MLX90111
128bit Read Write Transponder

Features

- 144bit EEPROM code, flexible Read Write Transponder IC
- Very Big reading range, and large write range.
- ID configured as 8 user words of 16 bits, and multiple write protection levels, including OTP
- 16 bit Configuration word with lock flags per word and option bits
- Different encoding and datarate options
- 250pF integrated tuning capacitance with wide post assembly tuning range
- 100,000 write cycle, 10 year EEPROM retention
- Guaranteed data integrity for reliable programming

Applications

Animal ID (ISO 11784, -85 compliant), ATM, Access Control, Material Logistics, Overmoulded assemblies with important detuning effects.

Ordering Information

Part No.	Temperature Range	Package
MLX90111	25 °C Consumer	Sawed wafer on frame
	-40 to 85 °C Automotive	Bare die in blistertape
		SOIC-8 150mils

Production parts available Q1 2001

Functional Diagram
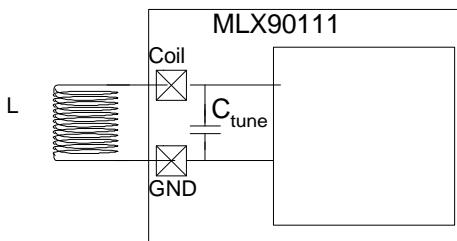
Description

The MLX90111 is a flexible 128 bit Read Write Transponder IC operating at 125kHz. It has been designed for high performant and highly reliable RFID systems requiring multiple write access to the transponder memory.

Clock and power supply are taken from the electromagnetic field. A resistor is switched in parallel to the resonant circuit formed by the integrated tuning capacitor and the external coil, to amplitude modulate the electromagnetic field. Encoding of the 128 bits ID and data rate can be defined by setting the corresponding EEPROM bits.

High quality factors can be applied as the frequency can be tuned over a range of +/-10% to +/-0.5% accurate after assembly, by changing the value of the tuning capacitor up to +/- 2pF.

The EEPROM is configured as 11 words of 16 bits. Words 1 to 8 form the ID and are continuously read out during normal operation. Each of these can be individually locked, or the complete EEPROM can be set to read only.

The transponder can be written over the full range from 0% to 60% of the normal reading distance. The transponder stops modulating when receiving an AM asynchronous pattern. It will then synchronize on the first bit it receives. The 32 bit write command is transmitted using Return to One modulation, including direct word addressing and multiple security checks. Data integrity is guaranteed by critical read out after programming.

MLX90111 Electrical Specifications

Operating Parameters are based on test set up (see Schematic below).

Toper = -40°C to 85°C, **Operating frequency = 120kHz** (unless otherwise specified)

| Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Regulated supply voltage	VDD	(3)	3.0		4.0	V
Power On Level	VPOR	Continuous normal reading of the ID	1.55	1.8	2.2	V
Sensitivity level (e.m.f.)	Vacsens	Continuous normal reading of the ID	200	170		mV
Modulation Depth ASK		Weak power: Vacmin = 200mVpp	0.2		4	V(4)
		Medium power: Vac = 5Vpp	2.8		7.5	V(4)
		High power: Vac = 20Vpp	5		10	V(4)
EEPROM writing supply voltage	Vacee	Critical reading ID		1		V
EEPROM writing supply current	Iee			10		µA
ACP modulation depth		Vachigh=Vacee		20		% (5)
EEPROM data retention	Tret	Critical reading ID	10			year
EEPROM write cycles	Ncycle	Critical reading ID	100k			cycles
Coil-GND tune capacitor		Toper=25°C		200		pF(6)
Total Tuning range		Toper=25°C, 5bits		124		pF(6)
Tuning accuracy		Toper=25°C, LSB/2		2.0		pF(6)
DC input current clamping	IclampLow	VdutDC = +/- 2V		40	1000	NA
	IclampHigh	VdutDC = +/- 10V	1	3.5	10	mA

Notes:

Note (1): Specifications are tested 100% or guaranteed by characterization.

Note (2): All specifications are valid for Manchester and Biphase encoding, and for 2kbaud and 4kbaud data rate options.

Note (3): Maximum supply voltage is generated by forcing 10mA between coil and ground pin.

