

## 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 200kHz
- Short response time
- 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

### 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<br>mV/mT |
|----------|--------------------|---------|-------------|--------------|------------------------------|
| MLX91209 | L (-40°C to 150°C) | VA      | CAA - 000   | RE           | 50                           |
| MLX91209 | L (-40°C to 150°C) | VA      | CAA - 001   | RE           | 15                           |
| MLX91209 | L (-40°C to 150°C) | VA      | CAA - 002   | RE           | 7.3                          |
| MLX91209 | L (-40°C to 150°C) | VA      | CAA - 003   | RE           | 19                           |

Table 1: Ordering Information

#### Legend:

|                   |                                          |
|-------------------|------------------------------------------|
| Temperature Code: | L: from -40°C to 150°C                   |
| Package Code:     | “VA” for SIP 4L (single in-line package) |
| Option Code:      | CAA: Sensitivity Range 5-150mV/mT        |
| Packing Form:     | “RE” for Reel                            |
| Ordering Example: | MLX91209LVA-CAA-000-RE                   |

Table 2: Legend for Ordering Information

## 5. Functional Diagram

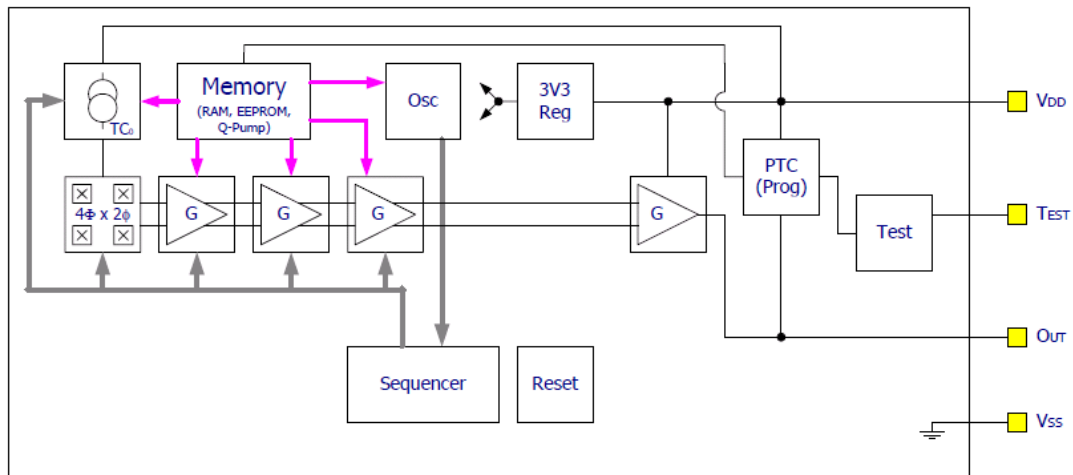


Figure 1: Block Diagram

## 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®)               |
| PTC   | Programming Through Connector                        |

Table 3: Glossary of Terms

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## 7. Absolute Maximum Ratings

| Parameter                              | Symbol           | Value       | Units |
|----------------------------------------|------------------|-------------|-------|
| Positive Supply Voltage (overvoltage)  | V <sub>dd</sub>  | +10         | V     |
| Reverse Supply Voltage Protection      |                  | -0.3        | V     |
| Positive Output Voltage <sup>(1)</sup> |                  | +10         | V     |
| Output Current                         | I <sub>out</sub> | ±70         | mA    |
| Reverse Output Voltage                 |                  | -0.3        | V     |
| Reverse Output Current                 |                  | -50         | mA    |
| Package Thermal Resistance             | R <sub>th</sub>  | 105         | °C/W  |
| Operating Ambient Temperature Range    | T <sub>A</sub>   | -40 to +150 | °C    |
| Storage Temperature Range              | T <sub>S</sub>   | -55 to +165 | °C    |
| Magnetic Flux Density                  |                  | infinite    | T     |

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     | VSS       | Ground  | Supply Voltage               |

Table 5: Pin definitions and descriptions

It is recommended to connect the unused pins to the Ground for optimal EMC results.

