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Features and Benefits

- Absolute 3D Position Sensor
- Simple & Robust Magnetic Design
- Tria⊗is® Hall Technology
- Programmable Linear Transfer Characteristics (Alpha, Beta)
- Selectable Analog (Ratiometric), PWM, Serial Protocol
- 12 bit Angular Resolution - 10 bit Angular Thermal Accuracy
- 40 bit ID Number
- Single Die – SO8 Package RoHS Compliant
- Dual Die (Full Redundant) – TSSOP16 Package RoHS Compliant

Applications

- 3D Position Sensor
- Joystick
- 4-Way Scroll Key
- Joypad
- Man Machine Interface Device
- Linear Position Sensor

Ordering Code

Product Code	Temperature Code	Package Code	Option Code	Packing Form Code
MLX90333	S	DC	BCH-000	RE
MLX90333	S	DC	BCH-000	TU
MLX90333	E	DC	BCH-000	RE
MLX90333	E	DC	BCH-000	TU
MLX90333	E	DC	BCH-100	RE
MLX90333	E	DC	BCH-100	TU
MLX90333	E	DC	BCT-000	RE
MLX90333	E	DC	BCT-000	TU
MLX90333	K	DC	BCH-000	RE
MLX90333	K	DC	BCH-100	TU
MLX90333	K	DC	BCH-100	RE
MLX90333	K	DC	BCT-000	RE
MLX90333	K	DC	BCT-000	TU
MLX90333	L	DC	BCH-000	RE
MLX90333	L	DC	BCH-000	TU
MLX90333	L	DC	BCT-000	RE
MLX90333	L	DC	BCT-000	TU
MLX90333	L	DC	BCH-100	RE
MLX90333	L	DC	BCH-100	TU
MLX90333	L	GO	BCH-000	TU
MLX90333	L	GO	BCH-000	RE
MLX90333	E	GO	BCH-000	RE
MLX90333	E	GO	BCH-000	TU
MLX90333	E	GO	BCH-100	RE
MLX90333	E	GO	BCH-100	TU
MLX90333	E	GO	BCT-000	RE
MLX90333	E	GO	BCT-000	TU
MLX90333	K	GO	BCH-000	RE
MLX90333	K	GO	BCH-000	TU

MLX90333	K	GO	BCH-100	RE
MLX90333	K	GO	BCH-100	TU
MLX90333	K	GO	BCT-000	RE
MLX90333	K	GO	BCT-000	TU
MLX90333	L	GO	BCH-100	TU
MLX90333	L	GO	BCH-100	RE
MLX90333	L	GO	BCT-000	RE
MLX90333	L	GO	BCT-000	TU

Legend:

Temperature Code:	L for Temperature Range -40°C to 150°C K for Temperature Range -40°C to 125°C S for Temperature Range -20°C to 85°C E for Temperature Range -40°C to 85°C
Package Code:	GO for TSSOP16 DC for SOIC8
Option Code:	AAA-xxx: Die version xxx-000: Standard version xxx-100: SPI version
Packing Form:	RE for Reel, TU for Tube

Ordering example: **MLX90333LGO-BCH-000-TU**

1. Functional Diagram

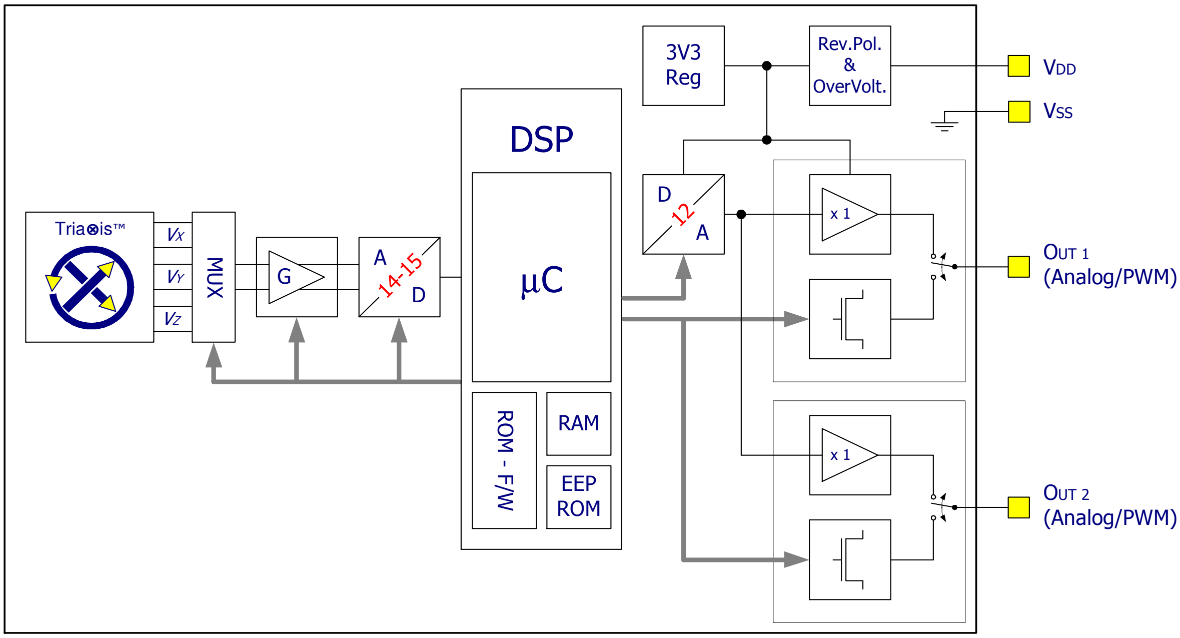

Figure 1 - Block Diagram (Analog & PWM)

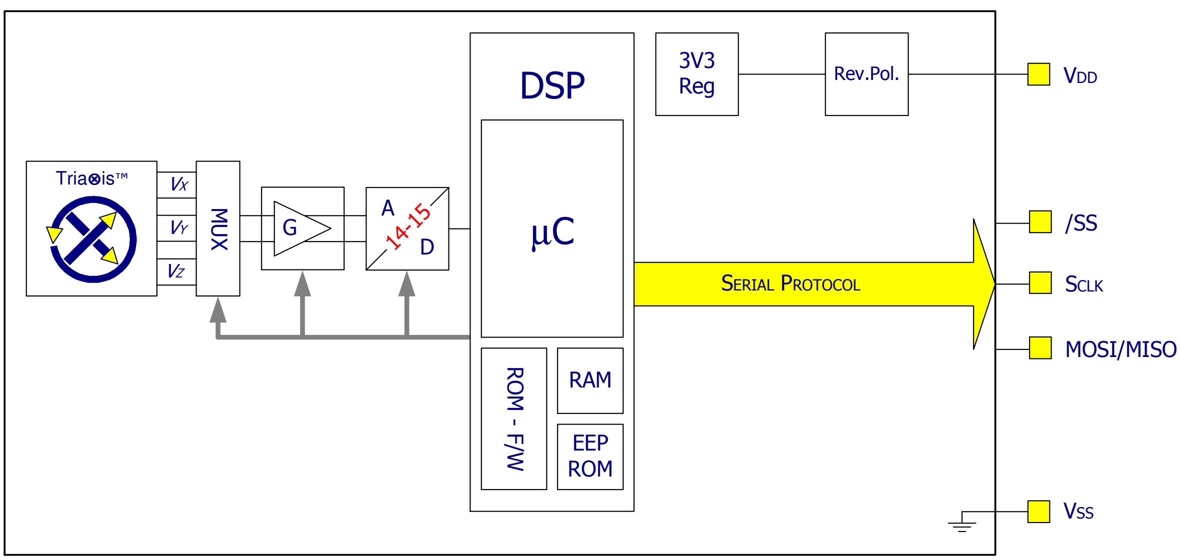

Figure 2 - Block Diagram (Serial Protocol)

1. Description

The MLX90333 is a monolithic sensor IC featuring the Tria⊗is® Hall technology. Conventional planar Hall technology is only sensitive to the flux density applied orthogonally to the IC surface. The Tria⊗is® Hall sensor is also sensitive to the flux density applied parallel to the IC surface. This is obtained through an Integrated Magneto-Concentrator (IMC®) which is deposited on the CMOS die (as an additional back-end step).