Note (4): Min = Vbottom (modulation on),
Max = Vtop (modulation off).
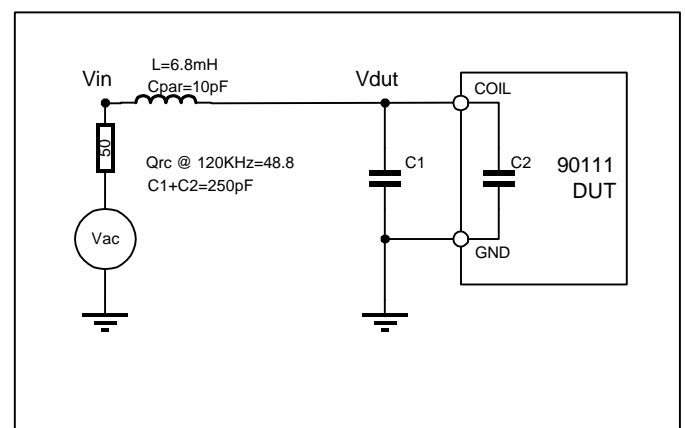
Note (5): Modulation depth is calculated as Vachigh -Vaclow / Vachigh + Vaclow. Lower modulation depths may be applied, but the performance of the system may vary along the distance between reader and transponder coil. Higher modulation levels will reduce the maximum Write distance.

Note (6): Lot to lot spread on capacitance is 20%. Temperature shift is typically 0% on -40°C, and +1% at 85°C.

Block diagram

MLX90111 clamping (DC)
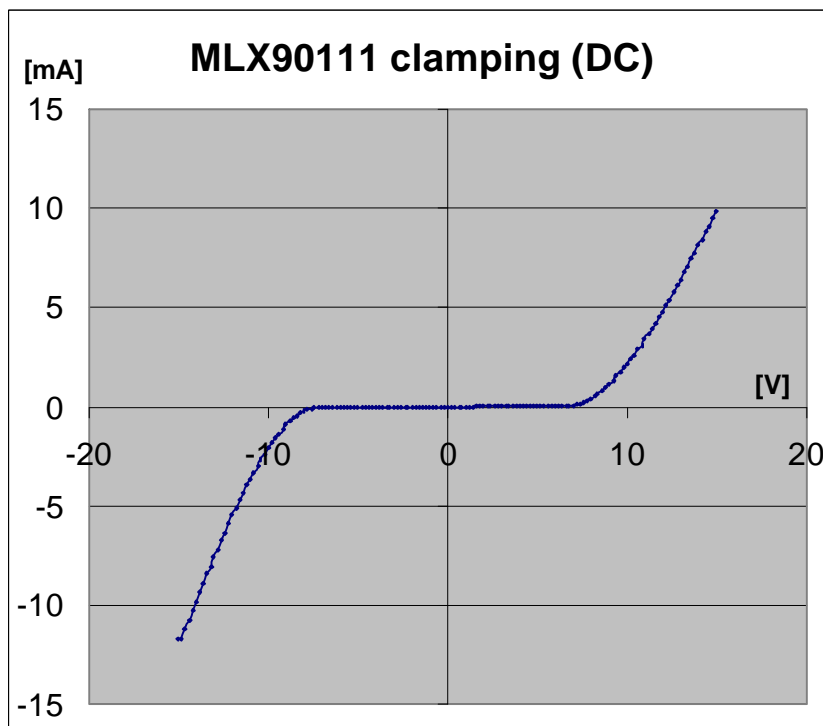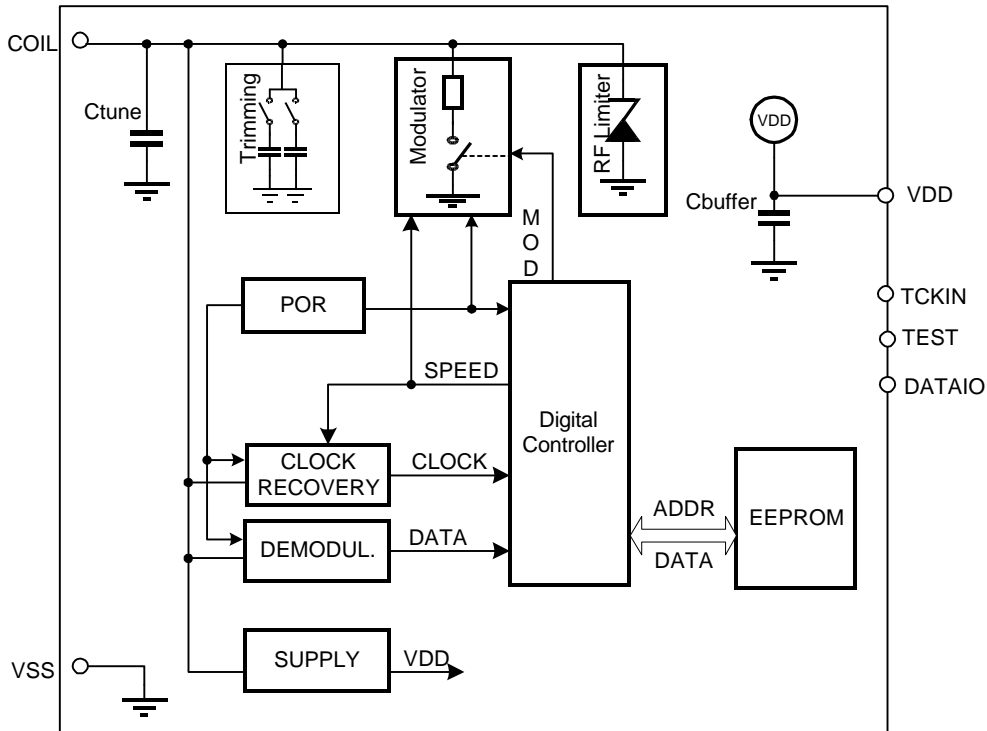
EEPROM memory maps

