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## Features and Benefits

Absolute Rotary & Linear Position Sensor IC  
 Triaxis® Hall Technology  
 Simple Magnetic Design  
 Programmable Transfer Characteristic (Multi-Points – Piece-Wise-Linear)  
 Selectable Output Mode: Analog (Ratiometric) – Pulse Width Modulation (PWM)  
 12 bit Resolution - 10 bit Thermal Accuracy  
 Open/Short Diagnostics  
 On Board Diagnostics  
 Over-Voltage Protection  
 Under-Voltage Detection  
 48 bit ID Number option  
 Automotive Temperature Range  
 AEC-Q100 Qualified  
 Single Die – SOIC-8 Package RoHS Compliant  
 Dual Die (Full Redundant) – TSSOP-16 Package RoHS Compliant




## Applications

Absolute Rotary Position Sensor  
 Pedal Position Sensor  
 Throttle Position Sensor  
 Ride Height Position Sensor

Absolute Linear Position Sensor  
 Steering Wheel Position Sensor  
 Float-Level Sensor  
 Non-Contacting Potentiometer

## Ordering Information<sup>1</sup>

Part No.	Temperature Suffix	Package Code	Die Revision	Option code	Packing
MLX90365	E (– 40°C to + 85°C)	DC [SOIC-8]	ABD	000	RE
MLX90365	K (– 40°C to + 125°C)	DC [SOIC-8]	ABD	000	RE
MLX90365	L (– 40°C to + 150°C)	DC [SOIC-8]	ABD	000	RE
MLX90365	L (– 40°C to + 150°C)	DC [SOIC-8]	ABD	200	RE
MLX90365	E (– 40°C to + 85°C)	GO [TSSOP-16]	ABD	000	RE
MLX90365	K (– 40°C to + 125°C)	GO [TSSOP-16]	ABD	000	RE
MLX90365	L (– 40°C to + 150°C)	GO [TSSOP-16]	ABD	000	RE

### Legend:

Temperature Code:	E for Temperature Range -40°C to 85°C K for Temperature Range -40°C to 125°C L for Temperature Range -40°C to 150°C
Package Code:	DC for SOIC-8 Package GO for TSSOP-16 Package (Dual Die – Full Redundant)
Option Code:	XXX-000 – Standard XXX-200 – Preprogrammed – See Section 13 for Default Settings.
Packing Form:	RE for Reel SP for Sample Pack
Ordering example:	MLX90365EDC-ABD-000-RE

<sup>1</sup> Other option code and packing form are available; see your sales representative for more details

## 1. Functional Diagram

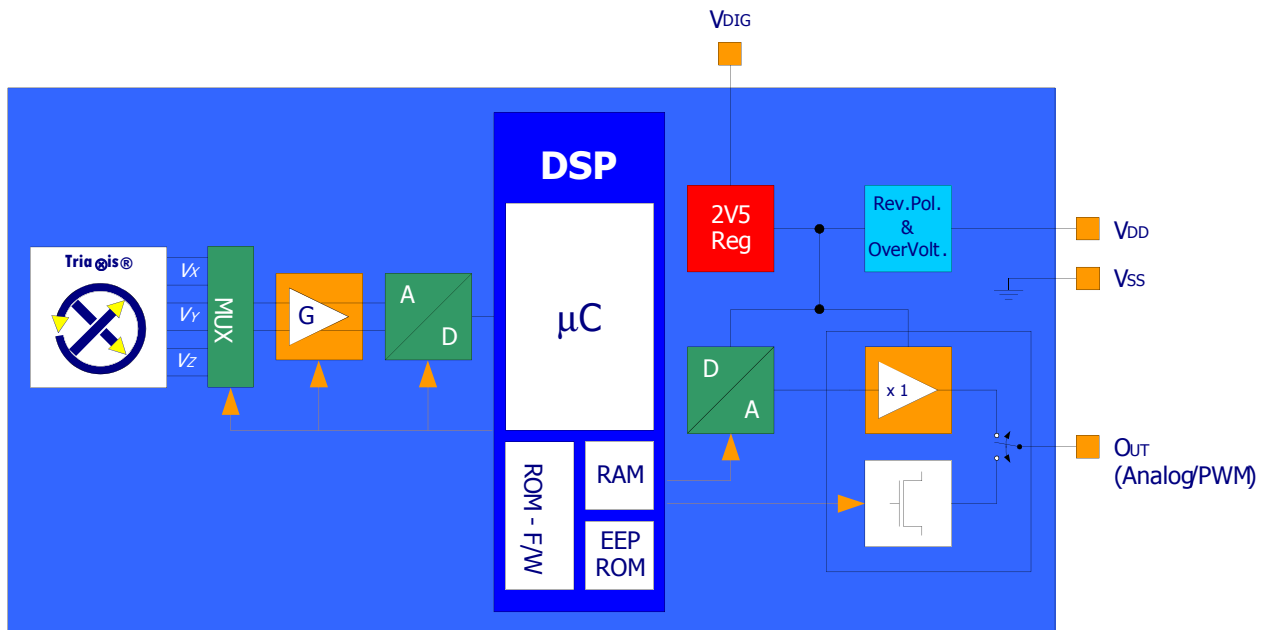


Figure 1 - MLX90365 Block Diagram

## 2. Description

The MLX90365 is a monolithic sensor IC sensitive to the flux density applied orthogonally and parallel to the IC surface.

The MLX90365 is sensitive to the three components of the flux density applied to the IC (i.e.  $B_x$ ,  $B_y$  and  $B_z$ ). This allows the MLX90365 with the correct magnetic circuit to decode the absolute position of any moving magnet (e.g. rotary position from 0 to 360 Degrees or linear displacement, stroke - Figure 2). It enables the design of novel generation of non-contacting position sensors that are frequently required for both automotive and industrial applications.

MLX90365 reports a programmable ratiometric analog output signal compatible with any resistive potentiometer or programmable linear Hall sensor. Through programming, the MLX90365 provides also a digital PWM (Pulse Width Modulation) output characteristic.

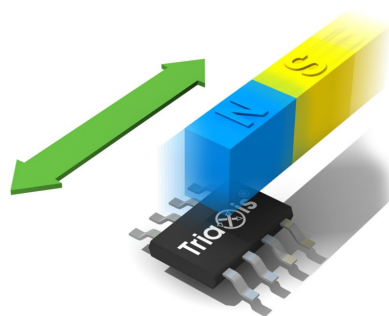


Figure 2 - Typical application of MLX90365 – Linear

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### 3. Glossary of Terms – Abbreviations – Acronyms

- Gauss (G), Tesla (T): Units for the magnetic flux density – 1 mT = 10 G
- TC: **T**emperature **C**oefficient (in ppm/Deg.C.)
- NC: **N**ot **C**onected
- PWM: **P**ulse **W**idth **M**odulation
- %DC: **D**uty **C**ycle of the output signal i.e.  $T_{ON} / (T_{ON} + T_{OFF})$
- ADC: **A**nalog-to-**D**igital **C**onverter
- DAC: **D**igital-to-**A**nalog **C**onverter
- LSB: **L**east **S**ignificant **B**it
- MSB: **M**ost **S**ignificant **B**it
- DNL: **D**ifferential **N**on-**L**inearity
- INL: **I**ntegral **N**on-**L**inearity
- RISC: **R**educed **I**nstruction **S**et **C**omputer
- ASP: **A**nalog **S**ignal **P**rocessing
- DSP: **D**igital **S**ignal **P**rocessing
- EMC: **E**lectro-**M**agnetic **C**ompatibility
- IMC: **I**ntegrated-**M**agneto **C**oncentrator
- MT3V: **M**ore **T**han **3V** internal analog voltage check

### 4. Pinout

Pin #	SOIC-8	TSSOP-16
1	VDD	VDIG <sub>1</sub>
2	Test 0	VSS <sub>1</sub> (Ground <sub>1</sub> )
3	Test 2	VDD <sub>1</sub>
4	Not Used	Test 0 <sub>1</sub>
5	OUT	Test 2 <sub>2</sub>
6	Test 1	OUT <sub>2</sub>
7	VDIG	Not Used <sub>2</sub>
8	VSS (Ground)	Test 1 <sub>2</sub>
9		VDIG <sub>2</sub>
10		VSS <sub>2</sub> (Ground <sub>2</sub> )
11		VDD <sub>2</sub>
12		Test 0 <sub>2</sub>
13		Test 2 <sub>1</sub>
14		Not Used <sub>1</sub>
15		OUT <sub>1</sub>
16		Test 1 <sub>1</sub>

For optimal EMC behavior, it is recommended to connect the unused pins (Not Used and Test) to the Ground (see section 16).

