



AK3103

Ultra Low Noise Coreless Current Sensor

1. General Description

AK3103 is an open-type current sensor using a Hall sensor which outputs the analog voltage in proportion to the AC/DC current. Ultra low noise property is realized by a III-V compound semiconductor Hall element of high sensitivity and signal processing technology. In addition, since AK3103 has a coreless structure and does not contain magnetic material, it has no hysteresis and is suitable for audio applications. AK3103 is especially suitable for a Motional Feedback system that feedbacks the current of voice coils of the speaker to the amplifier and controls the movement of the voice coils.

AK3103 adopts an ultra-small coreless package which is compliant with safety standards, suitable for applications such as motor control for industrial equipments. Since AK3103 has ultra low noise, it can detect the current by high resolution, which contributes to high-precision torque control of the motor.

2. Features

- ☐ Ultra low noise : -108 dBm / $\sqrt{\text{Hz}}$ (integrated noise 0.35 mV_{rms}, 100 Hz to 200 kHz integration)
- ☐ No hysteresis output, because of not containing the magnetic material
- ☐ Very small primary conductor resistance : 1.6 m Ω
- ☐ High Accuracy : 1.5% F.S. (T_a = -40 to 90 °C Typ.)
- ☐ Small and thin surface mount package : 7.9 mm × 7.6 mm × 1.15 mm
- ☐ Certified with safety standards of IEC / UL 60950, UL 1577 certification pending
- ☐ Isolation voltage : 3.0 kV_{rms} (AC 50/60 Hz, 60 s)
- ☐ Fast Response Time : 2 μ s Typ.
- ☐ Ratiometric output
- ☐ Operated by single power supply : V_{DD} = 5 V



3. Applications

- ☐ Speaker current detection (Motional Feedback)
- ☐ Motor Driver
- ☐ General-purpose inverter
- ☐ UPS
- ☐ Power Conditioner

Also, AK3103 is suitable for applications requiring quite small current resolution, and current measurement with isolation.

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| 4. Table of Contents |
|-----------------------------|

| | |
|--|----|
| 1. General Description | 1 |
| 2. Features | 1 |
| 3. Applications | 1 |
| 4. Table of Contents | 2 |
| 5. Block Diagram and Functions | 3 |
| 6. Pin Configurations and Functions | 4 |
| 7. Absolute Maximum Ratings | 5 |
| 8. Recommended Operating Conditions | 5 |
| 9. Electrical Characteristics | 7 |
| 10. Characteristics Definitions | 8 |
| 11. Recommended External Circuits | 10 |
| 12. Thermal Resistance Measurement Board | 11 |
| 13. Package | 12 |
| 14. Reliability Tests | 15 |
| 15. Precautions | 16 |
| IMPORTANT NOTICE | 17 |

5. Block Diagram and Functions

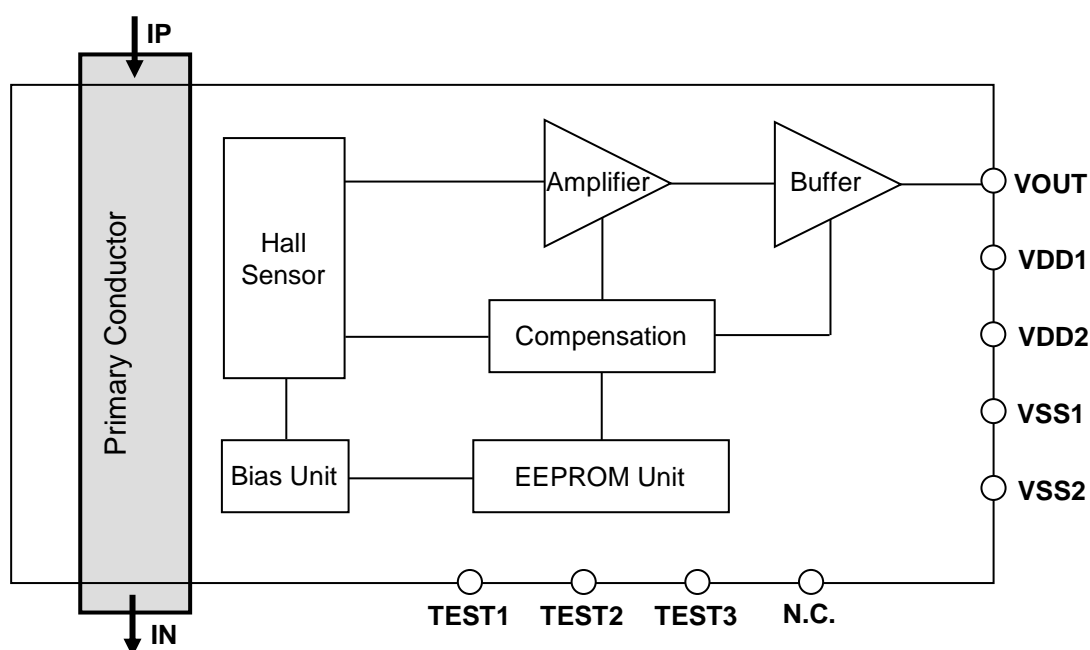


Figure 1. Functional block diagram of AK3103

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 absolute value and 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. |

