Active Tag Manual

AS3933 + AS3940 Active Tag

125 kHz LF Receiver + 2.4 GHz Transceiver

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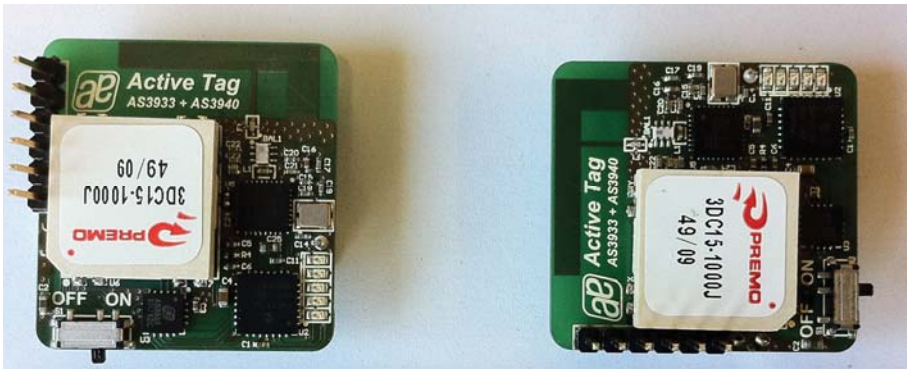


Table of Content

Features

- Fully operational active RFID tag reference design utilizing the industries highest sensitivity LF Wake-up Receiver and 2.4GHz Low Power FSK Transceiver with integrated link manager
- Small Size: 30x31x10mm
- Long Battery life with CR2032 3V coin cell (based on polling requirements)
- Up to 100 Tags per second
- Long, 10 meter max. range capability
- Direct storage of the TAG ID in the OTP memory (no external memory required)
- Power Supply: 3V coin cell CR2032
- ID Number: 24 bit
- Group address: 16 bit (Device Number for various application classification)
- High resistance to false system wake-up using 32-bit custom programmable pattern

LF Wakeup Receiver AS3933 Key features

- 1,2 or 3 channel ASK Wake-up Receiver
- 125kHz operation
- Very low standby current: 2.7µA
- 3D Antenna for orientation independent wakeup
- Best in class, highest sensitivity (80µVrms)
- 16 or 32 Correlation bits
- Received Signal Strength Indicator (RSSI)
- Best in class, Automatic Antenna Tuning

UHF Transceiver AS3940 Key features

- 2.4 GHz operation
- Frequency Range: 2.405 to 2.480 GHz
- 2Mbps Data Rate enabling very low power consumption
- Programmable Data Rate: 250/1000/2000Kbps
- Small 2.4GHz PCB Antenna
- Integrated Link Manager for easy SW development, fast time to market, low BOM and less MCU workload
- Max range: 100m at 2Mbps and 0dBm output power
- Programmable output power between -24dBm to 0dBm
- POR, battery level detector and digital RSSI
- Adaptive channel switching
- Excellent sensitivity and selectivity

Applications

- Real-Time locating systems (RTLS)
- Active RFID tags
- Container Tracking
- Body area networks
- Wireless sensor networks
- High value asset tracking
- Passive Keyless Entry (PKE)
- Security ID badges (operator, access control)
- Remote sensing and monitoring

System Description

The active RFID reference design is developed to help customers to reduce their time to market by demonstrating the high performance and high integration capabilities of our RF products.
The design utilizes the high performance AS3933 LF Wake-up Receiver and also the AS3940 2.4GHz FSK transceiver. The AS3933 and its best in class sensitivity, automatic antenna tuning and low power capabilities make it the lowest power LF Wake-up receiver in the industry.
This coupled with the high performing AS3940 2.4GHz FSK Transceiver with its high sensitivity, selectivity, integrated link manager, adaptive channel switching capabilities and low power capabilities ensure high performance. Along with the high performance and low power capabilities, the reference design demonstrates the high level of integration within each IC that allow for a smaller form factor and ultimately a lower Bill of Materials.
The Active RFID system is made up by a base station (interrogator) and the active TAG:

Base Station

The base station primary task is to transmit the LF wakeup pattern and the base station ID. Once done the base station collect RSSI information from the answering tags and communicates it to the PC. The base station consists of a LF wakeup transmitter, an AS3940 as 2.4GHz transceiver and a microcontroller, as shown in figure2-1. The Base station is supplied by the USB connection and in order to maximize the range a Power Management IC (PM) is used to increase the voltage for the LF antenna. A low power microcontroller (MCU) takes over the control of the LF and UHF protocol. The LF transmitter is based on a discrete transistor circuitry, which modulates the LF pattern over the antenna (KGEA). The UHF part is implemented via the AS3940 with its matching network (MN) and the PCB antenna. LED's indicate the status of the Base station.

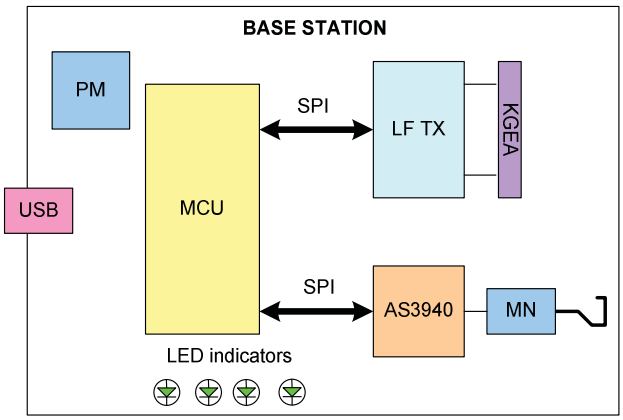
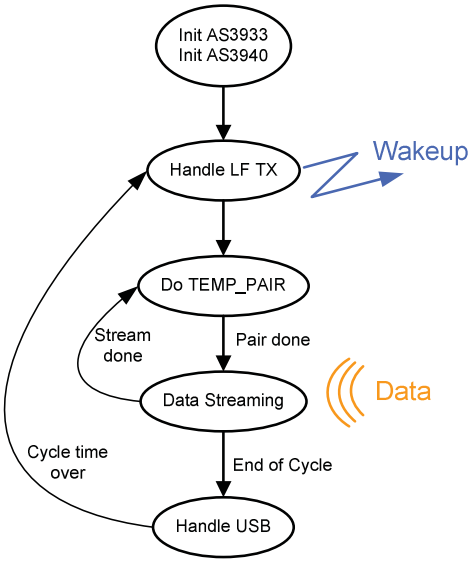


Figure 0-1: Base Station block diagram

The base station is working as the following:

1. The MCU is initializing the AS3933 and the AS3940 with the updated register settings.
2. The base station performs the LF wakeup signal via the discrete transistor circuitry.
3. After the LF transmission the MCU switch on the 2.4GHz Transceiver into receive mode, awaiting some tags to respond. First the Tag needs to be temporary paired to the base station.
4. Once the pairing is done, one streaming data packet is expected. ID, RSSI is transmitted via this streaming packet.
5. If the pairing is not done, the base station you should do another DO_TEMP_PAIR command after 219ms (timeout).
6. As soon as the streaming is over the base station switch back to receive mode, awaiting the next TAG to respond.
7. Before one cycle time is over, the GUI is updated via the USB interface.
8. At the end of the cycle time, the procedure starts from the beginning with the wakeup LF transmission.