## 5. Absolute Maximum Ratings

Parameter	Value
Supply Voltage, VDD (overvoltage)	+ 24 V
Reverse Voltage Protection	– 12 V (breakdown at -14 V)
Positive Output Voltage	+ 18 V (breakdown at 24 V)
Output Current (I <sub>OUT</sub> )	+ 30 mA (in breakdown)
Reverse Output Voltage	– 0.3 V
Reverse Output Current	– 50 mA (in breakdown)
Operating Ambient Temperature Range, T <sub>A</sub>	– 40°C ... + 150°C
Storage Temperature Range, T <sub>S</sub>	– 40°C ... + 150°C
Magnetic Flux Density	± 1 T

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

## 6. Description

As described on the block diagram the three vector components of the magnetic flux density (B<sub>X</sub>, B<sub>Y</sub> and B<sub>Z</sub>) applied to the IC are sensed through the sensor front-end. The respective Hall signals (V<sub>X</sub>, V<sub>Y</sub> and V<sub>Z</sub>) are generated at the Hall plates and amplified.

The analog signal processing is based on a fully differential analog chain featuring the classic offset cancellation technique (Hall plate 2-Phases spinning and chopper-stabilized amplifier).

The conditioned analog signals are converted through an ADC (15 bits) and provided to a DSP block for further processing. The DSP stage is based on a 16 bit RISC micro-controller whose primary function is the extraction of the position from two (out of three) raw signals (after so-called front-end compensation steps) through the following function:

$$\alpha = \angle(V_1, k \cdot V_2)$$

where alpha is the magnetic angle  $\angle(B_1, B_2)$ , V<sub>1</sub> = V<sub>X</sub> or V<sub>Y</sub> or V<sub>Z</sub>, V<sub>2</sub> = V<sub>X</sub> or V<sub>Y</sub> or V<sub>Z</sub> and k is a programmable factor to match the amplitude of V<sub>1</sub> and k V<sub>2</sub>.

The DSP functionality is governed by the micro-code (firmware – F/W) of the micro-controller which is stored into the ROM (mask programmable). In addition to the magnetic angle extraction, the F/W controls the whole analog chain, the output transfer characteristic, the output protocol, the programming/calibration and also the self-diagnostic modes.

The magnetic angular information is intrinsically self-compensated vs. flux density variations. This feature allows therefore an improved thermal accuracy vs position sensor based on conventional linear Hall sensors.

In addition to the improved thermal accuracy, the realized position sensor features excellent linearity performances taking into account typical manufacturing tolerances (e.g. relative placement between the Hall IC and the magnet).

Once the position (angular or linear stroke) information is computed, it is further conditioned (mapped) vs. the target transfer characteristic and it is provided at the output(s) as either a ratiometric analog output level through a 12 bit DAC followed by a buffer or a digital PWM output.

For instance, the analog output can be programmed for offset, gain and clamping to meet any rotary position sensor output transfer characteristic:

$$\begin{aligned} V_{out}(\alpha) &= \text{ClampLo} && \text{for } \alpha \leq \alpha_{\min} \\ V_{out}(\alpha) &= V_{\text{offset}} + \text{Gain} \times \alpha && \text{for } \alpha_{\min} \leq \alpha \leq \alpha_{\max} \\ V_{out}(\alpha) &= \text{ClampHi} && \text{for } \alpha \geq \alpha_{\max} \end{aligned}$$

where  $V_{\text{offset}}$ , Gain, ClampLo and ClampHi are the main adjustable parameters for the end-user.

The linear part of the transfer curve can be adjusted through a multi-point calibration:

This back-end step consists into either

- up to 4 arbitrary points (5 segments + clamping levels) calibration or
- a Piece-Wise-Linear (PWL) output transfer characteristics - 17 equidistant points w/ programmable origin over 16 different angle ranges from 65 to 360 degrees.

The calibration parameters are stored in EEPROM featuring a Hamming Error Correction Coding (ECC).

The programming steps do not require any dedicated pins. The operation is done using the supply and output nodes of the IC. The programming of the MLX90365 is handled at both engineering lab and production line levels by the Melexis Programming Unit PTC-04 with the dedicated MLX90316 daughterboard and software tools (DLL – User Interface).



## 7. MLX90365 Electrical Specification

Operating Parameters at Nominal Supply Voltage (unless otherwise specified) and for T<sub>A</sub> as specified by the Temperature suffix (E or K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Nominal Supply Voltage	VDD		4.5	5	5.5	V
Supply Current <sup>(2)</sup>	I <sub>dd</sub>	Power saving Enabled, All modes For Outmode=1		6	10 <sup>(3)</sup>	mA
		Power saving Disabled, All modes For Outmode=1		8	12	
Isurge Current <sup>(4)</sup>	I <sub>surge</sub>				20	mA
Power-On reset ( rising )	HPOR_LH	Refer to internal voltage V <sub>dig</sub>	2	2.25	2.5	V
Power-On reset Hysteresis	HPOR_Hyst		50		200	mV
Start-up Level ( rising )	MT4V_LH		3.8	4.0	4.2	V
Start-up Hysteresis	MT4V_Hyst		50		200	mV
PTC Entry Level ( rising )	MT7V_LH		5.8	6.2	6.6	V
PTC Entry Level Hysteresis	MT7V_Hyst		50		200	mV
Output Short Circuit Current	I <sub>short</sub>	V <sub>out</sub> = 0 V			15	mA
		V <sub>out</sub> = 5 V			15	mA
		V <sub>out</sub> = 18 V (T <sub>A</sub> = 25°C)			18	mA
Output Load Analog	R <sub>L</sub>	Pull-down to Ground	4.7	10	∞	kΩ
		Pull-up to 5V	4.7	10	∞	kΩ
Output Load PWM	R <sub>L_PWM</sub>	Pull-down to Ground	1			kΩ
		Pull-up to 5V	1			kΩ
Analog Saturation Output Level	V <sub>sat_lo</sub>	Pull-up load R <sub>L</sub> ≥ 10 kΩ to 5 V Pull-up load R <sub>L</sub> ≥ 5 kΩ to 18V		0.5 2	2 3	%VDD
	V <sub>sat_hi</sub>	Pull-down load R <sub>L</sub> ≥ 5 kΩ Pull-down load R <sub>L</sub> ≥ 10 kΩ	95 97.5	97 98.5		%VDD
Digital Saturation Level Open drain Output (R <sub>L_PWM</sub> to V <sub>bat</sub> )	V <sub>o_min</sub>	Pull-up load R <sub>L_PWM</sub> ≤ 1 kΩ to 5V	98			%V <sub>bat</sub>
		Pull-up load R <sub>L_PWM</sub> ≤ 1 kΩ to 14V	95			
		Pull-up load R <sub>L_PWM</sub> ≤ 1 kΩ to 18V	90			
		Pull-up load R <sub>L_PWM</sub> ≤ 5.6 kΩ to 5V	96			
		Pull-up load R <sub>L_PWM</sub> ≤ 5.6 kΩ to 14V	85			
Pull-up load R <sub>L_PWM</sub> ≤ 5.6 kΩ to 18V	73					
Active Diagnostic Output Level Digital Saturation Output Level	D <sub>sat_lo</sub>	Pull-up load R <sub>L</sub> ≥ 10 kΩ to 5 V Pull-up load R <sub>L</sub> ≥ 5 kΩ to 18V		0.5 2	2 3	%VDD
	D <sub>sat_hi</sub>	Pull-down load R <sub>L</sub> ≥ 5 kΩ Pull-down load R <sub>L</sub> ≥ 10 kΩ	95	97		%VDD

<sup>2</sup> For the dual version, the supply current is multiplied by 2.