6. Pin Configurations and Functions

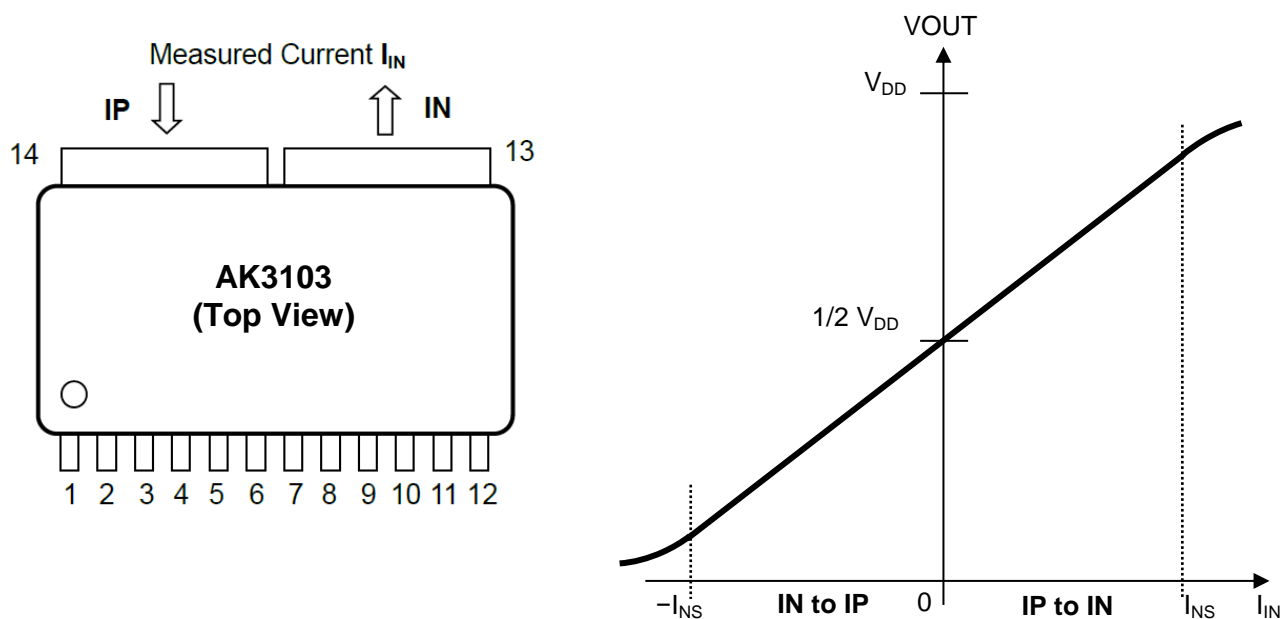


Figure 2. Pin assignment and typical output characteristics of AK3103

Table 2. Pin configuration and functions of AK3103

| No. | Pin Name | I/O | Function |
|-----|----------|-----|---|
| 1 | VSS1 | GND | Ground pin (0V) |
| 2 | VSS1 | GND | Ground pin (0V) |
| 3 | N.C. | - | N.C. pin, recommended to connect to GND |
| 4 | TEST1 | - | Test pin, recommended to connect to GND |
| 5 | VDD1 | PWR | Power supply pin, 5.0V |
| 6 | VDD2 | PWR | Power supply pin, 5.0V |
| 7 | TEST2 | - | Test pin, recommended to connect to GND |
| 8 | VOUT | O | Sensor output pin |
| 9 | TEST3 | - | Test pin, recommended to connect to GND |
| 10 | N.C. | - | N.C. pin, recommended to connect to GND |
| 11 | VSS2 | GND | Ground pin (0V) |
| 12 | VSS2 | GND | Ground pin (0V) |
| 13 | IN | I | Primary conductor pin (-) |
| 14 | IP | I | Primary conductor pin (+) |

7. Absolute Maximum Ratings

Table 3. Absolute maximum ratings

| Parameter | Symbol | Min. | Max. | Units | Notes |
|-----------------------|-----------|------|------|-------|-----------------|
| Supply Voltage | V_{DD} | -0.3 | 6.5 | V | VDD1, VDD2 pins |
| Analog Output Current | I_{OUT} | -10 | 10 | mA | VOUT pin |
| Junction Temperature | T_J | -40 | 125 | °C | |
| Storage Temperature | T_{STG} | -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.

