

## Features and Benefits

- Highly Integrated transmitter-receiver for 125kHz ASK transponders
- Parallel antenna gives factor of Qreader improved power efficiency over serial antenna implementations
- Minimum reader PCB size with SO8 reader IC and minimum external components
- Integrated hardwired decoding for Biphase and Manchester ASK, 2kbit and 4kbit transponders.
- Direct amplitude modulation on the reader antenna for downlink to transponder.
- Power down mode with Brown out protection
- Optimized system cost
- Fast design-in, ease of implementation.

## Applications

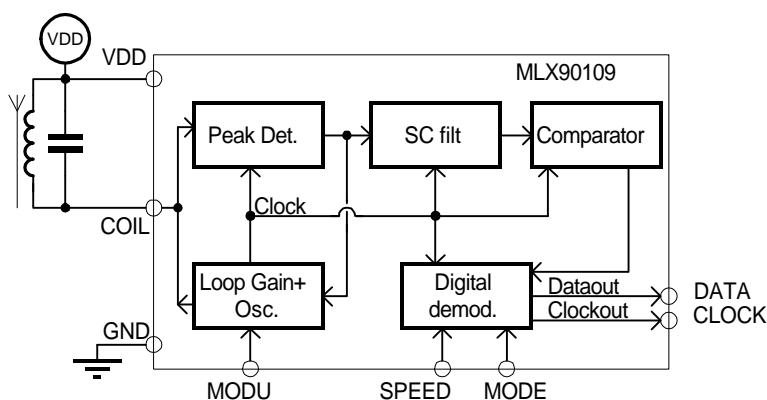
Car Immobilizers, portable readers, battery powered door locks, house held appliances, ...

## Ordering Information

Part No.	Temperature Range	Package
MLX90109	25°C -40°C to 85°C	SO: 150mils 8pins SOIC

Production parts available Q1 2001

## Functional Diagram



## Description

The MLX90109 is a single chip inductive RFID transmitter-receiver for the 125kHz range. It has been conceived for minimum system cost, and minimum power consumption, whilst offering all required flexibility for a state of the art AM Read-Write base station.

An external L and C are connected as a parallel resonant circuit, which will determine the carrier frequency and the oscillator frequency of the reader. This eliminates zero modulation effects, and avoids the need for an external oscillator.

The antenna amplitude can be adjusted externally on the fly. This allows straightforward modulation of the antenna amplitude to write to the transponder.

The reader IC can easily be switched to power down by switching the antenna amplitude to zero.

The MLX90109 can be configured to decode the transponder signal on-chip. In this case the decoded signal is available through a 2-wire interface of clock and data. For minimum interface wiring, the undecoded transponder signal can also be made available on a single wire interface.

### MLX90109 Electrical Specifications

DC Operating Parameters  $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ ,  $V_{DD} = 5\text{V}$  (unless otherwise specified)

General test conditions (see test set up blockdiagram)  $C_{reader} = 21\text{pF}$ ,  $Q_{reader} = 17$ ,  $L_{reader} = 75\text{uH}$ ,  $Z_{ant} = 1\text{k}\Omega$

T: 100% tested, C: guaranteed by Design & Characterization

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units	
Supply Voltage	VDD		4.5	5	5.5	V	T
Operating Resonance Freq.	Fres		100		150	kHz	C
Fres Temperature detuning	$\Delta(T)\text{Fres}$		-1		+1	%	T
Quality factor Antenna	Qant	See footnote <sup>1</sup>	10		50		C
Antenna Impedance	Zant		1		10	$\text{k}\Omega$	C
Power down Current	IDDsleep	MODU = 5V			1	$\mu\text{A}$	T
Max. Operating Current	IDDmax	MODU = 1V, excluding antenna driver current	0.6		1.5	mA	T
Coil pin clamping Voltage	Vclamp		21		26	V	T
Max Antenna Driver Current	Idrivemax	DC equivalent, See footnote <sup>2</sup>	5		8.5	mA	C
MODU power up current	Imodupor	See footnote <sup>3</sup>			60	$\mu\text{A}$	C
MODU power down voltage	Vmodupd	See footnote <sup>4</sup>	4.2	4.35	4.5	V	C
MODU minimum voltage	Vmodumin	See footnote <sup>5</sup>	0.8			V	C
Max. Antenna Voltage swing	Vantmax	MODU = 1V	8.0		8.6	V <sub>pp</sub>	T
Modulation depth	$\Delta V_{ant}$	MODU switched between 0.5 and 1.5V,	1.4	2	2.6	V	T

<sup>1</sup> A minimum Quality factor is required in order for the reader to recover the transponder signal. The maximum quality factor is not limited, since the transponder signal is picked up even.

