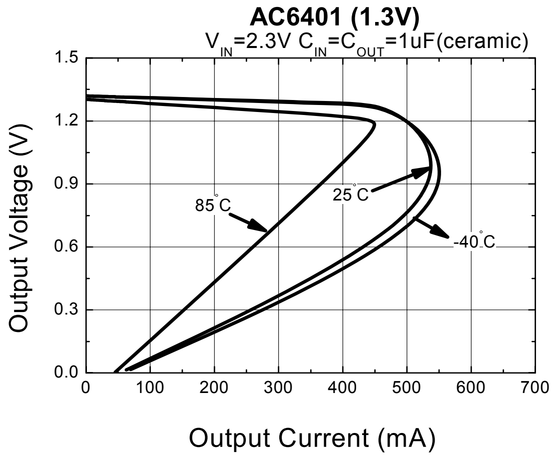
Dropout Voltage

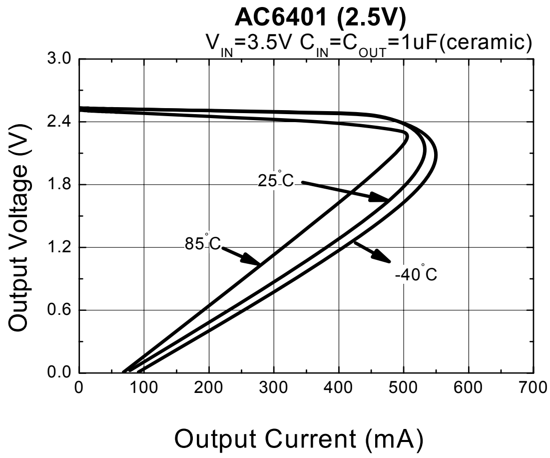
A regulator's minimum input-output voltage differential, or dropout voltage, determines the lowest usable supply voltage. In battery-powered systems, this will determine the useful end-of-life battery voltage. The AC6401 use a P- channel MOSFET pass transistor, its dropout voltage is a function of drain-to-source on-resistance $R_{DS(ON)}$ multiplied by the load current.

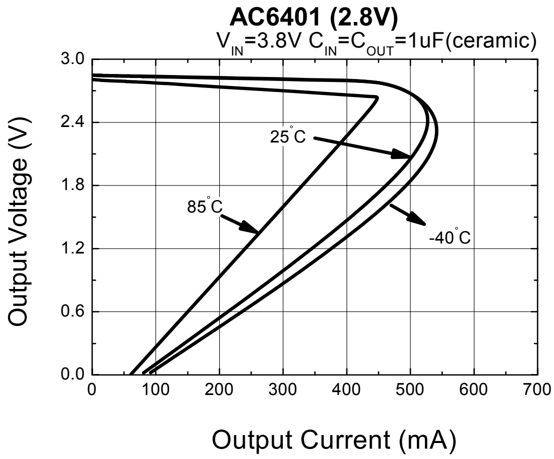
$$V_{DROPOUT} = V_{IN} - V_{OUT} = R_{DS(ON)} \times I_{OUT}$$