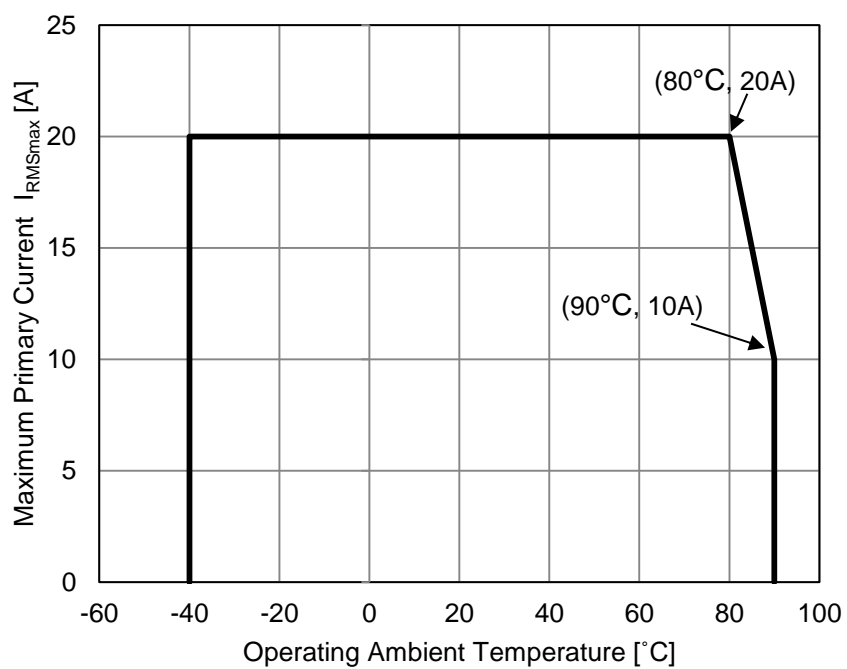
8. Recommended Operating Conditions

Table 4. Recommended operating conditions

| Parameter | Symbol | Min. | Typ. | Max. | Units | Notes |
|--|--------------|------|------|------|-----------|---|
| Supply Voltage | V_{DD} | 4.5 | 5.0 | 5.5 | V | VDD1, VDD2 pins |
| Analog Output Current | I_{OUT} | -0.5 | | 0.5 | mA | VOUT pin |
| Output Load Capacitance | C_L | | | 100 | pF | Between VOUT and VSS1, VOUT and VSS2 |
| Maximum Primary Current (RMS) (Note 1) | I_{RMSmax} | | | 20 | A_{rms} | DC value or RMS value which can be applied to primary conductor |
| Operating Ambient Temperature (Note 1) | T_a | -40 | | 90 | °C | |

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

Note 1. Maximum Primary Current is regulated by derating curve, see Figure 3.



Conditions: Mounted on the test board shown in Chapter 12. $V_{DD} = 5V$, without any cooling.
Note: Cooling or thermal radiation will improve the derating curve above.

Figure 3. Primary current derating curve of AK3103

9. Electrical Characteristics

Table 5. Electrical characteristics

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, $I_{IN}=0\text{A}$ | | 14 | 20 | mA |
| Sensitivity (Note 2) | V_h | See paragraph 10.1 $I_{IN}=\pm 10\text{A}$, 35ms | 59.4 | 60.0 | 60.6 | mV/A |
| Zero-Current Output Voltage (Note 2) | V_{of} | $I_{IN}=0\text{A}$, See paragraph 10.1 | 2.48 | 2.50 | 2.52 | V |
| Linear Sensing Range (Note 3) | I_{NS} | | -35 | | 35 | A |
| Linearity Error (Note 2) | ρ | See paragraph 10.1 | -0.6 | | 0.6 | %F.S. |
| Rise Response Time | t_r | $C_L = 100\text{pF}$, see paragraph 10.5 | | 2 | | μs |
| Fall Response Time | t_f | $C_L = 100\text{pF}$, see paragraph 10.5 | | 2 | | μs |
| Bandwidth | f_T | -3dB, $C_L = 100\text{pF}$ | | 210 | | kHz |
| Output Noise | V_{Nrms} | 100Hz to 200kHz integration | | 0.35 | | mV _{rms} |
| | V_N | 50Hz to 200Hz Termination 50 Ω | | -108 | | dBm/ $\sqrt{\text{Hz}}$ |
| Ratiometric Error of Sensitivity | V_{h-R} | $V_{DD} = 4.5\text{V}$ to 5.5V see paragraph 10.2 | -1.0 | | 1.0 | % |
| Ratiometric Error of Zero-Current Output Voltage | V_{of-R} | $V_{DD} = 4.5\text{V}$ to 5.5V , see paragraph 10.3 | -0.5 | | 0.5 | %F.S. |
| Power On Time (Note 4) | t_{on} | $I_{IN}=0\text{A}$ V_{DD} 4.5V to $V_{OUT} \pm 10\%$ | | | 35 | ms |
| Primary Conductor Resistance (Note 3) | R_P | | | 1.6 | | m Ω |
| Isolation Voltage (Note 5) | V_{INS} | AC 50/60Hz, 60s | 3.0 | | | kV _{rms} |
| Isolation Resistance (Note 3) | R_{INS} | DC 1kV | 500 | | | M Ω |

