# MLX90215

### Precision Programmable*
### Linear Hall Effect Sensor

*Patent Pending*

## Features and Benefits

- Programmable Linear Hall IC
- Quad Switched / Chopper Stabilized
- Ratiometric Output for A/D Interface
- Adjustable Quiescent Voltage ($V_{OQ}$ )
- Very Low Quiescent Voltage Temperature Drift
- Adjustable Sensitivity
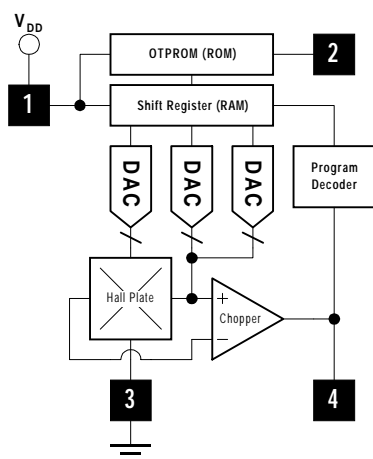- Adjustable Temperature Compensation of Sensitivity

## Applications

- Linear Position Sensing
- Rotary Position Sensing
- Current Sensing

## Ordering Information

| Part No. | Temperature Suffix | Package | Temperature Range |
|----------|--------------------|---------|--------------------|
| MLX90215 | L | VA(4 Lead SIP) | -40°C to 150°C |
| MLX90215 | E | VA(4 Lead SIP) | -40°C to 85°C |

## Functional Diagram



Pin 1 - $V_{DD}$ (Supply)
Pin 2 - Test/Readback Enable
Pin 3 - $V_{SS}$ (Ground)
Pin 4 - Output

*Note: Static sensitive device, please observe ESD precautions.*

## Description

The MLX90215 is a Programmable Linear Hall Effect sensor IC fabricated utilizing silicon-CMOS technology. It possesses active error correction circuitry which virtually eliminates the offset errors normally associated with analog Hall Effect devices. All magnetic response functions of the MLX90215 are fully programmable for even greater versatility. The $V_{OQ}$ ($V_{OUT}$@ B=0), sensitivity, direction of slope and the magnitude of sensitivity drift over temperature, are all programmable.

The ratiometric output voltage is proportional to the supply voltage. When using the supply voltage as a reference for an A/D converter, fluctuations of $\pm 10\%$ in supply voltage will not affect accuracy. When programmed for a conventional sensitivity (with a positive gain), the voltage at the output will increase as a South magnetic field is applied to the branded face of the MLX90215. Conversely, the voltage output will decrease in the presence of a North magnetic field. The MLX90215 has a sensitivity drift of less than $\pm 1\%$ error, and $V_{OQ}$ stability drift of less than $\pm 0.4\%$ error, over a broad temperature range.

## MLX90215 Electrical Specifications

DC Operating Parameters $T_A$ = -40$^o$C to 150$^o$C, $V_{DD}$ = 5.0V (Unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Supply Voltage | $V_{DD}$ | Operating | 4.5 | 5.0 | 5.5 | V |
| Supply Current | $I_{DD}$ | B = 0, $V_{DD}$ = 5V, $I_{OUT}$ = 0 | 2.5 | 4.0 | 5.5 | mA |
| Output Current [1] | $I_{OUT}$ | $V_{DD}$ = 5V $\pm$ 10% | -2 | - | 2 | mA |
| Quiescent Output Voltage [2] | $V_{OQ}$ | 10-Bit Programmable, B = 0 | 0.5 | - | 4.5 | V |
| Output Voltage [1] | $V_{OH}$ | $V_{DD}$ = 5V, $I_{OUT}$ = -2mA | 4.50 | 4.65 | | V |
| Output Voltage [1] | $V_{OL}$ | $V_{DD}$ = 5V, $I_{OUT}$ = 2mA | | 0.35 | 0.50 | V |
| Sampling Rate | $f_{SAMP}$ | RoughGain @ Max and Min | 4 | - | 40 | kHz |
| Bandwidth [3] | BW | RoughGain @ Min | | - | 1.300 | kHz |
| Bandwidth [3] | BW | RoughGain @ Max | 0.130 | - | | kHz |
| Impulse Response Time [6] | $T_{RMIN}$ | RoughGain @ Min | | - | 250 | µs |
| Impulse Response Time [6] | $T_{RMIN}$ | RoughGain @ Max | 25 | | | µs |
| Offset Voltage Drift | $\Delta V_{OQ}$ | B = 0, TA = 25$^o$C | -1.5 | - | 1.5 | mV |
| Offset Voltage Drift over Temperature | $\Delta V_{OQ}/\Delta T$ | B = 0, TA = -40$^o$C to 150$^o$C, S < 100mV/mT & $V_{OQ}$ > 0.75V | -20 | - | 20 | mV |
| Offset Voltage Drift [2] over Temperature | $\Delta V_{OQ}/\Delta T$ | B = 0, TA = -40$^o$C to 150$^o$C, S > 100mV/mT & $V_{OQ}$ < 0.75V | -40 | - | 40 | mV |
| Range of Sensitivity [7] | s | 13-Bit Programmable | 5 | - | 140 | mV/mT |
| Peak to Peak Noise [4] | | | 8 | 25 | 60 | mV |
| Output Resistance | $R_{OUT}$ | | | 6 | | $\Omega$ |
| Sensitivity Drift [5] | | TA = 25$^o$C | -1 | - | 1 | % |

## Notes:

(1) If output current and voltage specifications are exceeded, linearity will be degraded.