Active Tag

The Tag consists of an AS3933 (LF wakeup receiver) and an AS3940 (UHF Transceiver), as shown in the Figure 2-2. Both devices are controlled by a microcontroller. The choice of the MCU of the TAG is driven by low current consumption. As the mutual orientation between the base station and the Tag is not fix, the AS3933 has to rely on a 3D antenna system. Therefore 3 LF coils will be used, which are combined in one package. The tag is supplied via the CR2032 coin cell. The UHF part is implemented via the AS3940 with its matching network (MN) and the PCB antenna. LED's indicate the status of the Base station.

When the base station sends a wakeup signal to the tags, the AS3933 wakes up the MCU from sleep mode. Furthermore the AS3933 hands over the RSSI, which represents the distance of tag to the base station. The MCU turns on the AS3940 and establishes the 2.4GHz RF link to the base station to send back the RSSI value and the Tag ID.

In order to reduce the BOM the AS3933 uses the internal RC-oscillator and the calibration will be performed with the external antennas (RC_calib_LC). The AS3940 will need an external crystal of 16MHz to be connected for its RF functionality and for the standby and the sleep modes.

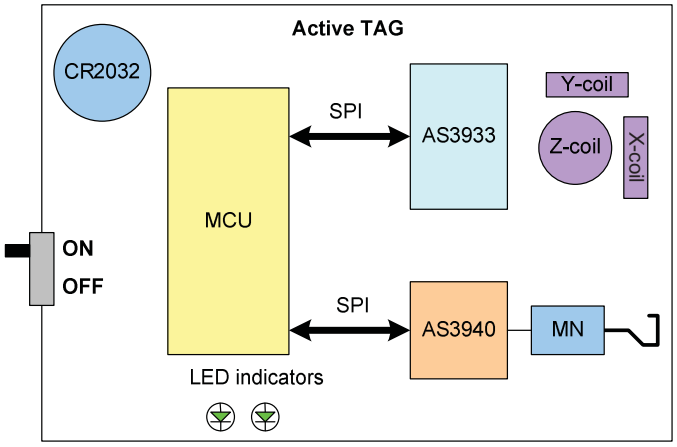
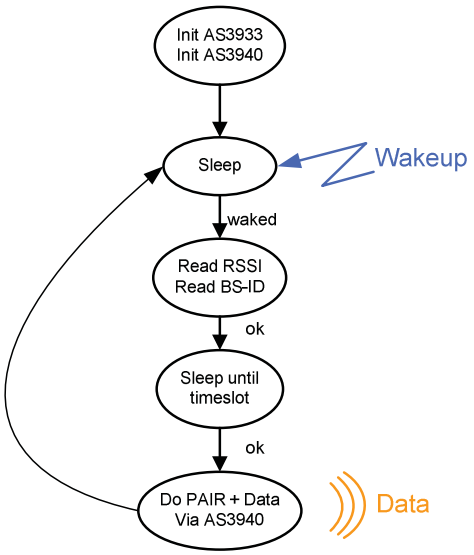


Figure 0-2: TAG block diagram

The tag is working as the following:

1. The MCU is initializing the AS3933 and the AS3940. The RC oscillator of the AS3933 is calibrated and the 3D antenna is automatically tuned. After that the tag is brought in sleep mode, sensing for a LF wakeup signal.
2. Once a wakeup signal is received and corresponds to the correct 32 bit wakeup pattern, the external interrupt brings the MCU out of the sleep mode. The MCU reads the RSSI and the base station ID which comes along with the LF signal.
3. Depending on the tag ID a certain timeslot is reserved for the pairing and data transmission via UHF. Until that the tag is set into sleep again.
4. During the reserved timeslot (10ms) the tag establishes the 2.4GHz connection doing pairing and streaming one data packet.
5. At the end the tag goes into sleep mode (LF receive mode) again.



Active Tag HW Description

Board Description

Figure 1: Active Tag Description Top

Figure 2: Active Tag Description Bottom

Active Tag Description

Label	Name	Info
A	**ON/OFF**	Power on/off the Demoboard.
B	**LF 3D Antenna**	125kHz 3-dimensional antenna
C	**UHF PCB Antenna**	2.4GHz Inverted-F antenna
D	**AS3940**	2.4GHz Transceiver
E	**AS3933**	125kHz Wakeup Receiver
F	**CR2032 BATTERY**	Insert CR2032 in here.
G	**MCU**	Microcontroller PIC24FJ16GA002

Indication LEDs

LEDs	Blinking Colour	Info
F	Red LEDs RSSI (5 bits)	Received Signal Strength Indication. Displays the actual received signal strength whenever a WAKEUP occurs.

Base Station HW Description

Board Description

Figure 3: Basestation Description Top

Base Station Description

Label	Name	Description	Info
A	**USB – Connector**	Mini USB 5-pin Connector	USB Interface for the GUI
B	**AS1340**	DC-DC Step-up Converter	Power Management
C	**LF Transmitter**	Discrete Transistor Circuit	125kHz transmitter sends Wakeup Pattern
D	**LF Antenna**		125kHz antenna
E	**Microcontroller**		PIC24FJ64GB002
G	**AS3940**		2.4GHz Low Power Transceiver
H	**UHF Antenna**		2.4GHz PCB Antenna

Indication LED's

LEDs	Blinking Colour	Info
STANDBY	Red LED	Basestation is on standby. No Wakeup Pattern is send.
LF Tx	Orange LED	Wakeup Pattern is transmitted.
UHF Rx	Green LED	Active Tag UHF signal is received.