Table 6. Temperature drift characteristics

Conditions (unless otherwise specified): $T_a = -40$ to 90°C , $V_{DD} = 5\text{V}$

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Units |
|---|-------------|---|------|-----------|------|-------|
| Temperature Drift of Sensitivity (Note 6) | V_{h-d} | $T_a = -40$ to 90°C Drift from the value at $T_a = 35^\circ\text{C}$ | | ± 1.7 | | % |
| Temperature Drift of Zero-Current Output Voltage (Note 6) | V_{of-d} | $T_a = -40$ to 90°C Drift from the value at $T_a = 35^\circ\text{C}$ $I_{IN} = 0\text{A}$ | | ± 3 | | mV |
| Total Accuracy (Note 6) | E_{total} | $T_a = -40$ to 90°C | | ± 1.5 | | %F.S. |

Note 2. These values can be drifted by long-term use or reflow process. Please see '14. Reliability Tests' for the reference of drift values.

Note 3. These parameters are guaranteed by design. Mass production test is not performed.

Note 4. This parameter is tested in wafer.

Note 5. This parameter is tested in mass-production line for all devices, 3.6kV_{rms}, 1s.

Note 6. The typical value is defined as the "average value $\pm 1\sigma$ " of the actual measurement result in a certain lot. VOUT pin condition is no loads.

10. Characteristics Definitions

10.1. Sensitivity V_h [mV/A], Zero-Current Output Voltage V_{of} [V], and Linearity error ρ [%F.S.] are defined as below:

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 the range of linear sensing range (I_{NS}). Zero-current output voltage is defined as the V_{out} when $I_{IN}=0A$.

Linearity error is defined as the ratio 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 as below:

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

Full scale (F.S.) is defined as 4.4V ($V_{DD} = 5V$).

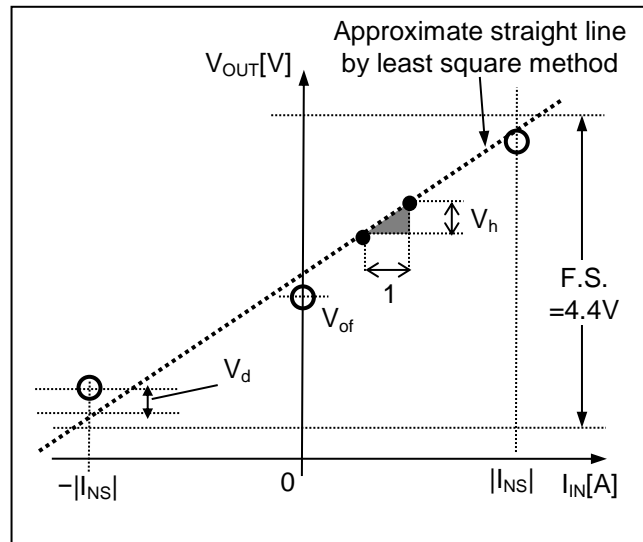


Figure 4. Characteristic definitions of AK3103

10.2. Ratiometric Error of Sensitivity V_{h-R} [%] is defined as below:

$$V_{h-R} = 100 \times \frac{\left\{ \frac{V_h(V_{DD})}{V_h(5V)} - \frac{V_{DD}}{5} \right\}}{\frac{V_{DD}}{5}}$$

10.3. Ratiometric Error of Zero-Current Output Voltage V_{of-R} [%F.S.] is defined as below:

$$V_{of-R} = 100 \times \frac{\left\{ V_{of}(V_{DD}) - \frac{V_{of}(5V) \times V_{DD}}{5} \right\}}{F.S.}$$

10.4. Total Accuracy E_{total} [%F.S.] is defined as below ($V_{DD} = 5V$):

$$E_{total} = \left| 100 \times \frac{V_{h_meas} - V_h}{V_h} \right| \times \frac{|I_{NS}|}{F.S. \times 1000} + \left| 100 \times \frac{V_{of_meas} - V_{of_meas_35}}{F.S.} \right| + |\rho_{meas}|$$

V_{h_meas} : Measured Sensitivity [mV/A]

V_{of_meas} : Measured Zero-current Output Voltage [V]

$V_{of_meas_35}$: Measured Zero-current Output Voltage [V] at $T_a = 35^\circ C$

ρ_{meas} : Measured Linearity Error [%F.S.]