<sup>2</sup> Antenna driver current is dimensioned, so as to guarantee that for Zant, within the specified range, the antenna driver can act as a perfect current source to drive the resonant circuit.

For a typical  $Z_{ant} = \omega L \cdot Q = 1\text{k}\Omega$  (e.g.  $L = 67\text{uH}$ ,  $Q = 19$ ), and MODU at 1V, MLX90109 will force 4V antenna amplitude, therefore should supply 4mA current amplitude on the first harmonic sine wave.

Duty cycle is 50%, therefore the equivalent DC current consumption for such a system is 1.3mA.

<sup>3</sup> Power up is realized by forcing a current into MODU through the external correction network. This will release an internal strap to VDD of the MODU pin.

<sup>4</sup> The MLX90109 goes in power down mode when the MODU pin is brought to VDD.

<sup>5</sup> Voltages below Vmodumin, may cause the antenna Voltage to drop below  $V_{SS} + 0.3\text{V}$ . This will degrade the performance of the current driver. There is always a slight overshoot of the antenna voltage due to the antenna resonance.

<sup>6</sup> Since the modulation is realized by altering ( $\Delta\text{duty}$ ) the duty cycle around the 50% value, the driver current setting influences directly the modulation depth, as  $\text{Moddepth} = Z_{ant} \cdot I_{drive} \cdot \Delta\text{duty}$ .

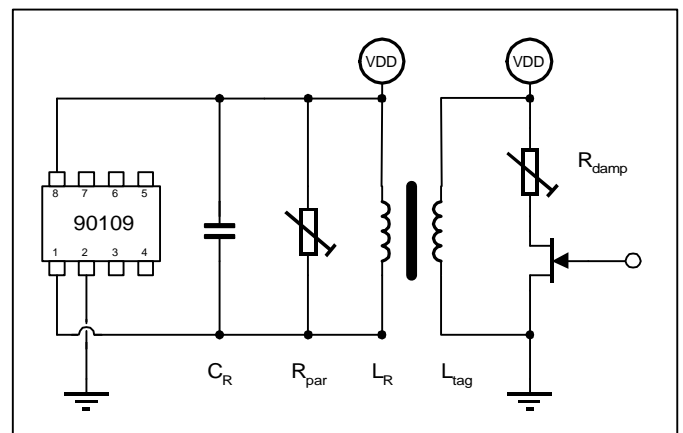
		See footnote <sup>6</sup>					
Modulation depth range		See footnote <sup>7</sup>			68	%	C
White Noise rejection		Schmitt trigger hysteresis	5	3		mV	C
Sensitivity	V <sub>sens</sub>		40		3	mV	T
Filter Gain				28		dB	C
Filter ripple				3		dB	C
Filter 3db BW slow		SPEED = 1	400 – 3.6k			Hz	C
Filter 3db BW fast		SPEED = 0	800 – 7.2k			Hz	C
Output voltage DATA and CLOCK pin	V <sub>out</sub>	I <sub>sink</sub> = 2.5mA			0.4	V	C
Start up time		MODU = 5V to 1V			8	ms	C
AM demodulation Delay time MODU-IN ANTENNA-OUT				0		us	C
AM demodulation Delay time Antenna input to Data output		2kHz square wave modulation Falling edge on antenna MODE= floating (See footnote <sup>8</sup> )		25		periods	C
AM demodulation Delay time Antenna input to Data output		2kHz square wave modulation Rising edge on antenna MODE= floating (See footnote <sup>8</sup> )		29		periods	C
Modulation pulse width deviation Antenna input to Data output		Antenna pulse width versus output pulse width. MODE= floating (See footnote <sup>8</sup> )	-4	0	+4	periods	C

### Test set up Block diagram

<sup>7</sup> Modulation on the reader antenna is limited towards maximum modulation depth, to prevent the reader from going into power down.  

$$\text{Moddepth} = (\text{VPPmax} - \text{VPPmin}) / (\text{VPPmax} + \text{VPPmin})$$
 Since Vppmin (Vmodu=4.2V)=1.6V,  
 and Vppmax (Vmodu=0.8V)=8.4, modudepthmax=68%.

