AK3102

Ultra Low Noise Coreless Current Sensor

1. General Description

AK3102 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 AK3102 has a coreless structure and does not contain magnetic material, it has no hysteresis and is suitable for audio applications. AK3102 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.

AK3102 adopts an ultra-small coreless package which is compliant with safety standards, suitable for applications such as motor control for industrial equipments. Since AK3102 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 / √ 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 mΩ
- ☐ 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 : 2µs 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, AK3102 is suitable for applications requiring quite small current resolution, and current measurement with isolation.

4. Table of Contents

5. Block Diagram and Functions

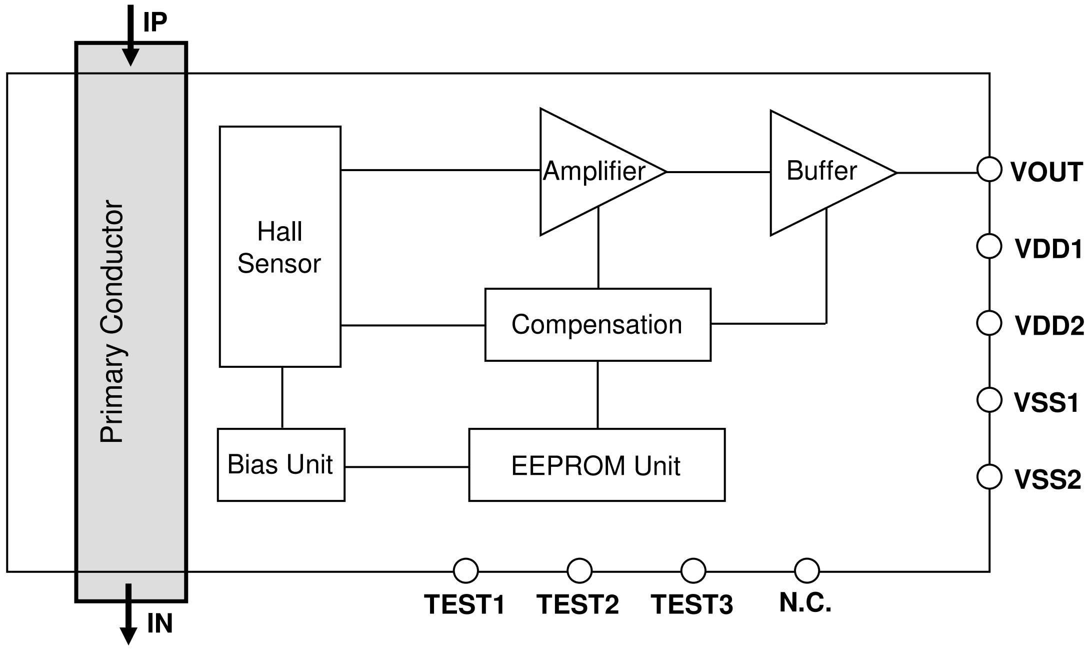


Figure 1. Functional block diagram of AK3102

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

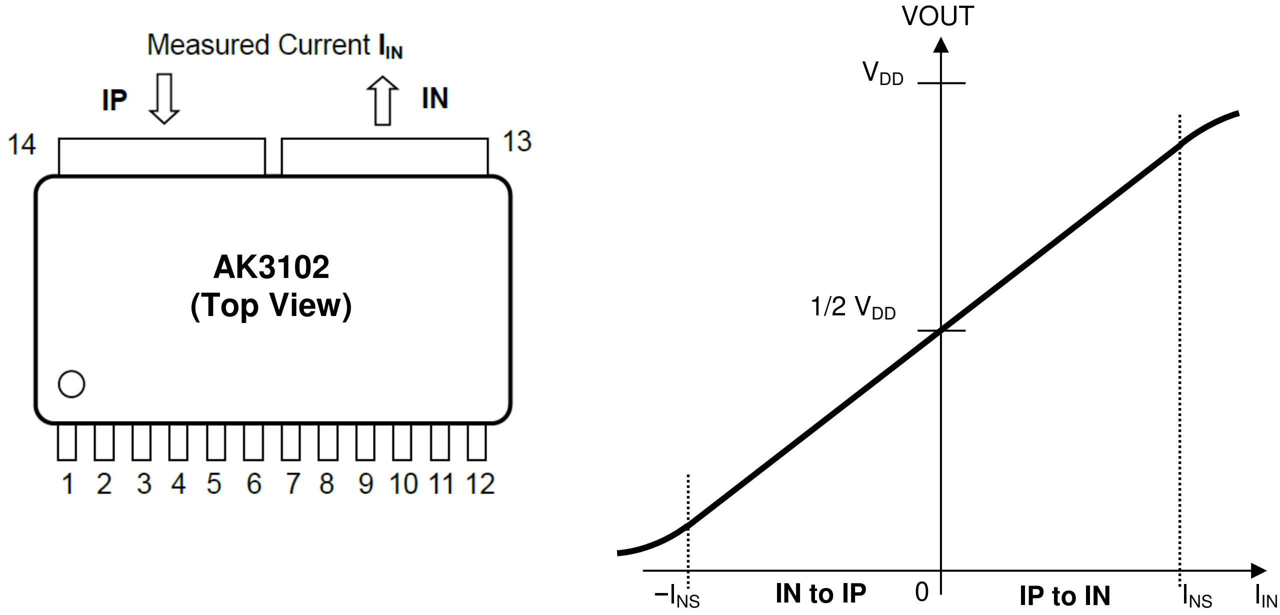


Figure 2. Pin assignment and typical output characteristics of AK3102

Table 2. Pin configuration and functions of AK3102

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.

