High Accuracy Current Sensor Module with 300ns Response Time,1.5MHz 3dB Bandwidth ±1000A, 5V, AEC-Q100 Qualified

MCHA-K1A-1000-5

FEATURES

- **TMR based current sensor module**
- **Superior Range & Accuracy**
  - **1.4% typical total error @25°C (MCHA-K1A-1000-5)**
- **Superior Frequency Response**
  - **1.5 MHz (typical 3dB BW)**
- **Fast output response time (300ns typical)**
- **Single 5.0V Supply Operation**
- **Low power consumption (30mW typical)**
- **Busbar mountable sensor module package (RoHS/REACH compliant)**
- **-40 to +125°C Operating Temperature Range**
- **AEC-Q100 qualified**
- **UL/IEC/EN62368-1 Certified**
  - **2.5 kV Dielectric Strength Voltage**
  - **1096 VRMS Basic Isolation Voltage**
  - **400 VRMS Reinforced Isolation Voltage**

APPLICATIONS

Automotive
- **EVs, Traction Inverters, Onboard Chargers**
- **Battery Management, DC-DC Converters**

Solar Inverters and Optimizers
- **Grid-Tie and Storage Current Monitoring**
- **MPPT Circuit Current Monitoring**
- **Central Inverter Current Monitoring**

Power Supplies
- **Welding, Uninterruptible Supplies**
- **Switched Mode Supplies, AC Variable Speed Drives, Servo Motor Drives**

Consumer
- **Motor Balance and Remote Device Monitoring**
- **Home Automation Control & IOT remote sensing**

DESCRIPTION

The MCHA-K1A-1000-5 is a ±1000A fully integrated bi-directional analog output current sensor module that delivers high accuracy, high bandwidth and fast response time. ACEINNA's state-of-the-art Tunneling Magneto Resistive (TMR) sensor technology provides inherently low noise, superior sensitivity, excellent linearity, and repeatability. The high bandwidth of 1.5MHz (3dB) and low phase delay expands the engineering space for current sense feedback loops in electric vehicle (EV) power management systems, DC Fast Charging (DCFC) stations, uninterruptable power supplies (UPS), solar inverters, and other high-power applications incorporating fast switching wide-bandgap SiC and GaN based power stages.

The module's pass-through port can accommodate conductors with cross-sectional dimensions up to 6mm x 20.50mm allowing ease of integration into preexisting power management designs. A package-integrated M4 through-hole provides secure mounting to busbar conductors. The module interface is an Amphenol 10142961 4 pin, 1.8mm pitch receptacle which provides sensor power and conductor current readout (Figures 1 & 2). The module is factory-calibrated to achieve low offset error and linearity across the operating temperature range while providing a precise analog voltage output that is linearly proportional to the bidirectional conductor current (AC or DC). The TMR sensor device structure is designed to eliminate sensitivity to stray and common mode magnetic fields.

Due to the inherently low output noise of ACEINNA's sensor technology, additional filtering is not required to reduce noise that reduces accuracy at low-level currents in systems with dynamic load profiles.

The MCHA-K1A-1000-5 sensor module package is simple to use with no external components enabling fast design, supports high isolation and are UL/IEC/EN62368-1 certified and AEC-Q100 qualified.

