

## Features and Benefits

- Battery operated stand alone RFID reader
- 10\$ BOM cost target
- Low power consumption (400uA average)
- Optimized form factor for easy integration

## Applications

- Short range contactless Door Access Control
- Short range RFID terminal

## Ordering Information

Part No.	Description
DEMO90121DA	RFID Door Access Demonstrator

## 1 Scope

The DEMO90121DA is a turnkey contactless door access example based on the RFID transceiver IC MLX90121. Once set up, it detects and reads ISO14443A cards and is capable through software configuration of lighting a red or a green LED.

As a stand alone application running on battery, the current consumption is optimized, taking into account a fast response time. The form factor is minimized to demonstrate the high level of integration allowed by the MLX90121. The bill of material of DEMO90121DA targets a cost of 10\$ per component set for 1000 modules.

Complete schematics, bill of material and layout are annexed to this document allowing a fast start for development. Source code of the firmware is based on the FW90121 library and is available on the CD ROM provided with the DEMO90121DA. This device is based on ISO14443A RFID standard, but the software library makes it is easy to adapt the firmware to use another ISO protocol.

This document includes fast start instructions, describes the performance of the demo and explains its hardware and software. One can see this document as a starting point for building their own access control system by adapting the functions and performances to their specific requirements.

## 2 Related Melexis Products

MLX90121 – 13.56MHz transceiver



Note 1: The device is for demonstration purpose and has not been tested for compliance with FCC, ETSI or any other regulations.

Note 2: The MLX90121 is limited to positive temperatures in the ISO14443A mode. Therefore and without any changes, this demonstrator is suitable for indoor applications. Should you require outdoor operations, you may modify its firmware to use the demonstrator with ISO14443B cards.

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### 3 Introduction

You purchased a DEMO90121DA. Thanks for choosing Melexis. This demonstrator is a contactless door access solution based on the MLX90121. This document contains the instructions to use and evaluate the functions and the performances of this demonstrator.

All the necessary hardware is provided in the packaging box and the microcontroller on-board is already programmed with the same firmware as the one present on the CD. All that you need to do is to plug the cables, and then to check visually the LED status when one or more of the tag cards are close to the antenna.

Should you want to start a development based on this demonstrator, you will find in this document and on the CD all information like schematics, board layout, list of component, firmware source (C code) and the related application note. Please note that all this material is provided to support the use of the related Melexis product. Duplication, circulation or storage on data carriers in any manner for any other type of use are not authorized by Melexis unless specific agreement.

### 4 Box Content

You will find in the box the following components.