## 9. General Electrical Specifications

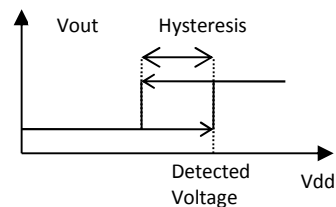
Operating Parameters:  $T_A = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_{dd} = 4.5\text{V}$  to  $5.5\text{V}$ ,  $I_{out} = -2\text{mA}$  to  $2\text{mA}$ , recommended application diagram, unless otherwise specified. Mentioned component values can have a  $\pm 20\%$  tolerance.

| Parameter                                   | Symbol             | Test Conditions                                                                        | Min  | Typ | Max  | Units         |
|---------------------------------------------|--------------------|----------------------------------------------------------------------------------------|------|-----|------|---------------|
| Nominal Supply Voltage                      | $V_{dd}$           |                                                                                        | 4.5  | 5   | 5.5  | V             |
| Supply Current                              | $I_{dd}$           | No output load, application mode, $T_A = -40^{\circ}\text{C}$ to $150^{\circ}\text{C}$ | 7    | 12  | 14   | mA            |
| DC Load Current                             | $I_{out}$          | $R_{load}$ in range [6k $\Omega$ , 100k $\Omega$ ]                                     | -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                           |                    | $V_{out} = 50\% V_{dd}$ , $R_L = 10\text{k}\Omega$                                     |      | 1   | 5    | $\Omega$      |
| Output Capacitive Load                      | $C_{load}$         | Capacitive load for the stability of the output amplifier                              |      |     | 10   | nF            |
| Output Resistive Load (pull-down resistor)  | $R_{load}$         | Output resistive load for high linearity                                               | 6    |     |      | k $\Omega$    |
| Output Short Circuit Current (Permanent)    | $I_{short}$        | Output shorted to $V_{dd}$                                                             | 35   |     | 180  | mA            |
|                                             |                    | Output shorted to $V_{ss}$                                                             | 35   |     | 180  | mA            |
| Output Leakage current                      | $I_{leak}$         | High impedance mode <sup>(1)</sup><br>$T_A = 150^{\circ}\text{C}$                      | 0.5  | 1.5 | 20   | $\mu\text{A}$ |
| Output Voltage Swing (Linear Range)         | $V_{out\_pd}$      | pull-down $\geq 10\text{ k}\Omega$                                                     | 10   |     | 90   | %Vdd          |
| High-impedance mode levels <sup>(1)</sup>   | $V_{out\_HiZ\_pd}$ | pull-down $R_L \leq 25\text{ k}\Omega$ , $T \leq 125^{\circ}\text{C}$                  |      |     | 5    | %Vdd          |
| Under-voltage detection <sup>(2)</sup>      | $V_{dd\_uvd}$      | Low to High Voltage                                                                    | 3.15 | 3.3 | 3.45 | V             |
|                                             | $V_{dd\_uvh}$      | Hysteresis                                                                             | 0.25 | 0.3 | 0.4  | V             |
| Ratiometry fault detection                  | $V_{ratio\_d}$     | Low to High Voltage                                                                    | 4    |     | 4.4  | V             |
|                                             | $V_{ratio\_h}$     | Hysteresis                                                                             | 0.05 |     | 0.5  | V             |
| Over-voltage detection <sup>(2)</sup>       | $V_{dd\_ovd2}$     | Low to High Voltage                                                                    | 6.7  |     | 7.6  | V             |
|                                             | $V_{dd\_ovh2}$     | 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  $T_A = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_{dd} = 4.5\text{V}$  to  $5.5\text{V}$ , unless otherwise specified.

| Parameter                          | Symbol | Test Conditions / Comments                                      | Min      | Typ | Max       | Units |
|------------------------------------|--------|-----------------------------------------------------------------|----------|-----|-----------|-------|
| Magnetic field range               | B      |                                                                 | $\pm 15$ |     | $\pm 450$ | mT    |
| Linearity Error                    | NL     | $V_{dd}$ in range [4.5V, 5.5V]<br>$V_{out}$ 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

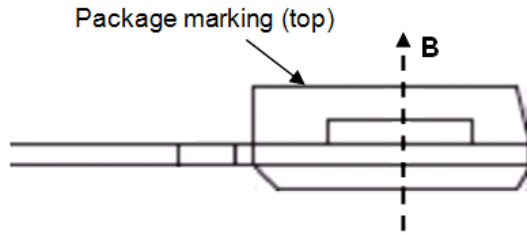


Figure 1: Magnetic Field Direction

## 11. Analog output specification

### 11.1. Timing specification

Operating Parameters  $T_A = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_{DD} = 4.5\text{V}$  to  $5.5\text{V}$  (unless otherwise specified).

