EE 318 Electronics Design Lab project report, EE Dept., IIT Bombay, April 2006

Measurement of Light Intensity

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Abstract

There is electronic equipment being powered by photovoltaic cells (PV cells). The current of the PV cells depends on the solar insolation incident on the panels. Solar insolation is the radiation received per unit horizontal surface. The SI unit is Watt/meter^2. The load on the PV cells must be varied so that the circuit operates at maximum efficiency. The light incident on the panels consists of two components-diffused and direct. The PV cells respond mostly to direct light and not diffused light. Hence it makes sense to be able to measure direct light. Once the direct incident light intensity is known, it can be used to track the maximum power point (on the Power-Voltage curve). This measured intensity can also be used to decide the operation of a back-up battery.

Such units measuring the direct light can be spread across an area of interest and used to find the intensity of light at various points and hence judge the movements of clouds. This information coupled with information about the maximum efficiency point can be conveyed to nodes forming part of an air-borne sensor network. The circuits of these sensor nodes can then adjust their load and also take decisions whether they should operate with the PV panel or the battery. They can also decide their position to avoid the cloud cover as much as possible.

Problem Statement:

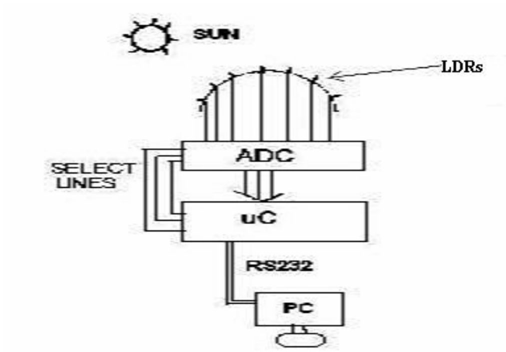
1. To design a circuit which can estimate the intensity of solar insolation using Light Dependent Resistors (LDRs), by interpolating from a previously generated look-up table and display the data on computer using serial interface.

2. To determine the minimum arc length of the semicircle at which the difference in received solar intensity by two adjacent LDRs can be detected.

3. To make the sensor boards obtained from Crossbow Technology Inc. operational so as to communicate different measured parameters from the nodes to the computer.

Design and Implementation:

The first part of the project involves interfacing and integration of four major components: LDRs, ADC, Microcontroller and the computer. Figure 1 shows the block diagram of the setup.



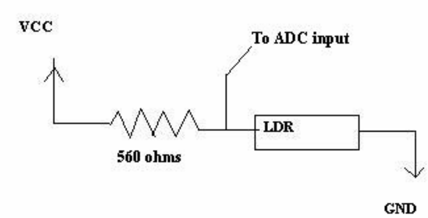


Figure 1: Block Diagram of the setup **Figure 2: LDR circuit**

To generate the look-up table we used three LDRs with characteristics as close as possible and attached them to a power meter obtained from the Applied Power Electronics Laboratory. Power meter is the instrument that shows the light intensity in BTU/hrft^2 (1 BTU/hrft^2 = 3.26 W/m^2). The LDRs were attached in such a way that the light received by the power meter and LDRs is almost equal. For varying the intensity of light, a lamp with a dimmer circuit was used in the lab. The height of the lamp was set in such a way that the intensity of the lamp could be varied (using the dimmer) in a range similar to that for the sun over a day. To reduce the diffused light component, the tubelights close to our setup(which were not being used by other groups) were switched off while taking the readings. Each of the LDRs was connected as in the circuit of figure 2. The resistor value of 560 ohms was chosen so that the voltage across the LDR has a considerable amount of variation.

This voltage measured across all the three LDRs was fed into the ADC and communicated to the computer via serial port (RS 232). An 8-channel ADC 0809 is used for this purpose to allow multiplexing the three LDRs. The ADC fed the data to a microcontroller. The AT89C51 is being used in the project. This has sufficient number of ports and features for our purpose. A 555 timer circuit in astable mode is used to provide the clock to ADC. The microcontroller communicates with the computer through serial port (RS 232). This uses the MAX 232 IC to generate voltage levels so as to communicate with the computer. Figure 3 shows the complete circuit diagram of the setup.

