Design and Development of an RFID Home Automation System

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Abstract
The main objective of this project and implementation is to develop a home automation system with radio frequency (RF) controlled remote. As technology is advancing, houses are getting smarter. Modern houses are gradually shifting from conventional switches to centralized control system, involving RF controlled switches. Presently, conventional wall switches located in different parts of the house makes it difficult for the user to go near them to operate. Furthermore, it becomes more difficult for the elderly or physically handicapped people to do so. Therefore, remote controlled home automation system provides simpler solution with RF technology. In other to achieve this, a RF remote is interfaced to the microcontroller on transmitter side which sends ON/OFF commands to the receiver where loads are connected. By operating the specified remote button on the transmitter, the loads can be turned ON/OFF remotely through wireless technology. The microcontroller used here is of the 8051 family (AT89C52). At the end of this project, we were able to design a simple but efficient circuit that operates on command and does exactly whatever the transmitter sends to the receiver.

Keyword: *Wireless Technology, 8051 Family, Transmitter*

1. INTRODUCTION

A circuit that allows total control over your equipment without having to move around is a revolutionary concept. Total control over household appliances with the use of remote control is a good development. It adds more comfort to everyday living by removing the inconvenience of having to move around to operate (switch on or switch off) the electrical and electronic appliances.

Today, remote control is a standard on electronic products, including VCRs, cable and satellite boxes, digital video disc players and home audio players. The remote control's function is to wait for the user to press a key and then translate that into infrared light signals that are received by the receiving appliance. The carrier frequency of such infrared signals is typically around 36 MHz to 60 MHz (www.electronics4u.com).The first machines to be operated by remote control were used mainly for military purposes. Radio-controlled motorboats, developed by the German navy, were used to hit enemy ships in world war one (WWI). Radio controlled bombs and other remote control weapons were used in (world war two) WWII. Once the wars were over, United States scientists experimented to find non-military uses for the remote control. In the late 1940′s automatic garage door openers were invented, and in the 1950′s the first TV remote controls were used. (Heckman, 2008).

2. LITERATURE REVIEW

A common definition of Home Automation is an "electronic networking technology to integrate devices and appliances so that the entire home can be monitored and controlled centrally as a single machine" (Potamitis, 2003). Another term that describe the same technology is "domotics", which derives from the Latin word domus, meaning home, and informatics, meaning the study of the processes involved in the collection, categorization, and distribution of data. However, since this technology is still very much in flux, other terms are also used in the literature with equivalent meaning, such as: "smart home", "smart house", "digital home" or "electronic home". (Potamitis, 2003).

2.1 History of Home Automation

Although the term "home automation" was first used in 1980s, the concept is far from new. The early documents attempt to envisage something very similar dates back to the 1960s, with Walt Disney's Experimental Prototype Community of Tomorrow (EPCOT), presented in 1966 (Potamitis, 2003). A Smart Home will not be able to accomplish much without appliances to control, nor will it be able to communicate to these devices in the absence of a control network ("home network" (Potamitis, 2003). Since appliances and home network are so interlinked with a Smart Home, the following sections provide a brief history on how these come into being.

2.3 RELATED WORKS

2.3.1 Television Remote Control

The first remote intended to control a television was developed by Zenith Radio Corporation in 1950. The remote, called "Lazy Bones", was connected to the television by a wire.

A wireless remote control, the "Flashmatic", was developed in 1955. It worked by shining a beam of light onto a photoelectric cell, but the cell did not distinguish between light from the remote and light from other sources. The Flashmatic also had to be pointed very precisely at the receiver in order to work.

Each bar emitted a different frequency and circuits in the television detected this sound. The invention of the transistor made possible cheaper electronic remotes that contained a piezoelectric crystal that was fed by an oscillating electric current at a frequency near or above the upper threshold of human hearing, though still audible to dogs. The receiver contained a microphone attached to a circuit that was tuned to the same frequency. Some problems with this method were that the receiver could be triggered accidentally by naturally occurring noises, and some people could hear the piercing ultrasonic signals. There was an incident in which a toy xylophone changed the channels on such sets because some of the overtones from the xylophone matched the remote's ultrasonic frequency. In 1980, a Canadian company, Viewstar, Incorporated, was formed by engineer Paul Hrivnak and started producing a cable TV converter with an infrared remote control. At the time the most popular remote control was the Starcom of Jerrold (a division of General Instruments) which used 40-kHz sound to change channels. (Alkar, 2005)

2.3.2 Radio Remote Control

Radio remote control (RF Remote Control) is a way to control distance objects using a variety of radio signals transmitted by the remote control device. By using radio remote control system, you can control a variety of mechanical or electronic devices to complete various operations, such as closing circuit, move handle, start motor, etc. A radio remote control system commonly has two parts: transmitter and receiver.