Read memory map

ADDRESS	FUNCTION	COMMAND	F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
			BITPOSITION (MSB first)																
0	ID	CONTINUOUS																
1																		
2																		
3																		
4																		
5																		
6																		
7																		
B	WPW	CMF1	Lock word: "01010101"								WPW(FLAGS)								
C	Tune+CFG	CMF1	0	T4	T3	T2	T1	T0	0	0	0	0	0	0	0	0	CODE	SPEED

Write memory map

ADDRESS	FUNCTION	COMMAND	F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
			BITPOSITION (MSB first)																
0	ID	CMF1																
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8	WPW	CMF2	Lock word: "01010101"								WPW(FLAGS)								
9	Tune	CMF2	0	T4	T3	T2	T1	T0	0	0	0	0	0	0	0	0	0	0
A	CFG	CMF2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CODE	SPEED

General Description

The MLX90111 is a 128bit Read Write transponder IC. The integrated tune capacitance and the external coil form a resonant LC antenna that absorbs part of the electromagnetic energy radiated by the transceiver LC antenna. Physically, a magnetic coupling occurs between the transceiver, also referred to as "reader", and transponder antennas

To amplitude modulate (AM) the RF carrier, the transponder damps the electromagnetic field by switching a resistor in parallel with its coil. This way the transponder repetitively transmits its 128bit-identification code (ID) to the transceiver, which recovers the envelope of the damped field, and decodes the ID.

The transceiver can send commands and data to the transponder by modulating the amplitude of the carrier.

POR level

When the transponder is placed in an external radio frequency (RF) field of appropriate frequency and amplitude, the internal power supply (VDD) can build up as charge on the integrated buffer capacitance. The modulation resistor is switched on and off as soon as VDD has reached the Power On Reset (POR) level. When the modulation resistor is switched on, the LC circuit is no longer tuned, therefore no energy is taken from the field, and VDD drops due to internal consumption. Hence, by switching the modulation resistor on and off, it is possible to oscillate around the POR level. This phenomenon is referred to as hiccuping.

The modulation resistor is switched off when the transponder drops below the POR level.

Sensitivity level

The minimum electromagnetic force (e.m.f.) needed to avoid hiccuping is defined by Vacsens. At this level the power supply will not drop below the POR level while the modulation resistance is switched on during modulation.

Clock recovery

The transponder takes its clock from the carrier frequency. Depending on the speed option, the carrier frequency is divided by 32(4kbaud), 64(2kbaud) to generate the bit rate.

Demodulator

If the external RF field is AM modulated according to the asynchronous control pattern (ACP), the transponder stops transmitting the ID and enters the Program Mode.

Data is then sent to the transponder using Return to One encoding. First half bit is low (0) or high (1), and the second half is high. In the middle of each half bit one sample is taken. In order for the transponder to detect the ACP modulation a minimum modulation depth is required. See timing specification below for more details on the write protocol.

RF limiter, or clamping

The build up of voltage on the resonant LC circuit is limited to avoid damaging the internal circuit.

Modulator

The modulator consists of a modulation resistor that is switched in parallel with the resonant LC circuit (antenna). Because in weak RF fields the rising edge is much slower than the falling edge of the envelope, a symmetrically driven modulator would give an asymmetrical envelope. This is anticipated by delaying each falling edge by a fixed number of RF clock pulses. The modulator is hence driven asymmetrical. Each ON state is reduced by 8 (4) clocks in 2 (4) kBaud mode, and each OFF state is prolonged by the same amount.