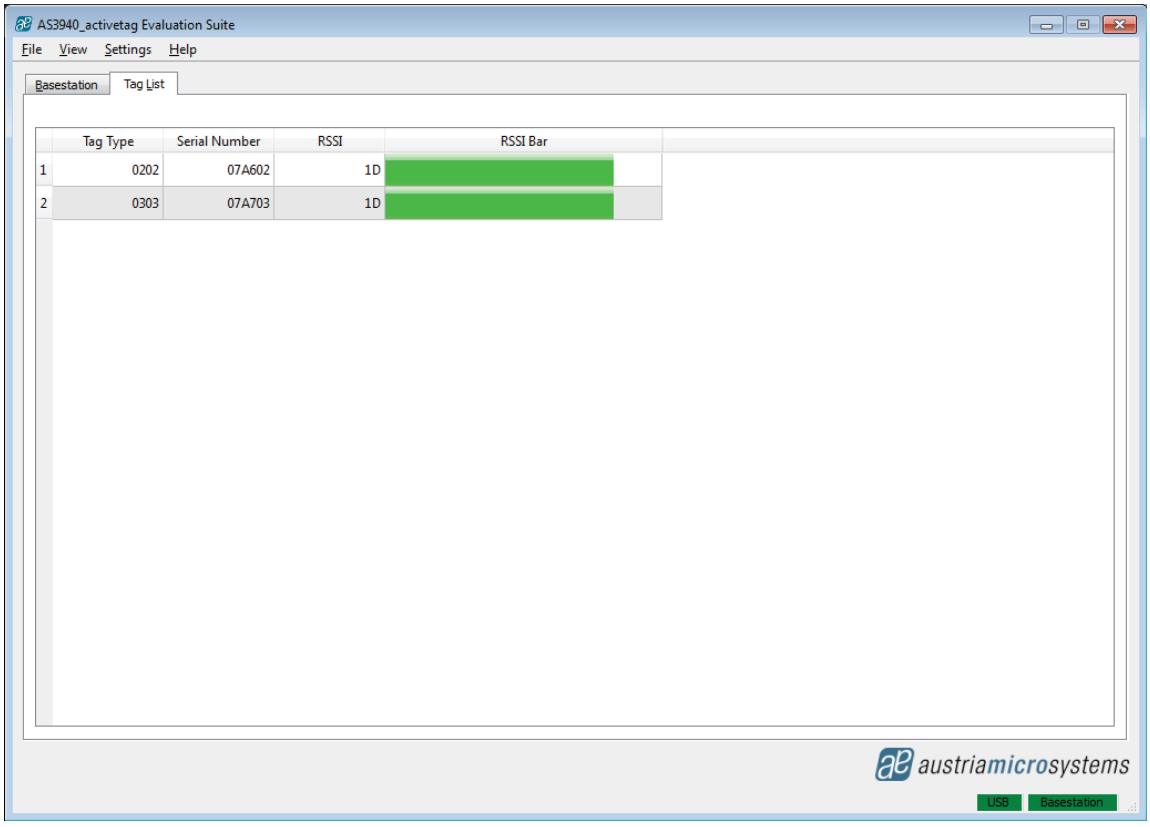
How to get started with the Active Tag demo kit

- Connect the Basestation with your PC via the USB Cable and start the GUI. The STANDBY led at "**F**" is continuously on.
- Insert the +3V Battery at **"F"** for all the Active Tags.
- Turn on all available Active Tags via the ON/OFF – switch **"A"**. When turning on the boards all indication-LEDs flash up once. Keep the tag minimum 40cm away from the base station, to avoid saturation and high voltages of the LF coil.
- As soon as the Active Tag receives a Wakeup Pattern, the RSSI LEDs flash up and show the actual Received Signal Strength.
- The LF pattern is transmitted once a second that is indicated by flashing the LF Tx led. As soon as the base station recognizes a valid tag, the UHF Rx led flashes up. The GUI shows the detail information of each tag that is recognized.

GUI Description

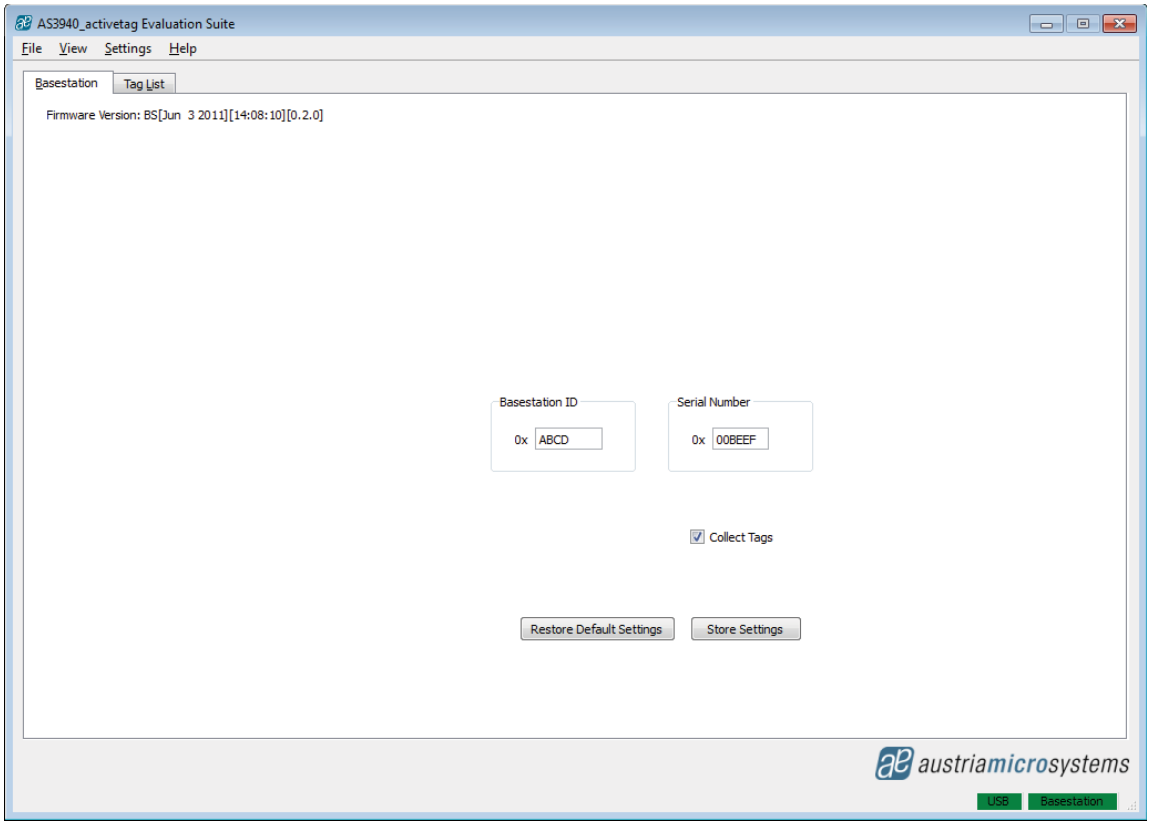
As soon as the Base station is connected with the PC, it starts to collect the available tags in the field.
The following parameters are read from the tag:

- Tag Type: Defines several device types, for different groups of tags.
- Serial Number: Unique tag ID, which is hard coded in the OTP registers of the AS3940
- RSSI: Receive Signal Strength of the 125 kHz LF Pattern. The range is between 0 to 1F, and is displayed at the LEDs on the tag as well.

