AN3990

Application note for the AS3990 UHF RFID reader System

Application note
Rev 0.9 November 2007

1 Introduction

The AS3990UHF reader development kit supports the **EPC generation 2** standards. The aim of the development kit is to show some of the features of the AS3990 UHF reader chip and to allow the customers to start development of the application software in the host system prior to reader hardware design completion.

The system comprises of two boards: the UHF board and the MCU board including the LCD. On the UHF board the main components are the AS3990 UHF chip, external RF power amplifier, circulator, external VCO, and TCXO. On the MCU board the main components are MSP430 micro controller, LCD display, and USB interface. The two boards are connected via 30 pin connector.

The demonstration board can both operate as stand-alone Reader as well as operate by graphic user interface (GUI) when connected to a USB PC port. All mandatory commands and some optional commands for the EPC generation2 standard are supported.

For development purposes the MCU board can be removed and the host system can directly access the AS3990 using a 30 pin connector. The operational RF part can be used to develop customized software that will control the AS3990. A description of the interface can be found in the chapter of technical description.

1.1 Getting started

1.1.1 System assembly

- Use a 50 Ohm coaxial cable to connect the SMA connector on the reader board with the SMA connector on the patch antenna.
- Use DC power supply or a stabilized laboratory power supply with current rating of at least 600 mA at output voltage with a voltage setting of 8 Vdc for supply the reader board. Use USB cable to connect PC and the reader board.

1.1.2 Stand-alone operation

When power is supplied to the board, Reader automatically starts stand-alone operation. In this operation Reader continuously searches transponders in antenna field and inventories them up to a maximum count of 8 pieces.
Basic data is displayed on LC-Display:

- in the first line selected frequency, Tari selection, modulation selection and link frequency are displayed
- second line shows current number of transponders in the field and number of slots that are used .
- PC and EPC information of inventoried transponders in hexadecimal format are displayed in the third and fourth line.

The 6 buttons on the digital board will compliment the built-in user interface

Stand-alone operation limitation

In stand-alone operation the number of transponders inventoried is limited to maximum of eight by MCU firmware.

1.1.3 Operation of the board PC based with graphic user interface control

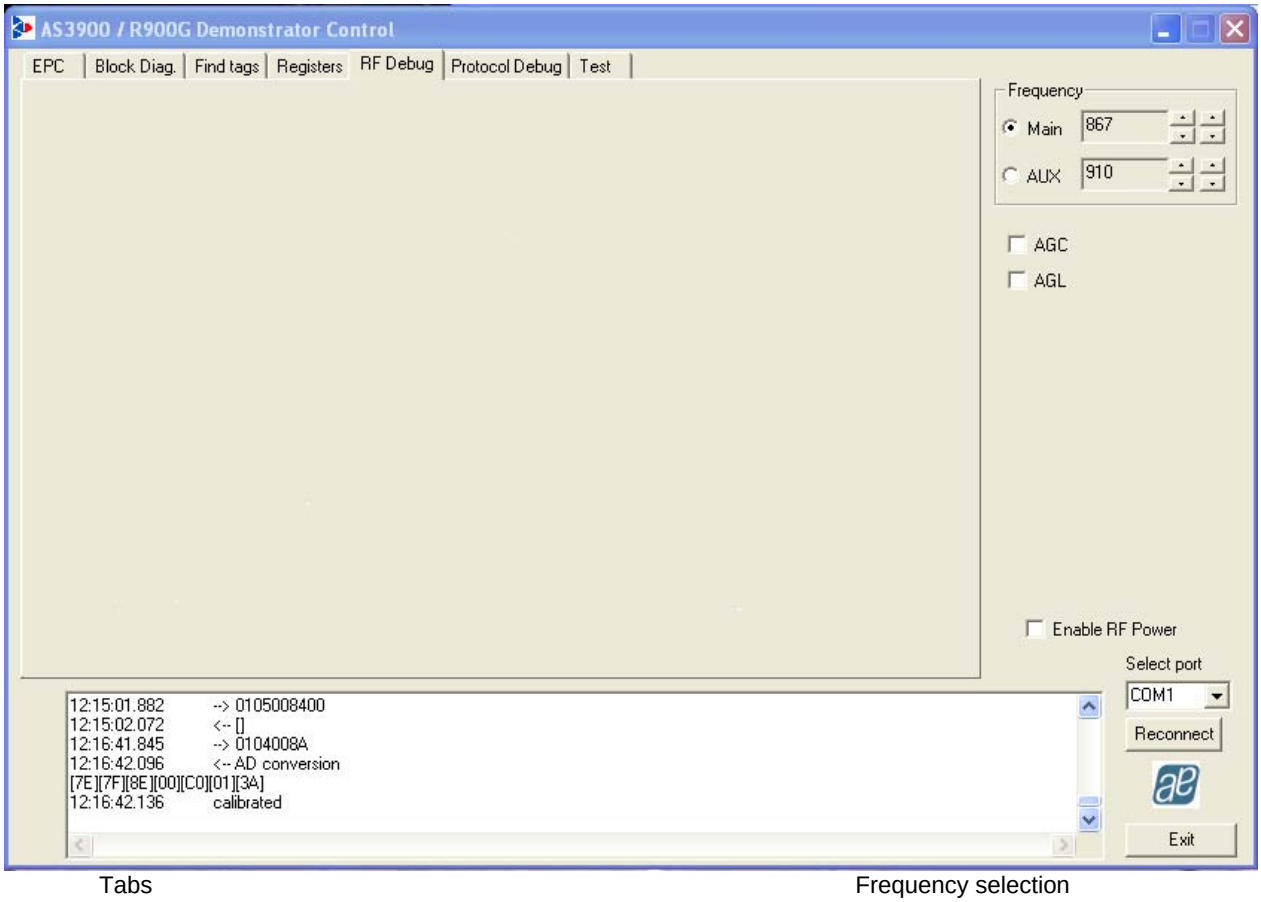
To be able to connect the Reader to a PC, drivers for USB circuit need to be installed first; they are available on CD that is supplied with AS3990 development kit.

