MLX90316

Rotary Position Sensor IC

Features and Benefits

Absolute Rotary Position Sensor IC
Simple & Robust Magnetic Design
Tria⊗is™ Hall Technology
Programmable Angular Range up to 360 Degrees
Programmable Linear Transfer Characteristic
Selectable Analog (Ratiometric), PWM, Serial Protocol
12 bit Angular Resolution
10 bit Angular Accuracy
40 bit ID Number
Single Die - SO8 Package RoHS Compliant
Dual Die (Full Redundant) - TSSOP16 Package RoHS Compliant

Applications

Absolute Rotary Position Sensor
Pedal Position Sensor
Throttle Position Sensor
Ride Height Position Sensor
Steering Wheel Position Sensor
Motor-shaft Position Sensor
Float-Level Sensor
Non-Contacting Potentiometer

Ordering Information

Part No.	Temperature Suffix	Package Code	Option code
MLX90316	S (– 20°C to + 85°C)	DC [SOIC-8]	-
MLX90316	E (– 40°C to + 85°C)	DC [SOIC-8]	-
MLX90316	K (– 40°C to + 125°C)	DC [SOIC-8]	-
MLX90316	E (– 40°C to + 85°C)	GO [TSSOP-16]	-
MLX90316	K (– 40°C to + 125°C)	GO [TSSOP-16]	-

1. Functional Diagram

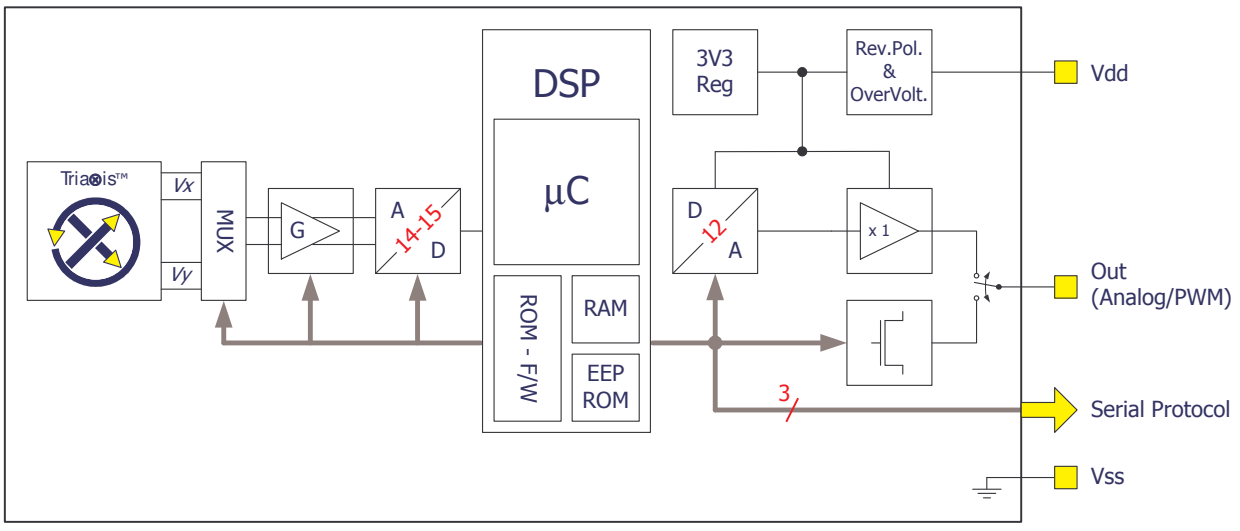


Figure 1 – Block Diagram

2. Description

The MLX90316 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 MLX90316 is only sensitive to the flux density coplanar with the IC surface. This allows the MLX90316 with the correct magnetic circuit to decode the absolute rotary (angular) position from 0 to 360 Degrees. It enables the design of novel generation of non-contacting rotary position sensors that are frequently required for both automotive and industrial applications.

In combination with the appropriate signal processing, the magnetic flux density of a small magnet (diametral magnetization) rotating above the IC can be measured in a non-contacting way (Figure 2). The angular information is computed from both vectorial components of the flux density (i.e. B_X and B_Y) MLX90316 produces an output signal proportional to the decoded angle. The output is selectable between Analog, PWM and Serial Protocol.

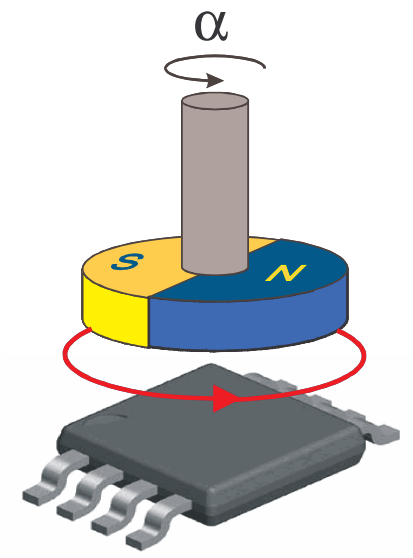


Figure 2 – Typical application of MLX90316

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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**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

4. Pinout

Pin #	SOIC-8		TSSOP-16	
	Analog / PWM	Serial Protocol	Analog / PWM	Serial Protocol
1	Vdd	Vdd	Vdig_1	Vdig_1
2	Test 0	Test 0	Vss_1 (Ground_1)	Vss_1 (Ground_1)
3	Not Used	/SS	Vdd_1	Vdd_1
4	Not Used	SCLK	Test0_1	Test 01
5	Out	MOSI / MISO	Not Used_2	/SS_2
6	Test 1	Test 1	Not Used_2	SCLK_2
7	Vdig	Vdig	Out_2	MOSI_2 / MISO_2
8	Vss (Ground)	Vss (Ground)	Test1_2	Test 12
9			Vdig_2	Vdig_2
10			Vss_2 (Ground_2)	Vss_2 (Ground_2)
11			Vdd_2	Vdd_2
12			Test0_2	Test 02
13			Not Used_1	/SS_1
14			Not Used_1	SCLK_1
15			Out_1	MOSI_1 / MISO_1
16			Test1_1	Test 11

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, V_{DD} (overvoltage)	+ 20 V
Reverse Voltage Protection	– 10 V
Positive Output Voltage	+ 10 V + 14 V (200 s max – T_A = + 25°C)
Output Current (I_{OUT})	± 30 mA
Reverse Output Voltage	– 0.3 V
Reverse Output Current	– 50 mA
Operating Ambient Temperature Range, T_A	– 40°C … + 150°C
Storage Temperature Range, T_S	– 40°C … + 150°C
Magnetic Flux Density	± 700 mT

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

6. Detailed Description

As described on the block diagram (Figure 1), the magnetic flux density parallel to the IC surface (i.e. $B_{//}$) 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 (blue area on Figure 3) and an Integrated Magneto-Concentrator (IMC® – yellow disk on Figure 3).

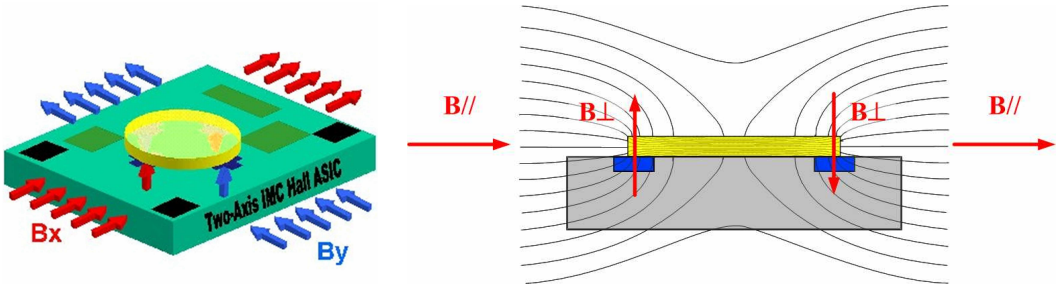


Figure 3 – Tria⊗is™ sensor front-end (4 Hall plates + IMC® disk)

Both components of the applied flux density $B_{//}$ are measured individually i.e. $B_{X//}$ and $B_{Y//}$. 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.

While a magnet (diametrally magnetized) rotates above the IC as described on Figure 2, the sensing stage provides two differential signals in quadrature (sine and cosine – Figures 4 & 5).

