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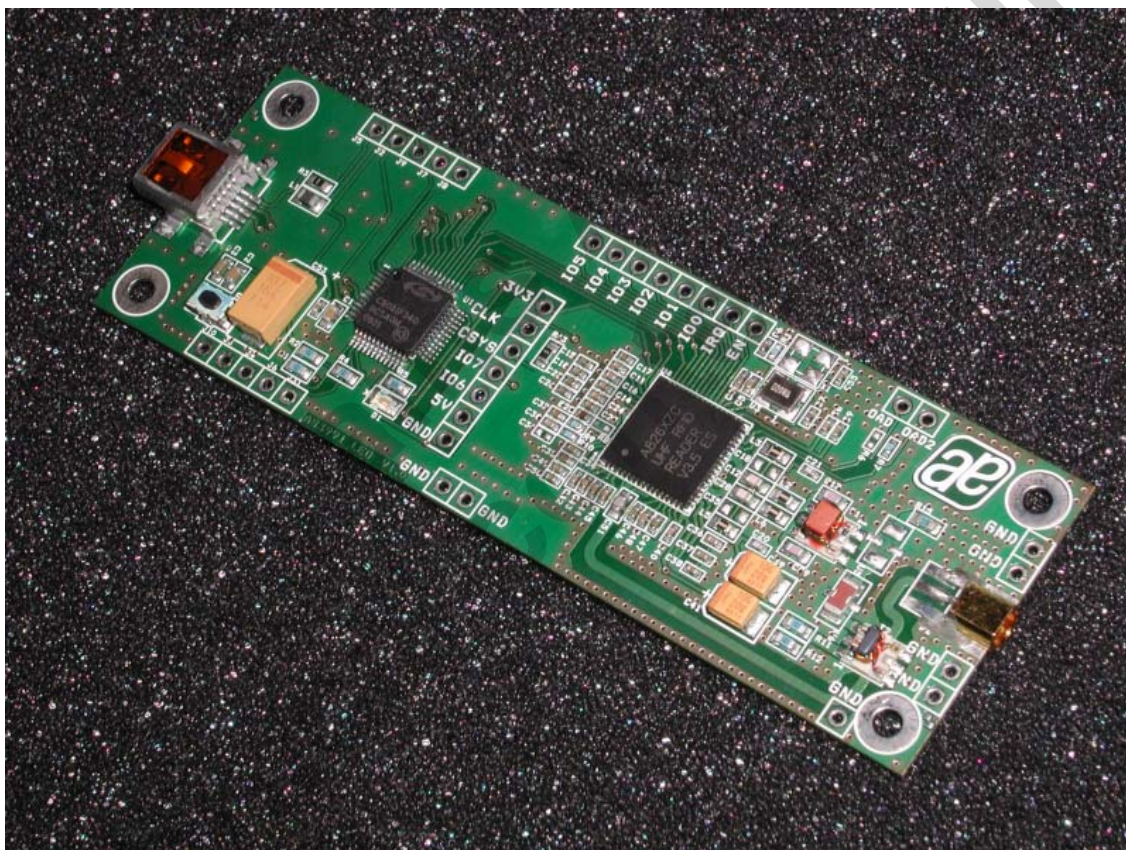
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Hardware Description of AS399x “LEO” - UHF RFID Reader System



Demo Kit Reference
Rev 0.3 Feb 2010

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1 Introduction

The AS399x UHF RFID Reader System Demo Kit supports the **ISO 18000-6b** and **EPC Generation 2** standards. The aim of the development kit is to demonstrate the performance and the features of the AS399x UHF RFID reader chip and to enable customers to develop their own application fast.

The AS399x UHF RFID Reader System is a single PCB solution offering two configurations:

- A UHF RFID reader stand alone operation aided by the on board microcontroller
- A direct access operation for development purposes with disabled MCU where the host system directly controls the AS399x using a pin header interface. The operational RF part can be used to develop customized software for controlling the AS399x. An access to the IO pins for an external microcontroller is provided to speed up the design phase of an UHF RFID reader application.

1.1 Key Features

- Reading and writing UHF RFID tags
- Communication with host computer using the USB interface
- USB HID device (automatically installed on host side)
- Low cost 8-bit micro controller is used
- Controller software written in C which can easily ported to a different controller type.
- Host software (AS399x Reader Suite) written in C++ and MFC
- Only 300mA current consumption needed provided by standard USB ports.
- USB powered device