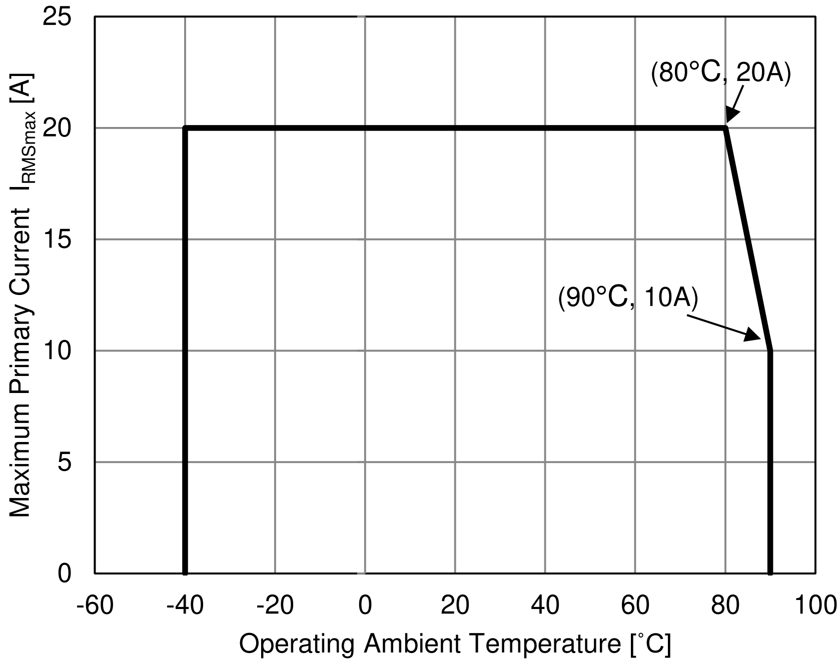
8. Recommended Operating Conditions

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 AK3102

9. Electrical Characteristics

Table 5. Electrical characteristics

Conditions (unless otherwise specified): T_a = 35°C, V_{DD} = 5V

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Current Consumption	I_{DD}	No loads, I_{IN}=0A		14	20	mA
Sensitivity (Note 2)	V_h	See paragraph 10.1 I_{IN}=±10A, 35ms	99	100	101	mV/A
Zero-Current Output Voltage (Note 2)	V_{of}	I_{IN}=0A, See paragraph 10.1	2.48	2.50	2.52	V
Linear Sensing Range (Note 3)	I_{NS}		−21		21	A
Linearity Error (Note 2)	ρ	See paragraph 10.1	−0.6		0.6	%F.S.
Rise Response Time	t_r	C_L = 100pF, see paragraph 10.5		2		μs
Fall Response Time	t_f	C_L = 100pF, see paragraph 10.5		2		μs
Bandwidth	f_T	−3dB, C_L = 100pF		210		kHz
Output Noise	V_{Nrms}	100Hz to 200kHz integration		0.35		mV_{rms}
	V_N	50Hz to 200Hz Termination 50Ω		-108		dBm/√Hz
Ratiometric Error of Sensitivity	V_{h-R}	V_{DD} = 4.5V to 5.5V see paragraph 10.2	−1.0		1.0	%
Ratiometric Error of Zero-Current Output Voltage	V_{of-R}	V_{DD} = 4.5V to 5.5V, see paragraph 10.3	−0.5		0.5	%F.S.
Power On Time (Note 4)	t_{on}	I_{IN}=0A V_{DD} 4.5V to VOUT ±10%			35	ms
Primary Conductor Resistance (Note 3)	R_P			1.6		mΩ
Isolation Voltage (Note 5)	V_{INS}	AC 50/60Hz, 60s	3.0			kV_{rms}
Isolation Resistance (Note 3)	R_{INS}	DC 1kV	500			MΩ

Table 6. Temperature drift characteristics

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

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°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°C I_{IN} = 0A		±3		mV
Total Accuracy (Note 6)	E_{total}	Ta = −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 ± 1σ" 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).

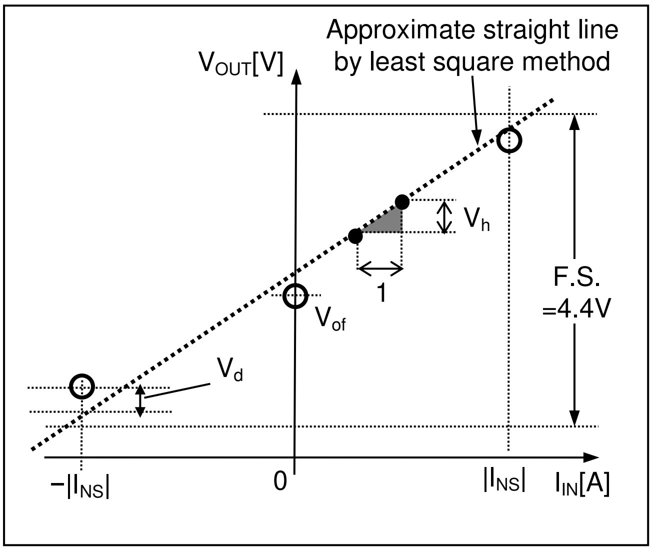


Figure 4. Characteristic definitions of AK3102

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°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).