F.S. = 4.4 [V]

10.5. Rise Response Time t_r [μsec] and Fall Response Time t_f [μsec] are defined as below:

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 VOUT pin voltage (V_{OUT}) under the pulse input of primary current (Figure 5).

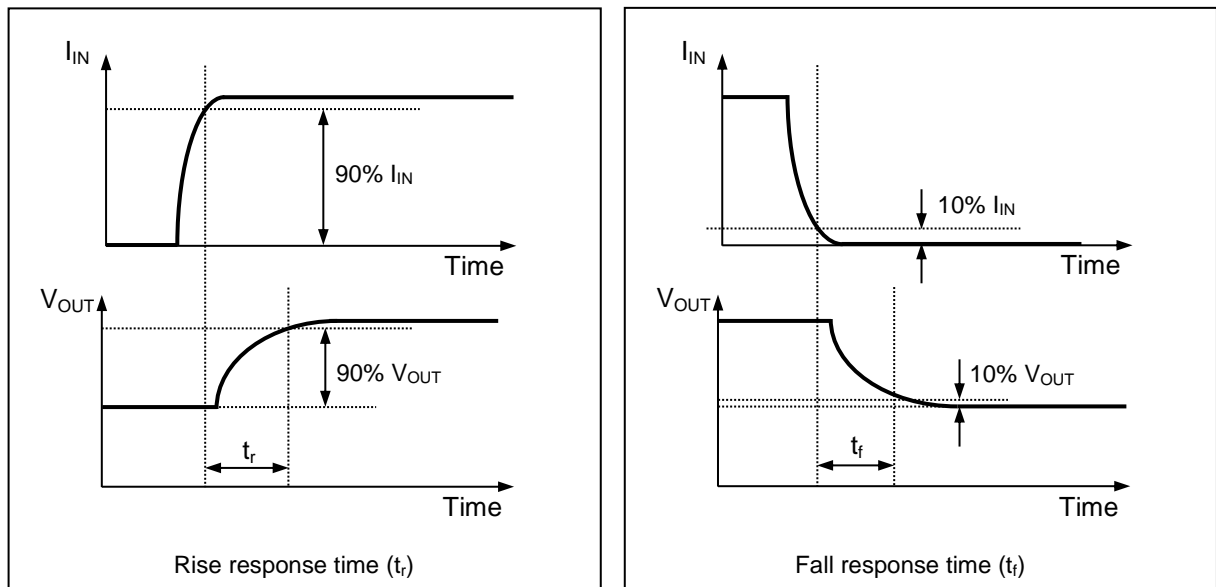


Figure 5. Definition of response time

11. Recommended External Circuits

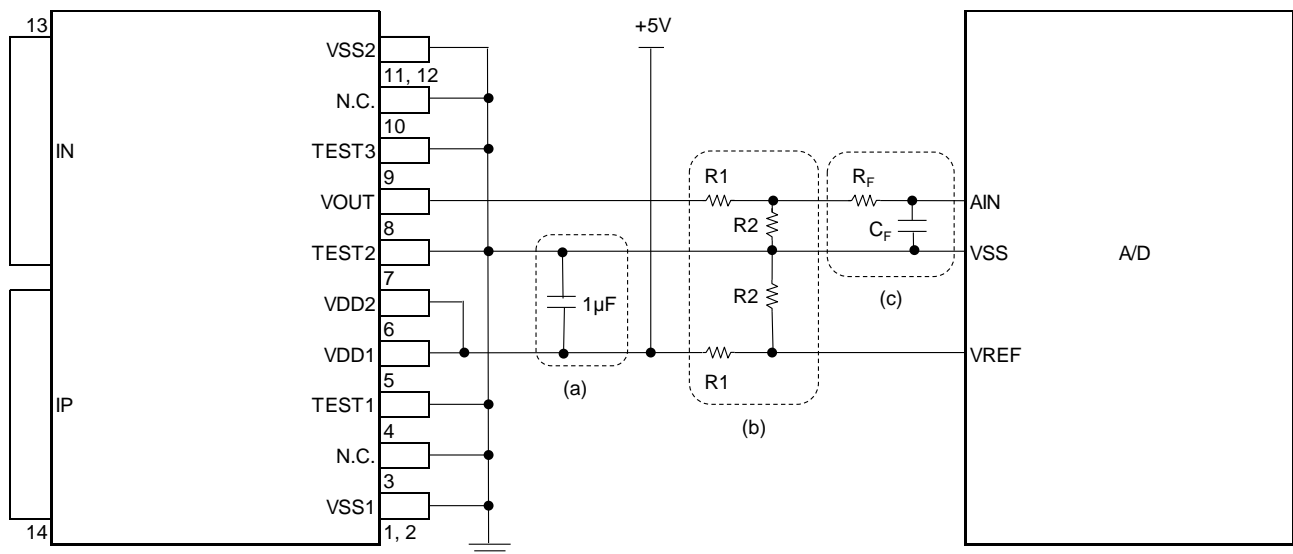


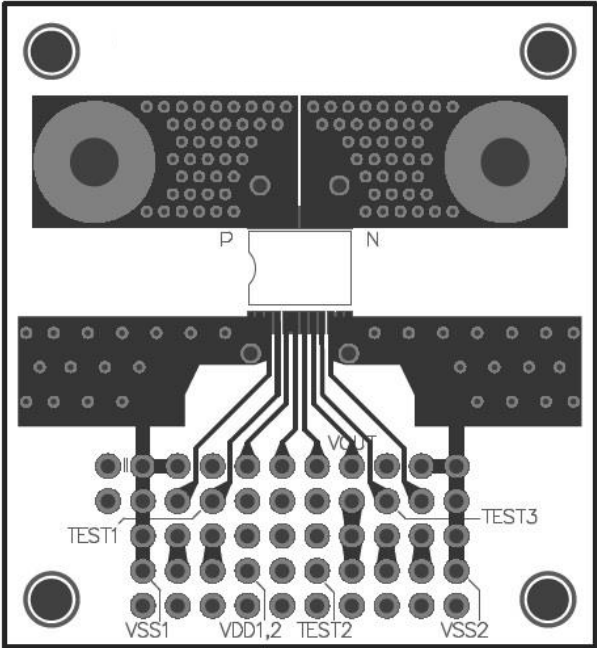
Figure 6. Recommended external circuits of AK3103

- (a) $1\mu\text{F}$ bypass capacitor should be placed close to the AK3103.