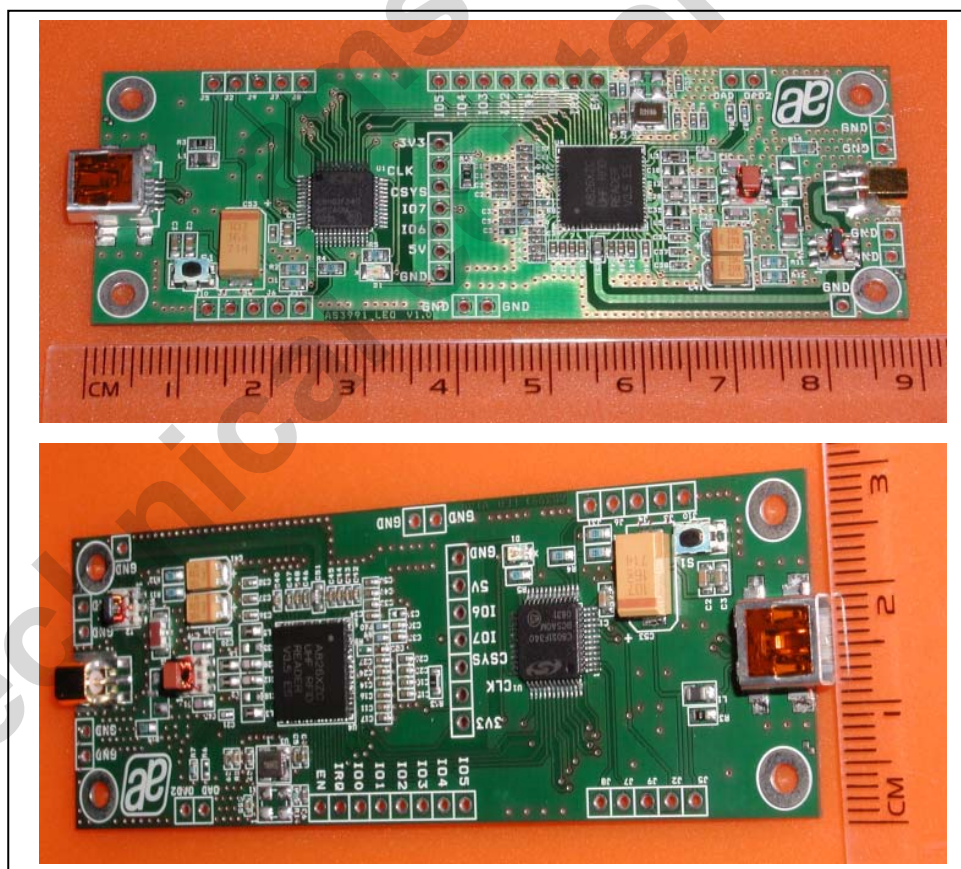
2 Short Description

The “LEO” UHF RFID Reader System is designed for short range tag detection and is optimized regarding PCB area and power consumption. In order to minimize PCB size no display or buttons (except Reset button) are used. To minimize costs no special RF connectors are required. The connection to the antenna is established by a MMCX connector.

For powering up the UHF RFID Reader System and for the communication with the host system the USB interface is used. After power up the internal registers of the reader chip are configured with default values which enables the reader system to be functional right from the beginning.

3 Hardware

For the RF communication with the tags the AS399x UHF RFID reader chip is used and a Silabs C8051F340 serves as controller. A description of the API can be found in the application note “AN399x LEO API Description”.



Picture 1: Dimensions of PCB

3.1 Port Definitions

3.1.1 Detailed Description

Pin	Signal	Description
P0.0	-	Not used
P0.1	-	Not used
P0.2	-	Not used
P0.3	IRQ	External Interrupt Input
P0.4	TX	UART Transmit Pin
P0.5	RX	UART Receive Pin
P0.6	-	Not used
P0.7	SCLK	System Clock Input

Table 1: Port 0

Pin	Signal	Description
P1.0	IO0	IO Data, Address and Ctrl Bit
P1.1	IO1	IO Data, Address and Ctrl Bit
P1.2	IO2	IO Data, Address and Ctrl Bit
P1.3	IO3	IO Data, Address and Ctrl Bit
P1.4	IO4	IO Data, Address and Ctrl Bit
P1.5	IO5	IO Data, Address and Ctrl Bit
P1.6	IO6	IO Data, Address and Ctrl Bit
P1.7	IO7	IO Data, Address and Ctrl Bit

Table 2: Port 1

Pin	Signal	Description
P2.0	CLK	Interface CLK Output
P2.1	EN	Device Enable Output
P2.2	LED	LED Output
P2.3	-	Not used
P2.4	-	Not used
P2.5	-	Not used
P2.6	-	Not used
P2.7	-	Not used

Table 3: Port 2

Note: Port 3 is not used.

Pin	Signal	Description
P4.0	-	Not used
P4.1	-	Not used
P4.2	-	Not used
P4.3	-	Not used
P4.4	-	Not used
P4.5	-	Not used
P4.6	-	Not used
P4.7	RESET	Output for resetting the MCU