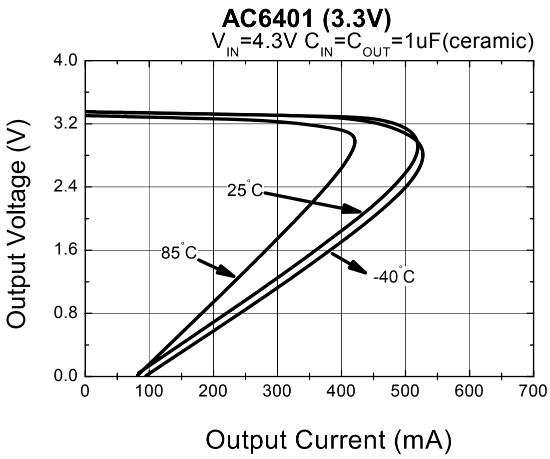
Typical Operating Characteristics

(1) Output Voltage vs. Output Current

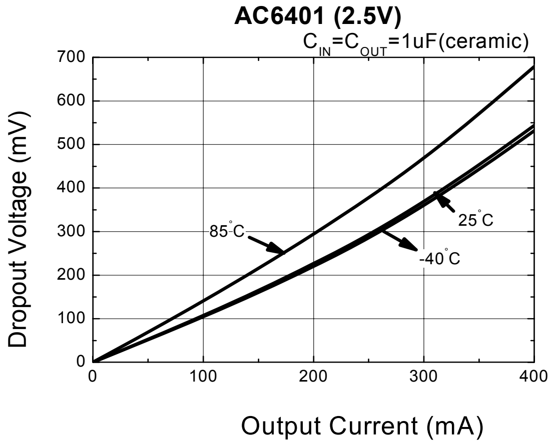


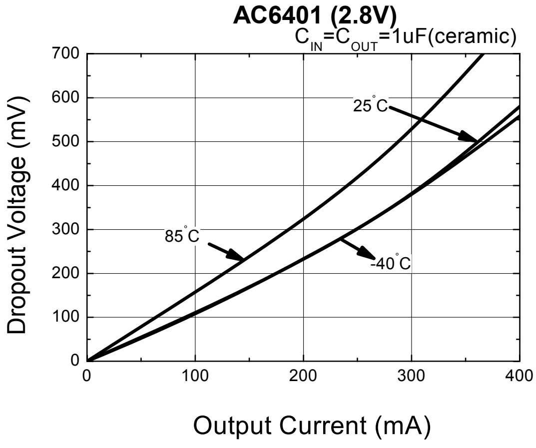


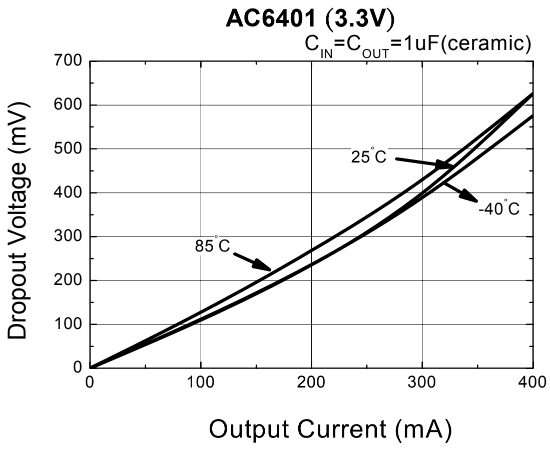




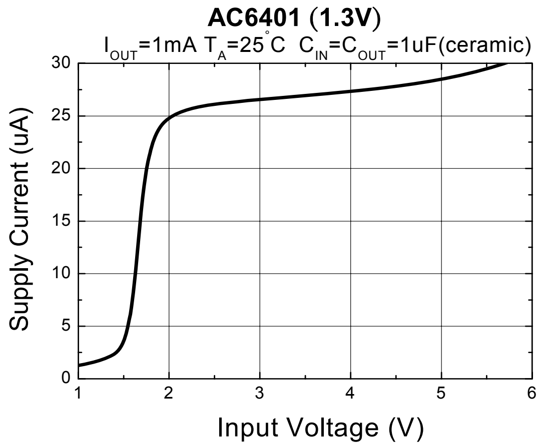
(2) Dropout Voltage vs. Output Current

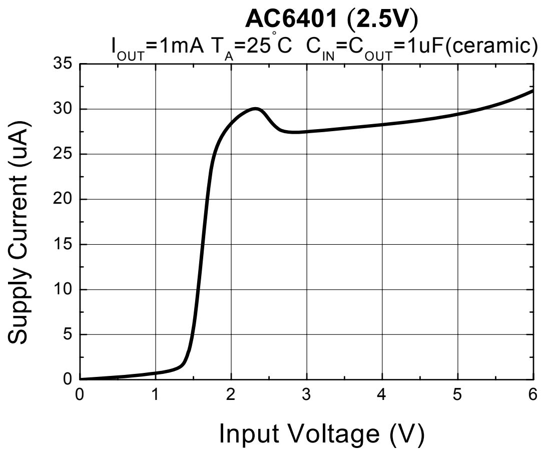


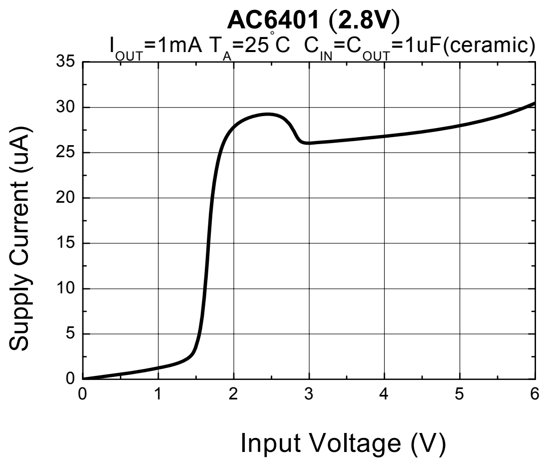


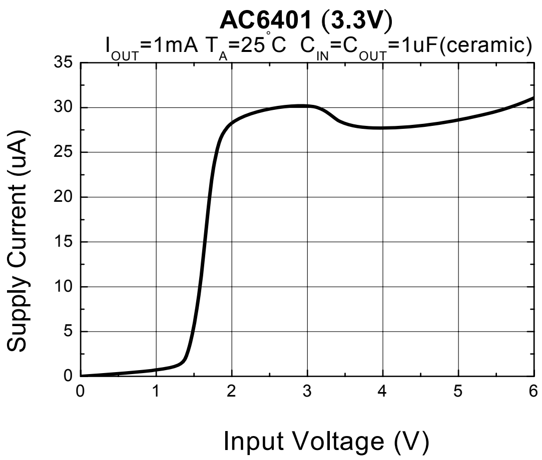


(3) Supply Current vs. Input Voltage

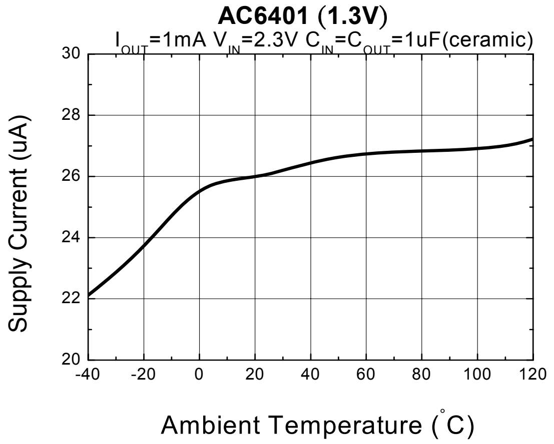


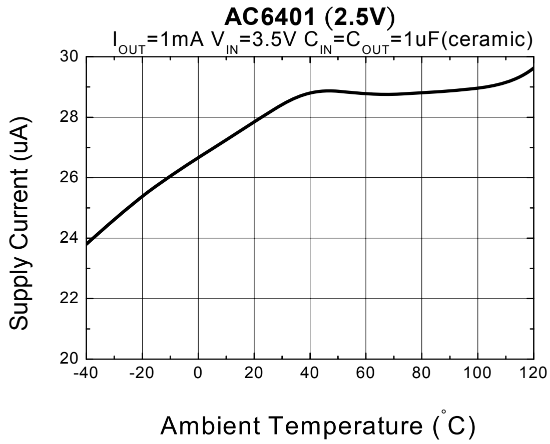