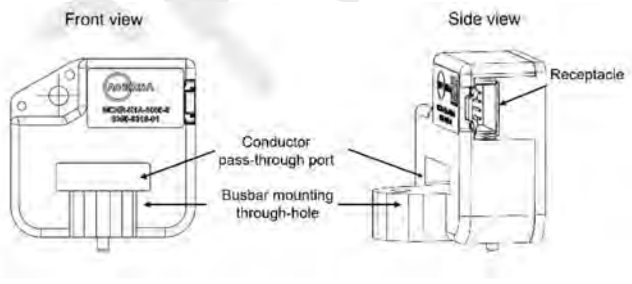


Figure 1 - Sensor module package

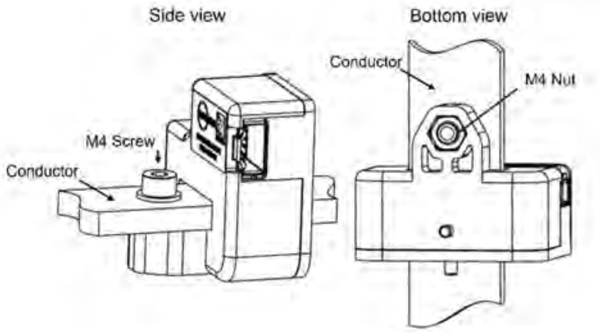


Figure 2 - Sensor module busbar mounting

ORDERING PART NUMBER

Ordering Part Number	Part Marking (See Page 9)	Current Range	VCC (Typical)	Dielectric Strength	Package
MCHA-K1A-1000-5	MCHA-K1A-1000-5	±1000Amp	5.0V	2500V	Busbar mountable sensor module

PIN DESCRIPTION

Pin # 4L receptacle	Name	Description
1	Vout	Analog output signal linearly proportional to primary path current.
2	GND	Connect to ground.
3	VCC	Module power supply.
4	NC	Used during initial factory calibration. This pin should be left floating during normal operation or connected to ground.

4-pin receptacle

BLOCK DIAGRAM

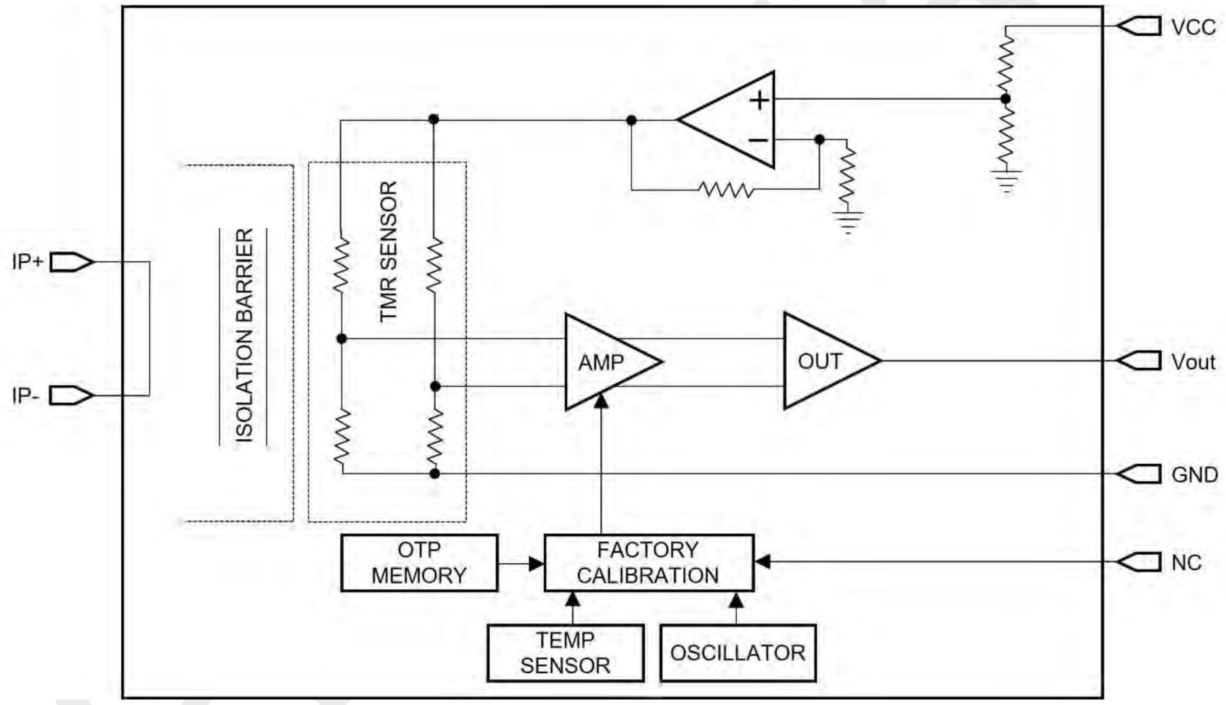


Figure 3 - Block diagram for the MCHA-K1A-1000-5

Table 1 – ABSOLUTE MAXIMUM RATINGS

Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation at these or any other conditions beyond those specified is not implied.