| Parameter                    | Symbol      | Test Conditions / Comments                                                                                                                                     | Min | Typ | Max | Units         |
|------------------------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|---------------|
| Refresh rate                 | $T_{rr}$    |                                                                                                                                                                | 0.8 | 1   | 2   | $\mu\text{s}$ |
| Step Response Time           | $T_{resp}$  | Delay between the input signal reaching 90% and the output signal reaching 90%, (2V step at the output, input rise time = $1\mu\text{s}$ )                     |     |     |     |               |
|                              |             | -Noise filter OFF                                                                                                                                              |     | 2   | 3   | $\mu\text{s}$ |
|                              |             | -Noise filter ON                                                                                                                                               |     | 5   | 6   | $\mu\text{s}$ |
| Bandwidth                    | BW          | -Noise filter OFF                                                                                                                                              | 200 | 250 | 300 | kHz           |
|                              |             | -Noise filter ON                                                                                                                                               | 120 | 150 | 180 | kHz           |
| Power on Delay               | $T_{POD}$   | $V_{out} = 100\%$ of FS<br>Pull-down resistor $\leq 100\text{k}\Omega$<br>During the Power-on delay, output will remain within the 10% fault band at all time. |     |     | 5   | ms            |
| Ratiometry Cut-off Frequency | $F_{ratio}$ |                                                                                                                                                                |     | 250 |     | Hz            |

Table 8: Timing specification for high speed analog output

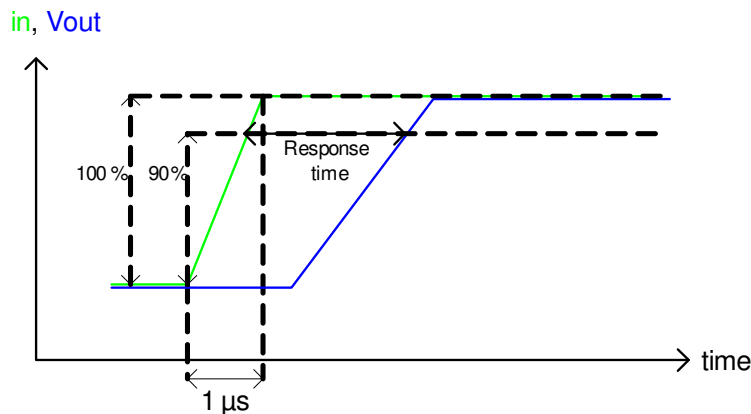


Figure 2: Response time definition

## 11.2. Accuracy specification

Operating Parameters  $T_A = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_{dd} = 4.5\text{V}$  to  $5.5\text{V}$  (unless otherwise specified).

| Parameter                            | Symbol                   | Test Conditions                                                                                   | Min  | Typ.  | Max  | Units                   |
|--------------------------------------|--------------------------|---------------------------------------------------------------------------------------------------|------|-------|------|-------------------------|
| Thermal Offset Drift <sup>(1)</sup>  | $\Delta^T \text{Voq}$    | In ref. to $T = 35^{\circ}\text{C}$<br>$V_{dd} = 5\text{V}$<br>$\text{Voq} = 50 \pm 0.2 \%V_{dd}$ | -10  |       | 10   | mV                      |
| Thermal Offset Drift Resolution      | $\Delta^T \text{VoqRes}$ |                                                                                                   |      | 0.075 |      | mV/ $^{\circ}\text{C}$  |
| Thermal Sensitivity Drift            | TC                       | In ref. to $T = 35^{\circ}\text{C}$<br>$V_{dd} = 5\text{V}$                                       | -1.5 | 0     | +1.5 | % of S                  |
| Thermal Sensitivity Drift resolution | TCres                    |                                                                                                   |      | 40    |      | ppm/ $^{\circ}\text{C}$ |
| RMS Output noise <sup>(2)</sup>      | $N_{\text{rms}}$         | $S = 50\text{mV/mT}$<br>-Noise filter OFF                                                         |      |       | 10   | mVrms                   |
|                                      |                          | -Noise filter ON                                                                                  |      |       | 6    | mVrms                   |
|                                      |                          | $S = 7.3\text{mV/mT}$<br>-Noise filter OFF                                                        |      | 2.8   |      | mVrms                   |
|                                      |                          | -Noise filter ON                                                                                  |      | 1.9   |      | mVrms                   |
| Ratiometry Error Offset              | $\Delta \text{Voq}$      | $\text{Voq} = 50\%V_{dd}$<br>$\Delta V_{dd} = 10\%V_{dd}$                                         | -0.4 |       | +0.4 | % of Voq                |
| Ratiometry Error Sensitivity         | $\Delta S$               | $\Delta V_{dd} = 10\%V_{dd}$                                                                      | -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 Output 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  $0.1\%V_{dd}$ . 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 <sup>1</sup> | 1    | 0<br>1          | Noise filter enablement                                                                          |
| PLATEPOL               | 1    | 0               | 0: default polarity as described in section 10.1<br>1: opposite polarity                         |
| 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.

