MLX90296

Micropower Linear Hall Sensor
Datasheet

General Description

1.1 Features & Benefits

- Linear Hall-effect sensor
- Ratiometric analog output
- µPower enable functionality
- Fast enable time – 25 µs typical
- Ultra-low power consumption
  - 7 nA when powered down
  - 55 µA with 1 kHz external enable rate
  - 5.5 µA with 100 Hz external enable rate
  - 2 mA when continuously enabled
- Bi-directional or unidirectional output
- Moving average filter product option
- Tri-state output (High Z in power down)
- Low input-referred noise of 0.35 mTpp
- Wide operating voltage range 1.65 V to 3.6 V
- Wide temperature range -40 °C to 105 °C
- Stable quiescent point and sensitivity over temperature and voltage
- Optional 1200 ppm/°C sensitivity TC for Neodymium magnet compensation
- Pre-defined sensitivity options at 1.8 V[1]:
  - 3.5 mV/mT (bipolar) 7 mV/mT (unipolar)
  - 8.1 mV/mT (bipolar) 16.2 mV/mT (unipolar)
  - 16 mV/mT (bipolar) 32 mV/mT (unipolar)
  - 30 mV/mT (bipolar) 60 mV/mT (unipolar)
  - 60 mV/mT (bipolar) 120 mV/mT (unipolar)
- Sensitivity at 3.3V operation scales linearly
- Small footprint and low-profile package
  - DFN-4L (1.2 mm x 1.6 mm x 0.4 mm) with lead pitch of 0.5mm nominal
- RoHS Compliant & Green Package

1.2 Applications Examples

- Linear Position
  - Trigger buttons
  - Push buttons
  - Liquid levels
  - Weight & Tilt
- Mobile/Battery Powered IoT
- Joystick & Rotary Position
- Flow Metering

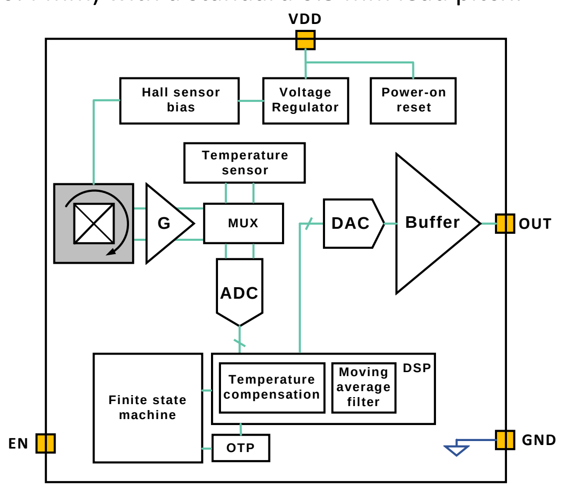
1.3 Description

The Melexis MLX90296 is a family of Micropower Linear Hall-effect sensors with ratiometric output. The device is designed to provide fast contactless measurement of linear motions with the lowest of power consumptions.

The output voltage is proportional to the applied magnetic field and to the chip supply voltage. It is ratiometric, uni and bi-directional, sensing magnetic field in both magnetic polarities[2]. The device operates at a wide range of voltage levels: from 1.65 V to 3.6 V and consumes 2 mA in continuous operation mode. Using the enable pin the device can be powered down to consume as little as 7 nA, whilst putting the output in high impedance state for easy analog multiplexing. This makes it an excellent match for battery-powered applications and mobile devices.

The device integrates a voltage regulator, Hall sensor with advanced offset cancellation system, filtering, NV memory and an analog output driver. Its digitally-assisted architecture provides for seamless control over the output saturation voltage, output offset and noise among others. A moving average filter option[2] is available to further smoothen the output voltage in applications, working at lower magnetic field frequencies.

The device is offered in small form factor - a RoHS compliant DFN-4L package (1.2 mm x 1.6 mm x 0.4 mm) with a standard 0.5 mm lead pitch.



[1] See available ordering codes

[2] Inverse polarity and moving average filter available on specific request

Ordering Information

Ordering code example:

MLX90296RLD-AAA-XYZ-RE

Temperature code:

R: (-40°C to 105°C)

Package code:

LD: DFN–4L

Option code structure:

AAA-XYZ:
AAA = die version

X = Power mode and magnetic sensing polarity

- 0: Low power & Bipolar magnetic sensing polarity
- 1: Fast mode & Bipolar magnetic sensing polarity
- 2: Low power & Unipolar magnetic sensing polarity
- 3: Fast mode & Unipolar magnetic sensing polarity