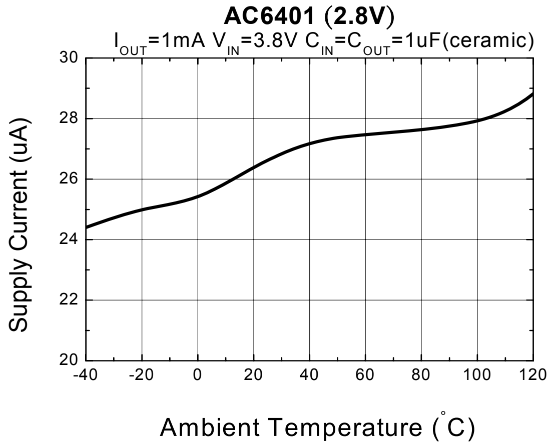


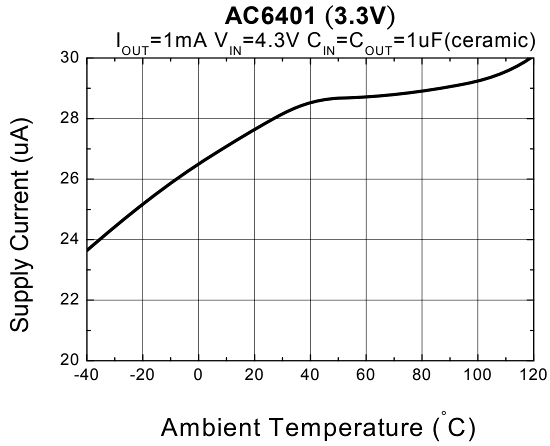


(4) Supply Current vs. Ambient Temperature

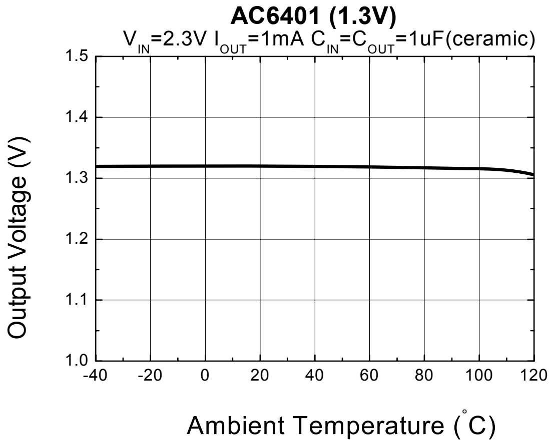


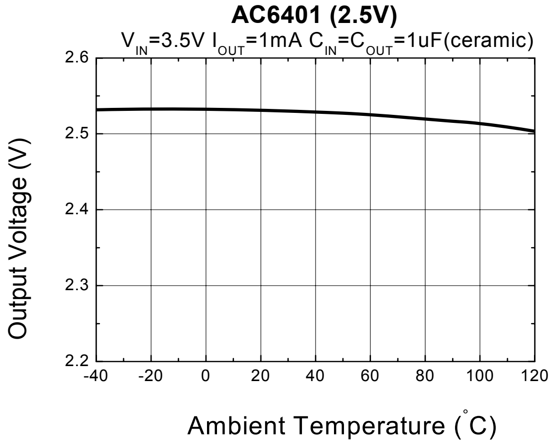


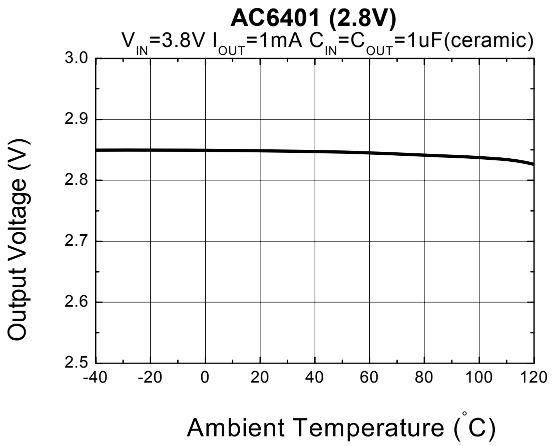


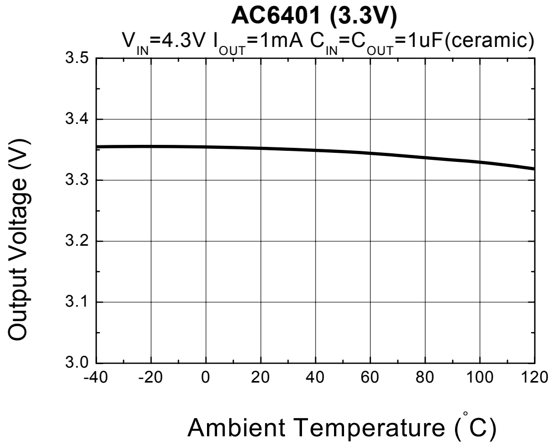


(5) Output Voltage vs. Ambient Temperature

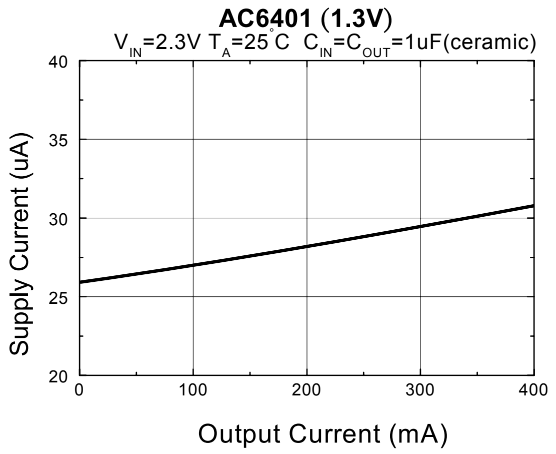


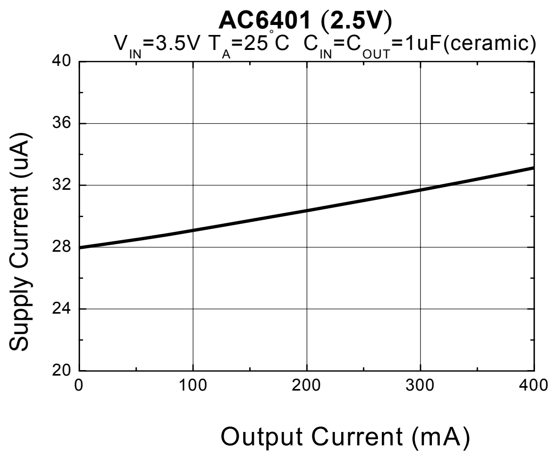


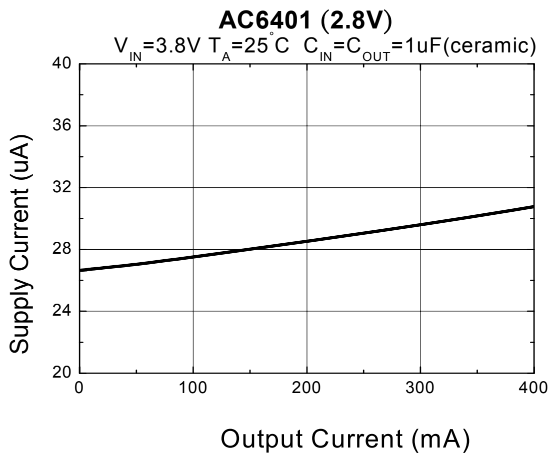


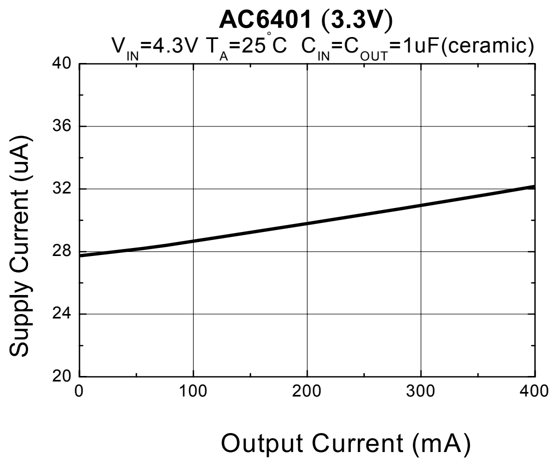


(6) Supply Current vs. Output Current

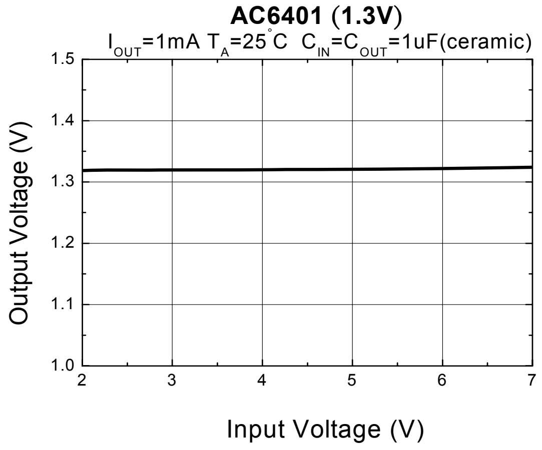