(2) If $V_{OQ}$ is programmed beyond these limits, the temperature compensation may become a problem at high temperatures. It is not recommended to program values of $V_{OQ}$ below 1V or above 4V when sensitivity exceeds 100 mV/mT. Temperature instability can occur on some devices under these conditions.

(3) Bandwidth is inversely proportional to ROUGHGAIN.

(4) Peak to Peak Noise is a function of ROUGHGAIN setting. See page 5, Peak to Peak Noise versus Sensitivity.

(5) Sensitivity drift is independent of other parameters and does not include individual tolerances ($\Delta V_{OQ}$ or $\Delta V_{OQ}/\Delta T$). The tolerance for sensitivity is $\pm$ 1% of its initial value. This does not include tolerance stack-up.

(6) If the impulse occurs in the middle of a sample interval, the small signal response delay will double. If a 50% to 100% impulse, slew rate may result in double or triple delay.

(7) 1 mT = 10 Gauss

## How does it Work?

The MLX90215 programming is done through the output pin, by changing supply voltage levels. Please note that the $V_{DD}$ is raised to approximately 13V and 18V during programming. **Any connected components must also tolerate this voltage excursion.** When the supply voltage is at 4.5V to 5.5V, the output behaves normally. If the supply voltage is raised to 13V, the output then behaves as an input, or LOAD mode, allowing the 31-bit word to be clocked in. All data is loaded through a single line, with no dedicated clock signal. Clock and data are integrated into one signal which is initiated with the beginning of the LOAD sequence, then clocked with the positive edge of each bit. Variables are changed with the PC software and loaded into the temporary register of the device (RAM) via the timings of the programmer's microcontroller. Data can be loaded as many times as desired while in LOAD mode. Once a word is loaded, results are checked by observing the output voltage. This can be done with an external Voltmeter attached directly to pin 4 of the device, or with the internal ADC of the programmer. Once the desired program is loaded, the word can be "Zapped" permanently into ROM.

This is done when the supply voltage rises above 18V, or ZAP mode, creating enough current to "Zap" 31 zener diodes which correspond to the temporary register. The ZAP function is a one-time function and cannot be erased.

The above description is only for reference. The voltage levels and data transfer rates are completely controlled by the ASIC programmer. For more information on the programmer hardware, contact Melexis and request a datasheet for the SDAP programmer.

**Programming The Quiescent Offset Voltage ($V_{OQ}$)**
10 bits, 1024 steps of resolution, are allotted to adjust the Quiescent Offset Voltage ($V_{OQ}$). By utilizing the HALFVDD function, the $V_{OQ}$ can be set to one of two ranges. With the HALFVDD function disabled, the $V_{OQ}$ can be programmed within a range of 10% to 90% $V_{DD}$ with about 5mV per step resolution. With the HALFVDD function enabled, the device may be programmed within a 2V to 3V window with less than 1mV per step resolution

**Programming the Sensitivity (Gain)**
The sensitivity is programmed with a ROUGHGAIN and a FINEGAIN adjustment. The ROUGHGAIN is adjusted by utilizing three bits, or 8 increments. The FINEGAIN is programmed with 10 bits or 1024 increments. The sensitivity can be programmed within a range of 5mV/mT to 140mV/mT. Another 1-bit function allows the direction of the sensitivity to be reversed. The INVERTSLOPE function, when activated, will cause the Voltage output of the MLX90215 to decrease in the presence of a South magnetic field, and to increase in the presence of a North magnetic field. Table 2 expresses examples of sensitivity resulting from programming ROUGH GAIN and FINE GAIN codes, with the INVERT SLOPE function turned off.

**Note:** *Tables 1 and 2 are examples how various codes affect the*

### Table 1 - Programming Offset Voltage (V $_{OQ}$)

| HalfVDD | OffsetDAC | Output | Units |
|---|---|---|---|
| 0 | 0 | 4.97 | V |
| 0 | 512 | 2.47 | V |
| 0 | 1023 | 0.03 | V |
| 1 | 0 | 3.07 | V |
| 1 | 512 | 2.45 | V |
| 1 | 1023 | 1.83 | V |

