

**CQ-3300****High-Speed Response Coreless Current Sensor****1. General Description**

CQ-3300 is an open-type current sensor using a Hall sensor which outputs the analog voltage proportional to the AC/DC current. Quantum well ultra- thin film InAs (Indium Arsenide) is used as the Hall sensor, which enables the high-accuracy and high-speed current sensing. Coreless surface mount package realizes the space-saving.

**2. Features**

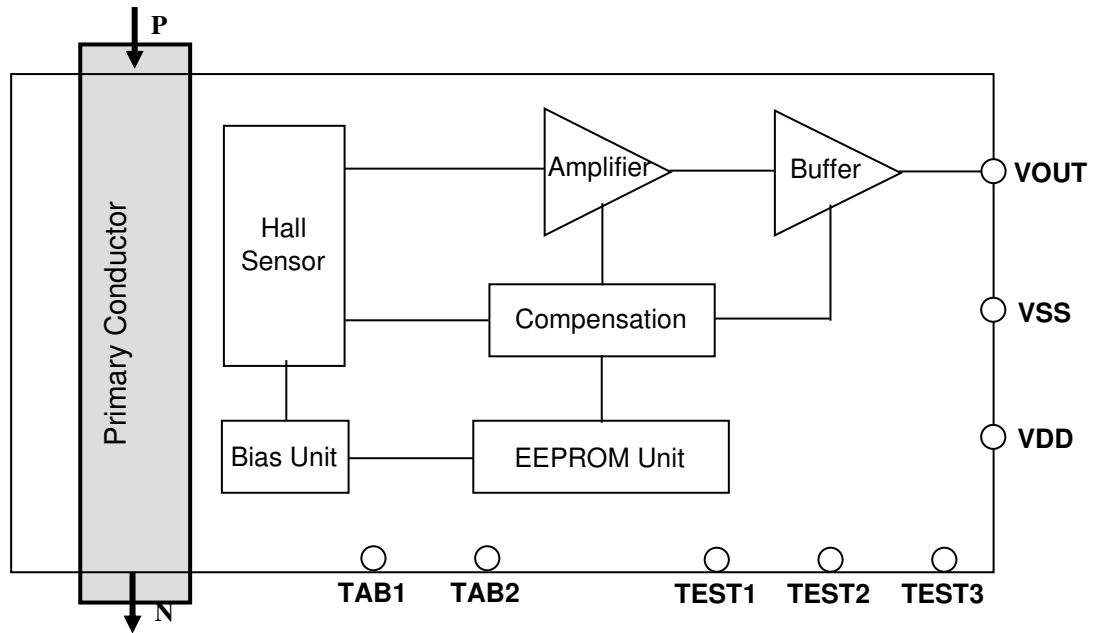
- Small-sized surface mount package: VSOP-24
- High isolation voltage: 3.0kV (50/60Hz, 60sec)
- Compliant to safety standards of IEC/UL-62368 and UL-508
- Ultra-fast response time: 0.5 $\mu$ sec (typ.)
- Low variation and low temperature drift of sensitivity and zero-current output voltage
- No output hysteresis
- Low noise output: 2.7mVrms (typ.)
- Bi-directional type
- 5V single power supply
- Ratiometric output
- Halogen free



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**4. Block Diagram and Functions**

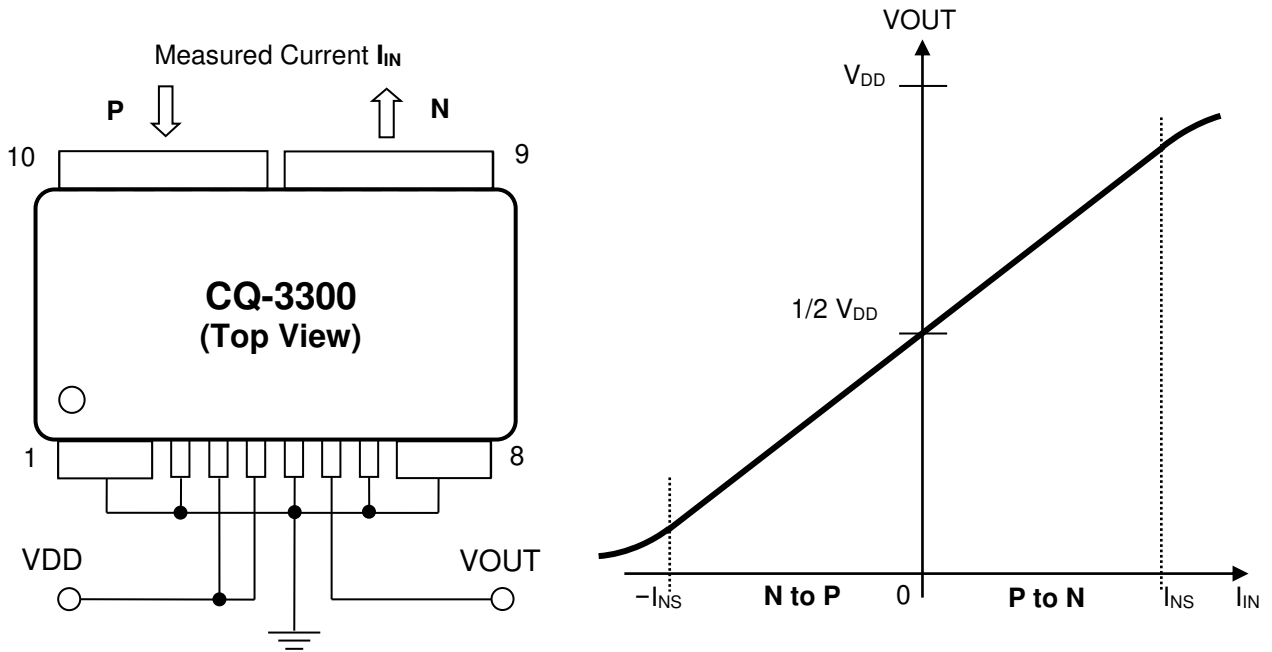


**Figure 1. Functional block diagram of CQ-3300**

**Table 1. Explanation of circuit blocks**

| Circuit Block     | Function  |
|-------------------|---|
| Primary Conductor | Conductor which measured current is applied.  |
| Hall Sensor       | Hall element which detects magnetic flux density generated from the measured current.   |
| Amplifier         | Amplifier of Hall element's output.   |
| Buffer            | Output buffer with gain. This block outputs the voltage ( $V_{OUT}$ ) proportional to the current applied to the primary conductor. |
| Compensation      | Compensation circuit which adjusts the temperature drifts of sensitivity and zero-current output voltage.                           |
| Bias Unit         | Drive circuit for Hall element.   |
| EEPROM Unit       | Non-volatile memory for setting adjustment parameters. The parameters are adjusted before the shipment.                             |

