Features and Benefits

- ❑ Output power of 1Watt
- ❑ Supports ISO15693 international standard
- ❑ RS232 communication
- ❑ 30$ BOM cost target

Application Examples

- ❑ Asset tracking
- ❑ Library's book inventory control
- ❑ Bicycle rental checkout

Ordering Information

Part No.	Description
DEMO90121LR	Long Range Demonstrator

1 Scope

The DEMO90121LR is a turnkey contactless long range reader example based on the RFID transceiver IC MLX90121. Once set up, it can inventory and access ISO15693 compliant tags and cards by sending corresponding commands.

The DEMO90121LR is connected to a computer through its RS232 serial interface. The Melexis user interface program UT121 can be used for easy and fast evaluation of the demonstrator. The form factor is minimized to demonstrate the high level of integration allowed by the MLX90121. The bill of material for DEMO90121LR targets a cost of 30$ per component set for 1000 modules.

Complete schematics, bill of material and layout are annexed to this document allowing a fast start for development work. Source code of the firmware is based on the FW90121 library and is available on the CD ROM provided with the DEMO90121LR. This device is based on ISO15693 RFID standard, maximizing the operating distance.

This document includes fast start instructions, describes the performance of the demo and explains its hardware and software. The demo and documentation are a starting point for building customized long range reader systems by adapting the functions and performance to meet specific requirements.

2 Related Melexis product

MLX90121 – 13.56MHz transceiver
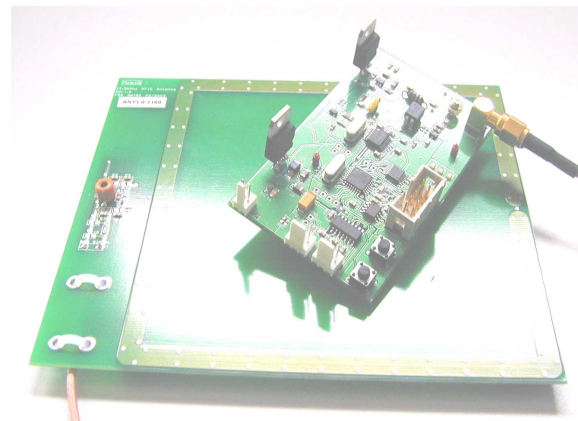
Important note: *The device is for demonstration purpose and has not been tested for compliance with FCC, ETSI or any other regulations.*

Table of Contents

3 Introduction

You purchased a DEMO90121LR. Thank you for choosing Melexis RFID solutions. This document contains the instructions to use and evaluate the functions and the performance of this demonstrator. All the necessary hardware is provided in the packaging box and the microcontroller on-board is pre-programmed with the firmware on the included CD. All that you need to do is connect the cables, start the UT121 user interface program, and then to send predefined ISO15693 commands to see the displayed answer from a compatible transponder(s) placed in front of the long range 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 under a specific agreement.

4 Box Content

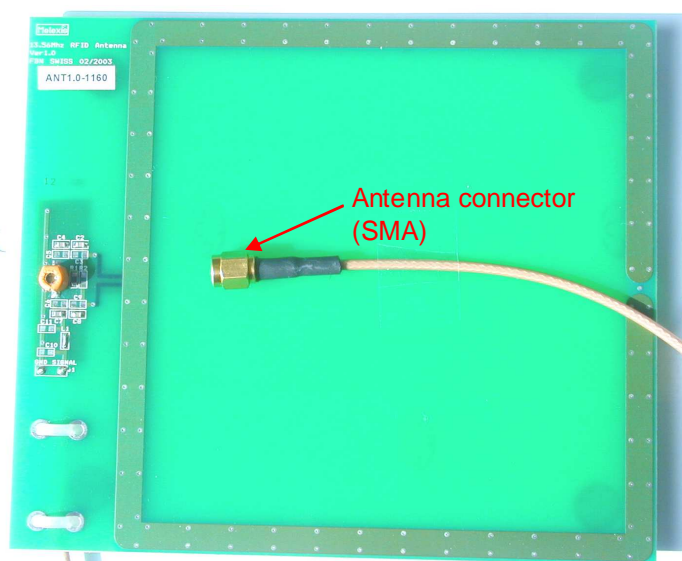You will find in the box the following components.

- 1 RFID Reader Board

Power supply connector

RS232 connector

Antenna connector (SMA)
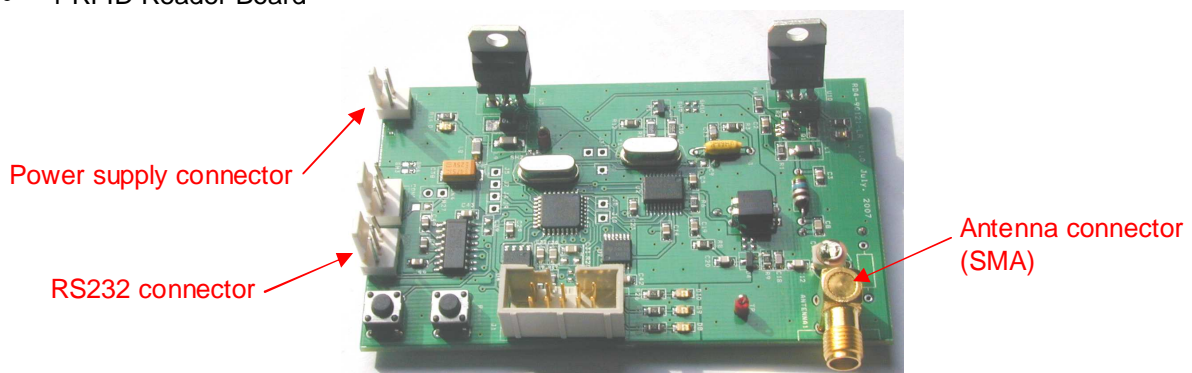
Figure 1: RFID reader board. Top side

- 1 Board antenna

Antenna connector (SMA)

