CHAPTER-3

SYSTEM DEVELOPMENT

The Chapter describes the working of the system with the help of block diagrams and circuit diagrams for system. Brief components description is also included along with the simulation model.

Home automation is an important area of research in present scenario. A lot of efforts are made by researchers not only to make home a comfort place with ease to use of appliances, but also to save electricity. Previous literature also suggested different communication media and protocols for automation. Both wired and wireless modules are available to control home appliances. IR remote controls are available to control the on/off status of appliances, which has the limitation of the line of sight. Limitations with already existing technologies are considered and a new approach in terms of an intelligent hybrid remote control is proposed in the current research.

Universal algorithm is developed to control the multiple appliances to support a low cost solution. To overcome the limitation of IR communication RF module is used for the designed system. The system it is divided into two parts receiver section and remote control. A remote control is used to control the receiver section, connected to the appliances to be controlled. Embedded system based control system is proposed with PID controller to control the diming levels of home appliances. Embedded system is basically used to perform a specific task.

For developing the prototype heater, exhaust fan and bulb are used and there diming levels are controlled in two modes- autonomous and semiautonomous. PID controller is used to control both linear and non-linear loads. It is helpful for smoothing of output response of the systems.

The three parameters Kp, Ki, Kd are tuned with different methods to optimize the step response. of the appliance. Further it is concluded that by using some optimizing algorithms, these parameters can be optimized more accurately. With the help of PID tuned parameters diming levels of home appliances can be controlled.

3.1 Embedded System

An embedded system is a system which is designed to perform a special-purpose. In this system the controller completely supports the essential features of device, it controls. Embedded systems are designed to carry out specific tasks for a particular system.

In other words embedded systems are the devices to monitor or control the operation of integrated system.

Features of Embedded system

- Designed to perform a specific task
- Energy Efficient
- Small code size
- Less execution time
- Less weight and cost
- High speed
- Real time execution
- Quick response
- Multiple peripherals
- Interaction with sensors
- Continues environment monitoring
- Minimal user interface
- User friendly
- Interactive
- Support to multimedia applications
- Flexible
- Simple software
- Hardware centric
- Availability of cross complier
- High level language
- Analog to digital convertor

- Special purpose machine
- Intelligent communication
- Precise
- Robustness
- Integrity

The embedded system industry was born with the invention of microcontrollers. Since then based on the demand of devices different processors and controller are designed. After identifying the task to be performed next step is to choose appropriate controller for defined task.

3.1.1 Selection of Microcontroller

A microcontroller is an integrated circuit containing a core processor, memory, and programmable input/output peripherals. Program memory in the form of RAM, flash and ROM is also included on the chip.

Classification of microcontrollers can be done on the basis of-

- Bits- 8bits, 16bits, 32bits
- Memory – Embedded memory, external memory
- Instruction set – RISC, CISC, CISC implemented on RISC core
- Memory Architecture – Harvard ,Princeton
- Family- 8051, Motorola, PIC, Hitachi, Texas, ARM, others
- Manufacturer - Intel, Philips, Atmel, Siemens, Dallas

Criteria for selecting the microcontroller includes-

- System Requirement
- Memory Architecture
- Availability
- Size
- Compatibility
- Functionality Testing
- Power Management

- Manufacturer's Track Record
- Manufacturer's Support
- Availability of Development Support
- Cost

A comparative study is done for different microcontrollers as shown in table-3.1 [www.atmel.com], to select accurate controller for system.

Table-3.1 Comparison for different microcontrollers

Characteristics	80C51	AT89C52	Atmega8	Atmega16	PIC16F8x	Strong ARM SA-1100
Bits	8	8	8	8	8	32
Flash	64 K	8 K	8 K	16 K	68 K	-
RAM	1024 bits	2 K	1 K	1 K	1 bit	-
ADC	0	0	8 bits	8 bits	-	-
Timers	1	3	3	3	1	-
Operating Voltage	2.7 – 5.5V	3 – 6.6V	4.5-5.5 V	4.5-5.5 V	2-6 V	3 – 3.6V
Power down mode	50 μA	100 μA	0.5 μA	0.1 μA	< 1 μA	25 μA

On the bases of comparison and system requirement AVR Atmega16 microcontroller is selected to develop the current system.

3.2 AVR Microcontroller

AVR is Alf-Egil Bogen and Vegard Wollan's Reduced Instruction Set Computer or Advanced Virtual RISC. In AVR microcontroller fetching of next command is done during execution of previous command and overall number of commands in 1second is almost equal to working frequency. AVR microcontrollers are manufactured using high quality CMOS technology, contain EEPROM memory inside it, and require less power at higher frequencies. The program can be uploaded directly on board using ISP programming. It has 32 general purpose registers and inbuilt ADC.

AVR Micro-controller Features [www.atmel.com]

- 8 and 16 bit programmable timers with separate pre-scalar
- 8 to 16-bit PWM
- 10-bit Multichannel ADC
- UART, SPI and I2C support
- JTAG Interface
- Internal and external Interrupt sources
- Programmable Watchdog with independent oscillator
- SLEEP and POWER DOWN modes of operation
- In System Programmable
- RISC Architecture
- 32 general purpose registers
- Low Power requirement
- Efficient 'C' Code Density
- 1K bytes (AT90S1200) to 128Kbytes (ATMega128)
- On chip SRAM (on most devices)
- On chip EEPROM
- Max frequency is 16 MHz
- A high performance watchdog reset circuit with user selectable timeout periods.
- Three 'Registers/Buffers' associated with each port
- Data Direction Register (e.g DDRB)
- Output Register (e.g. PortB)
- Input Buffer (e.g. PinB)
- UART Rx offers noise rejection by sampling the input multiple times.

