Scope

This application note gives some guidelines to design an antenna for the RFID interface of the HF enabled sensor IC MLX90129. Antenna parameters calculation and prototyping tips are explained. Also, two antenna reference designs are provided to be implemented in a custom design to allow a quick start.

Applications

- Cold chain monitoring
- Asset management and monitoring (security and integrity)
- Industrial, medical and residential monitoring

Related Melexis Products

Part No.	Temperature suffix	Package Code	Option code
MLX90129RGO	R (-40°C to 105°C)	GO [TSSOP 20]	-

Typical Circuit

Rectangular loop antenna

Circular loop antenna

Introduction

MLX90129 is designed for battery-less applications. In this application the MLX90129 is a passive sensor tag. The MLX90129 RFID interface enables the passive sensor tag and wireless datalogger applications. Indeed, the MLX90129 is designed for battery-less applications in which the energy is provided by the electromagnetic field emitted by the RFID reader. In order to catch the electromagnetic field an antenna has to be connected to the MLX90129. In addition of catching the energy the antenna enables a wireless communication between the RFID reader and the MLX90129 according the ISO15693 standard. For the RFID datalogger application, this communication channel is used for MLX90129 configuration purpose and to read back sensor data saved during the datalogging cycle (temperature, humidity, light, etc). In most of the applications the antenna is built directly on the application PCB. A simple PCB track loop with a fine tuned inductance works. This application note puts together all the necessary information to build an antenna and advice for performance optimization. A rectangular and circular antenna reference design are provided to allow a quick and easy development of a custom design.

Contents

1.MLX90129 wireless communication

The system RFID reader antenna and MLX90129 antenna allow to transfer energy and to exchange data between the reader and the MLX90129.
There are several parameters to take into account when designing the system:

- RFID reader power output
- RFID reader antenna size
- MLX90129 antenna size
- Environment

The operating volume, i.e. the volume in which the MLX90129 works, is defined taking into account all these parameters. For example the shape and size of reader and tag antenna impact the coupling factor which impacts the amount of energy transferred to the MLX90129 and consequently the reading distance. Also working in metal environments is possible but this will drastically reduce the reading distance whereas liquid environments do not impact the performance.

Operating volume or reading distance can be estimated using an inductive coupling mathematic model. However the experimentations and/or the advice from a RFID application specialist can not be avoided.

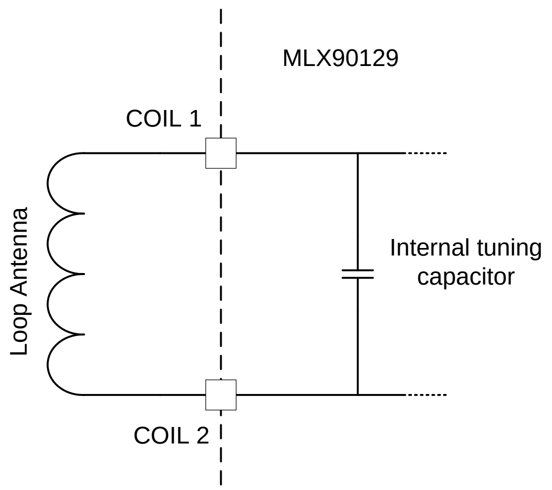
2.MLX90129 antenna

2.1. Resonance Frequency

The MLX90129 antenna is designed as a simple LC resonant circuit. L corresponds to the inductance of the antenna and with C corresponds to the parallel tuning capacitor. As the standard ISO15693 is based on a carrier frequency of 13.56 MHz the system MLX90129 and antenna should be tuned to resonate at 13.56 MHz. The resonance frequency is defined by the following formula:

$$f_{resonance} = \frac{1}{2\pi\sqrt{C \cdot L}}$$

The MLX90129 provides an internal tuning capacitor with a typical value of 75pF. This value is trimmed in production and can not be changed. The inductance of the loop antenna can be dimensioned to match with this capacitor.

