Application Note

General Information for Melexis Latch & Switch Sensors

Contents

1 Scope

This application note provides a tutorial on how to design-in Melexis Hall sensors solutions.

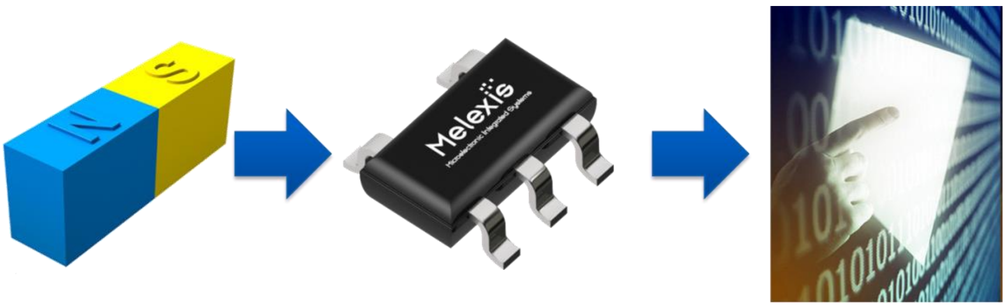
It describes the full functionality of our products including a general introduction and full documentation set.

2 Intro in L&S

A Hall IC switch is used as a digital hall sensor.
The output is On or Off depending on the applied magnetic field.
The sensor can be active with a sufficient North or in South field depending on the programmed thresholds.

Terminology:

- Bop: Magnetic operating point, defines when the output driver will be active (On)
- Brp: Magnetic Release point, defines when the output driver will be inactive (Off)
- Hysteresis: Difference between Bop and Brp Hyst = Bop-Brp



Hall-Effect “Latch and Switch” sensors converts magnet pole information (N or S) into a digital signal (1 or 0)

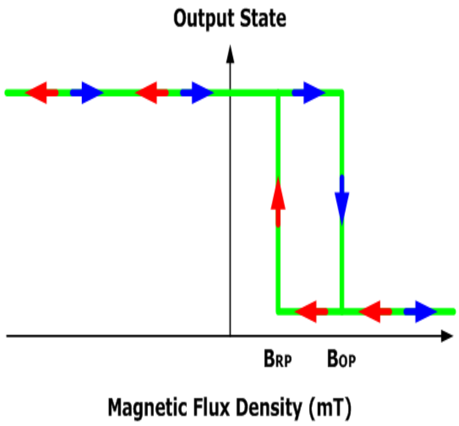
2.1 Magnetic fields

Each sensor has his specific active magnetic spectrum. Each application requires a specific magnetic field.
In general 4 types are applicable

2.1.1 Unipolar switch

Only active in one spectrum (North or South) , typically used for position sensing.
Bop and Brp will be enabled with the same magnetic pole. A minimum hysteresis is required to avoid unwanted togglings coming from magnet or mechanical variations.

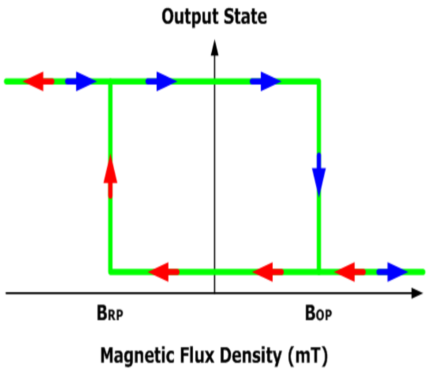
Typical applications are related to a position detection



2.1.2 Latch / Bipolar switch

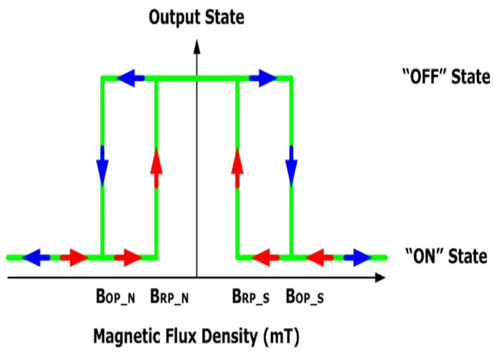
Is activated with one field and dis-activated with the opposite field.
The operating point and the release point are having the same absolute values but are opposite from sign.
Bop = - Brp.

Both thresholds are symmetrical centered around 0mT



2.1.3 Omnipolar

Omnipolar sensors are active in North and South field.
They are used to detect a change in both spectrums.
Bop_s and Brp_s are identifying the South pole operating and release points. Bop_n and Brp_n are referring to the Northe pole parameters.

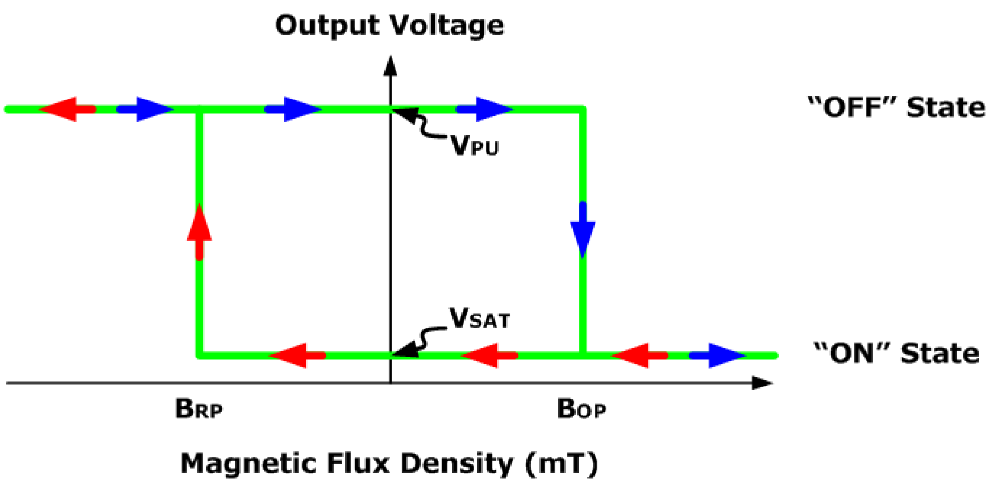


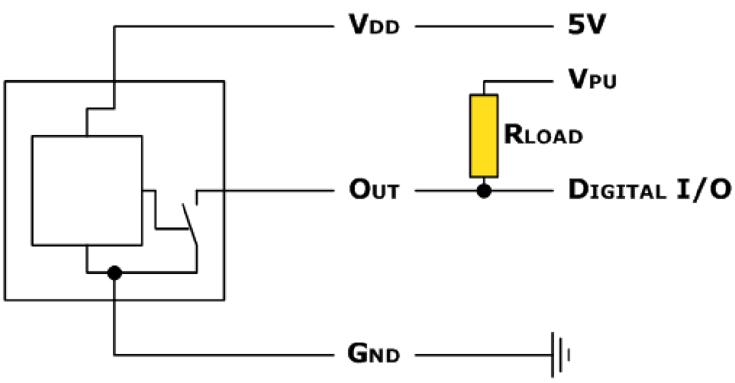
2.2 Output functionality

Melexis is proving sensors with different output options.
Most common output is the open drain output for 3-wire sensors.