- Rich interrupt structure
- Priority interrupts structure
- External interrupts with level or edge triggering.
- SLEEP allows most peripheral interrupts to operate. The CPU is stopped and only reset, WDR and interrupts resume controller operation
- Power down mode stop the oscillator and all peripherals. Only reset, WDR and external interrupts can wake up the system
- Available in 8-pin DIP/SOIC to 64-pin PLCC/TQFP packages
- It has Harvard architecture

3.3 Optimization Algorithms

A lot of complex arithmetic computational steps are required to get required tuned parameters to derive the system. To avoid this complexity, different optimizing techniques are used. Genetic algorithm and particle swarm optimization algorithms are identified as hardware compatible optimizing techniques to find out the optimal tuning parameters.

A comparative study has been done (details in chapter-6) and PSO with PID controller is proved as best suited algorithm to develop the system. The algorithm is implemented on the system with ATMEGA16 microcontroller.

3.3.1 Genetic Algorithm

Genetic Algorithms (GA) is based on the evolutionary ideas of natural genetics and selection. GA is based on the historical information for better performance of the search region. The principle of “survival of the fittest” was first discovered by Charles Darwin. It is inspired by the nature where individual survivor is the result of competition over the weaker ones.

For solving a problem, GA simulates the survival of the fittest for individual after each consecutive generation. Each individual represents a possible solution and a point in a search space. The individual in the population is gone through a process of evolution, to find its fittest value.

A fitness value is assigned to each solution, which represents the abilities of an individual to 'compete'. The individual having the optimal fitness value is selected. The GA goal is combining best information from the chromosomes to produce 'children' better than the parents by using selective 'breeding' of the solutions. Better solutions over successive generations will thrive while the least fit solutions die out [51].

Genetic algorithm involves following steps

1. Initialize the algorithm with population
2. Use objective function to evaluate the fitness of individual
3. Select the members with fitness value
4. Implement mutation process on individual
5. Select the chromosomes with best values
6. If the final criteria is met the process stops
7. If not satisfied then search for another best values.

Fig.3.1 shows the Flow chart for genetic algorithm with the steps followed by algorithm.

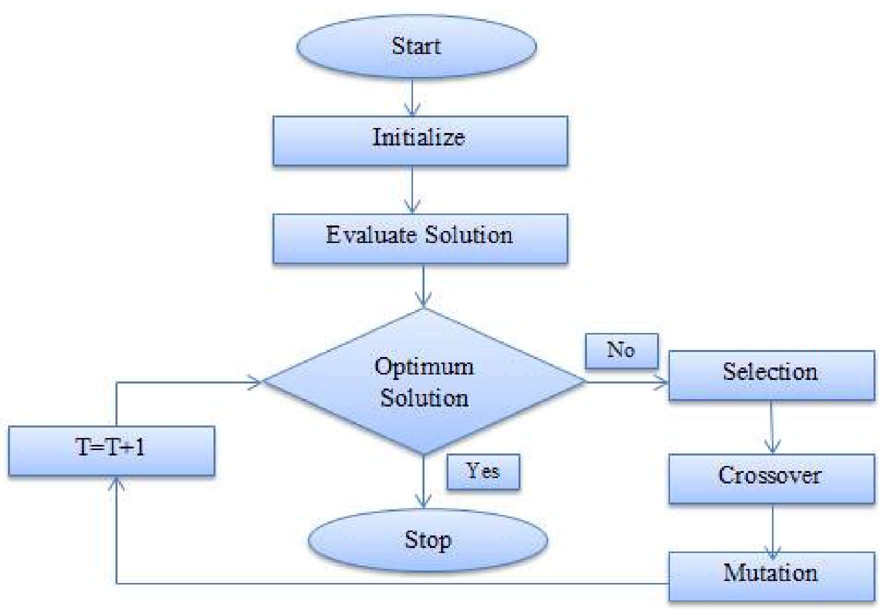

Fig.3.1 Flow chart for Genetic algorithm

3.3.2 Particle Swarm Optimization Algorithm

PSO was proposed by Eberhart and Kennedy in 1995. The social behavior a group of birds, are the main thought behind this algorithm. PSO is similar to the GA in the initialization's step which has to start with a population. But PSO doesn't work on crossover or mutation. The particles move as per the objective function with an initial velocity and position. Based on the iterations, particles try to update their velocities and positions. Then update their local best and global best positions accordingly [52].

Steps involved in PSO algorithm are as follows-

1. Input all the parameters, transfer function and PSO constants with no. of particles
2. Initialize the velocities and positions of the particle
3. Find the unit step response of the system
4. Calculate system parameters for every particle
5. Compare the parameter values of each particle with its previous value; if it is better than previous one, replace it.
6. The value with lowest error is considered as global best value.
7. Update particles with their new position and velocity values.
8. Start with step (3) and repeat until system requirements are satisfied

The parameters used to implement PSO are as follows.

```
n = 40;          % Size of the swarm 'no of birds'
birds =40;   % Maximum number of 'birds steps'
dimension= 2;   % Dimension of the problem
c2 =1.3;          % PSO parameter C1
c1 = 0.14;        % PSO parameter C2
w =0.9;           % PSO momentum or inertia
fitness=0*ones(n, bird);
```

For The optimization of parameters the following equation is used.