- (b) AK3103 has the ratiometric output. By making the supply voltage of AK3103 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, $R1=20\text{k}\Omega$, $R2=39\text{k}\Omega$ are recommended. If the reference voltage of A/D converter is different from its supply voltage level, other voltage divider is required.
- (c) Add a low-pass filter if it is necessary.

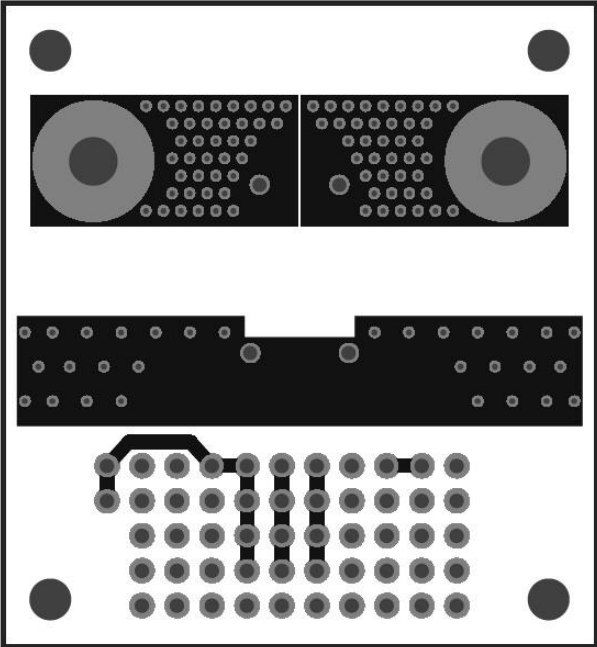
12. Thermal Resistance Measurement Board

Table 7. Board Information

| | |
|------------------------|-----------------|
| Board Size | 43.1mm × 46.9mm |
| Layer number | 2 |
| Copper layer thickness | 70μm |
| Board thickness | 1.6mm |