### Table 2 - Programming Sensitivity

| RoughGain | FineGain | Output | Units |
|---|---|---|---|
| 0 | 0 | 4.1 | mV/mT |
| 0 | 1023 | 9.4 | mV/mT |
| 1 | 0 | 6.2 | mV/mT |
| 1 | 1023 | 14.6 | mV/mT |
| 2 | 0 | 9.5 | mV/mT |
| 2 | 1023 | 22.4 | mV/mT |
| 3 | 0 | 14.2 | mV/mT |
| 3 | 1023 | 33.1 | mV/mT |
| 4 | 0 | 21.5 | mV/mT |
| 4 | 1023 | 50.4 | mV/mT |
| 5 | 0 | 31.3 | mV/mT |
| 5 | 1023 | 72.5 | mV/mT |
| 6 | 0 | 46.2 | mV/mT |
| 6 | 1023 | 107 | mV/mT |
| 7 | 0 | 68.9 | mV/mT |
| 7 | 1023 | 140 | mV/mT |

## Temperature Compensation

Temperature compensation (TC) is defined as the change in sensitivity over temperature. Expressed in (Parts Per Million per Degree Celcius) ppm/$^o$C.

$$TC = \frac{Sens_{T1} - Sens_{T2}}{Sens_{25}} * \frac{1}{T1 - T2} * 10^6 \frac{ppm}{^oC}$$

$Sens_{T1}$ = Sensitivity measured at Temperature 1 (T1)
$Sens_{T2}$ = Sensitivity measured at Temperature 2 (T2)
$Sens_{25}$ = Initial Sensitivity measured at 25$^o$C

### Table 3 - Temperature Compensation

| TC Code | Min | Typical | Max | Units |
|---|---|---|---|---|
| 0 | -600 | **-450** | -300 | ppm/$^o$C |
| 1 | -535 | **-385** | -235 | ppm/$^o$C |
| 2 | -465 | **-315** | -165 | ppm/$^o$C |
| 3 | -390 | **-240** | -90 | ppm/$^o$C |
| 4 | -300 | **-150** | 0 | ppm/$^o$C |
| 5 | -235 | **-85** | 65 | ppm/$^o$C |
| 6 | -150 | **0** | 150 | ppm/$^o$C |
| 7 | -85 | **65** | 215 | ppm/$^o$C |
| 8 | 125 | **275** | 425 | ppm/$^o$C |
| 9 | 125 | **360** | 510 | ppm/$^o$C |
| 10 | 210 | **435** | 585 | ppm/$^o$C |
| 11 | 285 | **515** | 665 | ppm/$^o$C |
| 12 | 450 | **600** | 750 | ppm/$^o$C |
| 13 | 535 | **685** | 835 | ppm/$^o$C |
| 14 | 600 | **750** | 900 | ppm/$^o$C |
| 15 | 680 | **830** | 980 | ppm/$^o$C |
| 16 | 1150 | **1300** | 1450 | ppm/$^o$C |
| 17 | 1230 | **1380** | 1530 | ppm/$^o$C |
| 18 | 1320 | **1470** | 1620 | ppm/$^o$C |
| 19 | 1405 | **1555** | 1705 | ppm/$^o$C |
| 20 | 1490 | **1640** | 1790 | ppm/$^o$C |
| 21 | 1575 | **1725** | 1875 | ppm/$^o$C |
| 22 | 1665 | **1815** | 1965 | ppm/$^o$C |
| 23 | 1750 | **1900** | 2950 | ppm/$^o$C |
| 24 | 2165 | **2365** | 2565 | ppm/$^o$C |
| 25 | 2340 | **2490** | 2640 | ppm/$^o$C |
| 26 | 2425 | **2575** | 2725 | ppm/$^o$C |
| 27 | 2500 | **2650** | 2800 | ppm/$^o$C |
| 28 | 2595 | **2745** | 2895 | ppm/$^o$C |
| 29 | 2680 | **2830** | 2980 | ppm/$^o$C |
| 30 | 2710 | **2910** | 3110 | ppm/$^o$C |
| 31 | 2775 | **2975** | 3175 | ppm/$^o$C |

## Programming the Temperature Compensation

The MLX90215 has a 5-bit (32 step) programmable adjustment that changes it's sensitivity drift over a given temperature range. By adjusting the TC code the sensitivity can be programmed to increase as temperature increases to counteract the decrease in magnetic flux most magnets display over temperature. For example a SmCo (Samarium Cobalt) magnet has a temperature coefficient of approximately –300 ppm/$^o$C. The MLX90215 can be programmed with a TC of 300 ppm/$^o$C to counteract the TC of the magnet and greatly improve linearity over temperature.

