MLX91209

Datasheet

Hall Current Sensor IC in VA package

1. Features and Benefits

- Programmable high speed current sensor
- Programmable linear transfer characteristic
- Selectable analog ratiometric output
- Measurement range from 15 to 450mT
- Single die VA package RoHS compliant
- Wideband: DC to 250kHz
- Short response time 2µsec
- Lead free component, suitable for lead free soldering profile 260°C (target), MSL1
- AEC-Q100 Automotive Qualified

2. Application Examples

- Inverter applications in HEV and EV
- BLDC motor current monitoring
- AC/DC converters
- Over current detection circuit

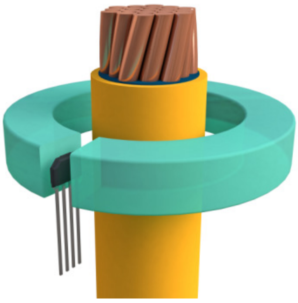


Figure 1: Typical Current Sensing Application

3. General Description

The MLX91209 is a monolithic programmable Hall sensor IC featuring the planar Hall technology, which is sensitive to the flux density applied orthogonally to the IC surface. The sensor provides an output signal proportional to the applied magnetic flux density and is preferably suited for current measurement. The transfer characteristic of the MLX91209 is programmable (offset, gain). The linear analog output is designed for applications where a very fast response is required, such as inverter applications.

In a typical application, the sensor is used in combination with a ring shaped soft ferromagnetic core. The Hall IC is placed in a small air gap and the current conductor is passed through the inner part of the ferromagnetic ring. The ring concentrates and amplifies the magnetic flux on the Hall sensor IC, which generates an output voltage proportional to the current flowing in the conductor.

4. Ordering Information

Product	Temperature	Package	Option Code	Packing Form	Default Sensitivity
MLX91209	L (-40°C to 150°C)	VA	CAA - 000	BU/CR	50 mV/mT (prog: 5..150mV/mT)
MLX91209	L (-40°C to 150°C)	VA	CAA - 001	BU/CR	15 mV/mT (prog: 5..150mV/mT)
MLX91209	L (-40°C to 150°C)	VA	CAA - 002	BU/CR	7.3 mV/mT (prog: 5..150mV/mT)
MLX91209	L (-40°C to 150°C)	VA	CAA - 003	BU/CR	19 mV/mT (prog: 5..150mV/mT)
MLX91209	L (-40°C to 150°C)	VA	CAA - 005	BU/CR	8.78mV/mT (prog: 5..150mV/mT)
MLX91209	L (-40°C to 150°C)	VA	CAA - 006	BU/CR	6.9 mV/mT (prog: 5..150mV/mT)

Table 1: Ordering Information

Legend:

Temperature Code:	**L**	from -40°C to 150°C ambient temperature
Package Code:	**VA**	SIP4-VA package, refer to Chapter 19 for detailed drawings
Option Code:	**CAx-000** **CAx-001** **CAx-002** **CAx-003** **CAx-005** **CAx-006**	for factory trimmed sensitivity 50mV/mT (prog: 5..150mV/mT) for factory trimmed sensitivity 15mV/mT (prog: 5..150mV/mT) for factory trimmed sensitivity 7.3mV/mT (prog: 5..150mV/mT) for factory trimmed sensitivity 19mV/mT (prog: 5..150mV/mT) for factory trimmed sensitivity 8.78mV/mT (prog: 5..150mV/mT) for factory trimmed sensitivity 6.9mV/mT (prog: 5..150mV/mT)
	CAA-xxx **CAR-xxx** **CAZ-xxx**	default straight leads (see chapter 19) Trim and Form shape: 90° 2x2x91.3 (h=5.34mm) Bending-STD2 (see chapter 19) Trim and Form shape: SMD style TFT4K1 (see chapter 19)
Packing Form:	**BU** **CR** **CA** **RE**	for Bulk, for Carton Reel - Radial taping – available for straight leads only for Carton Reel – Ammopack – available for straight leads only for Plastic Reel – available for selected Trim & Form options only
Ordering Example:	**"MLX91209LVA-CAA-003-RE"** MLX91209 Conventional Hall current sensor in SIP4 VA package, temperature range -40°C to 150°C. Sensitivity 19mV/mT. Parts delivered in Carton Reel (Radial Taping)	

