CHAPTER-4

METHODOLOGY

The chapter describes the methodology used for system development. First the calibration and testing of sensors are done with the help of standard instruments, then controller is programmed accordingly. Chapter also includes the theory of dimming operation of appliances.

Sensor Calibration is an important part for any system development. This is to achieve best possible accuracy. The calibration part is also important, as during manufacturing process lot of variations are introduced and even two sensors with same manufacturer may vary in similar conditions. No sensor is perfect to measure prescribed parameter, just after manufacturing. Some sensors' response also varies over time passing so a periodic re-calibration is required for those.

The most important characteristics of a sensor are precision and resolution. Accuracy is the combination of these two. But some external noise signals affect these characteristics, which results in bad accuracy. To avoid this problem, calibration is required. Now the question arises, how to calibrate the sensors to make them accurate. The answer is simple, for this purpose standard instruments can be taken as reference. Each sensor has a characteristic curve which defines the sensors' real time response to the given input. The calibration process is to map the sensor's response to its ideal response (aligning with standard formula).

4.1 Methodology Used

The basic Flow of the process is to make the system intelligent by applying PID controller with optimization algorithm. System performance is checked for PID, Genetic algorithm with PID and particle swarm optimization algorithm with PID on receiver unit. On the basis of experimental results, PSO is implemented on receiver with PID for final developed hardware prototype. The receiver collects the data from sensors, and an error signal is generated on the basis of difference between sensory data and input value, to maintain desired room conditions.

4.2 Calibration of Temperature/Humidity Sensor

Calibration of temperature/humidity sensor is achieved by standard instrument (Phycrometer).

It is required to make the system intelligent because after time passes there is increment in the previous temperature. Once the system has achieved the set temperature, it is necessary to lower it down after a time period to maintain constant temperature.

To analyze temperature and humidity level control for the system, temperature/humidity sensor [sunrom.com] is used.

Temperature/ Humidity sensor is connected in USART mode with microcontroller.

The following function is used to initialize the USART in Atmega16 microcontroller.

```
void START_USART(uint16_t BAUD_RATE)
{
  //Set Baud rate
  UBRRL = BAUD_RATE;
  UBRRH = (BAUD_RATE >>8);
  /*Set the Frame Format according to requirement
  >> Asynchronous mode
  >> No Parity is set
  >> 1 Stop bit
  >> character size is 8
  */
UCSRC=0b10000110; // make URSEL and UCSZ0 of UCSRC high (USART Control and Status Register)
  // Enable the transmitter and receiver and
UCSRB= ob00011000;
}
```

//This function is for reading the available data
//from USART. Until the data is
//available

The following function is used to read the character from USART data register (UDR)

```
char READ_USART( )
{
  //Wait for data availability

  while(!(UCSRA & (1<<RXC)))
  {
    //waiting
  }

  //UDR get data
  //and available in UDR

  return UDR;
}
//This function is for writing the given 'data' to
//the USART which then is transmitted through TX line
```

The following function is used to write the character to USART data register (UDR)

```
void WRITE_USART(char Byte)
{
  //Wait for transmitter availability
  while(!(UCSRA & (1<<UDRE)))
  {
```

```
    //waiting
  }

  //Data is available in Byte

  UDR=Byte;
}
```

The following function is used to write the string to USART data register (UDR)

void PRINT_STRING_USART(char *msg)

```
{
        while(*msg!='\0')
 {
        WRITE_USART(*msg);
        msg++;
 }
}
```

The following program is written to read the sensor in USART mode.

```
while(1)
        {
         H_sensor=(((sbuffer[3]-'0')*100) + ((sbuffer[4]-'0')*10) +(sbuffer[5]-'0'));
         T_sensor=(((sbuffer[9]-'0')*100) + ((sbuffer[10]-'0')*10) +(sbuffer[11]
'0'));
        WRITE_USART (0xEA);
        WRITE_USART (0x14);
        WRITE_USART (H_sensor);
        WRITE_USART (T_sensor);
        WRITE_USART (0x0D);
        _delay_ms(300);
```

```
            }
ISR(USART_RXC_vect)// Interrupt service routine for RX pin
{
            cli();
           sbuffer[Byte]=UDR;
          if(sbuffer[Byte]==0x0D)
          {
            Byte =0;
          }
          else
          Byte ++;
          sei();
}
```