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

## 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).

## 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<sup>2</sup> for TC2COLD and 0.6ppm/K<sup>2</sup> 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  $\pm 500$ ppm/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 | 100mV Hysteresis (typical)                     |

*Table 11: Self diagnostic*

## 14. Recommended Application Diagrams

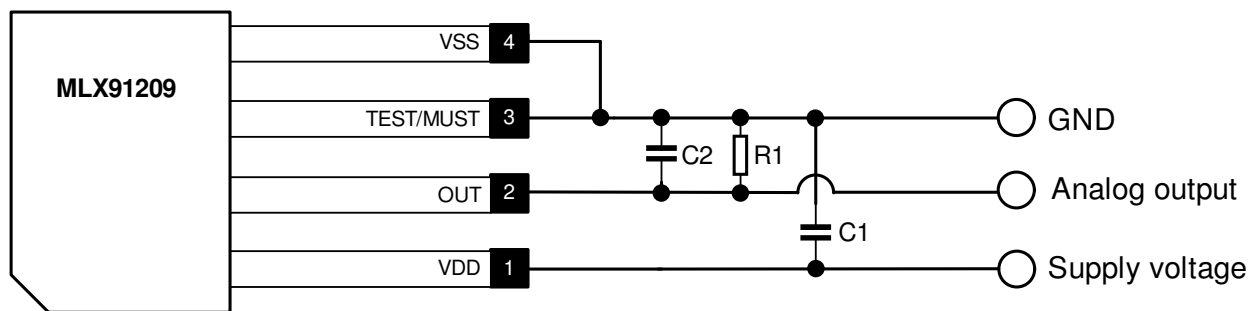
### 14.1. Resistor and capacitor values

| Part | Description                | Value               | Unit |
|------|----------------------------|---------------------|------|
| C1   | Supply capacitor, EMI, ESD | 100                 | nF   |
| C2   | Decoupling, EMI, ESD       | 2-10 <sup>(1)</sup> | 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 3: Diagnostic low*

## 15. Typical performance

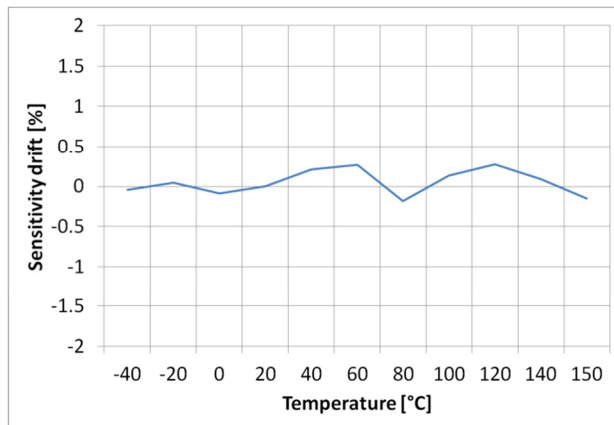


Figure 4: Thermal sensitivity drift.