- 1 RFID reader board

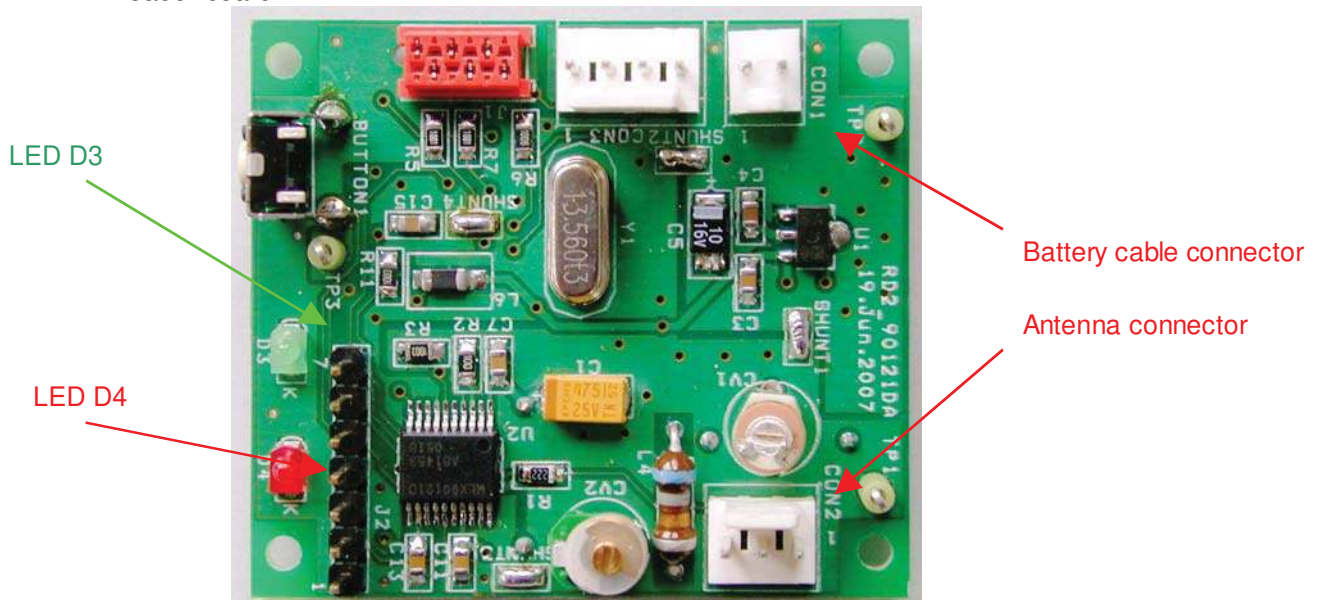


Figure 1 RFID reader board. Top side

- 1 antenna board

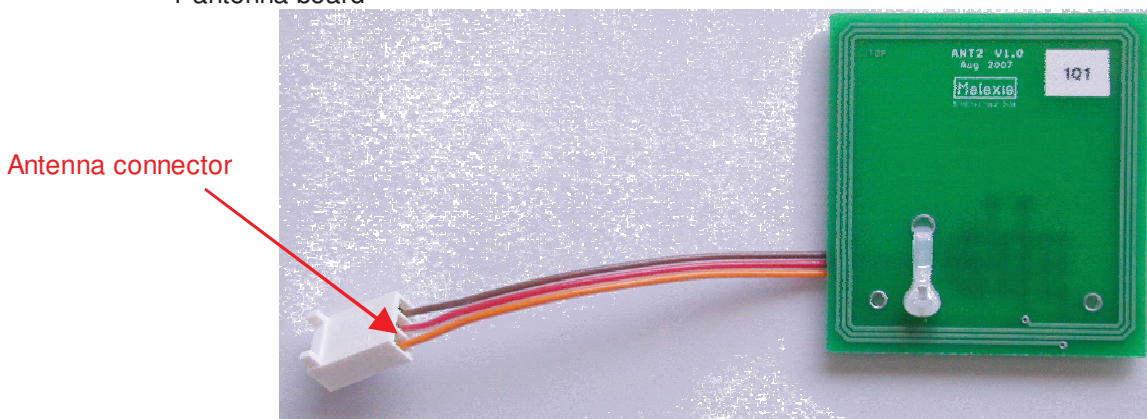
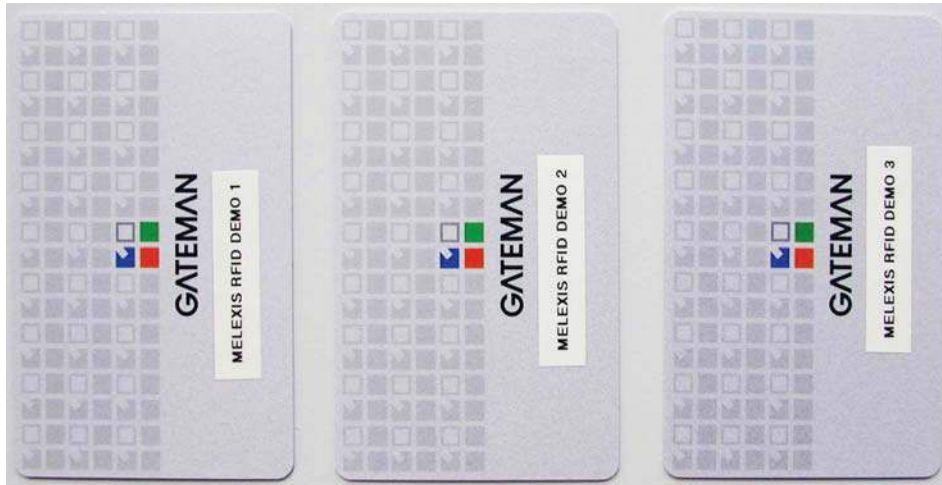


Figure 2 Antenna ANT2\_0

- 3 tag cards



**Figure 3 ISO14443A tag cards**

- 9V battery and battery cable



**Figure 4 The 9V battery and the power supply cable**

- 1 CD with the firmware and documentation  
The delivered CD contains the complete documentation of the hardware and firmware for DEMO90121DA, User Manual, Datasheet MLX90121, Source Code of the firmware (written in C, flavor AVR gcc), Hex file of the firmware, Schematics of the board (ORCAD 9.2 file), Layout of the board (GERBER files), Bill of materials of the board
- 1 User Manual (on paper) - this document
- 1 Box Content (on paper)

## 5 Connections

The first step is to connect the component. Connect antenna board to the RFID reader board (3 pin connector). Then, connect battery cable to the RFID reader board (2 pin connector). Plug the battery to the battery connector of the cable.

## 6 Working principle

Once connected, this demonstrator allows the use of several functions which are generally used in RFID door access devices. Its principle is based on the unique identification number (UID) of ISO14443A tags.

The demonstrator is able to store several UID. All cards which UID number is stored in the device can open the door. Each card is associated with a specific access privilege, Master Key or Valid Key. The highest card level (Master Key) which is unique (It can be only one card with Mater key privilege) can transfer its rights to open the door to a card which acquire by this way the second access level (Valid Key).

The device can be re-initialized. By this way, one can change the card with the Master Key privilege and remove all other card from the Valid Key card list. When powering on the module or resetting it through its reset button, the module starts an initialisation phase:

- If no tag is present in the reading range of the antenna, nothing changes in the configuration. The UIDs previously stored in the memory are kept.
- If one tag is present, the device will read its UID, store it and associate it with the Master Key privilege and delete other UID from memory.
- If two or more tags are present, nothing changes in the configuration. The UIDs previously stored in the memory are kept.

As this device could be an example for battery powered access control system, the power consumption was optimized. Therefore, the device is running in low power mode the main part of the time and switch on its tag detection function for few instant. In absence of tag, the device enters back in low power. In the opposite case, it starts an RFID communication and the door access function.

## 7 Functions and use

### 7.1 System initialization

Place a card on the antenna. Press **BUTTON1** (reset) of the DEMO90121DA and check that the LEDs **D3** and afterwards **D2** start to blink rapidly (microcontroller registers tag card nr.1 as **master card**)

### 7.2 Opening the door

The device executes this operation in 3 steps; tag detection, opening ISO14443A communication, reading and checking the UID. Approach any kind of card near to the antenna. LEDs **D2** and **D3** will be on together indicating that a tag is detected. If this card is compliant to ISO14443A, then **D2** will blink alone once. In the opposite case, nothing more happens. If this card has any access privilege (Master or Valid Key) then **D3** will blink alone once, meaning that the card is recognized as valid card. In other case, nothing more happens.

### 7.3 Transfer access right

Put the card with the Master Key privilege (card A) together with another card (card B) close to the antenna. LEDs **D2** and **D3** will be on together (tag detected), then **D2** alone will blink two times (two ISO14443A cards are detected), then **D3** alone will blink two times (two valid codes are stored in microcontroller memory). This means that right to open the door is transferred from the card A to the card B. The card B UID is added as Valid Key card one.

### 8 Observations

1. Reading range of the DEMO90121DA is about 10cm.
2. Tag detection is made by change of the antenna field load compared to previous cycle (one cycle is about 300ms or longer). Therefore, the LEDs **D2** and **D3** blinking once together indicating in this way the **field change**. It could occur that approaching objects to the antenna generates a tag detection indication
3. When one or more ISO14443 tag cards are already in the field, just after the tag detection indication **D2** will blink indicating **how many cards** it detected: once if only one card, twice if it detected two cards, etc.
4. In order to reduce a too strong coupling between tag cards, fan them a little when approaching two or more to the antenna.
5. The valid tag codes are stored in the non-volatile memory of the microcontroller of the DEMO90121DA, so after a power-off the codes are not lost.
6. The average current consumption is ~0.4mA (no change of the antenna load).