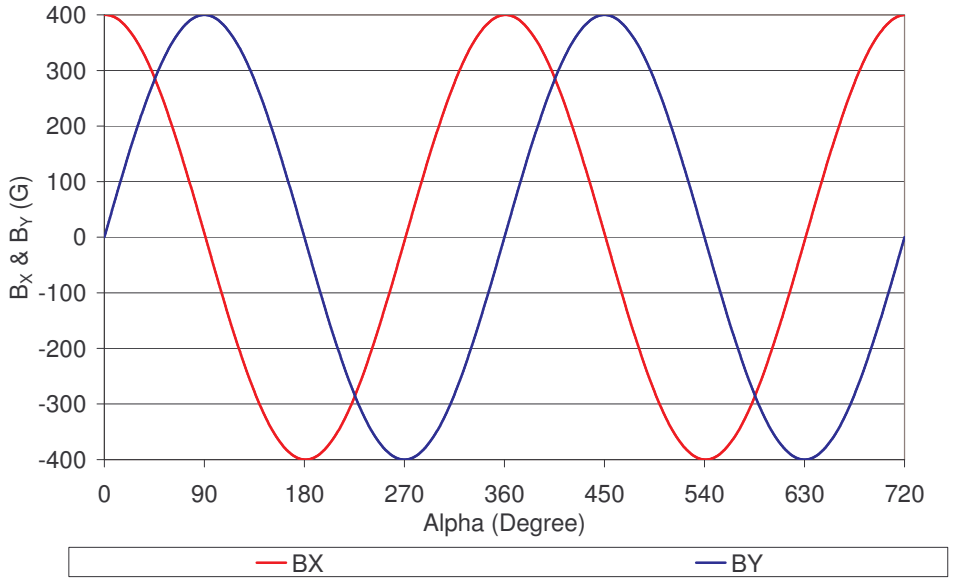


Figure 4 – Magnetic Flux Density – $B_X \propto \cos(\alpha)$ & $B_Y \propto \sin(\alpha)$

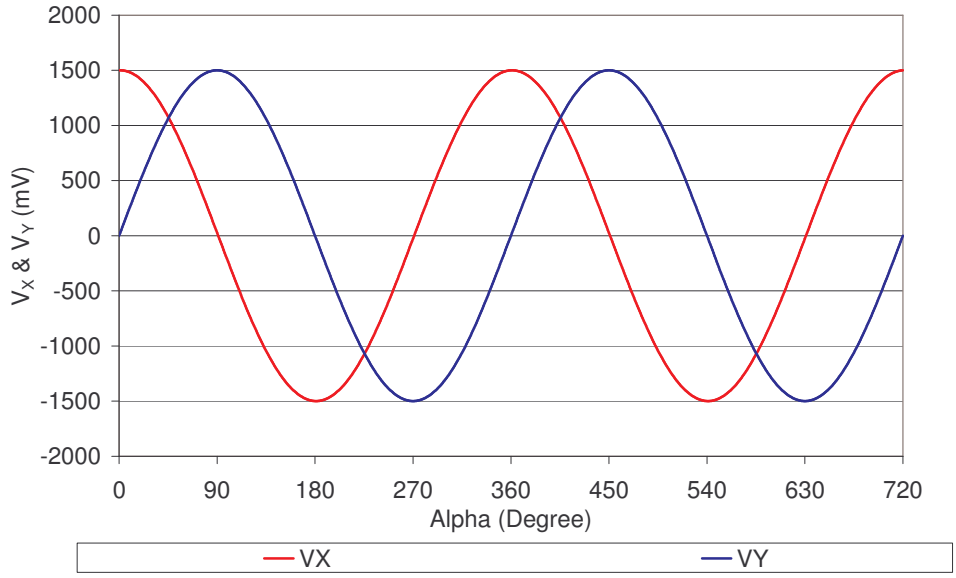


Figure 5 – Tria⊗is™ sensor front-end – Output signals – $V_X \propto B_X \propto \cos(\alpha)$ & $V_Y \propto B_Y \propto \sin(\alpha)$

Those 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 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 angular position from the two raw signals (after so-called front-end compensation steps) through the following operation:

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

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 MLX90316, 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 ratio ″V_Y/V_X″, the angular information is intrinsically self-compensated vs. flux density variations (due to airgap change, thermal or ageing effects) affecting both signals. This feature allows therefore an improved thermal accuracy vs. rotary position sensor based on conventional linear Hall sensors.

In addition to the improved thermal accuracy, the realized rotary position sensor is capable of measuring a complete revolution (360 Degrees) and the linearity performances are excellent taking into account typical manufacturing tolerances (e.g. relative placement between the Hall IC and the magnet).

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 – 14 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:

$$\begin{aligned} Vout(\alpha) &= ClampLo && \text{for } \alpha \le \alpha min \\ Vout(\alpha) &= Voffset + Gain \times \alpha && \text{for } \alpha min \le \alpha \le \alpha max \\ Vout(\alpha) &= ClampHi && \text{for } \alpha \ge \alpha max \end{aligned}$$

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 either a 2 point or a 3 point calibration depending on the linearity requirement.

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

7. MLX90316 Electrical Specification

DC Operating Parameters at Vdd = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (S, E or K).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Nominal Supply Voltage	Vdd		4.5	5	5.5	V
Supply Current (1)	Idd	Slow mode(2)			10	mA
		Fast mode(2)			16	mA
Output Current	Iout	Analog Output mode	-8		8	mA
		PWM Output mode	-20		20	mA
Output Short Circuit Current	I_{short}	Vout = 0 V		12		mA
		Vout = 5 V		12	15	mA
		Vout = 14 V (T_A = 25°C)		22	30	mA
Output Load	R_L	Pull-down to Ground (2)	4	10	∞	kΩ
		Pull-up to 5V (3)	4	5.6	∞ (4)	kΩ
Saturation Output Level	Vsat_lo	Pull-up load R_L > 10 kΩ			3	%Vdd
	Vsat_hi	Pull-down load R_L > 10 kΩ	96			%Vdd
Diagnostic Output Level	Diag_lo	Pull-down load R_L > 10 kΩ			1	%Vdd
		Pull-up load R_L > 10 kΩ			1.5	
	Diag_hi	Pull-down load R_L > 10 kΩ	97			%Vdd
		Pull-up load R_L > 10 kΩ	98			
Clamped Output Level	Clamp_lo	Programmable	0		100	%Vdd (5)
	Clamp_hi	Programmable	0		100	%Vdd (5)

(1) For the dual version, the supply current is multiplied by 2
(2) See section 14.1 for details concerning Slow and Fast mode
(3) Applicable for output in Analog and PWM (Open-Drain) modes
(4) $R_L < \infty$ for output in PWM mode
(5) Clamping levels are limited by Vsat_lo and Vsat_hi

8. MLX90316 Isolation Specification

DC Operating Parameters at Vdd = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (S, E or K). Only valid for the package code GO i.e. dual die version.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Isolation Resistor		Between 2 dies – TSSOP package	4			MΩ

9. MLX90316 Timing Specification

DC Operating Parameters at Vdd = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (S, E or K).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Main Clock Frequency	Ck	Slow mode ([6]) Fast mode ([6])		7 20		MHz MHz
Sampling Rate		Slow mode ([6]) Fast mode ([6])		600 200		µs µs
Step Response Time	Ts	Slow mode ([6]), Filter=5 ([7]) Fast mode ([6]), Filter=0 ([7])		 400	4 600	ms µs
Watchdog	Wd				5	ms
Start-up Cycle	Tsu	Slow and Fast mode ([6])			15	ms
Analog Output Slew Rate		Cout = 42 nF		200		V/ms
PWM Frequency	F_{PWM}		100		1000	Hz

([6]) See section 14.1 for details concerning Slow and Fast mode
([7]) See section 14.4 for details concerning Filter parameter

10. MLX90316 Accuracy Specification

DC Operating Parameters at Vdd = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (S, E or K).

All the errors expressed in Deg. Can be converted in %Vdd or %dc by using the following relationship:

- Err (%Vdd) = Err (Deg) × Output Span (%Vdd) / Angular Span (Deg) + Err_DAC + Err_OutBuf
- Err (%DC) = Err (Deg) × Output Span (%DC) / Angular Span (Deg)
- Err (Serial Protocol) = Err (Deg)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
ADC Resolution	R_{ADC}	Slow – 15 bits ADC (14 + sign) Fast – 14 bits ADC (13 + sign)		0.005 0.01		Deg/LSB_{15} Deg/LSB_{14}
Thermal Offset Drift #1		Thermal Offset Drift at the DSP input (excl. DAC and output stage)	-60		+60	LSB_{15} ([9])
Thermal Offset Drift #2		Thermal Offset Drift of the DAC and Output Stage Only for the Analog Output	- 0.2		+ 0.2	%Vdd
Analog Output Resolution	R_{DAC}	12 bits DAC (Theoretical – Noise free) INL DNL	 -4 0.05	0.025 1	 +4 2	%Vdd/LSB LSB LSB
Output stage Noise				0.05		% Vdd
Noise pk-pk ([10])		RG = 9, Slow mode, Filter=5 RG = 9, Fast mode, Filter=0		0.03 0.1	0.06 0.2	Deg Deg
Ratiometry Error			-0.1	0	0.1	%
PWM Output Resolution	R_{PWM}	12 bits (Theoretical – Jitter free)		0.025		%DC/LSB
PWM Jitter([11])	J_{PWM}	f_{PWM} = 250 Hz			0.2	%DC
Serial Protocol Output Resolution	R_{SP}	14 bits – 360 Deg. mapping (Theoretical – Jitter free)		0.022		Deg/LSB
Intrinsic Linearity Error([12])	Le	360 Deg	-2		2	Deg

([9]) Thermal Offset Drift #1 yields to max. ± 0.3 Deg. drift for the computed angular information (output of the DSP).
([10]) The application diagram used is described in the recommended wiring. For detailed information, refer to section filter in application mode.
([11]) Jitter is defined by ± 3 σ for 1000 acquisitions.
([12]) The Intrinsic Linearity Error refers to the IC itself (offset, sensitivity mismatch, orthogonality) taking into account an ideal rotating field. 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 2 point or 3 point end-user calibration that is available on the MLX90316.

11. MLX90316 Magnetic Specification

DC Operating Parameters at Vdd = 5V (unless otherwise specified) and for T_A as specified by the Temperature suffix (S, E or K).

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Magnetic Flux Density	B		20	50	70([13])	mT
Magnet Temperature Coefficient	TCm		-2400		0	ppm/°C

([13]) Above 70 mT, the IMC starts saturating yielding to an increase of the linearity error.

