XC9404 Series

Offline Controller for LED Lighting with Power Factor Correction

■GENERAL DESCRIPTION

The XC9404 series are LED lighting offline controllers that use PFM(Pulse Frequency Modulation) control and have a Power Factor improvement function. The operating input voltage range is 85VAC to 270VAC, and the current is controlled on the primary side without using a Opto-coupler or secondary side control circuit. Because LED current fluctuations caused by input voltage fluctuations and LED voltage fluctuations can be suppressed, a stable LED lighting power supply is obtained.

A high Power Factor and low THD are attained by synchronizing the input current with the input voltage, and operation in DCM(Discontinuous Current Mode) makes it possible to achieve high efficiency. An internal acceleration startup circuit enables the LED lighting to illuminate quickly.

Over Voltage Protection, Over Current Protection, UVLO and Thermal shutdown are provided as protective functions to protect the LED lighting in the event of LED Open/Short-circuiting.

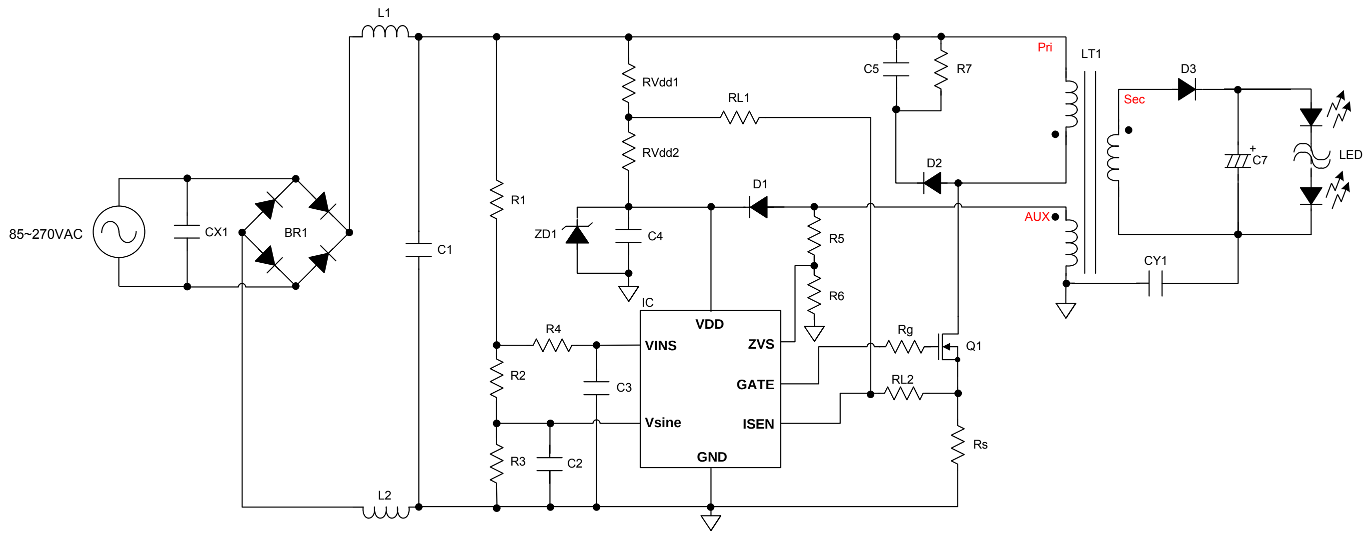
■APPLICATIONS

- LED Bulb
- LED spot Light
- LED Tube
- Street Light
- Residential Lighting
- Other applications with LED Lighting

■FEATURES

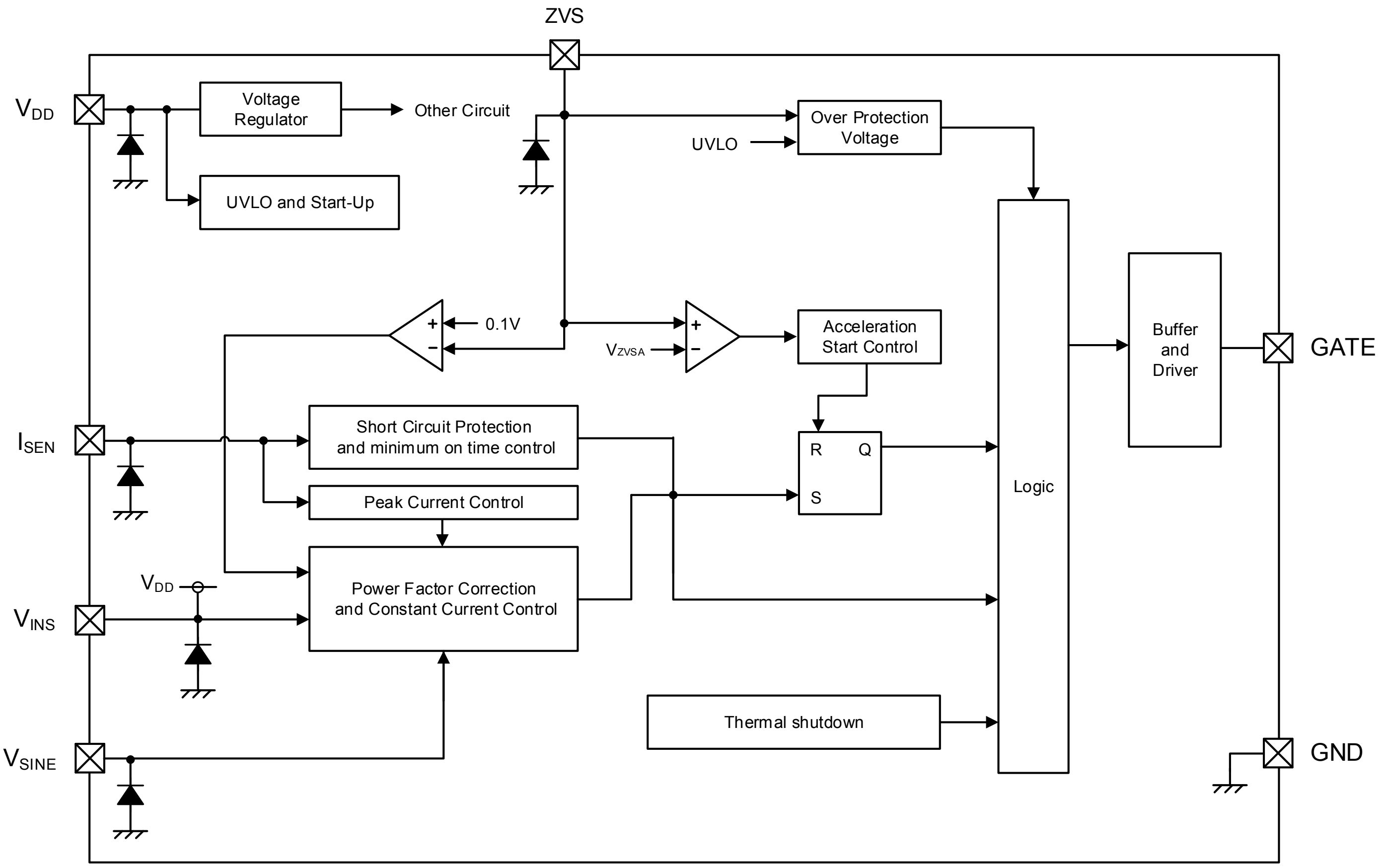
Operating Voltage	: 85VAC ~ 270VAC
Output Wattage	: up to 50W
Power Factor / THD	: Power Factor 0.95 or more / THD up to 10% attainable
Control Method	: PFM control
Function	: Opto-coupler free due to primary control Built-in acceleration Start Low Start up Current 20μA
Protection Function	: LED Open/Short protection Over Voltage Protection Over Current Protection UVLO Thermal shutdown
Package	: SOP-8D
Operating Ambient Temperature	: -40℃ ~ +105 ℃
Environmentally Friendly	: EU RoHS Compliant, Pb Free