## 9 Hardware

### 9.1 General

The DEMO90121DA is built around the MLX90121 RFID transceiver front-end and the 8bit microcontroller Atmel ATmega8. The MLX90121 handles the air interface in transmission and in reception. It drives the antenna through its Class E power driver in order to generate the HF magnetic field and modulation according to the protocol and command generated by the microcontroller. It demodulates the answer from the tag and provides digital signals to the microcontroller. The ATmega8 runs the protocol and the application software. The board has three interfaces, one for the door opening mechanism, a SPI connection for the uC programming, and a debug connector. It embeds a reset button, clock and power management functions and can be powered from a battery.

### 9.2 RF part

#### Emission

The MLX90121 integrates a class E driver capable of, providing up to 200mW to the antenna. The Class E driver (TX pin) is connected to the antenna through a resonant load and an adapter circuit. In order to give users the choice to connect to a variety of different antennas, the transceiver output is matched to 50Ω impedance. The adaptation impedance is composed by L2, C6 (resonant load), CV2, C8, L4, L3, C10, CV1 (impedance adaptor). In order to get the best performance, it is necessary to tune the adaptation circuit. The tuning operation starts by adjusting CV2 to get the maximum amplitude. Once CV2 is fixed, the adjustment of CV1 can be done. Any 13.56MHz antenna matched to 50Ω can be used. However, care should be taken for its quality factor, which has to be between 10 and 25. In case antennas with other than 50Ω impedance the capacitor C9 is used to match the output. Tuning of the antenna has to be done when placed in its final position because close proximity to metallic parts, including wires can cause changes from its characteristics in free-air. For some tips in building the antenna see [13.56MHz RFID systems and antennas design guide](#).

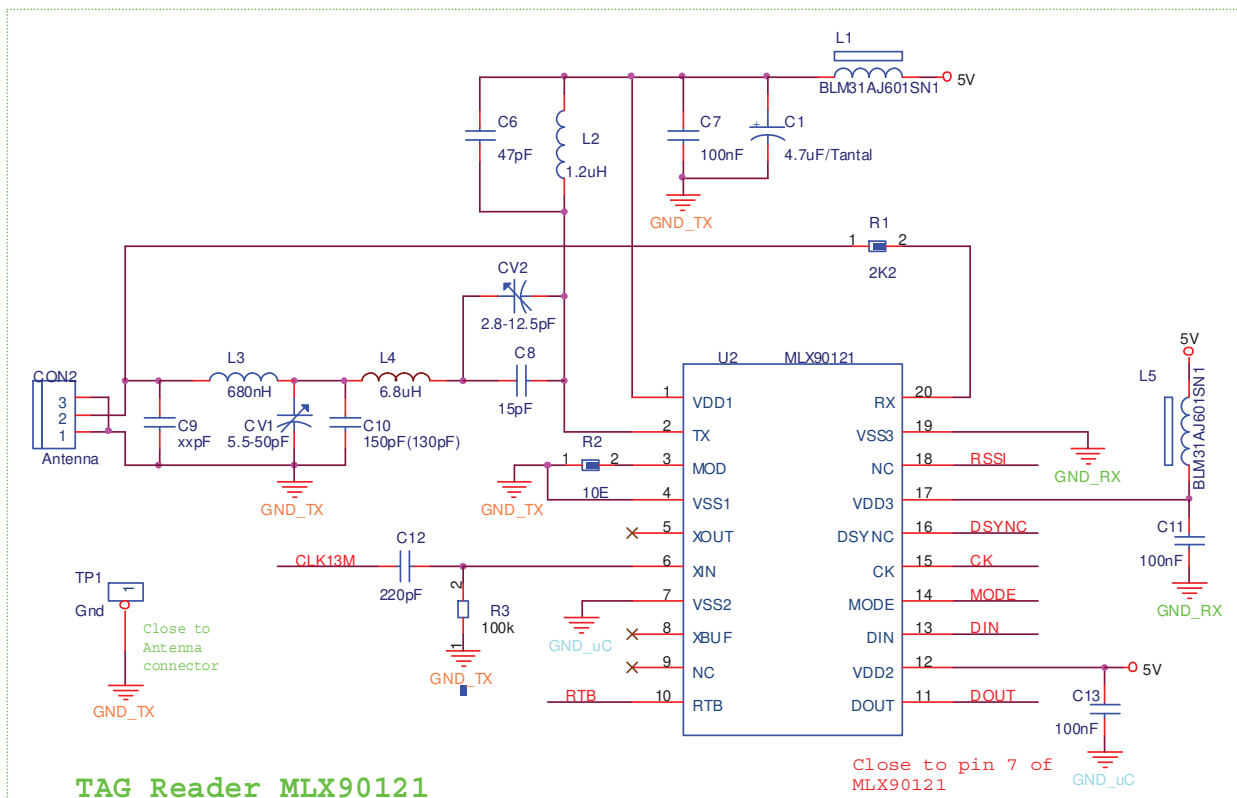


Figure 5 . MLX90121 transceiver block.

### Reception

The reception is done through the R1 resistor which connects the receiver part of the MLX90121 to the antenna. Its value can vary from 1kΩ up to 4.7kΩ depending in the back modulation amplitude and the reading distance. In this example 2.2kΩ gives the best compromise. Special care must be taken when using other values. If R1 is too big the DC bias voltage and the back modulation signal seen by the receiver are not enough for correct reception. If R1 is too small the DC bias voltage saturates the receiver input.

### Modulation depth

The 10Ω resistor R2 fixes the 10% modulation index for the ISO14443B communication. When using ISO14443A cards, the R1 resistor is bypassed by the internal modulation transistor. In case of OOK is used, resistor can be kept here or not mounted.

## 9.3 Microcontroller

### Connection to MLX90121

The microcontroller controls the MLX90121, manages the clock signals and interfaces the RFID function to the application, i.e the door lock mechanism. Port D is used to connect the MLX90121 through the signals CK, DSYNC, DOUT, DIN, RTB and MODE.