Speed	Total clocks per Bit	Clocks 'ON' state	Clocks 'OFF' state
2kbaud	64	Long ON = 64 - 8 Short ON = 32 - 8	Long ON = 64 + 8 Short ON = 32 + 8
4kbaud	32	Long ON = 32 – 4 Short ON = 16 – 4	Long ON = 32 + 4 Short ON = 16 + 4

EEPROM

1. Memory organization

The EEPROM memory is arranged as 11 words of 16 bits each (see memory map above). Each one of these words is individually programmable.

1.1 ID (Addresses #0 to #7)

The first 8 words hold the 128bits identification code (ID). Any of the 8 words of the ID can be individually written. The complete 128bits ID is send out when the device is in continuous/critical read mode.

1.2 Write Protect Word (Address #8)

The 9th word allows writing protect some words from the ID temporarily or permanently, or even block the complete ID: OTP feature.
Bits 0 to 7 (WPW flags) lock (1) or unlock (0) the write access to the corresponding word in the ID.
The most significant byte (Lock WPW) is ignored, except when written with a special pattern (01010101 -MSB to LSB-). Then it locks the WPW (#8), the Tuning bits (#9) and the Configuration word (#10). When writing FF55Hex to the WPW word, then the transponder becomes an OTP device.

1.3 Tuning bits (Address #9)

The tune bits select the status of the tuning capacitors (1=on, 0=off).
They can be written with command CMF2 at address 9 in the bit positions 14 to 10 (from the highest, 64 pF to the lowest, 4 pF). The tune bits can be read back at address 12 with command CMF1. As the tune bits do not overlap with the configuration bits they can be read together in word 12. Programming is kept separate, to avoid reprogramming of the tune bits in case the code/speed is changed.
The Tune capacitance can be delivered tuned to an absolute value of 250pF +/-2%, leaving 5% tuning after assembly, or tuned for maximum tuning range after assembly. The latter solution can only be provided with an absolute value ranging between 200 and 300pF, but over full lot tuned to 2%. This offer is only valid for large volume orders (>100k pieces).

Following table shows the configuration of the tune caps in relation to the tune bits:

Tune bit	Nominal capacitor value (pf)
T4	64
T3	32
T2	16
T1	8
T0	4

1.4 Configuration Word (Address #10)

Speed bit (bit 0) defines the internal clock extraction: set to 1 for divided by 32, set to 0 for divided by 64.

SPEED	Data rate	Baud rate
0	Freq/64	2kbaud
1	Freq/32	4kbaud

Code bit (bit 1) defines if the ID will be encoded in Manchester (set to 1) or Biphase (set to 0) amplitude modulation scheme.

CODE	Encoding
0	Biphase
1	Manchester

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2. Operating Modes

2.1 Continuous/critical read mode (ID)

In read mode, the transponder transmits its ID code to a transceiver by amplitude modulating (AM) the envelope of the carrier coming from the transceiver. The 128 bits of the ID are Manchester or Biphase encoded.

After POR the device will enter 'normal' read mode. The ID will be read out under optimal conditions. After programming any word of the ID, the device will automatically enter 'critical' read mode. The data is read at the 2 extremes of the reading window. When both readings are identical, the data retention is guaranteed as specified (Tret, Ncyc). If the two critical readings show a difference, the device is at its minimum coupling with the transceiver and it should be reprogrammed using a stronger field.

Critical read mode can only be reset by removing the transponder from the RF field.

2.2 Programming mode

Upon receiving an Asynchronous Control Pattern (ACP), the device enters program mode and waits during a Watchdog Delay period (TWD), for the start bit of the programming sequence.

The programming sequence consists of a start bit, and a 32 bit command. The command starts with a 3bit Command Field (CMF), a 4bit address, an odd parity bit calculated over the address, a 16bit data word and an 8bit CRC calculated over the full command.

If the programming sequence is received, the write access, parity and CRC are verified and command is executed if possible, else the transponders goes back into normal read mode.

In case the command has been executed, the transponder waits again for a Watchdog Delay period TWD for a new programming command. In case of a timeout the device starts sending the ID code in critical read mode, until removal from the RF field.

Minimum field strength for reliable programming is set by the minimum induced e.m.f. Vacee on the transponder coil.