2.2.1 3-wire Open drain

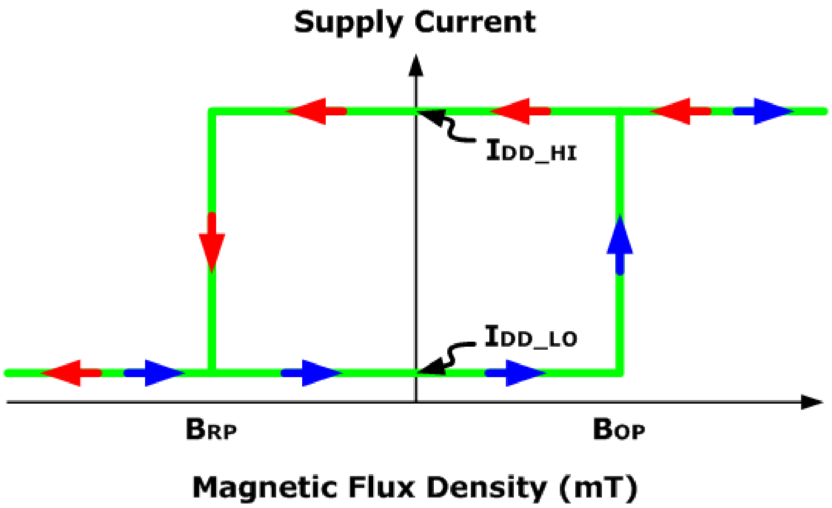
The 3- wire sensors are equipped with an open drain output.
For these sensors a resistive load has to be connected to the Vdd line.
Typical loads are between 10 and 100KOhm . The load can be connected on the module or at the ECU side.
The output will be close to 0V when the Bop Point is reached.
In case of the release point the output will be disabled hence and connected to the Vdd level through the pull-up resistor.

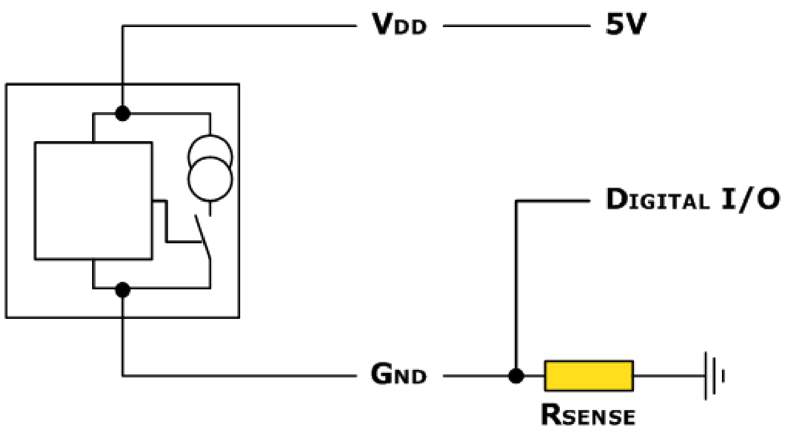




2.2.2 2-wire sensors

Two wire sensors are commonly used in a remote sensor application.
Major advantage of these sensors is that they can replace 2-wire mechanical sensors while still keeping the same wire harness. The current of the IC is used to identify if the sensor has reached his operating or release point.
I_{DD_LO} is the current that is drawn when the magnetic field is equal or lower then Brp. Two values can be applicable 3,3mA or 6mA, depending on the selected sensor. I_{DD_HI} is the current consumed by the part when the Bop point has been reached. This value is typical 14mA. The current levels are maintained over the full Vdd range, which is ensuring a stable read-out even when there are some Vdd level fluctuations.
A sense resistor is placed in the loop which convert the current output into a logical input for the ecu.

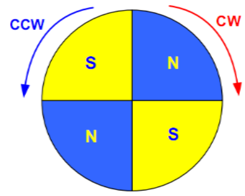




2.2.3 4-wire sensors

2.2.3.1 Speed and Direction

Speed and direction sensors are outputting 2 signals.
Speed is referring to the normal behavior of the latch sensor while the direction output is indicating clock or counter clockwise rotation. These sensors are equipped with two hall elements ensuring a fixed width between the plates by usage of CMOS processing.

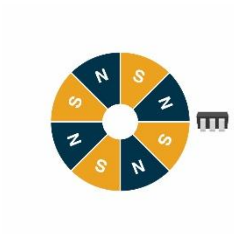


With latching magnetic characteristics, the speed(SP) output is turned low or high respectively with a sufficiently strong South or North pole facing the package top side. When removing the magnetic field, the device keeps its previous state.

The direction (DIR) output is latched in Low or High state depending on the movement direction of the applied magnetic field, as a result of certain magnetic pulse sequence on both Hall plates. Speed and direction is available on the MLX92251.
The MLX92256LSE-AAA-000 is featuring an IMC layer, allowing a combination of lateral and vertical sensitivity for a 4-wire speed & speed sensor enabling a pitch independent design.

2.2.3.2 Pulse and Direction

To achieve a higher frequency output the MLX92256LSE-ABA-000 has been equipped with a pulse & direction output. The pulse output will toggle when a Bx or a Bz field is crossing the 0 zone (latch behavior) this results in a double output signal for each transition in the lateral as well as the vertical component. The direction will change when the magnet is changing from CW or CCW direction. As indicated this approach has been made possible by lateral sensing on one hall element and perpendicular on the other integrated one. With this approach (combining lateral with vertical sensing) the total solution become pitch independent and should not be considered in the design, simplifying the magnetic design accordingly.


2.2.3.3 Speed and Speed + feedback

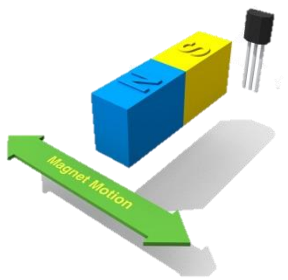
The MLX92255 combines a speed and speed sensor (as explained in the chapter earlier) combines a traditional 4-wire speed & speed sensor with an additional feedback option. This feedback option can be used to load the previous state of the output in the chip during start-up. With this approach the amount of missing pulses will be reduced, certainly applicable in applications where a sleep function is integrated while the sensor indicates a signal in the specified hysteresis zone.

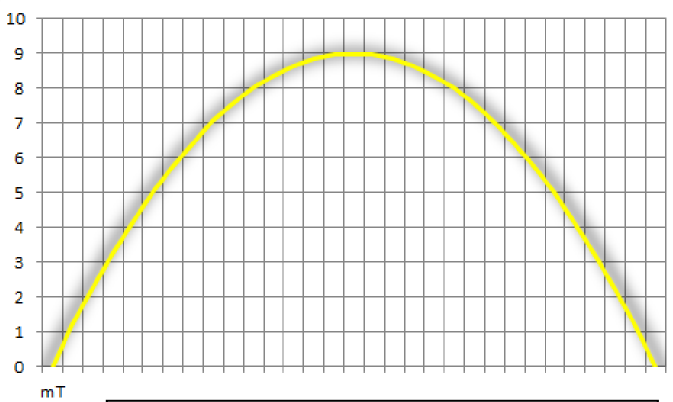
3 Magnetic concepts

Melexis products are supporting a wide variety of applications.
The major ones are described below. The optimal result is achieved by selecting the most appropriate sensor for you application by considering carefully the magnetic concept that can be applied into your design.

3.1 Slide-by

A slide by switch is working only in one spectrum of the magnetic field, in the example below the South field has been selected. The maximum field will be achieved when the magnet is directly in front of the IC.
Any movement in parallel direction to the IC will reduce the magnetic signal.
In this configuration a unipolar sensor is highly advised.

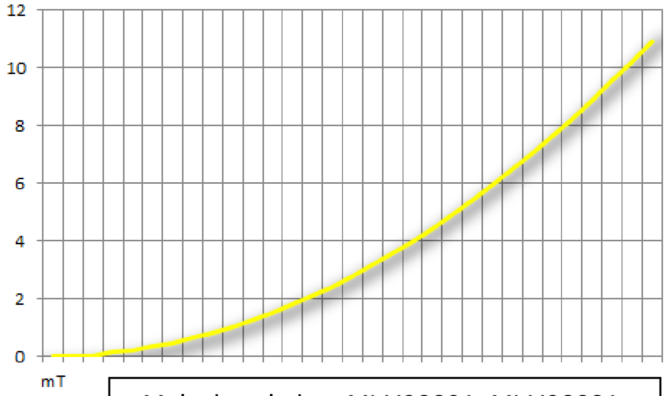




Melexis solution: MLX92291, MLX92231, US5x8x

3.2 Heads-on Proximity

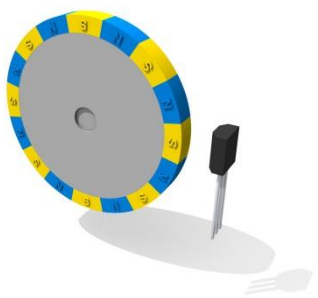
A proximity switch is also working in one spectrum of the magnetic field, in the example below the The maximum field will be achieved when the magnet is as close as possible to the IC. Any movement of the magnet towards the IC will increase the magnetic signal, for this configuration a unipolar switch should be appropriate.