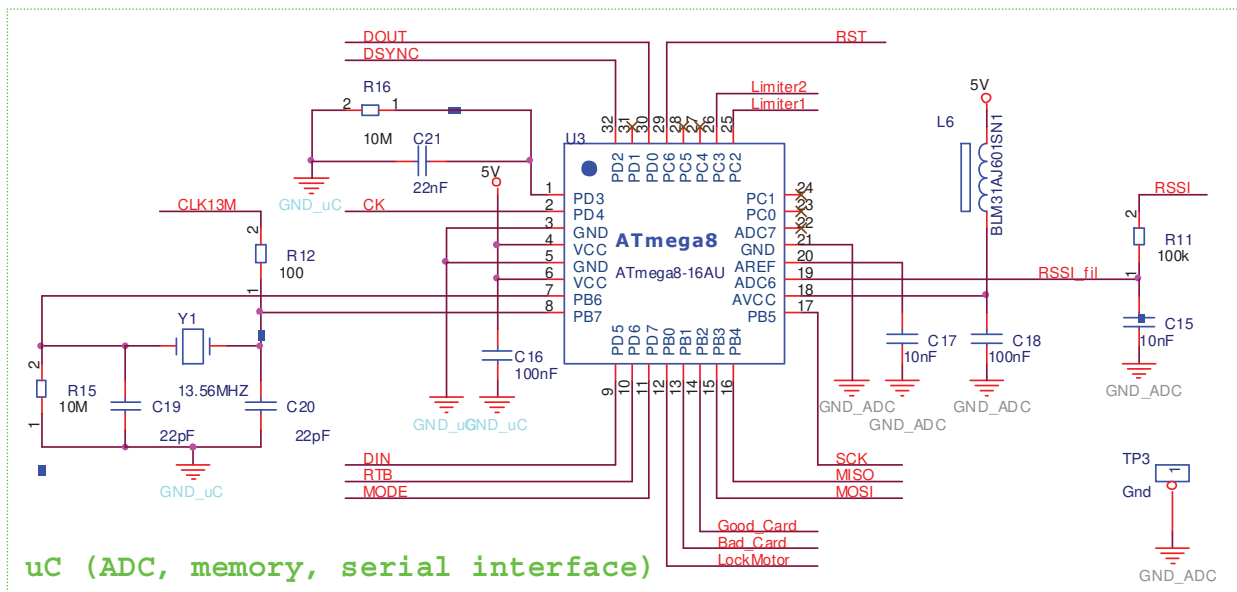


Figure 6. Microcontroller block.

### Clock

A 13.56MHz quartz crystal oscillator is connected between PB6 and PB7 for the generation of the clock. The resistor R12 is used to attenuate the fast transients generated by the clock connection between MLX90121 and ATmega8.

### Wakeup Cycles

In order to reduce the power consumption, the microcontroller alternates sleep and wakeup modes. This cycle is generated by means of a RC circuit composed of R16 and C21 connected on PD3. The time constant given by the RC enables an interrupt (INT) after about 280ms. The precision is given by the tolerances of R16 and C21.

### Programming and development

The microcontroller can be programmed onboard using the SPI interface. This serial interface associated with adequate hardware and software allows read and write access to all memory blocks of the microcontroller. This is useful for firmware updates or changes in case of adaptation to specific requirement.

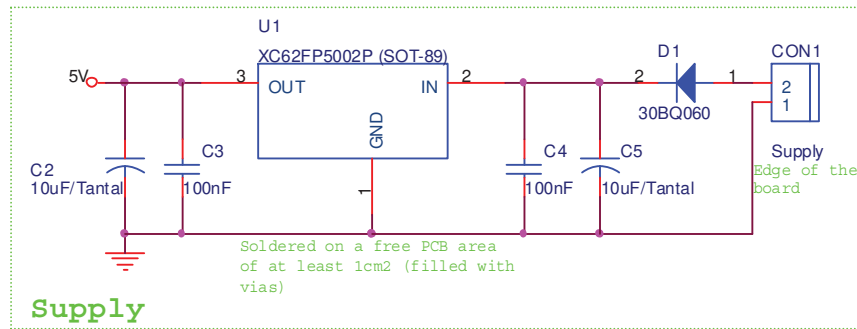


### Code size

The firmware used in the DEMO90121DA requires 5.2KBytes of program FLASH of the ATmega8. The microcontroller ATmega8 can be substituted by other pin-compatible ATMEL models, with different characteristics and prices.

### 9.4 Power

The DEMO90121DA embeds a 5V regulator and therefore requires at minimum a 6V DC voltage supply. A diode is used after the power connector to protect the board against reverse voltage.



**Figure 7 Voltage regulator 5V**

The MLX90121 has three sets of supply pins (power and ground) corresponding to its three main blocks: the digital block, the transmitter block and the receiver block. It is important to separate carefully the supply lines to reduce the noise issues. Therefore, supply pins are connected as follows:

- the digital block supply pins VSS2 and VDD2 respectively to the microcontroller digital ground and directly to the main +5V;
- the transmitter supply pins to the TX ground plane (VSS1) and the VDD1 insulated from the main +5V by a filtering circuit (L1, C7 and C1);
- the receiver supply pins to the RX ground plane (VSS3) and VDD3 to the main +5V through another filter (L5, C11).

The reference clock block of the MLX90121 is internally connected to the transmitter block, so the components at pins XIN, XOUT should be placed on the same ground plane (GND\_TX).

The microcontroller has two different sets of supply pins, the digital supply (GND\_uC and the main +5V) and the analog one for the ADC, (GDN\_ADC and AVCC pin) supplied from the main 5V through a filter (L6, C18).

The microcontroller is awake about 0.98% of the time, and the transmitter 0.25% of the time. The measured average supply current is below 0.41mA.