Table 2: Legend for Ordering Information

5. Functional Diagram

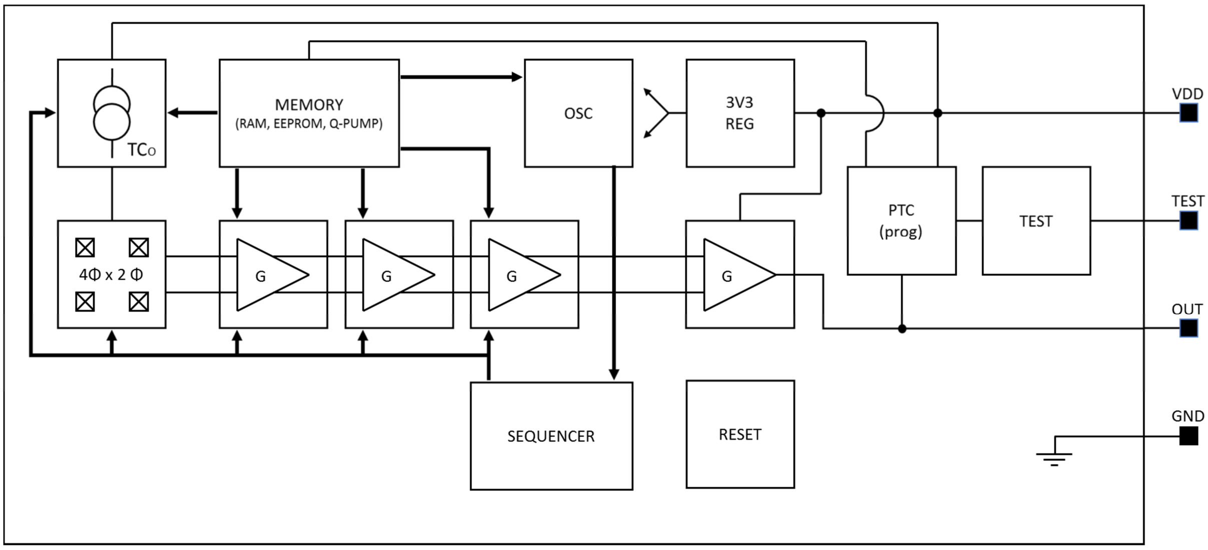


Figure 2: Block Diagram

Contents

6. Glossary of Terms

Terms	Definition
Tesla	Units for the magnetic flux density, 1 mT = 10 Gauss
TC	Temperature Coefficient in ppm/deg C
NC	Not Connected
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
LSB	Least Significant Bit
MSB	Most Significant Bit
DNL	Differential Non Linearity
INL	Integral Non Linearity
IMC	Integrated Magneto Concentrator (IMC-Hall®)
PTC	Programming Through Connector

Table 3: Glossary of Terms

7. Absolute Maximum Ratings

Parameter	Symbol	Value	Units
Positive Supply Voltage (overvoltage)	Vdd	+10	V
Reverse Supply Voltage Protection		-0.3	V
Positive Output Voltage$^{(1)}$		+10	V
Output Current	Iout	±70	mA
Reverse Output Voltage		-0.3	V
Reverse Output Current		-50	mA
Package Thermal Resistance *(junction-to-ambient)* θ_{ja} *is defined according JEDEC 1s0p board*	θ_{ja}	205	°C/W
Operating Ambient Temperature Range	T_A	-40 to +150	°C
Storage Temperature Range	T_S	-55 to +165	°C
Magnetic Flux Density		±3	T
Maximum Junction Temperature		-55 to 155	°C
ESD – Human Body Model *(applicable for all pins)*		2	kV

Table 4: Absolute maximum ratings

Exceeding the absolute maximum ratings may cause permanent damage. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

(1) Valid for supply=10V or supply-pin floating.

8. Pin Definitions and Descriptions

Pin №	Name	Type	Function
1	VDD	Supply	Supply Voltage
2	OUT	Analog	Current Sensor Output
3	TEST/MUST	Digital	Test and Factory Calibration
4	GND	Ground	Supply Voltage

Table 5: Pin definitions and descriptions

It is recommended to connect the TEST/MUST pin to the Ground for optimal EMC performance.

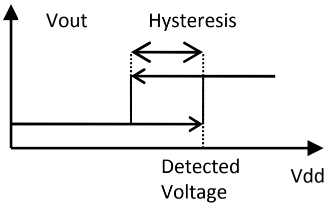
9. General Electrical Specifications

Operating Parameters: T_A = -40°C to 125°C, Vdd = 4.5V to 5.5V, Iout = -2mA to 2mA, recommended application diagram, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Nominal Supply Voltage	Vdd		4.5	5	5.5	V
Supply Current	Idd	No output load, application mode, T_A = -40°C to 150°C	9	12	14	mA
DC Load Current	I_{out}	R_{load} in range [6kΩ, 100kΩ]	-2		2	mA
Maximum Output Current (driving capability)	I_{max}	Inside this range, output voltage reaches 3 and 97%Vdd	-2		2	mA
Output Resistance		Vout = 50% Vdd, R_L = 6kΩ		1	5	Ω
Output Capacitive Load	C_{load}	Output amplifier is optimized for the capacitive load range.	1		10	nF
Output Resistive Load (pull-down resistor)	R_{load}	Output resistive load for high linearity	6			kΩ
Output Short Circuit Current (Permanent)	I_{short}	Output shorted permanent to Vdd Output shorted permanent to GND	Not destroyed Not destroyed			
Output Leakage current	I_{leak}	High impedance mode (1) T_A = 150°C			20	µA
Linear Output Voltage Range *Vout in [10%Vdd, 90%Vdd]*	V_{out_pd}	pull-down ≥ 10 kΩ	10		90	%Vdd
High-impedance mode levels (1)	$V_{out\_HiZ\_pd}$	pull-down R_L ≤ 25 kΩ, T≤125°C			5	%Vdd
Under-voltage detection (2)	V_{dd_uvd}	Low to High Voltage	3.0	3.3	4.0	V
	V_{dd_uvh}	Hysteresis	0.2	0.3	0.45	V
Ratiometry enable detection	V_{ratio_d}	Low to High Voltage	4		4.5	V
	V_{ratio_h}	Hysteresis	0.01		0.5	V
Over-voltage detection (2)	V_{dd_ovd}	Low to High Voltage	6.5		7.6	V
	V_{dd_ovh}	Hysteresis	0.05		0.7	V