After the installation of the drivers, you have to set the port properties. In the Windows Start menu, open Control Panel/System/Hardware/Device Manager/Ports. Double click on the 'USB Serial Port' and open the 'Port Settings' tab, choose **115200 bits/s, 8 Data bits, No parity, 1 Stop bit, No Flow control**. In case the COM port is assigned a very high number (above 6) use Advanced options to assign it a lower number.

Once this is complete you can connect reader board to a PC with the USB cable and start GUI program. The GUI should automatically detect the COM port number that the board is attached to. If it is different from the one that you have manually selected, please select the COM port that you used in the settings.

2 Graphic User Interface

2.1 Main Window



Tabs

Frequency selection

Log window

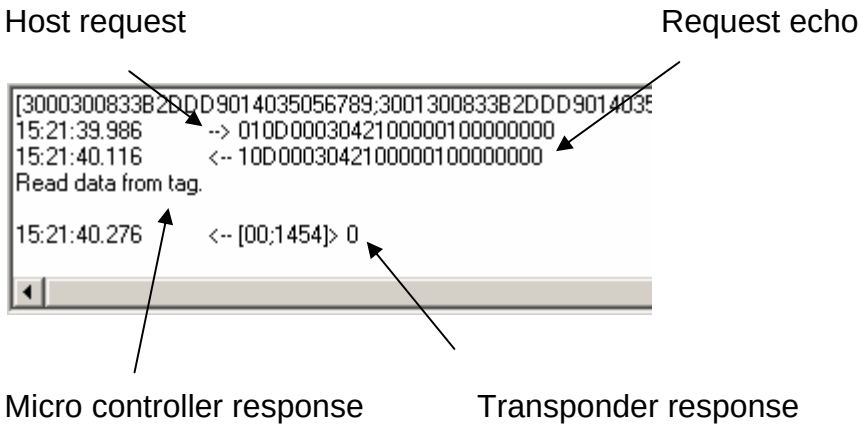
COM port selection

Most of the GUI window is used for tabs which allow user to perform different tasks:

- ***EPC*** tab is used to execute EPC operations on transponders;
- ***Block Diag.*** tab is used to set properties of individual blocks of AS3990;
- ***Find Tags*** tab is used to continuously scans for transponders in its RF field and displays their respective EPC values;
- ***Registers*** tab is used to observe and change values in registers of AS3990 reader IC;
- ***RF debug*** tab is used to check FR properties of the board, antenna, and environment;
- ***Test*** is used to send Host-Reader commands to the Reader.

- Log window

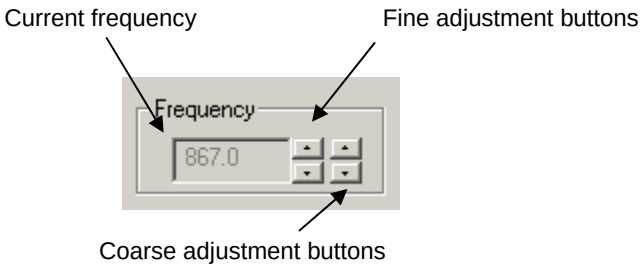
The log window is used to display all the messages and data sent to and from the reader board. This information is also stored in the *rfid-reader.log* file which can be opened with a text editor (Notepad).



The relevant information returned by the Reader (transponder response, register content) is always in brackets to distinguish it from other data in host-to-reader data exchange.

- Frequency selection

Frequency selection field and four buttons on the right side of the GUI window allow user to select operation frequency. The two buttons on the left change frequency in 200 kHz.



- Control buttons

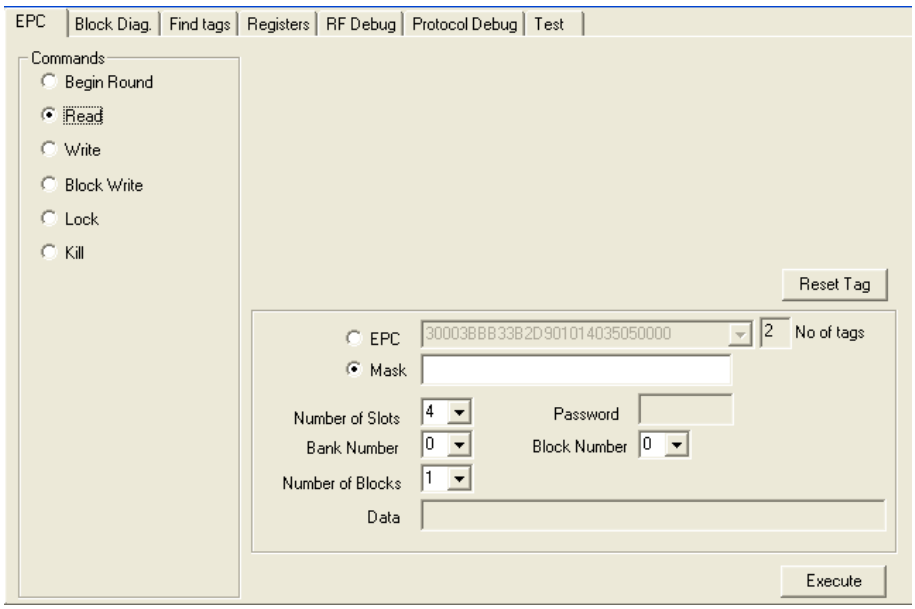
The following buttons change operation of the Reader:

- **AGC** – Automatic Gain Control setting
- **AGL** – Automatic Gain Leveling setting
- **Enable RF Power** – turn on / off RF power

- COM port

If automatic port selection fails upon GUI initialization you can select the port and try to execute the “Inventory Round” operation in the ***EPC*** tab. In case the Reader will be reset (or removes power during ***RF debug*** tab measurement) ***Reconnect*** button should be used to reestablish connection.

2.2 EPC Tab



When this tab is activated only *Inventory Round* operation is enabled. You have to click **Execute** to run this operation and inventory the transponders before you can **Execute** other operations. When operations other then Inventory *Round* are selected modification of appropriate text entry and selection controls is enabled.

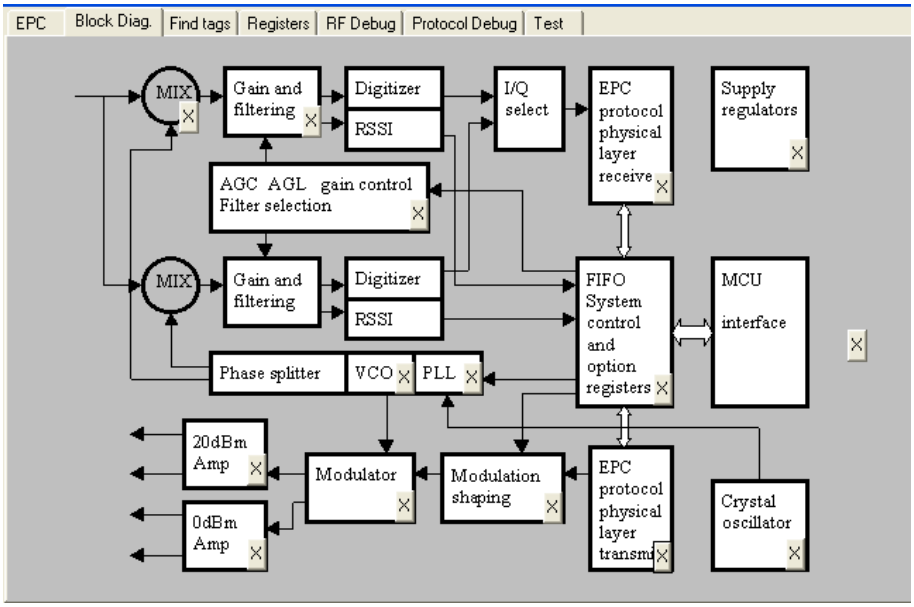
- ID mask

The mask can consist of arbitrary number of characters up to full EPC length (often 28 hexadecimal characters). Reader GUI currently enables modification of mask in 4 bit units (1 hexadecimal character). Mask offset is achieved by preceding the mask by non-hexadecimal characters (1 character = 4 bits).

- Changing EPC number

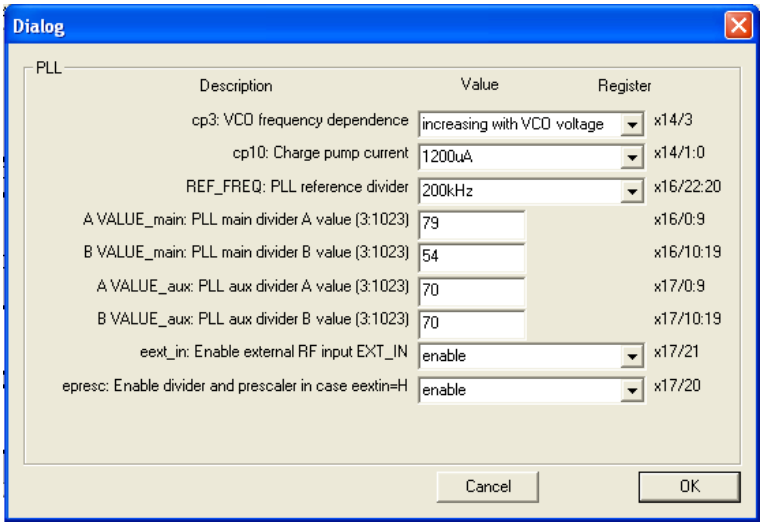
Transponders read their ID from non-volatile memory when they gather sufficient RF field from the reader side. it is possible to change EPC number by writing to bank 1 of the transponders memory. Once the number is changed transponder did not respond to further commands until the TAG is removed from the RF field and inserted again. This can be achieved by switching RF field off and on or clicking **Reset Tag** button.