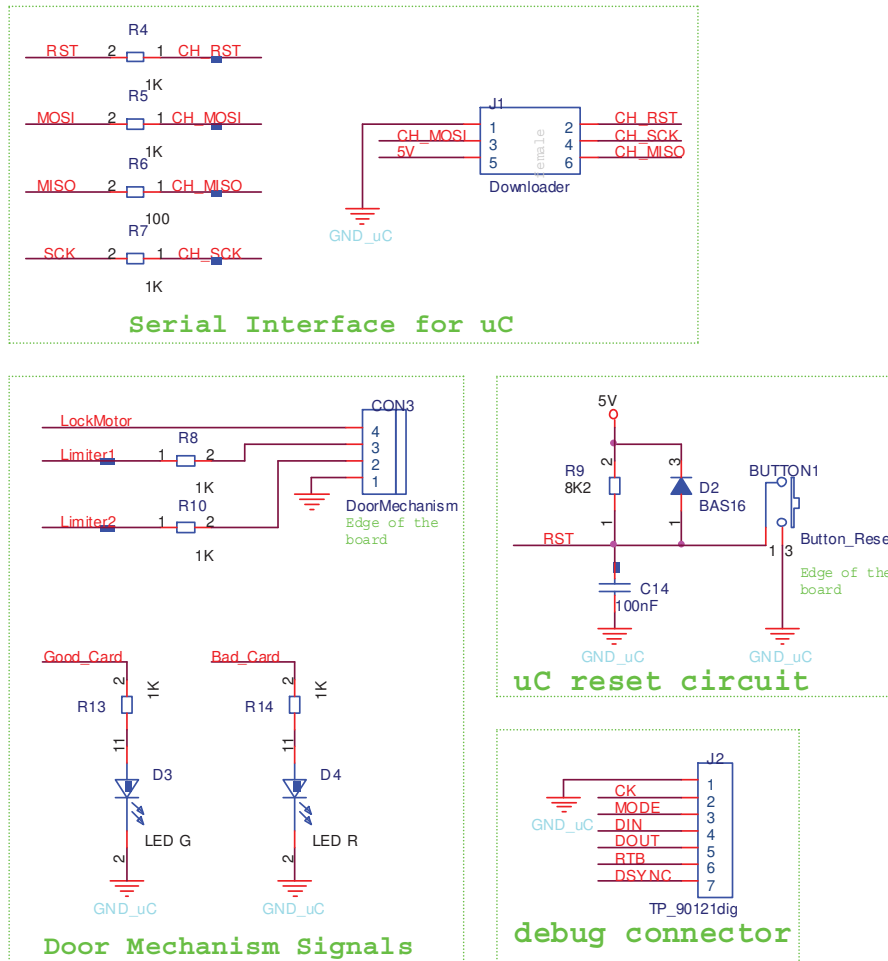
The two layer PCB has several ground planes that are connected one to each other by shunts that can be substituted by some small value resistors (0805 case) in order to reduce noise propagation between the different functional blocks:

### 9.5 Clock

The unique clock source reference is one quartz resonator of 13.56MHz connected to the microcontroller. In order to reduce the component count and the bill of material, the Xtal is shared and the clock output PB7 from the microcontroller is fed to the clock input XIN of the transceiver.

### 9.6 Interface

There are additional components that interface the microcontroller to the 'external world': An SPI interface which can be used for microcontroller programming, a reset switch for initialization of the system, a debug connector for the developer to verify the firmware changes and the functional interface composed of 2 LEDs , 2 digital level inputs for two position sensors (Limiter1 and Limiter2) and one low power digital level output (LockMotor).



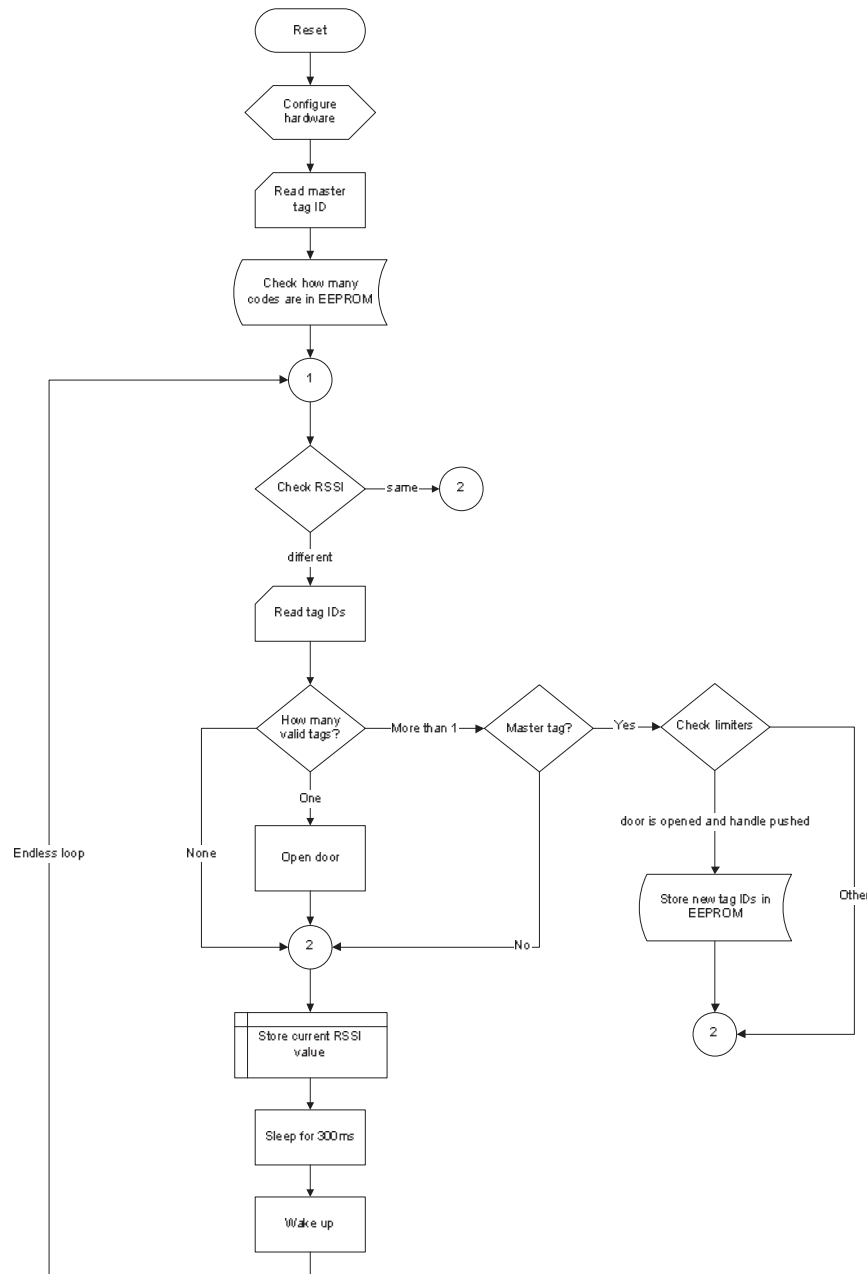
**Figure 8 Microcontroller interface to 'external' world**

Developers should add an adequate power buffer to be able to drive the door-lock motor or electromagnet.