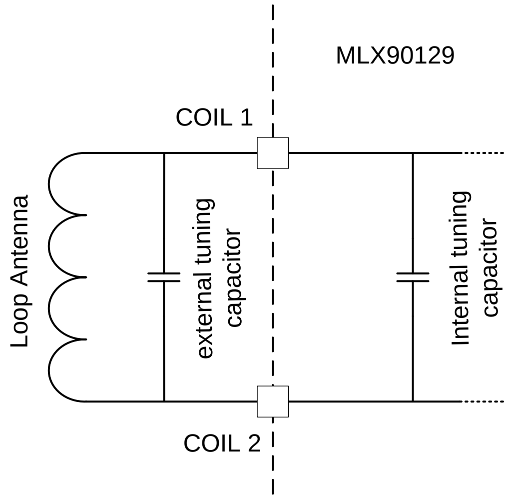


In this configuration the inductance of the loop antenna should be as close as possible to 1.837uH.

$$f_{resonance} = \frac{1}{2\pi\sqrt{75e-12 \times 1.837e-6}} = 13.56MHz$$

1.837uH is the maximal possible inductance value for the loop antenna to be tuned at 13.56MHz.

If there is constraint imposed on the loop antenna inductance, an external capacitor can be added in parallel of the MLX90129 internal capacitor.



For example if the inductance of the loop antenna has to be below 1uH, an external capacitor of 68pF can be added externally.

$$L = \frac{1}{(13.56e6 \times 2\pi)^2 \times (75e-12 + 68e-12)}$$

$$L = 0.963\mu H$$

In this case an antenna with an inductance of 0.963uH fits.

In case of resonance frequency not equal to 13.56MHz, the system is mistuned. The RFID interface could work, however the performance would be impacted.
To fine tune the system, the minimal and maximal possible value of the internal tuning capacitor (72pF -77pF) and the parasite capacitor added by the package (about 1-2pF) have to be taken into consideration.

2.2. Quality factor

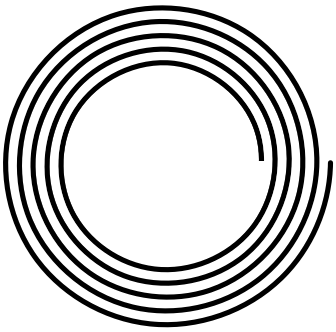
According to [3] the optima antenna quality factor (Q) for a MLX90129 tag, which is an ISO15693 tag, will be chosen between 9 and 16.

2.3. PCB loop antenna inductance calculation

From the paragraph 2.1, the inductance value of the loop antenna has been calculated. Now it has to be transformed into a real antenna shape on a PCB. The bibliography covering inductance calculation techniques abounds. Two formulas for rectangular and circular antenna inductance are provided respectively in Annex A and Annex B.

Rectangular loop antenna

Circular loop antenna



2.4. Prototyping

In best case theoretical calculations are +/- 5% accurate. In order to validate the antenna form factor it is necessary to build prototypes. A prototype based on copper wire antenna can allow validating the system outlines such as the minimal reading distance. Then a real PCB allows fine tuning the system.

2.5. Fine tuning

In order to enhance performance the previous defined parameters can be fine tuned:

- Resonance frequency: In case of reader antenna and tag antenna with similar form factor, i.e. with high coupling factor, the resonance frequency of the tag is largely impacted by the mistuning implied by the reader antenna. One solution could be to tune the tag at a higher frequency without impact of the reader antenna, 14.5MHz for example. In presence of the reader antenna, the mistuning allows the tag resonance frequency to converge to 13.56 MHz.
- Resonance frequency: If the application requires to have several tags on the RFID reader field, a mistuning of the tag antenna can be necessary in order to take into account the impact of the mistuning implied by the other tags.
- Quality factor: the Q factor of the antenna can be fine tuned in order to enhance the energy transmission and consequently the reading distance.