Transmitter part is generally divided into two types, namely, RF remote control and transmitter module, by the way of using, the RF remote control can be used independently as a whole while the transmitter module is used as a component in the circuit, the advantage of using transmitter model is that it can be seamlessly connected with application circuit, and it's size is small, but users must have a knowledge of circuit to use the transmitter module. (Alkar, 2005)

Receiver part also is generally divided into two types, namely, the super-regenerative receiver and the super heterodyne receiver. Super-regenerative receiver is actually working like the regeneration of under intermittent oscillation detection circuit, while super heterodyne type is working like the one in radio receiver. (Alkar, 2005)

2.4 FEATURES OF PROPOSED RESEACH

This research work consists of an RF receiver system and a remote control transmitter system. The RF receiver consists of the following components;

2.4.1 Atmel AT89C52 Microcontroller

AT89C52 is an 8-bit microcontroller and belongs to Atmel's 8051 family. AT89C52 has 8KB of Flash programmable and erasable read only memory (PEROM) and 256 bytes of RAM. AT89C52 has an endurance of 1000 Write/Erase cycles which means that it can be erased and programmed to a maximum of 1000 times. Its features are;

- 8K Bytes of In-System Reprogrammable Flash Memory
- Fully Static Operation: 0 Hz to 24 MHz
- Three-level Program Memory Lock
- 256 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Three 16-bit Timer/Counters
- Eight Interrupt Sources
- Programmable Serial Channel
- Low-power Idle and Power-down Modes
- 40-pin DIP

Table 1: Pin name, function and number of a AT89C52 microcontroller

<table>
<tr><th>Pin no.</th><th colspan="3">Function</th><th>Name</th></tr>
<tr><td>1</td><td colspan="3">External count input to timer/counter 2,clock out (T2)</td><td>P1.0</td></tr>
<tr><td>2</td><td colspan="3">Timer/counter 2 capture/reload trigger and direction control (T2 EX)</td><td>P1.1</td></tr>
<tr><td>3</td><td colspan="3" rowspan="6">8 bit input/output port(p1) pins</td><td>P1.2</td></tr>
<tr><td>4</td><td>p1.3</td></tr>
<tr><td>5</td><td>p1.4</td></tr>
<tr><td>6</td><td>p1.5</td></tr>
<tr><td>7</td><td>p1.6</td></tr>
<tr><td>8</td><td>p1.7</td></tr>
<tr><td>9</td><td colspan="3">Reset pin, active high</td><td>Reset</td></tr>
<tr><td>10</td><td>Input (receive) for serial communication.</td><td>RXD</td><td>PORT3</td><td>P3.0</td></tr>
<tr><td>11</td><td>Output(transmitter) for serial communication</td><td>TXD</td><td rowspan="4">8 bit input/output Port(p3) pins</td><td>P3.1</td></tr>
<tr><td>12</td><td>External interrupt 1</td><td>Int0</td><td>P3.2</td></tr>
<tr><td>13</td><td>External interrupt 2</td><td>Int1</td><td>P3.3</td></tr>
<tr><td>14</td><td>Timer1 external</td><td>T0</td><td>P3.4</td></tr>
</table>

	input			
15	Timer2 external input	T1		P3.5
16	Write to external data memory	Write		P3.6
17	Read from external data memory	Read		P3.7
18	Quartz crystal oscillator (up to 24 MHZ)			Crystal 2
19				Crystal 1
20	Ground(0V)			Ground
21	8bit input/output port(p2) pins/ High order address bit when interfacing with external memory			P2.0/A8
22				P2.1/A9
23				P2.2/A10
24				P2.3/A11
25				P2.4/A12
26				P2.5/A13
27				P2.6/A14
28				P2.7/A15
29	Program store enable ,read from external program memory			PSEN
30	Address latch enable			ALE
	Program pulse input during flash programming			Prog
31	Programming enable voltage 12v (during flash programming)			Vpp
32	8 bit input/output port(p0) pins Low order address bits when interfacing with external memory			P0.7/AD7
33				P0.6/AD6
34				P0.5/AD5
35				P0.4/AD4
36				P0.3/AD3
37				P0.2/AD2
38				P0.1/AD1
39				P0.0/AD0
40	Supply voltage, 5V (up to 6.6V)			VCC