Figure 2: Antenna ANT3_0
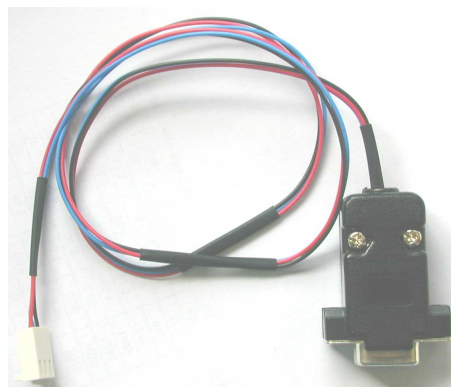
- 3 Transponder cards ISO15693

Figure 3: ISO15693 tag cards

- 1 Power supply block with adaptor

Figure 4: Power supply block

- 1 RS232 cable

Figure 5: RS232 cable

- 1 CD with the firmware and documentation
  The delivered CD contains the complete documentation of the hardware and firmware for DEMO90121LR, 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 Box Content (on paper)

5 Connections

The first step is to connect the component. Connect antenna board to the RFID reader board using the SMA connector. Then, connect the RS232 cable from the computer to the three pin connector CON3. Finally, connect the power supply block to the two pin connector CON1. The two LEDs D5 and D6 must be switched ON.

Important note: Should you want to connect you own power supply, please note that in order to avoid extra power dissipation, a maximum power supply (CON1) of **15 volts** must be applied.

6 Function and use

Once connected, the demonstrator is able to receive commands sent through the RS232 serial interface. The firmware of the DEMO90121LR handles the RFID communication, according to the ISO15693 international standard up to the level 2. Meaning that the Start Of Frame, the End Of Frame and the CRC calculation and check is supported by the firmware while, the protocol understanding has to be managed by a higher level of application software.

The communication with the long range demonstrator can be established by any RS232 terminal by configuring the following parameters:

- Data rate = 57600 BAUD
- Data bit = 8bits
- Parity = None
- Stop bits = 1
- Flow control = Hardware

For an easy and fast evaluation, the DEMO90121LR is supplied with the UT121 Melexis user interface. For more information on how to install and use the UT121, please refer to the documentation UT121 User Manual.

After starting the user interface program, one will have access to a list of predefined commands to start the communication with the demonstrator and with the ISO15693 transponders. For more information on the command format supported by the DEMO90121LR, please refer to the chapter Firmware below.

7 Observations

- The delivered output power is 1 Watt to a 50-ohm load.
- Reading range of the DEMO90121LR is about **32cm** in ISO15693 dual sub-carrier.
- The power consumption with the field ON is about **300 mA**.
- The DEMO90121LR supports the **Anti-collision procedure**. Therefore, several transponders can be put in the field and the Anti-collision command can be sent. The unique identifier (UID) of every transponder detected will be returned.

8 Hardware

8.1 General

The DEMO90121LR 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 a power booster configuration to provide up to 1Watt of output power to the 50-ohm antenna. It demodulates the tag answer using an external diode detector to reduce the power fed into the MLX90121 reception pin. The ATMega8 runs the protocol and the application software. The board has three interfaces, two for the RS232 and RS485 serial interfaces and a SPI connection for the uC programming. It includes a reset button and two linear regulators of +5 and +12V DC.

8.2 MLX90121 Power Booster

The power booster schematic is implemented according to the application note "A Power Booster for the MLX90121" included in the "MLX90121 Cookbook". For more information about the theory of operation, please refer to this document available on the Melexis WEB-site.
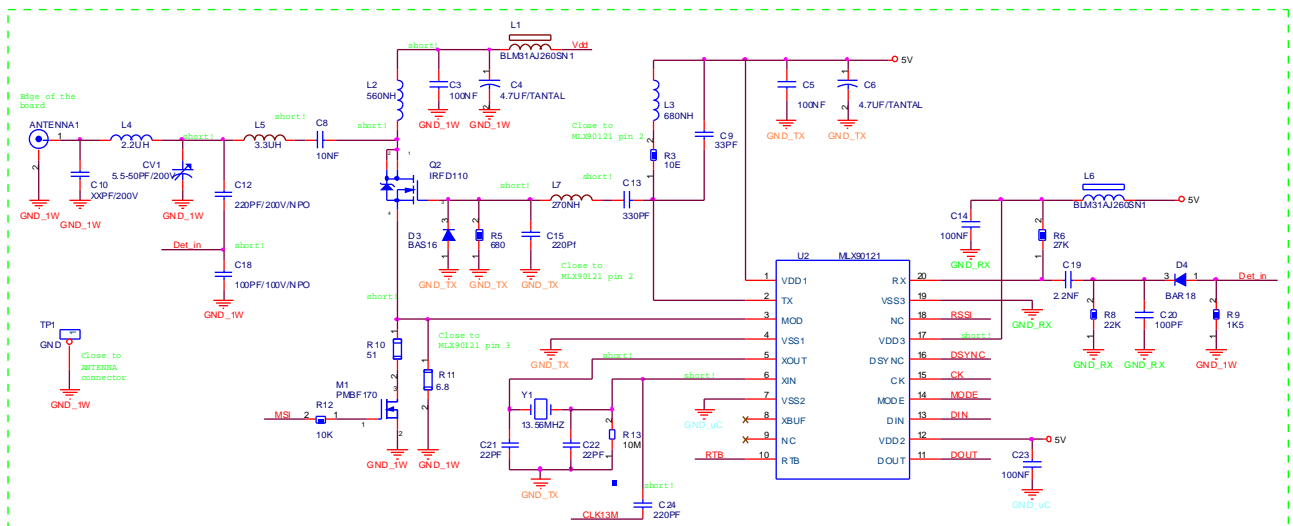

Figure 6: TAG Reader MLX90121 in power booster configuration

The output of the long range reader is matched for 50-ohm loads. In case other impedance values or more filtering are required, the capacitor C10 can be mounted to form a π filter with L4 and CV1. The output power supply Vdd is fixed to 12V by a linear regulator to provide 1 watt of output power.

The modulation depth is fixed by the resistor R11 to about 20% according to the ISO15693 specification. The resistors R10, R12 and the transistor M1 are anticipated in the layout to adjust the modulation depth on the fly by the microcontroller. This function is not used in the DEMO90121LR and these components are not mounted.