The MLX90333 is sensitive to the 3 components of the flux density applied to the IC (B_X, B_Y and B_Z). This allows the MLX90333 to sense any magnet moving in its surrounding and it enables the design of novel generation of non-contacting joystick position sensors which are often required for both automotive and industrial applications (e.g. man-machine interface).

Furthermore, the capability of measuring B_X, B_Y and B_Z allows the MLX90333 to be considered as universal non-contacting position sensor i.e. not limited to joystick applications. For instance, a linear travel can be sensed with the MLX90333 once included in a specific magnetic design.

In combination with the appropriate signal processing, the magnetic flux density of a small magnet (axial magnetization) moving above the IC can be measured in a non-contacting way (Figure 3). The two (2) angular information are computed from the three (3) vector components of the flux density (i.e. B_X, B_Y and B_Z). MLX90333 reports two (2) linear output signals. The output formats are selectable between Analog, PWM and Serial Protocol.

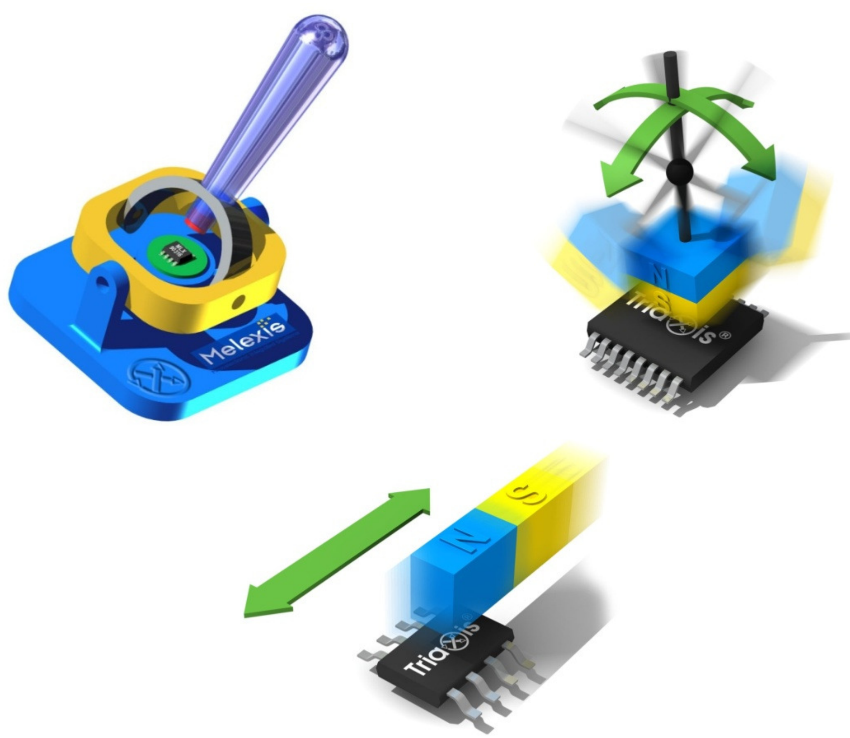

Figure 3 - Typical application of MLX90333

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2. 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**onnected
- 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
- ATAN: trigonometric function: arctangent (or inverse tangent)
- IMC: **I**ntegrated **M**agneto-**C**oncentrator (IMC®)
- CoRDiC: **Co**ordinate **R**otation **Di**gital **C**omputer (i.e. iterative rectangular-to-polar transform)
- EMC: **E**lectro-**M**agnetic **C**ompatibility

3. Pinout[1]

Pin #	SOIC-8		TSSOP-16	
	Analog / PWM	Serial Protocol	Analog / PWM	Serial Protocol
1	VDD	VDD	V_{DIG1}	V_{DIG1}
2	Test 0	Test 0	V_{SS1} (Ground$_1$)	V_{SS1} (Ground$_1$)
3	Not Used	/SS	V_{DD1}	V_{DD1}
4	Out 2	SCLK	Test 0_1	Test 0_1
5	Out 1	MOSI / MISO	Not Used	$/SS_2$
6	Test 1	Test 1	Out 2_2	$SCLK_2$
7	VDIG	VDIG	Out 1_2	$MOSI_2$ / $MISO_2$
8	VSS (Ground)	VSS (Ground)	Test 1_2	Test 1_2
9			V_{DIG2}	V_{DIG2}
10			V_{SS2} (Ground$_2$)	V_{SS2} (Ground$_2$)
11			V_{DD2}	V_{DD2}
12			Test 0_2	Test 0_2
13			Not Used	$/SS_1$
14			Out 2_1	$SCLK_1$
15			Out 1_1	$MOSI_1$ / $MISO_1$
16			Test 1_1	Test 1_1

For optimal EMC behavior, it is recommended to connect the unused pins (Not Used and Test) to the Ground (see section 15)

[1] See Section 13.1 for the Out 1 and Out 2 configuration

4. Absolute Maximum Ratings

Parameter	Value
Supply Voltage, V_{DD} (overvoltage)	+ 20 V
Reverse Voltage Protection	– 10 V
Positive Output Voltage (Analog or PWM) Both outputs OUT 1 & OUT 2	+ 10 V + 14 V (200 s max – T_A = + 25°C)
Output Current (I_{OUT})	± 30 mA
Reverse Output Voltage Both outputs OUT 1 & OUT 2	– 0.3 V
Reverse Output Current Both outputs OUT 1 & OUT 2	– 50 mA
Operating Ambient Temperature Range, T_A	– 40°C … + 150°C
Storage Temperature Range, T_S	– 40°C … + 150°C
Magnetic Flux Density	± 4 T

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

5. Detailed Description

As described on the block diagram (Figure 1 and Figure 2), the magnetic flux density applied to the IC is sensed through the Tria⊗is® sensor front-end. This front-end consists into two orthogonal pairs (for each of the two directions parallel with the IC surface i.e. X and Y) of conventional planar Hall plates (sensitive element – blue area on Figure 4) and an Integrated Magneto-Concentrator (IMC® yellow disk on Figure 4).