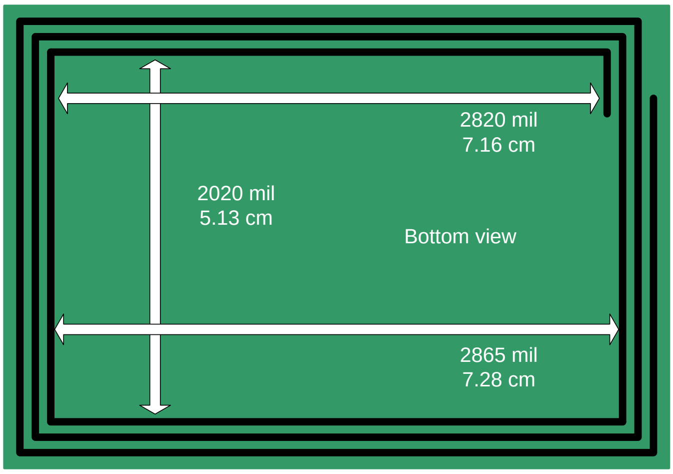
2.6. PCB layout guidelines

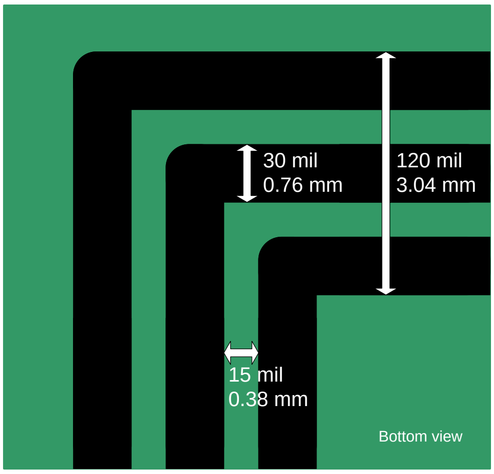
Few rules as to be followed for the MLX90129 PCB layout

- The MLX90129 pins, COIL1 and COIL2 have to be as close as possible to the antenna connection. Long connection wire could impact the antenna tuning.
- A ground plan inside or behind the antenna shall be avoided.

3. Example: EVB90129 antenna

The EVB90129 board is an evaluation board which simplifies evaluation of the MLX90129 and facilitates the development of the wireless sensor application. The board size is 84mm x 62mm. More information can be found in the user manual [6]. The EVB90129 antenna is a rectangular antenna designed after calculation and prototyping. The following parameters allow reproducing this antenna for a custom design.





The theoretical inductance values (L_{T1} and L_{T2}) are calculated according the equations provided in Annex A.

$L_{T1} = 1.814\mu H \quad L_{T2} = 1.863\mu H$

The measured inductance is L: $L = 1.838\mu H$

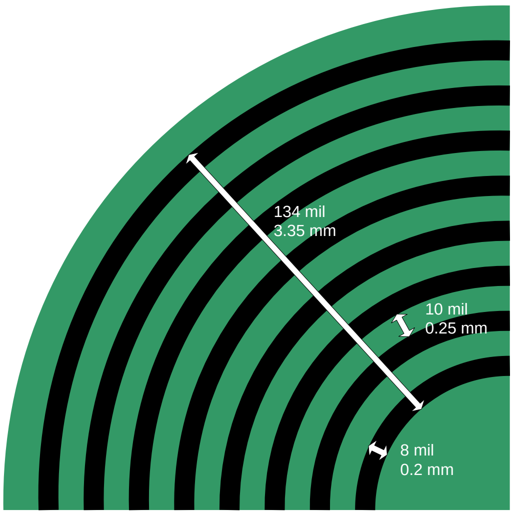
Consequently the resonance frequency is:

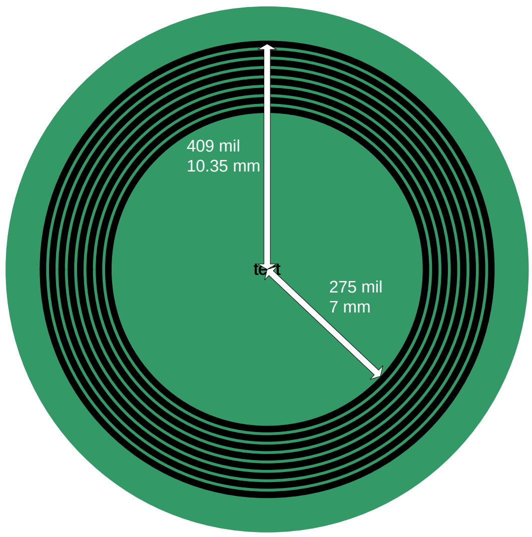
$$f_{resonance} = \frac{1}{2\pi\sqrt{75e-12 \times 1.838e-6}} = 13.55MHz$$

The EVB90129 is exactly tuned on the frequency defined in ISO15693.

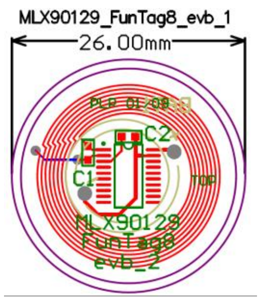
4.Exemple: Fun Tag

The FunTag is the minimalist hardware for MLX90129 application. It is composed of a small loop antenna, a capacitor on the pin Vfield and a footprint to solder a button battery for datalogging application. The PCB diameter is 26 mm (1.024 inches). The following parameters allow reproducing this antenna for a custom design.