Y= Sensitivity

- 1: For Bipolar 3.5 mV/mT @ V_{DD} = 1.8 V Or For Unipolar 7.0 mV/mT @ V_{DD} = 1.8 V
- 2: For Bipolar 8.1 mV/mT @ V_{DD} = 1.8 V Or For Unipolar 16.2 mV/mT @ V_{DD} = 1.8 V
- 3: For Bipolar 16 mV/mT@ V_{DD} = 1.8 V Or For Unipolar 32 mV/mT @ V_{DD} = 1.8 V
- 4: For Bipolar 30 mV/mT @ V_{DD} = 1.8 V Or For Unipolar 60 mV/mT @ V_{DD} = 1.8 V
- 5: For Bipolar 60 mV/mT @ V_{DD} = 1.8 V Or For Unipolar 120 mV/mT @ V_{DD} = 1.8 V

Z = TCS

- 0: 0 ppm/°C
- 1: 400 ppm/°C
- 2: 1200 ppm/°C
- 3: 2000 ppm/°C

Important:

The sensitivity is expressed as mV/mT for V_{DD} = 1.8 V. It scales linearly with the supply voltage.

Production version:

Sensitivity is specified at V_{DD} = 1.8 V, moving average filter not enabled (unless otherwise specified)

Ordering Code	Polarity	Power Mode	Sensitivity [1]	TC
MLX90296RLD-AAA-012-RE	Bipolar Positive	Low	3.5 mV/mT	1200 ppm/°C
MLX90296RLD-AAA-022-RE	Bipolar Positive	Low	8.1 mV/mT	1200 ppm/°C
MLX90296RLD-AAA-032-RE	Bipolar Positive	Low	16 mV/mT	1200 ppm/°C
MLX90296RLD-AAA-042-RE	Bipolar Positive	Low	30 mV/mT	1200 ppm/°C
MLX90296RLD-AAA-222-RE	Unipolar Positive	Low	16.2 mV/mT	1200 ppm/°C
MLX90296RLD-AAA-232-RE	Unipolar Positive	Low	32 mV/mT	1200 ppm/°C

Table 1 – Product codes

[1] Positive sensitivity indicates increasing output voltage with increasing south pole magnetic field strength, facing the branded side of the chip

CONTENTS

Pins Description and Block Diagram

1.4 Pins description for DFN-4L package

Pin #	Name	I/O	Description
1	GND	Ground	Ground pin
2	EN	Input	Enable input
3	OUT	Output	Output pin
4	VDD	Supply	Voltage supply pin