12. MLX90316 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

13. MLX90316 End-User Programmable Items

Parameter	Comments	# bit
Output stage Mode	Define the output stage mode	16
PWMPOL1	PWM Polarity	1
PWM_Freq	PWM Frequncy	16
CLOCKWISE		1
DP	Discontinuity Point	15
LNR_S0	Initial Slope	16
LNR_A_X	AX Coordinate	16
LNR_A_Y	AY Coordinate	16
LNR_A_S	AS Coordinate	16
LNR_B_X	BX Coordinate	16
LNR_B_Y	BY Coordinate	16
LNR_B_S	BS Coordinate	16
LNR_C_X	CX Coordinate	16
LNR_C_Y	CY Coordinate	16
LNR_C_S	CS Coordinate	16
CLAMP_HIGH	Clamping_High	16
CLAMP_LOW	Clamping_Low	16
DEADZONE		8
FHYST		8
MELEXISID1		16
MELEXISID2		16
MELEXISID3		16
CUSTUMERID1		8
CUSTUMERID2		16
CUSTUMERID3		16
HIGHSPEED		1
FILTER		8
AUTO_RG		1
RGThresL		4
RGThresH		4
EEHAMHOLE		16
RESONFAULT		1
DACTHRES		8
FORCERA75		1
MLXLOCK		1
LOCK		1
CRC	Automatically computed and programmed by the IC	16

14. Description of End-User Programmable Items

14.1. Output_Mode

The MLX90316 output type is defined by the Ouput_Mode parameter.

Parameter	Value	Unit
Output_Mode	Analog PWM NMOS Serial	

14.1.1. Analog Output Mode

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

14.1.2. PWM Output Mode

When PWM NMOS is selected, the output signal is a PWM modulation. The output stage is an open drain NMOS transistor, to be used with a pull-up resistor (low side).

The PWM polarity is selected by the PWMPOL1 parameter:

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

The PWM frequency is selected by the PWM_Freq parameter.

Parameter	Value	Unit
PWMPOL1	0 1	
PWM_Freq	100 … 1000	Hz

14.1.3. Serial Protocol Output Mode

The MLX90316 features a digital Serial Protocol mode. The MLX90316 is considered as a Slave node. See the dedicated Serial Protocol section for a full description (Section 17).

14.2. Output Transfert Characteristic

Parameter	Value	Unit
CLOCKWISE	CCW = 0 CW = 1	
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 LNR_C_S	0 … 64	%/Deg.
CLAMP_LOW	0 … 100	%
CLAMP_HIGH	0 … 100	%
DEADZONE	0 … 359.9999	Deg.
FHYST	0 … 255	LSB

14.2.1. CLOCKWISE Parameter

The CLOCKWISE parameter defines the magnet rotation direction.

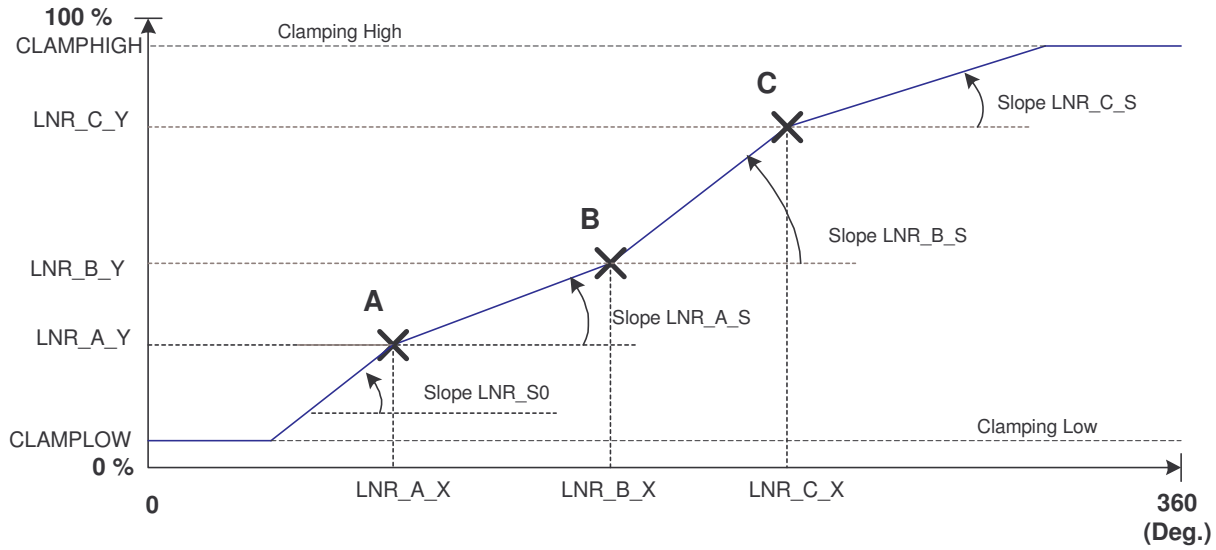
- CCW is the defined by the 1-4-5-8 pin order direction for the SOIC8 package and 1-8-9-16 pin order direction for the TSSOP16 package.
- CW is defined by the reverse direction: 8-5-4-1 pin order direction for the SOIC8 and 16-9-8-1 pin order direction for the TSSOP16 package.

Refer to the drawing in the IMC positioning sections (Section 19.3 and 19.6).

14.2.2. 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 90316 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 five calibration points are then available, reducing the overall non-linearity of the IC by almost an order of magnitude each time. Three or five point calibration 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.



14.2.3. 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 with a resolution of approximately 0.076 mV.

14.2.4. DEADZONE Parameter

The dead zone is defined as the angle window between 0 and 359.9999.
When the digital angle lies in this zone, the IC is in fault mode.

14.2.5. FHYST Parameter

The FHYST parameter is an 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.

14.3. Identification

Parameter	Value	Unit
MELEXSID1 MELEXSID2 MELEXSID3	0 … 65535 0 … 65535 0 … 65535	
CUSTUMERID1 CUSTUMERID2 CUSTUMERID3	0 … 255 0 … 65535 0 … 65535	

Identification number: 40 bits freely useable by Customer for traceability purpose.

14.4. Sensor Front-End

Parameter	Value	Unit
HIGHSPEED	0 = Slow mode 1 = Fast mode	
FILTER	0 … 5	
AUTO_RG	0 = disable 1 = enable	
RGThresL	0 … 15	
RGThresH	0 … 15	

14.4.1. HIGHSPEED Parameter

The HIGHSPEED parameter defined the main frequency for the DSP.

- HIGHSPEED = 0 selects the Slow mode with a 7 MHz master clock.
- HIGHSPEED = 1 selects the Fast mode with a 20 MHz master clock.

For a better accuracy, the Slow mode must be enable.

14.4.2. FILTER Parameter

The MLX90316 includes a programmable low-pass filter controlled with the Filter parameter. 6 values are possible described in the next table.

Filter Value	Attenuation (dB)	Speed Mode	Response time (ms)
0	na		
1	2.9	Low	2.22
		High	0.75
2	3.6	Low	3
		High	1
3	5	Low	3.75
		High	1.25
4	6.1	Low	3.75
		High	1.25
5	7	Low	4.5
		High	1.5

14.4.3. AUTO_RG, RGThresL, RGThresH Parameters

AUTO_RG parameter enables the automatic gain control to optimize the ADC span. RGThresL defines the minimum RG value while RGThresH defines the maximum RG value. When AUTO_RG is enabled, the optimized value for RGThresL is 0.

14.5. Diagnostic

Parameter	Value	Unit
EEHAMHOLE	0 3131h	
RESONFAULT	0 1	
DACTHRES	0 … 255	
FORCERA75	0 1	

14.5.1. EEHAMHOLE Parameter

The EEHAMHOLE parameter disables the memory recovery (Hamming code) check when a fault is detected by the CRC when it is equal to 3131h. By default the parameter is set to 0 (enable memory recovery)

14.5.2. RESONFAULT Parameter

This RESONFAULT parameter disables the soft reset when a fault is detected by the CPU when the parameter is to 1. By default, the parameter is set to 0.

14.5.3. DACTHRES Parameter

The DACTHRES is the high threshold of the DAC monitor. The DAC monitor senses an output DAC voltage for one fixed code. The table hereafter highlights the effect of the DACTHRES on the output Vs supply voltage.

14.5.4. FORCERA75 Parameter

This parameter forces the circle radius adjustment to 75% instead of 90% when the parameter is set to 1. By default, the parameter is set to 0.

14.6. Lock

Parameter	Value	Unit
MLXLOCK	0 1	
LOCK	0 1	

14.6.1. MLXLOCK Parameter

MLXLOCK locks all the parameters set by Melexis.

14.6.2. LOCK Parameter

LOCK locks all the parameters set by the user.

15. MLX90316 Self Diagnostic

The MLX90316 provides numerous self-diagnostic features. Those features increase the robustness of the IC functionality as it will prevent the IC to provide erroneous output signal in case of internal or external failure modes ("fail-safe").