Parameters / Test Conditions	**Symbol**	**Value**	**Unit**
Supply Voltage	VCC_{MAX}	-0.5 to 5.5	V
Primary Current (IP+, IP-), 1000Amp products	IP_{MAX}	±1000	A
Maximum Module Temperature	T_{MMAX}	150	°C
Storage Temperature	T_{STG}	-60 to 150	°C
Operating Ambient Temperature Range	T_A	-40 to 125	°C
EMC Immunity to electrostatic discharges / per ISO 10605 (07/2008)	ESD	TBD	V
EMC Immunity to conducted disturbances/ per ISO 11452-4 (12/2011)	BCI	TBD	V
Ingress Protection Rating	IPX	IPX-2	

Table 2 – ISOLATION CHARACTERISTICS

Parameters / Test Conditions	**Symbol**	**Value**	**Unit**
Dielectric Strength Test Voltage (Agency type-tested for 60 seconds per UL standard 62368-1. Production tested at 3kVrms per UL 62368-1.	V_{ISO}	2500	V
Working Voltage for Basic Isolation. Maximum approved working voltage according to UL 62368-1 ($V_{PK/DC}$ / V_{RMS})	V_{WVBI}	1550 / 1097	V
Working Voltage for Reinforced Isolation ($V_{PK/DC}$ / V_{RMS})	V_{WVRI}	565 / 400	V
Clearance distance (Minimum distance through air from IP leads to signal leads)	D_{CL}	7.53	mm
Creepage distance (Minimum distance along package body from IP leads to signal leads)	D_{CR}	10.66	mm

Table 3 – ELECTRICAL CHARACTERISTICS

Unless otherwise noted: 4.5V ≤ VCC ≤ 5.5V, -40°C ≤ T_A ≤ 125°C, I (Vout) = 0 (Recommended Operating Conditions).
Typical values are for VCC = 5.0V and T_A = 25°C.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Vout Output						
Load Regulation	$Vout_{LR}$	Increase I (Vout) from 0 to -250μA. Measure change in Vout voltage		2	4	mV
Source Current	$Vout_{SRC}$	Vout shorted to GND			50	mA
Sink Current	$Vout_{SNK}$	Vout shorted to VCC			30	mA
Frequency Response (-3dB)	$Vout_{BW}$	(Note 1)		1500		kHz
Capacitive Loading	$CVout_{MAX}$	(Note 1)			200	pF
Resistive Loading	RL_{MIN}	Minimum load resistance on Vout (Note 1)	10			kohm
Response Time	t_{RESP}	IP± = 0 to ±100% step input, interval from 80% of the IP to 80% of the Vout. (Note 1)		300		ns
Noise Density	I_{ND}	Input Referred, VCC = 5.0V, TA = 25°C, CL=200pF, 10 kHz~1MHz		10		μA/√Hz
Noise (Input Referred)	$Vout_{NOISE}$	IP± = 0, Measure (Vout – GND). BW defined from DC to 10 kHz. (Note 1)		10		mA (rms)
VCC Supply						
Supply Voltage	VCC		4.5		5.5	V
Supply Current	IVCC	VCC=5.0 V	5.5	6.0	6.5	mA
Power Up Time	TVCC	Time from VCC > 4.5V to valid Vout (Note 1)		0.75	1.25	ms

Note 1 – Guaranteed by design and characterization. Not production tested.

Table 4 – PERFORMANCE CHARACTERISTICS (MCHA-K1A-1000-5)

Unless otherwise noted: 4.5V ≤ VCC ≤ 5.5V, -40°C ≤ T_A ≤ 125°C, I (Vout) = 0 (Recommended Operating Conditions).
Typical values are for VCC = 5.0V and T_A = 25°C.