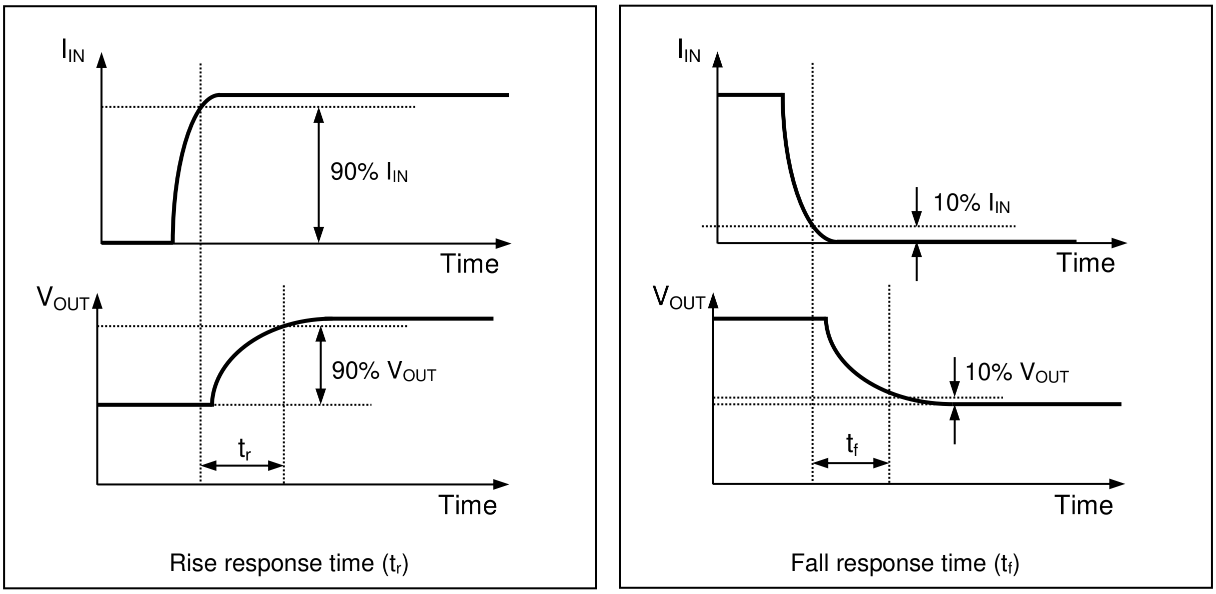


Figure 5. Definition of response time

11. Recommended External Circuits