<sup>3</sup> To reach 10mA, the power saving options should be enabled. This option switches off and on internal blocks dynamically. It can be disabled in case of extreme emission requirements or if an analog output is required with a resistor on either supply or output line.

<sup>4</sup> The specified value is valid during early start-up time only; the current might dynamically exceed the specified value, shortly, during the Start-up phase.

			97.5	98.5		
Passive Diagnostic Output Level (Broken Track Diagnostic) <sup>(5)</sup>	BVssPD <sup>6</sup>	Broken Vss & Pull-down load $R_L \geq 5\text{ k}\Omega$ Pull-down load $R_L \geq 10\text{ k}\Omega$	95 97.5			%VDD
	BVssPU	Broken Vss & Pull-up load $R_L \geq 1\text{ k}\Omega$	99.5	100		%VDD
	BVDDPD	Broken VDD & Pull-down load $R_L \geq 1\text{ k}\Omega$		0	0.5	%VDD
	BVDDPU	Broken VDD & Pull-up load $R_L \geq 5\text{ k}\Omega$			2	%VDD
Clamped Output Level	Clamp_lo	Programmable	0		100	%VDD <sup>(7)</sup>
	Clamp_hi	Programmable	0		100	%VDD <sup>(7)</sup>

As an illustration of the previous table, the MLX90365 fits the typical classification of the output span described on the Figure 6.

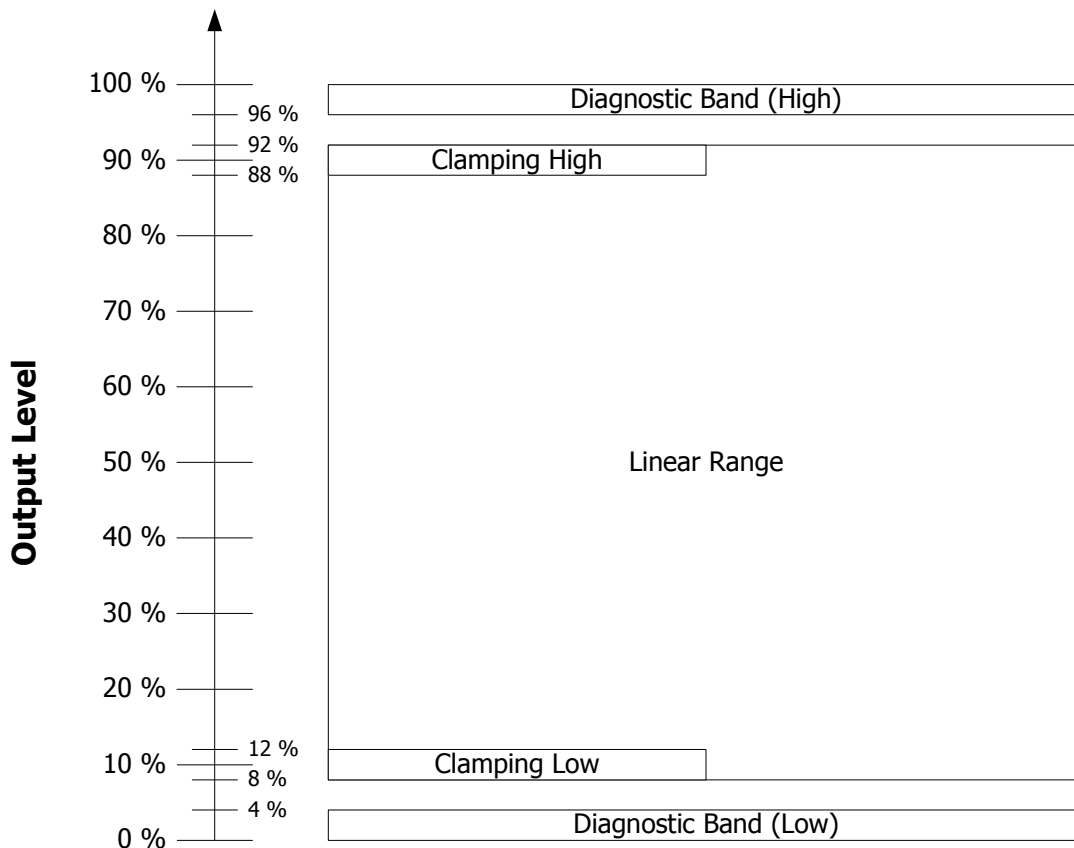


Figure 6 – Example of Output Span Classification for typical application.

<sup>5</sup> For detailed information on diagnostics, see also section 15

<sup>6</sup> In case the dual-die variant is used BVssPD level can be influenced. Refer to Technical note MLX90365\_Broken\_Vss\_DualDie

<sup>7</sup> Clamping levels need to be considered vs the saturation of the output stage (see Vsat\_lo and Vsat\_hi)

## 8. MLX90365 Isolation Specification

DC Operating Parameters at Nominal Supply Voltage (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix (E or K or L). Only valid for the package code GO i.e. dual die version.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Isolation Resistance		Between 2 dies	4			MΩ

## 9. MLX90365 Timing Specification

**ANALOG OUTPUT** - DC Operating Parameters at Nominal Supply Voltage (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix (E or K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Main Clock Frequency	Ck	All contributors included thermal drift	12.6	13.3	14	MHz
Main Clock Frequency Thermal Drift	$\Delta T_{Ck}$				$\pm 3\%$	Ck <sub>NOM</sub>
Refresh Rate			275	290	305	μs
Step Response Time	Ts	Filter=0 <sup>(8)</sup> Filter=1 Filter=2		657 <sup>(9)</sup> 876 1095	896 1195 1494	μs
Watchdog	Twd		114.5	118	121.5	ms
Start-up Cycle	Tsu	Analog OUT Slew-rate excluded			5	ms
Analog OUT Slew-rate		Mode 1 from C <sub>OUT</sub> = 47 nF to 330 nF Mode 2 up to C <sub>OUT</sub> = 10 nF Mode 3 up to C <sub>OUT</sub> = 47 nF Mode 4 up to C <sub>OUT</sub> = 330 nF	25 300 17 1.8	37 320 19 2.5		V/ms