2.3 Programming commands

Two Command Fields are defined:

CMF	Code	Action
CMF1	001	- Write ID words: addresses 0…7, - Read address 8,9,10
CMF2	000	- Write address 8,9,10

To write data, the respective CMF and address are sent out. If the write access, parity and CRC are verified, the data are written in the EEPROM at the specified location. For 2kbaud devices EEPROM programming takes 20ms, for 4kbaud devices programming is done in 10ms.

To read the data in addresses 8, 9 and 10 CMF1 is used.
- address 11 for reading the configuration word.
- address 12 for reading the tuning (bit positions 14 to 10) and the configuration (bit positions 0 to 1) bits, see the memory map.
If the parity and CRC are verified, the data is sent out during the time window normally allocated for the EEPROM programming. Data is sent with a start bit of ½ bit (!) time first, followed by twice the 16-bit data word, with critical read levels. The startbit allows to detect a leading 0 in Manchester coding, and allows the microcontroller to synchronize. Remark that this startbit is different from the start bit sent by the reader, which is a full bit.
HINT: In case the reader requires more time to switch from write to read mode, the dummy data should be chosen such that the last CRC bits are 1, i.e. in Return to Zero code: no modulation needed on the reader antenna. This way the time for switching the reader can be extended.

2.3 Parity, CRC

PAR is an odd Parity bit is calculated over the 4-bit address
The 8-bit CRC with polynomial $u^8 + u^4 + u^3 + u^2 + u^0$ is calculated over the complete command string [CMF-ADDRESS-PAR-DATA].
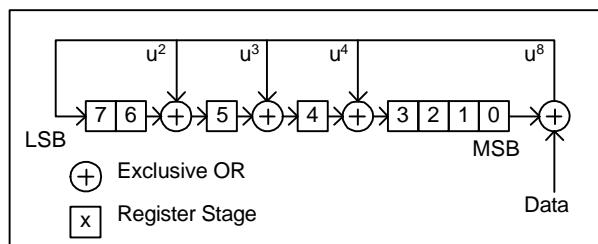
3 Timing specification

3.1 Asynchronous Control Pattern

The Asynchronous Control Pattern (ACP) is sent by the reader to render the transponder silent (stop transmitting), and listen for a programming sequence.

Before starting the ACP, the field must be stable at FHIGH for at least 5 bit periods (Tsetup). This guarantees that the reference level FTHRESHOLD is adjusted.

The control pattern itself contains 4 transitions between high field FHIGH and low field FLOW, each of which should be 2.5bitperiods apart. The threshold level FTHRESHOLD adjusts itself exponentially to the average FHIGH over the last 20 periods (TCLK).

The optimum modulation depth forced by the reader depends on the application and stretches between:

$$90\% > (FHIGH-FLOW) / (FHIGH+FLOW) > 20\%$$

The transponder samples the field 2 times per bit. A first time is after the first quarter, the second time after the third quarter. The sample values are only retained when the modulation resistor is off. The other samples are dropped.

3.2 Synchronous Command

When the ACP has been detected, the transponder modulation will be turned off, within maximum 6 bit periods after the last rising edge of the ACP. The transponder will now synchronize on the first falling edge it sees. This edge is generated by a startbit (SB=0), which has to be sent within a Timeout Window TWD.

If no SB is detected the transponder will return to its original read mode.

The SB may used to optimize the synchronization between tag and reader.

Tip: always try to put the sampling time of the transponder at the end of the first half bit. This minimizes the influence of an increased the transponder Q at larger distance.

However, if the modulated signal on the transponder takes several periods to drop, the SB may be extended with this time. This will shift the sampling moment forward.

After this synchronisation step, a synchronous command can be sent from the base station. Make sure to respect the nr of transponder clocks per bit, as specified below.

All data sent by the reader have to be Return-To-One encoded.

3.3 Transponder action

The command is verified on its Parity and CRC values after the full command has been received.

If verification is successful the command will be executed during the next 32 bit periods.

Else if no valid command is received, due to a verification error, the transponder will immediately, i.e. 32 bit periods after the SB, start modulating its 128bit ID code.

3.3 Multiple commands

After successfully receiving a command, the transponder will wait for a new command. This new timeout window (TWD) starts after the 32 bit period it requires to execute the received command.

To limit time skew between microcontroller and the transponder, a new synchronization is done before each new command.

The transponder will start modulating its ID code approximately 52 btiperiods after successfully having received its last command.

3.4 Other timings

See timing table below for an overview of all timings. All timings are bitperiod based, and are therefore related to the resonance frequency and datarate.