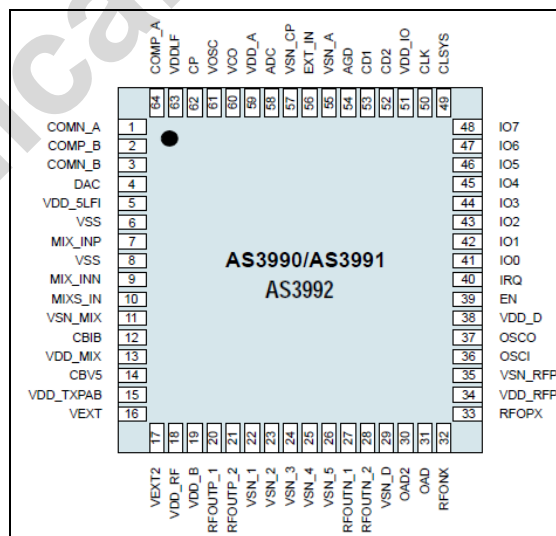
Table 4: Port 4

Pin	Signal	Description
7	GND	GND Pin
8	D+	USB Data + Signal
9	D-	USB Data - Signal
10	VDD	VDD Pin
11	REGIN	Not used
12	VBUS	USB Power In
13	RST	Reset Pin
14	C2D	Debugging Interface

Table 5: Other uC Pins

3.2 AS399X Pinout:

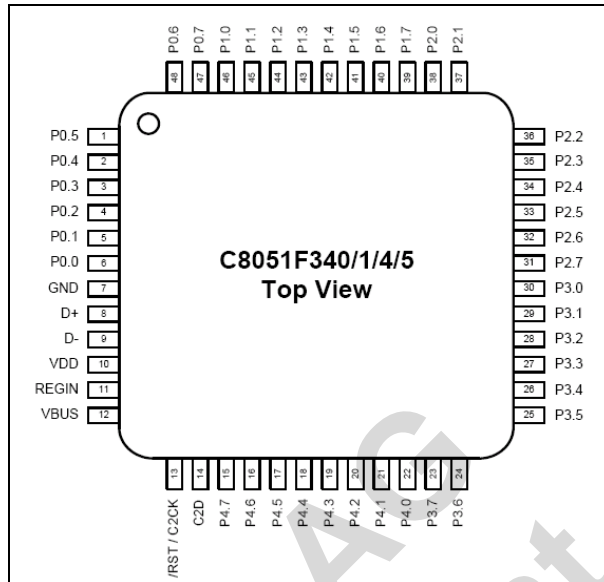
Pinout of AS399x



Picture 2: AS399x Pinout

3.3 C8051F340 Pin out

The pinout from Silabs microcontroller C8051F340 is shown below.



Picture 3: C8051F340 Pin out [Silabs 2006]

3.4 Power Connector

No separate power connector is needed. Power is supplied through the USB connector.

3.5 USB Connector

USB is used for communication with the host and power supply. No external matching and pull down resistors are needed, since all parts are integrated in the microcontroller.

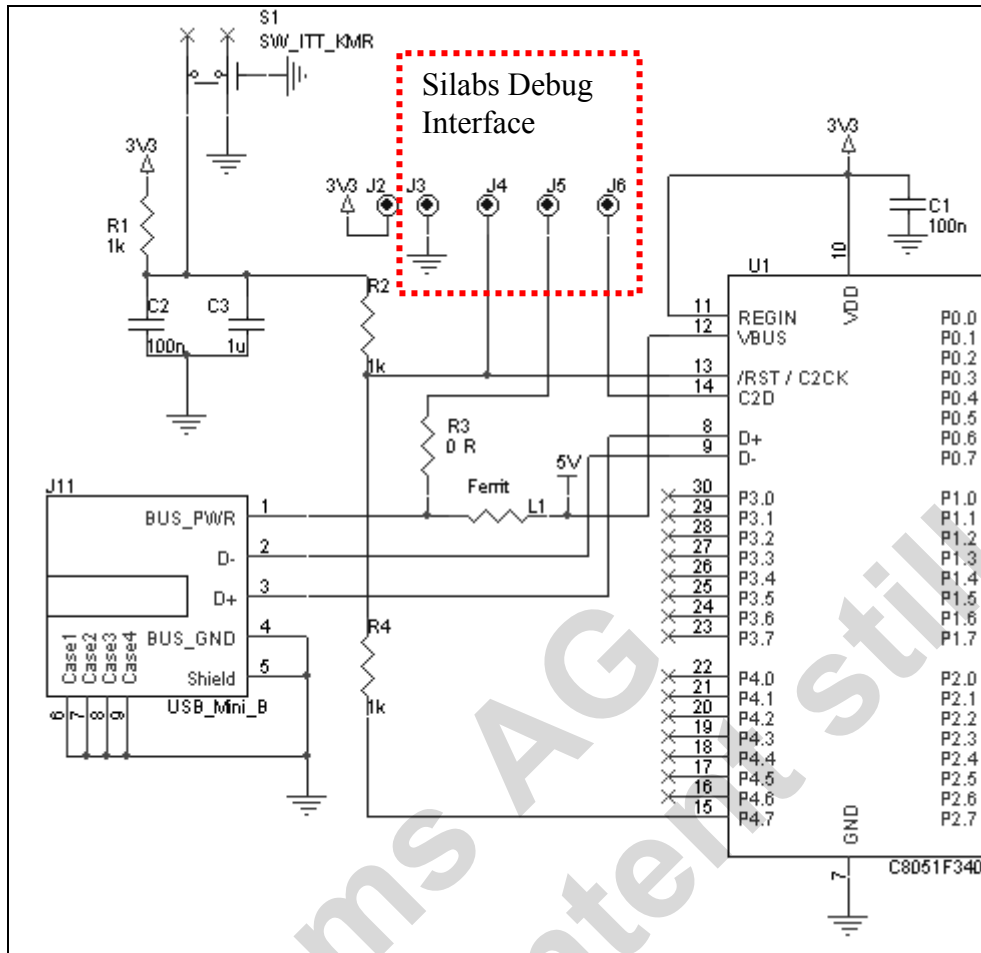
3.6 RS232 Connector

For debugging, the controller board has solder pads to connect an external RS232 circuit. Power for the external circuit is delivered through the connector.