For calibration of sensor, Phycrometer is used as per the calculation given on [http://www.4wx.com/wxcalc/formulas/rhTdFromWetBulb.php]

Table- 4.1 Humidity and temperature values from standard instrument and sensor

Data points	Time	Dry temperature by standard instrument (in ^{0}C)	Wet Temperature by standard instrument (in ^{0}C)	temperature by sensor(in ^{0}C)	Temperature error (%)	Relative humidity by standard instrument (%)	Relative humidity by sensor (%)	Humidity error (%)
1	9:30AM	20	12.1	20	0	44.8	45	-0.004
2	10:00 AM	21	12.7	21	0	43.6	44	-0.009
3	10:30 AM	22	13.4	22	0	43.1	43	0.0023
4	11:00 AM	23	13.8	23	0	41	41	0
5	11:30	24	14.1	24	0	41.6	42	-0.009

	AM							
6	12:00 PM	25	15.1	25	0	40	40	0
7	12:30 PM	26	16.1	26	0	40.7	41	-0.007
8	1:00PM	27	16.5	27	0	39	39	0
9	1:30PM	28	17.1	28	0	38.2	38	0.0052

Fig. 4.1 shows the comparison between relative humidity values given by sensor and the standard instrument and Fig.4.2 shows Comparison between temperature values by sensor and standard instrument.

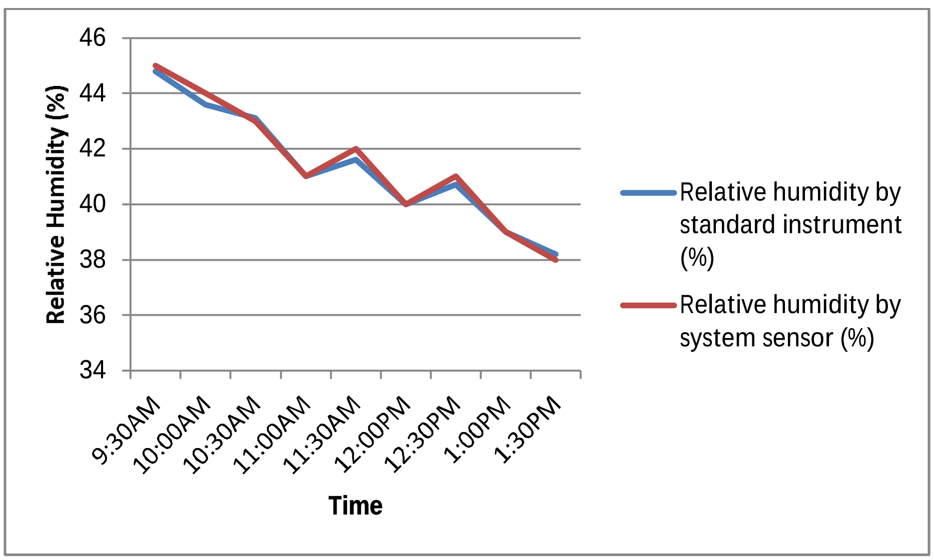

Fig.4.1 Comparison between relative humidity values by sensor and standard instrument

Fig.4.2 shows that there is no error in temperature value given by sensor and standard instrument, as both the values are totally overlapped. But there is slight difference between humidity values, which is overcome with the help of programming and calibration for temperature/humidity sensor is achieved accurately.