**5. Pin Configurations and Functions**



**Figure 2. Pin assignment and typical output characteristics of CQ-3300**

**Table 2. Pin configuration and functions of CQ-3300**

| No. | Pin Name | I/O | Function                                     |
|-----|----------|-----|--|
| 1   | TAB1     | -   | Radiation pin, recommended to connect to GND |
| 2   | TEST1    | -   | Test pin, recommended to connect to GND      |
| 3   | VDD      | PWR | Power supply pin, 5.0V                       |
| 4   | TEST2    | -   | Test pin, recommended to connect to VDD      |
| 5   | VSS      | GND | Ground pin (GND)                             |
| 6   | VOUT     | O   | Analog output pin                            |
| 7   | TEST3    | -   | Test pin, recommended to connect to GND      |
| 8   | TAB2     | -   | Radiation pin, recommended to connect to GND |
| 9   | N        | I   | Primary conductor pin                        |
| 10  | P        | I   | Primary conductor pin                        |

**6. Safety Standards**

- IEC/UL 62368-1 Audio/video, information and communication technology equipment Part 1: Safety requirements Edition 2. (File No. E359197)
- CSA C22.2 No.62368-1-14 Audio/video, information and communication technology equipment Part 1: Safety requirements Edition 2. (File No. E359197)
- UL 508 – Industrial Control Equipment – Edition 17. (File No. E353882)

**7. Absolute Maximum Ratings**

**Table 3. Absolute maximum ratings**

| Parameter             | Symbol           | Min. | Max. | Units | Notes    |
|-----------------------|------------------|------|------|-------|----------|
| Supply Voltage        | V <sub>DD</sub>  | -0.3 | 6.5  | V     | VDD pin  |
| Analog Output Current | I <sub>OUT</sub> | -1   | 1    | mA    | VOUT pin |
| Storage Temperature   | T <sub>stg</sub> | -40  | 125  | °C    |          |

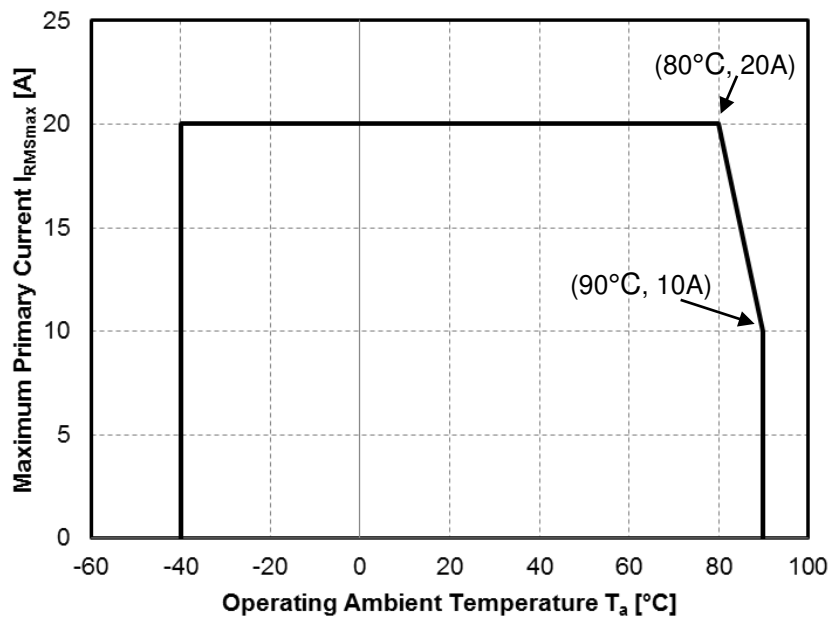
WARNING: Operation at or beyond these limits may result in permanent damage to the device. Normal operation is not guaranteed at these extremes.

**8. Recommended Operating Conditions**

**Table 4. Recommended operating conditions**

| Parameter                     | Symbol              | Min. | Typ. | Max. | Units | Notes  |
|-------------------------------|---------------------|------|------|------|-------|--|
| Supply Voltage                | V <sub>DD</sub>     | 4.5  | 5.0  | 5.5  | V     |  |
| Analog Output Current         | I <sub>OUT</sub>    | -0.5 |      | 0.5  | mA    | VOUT pin   |
| Output Load Capacitance       | C <sub>L</sub>      |      |      | 100  | pF    | VOUT pin   |
| Maximum Primary Current (RMS) | I <sub>RMSmax</sub> | -20  |      | 20   | A     | DC value or RMS value which can be applied to primary conductor see <a href="#">Figure 3</a> |
| Operating Ambient Temperature | T <sub>a</sub>      | -40  |      | 90   | °C    | see <a href="#">Figure 3</a>   |

WARNING: Electrical characteristics are not guaranteed when operated at or beyond these conditions.



Conditions: Mounted on the test board shown in [Figure 12](#). VDD = 5V  
**Figure 3. Primary current derating curve of CQ-3300**

Cooling or thermal radiation will improve the derating curve above.