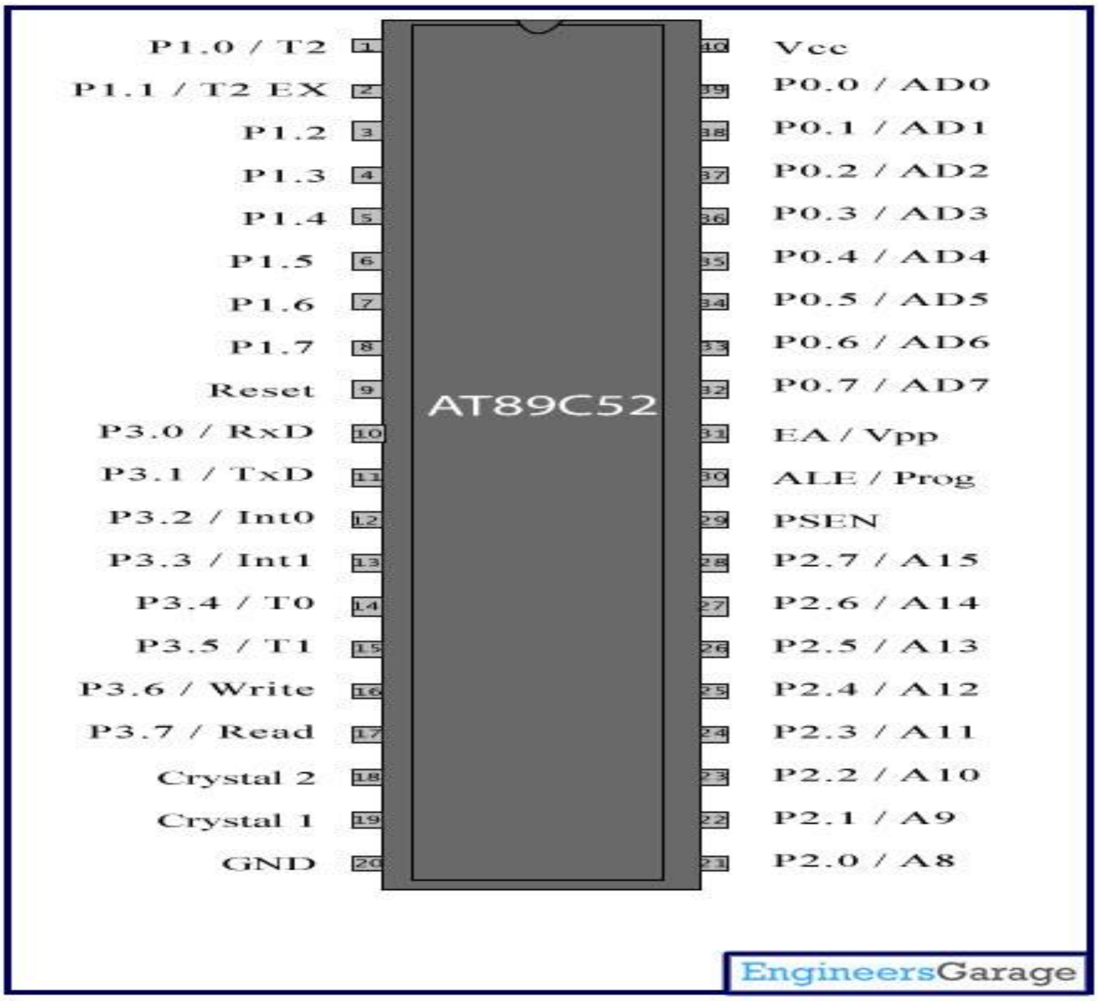

Fig. 1: Atmel AT89C52 Pin Configuration

2.4.2 HT12D Microcontroller

HT12D is a decoder integrated circuit that belongs to 2^{12} series of decoders. This series of decoders are mainly used for remote control system applications, like burglar alarm, car door controller, security system etc. It is mainly provided to interface RF and infrared circuits. They are paired with 2^{12} series of encoders.

Table 2: HT12D Decoder Pin Description

Pin No	Function	Name
1	8 bit Address pins for input	A0
2		A1
3		A2
4		A3
5		A4
6		A5
7		A6
8		A7
9	Ground (0V)	Ground
10	4 bit Data/Address pins for output	D0
11		D1

12		D2
13		D3
14	Serial data input	Input
15	Oscillator output	Osc2
16	Oscillator input	Osc1
17	Valid transmission; active high	VT
18	Supply voltage; 5V (2.4V-12V)	Vcc

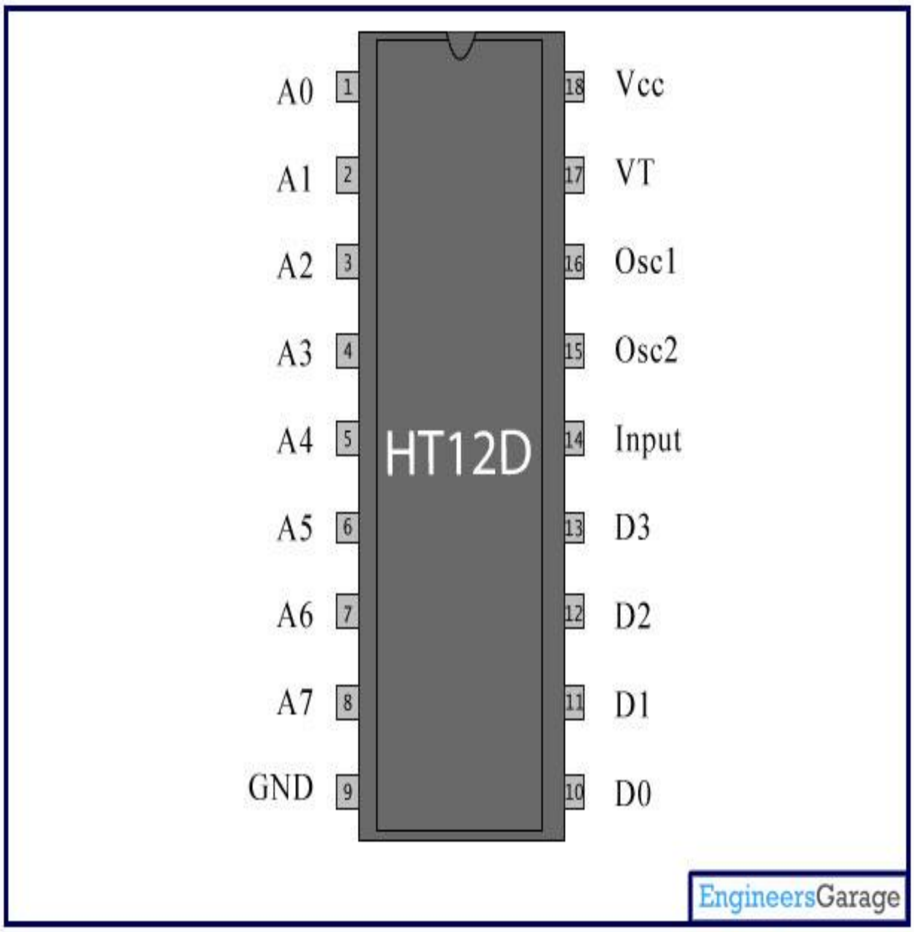

Fig.2: HT12D Pin Configuration

2.6 RADIO FREQUENCY TRANSMISSION

Radio frequency (RF) is a rate of oscillation in the range of around 3 kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals. RF usually refers to electrical rather than mechanical oscillations; however, mechanical RF systems do exist.