<sup>8</sup> The data slicer samples every 4 clock periods(=1/Fres), therefore any pulse on the output can be 4 periods off.



### General Description

The MLX90109 is designed for use with a parallel antenna. This set up requires Qantenna times less current compared to traditional serial antennas, for building up the same magnetic field strength. Draw back is that the voltage swing (Vpp) is limited by the applied supply voltage.

$$V_{ppmax} \sim 2 * VDD.$$

In practice the antenna driver on the COIL pin limits the voltage swing some more.

The MODU pin can regulate Vpp. The voltage level on MODU defines the reference level of the antenna voltage, as follows

$$V_{pp} \sim 2 * (VDD - V_{MODU})$$

See specifications for VMODU values.

### Oscillator

The oscillator frequency is locked on the antenna frequency. The clock of the filter is derived from the oscillator. In this way the filter characteristics are locked to the transmission frequency. Consequently the MLX90109 is not sensitive to zero modulation.

### Power Down

By setting  $V_{MODU} = VDD$ , Antenna Voltage will fade to 0. At that moment MLX90109 stops oscillations, setting the device in power down mode. Wake up time depends on Qantenna, such that increased Q, will lead to increased wake up time.

### Write operation

Not only is the MODU pin used to set the carrier amplitude, it can also be used to put modulation on the carrier for write operations.

Taking into account the transfer function of the regulation mechanism, a correction network is required to compensate for the system poles and zeroes. These poles and zero depend not only on internal parameters, but also on the antenna parameters.

See annex for calculating the correction network.

### Amplitude detection

The amplitude demodulator of the transceiver detects the AM signal generated by the tag. This signal is filtered and amplified by an on-chip switched capacitor filter before feeding it to the digital decoder. The same signal is used to control the antenna voltage.

### Filter settings

By setting the SPEED pin to VDD or to GND the filtering characteristics are optimized for either 2kbaud or 4kbaud respectively.

### Digital decoding

The MODE pin allows to define whether to issue directly the filtered data stream on the DATA pin (MODE floating), or to have the MLX90109 decoding Manchester (MODE = VDD) or biphasic (MODE = VSS) data.

In the decoding mode, the digital receiver gets the filtered data stream and issues the tag data on the DATA pin at the rising edge of the clock, which is issued on the CLOCK pin. Both CLOCK and DATA are open drain outputs and require external pull-ups.

Remark that the clockwidth and duty cycle can vary from bit to bit, between a half and one and a half bit periods on the tag coil especially in manchester mode.

	VSS	FLOAT (*)	VDD
<b>SPEED</b>	4kBaud	-	2kBaud
<b>MODE</b>	Biphase	No decoding	Manchester

(\*) Internally strapped to VDD/2

### Noise cancellation

Capacitance C2 should always be connected to VDD. Noise on VDD is coupled through to MODU, optimizing the power supply rejection ration (PSRR) through internal cancellation. This improves sensitivity in noisy environments. Maximum precautions should however be taken to minimize noise level, to benefit from the reader sensitivity, and obtain the maximum reading distances.

### Correction network

For a typical application, where 2kbaud data has to be sent to a transponder using a Manchester or Biphase encoding scheme, the most important harmonics lie in a bandwidth between 400Hz and 3.6kHz.

As can be seen from the graphs below, the antenna parameters can significantly reduce the available bandwidth [FL, FH].

With a suitable correction network, the 3dB points can be shifted to extend the possibilities.

Important system parameters are data rate, antenna inductance (Lreader) and antenna quality factor (Qreader).

In the time domain we optimize the shape of the amplitude modulation on the reader antenna by applying that correction network.