|                                      |
|--------------------------------------|
| <b>9. Electrical Characteristics</b> |
|--------------------------------------|

|  |
|--|
| <b>Table 5. Electrical characteristics</b> |
|--|

Conditions (unless otherwise specified):  $T_a = 35^\circ\text{C}$ ,  $V_{DD} = 5\text{V}$

| Parameter  | Symbol        | Conditions  | Min.  | Typ.      | Max.  | Units            |
|--|---------------|---|-------|-----------|-------|------------------|
| Current Consumption  | $I_{DD}$      | No loads  |       | 8.3       | 11    | mA               |
| Sensitivity<br>(<br>Note 1, Note 2, Note 3)                        | $V_h$         | See paragraph 10.1  | 321   | 325       | 329   | mV/A             |
| Zero-Current Output<br>Voltage (<br>Note 1, Note 2)                | $V_{of}$      | See paragraph 10.1  | 2.480 | 2.500     | 2.520 | V                |
| Linear Sensing Range   | $I_{NS}$      |   | -6.4  |           | 6.4   | A                |
| Linearity Error<br>(<br>Note 1, Note 2)                            | $\rho$        | See paragraph 10.2  | -0.6  |           | 0.6   | %F.S.            |
| Rise Response Time   | $t_r$         | $C_L = 100\text{pF}$ ,<br>see paragraph 10.5                      |       | 0.5       |       | $\mu\text{sec}$  |
| Fall Response Time   | $t_f$         | $C_L = 100\text{pF}$ ,<br>see paragraph 10.5                      |       | 0.5       |       | $\mu\text{sec}$  |
| Bandwidth  | $f_T$         | -3dB, $C_L = 100\text{pF}$  |       | 1000      |       | kHz              |
| Output Noise (Note 2)  | $V_{Nrms}$    | 100Hz to 4MHz   |       | 2.7       |       | mVrms            |
| Temperature Drift of<br>Sensitivity (Note 2)                       | $V_{h-dmax}$  | $T_a = -40$ to $90^\circ\text{C}$                                 |       | $\pm 1.8$ |       | %                |
| Temperature Drift of<br>Zero-Current Output<br>Voltage (Note 2)    | $V_{of-dmax}$ | $T_a = -40$ to $90^\circ\text{C}$<br>$I_{IN} = 0\text{A}$         |       | $\pm 26$  |       | mV               |
| Ratiometricity Error of<br>Sensitivity (Note 2)                    | $V_{h-R}$     | $V_{DD} = 4.5\text{V}$ to $5.5\text{V}$                           | -1.0  |           | 1.0   | %                |
| Ratiometricity Error of<br>Zero-Current Output<br>Voltage (Note 2) | $V_{of-R}$    | $V_{DD} = 4.5\text{V}$ to $5.5\text{V}$ ,<br>$I_{IN} = 0\text{A}$ | -0.7  |           | 0.7   | %F.S.            |
| Total Accuracy (Note 5)  | $E_{TO}$      | $T_a = -40$ to $90^\circ\text{C}$                                 |       | $\pm 1.5$ |       | %F.S.            |
| Primary Conductor<br>Resistance (Note 4)                           | $R_1$         |   |       | 1.6       |       | $\text{m}\Omega$ |
| Isolation Voltage (Note 6)   | $V_{INS}$     | AC 50/60Hz, 60sec   | 3.0   |           |       | kV               |
| Isolation Resistance<br>(Note 4)                                   | $R_{INS}$     | DC 1kV  | 500   |           |       | $\text{M}\Omega$ |
| Clearance Distance<br>(Note 4)                                     | $d_{CL}$      | between primary and<br>secondary conductors                       | 5.0   | 5.2       |       | mm               |
| Creepage Distance<br>(Note 4)                                      | $d_{CP}$      | between primary and<br>secondary conductors                       | 5.0   | 5.2       |       | mm               |

Note 1. These parameters can drift by long-term use or reflow process. Please see '14. Reliability Tests' for the reference of drift values.

Note 2. The primary current ( $I_{IN}$ ) is swept within  $\pm 6\text{A}$ . Current is applied within 35msec in each step.

Note 3. This parameter is tested on condition that current density is uniform. Sensitivity may change slightly depending on a primary conductor layout on PCB. Please see the application note provided in the AKM website.

Note 4. These parameters are guaranteed by design.

Note 5. Total accuracy  $E_{TO}$  is calculated by the equation below.

$$E_{TO} = |100 \times (V_{h\_meas} - 325) / (325 \times 2)| + |100 \times (V_{of\_meas} - V_{of\_meas\_35}) / (325 \times 6.4 \times 2 / 1000)| + |\rho_{meas}|$$

where  $V_{h\_meas}$ [mV/A],  $V_{of\_meas}$ [V],  $\rho_{meas}$ [%F.S.] represent the measured value of sensitivity,

zero-current output voltage and linearity error respectively,  $V_h$ [mV/A] represent the typical value of sensitivity, and  $V_{of\_meas\_35}$ [V] represent the measured value of zero-current output voltage at  $T_a = 35^\circ\text{C}$ .

Note 6. This parameter is tested in mass-production line for all devices.

## 10. Characteristics Definitions

### 10.1. Sensitivity $V_h$ [mV/A], Zero-current output Voltage $V_{of}$ [V]

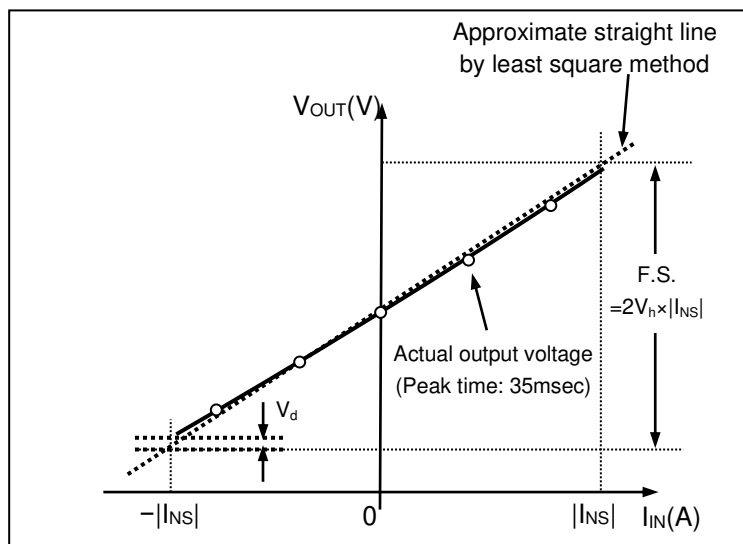
Sensitivity is defined as the slope of the approximate straight line calculated by the least square method, using the data of VOUT pin voltage ( $V_{OUT}$ ) when the primary current ( $I_{IN}$ ) is swept within  $\pm 6\text{A}$ . Zero-current output voltage is defined as the intercept of the approximate straight line above.