3.7 Debugging Connector

In the following picture a special interface is highlighted which is used to directly connect the Silabs USB Debug Adapter. The circuit is taken from the Silabs Development Kit data sheet [SilabsDK 2006].

The resistor R3 can be used to supply the board via the debugging connector.



Picture 4: Schematic - Debug Interface

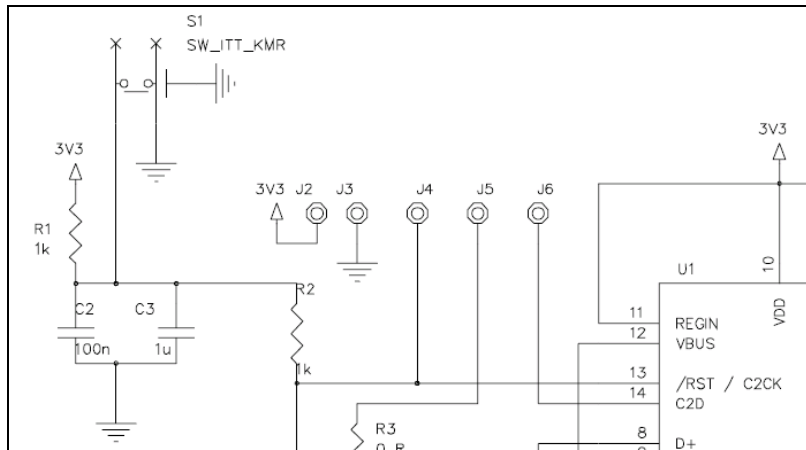
3.8 Supply Concept

To filter out noise on the USB supply voltage a ferrite ($L1$) and two capacitors ($C52$, $C53$) are used. Additionally, each AS399X V_{DD} pin is featured with two capacitors (10 nF & 2.2 μ F). The microcontroller supply V_{DD} (pin 10) only needs one 100nF capacitor ($C1$).

During power down mode the majority of the AS399x reader chip is switched off but still generates a 3.3V supply voltage (V_{DD_D} = pin 38) which supplies the microcontroller unit (MCU). This mode is configured by the resistor $R7$ (10k Ω) at $OAD2$ (pin 30) to GND. After start up the microcontroller has to pull the AS399X enable pin (EN = pin 39) to high in order to start the operation of the AS399X finalizing the power up sequence.

3.9 Microcontroller Reset Circuit

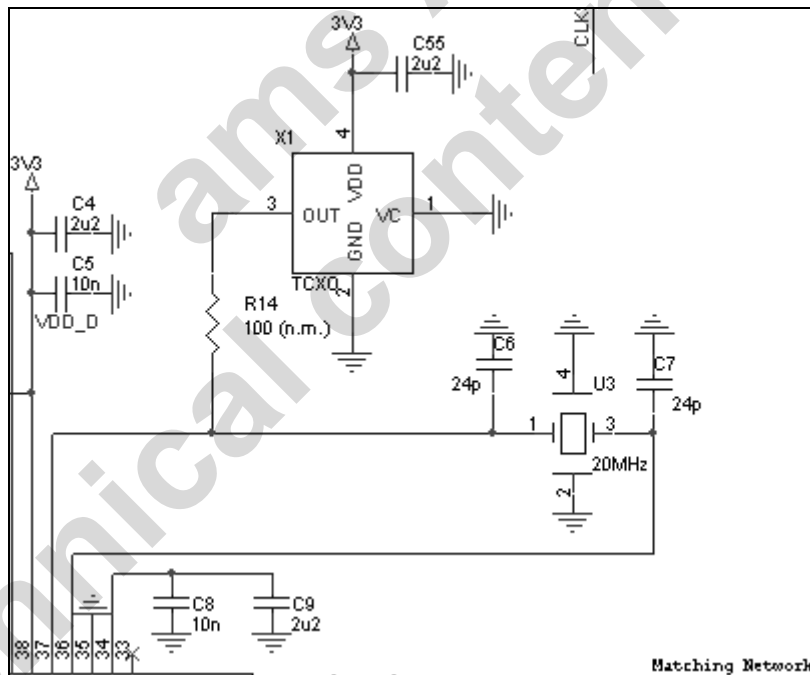
The reset circuit needs only two capacitors ($C2$, $C3$) for power on reset. A pull-up resistor ($R1$), a series resistor ($R2$) and a push button ($S1$) for resetting during normal operation is used (see Picture 5). To enable a reset trough the software, resistor $R4$ is connected between port pin $P4.7$ and the reset pin ($/RST$ = pin 13). If the microcontroller needs to be reset, the software has to write a logic zero to $P4.7$.