In addition the gerber files of the complete FunTag board are provided on the Melexis website www.melexis.com



The theoretical inductance value (L_T) is calculated according to the equation provided in Annex B.

$$L_T = 1.767uH$$

The measured inductance is L:

$$L = 1.7uH$$

Consequently the resonance frequency is:

$$f_{resonance} = \frac{1}{2\pi\sqrt{75e-12 \times 1.7e-6}} = 14.09MHz$$

This is not exactly fine tuned, however the performance is good enough to keep that design as reference. (cf paragraph 5)

5.Reading distance

In a general way, RFID vicinity communication is possible up to one meter. In most cases a reading distance between 20 and 30 cm has to be considered. In order to give some references about reading distance, the following table summarizes the maximum reading distance with a 12 x 12 cm (4.7 x 4.7 inches) reader antenna used with a 250mW and 1W reader. These correspond respectively to the setup of the DVK90121 [4] and the Demo 90121 Long Range [5] which are development kits of the Melexis RFID Front End MLX90121. More information can be found on www.melexis.com.

Board	CMD*	DVK90121	Demo 90121 LR
EVB90129	Inventory	19 cm	23 cm
	ITS conversion	18 cm	22 cm
FunTag	Inventory	10 cm	13.5 cm
	ITS conversion	9cm	13 cm

* The energy needed by the MLX90129 is less important to process an inventory command than to run a sensor conversion with the internal temperature sensor (ITS).

6.References

[1] "Design of Planar Rectangular Microelectronic Inductors", H.M Greenhouse, IEEE Trans. 1974
[2] "Simple inductance formulas for radio coils", Harold A Wheller, Oct., 1982
[3] "13.56MHz RFID systems and antennas design guide"
http://www.melexis.com/Assets/1356MHz_RFID_systems_and_antennas_design_guide_3929.aspx
[4] "DVK90121 User Manual"
http://www.melexis.com/Hardware_and_Software_Tools/Other_Development_Tools/DVK90121_36.aspx
[5] "DEMO90121LR User Manual"
http://www.melexis.com/Assets/DEMO90121LR_User_Manual_5336.aspx
[6] "EVB90129 User Manual"
http://www.melexis.com/Assets/EVB90129_User_Manual_5682.aspx

7.Trouble shooting notes

In case of lack of RFID communication the following list has to be checked in order to identify the issue.

Possible problems with the MLX90129 power supply (RFID field)
Check if the voltage on pin COIL1 and COIL2 is compliant with the MLX90129 datasheet specifications.
Check if the voltage on pin Vreg is compliant with the MLX90129 datasheet specifications.

8.Conclusion

This application note gives an overview of the requirements to build an antenna for the MLX90129. The antenna examples provided in this document could be used as a base to develop a custom application. There is no specific difficulty to prototype and build an antenna and to enable a RFID communication. However performance improvement and environment constrain management require deep knowledge about antenna and RFID. Melexis provides a list of specialists which can support the development of a custom application.

For additional information, please contact our Direct Sales team and get help for your specific needs:

Europe, Africa	Telephone: +32 13 67 04 95
	Email : sales_europe@melexis.com
Americas	Telephone: +1 603 223 2362
	Email : sales_usa@melexis.com
Asia	Email : sales_asia@melexis.com

9.Disclaimer

The content of this document is believed to be correct and accurate. However, the content of this document is furnished "as is" for informational use only and no representation, nor warranty is provided by Melexis about its accuracy, nor about the results of its implementation. Melexis assumes no responsibility or liability for any errors or inaccuracies that may appear in this document. Customer will follow the practices contained in this document under its sole responsibility. This documentation is in fact provided without warranty, term, or condition of any kind, either implied or expressed, including but not limited to warranties of merchantability, satisfactory quality, non-infringement, and fitness for purpose. Melexis, its employees and agents and its affiliates' and their employees and agents will not be responsible for any loss, however arising, from the use of, or reliance on this document. Notwithstanding the foregoing, contractual obligations expressly undertaken in writing by Melexis prevail over this disclaimer.

This document is subject to change without notice, and should not be construed as a commitment by Melexis. Therefore, before placing orders or prior to designing the product into a system, users or any third party should obtain the latest version of the relevant information.
Users or any third party must determine the suitability of the product described in this document for its application, including the level of reliability required and determine whether it is fit for a particular purpose.