■TYPICAL APPLICATION CIRCUITS



■BLOCK DIAGRAM

XC9404 Series



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

■PRODUCT CLASSFICATION

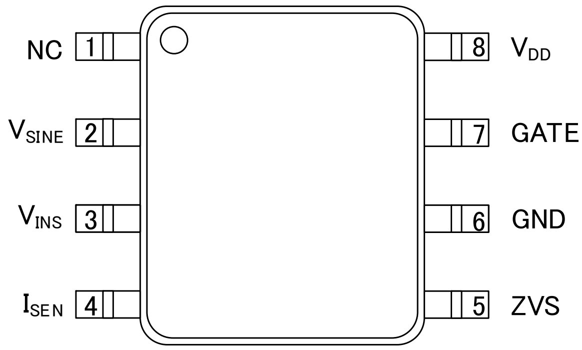
●Ordering Information

XC9404①②③④⑤⑥-⑦(*1)

DESIGNATOR	ITEM	SYMBOL	DESCRIPTION
①	Type	A	With PFC Function
②	Application	L	For Off-line Driver for LED Lighting
③④	Accuracy	03	LED Current Accuracy is ±3%
⑤⑥-⑦	Package (Order Unit)	SR-G	SOP-8D (2,500pcs/Reel)(*2)

(*1) The "-G" suffix denotes Halogen and Antimony free as well as being fully EU RoHS compliant.
(*2) The XC9404 reels are shipped in a moisture-proof packing.

■PIN CONFIGURATION



SOP-8D
(TOP VIEW)

■PIN ASSIGNMENT

PIN NUMBER	PIN NAME	FUNCTIONS
1	NC	No connection.
2	V_{SINE}	V_{SINE} pin to detect the rectified sine waveform of input voltage.
3	V_{INS}	V_{INS} pin to detect the rectified sine waveform peak value of input voltage.
4	I_{SEN}	I_{SEN} pin monitors the primary current.
5	ZVS	ZVS pin to detect the feedback voltage from the auxiliary winding. ZVS voltage is used to control Over Voltage Protection and Acceleration Mode.
6	GND	Ground pin.
7	GATE	External power MOSFET drive pin.
8	V_{DD}	Power Input pin.

■ABSOLUTE MAXIMUM RATINGS

Ta=25℃

PARAMETER	SYMBOL	RATINGS	UNITS
V_{DD} Pin Voltage	V_{DD}	-0.3 ~ +35	V
V_{INS} Pin Voltage	V_{INS}	-0.3 ~ +7.0	V
V_{SINE} Pin Voltage	V_{SINE}	-0.3 ~ +7.0	V
I_{SEN} Pin Voltage	V_{ISEN}	-0.3 ~ +7.0	V
ZVS Pin Voltage	V_{ZVS}	-40.0 ~ +10.0	V
GATE Pin Maximum Current	I_{GATE}	300	mA
Power Dissipation	P_D	0.525	W
Operating Ambient Temperature	Ta	-40 ~ 105	℃
Storage Temperature	Tstg	-65 ~ +150	℃

(*1) All voltages are described based on GND.