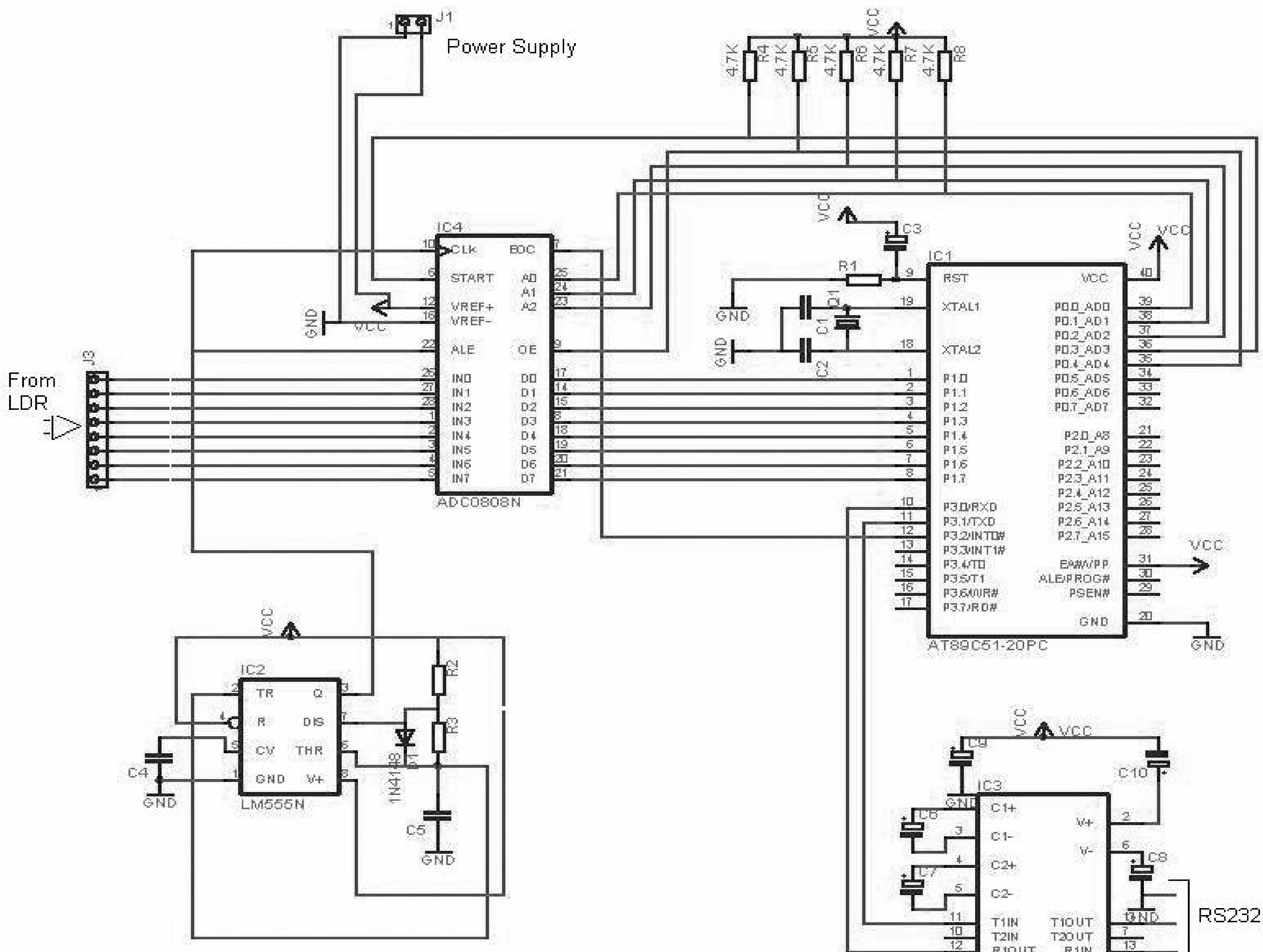


Figure 3: Complete circuit diagram of the setup used.