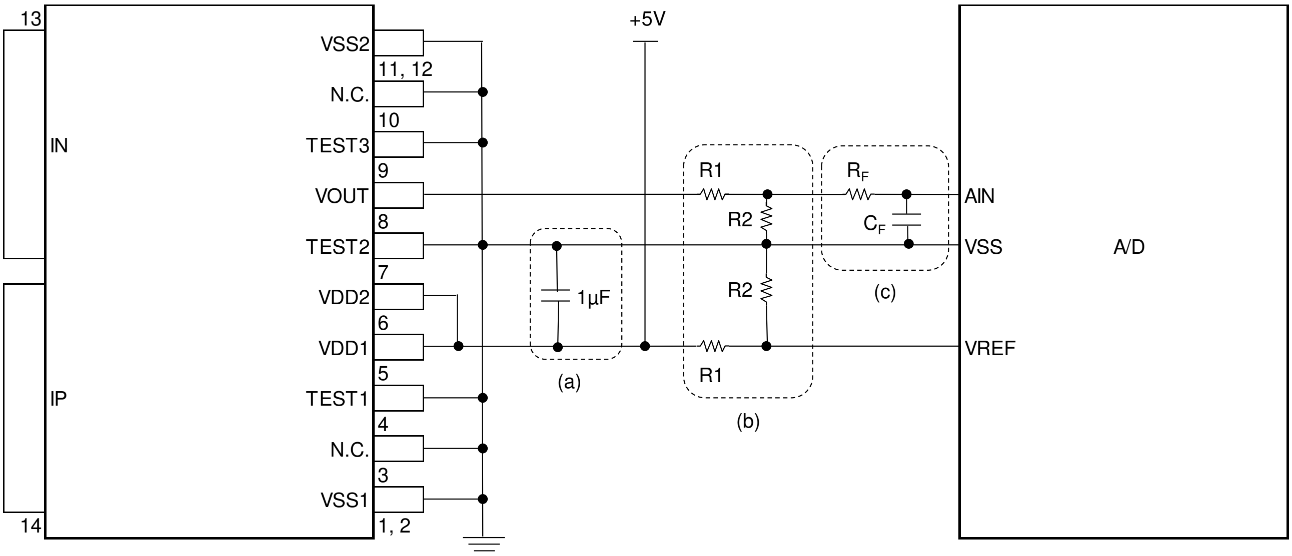


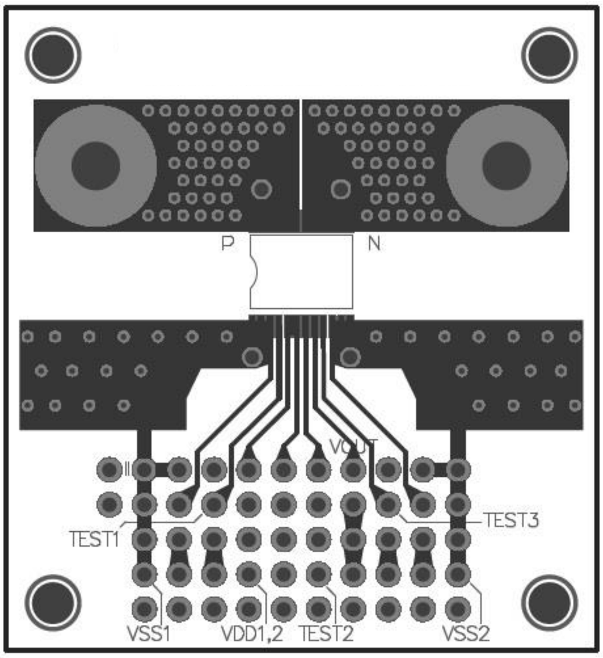
Figure 6. Recommended external circuits of AK3102