Table 6: General electrical parameters

(1) Refer to section *Self-diagnostic*, Table 11.
(2) According to the following diagram:



10. Magnetic specification

Operating Parameters T_A = -40°C to 125°C, Vdd = 4.5V to 5.5V, unless otherwise specified.

Parameter	Symbol	Test Conditions / Comments	Min	Typ	Max	Units
Magnetic field range	B		±15		±450	mT
Linearity Error	NL	Vdd in range [4.5V, 5.5V] Vout in [10%Vdd, 90%Vdd]	-0.4		+0.4	%FS
Programmable Sensitivity	S		5		150	mV/mT
Sensitivity programming Resolution	Sres			0.1		%

Table 7: Magnetic specification

10.1. Sensor active measurement direction

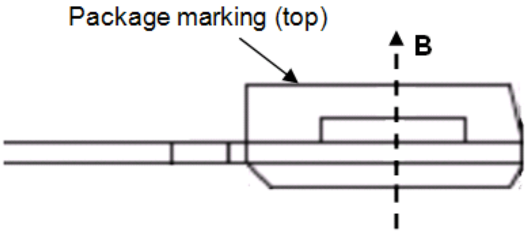


Figure 3: Magnetic Field Direction

11. Analog output specification

11.1. Timing specification

Operating Parameters T_A = -40°C to 125°C, Vdd = 4.5V to 5.5V (unless otherwise specified).

Parameter	Symbol	Test Conditions / Comments	Min	Typ	Max	Units
Refresh rate	Trr		0.8	1	2	µs
Step Response Time	Tresp	Delay between the input signal reaching 90% and the output signal reaching 90%, (2V step at the output, input rise time = 1µs) -Noise filter OFF -Noise filter ON		 2 5	 3 6	 µs µs
Bandwidth	BW	-Noise filter OFF -Noise filter ON		250 70		kHz kHz
Power on Delay	T_{POD}	Vout =100% of FS Pull-down resistor ≤100kOhm During the Power-on delay, output will remain within the 10% fault band at all time.			1	ms
Ratiometry Cut-off Frequency	Fratio			250		Hz

Table 8: Timing specification for high speed analog output

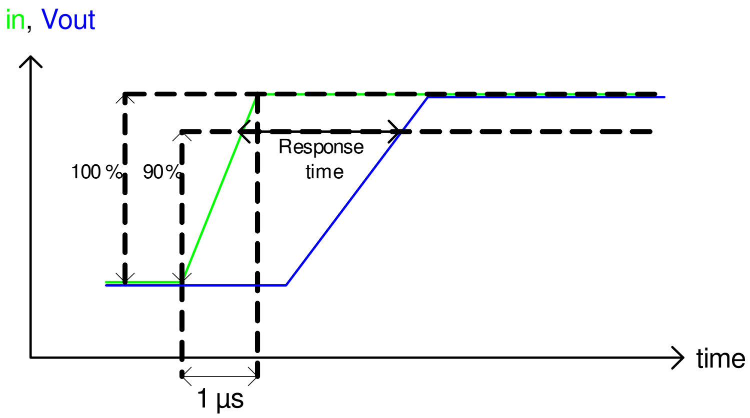


Figure 4: Response time definition

11.2. Accuracy specification

Operating Parameters T_A = -40°C to 125°C, Vdd = 4.5V to 5.5V (unless otherwise specified).

Parameter	Symbol	Test Conditions	Min	Typ.	Max	Units
Thermal Offset Drift (1)	Δ^{T}Voq	In ref. to T = 35°C Vdd = 5V Voq = 50 ±0.2 %Vdd	-10		10	mV
Thermal Sensitivity Drift	TC	In ref. to T= 35°C Vdd = 5V	-1.5	0	+1.5	% of S
RMS Output noise(2)	N_{rms}	S = 50mV/mT				
		-Noise filter OFF			10	mVrms
		-Noise filter ON			6	mVrms
		S = 7.3mV/mT				
		-Noise filter OFF		2.8		mVrms
		-Noise filter ON		1.9		mVrms
Ratiometry Error Offset	ΔVoq	Voq = 50%Vdd ΔVdd = 10%Vdd	-0.4		+0.4	% of Voq
Ratiometry Error Sensitivity	ΔS	ΔVdd = 10%Vdd	-0.4		+0.4	% of S

Table 9: Accuracy specification for high speed analog output

(1) Thermal offset drift specification is only valid when ENRATIO and PLATEPOL parameters are kept in their default configuration.
(2) The RMS Ouput Noise depends on the factory sensitivity [mV/mT].