### 10.2. Linearity Error $\rho$ [%F.S.]

Linearity error is defined as the ration of the maximum error voltage ( $V_d$ ) to the full scale (F.S.), where  $V_d$  is the maximum difference between the VOUT pin voltage ( $V_{OUT}$ ) and the approximate straight line calculated in the sensitivity and zero-current output voltage definition. Definition formula is shown in below:

$$\rho = V_d / \text{F.S.} \times 100$$

Full scale (F.S.) is defined by the multiplication of the linear sensing range and sensitivity (Figure 4).



**Figure 4. Output characteristics of CQ-3300**

### 10.3. Ratiometric Error of Sensitivity $V_{h-R}$ [%] and Ratiometric Error of Zero-Current Output Voltage $V_{of-R}$ [%F.S.]

Output of CQ-3300 is ratiometric, which means the values of sensitivity ( $V_h$ ) and zero-current output voltage ( $V_{of}$ ) are proportional to the supply voltage ( $V_{DD}$ ). Ratiometric error is defined as the difference between the  $V_h$  (or  $V_{of}$ ) and ideal  $V_h$  (or  $V_{of}$ ) when the  $V_{DD}$  is changed from 5.0V to  $V_{DD1}$  ( $4.5\text{V} \leq V_{DD1} \leq 5.5\text{V}$ ). Definition formula is shown in below:

$$V_{h-R} = 100 \times \{ (V_h(V_{DD} = V_{DD1}) / V_h(V_{DD} = 5.0\text{V})) - (V_{DD1} / 5.0) \} / (V_{DD1} / 5.0)$$

$$V_{of-R} = 100 \times (V_{of}(V_{DD} = V_{DD1}) - V_{of}(V_{DD} = 5.0\text{V}) \times V_{DD1} / 5.0) / \text{F.S.}$$

Full scale (F.S.) is defined by the multiplication of the linear sensing range and sensitivity at the condition of  $V_{DD} = 5.0\text{V}$  (Figure 4).

### 10.4. Temperature Drift of Sensitivity $V_{h-d}$ [%] , Temperature Drift of Zero-current output Voltage $V_{of-d}$ [mV]

Temperature drift of sensitivity is defined as the drift ratio of the sensitivity ( $V_h$ ) at  $T_a = T_{a1}$  ( $-40^\circ\text{C} \leq T_{a1} \leq 90^\circ\text{C}$ ) to the  $V_h$  at  $T_a = 35^\circ\text{C}$ , and calculated from the formula below:

$$V_{h-d} = 100 \times (V_h(T_a = T_{a1}) / V_h(T_a = 35^\circ\text{C}) - 1)$$

Maximum temperature drift of sensitivity ( $V_{h-dmax}$ ) is defined as the maximum value of  $|V_{h-d}|$  through the defined temperature range.

Temperature drift of zero-current output voltage is defined as the drift value between the zero-current output voltage ( $V_{of}$ ) at  $T_a = T_{a1}$  ( $-40^\circ\text{C} \leq T_{a1} \leq 90^\circ\text{C}$ ) and the  $V_{of}$  at  $T_a = 35^\circ\text{C}$ , and calculated from the formula below:

$$V_{of-d} = V_{of}(T_a = T_{a1}) - V_{of}(T_a = 35^\circ\text{C})$$

Maximum temperature drift of zero-current output voltage ( $V_{of-dmax}$ ) is defined as the maximum value of  $|V_{of-d}|$  through the defined temperature range.

Reference data of the temperature drift of sensitivity and zero-current output voltage are shown in [Figure 5](#).

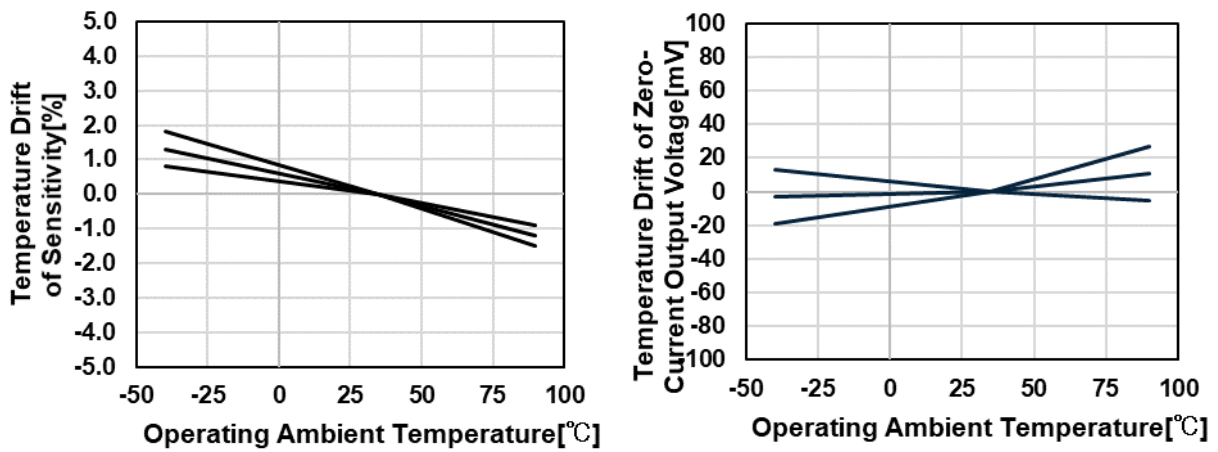


Figure 5. Temperature Drift of Sensitivity and Zero-current output Voltage.



### 10.5. Rise Response Time $t_r$ [ $\mu\text{sec}$ ] and Fall Response Time $t_f$ [ $\mu\text{sec}$ ]

Rise response time (or fall response time) is defined as the time delay from the 90% (or 10%) of input primary current ( $I_{IN}$ ) to the 90% (or 10%) of the  $V_{OUT}$  pin voltage ( $V_{OUT}$ ) under the pulse input of primary current (Figure 6).

