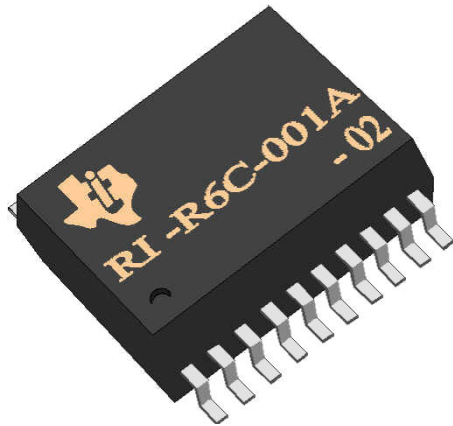




# HF Training

## Multi-Protocol Transceiver IC



**RI-R6C-001A**

## ▶ Multi-Protocol Transceiver IC

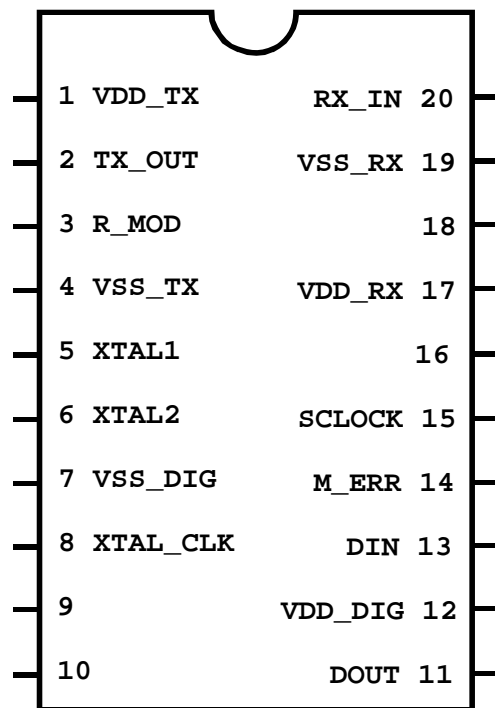
- Complies with Tag-it™ protocol
- Complies with ISO 15693-2 .
- Complies with ISO 14443-2 (Type A)
- Supports “Transparent Mode”

## ▶ Functionality

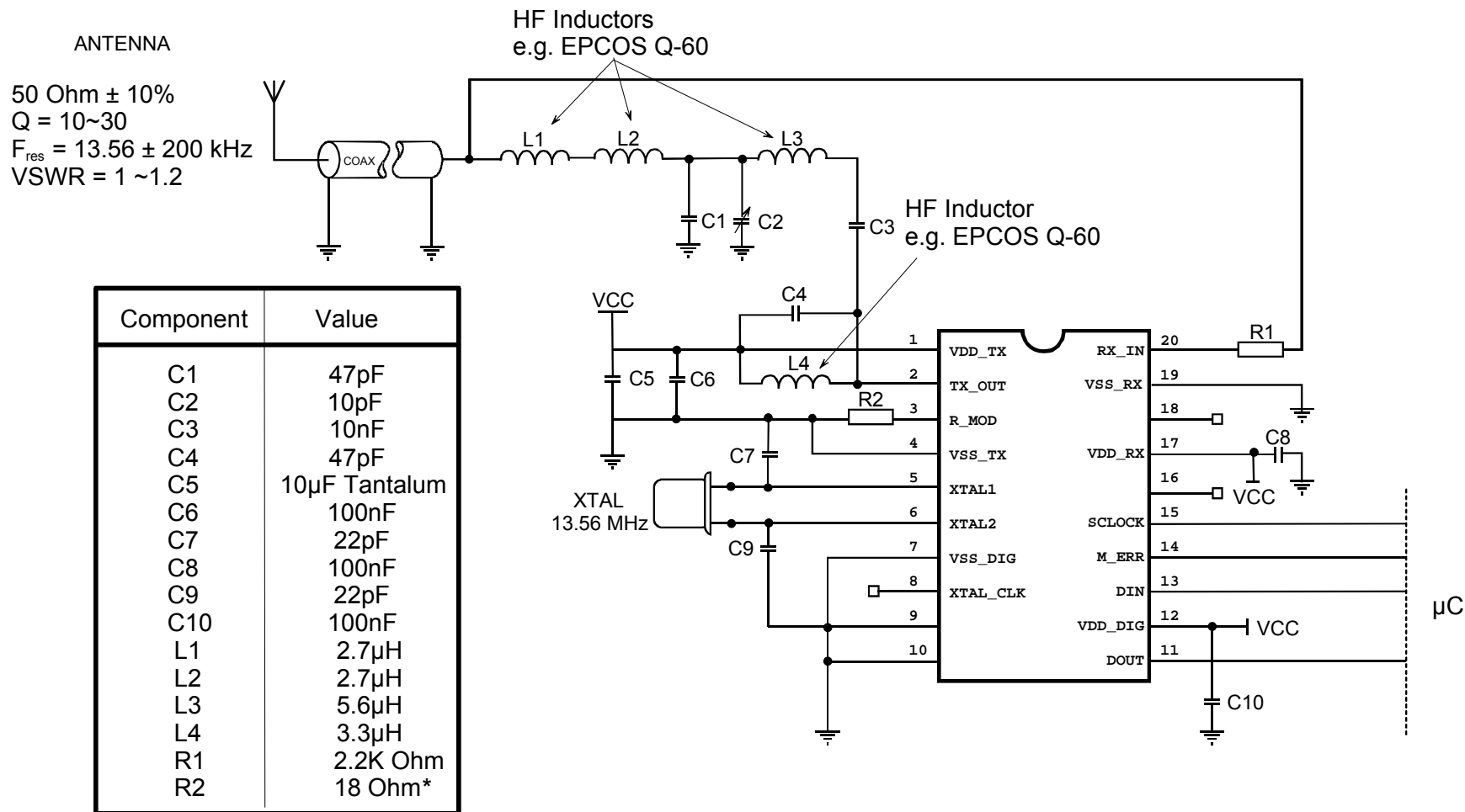
- Short to mid range applications
- Low additional component count
- Low power consumption
- 200 mW RF power into 50 Ohms
- Serial interface



## ► Transceiver IC Pinouts



1	VDD_TX	Transmitter power supply
2	TX_OUT	Output transistor drain connection
3	R_MOD	External resistor to set 10% modulation depth mode
4	VSS_TX	Transmitter section ground
5	XTAL1	Pin 1 of Xtal resonator
6	XTAL2	Pin 2 of Xtal resonator and external system clock input
7	VSS_DIG	Digital section ground
8	XTAL_CLK	Buffered output of Xtal oscillator
9	not used	To be grounded for normal operation
10	not used	To be grounded for normal operation
11	DOUT	Data output for serial link
12	VDD_DIG	Digital section power supply
13	DIN	Data input for serial link
14	M_ERR	Manchester Protocol error flag
15	SCLOCK	Serial link clock
16	not used	To be left unconnected for normal operation
17	VDD_RX	Receiver section power supply
18	not used	To be left unconnected for normal operation
19	VSS_RX	Receiver section ground
20	RX_IN	Receiver input



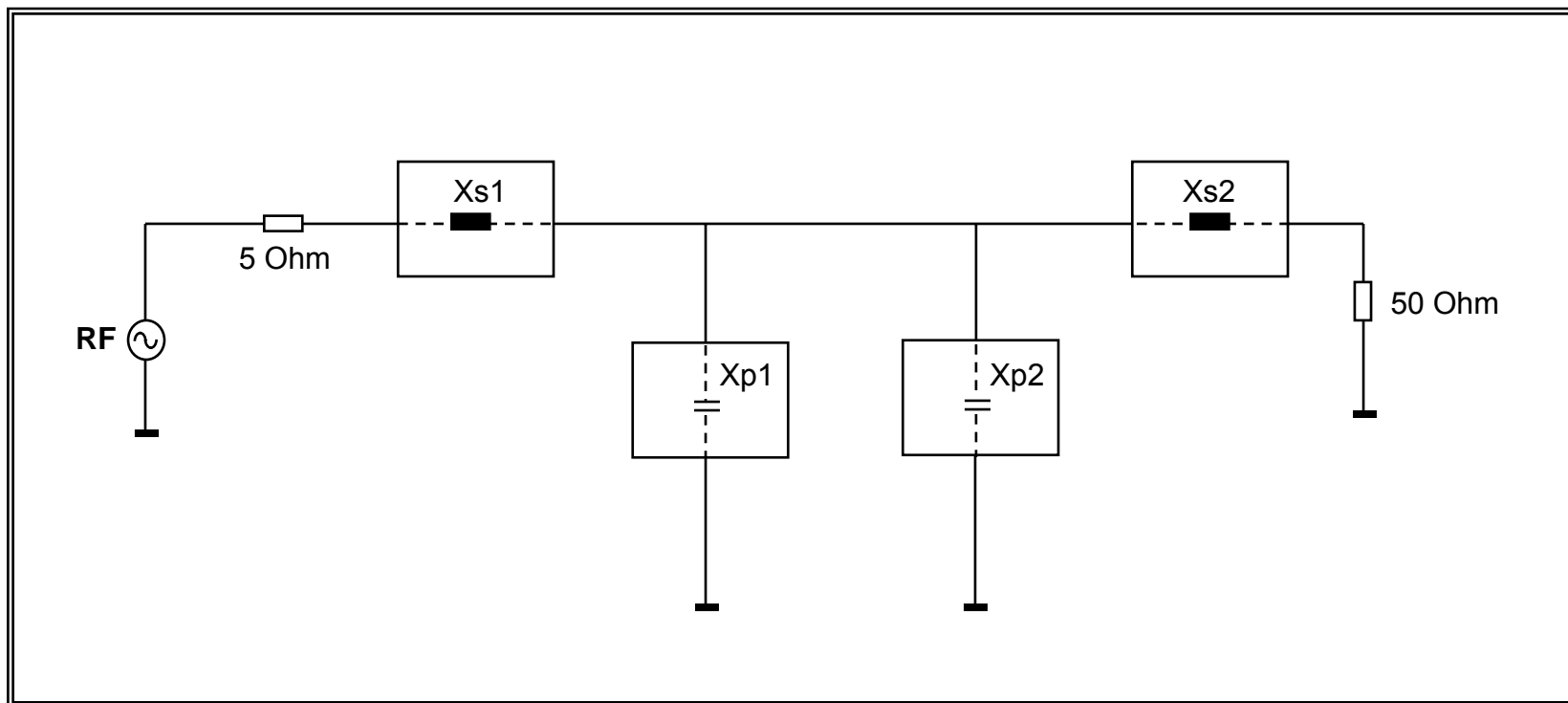
\* 18 Ohm = 20% Modulation (Recommended)  
12 Ohm = 10% Modulation

## Improved Matching Circuit



## ▶ Matching circuit calculation:

- Schematic of a double L matching circuit = T matching network





## Calculation:

$$R_s = 5\Omega \quad Q = 40 \quad R_l = 50\Omega \quad f = 13,56\text{Mhz}$$

$$R = R_s \cdot (Q^2 + 1) \quad R = \text{Virtual resistance (instead of } X_{p1} // X_{p2} \text{)}$$

$$X_{s1} = Q \cdot R_s$$

$$L1 = \frac{X_{s1}}{2 \cdot \pi \cdot f} \quad L1 = 2,3 \mu\text{H}$$

$$X_{s2} = Q^2 \cdot R_l$$

$$L2 = \frac{X_{s2}}{2 \cdot \pi \cdot f} \quad L2 = 7,4 \mu\text{H}$$

$$X_{p1} = \frac{R}{Q} \quad Q^2 = \sqrt{\frac{R}{R_l}} - 1 \quad X_{p2} = \frac{R}{Q^2} \quad X_p = \frac{X_{p2} \cdot X_{p1}}{X_{p2} + X_{p1}}$$

$$C = \frac{1}{2 \cdot \pi \cdot f \cdot X_p} \quad C = 77 \text{pF}$$



## Caution:

- Check the resonant frequency of the inductor!
- Use only low tolerance components for the matching network to achieve optimum SWR!

### For Example:

**L1 and L2:      +/-10% tolerance**

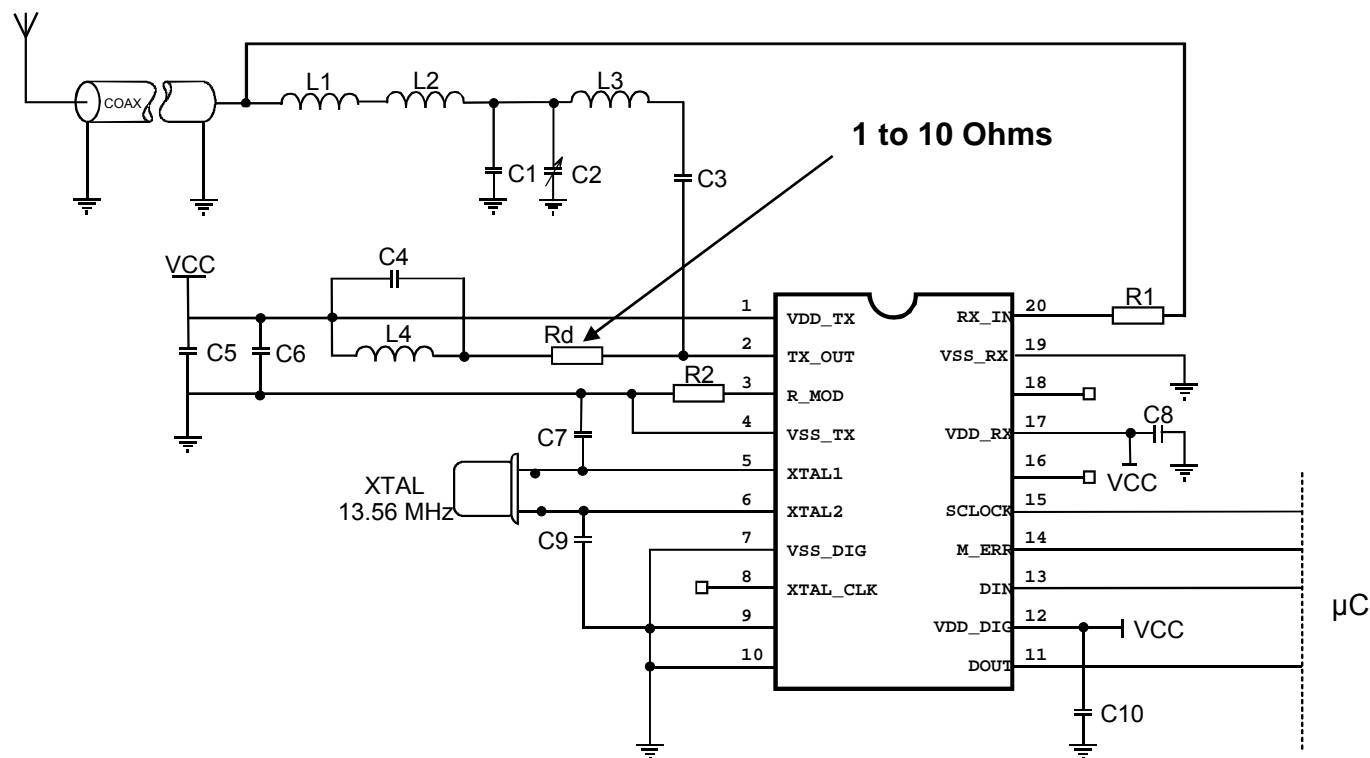
**C2:                +/-2% tolerance, temp. coefficient +/-30ppm COG (Murata),**

**Bad choice:      Z5U material   +22/-85% tolerance!!!**



► **Suggested improvements to the application circuit:**

- Add a resistor between L4/C4 and TX\_OUT/C3

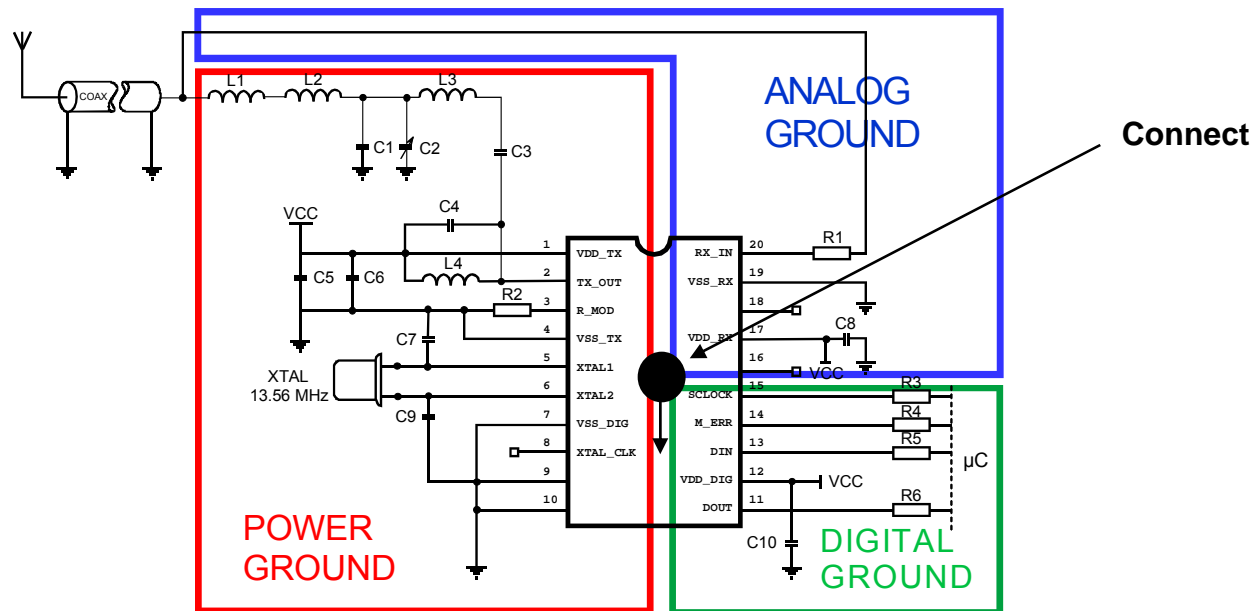


- This action improves the EMC due to the decrease of the slew rate of the output MOS-FET.





- Further decoupling of VCC and Interface lines with series resistance
  - » Very cheap improvement regarding noise behavior
- Split the receive and transmit ground-planes



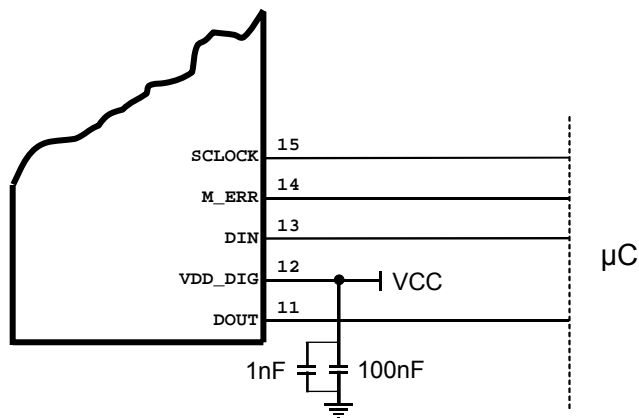
» Better de-coupling of receiver

- Avoid using RS232 drivers that use switching frequencies in the range of 424 to 484 kHz or their harmonics (e.g. 141 kHz x 3 = 424 kHz)

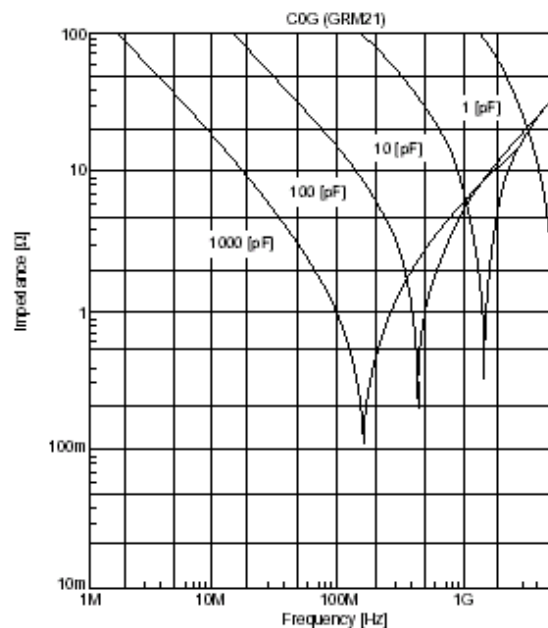


- Add 1 nF ceramic capacitors in parallel to the C6, C8 and C10, 100 nF blocking capacitors at the IC VDD pins
  - » These capacitors should be placed closest to the supply pins!
  - » Ceramic capacitors have a much better HF noise filtering behavior due to their low inductance.

### ■ Impedance-Frequency Characteristics



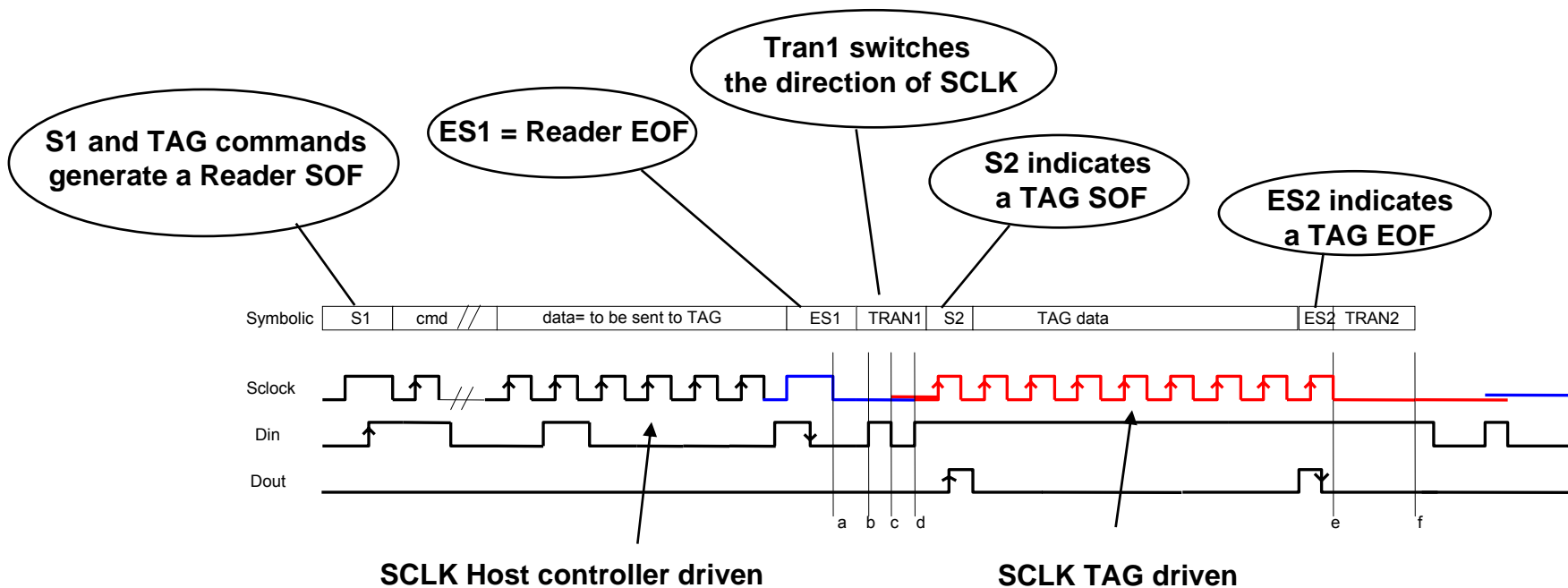
Example (C10)





► **Basic communication structure:**

**Basic Request / Response**

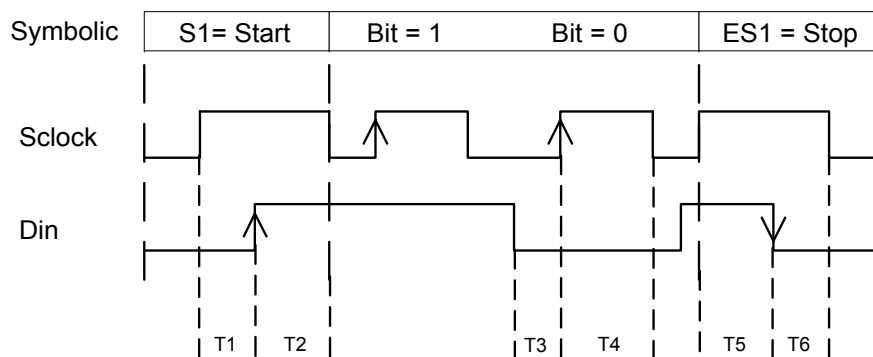




► **First steps after assembly of a prototype board:**

1. **Check soldering and schematic**
2. **Switch on power supply and check supply voltages**
3. **Check timing!**

**Definitions**



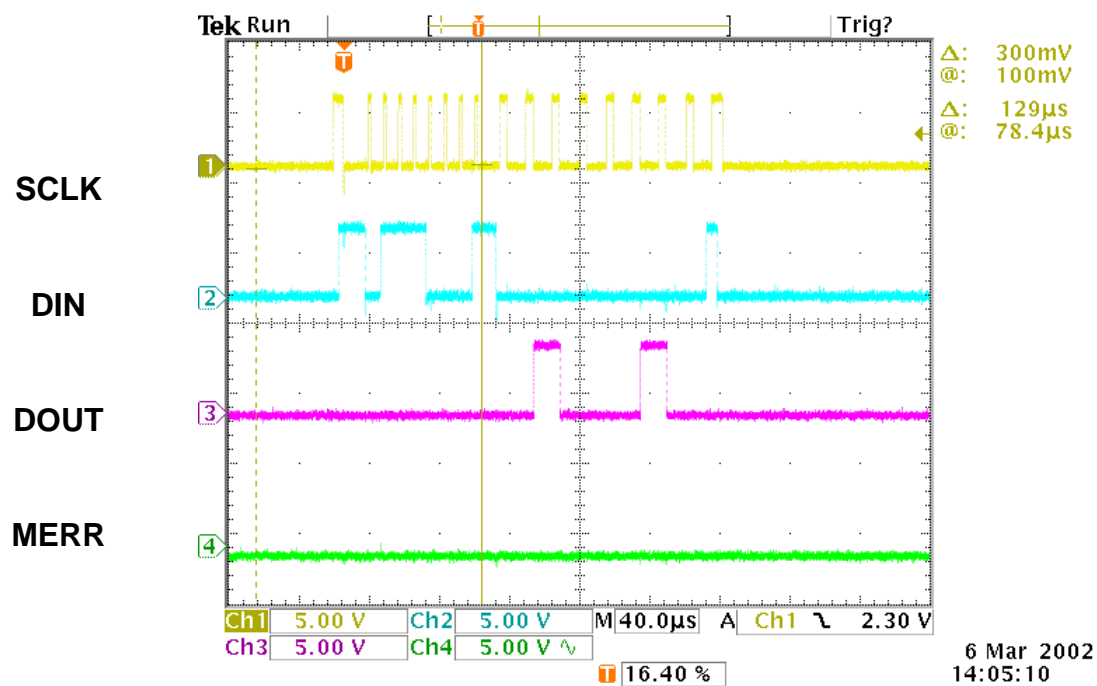
**Minimum timings**

T1: 300ns	T4: 600ns
T2: 300ns	T5: 300ns
T3: 66ns	T6: 300ns



## 4. Read configuration register 0x71<sub>hex</sub> (MSB first)

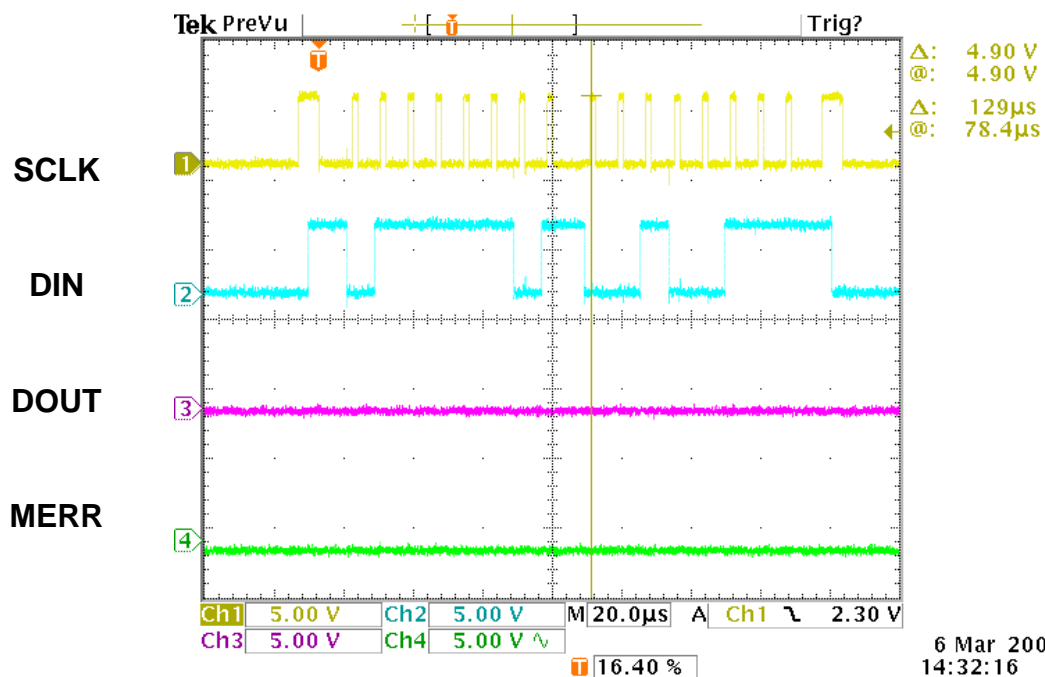
Result = **0x22** (MSB first)





## 5. Write to configuration register 0x7D<sub>hex</sub> (MSB first)

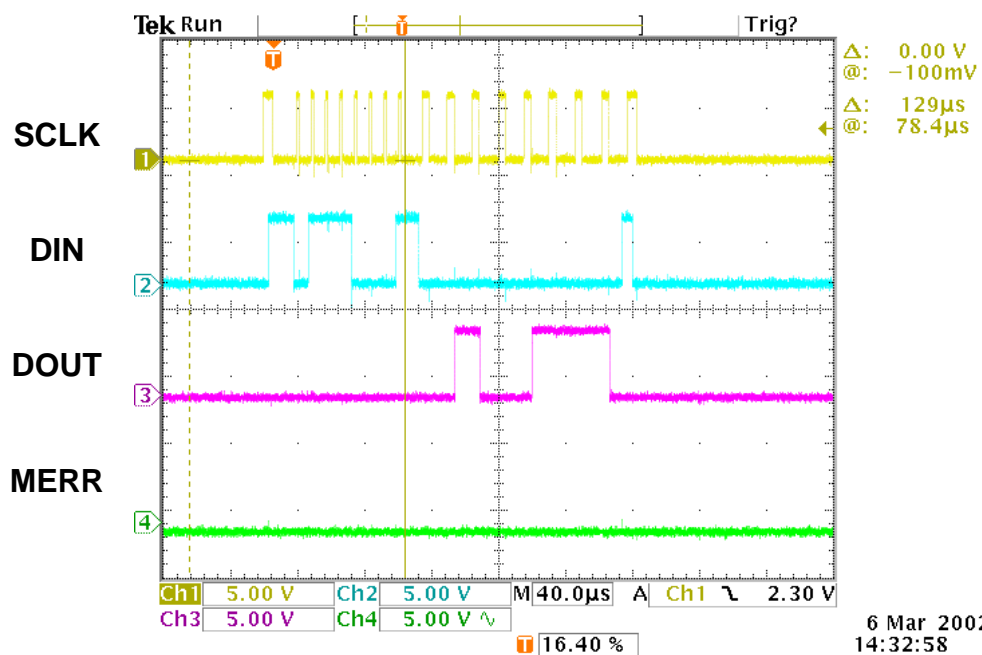
Content = **0x27** (MSB first)    ISO 15693 / down link 1 out of 4, 100% modulation, one subcarrier (ASK) high data-rate (~26 kb), Manchester decoder disabled





## 6. Read configuration register 0x71<sub>hex</sub> (MSB first)

Result = 0x27 (MSB first)

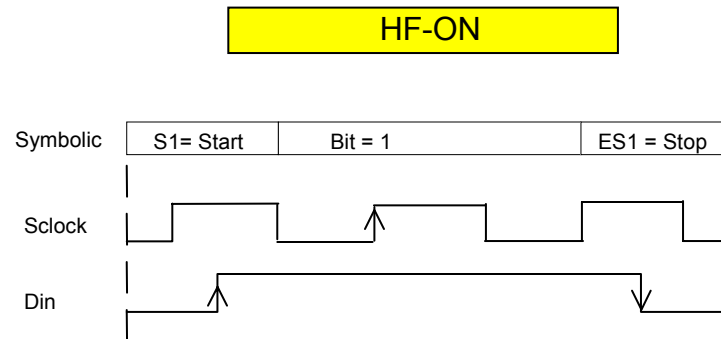


6 Mar 2002  
14:32:58



## 7. Switch on HF:

This operation must be performed first, otherwise SOF of the reader is not modulated properly.







## 8. Send a read TAG command (e.g. get Inventory)

### ISO Command Set:

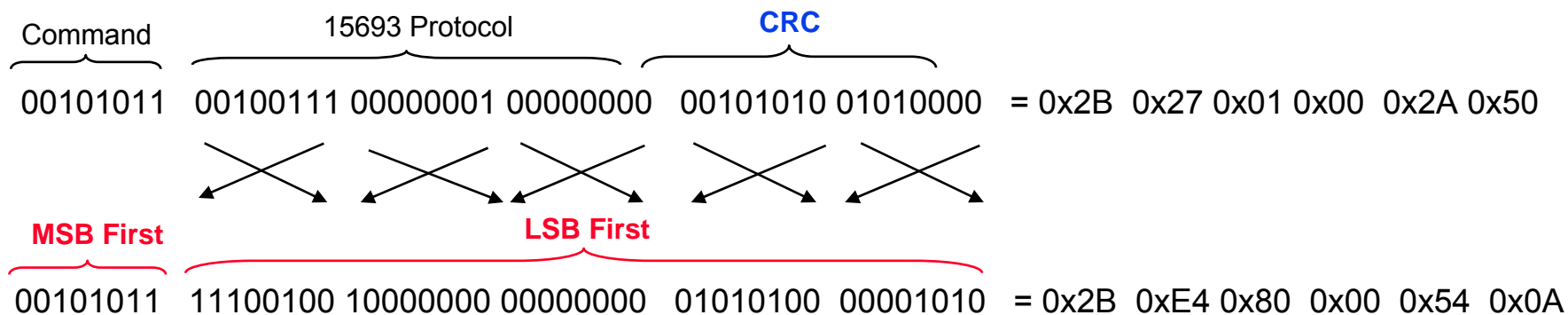
Command Code		Function	Request Mode						Opt. Flag
Hex	Binary (LSB)		Inven-tory	Addr.	Non Addr.	Select	AFI		
<b>ISO15693 Mandatory Commands</b>									
0x00	0000 0000	RFU	-	-	-	-	-	-	
0x01	0000 0001	Inventory	√	-	-	-	√	0	
0x02	0000 0010	Stay Quiet	-	√	-	-	-	0	
0x03-0x1F	0000 0100	RFU	-	-	-	-	-	-	
<b>ISO15693 Optional Commands</b>									
0x20	0010 0000	Read_Single_Block	√	√	√	√	√	0/1	
0x21	0010 0001	Write_Single_Block	-	√	√	√	-	-/1	
0x22	0010 0010	Lock_Block	-	√	√	√	-	-/1	
0x23	0010 0011	Read_Multi_Blocks	√	√	√	√	√	0/1	
0x24	0010 0100	Write_Multi_Blocks	-	-	-	-	-	-	
0x25	0010 0101	Select_Tag	-	√	-	-	-	0	
0x26	0010 0110	Reset_to_Ready	-	√	√	√	-	0	
0x27	0010 0111	Write_AFI	-	√	√	√	-	-/1	
0x28	0010 1000	Lock_AFI	-	√	√	√	-	-/1	
0x29	0010 1001	Write_DSFD	-	√	√	√	-	-/1	
0x2A	0010 1010	Lock_DSFD	-	√	√	√	-	-/1	
0x2B	0010 1011	Get_System_info	√	√	√	√	√	0	
0x2C	0010 1100	Get_M_Blks_Sec_St	√	√	√	√	√	0	
0x2D-0x9F	0010 1101	RFU	-	-	-	-	-	-	
<b>TI Custom Commands</b>									
0xA0	1010 0000	RFU	-	-	-	-	-	-	
0xA1	1010 0001	RFU	-	-	-	-	-	-	
0xA2	1010 0010	Write_2_Blocks	-	√	√	√	-	-/1	
0xA3	1010 0011	Lock_2_Blocks	-	√	√	√	-	-/1	
0xA4-0xDF		RFU	-	-	-	-	-	-	
<b>TI Proprietary Commands</b>									
0xE0-0xFF		RFU	-	-	-	-	-	-	



## ► Inventory Command Sequence:

<b>Calculate CRC on these bytes</b>	{	<b>0x2B</b> (Command, Transceiver)	ISO 15693, 1 out of 4, 100% modulation, FM, high data-rate
		<b>0x27</b> , (Request flags):	FM, <b>high data-rate</b> , use <b>table 5 of ISO-spec</b> , no protocol format extension, AFI not present, <b>1 slot</b> , <b>Option flag = 0</b> , <b>RFU = 0</b> (see ISO 15693-3 for details)
		<b>0x01</b> , (Command, Tag):	Inventory Command
		<b>0x00</b> , Mask length:	0
		<b>0x2A, 0x50</b> :	CCITT-CRC (Reverse, Start value 0xFFFF, 1's compliment)

### Command string :





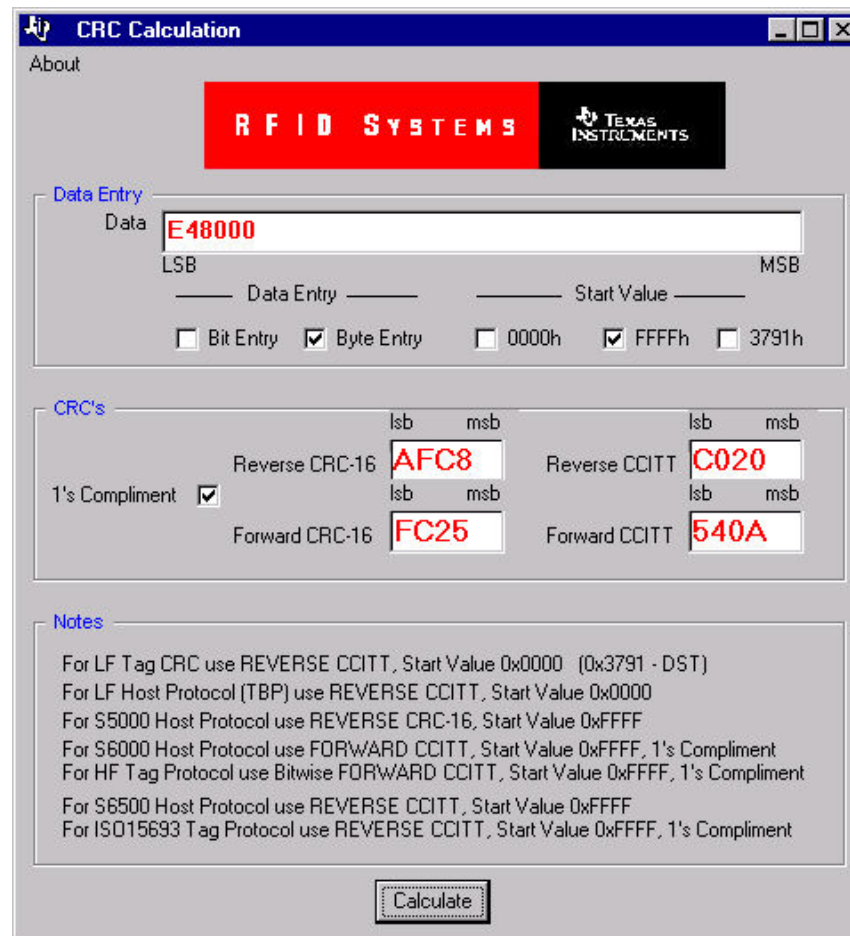
## ◆ CRC calculation:

For the ISO 15693 tag protocols use:

- ◆ CCITT-CRC, Byte entry, Reverse direction, Start value 0xFFFF, 1's Complement

For the Tag-it™ HF tag protocol use:

- ◆ CCITT-CRC, Bit entry, Forward direction, Start value 0xFFFF, 1's Compliment

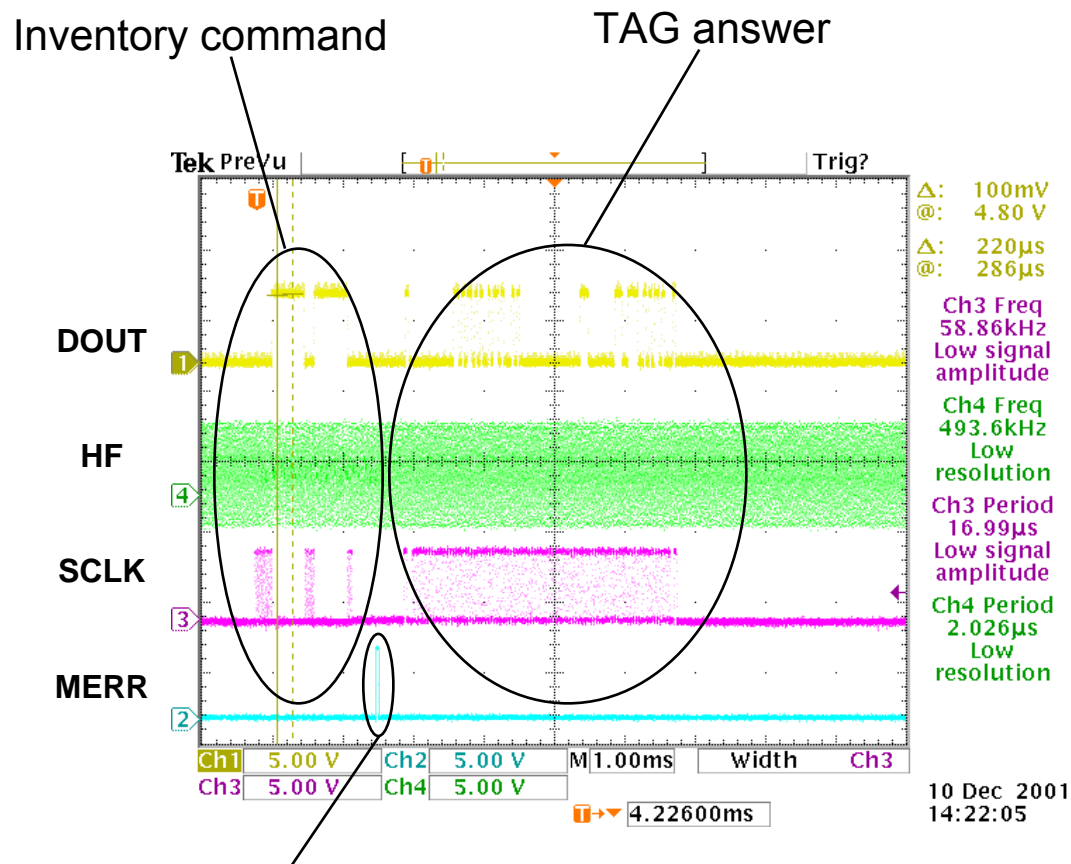


The screenshot shows a software window titled "CRC Calculation" with a blue header bar. Below the header is an "About" section with logos for "RFID SYSTEMS" and "TEXAS INSTRUMENTS". The main interface is divided into several sections:

- Data Entry:** A text box contains "E48000". Below it are labels for "LSB" and "MSB". There are two sets of radio buttons: "Data Entry" (with "Bit Entry" selected) and "Start Value" (with "0000h", "FFFFh" selected, and "3791h" unselected).
- CRC's:** A section with four input fields:
 

Reverse CRC-16	lsb	msb	Reverse CCITT	lsb	msb
		AFC8			C020
1's Compliment	<input checked="" type="checkbox"/>				
Forward CRC-16		FC25	Forward CCITT		540A
- Notes:** A text area containing the following text:
 

For LF Tag CRC use REVERSE CCITT, Start Value 0x0000 (0x3791 - DST)  
 For LF Host Protocol (TBP) use REVERSE CCITT, Start Value 0x0000  
 For S5000 Host Protocol use REVERSE CRC-16, Start Value 0xFFFF  
 For S6000 Host Protocol use FORWARD CCITT, Start Value 0xFFFF, 1's Compliment  
 For HF Tag Protocol use Bitwise FORWARD CCITT, Start Value 0xFFFF, 1's Compliment  
 For S6500 Host Protocol use REVERSE CCITT, Start Value 0xFFFF  
 For ISO15693 Tag Protocol use REVERSE CCITT, Start Value 0xFFFF, 1's Compliment
- Calculate:** A button at the bottom right of the window.



MERR pulse indicates that modulation on HF is finished

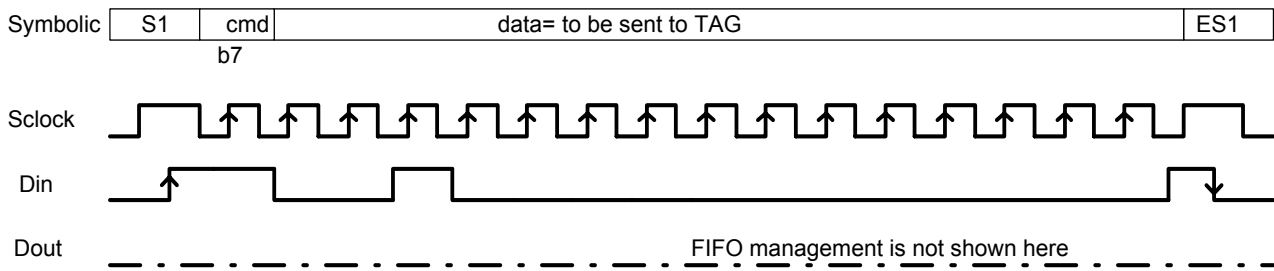
Two zeroes are added to the TAG answer in front of EOF!



▶ **Register mode:**

Once the transceiver is initialized by the command byte in front of the data to be sent to the TAG, **or** by initializing the configuration register, the command byte does not need to be sent again, until the configuration needs changing again.

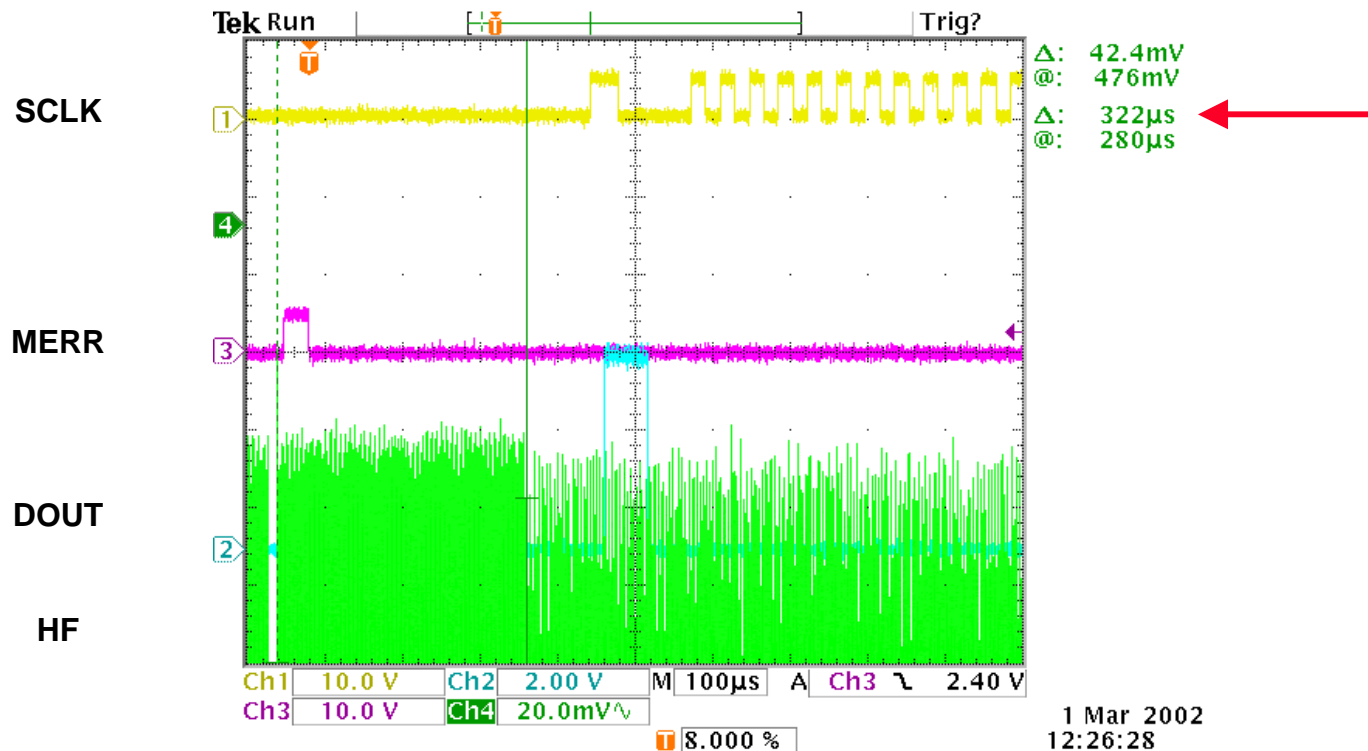
Register mode





▶ **Set timing initialization:**

318,64 – 323,34  $\mu$ s after the rising edge of EOF of the reader, the TAG should send its answer (ISO 15693-3).



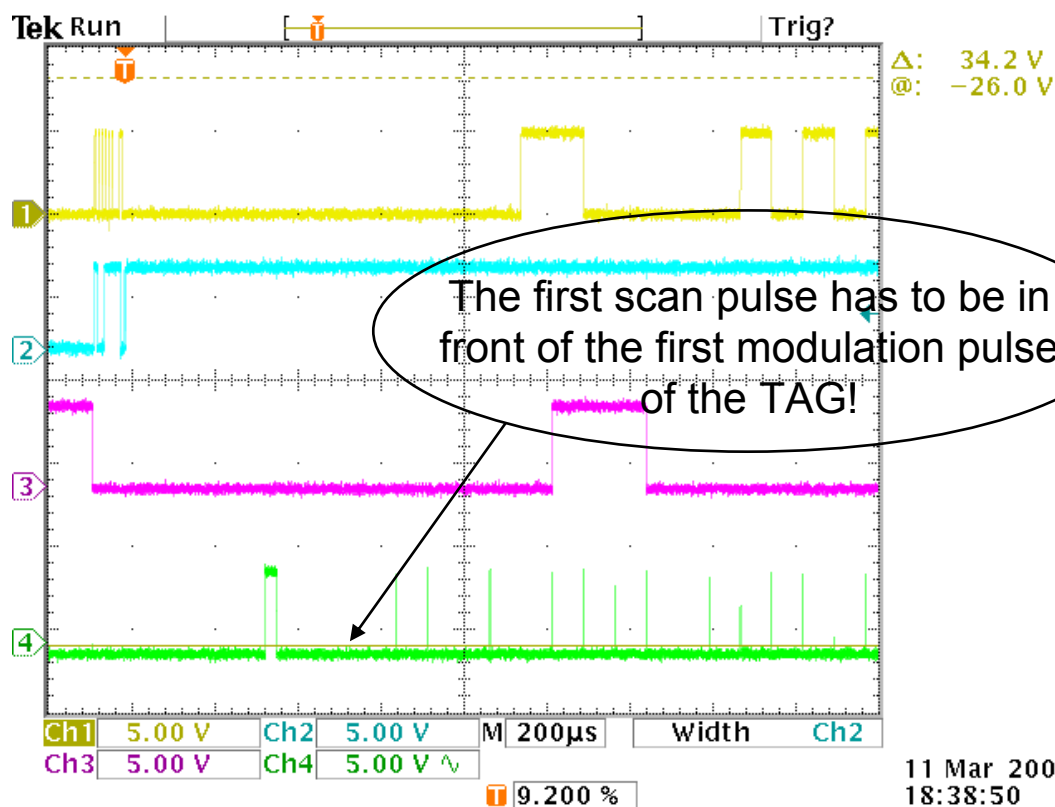


## ▶ Checking the Delay

- Due to differences in the circuitry, it is possible, that there might be an additional delay in the answer.
- If this occurs, the Manchester decoder of the Transceiver IC will not work properly anymore.
- You can visualize the scan pulses of the Manchester decoder with following command sequence:

**0x7B Data: 1100 0101 0110 0**

(Boundary scan ON, Tdelay = 319 μs)

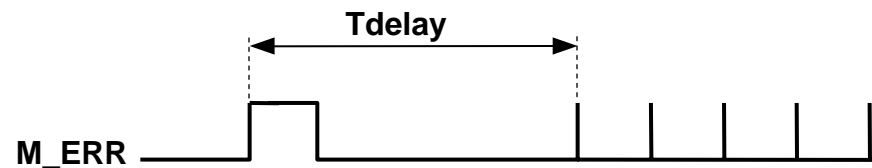


11 Mar 2002  
18:38:50



► **Solution** - Change the Delay

	Tdelay [ $\mu$ s]	Timing offset [7 bits]
Minimum Value	306 $\mu$ s	0000000
Typical	319 $\mu$ s	0101100
Maximum Value	343 $\mu$ s	1111111