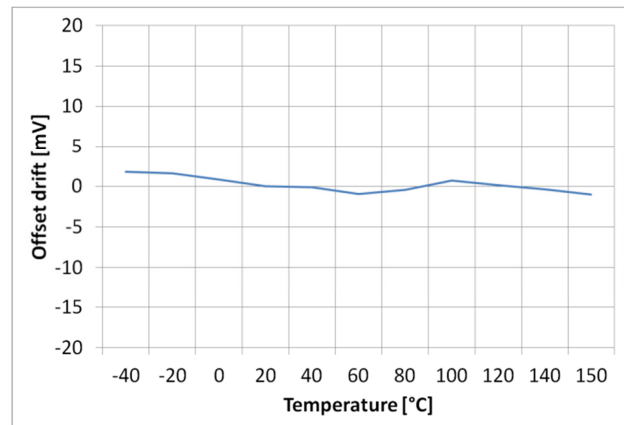


Figure 5: Thermal offset drift

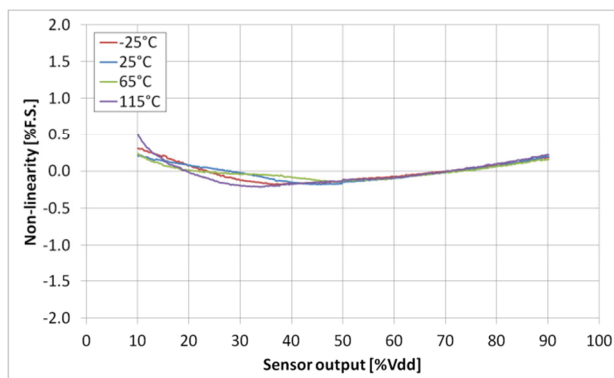


Figure 6: Non-linearity over temperature

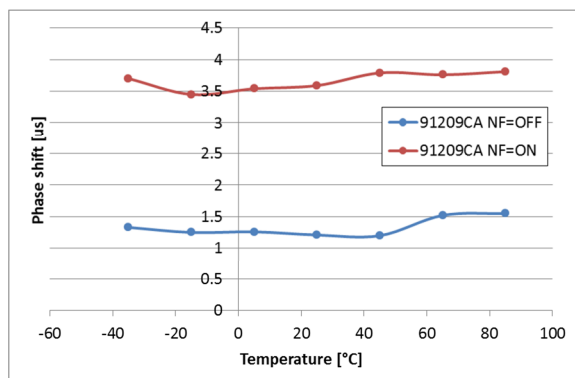


Figure 7: Phase shift over temperature.

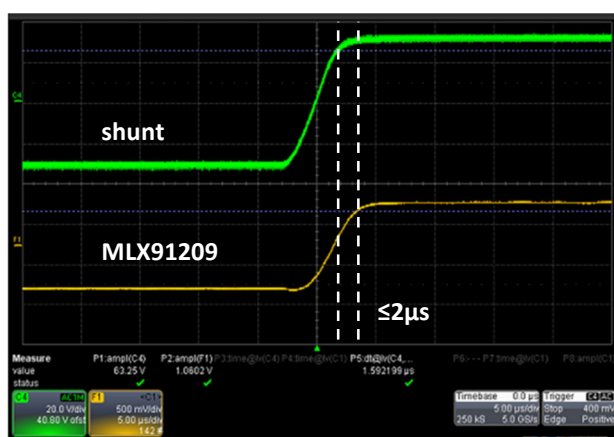


Figure 8: Response time with noise filter OFF.

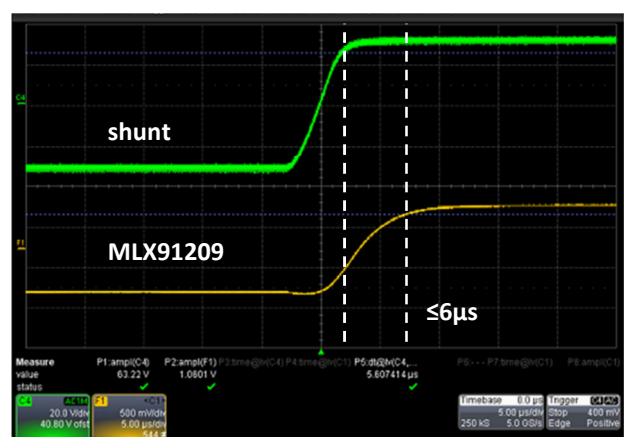


Figure 9: Response time with noise filter ON.

## 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](http://www.melexis.com/Quality_soldering.aspx) ([http://www.melexis.com/Quality\\_soldering.aspx](http://www.melexis.com/Quality_soldering.aspx)) as well as [trim&form recommendations](http://www.melexis.com/Assets/Trim-and-form-recommendations-5565.aspx) (<http://www.melexis.com/Assets/Trim-and-form-recommendations-5565.aspx>).