### Calculation

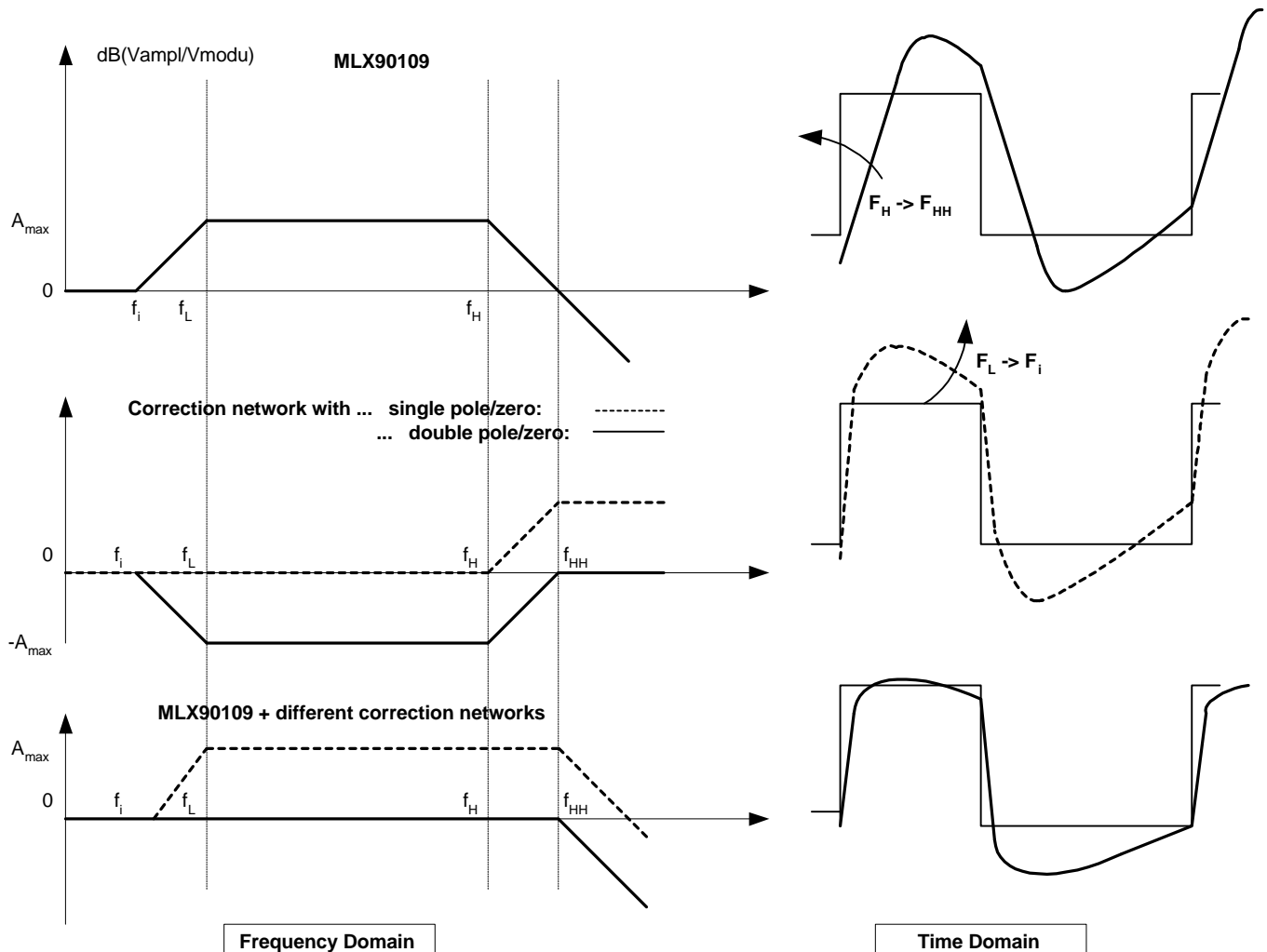
In the graph below the transfer function of the MLX90109 is given.

- The first Zero ( $F_i$ ) is determined by the MLX90109 and is typically 70Hz.
- The Poles ( $F_L$  and  $F_H$ ) are set by the Open loop Gain ( $G=2\text{mA/V}$ ) of the MLX90109 and the Antenna Impedance  $Z_{ant}$ , which is system dependent. In the graphs below the dependency of both poles on applied inductance and for 2 quality factors are reflected. It is clear that the bandwidth reduces significantly with increase of  $Q_{reader}$ .