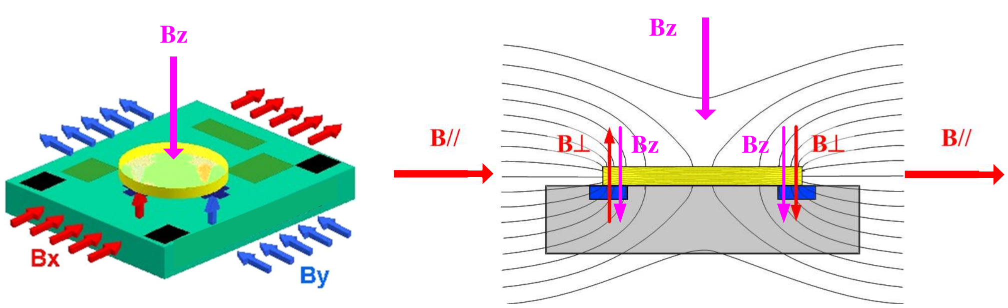


Figure 4 - Tria⊗is® sensor front-end (4 Hall plates + IMC® disk)

Two orthogonal components (respectively $B_{X\perp}$ and $B_{Y\perp}$) proportional to the parallel components (respectively $B_{X//}$ and $B_{Y//}$) are induced through the IMC and can be measured by both respective pairs of conventional planar Hall plates as those are sensitive to the flux density applied orthogonally to them and the IC surface. The third component B_Z is also sensed by those four (4) conventional Hall plates as shown above.

In summary, along X-axis, the left Hall plate measures “$B_{X\perp}$ - B_Z” while the right Hall plate measures “-$B_{X\perp}$ - B_Z”. Similarly, along the Y-axis, the left Hall plate measures “$B_{Y\perp}$ - B_Z” while the right Hall plate measures “-$B_{Y\perp}$ - B_Z”.

Through an appropriate signal processing, the Tria⊗is® sensor front-end reports the three (3) components of the applied magnetic flux density B i.e. B_X, B_Y and B_Z.

Indeed, by subtracting the signals from the two (2) Hall plates in each pair, the components $B_{X\perp}$ and $B_{Y\perp}$ are measured while B_Z is cancelled. To the contrary, by adding the signals from the two (2) Hall plates in each pair, the component B_Z is measured while $B_{X\perp}$ and $B_{Y\perp}$ are cancelled

In a joystick based on a “gimbal” mechanism as shown on Figure 3 (left), the magnet (axial magnetization) moves on a hemisphere centered at the IC. The flux density is described through the following relationships:

$$B_X = COS(\alpha) \cdot SIN(\beta)$$
$$B_Y = SIN(\alpha) \cdot COS(\beta)$$
$$B_Z = SIN(\alpha) \cdot SIN(\beta)$$

Those components are plotted on the Figure 5, Figure 6 and Figure 7.

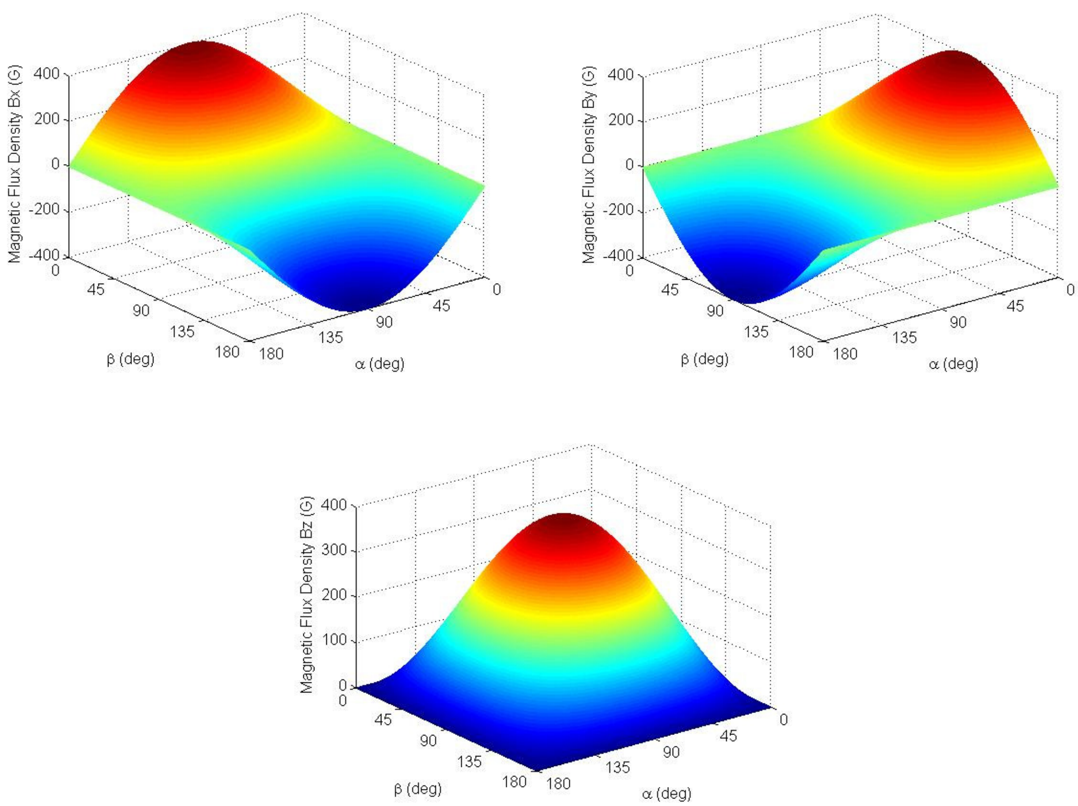


Figure 5 – Magnetic Flux Density – B_X, B_Y, B_Z

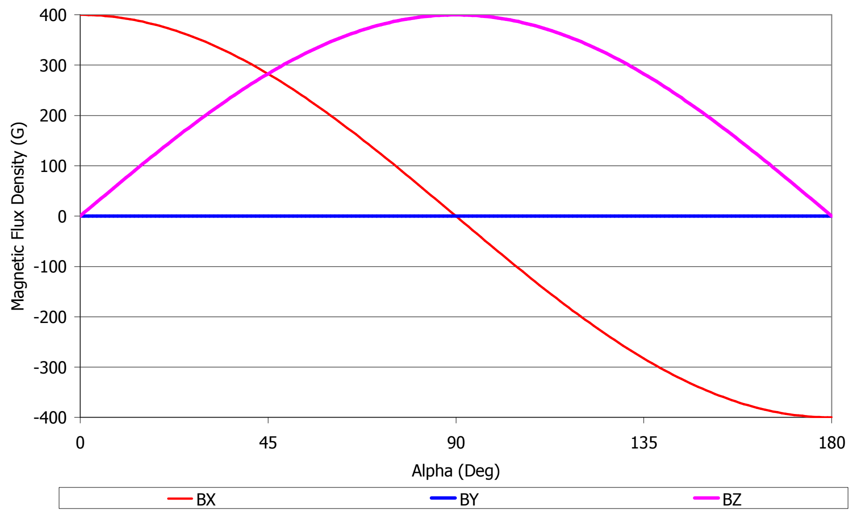


Figure 6 – Magnetic Flux Density – β = 90 Deg – $B_X \propto \cos(\alpha)$, $B_Y = 0$ & $B_Z \propto \sin(\alpha)$