Data is transmitted to the computer only after the microcontroller receives a particular input (the space bar in our case). Table 1 shows the readings obtained to verify the interfacing.

Table 1: Verification of ADC, microcontroller, serial port interfacing

S. No.	ADC Input Voltage (V)	Serial Port Reading (ASCII)
1	0.00792	0
2	0.232	12
3	0.673	34
4	0.899	46
5	1.080	55
6	1.635	83
7	2.023	103
8	2.453	124
9	2.954	150
10	3.472	177
11	3.907	200
12	4.323	221
13	4.628	237
14	4.788	245
15	4.988	255

A computer program then calculates the value of the LDR resistance from the obtained voltage. Since the LDRs used were not standard, depending on the position and orientation of the LDRs with respect to the lamp, different values of resistance can be obtained for the same reading of the power meter. This is why we took around 120 different reading for the three LDRs with varying intensity of the lamp to average out the results. These readings were then plotted using matlab. The graphs were then smoothened with appropriate approximations to obtain a band in which the LDR resistance would lie for a given intensity of received light. The final look-up table was generated from this approximated graph. These graphs are also included in this report.

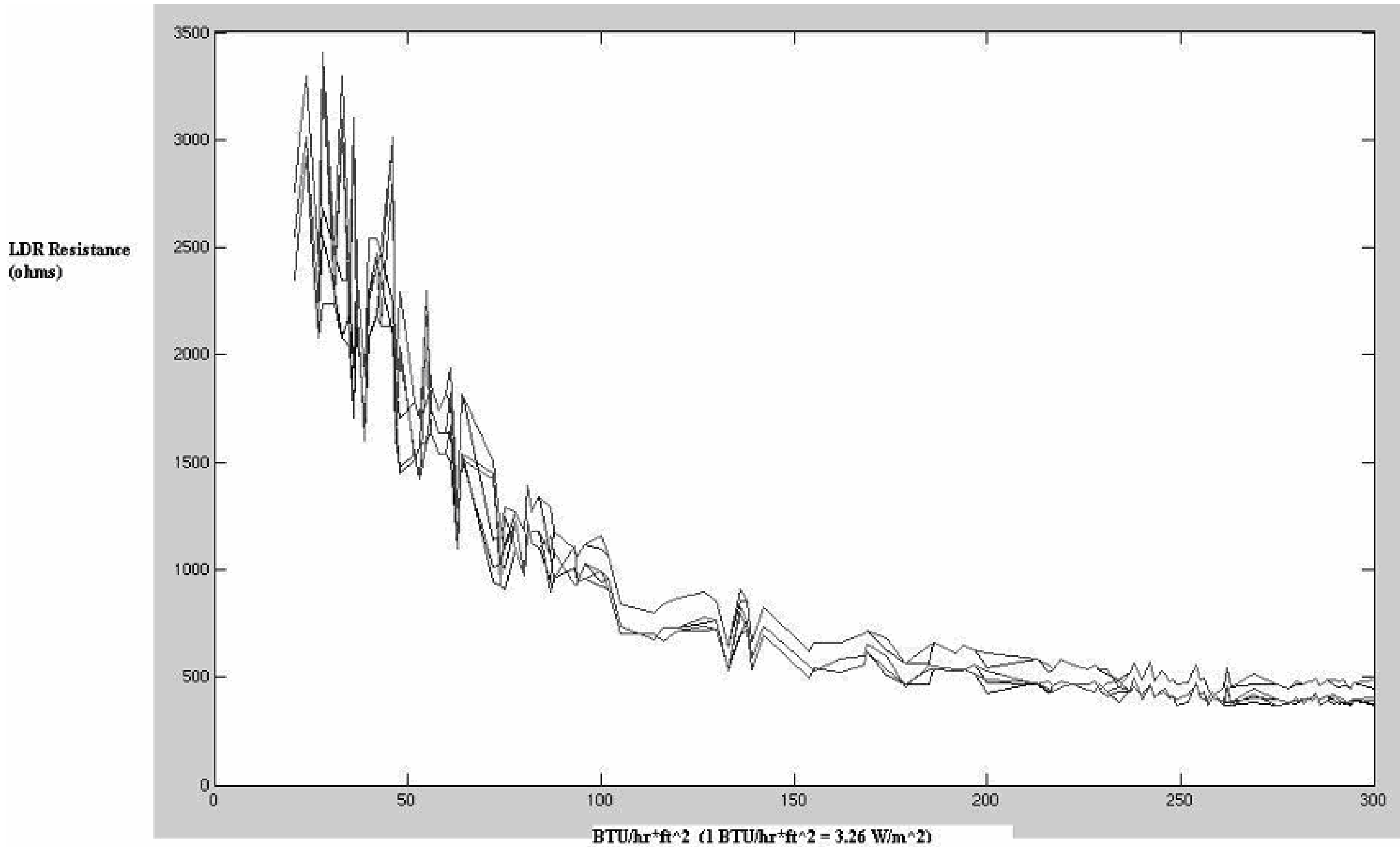


Figure 4: LDR Resistance at different intensities for 3 LDRs

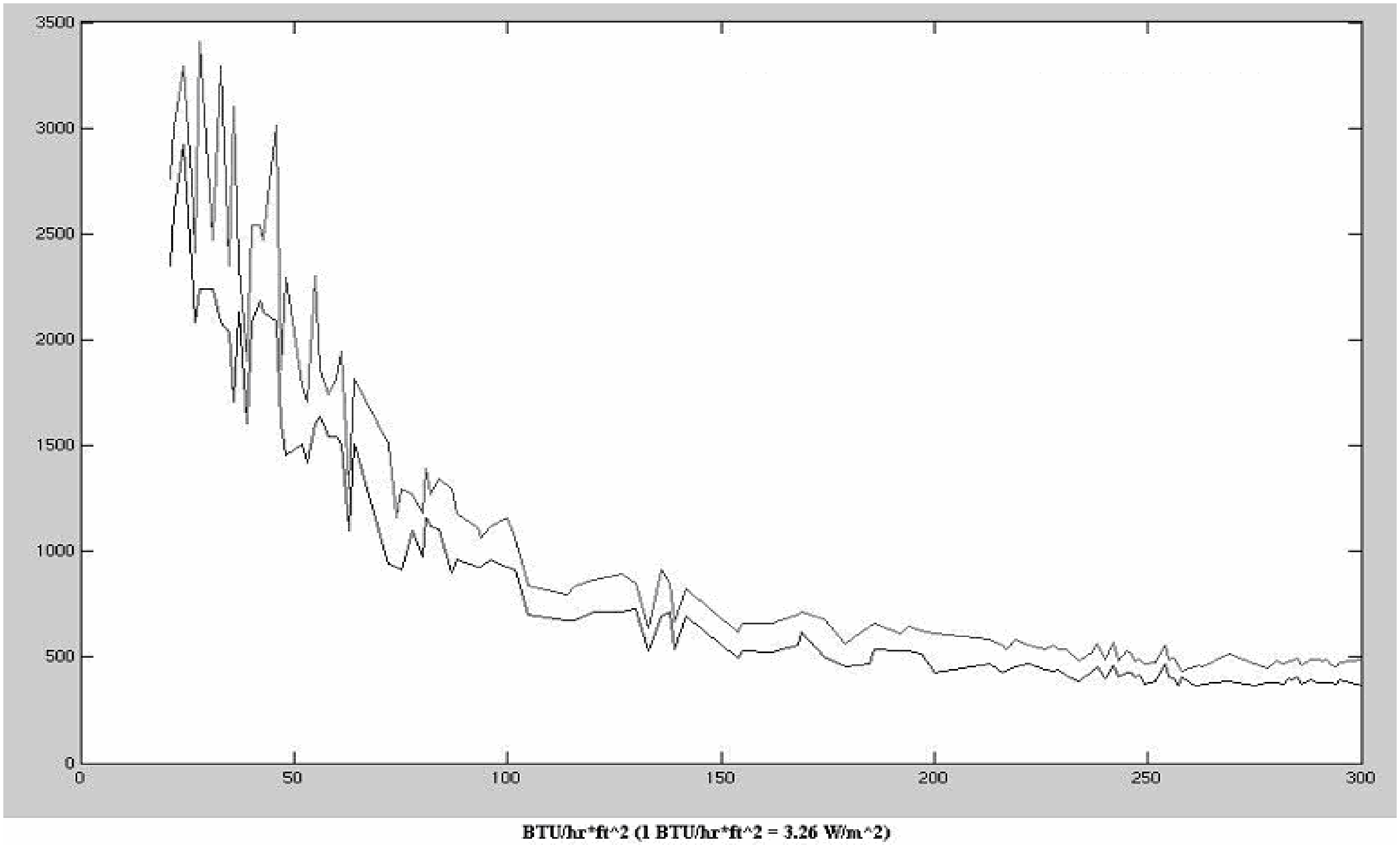


Figure 5: Maximum and minimum LDR resistance at different intensities for 3 LDRs

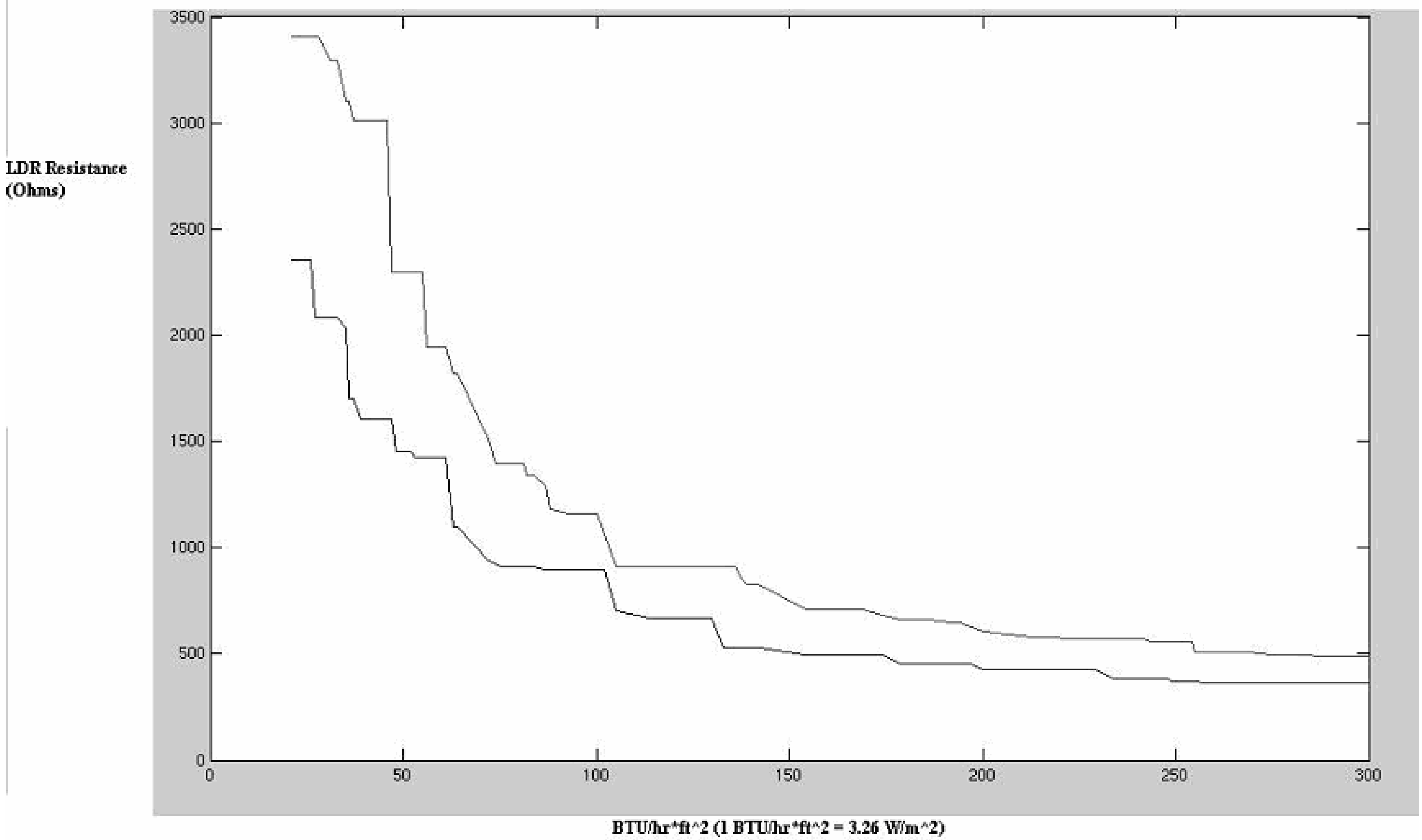


Figure 6: Approximated maximum and minimum LDR resistance used for interpolation

As the next step the functioning was modified. The power meter is eliminated from the setup and only the LDRs are required. The value of LDR voltage is communicated to the computer through the serial port. The LDR resistance is calculated from the value of voltage across it. This value is then used to estimate the value of intensity (as a range) using the previously generated look-up table. The final setup would take inputs from three LDRs and estimate the intensity corresponding to each of them.

The second part involves finding out the minimum arc length at which the intensity of solar insolation can be differentiated using the available LDRs. For this, three LDRs with