Velocity= w*velocity + c1*(R1.*(lb_position-c_position)) + c2*(R2.*(gb_position-c_position)); and cp = cp + velocity;

Where,

cp is current position, lb is local best, gb is global best

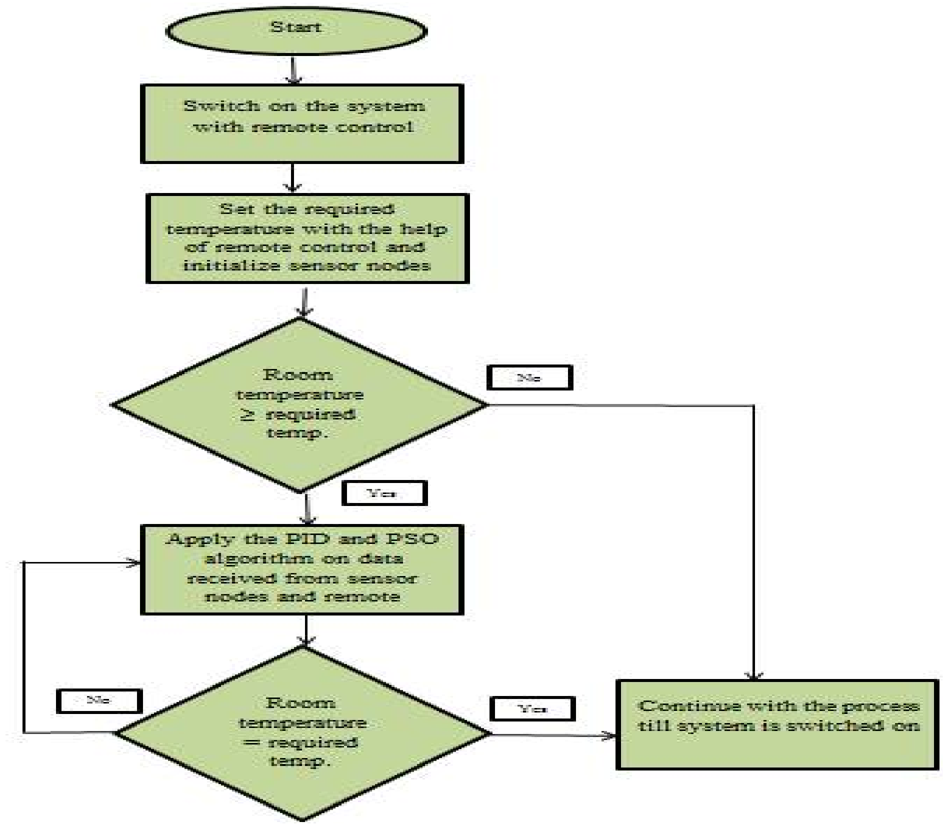

Fig.3.2 Flow chart for PSO algorithm

3.4 PID Controller

The system is tuned to obtain the tuning parameters of PID with MATLAB Simulink, for desired closed loop response.

The transfer function for PID controller is given by equation-3.1.

$$G(s) = Kp + Ki/s + Kds \quad \text{...(3.1)}$$

Where

Kp – Proportional gain

Ki– Integral gain

Kd –Derivative gain

Performance Indices for PID controller

The PID controller system is optimized by adjusting certain performance index. The performance indices is calculated for a time interval T.

The performance indices [35] are given as follows.

- **Integral Absolute Error (IAE)**

  IAE = $\int_0^T e(t)dt$

- **Integral Square Error (ISE)**

  ISE= $\int_0^\infty e^2\,(t)dt$

- **Integral Time Absolute Error (ITAE)**

  ITAE = $\int_0^T t|e(t)|dt$

- **Integral Square Time Error (ISTE)**

  ISTE =$\int_0^T te^2\,(t)dt$

3.5 Sensors

A sensor is a device which detects the changes in quantities and provides a corresponding output, generally in the form of electrical or optical signal.

Digital Sensor- A digital sensor is an electronic or electrochemical sensor, where data transmission is in form of digital. These are event based i.e. whenever an event will occur they will be activated and give output.

Analog Sensor – It produces the output voltage with respect to the change in environment parameters. It continuously senses the change in environment.

In the developed system temperature/ humidity sensor with model no.-1211[sunrom.com] is used for measuring temperature/humidity and LDR with model no.-3190 [sunrom.com] is used for measuring light intensity.

3.5.1 Temperature/Humidity Sensor

This sensor measures both Relative Humidity and Temperature of the surroundings. It gives output at serial interface with 9600 bps data rate. It has fast response time and operates on 5V DC Supply. For relative humidity it has measuring range from 1%-100% and for temperature it is from +2 deg C to +60 deg C.

Table-3.2 Pin Description of Temperature/humidity sensor [sunrom.com]

Pin no.	Details
1 (GND)	Power Supply Ground
2 (+5V)	Regulated +5V DC supply
3(TXO)	Transmit pin

Serial Data Output Format

This data is output in ASCII format in 13 bytes.

E.g.: H:058 T:024

Table-3.3 Data Format for temperature/humidity sensor [sunrom.com]

BYTE	Details
1	New Line Char
2	Char H
3	Char:
4	Humidity Char-Hundredth place
5	Humidity Char-Tenth place
6	Humidity Char-Ones place
7	Space line
8	Char T
9	Char :
10	Temperature Char- Hundredth place
11	Temperature Char-Tenth place
12	Temperature Char-Ones place
13	New Line Char

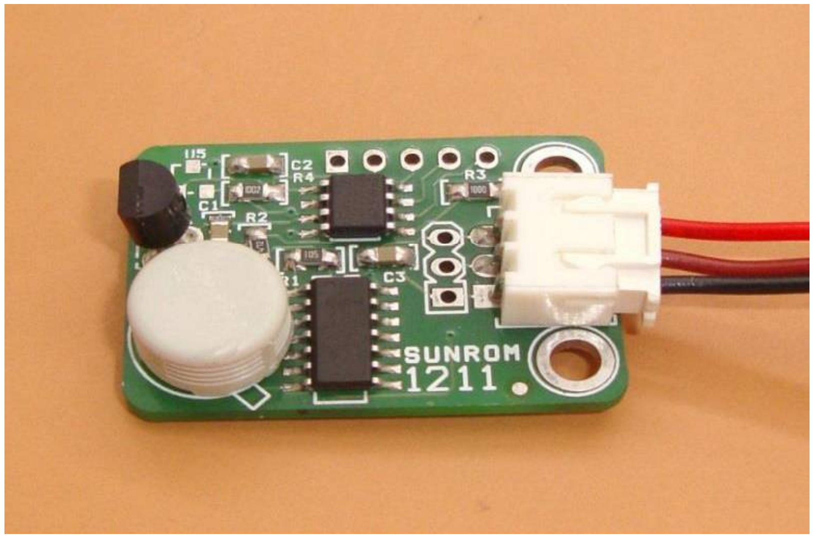

Fig.3.3 Temperature/humidity sensor

3.5.2 LDR

Light-dependent resistor (LDR) [sunrom.com], is a light-controlled variable resistor also known as photoelectric device. The resistance of a LDR decreases with increasing incident light intensity. It is made of a high resistance semiconductor. In the dark, it has a high resistance and decreases as intensity increases. It is having operating temperature range of -60 degree Celsius to +75 degree Celsius. It has maximum power dissipation of 100mW.