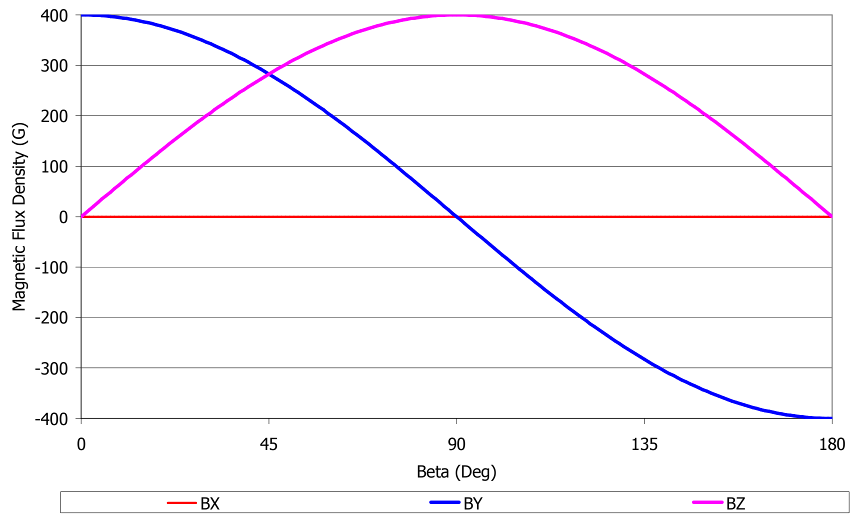


Figure 7 – Magnetic Flux Density – α = 0 Deg – $B_X = 0$, $B_Y \propto \cos(\beta)$ & $B_Z \propto \sin(\beta)$

Three (3) differential voltages corresponding to the three (3) components of the applied flux density are provided to the ADC (Analog-to-Digital Converter – Figure 8 and Figure 9). The Hall signals are processed through a fully differential analog chain featuring the classic offset cancellation technique (Hall plate quadrature spinning and chopper-stabilized amplifier).

The amplitude of V_Z is smaller than the other two (2) components V_X and V_Y due to fact that the magnetic gain of the IMC only affects the components parallel to the IC surface.

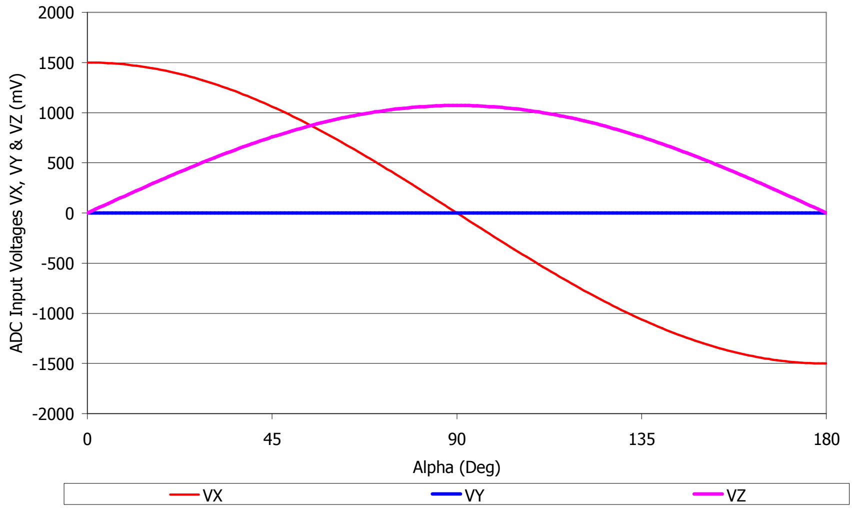


Figure 8 – ADC Input Signals – β = 90 Deg – $V_X \propto B_X \propto \cos(\alpha)$, $V_Y = B_Y = 0$ & $V_Z \propto B_Z \propto \sin(\alpha)$

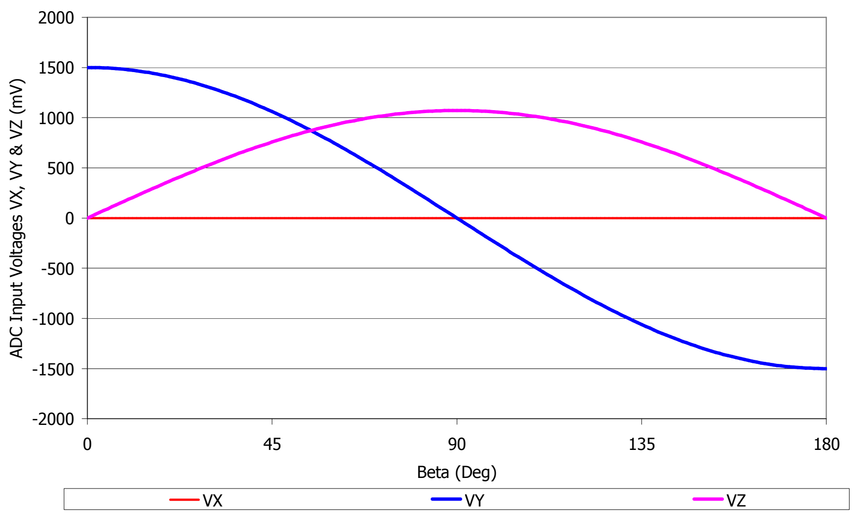


Figure 9 – ADC Input Signals – α = 90 Deg – $V_X = B_X = 0$, $V_Y \propto B_Y \propto \cos(\beta)$ & $V_Z \propto B_Z \propto \sin(\beta)$

The conditioned analog signals are converted through an ADC (configurable – 14 or 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 two (2) angular information from the three (3) raw signals (after so-called front-end compensation steps) through the following operations:

$$\alpha = ATAN\left(\frac{k_Z V_Z}{V_X}\right)$$

$$\beta = ATAN\left(\frac{k_Z V_Z}{V_Y}\right)$$

where k_Z is a programmable parameter. First of all, k_Z is used to compensate the smaller amplitude of V_Z vs. V_X & V_Y. On the other hand, k_Z allows also a targeted reduction of the linearity error through a normalization of the raw signals prior to performing the "ATAN" function.

In a joystick based on a "ball & socket" joint as shown on Figure 3 (right), the magnet (axial magnetization) moves on a hemisphere centered at the pivot point. The flux density is described through slightly more complex equations but the MLX90333 offers an alternate algorithm to extract both angular informations:

$$\alpha = ATAN\left(\frac{\sqrt{(k_Z V_Z)^2 + (k_t V_Y)^2}}{V_X}\right)$$

$$\beta = ATAN\left(\frac{\sqrt{(k_Z V_Z)^2 + (k_t V_X)^2}}{V_Y}\right)$$

where k_Z and k_t are programmable parameters.

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 ″ATAN″ function, the F/W controls the whole analog chain, the output transfer characteristic, the output protocol, the programming/calibration and also the self-diagnostic modes.

In the MLX90333, the ″ATAN″ function is computed via a look-up table (i.e. it is not obtained through a CoRDiC algorithm).

Due to the fact that the ″ATAN″ operation is performed on the ratios ″V_Z/V_X″ and ″V_Z/V_Y″, the angular information are intrinsically self-compensated vs. flux density variations (due to airgap change, thermal or ageing effects) affecting the magnetic signal. This feature allows therefore an improved thermal accuracy vs. joystick based on conventional linear Hall sensors.