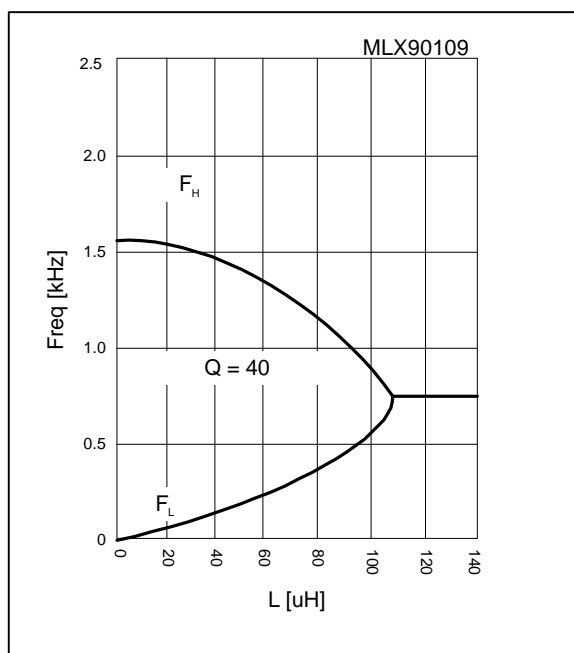
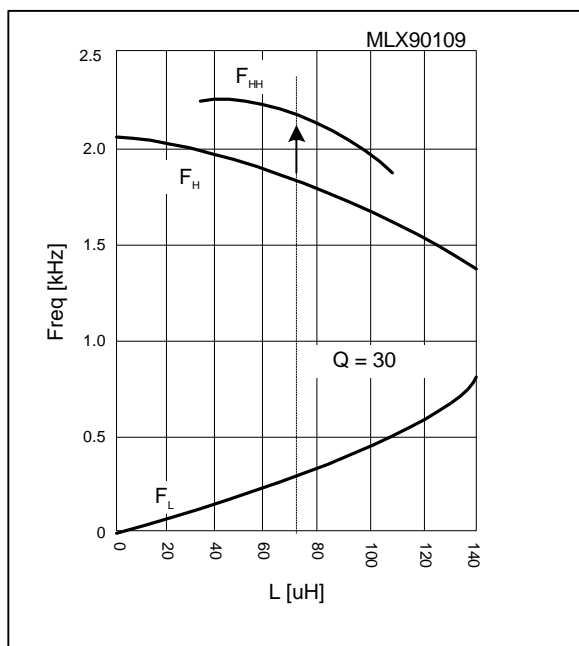
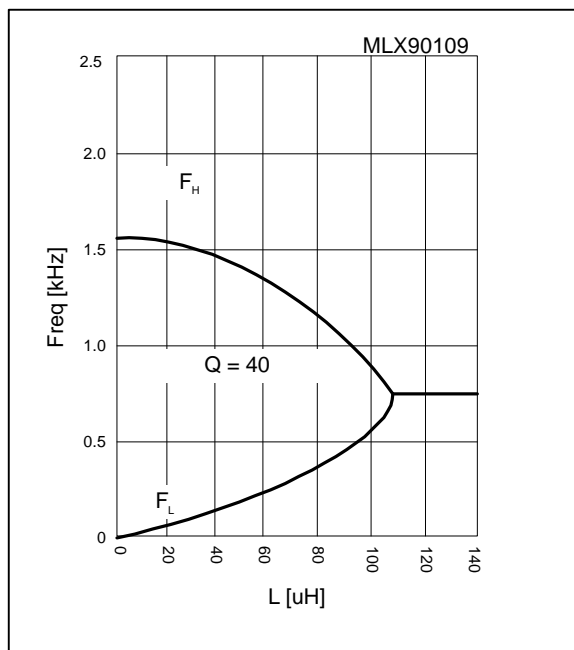
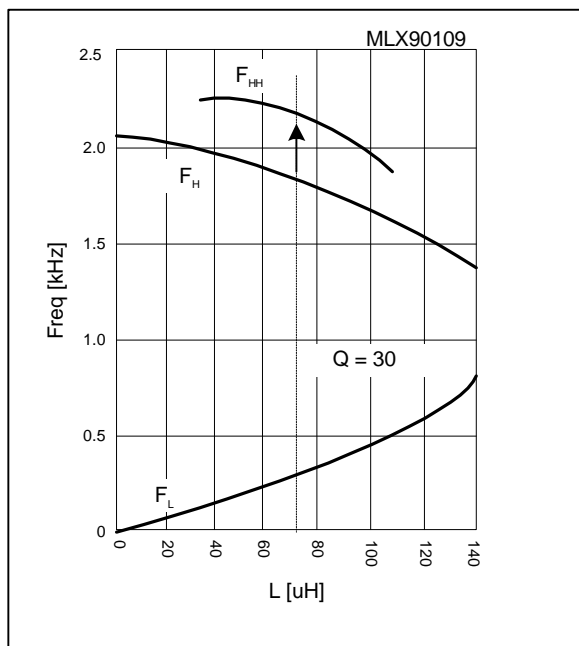
Remark:  $A_{max} = G \cdot Z_{ant}$

