Application Note 417

Title: **EM4094 Demo Board**

Product Family: **RFID**

Part Number: EM4094
Keywords: ISO15693 / ISO1443 Analog Front End Integrated Circuit. Contactless Identification
Date: October 13, 2003

Table of Contents

Glossary

AFE	Analog Front End
ASK	Amplitude shift keying
VCD	Vicinity coupling device (reader)
VICC	Vicinity integrated circuit card (tag)
Uplink	Reader to tag communication link
UID	Unique identifier

1. General Description

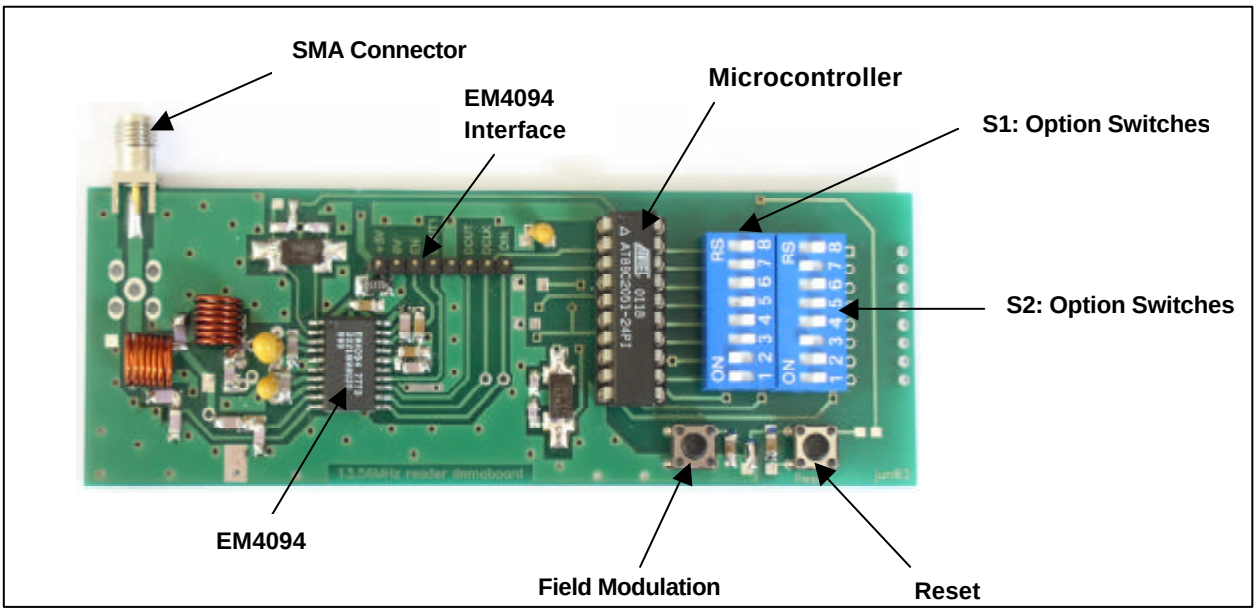


Fig. 1

The EM4094 Demo board comprises:

- ❑ EM4094 development board
- ❑ 50 Ohms RFID Antenna

2. Applications

The EM4094 Demo Board is a good introduction of the EM4094 base station functionalities. It is an easy way to start a new development with the EM4094 AFE.
The demo board allows the selection of all the EM4094 IC options. It permits also to see directly the influence of each IC parameter, for example, on the reading distance.

After a preliminary evaluation, one acquires a high knowledge level on the EM4094 features. Like this, the user is able to design its own application by using the EM4094 demo board.

3. Quick start

To get a first contact with the EM4094 and observe, for example, the IC demodulation capabilities, one has to follow the next actions:

- ❑ Connect the 50 Ohms RFID antenna on the SMA connector.
- ❑ On the EM4094 demo board interface, apply a stable 5V DC supply voltage (5V / 150mA).
- ❑ On the EM4094 interface, set EN input to a high level.
- ❑ Select the EM4094 option bits by S1 & S2 row switches
- ❑ To send continuously an ISO15693 Inventory command, set switch number 8 of S2. This mode is validated without an external reset.
- ❑ Plug an oscilloscope probe on the DOUT EM4094 interface.
- ❑ Place a VICC in front of the 50 Ohms RFID antenna.
- ❑ Observe, on the oscilloscope, the data stream sent by the VICC.

To increase the reading distance performance, one has the possibility to change the EM4094 internal options. For such operation, please, refer to the Option bits in the EM4094 datasheet or/and to chapter 4.1.3 of this application note.

4. Functional Description

4.1 EM4094 Demo Board Schematic

As showed in figure 2, the EM4094 demo board is mainly built around the EM4094 AFE.

The EM4094 development board integrates the following elements:

- ❑ The EM4094 13.56MHz Base station
- ❑ 8 bit microcontroller
- ❑ 2 row of 8 switches for EM4094 Options bits selection
- ❑ Reset switch
- ❑ Field Modulation switch
- ❑ An external interface to connect the customer application (called EM4094 Interface).

4.1.1 EM4094 AFE description

The EM4094 is an integrated analog system for 13.56MHz RFID reader system. It is highly versatile so it can be used in different reader systems having sub-carrier frequencies from 212kHz to 848kHz, hence covering ISO 14443 and ISO 15693 standards.
The adaptability is achieved using a 3 wires serial interface to program the system option bits.

The IC transmitter generates 200mW output power into 50Ω load and is capable of OOK or ASK modulation. For more information on the AFE, please, refer to the EM4094 data sheet.

4.1.2 8 bit microcontroller
The on board microcontroller has a double function:

- At power up or if the reset switch is activated, the microcontroller reads S1 and S2 options switches and sends their contents on the EM4094 Serial Protocol Interface to configure the EM4094 AFE options. This communication can observed directly on the EM4094 interface:
  - ➔ DIN: SPI data input
  - ➔ DCLK: SPI clock input

  For a complete serial interface description, please, refer to the EM4094 datasheet at chapter 4.11.

- Send an ISO15693 Inventory command to the VICC. The Uplink communication can be observed on the EM4094 demodulation input (DIN).

4.1.3 Options switches
The 16 switches (two 8 switches rows) permits to change the EM4094 internal configuration according to the IC datasheet (Chapter 5, Option bits).
The EM4094 options switches are configured as following on S1 switches row:

Switches	EM4094 Option bits	Remarks
1	Power up flag	Bit1 in the EM4094 datasheet. Should be On for normal mode
2,3,4	Modulation Index Selection	Bit 1,2 and 3 in the EM4094 datasheet
5	Short Circuit protection enable	Bit 5 in the EM4094 datasheet
6,7,8	Receiver gain selection	Bits 11,12 and 13 in the EM4094 datasheet

The EM4094 Options switches are configured as following on S2 switches row:

Switches	EM4094 Option bits	Remarks
1,2	Receiver sub-carrier selection	(note 1)
3	AM/PM setting	Bit 14 in the EM4094 datasheet
4	AGC on/off Selection	Bit 15 in the EM4094 datasheet (note 2)
5	Output selection BPSK	Bit 22 in the EM4094 datasheet
6	BPSK automatic frequency adjust	Bit 23 in the EM4094 datasheet
7	Output selection analogue	Bit 24 in the EM4094 datasheet
8	Inventory Command	(note 3)

4.1.4 Reset switch
It is used to send the option bit switches selection to the EM4094 AFE. Every time, one wants to use different option bits setting, the RESET switch needs to be activated to configure the EM4094 with the new option bits values.

4.1.5 Field Modulation switch
It is used to manually modulate the electromagnetic field. Modulation index, set by option bits 2,3 and 4, can be measured while pressing the mod key. Also impedance matching filter can be checked by this way.
While MOD is pressed (field stop, option bit 2 = high and option bits 3 & 4 = low), the input impedance at the SMA connector (transmitter output impedance) can be measured. For a correct matching, the output impedance should be 50Ω.

4.1.6 EM4094 Interface
The EM4094 interface permits to connect an external board (customer application) to drive/read the data stream sent/receive to/from the EM4094 AFE.
The EM4094 interface is composed by:

- ❑ +5V : Positive power supply (note 5)
- ❑ 0V : Ground (note 5)
- ❑ EN : EM4094 Enable input (note 6)
- ❑ DOUT1:BPSK bit clock / analogue receive output.
- ❑ DOUT : Digitized receive output / BPSK bit stream output.
- ❑ DLCK : SPI data clock
- ❑ DIN : SPI data input

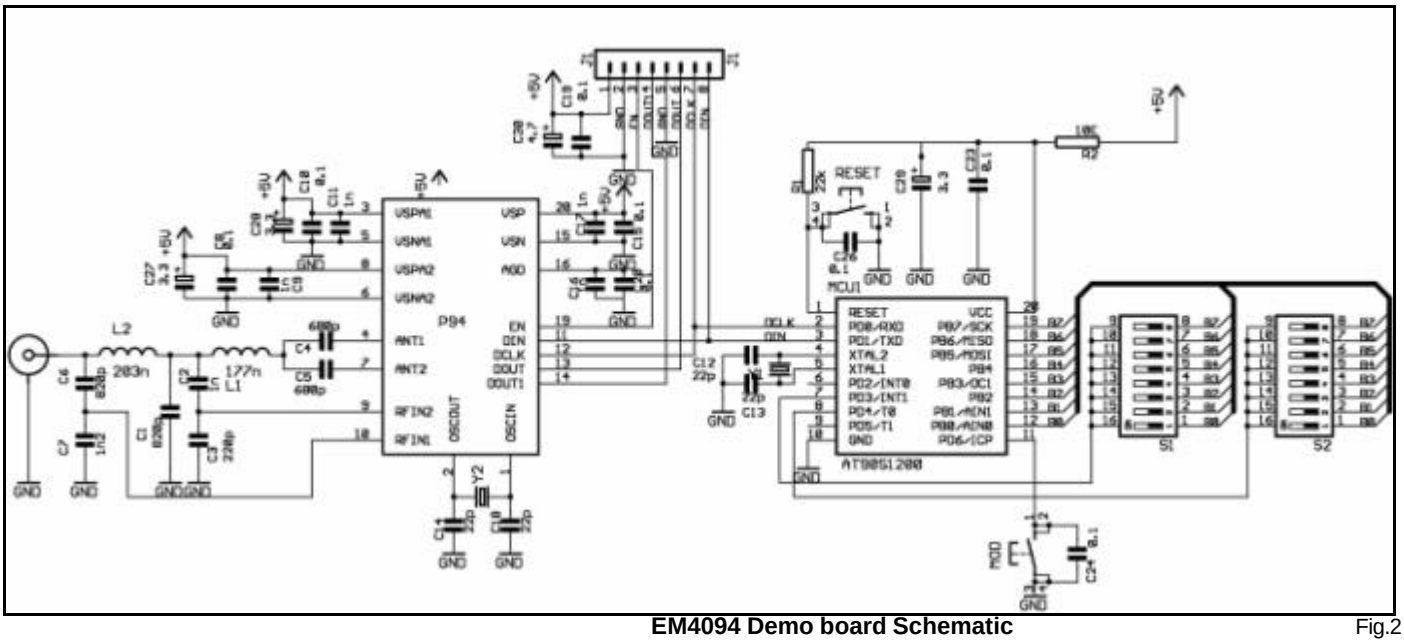
Note 1: Receiver sub carrier selection / Filter setting

SW1	SW2	Sub-carrier Frequency	Bit 8	Bit 9	Bit 10
0	1	212kHz	0	1	1
0	0	424kHz	1	0	0
1	0	848kHz	0	0	0

Note 2: Should be set to high for AGC mode. To enter in the AGC mode, do not place a VICC in the field at power up (to avoid a continuously data emitting tag). If such tag is inside the electromagnetic field at power up, the AGC may lock.

Note 3: ISO15693 command mode. This is not an EM4094 option bit. It is an EM4094 demo board operating mode. When this switch is set (on), the EM4094 demo board transmits continuously an ISO15693 Inventory command (according to ISO15693-3) to get the VICC unique serial number. By placing an EM4035 or/and EM4135 in front of the reader antenna, the VICC unique identifier can be directly observed on the EM4094 DOUT output. This mode is entered directly without the RESET key.

Note 4: *General note on the EM4094 option bits*
Some option bits in the EM4094 are related to the schematic configuration (RF driver selection, driver phase selection, external clock source/internal oscillator, oscillator gm selection). These bits are not available in the EM4094 demo board, not to cause wrong settings. Also option bits used for testing and most bits controlling the AGC modes are not available. The AGC is set to the fastest possible mode.



EM4094 Demo board Schematic Fig.2

4.2 EM4094 Demo Board description

The EM4094 demo board is composed of:

- RF interface
- Microcontroller

4.2.1 RF Interface description

The RF part is built around the EM4094 and the LC impedance matching filter. The matching circuit transforms impedance from 5Ω (EM4094 output impedance) in two steps to 50Ω coaxial cable impedance. The same circuit is used for AM to PM.

The network transforms AM at one RF input to PM on the other RF input and vice versa. When sub-carrier type transponder is used typically both types of the modulation are partly present at both RF inputs. The only difference is in amplitude and shape.
When the signal at one input is mostly in PM modulation, it is seen significantly smaller than on the other one or to distorted to correct recognition (duty ratio or double frequency of subcarrier). In that cases the other input gives reliable data.

4.2.2 Microcontroller interface description

16 dipswitches are connected on the microcontroller inputs for the EM4094 option bits selection.
2 switches are also connected to the 8-bit microcontroller: RESET and MOD keys.

5. EM4094 Demo Board Operation Modes Examples

In chapters 5.1 to 5.4, coding or mode mentions are related to tag's modulation.

5.1 Manchester OOK coding, 424kHz Sub-Carrier

Figure 3 shows the analogue output signal (on DOUT1 output) in normal mode. The VICC, which is inside the field, is configured as following:

- Modulation Index: OOK
- Sub-Carrier: 424kHz.

Option bits setting are selected as following:
S1 switches:

1	high (on)
2,3,4,5,6,7,8	low (off)

S2 switches:

1,2	filter setting	low
3	AM/PM	high
4	AGC	high
5,6	BPSK	low
7	analogue out	high
8	ISO	low

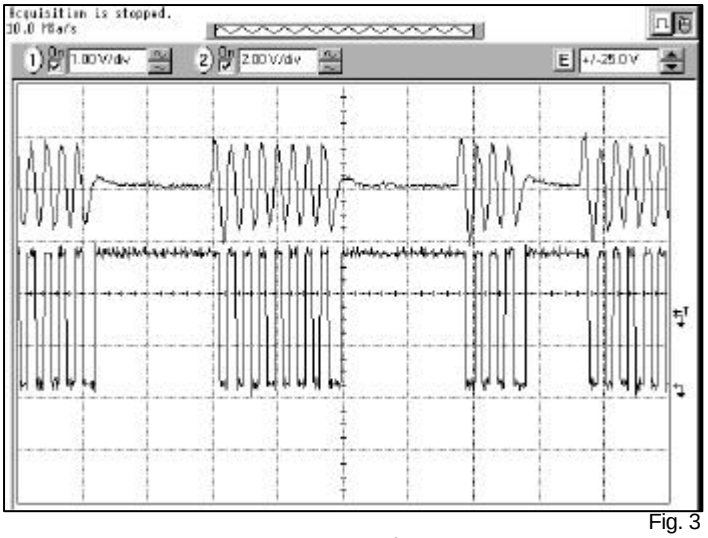


Fig. 3

- Upper trace: DOUT1 Analogue Output
- Bottom trace: DOUT Digital Output
- Transponder IC configured as following:
  - Modulation Index: OOK
  - Sub-Carrier: 424kHz
  - Pseudo random sequence

5.2 BPSK encoding, 848kHz Sub-Carrier

Figure 4 shows the analogue output signal (on DOUT1 output) in normal mode. The VICC, which is inside the field, is configured as following: BPSK mode, 848kHz.

Option bits setting are selected as following:

S1 switches:

1	power up	high (on)
2,3,4,5,6,7,8		low (off)

S2 switches:

1	filter setting	high
2	filter setting	low
3	AM/PM	high
4	AGC	high
5,6	BPSK	low
7	analogue out	high
8	ISO	low

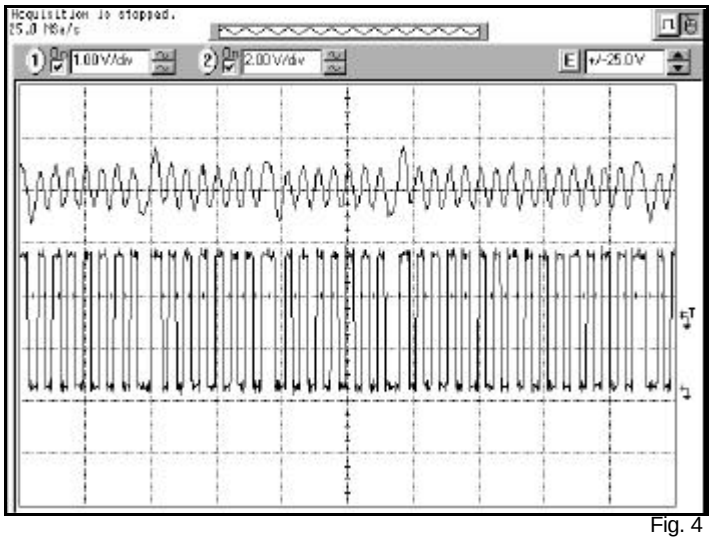


Fig. 4

- Upper trace: analogue output (DOUT1)
- Bottom trace: digital output (DOUT)
- Transponder in the field is BPSK, 848kHz, pseudo random sequence

5.3 BPSK mode: Data decoding

Figure 5 shows a BPSK operating mode with analogue output signal (DOUT1). Transponder, which is inside the field, is configured as following: BPSK mode, Sub-Carrier: 848kHz, pseudo random sequence

Option bits setting are selected as following:

S1 switches:

1	power up	high (on)
2,3,4,5,6,7,8		low (off)

S2 switches:

1	filter setting	high
2	filter setting	low
3	AM/PM	high
4	AGC	high
5	BPSK mode	high
6	BPSK adj.	low
7	analogue out	high
8	ISO	low

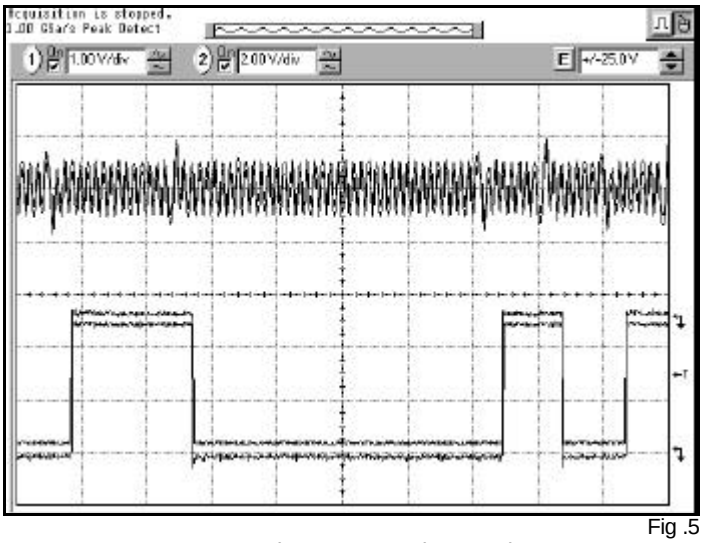


Fig .5

- Upper trace: analogue output (DOUT1)
- Bottom trace: digital output (DOUT) BPSK decoded data
- Transponder in the field is BPSK, 848kHz, pseudo random sequence

5.4 BPSK mode: BPSK Clock and Data outputs

Figure 6 presents operation in BPSK mode with BPSK CLOCK output. Transponder, which is inside the field, is configured in BPSK mode, sub-carrier 848kHz, pseudo random sequence.

Option bits setting are selected as following:

S1 switches:

1	power up	high (on)
2,3,4,5,6,7,8		low (off)

S2 switches:

1	filter setting	high
2	filter setting	low
3	AM/PM	high
4	AGC	high
5	BPSK mode	high
6	BPSK adj.	low
7	analogue out	low
8	ISO	low

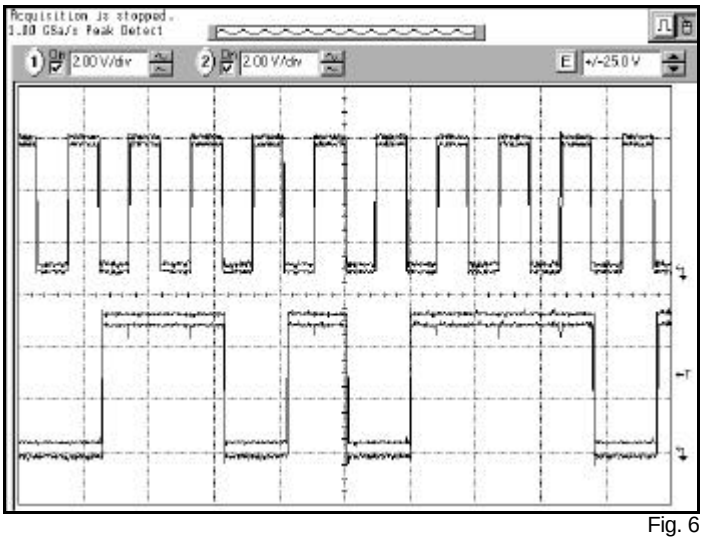


Fig. 6

- Upper trace: digital output (DOUT1) BPSK clock
- Bottom trace: digital output (DOUT) BPSK decoded data
- Transponder in the field is BPSK, 848kHz, pseudo random sequence.

5.5 ISO15693 mode: Analogue and Digital outputs

Figure 7 & 8 represent operations in ISO15693 mode The oscilloscope plots show the analogue output signal when a tag is inside and outside the field.

On figure 7, there is no transponder inside the field. Transitions on the plot are caused by reader modulation when sending ISO15693 command.

On figure 8, an EM4135 VICC is placed inside the field. The first burst is caused by reader modulation (as on the first plot). The second burst (~300µs later) corresponds to the transponder response.

Option bits setting are selected as following:

S1 switches:

1	power up	high (on)
2	ASK 100%	high
3,4,5,6,7,8		low (off)

S2 switches:

1	filter setting	low
2	filter setting	low
3	AM/PM	high
4	AGC	high
5,6	BPSK	low
7	analogue out	high
8	ISO	high

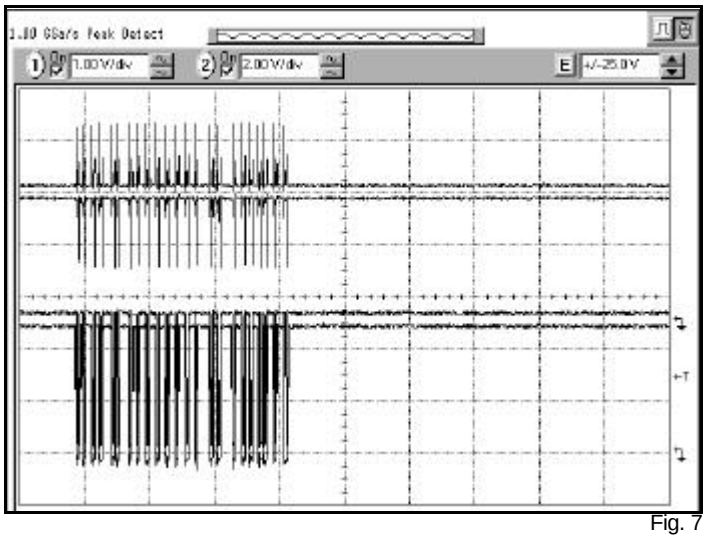


Fig. 7

- Upper trace: analogue output (DOUT1)
- Bottom trace: digital output (DOUT)
- There is no transponder in the field, reader modulation pulses are seen on the digital output.

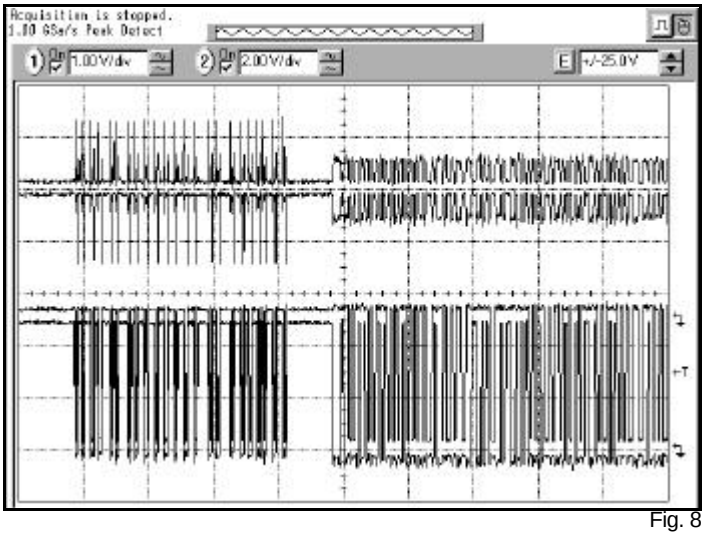


Fig. 8

- Upper trace: analogue output (DOUT1)
- Bottom trace: digital output (DOUT)
- Transponder in the field is ISO, reader modulation pulses are seen in the left half of the plot, transponders response is seen on the right half of the plot.

5.6 ISO15693 mode: Field Modulation

Figure 9 & 10 represent the electromagnetic field reader's modulation. ISO15693 command pulses are observed via a coil inside the field.

On figure 9, the modulation index is set to 100% (OOK). On figure 10, the modulation index is set to 16% ASK.

Option bits setting are selected as following:

S1 switches:

1	power up	high (on)
2	modulation	high
3	modulation	low (off)
4	mod. 100%	low
4	mod. 16%	high
5,6,7,8		low

S2 switches:

1	filter setting	low
2	filter setting	low
3	AM/PM	high
4	AGC	high
5,6	BPSK	low
7	analogue out	high
8	ISO	high

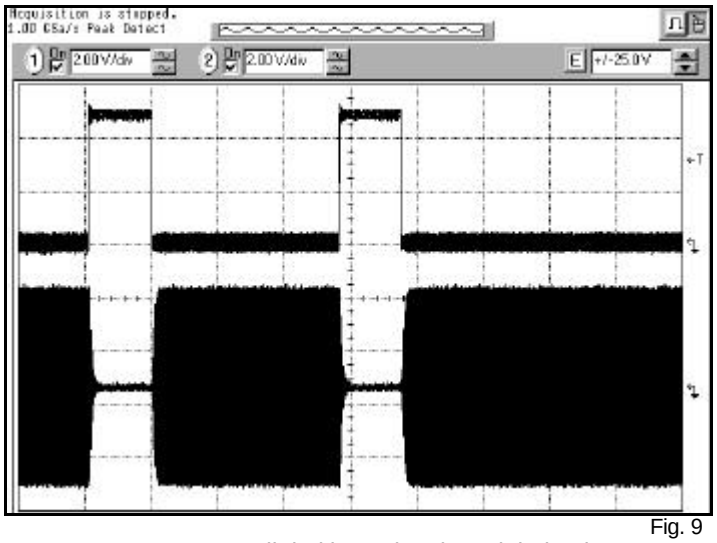


Fig. 9

- Upper trace: digital input (DIN) modulation input
- Lower trace: transmitted field
- Reader modulation is set to OOK (100% AM)

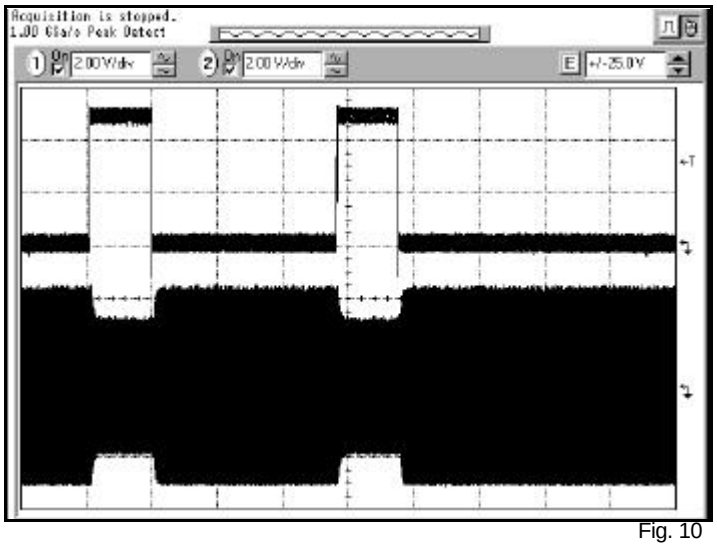


Fig. 10

- Upper trace: Digital input (DIN) modulation input
- Lower trace: Transmitted field
- Reader modulation is set to 16% ASK

6. Reader antenna

The antenna supplied with the EM4094 demo board is appropriate for communication with a card size transponder. For different transponder size, the reader coil has to be redefined.

The EM4094 demo board antenna is designed as following (refer to Figure 12):

- ➔ 2 turns on the PCB.
- ➔ Coil diameter=12cm
- ➔ Q factor = 23 setted by the 3.3kΩ parallel resistor (R1=3.3kΩ)
- ➔ Capacitive impedance matching network composed from 120pF+8.2pF/680pF+56pF capacitors (calculated 124.5pF/727pF).

The normalized antenna input impedance is 1.1+j0.06 in the environment, at room temperature. At high temperature the impedance changes to 1.04+j0.29, at low temperature to 0.79-j0.33.
Figure 11 presents the impedance measurement diagram (sweep 13MHz to14MHz, normalized impedance at 13.56MHz is 1.03+j0.08).

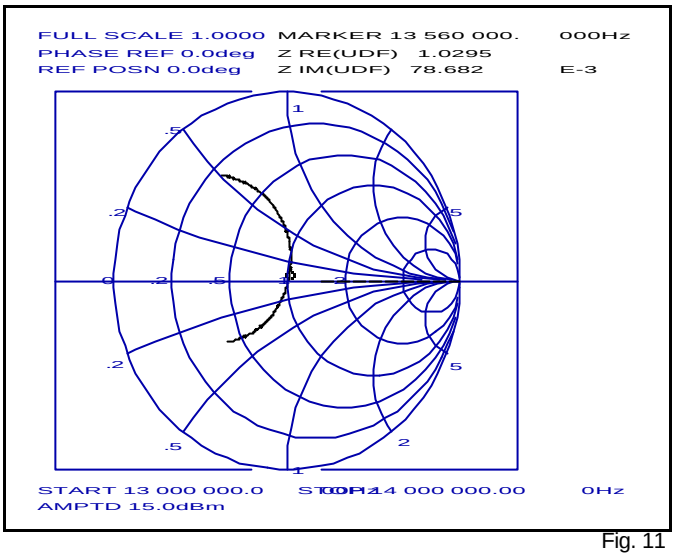


Fig. 11

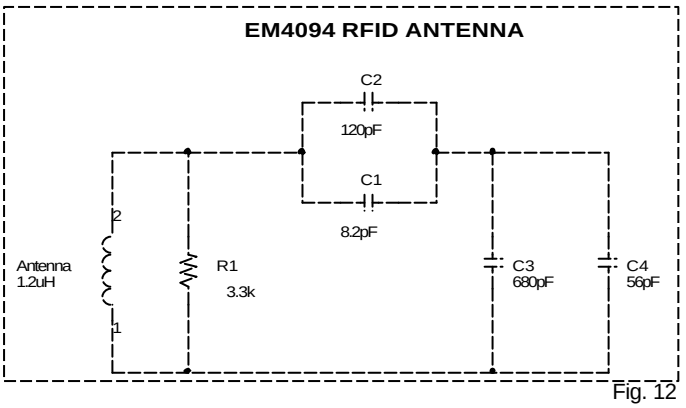


Fig. 12

7. PCB Layout design

The two next figures show the EM4094 Demo Board Bottom and Top layers.
The PCB layout should be designed in double sided with bottom layer mainly untouched. During the PCB layout, please, try to follow the above rules:

- All connections should be as short as possible.
- Avoid connecting the IC analog ground (VSS pad) to VSSA1 & VSSA2 pads due to the high current for antenna drivers, otherwise there is a risk of noise increasing in the system.
- VDD and VDDA power supply lines should be de-coupled and separately connected to 5V supply.
- The connection from impedance matching circuit to the antenna connector should be a 50Ω micro strip line.

TOP Layer:

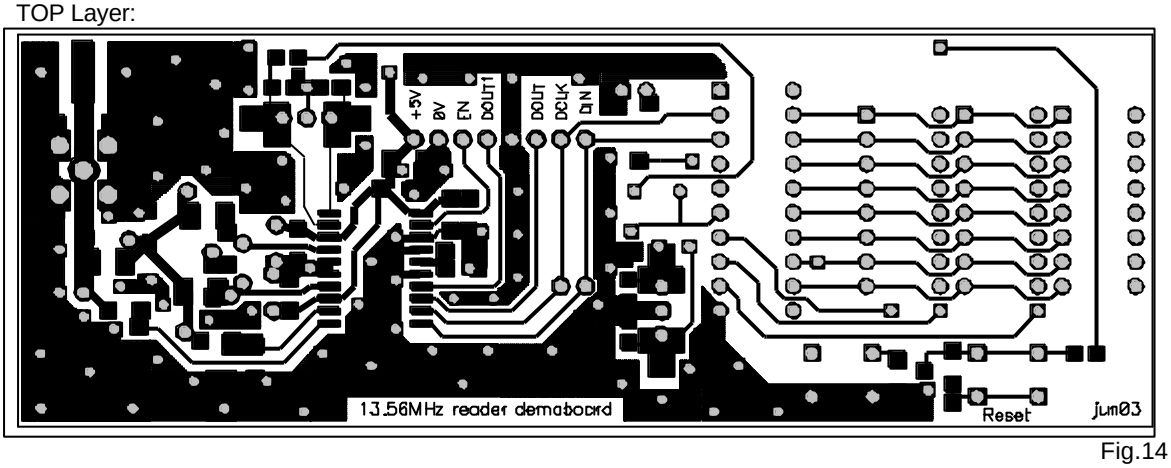
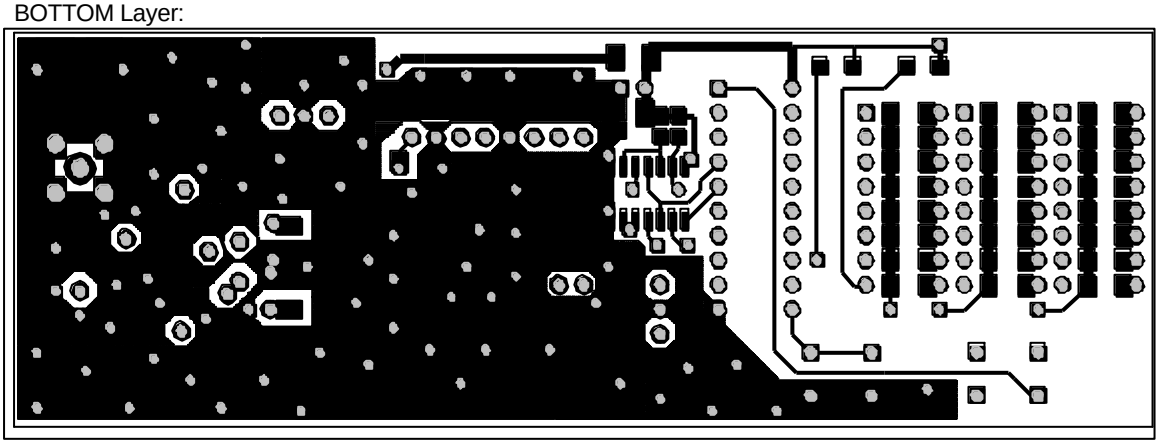


Fig.14

BOTTOM Layer:



8. Ordering information

Please order the following part number:

Part Number	Name
EMDB406	EM4094 Demo Board