## 10 Firmware

### 10.1 Structure

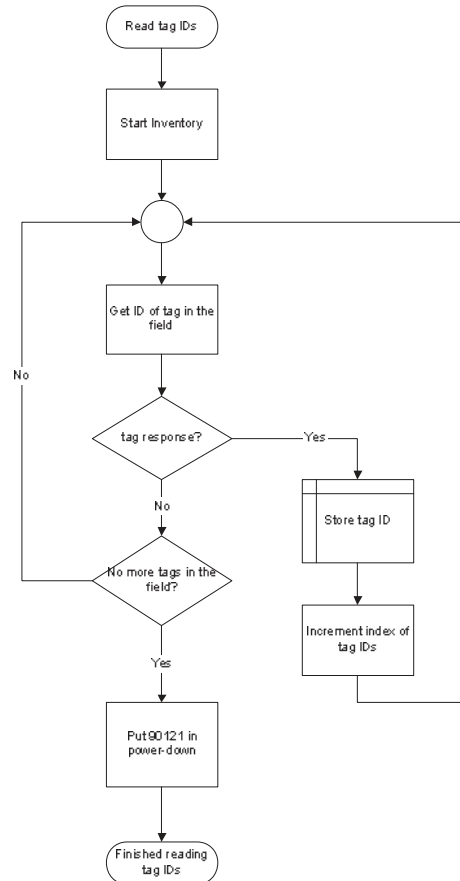
The firmware developed for the DEMO90121DA provides master tag programming, anticollision handling and tag detection as the basic service functions of the door lock application. The flowchart below shows the main structure of the firmware:



**Figure 9 Main flowchart of the DEMO90121DA firmware**

After power-on or reset the microcontroller sends a read command to the first tag in the field and stores its ID in memory. This will become the ID of the master tag for the application. In the event of absence of tag in the field, the codes previously stored remain valid, including the master one.

Once done, the firmware enters in its main loop. The RSSI level is measured and compared to the reference stored in the microcontroller memory in order to detect the presence of a tag in the field. Without any tag, the system will enter into sleep mode for the period defined by the RC circuit connected on PD3. If a tag is in the field, it starts an inventory according to ISO14443A protocol (see Figure 10) and reads all the IDs (identification codes) answering to its requests. (See Figure 9)



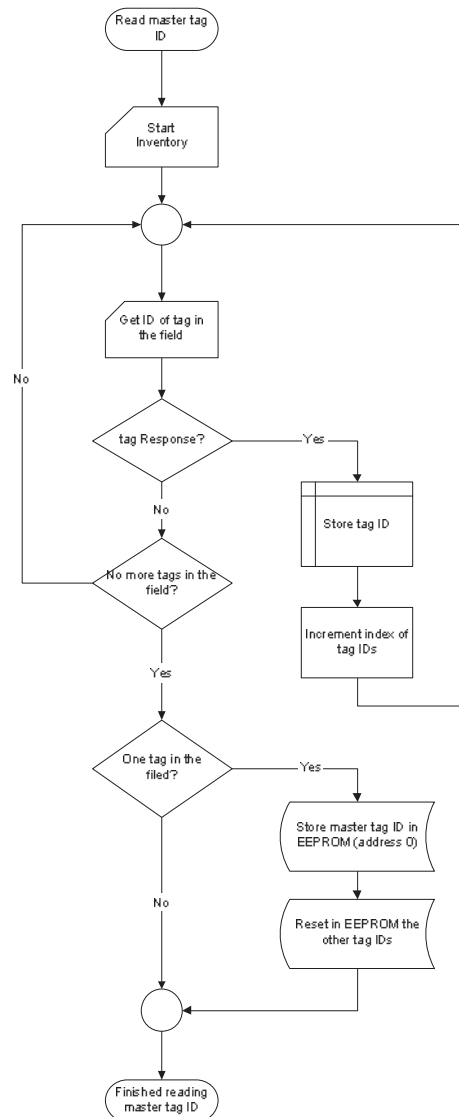
**Figure 10 Reading the tag codes in the field**

If only one valid tag is in the field the microcontroller sends the command to open the door. If there are several valid tags in the field but not the master tag, they will be ignored and the door will not be opened. (See Figure 9)

If the master tag is detected together with other tags (ISO14443A), the firmware registers all codes as valid, and will reset all previous valid ones. In order to prevent valid codes redefinition by error, this registering is conditioned by the state of the two limiters: door-lock should be opened and door handle pushed. If only the master tag is in the field, the list stays as-is, and the command to open the door is sent. (See Figure 9)

In order to reduce the success rate of code-scan hacking devices, the door-lock can be opened in the presence of only one valid tag in the field. This applies to the master tag too. A closed door limit switch condition restricts the firmware to access the function to open the door, and for only one valid tag present in the field. (See Figure 9)

After a hardware reset there is the possibility to clean the list of all valid codes and redefine the master tag code. (See Figure 11)



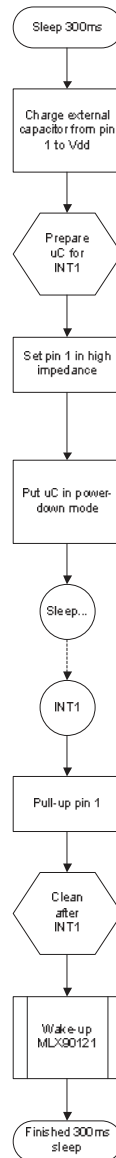
**Figure 11 Reading the master tag code at reset**

**Observations:**

- The valid tag codes can be up to 12 bytes long (96bits).
- The algorithm can be modified in order to comply with the specific needs of the targeted application.