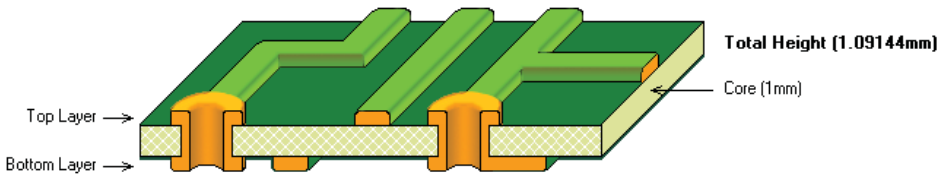


The following parameters can be defined on the base station:

- Base station ID: The ID of the base station can be changed for multiple base station application. The ID is send via the LF wakeup pattern to the tag, in order to set up the UHF communication with the identified base station. The base station ID is therefore inserted into the device type table of the tag (AS3940) in order to pair the tag to the correct base station.
  Note: For testing multiple base stations, please make sure that each base station has a unique ID.
- Serial Number: Unique Serial Number, which is send via the UHF link to the tag.
- Collect Tags: The base station can be stopped collecting tags by disabling this checkbox.
- Restore Default Settings/ Store Settings: Only needed if anything was changed in the register map of the AS3940. The register map of the AS3940 can be accessed via View/Register Map.



Layer Stack of Active Tag and Basestation



- PCB Material: FR4 1mm for Active Tag. FR4 1.6mm for Basestation
- 2 layer board
- Solder surface: chemical - tin
- Width of copper: 35µm
- Silk screen top/bottom: white

Layout Recommendations

AS3940:

- All external matching components should be as close as possible at the AS3940
- The differential outputs (RFINP, RFINN) should be symmetrically routed.
- The impedance of the differential micro strip line should be 200 Ohms
- The impedance of the single ended micro strip line (from the balun to the inverted-F antenna) should be 50 Ohms.
- The inverted-F antenna should not be near by a ground plane.
- All matching components should be filled by a ground plane. This ground plane should be low impedance to the chip ground of the AS3940. It is recommended to place many vias around the UHF path. All ground layers should be connected low impedance.
- Do not cross the UHF path with fast switching digital I/O lines.
- Make sure that VDD is low impedance. That can be achieved by putting a couple of capacitors between VDD and GND close to the AS3940. Capacitor values of 1uF, 100nF, 100pF are recommended.

AS3933:

- Do not cross the SPI lines with the sensitive inputs of the 3D antenna.
- Below the 125 kHz LF antenna there should not be a GND plane.
- Make sure that the GND plane is routed carefully.

Design Considerations of the Tag

In order to consume very little power out of the battery, it is necessary to set all devices into Sleep mode for 96% of the time.

- MCU: The microcontroller is by default set in Sleep mode until an external interrupt occur. The internal system clock is shut down and the current consumption will be reduced to 3.5µA.
  Since all tags are divided into separate timeslots, it is necessary to implement a Wait mode until the tag transmits the ID via the UHF link. In order to consume very little current during this wait interval, a watchdog timer was implemented. The watchdog brings the microcontroller periodically into the Sleep mode, and consumes 150µA.

- AS3933: The LF wakeup receiver is polling after an LF pattern by enabling the receiver every 8ms. The AS3933 is in on/off mode awaiting a wakeup pattern. In this mode the current consumption can be reduced to 1.7µA. Once a correct wakeup pattern is received, the external interrupt line of the microcontroller is triggered.

- AS3940: The UHF transceiver is set by default into Power Down, until the reserved timeslot is reached. In Power Down (CE=0) the AS3940 consumes only 1.5µA.

Note: It is important to sustain the battery with additional parallel capacitors (10µF), in order to supply the current spikes.