Once the angular information is computed (over 360 degrees), it is further conditioned (mapped) vs. the target transfer characteristic and it is provided at the output(s) as:

- an analog output level through a 12 bit DAC followed by a buffer
- a digital PWM signal with 12 bit depth (programmable frequency 100 Hz … 1 kHz)
- a digital Serial Protocol (SP – 16 bits computed angular information available)

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

$$Vout(\alpha) = ClampLo \quad \text{for } \alpha \leq \alpha min$$
$$Vout(\alpha) = Voffset + Gain \times \alpha \quad \text{for } \alpha min \leq \alpha \leq \alpha max$$
$$Vout(\alpha) = ClampHi \quad \text{for } \alpha \geq \alpha max$$

$$Vout(\beta) = ClampLo \quad \text{for } \beta \leq \beta min$$
$$Vout(\beta) = Voffset + Gain \times \beta \quad \text{for } \beta min \leq \beta \leq \beta max$$
$$Vout(\beta) = ClampHi \quad \text{for } \beta \geq \beta max$$

where Voffset, 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 3 point calibration. Once only one output is used, a 5 point calibration is also available for further improvement of the linearity.

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 MLX90333 is handled at both engineering lab and production line levels by the Melexis Programming Unit PTC-04 with the MLX90316 daughterboard and dedicated software tools (DLL – User Interface).

6. MLX90333 Electrical Specification

DC Operating Parameters at VDD = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Nominal Supply Voltage	VDD		4.5	5	5.5	V
Supply Current(2)	Idd	Slow mode(3) Fast mode(3)		8.5 13.5	11 16	mA mA
POR Level	VDD POR	Supply Under Voltage	2	2.7	3	V
Output Current Both outputs OUT 1 & OUT 2	Iout	Analog Output mode PWM Output mode	-8 -20		8 20	mA mA
Output Short Circuit Current Both outputs OUT 1 & OUT 2	I_{short}	Vout = 0 V Vout = 5 V Vout = 14 V (T_A = 25°C)		12 12 24	15 15 45	mA mA mA
Output Load Both outputs OUT 1 & OUT 2	R_L	Pull-down to Ground Pull-up to 5V(4)	1 1	10 10	∞(5) ∞(5)	kΩ kΩ
Analog Saturation Output Level Both outputs OUT 1 & OUT 2	Vsat_lo	Pull-up load $R_L \geq$ 10 kΩ			3	%VDD
	Vsat_hi	Pull-down load $R_L \geq$ 5 kΩ	96			%VDD
Digital Saturation Output Level Both outputs OUT 1 & OUT 2	VsatD_lo	Pull-up Low Side $R_L \geq$ 10 kΩ Push-Pull (IOUT = -20mA)			1.5	%VDD
	VsatD_hi	Push-Pull (IOUT = 20mA)	97			%VDD
Active Diagnostic Output Level Both outputs OUT 1 & OUT 2	Diag_lo	Pull-down load $R_L \geq$ 5 kΩ Pull-up load $R_L \geq$ 10 kΩ			1 1.5	%VDD
	Diag_hi	Pull-down load $R_L \geq$ 5 kΩ Pull-up load $R_L \geq$ 5 kΩ	96 98			%VDD
Passive Diagnostic Output Level Both outputs OUT 1 & OUT 2 (Broken Track Diagnostic) (6)	BVSSPD	Broken VSS& Pull-down load $R_L \leq$ 10 kΩ			4(6)	%VDD
	BVSSPU	Broken VSS(6) & Pull-up load $R_L \geq$ 1kΩ	99	100		%VDD
	BVDDPD	Broken VDD(6) & Pull-down load $R_L \geq$ 1kΩ		0	1	%VDD
	BVDDPU	Broken VDD & Pull-up load to 5V	No Broken Track diagnostic			%VDD
Clamped Output Level Both outputs OUT 1 & OUT 2	Clamp_lo	Programmable	0		100	%VDD(7)
	Clamp_hi	Programmable	0		100	%VDD(7)

2 For the dual version, the supply current is multiplied by 2
3 See section 13.5.1 for details concerning Slow and Fast mode
4 Applicable for output in Analog and PWM (Open-Drain) modes
5 RL < ∞ for output in PWM mode
6 For detailed information, see also section 14
7 Clamping levels need to be considered vs the saturation of the output stage (see Vsat_lo and Vsat_hi)

As an illustration of the previous table, the MLX90333 fits the typical classification of the output span described on the Figure 10.

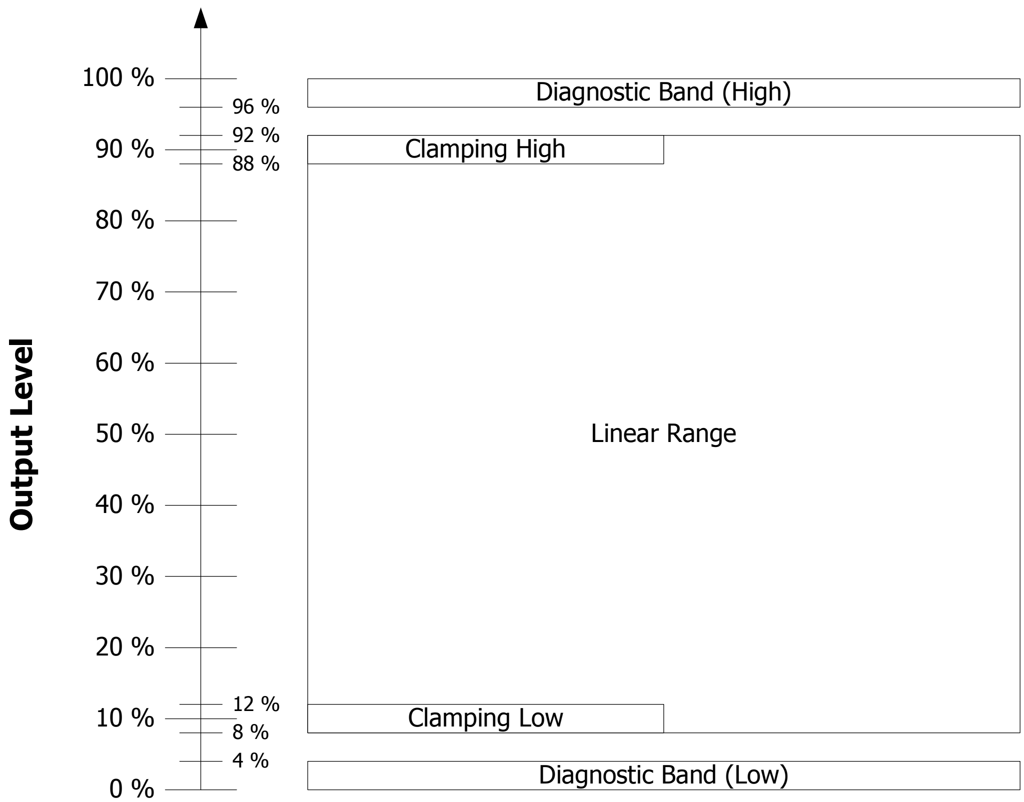


Figure 10 - Output Span Classification

7. MLX90333 Isolation Specification

DC Operating Parameters at VDD = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (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