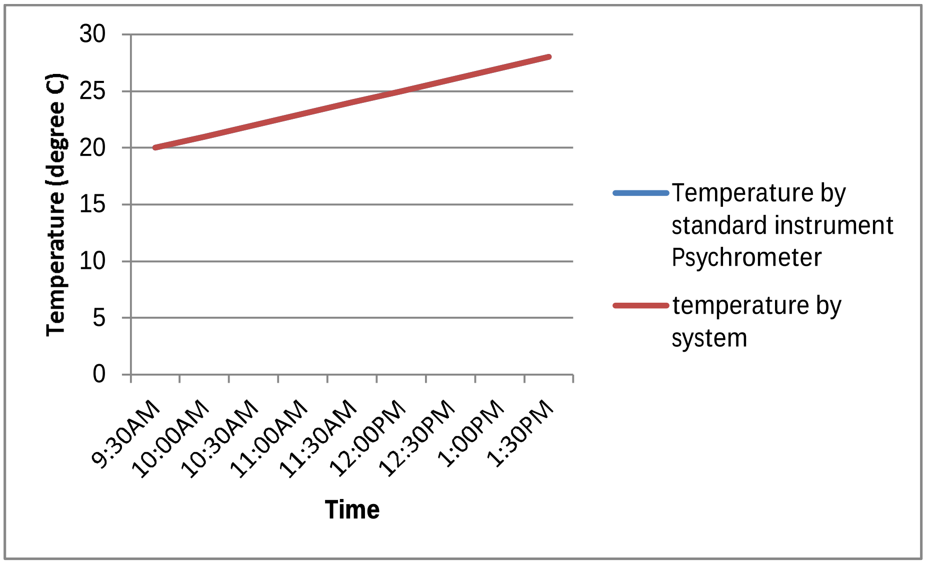

Fig.4.2 Comparison between temperature values by sensor and standard instrument

After calibration, testing is also performed with standard instruments. For temperature testing, thermometer is used and for humidity test humidity cabinet is used as shown in Fig.-4.3 and 4.4 and results shows perfect calibration of sensor.

Fig.4.3 Snapshot for the testing of temperature sensor with standard thermometer

Fig.4.4 Snapshot for the testing of humidity sensor with standard instrument

4.3 Calibration of LDR

A LDR have variation of resistance with light intensity falling on it. When Light falls on LDR, it turns on the circuit and when there no light on it then the resistance of LDR increases and disrupts the circuit.

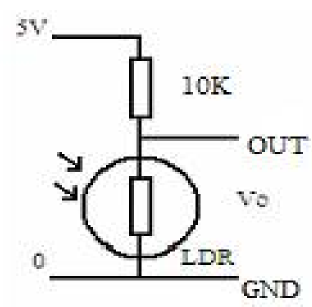

Fig.4.5 LDR circuit

The resistance of the Light Dependent Resistor (LDR) [sunrom.com, model no.-3190] varies according to the amount of light that falls on it. The relationship between the load resistance R_L and light intensity Lux for a typical LDR is as given in equation-4.3.

R_L = 500 / Lux K ohm ……………………………………………………..…. (4.3)

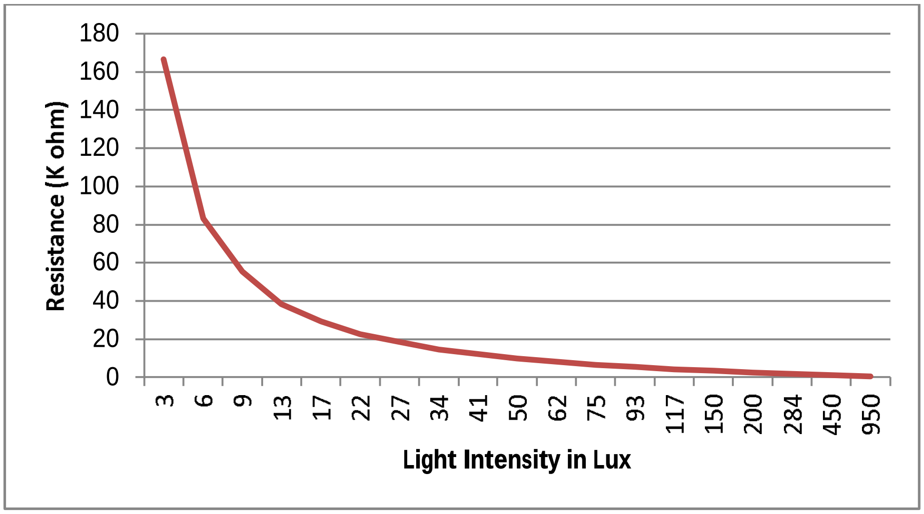

Fig.4.6 Relation between load resistance (K ohm) and light intensity (Lux)

With the LDR connected to 5V through a 10K resistor, the output voltage of the LDR is

Vo = 5*R_L / (R_L+10) …………………….…………..…………..…………..(4.4)

LDR performance has been experimentally analyzed and result shows that calibration of system is accurately achieved.