Parameter	**Symbol**	**Test Conditions**	**Min**	**Typ**	**Max**	**Unit**
NOMINAL Vout TRANSFER FUNCTION MCHA-K1A-1000-5, Vout = 2.5V + I_{IN} x 2mV/A						
Input Range	I_{IN}	Calibrated Range	-1000		+1000	A
Sensitivity	GAIN	MCHA-K1A-1000-5		2		mV/A
DC ACCURACY						
Zero Current Offset	I_{OFFSET}	I_{IN} = 0, T_A = 0°C to 125°C (Note 2)		±4.0		A
		I_{IN} = 0, T_A = -40°C to 0°C (Note 2)		±5.2		
Sensitivity Error	E_S	I_{IN} = I_{FS}, T_A = 0°C to 125°C (Note 2)		±0.7		%
		I_{IN} = I_{FS}, T_A = -40°C to 0°C (Note 2)		±0.7		
Linearity Error	E_L	I_{IN} = I_{FS}, T_A = 0°C to 125°C (Note 2)		±1.0		%FS
		I_{IN} = I_{FS}, T_A = -40°C to 0°C (Note 2)		±0.9		
Total Error	E_{TOT}	I_{IN} = I_{FS}, T_A = 0°C to 125°C (Note 2)		±1.4		% FS
		I_{IN} = I_{FS}, T_A = -40°C to 0°C (Note 2)		±1.0		

Note 2: Typ values are 1σ.

TMR TECHNOLOGY

Aceinna's TMR sensor technology incorporates Magnetic Tunnel Junctions (MTJs) each consisting of an insulating layer of MgO sandwiched between two layers of CoFeB, a ferromagnetic alloy, with their magnetic domains aligned antiparallel with each other. Absent of an external magnetic field, the domains remain antiparallel while with an external magnetic field the domains align parallel. When an MTJ is biased, current passes through the insulating MgO layer from one CoFeB layer to the other via the quantum mechanical tunnelling. In the antiparallel state the tunneling resistance is high while in the parallel state the tunnelling resistance is low; this is the basis for sensing current using TMR. When near a current carrying wire, the magnetic field surrounding the wire modulates the tunneling resistance between the CoFeB layers of the MTJ.

TMR is more sensitive to magnetic fields compared to other Magneto Resistive (MR) and Hall effect sensors and the principle of operation, quantum mechanical tunneling, is less sensitive to temperature providing a robust and reliable method to sense current. Additionally, consisting of a simple layered CoFeB and MgO heterostructure, they can be manufactured to considerably small length scales compared to other sensing methods which gives superior temperature stability and lower thermal noise.

FUNCTIONAL DESCRIPTION

The block diagram of the MCHA-K1A-1000-5 is shown in figure 3. The conductor is inserted through the busbar pass-through hole and the sensor is fixed in position relative to the conductor using the mounting holes. The positive or negative current flowing through the conductor generates a proportional magnetic field measured by TMR sensors placed at precise positions around sensor pass-through hole. The orientation and positions of the sensors allows rejection of common-mode external magnetic interference. The TMR sensors output a voltage which is fed to a differential amplifier whose gain is temperature compensated. This is followed by an instrumentation amplifier output stage that provides a voltage that indicates the current passing through the conductor. To provide both positive and negative current data the Vout output pin is referenced to the GND output pin. With no current flowing in the conductor, the voltage on the Vout output will typically equal 2.5V (VCC/2). Positive conductor current causes the voltage on Vout to increase relative to GND while negative conductor current will cause it to decrease.

POWER UP / DOWN

An under-voltage lockout circuit monitors the voltage on the VCC pin. If the VCC voltage is less than the under-voltage threshold the MCHA-K1A-1000-5 is in an inactive state. Vout drives to ground. If the VCC voltage exceeds the under-voltage threshold Vout is released and will drive to approximately half the VCC supply voltage and an initial calibration will commence. Once the initial calibration has completed the MCHA-K1A-1000-5 becomes active. Vout will slew to indicate the value of current flowing in the conductor. Current flow in the conductor with a VCC voltage less than the under-voltage threshold will not cause damage to the sensor.

RESPONSE TIME

Vout response time is the time interval from 80% of the IP to 80% of the Vout. The response time is 300ns typical.

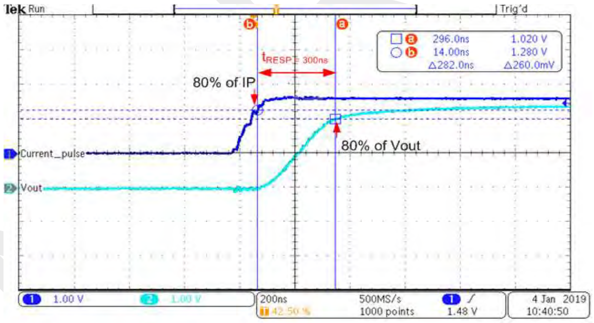


Figure 4 - Vout response time

FREQUENCY RESPONSE

The MCHA-K1A-1000-5 offers a low noise and wideband response, with a 3dB bandwidth of > 1.5MHz, as shown in the plots below.