	Action	Effect on Outputs	Remark
ROM CRC Error at start up (64 words including Intelligent Watch Dog - IWD)	CPU Reset ([14])	Diagnostic low ([15])	All the outputs are already in Diagnostic low - (start-up)
ROM CRC Error (Operation - Background task)	Enter Endless Loop: - Progress (watchdog Acknowledge) - Set Outputs in Diagnostic low	Immediate Diagnostic low	
RAM Test Fail (Start up)	CPU Reset	Diagnostic low	All the outputs are already in Diagnostic low** ** (start-up)
Calibration Data CRC Error (Start-Up)	Hamming Code Recovery		Start-Up Time is increased by 3 ms if successful recovery
Hamming Code Recovery Error (Start-Up)	CPU Reset	Immediate Diagnostic low	
Calibration Data CRC Error (Operation - Background)	CPU Reset	Immediate Diagnostic low	
Dead Zone	Set Outputs in Diagnostic low. Normal Operation until the "dead zone" is left.	Immediate Diagnostic low	Immediate recovery if the "dead zone" is left
ADC Clipping (ADC Output is 0000h or 7FFFh)	Set Outputs in Diagnostic low Normal mode and CPU Reset If recovery	Immediate Diagnostic low	
Radius Overflow (> 100%) or Radius Underflow (< 50 %)	Set Outputs in Diagnostic low Normal mode and CPU Reset If recovery	Immediate Diagnostic low	(50 % - 100 %) No magnet / field too high
Fine Gain Clipping (FG < 0d or > 63d)	Set Outputs in Diagnostic low Normal mode, and CPU Reset If recovery	Immediate Diagnostic low	
Rough Offset Clipping (RO is < 0d or > 127d)	Set Outputs in Diagnostic low Normal mode, and CPU Reset If recovery	Immediate Diagnostic low	
Rough Gain Clipping (RG < RGTHRESLOW or RG > RGTHRESHIGH)	Set Outputs in Diagnostic low Normal mode, and CPU Reset If recovery	Immediate Diagnostic low	
DAC Monitor (Digital to Analog converter)	Set Outputs in Diagnostic low. Normal Mode with immediate recovery without CPU Reset	Immediate Diagnostic low	
ADC Monitor (Analog to Digital converter)	Set Outputs in Diagnostic low. Normal Mode with immediate recovery without CPU Reset	Immediate Diagnostic low	ADC Inputs are Shorted
MLX90316 Fault Mode continue...			

...MLX90316 Fault Mode			
Fault Mode	**Action**	**Effect on Outputs**	**Remark**
Undervoltage Mode	At Start-Up, wait Until Vdd > 3V. During operation, CPU Reset after 3 ms debouncing	- Vdd < POR level => Outputs high impedance - POR level < Vdd < 3 V => Outputs in Diagnostic low.	
Firmware Flow Error	CPU Reset	Immediate Diagnostic low	Intelligent Watchdog (Observer)
Read/Write Access out of physical memory	CPU Reset	Immediate Diagnostic low	100% Hardware detection.
Write Access to protected area (IO and RAM Words)	CPU Reset	Immediate Diagnostic low	100% Hardware detection.
Unauthorized entry in "SYSTEM" Mode	CPU Reset	Immediate Diagnostic low	100% Hardware detection.
Vdd > 7 V	Set Output High Impedant (Analog)	Pull down resistive load => Diag. Low Pull up resistive load => Diag. High([15])	100% Hardware detection.
Vdd > 9.4 V	IC is switched off (internal supply) CPU Reset on recovery	Pull down resistive load => Diag. Low Pull up resistive load => Diag. High	100% Hardware detection.
Broken Vss	CPU Reset on recovery	Pull down resistive load => Diag. Low Pull up resistive load => Diag. High	100% Hardware detection. Pull down load < 10 kΩ to meet Diag Lo spec < 2% Vdd
Broken Vdd	CPU Reset on recovery	Pull down resistive load => Diag. Low Pull up resistive load => Diag. High	100% Hardware detection. Pull up load to Vpullup> 8 V to meet Diag Hi spec > 96% Vdd

([14]) CPU Reset means:
1. Core Reset (same as Power-On-Reset). It induces a typical start up time.
2. Periphery Reset (same as Power-On-Reset)
3. Fault Flag/Status Lost

([15]) Refer to Section 7 for the Diagnostic Output Level specifications

16. Serial Protocol

16.1. Introduction

The MLX90316 features a digital Serial Protocol mode. The MLX90316 is considered as a Slave node. The serial protocol of the MLX90316 is a three wires protocol (/SS, SCLK, MOSI-MISO):

- /SS pin is a 5 V tolerant digital input
- SCLK pin is a 5 V tolerant digital input
- MOSI-MISO pin is a 5 V tolerant open drain digital input/output

The basic knowledge of the standard SPI specification is required for the good understanding of the present section.

16.2. SERIAL PROTOCOL Mode

- CPHA = 1 → even clock changes are used to sample the data
- CPOL = 0 → active-Hi clock

The positive going edge shifts a bit to the Slave's output stage and the negative going edge samples the bit at the Master's input stage.

16.3. MOSI (Master Out Slave In)

The Master sends a command to the Slave to get the angle information.

16.4. MISO (Master In Slave Out)

The MISO of the slave is an open-collector stage. Due to the capacitive load (TBD) a >1 kΩ pull-up is used for the recessive high level (in fast mode). Note that MOSI and MISO use the same physical pin of the MLX90316.

16.5. /SS (Slave Select)

The /SS pin enables a frame transfer (if CPHA = 1). It allows a re-synchronisation between Slave and Master in case of communication error.

16.6. Master Start-up

/SS, SCLK, MISO can be undefined during the Master start-up as long as the Slave is re-synchronized before the first frame transfer.

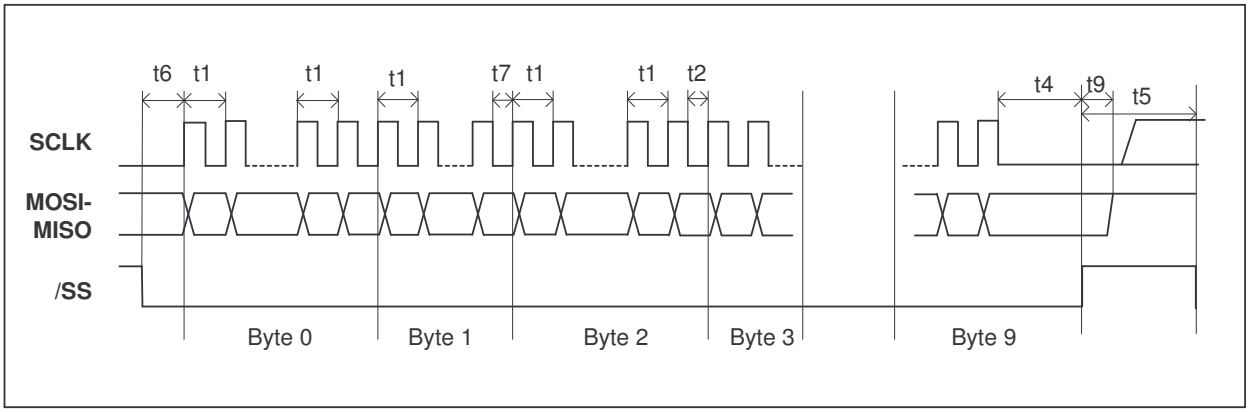
16.7. Slave Start-up

The slave start-up (after power-up, or an internal failure) takes 16 ms. Within this time /SS and SCLK is ignored by the Slave. The first frame can therefore be sent after 16 ms. MISO is Hi-Z (i.e. Hi-impedant) until the Slave is selected by its /SS input. MLX90316 will cope with any signal from the Master while starting up.

16.8. Timing

To synchronize communication, the Master deactivates /SS high for at least t5 (1.5 ms). In this case, the Slave will be ready to receive a new frame. The Master can re-synchronize at any time, even in the middle of a byte transfer.

Note: Any time shorter than t5 leads to an undefined frame state, because the Slave may or may not have seen /SS inactive.



Timings	Min[15]	Max	Remarks
t1	2.3 µs / 6.9 µs	-	No capacitive load on MISO. t1 is the minimum clock period for any bits within a byte.
t2	12.5 µs / 37.5 µs	-	t2 the minimum time between any other byte
t4	2.3 µs / 6.9 µs	-	Time between last clock and /SS=high=chip de-selection
t5	300 µs / 1500 µs	-	Minimum /SS = Hi time where it's guaranteed that a frame re-synchronizations will be started.
t5	0µs	-	Maximum /SS = Hi time where it's guaranteed that NO frame re-synchronizations will be started.
t6	2.3 µs / 6.9 µs	-	The time t6 defines the minimum time between /SS = Lo and the first clock edge
t7	15 µs / 45 µs	-	t7 is the minimum time between the StartByte and the Byte0
t8	0 µs	-	the minimum time where SS is deactivated between a ID Byte and a StartByte
t9	-	<1 µs	Maximum time between /SS = Hi and MISO Bus High-Impedance
$T_{StartUp}$	-	< 10 ms / 16 ms	Minimum time between reset-inactive and any master signal change

([15]) Timings shown for oscillator base frequency of 20MHz (Fast Mode) / 7MHz (Slow Mode).