<sup>8</sup> See section 14.6 for details concerning Filter parameter

<sup>9</sup> This represents a theoretical average response time

**PWM OUTPUT** - DC Operating Parameters at Nominal Supply Voltage  $V_{DD} = V_{PU}$  (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix L.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
PWM Frequency	$F_{PWM}$	Programmable Range (PWM Output Enabled)	100		1000	Hz
		Initial Tolerance (25 Deg.C.)			$\pm 2\%$	$F_{PWM}$
		After EOL tuning (25 Deg.C.)			$\pm 1\%$	$F_{PWM}$
		Thermal/Lifetime drift			$\pm 3\%$	$F_{PWM}$
Start-up Cycle	Tsu	PWM OUT Slew-rate excluded 100Hz		11.8	13	ms
		250Hz		5.8	7	
		1000Hz		5.8	7	
Digital Output Rise Time		LSD – Mode 5				
		4.7nF, $R_L = 1\text{ k}\Omega$ PU		10	12	$\mu\text{s}$
		4.7nF, $R_L = 10\text{ k}\Omega$ PU		100	120	$\mu\text{s}$
		10nF, $R_L = 1\text{ k}\Omega$ PU		20	24	$\mu\text{s}$
		PP – Mode 7				
		4.7nF, $R_L = 1\text{ k}\Omega$ PU		3	5	$\mu\text{s}$
4.7nF, $R_L = 10\text{ k}\Omega$ PU		3	5	$\mu\text{s}$		
10nF, $R_L = 1\text{ k}\Omega$ PU		4	7	$\mu\text{s}$		
Digital Output Fall Time		LSD – Mode 5				
		4.7nF, $R_L = 1\text{ k}\Omega$ PU		2	3	$\mu\text{s}$
		4.7nF, $R_L = 10\text{ k}\Omega$ PU		2	3	$\mu\text{s}$
		10nF, $R_L = 1\text{ k}\Omega$ PU		4	7	$\mu\text{s}$
		PP – Mode 7				
		4.7nF, $R_L = 1\text{ k}\Omega$ PU		2	3	$\mu\text{s}$
4.7nF, $R_L = 10\text{ k}\Omega$ PU		2	3	$\mu\text{s}$		
10nF, $R_L = 1\text{ k}\Omega$ PU		4	7	$\mu\text{s}$		

## 10. MLX90365 Accuracy Specification

**ANALOG OUTPUT** - DC Operating Parameters at Nominal Supply Voltage (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix (E or K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
ADC Resolution on the raw signals sine and cosine <sup>(10)</sup>	R <sub>ADC</sub>			15		bits
Thermal Offset Drift #1 <sup>(11)</sup> at the DSP input (excl. DAC and output stage)		Temperature suffix E Temperature suffix K Temperature suffix L	-60 -60 -90		+60 +60 +90	LSB <sub>15</sub>
Thermal Offset Drift #2 (DAC and Output Stage)			-0.2		+0.2	%VDD
Thermal Drift of Sensitivity Mismatch <sup>(12)</sup>		XY axis – Temp. suffix E XY axis – Temp. suffix K & L XZ (YZ) axis – Temp. suffix E XZ (YZ) axis – Temp. suffix K & L	-0.3 -0.5 -1 -1		+0.3 +0.5 +1 +1	%
Magnetic Angle phase error		T <sub>A</sub> = 25°C – XY axis T <sub>A</sub> = 25°C – XZ axis T <sub>A</sub> = 25°C – YZ axis	-0.3 -2 -2		0.3 2 2	Deg.
Thermal Drift of Magnetic Angle phase error		axis, XZ (YZ) axis		0.01		Deg.
XY – Intrinsic Linearity Error <sup>(13)</sup>	Le	T <sub>A</sub> = 25°C – factory trim. “SMISM”	-1		1	Deg
XZ - Intrinsic Linearity Error <sup>(13)</sup>	Le	T <sub>A</sub> = 25°C – “k” trimmed for XZ	-2.5	±1.25	+2.5	Deg
YZ - Intrinsic Linearity Error <sup>(13)</sup>	Le	T <sub>A</sub> = 25°C – “k” trimmed for YZ	-2.5	±1.25	+2.5	Deg
Analog Output Resolution	R <sub>DAC</sub>	12b DAC (Theoretical, Noise free) INL (before EOL calibration) DNL	-4 0.05	0.025 1	+4 3	%VDD/LSB <sub>12</sub> LSB <sub>12</sub> LSB <sub>12</sub>
Output stage Noise		Clamped Output		0.05	0.075	%VDD
Noise pk-pk <sup>(14)</sup>		Filter = 0, 40mT Filter = 2, 20mT		0.10 0.10	0.2 0.2	Deg
Ratiometry Error (Analog output only)		4.5V ≤ VDD ≤ 5.5V LT4V ≤ VDD ≤ MT7V	-0.05 -0.1		+0.05 +0.1	%VDD

<sup>10</sup> 16 bits corresponds to 15 bits + sign. Internal computation is performed using 16 bits.

<sup>11</sup> For instance, in case of a rotary position sensor application, Thermal Offset Drift #1 equal ± 60LSB<sub>15</sub> yields to max. ± 0.3 Deg. angular error for the computed angular information (output of the DSP). This is only valid if k = 1.

<sup>12</sup> For instance, in case of a rotary position sensor application, Thermal Drift of Sensitivity Mismatch equal ± 0.5% yields to max. ± 0.15 Deg. angular error for the computed angular information (output of the DSP).

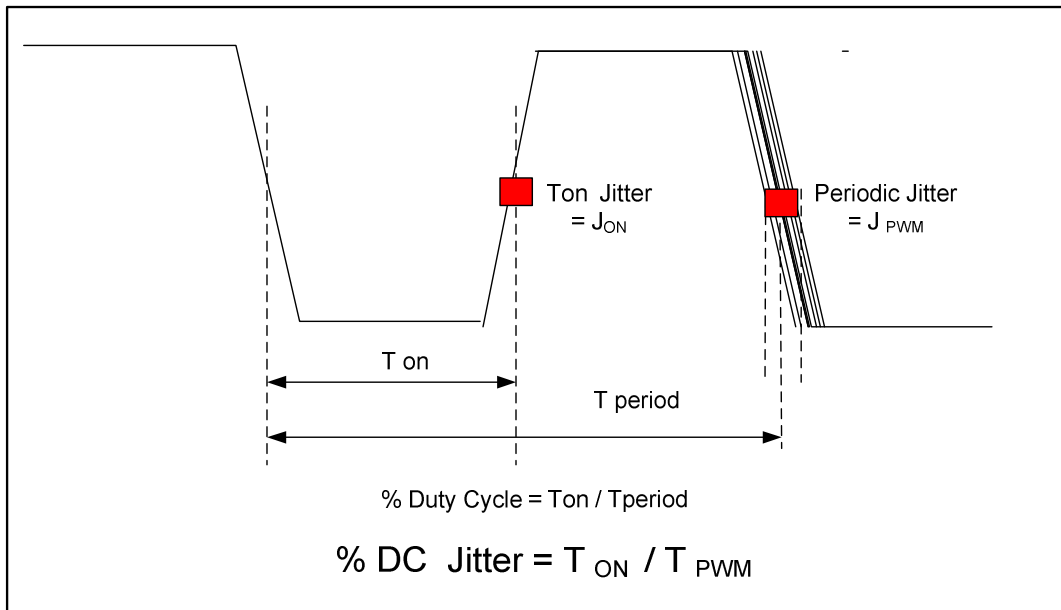
<sup>13</sup> The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) taking into account an ideal rotating field for B<sub>x</sub> and B<sub>y</sub>. Once associated to a practical magnetic construction and the associated mechanical and magnetic tolerances, the output linearity error increases. However, it can be improved with the multi-point end-user calibration.

<sup>14</sup> Noise pk-pk (peak-to-peak) is here intended as 6 times the Noise standard Deviation. The application diagram used is described in the recommended wiring. For detailed information, refer to section Filter in application mode (Section 14.6).