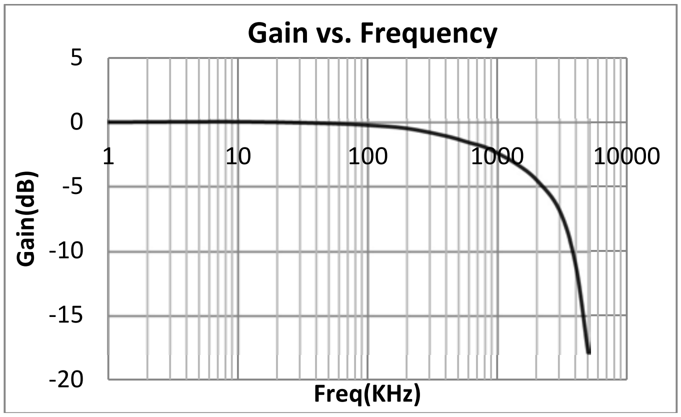


Figure 5 - Gain vs. Frequency

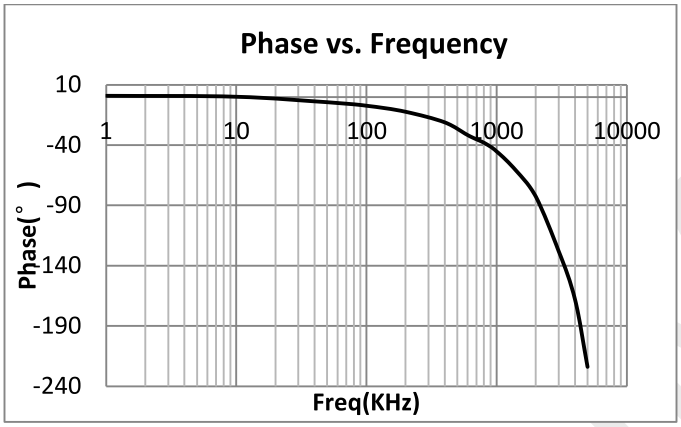


Figure 6 - Phase vs. Frequency

APPLICATIONS INFORMATION

The MCHA-K1A-1000-5 detects current by measuring the magnetic field generated by the conductor current therefore it's important to consider the effect of externally generated magnetic fields, whether from a nearby current-carrying conductor, a magnet, or electro-magnetic component.

To provide immunity to external magnetic fields, MCHA-K1A-1000-5 senses a differential magnetic field generated by the primary current, which flows through the conductor inserted through the sensor module's pass-through hole. Therefore, to first order, the sensor will reject any common mode field originating from outside of its package.

However, it's still prudent to minimize the exposure to external fields. The MCHA-K1A-1000-5 is most sensitive to magnetic fields in the X-Y plane (i.e. the plane of the pass-through hole), and is relatively insensitive to fields in the Z direction (direction pointing through the pass-through hole). When installing, care should be taken to avoid placement of the sensor too close to an adjacent conductor aligned in a similar direction. To guarantee minimal interference, the following minimum distance thresholds are suggested:

- To guarantee < 1% interference, D > 27.5mm
- To guarantee < 0.5% interference, D > 36.5mm
- To guarantee < 0.1% interference, D > 75mm

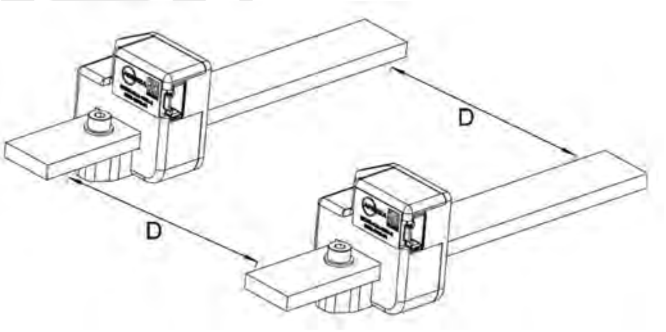


Figure 7 – Minimum distance between adjacent conductors

DC ACCURACY DESCRIPTIONS

- **ZERO CURRENT OFFSET**

Zero current offset is defined as:

$$I_{OFFSET} = \frac{V_{out}[I=0] - {}^{V_{CC}}/_{2}}{GAIN}$$

where $V_{out}[I=0]$ is the sensor output voltage with zero current passed through the module pass-through hole, V_{CC} is the supply voltage and $GAIN$ is the sensitivity found in table 4.