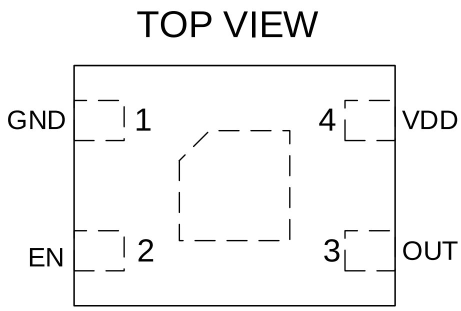


Table 2 – MLX90296 DFN-4 package pins description

1.5 Block diagram

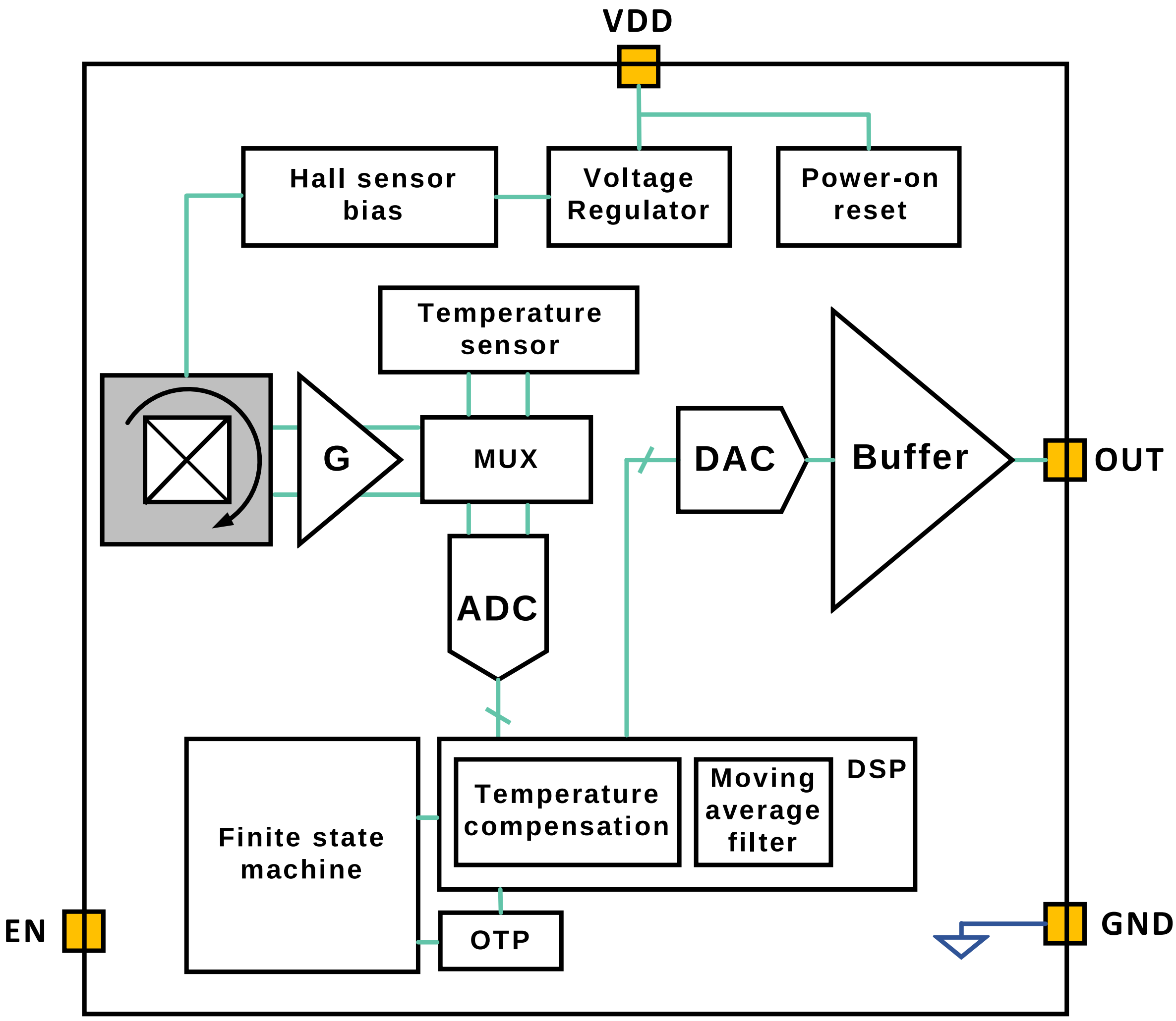


Table 3 MLX90296AA Functional Block Diagram

Conditions and Specifications

1.6 Absolute Maximum Ratings (AMR)

T_A = -40°C to 105°C (unless otherwise specified)

Parameter	Symbol	Min.	Max.	Unit	Condition
Supply voltage	V_{DD}	-0.3	4	V	
Supply current[1]	I_{DD}	-20	20	mA	
Output voltage	V_{OUT}	-0.3	V_{DD}+0.3	V	
Output current[1]	I_{OUT}	-20	20	mA	
Magnetic flux density	B	Infinite		T	
ESD voltage	$V_{ESD-HBM}$	-2	2	kV	HBM (AEC-Q100-002), all pins
	$V_{ESD-CDM}$	-500	500	V	CDM (AEC-Q100-011), all pins
Storage temperature	T_{STG}	-55	165	°C	
Operating temperature	T_A	-40	105	°C	Ambient temperature
Junction temperature	T_J	-40	125	°C	

Table 4 – Absolute Maximum Ratings

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

1.7 Electrical operating conditions & specifications

Operating Parameters VDD = 1.65V to 3.6V, T_A = -40°C to 105°C (unless otherwise specified).

Parameter[2]	Symbol	Min.	Typ.	Max.	Unit	Condition
Nominal supply voltage	V_{DDnom}	-	1.8	-	V	
Average active current consumption	I_{DD}	-	2	2.5	mA	V_{EN}>V_{IH} MLX90296RLD-AAA-0yz-RE MLX90296RLD-AAA-2yz-RE
		-	2.3	2.8	mA	V_{EN}>V_{IH} MLX90296RLD-AAA-1yz-RE MLX90296RLD-AAA-3yz-RE
		-	7	-	nA	V_{DD}=1.8V, T_A=35°C, V_{EN}<V_{IL}
Load current	I_{LOAD}	-1	-	1	mA	
Load resistance range	R_L	3.6	-	-	kΩ	
Load capacitor range	C_L	-	-	2	nF	
Minimum output saturation voltage high	V_{OSHI}	0.96 x V_{DD} - |V_{OFF}|			V	V_{OSHI} is ratiometric with V_{DD}
Maximum output saturation voltage low	V_{OSLO}	0.04 x V_{DD} + |V_{OFF}|			V	V_{OSLO} is ratiometric with V_{DD}
Output resistance	R_{OUT}	-	1	2.3	Ω	V_{EN}>V_{IH}
		100	-	-	MΩ	V_{EN}<V_{IL}
Enable (EN) pin high voltage	V_{IH}	60	-	-	%V_{DD}	
Enable (EN) pin low voltage	V_{IL}	-	-	30	%V_{DD}	

Table 5 – Electrical specifications

[1] Including the current flowing through the protection structure
[2] Limits set ±3σ around the typical value

1.8 General timing specifications

Operating Parameters VDD = 1.65V to 3.6V, T_A = -40°C to 105°C (unless otherwise specified).