8. MLX90333 Timing Specification

DC Operating Parameters at VDD = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Main Clock Frequency	Ck	Slow mode[8] Fast mode[8]		7 20		MHz MHz
Sampling Rate	C_T	Slow mode[8] Fast mode[8]		600 200	1000 330	µs µs
Step Response Time	Ts	Slow mode[8], Filter=5[9] Fast mode[8], Filter=0[9]		 400	4 600	ms µs
Watchdog	Wd	See Section 14			5	ms
Start-up Cycle	Tsu	Slow and Fast mode[8]			15	ms
Analog Output Slew Rate		C_{OUT} = 42 nF C_{OUT} = 100 nF		200 100		V/ms
PWM Frequency	F_{PWM}	PWM Output Enabled	100		1000	Hz
Digital Output Rise Time Both outputs OUT 1 & OUT 2		Mode 5 – 10nF, R_L = 10 kΩ Mode 7 – 10nF, R_L = 10 kΩ		120 2.2		µs µs
Digital Output Fall Time Both outputs OUT 1 & OUT 2		Mode 5 – 10nF, R_L = 10 kΩ Mode 7 – 10nF, R_L = 10 kΩ		1.8 1.9		µs µs
Maximum Field amplitude Change[10] (%) vs. Field Frequency(Hz)		AGC 90%[11] Slow mode[8] - Field Freq> 40Hz Field Freq= 20Hz Fast mode[8] -Field Freq> 150Hz Field Freq= 50Hz AGC 64% (90333BCT only) Slow mode[8] -Field Freq> 80Hz Field Freq=50Hz Fast mode[8] - Field Freq> 250Hz Field Freq=50Hz	 -10 -30 -12 -30 -22 -30 -30 -60		 10 30 12 30 22 30 30 60	 % % % % % % % %

[8] See section 13.5.1 for details concerning Slow and Fast mode
[9] See section 13.6 for details concerning Filter parameter
[10] Ex.: Magnetic field amplitude change in case of vibration.
[11] Automatic Gain Control – see Section 13.5.2 for more information.

9. MLX90333 Accuracy Specification

DC Operating Parameters at V_{DD} = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
ADC Resolution on the raw signals X, Y and Z	R_{ADC}	Slow Mode(12) Fast Mode(12)		15 14		bits bits
Offset on the Raw Signals X, Y and Z	X0, Y0, Z0	T_A = 25°C	-60		60	LSB_{15}
Mismatch on the Raw Signals X, Y and Z	$SMISM_{XY}$ $SMISM_{XZ}$ $SMISM_{YZ}$	T_A = 25°C Between X and Y Between X and Z(13) Between Y and Z(13)	-1 -30 -30		1 30 30	% % %
Magnetic Angle Phase error	$ORTH_{XY}$ $ORTH_{XZ}$ $ORTH_{YZ}$	T_A = 25°C Between X and Y Between X and Z Between Y and Z	-0.3 -10 -10		0.3 10 10	Deg Deg Deg
Thermal Offset Drift #1 on the raw signals X, Y and Z(14)		Thermal Offset Drift at the DSP input (excl. DAC and output stage) Temperature suffix K Temperature suffix L	-60 -90		+60 +90	LSB_{15} LSB_{15}
Thermal Offset Drift #2 (to be considered only for the analog output mode)		Thermal Offset Drift of the DAC and Output Stage Temperature suffix K Temperature suffix L	- 0.3 - 0.4		+ 0.3 + 0.4	$\%V_{DD}$ $\%V_{DD}$
Thermal Drift of Sensitivity Mismatch	$\Delta SMISM_{XY}$	Temperature suffix K Temperature suffix L	- 0.3 - 0.5		+ 0.3 + 0.5	% %
	$\Delta SMISM_{XZ}$ $\Delta SMISM_{YZ}$	Temperature suffix K Temperature suffix L	- 1 - 1.5		+ 1 + 1.5	% %
Analog Output Resolution	R_{DAC}	12 bits DAC (Theoretical – Noise free) INL DNL	 -4 -1	0.025 0	 +4 1	$\%V_{DD}$/LSB LSB LSB
Output stage Noise		Clamped Output		0.05		$\%V_{DD}$
MLX90333 Accuracy Specification continues…						
… MLX90333 Accuracy Specification						
Noise pk-pk(15)		Gain = 14, Slow mode, Filter=5		5	10	LSB_{15}

[12] 15 bits corresponds to 14 bits + sign and 14 bits corresponds to 13 bits + sign. After angular calculation, this corresponds to 0.005Deg/LSB_{15} in Low Speed Mode and 0.01Deg/LSB_{14} in High Speed.
[13] The mismatch between X and Z (Y and Z) can be reduced through the calibration of the 2 parameters k_Z and k_t as described in the formulas page 12 in order to take into account the IC mismatch and system tolerances (magnetic and mechanical).
[14] To evaluate the error affecting the computed angle i.e. "ATAN" function (See section 5), it is important to take into account the actual value of the factor k_Z as it amplifies the signal V_Z and consequently its drift too.
[15] The application diagram used is described in the recommended wiring. For detailed information, refer to section Filter in application mode (Section 13.6).

		Gain = 14, Fast mode, Filter=0		10	20	LSB_{15}
Ratiometry Error			-0.1	0	0.1	$\%V_{DD}$
PWM Output Resolution	R_{PWM}	12 bits (Theoretical – Jitter free)		0.025		%DC/LSB
PWM Jitter	J_{PWM}	Gain = 11, F_{PWM} = 250 Hz – 800Hz			5	LSB_{12}
Serial Output Resolution	R_{SPI}	Theoretical – Jitter free		16		bits

10. MLX90333 Magnetic Specification

DC Operating Parameters at V_{DD} = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (K or L).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Magnetic Flux Density	B_X, B_Y [16]		20	50	70 [17]	mT
Magnetic Flux Density	B_Z [16]		24	75	140	mT
Magnet Temperature Coefficient	TCm		-2400		0	ppm/°C
IMC Gain [18]	GainIMC		1.2	1.4	1.8	

11. MLX90333 CPU & Memory Specification

The DSP is based on a 16 bit RISC µController. This CPU provides 5 Mips while running at 20 MHz.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
ROM				10		kB
RAM				256		B
EEPROM				128		B

[16] The condition must be fulfilled for at least one field B_X, B_Y or B_Z.
[17] Above 70 mT, the IMC starts saturating yielding to an increase of the linearity error.
[18] This is the magnetic gain linked to the Integrated Magneto Concentrator structure. It applies to BX and BY and not to BZ. This is the overall variation. Within one lot, the part to part variation is typically ± 10% versus the average value of the IMC gain of that lot.