2.3 Block Diagram Tab



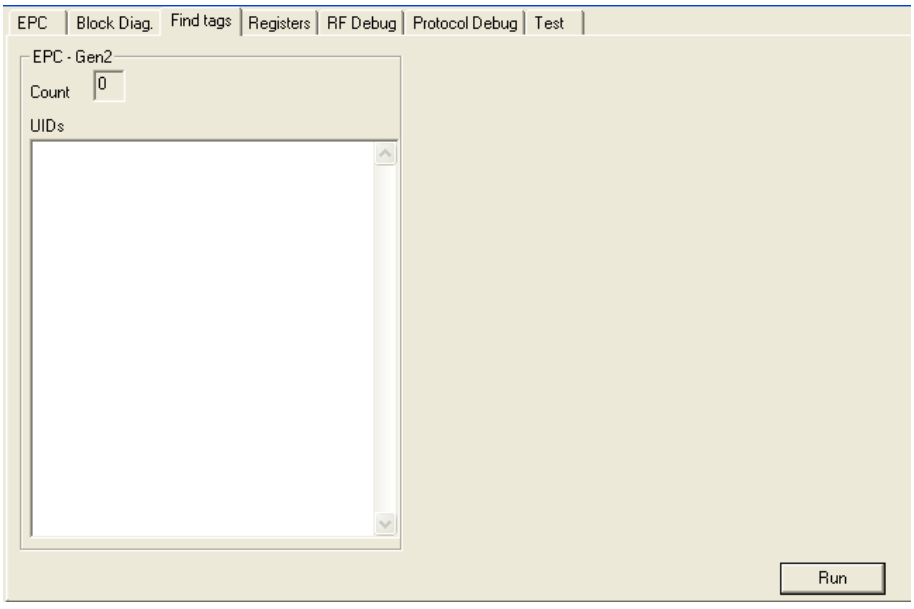
A block diagram of the circuit is presented to give a convenient possibility to change registers and modify properties of circuit blocks by clicking the **X** button in the lower right corner of some blocks. A new dialog box is opened where you can modify values of registers by entering new values in the text entry controls or selecting appropriate values from selection controls.

All values shown in the controls are read from AS3990 registers when the dialog box is opened. Writing to the registers is executed upon clicking the OK button. You will be not asked for confirmation. There is no undo. Some combinations of register values can severely degrade operation of the Reader. You can restore default values in ***Registers*** tab clicking S**et Defaults** button.



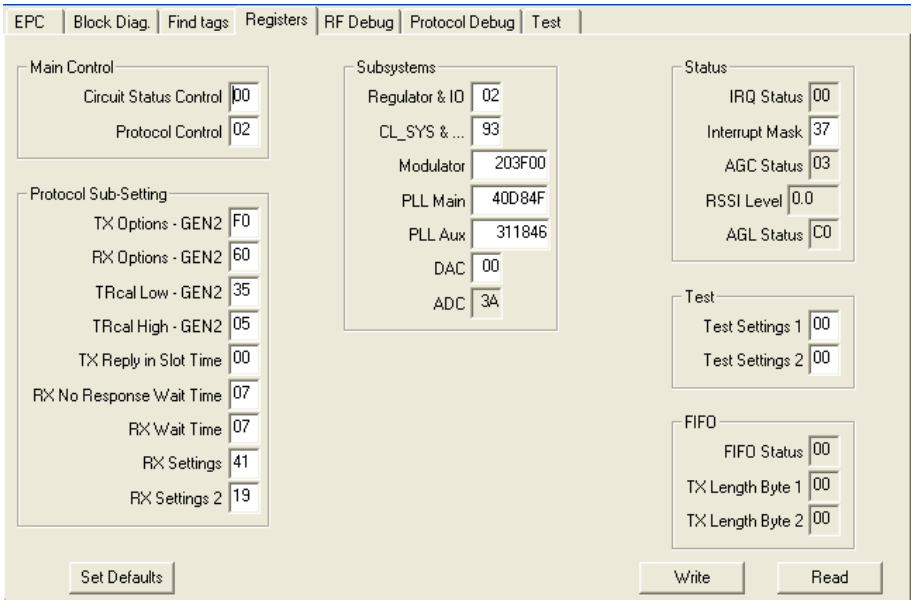
The ***Block Diagram*** tab enables modification of majority of registers. All register values may be modified in the ***Registers*** Tab.

2.4 Find Tags Tab



By changing into this tab, the active Reader is trying to identify all tags or labels in the RF field. The EPC numbers of the tags will be shown. This operation can be stopped and restarted with the **Stop** / **Run** button. No Reader to PC communication is echoed to the log window but it is still written to the log file (rfid-reader.log).

2.5 Registers Tab



The content of the registers in AS3990 can be read and written in the ***Registers*** tab. Do not alter the register content unless you are familiar with the functions described in the AS3990 specifications. If you change the content by mistake, press the **Set Defaults** button.