Layout of Active Tag

Board schematics

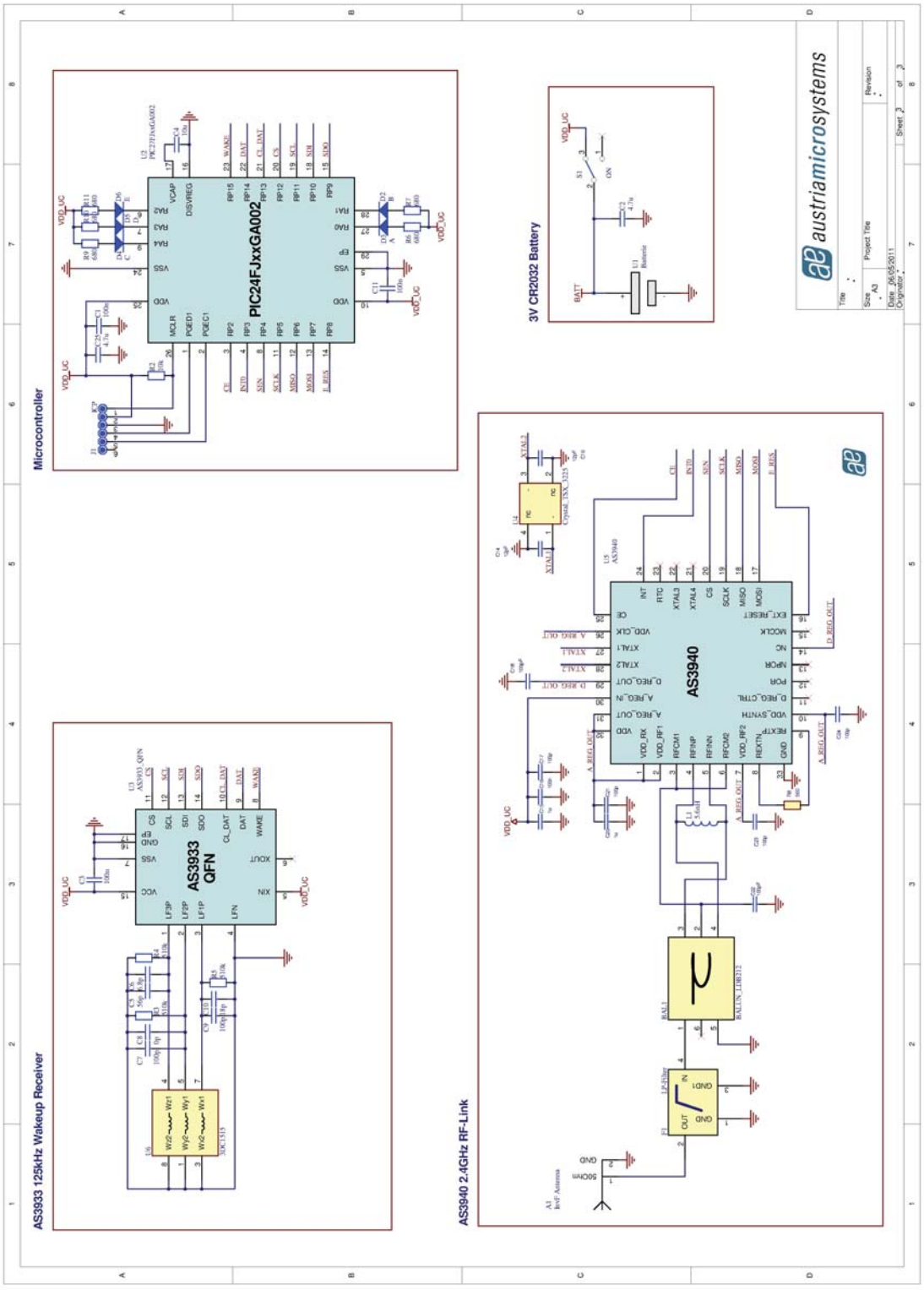


Figure 3: Schematics

Board Layout

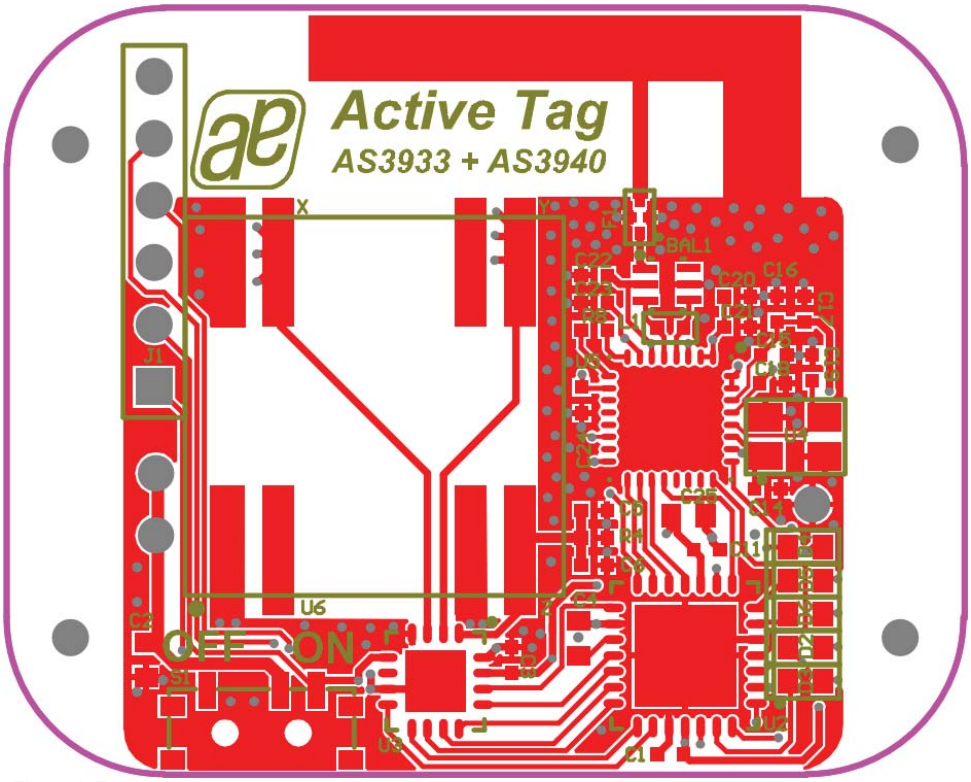


Figure 4: Top Layer

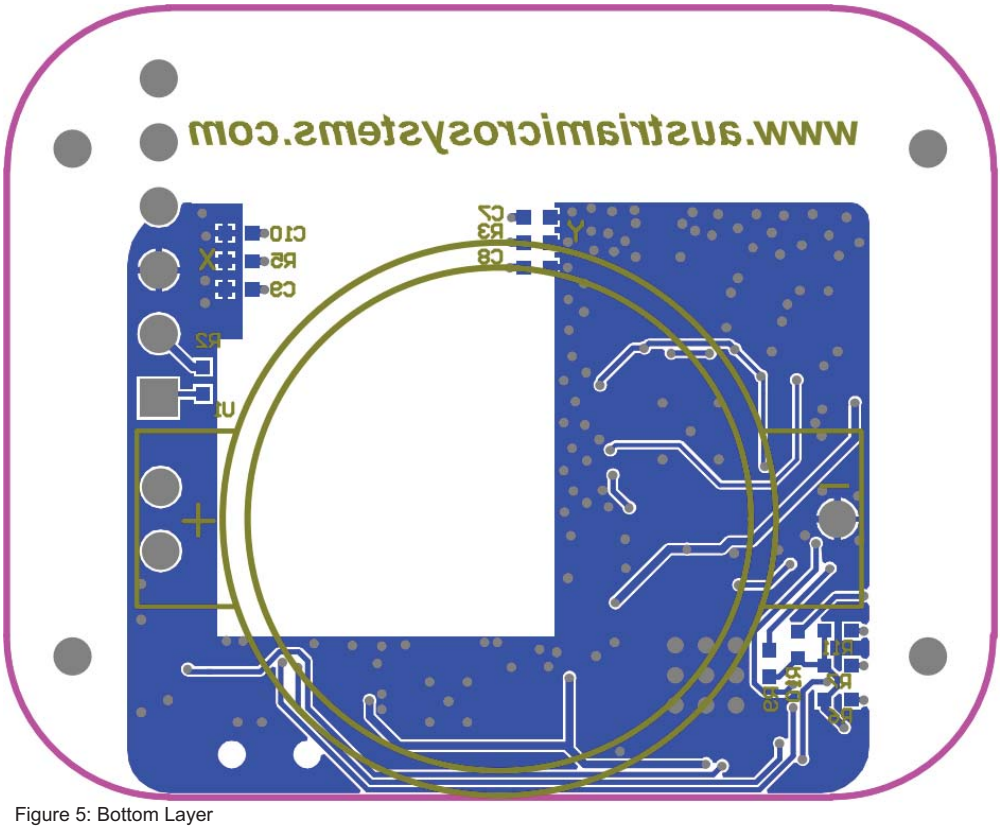


Figure 5: Bottom Layer

Bill of Material of Active Tag

Bill of Materials

Active Tag Rev 1.0

Business Unit:	**SBU Communications**
Originator:	**Josef Pertl**
PCB Name:	**Active Tag**
PCB Version:	**V1.0**
BOM Revision:	**1**
Report Date:	**10/02/2011**