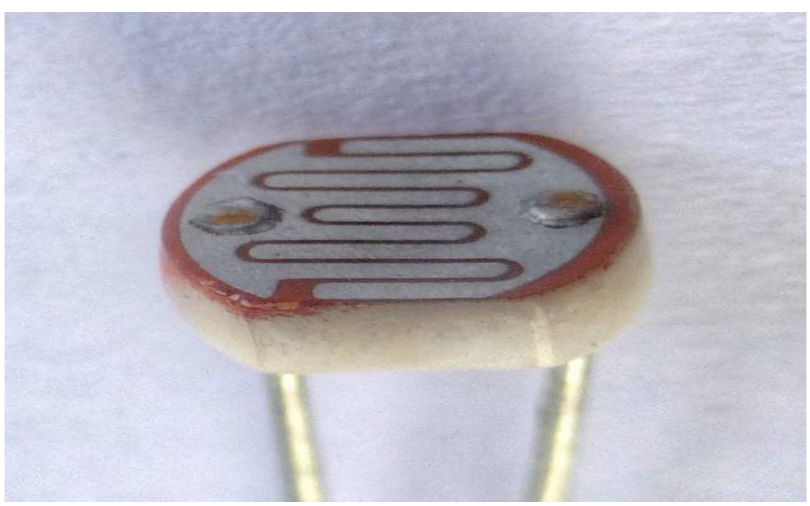

Fig.3.4 LDR

3.6 System Description

In this thesis a system is designed for remote dynamic control for appliances to maintain the optimum conditions for a room. A smart remote controlled system is fabricated, which provides a low cost power saving solution. One heater of 1KW, 100W bulb and 18W exhaust are used for experimental set up. Dimming level of appliances is optimized by using different optimization algorithm, and comparison analysis is done with the help of system modeling.

The developed system provides a solution in the form of a single remote control to control the heating, lighting and humidity of a room.

The whole system comprises of two parts-

- Remote control
- Receiver section

3.6.1 Remote Control

The remote control as shown in Fig.3.5 comprises of temperature/Humidity sensor (T/H) and Light dependent resistors (LDR), atmega16, RF modem, LCD 16*2 display unit, switches and battery. Switch array is used to control the appliances. The temperature/humidity sensor provides temperature and humidity information as feedback signal to the system. The remote control has nine switches for various operations. Two switches are for mode selection of operation as semiautonomous or autonomous mode. Three pairs of UP/DOWN keys are kept in the remote control in order to increase/decrease the three parameters namely exhaust fan speed, heater temperature and light intensity. The 'OK' switch is used for sending the information packet to receiver section. Further these switches can be reduced to lower number by using same keys for level shifting of every appliance, which can be achieved by multiplexing of switches. Li ion battery is used as power supply module for remote control. All the devices at the remote control end operates at +5V DC power supply.