To avoid any perturbation, the MLX90121 use its own 13.56MHz signal provided by the crystal resonator Y1. This signal can be supplied by the microcontroller ATmega8 by replacing the capacitor C24 with a jumper wire. Care should be taken that the crystal oscillator has to be removed and the microcontroller has to be configured to be able to drive the clock of the MLX90121. To improve the performance of the long range reader, the external diode detector solution was chosen to receive the modulation signal from the transponder (R9, D4, C20, R8 and C19). The reception point was moved after the inductor L5 because a "notch" in the reception path was observed at the output ANTENNA1. Therefore, two capacitors C12 and C18

have been placed to provide a divide-by-three to protect the diode of the detector from high voltages, and also form a 68pF equivalent resistor which helps in the 50-ohm output matching.

8.3 Progressive Field increase

It has been observed that some RFID transponders do not operate properly when the field intensity reaches its maximum in a very short time. Consequently, a progressive field increase mechanism was implemented. For more information about the theory of operation, please refer to the application note "Progressive Field Increase for the MLX90121" in the "MLX90121 Cookbook" available on the Melexis internet site (www.melexis.com).
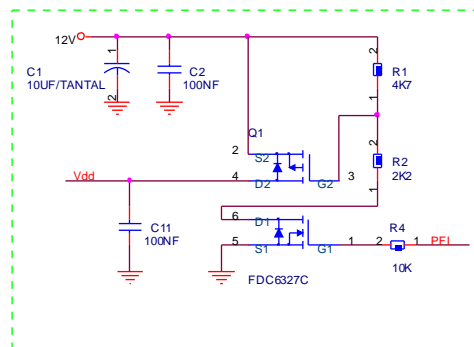

Figure 7: Soft Start PWM Drive

Important note: The Progressive field increase method is not implemented in the version 1.0 of the firmware but could be in the next revision. Please contact your Melexis representative to get the last revision of the firmware. The description of the change in the revision list of the firmware will give an indication if the function has been implemented.

8.4 Serial interfaces

The demonstrator can be externally controlled with an RS232 (CON3) or RS485 (CON2) serial interfaces. The reception signal Rx can be selected from RS232 or RS485 by firmware with the bit RS232_485.
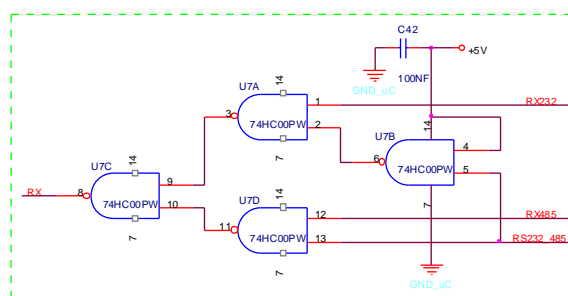

Figure 8: RS485/RS232 Rx signal switch

The RS232 allow for connecting the board to a serial COM port of a computer through the connector CON3 (T1OUT, R1IN and Ground). The voltage level is adapted using the MAX202 RS232 transceiver (U1).
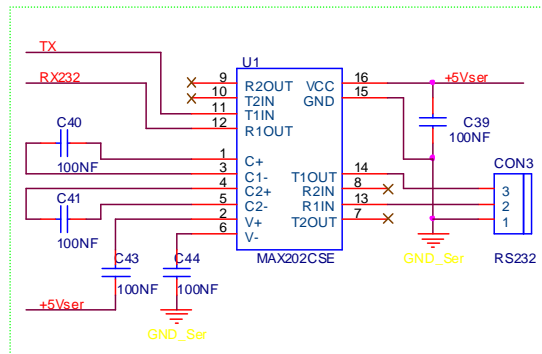
Figure 9: RS232

The RS485 is a complement to the RS232 serial connection as it allows connecting several devices on the same bus. The voltage level conversion is controlled by the LMS485 transceiver (U6). The communication is controlled by the signals 485_DE (Output driver enabled, for DATA transmission). A termination load of 120-ohms (R27) is also available to correctly match the end of the RS485 cable (Jumper CON4).
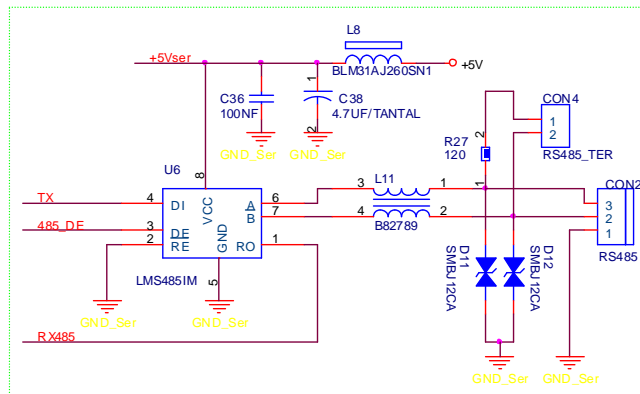

**Figure 10: RS485**

8.5 Power supplies and LEDs

The DEMO90121LR is supplied through the connector CON1. A protection diode D1 protects the board from supply inversion while a suppression diode D2 protects against over voltage. Two linear regulators have been chosen to provide clean power supplies of +12 volts for the power booster circuit and +5 volts for the MLX90121 and the microcontroller. Two LEDs are available at the output of the regulators (D5 and D6) to indicate operation of the power supplies.
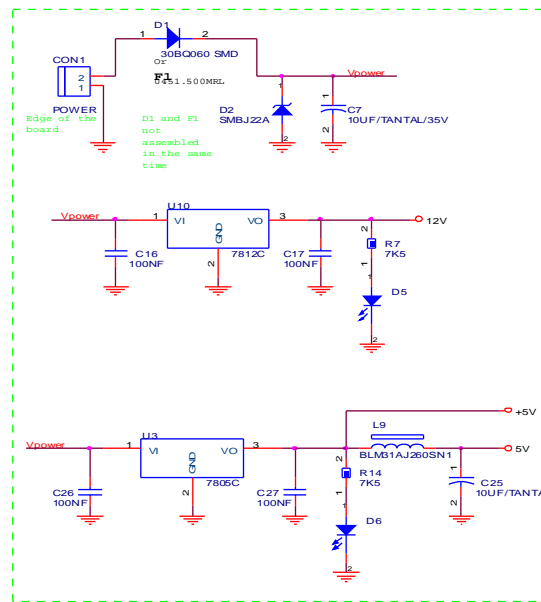
Figure 11: Power supplies