Picture 5: Reset Circuit

3.10 Oscillator Circuit

The AS399X can be used with a conventional quartz crystal or a TCXO. The crystal should have an accuracy of 10ppm. Most crystals do not provide this high accuracy for this reason a TCXO is recommended. Besides good frequency stability a TCXO inherently provides better temperature stability.



Picture 6: Schematic - Oscillator Circuit

3.11 VCO Concept.

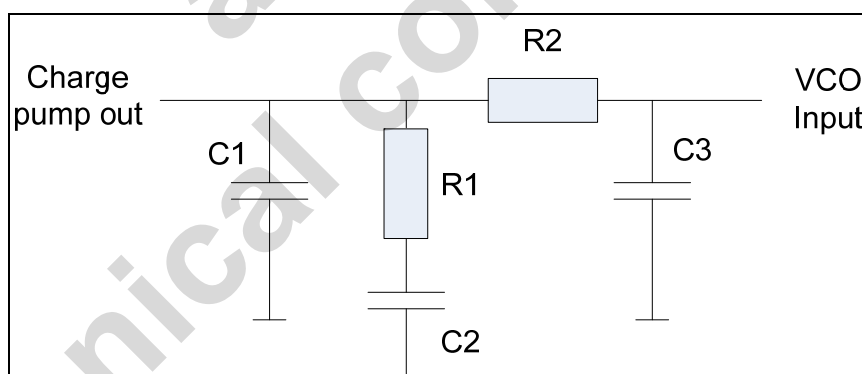
To generate the high frequency carrier signal for the communication with the tag (840 MHz – 960 MHz) the internal VCO is used and thus only a few passive components are needed. The external loop filter components need to be calculated for each parameter set of loop filter current, reference frequency and charge pump current. For this particular reference design following settings were used:

- 915 MHz
- 1.2 mA charge pump current
- 50 kHz reference frequency
- Internal VCO

In following table, one can also find other settings for reference:

VCO	Reference Frequency [kHz]	Charge Pump Current [mA]	C1 [pF]	R1 [kΩ]	C2 [nF]	R2 [kΩ]	C3 [pF]
20 MHz / V	50	1.2	220	27	3.3	56	110
20 MHz / V	50	0.6	120	56	1.5	110	56
20 MHz / V	100	1.2	150	27	1.8	47	68

Table 6: Loop Filter Reference Settings



Picture 7: Loop Filter Circuit

3.12 LED

For an easy and fast functional check, an external LED with a current limitation resistor is included. During normal operation, the LED is continuously flashing.