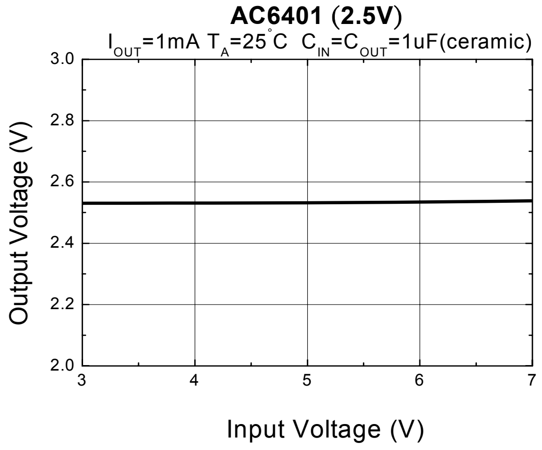


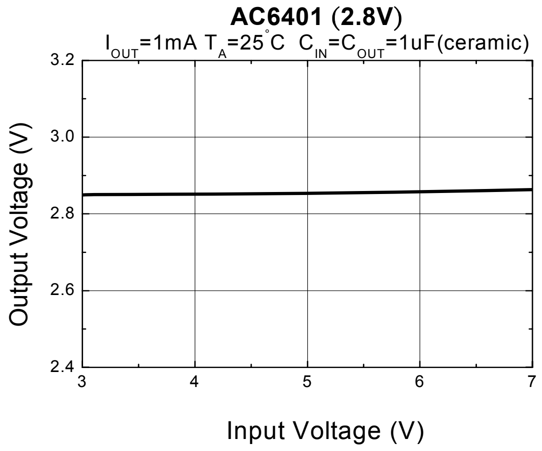


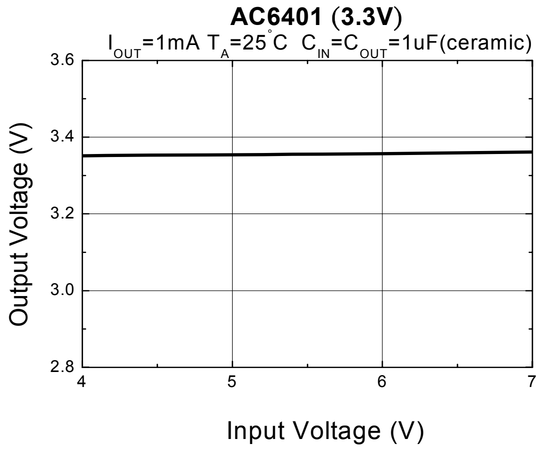


(7) Output Voltage vs. Input Voltage

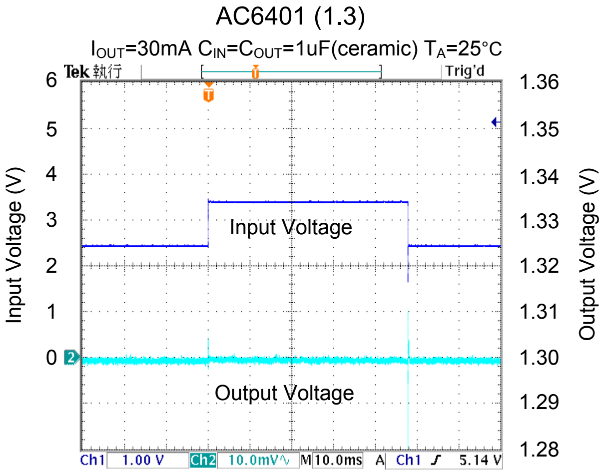


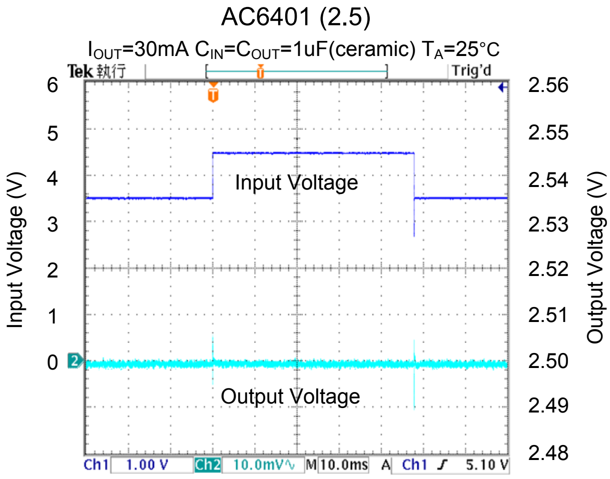


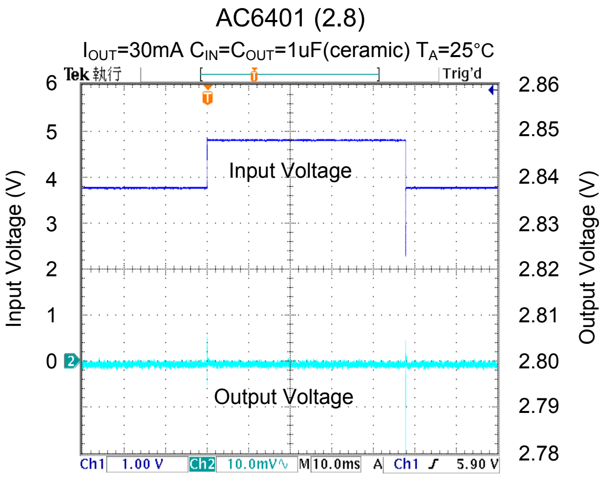


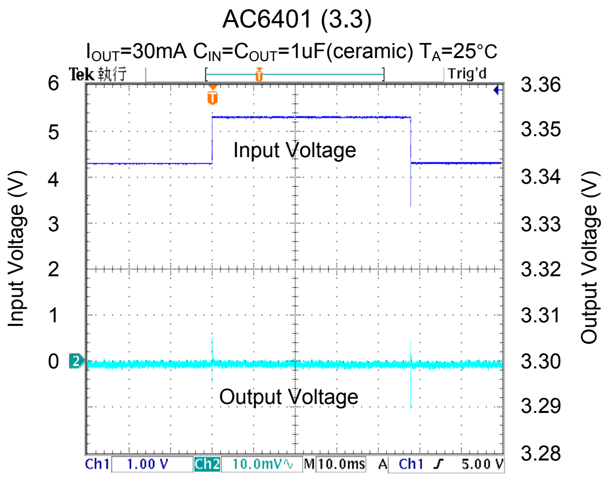


(8) Input Transient Response



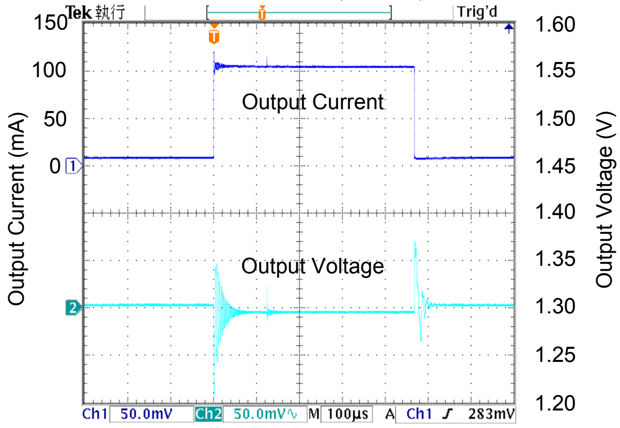




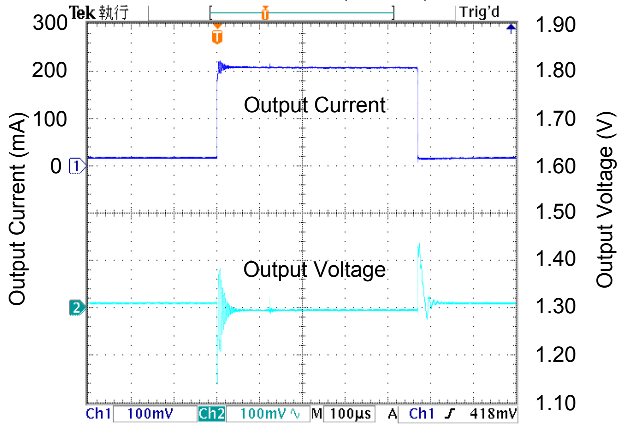


(9) Load Transient Response

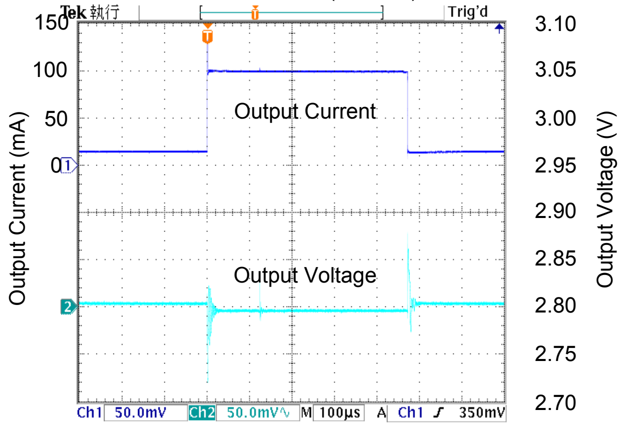
AC6401 (1.3)
V_{IN}=2.3V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