**Table 3** (left) illustrates the way the TC code affects the sensitivity temperature drift. Also note in Table 3, the overlap in TC codes. The numbers in the table represent typical results and are for reference only. For accurate results the TC code must be determined experimentally.
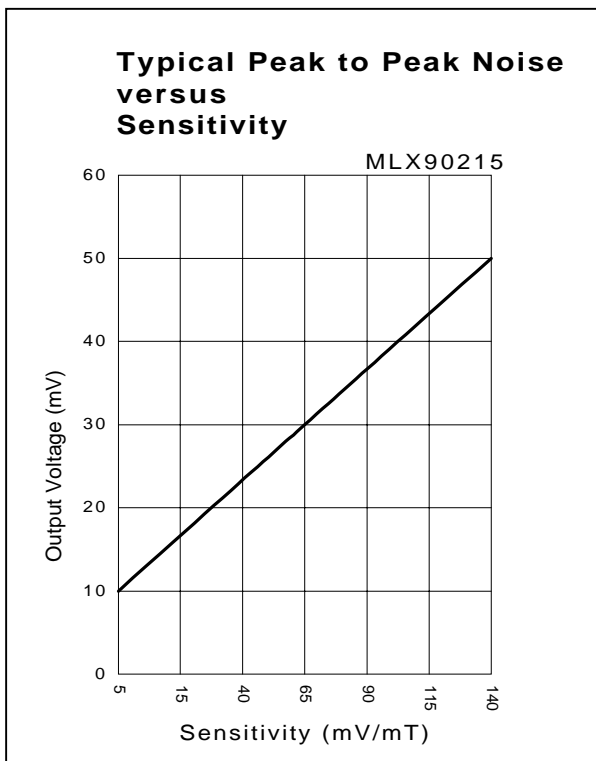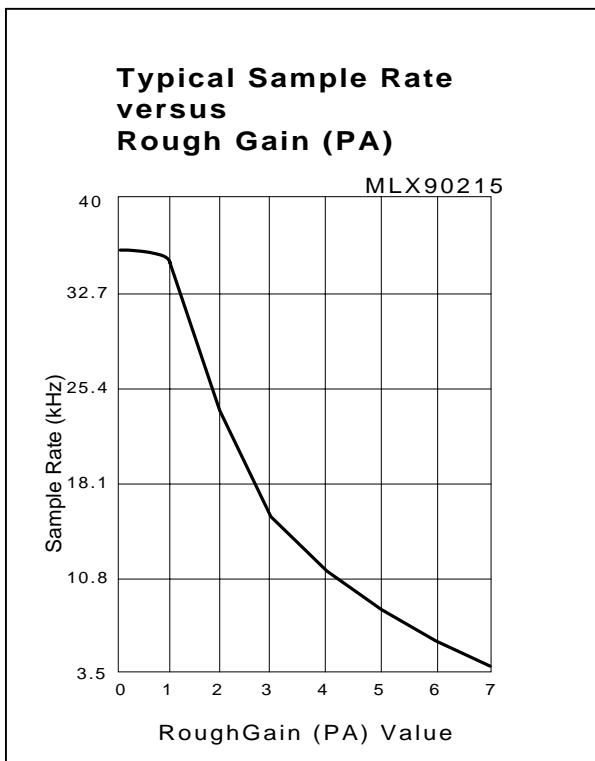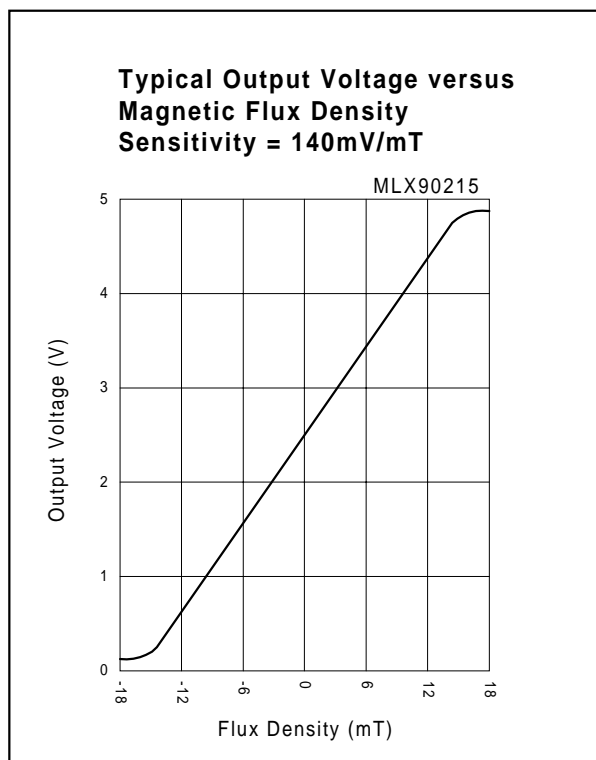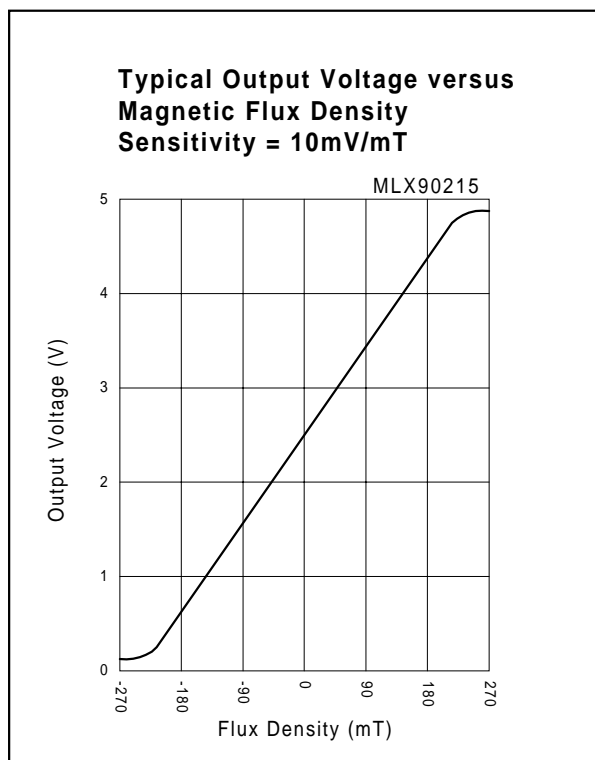
### Special Note