■ ELECTRICAL CHARACTERISTICS

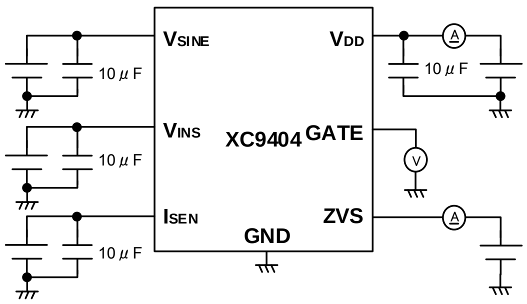
XC9404 Series

Ta=25℃

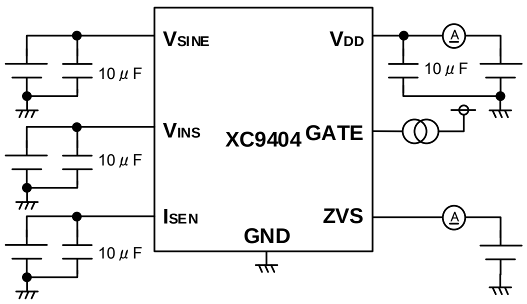
PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNITS	CIRCUIT
V_{DD} Voltage Range	V_{DD}		9	-	21	V	-
Start-up Threshold Voltage	V_{ST}	V_{SINE}=V_{INS}=3V,V_{ISEN}=2V,V_{ZVS}=0V The voltage which V_{DD} pin current becomes 200uA or more while V_{DD} is increasing.	18	19	20	V	①
UVLO Detect Voltage	V_{UVLO}	V_{SINE}=V_{INS}=3V,V_{ISEN}=2V,V_{ZVS}=0V The voltage which V_{DD} pin current becomes 200uA or less while V_{DD} is decreasing.	7.5	8.0	8.5	V	①
V_{DD} Over Voltage Protection	V_{DD_OVP}	V_{SINE}=V_{INS}=3V,V_{ISEN}=V_{ZVS}=0V,V_{DD}=20V The voltage which GATE Voltage becomes "L" while V_{DD} is increasing.	28	32	34	V	②
Start-up Current	I_{ST}	V_{SINE}=V_{INS}=3V,V_{ISEN}=2V,V_{ZVS}=0V V_{DD}=V_{ST}-0.5V	-	-	20	μA	①
Supply Current	I_{DD1}	V_{SINE}=V_{INS}=3V,V_{ISEN}=1.2V,V_{ZVS}=0V V_{DD}=20V→15V	-	1000	1300	μA	①
GATE "H" level Voltage	V_{GATEH}	V_{SINE}=V_{INS}=3V,V_{ZVS}=V_{ISEN}=0V V_{DD}=20V→12V	10	-	-	V	①
GATE "L" level Voltage	V_{GATEL}	V_{SINE}=V_{INS}=3V,V_{ZVS}=V_{ISEN}=0V,V_{DD}=20V→15V V_{ISEN} is increased until GATE "L" occurs, 20 mA is applied to the GATE pin, and the GATE pin voltage is measured.	-	-	1	V	②
GATE clamp Voltage	V_{GATEC}	V_{SINE}=V_{INS}=3V,V_{ZVS}=V_{ISEN}=0V,V_{DD}=20V	12	13	15	V	①
(V_{SINE}/V_{INS}) maximum Value	(V_{SINE}/V_{INS})_max	V_{SINE}=V_{INS}=3V,V_{ZVS}=0V,V_{DD}=20V→15V The voltage which GATE voltage becomes "L" while V_{ISEN} is increasing.	0.8	1.0	1.2	V	②
(V_{SINE}/V_{INS}) minimum Value	(V_{SINE}/V_{INS})_min	V_{SINE}=0V,V_{INS}=3V,V_{ZVS}=0V,V_{DD}=20V→15V The voltage which GATE voltage becomes "L" while V_{ISEN} is increasing.	-	-	0.2	V	②
Minimum On Time	t_{ONMIN}	V_{SINE}=V_{INS}=3V,V_{ZVS}=0V,V_{ISEN}=2V VDD is raised from 0V to 20V, and the GATE signal pulse width is measured.	500	750	1000	ns	①
Short Circuit Protection Voltage	V_{OCP}	V_{SINE}=3V,V_{INS}=0.5V,V_{ZVS}=V_{ISEN}=0V, V_{DD}=20V→15V The voltage which GATE voltage becomes "L" while V_{ISEN} is increasing.	3.0	4.0	-	V	②
ZVS Leakage Current	I_{ZVS}	V_{DD}=20V→15V,V_{ZVS}=4V	-	2	8	μA	③
ZVS Acceleration Threshold Voltage	V_{ZVSA}	V_{SINE}=1V,V_{INS}=3V,V6=1.5V,V_{DD}=20V→15V The V6 voltage is raised, and the voltage at which the GATE pin voltage oscillation period slows is measured.	1.4	1.8	2.2	V	④
ZVS CV Threshold Voltage	V_{ZVSN}	V_{SINE}=1V,V_{INS}=3V,V6=2.8V,V_{DD}=20V→15V The V6 voltage is raised, and the voltage at which the GATE pin voltage oscillation stops is measured.	3.8	4.0	4.4	V	④
ZVS Over Voltage Threshold Voltage	V_{OVP}	V_{SINE}=V_{INS}=3V,V_{ZVS}=V_{ISEN}=0V,V_{DD}=20V→15V The voltage which GATE voltage becomes "L" while V_{ISEN} is increasing.	5.6	6.0	6.9	V	②

■TEST CIRCUITS

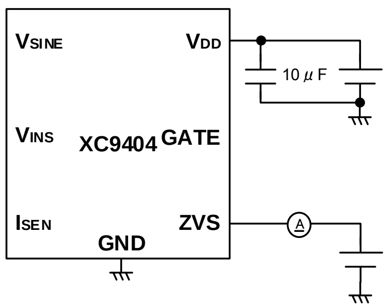
1) Circuit ①



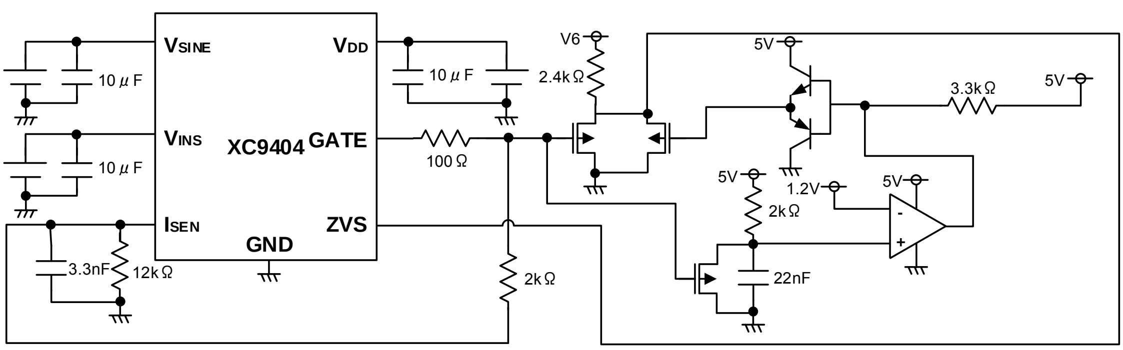
2) Circuit②



3) Circuit③



4) Circuit④



■OPERATIONAL EXPLANATION

The internal circuitry of the XC9404 series consists of a power factor improvement circuit, buffer drive circuit, over-current protection circuit, over-voltage protection circuit, UVLO circuit and Thermal shutdown circuit.
(Refer to the block diagram)

<Operation description>
The operation of the XC9404 series is described below using an isolated flyback type circuit.