Three additional LEDs can be controlled by the firmware. In the version 1.0 of the firmware, the LEDs D8, D9 and D10 will be always switched ON.
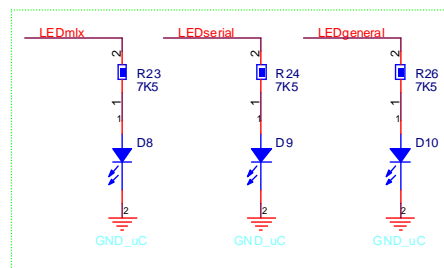
Figure 12: LEDs

8.6 SPI and Serial memory

An external serial memory of type FRAM is available to store the current UIDs of the RFID transponders inventoried in the field, in stand alone mode. It is accessed by the microcontroller through the SPI serial interface (MISO, MOSI and SCK). The FRAM has to be selected using the signal EEPROM_CS.
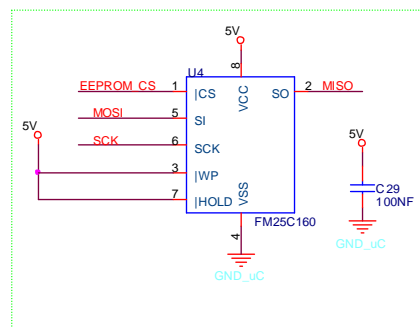
Figure 13: Serial memory

Important note: The stand alone application is not implemented in the version 1.0 of the firmware but could be in the next revision. Please contact your Melexis representative to get the latest revision of the firmware. The description of the change in the revision list of the firmware will give an indication if the function has been implemented.

The connector J1 is used to program the microcontroller with the application firmware.
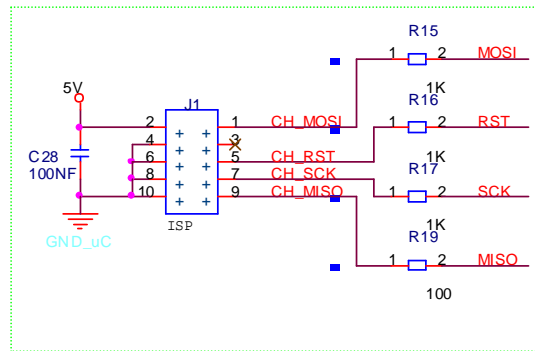
Figure 14: Microcontroller programming

8.7 External push button

The button BUTTON1 is used to perform hardware reset of the DEMO90121LR board.

Important note: The extra button BUTTON2 is not implemented in the version 1.0 of the firmware but could be in the next revision. Please contact your Melexis representative to get the latest revision of the firmware. The description of the change in the revision list of the firmware will give an indication if the function has been implemented.
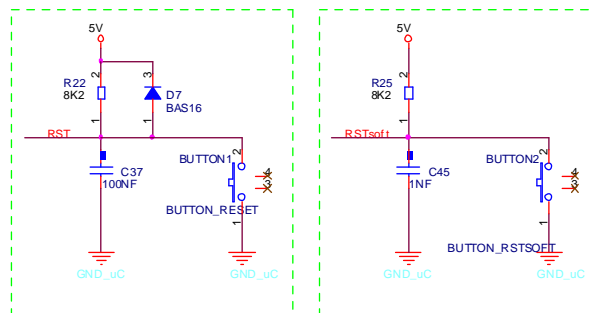
Figure 15: Push buttons

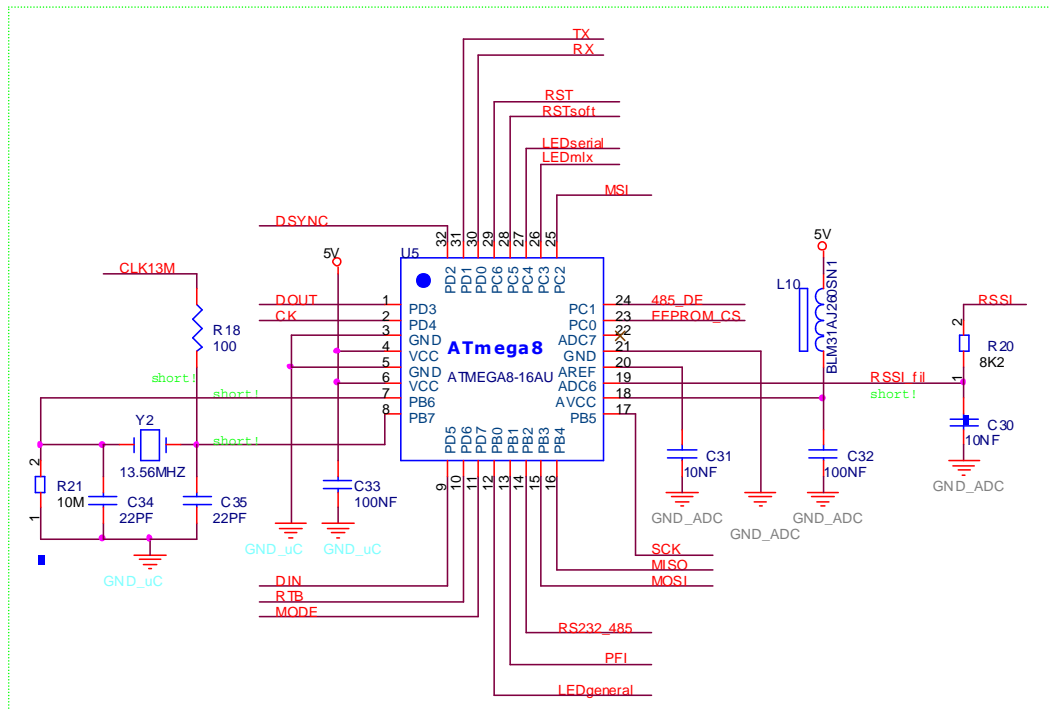## 8.8 Microcontroller ATmega8

The DEMO90121LR is controlled by an Atmel microcontroller ATmega8. It contains the firmware example written by Melexis to handle the RFID communication and the serial communication with a computer.