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

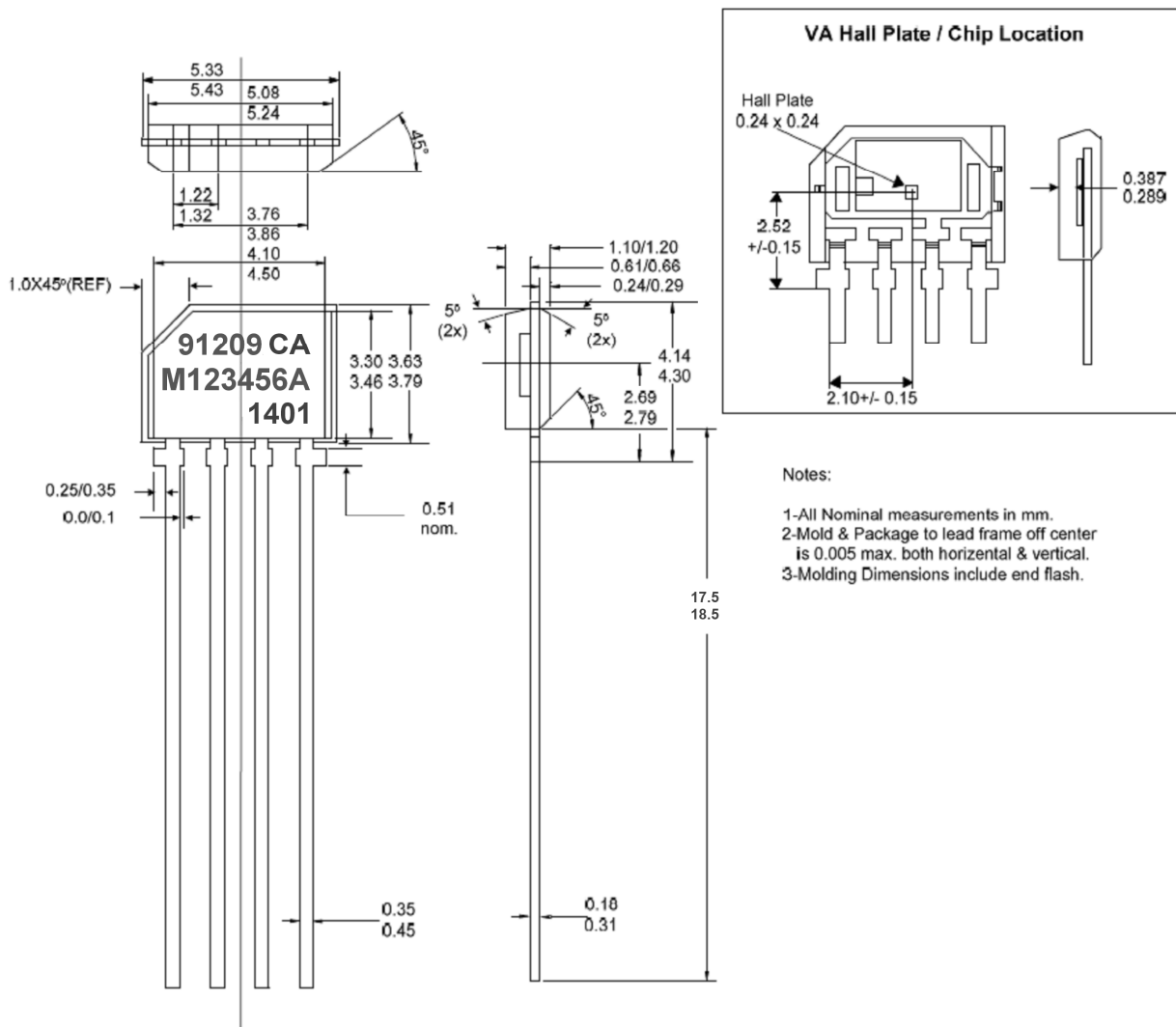


Figure 10: VA / SIP 4L (single in-line package) dimensions

## 20. Contact

For the latest version of this document, go to our website at [www.melexis.com](http://www.melexis.com).

For additional information, please contact our Direct Sales team and get help for your specific needs:

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