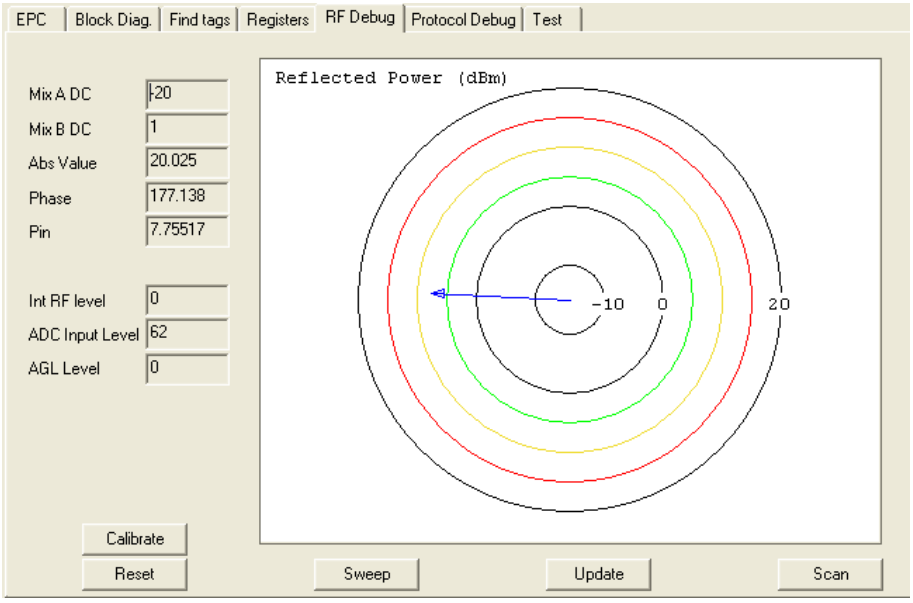
The register values are updated automatically every time the user enters the Registers tab or when the Special functions on the Main Window are changed.

2.6 RF Debug Tab

The transmission wave propagates from power amplifier through directional device (circulator), and coax cable, and is transmitted by an antenna. Leakage or reflections on this path increase reflected (transmission) power level of the un-modulated carrier at the receiver input. (self jamming) High level of reflected power affects the receiver operation.

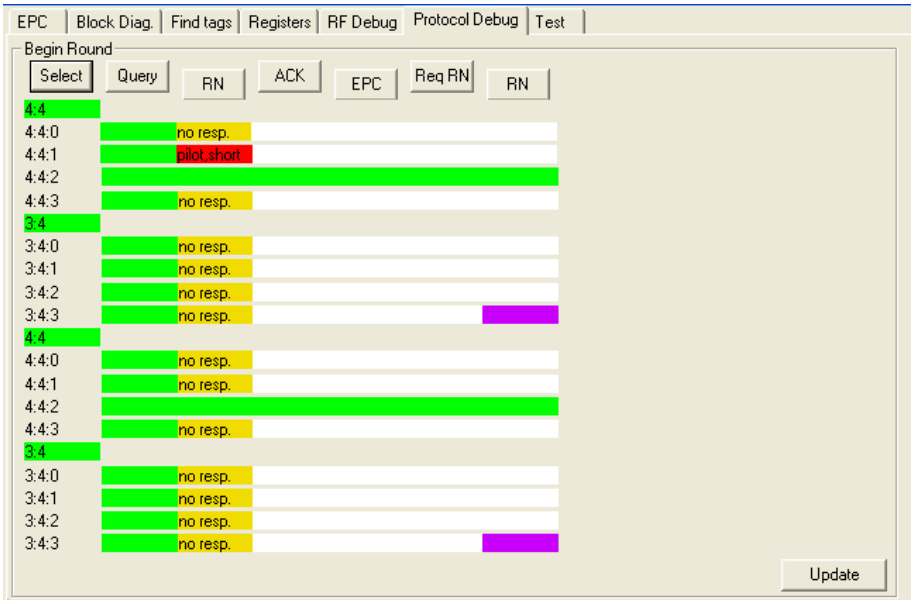
To check the reflected power level we have integrated a diagnostic system in the AS3990 which observes the amplitude and phase of the down converted received carrier. The result can be converted by DAC and read by the MCU (see device specification for details).

In the RF debug tab the amplitude and phase of the received carrier (reflected power) is shown graphically. The acceptable levels are marked by green and yellow marks. On the left side you can also observe the two values coming directly from the ADC conversion, their absolute value, phase and approximate reflected power calculated to dBm.



Update soft key is used update the readout on selected frequency. Scan soft key is used for continuously update. Sweep key is used to show results in a frequency domain using a wide frequency sweep. It is also possible to store the response shape by pressing calibrate key and in next sweep observe only the difference between actual reflectivity and the stored previous one.