Table 3: The Electromagnetic Spectrum

Spectrum of Electromagnetic Radiation				
Region	**Wavelength (Angstroms)**	**Wavelength (centimeters)**	**Frequency (Hz)**	**Energy (eV)**
Radio	> 10^9	> 10	< 3 x 10^9	< 10^{-5}
Microwave	10^9 - 10^6	10 - 0.01	3 x 10^9 - 3 x 10^{12}	10^{-5} - 0.01
Infrared	10^6 – 7000	0.01 - 7 x 10^{-5}	3 x 10^{12} - 4.3 x 10^{14}	0.01 - 2
Visible	7000 - 4000	7 x 10^{-5} - 4 x 10^{-5}	4.3 x 10^{14} - 7.5 x 10^{14}	2 - 3

Ultraviolet	4000 – 10	4 x 10^{-5} - 10^{-7}	7.5 x 10^{14} - 3 x 10^{17}	3 - 10^{3}
X-Rays	10 - 0.1	10^{-7} - 10^{-9}	3 x 10^{17} - 3 x 10^{19}	10^{3} - 10^{5}
Gamma Rays	< 0.1	< 10^{-9}	> 3 x 10^{19}	> 10^{5}

3. DESIGN ANALYSIS

3.1 CIRCUIT LAYOUT

The circuit is made up of two sections, the remote control section and the main circuitry. The block diagram is shown below.

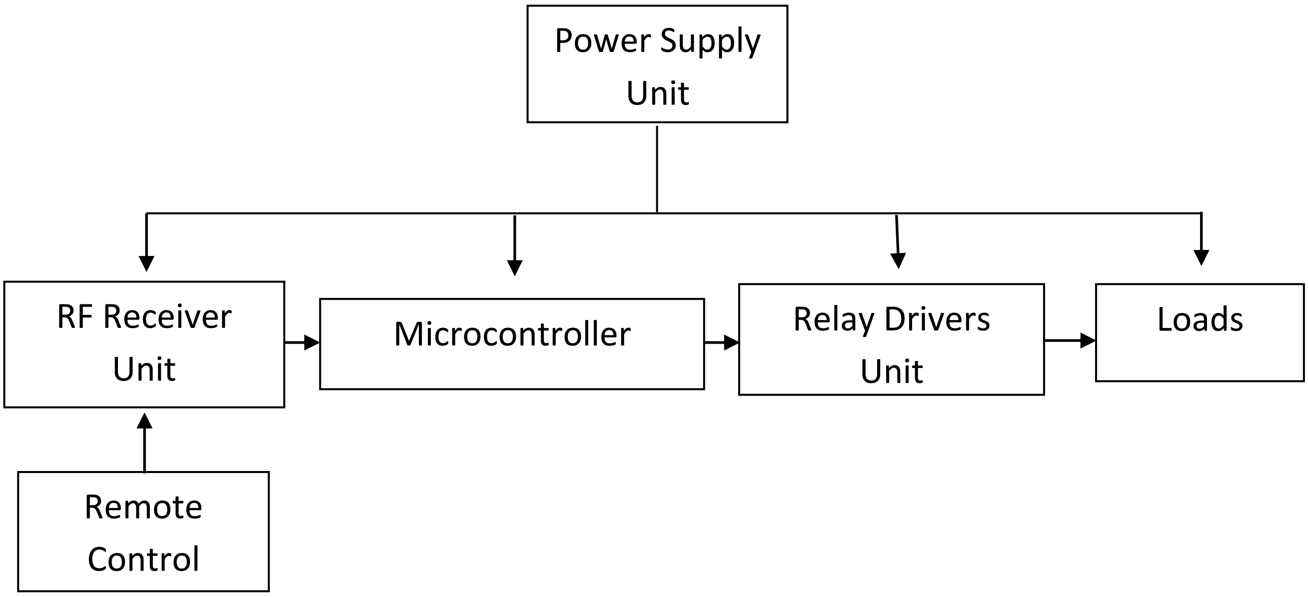

Fig 3 Block diagram of microcontroller based RF home automation.

The circuit made use of an embedded system and wireless module in controlling several loads. The circuit has four sections, the input unit, the control unit and the output unit.

1. **Power supply unit**
2. **Input unit:** RF receiver unit
3. **Control unit:** Microcontroller (AT89C52)
4. **Output unit:** Load (bulbs and socket).

3.2 Design Analysis

The circuit diagram in figure 3 and 3.9 shows the main control and the remote control circuit diagrams. The circuit diagrams will be explained below based on the power supply unit, input unit, control unit and the output unit.

3.2.1 Power Supply Unit

This supplies power to the whole circuit. It serves as the main source of power supply to the circuit as well as the output units. It consists of the following components;

1. Transformer12V-0V-12V
2. Bridge rectifier
3. Capacitor
4. Voltage regulator
5. Resistor
6. Indicator (LED)

The circuit diagram is shown below.