The MLX90215 programmed with a zero TC code (default) has a typical TC value between the range of –300 to –600 ppm/$^o$C. This means sensitivity will decrease slightly as temperature increases. The slightly negative initial TC value allows the MLX90215 to be accurately programmed up to 0 TC. Almost all magnets have a naturally negative TC code. The natural TC of a magnet added with the initial negative TC value of the MLX90215 could degrade linearity over a large temperature span. Using a TC code of 6, 7, or 8 will give the MLX90215 a slightly positive TC code.

## Diagnostic Characteristics

| Condition | Output Level |
|---|---|
| $V_{OUT}$ Shorted to $V_{DD}$ | $V_{OUT} = V_{DD}$ |
| $V_{OUT}$ Shorted to $V_{SS}$ | $V_{OUT} = V_{SS}$ |
| $V_{OUT}$ open with pull up load | $V_{OUT} = V_{DD}$ |
| $V_{OUT}$ open with pull down load | $V_{OUT} = V_{SS}$ |
| $V_{SS}$ open with pull up load | $V_{OUT} = V_{DD}$ |
| $V_{SS}$ open with pull down load > 10 K Ohms | $V_{OUT} = V_{DD}$ or 94% $V_{DD}$ |
| $V_{DD}$ open with pull up load > 4.7 K Ohms | $V_{OUT} = V_{SS}$ or 3% $V_{DD}$ |
| $V_{DD}$ open with pull down load | $V_{OUT} = V_{SS}$ |

## *MLX90215 Performance*

**Typical Output Voltage versus
Magnetic Flux Density
Sensitivity = 10mV/mT**



**Typical Output Voltage versus
Magnetic Flux Density
Sensitivity = 140mV/mT**



**Typical Sample Rate
versus
Rough Gain (PA)**



**Typical Peak to Peak Noise
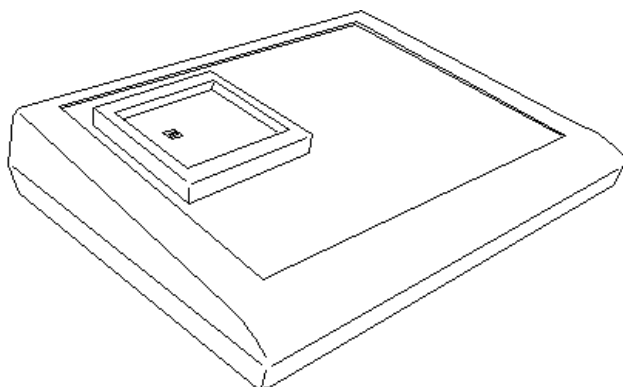versus
Sensitivity**

## Melexis Programmer

Melexis offers a programmer (PTC-01) for programming the MLX90215. The PTC-01 comes complete with windows based software that makes programming the MLX90215 simple. The programmer communicates with a PC via a RS232 serial interface. The programmer and software allows users to load settings in the MLX90215, take measurements, calibrate sensors, and program the MLX90215. For more information the PTC-01 goto
www.melexis.com, or contact Melexis.
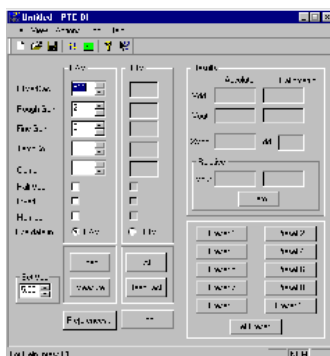


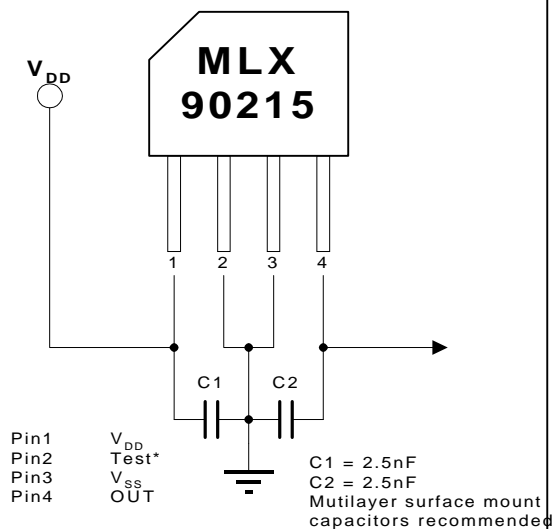*Left, PTC-01 windows based software. Works with any IBM compatible PC running windows 9x.*