A correction network with a single pole/zero couple can increase the bandwidth by moving  $F_H$  to  $F_{HH}$ .

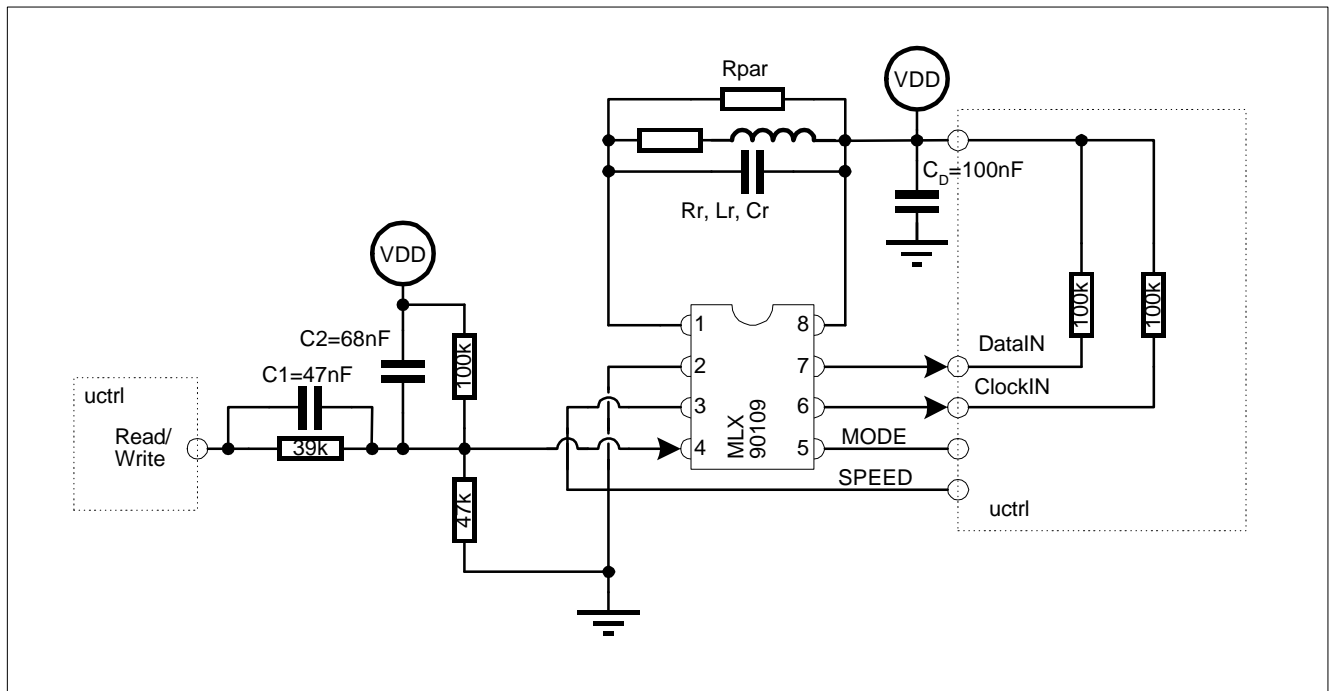
A more complex correction network with 2 pole/zero couples can also improve the signal loss in case of important low frequency harmonics (DC like signals). In the Frequency domain this means  $F_L$  is shifted towards  $F_i$



### Bandwidth graphs



## Applications Information



### MLX90109 Read/Write demokit:

Above schematic is used in a demokit which allows to

- read and write
  - the MLX90111 with 2cm diameter aircoils
  - at 2 and 4kbaud, using Manchester and Biphase encoding
  - up to 7cm
- whilst consuming only 5mA, including antenna current.