**PWM OUTPUT** - DC Operating Parameters at  $V_{DD} = V_{PU} = 5V$  (unless otherwise specified) and for  $T_A$  as specified by the Temperature suffix L.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
PWM Output Resolution	$R_{PWM}$	12 bits		0.025		%DC/LSB
PWM % DC Jitter	$J_{DC}$	LSD – Mode5 100Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 200Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 1000Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU  PP – Mode7 100Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 200Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 1000Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU		$\pm 0.003$ $\pm 0.005$ $\pm 0.009$  $\pm 0.003$ $\pm 0.005$ $\pm 0.009$	$\pm 0.016$ $\pm 0.02$ $\pm 0.035$  $\pm 0.016$ $\pm 0.02$ $\pm 0.035$	%DC
PWM Freq Jitter	$J_{PWM}$	LSD – Mode5 100-1000 Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU  PP – Mode7 100-1000 Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU		$\pm 0.04$  $\pm 0.04$	$\pm 0.15$  $\pm 0.15$	Hz
PWM % DC thermal drift		LSD – Mode5 100Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 200Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 1000Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU  PP – Mode7 100Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 200Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU 1000Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU		$\pm 0.02$ $\pm 0.02$ $\pm 0.02$  $\pm 0.02$ $\pm 0.02$ $\pm 0.02$	$\pm 0.03$ $\pm 0.03$ $\pm 0.05$  $\pm 0.03$ $\pm 0.03$ $\pm 0.05$	%DC
PWM % DC Level drift (Trigger level= 25/50/75%)		LSD – Mode5 100Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU  PP – Mode7 100Hz, 4.7nF, $R_L = 1\text{ k}\Omega$ PU		$\pm 0.1$  $\pm 0.05$	$\pm 0.15$  $\pm 0.1$	%DC
PWM % DC Level drift		100Hz – PP Application Diagram (see below) $R_s = 0, 50, 100, 150\text{ Ohm}$ Tolerance on R $\pm 20\%$ Tolerance on C $\pm 30\%$		$\pm 0.05$	$\pm 0.1$	%DC

Jitter is defined by  $\pm 3 \sigma$  for 1000 successive acquisitions with clamped output, see also jitter definition.



Parameter	Symbol	Test Conditions
PWM TON, Tperiod	$T_{ON}$ $T_{PWM}$	Trigger level = 50 % Vpp
Rise time, Fall time		10% and 90% of amplitude
Jitter	$J_{on}$ $J_{period}$	$\pm 3 \sigma$ for 1000 successive acquisitions
Duty Cycle	% DC	$T_{on} / T_{Period}$

Figure 7 – MLX90365 PWM measurement conditions.

## 11. MLX90365 Magnetic Specification

DC Operating Parameters at Nominal Supply Voltage (unless otherwise specified) and for TA as specified by the Temperature suffix (E or K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Magnetic Flux Density	B <sub>X</sub> , B <sub>Y</sub> <sup>(15)</sup>	$\sqrt{B_X^2 + B_Y^2}$			70 <sup>(16)</sup>	mT
Magnetic Flux Density	B <sub>Z</sub>				126	mT
Magnetic Flux Norm	Norm	$\sqrt{B_X^2 + B_Y^2 + (B_Z/1.2)^2}$	20 <sup>(17)</sup>			mT
IMC Gain	GainIMC		1.2	1.3	1.4	
Magnet Temperature Coefficient	TCm		-2400		0	ppm/°C

## 12. MLX90365 CPU & Memory Specification

The DSP is based on a 16 bit RISC µController. This CPU provides 2.5 Mips while running at 10 MHz.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
ROM				10		KB
RAM				384		B
EEPROM				128		B

<sup>15</sup> The condition must be fulfilled for at least one field BX or BY.

<sup>16</sup> Above 70 mT, the IMC® starts saturating yielding to an increase of the linearity error.

<sup>17</sup> Below 20 mT, the performances slightly degrade due to a reduction of the signal-to-noise ratio, signal-to-offset ratio.



## 13. MLX90365 End-User Programmable Items

Parameter	Comments	Default Values		
		Standard	PPAR	# bit
OUT mode	Define the output stage mode	1	1	3
DIAG mode	Diagnostic mode	7	7	3
DIAG Level	Diagnostic Level	0	0	1
MAPXYZ	Mapping fields for output angle	0	0	2
CLAMP_HIGH	Clamping High (50%)	50%	10%	16
CLAMP_LOW	Clamping Low (50%)	50%	90%	16
FILTER	Filter mode selection	0	1	2
SMISM	Sensitivity mismatch factor X,Y	MLX	MLX	15
k	Sensitivity mismatch factor X (Y) , Z	MLX	N/A	15
SEL_k	Affected signal component by k: B1 or B2 (in combination of MAPXYZ)	0	0	1
GAINMIN	Low threshold for virtual gain	00h	00h	8
GAINMAX	High threshold for virtual gain	28h	28h	8
GAINSATURATION	Gain Saturates on GAINMIX and GAINMAX	0h	0h	1
FIELDTHRESH_Low	Field limit under which a fault is reported	10mT	10mT	8
FIELDTHRESH_High	Field limit above which a fault is reported	FFh	FFh	8
PWM	PWM function	0h	N/A	1
PWMPOL	PWM polarity	0h	N/A	1
PWMT	PWM Frequency ( trimmed at 200Hz )	MLX	N/A	8
DC_FAULT	PWM Duty Cycle if Fault	1h	N/A	8
DC_FTL	PWM Duty Cycle if Field Strength Too Low	1h	N/A	8
DC_WEAK	PWM Duty Cycle if Weak Magnet	1h	N/A	8
WEAKMAGTHRESH	Weak Magnet threshold Byte (1lsb = 1mT)	0h	N/A	8
DP	Discontinuity point	0h	0h	15
CW	Clock Wise	0h	0h	1
FHYST	Hysteresis filter	0h	0h	8
MELEXISID1	Melexis identification reference	MLX	MLX	16
MELEXISID2	Melexis identification reference	MLX	MLX	16
MELEXISID3	Melexis identification reference	MLX	MLX	16
4POINTS	Selection of correction method 4 or 16 pts	1h	1h	1
LNR_S0	4pts – Initial Slope	0 %/deg	0 %/deg	16
LNR_A_X	4pts – AX Coordinate	0 deg	0 deg	16
LNR_A_Y	4pts – AY Coordinate	10 %	10 %	16
LNR_A_S	4pts – AS Coordinate	0.22%/deg	0.22%/deg	16
LNR_B_X	4pts – BX Coordinate	360 deg	360 deg	16
LNR_B_Y	4pts – BY Coordinate	100%	100%	16
LNR_B_S	4pts – BS Coordinate	0 %/deg	0 %/deg	16
LNR_C_X	4pts – CX Coordinate	360 deg	360 deg	16
LNR_C_Y	4pts – CY Coordinate	100%	100%	16
LNR_C_S	4pts – CS Coordinate	0 %/deg	0 %/deg	16
LNR_D_X	4pts – DX Coordinate	360 deg	360 deg	16
LNR_D_Y	4pts – DY Coordinate	100%	100%	16
LNR_D_S	4pts – DS Coordinate	0 %/deg	0 %/deg	16
W	17pts – Output angle range	0h	N/A	4
USERID1	Cust. id reference	Bin1	Bin1	16

USERID2	Cust. id reference	204h	3h	16
USERID3	Cust. id reference	MLX	MLX	16
LNR_Yn	17pts – Y-coordinate point n (n = 2,1,2 ...16)	N/A	N/A	16
DIAG Settings	16 Bit Diagnostics enabling	FDFh	4080h	16
CRC_DISABLE	Enable EERPOM CRC check ( 3131h= disable)	0h	0h	16
MEMLOCK	Write-protects USER/MLX EEPROM param.	0h	3h	2

Note: Ordering Information for PPAR: MLX90365EDC-ABD-000-RE or TU

## 14. Description of End-User Programmable Items

### 14.1. Output modes

#### 14.1.1. OUT mode

Defines the Output Stage mode (analog, digital, high-impedance, standby) in application.