(a) Top pattern

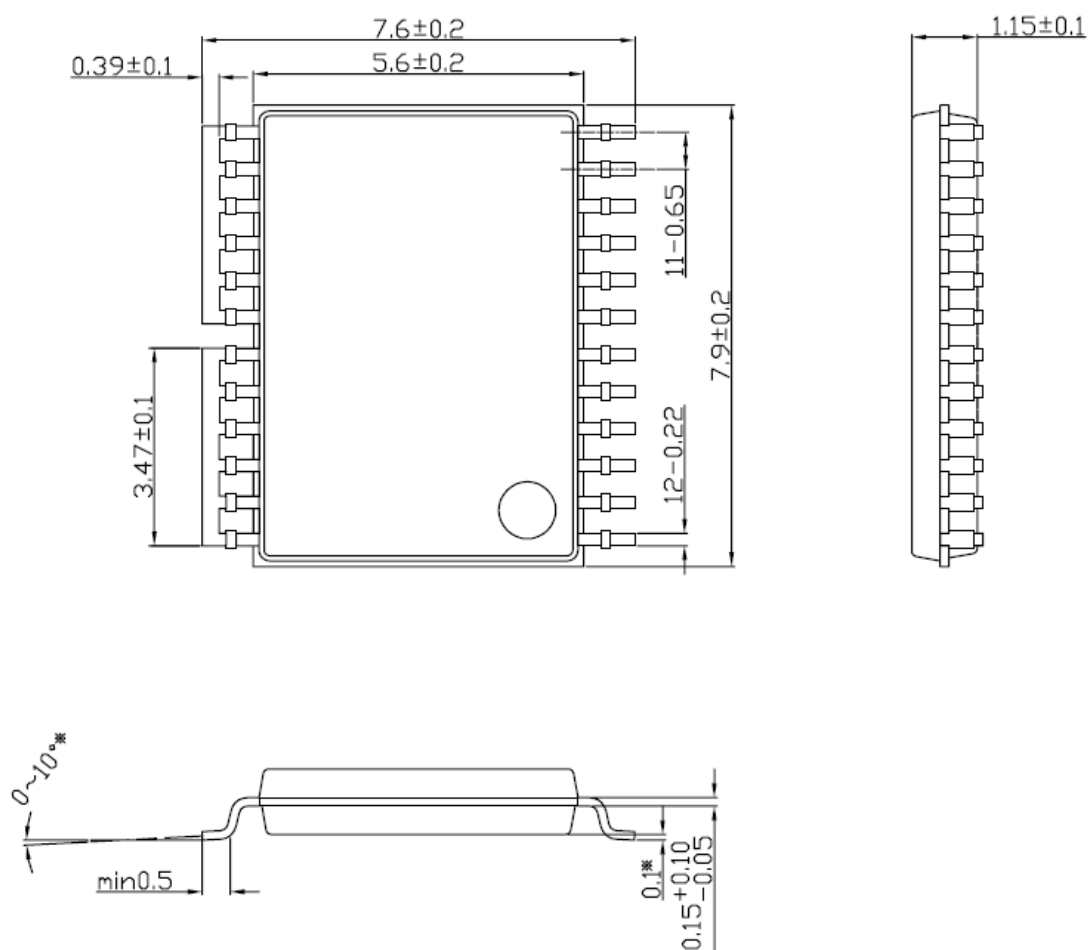


(b) Bottom pattern

Figure 7. Thermal Resistance Measurement Board of AK3103

13. Package

13.1. Outline Dimensions



Unit: mm

The tolerances of dimensions without any mention are ± 0.1 mm.
The symbol of “*” are design target.

Figure 8. Outline dimensions of AK3103

Terminals: Cu

Plating for Terminals: Sn-Bi

Package material: RoHS compliant, halogen-free

Table 8. Package Characteristics

| Parameter | Symbol | Min. | Typ. | Max. | Units |
|--------------------|--------|------|------|------|-------|
| Clearance Distance | C_l | 5.0 | | | mm |
| Creepage Distance | C_r | 5.0 | | | mm |

*Flammability standard is V0. (According to UL94)

*Comparative tracking index (CTI) is 600V. Material Group is “I”.

13.2. Standards

- IEC/UL 60950-1 – Information Technology Equipment – Edition 2. (File No.E359197)
- CSA C22.2 NO. 60950-1-07 – Information Technology Equipment – Edition 2. (File No. E359197)

13.3. Recommended Pad Dimensions

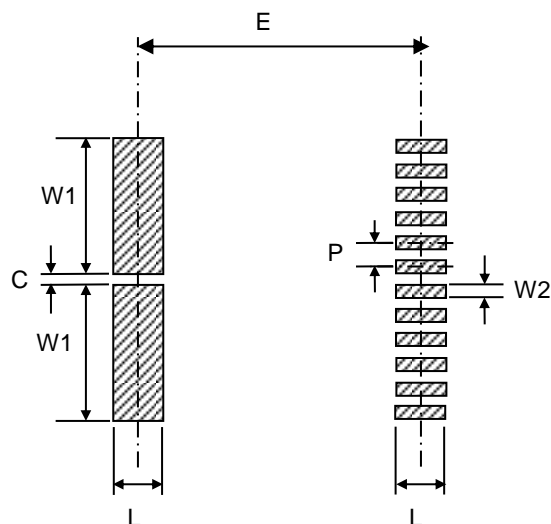


Figure 9. Recommended Pad dimensions of AK3103

Table 9. Recommended pad dimensions

| | |
|----|------|
| L | 1.42 |
| E | 7.62 |
| W1 | 3.60 |
| W2 | 0.35 |
| C | 0.30 |
| P | 0.65 |

Unit: mm

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. In order to make heat dissipation better, it is recommended that Pad on Via should be provided on the pad of the primary conductor.