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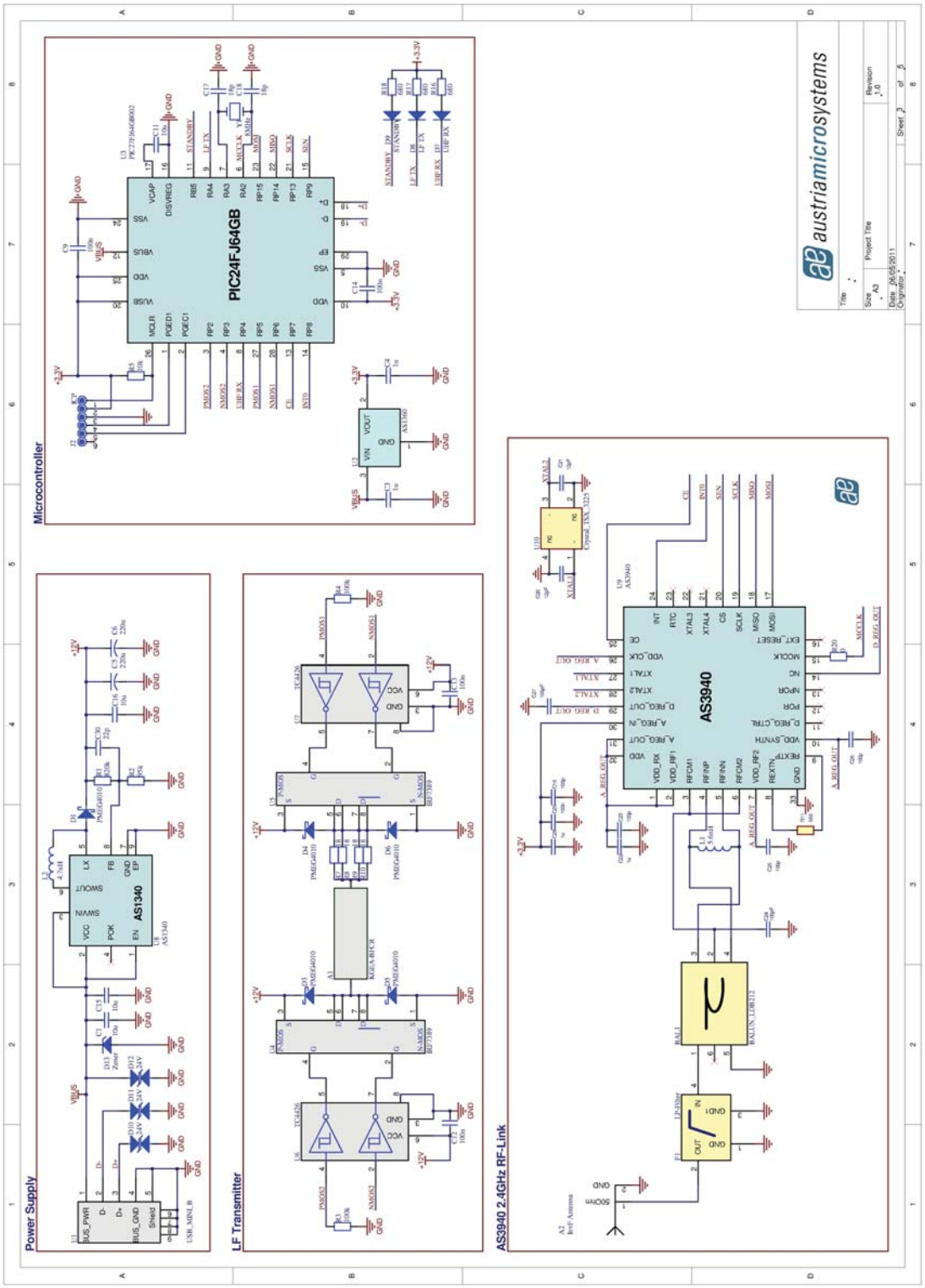
#	Comment	Designator	Footprint	Description	Producer	Distributor	Order Number	Quantity	optional
1	3DC1515	U6	3DC1515_16x18	10mH @ 125kHz	Premo	Premo	3DC1515	1	
2	AS3940	U5	QFN-32 5x5	AS3940-BQFT	AMS	AMS	**austriamicrosystems**	1	
3	Crystal_TSX_3225	U4	TSX-3225_Crystal	16MHz Oszillator	EPSON TOYOCOM	Farnell	1712841	1	
4	AS3933	U3	QFN16_4X4_0.65mmPitch	AS3933-BQFT	AMS	AMS	**austriamicrosystems**	1	
5	PIC24FJxxGA002	U2	QFN28_6x6	PIC24FJ16GA002-I/ML	Microchip	Mouser	579-24FJ16GA002I/ML	1	
6	Batterie	U1	CR2032_BATTHOLDER	HU2032-LF	Renata	Mouser	614-HU2032-LF	1	
7	ON	S1	PCM12SMTR_sw	Schiebeschalter SPDT	C&K Components	Farnell	9575146	1	**optional**
8	560	R8	R0402-ss	0402/1%/0.1W	Stackpole Electronics	Digikey	RMCF0402FT560RTR-ND	1	
9	680	R6, R7, R9, R10, R11	R0402-ss	0402/1%/0.1W	Panasonic	Digikey	P680JTR-ND	5	**optional**
10	510k	R3, R4, R5	R0402-ss	0402/1%/0.1W	Panasonic	Digikey	P510KJTR-ND	3	
11	10k	R2	R0402-ss	0402/1%/0.1W	Panasonic	Digikey	P10KJTR-ND	1	
12	5.6nH	L1	R0402	LQW15AN5N6C10D	Murata	Digikey	LQW15AN5N6C10D-ND	1	
13	ICP	J1	PLUG_THMD_STRIP6	6 poles, 1 row, female		diverse		1	**not assembled**
14	LP-Filter	F1	LP-Filter LFL152	LFL152G45TC1A219	Murata	Mouser	81-LFL152G45TC1A219	1	
15	E, D, C, A, B	D6, D5, D4, D3, D2	D0603	0603/SUPER BRT	Kingbright Corp	Digikey	754-1123-2-ND	1	**optional**
16	1u	C20	C0402-ss	1uF/10V/0402/10%/X5R	TDK Corporation	Digikey	445-4114-2-ND	1	
17	100pF	C7, C9	C0402-ss	100pF/50V/0402/2%/COG	TDK Corporation	Digikey	445-5365-2-ND	2	
18	1u	C15	C0402-ss	1uF/10V/0402/10%/X5R	TDK Corporation	Digikey	445-4114-2-ND	1	
19	12pF	C14, C19	C0402-ss	12pF/50V/0402/10%/COG	TDK Corporation	Digikey	445-1236-2-ND	2	
20	18p	C10	C0402-ss	18pF/50V/0402/2%/COG	Johanson Tech.	Digikey	712-1264-2-ND	1	
21	0p	C8	C0402-ss				**not assembled**	1	**not assembled**
22	100p	C17, C18, C21, C22, C23,	C0402-ss	100pF/50V/0402/10%/COG	Yageo	Digikey	311-1024-2-ND	6	
23	6.8p	C6	C0402-ss	6.8pF/50V/0402/2%/COG	TDK Corporation	Digikey	445-4886-2-ND	1	
24	56p	C5	C0402-ss	56pF/50V/0402/2%/COG	Murata	Digikey	490-1288-2-ND	1	
25	10u	C4	C0603-ss	10uF/6.3V/0603/20%/X5R	TDK Corporation	Digikey	445-1796-2-ND	1	
26	4.7u	C2, C25	C0603-ss	4.7uF/6.3V/0603/20%/X5R	TDK Corporation	Digikey	445-5178-2-ND	2	
27	100n	C1, C3, C11, C16	C0402-ss	100nF/10V/0402/10%/X5R	TDK Corporation	Digikey	445-4984-2-ND	4	
28	BALUN_LDB212	BAL1	LDB212G4020-001	TRANSFORMER BALUN 2.45GHZ	Murata	Mouser	81-LDB212G4020C-001	1	