- **SENSITIVITY ERROR**

The sensitivity error is defined as:

$$E_S = \left(\frac{GAIN_{meas}}{GAIN} - 1\right) * 100\%$$

where $GAIN$ is the ideal sensor sensitivity found in table 4 and $GAIN_{meas}$ is the measured sensitivity found by fitting the sensor response to the linear function:

$$V_{out}[I] = V_{OFFSET} + GAIN_{fit} * I$$

where $GAIN_{fit}$is the fit sensitivity

$$GAIN_{meas} = GAIN_{fit} * 5V/V_{CC}$$

and $GAIN_{meas}$ is found by scaling the fit sensitivity by $5V/V_{CC}$ which accounts for variations in the supply voltage V_{CC}.

- **TOTAL ERROR**

The total error is defined as:

$$E_{TOT} = \left(\frac{V_{out}[I_{FS}] - V_{out,ideal}[I_{FS}]}{V_{out,ideal}[I_{FS}]}\right) * 100\%$$

where $V_{out,ideal}[I] = GAIN * I$ and $V_{out}[I]$ is the sensor output for input current I. E_{TOT} is evaluated at the full scale positive and negative current $\mp I_{FS}$ and the largest value of E_{TOT} is used (Figure 8)

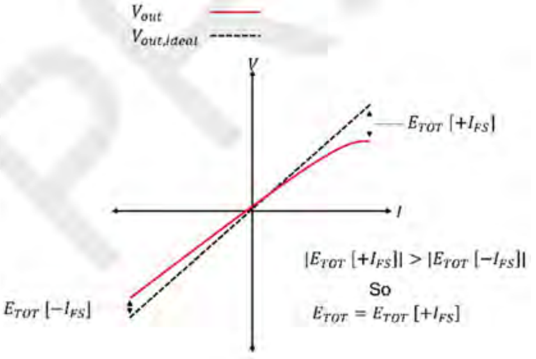


Figure 8 - Total error example

- **LINEARITY ERROR**

Linearity error is derived from the other sources of error. The sensor output with can be described as:

$$V_{out}[I_{FS}] = V_{OFFSET} + GAIN_{meas} * I_{FS} + \sum_{k>1} c_k {I_{FS}}^k$$

where $V_{OFFSET} = GAIN * I_{OFFSET}$ the second term is the linear response, and the last term represents the nonlinear response of the sensor. Using the definition of E_{TOT}:

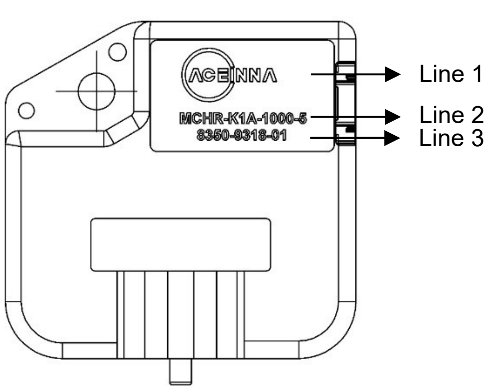
$$\begin{aligned} E_{TOT} &= \left(\frac{V_{OFFSET}}{GAIN * I_{FS}} + \frac{(GAIN_{meas} - GAIN)}{GAIN} + \frac{\sum_{k>1} c_k {I_{FS}}^k}{GAIN I_{FS}}\right) * 100\% \\ &= E_{OFFSET} + E_S + E_L \end{aligned}$$

Here E_{offset} is the offset error and E_S is the sensitivity error and E_L is the linearity error. The Linearity error is thusly derived as

$$E_L = E_{TOT} - E_{OFFSET} - E_S$$

DEVICE MARKING

Production information is printed on the package surface by laser marking. Markings consist of 3 lines of characters including ACEINNA logo.