The long sleep period of about 300ms is hardware based (see Figure 12): a RC circuit connected to pin INT1 (pin 1 of ATmega8) is discharged from VDD towards the input level 'LOW' triggering in this way an interrupt (see Figure 12).

In order to reduce the power consumption of the device, we use POWER DOWN mode of the microcontroller. All clocks are stopped and only the watch-dog is running. The watch-dog is reset at the end of the main loop, and also after long delays.



**Figure 12 Sleep 300ms sequence**

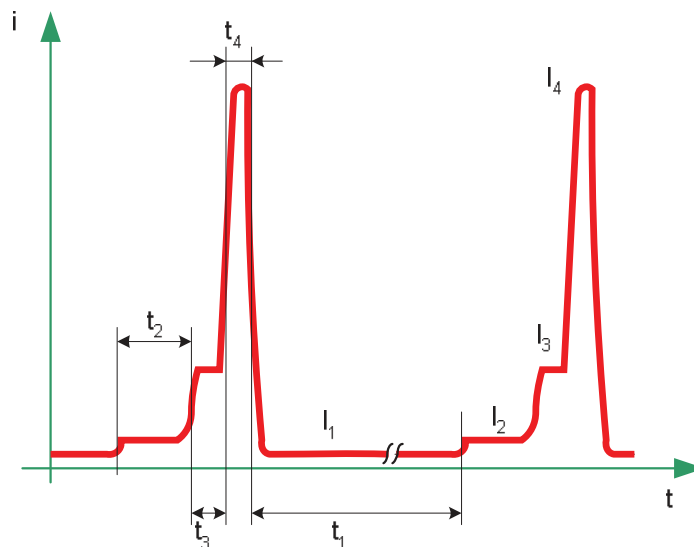
### 10.2 Practical information

The firmware of the DEMO90121DA is based on the FW121 library. (FW90121: Firmware description) This library provides the ISO15693 and ISO14443 protocol functions as specific commands to control the MLX90121, address its internal registers, and read/write to the EEPROM of the ATMEL microcontroller. At power-on or reset, the microcontroller IO ports, timers, ADC, and watch-dog, and the MLX90121 transceiver registers are configured for the ISO14443A protocol as described in the MLX90121 datasheet.

The firmware was developed using GCC under AVR Studio 4. The firmware can be loaded in the microcontroller using the SPI interface connected to a STK500, STK300, AVRISP mkII module or similar, driven by appropriate software (AVR Studio, PonyProg2000, etc). **FW\_DA21\_14A.c** and **FW\_DA21\_14A.h** contain the firmware specific gcc code and the functions' prototypes. **HwDefs.h** describes the hardware (input, output pins, etc.). The file **FW\_DA21\_14A.aps** is the AVR Studio 4 project file.

### 11 Power consumption

The DEMO90121DA is built for running on battery power and the current consumption is therefore optimized. The picture below (Figure 13) shows the typical current consumption variation during one cycle (loop).



**Figure 13 Supply current variation (No tag in field)**

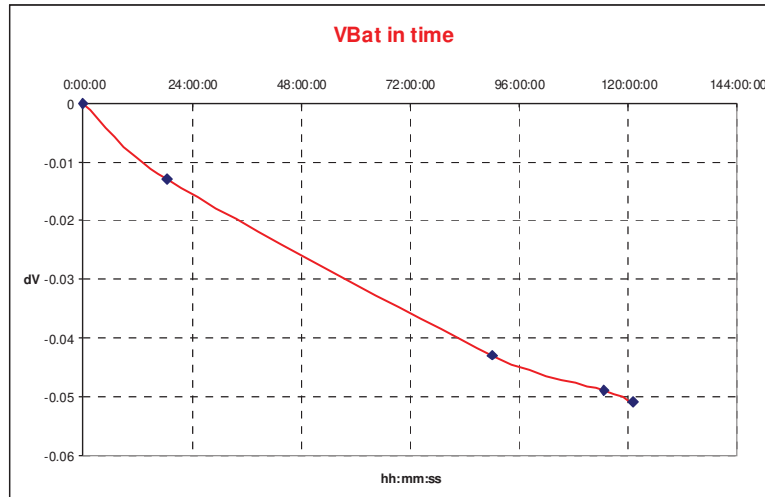
The average current consumption is about 0.41mA giving 100 days autonomy using a 1000mAh battery. This value is of course dependant on the number of access events and is deeply impacted by the consumption of the door lock mechanism. Special care should be taken for the choice of RSSI threshold (dVrssi parameter). If its value is too small, noise can make the device start inventory attempts without tags in proximity.

**Current consumption values:**

Working phase: parameters	Current [mA]	Period [ms]
both microcontroller and MLX90121 in power-down: $I_1$ and $t_1$	0.16	288
microcontroller active and MLX90121 in power-down: $I_2$ and $t_2$	4.6	1.64
wake-up phase of MLX90121 (idle mode) and microcontroller activ: $I_3$ and $t_3$	18.5	0.49
MLX90121 in transmit mode and microcontroller active: $I_4$ and $t_4$	75	0.74

As shown in the table, MLX90121 is in power-down most of the time ( $t_1 \approx 288$ ms). The transmitter is on for very short time if the RSSI signal didn't change since last loop, then the microcontroller puts MLX90121 in power-down. If the RSSI signal changed significantly MLX90121 sends the inventory commands, and is afterwards put in power-down mode ( $t_4$  increases to tens of ms). The microcontroller will continue to check the inventory results and eventually open the door-lock, or store the new codes in EEPROM.

Using four alkaline AA batteries to supply the application board DEMO90121DA with 10 actuations (ISO14443A tag cards passed through the 13.56MHz field) per day, the voltage variation looks like depicted in Figure 14.



**Figure 14** Battery voltage variation during a few days

## 12 Conclusion

The DEMO90121DA is an example of a small, cost effective, and simple control module for door access based on the Melexis 13.56MHz transceiver MLX90121. It can also be considered as an advanced starting point for developers who want to build their own system meeting their specific requirements.