11.3. Remarks to the achievable accuracy

The achievable target accuracy depends on end-of-line calibration in the application. Resolution for offset calibration is better than 0.1%Vdd. Trimming capability is higher than measurement accuracy. End-of-line calibration can increase overall system accuracy.

12. Programmable items

12.1. Parameter table

Parameter	Bits	Factory Setting	Comment
VOQ[11:0]	12	trimmed	Quiescent output level (0 Gauss) adjustment
RG[2:0]	3	trimmed	Rough gain adjustment
FG[9:0]	10	trimmed	Fine gain adjustment
ENRATIO	1	1	Ratiometry enablement
TC1[7:0]	8	trimmed	Adjustment of the first order temperature compensation of the magnetic sensitivity
TC2HOT[4:0]	5	trimmed	Adjustment of the extra temperature compensation of the magnetic sensitivity at high temperature
TC2COLD[4:0]	5	trimmed	Adjustment of the extra temperature compensation of the magnetic sensitivity at low temperature
OFFDR2C[5:0]	6	trimmed	Adjustment of the offset drift at low temperature after the VGA
OFFDR2H[5:0]	6	trimmed	Adjustment of the offset drift at high temperature after the VGA
NOISEFILT[1]	1	0 1	0 : Noise filter deactivated 1 : Noise filter enabled
ID[47:0]	48	Programmed	Melexis traceability ID

Table 10: Customer programmable items

12.2. Sensitivity programming (RG, FG)

The sensitivity can be programmed from 5 to 150 mV/mT, with the ROUGHGAIN (3 bits) and FINEGAIN (10 bits) parameters.

12.3. Offset / output quiescent voltage programming (VOQ)

The offset is programmable with 12 bits in 1.5 mV steps over the full output range. This corresponds to a calibration resolution of 0.03 %VDD. (The typical step would be 5V/4096 = 1.22 mV, the actual step size can differ from the nominal value because of internal gain tolerance. The maximum step size of 1.5 mV is guaranteed).

Note: for optimal performance over temperature, VOQ should be programmed in the range 2 to 3V.

12.4. Output ratiometry (ENRATIO)

The ratiometry of the output versus the supply can be disabled by setting this bit to 0.

Note: for optimal performance over temperature, ratiometry should always be enabled (ENRATIO=1).

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[1] Noise Filter enabled by default (NOISEFILT = 1) in MLX91209LVA-CAA-003. All other option codes use NOISEFILT = 0 in their default configuration

12.5. Sensitivity temperature drift programming (TC1, TC2COLD, TC2HOT)

First order sensitivity temperature drift can be trimmed from -2000 to 2000ppm/K with TC1. The programming resolution is 40ppm/K.

Second order sensitivity temperature drift can be trimmed from TC2COLD and TC2HOT. The programming resolution is 2ppm/K^2 for TC2COLD and 0.6ppm/K^2 for TC2HOT.The second order can also be seen as third order correction since cold and hot sides are independently adjusted.

Note: for optimal performance over temperature, the first order sensitivity drift compensation (TC1ST) should not exceed ±500ppm/K.

12.6. Offset temperature drift programming (OFFDR2C, OFFDR2H)

Offset temperature drift caused by the output amplifier can be compensated with these two parameters. This first order correction is done independently for temperatures over and below 25°C.

Note: two additional parameters (OFFDR1C, OFFDR1H) are calibrated by Melexis to compensate for the offset temperature drift caused by the Hall element (before the variable gain amplifier). These parameters should not be adjusted on customer-side.

12.7. Noise filter (NOISEFILT)

Setting this bit to 1 enables the noise filter, reducing noise and increasing response time.

12.8. Identification code (ID)

48 bits programmable identification code.

13. Self-diagnostic

The MLX91209 provides self-diagnostic features to detect internal memory errors and over- / under-voltage conditions. These features increase the robustness of the IC functionality, as they prevent erroneous output signal in case of internal or external failure modes.