Output mode[2:0]	Type	Descriptions	Comments
0	Disable	Output HiZ	Not recommended
1	Analog	Analog Rail-to-Rail for $C_{out_{min}} = 47nF$	Analog Only (Default)
2	Analog	Analog Rail-to-Rail for $C_{out_{max}} = 10nF$	Analog Only
3	Analog	Analog Rail-to-Rail for $C_{out_{max}} = 68nF$	Analog Only
4	Analog	Analog Rail-to-Rail for $C_{out_{max}} = 330nF$	Analog Only
5	Digital	open drain NMOS	PWM
6	Digital	open drain PMOS	PWM
7	Digital	Push-Pull	PWM

#### 14.1.2. PWM Output Mode

If PWM output mode is selected, the output signal is a digital signal with Pulse Width Modulation (PWM). The PWM polarity is selected by the PWMPOL parameter:

- PWMPOL = 1 for a low level at 100%
- PWMPOL = 0 for a high level at 100%

The PWM frequency is selected by the PWMT parameter. The following table provides typical code for different target PWM frequency and for both low and high speed modes.

PWW F (Hz)	PWMT (LSB) @13.3MHz	PWM res. (us)	PWM res. (%)	PWM res. (bit)
100	44333	0.240	0.0024	15.0
250	17733	0.240	0.006	14.0
500	8866	0.240	0.012	13.0
1000	4433	0.240	0.024	12.0

#### Notes:

- A more accurate trimming can be performed to take into account initial tolerance of the main clock.
- The PWM frequency is subjected to the same tolerances as the main clock (see  $\Delta^T Ck$ ).

## 14.2. Output Transfer Characteristic

There are 2 different possibilities to define the transfer function (LNR):

- With 4 arbitrary points (defined on X and Y coordinates) and 5 slopes
- With 17 equidistant points for which only the Y coordinates are defined.

Parameter	LNR type	Value	Unit
<b>CLOCKWISE</b>	<b>Both</b>	<b>0 → CounterClockWise 1 → ClockWise</b>	<b>LSB</b>
DP	Both	0 ... 359.9999	deg
LNR_A_X LNR_B_X LNR_C_X LNR_D_X	Only 4 pts	0 ... 359.9999	deg
LNR_A_Y LNR_B_Y LNR_C_Y LNR_D_Y	Only 4 pts	0 ... 100	%
LNR_S0 LNR_A_S LNR_B_S LNR_C_S LNR_D_S	Only 4 pts	-17 ... 0 ... 17	%/deg
LNR_Y0 LNR_Y1 ... LNR_Y16	Only 17 pts	-50 ... + 150	%
W	Only 17 pts	65.5 ... 360	Deg
CLAMP_LOW	Both	0 ... 100	%
CLAMP_HIGH	Both	0 ... 100	%

### 14.2.1. Enable scaling Parameter (only for LNR type 4 pts)

This parameter enables to scale LNR\_x\_Y from -50% - 150% according to the following formula

$$(\text{Scaled Out})\%V_{DD} = 2 \times \text{Out}\%V_{DD} - 50\%$$

### 14.2.2. CLOCKWISE Parameter

The CLOCKWISE parameter defines the magnet rotation direction.

- CCW is the defined by the 1-4-5-8 pin order direction for the SOIC8 package and 1-8-9-16 pin order direction for the TSSOP16 package.
- CW is defined by the reverse direction: 8-5-4-1 pin order direction for the SOIC8 and 16-9-8-1 pin order direction for the TSSOP16 package.

Refer to the drawing in the sensitive spot positioning sections (Section 19.3)

### 14.2.3. Discontinuity Point (or Zero Degree Point)

The Discontinuity Point defines the 0° point on the circle. The discontinuity point places the origin at any location of the trigonometric circle. The DP is used as reference for all the angular measurements.

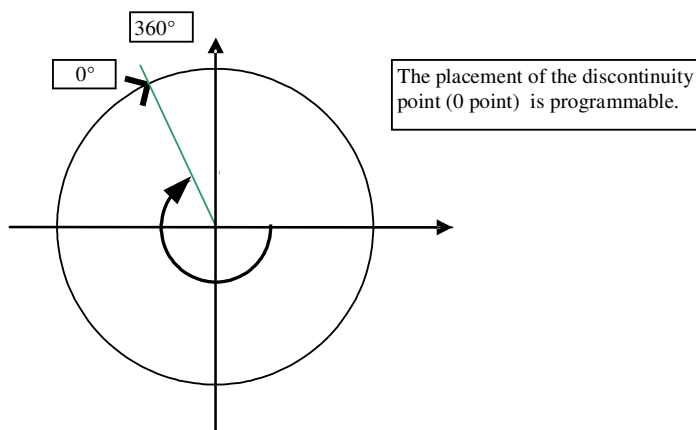


Figure 8 - Discontinuity Point Positioning

### 14.2.4. 4-Pts LNR Parameters

The LNR parameters, together with the clamping values, fully define the relation (the transfer function) between the digital angle and the output signal.

The shape of the MLX90365 transfer function from the digital angle value to the output voltage is described by the drawing below. Six segments can be programmed but the clamping levels are necessarily flat.

Two, three, or even six calibration points are then available, reducing the overall non-linearity of the IC by almost an order of magnitude each time. Three to six calibration points will be preferred by customers looking for excellent non-linearity figures. Two-point calibrations will be preferred by customers looking for a cheaper calibration set-up and shorter calibration time.

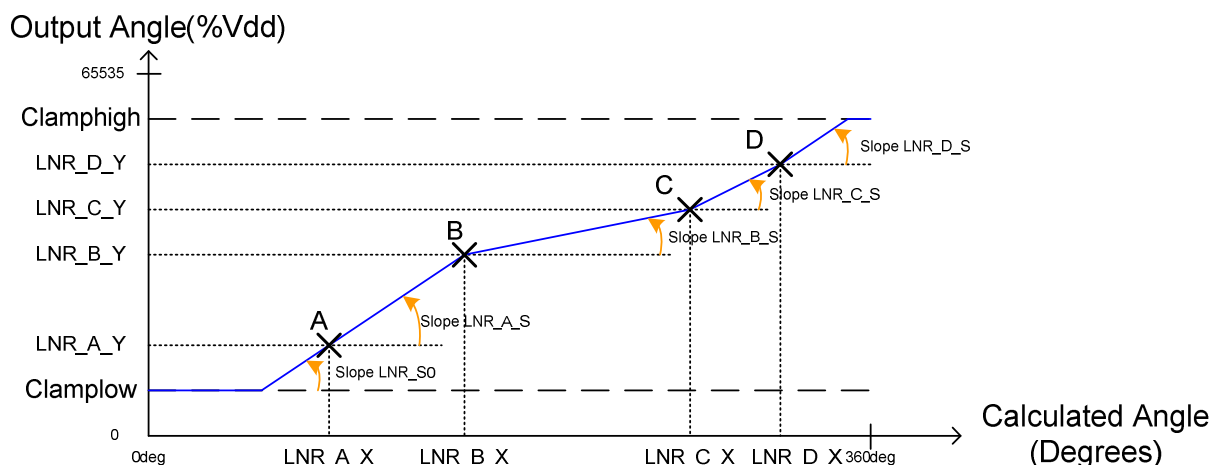


Figure 9

### 14.2.5. 17-Pts LNR Parameters

The LNR parameters, together with the clamping values, fully define the relation (the transfer function) between the digital angle and the output signal.