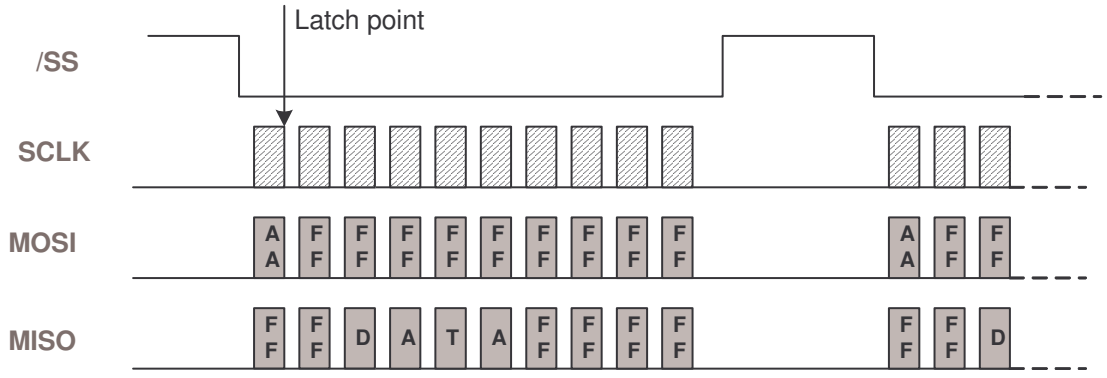
16.9. Slave Reset

On internal soft failures the Slave resets after 1 second or after an (error) frame is sent. On internal hard failures the Slave resets itself. In that case, the Serial Protocol will not come up. The serial protocol link is enable only after the completion of the first synchronization (the Master deactivates /SS for at least t5).

16.10. Frame Layer

16.10.1. Command Device Mechanism

Before each transmission of a data frame, the Master should send a byte AAh to enable a frame transfer. The latch point for the angle measurement is at the last clock of the first data frame byte.



Timing diagram

16.10.2. Data Frame Structure

A data frame consists of 10 bytes:

- 2 start bytes (AAh followed by FFh)
- 2 data bytes (DATA16 – most significant byte first)
- 2 inverted data bytes (/DATA16 - most significant byte first)
- 4 all-Hi bytes

The Master should send AAh followed by 9 bytes FFh. The Slave will answer with two bytes FFh followed by 4 data bytes and 4 bytes FFh.

16.10.3. Timing

There are no timing limits for frames: a frame transmission could be initiated at any time. There is no inter-frame time defined.

16.10.4. Data Structure

The DATA16 could be a valid angle, or an error condition. The two meanings are distinguished by the LSB.

DATA16: Angle A[13:0] with (Angle Span)/2^{14}

Most Significant Byte								Less Significant Byte							
MSB							LSB	MSB							LSB
A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	0	1

DATA16: Error

Most Significant Byte								Less Significant Byte							
MSB							LSB	MSB							LSB
E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2	E1	E0

BIT	NAME	
E0	0	
E1	1	
E2	F_ADCMONITOR	ADC Failure
E3	F_ADCSATURA	ADC Saturation (Electrical failure or field too strong)
E4	F_RGTOOLOW	Analog Gain Below Trimmed Threshold (Likely reason : field too weak)
E5	F_MAGTOOLOW	Magnetic Field Too Weak
E6	F_MAGTOOHIGH	Magnetic Field Too Strong
E7	F_RGTOOHIGH	Analog Gain Above Trimmed Threshold (Likely reason : field too strong)
E8	F_FGCLAMP	Never occurring in serial protocol
E9	F_ROCLAMP	Analog Chain Rough Offset Compensation : Clipping
E10	F_MT7V	Device Supply VDD Greater than 7V
E11	-	
E12	-	
E13	-	
E14	F_DACMONITOR	Never occurring in serial protocol
E15	-	

16.10.5. Angle Calculation

All communication timing is independent (asynchronous) of the angle data processing. The angle is calculated continuously by the Slave:

- Slow Mode: every 1.5 ms at most.
- Fast Mode: every 350 µs at most.

The last angle calculated is hold to be read by the Master at any time. Only valid angles are transferred by the Slave, because any internal failure of the Slave will lead to a soft reset.

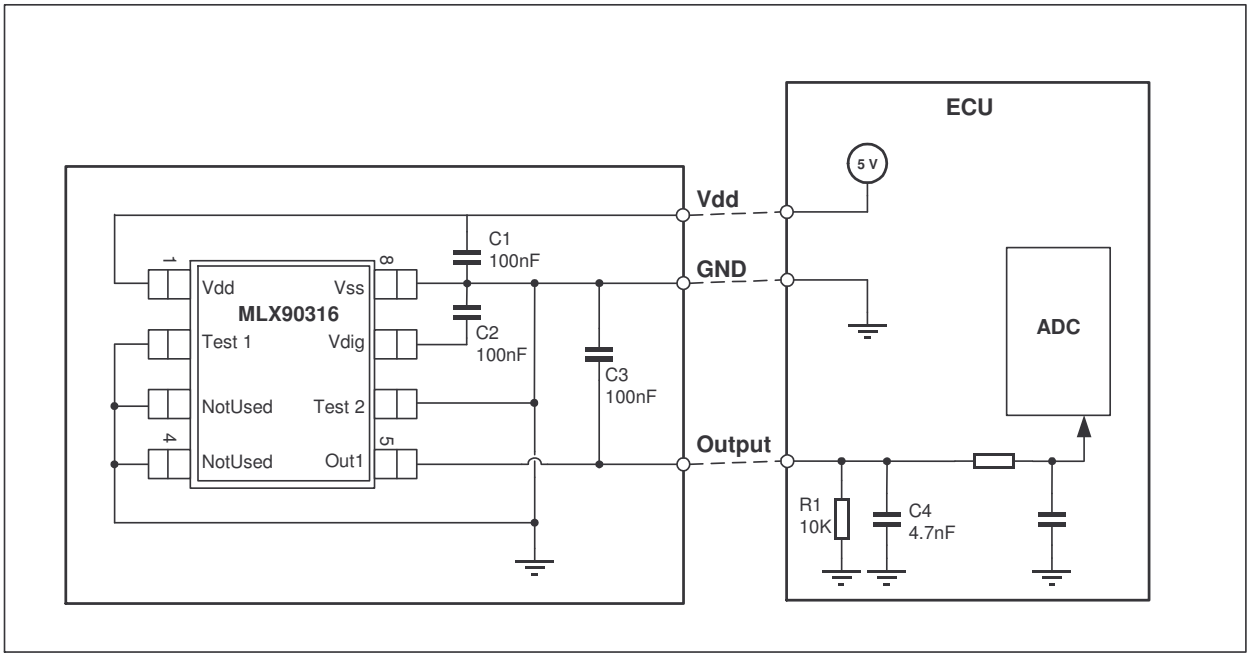
16.10.6. Error Handling

In case of any errors listed in section 16.10.4, the Serial protocol will be initialized and the error condition can be read by the master. The slave will perform a soft reset once the error frame is sent.

In case of any other errors (ROM CRC error, EEPROM CRC error, RAM check error, intelligent watchdog error…) the Slave's serial protocol is not initialized. The MOSI/MISO pin will stay Hi-impedant (no error frame are sent).