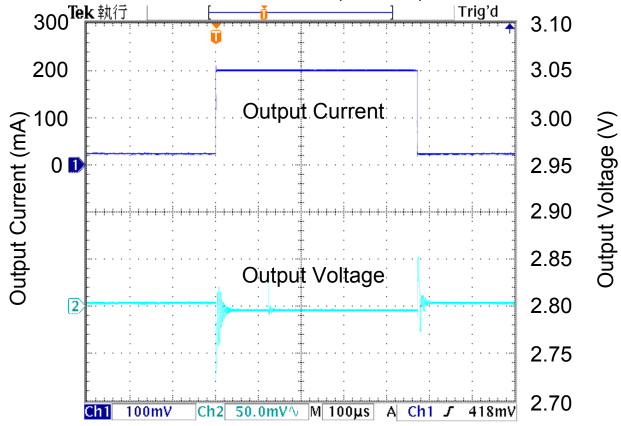
AC6401 (1.3)
V_{IN}=2.3V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



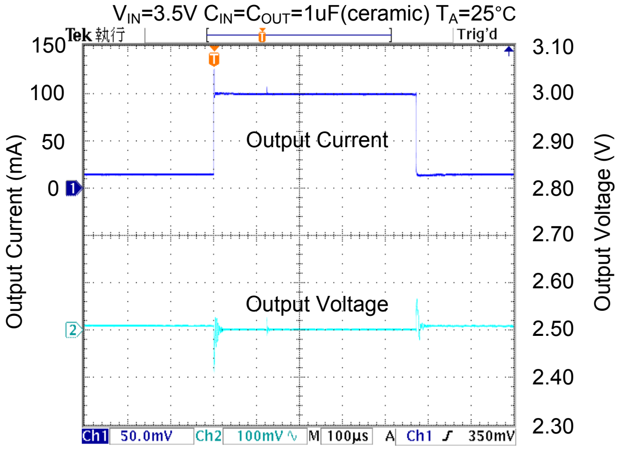
AC6401 (2.8)
V_{IN}=3.8V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



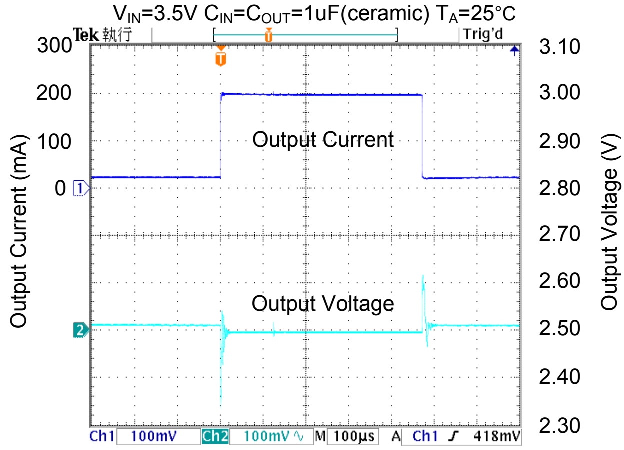
AC6401 (2.8)
V_{IN}=3.8V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



AC6401 (2.5)
V_{IN}=3.5V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



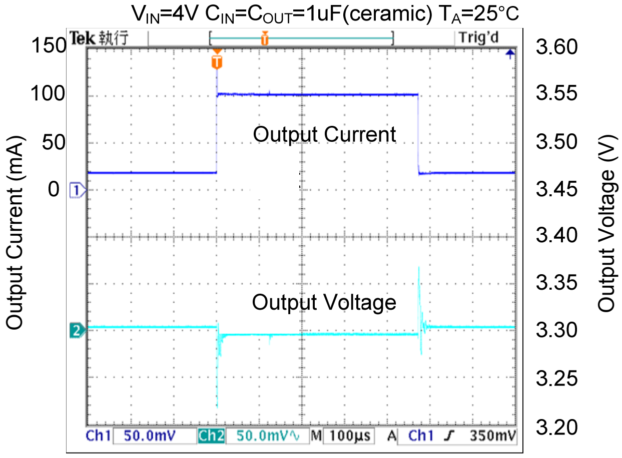
AC6401 (2.5)
V_{IN}=3.5V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



(9) Load Transient Response (Continued)

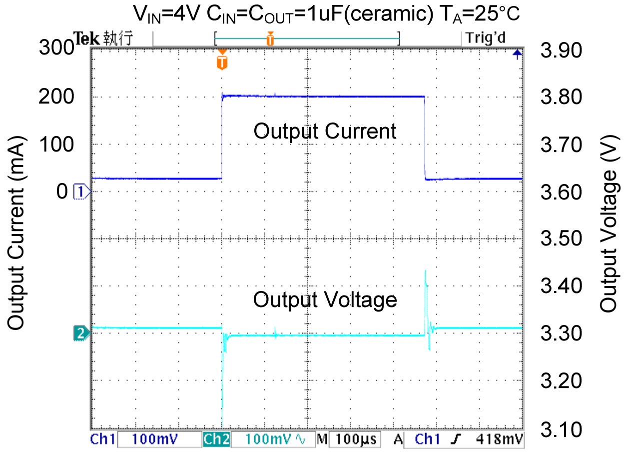
AC6401 (3.3)

V_{IN}=4V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



AC6401 (3.3)

V_{IN}=4V C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C

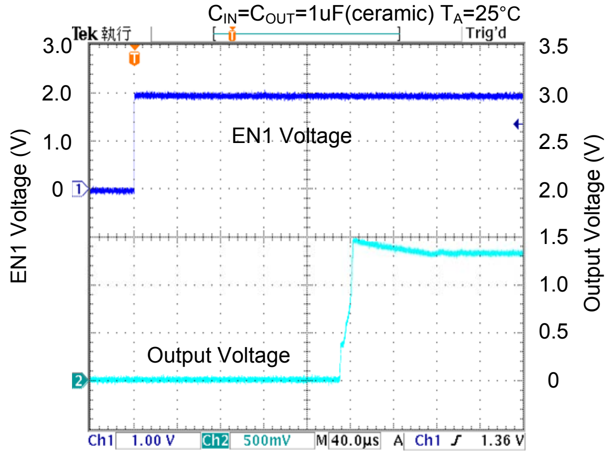


(10) Start Up & Discharge Time

AC6401 (1.3)

V_{IN}=4V EN2=0V I_{OUT}=1mA

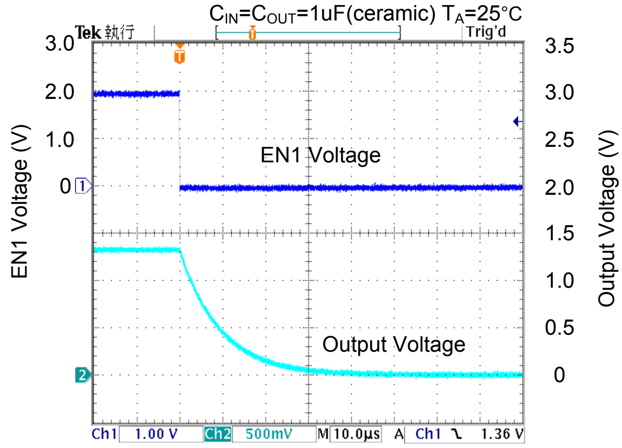
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