(a) 1μF bypass capacitor should be placed close to the AK3102.
(b) AK3102 has the ratiometric output. By making the supply voltage of AK3102 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, 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

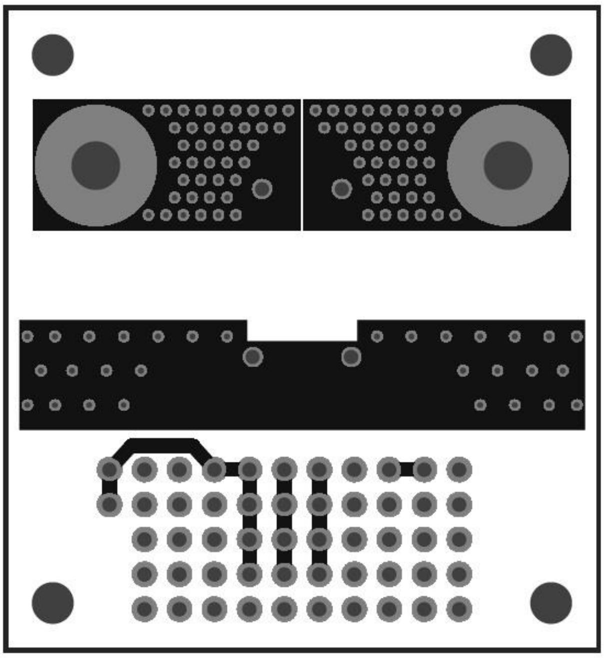
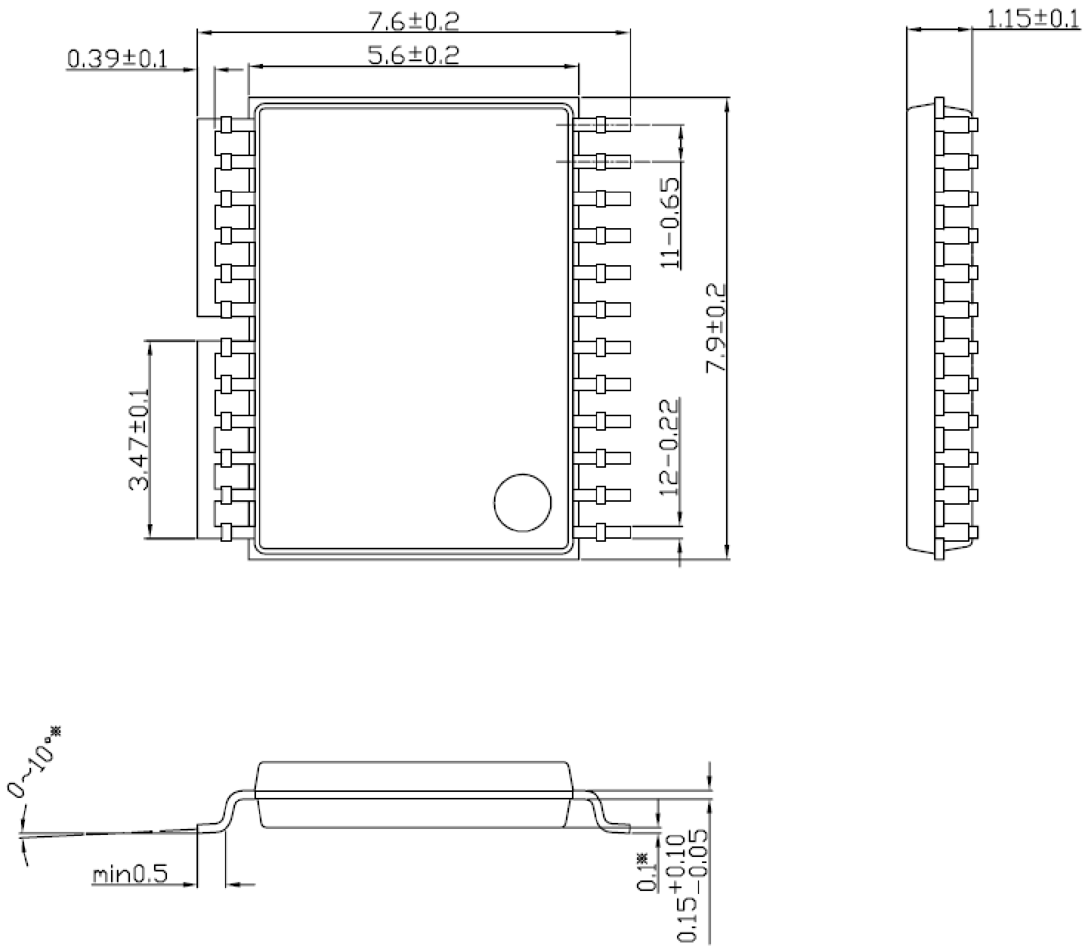