Parameter [1]	Symbol	Min.	Typ.	Max.	Unit	Condition
VDD ramp rate	-	0.004	-	4	V / µs	
Power-On time[2]	t_{ON}	-	56	60	µs	T_A=35°C
Enable Response time[3] (Including T_{SAMPLE} & t_{SETTLE})	t_{EN}	-	25	30	µs	
Sample / Update period	T_{SAMPLE}	-	5.5	-	µs	Fast Mode MLX90296RLD-AAA-1yz-RE MLX90296RLD-AAA-3yz-RE
		-	12.5	-	µs	Low Power Mode MLX90296RLD-AAA-0yz-RE MLX90296RLD-AAA-2yz-RE
Settling time[4]	t_{settle}			4	µs	

Table 6 – Timing specifications

[1] Limits set ±3σ around the typical value
[2] Defined as the time interval between V_{DD}≥1.7V and the time 95% of the settled output voltage value is available at the output (includes t_{settle})
[3] Defined as the time interval between V_{EN}≥V_{IH} and the time 95% of the settled output voltage value is available at the output (includes t_{settle})
[4] Defined as the time the output buffer needs to settle within 95% of its final value after magnetic field acquisition

1.9 Magnetic specifications

Operating Parameters VDD = 1.65V to 3.6V, T_A = -40°C to 105°C (unless otherwise specified).

Parameter [1]	Symbol	Min.	Typ.	Max.	Unit	Condition
Sensitivity [2,3]	S_{VDDnom}	3.15	3.5	3.85	mV/mT	V_{DDnom}, Bipolar mode, MLX90296RLD-AAA-x1z-RE, T_A=35°C
		7.29	8.1	8.91	mV/mT	V_{DDnom}, Bipolar mode, MLX90296RLD-AAA- x2z-RE, T_A=35°C
		14.4	16	17.6	mV/mT	V_{DDnom}, Bipolar mode, MLX90296RLD-AAA- x3z-RE, T_A=35°C
		27	30	33	mV/mT	V_{DDnom}, Bipolar mode, MLX90296RLD-AAA- x4z-RE, T_A=35°C
		54	60	66	mV/mT	V_{DDnom}, Bipolar mode, MLX90296RLD-AAA- x5z -RE, T_A=35°C
		6.3	7	7.7	mV/mT	V_{DDnom}, Unipolar mode, MLX90296RLD-AAA- x1z-RE, T_A=35°C
		14.6	16.2	17.8	mV/mT	V_{DDnom}, Unipolar mode, MLX90296RLD-AAA-x2z-RE, T_A=35°C
		28.8	32	35.2	mV/mT	V_{DDnom}, Unipolar mode, MLX90296RLD-AAA-x3z-RE, T_A=35°C
		54	60	66	mV/mT	V_{DDnom}, Unipolar mode, MLX90296RLD-AAA-x4z-RE, T_A=35°C
		108	120	132	mV/mT	V_{DDnom}, Unipolar mode, MLX90296RLD-AAA- x5z-RE
Magnetic sensing bipolar range [2]	B_R	±200	-	-	mT	MLX90296RLD-AAA-x1z-RE, T_A=35°C
		±84	-	-	mT	MLX90296RLD-AAA-x2z-RE, T_A=35°C
		±43	-	-	mT	MLX90296RLD-AAA-x3z-RE, T_A=35°C
		±22	-	-	mT	MLX90296RLD-AAA-x4z-RE, T_A=35°C
		±11	-	-	mT	MLX90296RLD-AAA-x5z-RE, T_A=35°C
Sensitivity temperature coefficient	TC_{SHT}	1000	1200	1500	ppm/°C	MLX90296RLD-AAA-0y2-RE
	TC_{SLT}	950		1500		MLX90296RLD-AAA-2y2-RE
	TC_{SHT}	1000		1650		MLX90296RLD-AAA-1y2-RE
	TC_{SLT}	550		1200		MLX90296RLD-AAA-3y2-RE
Sensitivity linearity error	ε_{LE}		0.1	0.4	%	Best-fit method
Sensitivity symmetry error	ε_{SE}	-0.4	-	0.4	%	
Sensitivity ratiometricity error	ε_{RE}	-1	-	1	%	
Output offset	V_{OFF}	-30	-	30	mV	
Output quiescent voltage thermal drift	V_{OQUTD}	-10	-	10	mV	T_A from -40°C to 105°C vs. 35°C
Output quiescent voltage	V_{OQB}	0.5 x V_{DD} - |V_{OFF}|	0.5 x V_{DD}	0.5 x V_{DD} + |V_{OFF}|	mV	Bipolar magnetic sensing polarity, B = 0mT
	V_{OQU}	0.04 x V_{DD} - |V_{OFF}|	0.04 x V_{DD}	0.04 x V_{DD} + |V_{OFF}|		Unipolar magnetic sensing polarity, B = 0mT
V_{OQ} ratiometricity error	ε_{VOQRE}	-0.1	-	0.1	%	Bipolar magnetic sensing polarity, B = 0mT
		-0.8	-	0.8		Unipolar magnetic sensing polarity, B = 0mT
Input-referred noise	B_{Npp}	-	0.35	-	mT_{pp}	Peak-to-peak without external filtering, T_A=35 °C
			0.175		mT_{pp}	Peak-to-peak without external filtering, T_A=35 °C and moving average filter with four samples window size[4]