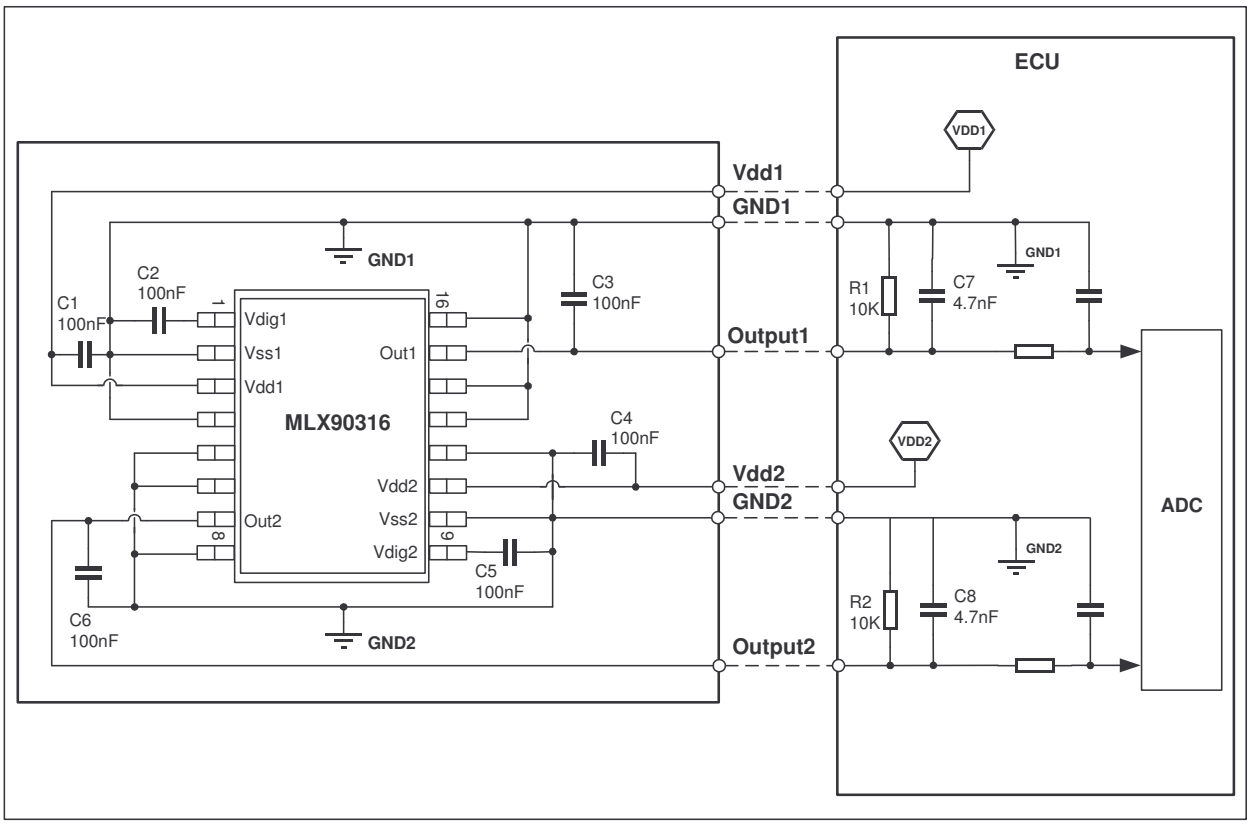
17. Recommended Application Diagrams

17.1. Analog Output Wiring with the MLX90316 in SOIC Package



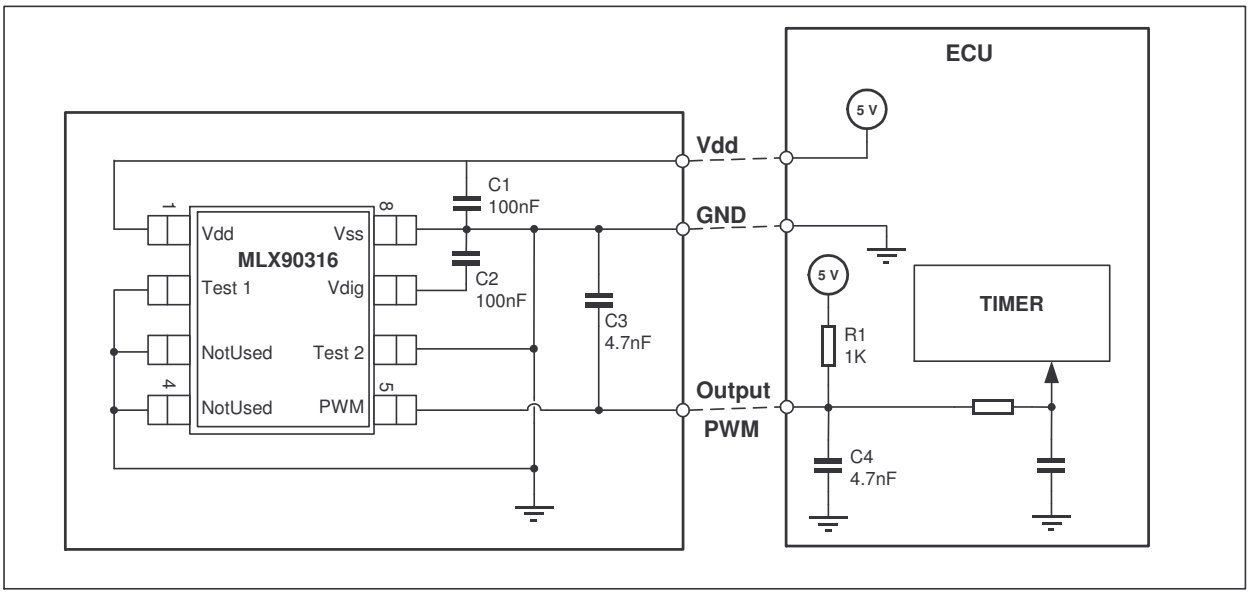
Recommended wiring for the MLX90316 in SOIC8 package.

17.2. Analog Output Wiring with the MLX90316 in TSSOP Package



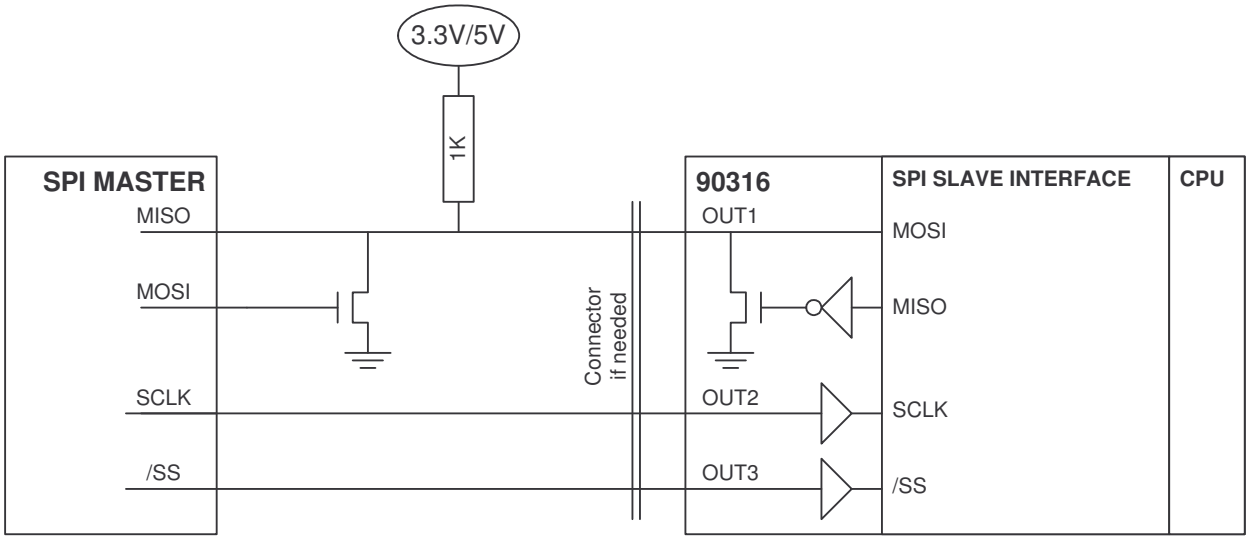
Recommended wiring for the MLX90316 in TSSOP16 package (dual die).

17.3. PWM Low Side Output Wiring

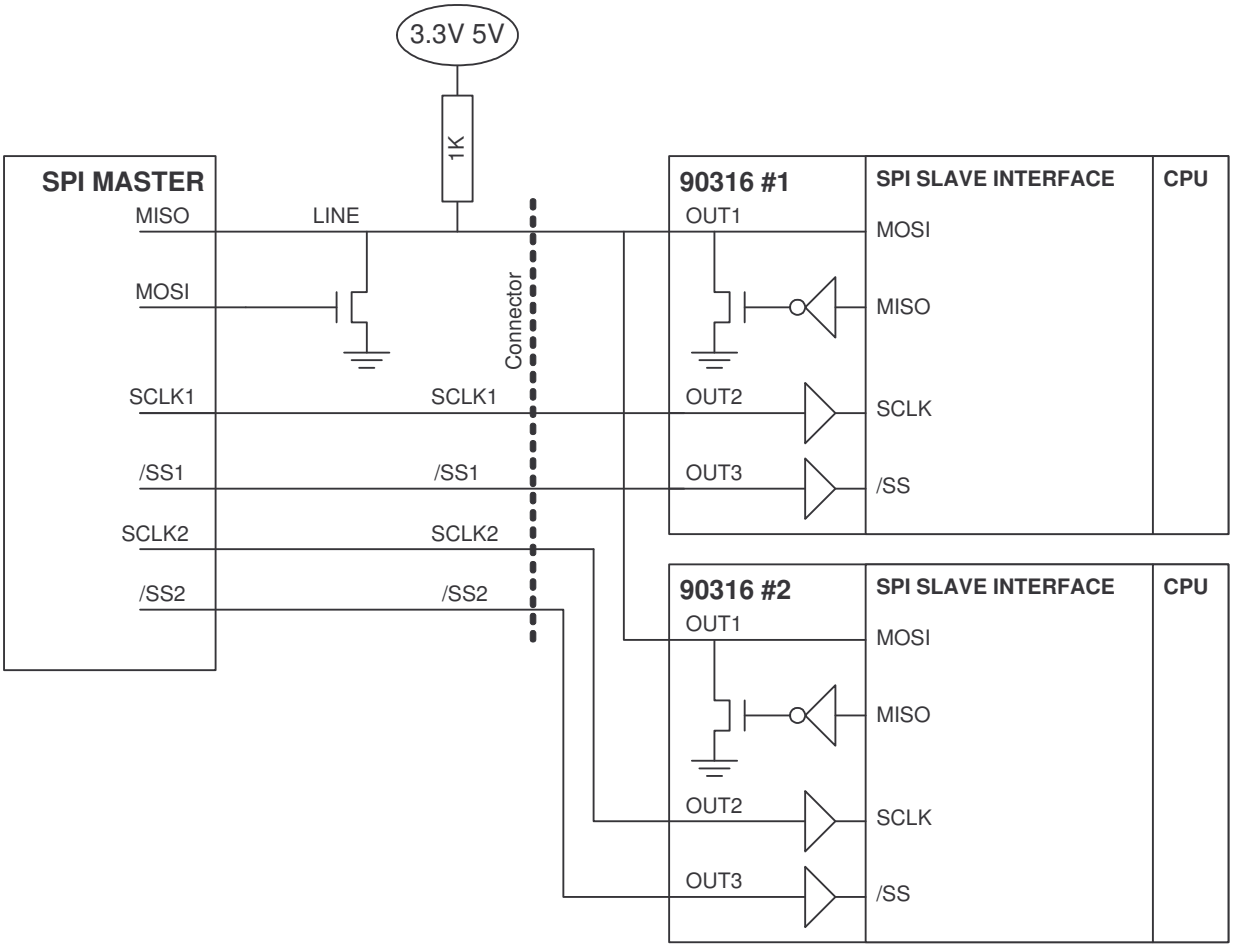


Recommended wiring for a PWM Low Side Output configuration.