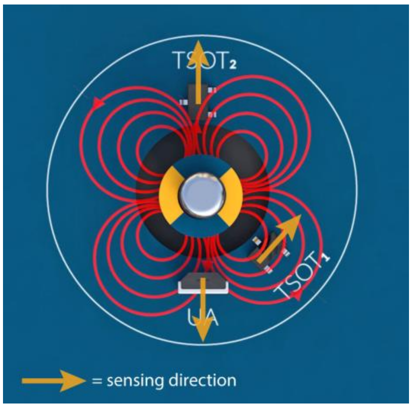


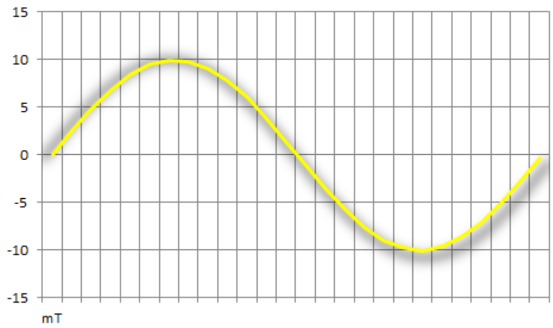
Melexis solution: MLX92291, MLX92231, MLX92241

3.3 Rotating encoder magnet

Disk magnets are commonly used in index counting applications. The sensor will be enabled with a South Pole and disabled with a North Pole. The sensor will toggle twice for each magnetic pole pair.
For these configurations latch sensors are the best choice as they are operating and releasing with the opposite field.
A direction sensor can be an advantage in case the direction information is requested



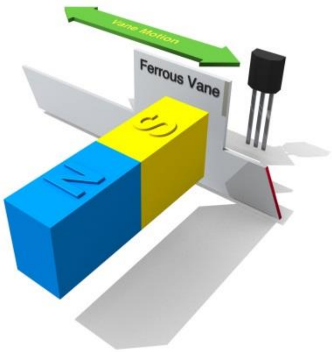


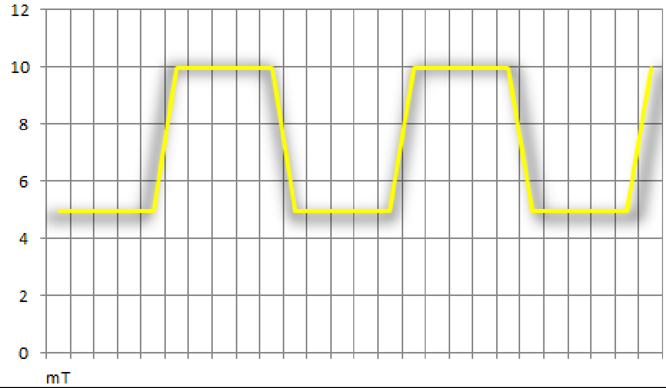


Melexis solution: MLX92211,MLX92212, MLX92221,MLX92255

3.4 Vane interrupt

A ferrous vane can be used to interrupt the magnetic signal.
This vane will deflect the magnetic flux and trigger the output of the sensor.
A small field might still be applied to the sensor. For these applications a unipolar sensor is preferred.





Melexis solution: MLX92291, MLX92231, MLX92241

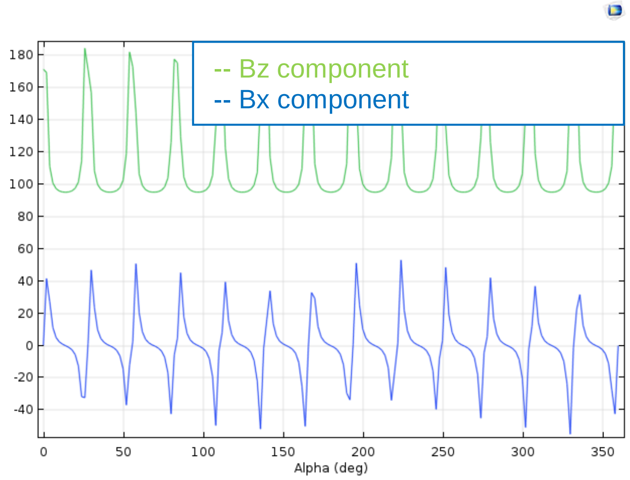
3.5 Back-biased applications

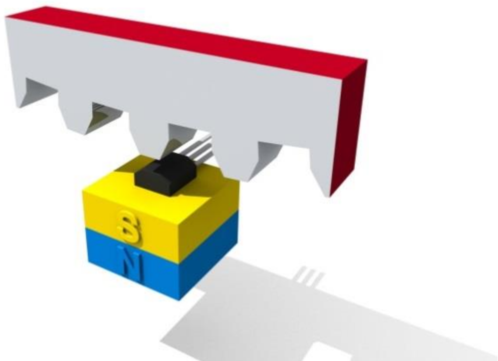
Several implementations are possible with this configuration.
A first approach can be realized with more expensive zero gauss magnets, creating a physical zero field zone where the sensor sensitive spot is placed. That will allow the use of preprogrammed sensors.

A second approach can be realized by the use of a traditional magnet that is however sensitive to the lateral field component. This has been made possible with the Melexis IMC technology. Thanks to this approach a normal magnet can be used while still being robust over temperature as the lateral field component is close to zero. A simple programming after mounting on the magnet is advisable in this configuration to secure a smooth operation.

The plot below represents the magnetic components Bx and Bz for a normal magnet configuration. Bz (indicated by the green line) is showing a significant offset in the application (100mT) which makes it extremely challenging for a good operation over temperature as the impact is significant when the temperature changes (See TC in paragraph 5). Usually for these application a dynamic compensation sensor is used, however is resulting in a higher BOM cost.

The magnetic field that is visible in the lateral component (Bx) is symmetrical around 0mT which allow a better temperature behavior resulting in a more stable design. With this approach (going through 0mT) a static switch sensor can be used to control the desired duty cycle, programmability after mounting is key to increase the accuracy.
A small hysteresis of +_ 1mT is advisable in this configuration.





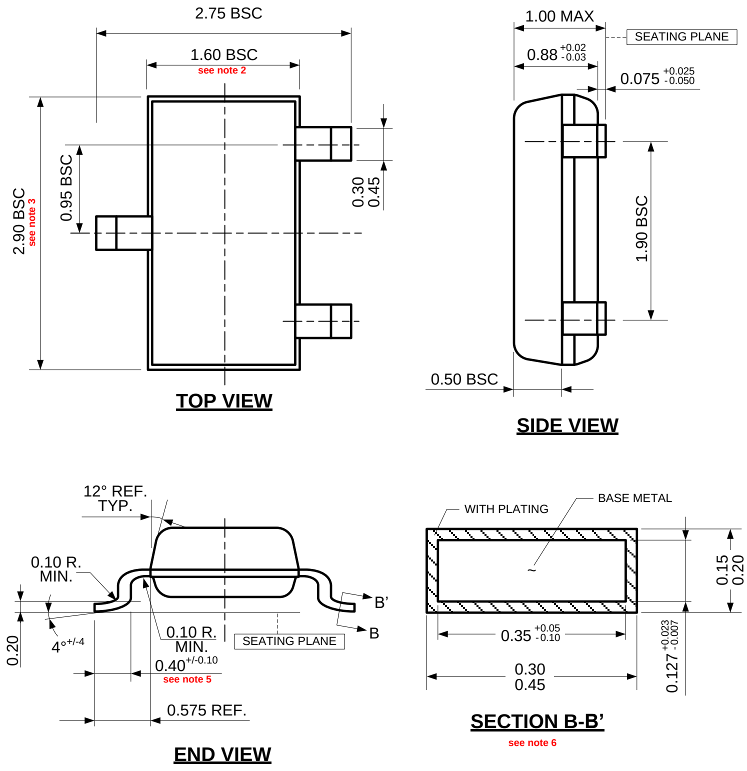
Melexis solution: MLX92232 , MLX92242, MLX92292

4 Package and delivery forms for L&S products

4.1 Package

Melexis is proving most of their magnetic switches and latches into a TSOT or UA package.
These package styles are standard in the market and are allowing us to easily reuse the same footprints on the pcb.