## Absolute Maximum Ratings

| | |
|---|---|
| Supply Voltage (Over Voltage) | 18V |
| Supply Voltage (Operating) | 5V $\pm$ 10% |
| Reverse Voltage Protection | -14.5V |
| Magnetic Flux Density | Unlimited |
| Supply Current, $I_{DD}$ | 6mA |
| Output Current (Short to $V_{DD}$) | +12mA |
| Output Current (Short to $V_{SS}$) | -12mA |
| Operating Temperature Range, $T_A$ | -40°C to 150°C |
| Storage Temperature Range, $T_S$ | -55°C to 165°C |
| ESD Sensitivity | $\pm$7kV |

## Cross Reference

The MLX 90215VA can replace the following Hall Effect devices: Allegro A3503, A3506, A3508, 3515, A3516; Siemens TL4910 series; Honeywell SS9 series; Micronas HAL800.

## Melexis PTC-01
## Programmer



### Pin Description
### Recommended Wiring



**MLX 90215**

$V_{DD}$

1  2  3  4

C1   C2

| Pin1 | $V_{DD}$ |
| Pin2 | Test* |
| Pin3 | $V_{SS}$ |
| Pin4 | OUT |

C1 = 2.5nF
C2 = 2.5nF
Mutilayer surface mount capacitors recommended

*Readback diagnostic use only. Pin 2 is NOT for progra device. For best results, tie to GND.

## Clamping the Output Voltage

The MLX90215 has a 2-bit CLAMP feature which allows Four output voltage options. The CLAMP feature is independent of the gain, and will not effect sensitivity of the device. The table below illustrates limits for each of the four options.

| Bit Value | Limits (% $V_{DD}$) |
|---|---|
| 0 (default)) | no clamp |
| 1 | 5 to 45 |
| 2 | 10 to 90 |
| 3 | 5 to 95 |

## Application Comments

The following is a list of recommended operating parameters that will help to ensure the accuracy and stability of the MLX90215. These are not the absolute programming limits of the device.

1.) $V_{OQ}$ is best programmed in the absence of any magnetic influence and to voltages closest to 1/2 $V_{DD}$, where temperature drift will be +/-0.4% or less. It is not recommended to use $V_{OQ}$ values close to 0 volts or $V_{DD}$ when programming extremely high sensitivity (> 100 mV/mT) values. Temperature instability may be observed on some devices under these conditions.

2.) Best linearity of sensitivity is obtained when $V_{OQ}$ is programmed at 1/2 $V_{DD}$. This is with the 1/2 $V_{DD}$ function enabled.

3.) Best linearity of sensitivity is obtained when the gain is programmed between 5mV/mT and 100mV/mT.

4.) Best temperature stability is realized when the temperature compensation function is programmed to zero ppm/$^{o}$C.