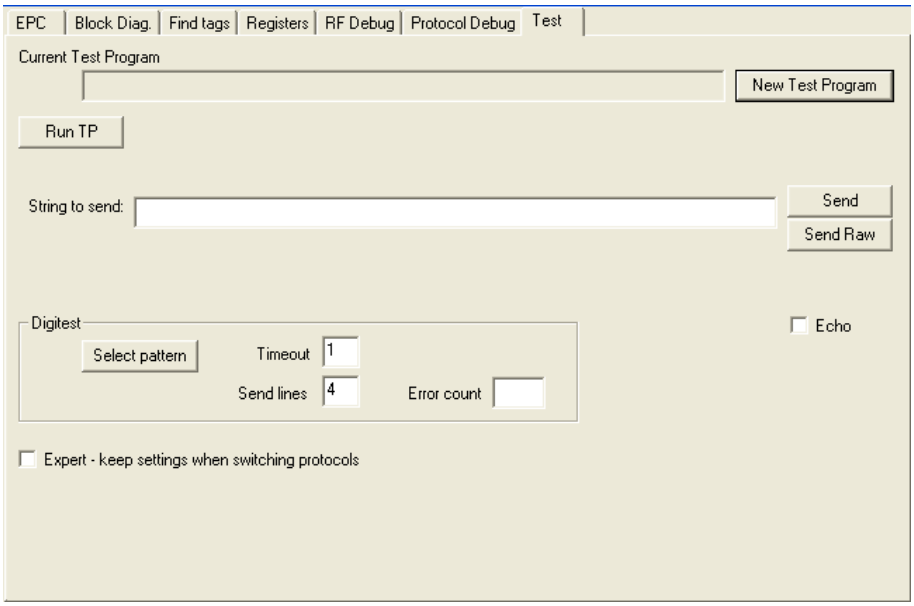
2.7 Protocol Debug Tab



This tab is used to debug the EPC protocol using graphics. Details of communication required to execute one EPC operations Inventory *Round*, *Read*, and *Write* are shown. Rounds with slots and all EPC commands of communication are shown in color codes. Green color is used

to show normal operation, yellow is used to show slots with no response and red is used to show unexpected slot termination. The meaning of the interrupt or error code returned by AS3990 is shown in the red area. Rounds are repeated at least twice to find all the transponders. When reader finds a round with all empty slots it assumes that all tags are inventoried. This is marked in magenta at the end of the line.

2.8 Test Tab



All Host to Reader commands that are described in the enclosed Interface description can be manually send in the Test tab using a string and the Send button. you simply has to fill the 'Command + parameters' field as shown. All other fields in the protocol are automatically generated by the program when **Send** button is pressed:

SOF (0x01)	Number of bytes	Number of bytes 2	**Command + parameters**

The same text can be send without the header with the **Send Raw** button. Check **Host to Reader Board Protocol** for the list of available Host-Reader commands.

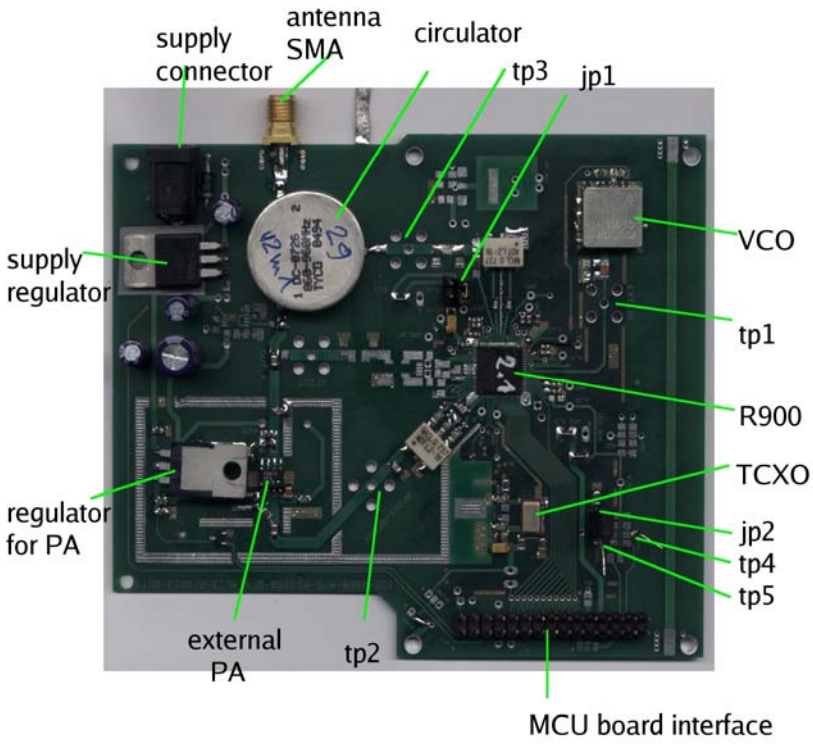
- Test programs

You can also write a number of Host-Reader commands that should be executed in succession in a test file. Verification of return values, loops and user interaction are also supported. Please, check syntax and samples of test programs on your CDROM.

3 Hardware Description

3.1 UHF board

The system comprises of two boards: the UHF board and the MCU board including LC Display. The main components on the UHF board are the AS3990 UHF chip, TCXO, external VCO, external RF power amplifier, circulator, and two supply regulators. Components positions are shown on the figure below.

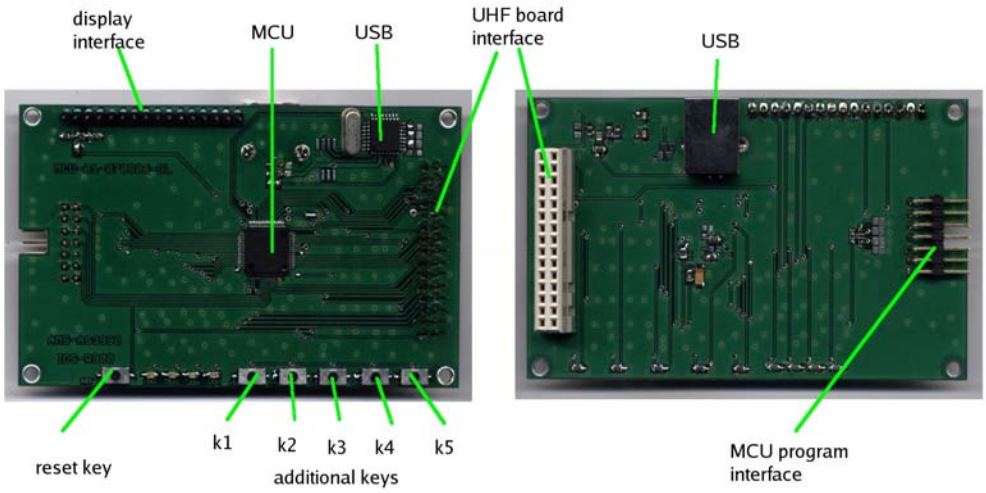


Two jumpers' jp1 and jp2 should be set for correct operation. Via the jp1 AS3990 is supplied and can be used for current consumption measurement. The jp2 is used to enable MCU support mode connecting the OAD2 pin to ground via 10k resistor (see details in the device specification).
On the tp1, tp2, tp3 additional SMA connectors can be soldered and used for observing the system operation. Note that connecting anything to sensitive RF lines can corrupt operation from changing the signal level to severe operation degradation. On the tp1, tp2, and tp3 points the VCO's signal, AS3990's transmission signal, and AS3990's reception signal are presented respectively. The three SMAs (tp1(VCO Signal, tp2(Tx Signal, tp3(Rx Signal)) can also be used to embed the on board AS3990 into another RFID system
The tp4 and tp5 test points are connected to the OAD and OAD2 pins. In case the AS3990 option bit e_anasubc (reg14) is high the two outputs present received analogue subcarrier. In case the AS3990 option bit e_anamix (reg14) is high the two outputs present mixers output DC levels which are used for detection of reflected carrier power shown in the RF debug tab (see details in the device specification).

The demonstration and development board uses external TCXO, VCO and PA for optimal performance. RFID system can be built with AS3990 also without these external components giving a lower Bill of Material but however with decreased performance. External VCO is used to achieve good transmission spectrum, TCXO is used for accurate transmission frequency, and external PA is used to increase the transmitted output power.

3.2 MCU board

Main components on the MCU board are MSP430 micro controller, LC Display, and USB interface. Components positions are shown on the figure below.



The MCU's reset can be done by reset key. Additional keys k4 and k5 are used for RF frequency setting while k1, k2, k3 are used for test purposes The two boards are connected via 30 pin connector.

4 Operation

It is advised to connect the antenna or appropriate RF load prior connecting the supply.(and also turn off power before removing antenna)
The optimum board supply is 8V-9V DC. Current consumption is 0.6A. Supply should be free of spurious signals in frequency range that is similar to available link frequencies (between 20kHz and 2MHz). Power line adapters based on classical line transformers or switching supplies with better shielding and filtering should be used for good performance. Laboratory supplies are also sufficient.

On the UHF board the majority of the RFID functions is done by the AS3990

The datas that will be sent to the tag are generated from AS3990 based on the datas that are being read out from FIFO which is filled from the microcontroller. AS3990's coded according to the protocol, The preamble and CRC is added. The shape of the modulation signal is prepared with internal shaping circuit. The UHF is generated by the internal PLL in conjunction with external or internal VCO, the modulation is done with internal modulator. The transmit signal is then amplified using external power amplifier. The TX to RX isolation is achieved by circulator.

Receiving signal is down converted with double (IQ) internal wide input range mixers, passed to the internal base band filter and gain stages via internal fast feedback AC coupling stage. Then internal digitizer and decision circuit prepares signal for the bit decoder and framer that extracts bits, removes the preamble, checks the CRC, arranges bits in bytes. The clean data is accessible to the MCU in the FIFO. Different building blocks of the chip are supplied with a set of internal regulators. TCXO or internal oscillator with external crystal is used as reference clock source.

The supply and clock for the MCU board is generated in the AS3990 using the MCU support mode.

External regulator is used to supply the AS3990 (5.3V typically) and another external regulator is used to supply the external PA (4.5V typically). The relatively high supply voltage for the AS3990 brings the advantage for a high dynamic range and for better operation in case of large self jamming signal at the input of the mixers. This condition is observed in case the directional device directivity, antenna impedance or antenna environment causes reflections.

4.1 MCU board to UHF board interface

This interface can be used for development purposes. In this case the MCU board is removed and interface is driven directly from the host system. The AS3990 interface is accessible via the 30 pin connector. The Interface specification is given in the AS3990 device specification. Pin positions are given in the table below.