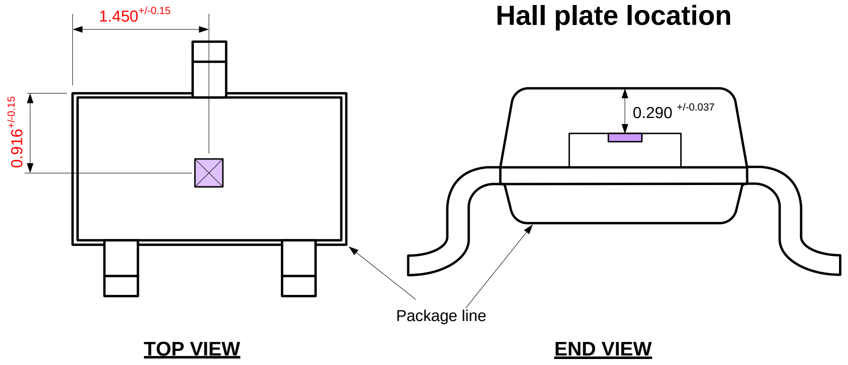
4.1.1 SE (TSOT-23)



Notes:

1. All dimensions are in millimeters
2. Outermost plastic extreme width does not include mold flash or protrusions. Mold flash and protrusions shall not exceed 0.15mm per side.
3. Outermost plastic extreme length does not include mold flash or protrusions. Mold flash and protrusions shall not exceed 0.25mm per side.
4. The lead width dimension does not include dambar protrusion. Allowable dambar protrusion shall be 0.07mm total in excess of the lead width dimension at maximum material condition.
5. Dimension is the length of terminal for soldering to a substrate.
6. Dimension on SECTION B-B' applies to the flat section of the lead between 0.08mm and 0.15mm from the lead tip.
7. Formed lead shall be planar with respect to one another with 0.076mm at seating plane.

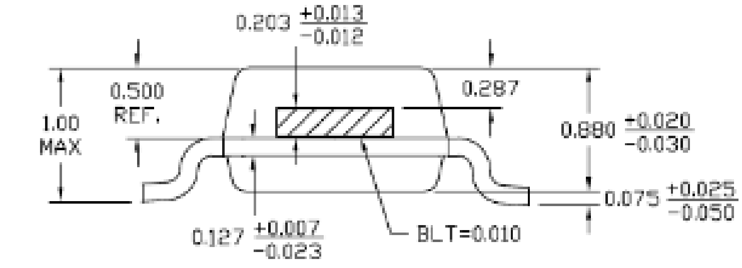
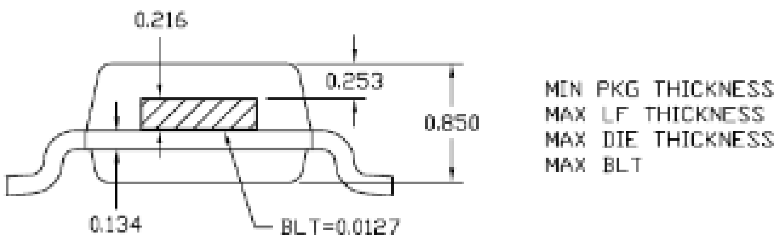
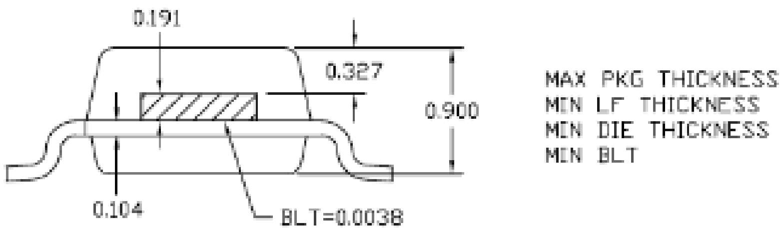
Hall plate location

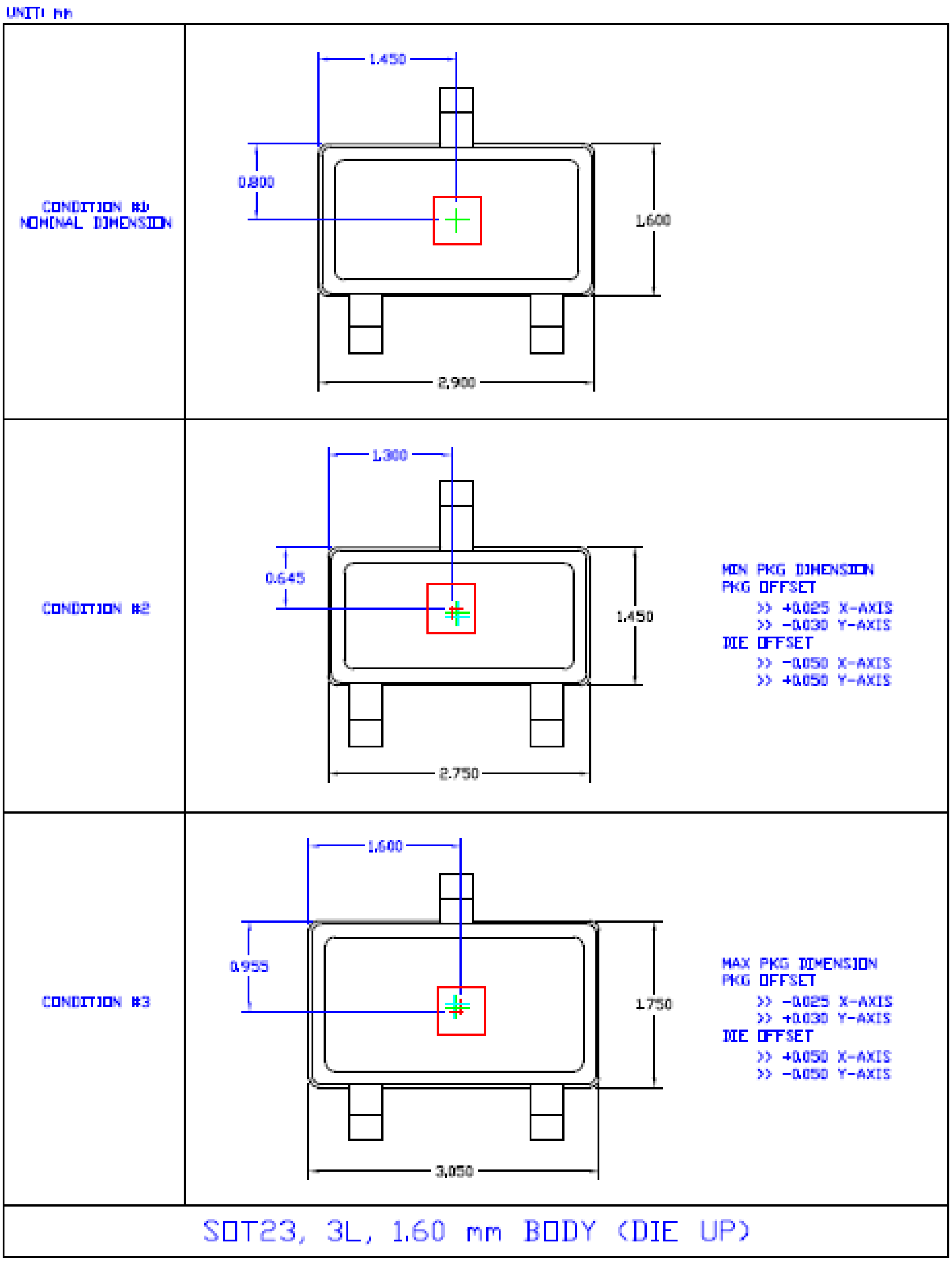


Notes:

1. All dimensions are in millimeters

4.1.2 Min Max tolerances on TSOT -23 package

CONDITION #1: NOMINAL DIMENSION	
CONDITION #2	
CONDITION #3	
SOT23, 3L, 1.60 mm BODY (DIE UP)	



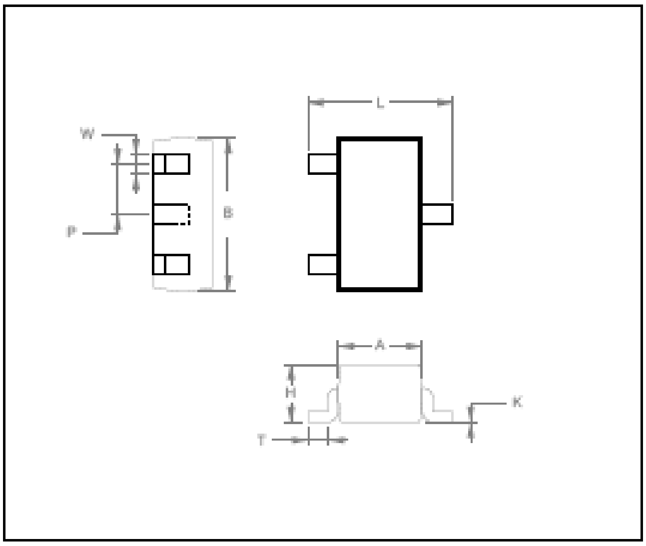
* Hall sensor location are specified in the datasheet as it differs from part to part

4.1.3 Recommended Land-pattern TSOT

Component (Fig. 1)

```
Small Outline Transistor (SOT23 type)
Pitch......................0.95
Pin Package...............6
Pin Count.................3
Lmin......................2.60
Lmax......................2.90
Tmin......................0.30
Tmax......................0.50
Wmin......................0.30
Wmax......................0.45
Amin......................1.50
Amax......................1.70
Bmin......................2.80
Bmax......................3.00
Hmax......................1.10
Kmin......................0.00
```

Fig.1

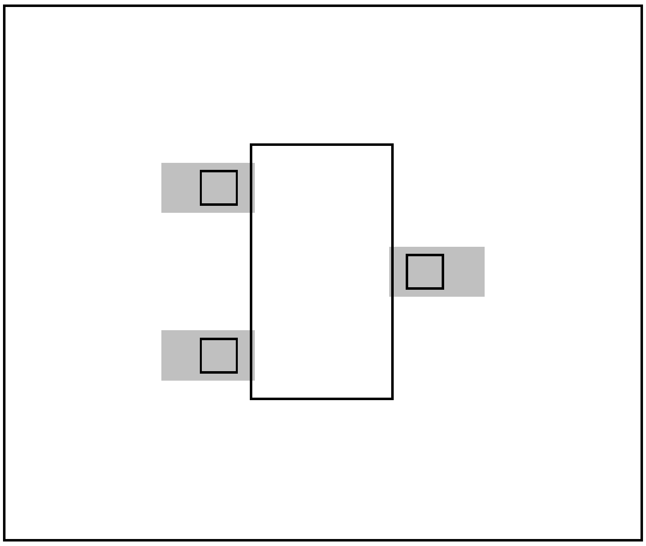


Solder Joint Goals (Fig. 2)

```
Environment is B - NOMINAL

Toe(Outside)Goal...........0.35
Toe min....................0.36
Toe max....................0.53
Heel(Inside)Goal...........0.35
Heel Min...................0.08
Heel max...................0.31
Side Goal..................0.03
Side Min...................-0.25
Side max...................-0.15
```

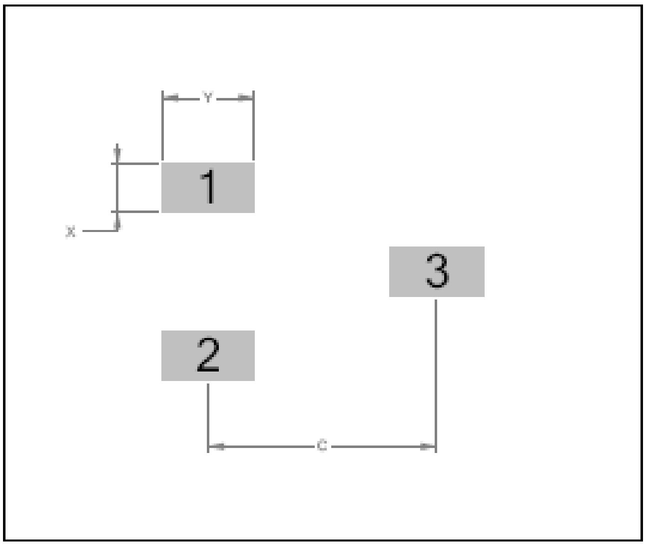
Fig.2



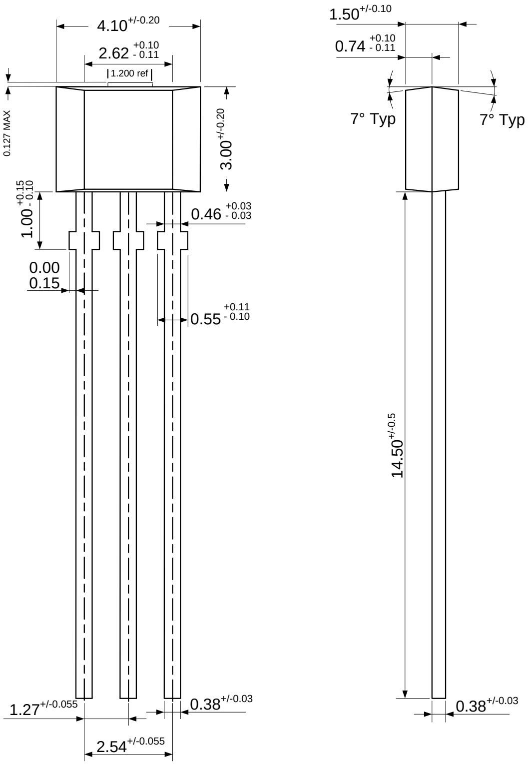
Land Pattern (Fig. 3)

```
Pitch......................0.95
C..........................2.60
Y..........................1.05
X..........................0.55
```

Fig.3



4.1.4 UA (TO-92)



Notes:

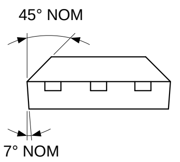
1. All dimensions are in millimeters
2. Package dimension exclusive molding flash.
3. The end flash shall not exceed 0.127 mm on the top side.