Table 7 – Magnetic specifications

[1] Limits set ±3σ around the typical value
[2] The sensitivity value is scaled by the ratio V_{DD}/V_{DDnom}. Positive sensitivity indicates increasing output voltage with increasing south pole magnetic field strength, facing the branded side of the chip
[3] This parameter is specified for ordering variants with bipolar magnetic sensing polarity - MLX90296RLD-AAA-0yz-RE or MLX90296RLD-AAA-1yz-RE
[4] The settling time of the output voltage during, e.g., a step response increases with the settling time of the moving average filter

Parameters Description

1.10 Power-On time

Defined as the time interval between V_{DD}≥1.7V and the time 95% of the settled output voltage value is available at the output.

1.11 Enable Response time

Defined as the time interval between V_{EN}≥V_{IH} and the time 95% of the settled output voltage value is available at the output.

1.12 Sample / Update period

The period at which the output voltage is updated in normal operation.

1.13 Output Propagation delay

The time interval after which the output voltage is settled to 95% of its final value for a step magnetic field change. Due to the magnetic field being updated asynchronously to the internal sampling moment, the worst case expected value can be calculated according to the equations below:

$$t_{PD\_fast} = 3 \cdot T_{sample} + t_{settle} \quad (1)$$

$$t_{PD\_low\_power} = 2 \cdot T_{sample} + t_{settle} \quad (2)$$

1.14 Sensitivity (S)

The sensitivity is defined as the slope of the transfer function of MLX90296 with linearly changing magnetic field.

$$S_{VDD} = \frac{V_{DD}}{V_{DDnom}} \times S_{VDDnom} \quad (3)$$

In Eq. (1), S_{VDD} and S_{VDDnom} are the sensitivity at supply voltage V_{DD} and V_{DDnom} respectively.

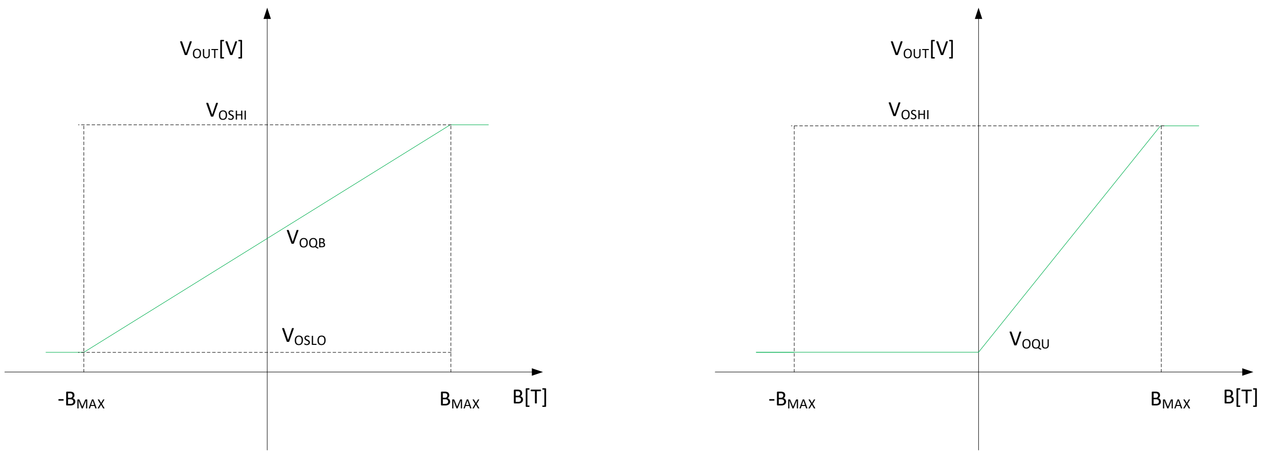


Figure 1 Bipolar magnetic behavior (left), Unipolar magnetic behavior (right)

The output voltage can be expressed with the following equation:

$$V_{OUT}(V_{DD}, B) = V_{OQ}(V_{DD}) + S_{VDD}(V_{DD}) \cdot B + V_{OFF} \quad (4)$$

The output will be clamped to V_{OSHI} and V_{OSLO} for magnetic fields which are not in the operating range of the device.