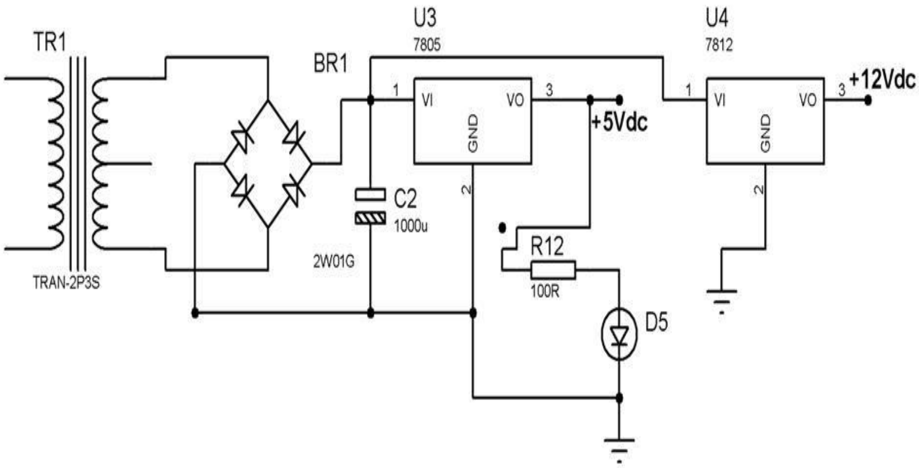

Fig 4: Circuit diagram of the power supply unit

A two terminal transformer was used to step down main 220V to 12V. It converts the high voltage from PHCN to a voltage that can be used by the electronic components. The following calculation was considered for the choice of the transformer used for the circuit. The transformer has three terminals both in its input and output of 12Vac – 0Vac – 12Vac of the secondary part. The primary side of the transformer has a rating of $220V_{ac,}$ while the secondary side has a rating of $12V_{dc}$.

$$\frac{E_p}{E_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p} = \frac{N_p}{N_s} = k$$

Where K = transformer constant ratio

The transformer of the circuit was chosen in respect to the load of the circuit. The circuit requires a voltage of 12V and 5V source (DC). So the transformer of 12V – 0 – 12V will be able to supply voltage to the circuit.

The mains power supply in Nigeria is not always 220V. So this was taken into account.

$V_p = 220, \quad V_s = 12$

$$\therefore K = \frac{V_p}{V_s} = \frac{220}{12} = 18.33$$

$K = 18.33$

When the main voltage becomes 180V, the secondary voltage will be

$$V_1 = \frac{V_p}{18.33} = \frac{180}{18.33} = 9.8299V$$

Since this is lower than the voltage required by the circuit. The centre tap wire of the transformer need not to be used.

$V_p = 220V, \quad V_S = 24V$

$$K = \frac{220}{24} = 9.167$$

$when\, V_p = 180V$

$$V_s = \frac{180}{9.167} = 19.636V$$

This voltage will be enough for the required voltage of the circuit.

3.2.2 Input Unit

This is the remote control unit. It is made up of a matrix keypad that inputs a digital signal into the microcontroller. The microcontroller sends an eight bit signal via an RF module to the receiver circuit. The diagram is shown below.

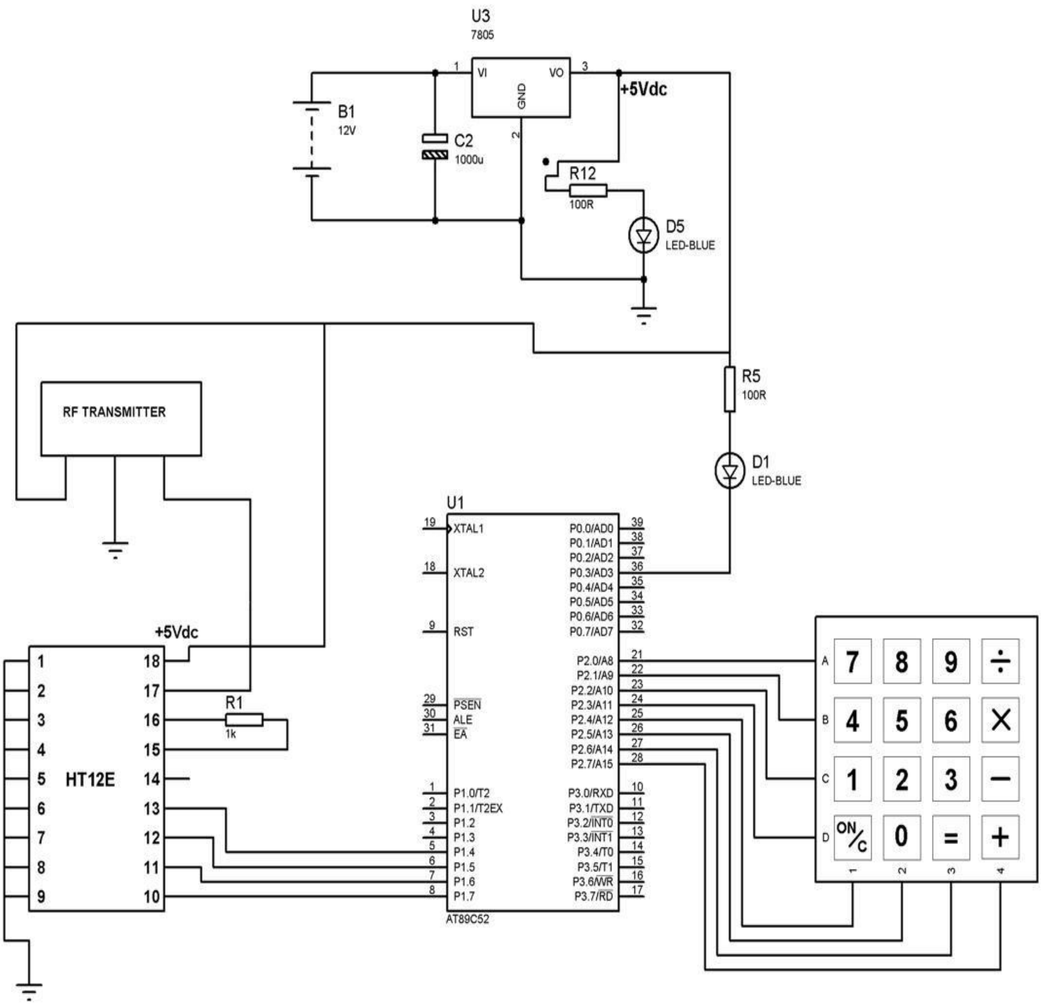

Fig 5: Circuit Diagram of Remote Control

The circuit made use of an encoder IC that encode the eight bit from the microcontroller with its address bits and send this code to the receiver unit via the RF transmitter, within a frequency of 434 MHz (available value of crystal oscillator found in the market). It receives the eight bit from the microcontroller in a parallel format and transmits serially through the RF transmitter. The RF receiver receives this serial data and converts into parallel form and sends it to the microcontroller. The RF receiver is made up of the HT12D, it decodes the address bit and code from the encoder IC and sends it to the microcontroller which decodes this signal.