Data send to transponder as number of bit periods												
Asynchron	Tsetup	ACP	TWD									TWD	
Synchron				SB	CMF	ADDR	PAR	DATA	CRC	PROG/READ		SB
Bit periods	>5	3*Tas + 6bit	20	1	3	4	1	16	8	32	20	1

Transponder mode / operations				
Normal read	Enter program mode: - Stop modulation - Synchronize on Start bit	Read (32-bit) command	Verify command + Write / Read EEPROM data	Resynchronize on Start bit

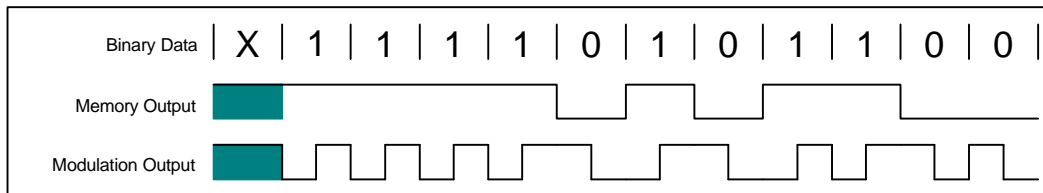| MLX90111 Timing Specifications in ms for a Carrier Freq = 125kHz, Tclk=8µs					
Speed	**Bit Period**	**Tas**		**TWD**	**PROG/READ**
		Min (2 bit)	**Max (3 bit)**	**20 bit**	**32 bit**
		Tclk*128	Tclk*192	Tclk*1280	Tclk*2048
Freq/64 (2kbaud)	Tclk*64 = 0.512	1.024	1.536	10.24	16.384
Freq/32 (4kbaud)	Tclk*32 = 0.256	0.55	0.7	5.12	8.192