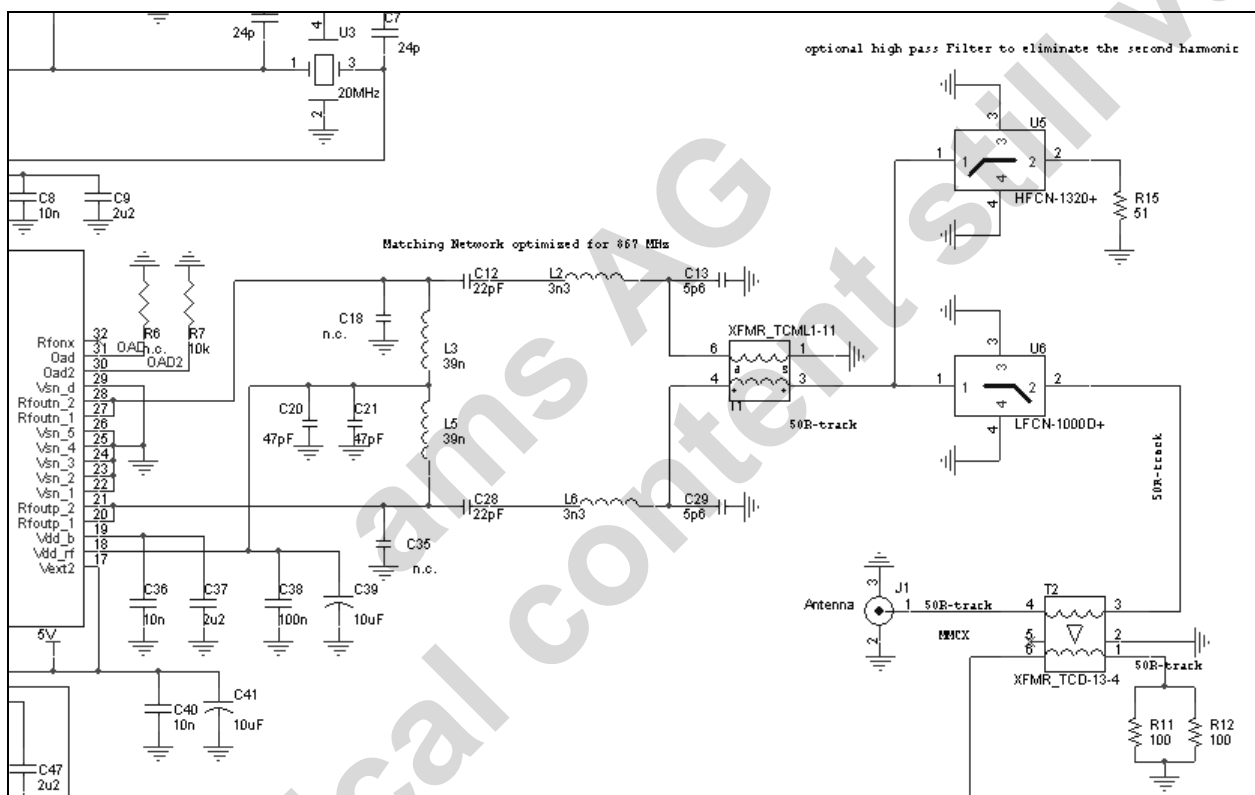
3.13 Serial RS232 Interface

For debugging an external RS232 interface may be used.

3.14 High Frequency RFID Output

The 20 dBm main differential outputs are used. The differential outputs need to be converted to single-ended outputs. This is done by a Balun (Balanced/ Unbalanced) *XFMR_TCML1-11* from Mini-Circuits®.

The low pass filter (*U6*) is used to filter out second and higher order harmonics generated by the PA and the high pass filter (*U5*) can be used to shortcut the second harmonic. This high pass filter is optional.



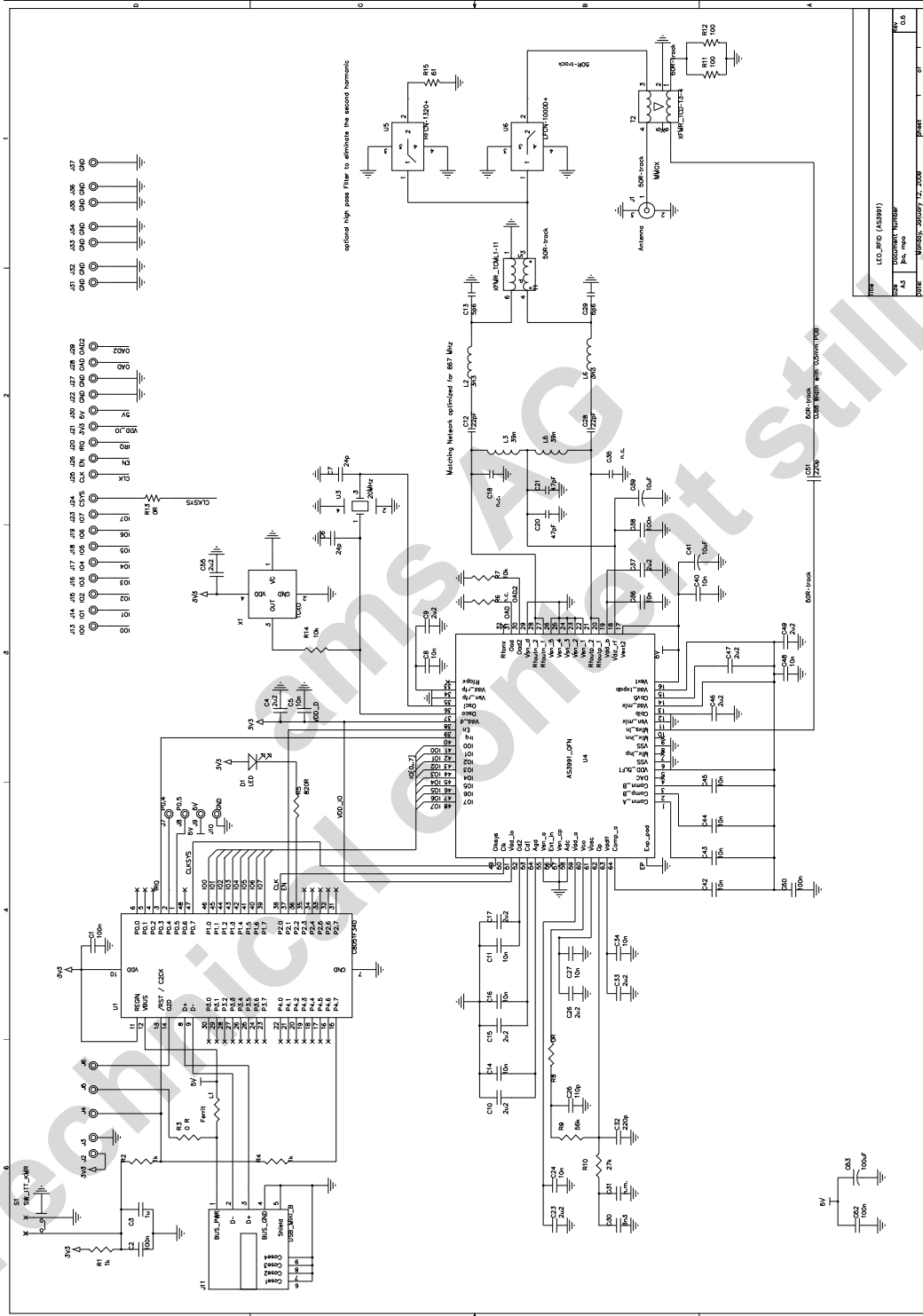
Picture 8: Schematic - HF RFID Output Path

3.15 Decoupling Tx/Rx

To separate transmit and receive path a directional coupler is used. Between the power amplifier and directional coupler respectively between the directional coupler and the input pin (*Mixs_in*) in the receive path, π - networks may be inserted. These networks are used for matching but are normally not required.