An Atmel microcontroller (AT90S8515) was used to have enough ports to drive a ledbar.

Antenna parameters:

- Lr= 89uH, Cr= 18nF
- Qr=30
- Rpar= Optional parallel resistance

### Coil design considerations

Let's start from an operation frequency of 120 kHz. In order for the antenna not to get detuned by stray capacitance to ground, it is good not to have a high L value. In this way C is big and the detuning is minimal.

The field of the coil is proportional to the number of windings and to the current flowing through it:

$$H \sim N.I = N.V/(\omega.L)$$

with V the ac voltage across the coil, and  $\omega.L$  the impedance of the coil.

Furthermore the inductance of the coil is proportional to the square of the number of windings.

$$L = L_0 \cdot N^2$$

With  $L_0$  the inductance of 1 turn.

So

$$H \sim V/(\omega.L_0.N)$$

Reducing the number of turns on the coil is good for improving the field strength as well as for making the construction of the coil easier.

Antenna impedance specification is determined by the current that the antenna driver can supply. Outside the specification, the feedback loop will not operate as designed for, and functionality will deteriorate drastically.

$$Z_{ant} = Z_r // R_{par} \quad \text{with } Z_r = L_r/(R_l \cdot C_r)$$



### Unique Features

Use of a parallel antenna offers multiple advantages:

- maximum power efficiency.
- minimum system components

Ease of use thanks to:

- self resonating principle avoids zero modulation
- flexible system configuration with higher Q's
- High level of integration.

A complete reader can be integrated on an ultra small PCB thanks to:

- small body (150mills) SOIC8 package
- limited amount of external components
- Integrated decoding minimize demands on microcontroller side.

### Cross Reference

The MLX90109 can replace any integrated front-end base station chip for read write operation to 125kHz transponders in the 125kHz range.

All competitive products are with serial antenna, e.g. Marin p4092, or TEMIC U2270B.

### Absolute Maximum Ratings

Supply Voltage, $V_{DD}$ (Overvoltage)	VSS-0.3V to VSS+6V
Storage Temperature Range, $T_s$	[-55, 125]°C
ESD Sensitivity	2kV

### ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).

Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

### Disclaimer

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### FAQ

1. Since the MLX90109 under the specified working conditions does not influence the antenna resonance frequency, the spread and temperature drift are determined by the discrete antenna components only.
2. The same feature allows significantly detuned transponders to change the resonance frequency in case of good coupling. This can be used to tune the MLX90111 after assembly, to allow use of high Q factors at minimum assembly cost.
3. Q = quality factor of the antenna reflects the ratio between the stored electromagnetic energy vs. the ohmic dissipated energy. Without degrading Rpar:  

$$Q_{reader} = (2 \cdot \pi \cdot f_{res} \cdot L_r) / R_r$$
 Else  $R_r$  can often be neglected resulting in:  

$$Q_{reader} = R_{par} \cdot \sqrt{C_r / L_r}$$
4. Zero Modulation  
 Due to mistuning of the resonance frequency of transponder and reader antennas compared to an external oscillator frequency, the amplitude modulation induced by the transponder on the reader antenna is a mixture of amplitude and phase modulation. At special combinations of the three frequencies a pure phase modulation, or zero (amplitude) modulation occurs. Since the MLX90109 clock is extracted from the antenna resonance frequency it is not susceptible to this phenomenon.
5. The MLX90109 is insensitive to DC magnetic levels.
6. Modudepth =  $(V_{PPmax} - V_{PPmin}) / (V_{PPmax} + V_{PPmin})$

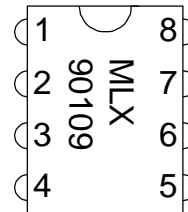
### Glossary of Terms

1. Base station = reader IC + microcontroller
2. Transceiver = Write (Transmitter) and read (receiver) unit
3. Q = antenna quality factor.
4. Modulation depth = ratio between the antenna amplitudes that are used for sending data with amplitude modulation.



### SO8 Pinout

Pin	Name	Function
1	COIL	Antenna connection: pull down NMOSFET
2	VSS	Ground
3	SPEED	Digital input, strapped to VSS or VDD.
4	MODU	Modulation input
5	MODE	Digital input, strapped to VSS or VDD.
6	CLOCK	Clock output
7	DATA	Data output
8	VDD	Supply



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