1. Modulation on Reader Antenna
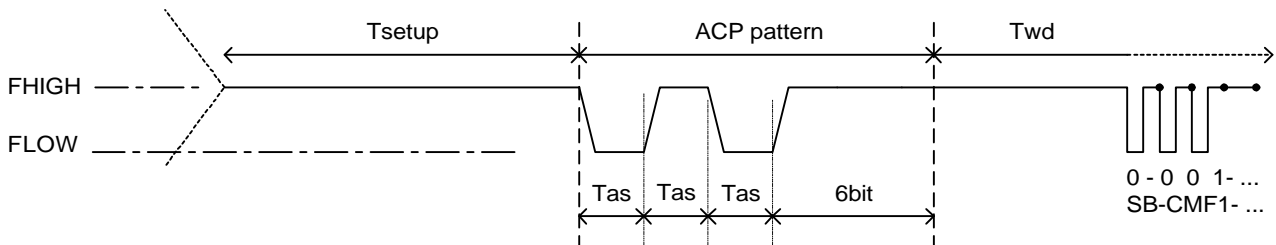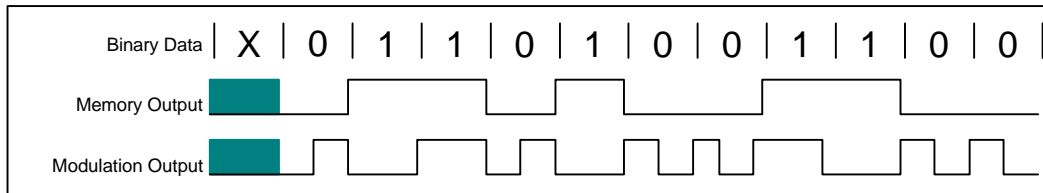

2. Modulation on Tag Antenna
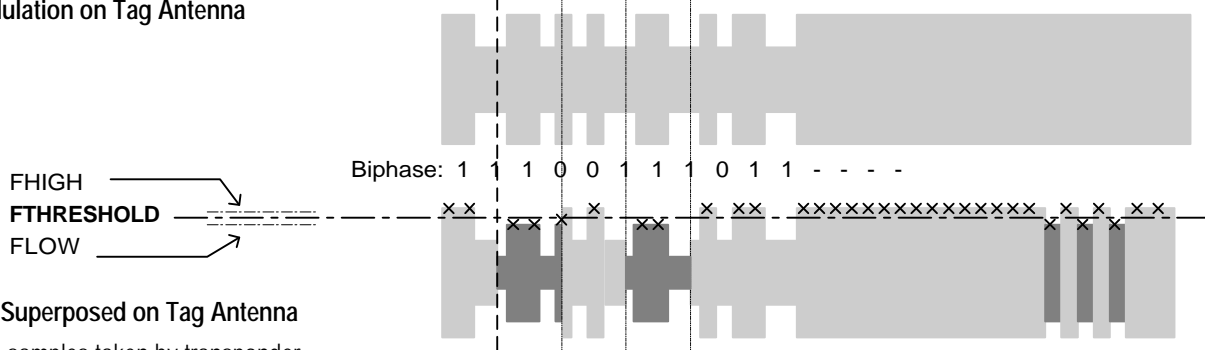
3. 1+2 Superposed on Tag Antenna

- X: samples taken by transponder
- Dark shaded: reader coil modulation ON
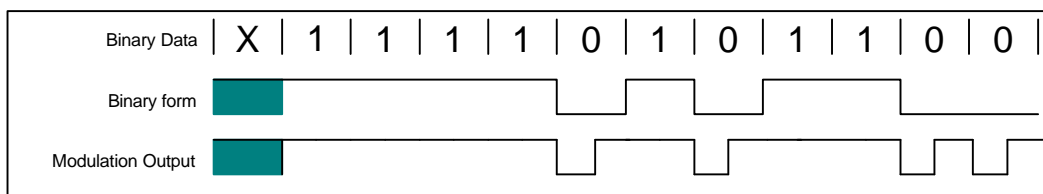- Light shaded: reader coil modulation OFF

Manchester Code

| Binary Data | X | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |

Memory Output

Modulation Output

Biphase Code

| Binary Data | X | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |

Memory Output

Modulation Output

Return to One

| Binary Data | X | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |

Binary form

Modulation Output

Coding schemes

Manchester

For a "1" bit, there is a transition from 0 to 1 in the middle of the bit period. Reciprocal, for a "0" logic bit there is a transition from 1 to 0 in the middle of the bit period.

Biphase

At the beginning of each bit, a transition will occur. A logic bit "1" will keep its state for the whole bit duration and a logic bit "0" will show a transition in the middle of the bit duration.

Return to One

This encoding is used to modulate the reader antenna to send the commands to the transponder.
For a "0" bit, there is a transition to 0 in the beginning of the bit period. In the middle of the bit period the state returns to 1.

For a "1" bit, the level remains high for the entire bit period.

Flow Chart.

Upon entering the RF field, the transponder "sees" increasing amplitude of the voltage between COIL and GND pins. It passes through a POR sequence, and enters the normal read mode, transmitting the ID continuously.
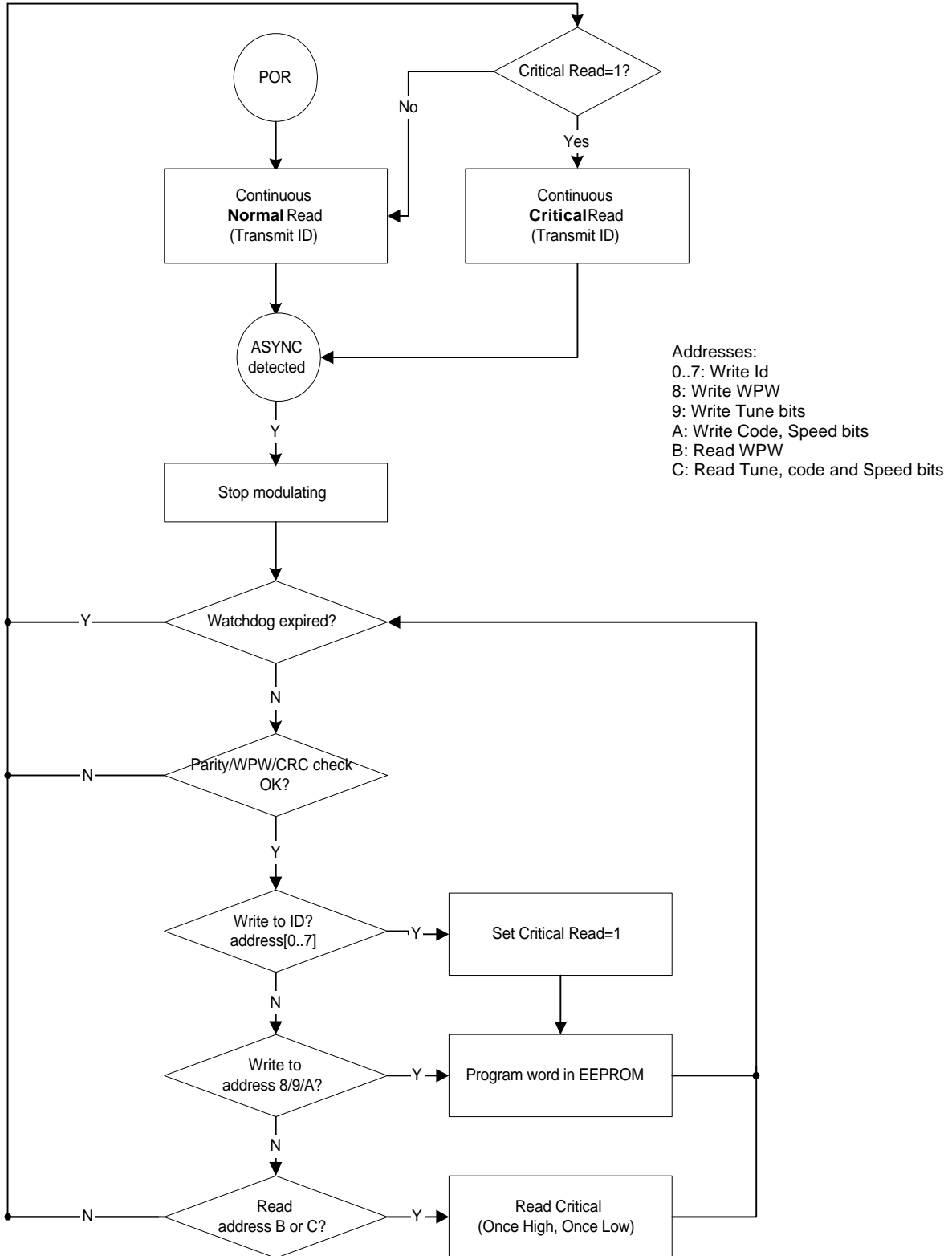If the reader sends an asynchronous control pattern (ACP), the transponder enters program mode. It receives an address, parity, a 16-bit data word and a CRC.
When a write command has been successfully received, the word is stored at the given address. When a word of the ID is written, the critical read flag will be set. This flag can only be reset by removing the transponder from the electromagnetic field.
When a read command for addresses #B (WPW) or #C (tune-bits, speed and code) has successfully been received, the transponder immediately sends back the requested information, once critical high and once critical low.
If no new programming pattern is received during the Watchdog Delay period (TWD), the transponder checks the critical read flag and enters the appropriate read mode.