(b) Bottom pattern

Figure 7. Thermal Resistance Measurement Board of AK3102

13. Package

13.1. Outline Dimensions



Unit: mm

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

Figure 8. Outline dimensions of AK3102

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

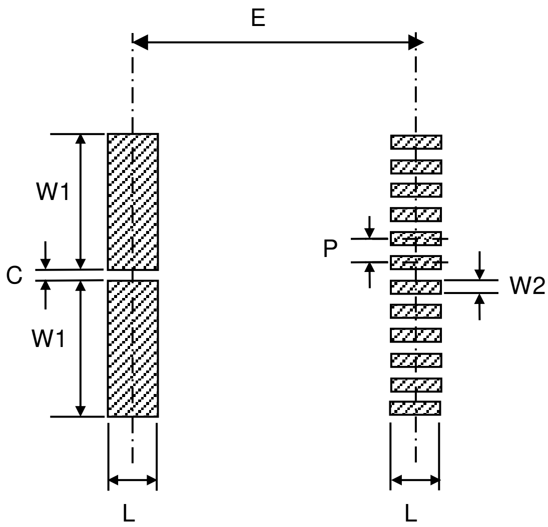


Figure 9. Recommended Pad dimensions of AK3102

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.

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13.4. Marking

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

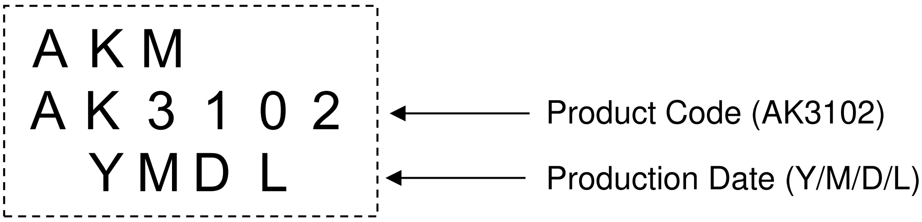

Figure 10. Markings of AK3102

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°C, 85%RH, continuous operation	22	200h
2	High Temperature Bias Test	【JEITA ED-4701 101】 T_a = 150°C, continuous operation	22	1000h
3	High Temperature Storage Test	【JEITA ED-4701 201】 T_a = 150°C	22	1000h
4	Low Temperature Operating Test	T_a = −40°C, continuous operation	22	1000h
5	Heat Cycle Test	【JEITA ED-4701 105】 −65°C ⇔ 150°C 30min. ⇔ 30min Tested in vapor phase.	22	200 cycles

Tested samples are pretreated as below before each reliability test:
Desiccation: 125°C/24h → Moisture Absorption: 60°C/60%RH/120h → 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°C) : Within ±3%
Zero-Current Voltage Vof (T_a=35°C) : Within ±20mV
Linearity Error ρ (T_a=35°C) : Within ±1%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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