4 Hardware Description UHF board

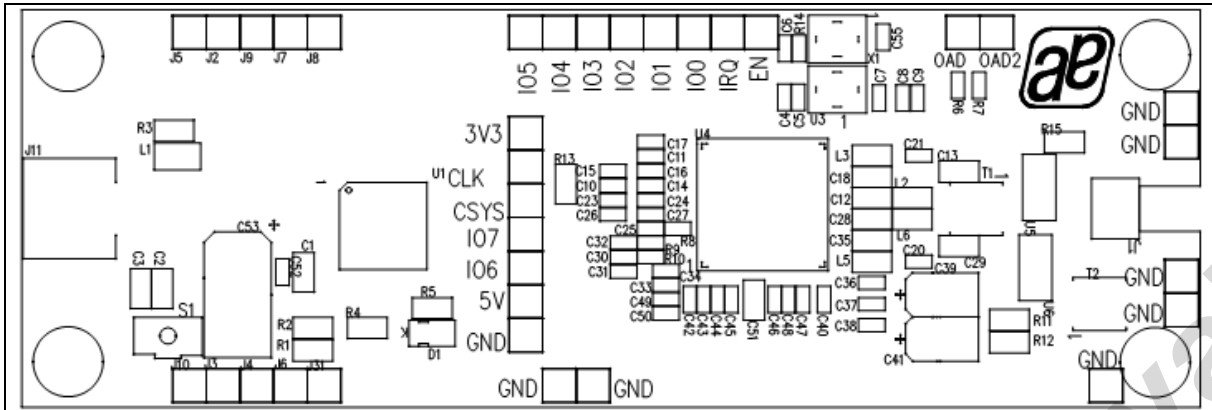
4.1 LEO- Schematic



Picture 9: LEO Schematic

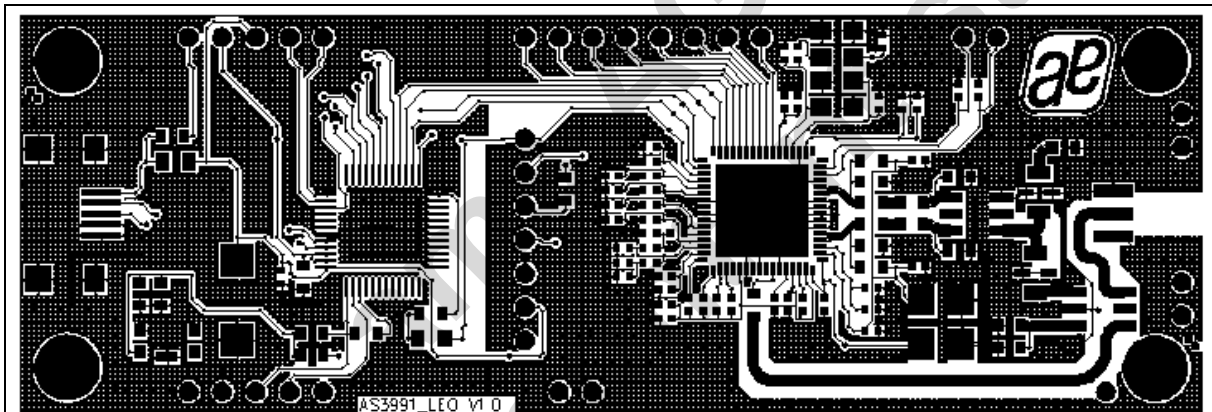
Note that the component values in the schematic may have been changed. Please review the current BOM for the latest status.