Error	Action	Effect on Outputs	Remarks
Calibration Data CRC Error (at power up and in normal working mode)	Fault mode	High Impedance mode	Pull down resistive load => Diag Low
Power On delay		High Impedance mode	5ms max in high impedance followed by settling
Undervoltage Mode	IC is reset	High Impedance mode	300mV Hysteresis (typical)
Overvoltage detection	IC is reset	High Impedance mode	500mV Hysteresis (typical)

Table 11: Self diagnostic

14. Recommended Application Diagrams

14.1. Resistor and capacitor values

Part	Description	Value	Unit
C1	Supply capacitor, EMI, ESD	100	nF
C2	Decoupling, EMI, ESD	1-10(1)	nF
R1	Pull-down resistor	6-100	kΩ

Table 12: Recommended Resistors and Capacitors Values

(1) 10nF is recommended for better EMC and ESD performance.

14.2. Pull down resistor for diagnostic low

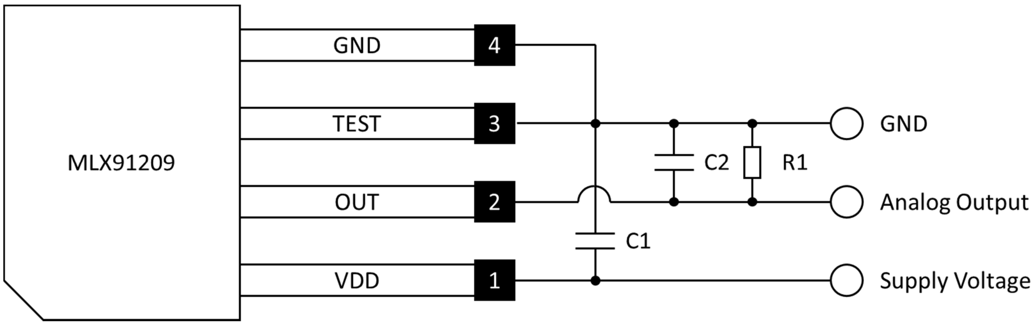


Figure 5: Diagnostic low

15. Typical performance

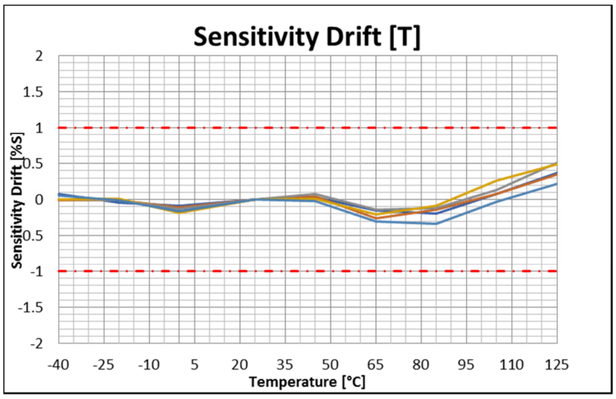


Figure 6: Thermal sensitivity drift.

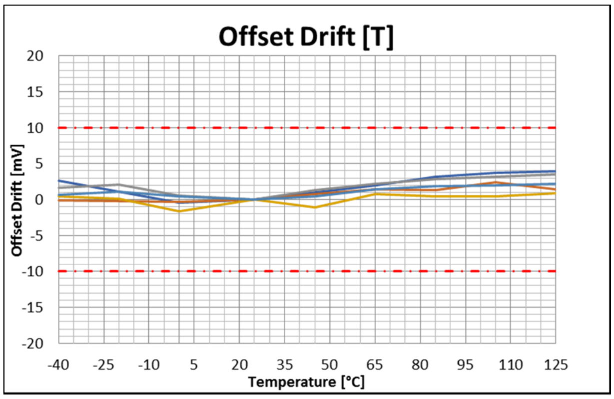


Figure 7: Thermal offset drift

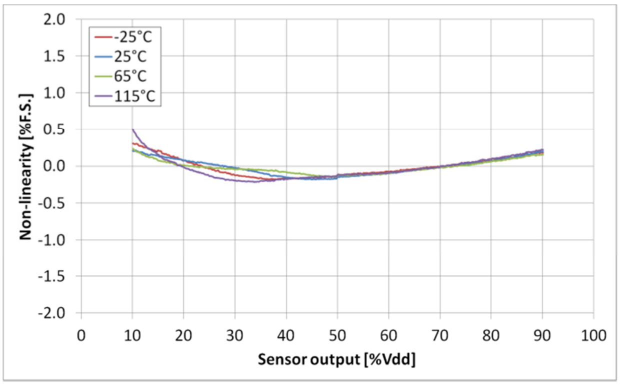


Figure 8: Non-linearity over temperature

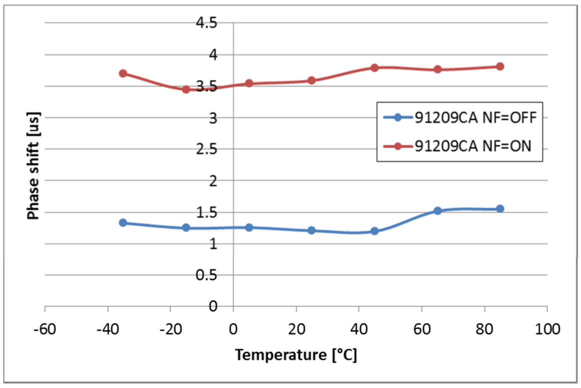


Figure 9: Phase shift over temperature.