13.4. Marking

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

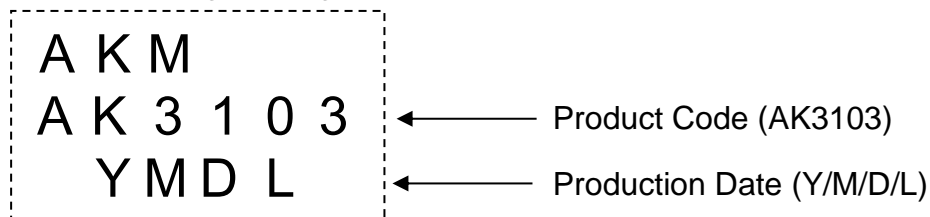


Figure 10. Markings of AK3103

Table 10. Production date code table

| Y | | M | | D | | L | |
|-----------|------|-----------|-----------|-----------|-----|-----------|---------|
| Character | Year | Character | Month | Character | Day | Character | Lot No. |
| 8 | 2018 | C | January | 1 | 1 | 1 | 1 |
| 9 | 2019 | D | February | 2 | 2 | 2 | 2 |
| A | 2020 | E | March | 3 | 3 | 3 | 3 |
| B | 2021 | F | April | 4 | 4 | 4 | 4 |
| C | 2022 | G | May | 5 | 5 | 5 | 5 |
| D | 2023 | H | June | 6 | 6 | 6 | 6 |
| E | 2024 | J | July | 7 | 7 | 7 | 7 |
| F | 2025 | K | August | 8 | 8 | 8 | 8 |
| G | 2026 | L | September | 9 | 9 | 9 | 9 |
| H | 2027 | M | October | 0 | 10 | 0 | 10 |
| J | 2028 | N | November | A | 11 | A | 11 |
| K | 2029 | P | December | B | 12 | B | 12 |
| L | 2030 | | | C | 13 | C | 13 |
| N | 2031 | | | D | 14 | D | 14 |
| P | 2032 | | | E | 15 | E | 15 |
| R | 2033 | | | F | 16 | F | 16 |
| S | 2034 | | | G | 17 | G | 17 |
| T | 2035 | | | H | 18 | H | 18 |
| U | 2036 | | | J | 19 | J | 19 |
| V | 2037 | | | K | 20 | K | 20 |
| W | 2038 | | | L | 21 | L | 21 |
| X | 2039 | | | N | 22 | M | 22 |
| | | | | P | 23 | N | 23 |
| | | | | R | 24 | P | 24 |
| | | | | S | 25 | R | 25 |
| | | | | T | 26 | S | 26 |
| | | | | U | 27 | T | 27 |
| | | | | V | 28 | U | 28 |
| | | | | W | 29 | V | 29 |
| | | | | X | 30 | W | 30 |
| | | | | Y | 31 | X | 31 |
| | | | | | | Y | 32 |
| | | | | | | Z | 33 |

| |
|------------------------------|
| 14. Reliability Tests |
|------------------------------|

Table 11. Test parameters and conditions of reliability tests

| No. | Test Parameter | Test Conditions | n | Test Time |
|-----|--------------------------------|--|----|------------|
| 1 | Highly Accelerated Stress Test | 【JEITA ED-4701 102】 $T_a = 130^{\circ}\text{C}$, 85%RH, continuous operation | 22 | 200h |
| 2 | High Temperature Bias Test | 【JEITA ED-4701 101】 $T_a = 150^{\circ}\text{C}$, continuous operation | 22 | 1000h |
| 3 | High Temperature Storage Test | 【JEITA ED-4701 201】 $T_a = 150^{\circ}\text{C}$ | 22 | 1000h |
| 4 | Low Temperature Operating Test | $T_a = -40^{\circ}\text{C}$, continuous operation | 22 | 1000h |
| 5 | Heat Cycle Test | 【JEITA ED-4701 105】 $-65^{\circ}\text{C} \leftrightarrow 150^{\circ}\text{C}$ 30min. \leftrightarrow 30min Tested in vapor phase. | 22 | 200 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 Level 2a)

Criteria :

Products whose drifts between after pretreatment 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 $\pm 3\%$ |
| Zero-Current Voltage V_{of} ($T_a=35^{\circ}\text{C}$) | : Within $\pm 20\text{mV}$ |
| Linearity Error ρ ($T_a=35^{\circ}\text{C}$) | : Within $\pm 1\%\text{F.S.}$ |
| EEPROM | : No change |

15. Precautions

<Storage Environment>

Products should be stored at an appropriate temperature (5 to 35°C), and at as low humidity as possible by using desiccator. It is recommended to use the products within 4 weeks since packing was opened. Keep products away from chlorine and corrosive gas. When stored in an inappropriate environment, it can affect the product properties.

<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 should be checked as for 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 Sn-Bi. 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 characteristics can be changed by the influences of nearby current and magnetic field and electric 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.

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