Fig.4.7 shows relation between resistance value of LDR with % illuminance level.

Table-4.2 Relation between resistance values of LDR with % illuminance level

Illuminance level (%)	R(K ohm)
0	18
5	15
10	12.9

15	11.74
20	10.7
25	10.5
30	9.8
35	8.9
40	7.5
45	6.5
50	5.5
55	4.7
60	3.9
65	3
70	2.4
75	2.1
80	1.9
85	1.2
90	0.5
95	0.3
100	0

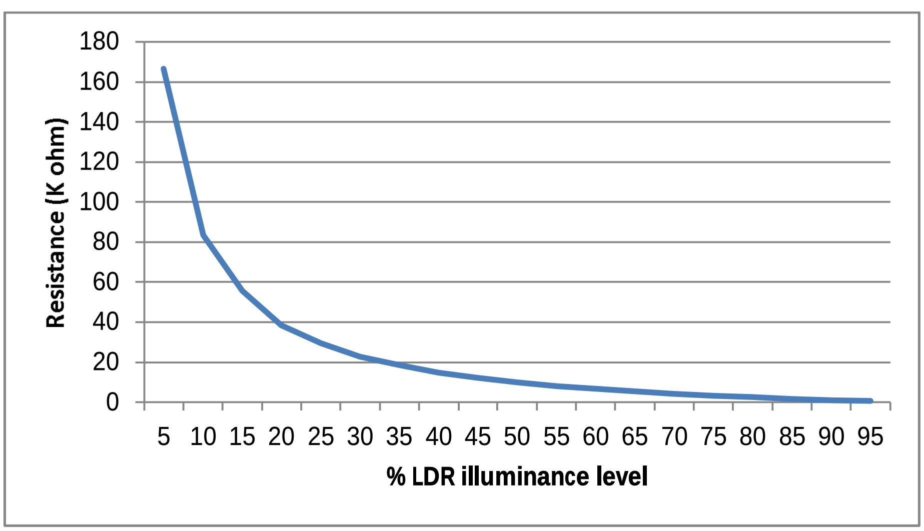

Fig.4.7 Relation between resistances (K ohm) of LDR with % illuminance level

Table- 4.3 Relation between Lux and LDR % illuminance level.

Illuminance of LDR in (%)	Light Intensity (lux)
0	0
5	3
10	6
15	9
20	13
25	17
30	22
35	27
40	34
45	41
50	50
55	62
60	75
65	93
70	117
75	150
80	200
85	284
90	450
95	950

The LDR gives the output as analog signal, so it is connected to the ADC pin of microcontroller.

The following function is used to initialize the ADC of Atmega16 microcontroller.

```
void Initialize_ADC( )
{
```

```
ADMUX== 0b10000000; (0x00); // For Aref=AVcc;
ADCSRA= 0b10000001; // set ADEN(ADC Enable) and ADPS0(ADC Prescaler
Select Bits) pins high
}
```

The following function is used to read the analog data from sensor.

```
uint16_t Read_ADC (uint8_t channel)
{
        //Select ADC Channel ch must be 0-7
        ADMUX&=0xf8;
        channel = channel &0b00000111;
        ADMUX|= channel;

        //Start Single conversion
        ADCSRA=ADCSRA|(1<< ADSC); // set ADSC(ADC Start Conversion)
pin high

        //Waiting
        while(!(ADCSRA & (1<<ADIF))); // check ADIF (ADC Interrupt Flag)
bit

        //Clear ADIF by writing one to it
        ADCSRA=ADCSRA|(1<<ADIF);
        return(ADC);
}
```

The following function is written to read the LDR

```
void main( )
{
  uint16_t LDR_LEVEL;
```

```
  Initialize_ADC( );   //Initialize ADC
  while(1)
  {
    LDR_LEVEL =Read_ADC(0);          // Read Analog value of ADC from
channel-0
    delay_ms(100);
  }
}
```

4.4 Theory of Operation of the Dimming System

In the dimmer circuit, the alternating current (AC) phase control method is used to control the intensity of appliance. The rms value of the voltage supplied to the appliance is varied w.r.t firing angle of a Triac. By controlling the firing angle, the rms voltage supplied to the load changes and according to the voltage dimming level of appliance is varied.