5.) The Test/Readback pin is for diagnostic use only. This pin is normally tied to GND. Contact Melexis for more details on programming this device.
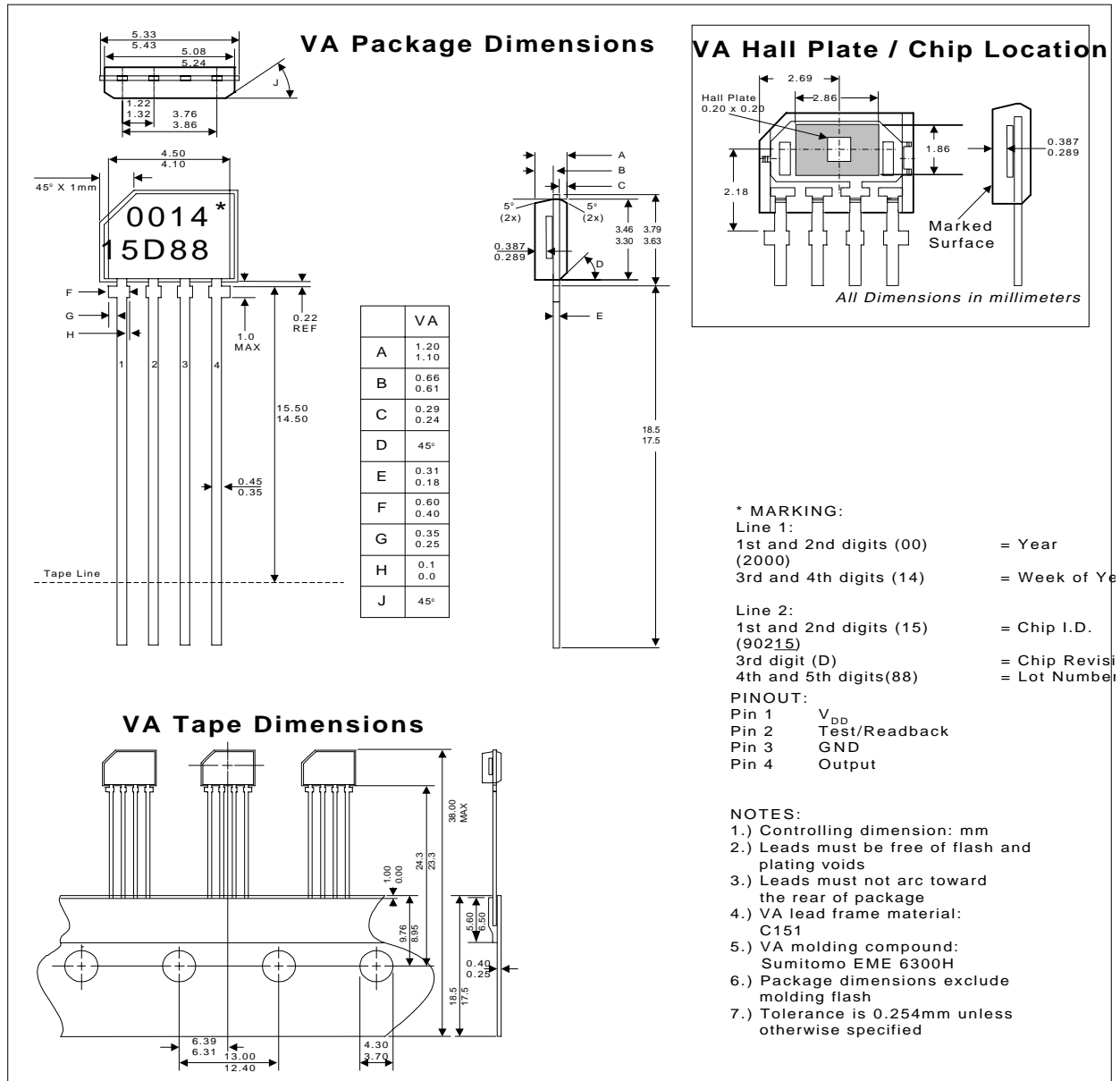
## Installation Comments

1.) Avoid mechanical stress on leads or package. Stress may cause $V_{OQ}$ shift.
   A.) Avoid bending leads at the package interface.
   B.) Support the leads by clamping, when bending.
   C.) Avoid gluing device to another material. This may cause temperature-related stress.

2.) CMOS products are static sensitive devices, please observe ESD precautions.

3.) Observe temperature limits during soldering.

## Bit Allocation Table

| Bit | Function |
|---|---|
| 1 | INVERTSLOPE |
| 2 | OFFSETDAC 5 |
| 3 | OFFSETDAC 6 |
| 4 | OFFSETDAC 7 |
| 5 | OFFSETDAC 8 |
| 6 | OFFSETDAC 9 |
| 7 | OFFSETDAC 4 |
| 8 | OFFSETDAC 3 |
| 9 | OFFSETDAC 2 |
| 10 | OFFSETDAC 1 |
| 11 | OFFSETDAC 0 |
| 12 | FINEGAIN 0 |
| 13 | FINEGAIN 1 |
| 14 | FINEGAIN 2 |
| 15 | HALFVDD |
| 16 | FINEGAIN 3 |
| 17 | FINEGAIN 4 |
| 18 | FINEGAIN 5 |
| 19 | FINEGAIN 8 |
| 20 | FINEGAIN 9 |
| 21 | FINEGAIN 6 |
| 22 | FINEGAIN 7 |
| 23 | ROUGHGAIN 2 |
| 24 | ROUGHGAIN 1 |
| 25 | ROUGHGAIN 0 |
| 26 | TEMP CO 0 |
| 27 | TEMP CO 1 |
| 28 | TEMP CO 2 |
| 29 | TEMP CO 3 |
| 30 | TEMP CO 4 |
| 31 | CLAMP 1 |
| 32 | CLAMP 0 |
| 33 | MEMLOCK |
| 34 | TEST 0 |
| 35 | TEST 1 |
| 36 | TEST 2 |
| 37 | TEST 3 |

## Physical Characteristics

### VA Package Dimensions



0014 *
15D88

45° X 1mm

0.22 REF

1.0 MAX

15.50
14.50

0.45
0.35

Tape Line

5.33 / 5.43
5.08 / 5.24
1.22 / 1.32
3.76 / 3.86
4.50 / 4.10

F
G
H

1  2  3  4

A
B
C

5° (2x)   5° (2x)

0.387 / 0.289

3.46 / 3.30
3.79 / 3.63

D

E

18.5 / 17.5

| | VA |
|---|---|
| A | 1.20 / 1.10 |
| B | 0.66 / 0.61 |
| C | 0.29 / 0.24 |
| D | 45° |
| E | 0.31 / 0.18 |
| F | 0.60 / 0.40 |
| G | 0.35 / 0.25 |
| H | 0.1 / 0.0 |
| J | 45° |