The shape of the MLX90365 transfer function from the digital angle value to the output voltage is described by the drawing below. In the 16-Pts mode, the output transfer characteristic is Piece-Wise-Linear (PWL).

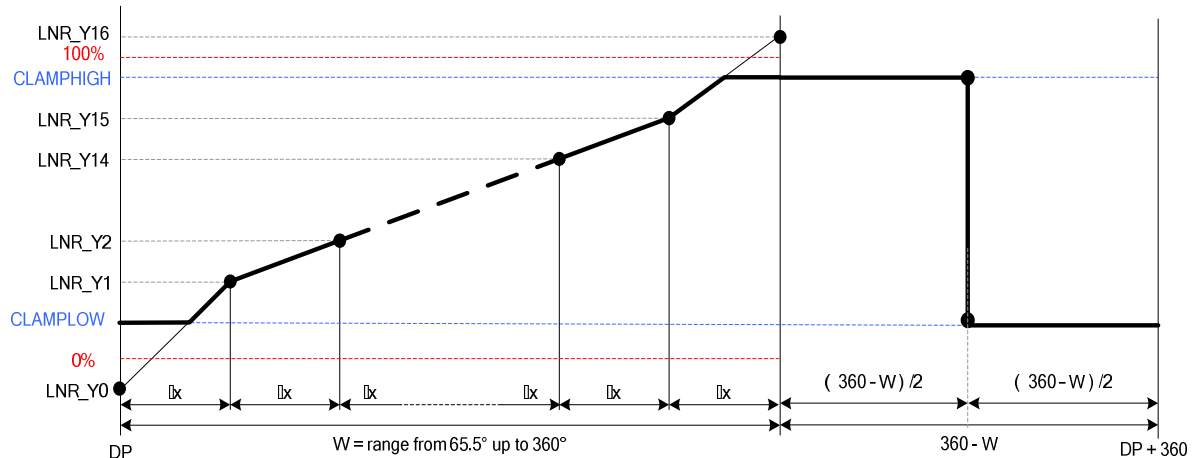


Figure 10 - Input range from 65.5° up to 360°

All the Y-coordinates can be programmed from -50% up to +150% to allow clamping in the middle of one segment (like on the figure), but the output value is limited to CLAMPLOW and CLAMPHIGH values.

Between two consecutive points, the output characteristic is interpolated.

The parameter W determines the input range on which the 17 points (16 segments) are uniformly spread:

W	Range	Δx
0 (0000b)	360.0deg	22.5deg
1	320.0deg	20.0deg
2	288.0deg	18.0deg
3	261.8deg	16.4deg
4	240.0deg	15.0deg
5	221.5deg	13.8deg
6	205.7deg	12.9deg
7	192.0deg	12.0deg

W	Range	Δx
8	180.0deg	11.3deg
9	144.0deg	9.0deg
10	120.0deg	7.5deg
11	102.9deg	6.4deg
12	90.0deg	5.6deg
13	80.0deg	5.0deg
14	72.0deg	4.5deg
15 (1111b)	65.5deg	4.1deg

Outside of the selected range, the output will remain in clamping levels.

### 14.2.6. CLAMPING Parameters

The clamping levels are two independent values to limit the output voltage range. The CLAMPLOW parameter adjusts the minimum output voltage level. The CLAMPHIGH parameter sets the maximum output voltage level. Both parameters have 16 bits of adjustment and are available for both LNR modes. In analog mode, the resolution will be limited by the D/A converter (12 bits) to 0.024%V<sub>DD</sub>. In PWM mode, the resolution will be 0.024%DC.

### 14.3. Identification

Parameter	Value
MELEXISID1	0 ... 65535
MELEXISID2	0 ... 65535
MELEXISID3	0 ... 65535
USERID1	0 ... 65535
USERID2	0 ... 65535
USERID3	0 ... 65535

Identification number: 48 bits (3 words) freely useable by Customer for traceability purpose.

### 14.4. Lock

The MEMLOCK write protects all the EEPROM parameters set by the Melexis and user. Once the lock is enabled, it is not possible to change the EEPROM values anymore. Note that the Memlock bits should be set by the solver function "MemLock".

### 14.5. Sensor Front-End

Parameter	Value
MAPXYZ	0..3
SMISM	0 .. 32768
k	0 .. 32768
SEL_k	0 or 1
GAINMIN	0 ... 41
GAINMAX	0 ... 41
GAINSATURATION	0.. 1

#### 14.5.1. MAPXYZ

The MAPXYZ parameter defines which fields are used to calculate the angle. The different possibilities are described in the tables below. This 2 bits value selects the first (B1) and second (B2) field components according the table below.

MAPXYZ	B1	B2	Angular
0 – 00b	X	Y	XY mode
1 – 01b	Zx	X	XZx mode
2 – 10b	Y	Zx	YZx mode
3 – 11b	Y	Zy	YZy mode

Note: MAPXYZ = 3 is not recommended.

#### 14.5.2. SMISM, k and SEL\_k Parameters

##### (i) SMISM

When the mapping (B1=X, B2=Y) is selected, SMISM defines the sensitivity mismatch factor that is applied on B1, B2; When another B1, B2 mapping is selected, this parameter is “don’t care”. This parameter is trimmed at factory; Melexis strongly recommends TO NOT overwrite it for optimal performances.

##### (ii) k

When the mapping (B1=X, B2=Y) is **NOT** selected, k defines the sensitivity mismatch factor that is applied on B1 or B2 (according to parameter SEL\_k – see below). When the mapping (B1=X, B2=Y) is selected, this parameter is “don’t care”.

This parameter is trimmed at factory for mapping (B1=Z, B2=X). Melexis recommends to fine trim it when a smaller linearity error (Le) is required and a different mapping than (B1=X, B2=Y) is selected.

##### (iii) SEL\_k

When the mapping (B1=X, B2=Y) is **NOT** selected, SEL\_k defines the component on which the sensitivity mismatch factor k (see above): SEL\_k = 0 means  $B1 \rightarrow k \cdot B1$  and SEL\_k = 1 means  $B2 \rightarrow k \cdot B2$ .

#### 14.5.3. GAINMIN and GAINMAX Parameters

GAINMIN and GAINMAX define the thresholds on the gain code outside which the fault “GAIN out of Spec.” is set;

If GAINSATURATION is set, then the virtual gain code is saturated at GAINMIN and GAINMAX, and no Diagnostic fault is set since the saturations applies before the Diag. check.