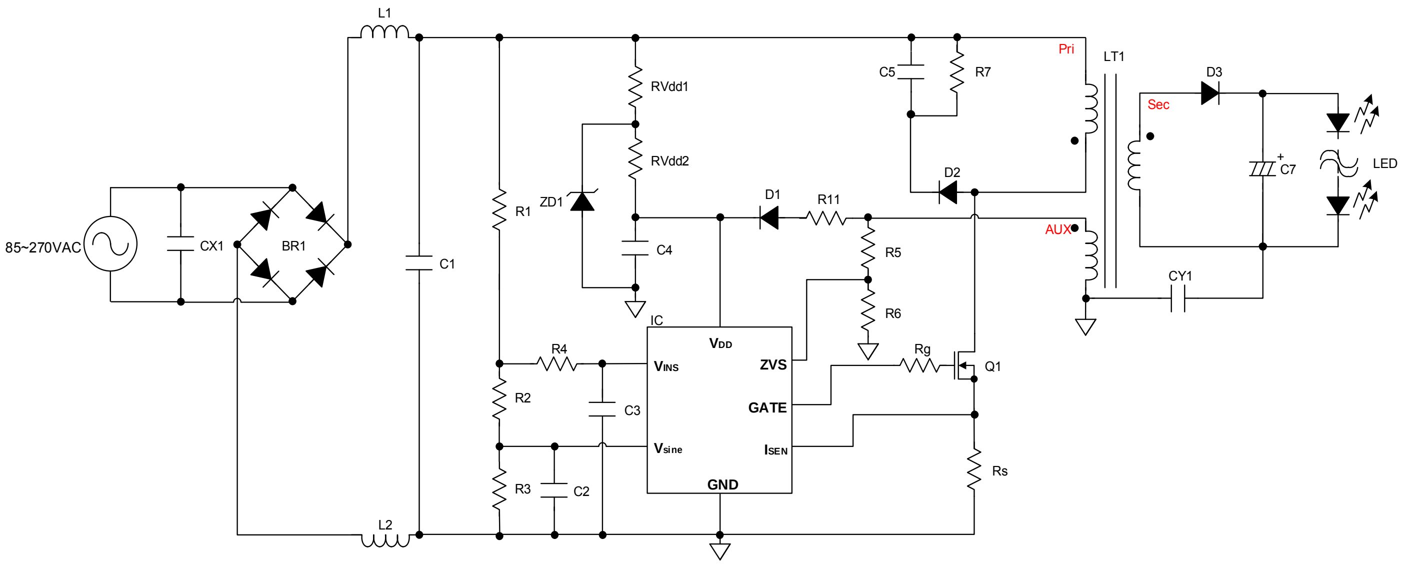


Fig.1 XC9404 Isolated flyback circuit

By controlling the primary peak current of the transformer so that it matches the V_{ISEN} voltage, which has the same phase as the input voltage, the IC improves the power factor. (Refer to Fig. 2)
In addition, by controlling the on-time/off-time so that it is optimum for the input voltage, phase and LED voltage, a stable constant current can be supplied within the input voltage range 85VAC to 270VAC.

The on-time,off-time can be adjusted with external resistances R1 to R3, enabling the optimum constant to be set for the input voltage, LED voltage, LED current. Operation in discontinuous mode (DCM) is recommended for this IC, so the external resistances R1 to R3 should be adjusted to enable discontinuous mode.

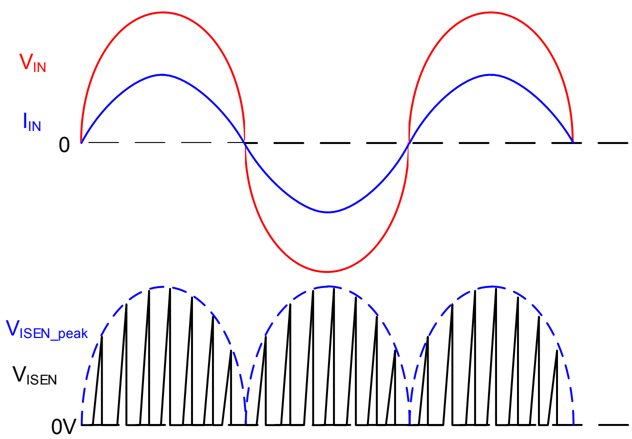


Fig.2 XC9404 Operation Waveform

■OPERATIONAL EXPLANATION

<Operation modes>
The XC9404 series operates in modes (a) to (d) based on the ZVS pin voltage.

(a) Acceleration Mode
Acceleration Mode is used for fast startup.
To shorten the startup time, the output voltage is low, and when the ZVS pin voltage is below the ZVS Acceleration Threshold Voltage, the IC operates in critical mode rather than Discontinuous Current Mode to reduce the startup time.
When the ZVS pin voltage rises above the ZVS Acceleration Threshold Voltage, the mode changes to CC Mode.

(b) CC Mode
CC mode provides the high power factor and low THD that are desirable in a LED lighting power source, and outputs a stable constant current that is not affected by fluctuations of input voltage and LED voltage. While in CC Mode, the IC operates in Discontinuous Current Mode.

(c) CV Mode
CV Mode prevents the output voltage from exceeding a set voltage. In the event that the output voltage reaches the over-voltage state, the ZVS pin voltage rises. When the ZVS pin voltage rises above the ZVS CV Threshold Voltage, the GATE pin outputs “L” voltage, and maintains “L” voltage until the ZVS pin voltage drops below the ZVS CV Threshold Voltage.

(d) Over-Voltage Protection
This mode prevents damage to peripheral devices in the event that the output voltage reaches the over-voltage state. When the output voltage reaches the over-voltage state, the ZVS pin voltage rises. When the ZVS pin voltage rises above the ZVS Over-Voltage Threshold Voltage, the GATE pin voltage is forcibly latched to the “L” state. To release the voltage from the latched state and return to normal operation, the V_{DD} pin voltage is lowered below the latch release at 5.6V voltage and then raised above the Start-up Threshold Voltage.
Even when the LED is in the open state, this function can suppress destruction of external components.

<Minimum On Time>
Because the charge stored on the capacitance between Q1 Drain-Source flows to the sense resistance Rs immediately after power MOSFET Q1 turns on, a spike occurs in the I_{SEN} pin voltage. To prevent this spike noise from causing malfunctioning of the internal circuitry, a minimum on-time t_{ONMIN} is established. The GATE pin voltage is forcibly held in the “L” state until the minimum on-time elapses.

<GATE pin Voltage>
When in the GATE pin “H” state, the GATE pin Voltage is controlled so as not to exceed the GATE clamp voltage. This prevents over-voltage between Gate-Source of FET Q1 that may destroy the FET.
The GATE pin voltage in the GATE pin "H" state varies depending on the V_{DD} pin voltage.