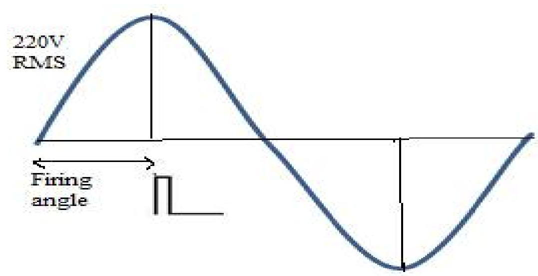

Fig.4.8 Firing angle with rms value

Formula for firing angle calculation [53]-

$V_0 = Vs\sqrt{1/\pi(\pi - \alpha + (\sin 2\alpha)/2}$ ………………………………………………(4.5)

Here-

V_0 = r.m.s value of output voltage

Vs= applied voltage

α=firing angle

From formula given in equation (4.5), it is concluded that to control the dimming level of appliance, triggering is required in different 16 levels as shown in Table-4.4

Table-4.4 Relation between firing angle and Vr.m.s

Dimming level	Firing angle (α) in degree	$V_{r.m.s}$ (V)
0	180	0
1	175	2
2	167	10
3	159	22
4	149	39
5	140	55
6	132	72
7	123	89
8	113	110
9	105	126
10	95	145
11	85	163
12	83	167
13	74	180
14	62	195
15	7	220

Fig.4.9 shows the variation in $V_{r.m.s}$ w.r.t firing angle. Fig.4.12 shows the relation between these two terms and it can be clearly observed that with increase in firing angle $V_{r.m.s}$ decreases.

According to firing angle and $V_{r.m.s}$ values for dimming levels current is measured and the total power consumption is calculated.

Table- 4.5 shows voltage, current and power consumed by bulb, exhaust fan and heater in different dimming levels according to firing angle. It is observed that with increase in level power consumption is also increasing and appliance consumes more power at higher levels.