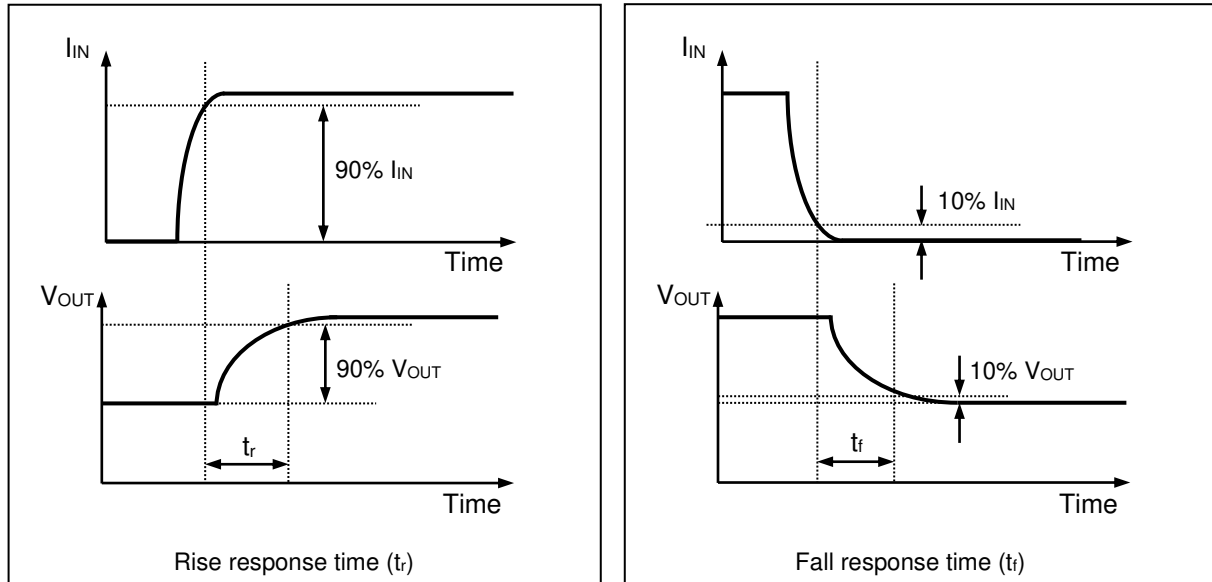
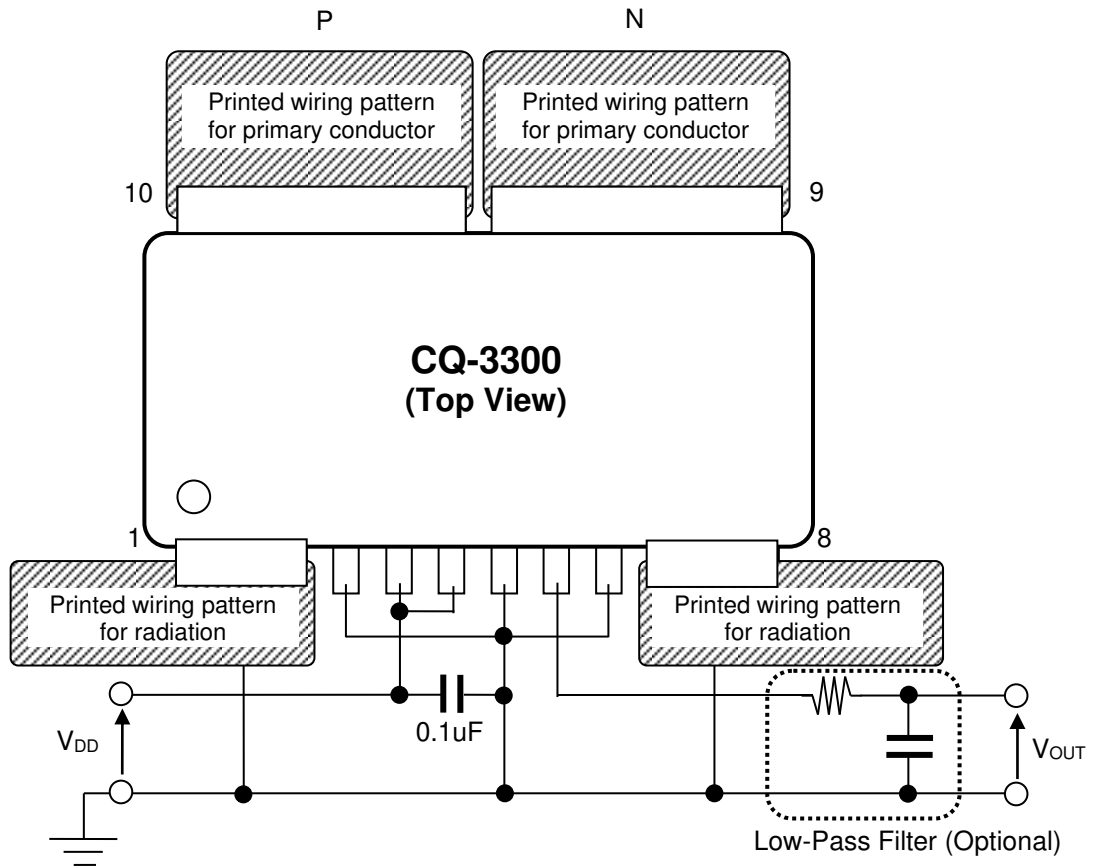