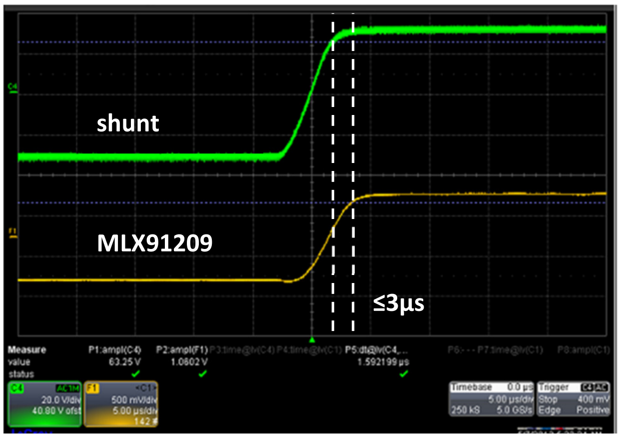


Figure 10: Response time with noise filter OFF.

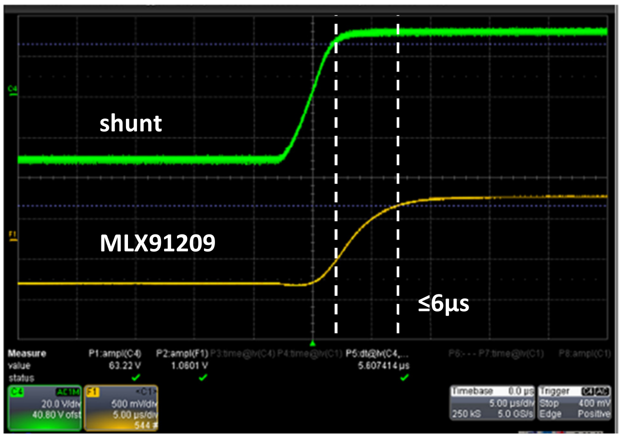


Figure 11: Response time with noise filter ON.

16. Standard information regarding manufacturability of Melexis products with different soldering processes

Our products are classified and qualified regarding soldering technology, solderability and moisture sensitivity level according to following test methods:

Reflow Soldering SMD's (Surface Mount Devices)

- IPC/JEDEC J-STD-020
  Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
  (classification reflow profiles according to table 5-2)
- EIA/JEDEC JESD22-A113
  Preconditioning of Nonhermetic Surface Mount Devices Prior to Reliability Testing
  (reflow profiles according to table 2)

Wave Soldering SMD's (Surface Mount Devices) and THD's (Through Hole Devices)

- EN60749-20
  Resistance of plastic- encapsulated SMD's to combined effect of moisture and soldering heat
- EIA/JEDEC JESD22-B106 and EN60749-15
  Resistance to soldering temperature for through-hole mounted devices

Iron Soldering THD's (Through Hole Devices)

- EN60749-15
  Resistance to soldering temperature for through-hole mounted devices

Solderability SMD's (Surface Mount Devices) and THD's (Through Hole Devices)

- EIA/JEDEC JESD22-B102 and EN60749-21
  Solderability

For all soldering technologies deviating from above mentioned standard conditions (regarding peak temperature, temperature gradient, temperature profile, etc.) additional classification and qualification tests have to be agreed upon with Melexis.

The application of Wave Soldering for SMD's is allowed only after consulting Melexis regarding assurance of adhesive strength between device and board.

Melexis recommends reviewing on our web site the General Guidelines **soldering recommendation** (https://www.melexis.com/en/tech-info/ic-handling-and-assembly/soldering) as well as **trim&form recommendations** (https://www.melexis.com/en/tech-info/ic-handling-and-assembly/lead-forming).

Melexis is contributing to global environmental conservation by promoting **lead free** solutions. For more information on qualifications of **RoHS** compliant products (RoHS = European directive on the Restriction Of the use of certain Hazardous Substances) please visit the quality page on our website: http://www.melexis.com/quality.aspx

17. ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).
Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