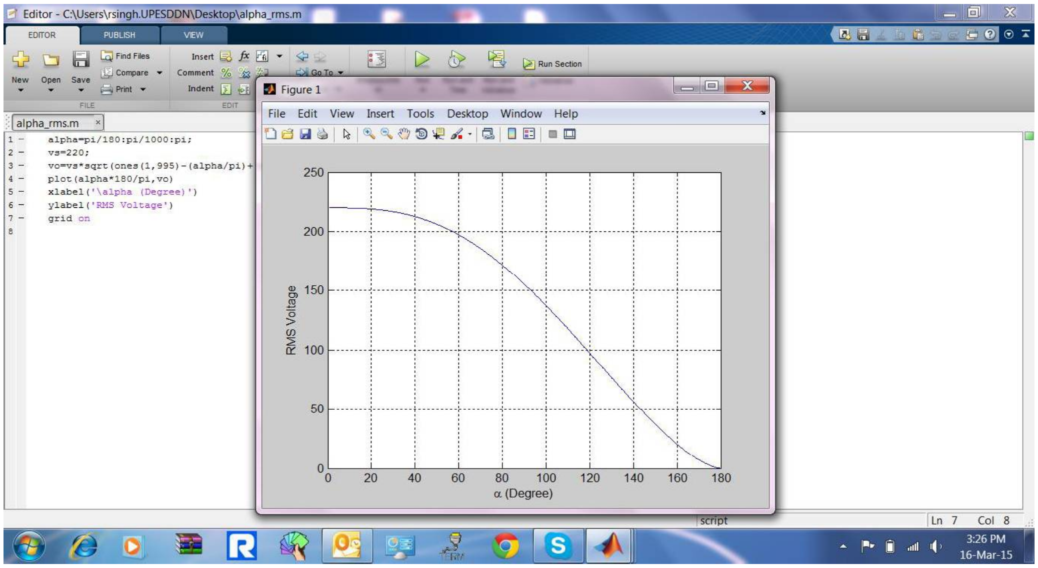

Fig.4.9 Variation of $V_{r.m.s}$ w.r.t firing angle

Table-4.5 Power consumption by bulb, heater and exhaust fan w.r.t dimming levels

Dimming levels	Firing angle	Voltage (V)	Current (mA) for bulb	Current (mA) for heater	Current (mA) for exhaust	power consumption by 100W Bulb (W)	power consumption by 1KW Heater (W)	power consumption by 18W exhaust (W)
0	180	0	0	0	0	0	0	0
1	175	2	4	38	0	0.008	0.076	0
2	167	10	20	192	0	0.2	1.92	0
3	159	22	45	423	8	0.99	9.306	0.176
4	149	39	80	750	14	3.12	29.25	0.546
5	140	55	113	1058	20	6.215	58.19	1.1

6	132	72	149	1385	26	10.728	99.72	1.872
7	123	89	184	1170	32	16.376	104.13	2.848
8	113	110	227	2110	40	24.97	232.1	4.4
9	105	126	260	2423	46	32.76	305.29	5.796
10	95	145	300	2780	53	43.5	403.1	7.685
11	85	163	337	3130	60	54.931	510.19	9.78
12	83	167	345	3210	61	57.615	536.07	10.187
13	74	180	351	3269	62	63.18	588.42	11.16
14	62	195	358	3327	63	69.81	648.76	12.285
15	7	220	455	4347	81	100	956.34	17.82

Fig.4.10 shows the power consumption by 100W bulb, Fig.4.11 shows the power consumption by 18W exhaust fan and Fig. 4.12 shows the power consumption by 1KW heater for all the sixteen dimming levels.