AC6401 (1.3)

V_{IN}=4V EN2=0V I_{OUT}=1mA

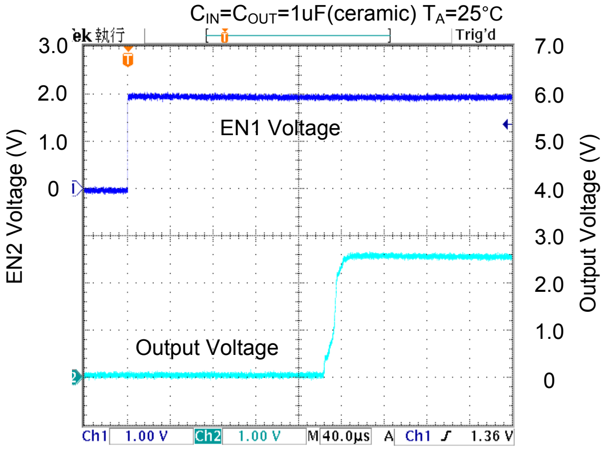
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



AC6401 (2.5)

V_{IN}=4V EN1=0V I_{OUT}=1mA

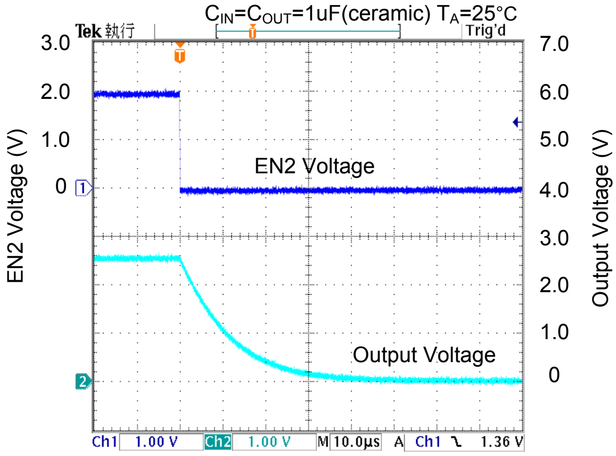
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



AC6401 (2.5)

V_{IN}=4V EN1=0V I_{OUT}=1mA

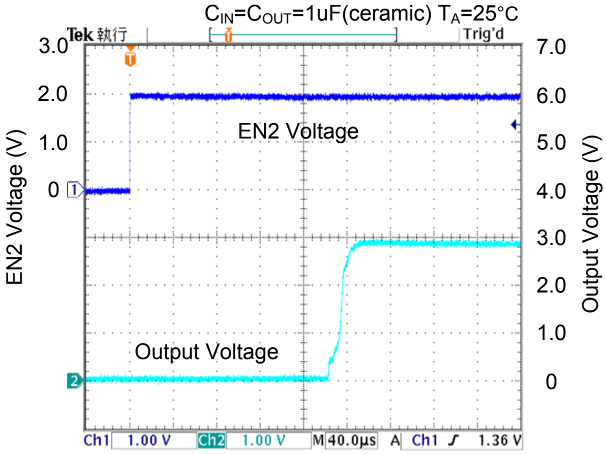
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



(10) Start Up & Discharge Time (Continued)

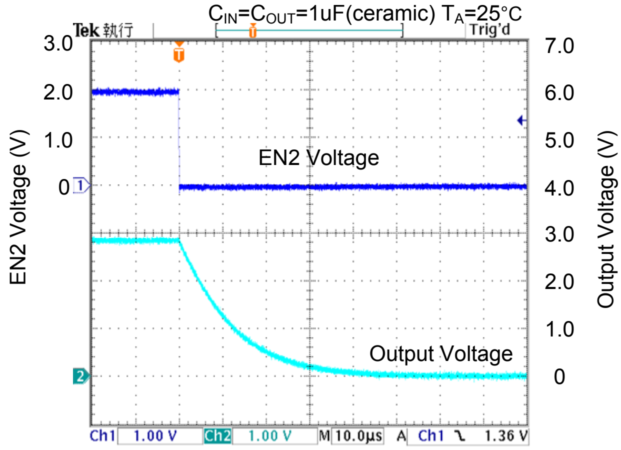
AC6401 (2.8)

V_{IN}=4V EN1=0V I_{OUT}=1mA
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



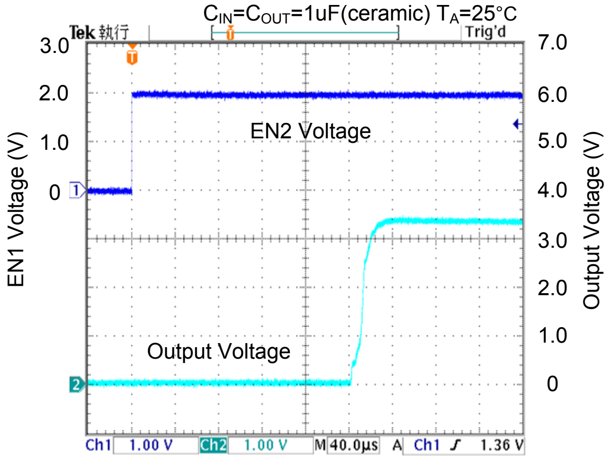
AC6401 (2.8)

V_{IN}=4V EN1=0V I_{OUT}=1mA
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



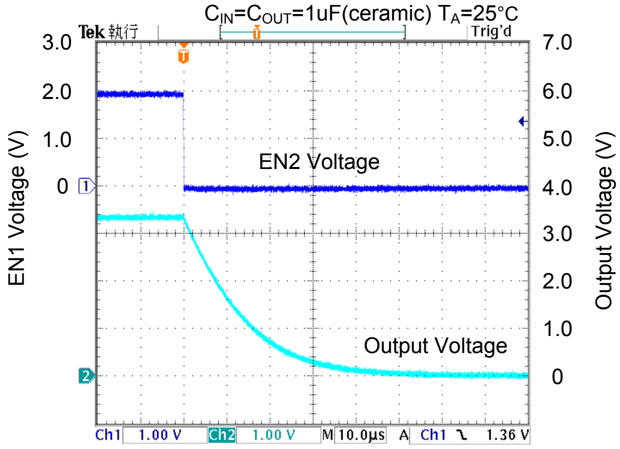
AC6401 (3.3)

V_{IN}=4V EN2=0V I_{OUT}=1mA
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



AC6401 (3.3)

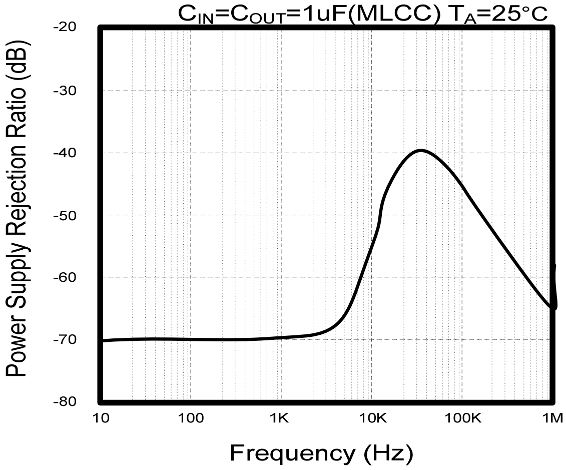
V_{IN}=4V EN2=0V I_{OUT}=1mA
C_{IN}=C_{OUT}=1uF(ceramic) T_A=25°C