Flow Chart.

Addresses:
0..7: Write Id
8: Write WPW
9: Write Tune bits
A: Write Code, Speed bits
B: Read WPW
C: Read Tune, code and Speed bits

Unique Features

- Flexible configuration.
- Simple fast programming.
- Large programming range.
- State of the art reading distance.
- 20% tuning range of resonance frequency after assembly.

Cross Reference

This product can typically replace Marin EM4069, TEMIC e5550, Philips HITAG or any other RW transponder in the 120kHz range. It provides an easy configurable, high performant replacement.

Absolute Maximum Ratings

Maximum Power Supply (VDDmax)	-0.7 to 7V
Maximum current forced between coil and ground pin (Icoilmax)	+ / - 30mA
Operating Frequency (Freq)	60 to 150kHz
Normal Operating Temperature (Toper)	-40 to 85°C
Maximum Storage Temperature in SO8 (Tstore)	-55 to 125°C
Electrostatic discharge (HBM) on coil pin (Vesdcoil)	500V
Electrostatic discharge (HBM) on other pins (Vesd)	1500V

ESD Precautions

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

Disclaimer

Melexis reserves the right to periodically make modifications to product specifications. The information included herein is believed to be accurate and reliable. However, Melexis assumes no responsibility for its use, nor for any infringements of patents or other rights of third parties which may result from its use.

SO8 Pinout

Pin	Name	Function
1	COIL	Coil connection 1
2	TEST	Pin to set chip in test mode
3	TEST	Pin to set chip in test mode Keeping at Vdd/2 will reset the chip
4	VSS(*)	Coil connection 2 / ground connection
5	VSS(*)	Coil connection 2 / ground connection
6	TEST	Pin to set chip in test mode
7	VDD	External chip supply for test mode
8	VSS (*)	Coil connection 2 / ground connection

(*) All three VSS pins are connected together thanks to the use of a fused lead frame.
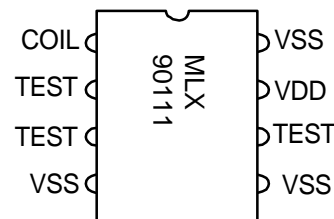
Chip dimensions

These are good approximations; exact position info is available on request.