(a) V_{DD} pin Voltage < GATE clamp Voltage + (12V - GATE "H" level Voltage)
GATE "H" Voltage = V_{DD} - (12V - GATE "H" level Voltage)

(b) V_{DD} pin Voltage > GATE clamp Voltage + (12V - GATE "H" level Voltage)
GATE "H" Voltage = GATE clamp Voltage

■OPERATIONAL EXPLANATION

<UVLO>

If the V_{DD} pin voltage drops below the UVLO detect voltage (V_{UVLO}), the GATE pin voltage is forcibly put in the “L” state to prevent IC malfunctioning. When the V_{DD} pin voltage rises above the Start-up Threshold Voltage, the UVLO state is released and normal operation starts. The IC quiescent current is held below 20μA in the UVLO state, enabling reduction of standby power and the need for high resistances for R_{VDD}1, 2.

When a LED short circuits, the V_{DD} pin voltage drops below the UVLO detect voltage, and thus the UVLO function can suppress destruction of external components.

<V_{DD} Over Voltage Protection>

This prevents IC destruction caused by V_{DD} pin over-voltage. When the V_{DD} pin voltage rises above the V_{DD} Over-Voltage Protection voltage, the GATE pin voltage is forcibly kept in the “L” state to suppress any further increases of the V_{DD} pin voltage.

<Short Circuit Protection Voltage>

This prevents peripheral component destruction in the event that excessive current flows to the sense resistance Rs due to short-circuiting of an external component or otherwise.

This function protects external components in the event that excessive current flows to the sense resistance Rs due to short-circuiting of an external component or otherwise.

When excessive current flows to the sense resistance Rs and the I_{SEN} pin voltage rises above the Short Circuit Protection Voltage, the GATE pin voltage is forcibly latched to the “L” state. This suppresses damage to external components due to over-current.

The latched state is released and normal operation resumes when the V_{DD} pin voltage is lowered below the latch release voltage at 5.6V and then raised above the Start-up Threshold Voltage.

<Thermal shutdown>

To protect the IC from thermal destruction, the thermal shutdown function activates when the chip temperature reaches 170°C and forcibly puts the GATE pin voltage in the “L” state. When the chip temperature drops down to 145°C, normal operation resumes.

■NOTES ON USE

1) Take care that the absolute maximum ratings of external components and the IC are not exceeded.

2) External components and the circuit board layout have a large effect on characteristics.
Test sufficiently with the actual device before use.

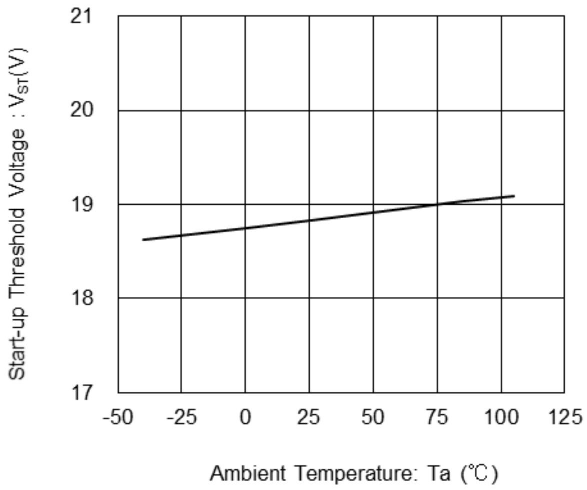
3) Give consideration to derating when selecting external components.
In particular, external components may become hot due to heat generated by LEDs and other components.
Select components and design for heat radiation.

4) Select external components and design the test circuit board so as to satisfy applicable regulations and standards.

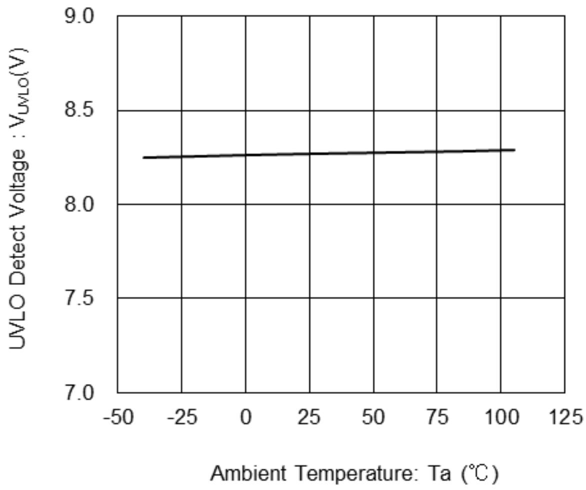
5) Torex places an importance on improving our products and their reliability.
We request that users incorporate fail-safe designs and post-aging protection treatment when using Torex products in their systems.

■TYPICAL PERFORMANCE CHARACTERISTICS

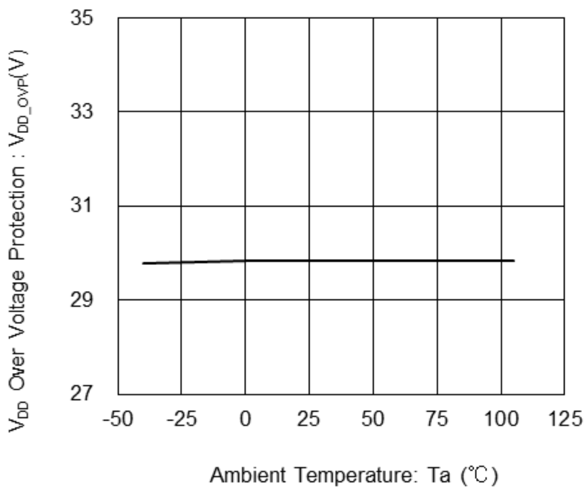
(1) Start-up Threshold Voltage vs. Ambient Temperature



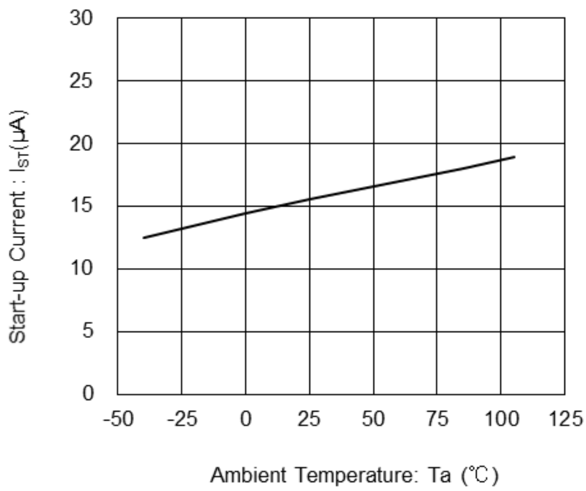
(2) UVLO Detect Voltage vs. Ambient Temperature