Marking:

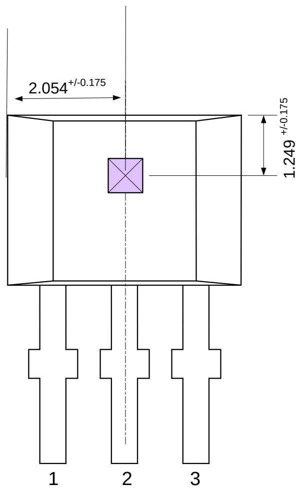
1st Line : xxx – last three digits from lot number

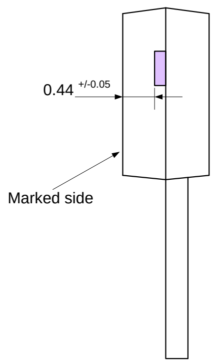
2nd Line : yww

y - last digit of year
ww - calendar week



Hall plate location

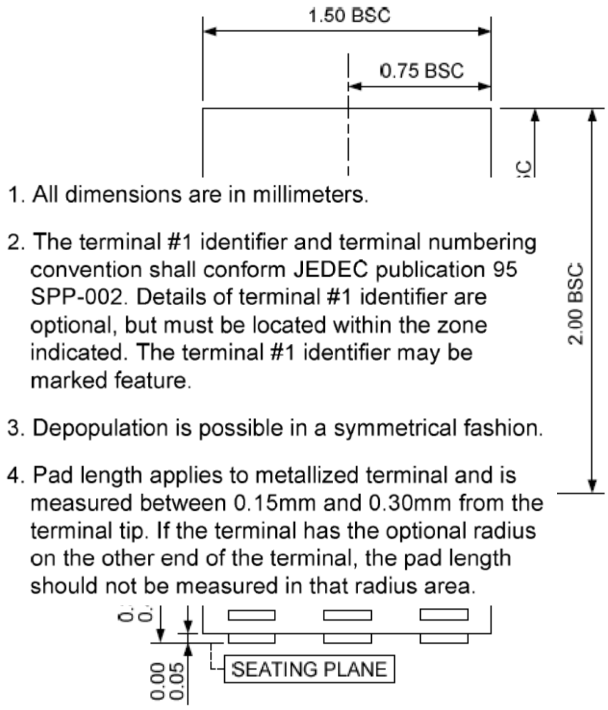




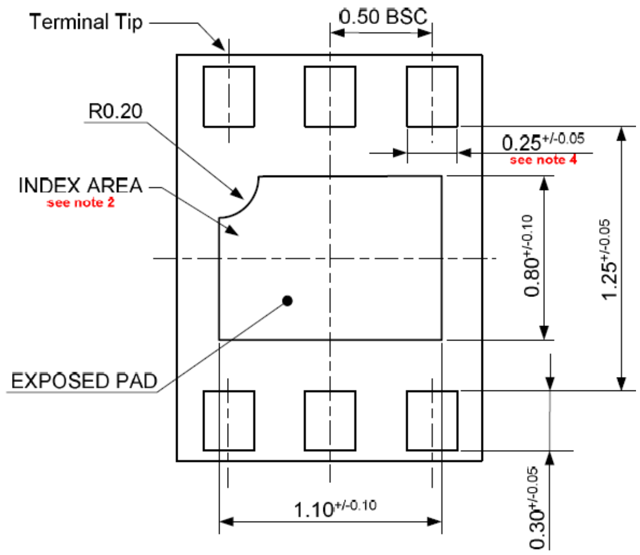
Notes:

1. All dimensions are in millimeters

4.1.5 UTQFN



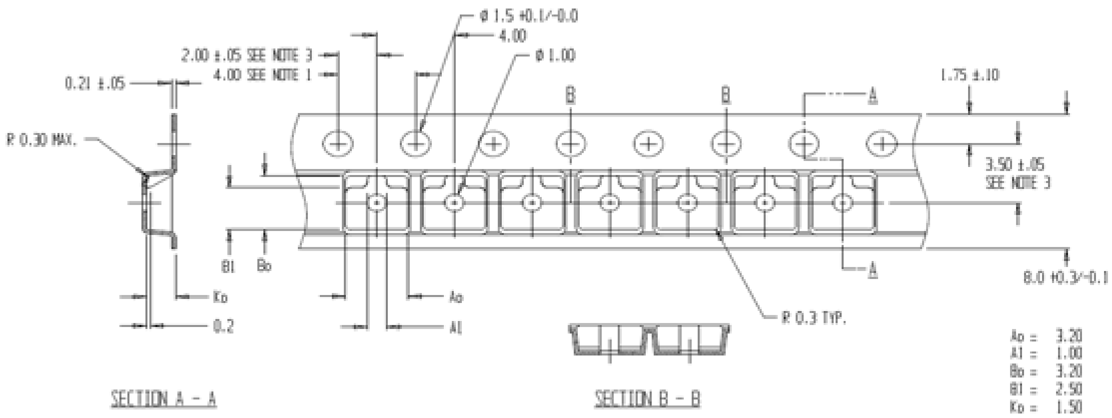
1. All dimensions are in millimeters.
2. The terminal #1 identifier and terminal numbering convention shall conform JEDEC publication 95 SPP-002. Details of terminal #1 identifier are optional, but must be located within the zone indicated. The terminal #1 identifier may be marked feature.
3. Depopulation is possible in a symmetrical fashion.
4. Pad length applies to metallized terminal and is measured between 0.15mm and 0.30mm from the terminal tip. If the terminal has the optional radius on the other end of the terminal, the pad length should not be measured in that radius area.

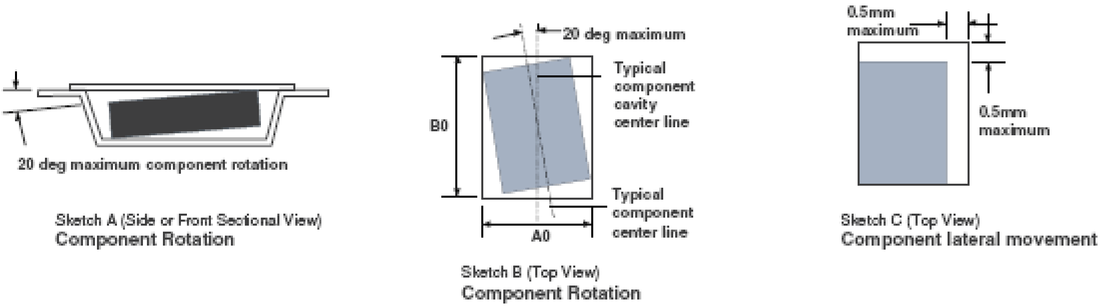


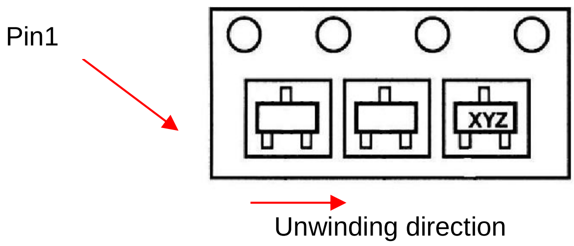
4.2 Delivery Forms

4.2.1 Tape on Reel (TSOT-23)➔ Packing Ordering code: -RE

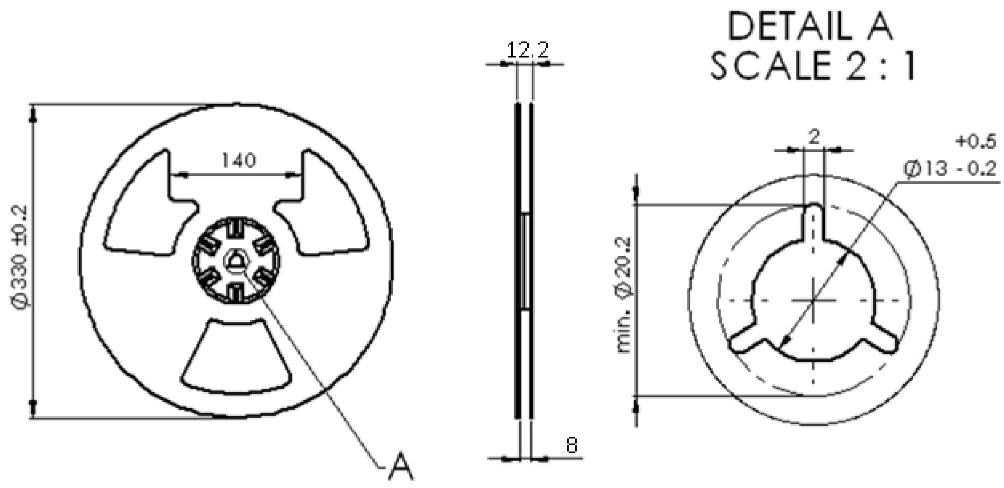
Plastic Carrier Tape Drawing and component orientation