Layout of Basestation

Board schematics



Board Layout

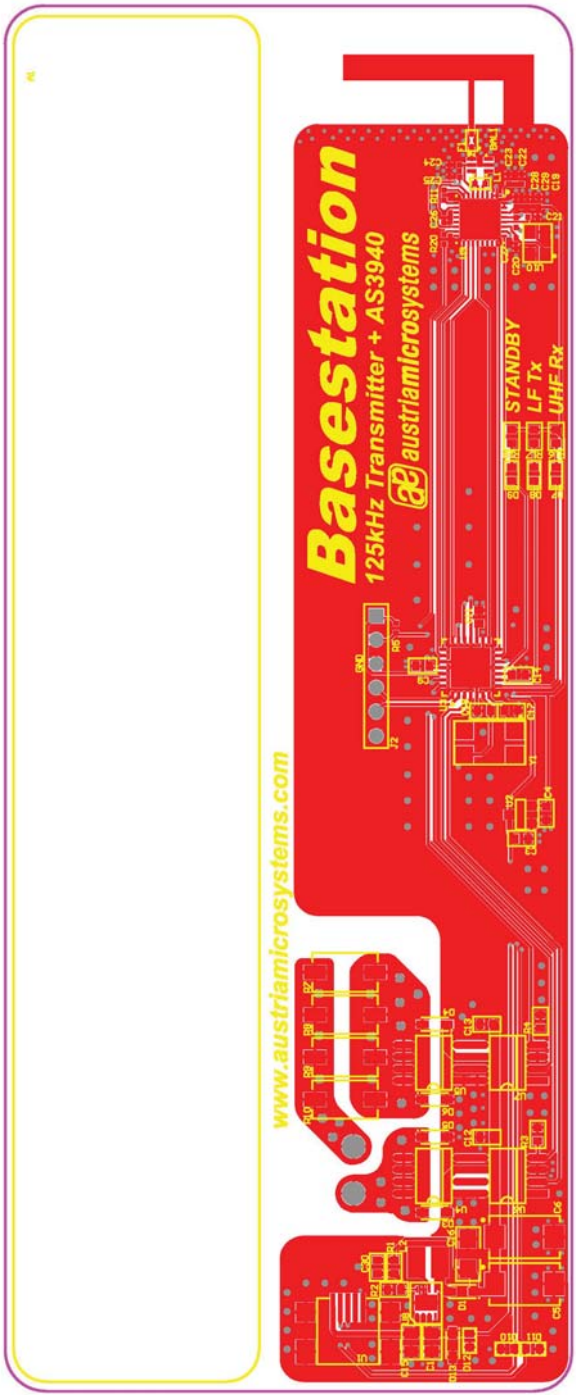


Figure 4: Top Layer

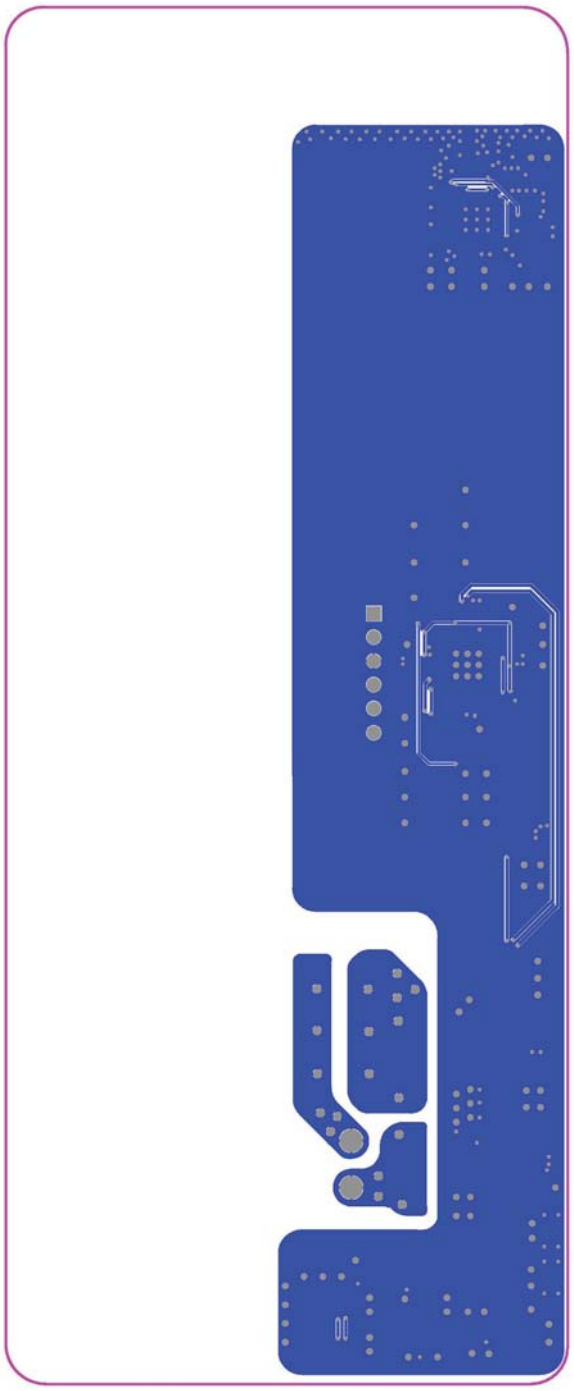


Figure 5: Bottom Layer

Bill of Material of Base station

Designator	Comment	Footprint	Description	Supplier	Supplier Part#	Quantity
A1	KGEA-BFCR-B-0500J	KGEA-BFCR	LF Antenna	Premo		1
BAL1	BALUN_LDB212	LDB212G4020-001	LDB212G4020C-001	Digi-Key	490-4744-2-ND	1
C1, C15	10u	C0805	10V	Farnell	1463364	2
C3, C4	1u	C0603	10V	miscellaneous		2
C5, C6	220u	C_SMD_D	16V	Farnell	1793889	2
C9, C12, C13, C14	100n	C0603	16V	miscellaneous		4
C11	10u	C0603-ss	10V	miscellaneous		1
C16	10u	C1206	16V	Farnell	1833825	1
C17, C18	18p	C0603	10V	miscellaneous		2
C19, C23, C25, C26	100p	C0402-ss	10V	miscellaneous		4
C20, C21	12pF	C0402-ss	10V	miscellaneous		2
C22, C28	1u	C0402-ss	10V	miscellaneous		2
C24, C27	100pF	C0402-ss	10V	miscellaneous		2
C29	100n	C0402-ss	10V	miscellaneous		1
C30	22p	C0603	16V	miscellaneous		1
D1, D3, D4, D5, D6	PMEG4010	SOD323F (SC-90)	40V	Farnell	1757777	5
D7	UHF RX	D0603	Orange Diode Superbright	Farnell	1716772	1
D8	LF TX	D0603	Green Diode Superbright	Farnell	1716771	1
D9	STANDBY	D0603	Red Diode Superbright	Farnell	1716774	1
D10, D11, D12	24V	D0603_SUPRESSOR		Farnell	1470613	3
D13	Zener	SOD323F (SC-90)		Farnell	1431206	1
F1	LP-Filter	LP-Filter LFL152	LP-Filter	Farnell	1294694	1
J2	ICP	PLUG_THMD_STRIP6	6pol, 1row, female	miscellaneous		1
L1	5.6nH	R0402		miscellaneous		1
L2	4.7uH	XFL3012_472MEC		miscellaneous		1
R1	820k	R0603	1%, 0.1W	miscellaneous		1
R2	95k	R0603	1%, 0.1W	miscellaneous		1
R3, R4	100k	R0603	1%, 0.1W	miscellaneous		2
R5	10k	R0402-ss	1%, 0.1W	miscellaneous		1
R7, R8, R9, R10	18	RSMD2W	5%, 2W	Farnell	1086291	4
R11	560	R0402-ss	1%, 0.1W	miscellaneous		1
R16, R17, R18	680	R0603	1%, 0.1W	Farnell	1738903	3
R20	0	R0402-ss		not assembled		1
U1	USB_MINI_B	USB_MINI_B_SMD_JPE	USB MINI B	miscellaneous		1