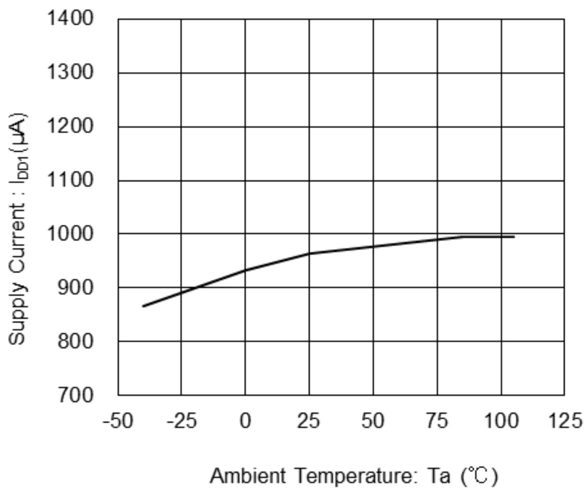
(3) V_{DD} Over Voltage Protection vs. Ambient Temperature



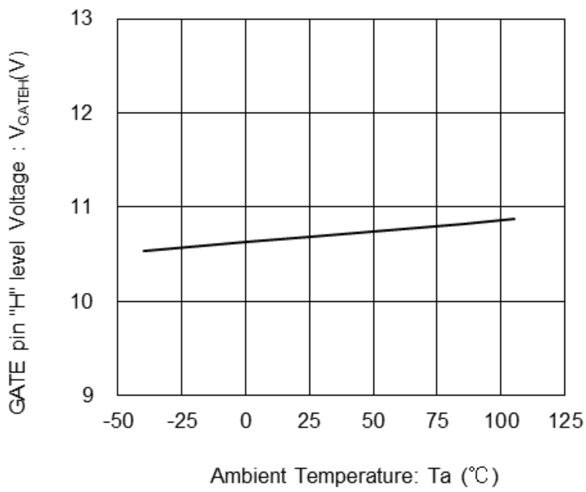
(4) Start-up Current vs. Ambient Temperature



(5) Supply Current vs. Ambient Temperature

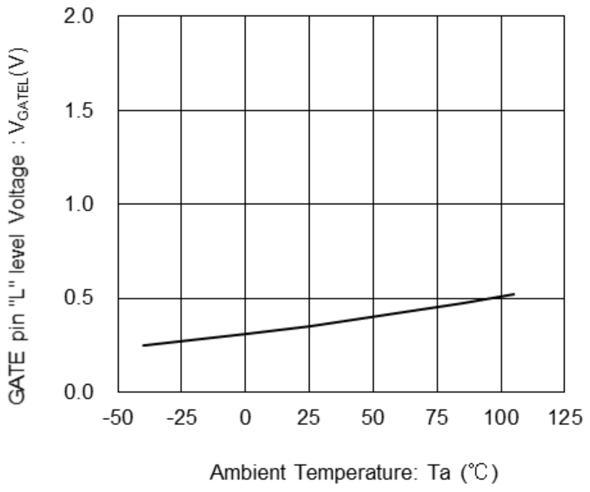


(6) GATE pin "H" level Voltage vs. Ambient Temperature

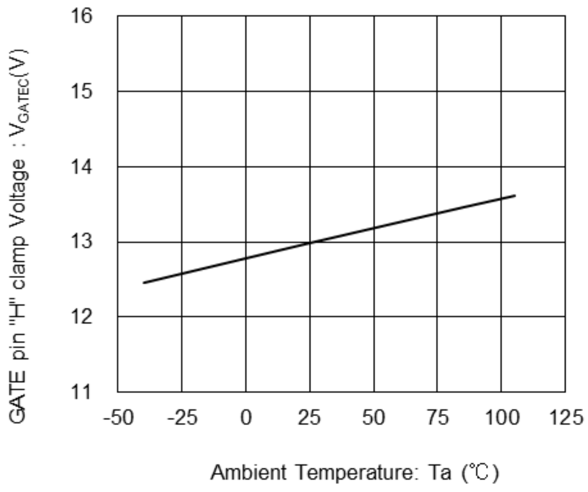


■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

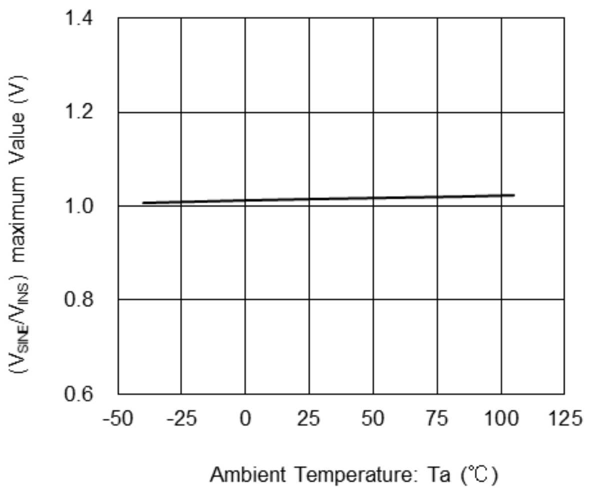
(7) GATE pin "L" level Voltage vs. Ambient Temperature



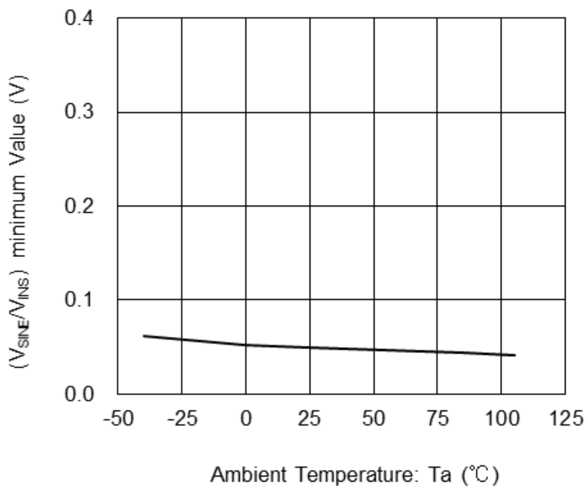
(8) GATE pin clamp Voltage vs. Ambient Temperature