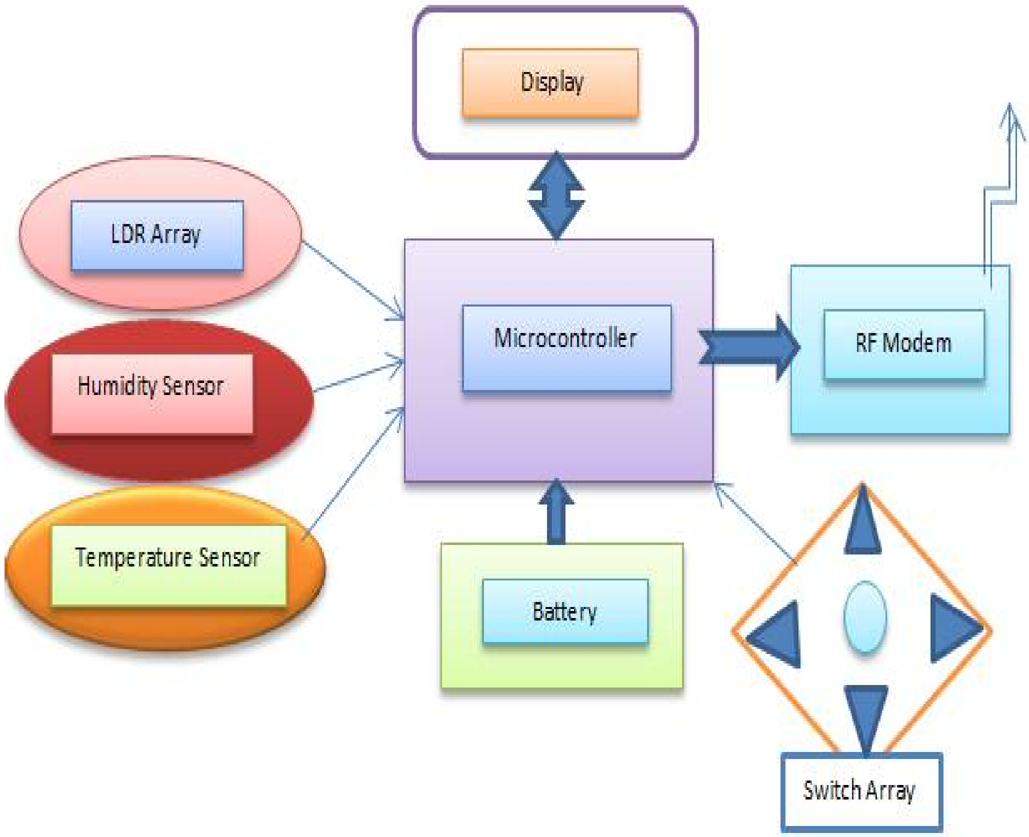

Fig.3.5 Block diagram of remote control

3.6.2 Receiver Section

Fig.3.6 shows the receiver board comprises of three dimmer circuit, atmega16 microcontroller, RF modem, LCD 16*2 display unit, power supply, exhaust fan(EF), heater(H) and bulb(B). Dimming circuits are useful to control the dimming levels of exhaust, heater and bulb. PID controller is implemented with dimmer in receiver section to control dimming of room appliances, by setting the firing angle. The receiver section will receive packet which contain the data from remote control in the form temperature, humidity and light intensity. If the packet contains the data on temperature, then the corresponding error signal is generated and then provides the signal to PID controller to control the temperature of heater. The same is the case with the humidity and light intensity.

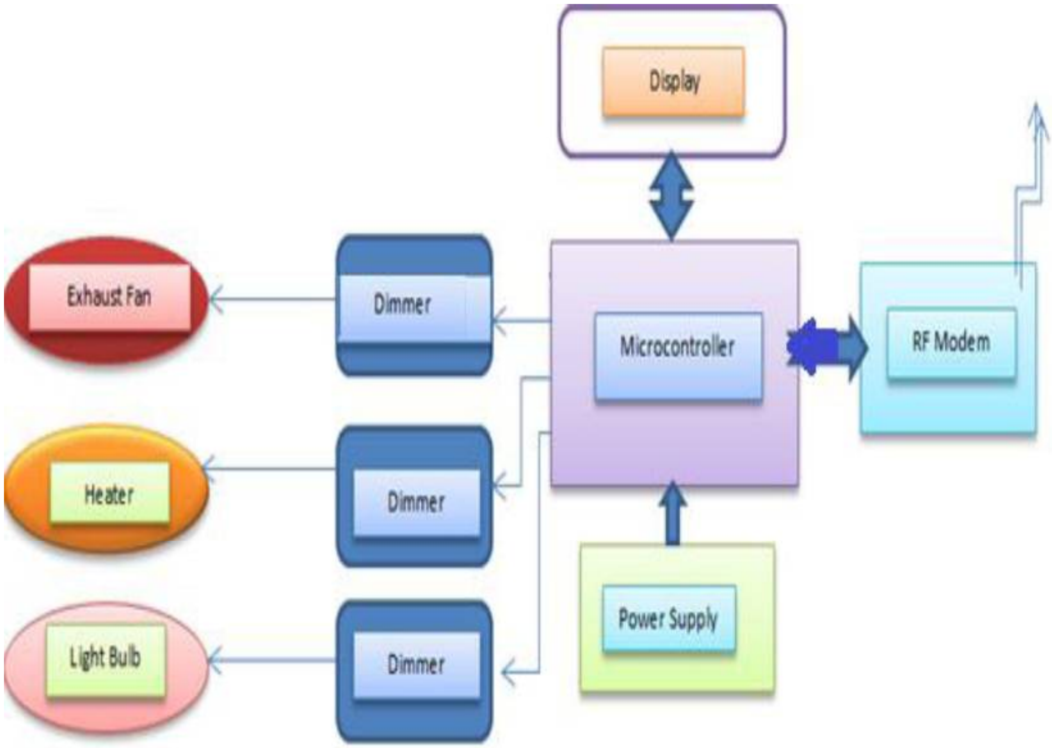

Fig.3.6 Block diagram of receiver section

3.7 Component Description

Table 3.4 gives the brief description of model no. and features of the main components used to develop the system.

Table-3.4 Brief description of components used to develop the system

S.No.	Device/Module	Specifications and working
1.	Atmega16	Atmega16 is a 8-bit microcontroller.
2.	RF modem	It operates at 2.4 GHz frequency. Transmits and Receives serial data of baud rate 9600/4800/2400/19200 bps at 5V or 3V level.
3.	LDR	[Sunrom.com] Model no. 1390, Light dependent resistor used to measure light intensity of room.
4.	Temperature/Humidity	[Sunrom.com] Model no. 1211. Serial data output at 9600 baud rate

	Senor	Relative Humidity with range 1%-100% and temperature with range +2 deg C to +60 deg C
5.	Dimmer	The input can be simple 3 bit binary signal which is isolated with the use of opto-isolator. Output can switch on AC Load upto 12 Amp. Input and output are optically isolated [Sunrom.com].
6.	LCD	16*2 LCD to display the information on remote section and receiver section
7.	Crystal	14.7456MHz frequency crystal is used to control the baud rate of microcontroller at 9600bps.
8.	Switch array	DPDT switches are placed on remote control.
9.	Battery	Chargeable Li-ion battery to operate the remote control.
10.	Power supply	Household power supply is used for the Receiver section.

3.8 Circuit Diagram of the System

Fig.3.7 shows the circuit diagram of remote control. The connections of remote control are as follows-

1. Pins 1, 3, 16 of LCD are connected to ground and Pins 2, 15 pins are connected to Vcc.
2. Control pins of LCD RS, RW and E are connected to PD6, PD5 and PD7 of microcontroller.
3. The data pins of LCD (D4 to D7) are connected to Atmega16 (PC0 to PC3).
4. The TX pin of Atmega16 is connected to RX pin of RF modem, The RX pin of Atmega16 to TX pin of RF modem.
5. Ground & +Vcc pins of RF modem and Atmega16 is connected to ground and +5V of the circuit.