Line 1: ACEINNA Logo
Line2: Part Marking
Line3: Date Code

PART MARKING (Line 2)

MCH A K1 A 1000 5

Supply voltage, VCC: 4.5 – 5.5V

Nominal current rating: 1000 – 1000A

Sensor application: A - Automotive

Sensor packaging: K1 - Type 1

Output gain version: A - Fixed gain

Product family: MCH - Magnetic current high-range sensor

DATE CODE (Line 3)

XXXX YYYY ZZ

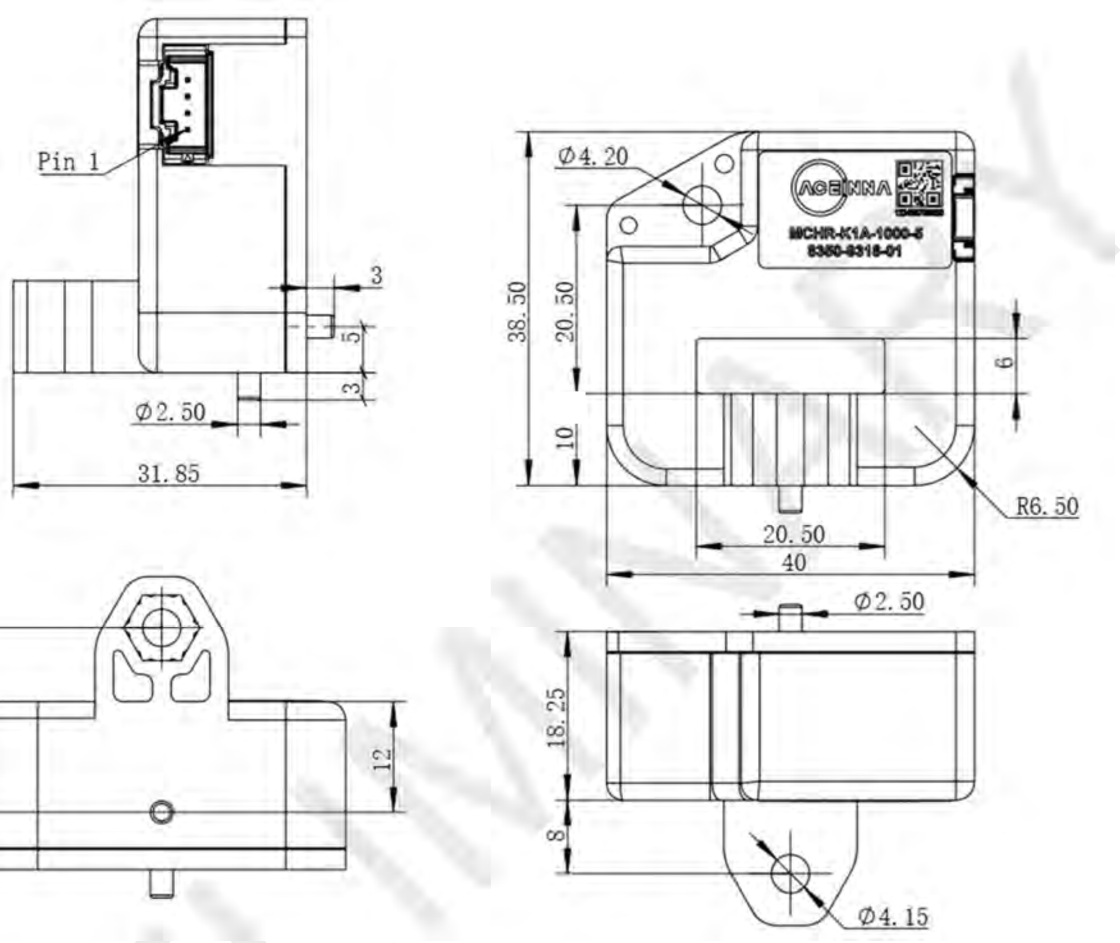
Version

Internal code

Internal code

PACKAGE OUTLINE INFORMATION – Busbar Module

PACKAGE OUTLINE DRAWING



Notes:
Units are in mm.
Angular Tolerances = ± 1.0°
Linear Tolerances = ±0.25mm