18. FAQ

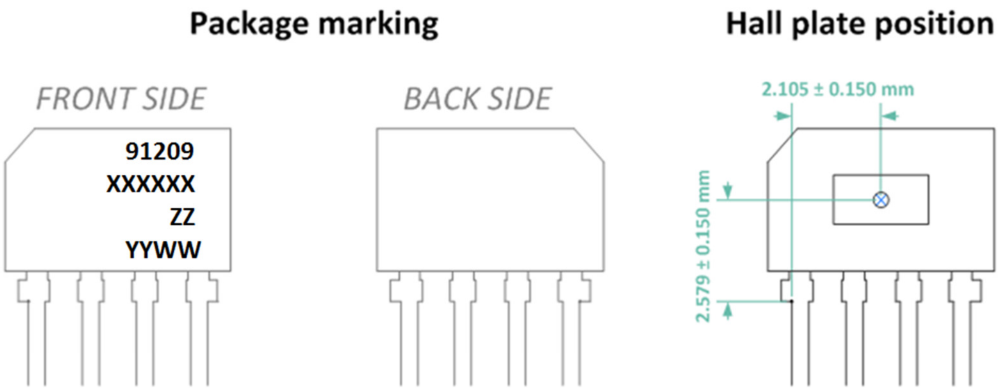
For which current range can the sensor be used?
The magnetic field [mT] seen by the sensor for a given current [A] depends on the design of the enclosing ferromagnetic core (air gap size, material type, etc.). Therefore, the current range is not limited by the sensor itself, but rather by the magnetic properties of the core (saturation, hysteresis, etc.).

What is the default sensitivity of the sensor?
The sensor is factory calibrated for a typical sensitivity of 50mV/mT.

How can I program the sensor?
The sensor uses a 3 wires communication protocol (Vdd, GND and Out) and can be programmed using Melexis Universal Programmer (PTC-04), with the dedicated daughter board PTC04-DB-HALL05. For more information, please visit http://www.melexis.com/Hardware-and-Software-Tools/Programming-Tools/PTC-04-568.aspx.

19. Package Information

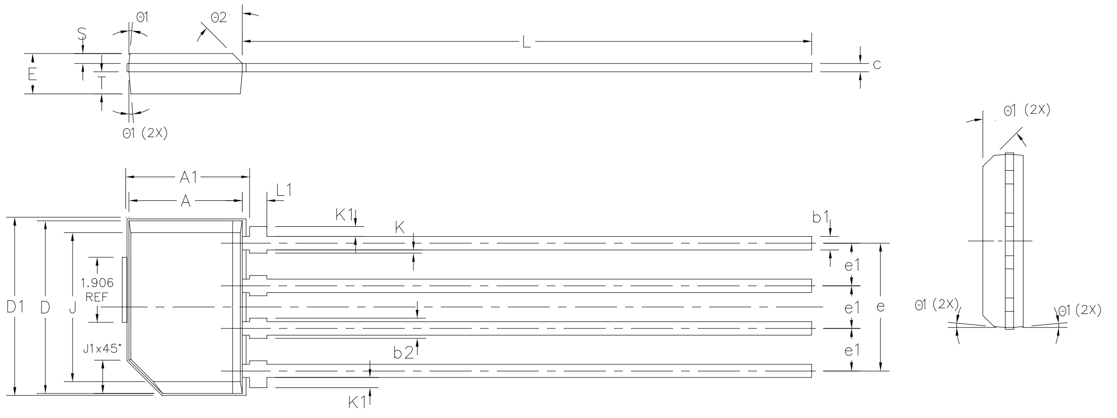
19.1. Package Marking & Hall Plate Position



Line 1: Product ID
Line 2: Wafer Lot number
Line 3: IC revision
Line 4: Assembly Date Code (year=yy; week=ww)