6. RF modem works on TTL logic, so it is directly connected to Atmega16. Configure Atmega16 at 9600 baud rate to communicate with RF modem.
7. 14.7456MHz crystal is connected with Atmega16 to set the baud rate 9600 of remote section.
8. The data out pins of temperature/humidity sensor and LDR are connected to PA0 (40), PA1 (39) and PA2 (38) pins of Atmega16. These pins are ADC of Atmega16.

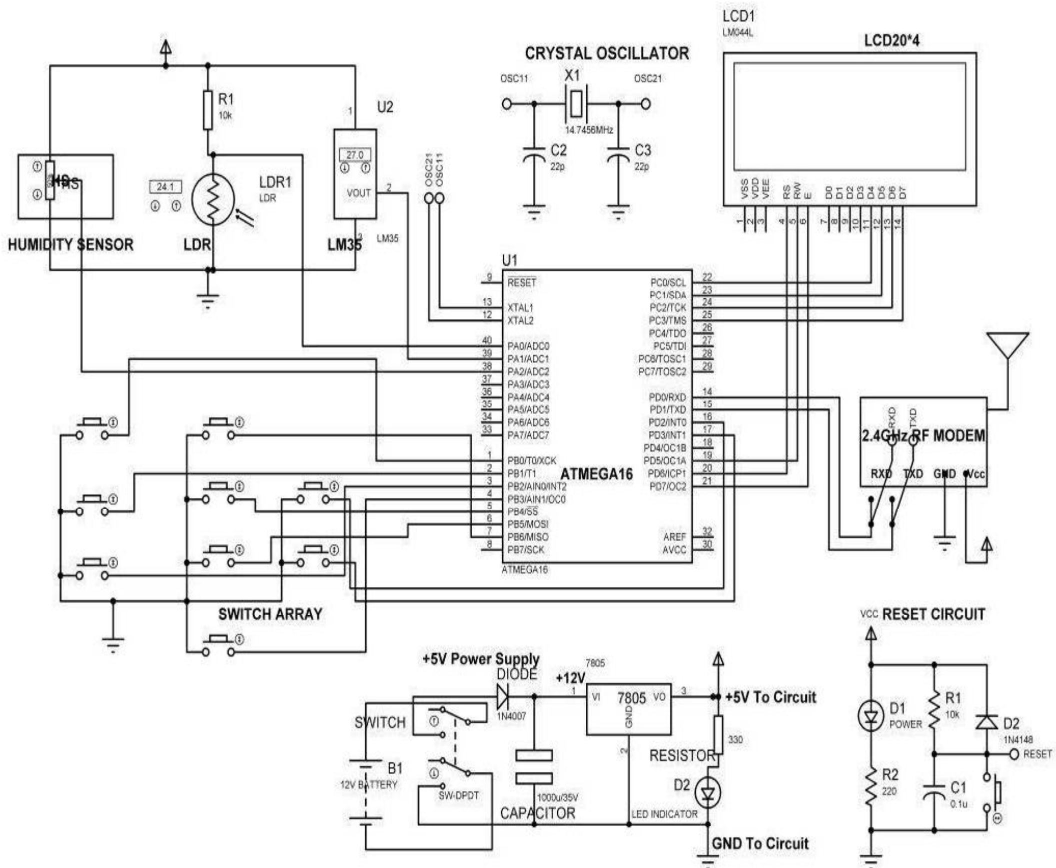

Fig.3.7 Circuit diagram for remote control

Fig.3.8 shows the circuit diagram for the power supply. Fig.3.9 shows the circuit diagram of receiver board. The connections of receiver board are as follows-

1. LCD 1, 3, 16 pins are connected to ground and 2, 15 pins are connected to Vcc.
2. Control pins RS, RW and E of LCD are connected to PD6, PD5 and PD7 of Atmega16.
3. The data pins of LCD (D4 to D7) are connected to Atmega16 (PC0 to PC3).
4. The TX pin of Atmega16 is connected to RX pin of RF modem, The RX pin of Atmega16 is connected to TX pin of RF modem.
5. Ground & +Vcc pins of RF modem and Atmega16 is connected to ground and +5V of the circuit.
6. RF modem works on TTL logic so it is directly connected to Atmega16. Configure Atmega16 at 9600 baud rate to communicate with RF modem.
7. 14.7456MHz crystal is connected with Atmega16 to set the baud rate 9600.
8. Fan dimmer is connected to lower port B pins of Atmega16 of receiver board.
9. Heater dimmer is connected to upper port B pins of Atmega16 of receiver board.
10. Light bulb dimmer is connected to upper port A pins of Atmega16 of receiver board.