Leader: 260 empty pockets (1040 mm)
Trailer: 100 empty pockets (400 mm)
Plastic ESD Reel 13''



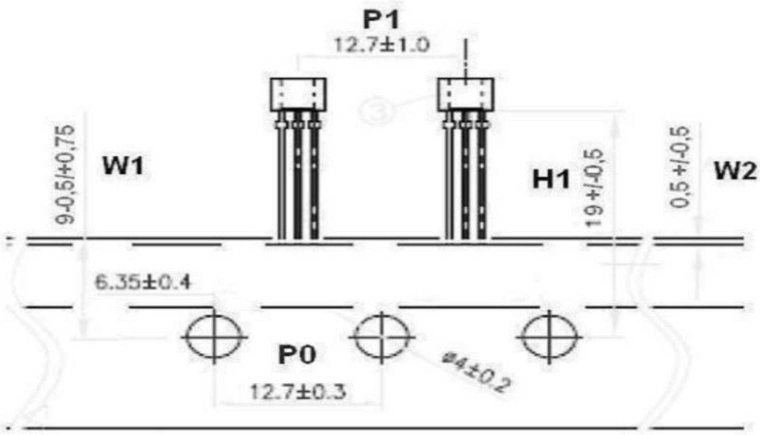
TSOT 23 3L Packaging information		
Parameter	**Carton packing type S02***	
	Carton Box A	**Carton Box B****
Box Size (mm)	460 x 420 x 320	460 x 420 x 230
QTY/Reel	10000pcs	10000pcs
Reel Size	13''	13''
Reels/Box	14pcs	10pcs
QTY/Box	140 000pcs	100 000pcs
Weight/Box (kg)	10.2	7.7

***** The packing type depends on product. For more information ask your *Melexis* contact person.
** Carton box B is used as last box in shipment, or when the shipping reel quantity is lower, or equal than 6 /10 reels (depending on the packing type).

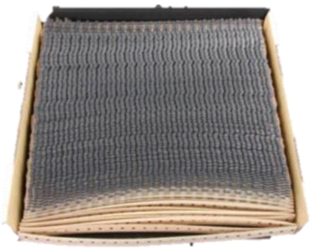
4.2.2 Bulk delivery Form (UA-package) ➔ Packing Ordering code: -BU

1000 devices placed in antistatic bag in bulk.7 Up to 10 antistatic bags with devices placed in the inner carton box with bubbles.Up to 2 inner boxes placed in the outer carton box.

4.2.3 Ammopack delivery Form (UA-packages) ➔ Packing Ordering code: - CA



BOM List	Description
Carrier paper tape	Cardboard paper 480g/sqm, 0.4mm thick and 18mm wide
Ammpopack box	Inner conductive layer
Adhesive tape	6mm wide
Splice adhesive	16x63mm with 5holes (3.1830.60)

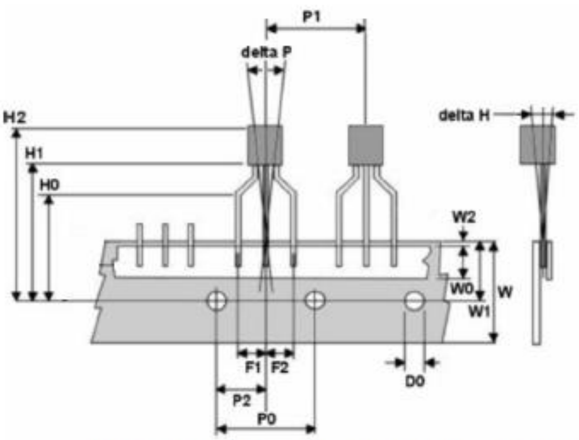


Ammopack box & Outer box parameters				
Size	Ammopack box	Outer box	Label	length of the leader and trailer
length	330 mm	350 mm	100 mm	150 indexes
width	325 mm	355 mm	60 mm	
height	40 mm	260 mm	label stick on box cover	
Weight of box	0.2 kg	1.0 kg		
Weight include goods	1.8 kg	10Kg (9kg+1kg) *		

* A outer box contains 5 inner

Carton Ammopack Box, LxBxH (internal): 325mm x 330mm x 28mm
Quantity per Ammopack Box: 7500 pcs. (mixed Box with components from 2 different lots is allowed).
Carton Package: 5 Ammopack Boxes per carton

Ammopack delivery 2.54mm forming (UA-packages)



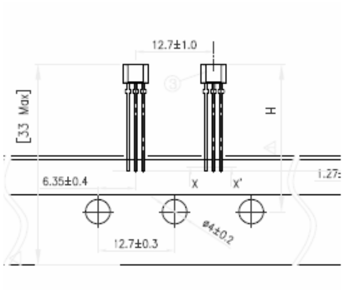
Meax Lead Length after cut = 10mm.

Parameter	1	2	3	4	5	6	7	8 & 9	10	11	12	13	14	15
	Component Height (H1)	Component Position (P2)	Hole Diameter (D0)	Hole Position (W1)	Hole Pitch (P0)	Component Pitch (P1)	Right-Left Bending (ΔP)	Lead Spacing (F1&F2)	Front-Rear Bending (ΔH)	Tape Width (W)	Adhesive Tape Width (W0)	Adhesive to Carrier Tape Gap (W2)	Vertical Lead Length (H0)	Component Height Top (H2)
Nominal & Toler.	18,0 (+/-0,5)	6,35 (+/-0,4)	4 (+/-0,2)	9 (-0,5/+0,75)	12,7 (+/-0,3)	12,7 (+/-1)	+/-0.4 mm	2,54 (+/-0,25)	+/-3 deg	18 (+/-0,5)	6 (+/-0,2)	0,5 (-0,5/0,3)	14,4 (+/-0,5)	21,0 (+/-0,8)
Measuring Tool	AOI	AOI	Microscope	Microscope	Microscope	Microscope	AOI	AOI	AOI	Caliper	Caliper	Microscope	AOI	AOI

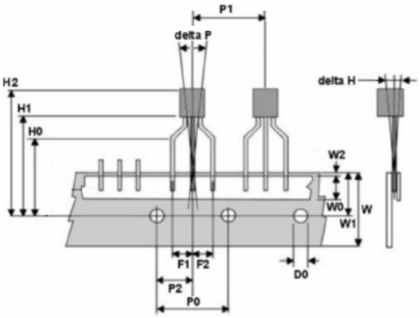
AOI – 100% Automatic Optical Inspection

4.2.4 Reel delivery Form (UA-packages) ➔ Packing Ordering code: -CR

Radial Taping Specification UA-14.5mm-Pitch 1.27 or 2.54mm



Pitch 1.27mm - Max lead length after cut = 11.5mm



Pitch 2.54mm - Maxx Lead Length after cut = 10mm.

Packaging

Carton Reel, D=357 mm
Single Package: separate ESD bag
Quantity per Reel: 3000 pcs.
Carton Package: 3/5 Reels per box (depending on reel quantity)

Reel Data	
Space between flanges	44 mm
Flange diameter	357 mm
Center hole diam.	30 mm
Hub size (diam)	82 mm
Hub material	plastic

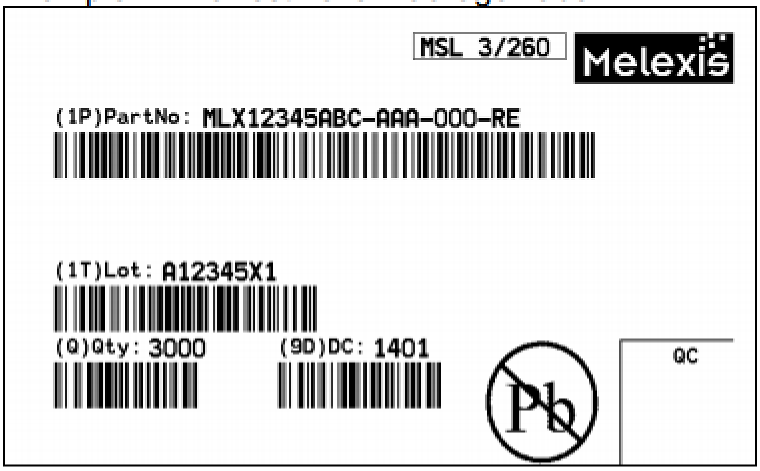
4.2.5 Packing Ordering code: -SP

Samples are shipped with an –SP ordering code. This stands for “sample pack” which means that the delivery form is chosen in production. This can be reel/ bulk or ammopack. Normally standard packaging method that is defined in the option code will be used.