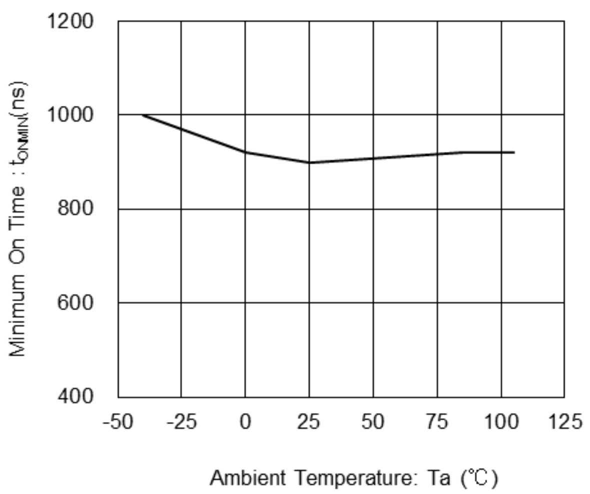
(9) (V_{SINE}/V_{INS}) maximum Value vs. Ambient Temperature



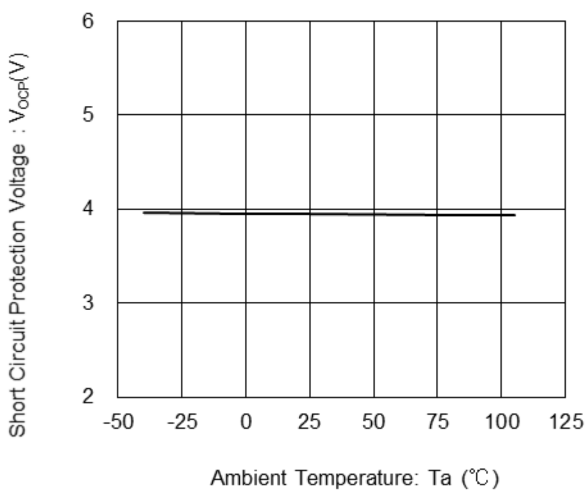
(10) (V_{SINE}/V_{INS}) minimum Value vs. Ambient Temperature



(11) Minimum On Time vs. Ambient Temperature

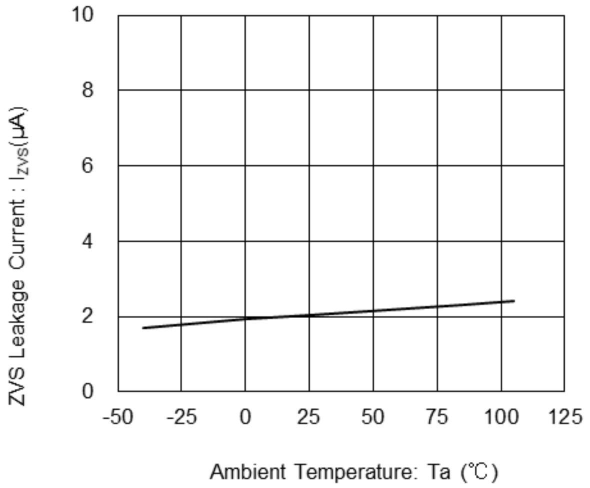


(12) Short Circuit Protection Voltage vs. Ambient Temperature

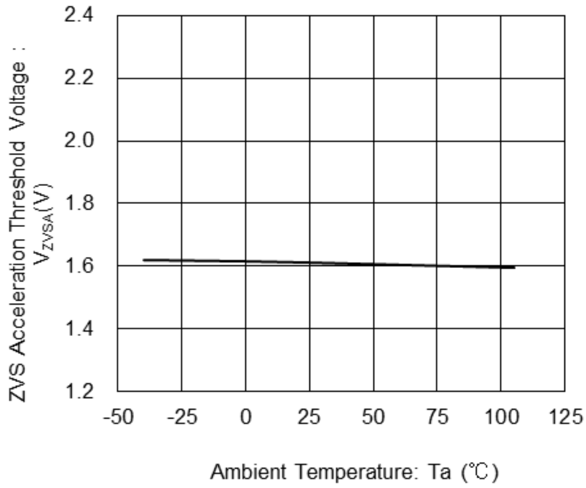


■TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

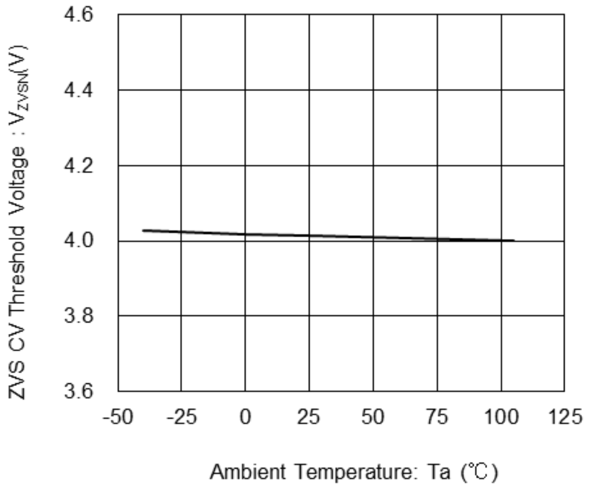
(13) ZVS Leakage Current vs. Ambient Temperature



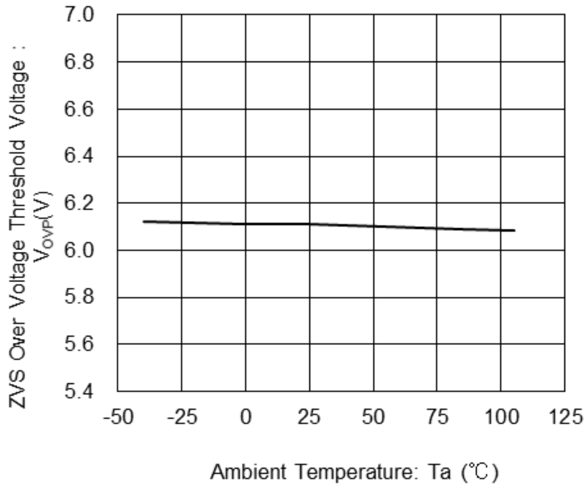
(14) ZVS Acceleration Threshold Voltage vs. Ambient Temperature