17.4. Serial Protocol



MLX9031 – Single Die – Serial Protocol Mode



MLX90316 Dual Die – Serial Protocol Mode (Dual Slave)

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

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

Reflow Soldering SMD's (Surface Mount Devices)

- IPC/JEDEC J-STD-020
  Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
  (classification reflow profiles according to table 5-2)
- EIA/JEDEC JESD22-A113
  Preconditioning of Nonhermetic Surface Mount Devices Prior to Reliability Testing
  (reflow profiles according to table 2)
- Melexis Working Instruction 341901308

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

- EN60749-20
  Resistance of plastic- encapsulated SMD's to combined effect of moisture and soldering heat
- EIA/JEDEC JESD22-B106 and EN60749-15
  Resistance to soldering temperature for through-hole mounted devices
- Melexis Working Instruction 341901309

Iron Soldering THD's (Through Hole Devices)

- EN60749-15
  Resistance to soldering temperature for through-hole mounted devices
- Melexis Working Instruction 341901309

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

- EIA/JEDEC JESD22-B102 and EN60749-21
  Solderability
- Melexis Working Instruction 3304312

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

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

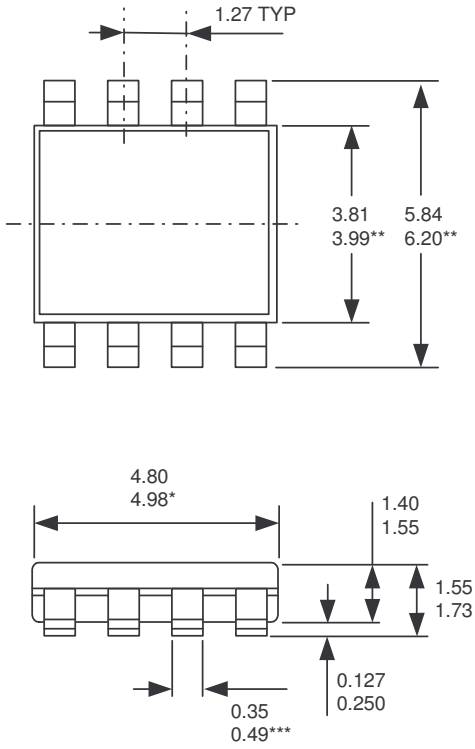
For more information on the lead free topic please see quality page at our website:
http://www.melexis.com/quality.asp

19. ESD Precautions

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

20. Package Information

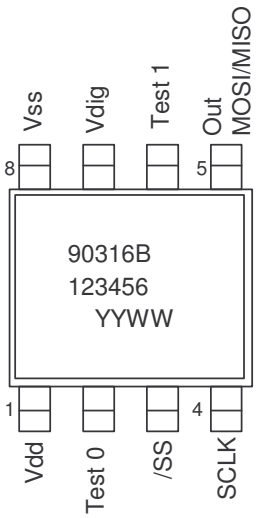
20.1. SOIC8 - Package Dimensions



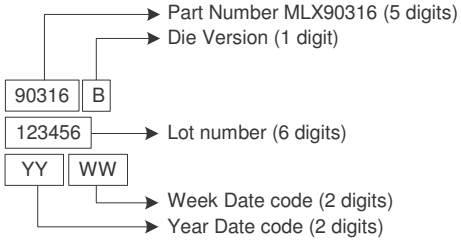
NOTES:

All dimensions are in millimeters (anlges in degrees).
* Dimension does not include mold flash, protrusions or gate burrs (shall not exceed 0.15 per side).
** Dimension does not include interleads flash or protrusion (shall not exceed 0.25 per side).
*** Dimension does not include dambar protrusion. Allowable dambar protrusion shall be 0.08 mm total in excess of the dimension at maximum material condition. Dambar cannot be located on the lower radius of the foot.

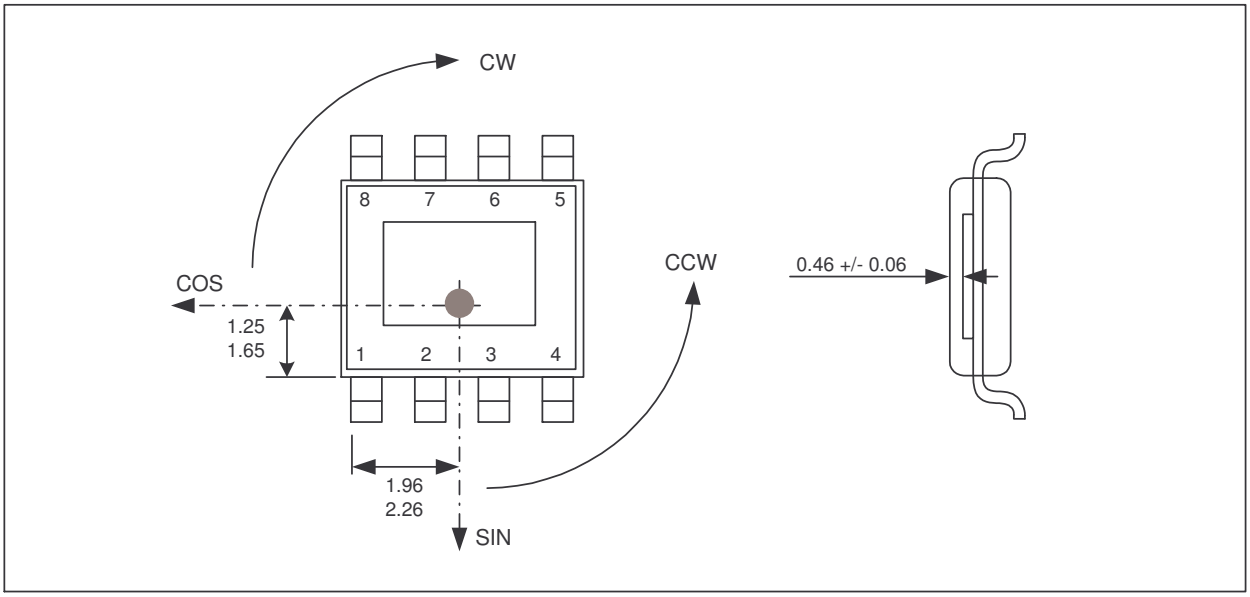
20.2. SOIC8 - Pinout and Marking



Marking :

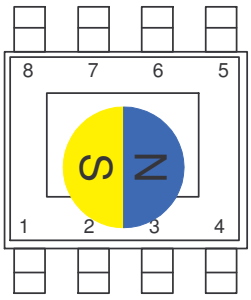


20.3. SOIC8 - IMC Positionning

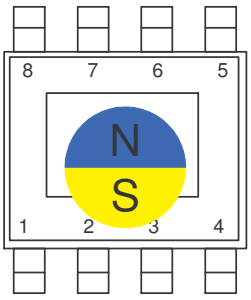


Angle detection MLX90316 SOIC8

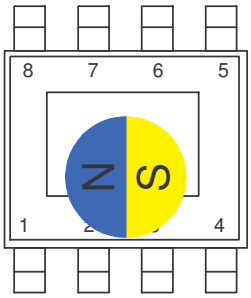
0 Deg.



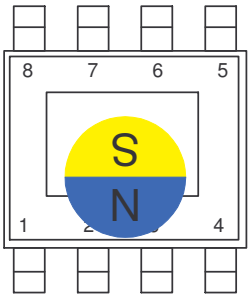
90 Deg.



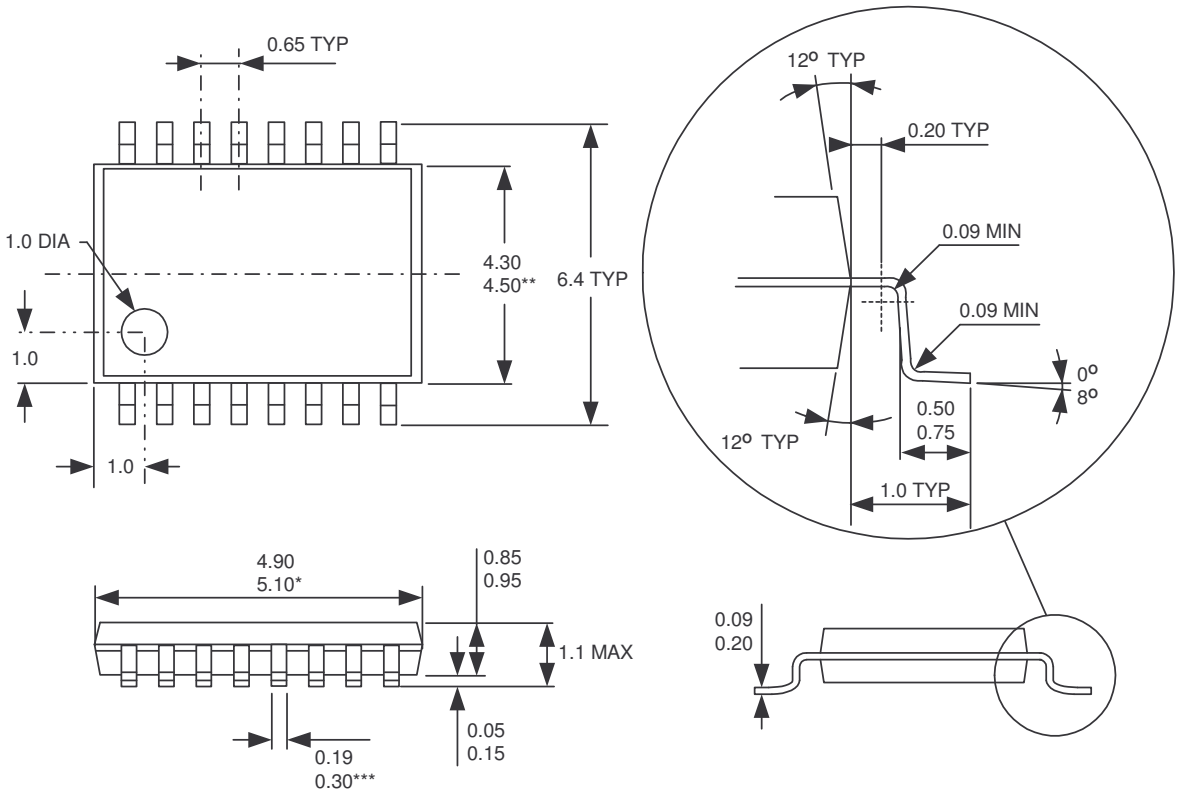
180 Deg.