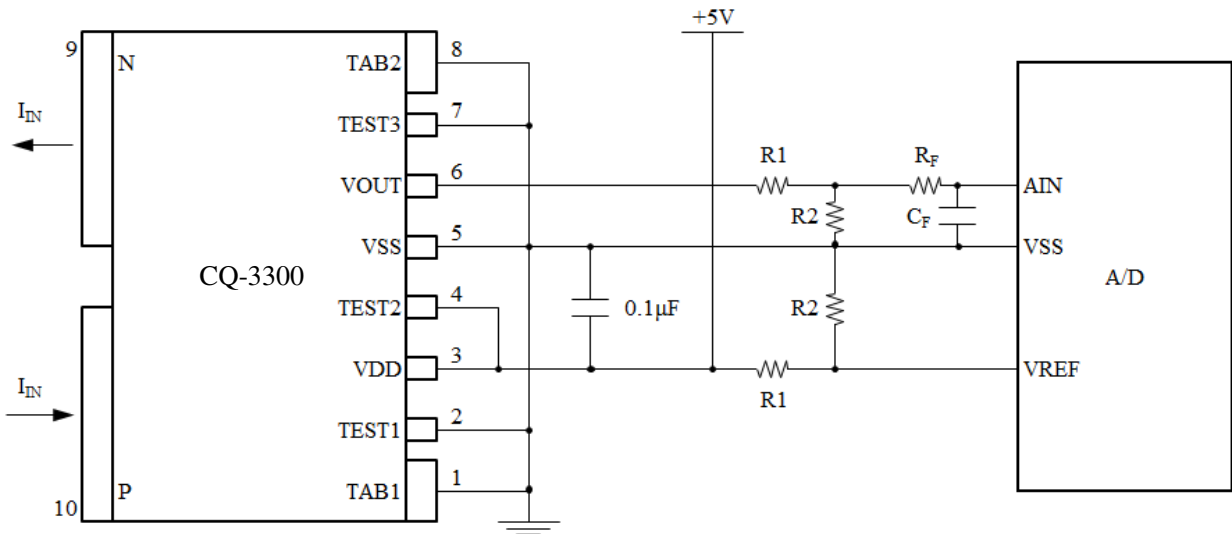
Figure 6. Definition of response time

**11. Recommended External Circuits**



**Figure 7. Recommended external circuits**

Radiation pattern should be designed as wide as possible, so that the clearance and creepage distances satisfy the requirement.

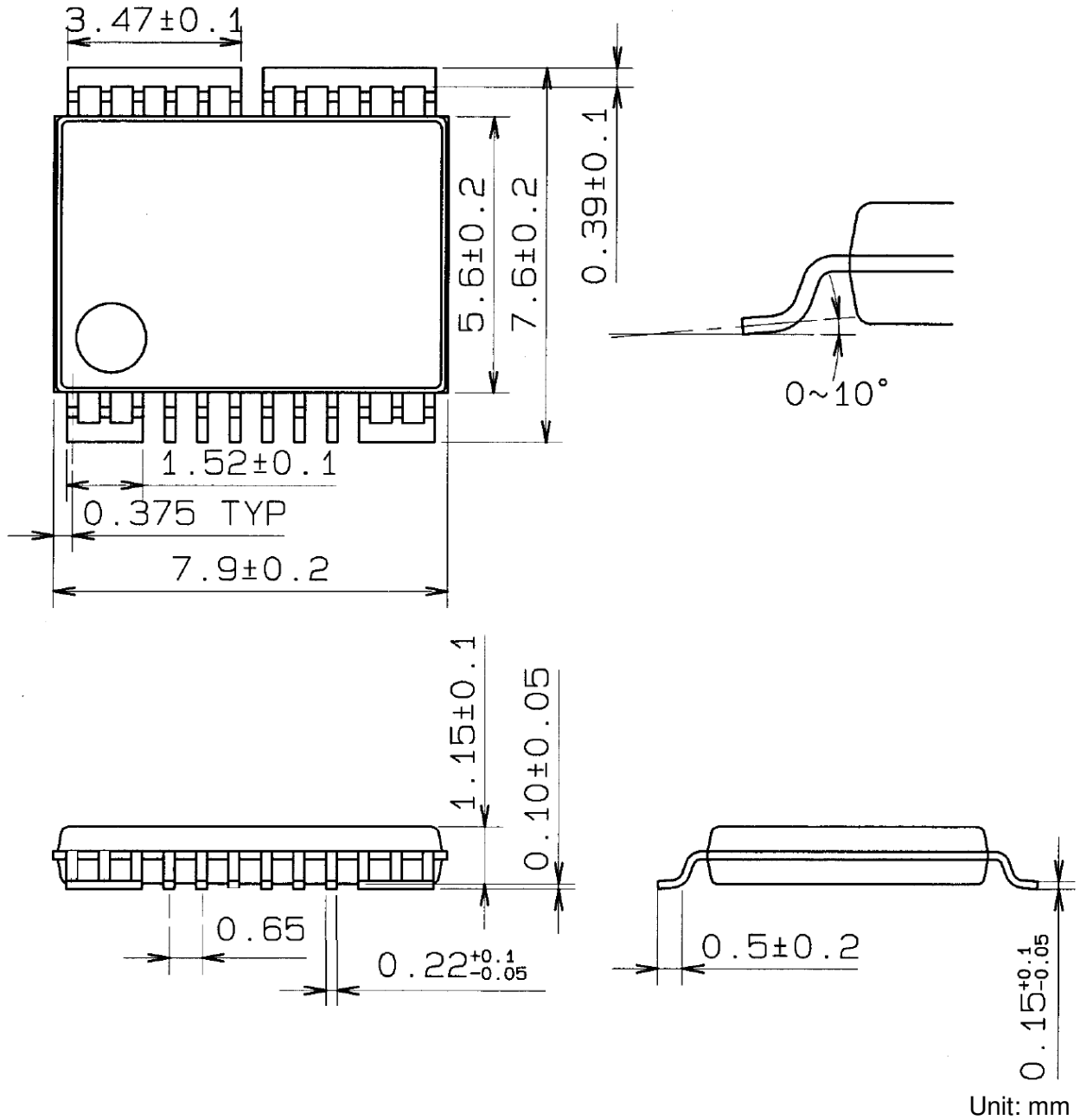


**Figure 8. Recommended external circuits of CQ-3300**

- (a) 0.1µF bypass capacitor should be placed near by the CQ-3300.
- (b) CQ-3300 has the ratiometric output. By making the supply voltage of CQ-3300 and the reference voltage of A/D converter common, the A/D conversion error caused by the fluctuation of supply voltage is decreased. Voltage dividers (R1 and R2) are required if the reference voltage of A/D converter is less than +5V. For example, if the reference voltage of A/D converter is +3.3V which is its supply voltage level, R1=20kΩ, R2=39kΩ are recommended. If the reference voltage of A/D converter is different from its supply voltage level, one more voltage divider is required.
- (c) Add a low-pass filter if it is necessary.