Figure 12: VA/SIP 4L Package Marking and Hall Plate Position

19.2. VA / SIP 4L (single in-line package)

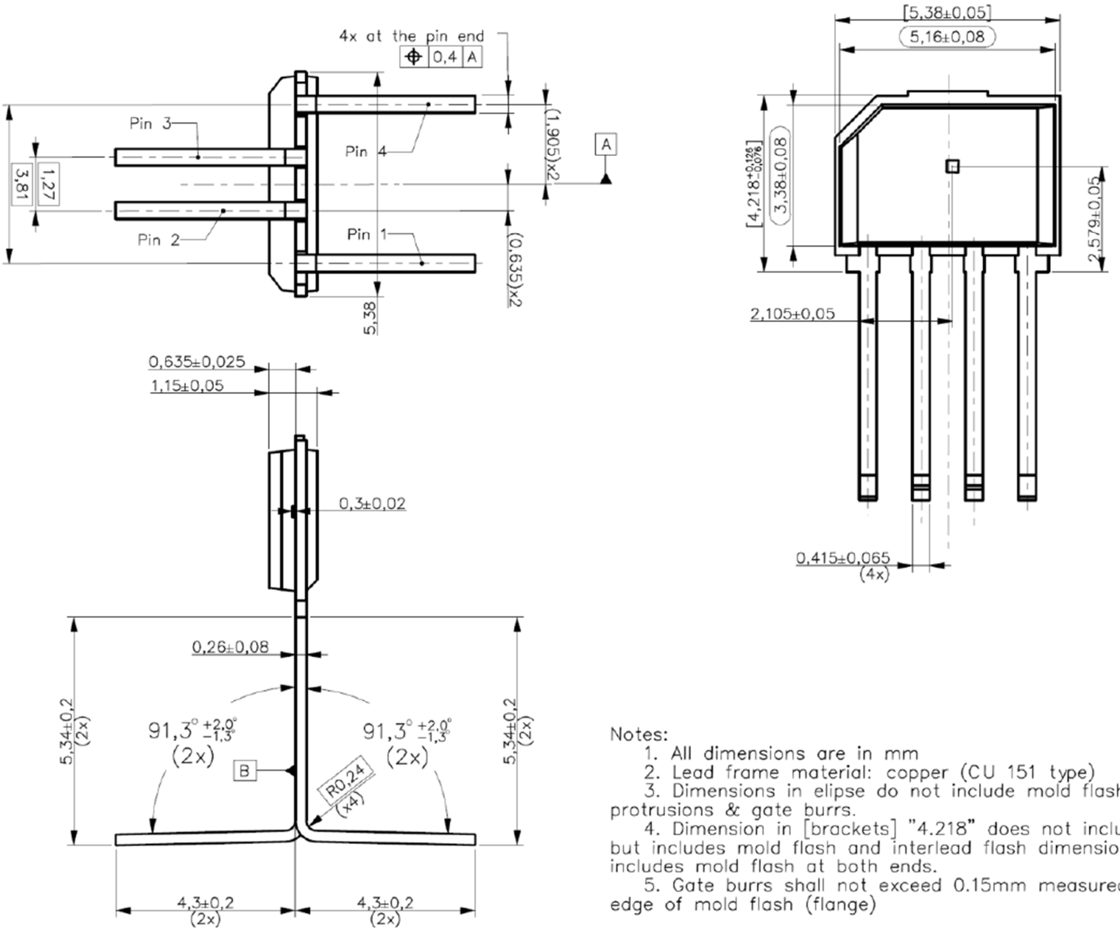


SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	3.30	3.38	3.46
A1	3.63	3.71	3.79
D	5.08	5.16	5.24
D1	5.33	5.38	5.43
E	1.10	---	1.20
J	4.10	4.30	4.50
J1	1.00 REF		
K	0.00	---	0.15
K1	0.25	0.30	0.35
L	17.5	18.0	18.5
L1	0.48	0.53	0.58
S	0.24	---	0.29
T	0.61	---	0.66
b1	0.35	---	0.48
b2	0.40	---	0.60
c	0.18	---	0.34
e	3.76	---	3.86
e1	1.22	1.27	1.32
Θ1	5° REF		
Θ2	45° REF		

Note:

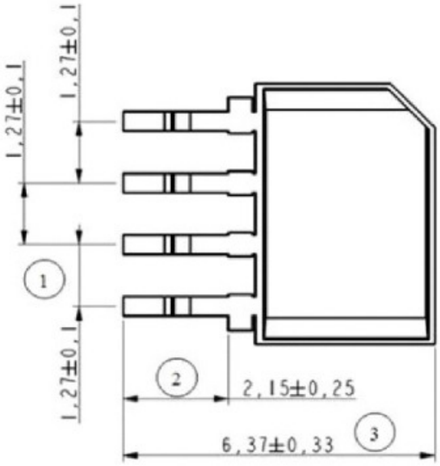
1. DIMENSIONS "A" AND "D" DO NOT INCLUDE MOLD FLASH, PROTRUSIONS AND GATE BURRS.
2. DIMENSIONS "A1" DOES NOT INCLUDE GATE BURRS BUT INCLUDES MOLD FLASH AT BOTH ENDS.
3. MOLD GATE BURRS SHALL NOT EXCEED 0.15 mm MEASURED FROM EDGE OF MOLD FLASH (FLANGE).
4. DIMENSION "D1" INCLUDES MOLD FLASH AT BOTH ENDS.
5. LEAD PLATING; MATTE TIN PLATING THICKNESS 7.62 - 15.42 um.

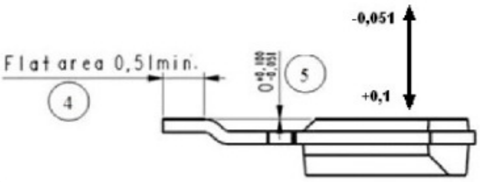
19.3. Trim and form type: 90° 2x2x91.3 (h=5.34mm); Bending-STD2 (CAR-xxx)



Notes:
1. All dimensions are in mm
2. Lead frame material: copper (CU 151 type)
3. Dimensions in elipse do not include mold flash protrusions & gate burrs.
4. Dimension in [brackets] "4.218" does not include gate burrs, but includes mold flash and interlead flash dimension "5.38" includes mold flash at both ends.
5. Gate burrs shall not exceed 0.15mm measured from edge of mold flash (flange)

19.4. Trim and form type: SMD style TFT4K1 (CAZ-xxx)





Parameter				
Dim# 1 [mm]	Dim# 2 [mm]	Dim# 3 [mm]	Dim# 4 [mm]	Dim# 5 [mm]
1.27 +/- 0.10	2.15 +/- 0.25	6.37 +/- 0.33	min. 0.51	0 -0.051/+0.10

20. Contact

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