This document as well as the product here described may be subject to export control regulations. Be aware that export might require a prior authorization from competent authorities. The product is not designed, authorized or warranted to be suitable in applications requiring extended temperature range and/or unusual environmental requirements. High reliability applications, such as medical life-support or life-sustaining equipment or avionics application are specifically excluded by Melexis. The product may not be used for the following applications subject to export control regulations: the development, production, processing, operation, maintenance, storage, recognition or proliferation of:
1. chemical, biological or nuclear weapons, or for the development, production, maintenance or storage of missiles for such weapons;
2. civil firearms, including spare parts or ammunition for such arms;
3. defense related products, or other material for military use or for law enforcement;
4. any applications that, alone or in combination with other goods, substances or organisms could cause serious harm to persons or goods and that can be used as a means of violence in an armed conflict or any similar violent situation.

No license nor any other right or interest is granted to any of Melexis' or third party's intellectual property rights.

If this document is marked “restricted” or with similar words, or if in any case the content of this document is to be reasonably understood as being confidential, the recipient of this document shall not communicate, nor disclose to any third party, any part of the document without Melexis’ express written consent. The recipient shall take all necessary measures to apply and preserve the confidential character of the document. In particular, the recipient shall (i) hold document in confidence with at least the same degree of care by which it maintains the confidentiality of its own proprietary and confidential information, but no less than reasonable care; (ii) restrict the disclosure of the document solely to its employees for the purpose for which this document was received, on a strictly need to know basis and providing that such persons to whom the document is disclosed are bound by confidentiality terms substantially similar to those in this disclaimer; (iii) use the document only in connection with the purpose for which this document was received, and reproduce document only to the extent necessary for such purposes; (iv) not use the document for commercial purposes or to the detriment of Melexis or its customers. The confidentiality obligations set forth in this disclaimer will have indefinite duration and in any case they will be effective for no less than 10 years from the receipt of this document.

This disclaimer will be governed by and construed in accordance with Belgian law and any disputes relating to this disclaimer will be subject to the exclusive jurisdiction of the courts of Brussels, Belgium.

The invalidity or ineffectiveness of any of the provisions of this disclaimer does not affect the validity or effectiveness of the other provisions.
The previous versions of this document are repealed.

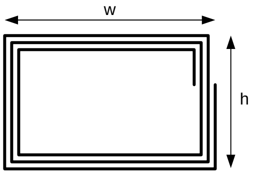
IATF 16949 and ISO 14001 Certified

Annex A: rectangular antenna inductance

The inductance of a N turn planar rectangular antenna coil is expressed by the following formula:

$$L_{T1} = \frac{N^2\mu_0}{\pi}\left[-2(w+h)+2\sqrt{h^2+w^2}-h\ln\left(\frac{h+\sqrt{h^2+w^2}}{w}\right)-w\ln\left(\frac{w+\sqrt{h^2+w^2}}{h}\right)+h\ln\left(\frac{2h}{a}\right)+w\ln\left(\frac{2w}{a}\right)\right]\mu H$$

N is the number of turns.
w width of the rectangle in meter
h height of the rectangle in meter
a is the track width in meter



Concerning the EVB90129 antenna, the parameters are:
N = 3
w = 7.28e-2+2*3.04e-3 = 78.88e-3 m
h = 5.13e-2+2*3.04e-3 = 57.38e-3 m
a = 0.76e-3 m

$$L_{T1} = 1.814\mu H$$

Another approach can be found in [1]. For the EVB90129 antenna it has to be assumed that the antenna is composed of 12 segments of planar rectangular inductors shared in 3 turns. The total inductance of the coil is the sum of the self-inductances of these segments and mutual inductances between the segments. The EVB90129 antenna inductance calculated by the method defined in [1] is: $L_{T2} = 1.863\mu H$

Annex B: circular antenna inductance

The inductance of a single-layer spiral coil is expressed in formula provided by Wheeler (1927) [2]:

$$L_T = \frac{A^2n^2}{30A-11D}\mu H \quad \text{with } A = \frac{D+N(w+s)}{2}$$

D is inner diameter in inches.
s is the space between windings in inches.
w is the track width in inches.
N is the number of turns.
1 inch = 1000mil = 0,0254m=2,54cm = 25,4mm.
The accuracy will be reduced as the number of turns is low or the spacing between turns is large.

Concerning the FunTag antenna, the parameters are:

D = 0.275 * 2 = 0.550 inches
s = 0.01 inches
w = 0.008 inches
N = 8

$$A = \frac{0.55+8\times(0.008+0.01)}{2} = 0.347 \qquad L_T = \frac{0.347^2\times 8^2}{30\times 0.347-11\times 0.55} = 1.767\mu H$$