**12. Package**

12.1. Outline Dimensions

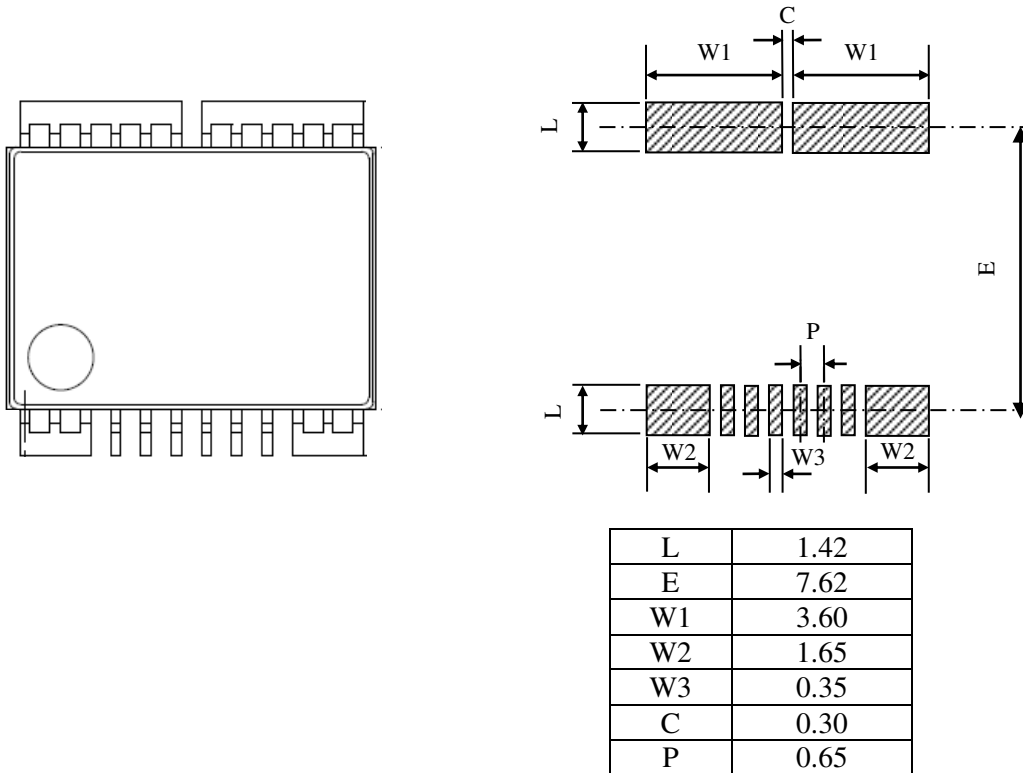


The tolerances of dimensions without any mention are  $\pm 0.1$ mm.

Terminals: Cu  
 Plating for Terminals: Sn-100% (10 $\mu$ m)  
 RoHS compliant, halogen-free

**Figure 9. Outline dimensions of CQ-3300**

12.2. Recommended Pad Dimensions



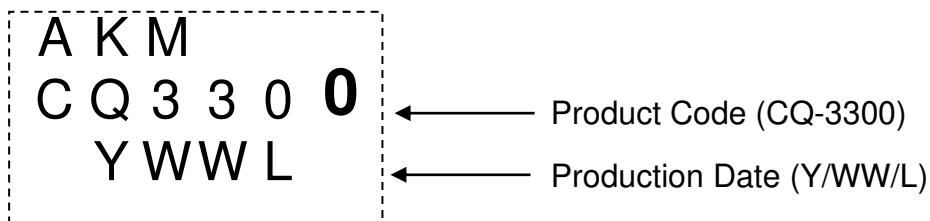
Unit: mm

Figure 10. Pad dimensions of CQ-3300

If two or more trace layers are used as the current paths, please make enough number of through-holes to flow current between the trace layers.

12.3. Marking

Production information is printed on the package surface by laser marking. Markings consist of 10 characters excluding AKM logo.