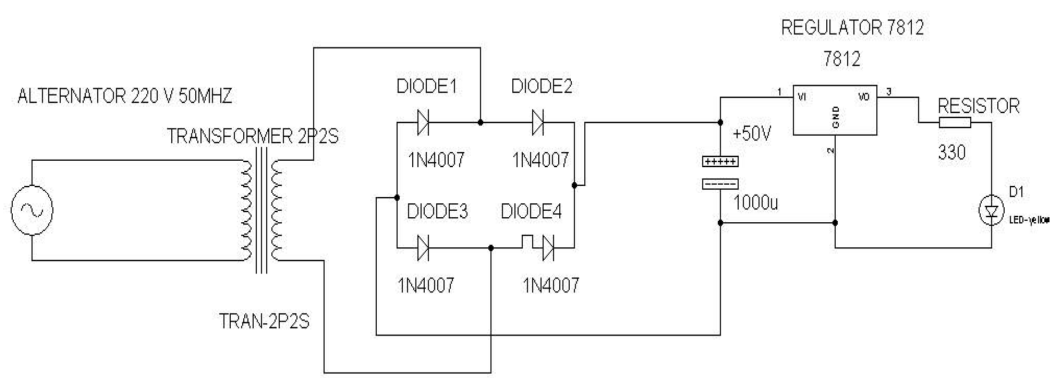

Fig.3.8 Circuit diagram for power supply

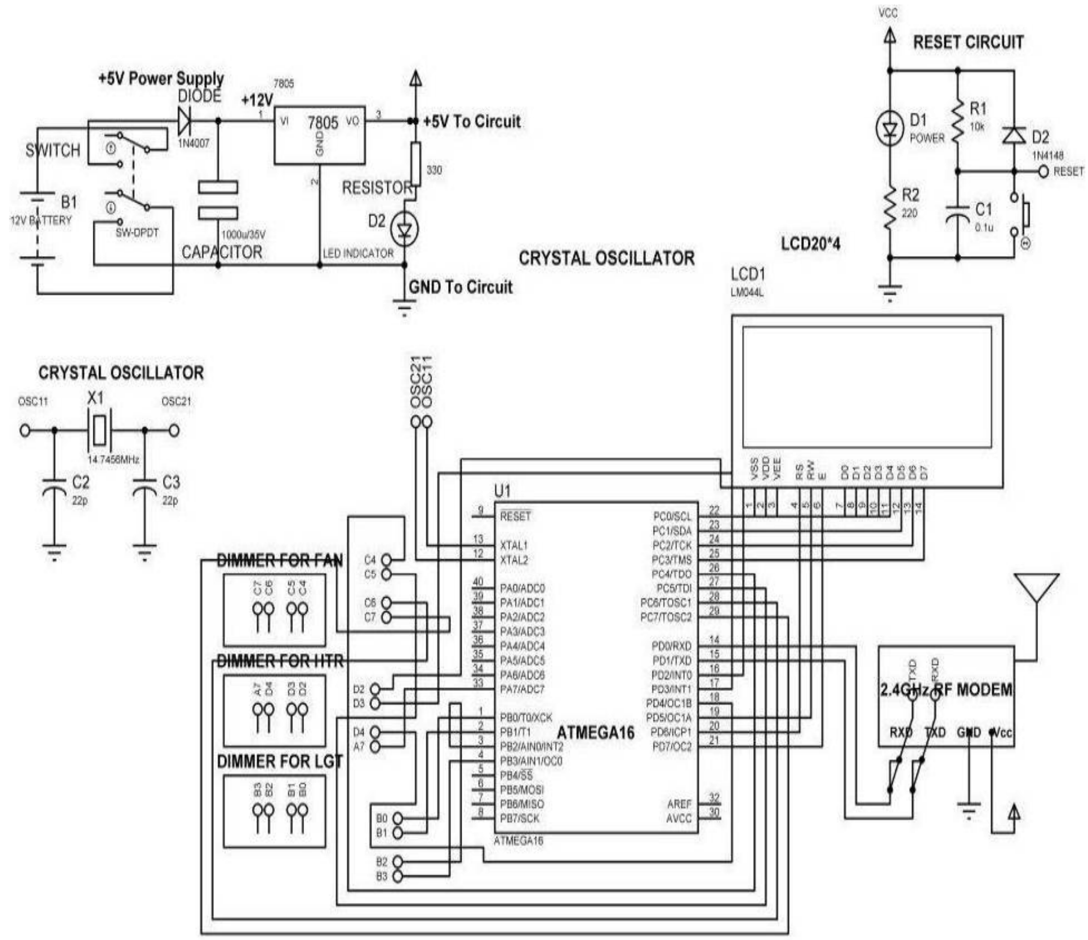

Fig.3.9 Circuit diagram of the receiver section

3.9 Proteus Simulation Model

It is software for simulation, schematic capture and printed circuit board (PCB). It is developed by Lab center Electronics. It is a Virtual System Modeling (VSM), circuit simulation, animated components and microcontroller models to simulate the designs. This is a tool to test the microcontroller designs before building a physical prototype in real time. This software is for interacting with the design with on-screen displays. A key component of Proteus 7.0 is the Circuit Simulation. It is a product that uses a SPICE3F5 analogue simulator kernel with an event-driven digital simulator that allows users to use a SPICE model from each manufacturer. Fig.3.10 & Fig.3.11 shows Proteus simulation for receiver and remote control respectively.