3.2.3 Control Unit

The control unit is made of the Atmel AT89C52 microcontroller. The microcontroller is connected to the RF receiver unit via is port 1 terminal. A program is written in assembly language to scan the code received from the RF receiver. Each code is assigned to do a switch on a specific load.

Table 4 Keypad and Transmitted codes

Keypad Number	Transmitted Codes
0	0100
1	1110
2	1101
3	1011
4	0111
5	1100
6	1001
7	0011
8	1001
9	0010

3.2.4 Output Unit

The output unit is made up of the liquid crystal display and the loads. The 016-M002B LCD screen is used to display the bulb that turns on and the bulbs that turn off; this is possible due to its data terminals and command register that the microcontroller is connected to.
Light bulbs come on when button is pressed on the remote control. The loads used in this research are three 60W AC light bulbs and one 13A wall socket.

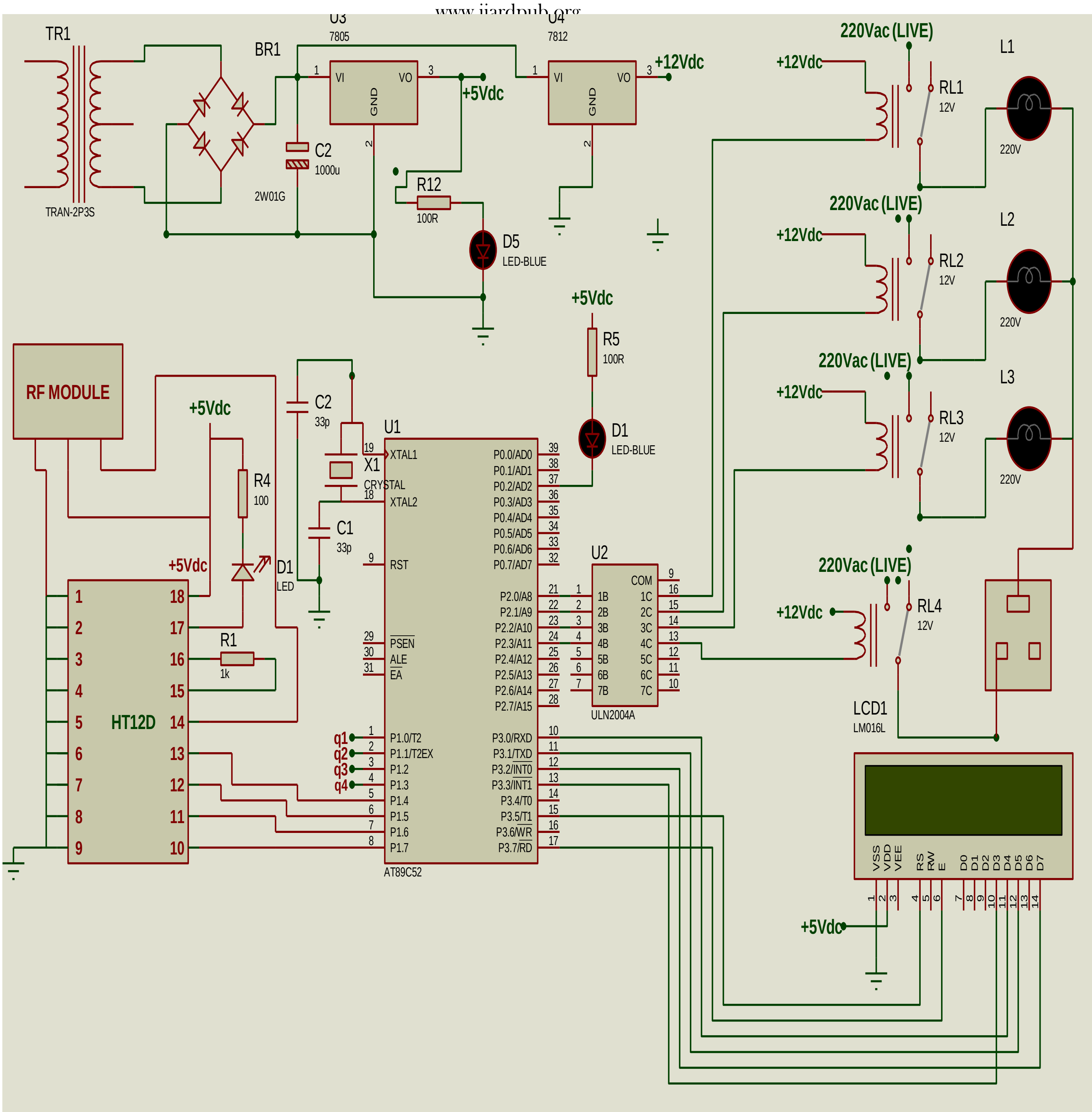

Figure 6: Circuit layout of microcontroller based RF home automation

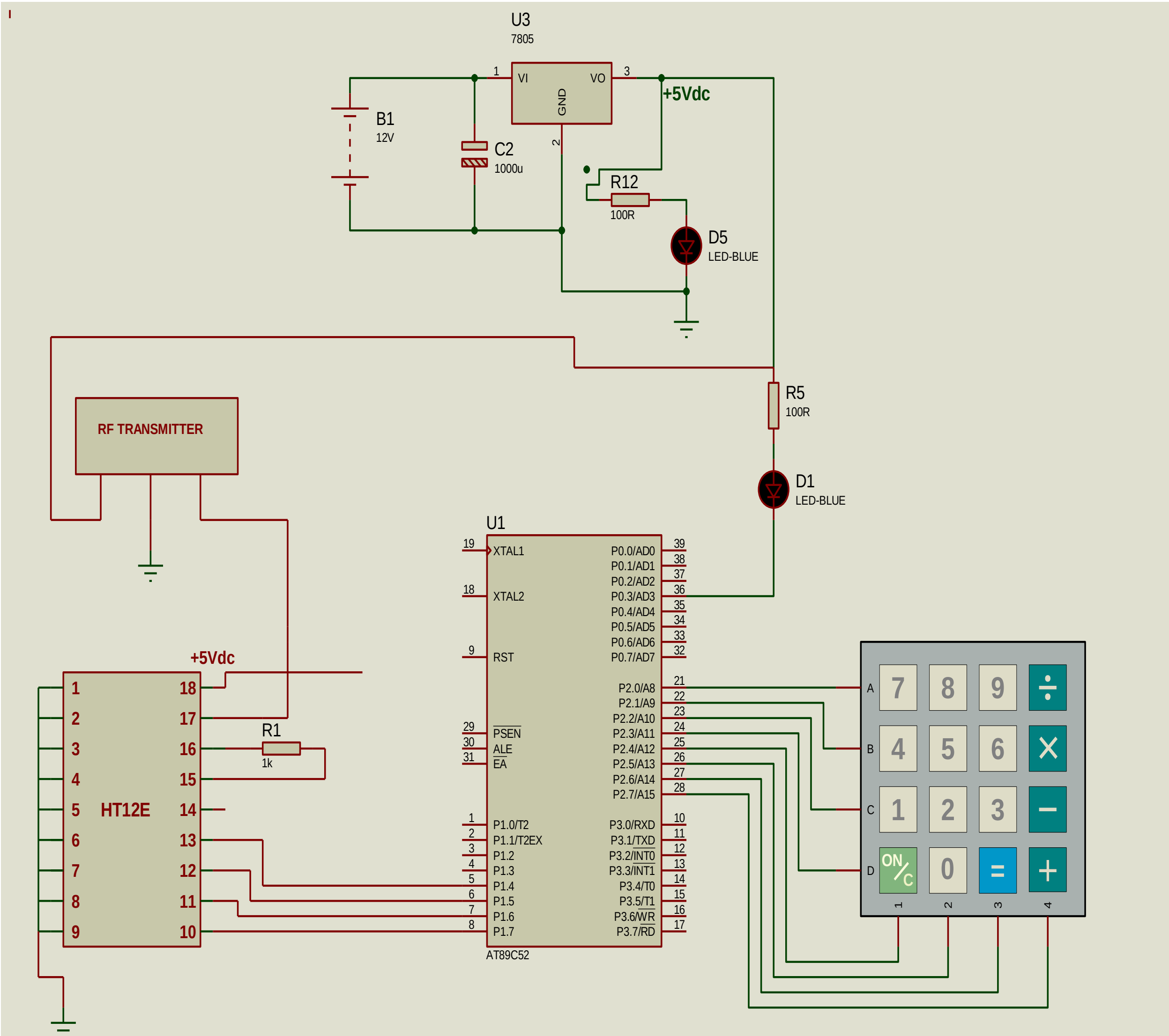

Fig 7: Circuit Diagram of Remote Control

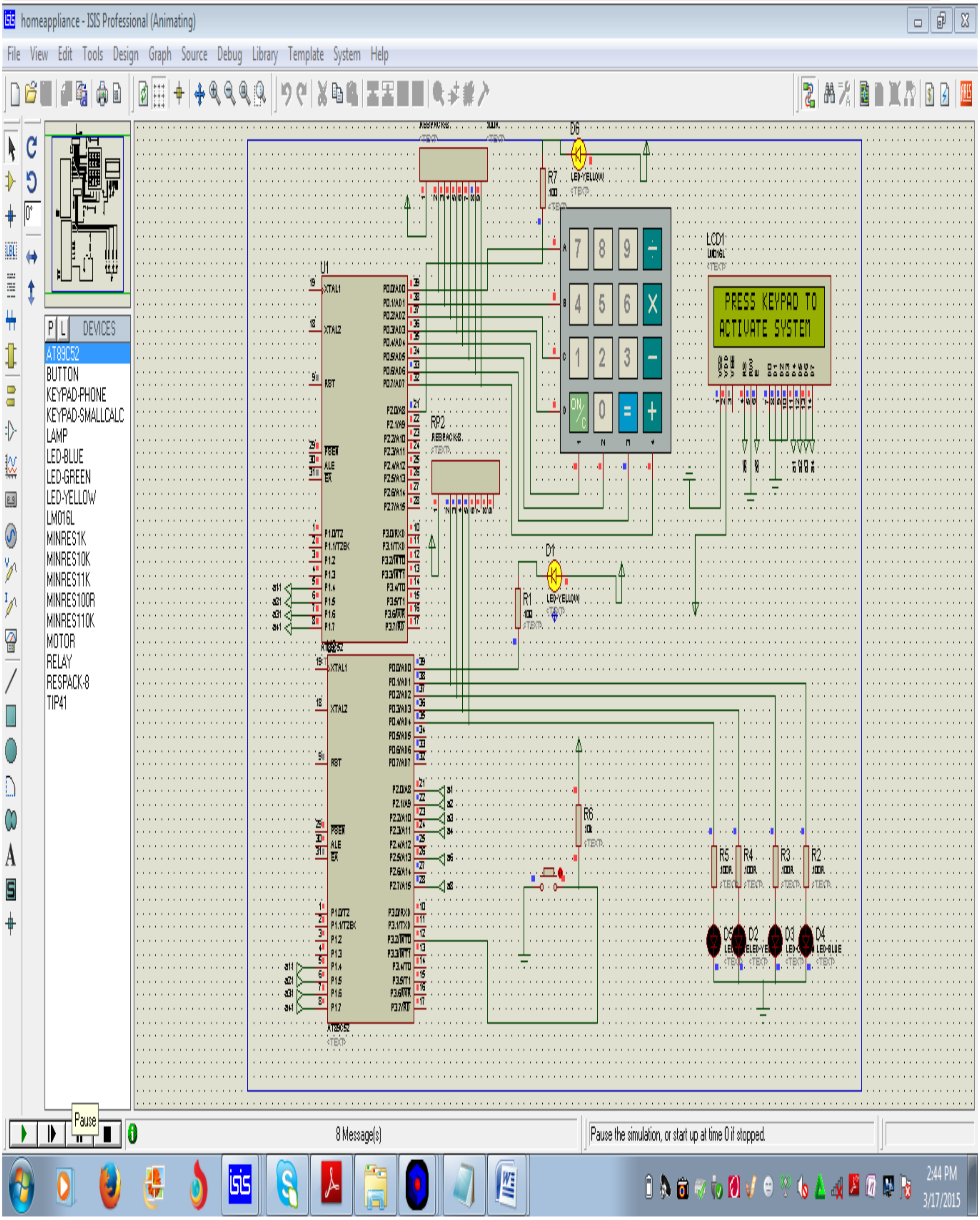

Fig. 8: ISIS Professional Simulation Snapshot

4. RESULTS AND DISCUSSIONS

4.1 TESTING

Testing is one of the important stages in the development of any new product or repair of existing ones. Because it is very difficult to trace a fault in a finished work, especially when the work to be tested is too complex. For the purpose of this project, two stages of testing are involved

i. Pre-implementation testing

ii. Post-implementation testing.

4.1.1 PRE-IMPLEMENTATION TESTING