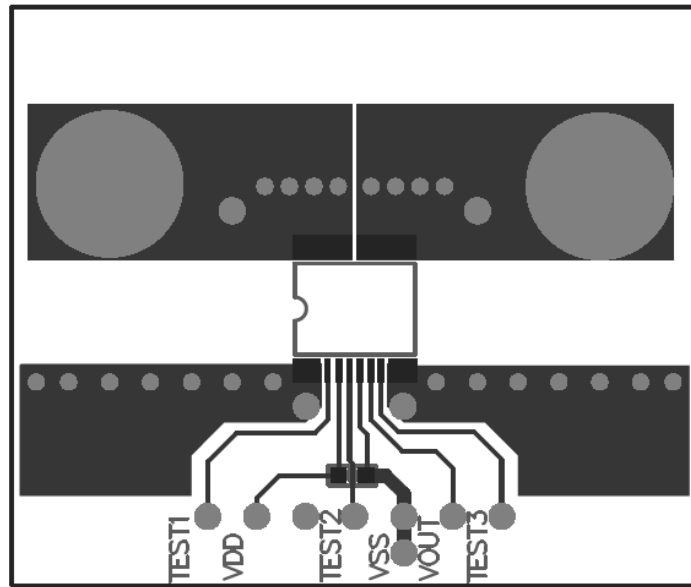


**Figure 11. Markings of CQ-3300**

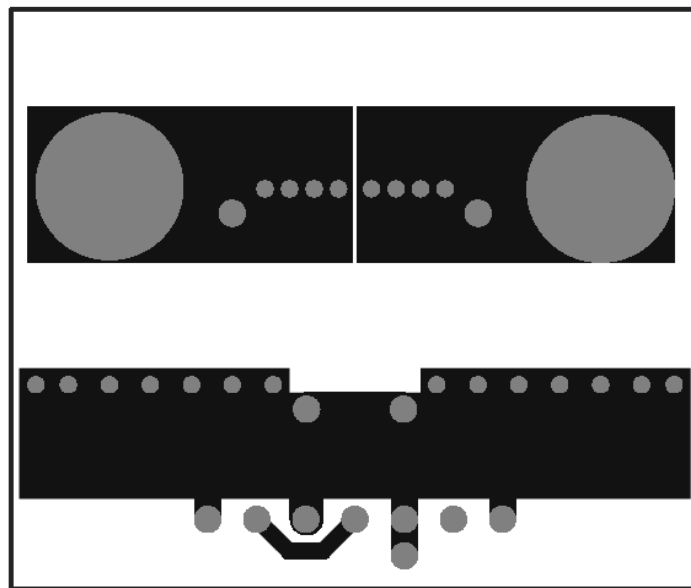
**Table 6. Production date code table**

| Last Number of Year |        | Week Date |      | Production Times |       |
|---------------------|--------|-----------|------|------------------|-------|
| Character           | Number | Character | Week | Character        | Times |
| 0                   | 0      | 01        | 1    | 1                | 1     |
| 1                   | 1      | 02        | 2    | 2                | 2     |
| 2                   | 2      | 03        | 3    | 3                | 3     |
| 3                   | 3      | 04        | 4    | 4                | 4     |
| 4                   | 4      | :         | :    | 5                | 5     |
| 5                   | 5      |           |      | 6                | 6     |
| 6                   | 6      |           |      | 7                | 7     |
| 7                   | 7      |           |      | 8                | 8     |
| 8                   | 8      | 51        | 51   | 9                | 9     |
| 9                   | 9      | 52        | 52   | 0                | 10    |
|                     |        | 53        | 53   | A                | 11    |
|                     |        | 54        | 54   | B                | 12    |
|                     |        |           |      | C                | 13    |
|                     |        |           |      | D                | 14    |
|                     |        |           |      | E                | 15    |
|                     |        |           |      | F                | 16    |
|                     |        |           |      | G                | 17    |
|                     |        |           |      | H                | 18    |
|                     |        |           |      | J                | 19    |
|                     |        |           |      | K                | 20    |
|                     |        |           |      | L                | 21    |
|                     |        |           |      | M                | 22    |
|                     |        |           |      | N                | 23    |
|                     |        |           |      | P                | 24    |
|                     |        |           |      | R                | 25    |
|                     |        |           |      | S                | 26    |
|                     |        |           |      | T                | 27    |
|                     |        |           |      | U                | 28    |
|                     |        |           |      | V                | 29    |
|                     |        |           |      | W                | 30    |
|                     |        |           |      | X                | 31    |
|                     |        |           |      | Y                | 32    |
|                     |        |           |      | Z                | 33    |

**13. Board Layout Sample**



(a) Top pattern



(b) Bottom pattern

Board size: 35.5mm × 42.0mm  
 Board thickness: 1.6mm  
 Copper layer thickness: 70μm

For more information about board layout, please see the application note provided in the AKM website.

**Figure 12. Board layout sample of CQ-3300**

|                              |
|------------------------------|
| <b>14. Reliability Tests</b> |
|------------------------------|

**Table 7. Test parameters and conditions of reliability tests**

| No. | Test Parameter                | Test Conditions   | n  | Test Time  |
|-----|-------------------------------|---|----|------------|
| 1   | High Humidity Bias Test       | [JEITA EIAJ ED-4701 102]<br>$T_a = 85^\circ\text{C}$ , 85%RH, continuous operation  | 22 | 1000h      |
| 2   | High Temperature Bias Test    | [JEITA EIAJ ED-4701 101]<br>$T_a = 125^\circ\text{C}$ , continuous operation  | 22 | 1000h      |
| 3   | High Temperature Storage Test | [JEITA EIAJ ED-4701 201]<br>$T_a = 150^\circ\text{C}$   | 22 | 1000h      |
| 4   | Low Temperature Storage Test  | [JEITA EIAJ ED-4701 202]<br>$T_a = -55^\circ\text{C}$   | 22 | 1000h      |
| 5   | Heat Cycle Test               | [JEITA EIAJ ED-4701 105]<br>$-65^\circ\text{C} \leftrightarrow 150^\circ\text{C}$<br>30min. $\leftrightarrow$ 30min.<br>Tested in vapor phase | 22 | 100 cycles |

Tested samples are pretreated as below before each reliability test:

Desiccation:  $125^\circ\text{C}/24\text{h}$   $\rightarrow$  Moisture Absorption:  $60^\circ\text{C}/60\%\text{RH}/120\text{h}$   $\rightarrow$  Reflow: 3 times (JEDEC Level2a)

No.1~4 are tested on devices using the same process.

No.5 is tested on this product.

Criteria:

Products whose drifts before and after the reliability tests do not exceed the values below are considered to be in spec.

|   |                               |
|---|-------------------------------|
| Sensitivity $V_h$ ( $T_a=35^\circ\text{C}$ )                    | : Within $\pm 1.5\%$          |
| Zero-current output Voltage $V_{of}$ ( $T_a=35^\circ\text{C}$ ) | : Within $\pm 350\text{mV}$   |
| Linearity $\rho$ ( $T_a=35^\circ\text{C}$ )                     | : Within $\pm 1\%\text{F.S.}$ |
| EEPROM data   | : Unchanged                   |



## 15. Precautions

### <Storage Environment>

Products should be stored at an appropriate temperature, and at as low humidity as possible by using desiccator(5 to 35°C). It is recommended to use the products within 4 weeks since it has opened. Keep products away from chlorine and corrosive gas.

### <Long-term Storage>

Long-term storage may result in poor lead solderability and degraded electrical performance even under proper conditions. For those parts, which stored long-term shall be check solderability before it is used. For storage longer than 1 year, it is recommended to store in nitrogen atmosphere. Oxygen of atmosphere oxidizes leads of products and lead solderability get worse.

### <Other Precautions>

- 1) This product should not be used under the environment with corrosive gas including chlorine or sulfur.
- 2) This product is lead (Pb) free. All leads are plated with 100% tin. Do not store this product alone in high temperature and high humidity environment. Moreover, this product should be mounted on substrate within six months after delivery.
- 3) This product is damaged when it is used on the following conditions:
  - Supply voltage is applied in the opposite way.
  - Overvoltage which is larger than the value indicated in the specification.
- 4) This product will be damaged if it is used for a long time with the current (effective current) which exceeds the current rating. Careful attention must be paid so that maximum effective current is smaller than current rating.
- 5) The characteristic can change by the influences of nearby current and magnetic field. Please make sure of the mounting position.

As this product contains gallium arsenide, observe the following procedures for safety.

- 1) Do not alter the form of this product into a gas, powder, liquid, through burning, crushing, or chemical processing.
- 2) Observe laws and company regulations when discarding this product.

**16. Revision History**

| Date (Y/M) | Revision | Page | Contents   |
|------------|----------|------|--|
| 15/06      | 02       | 15   | Change printing rules of lot identification                              |
| 22/01      | 03       | 1,5  | -Acquisition of successor standards due to revision of safety standards. |
|            |          | 6,8  | -Revised specifications values.  |
|            |          | 16   | - Reliability Tests  |

**IMPORTANT NOTICE**

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