4.3 Labels

4.3.1 Example

Example 1 – Lowest Level Package Label:



4.3.2 Barcode

All our barcodes are based on CODE128 barcode type. Where applicable, the encoded data contains data identifiers. Which data identifiers are used is explained in section A1 Data Catalog. Data identifiers are also shown in the field names mentioned in brackets, e.g. (1P).
Barcode parameters:

- Barcode type: CODE128
- Encoding type: Auto
- Narrow bar width (dots): 3 or 2 (depending on the length of data)
- Barcode height: ~6mm
- Check characters: 1 digit

5 Magnetic background information

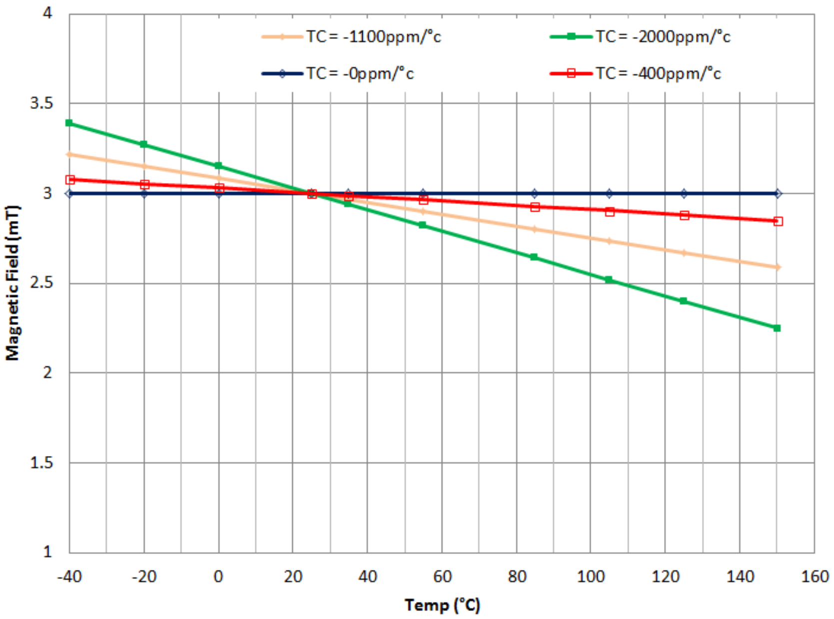
There are three major families of permanent magnet materials commercially available. They range from ferrite, which is low cost and low energy to rare earth (RE), which is high cost and high energy. Most important factors that affect the choice of magnetic material are presented in the table below, and explained in the following text. Note that each family of materials has several grades with a range of magnetic properties**.**

Material	Temperature coefficient of B_r [ppm/ºC]	Max. Operating Temperature [ºC]	Magnetic Remanence B_r [Gauss]	Coercivity H_c	Relative Cost
NdFeB	-1100	±150	11200 – 13500	High	High
SmCo	-400	±300	8300 - 10900	Very High	Very High
Ceramic Ferrite	-2000	±300	2300 - 3850	Moderate	Very Low

Remanence B_r - represents the magnetization left behind in a ferromagnetic material after an external field is removed. It can be given in Gauss or Tesla (10 Gauss = 1 mT).

Coercivity H_c - represents the resistance to demagnetization, and is given in Oersted [Oe] or Ampere/meter [Am^{-1}] units. When the coercive field of a ferromagnet is high, the material is said to be hard. A ferromagnet with a low coercive field is said to be soft.

Temperature coefficient (of Remanent Flux Density, B_r) – it describes the temperature-dependent behavior of the magnetic remanence parameter. At high temperature the magnetic field is lower than at low temperatures. For example, a temperature rise of 1ºC reduces the remanence of a ferrite magnet by 0.2%. The magnetic remanence of high temperature-coefficient magnets may decrease if they are operated at high temperatures for extended periods of time.



Temperature coefficient is calculated using the following formula:

$$\frac{B_{OPT\,2} - B_{OPT\,1}}{B_{OP\,25^o C} \times (T_2 - T_1)} * 10^6, \, ppm / ^o C; T_1 = 25^o C; T_2 = 150^o C$$

5.1 Technical calculation of the magnetic flux density

The basic calculation of the flux density along the axis of permanent magnets of simple shapes can be done using only the dimensions and residual induction (B_r) of the material. In the formula, the dimensions are given in mm.

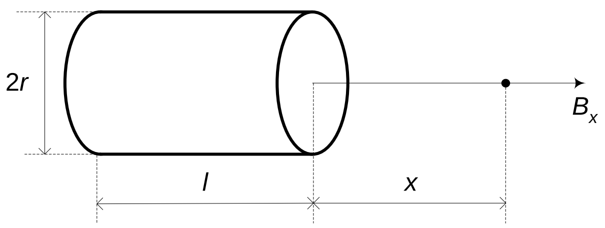
Cylindrical magnet
For a cylindrical magnet magnetized axially, with radius *r* and length *l*, the flux density at a distance *x* from the surface, along its axis, is given by:

$$B_x = \frac{B_r}{2}\left(\frac{(l+x)}{\sqrt{r^2+(l+x)^2}} - \frac{x}{\sqrt{r^2+x^2}}\right)$$

<u>Example (NdFeB 38 magnet):</u>
r = 3mm, *l* = 5mm, *x* = 10mm
B_r = 12,6 (min 12,2) Kgauss

➔ **B = 143,35 Gauss**

<u>Measurement (with Gaussmeter) :</u>
➔ **B = 135~145 Gauss** [(1)]

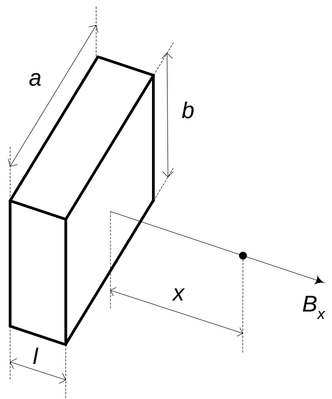


Note 1: Knowing that the magnet used for this measurement is covered with nickel coating (reducing the Br), and taking into account the magnet's tolerances and external magnetic disturbances, practical measurements show results quite close to the theoretical formula.

Rectangular magnet
For a rectangular magnet magnetized along its length, with thickness *l*, width *b* and length *a*, the flux density at a distance *x* from the surface, along its magnetized axis, is given by:

$$B_x = \frac{B_r}{\pi}\left(\tan^{-1}\frac{ab}{2x\sqrt{4x^2+a^2+b^2}} - \tan^{-1}\frac{ab}{2(l+x)\sqrt{4(l+x)^2+a^2+b^2}}\right)$$

Several simulation tools are also available online: i.e.
http://www.magnetfabrik.de/magnetfabrik_en/produkte.php?category=616



6 Documentation

Website

www.melexis.com

Product pages

https://www.melexis.com/en/products/sense/latch-and-switch-sensors

Selection guide

https://www.melexis.com/en/documents/documentation/selection-guides/selection-guide-latch-switch

Youtube channel

https://www.youtube.com/channel/UCvC0aUJf98g0O20FvjnXRfA

Lateral sensing

General landing page
Automotive applications
BLDC motors
DC motors
Back-biased applications

Softdist

http://softdist.melexis.com/

Sample request form

Sample request