U2	AS1360-33-T	SOT23	LDO	austriamicrosystems		1
U3	PIC27FJ64GB002	QFN28_6x6	Microcontroller	Newark	07P9737	1
U4, U5	IRF7389	SO8_NARROW	NMOS, PMOS	Farnell	1374982	2
U6, U7	TC4426	SO8_NARROW	MOSFET DRIVER	Farnell	1332309	2
U8	AS1340A-BTDT-10	TDFN8_3X3_0.65	50V, Micropower, DC-DC E	austriamicrosystems		1
U9	AS3940-BQFT	QFN32	2.4GHz Transceiver	austriamicrosystems		1
U10	Crystal_TSX_3225	TSX-3225_Crystal	16MHz Crystal TSX_3225	Farnell	1712841	1
Y1	8MHz	ABMM2_Crystal	Crystal 8MHz ABMM2	Farnell	1611803	1

Current Profile and Lifetime Calculation of Active Tag

In order to minimize the current consumption the following concept is applied:

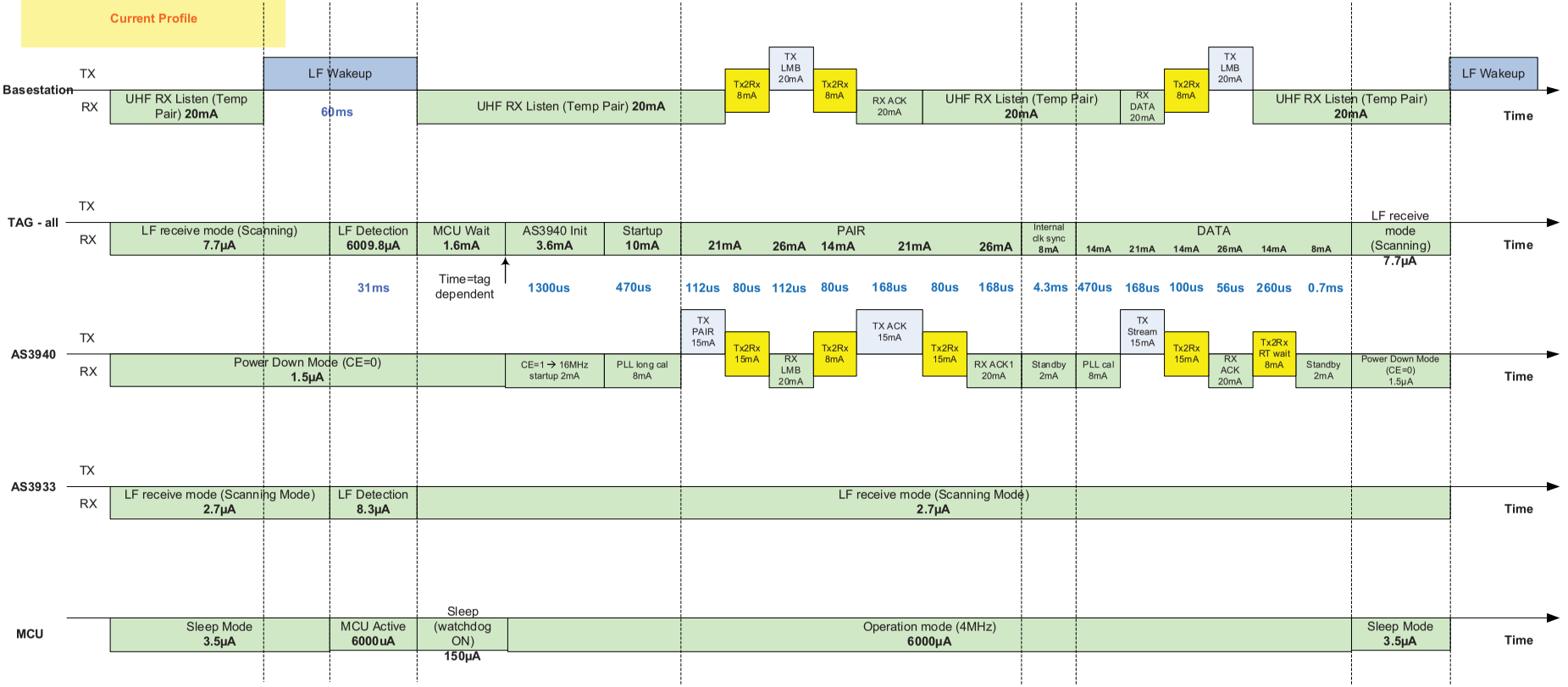
1. The Active Tag is in sleep mode and waits for an LF wakeup event.
2. The Base Station transmits a LF wakeup signal once a second. After the LF transmission the base station goes into UHF listening mode awaiting feedback from the tags in the field.
3. The Active Tag wakes up and responds with a UHF packet for pairing and data transmission. After successful transmission the tag goes into sleep mode again.
4. The Base Station continues listening for further tags until the next wakeup transmission.

AS3940 Currents	[uA]
Tx Current (-15dBm)	15000
Rx Current	20000
Power Down	1,5
Standby	2000
Tx2Rx or PLLlong cal	8000
Tx2Rx2	15000

AS3933 Currents	[uA]
Scanning Mode	2,7
LF Detection	8,3

MCU Currents	[uA]
Sleep Mode	3,5
Operation Mode	6000
Watchdog Wait Mod	150

Current Profile



Settings:

MCU: 4MHz, SPI Speed: 2MHz

AS3940: 2Mbps, 3Byte Data, Pout= -15dBm, Pairing + Data

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HW Disclaimer

This hardware is for development use only.
This device has not been certified per FCC requirements. This device is not, and may not be, offered for sale or lease until authorization or certification is obtained.

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