It is carried out on the components before they are soldered to the vero board. This is to ensure that each component is in good working condition before they are finally soldered to the board. The components used in this design are grouped into two.

- **Discrete components** e.g. resistors, light emitting diodes, capacitors, transistors. Etc.
- **Integrated Circuit (IC) components** e.g. Atmel AT89C52, HT12D, HT12E microcontrollers and Uln2004 relay drivers.

The discrete components are tested with a multi-meter by switching the meter to the required value and range corresponding to each discrete component to check for continuity/proper working condition.

4.1.2 POST-IMPLEMENTATION TESTING

After implementing the circuit on a project board, the different sections of the complete system were tested to ensure that they were in good operating condition. The continuity test carried out is to ensure that the circuit or components are properly linked together. This test was carried out before power was supplied to the circuit. Finally, after troubleshooting has been done on the whole circuit, power was supplied to the circuit at the voltage shown in table 4.1. Visual troubleshooting was also carried out at this stage to ensure that the components do not burn out. Different load was added or connected to the power outlet ranging from 25 watts to 200 watts of power to check if the circuit can carry it without any effect to the circuit. After all the test and observations as explained above, the project was now certified ready for packaging.
This test was carried out with the use of a multi-meter to ascertain the measured values from the actual values.

Table 5 Measurement and Results

Power output	Expected values	Measured values
7812 regulator 7805 regulator 7805 regulator	+ 12v + 5v + 5v	+12.01v + 5.02v + 5.02v