(15) ZVS CV Threshold Voltage vs. Ambient Temperature

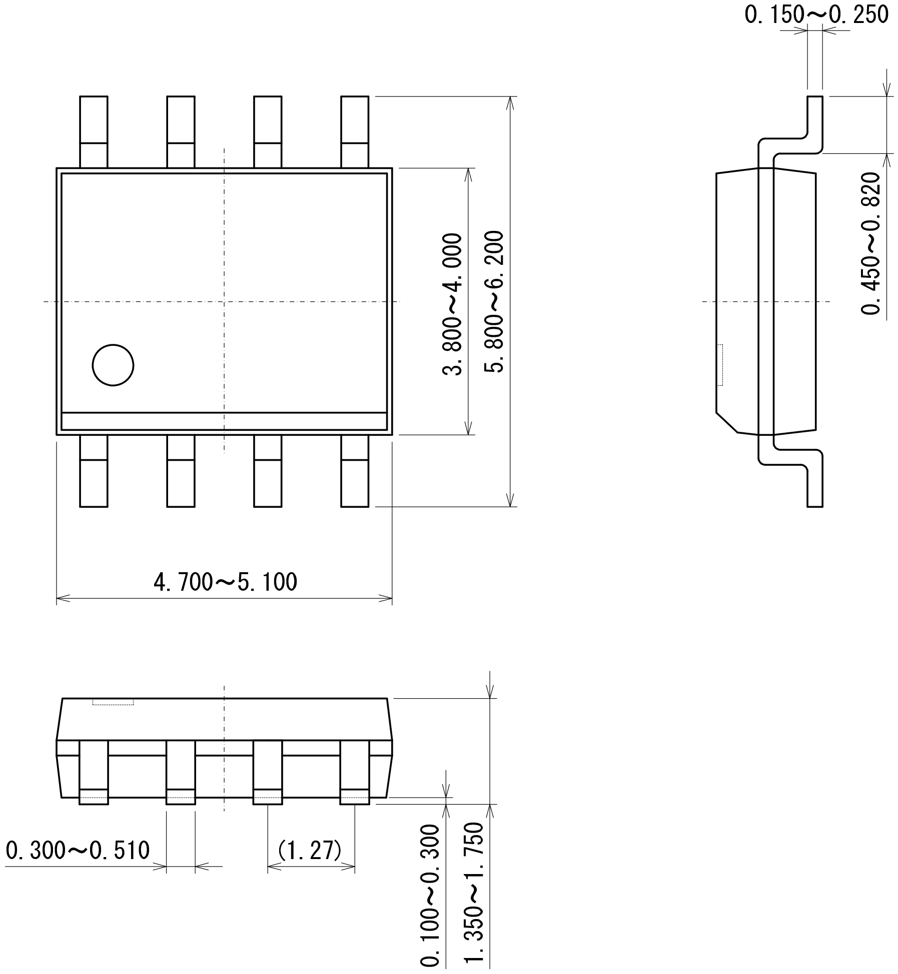


(16) ZVS Over Voltage Threshold Voltage vs. Ambient Temperature

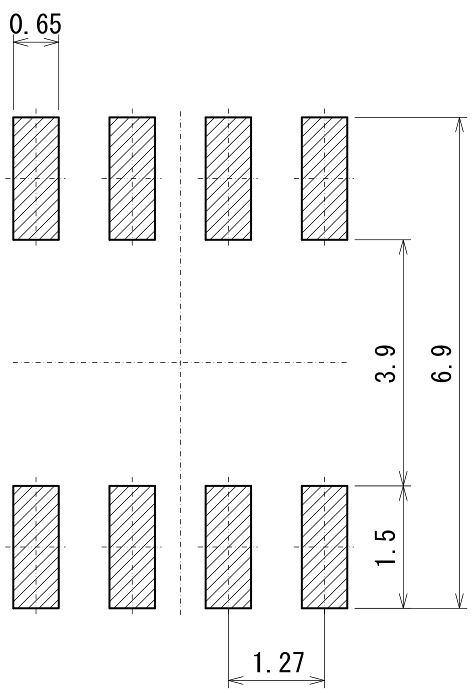


■PACKAGING INFORMATION

●SOP-8D (unit:mm)

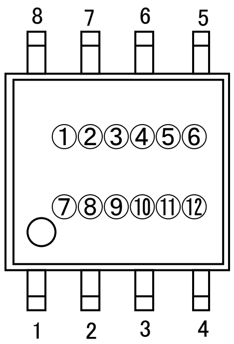


●SOP-8DReference Pattern Layout (unit:mm)



■MARKING RULE

●SOP-8D



①～⑥ represents Marking ID

MARK						PRODUCT SERIES
①	②	③	④	⑤	⑥	
X	C	9	4	0	4	XC9404******-G

⑦ represents Last digit of manufacture year

Example

MARK	MANUFACTURE YEAR
5	Y2015

⑧,⑨ represents working week at molding process

⑩ represents Assembly Site Code
N : Nantong Fujitsu

⑪,⑫ represents Batch No.

1. The product and product specifications contained herein are subject to change without notice to improve performance characteristics. Consult us, or our representatives before use, to confirm that the information in this datasheet is up to date.

2. The information in this datasheet is intended to illustrate the operation and characteristics of our products. We neither make warranties or representations with respect to the accuracy or completeness of the information contained in this datasheet nor grant any license to any intellectual property rights of ours or any third party concerning with the information in this datasheet.

3. Applicable export control laws and regulations should be complied and the procedures required by such laws and regulations should also be followed, when the product or any information contained in this datasheet is exported.

4. The product is neither intended nor warranted for use in equipment of systems which require extremely high levels of quality and/or reliability and/or a malfunction or failure which may cause loss of human life, bodily injury, serious property damage including but not limited to devices or equipment used in 1) nuclear facilities, 2) aerospace industry, 3) medical facilities, 4) automobile industry and other transportation industry and 5) safety devices and safety equipment to control combustions and explosions. Do not use the product for the above use unless agreed by us in writing in advance.

5. Although we make continuous efforts to improve the quality and reliability of our products; nevertheless Semiconductors are likely to fail with a certain probability. So in order to prevent personal injury and/or property damage resulting from such failure, customers are required to incorporate adequate safety measures in their designs, such as system fail safes, redundancy and fire prevention features.

6. Our products are not designed to be Radiation-resistant.

7. Please use the product listed in this datasheet within the specified ranges.

8. We assume no responsibility for damage or loss due to abnormal use.

9.

TOREX SEMICONDUCTOR LTD.