### 14.6. Filter

Parameter	Value
FILTER	0 ... 2
FHYST	0 ... 255

The MLX90365 includes 2 types of filters:

- Hysteresis Filter: programmable by the FHYST parameter
- Low Pass FIR Filters controlled with the FILTER parameter

### 14.6.1. Hysteresis Filter

The FHYST parameter is a hysteresis filter. The output value of the IC is not updated when the digital step is smaller than the programmed FHYST parameter value. The output value is modified when the increment is bigger than the hysteresis. The hysteresis filter reduces therefore the resolution to a level compatible with the internal noise of the IC. The hysteresis must be programmed to a value close to the noise level. ( 1 lsb = +/- 0.012%)

### 14.6.2. FIR Filters

The MLX90365 features 2 FIR filter modes controlled with Filter = 1...2. Filter = 0 corresponds to no filtering. The transfer function is described below:

$$y_n = \frac{1}{\sum_{i=0}^j a_i} \sum_{i=0}^j a_i x_{n-i}$$

The filters characteristic is given in the following table:

Filter No	0	1	2
J	0	1	3
Type	Disable	Finite Impulse Response	
Coefficients a <sub>i</sub>	1	11	1111
Title	No filter	ExtraLight	Light
99% Response Time	1	2	4
Efficiency RMS (dB)	0	3.0	6.0

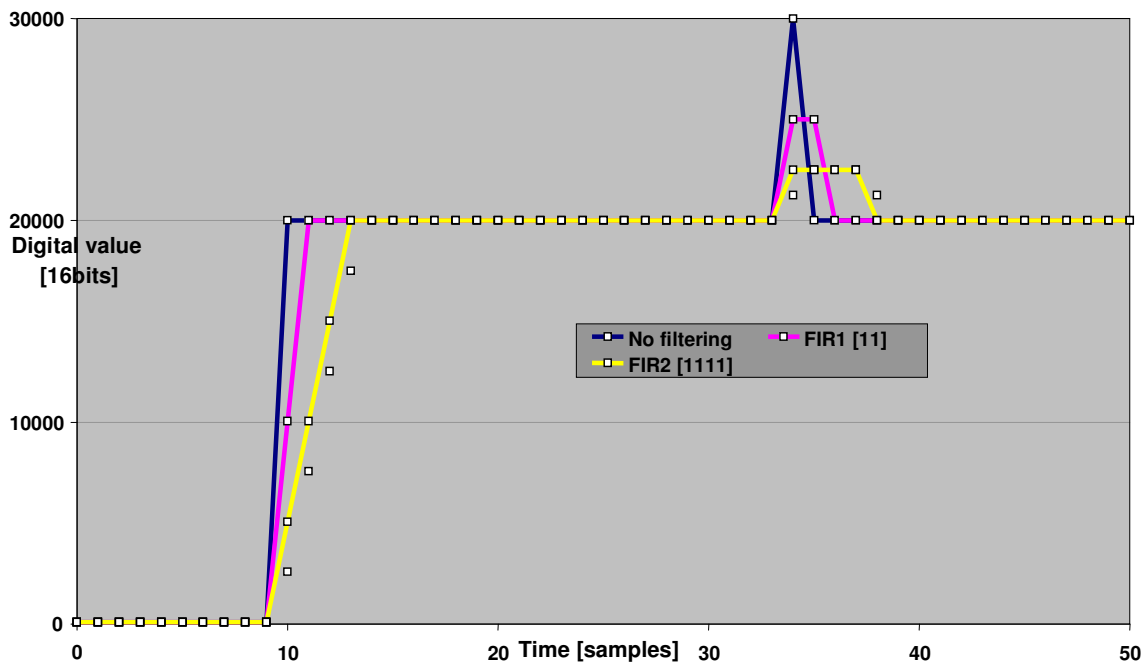


Figure 11 - Step and impulse response of the different filters



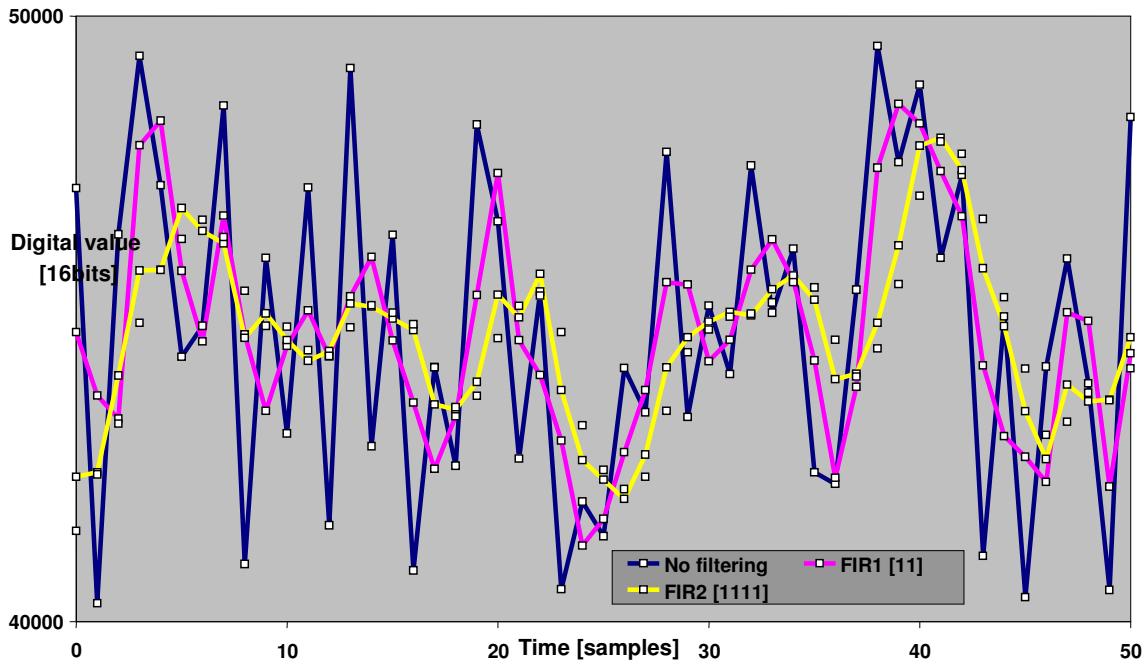


Figure 12 - Noise response of the different filter

## 14.7. Programmable Diagnostic Settings

### 14.7.1. DIAG mode

Defines the Output Stage mode in case of Diag.

DIAG mode [2:0]	Type	Descriptions	Comments
0	Disable	Output HiZ	Not recommended
5	Digital	open drain NMOS	
6	Digital	open drain PMOS	
7	Digital	Push-Pull	

### 14.7.2. DIAG Level

Determines the reporting level (diagnostic low, diagnostic high) during start-up (both analog and PWM mode), or during a fault reporting (Only in Analog mode).

In PWM mode, the fault reporting level shall in principle be 0 when the leading edge is a rising edge, (resp. 1 for a falling edge) in order to detect the first cycle after start-up. MLX recommends then DIAG Level = PWMPOL.

---

### 14.7.3. Field Strength Diagnostic

(i) FIELDTHRESHLOW

Defines the field strength limit under which a fault is reported.  
The run-time field strength estimation (FieldStrength) is compared to  $2^8 * \text{FIELDTHRESHLOW}$ .  
The sensitivity of FIELDTHRESHLOW is typically 1mT/LSB. By default it is programmed to 10mT

(ii) FIELDTHRESHHIGH

Defines the field strength limit under which a fault is reported. See above for more details.

### 14.7.4. PWM Diagnostic

(i) DC FAULT

Defines the duty-cycle that is outputted in case of diagnostic reporting.

(ii) WEAKMAGTHRESH

Defines the threshold on the field strength which determines the weak magnet condition; when WEAKMAGTHRESH = 0, there is no reporting of weak magnet condition.

(iii) DC FTL

Defines the duty-cycle that is outputted in case of Field Too Low; the Field Too Low Diagnostic is stronger than the Weak Magnet Diagnostic, from 0% till 255% by steps of (100/256)%

(iv) DC WEAK

Defines the duty-cycle that is outputted in case of Weak Magnet, from 0% till 255% by steps of (100/256)%

### 14.7.5. Diagnostic Features

It is recommended to enable the diagnostic features for safety critical applications.  
Refer to Application\_note\_Diagnostic\_Behavior\_90365 for EE\_CRC\_Enable function description and for Diagnostic features which can be enabled by user.

## 14.8. EEPROM endurance

Although the EEPROM is used for Calibration Data Storage (similarly to an OTPROM), the MLX90365 embedded EEPROM is qualified to guarantee an endurance of minimum 1000 write cycles at 125°C for (engineering/calibration purpose).