(11) Power Supply Rejection Ratio

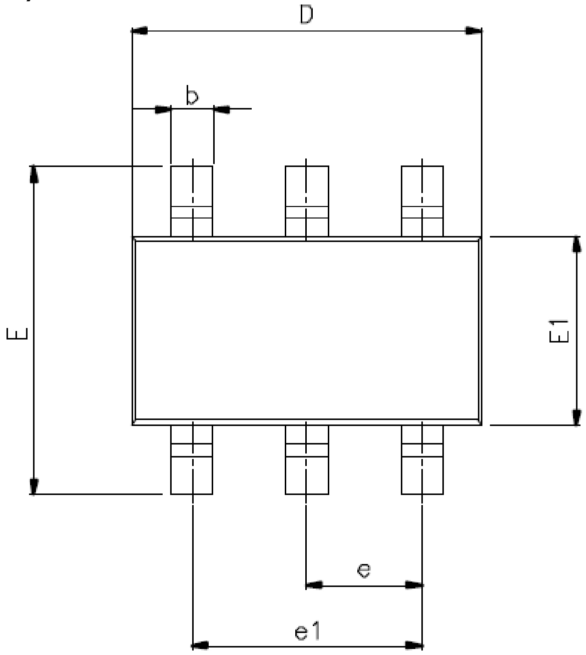
AC6401 (2.8V)

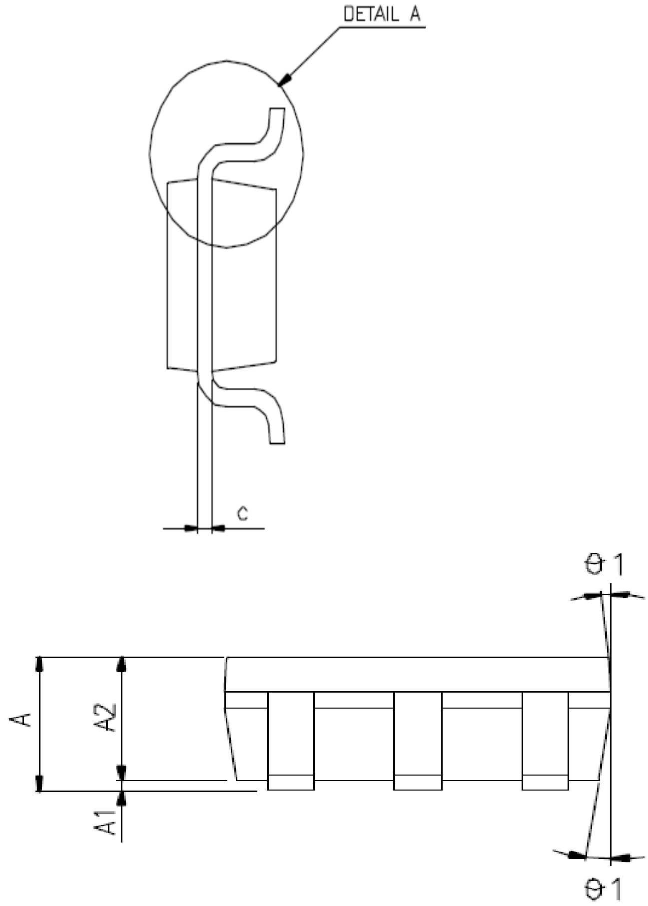
V_{IN}=3.8V+0.5V_{AC} I_{OUT}=30mA
C_{IN}=C_{OUT}=1uF(MLCC) T_A=25°C