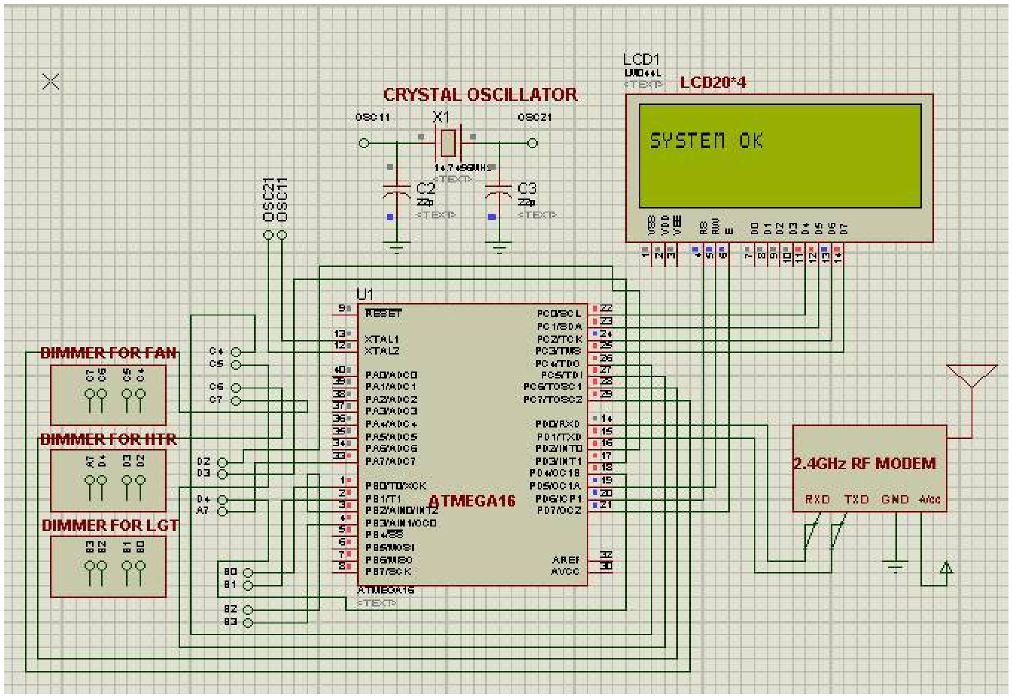

Fig.3.10 Proteus Simulation model for the receiver section

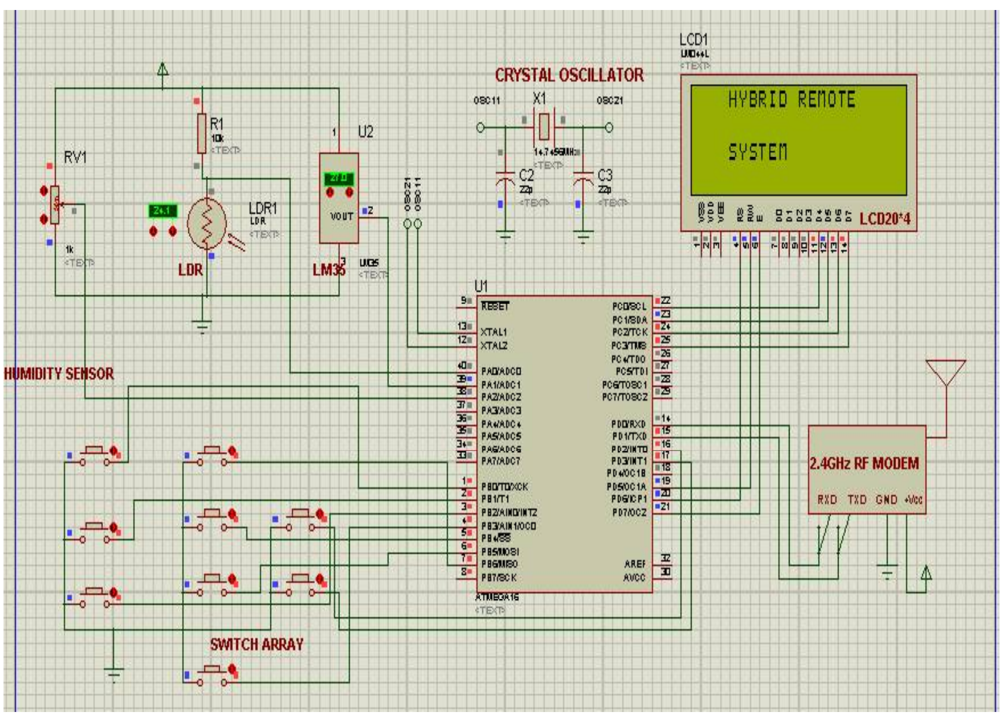

Fig.3.11 Proteus Simulation model for remote control

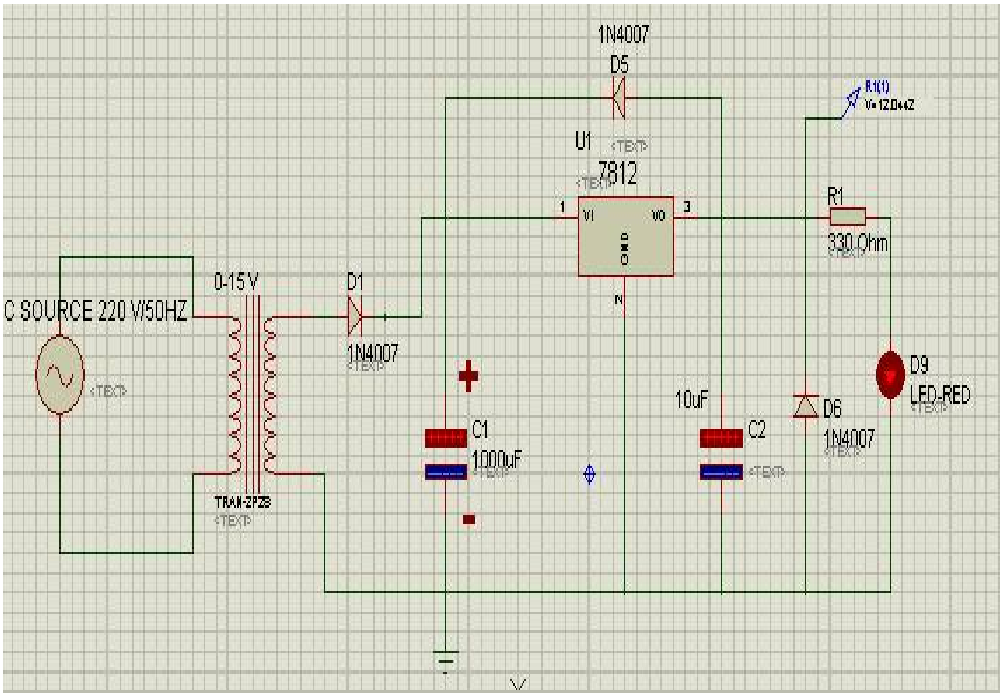

Fig.3.12 Power supply model

3.10 Chapter Summary

On the basis of the problem statement the chapter describes the selection criteria for selecting the main components to develop the system. Brief description of major components is included. The chapter concludes the block diagram and circuit diagrams of the remote control and receiver section. Simulation with the help of Proteus simulation software is also discussed to check the proper working of designed system with selected components, before its actual hardware implementation. It is concluded that Atmega16 is suitable microcontroller to design the system. To measure the temperature/humidity with model no.1211 [sunroom.com] and to measure light intensity the LDR with model no. 1390 [sunroom.com] is used.