1.15 Sensitivity Temperature coefficient (TC_S)

The temperature coefficient of the sensitivity is defined as the 1st order sensitivity gain from 35°C to 105°C (TC_{SHT}) and from - 40°C to 35°C (TC_{SLT}).

$$TC_{SHT}\left[\frac{ppm}{°C}\right] = \frac{S_{VDD}^{T_{HT}} - S_{VDD}^{T_{35}}}{S_{VDD}^{T_{35}} \times (T_{HT} - T_{35})} \times 10^6 \tag{5}$$

$$TC_{SLT}\left[\frac{ppm}{°C}\right] = \frac{S_{VDD}^{T_{35}} - S_{VDD}^{T_{LT}}}{S_{VDD}^{T_{35}} \times (T_{35} - T_{LT})} \times 10^6 \tag{6}$$

In the equations above T_{35} = 35°C, T_{HT} = 105°C and T_{LT} = - 40°C.

1.16 Sensitivity linearity error (ε_{LE})

The sensitivity linearity error is defined by the following equation:

$$\varepsilon_{LE}[\%] = \left|\frac{V_{OUT} - B_{IN} \cdot S_{FIT} - V_{OQ}}{V_{FS}}\right| \times 100 \tag{7}$$

In Eq. (2), V_{OUT} is the output voltage with maximum deviation from the straight line defined by the best fit sensitivity S_{FIT}, occurring at input magnetic field B_{IN}. V_{OQ} is the output quiescent voltage, occurring in the absence of externally applied magnetic field. V_{FS} is the full-scale output linear range.

1.17 Sensitivity symmetry error (ε_{SE})

The sensitivity symmetry error is defined by the following equation:

$$\varepsilon_{SE}[\%] = \frac{2 \cdot (S_B - S_{nB})}{S_B + S_{nB}} \times 100 \tag{8}$$

In Eq. (3), S_B is the sensitivity for an input magnetic field B, S_{nB} is the sensitivity for an input magnetic field -B. This parameter is relevant only for bipolar operation.

1.18 Sensitivity ratiometricity error (ε_{RE})

The sensitivity ratiometricity error is defined by the following equation:

$$\varepsilon_{RE}[\%] = \left(1 - \frac{\frac{S_{VDD}}{S_{VDDnom}}}{\frac{V_{DD}}{V_{DDnom}}}\right) \times 100 \tag{9}$$

In Eq. (5), S_{VDD} and S_{VDDnom} are the sensitivity at supply voltage V_{DD} and V_{DDnom} respectively.

1.19 Output voltage ratiometricity error (ε_{VOQRE})

The output voltage ratiometricity error is defined by the following equation:

$$\varepsilon_{VOQRE}[\%] = \left(1 - \frac{\frac{V_{OQ}}{V_{OQnom}}}{\frac{V_{DD}}{V_{DDnom}}}\right) \times 100 \tag{10}$$

In Eq. (5), V_{OQ} and V_{OQnom} are the output quiescent voltage at supply voltage V_{DD} and V_{DDnom} respectively. This parameter is relevant only for bipolar operation.