The microcontroller also controls the progressive field increase (PFI) block, the external FRAM through the SPI serial interface, the RS232/RS485 selection and the LEDs.

Figure 16: Microcontroller ATmega8

The microcontroller contains its own 13.56MHz crystal oscillator. When correctly programmed (fuse CKOPT has to be checked), this 13.56MHz clock generation can be used to drive the MLX90121 by short circuitng the resistor R18.

The following table shows the digital connections between the I/O of the microcontroller and the different blocks of the long range demonstrator.

MLX90121				Reset			
PD2	↔	DSYNC	Data Synchronization	PC6	↔	RST	Reset
PD3	↔	DOUT	Data OUT				
PD4	↔	CK	Clock	**Serial communication RS232/RS485**			
PD5	↔	DIN	Data IN	PB2	↔	RS232_485	RS232/485 selection
PD6	↔	RTB	Receive/Transmit	PC1	↔	485_DE	RS485 driver enable
PD7	↔	MODE	Config/Comm	PD0	↔	RX	Reception
				PD1	↔	TX	Transmission
LEDs							
PB0	↔	LEDgeneral	Not used	**External FRAM**			
PC3	↔	LEDmlx	RFID communication	PC0	↔	EEPROM_CS	Serial FRAM selection
PC4	↔	LEDserial	Serial communication				
PFI block				**SPI**			
PB1	↔	PFI	Progressive field incr.	PB3	↔	MOSI	Maste Out Slave In
				PB4	↔	MISO	Master In Slave Out
				PB5	↔	SCLK	Serial Clock

Table 1: Connections to microcontroller ATmega8

8.9 Ground plane connections

To reduce as much as possible the ground disturbances, ground connections have been split into several ground planes: GND (power supply) GND_1W (power booster), GND_TX (RFID transmission), GND_DIG (Digital), GND_Ser (Serial communication), GND_RX (RFID reception).

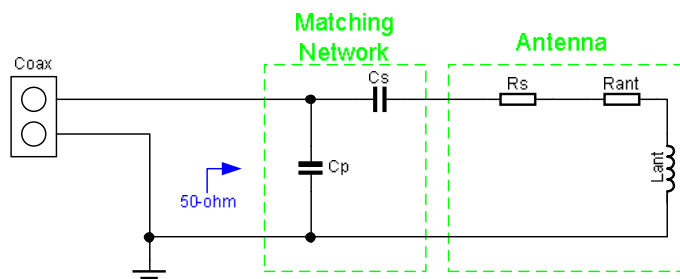These ground planes are connected to the power supply as shown in the picture below.
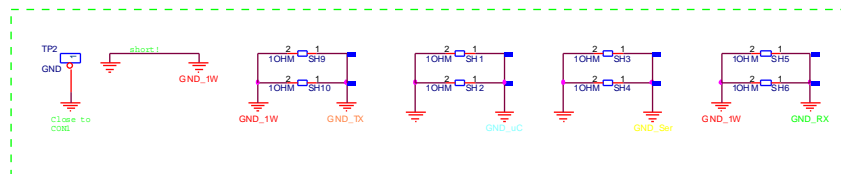
Figure 17: Ground plane connections

8.10 RFID Antenna

A 50-ohm antenna is supplied with the demonstrator. It is a loop 12x12 square antenna shielded on one side and matched to 50-ohms.

Following schematic shows the principle of the antenna:

Figure 18: Antenna principal schematic

The loop antenna is formed by an inductance Lant of 523nH and a serial resistor Rant of 290mOhm. The natural quality factor of the antenna (154 at 13.56MHz) is too big to allow a correct communication at 26kbps (ISO15693) and has to be reduced by adding the serial resistor Rs of 800mOhm.

The loop antenna is matched to 50-ohm by using two capacitors Cs and Cp. The serial one Cs is used to adjust the resonance frequency and the parallel one is used to adjust the matching on 50-ohms at 13.56MHz.

Below are the measured values of the long range antenna:

- Lant = 523nH (calculated).
- Rant = 290mOhm (calculated).
- Rs = 800mOhm.
- Cs = 270pF.
- Cp = 1nF + 220pF.
- Qant = 17 (measured)

Orcad schematics and layout of the antenna are provided in Annexes A and B.

The following serial and parallel capacitors have been calculated to provide a resistive 50-ohm load at 13.56MHz.

- Cs = 270pF
- Cp = 1nF

Remarks: The resistive element of the RFID antenna will dissipate the complete amount of power. Therefore, Rs has to be dimensioned to dissipate at least one watt. Moreover, the quality factor and the voltage swing of the capacitors which form the matching network have to be chosen as high as possible. Mica capacitors have quality factor of about 1000 and support voltage swing up to 200V.