4.2 Top mounted



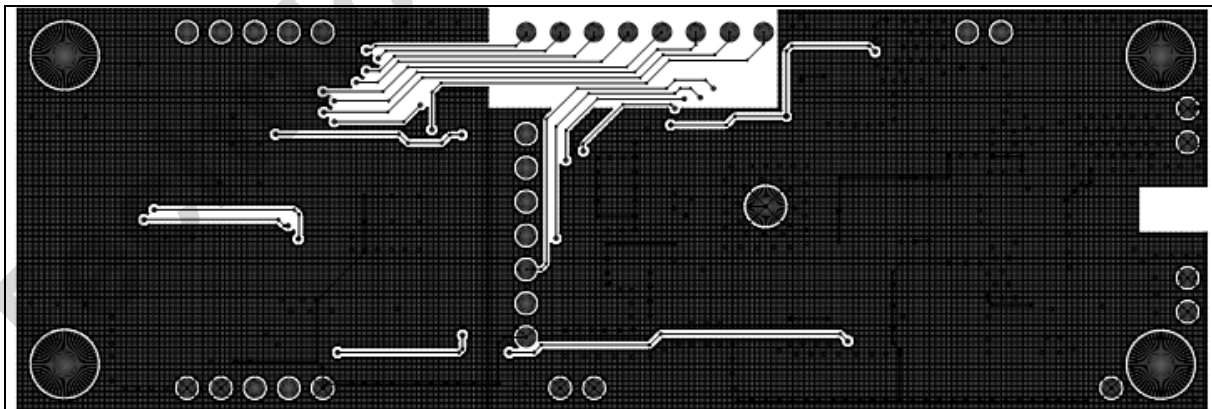
Picture 10: Assembly Top

4.3 Top layer



Picture 11: Top Layer

4.4 Bottom layer



Picture 12: Bottom Layer

4.5 Bill of Material

Part Info	Reference	Footprint	ordering information
Integrated Circuits (IC)			
AS3991	U4	QFN 64 9x9	AS3991-BQFT
C8051F340	U1	TQFP 48	Digikey: 336-1298-ND
Other semiconductors			
LED	D1	0805	Digikey/160-1423-1-ND
SMD resistor			
1k	R1, R2, R4	0603	Schukat / RL0603K001-1
0R	R8	0402	Digikey/541-1.00LCT-ND
0R	R3, R13	0603	Schukat/ RL0603E000
820R	R5	0603	Schukat/ RL0603E820-1
10k	R7, R14	0402	Digikey/541-10.0k LCT-ND
27k	R10	0402	Digikey/541-6.80k LCT-ND
100R	R11, R12	0603	Schukat/ RL0603E100-1
51	R15	0603	Digikey/541-51.0 HCT-ND
56k	R9	0402	Digikey/541-15.0k LCT-ND
SMD capacitors			
100n	C1, C2	0603	DigiKey/ PCC2277CT-ND
100n	C38, C50, C52	0402	DigiKey/ PCC2146CT-ND
110p	C25,	0402	DigiKey/ PCC1718CT-ND
100u	C53	SMD-D	Schukat/CTUF100U10D
10n	C5,C8,C11,C14,C16;c24,C27,C34,C36, C40,C42,C43,C44,C45,C48	0402	DigiKey/ PCC103BQCT-ND
10u	C39,C41	SMD-B	Schukat/CTUF010U20B
18p	C12, C28	0603	DigiKey/
1u	C3	0603	DigiKey/ PCC2174CT-ND
2u2	C4, C9, C10,C15, C17, C23,C26, C33, C37,C46,C47,C49,C55	0402	DigiKey/ PCC2421CT-ND
220p	C51	0603	DigiKey/ 490-1435-1-ND
3n3	C30	0402	DigiKey/ PCC1700CT-ND
24p	C6, C7	0402	DigiKey/ 490-3219-1-ND
4p7	C13,C29	0603	DigiKey/
47p	C20,C21	0402	DigiKey/ PCC470CQCT-ND
220p	C32,	0402	DigiKey/ 490-1303-1-ND
SMD inductor			
3n3	L2, L6	0603	0 Würth 744 786 03
39n	L3, L5	0603	0 Würth 744 902 139
TCML1-11	T1	TCML1-11	Municom
LFCN-100D	U6	1206	Municom Digikey: 712-1120-1-ND
Ferrite	L1	0805	Farnell: 1515663
Ferrite	L1	TCD-13-4	Municom
Mechanical components			
20 MHZ crystal TSX-3225	U3	3.2x2.5	KDS- TSX-3225
Switch	S1	SMD Type	Farnell: 1201424
USB Connector	J11		Buerklin:72F2280
MMCX Connector	J1		Samtec:MMCX-J-P-H-ST-EM1

5 Printed Circuit Board Instructions

Name	AS3990 UHF Board
Dimensions	90 x 30 mm
Edges	milled
PCB Material	FR4 Dielectric DE117
PCB Thickness	0.51 mm
Layer Count	2

5.1 Attached files for PCB Production

Format Gerber RS274x / Excellon

Gerber files

Top Side layer: Layer 01	AS3990_UHF_READER_PRINTER-17.top
Bottom Side Layer: Layer 04	AS3990_UHF_READER_PRINTER-17.bot
Solder stop top	AS3990_UHF_READER_PRINTER-17.smt
Solder stop bottom	AS3990_UHF_READER_PRINTER-17.smb
Silk screen top	AS3990_UHF_READER_PRINTER-17.sst

Drill files

Thruhole Data for drills und holes

PCB Layer Properties

Material	Thickness [µm]	Layer	Layer Name	Comments
Copper Plated	36 (43 final thickness)		*.top	Top side Layer 1
Pre Preg	500			DE117 Dielectric constant 4,7
Copper Plated	36 (43 final thickness)		*.bot	Bottom side Layer 4

Table 7: PCB Layer Properties

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