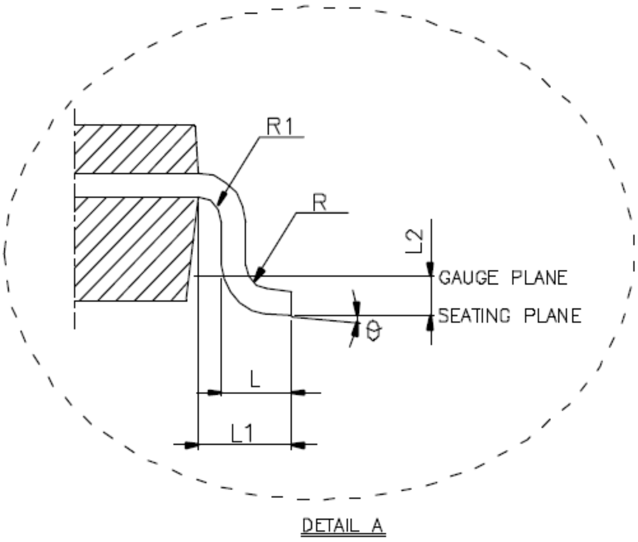


Package Outline

A) SOT-26





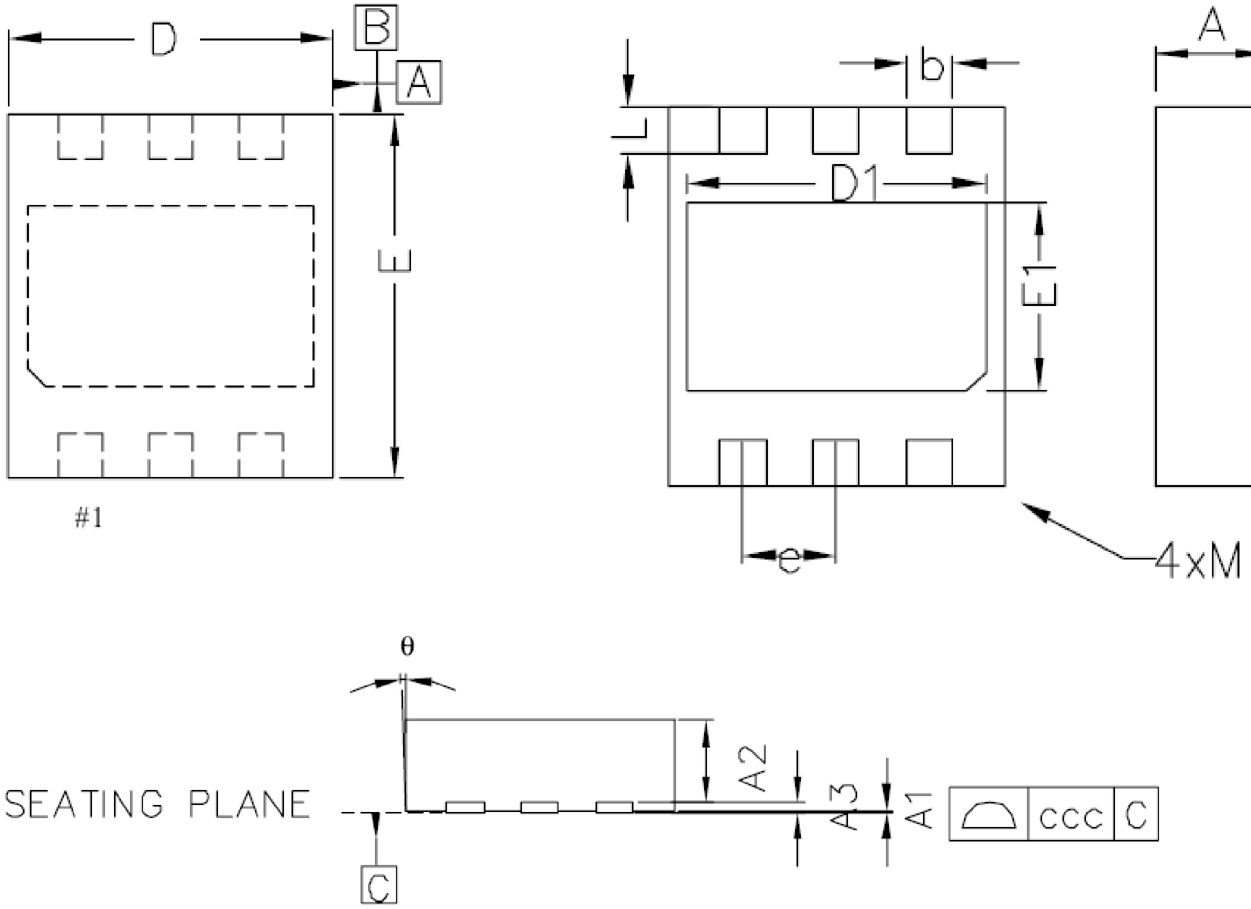


VARIATION(ALL DIMENSIONS SHOWN IN MM)

SYMBOL	MIN.	NOM.	MAX.
A	–	–	1.45
A1	–	–	0.15
A2	0.90	1.15	1.30
b	0.30	–	0.50
c	0.08	–	0.22
D	2.90 BSC.		
E	2.80 BSC.		
E1	1.60 BSC.		
e	0.95 BSC		
e1	1.90 BSC.		
L	0.30	0.45	0.60
L1	0.60 REF.		
L2	0.25 BSC.		
R	0.10	–	–
R1	0.10	–	0.25
θ	0°	4°	8°
θ1	5°	10°	15°

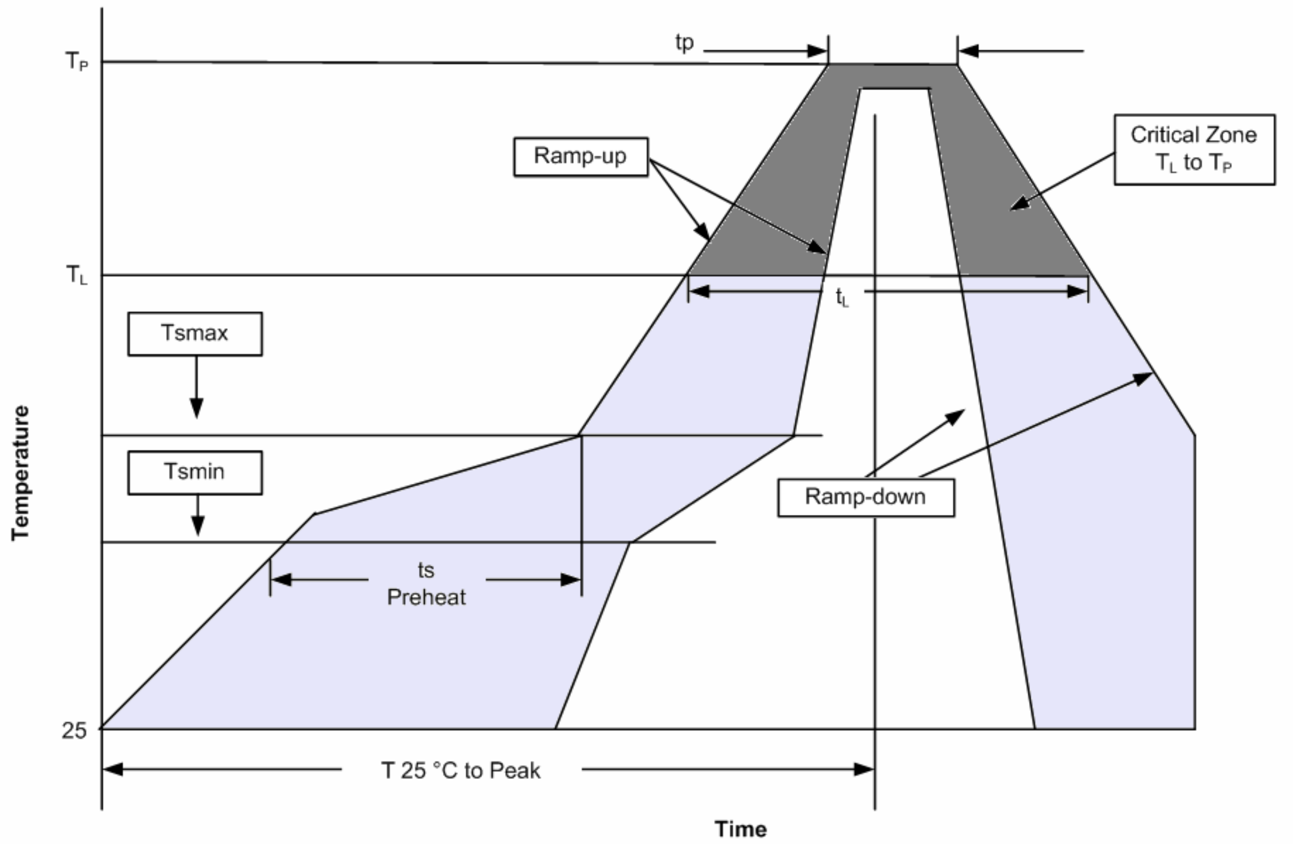
NOTE : 1.JEDEC OUTLINE : TO–178 AB

B) UFN-6



Dimension	mm		
	Min.	Nom.	Max.
A	0.55	0.60	0.65
A1	0.000	0.002	0.004
A2	0.51	0.54	0.59
A3	---	0.06REF	---
b	0.20	0.25	0.30
D	1.95	2.00	2.03
D1	---	1.60BSC	---
E	1.95	2.00	2.03
E1	---	1.0BSC	---
e	---	0.50BSC	---
L	0.20	0.25	0.30
θ	-12	---	0
ccc	---	0.08	---
M	---	---	0.05
Burr	0.00	0.03	0.06

Reflow Condition (IR/Convection or VPR Reflow)



Classification Reflow Profiles

Profile Feature	Pb-Free / Green Assembly
Average ramp-up rate (T_L to T_P)	3°C/second max
Preheat - Temperature Min (Tsmin) - Temperature Max (Tsmax) - Time (min to max) (ts)	150°C 200°C 60-180 seconds
Time maintained above: - Temperature (T_L) - Time (t_L)	217°C 60-150 seconds
Peak/Classification Temperature (Tp)	See table 1
Time within 5°C of actual Peak Temperature (tp)	20-40 seconds
Ramp-down Rate	6°C/second max
Time 25°C to Peak Temperature	8 minutes max

Notes：
1) All temperatures refer to topside of the package.
2) Measured on the body surface.

Classification Reflow Profiles (Continued)

Table 1. Pb-free / Green Process – Package Classification Reflow Temperatures

Package Thickness	Volume mm^3 <350	Volume mm^3 350~2000	Volume mm^3 ≧2000
<2.5 mm	260 +0°C*	260 +0°C*	260 +0°C*
1.6-2.5 mm	260 +0°C*	250 +0°C*	245 +0°C*
≧2.5 mm	250 +0°C*	245 +0°C*	245 +0°C*

Notes：

* Tolerance: The device manufacturer/supplier shall assure process compatibility up to and including the stated classification temperature (this means Peak reflow temperature +0°C. For example 260°C+0°C) at the rated MSL level.