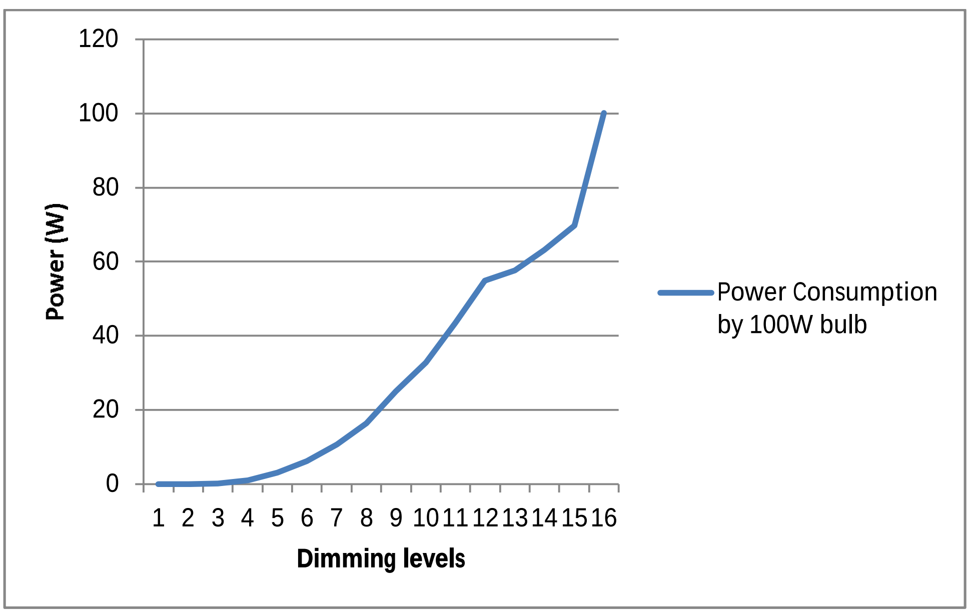

Fig.4.10 Power consumption (W) w.r.t dimming levels for 100W bulb

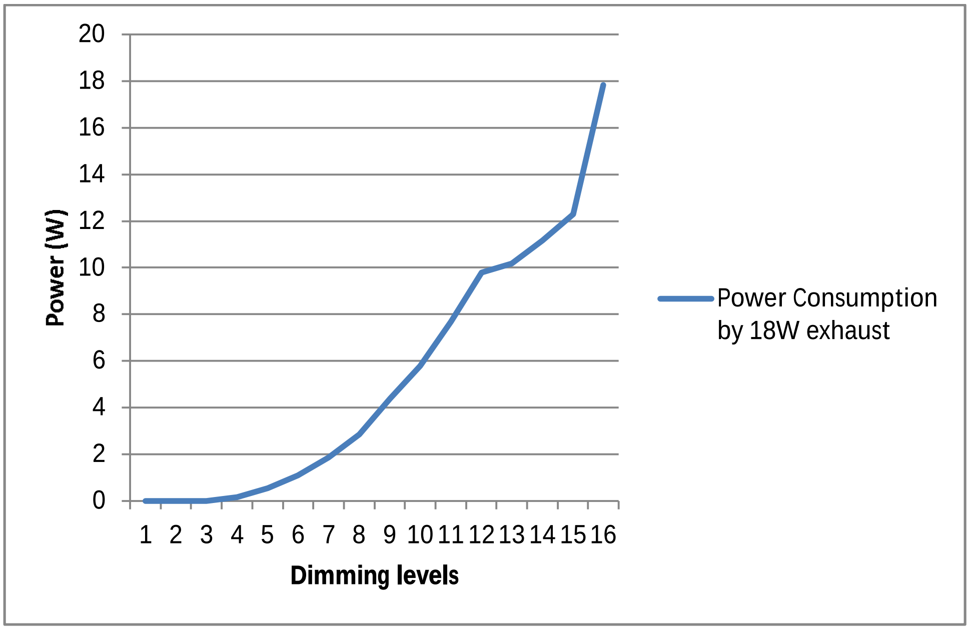

Fig.4.11 Power consumption (W) w.r.t dimming levels for 18W exhaust

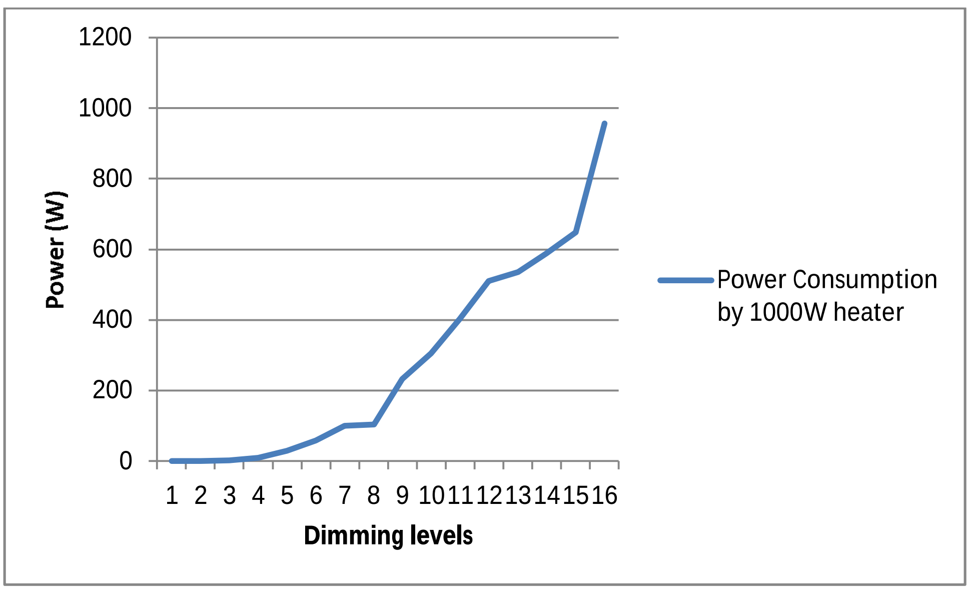

Fig.4.12 Power consumption (W) w.r.t dimming levels for 1000W heater

4.5 Chapter Summary

The chapter describes the calibration of the sensors used for system development. The calibration and testing of sensors is done with the help of standard instruments and results are verified. Dimming methodology is also discussed in detail and power consumption for each level is calculated. Calibration steps and program function used to initialize the sensors are discussed in detail. It is observed that LDR gives output as analog signal so it needs to connect at ADC pin of controller. Temperature/ humidity sensor is operated in USART mode so it needs to connect at Rx pin of the controller. The is observed that at lower dimming level appliance consumes less power and power can be saved if appliance is made to operate on the desired level, instead of at highest level.