The software library FW121 facilitates the software development for MLX90121 transceiver, and the programmer can use high level commands to communicate with the MLX90121. By this way, they can concentrate on the management of the microcontroller and the upper level functionality of the application.

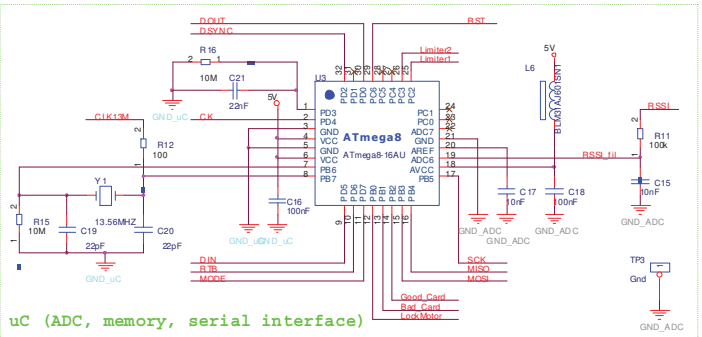
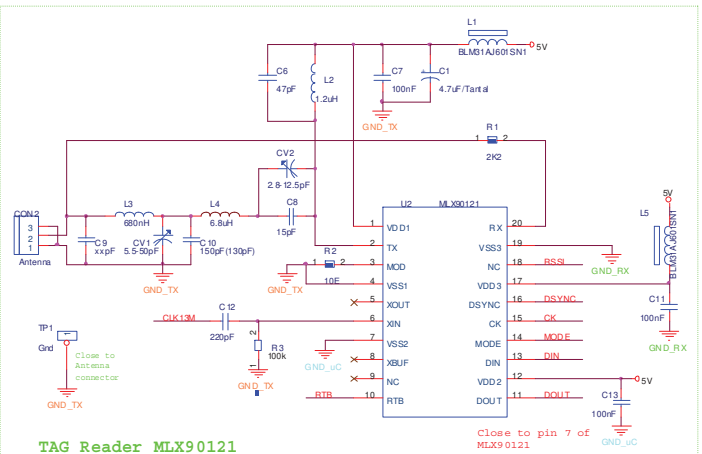
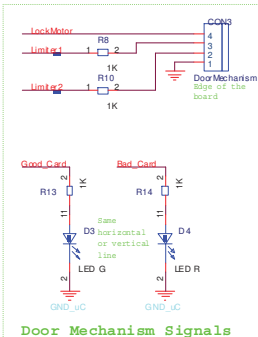
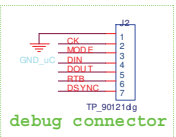
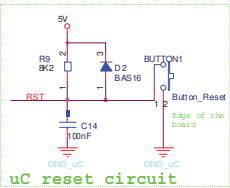
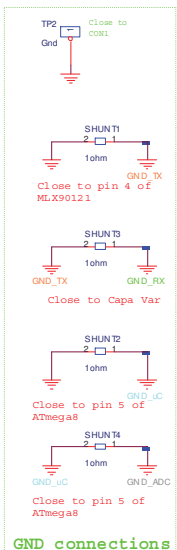
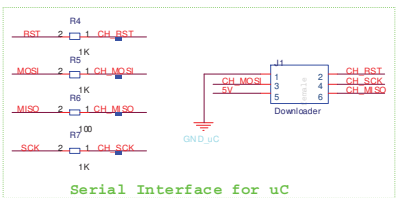
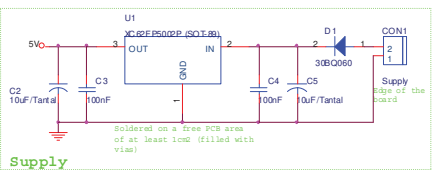
## References

source files: FW\_DA21\_14A.h, FW\_DA21\_14A.c, FW\_DA21\_14A.apc, HwDefs.h.  
schematics: See below  
Layout: See below  
MLX90121 datasheet  
ATMega8 datasheet  
FW90121: Firmware description  
13.56MHz RFID systems and antennas design guide



13 Annexes

Schematics



Thursday, August 09, 2007	Size	A3	DWG NO	MELEXIS Technologies SA	Rev	1.1
	Scale		Sheet	1	of	1

### List of components

Quantity	Reference	Part	Type of component
1	BUTTON1	Button_Reset	button
1	CON1	Supply	connector
1	CON2	Antenna	connector
1	CON3	DoorMechanism	connector
2	CV1, CV2	5.5-50pF	variable capacitor
1	C1	4.7uF/Tantal	tantalum capacitor
2	C2, C5	10uF/Tantal	tantalum capacitor
8	C3,C4,C7,C11,C13,C14,C16,C18	100nF	capacitor
1	C6	47pF	capacitor
1	C8	15pF	capacitor
1	C9*	0pF**	capacitor
1	C10	150pF(130pF)	capacitor
1	C12	220pF	capacitor
1	C15	1nF	capacitor
1	C17	10nF	capacitor
2	C20,C19	22pF	capacitor
1	C21	22nF	capacitor
1	D1	30BQ060	Schottky diode
1	D2	BAS16	low-power diode
1	D3	LED G 1,8MM	LED
1	D4	LED R 1,8MM	LED
1	J1	Downloader	connector
1	J2*	TP_90121dig	connector
3	L1,L5,L6	BLM31AJ601SN1	EMI filter
1	L2	1.2uH	inductor
1	L3	680nH	inductor
1	L4	6.8uH	inductor
1	R1	4K7**	resistor
1	R2	10**	resistor
2	R3,R11	100K	resistor
4	R4,R5,R7,R8	1K	resistor
2	R12,R6	100	resistor
1	R9	8K2	resistor
3	R10,R13,R14	1K	resistor
1	R15	10M	resistor
1	R16	10M	resistor
4	SHUNT1,SHUNT2,SHUNT3,SHUNT4	0ohm**	resistor
3	TP1,TP2,TP3	Gnd	test point
1	U1	XC62FP5002P (Torex)	voltage regulator
1	U2	MLX90121 (Melexis)	13MHz transceiver
1	U3	ATmega8-16AU (Atmel)	uC
1	Y1	13.56MHZ	quartz resonator

\* Optional component.

\*\* Value to be adjusted if necessary



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