9 Firmware

9.1 Structure

The firmware of the DEMO90121LR handles the RS232 serial communication with a computer as well as the communication with the MLX90121 RFID reader. It can be illustrated by the following flow chart.
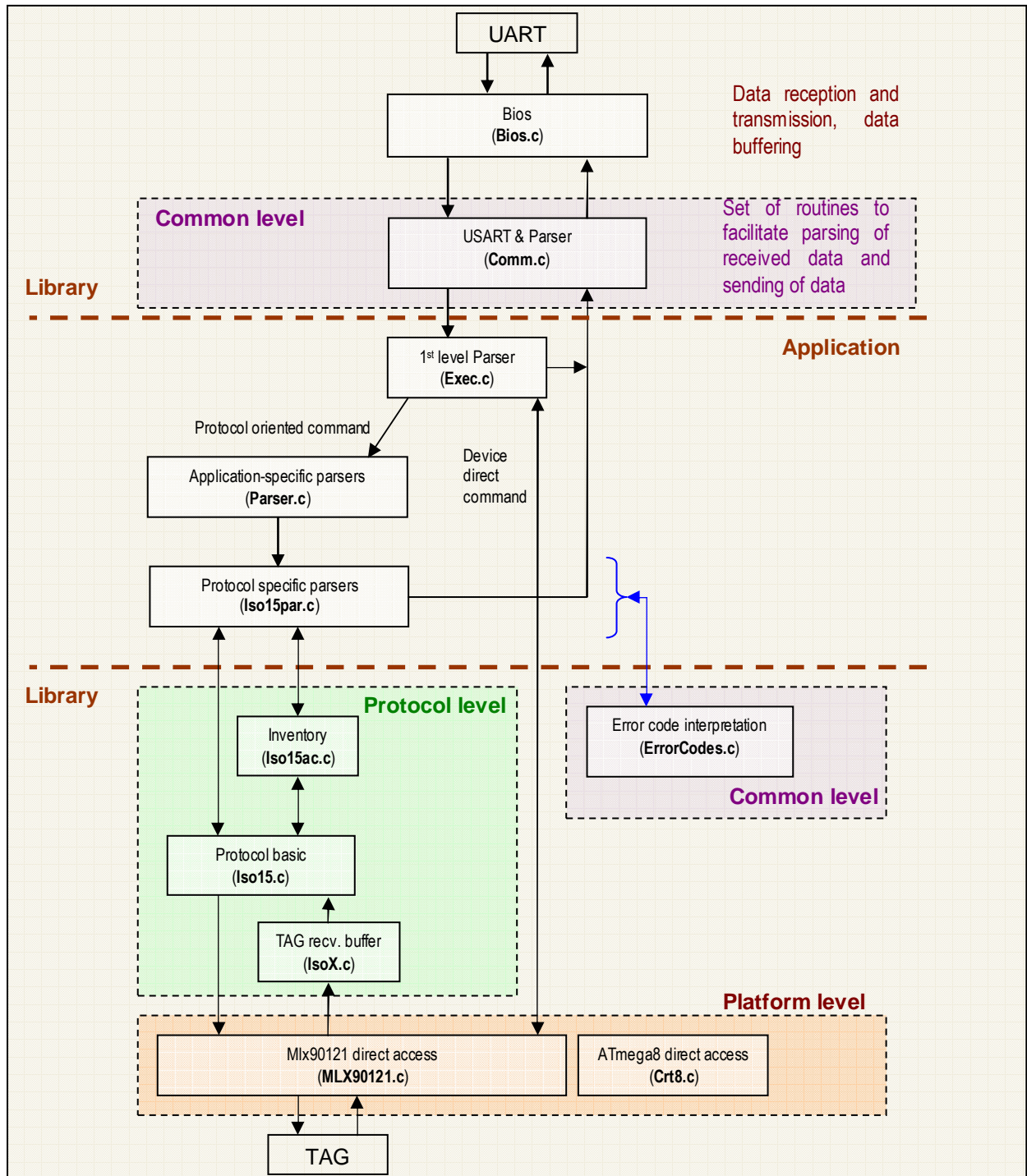
9.2 Practical information

The firmware of the DEMO90121LR is based on the FW121 library. (FW90121: Firmware description) This library provides the ISO15693 protocol functions as specific commands to control the MLX90121 and address its internal registers. At power-on or reset, the microcontroller IO ports, timers, ADC, and watch-dog, and the MLX90121 transceiver registers are configured for the ISO15693 protocol as described in the MLX90121 datasheet.

The firmware was developed using GCC under AVR Studio 4. The firmware can be loaded into 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_LR21_15.c** and **FW_LR21_15.h** contain the firmware specific gcc code and the functions' prototypes. **HwDefs.h** describes the hardware (input, output pins, etc.). The file **FW_LR21_15.aps** is the AVR Studio 4 project file.

9.3 Instruction set

The instructions sent to the DEMO90121 are composed by ASCII parameters which form the operational code (op-code) and the command parameters. Three main types of command can be sent, MLX90121 registers configuration, RFID commands and Anti-collision sequence.

MLX90121 registers configuration
The write register command starts with the op-code WrReg followed by the hexadecimal values of the MLX90121's 13 registers from register 0 to register 12.

WrReg $R_0R_0R_1R_1R_2R_2R_3R_3R_4R_4R_5R_5R_6R_6R_7R_7R_8R_8R_9R_9R_{10}R_{10}R_{11}R_{11}R_{12}R_{12}$ ↵

Identification
The identification command is used to identify the module. It has to be sent accordingly.

Idn ↵

RFID commands
The RFID commands start with the op-code Iso15 followed by a variable number of Hexadecimal parameters which form the RFID command. It has to be filled in accordance with the international standard specification ISO15693-3. The instruction is ended by several key words according to the command itself.

Iso15   ISO15693 parameters   CRC   SLOTx ↵

CRC: The firmware will automatically calculate the CRC according to the ISO15693 specification and will incorporate it into the command sent to the transponder.

SLOTx: Define the number of slots used during an Inventory or Write command. X must be between 1 and 16.

Anti-collision sequence
The firmware will execute a complete anti-collision sequence as defined in the ISO15693-3 specification. All the detected UIDs will be returned. The anti-collision command will not select any transponder.

Iso15   Inventory   DS ↵

DS: Specified only when using dual sub-carrier protocol. With single sub-carrier, DS has to be removed.

10 Conclusion

The DEMO90121LR is an example of a small, cost effective, and simple control module for long range applications, 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 customized system meeting their specific requirements.