Application

1.20 Recommended Application diagram

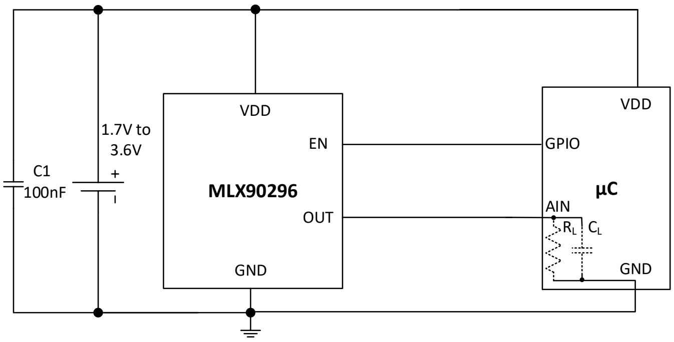


Figure 2 Recommended application diagram

1.21 Micropower operation with enable functionality

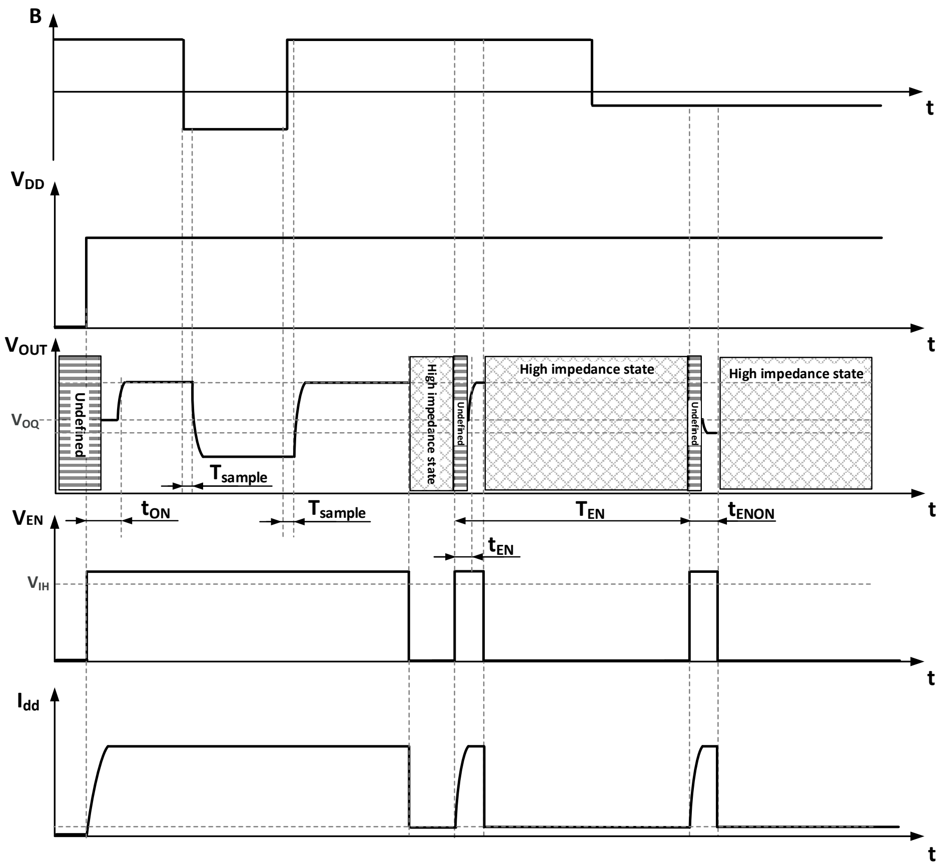


Figure 3 Timing diagram

The average current can be calculated as follows:

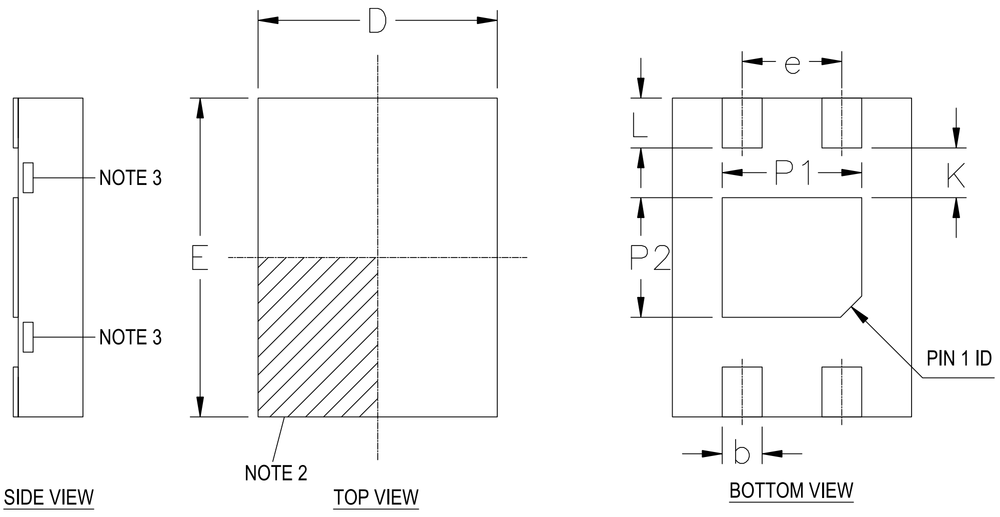
$$Idd_{avg} = I_{dd} \cdot \frac{t_{ENON}}{T_{EN}} + I_{sleep} \cdot \left(1 - \frac{t_{ENON}}{T_{EN}}\right) \quad (9)$$

t_{ENON} is the time duration EN pin voltage is ≥ V_{IH}.
For example, at T_{EN}=1ms and t_{ENON}=t_{EN} (1kHz enable frequency from the microcontroller), the average typical current consumption is Idd_{avg}=50µA. I_{sleep} is the current drawn by the chip, when V_{EN}<V_{IH}.