270 Deg.



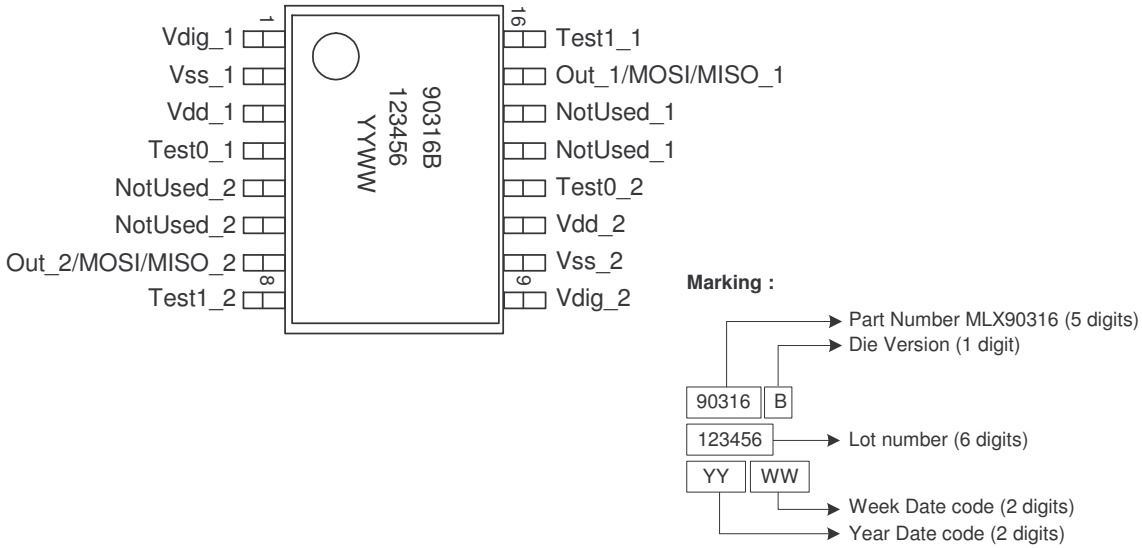
20.4. TSSOP16 - Package Dimensions



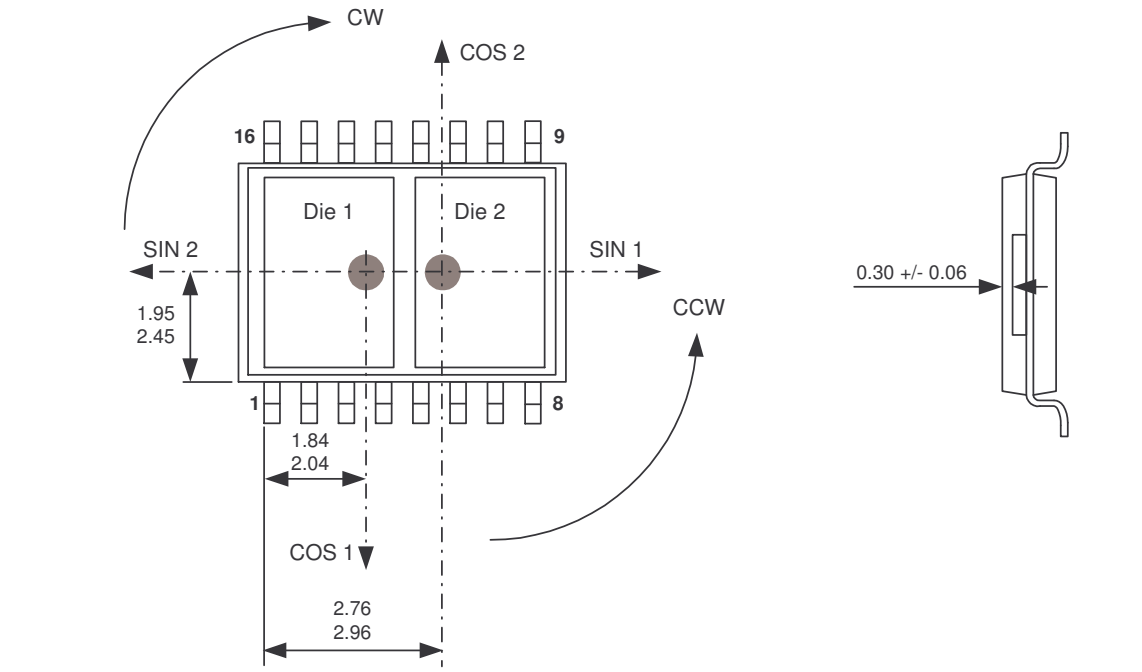
NOTES:

All dimensions are in millimeters (anlges in degrees).
* Dimension does not include mold flash, protrusions or gate burrs (shall not exceed 0.15 per side).
** Dimension does not include interleads flash or protrusion (shall not exceed 0.25 per side).
*** Dimension does not include dambar protrusion. Allowable dambar protrusion shall be 0.08 mm total in excess of the dimension at maximum material condition. Dambar cannot be located on the lower radius of the foot.

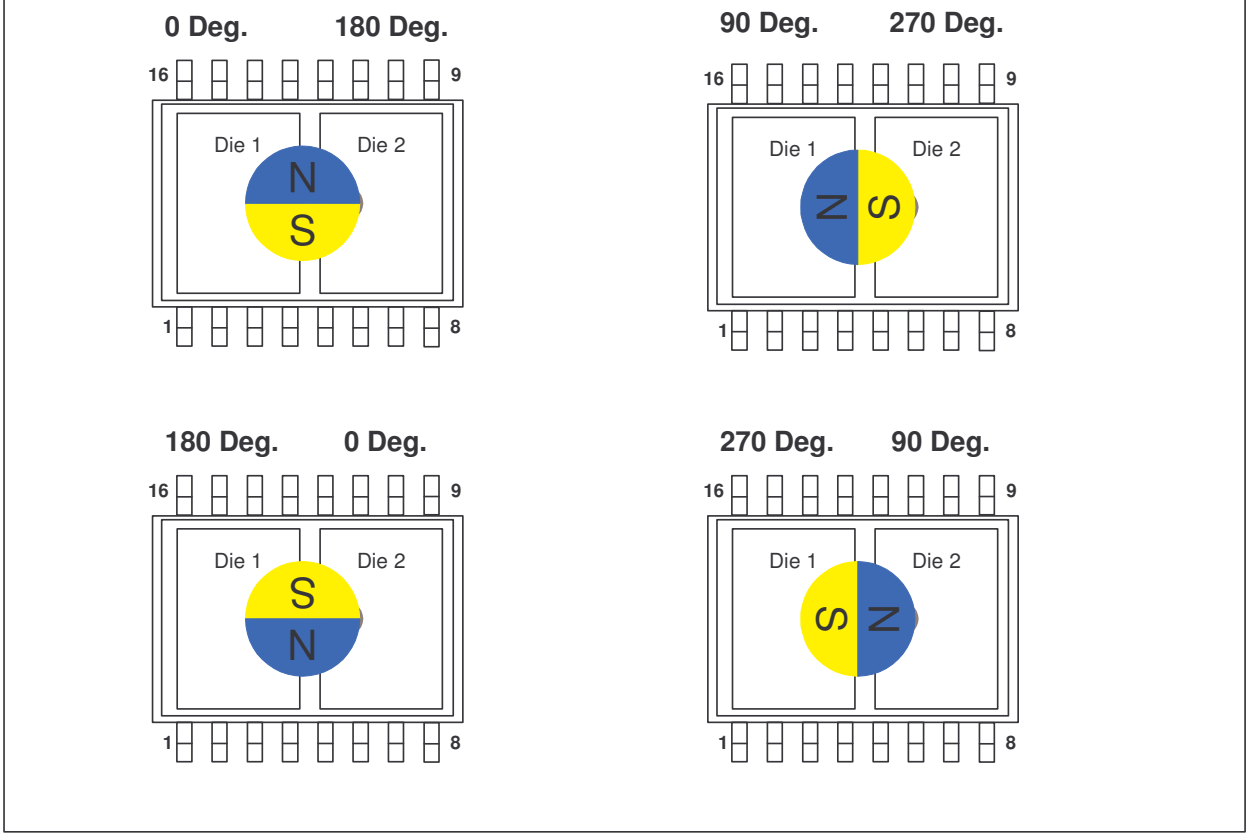
20.5. TSSOP16 - Pinout and Marking



20.6. TSSOP16 - IMC Positionning



Angle detection MLX90316 TSSOP16



21. Disclaimer

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