The software library FW121 facilitates software development for the 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.
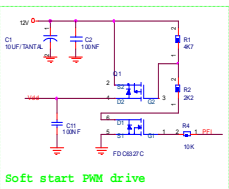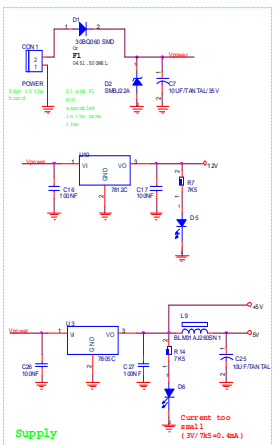
References

- source files: FW_LR21_15.h, FW_LR21_15.c, FW_LR21_15.aps, Bios.c, Exec.c, Parser.c, Iso15Par.c, HwDefs.h.
- schematics: See below
- Layout: See below
- MLX90121 datasheet
- ATMega8 datasheet
- FW90121: Firmware description
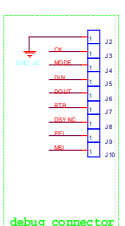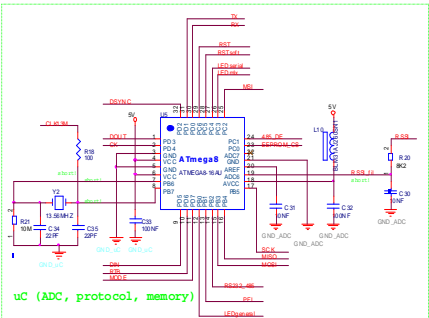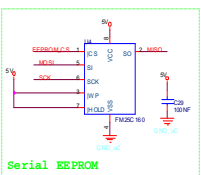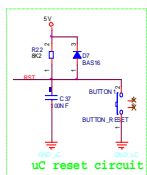- 13.56MHz RFID systems and antennas design guide

Microelectronic Integrated Systems

11 Annexes

11.1 Schematics

DEMO90121LR:

DEMO90121LR

RFID Long Range Demo Demo User Manual

TAG Reader MLX90121

Soft start PWM drive

Supply

Current too small
(3V/ 7k5 =0. 4mA)

uC (ADC, protocol, memory)

RS232

RS485/RS232_RX Signal_Switch

Serial Interface

RS485

debug connector

Serial EEPROM

uC reset circuit

Soft reset circuit

ISP Interface for uC

LEDs

GND connections
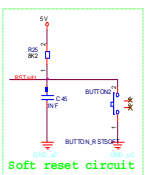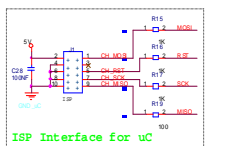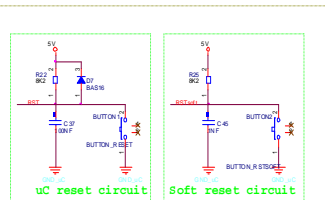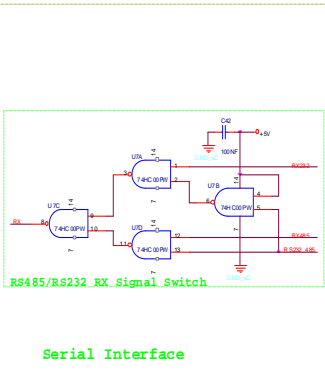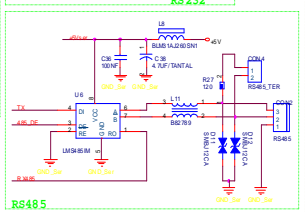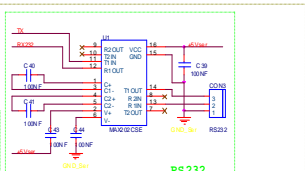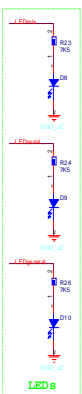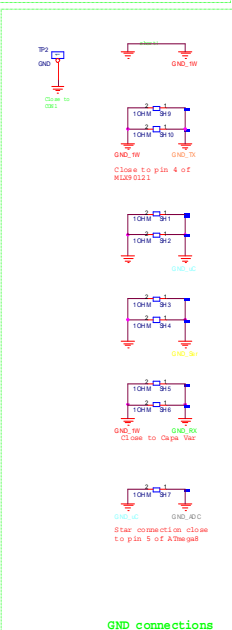
Size A2	CAGE Code	DWG NO		Rev
	MELEXIS Technologies SA	RD 49012 1 V1.0LR: 13.56MHz 1W Tag Reader		1.0
Wednesday, September 12, 2007	Scale		Sheet 1 of 1	

RFID ANTENNA:

Melexis
Microelectronic Integrated Systems

DEMO90121LR
RFID Long Range Demo Demo User Manual

CV2
5-50pF

C8
1   2
CAP

C7
1   2
CAP

C6
1   2
CAP

Rs3 R

Rs2 R

C5
1   2
CAP

Rs1 R

Signal

J1

2

1

Coax

C1
1
CAP
2

C2
1
CAP
2

C3
1
CAP
2

C4
1
CAP
2

CV1
5-50pF

GND

Copper
antenna
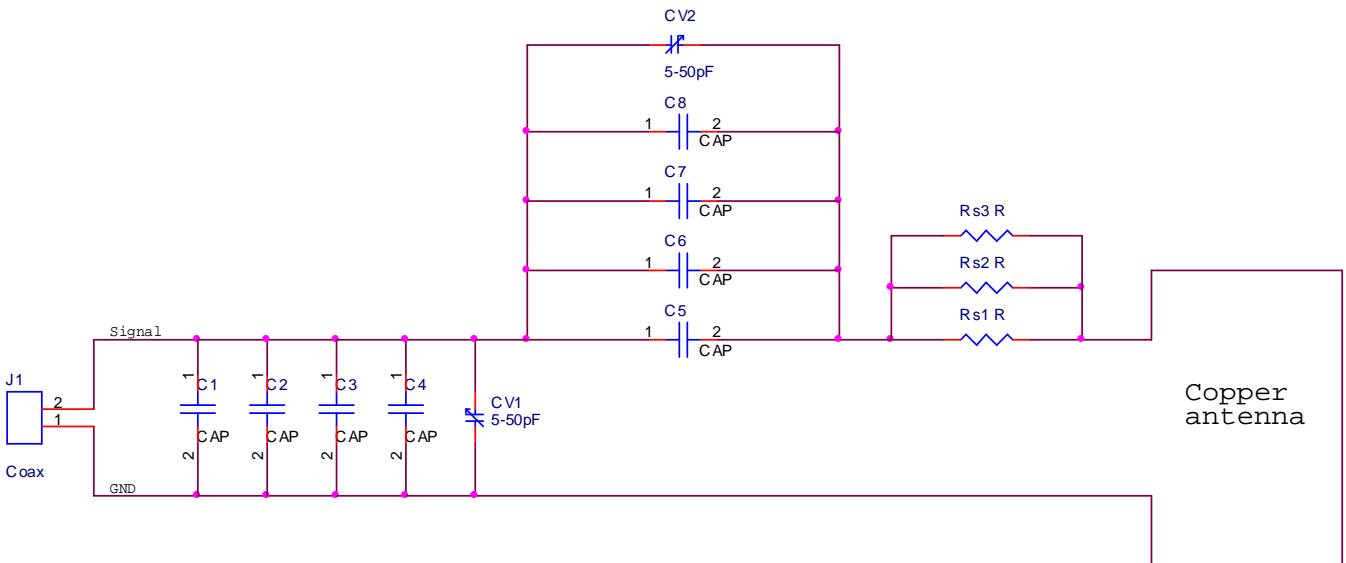
Title		
	13.56Mhz RFID_antenna	
Size A	Document Number <Doc>	Rev 2
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11.2 List of components

DEMO90121LR:

Quantity	Reference	Value	Description
1	ANTENNA1	SMA	Antenna connector
1	BUTTON1	Reset	Push button
1	BUTTON2	RSTsoft	Push button
1	CON1	Power supply	Connector
1	CON2	RS485	Connector
1	CON3	RS232	Connector
1	J1	ISP Connector	Connector
1	CV1	5.5-50pF	Trimming capacitor
2	C1,C25	10uF	Tantalum capacitor
3	C4,C6,C38	4.7uF	Tantalum capacitor
1	C7	10uF	Tantalum capacitor
22	C2,C3,C5,C11,C14 C16,C17,C23,C26,C27 C28,C29,C32,C33,C36 C37,C39*,C40,C41,C42 C43,C44	100nF	Ceramic X7R capacitor
3	C8,C30,C31	10nF	Ceramic X7R capacitor
1	C19	2.2nF	Ceramic X7R capacitor
1	C45	1nF	Ceramic X7R capacitor
1	C9*	33pF	Ceramic NPO capacitor
1	C10*	xxpF/200V	Ceramic NPO capacitor
2	C12,C20	100pF	Ceramic NPO capacitor
1	C13	330pF	Ceramic NPO capacitor
2	C15, C18	220pF	Ceramic NPO capacitor
4	C21,C22,C34,C35	22pF	Ceramic NPO capacitor
1	C24*	220pF	Ceramic NPO capacitor
1	D1	30BQ060	Schottky diode
1	D4	BAR18	Schottky diode
1	D2	SMBJ22A	Suppression diode
2	D11,D12	SMBJ12CA	Suppression diode
2	D3,D7	BAS16	Commutation diode
2	D5,D6	Red LED	???
3	D8,D9,D10	Yellow LED	QTLP630C-Y
1	F1*	0451.500MRL	Fuse
9	J2*,J3*,J4*,J5*,J6*,J7*,J8* J9*,J10*	PIN_HEADER_SIL1	Test pin
2	TP1,TP2	Gnd	Ground connection
5	L1,L6,L8,L9,L10	BLM31AJ260SN1	EMI filter inductor
1	L2	560nH	Matching coil
1	L3	680nH	Matching coil
1	L4	2.2uH	Matching coil
1	L5	3.3uH	Matching coil
1	L7	0.27uH	Matching coil
1	M1*	PMBF170	10% modulation transistor

1	Q1	FDC6327C	Soft start PWM transistor
1	Q2	IRFD110	Power booster transistor
1	R1	4K7	Thick film resistor 0805
1	R2	2K2	Thick film resistor 0805
1	R3	10E	Thick film resistor 0805
2	R12*,R4	10K	Thick film resistor 0805
1	R5	680	Thick film resistor 0805
1	R6	27K	Thick film resistor 0805
5	R7,R14,R23,R24,R26	7K5	Thick film resistor 0805
1	R8	22K	Thick film resistor 0805
1	R9	1K5	Thick film resistor 0805
1	R10*	5,6	Thick film resistor 1206
1	R11	6,8	Thick film resistor 1206
1	R13*,R21*	10M	Thick film resistor 0805
3	R15,R16,R17	1K	Thick film resistor 0805
2	R18*,R19	100	Thick film resistor 0805
3	R20*,R22,R25	8K2	Thick film resistor 0805
1	R27*	120	Thick film resistor 0805
10	SH1,SH2,SH3,SH4 SH5,SH6,SH7,SH8 SH9,SH10	1ohm	Ground plane shunt
1	U1	MAX202CSE	RS232 transceiver
1	U2	MLX90121	RFID transceiver
1	U3	7805C	+5V regulator TO220
1	U8	7812C	+12V regulator TO220
1	U4	FM25C160	Serial FRAM
1	U5	ATmega8-16AU	Microcontroller
1	U6	LMS485IM	RS485 transceiver
1	U7	74HC00PW	4 NAND logical circuit
2	Y1,Y2	13.56MHZ	Quartz resonator

RFID ANTENNA:

Quantity	Reference	Value	Description
1	C1	1nF	Mica capacitor
1	C2	220pF	Mica capacitor
1	C3*,C4*	-	Mica capacitor
1	CV1*	5-50pF	Trimer capacitor
1	C5	270pF	Mica capacitor
1	CV1	5-50pF	Trimer capacitor
1	C6*,C7*,C8*	-	Mica capacitor
3	Rs1,Rs2,Rs3	2.4-ohm	Thick film resistor 1210

*These components are not mounted.

Microelectronic Integrated Systems

DEMO90121LR
RFID Long Range Demo User Manual

11.3 Layout

DEMO90121LR:

TOP

BOTTOM

RFID ANTENNA: