EE 389 EDL Report, EE Dept, IIT Bombay
10th November, 2005

RFID System With Anti-collision Algorithm

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Abstract

This project is aimed at building RFID system protocol with a passive tag. The Reader operates at two frequencies 100 kHz and 170 kHz. Reader and tag communication occurs through coil antenna. Reader, 89c2051 performs all the functions. Signal sent to the tag provides power to it, so that it can respond to the signal given by the reader. The 16 bit address of tag is identified by the response given by the tag using an efficient anti-collision algorithm and addresses of the detected tags are displayed on PC screen.

Contents

I. INTRODUCTION

Radio Frequency Identification (RFID) is an automatic identification method, based on storing and retrieving data using RFID Tags or transponders. RFID tag is a small object with a unique identifier and it can store data. It can be attached to or incorporated into a product, animal or person. There are two types of RFID tags, passive tags which require no internal power source and active tags which require a power source.

- Objective

  This project aims to establish low frequency communication between Reader IC (89c2051) and Tag IC (89c2051) in the 100 - 200 kHz frequency range. Each Tag has a unique 16 bit address which is identified by the Reader when the former comes in proximity of the latter. When all the tags have been identified, the Reader needs to display addresses of all the tags on a PC.

- Main components used and Block Diagram

  1) Reader IC: The Reader IC is micro controller AT89c2051. It is a low-voltage CMOS 8 bit microcomputer with 2K bytes of Flash programmable and erasable read only memory.

  It provides the following features

  - 2K bytes Flash memory
  - 128 bytes of RAM
  - 15 I/O lines
  - Two 16-bit timers/counters

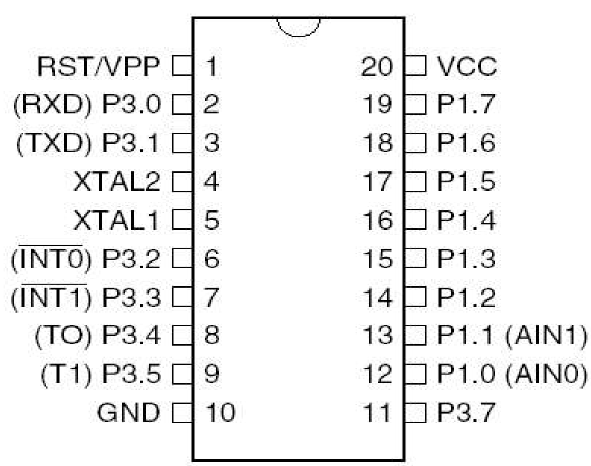


Fig. 1: Pin Diagram of AT89c2051

2)FSK Modulator: IC used for modulation is XR2206. It is a monolithic function generator and works at voltages 10 - 24 volts. Frequency of operation is from 0.1Hz to 1 MHz. This IC is used for modulation the signal transmitted by Reader to Tag. Corresponding to bit ‘0’ a 100 kHz frequency and corresponding to bit ‘1’ a 170 kHz frequency is transmitted.

A 555 timer based modulator could also be used.

Table 1: Pin Description of XR2206

PIN DESCRIPTION

Pin #	Symbol	Type	Description
1	AMSI	I	Amplitude Modulating Signal Input.
2	STO	O	Sine or Triangle Wave Output.
3	MO	O	Multiplier Output.
4	V_{CC}		Positive Power Supply.
5	TC1	I	Timing Capacitor Input.
6	TC2	I	Timing Capacitor Input.
7	TR1	O	Timing Resistor 1 Output.
8	TR2	O	Timing Resistor 2 Output.
9	FSKI	I	Frequency Shift Keying Input.
10	BIAS	O	Internal Voltage Reference.
11	SYNCO	O	Sync Output. This output is a open collector and needs a pull up resistor to V_{CC}.
12	GND		Ground pin.
13	WAVEA1	I	Wave Form Adjust Input 1.
14	WAVEA2	I	Wave Form Adjust Input 2.
15	SYMA1	I	Wave Symetry Adjust 1.
16	SYMA2	I	Wave Symetry Adjust 2.

3)Tag IC: The Tag IC used is also AT89c2051. We need a low voltage IC because we aim at developing passive Tag which is powered by incoming signals from Reader. AT89c2051 serves this purpose as it operates between 3-5 volts. Tag also demodulates the signal coming from Reader and responds accordingly.

4)Amplifier: For power amplification a Darlington pair transistor is used. The current gain of common collector configuration is typically 1000 for this transistor. It is used as Class A amplifier.

5)ADC: Reader IC needs to sense the voltage level at the reader coil for tag response detection. The analog voltage at coil is converted to digital code using AD0804. This digital value can now be fed to the reader IC for measurement. AD0804 gives an 8-bit digital output.

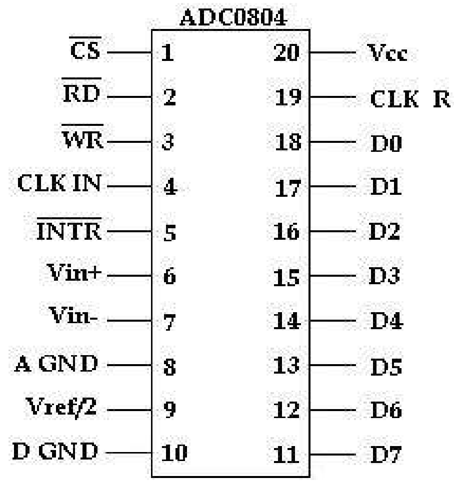


Fig. 2: Pin Diagram for ADC0804

6)Antenna : A PCB antenna is used as tag coil while reader uses a spiral coil antenna for communication.

7)Serial Port: A PC interface is needed for displaying the detected addresses. MAX232 line driver used for this purpose using which data is serially transferred to PC from the reader.

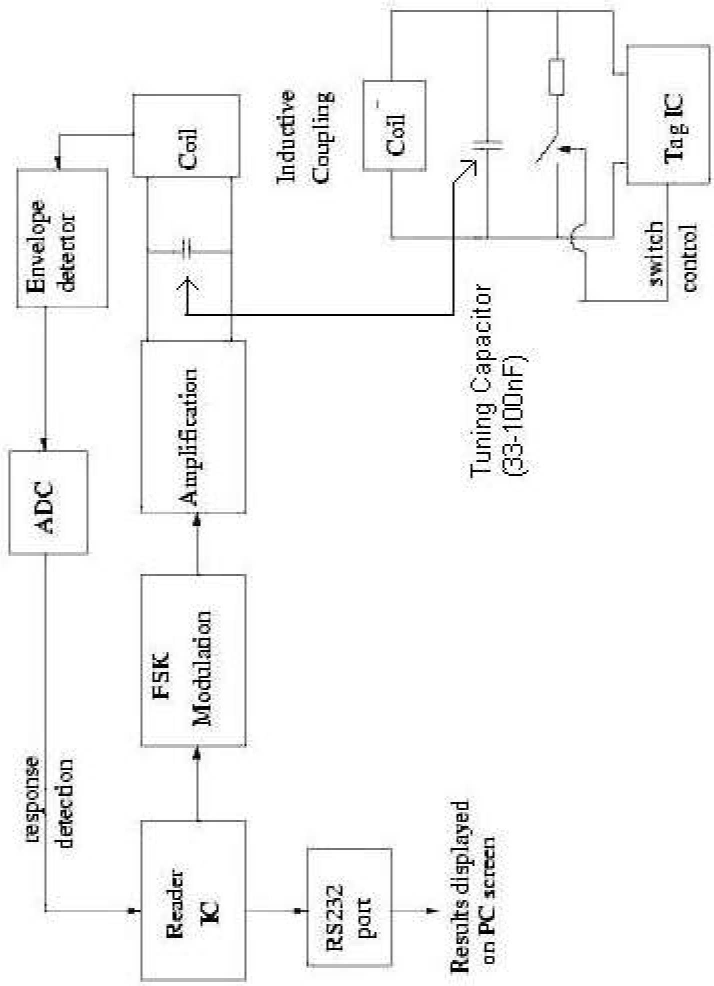


Fig.3: Circuit Block Diagram

II. DESIGN APPROACH

Below we have discussed some of the design options we had for the circuit and reason for choosing one of them.

- **FSK Modulator Design**

The need for modulator is for transmitting the signal from Reader to Tag. We had two options

1) Using two *Wien-Bridge Oscillators* of frequency 100 kHz and 200 kHz and switching between the two frequencies depending on the bit sent by Reader. This

scheme was not used as the sine wave generated at this frequency range (100-200 kHz) by the oscillator was highly distorted and also the output waveform was not continuous. It had a discontinuity at the points where frequency was switched from one value to another depending on incoming bit.

2) Using a Voltage Controlled Oscillator (VCO) to generate these two frequencies. Here we had two options of using either CD4046 (PLL Chip) or XR2206 (discussed previously). IC CD4046 has a VCO which can be used to generate FSK but the FSK output was square wave rather than sine wave which we needed. One option was to convert the square wave to sine wave using band pass filter. But this gives distorted sine wave with a very low amplitude.
Other option was of using XR2206. This IC gives sine wave FSK output with peak to peak voltage of 6 volts.
This output is further amplified so that sufficient power can be transferred to tags for proper operation.

Therefore, IC XR2206 was used for FSK modulation.

- Reader and Tag Communication

  Data to be sent by the reader is sent to XR2206 based FSK modulator. Bit '1' is represented by a frequency of 170 kHz while a 100 kHz frequency signal represents bit '0'. A bit period of 1 *ms* is being used. The FSK modulated signal is amplified by a power amplifier to which reader coil is connected. This signal is transmitted to tag antenna by inductive coupling. Tag IC receives this signal and measures its frequency during each period of 1 *ms*. Frequency measurement is done by counting the number of zero crossings using timer in each millisecond. If a frequency of 170 kHz is detected,bit is read as '1' and '0' if frequency comes out to be 100 kHz.
  For sending a response from tag to the reader, technique of load modulation is used,which is discussed in a later section.

- **Reader Anti-Collision Algorithm**

If there are more than one Tag in proximity of Reader then all of them will respond to the reader simultaneously when reader sends the data. This will result in interfering (collision) of responses sent by the tags. Hence, there is a need for Anti-Collision algorithm so that Reader is able to read responses of all the Tags and hence detect all of them successfully.

Each algorithm generates a frame which is transmitted to the tag. Format of the frame is

Carrier	SOF	Command	Data	EOF	Carrier	Response
x	a	c		b	y	

where:
x : time required by the reader's processor to process the response from tag
a : length of start of frame
b : length of end of frame
c : length of command
y : time required by the tag's processor to process the data received
z : total length of frame

Command field determines the packet corresponding to which the tag field will respond
Data field contains the data sent to tag and determines which tag will respond

Some of the algorithms thought upon were:

1) Binary search scheme:

   In this scheme first m bit of the tag address is sent in the data field of the frame. There is no command field. The tags with same first m bits will respond to the reader by sending a response and other will not respond to this or any other reader frame sent after this. Let n be the number of bits in tag address, p be the number of tags and length of frame is z.
   No of frame sent = $(n+1)p$
   No of clock cycles = $[(1+np)z + n(n+1)/2 + 1]$ x 12000

2) Nibble based search :

   In this scheme the tag address was broken down into nibbles. And a command word and data is sent from the reader. Corresponding to this command word which contains to which nibble of the address tag has to respond, the tag sends a pulse after a delay of n millisecond, where n is equal to the value of that nibble. Whether to send pulse or not is decided by the data which contains the initial nibbles of the address which should match the tag address for it to respond. By evaluating the time after which the reader receives the pulses, reader can identify the nibbles and hence the address of the tags.

   No. of frames sent = $1+4p$
   No. of clock cycles= $z + (10n+4z)p + (1+4p)\,2^m$

   Where : p= number of tags present in proximity of reader
   z= frame width

n= number of bits in tag’s address

3) For the last algorithm a different frame was used

position of bit (5 bits long)	last response from any tag (1 bit long)

The frame is of 6 bits. The first five bits carry the information about the position of the bit sent. Last bit is set if there is response from any of the tag for the last frame sent. Five bits are chosen for the position of the bit so that the reader can detect tags up to 32 bit of addresses.

Number of clock cycles used by this algorithm is (6*n* x *p* x 12000)
Thus this algorithm takes up minimum number of clock cycles and provides power to the tag for most of the functioning and hence is best for the anti collision algorithm.

The last algorithm explained above is being used in the system we have designed.
This algorithm has been devised for this specific design. In most of the RFID systems,tag sends most of the data to the reader. But in the algorithm we are using tag is only required to send small responses according to its address.
Also,this algorithm has an effective anti-collision scheme and is able to correctly detect the addresses of the multiple tags present in reader's range.

III. ALGORITHM DESCRIPTION

- Reader :
  1) Reader sends a synchronization frame for synchronizing tag and reader communication.
  2) Reader sends a frame consisting of 6 bits of data and then listens for tag response for 2 bit periods. Bit period has been taken to be 1 *ms*. long.
  First 5 data bits correspond to the position of the address bit being checked by reader and the 6th bit carries tag response corresponding to previous address bit.

m : Position of bit (5 bits long)	Response for previous*(m-1)th* bit (1 bit long)	Listening to tag response for 2 bit periods

  3) If the reader receives a response, corresponding address bit of tag is identified as '1' and '0' if no response is detected.

4) Once all the 16 bits have been identified, this address is displayed on PC screen.
5) Reader keeps running this algorithm again to detect any other tag present in its proximity. If another tag is detected, its address is also displayed and algorithm is repeated again.
6) If reader does not receive a response for any of the bits, this implies that there is no tag present in reader's range.

- Tag :

1) Initially tag synchronizes itself to reader using the synchronization frame being sent.

2) Tag receives the 6 bit frame from reader and sends its response during the 2 *ms*. blank period according to its address bits.

3) Tag has three variables which change with each frame according to tag address :

-- counter :- one more than the number of address bits already identified by reader, initially set to 1.
-- response bit :- set if tag needs to send a response
-- flag :- initially set to 0,set to 1 once the tag has been detected i.e. deactivates the tag.

4) After reading the 6 bit frame sent by reader, tag wills send a response only if all the following conditions hold :

-- flag is 0 i.e. tag has not already been detected.
-- counter = m (current bit position) i.e. previous $(m-1)$ bits have been correctly identified.
-- *mth* tag bit is 1.

5) Counter is incremented by 1 in each of the following cases:

-- m^{th} tag bit is 1 and counter = m i.e. previous $(m-1)$ bits have been identified by the reader
-- response for $(m-1)^{th}$ bit is 0 (6^{th} bit of the frame) which will mean that *(m-1)th* bit was '0' .

6) When counter equals 17 (16 bits have been identified by reader), flag is set to 1 and hence tag becomes dead and does not send any further responses.

7) In case, $(m-1)^{th}$ tag bit is '0', but corresponding response bit is '1', this means response was sent by some other tag. Hence this tag's counter will not be incremented resulting in mismatch between bit position as read from the frame and counter. Because of mismatch in case of this tag, only other tag will be detected. In this manner, collision between tag responses is taken care of.

Once the other tag has been detected and deactivated, current tag will get detected during reader's next iteration.

IV. DESIGN OF MAIN CIRCUIT

The whole design can be broken into following six blocks

1) Reader
2) Modulation circuit
3) Tag
4) Tag response detection
5) Coil Antenna
6) PC Interface

The communication between reader and tag is through a coil antenna. The output of Reader, i.e; a frame or a bit sequence, is the input to the modulation circuit. The modulated output is sent as an input to the Tag. This modulated signal also powers the Tag.

Each block is explained in details in following section:

1) Reader :

The Reader (AT89c2051) transmits a frame of 6 bits, with each bit 1 *ms* long.
This frame is FSK modulated by the modulating circuit and then transmitted to the tag.
The reader then waits for any tag to respond for 2 *ms*. If a response is received it transmits the frame corresponding to the next address bit. Once the entire 16 bit address has been detected it is displayed on PC, reader algorithm is run again to the address of any other tag present in its range.

2) Modulating circuit

- FSK Generation:

The circuit takes the bit sequence sent by reader as input. This input goes to IC XR2206 which modulates the input and generates sine wave FSK. XR2206 works

at 12 volts and has input current of 1.5mA. It works in frequency range of 0.1Hz to 1 MHz. Corresponding to bit ‘0’ a frequency of 100 kHz is generated and for bit ‘1’ frequency of 200 kHz is generated.
Equation governing the frequency output of XR2206 is

$f = 1/(RC)$

Where:
f – Frequency generated

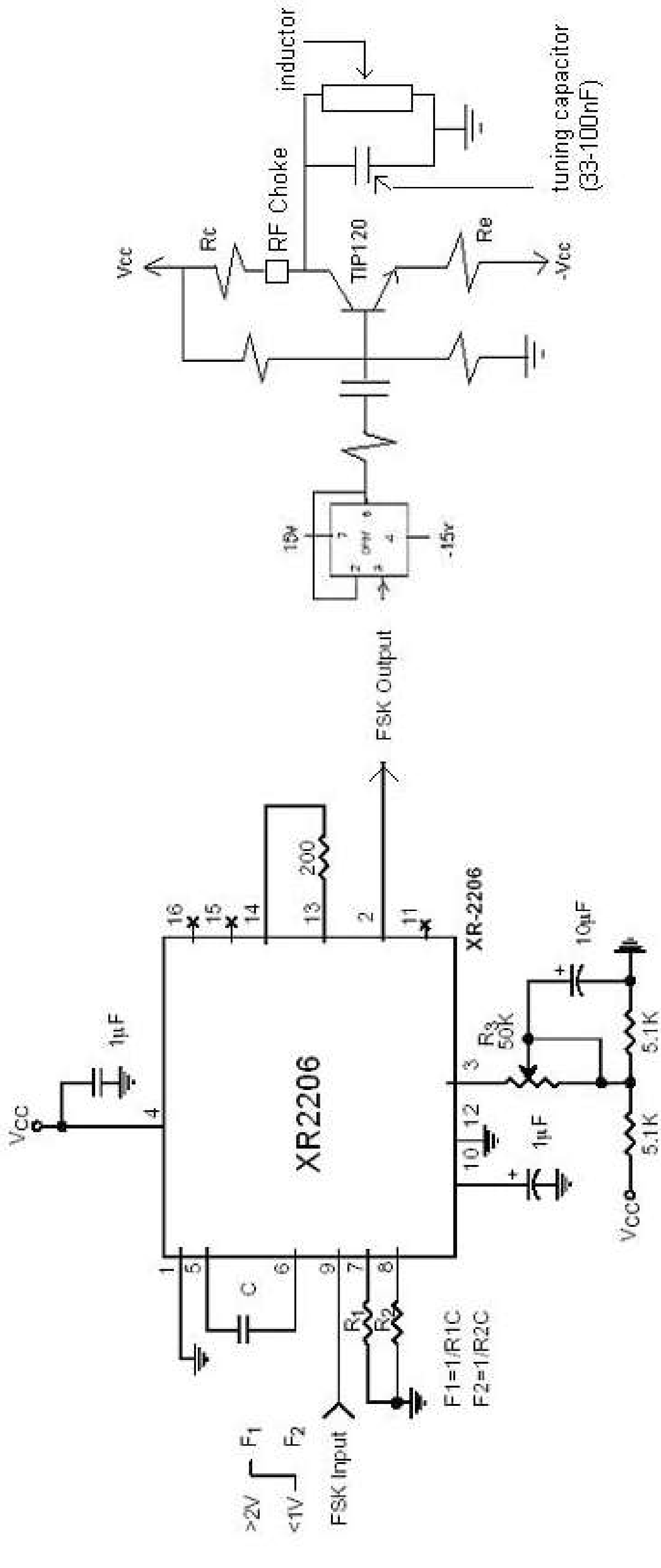
R - resistance at pin 7 or pin 8
(When input at pin 9 is low then frequency corresponding to pin 7 is produced at pin 2 and if input at pin 9 is high then frequency corresponding to pin 8 is produced)

C – Capacitance between pin 4 and 5

The sine wave generated has peak to peak voltage of 5.8 volts. The amplitude of sine wave depends on value of resistance at pin 3. Maximum value of this resistance can be 60K ohm which corresponds to peak to peak voltage of 6 volts.

- Amplification of the modulated signal:

This FSK wave is then amplified using a Darlington-based power amplifier. A Darlington pair has very high current gain (typically 1000). As the Power received at the receiver coil is directly proportional to the derivative of the current in the Transmitting coil, a common collector current amplification circuit is used to amplify the current in the LC-resonant circuit of the Reader coil.



XR2206
XR-2206
Vcc
1µF
200
FSK Output
10µF
R3
50K
5.1K
5.1K
Vcc
C
R1
R2
F1=1/R1C
F2=1/R2C
>2V
<1V
F1
F2
FSK Input
15v
-15v
Vcc
Rc
RF Choke
TIP120
Re
-Vcc
inductor
tuning capacitor
(33-100nF)

Fig 4

3) Tag

The Tag (IC AT89c2051) first demodulates the incoming sine wave FSK (of the frame transmitted by reader) using its Timer 1 as counter. The timer counts number of zero crossings in 1 *ms*. For 170 kHz it should be approximately 170 in 1 *ms* and for 100 kHz it is 100. Timer 0 is used as timer of 1 *ms* to restart the counter after each millisecond. For 12 MHz crystal the maximum frequency that a counter can count is 500 kHz. After the frame has been read by the tag it checks whether it needs to respond to the reader or not according to the algorithm explained in previous section..

Tag uses technique of ***load modulation*** to respond to the reader. This technique involves tuning and de-tuning the tag coil. This is achieved by switching on and off a small resistor placed in parallel to the coil. A transistor, 2N2222, is being used as a switch and is controlled by Tag IC. The switch is normally in 'off' state and hence the antenna is tuned to frequency of reader coil. When the tag needs to send a response it is switched on for 1 *ms*. As a result of this tag antenna is detuned (its resonance frequency changes) and hence reader antenna sees a change in impedance and voltage level.
If the tag has responded to a particular frame i.e; address has been matched up to a certain no. of bits, it waits for next frame from the reader. However,if any of the address bits doesn't match, tag does not respond to subsequent frames.

4) Tag Response Detection

Reader detects whether any of the tags has responded or not by sensing changes in the voltage level at the coil. Reader waits for 2 *ms* for tags to respond after every frame. Values recorded during 1st *ms* correspond to the case when tag antennas are tuned to reader coil frequency. During the next *ms*, if any tag has sent a response, its antenna will be detuned and voltage of reader coil will increase. Reader senses this voltage and compares it with the value recorded in previous *ms*. If the difference is above a certain threshold, at least one of the tags has sent a response. And the algorithm proceeds further accordingly.

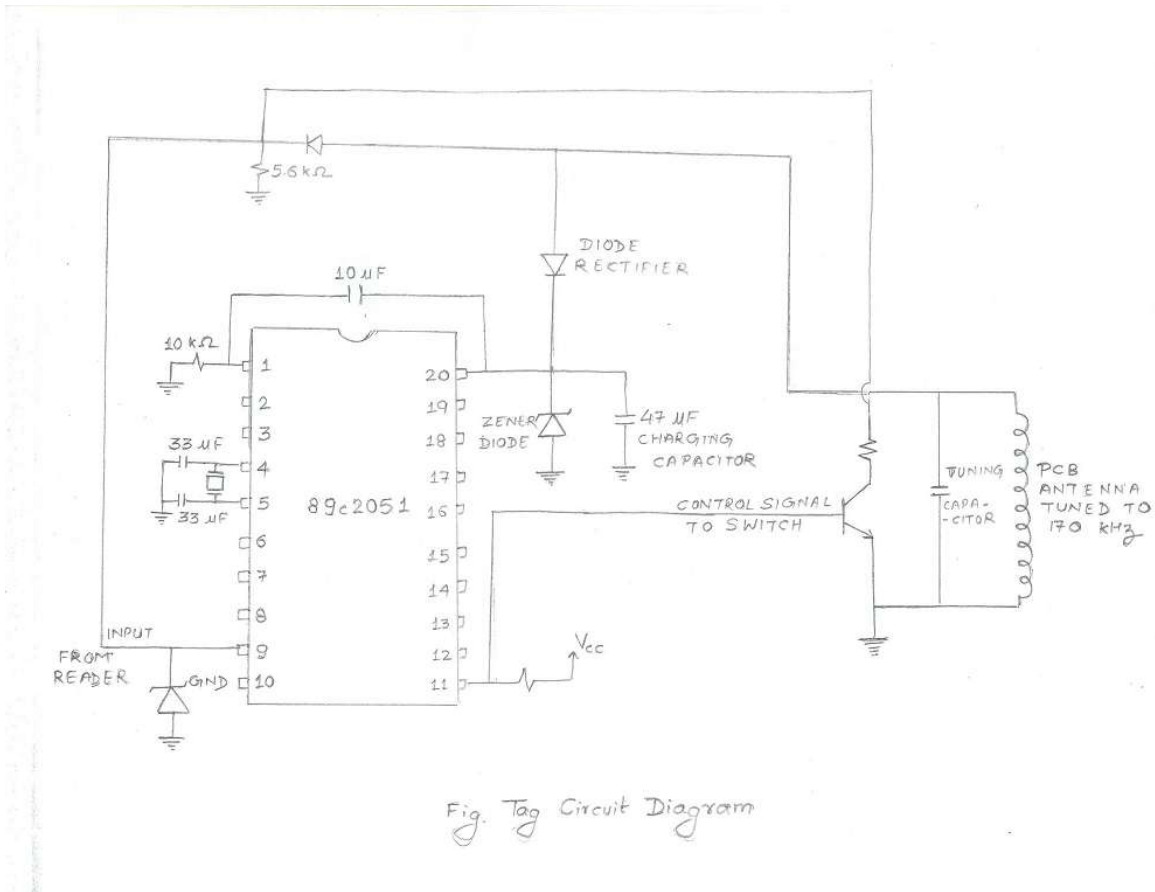


Fig 5. Tag Circuit

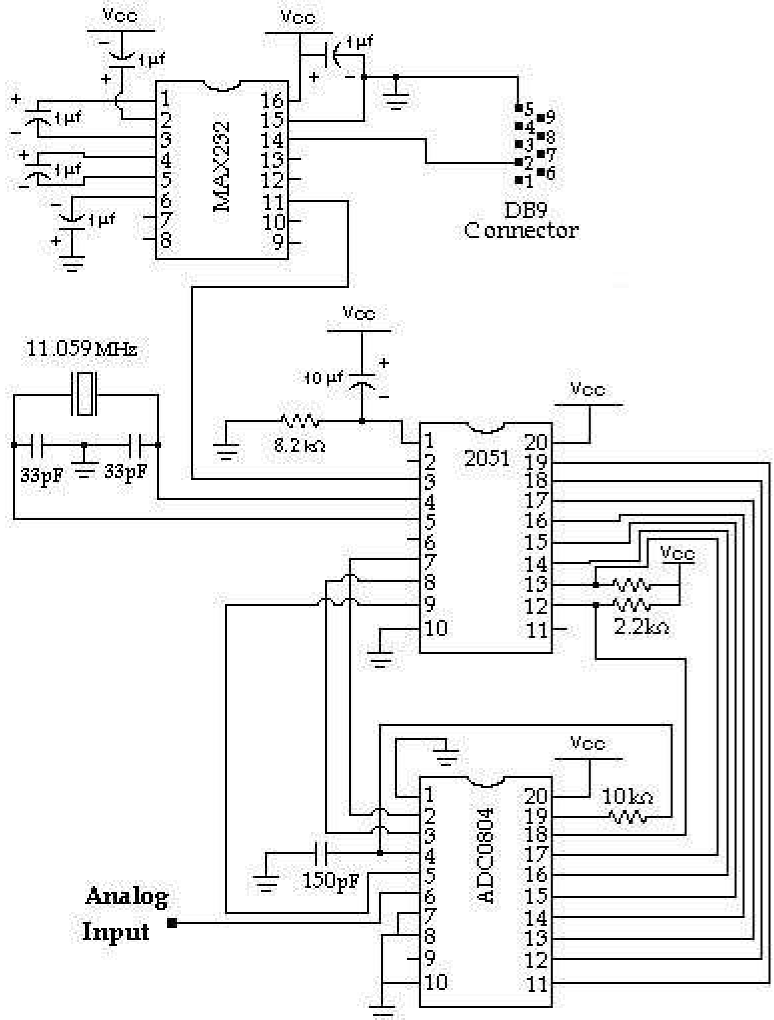


Fig. 6: Reader, Response detection and PC-Interface

5) Antenna Coil

Inductively coupled coils are used to transfer power from reader to the tag. Antenna on reader end is actually a helical coil tuned to a frequency of around 150 kHz. The inductance of the reader coil is approximately 40 µH

As the Tag needs to be small, it uses a PCB antenna whose dimensions are 3.5" x 3.5". The inductance of the coil is approximately 65 µH.

Antenna coil of the tag penetrates the field generated by reader coil and a voltage is generated in the coil. This voltage is rectified using a diode as a rectifier and fed to a charging capacitor which provides the required operating voltage to tag (89c2051).

Reader coil uses a Darlington-based power amplifier so that sufficient power for operation of tag can be transferred.

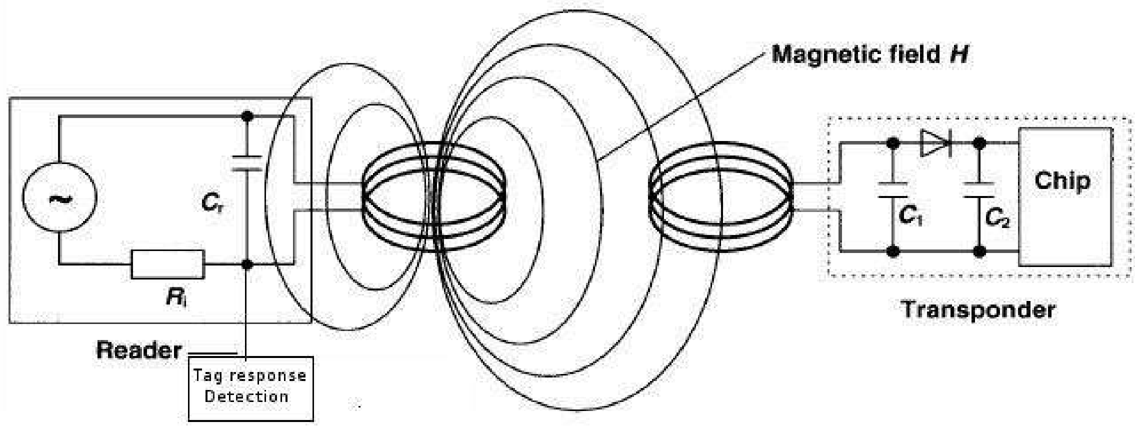


Fig.7: Power Supply using inductively coupled coils

IV. TESTING OF BLOCKS

1) Modulating circuit

Testing of XR2206

On making the circuit of FSK modulation as shown in *Fig. 6*, the input pin 9 was given a constant low voltage which corresponds to frequency of pin 7. As expected, a very high quality sine wave was produced but it has DC offset which was directly proportional to voltage at pin 3. Therefore, a capacitor of value 10 microfarad was used at the output to remove the offset.

The sine wave was of amplitude 2.8 volts for 170 kHz and 3.0 volts for 100 kHz.

2) Reader

The reader IC program was tested using keil programmer. First, only two bit tag address was assumed and the testing was done. After successful result a 7 bit and finally a 16 bit tag address was used and tested. The program which was initially

written in assembly language, has been converted to C.

3) Tag

The tag IC program was also tested using keil programmer. First, the demodulation of the incoming wave was tested. The error was quite low and within bounds so that received bit could be detected correctly. After successful demodulation a 2 bit address was defined for the tag. Using keil programmer the response of the tag, to the reader, was checked for each bit of its address. When both the responses were positive then the testing was done for 7 bit and later, 16 bit address. Tag IC program has also been converted to C code.

4) Tag Response Detection
   Voltage at reader coil was measured for the cases when tag coil was tuned and detuned using a BJT switch. The signal at reader coil was fed to an envelope detector followed by a potential divider (to bring down the voltage to maximum limit of ADC i.e; 5V). This analog input was converted to a digital value which is read by the reader. The difference in voltages for two levels was found to be around 3.5 – 4.5 V which was found sufficient for successfully detecting tag response.

5) Antenna Coil
   Both reader and tag coils were tuned to a frequency of around 170 kHz. Reader coil has an inductance of around 40 µH while that of tag coil is 65 µH. The voltage generated at the output of charging capacitor (which provides power supply to tag IC) was measured as a function of distance between two coils with a 135 kHz input from function generator. The values obtained are tabulated below:

Distance between two coils(cm)	***Voltage (V)***
2.0	4.5
4.0	3.5
6.0	2.1
7.5	1.9
8.5	1.3
9.0	1

A Darlington pair of transistors was also tested for use as a amplifier at the reader coil which provided voltage amplification by a factor of 8 and current amplification of around 100.

V. EXPERIMENTAL RESULT

When there were two tags each of 16 bit address, the reader was able to detect both of them and display their addresses. The two tag addresses used were

Tag 1 : 35h(higher byte) 0AAh(lower byte)

Tag 2 : 0D0h 44h

Both the addresses were correctly displayed on the PC screen as:

35 AA D0 44

The range of the reader is up to 3 inches.

But the response part of the tag (load modulation) is not working properly. The tag was not was not getting completely detuned using the BJT. So the demonstration is given using wire to send the tag response to the reader.

VI. CONCLUSION AND FUTURE WORK

A. CONCLUSION

The project aims at developing a protocol for detecting tags which are in close proximity of the reader and implementing it on the hardware. The protocol developed is working perfectly but in the hardware implementation part, tag response using load modulation technique is not working as expected.

B. FUTURE WORK

- The response part of the tag need to be improved, a MOSFET instead of BJT might solve the problem.
- The system can be modified for detecting tag addresses with higher number of bits. This will allow a larger range for possible tag addresses.
- AT89c2051 being used as tag can be replaced by some other microprocessor like MSP430 which consumes still lesser power. This will allow detection over a larger range.
- Tag can be converted to re-programmable tag via reader. A reader can send a frame receiving which the tag prepares itself to re-program its address according to the next incoming bits.

VII. APPENDIX

Table2. Component list for the circuit

A. COMPONENTS

S.No	**Component**	**Type**	**Quantity**	**Remarks**
	IC			
1	89c2051	Microcontroller	3	Tag and reader IC
2	XR2206	Function generator	1	Modulation circuit
3	Max232	IC	1	PC Reader Interface
4	OP37	Operational amp.	3	
5	2N2222	BJT	1	Tag switching circuit
6	ADC0804	Analog to Digital Converter	1	For Tag response detection
	Capacitors			
1	330 pf	NP0,SMD	2	
2	22 pf	NP0,SMD	4	
3	1 μ f	Electrolytic	2	
4	10 μ f	Electrolytic	3	
5	47 μ f	Electrolytic	2	
	Resistors			
1	220	NP0,SMD	1	
2	1k	NP0,SMD	3	
3	2.2k	NP0,SMD	2	
4	5.6k	NP0,SMD	3	
5	10k	NP0,SMD	5	
6	22k	NP0,SMD	2	
7	56k	NP0,SMD	3	
	Diodes			
1	IN 914	Rectifier diodes	3	Rectifier circuit
	Crystal			
1	12 MHz	Quartz crystal	3	

B. References

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http://atmel.com/dyn/resources/prod_documents/doc0368.pdf

Data sheet of XR2206
http://www.exar.com/product.php?ProdNumber=XR2206&areaID=7

Data sheet of MAX232
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Data sheet of TIP120 (Darlington Transistor)
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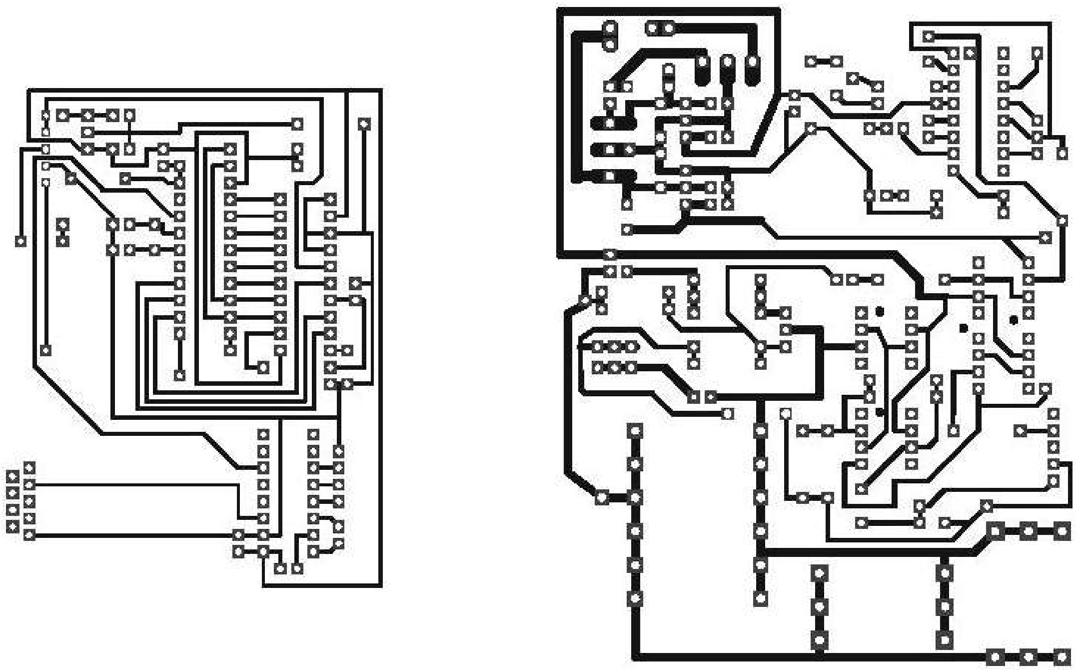
PCB layout of the circuits used

1) Reader



a) Reader

b) Modulator

Fig.8 Reader PCB layout

2) Tag

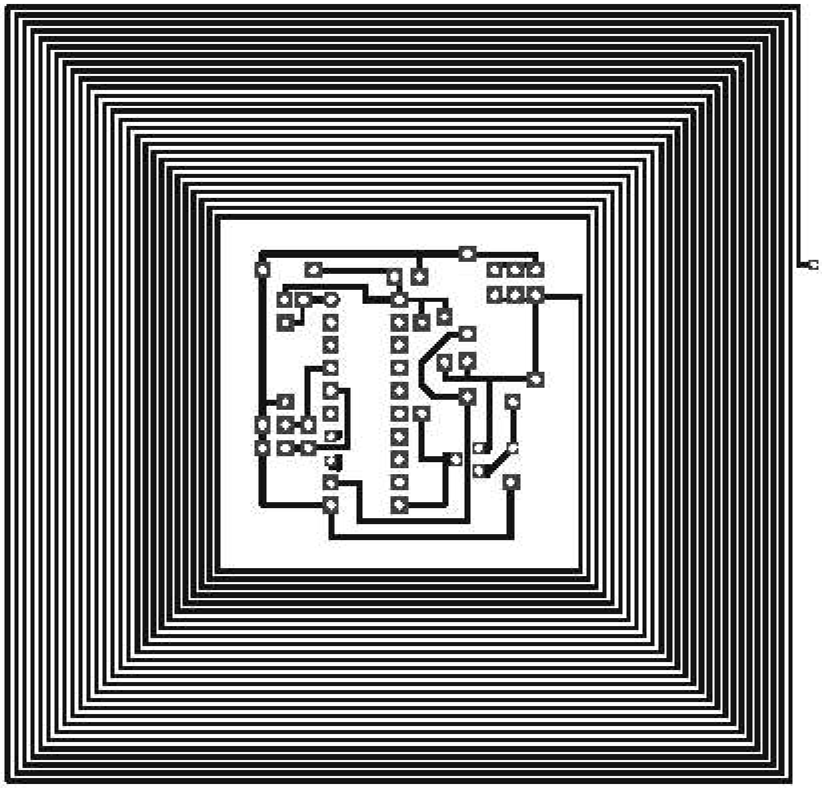


Fig.9 Tag PCB layout