### VA Hall Plate / Chip Location



Hall Plate 0.20 x 0.20

2.69
2.86
1.86
2.18

0.387 / 0.289

Marked Surface

*All Dimensions in millimeters*

### VA Tape Dimensions



38.00 MAX

24.3 / 23.3

1.00 / 0.00

9.76 / 8.95

5.60 / 5.50

0.40 / 0.25

18.5 / 17.5

6.39 / 6.31
13.00 / 12.40

4.30 / 3.70

* MARKING:
Line 1:
1st and 2nd digits (00)          = Year (2000)
3rd and 4th digits (14)          = Week of Ye

Line 2:
1st and 2nd digits (15)          = Chip I.D. (90215)
3rd digit (D)                          = Chip Revisi
4th and 5th digits (88)          = Lot Number

PINOUT:
Pin 1        $V_{DD}$
Pin 2        Test/Readback
Pin 3        GND
Pin 4        Output

NOTES:
1.) Controlling dimension: mm
2.) Leads must be free of flash and plating voids
3.) Leads must not arc toward the rear of package
4.) VA lead frame material: C151
5.) VA molding compound: Sumitomo EME 6300H
6.) Package dimensions exclude molding flash
7.) Tolerance is 0.254mm unless otherwise specified

CERTIFIED ISO 9002

## *Application Notes*

### *Linear Precision Current Sensor*

The Programmable gain, offset, and temperature compensation of MLX90215 allows great flexiblity in the design of a current sensor.

Current flowing through a conductor can produce a proportional magnet field. The MLX90215 can then produce an output voltage proportional to the current. Using the programmable gain and offset function the output of the MLX90215 can be adjusted to sense a wide range of current allowing for a flexible design.

**Slotted Torroid Example** Assuming infinite permeabilty of the core, the magnetic field through the air gap produced by a single wire turn is given by equation 2

**Equation 2**

$$B = \frac{I}{l_g} u_o$$

Where: I = current in Amperes
B = magnetic field in Tesla
$l_g$ = length of air gap in Meters
$u_o$ = Permeability of free space ($4\pi 10^{-7}$ H/m)

This equation is a close estimate for the field in the air gap, but does not take into account magnetic losses in the core, fringing effects, and mechanical tolerances of the air gap. The programmable MLX90215 can be adjusted to compensate for these errors simplifying the design. The temperature compensation of MLX90215 can also be adjusted to counteract temperature losses of core.
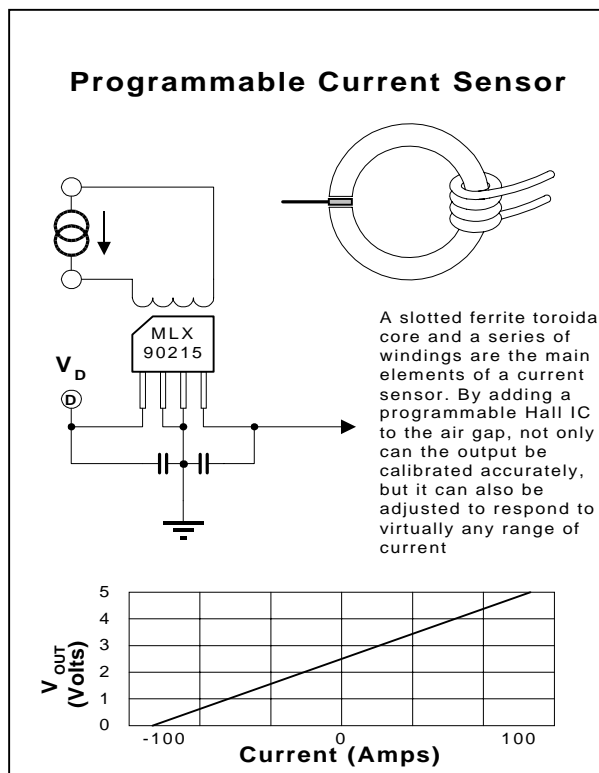
For sensing a current ±100A, with an air gap of 2mm equation 2 yields a magnetic field range of ±63mT. The output range of the MLX90215 is 0.5V to 4.5V (4V full scale). Equations 3a and 3b yield a sensitivity of 32mV/mT and a $V_{oq}$ of 2.5V.

**Equation 3**
**a)** S = 4000mV/ 126mT
**b)** Voq = 4V/2 + 0.5V

The resulting gain of the current sensor is 20mV/A with an offset of 2.5V. For best results it is recommend that MLX90215 be programmed with a Voq of 50% Vdd 1/2 Vdd bit set.



**Programmable Current Sensor**

$V_D$
Ⓓ
MLX 90215

A slotted ferrite toroidal core and a series of windings are the main elements of a current sensor. By adding a programmable Hall IC to the air gap, not only can the output be calibrated accurately, but it can also be adjusted to respond to virtually any range of current

$V_{OUT}$ (Volts)
Current (Amps)
-100    0    100

Magnetic Suppliers

Elna Ferrites Technologies Inc

Eastern Components

Fair Rite Products Corp