Pin number	Type (from UHF board point of view)	Pin name	Pin description	Comment
1	OUT	CL_20M	20MHz clock from TCXO	Not used
2	OUT	CLSYS	10MHz clock from AS3990	MCU clock, generated by AS3990 in MCU support mode
3	SUP	GND	Ground	
4	SUP	GND	Ground	
5	OUT	D_PWD	VCO type Note1	Signal to MCU - L: ext. VCO, int. PLL, Z: int. VCO, H: ext. RF source
6	BID	PA_PWD	PA type Note1/PA_PWD	Signal to MCU - L: int. PA, Z: ext PA, MCU set it high to power down the external PA and it's regulator.
7	-	S1_1	Reserved	
8	OUT	S10_1	Circulator type Note1	Signal to MCU - L: FCC, Z: ETSI
9	-	S9_1	Reserved	
10	IN	EN	AS3990 interface pin	Detailed data in device specification.
11	OUT	IRQ	AS3990 interface pin	Detailed data in device specification.
12	BID	IO0	AS3990 interface pin	Detailed data in device specification.
13	BID	IO1	AS3990 interface pin	Detailed data in device specification.
14	BID	IO2	AS3990 interface pin	Detailed data in device specification.
15	BID	IO3	AS3990 interface pin	Detailed data in device specification.
16	BID	IO4	AS3990 interface pin	Detailed data in device specification.
17	BID	IO5	AS3990 interface pin	Detailed data in device specification.
18	BID	IO6	AS3990 interface pin	Detailed data in device specification.
19	BID	IO7	AS3990 interface pin	Detailed data in device specification.
20	IN	CLK	AS3990 interface pin	Detailed data in device specification.
21	IN	P1.5	Reserved	Used in case external receiver enable control is needed.
22	-	nc		
23	SUP	5V3	5.3V supply	Used for display.
24	SUP	3V3	3.3V supply	Used for MCU supply, generated by AS3990 in the MCU support mode.
25	SUP	GND	Ground	
26	SUP	GND	Ground	
27	BID	OAD2	AS3990 pin	For test purposes.
28	BID	OAD	AS3990 pin	For test purposes.
29	BID	DAC	AS3990 pin	For test purposes.
30	BID	ADC	AS3990 pin	For test purposes.

Note1: Signal is used to inform the MCU software about the board configuration. At power on the MCU checks the status of this lines and sets the AS3990 registers accordingly. L: connect to ground, Z: high impedance, H: connect to 3.3V supply.

4.2 Host to Reader Board Protocol

(Informative Description)
The communication from host to reader is organized into frames. Each frame consists of 4 fields:

SOF (0x01)	Number of bytes	Number of bytes 2	Command + parameters

The communication starts with SOF (0x01). The second byte defines the number of bytes in the frame including SOF. The fourth byte is the command code, which is followed by parameters or data.

Command	Parameters	Example
0x01 Serial mode with SS	See below	
0x02 Serial mode without SS	See below	
0x0110 Write single register	Address, data, address, data...	01 0A 00 **01 10 15 67**
0x0111 Write continuous	Address, data, data...	01 0C 00 **01 11 13 67 46 A4**
0x0112 Read single register	Address, address, ...	01 0B 00 **01 12 01 0A 13**
0x0113 Read continuous	NR. of bytes to read, start address	01 0A 00 **01 13 05 03**
0x0199 Soft reset of circuit	NR. of bytes to read, start address	01 0A 00 **01 99**
0x01FF Exit serial mode	NR. of bytes to read, start address	01 0A 00 **01 FF**
0x10 Write single register	Address, data, address, data...	01 0A 00 **10 15 67**
0x11 Write continuous	Address, data, data...	01 0C 00 **11 13 67 46 A4**
0x12 Read single register	Address, address, ...	01 0B 00 **12 01 0A 13**

Command	Parameters	Example
0x13 Read continuous	NR. of bytes to read, start address	01 0A 00 **13 05 03**
0x20 Inventory round		01 08 00 2**0**
0x21 Read data	Bank, address, nWords, maskOffset, maskLen(bits), mask	01 10 00 **21 04 04 10 10 01 02 03 04**
0x22 Write data	Bank, address, word (2 bytes), maskOffset, maskLen(bits), mask	01 0F 00 **22 00 01 AA BB 08 08 00**
0x27 Save password	Password (3 bytes – 4 LSB bits of byte 3 are used), maskOffset, maskLen(bits), mask	01 0E 00 **27 AA BB CC 08 08 00**
0x99 Soft reset		01 08 00 99
0xFE Stand alone operation		01 08 00 **FE**
0xFF GUI operation		01 08 00 **FF** 0000

4.3 AS3990 demonstration and development board performances.

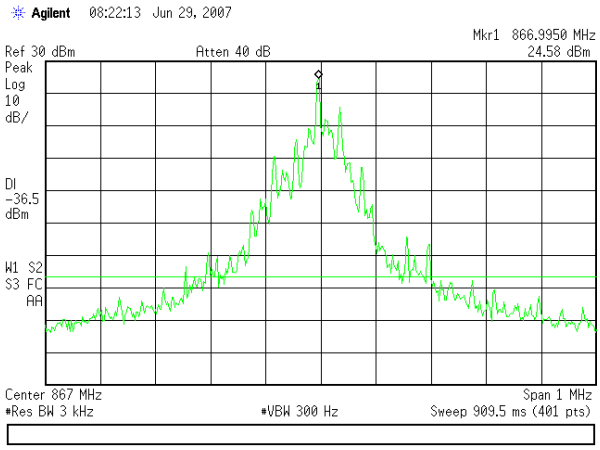
The demonstration and development system is supplied with DC supply. Optimum voltage is 8-9V. Current consumption is 500mA typically.

RF output power is 27dBm typically.
Carrier phase noise of the internal oscillator is typically –94dBc/Hz at 100 kHz offset.
ASK Modulation depth is 40dB typically.

Receiver sensitivity is set to –55dBm. Received I and Q analogue signals after gain and filter stages are presented.

Typical reliable operating range is 2m.

Typical modulated TX spectrum is shown on a picture below (Tari=25µs, PW=0.5, TX-one length=2).



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