12. MLX90333 End-User Programmable Items

Parameter	Comments	Default Values BCH STD/IP1	BCH SPI	BCT STD/IP1	# bit
MAINMODE	Select Outputs Configuration	0	0	0	2
Outputs Mode	Define the output stages mode	2	N/A	2	3
PWMPOL1	PWM Polarity (Out 1)	0	N/A	0	1
PWMPOL2	PWM Polarity (Out 2)	0	N/A	0	1
PWM_Freq	PWM Frequency	1000h	N/A	1000h	16
3-Points	4 segments transfer curve for single angle output	0	0	0	1
ALPHA_POL	Revert the Sign of Alpha	0	0	0	1
ALPHA_MOD180	Modulo Operation (180deg) on Alpha	1	1	1	1
ALPHA_DP	Alpha Discontinuity Point	0	0	0	8
ALPHA_DEADZONE	Alpha Dead Zone	0	0	0	6
ALPHA_S0	Initial Slope	4000h	4000h	4000h	16
ALPHA_X	Alpha X Coordinate	4000h	4000h	4000h	16
ALPHA_Y	Alpha Y Coordinate	8000h	8000h	8000h	16
ALPHA_S1	Alpha S Coordinate	4000h	4000h	4000h	16
BETA_POL	Revert the Sign of Beta	0	0	0	1
BETA_MOD180	Modulo Operation (180deg) on Beta	1	1	1	1
BETA_DP	Beta Discontinuity Point	0	0	0	6
BETA_DEADZONE	Beta Dead Zone	0	0	0	8
BETA_S0	Beta Dead Zone	4000h	4000h	4000h	16
BETA_X	Beta X Coordinate	4000h	4000h	4000h	16
BETA_Y	Beta Y Coordinate	8000h	8000h	8000h	16
BETA_S1	Beta S Coordinate	4000h	4000h	4000h	16
CLAMP_LOW	Clamping Low	0%	0%	0%	16
CLAMP_HIGH	Clamping High	100%	100%	100%	16
2D		0	0	0	1
XYZ	SPI Only	0	0	0	1
KZ		B3h	B3h		8
KT[19]		80h	80h	N/A	8
FIELDTHRES_LOW		0h	0h	0h	8
FIELDTHRES_HIGH		0h	0h	0h	8
DERIVGAIN		40h	40h	40h	8
FILTER		3	0	3	8
FILTER A1	Filter coefficient A1 for FILTER=6	6600h	6600h	6600h	16
FILTER A2	Filter coefficient A2 for FILTER=6	2A00h	2A00h	2A00h	16
FILTERFIRST		0	0	0	1
FHYST		0	0	0	8
MELEXISID1		MLX	MLX	MLX	16
MELEXISID2		MLX	MLX	MLX	16
MELEXISID3		MLX	MLX	MLX	16
CUSTUMERID1		1	1	1	16
CUSTUMERID2		17d[20]	37d	38d	16
CUSTUMERID3		MLX	MLX	MLX	16
HIGHSPEED		0	0	0	1
GAINMIN		0	0	0	8

[19] Only applicable for 90333BCH
[20] CUSTUMERID2 = 29d for MLX90333SDC–BCH–STANDARD

GAINMAX		41d	41d	41d	8
End-User Programmable Items continues... ***... End-User Programmable Items***					
EEHAMHOLE		3131h	0h	3131h	16
RESONFAULT	Diagn mode	1h	N/Ah	0h	2
MLXLOCK		0h	0h	0h	1
LOCK		0h	1h	0h	1
Extra end-User Programmable Items 90333BCT					
AGCRADIUSTARGET(21)	Define Gain target 64% / 90% ADC	N/A	N/A	0	1
SWTHRES	Angle Trigger level for switch on out2	N/A	N/A	FFFFh	16
SWLOW	Switch Low level output on out2	N/A	N/A	40h	8
SWHIGH	Switch high level output on out2	N/A	N/A	FFh	8
SWHYST	Switch hysteresis	N/A	N/A	0	8
CodePWMLATCH	Enable synchronized % DC update	N/A	N/A	1	1
OUT1DIAG	Active Diagnostic Output 1 behavior	N/A	N/A	0	1
OUT2DIAG	Active Diagnostic Output 2 behavior	N/A	N/A	0	1
CodeKTALPHA	"Joystick" ALPHA angle correction parameter	N/A	N/A	80h	8
CodeKTBETA	"Joystick" BETA angle correction parameter	N/A	N/A	80h	8
CodeORTHZXALPHA	Front-end "Joystick" angle correction parameter	N/A	N/A	0	8
CodeORTHZYALPHA	Front-end "Joystick" angle correction parameter	N/A	N/A	0	8
CodeORTHZXBETA	Front-end "Joystick" angle correction parameter	N/A	N/A	0	8
CodeORTHZYBETA	Front-end "Joystick" angle correction parameter	N/A	N/A	0	8
CodeENHORTH	Enable enhanced Front-end "Joystick" angle correction	N/A	N/A	0	1

21 Option to use same ADC target as 90333BCH. Default value equals lowered % ADC target

13. Description of End-User Programmable Items

13.1. Output Configuration

The parameter MAINMODE defines the output stages configuration

MAINMODE	OUT1	OUT2
0	ALPHA	BETA
1	BETA	ALPHA
2	ALPHA	ALPHA DERIVATE / SWITCH[22]
3	BETA	BETA DERIVATE / SWITCH[22]

13.2. Output Mode

The MLX90333 outputs type is defined by the Output Mode parameter.

Parameter	Value	Description
Analog Output Mode	2	Analog Rail-to-Rail
PWM Output Mode	5 7	Low Side (NMOS) Push-Pull
Serial	N/A	Low Side (NMOS)

13.2.1. Analog Output Mode

The Analog Output Mode is a rail-to-rail and ratiometric output with a push-pull output stage configuration allows the use of a pull-up or pull-down resistor.

13.2.2. PWM Output Mode

If one of the PWM Output modes is selected, the output signal is a digital signal with Pulse Width Modulation (PWM).
In mode 5, the output stage is an open drain NMOS transistor (low side), to be used with a pull-up resistor to V_{DD}.
In mode 7, the output stage is a push-pull stage for which Melexis recommends the use of a pull-up resistor to V_{DD}.

The PWM polarity of the Out 1 (Out 2) is selected by the PWMPOL1 (PWMPOL2) parameter:

- PWMPOL1 (PWMPOL2) = 0 for a low level at 100%
- PWMPOL1 (PWMPOL2) = 1 for a high level at 100%

The PWM frequency is selected by the PWM_Freq parameter.

PWM Frequency Code				
Oscillator Mode	Pulse-Width Modulation Frequency (Hz)			
	100	200	500	1000
Low Speed	35000	17500	7000	3500

[22] Derivate = BCH , Switch = BCT

High Speed	-	50000	20000	10000

For instance, in Low Speed Mode, set PWM_Freq = 7000 (decimal) to set the PWM frequency at 500Hz.

13.2.3. Serial Protocol Output Mode

The MLX90333 features a digital Serial Protocol mode. The MLX90333 is considered as a Slave node. The frame layer type is defined by the parameter XYZ as described in the next table.

Parameter	Value	Description
XYZ	0 1	Regular SPI Frame Alpha, Beta X,Y, Z Frame

See the dedicated Serial Protocol section for a full description (Section 15).

13.2.4. Switch Out

Parameter	Value	Unit
SWTHRES	0…100	%
SWHYST	0 … 0.39	%
SWLOW	0…100	%
SWHIGH	0…100	%

The output level on out2 is changed from SWLOW to SWHIGH when the output value is greater than the value stored in the SWTHRES parameter.

The SWHYST defines the hysteresis amplitude around the Switch point. The switch is actually activated if the digital output value is greater than SWTHRES+SWHYST. It is deactivated if the digital output value is less than SWTHRES-SWHYST.

If the Switch feature is not used in the application, the output pin needs to be connected to the ground and disabled in EEPROM.

13.3. Output Transfer Characteristic

Parameter	Value	Description
3-Points	0 1	Regular Alpha, Beta Output (2 times 2 segments) Alpha (or Beta) Single Output (1 time 4 segments)

The 3-Points parameters allow the user to use the 3-points mapping (4 segments). This mode can only be used for Mainmode equals 2 and 3.