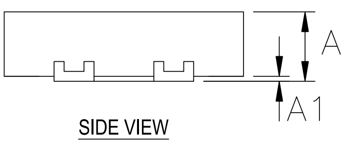
If one does not wish to use the micro-power functionality, then connecting the EN pin to the VDD pin would keep the device turned on constantly, updating its output at the defined maximum update rate.

Package, IC Handling and Assembly

1.22 DFN-4L Package information

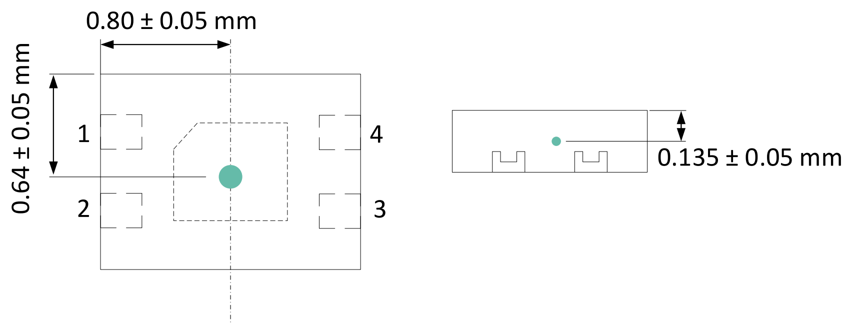


SYMBOL	MIN.	NOM.	MAX.
A	0.35	0.38	0.40
A1	0.00	---	0.05
D	1.15	1.20	1.25
E	1.55	1.60	1.65
P1	0.60	0.70	0.80
P2	0.50	0.60	0.70
L	0.15	0.25	0.35
K	0.25 REF		
b	0.15	0.20	0.25
e	0.50 BSC		

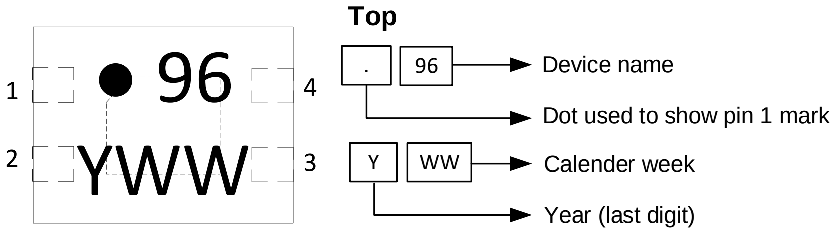


NOTE :
1. ALL DIMENSIONS IN MILLIMETERS (mm).
2. TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM JEDEC PUBLICATION 95 SPP-002. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE IDENTICATED. THE TERMINAL #1 IDENTIFIER MAY BE MARKED FEATURE.
3. EXPOSED TIE BAR SHOULD BE KEPT FREE FROM SOLDER.

1.23 DFN-4L Sensitive spot



1.24 DFN-4L Package marking



1.25 Storage and handling of plastic encapsulated ICs

Plastic encapsulated ICs shall be stored and handled according to their MSL categorization level (specified in the packing label) as per J-STD-033.

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD). The component assembly shall be handled in EPA (Electrostatic Protected Area) as per ANSI S20.20

For more information refer to Melexis *Guidelines for storage and handling of plastic encapsulated ICs* [1]

1.26 Assembly of encapsulated ICs

For Surface Mounted Devices (SMD, as defined according to JEDEC norms), the only applicable soldering method is reflow.

For Through Hole Devices (THD), the applicable soldering methods are reflow, wave, selective wave and robot point-to-point. THD lead pre-forming (cutting and/or bending) is applicable under strict compliance with Melexis *Guidelines for lead forming of SIP Hall Sensors* [1].

Melexis products soldering on PCB should be conducted according to the requirements of IPC/JEDEC and J-STD-001. Solder quality acceptance should follow the requirements of IPC-A-610.

For PCB-less assembly refer to the relevant application notes [1] or contact Melexis.

Electrical resistance welding or laser welding can be applied to Melexis products in THD and specific PCB-less packages following the *Guidelines for welding of PCB-less devices*[1].

Environmental protection of customer assembly with Melexis products for harsh media application, is applicable by means of coating, potting or overmolding considering restrictions listed in the relevant application notes [1]

For other specific process, contact Melexis via www.melexis.com/technical-inquiry

1.27 Environment and sustainability

Melexis is contributing to global environmental conservation by promoting non-hazardous solutions.
For more information on our environmental policy and declarations (RoHS, REACH…) visit www.melexis.com/environmental-forms-and-declarations

[1] www.melexis.com/ic-handling-and-assembly

Disclaimer

IATF 16949 and ISO 14001 Certified

For the latest revision of this document, visit www.melexis.com/MLX90296
Happy to help you! www.melexis.com/contact