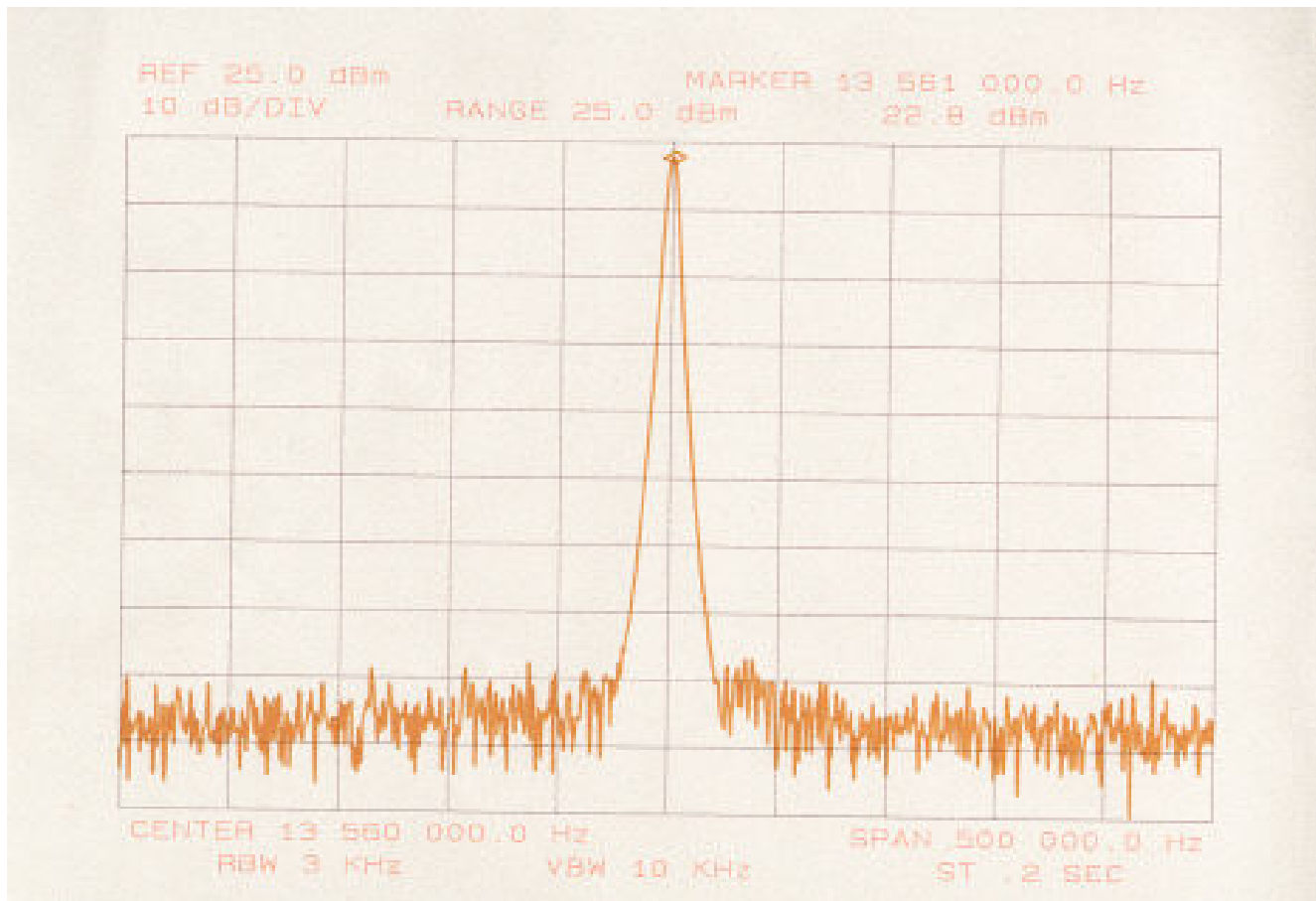
Example:  $7 \text{ bits} = 0101100 = 2C_{\text{hex}} = 44_{\text{dec}}$   
 $1 \text{ Bit equals } 295 \text{ ns} \quad 44 \times 295 = 12980\text{nS} = 13 \mu\text{s}$   
 $T_{\text{delay}} = 306 + 13 = 319 \mu\text{s}$





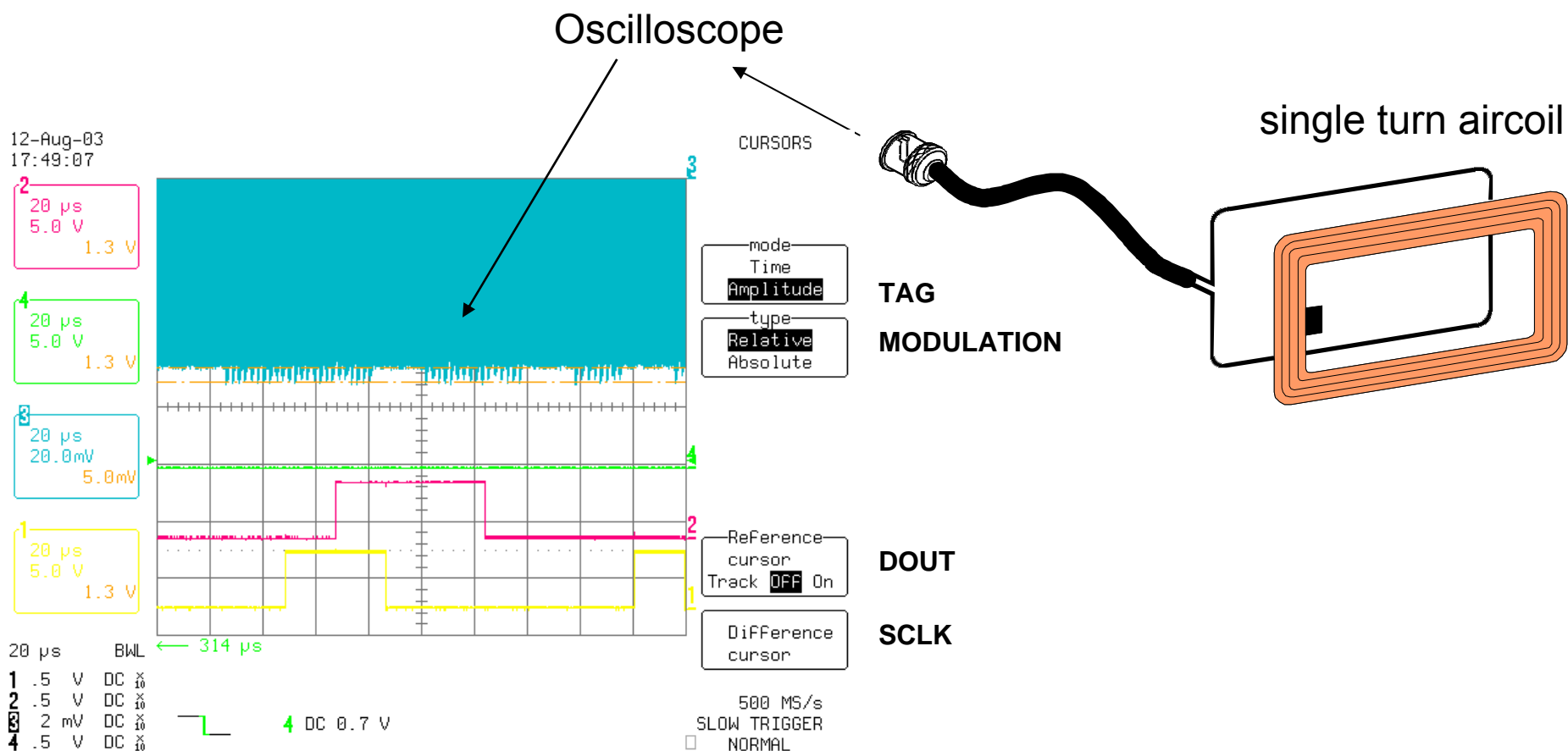
## ► Output power measurement:

22.8dBm = ~200mW





## ▶ Transponder modulation measurement:

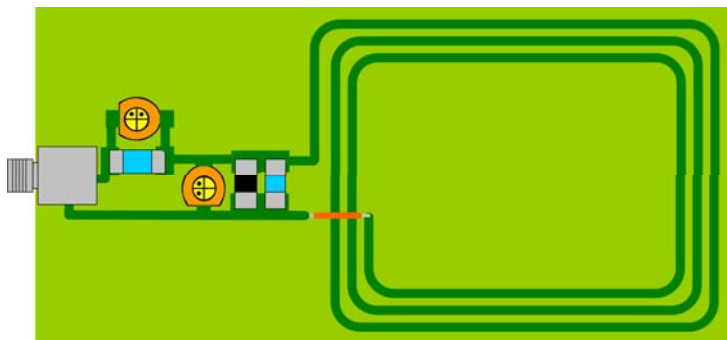




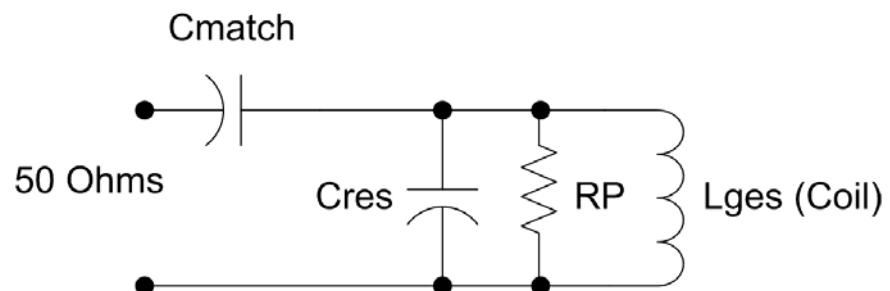
## ▶ Antenna design:

### 1. Define and create Antenna Loop

PCB or wire wound



Equivalent circuit



### 2. Measure the inductance of the Loop



## 3. Calculate the components

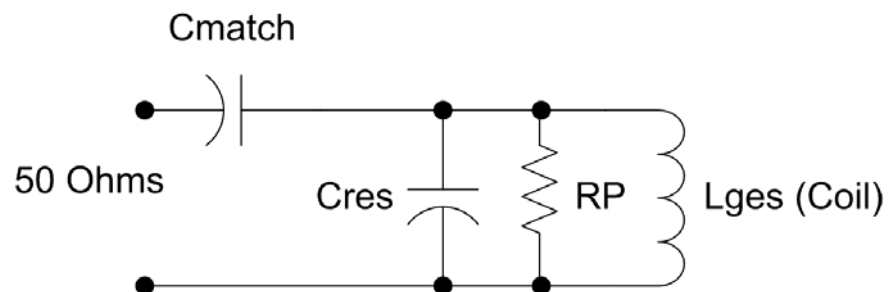
$$L_{ges} = 1.27 \mu\text{H} \quad (\text{given 3 turn PCB, } 30 \times 40 \text{ mm})$$

$$Q = 20$$

$$R_s = 50 \text{ Ohms}$$

$$f = 13.56 \times 10^6 \text{ Hz}$$

$$\omega = 2\pi f$$



$$R_p = (Q^2 + 1) \times R_s$$

$$R_p = 2.005 \times 10^4 \text{ Ohms}$$

$$X_s = Q \times R_s$$

$$X_s = 1000$$

$$C_{match} = \frac{1}{\omega X_s}$$

$$C_{match} = 1.174 \times 10^{-11} \text{ F}$$

$$X_p = \frac{R_p}{Q}$$

$$X_p = 1.0025 \times 10^3$$

$$L_1 = \frac{X_p}{\omega}$$

$$L_1 = 1.177 \times 10^{-5} \text{ H} \quad \text{intermediate inductor, for calculation only!}$$

$$L_2 = \frac{L_{ges} \times L_1}{L_1 - L_{ges}}$$

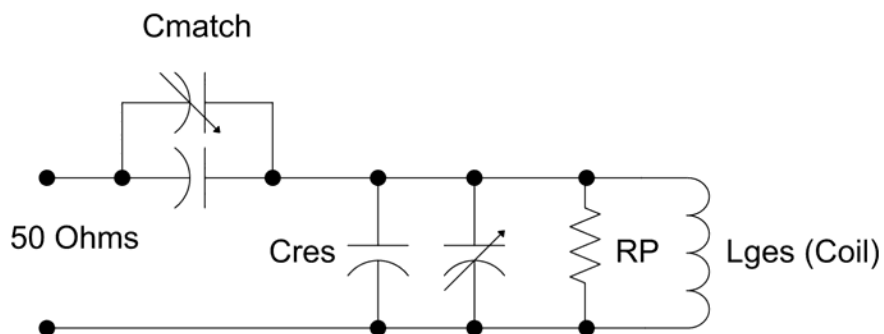
$$L_2 = 1.424 \times 10^{-6} \text{ H} \quad \text{intermediate inductor, for calculation only!}$$

$$C_{res} = \frac{1}{\omega^2 \times L_2}$$

$$C_{res} = 9.676 \times 10^{-11} \text{ F}$$



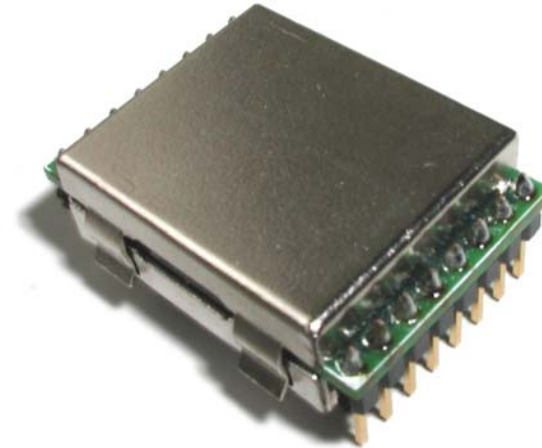
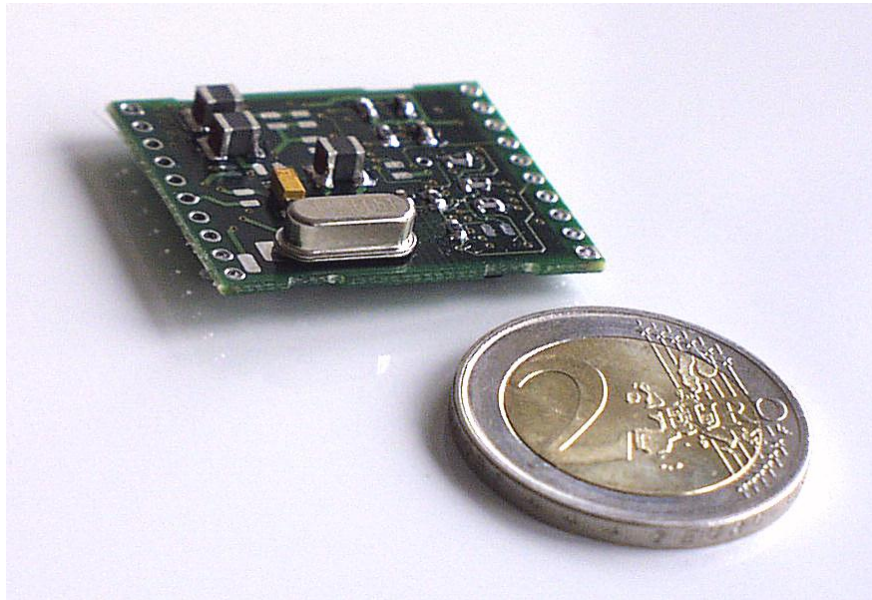
## 4. Add variable (fixed) capacitors for fine tuning:



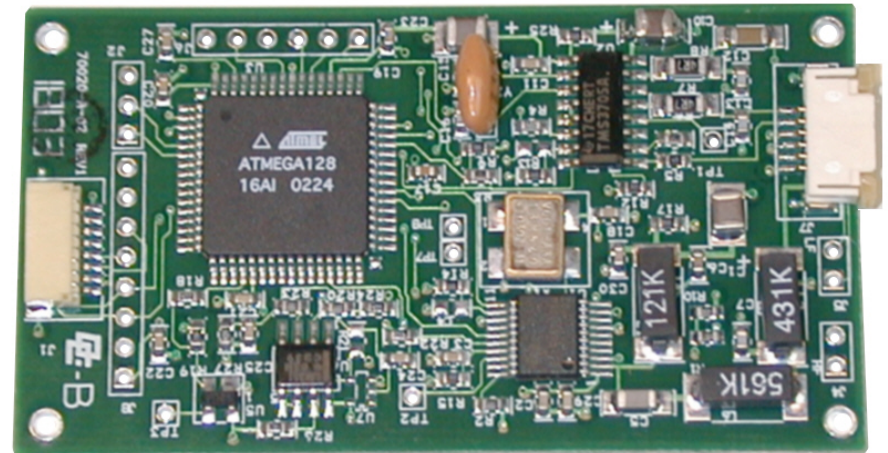
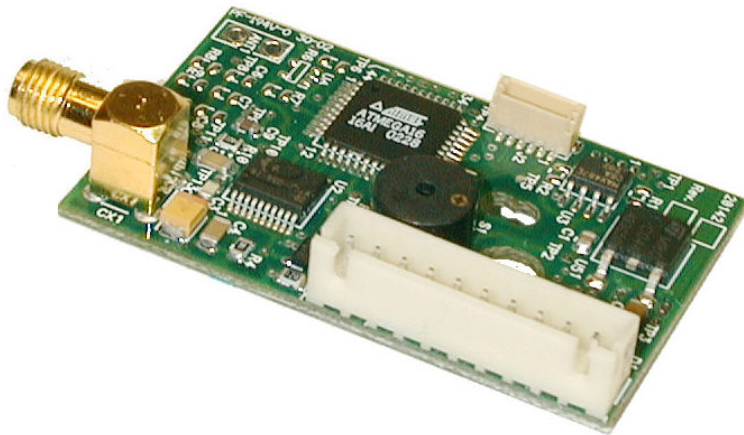
- low tolerance components should be used – COG or NPO type capacitors
- when optimum capacitor values have been found, the variable capacitors can be removed,
- plan the space for 2 fixed, fine tuning capacitors at  $C_{res}$  and  $C_{match}$



**Very small and cheap products are available already!**



# HF Multi-Protocol Transceiver IC





## ▶ Resources

- Reference Guide (11-07-21-001) <http://www.ti.com/tiris>
- ISO/IEC 15693 Part 2/3 <http://www.iso.ch>
- ISO/IEC 14443 Part 2/3/4 <http://www.iso.ch>
- Antenna design notes  
<http://www.ti.com/tiris/docs/manuals/appNotes/HFAntennaDesignNotes.pdf>