- 3-Points = 0, the parameters list is described as bellow (Angle Alpha and Beta):

Parameter	Value	Unit
ALPHA_POL BETA_POL	0 1	

ALPHA_MOD180 BETA_MOD180	0 1	
ALPHA_DP BETA_DP	0 … 359.9999	deg
ALPHA_X BETA_X	0 … 359.9999	deg
ALPHA_Y BETA_Y	0 … 100	%
ALPHA_S0 ALPHA_S1 BETA_S0 BETA_S1	0 … 17	%/deg
CLAMP_LOW	0 … 100	%
CLAMP_HIGH	0 … 100	%
ALPHA_DEADZONE BETA_DEADZONE	0 … 359.9999	deg

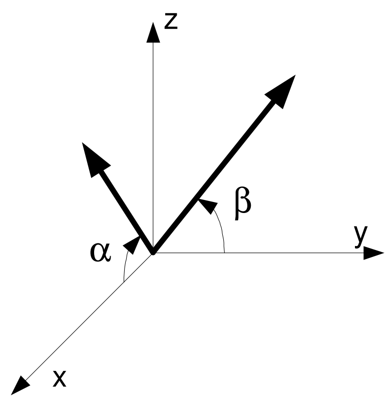
- 3-Points = 1, the parameters list is described as bellow (Alpha or Beta):

Parameter	Value	Unit
ALPHA_POL	0 → CCW 1 → CW	
DP	0 … 359.9999	deg
LNR_A_X LNR_B_X LNR_C_X	0 … 359.9999	deg
LNR_A_Y LNR_B_Y LNR_C_Y	0 … 100	%
LNR_S0 LNR_A_S LNR_B_S	0 … 17	%/deg
LNR_C_S	-17… 0 … 17	%/deg
CLAMP_LOW	0 … 100	%
CLAMP_HIGH	0 … 100	%
DEADZONE	0 … 359.9999	deg

13.3.1. The Polarity and Modulo Parameters

The angle Alpha is defined as the arctangent of Z/X and Beta as the arctangent of Z/Y. It is possible to invert the polarity of these angles via the parameters ALPHA_POL and BETA_POL set to “1”.

The MLX90333 can also be insensitive to the field polarity by setting the ALPHA_MOD180/BETA_MOD180 to “1”.



13.3.2. Alpha/Beta Discontinuity Point (or Zero Degree Point)

The Discontinuity Point defines the zero point of the circle (Alpha or Beta). The discontinuity point places the origin at any location of the trigonometric circle (see Figure 13).
For a Joystick Application, Melexis recommends to set the DP to zero.

13.3.3. LNR Parameters

The LNR parameters, together with the clamping values, fully define the relation (the transfer function) between the digital angles (Alpha and Beta) and the output signals.
The shape of the MLX90333 transfer function from the digital angle values to the output voltages is described by the drawing below (See Figure 11). Four segments can be programmed but the clamping levels are necessarily flat (3-Points = 0).

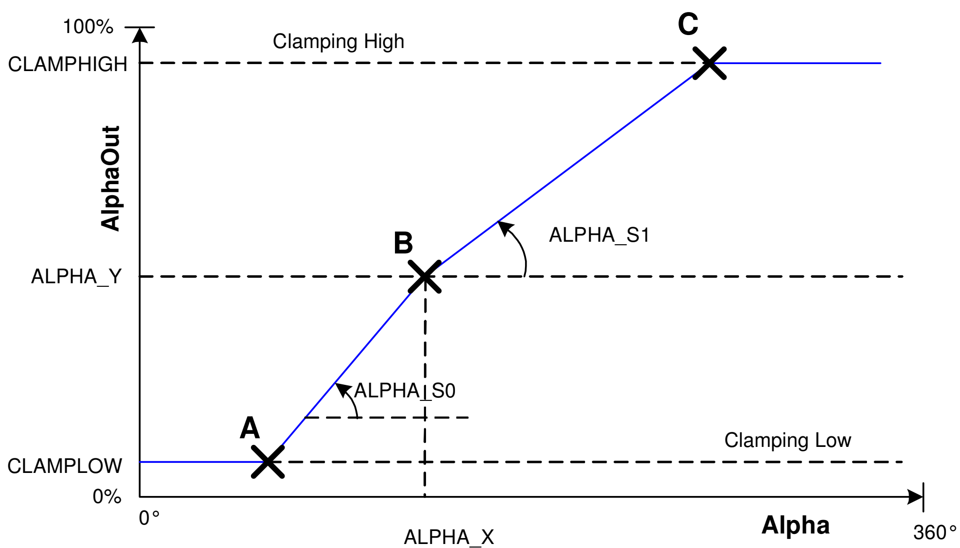


Figure 11 - Digital Angle (Alpha) Transfer Characteristic (Idem ditto for Beta)

In the case of one single angle output (3-Points = 1), the shape of the MLX90333 transfer function from the digital angle values to the output voltage is described by the drawing below (See Figure 12). Six segments can be programmed but the clamping levels are necessarily flat.

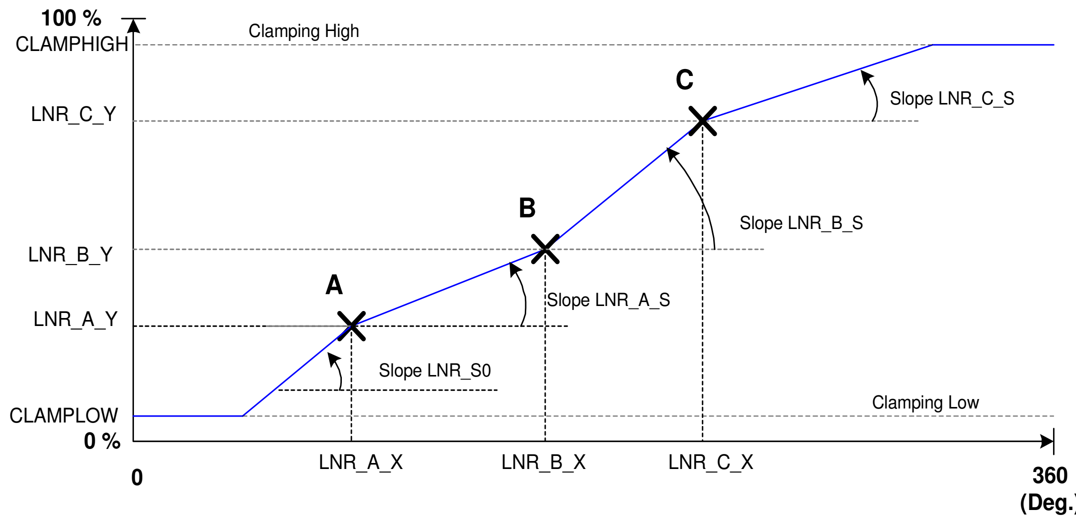


Figure 12 – Digital Angle (Alpha) Transfer Characteristic for Single Angle Output

13.3.4. CLAMPING Parameters

The clamping levels are two independent values to limit the output voltage range. The CLAMP_LOW parameter adjusts the minimum output voltage level. The CLAMP_HIGH parameter sets the maximum output voltage level. Both parameters have 16 bits of adjustment. In analog mode, the resolution will be limited by the D/A converter (12 bits) to 0.024%VDD. In PWM mode, the resolution will be 0.024%DC. In SPI mode, the resolution is 14bits or 0.022deg over 360deg.

13.3.5. DEADZONE Parameter

The dead zone is defined as the angle window between 0 and 359.9999 (See Figure 13).
When the digital angle (Alpha or Beta) lies in this zone, the IC is in fault mode (RESONFAULT must be set to “1” – See 13.8.2).

In case of ALPHA_MOD180 (or BETA_MOD180) is not set, the angle between 180° and 360° will generate a “deadzone” fault, unless DEADZONE=0.