IC relay drivers	180mA	150.0mA
AT89C52 Current Voltage	 20mA +5v	 19.82mA +4.99v
Input voltage PHCN	220Vac	208.14Vac

4.1.3 TESTING OF PROTOTYPE

For the system we designed, we assigned different keys for the different devices to be controlled for the work because of its ease. The following keys were used to control the system;

Table 6 Functions Buttons of the Remote Control

BUTTONS	CONTROL FUNCTION
Button 1	ON Bulb 1

Button 2	ON Bulb 2
Button 3	ON Bulb 3
Button 4	ON Switch
Button 5	OFF All
Button 6	OFF Bulb 1
Button 7	OFF Bulb 2
Button 8	OFF Bulb 3
Button 9	OFF Switch
Button 0	ON All

4.2 RESULT

The results obtained from table 4 and figure 5 after the test showed that the system is working perfectly. The microcontroller functions according to the program used for the software design implementation. It is worth mentioning how fascinating it is to see a designed project working satisfactorily.

5. CONCLUSION

Designing and implementation of An RF based remote control system was of a truth a fascinating task to undergo. The climax of the whole process was to see that the hardware and software implementation are working as desired after several process of trial and adjustment. This project has given us a great deal of insight into the field of communication and control engineering. The theories of communication which we have being learning from our third year was made more practicable .The ability to be able to effect control over your systems (electrical appliances, laboratory equipment, house hold appliance etc.) from far distance and in some cases from another country is of immense importance in control engineering regarding your field or your level of education.