the closest characteristics were mounted on a semicircular structure made up of styrofoam. The LDRs were surrounded with cones lined with shining paper from inside to ensure that they receive only the direct light. These LDRs were placed on the semicircular structure one at the top and one each at 22.5 degrees on either side. The LDR which is facing the sun will show minimum resistance. Readings were taken for the three LDRs at different times of the day with semicircular structures of different radii. It was found that the intensity could be distinguished even with the smallest radii and at noon. Table 2 shows the readings obtained.

Table 2: Readings of 3 LDRs placed on semicircular structure in sun

TIME	Size of semicircular structure (dia in Cm)	LDR 1 (ohms)	LDR 2 (ohms)	LDR 3 (ohms)
10:15	5	344	688	1210
10:15	4.5	315	610	1280
10:15	4	300	520	1330
10:15	3	390	580	1060
12:00	5	200	95	280
12:00	4.5	290	105	390
12:00	4	179	97	310
12:00	3	174	97	315
15:00	5	930	456	355
15:00	4.5	795	430	310
15:00	4	830	510	390
15:00	3	795	540	450

For the third part of the project we worked on the sensor network boards obtained from Crossbow Technology Inc. The setup consists of a PC interface board, three motes (communicating nodes) and two sensor boards. Motes can be programmed for measuring various parameters. Two sensor boards are attached to two of the motes, powered by batteries and placed at remote locations. These two motes are programmed so as to receive all the sensor data from the sensor boards and communicate it to the base station through RF link. The third mote is connected to the PC interface board powered through AC supply and is programmed to receive the data from the two sensor board-mote assembly and display it on the computer. The working had to be studied to make the setup functional. As of now, we have successfully obtained readings from the different sensors on the computer.

Conclusions:

The setup was successfully able to estimate the value of light intensity by interpolating from the lookup table. Readings of adjacent LDRs could be distinguished for a diameter as small as 3 cm which is satisfactory. The crossbow boards are also working properly and displaying all the data on the computer.

Suggestions for further improvement:

1. In the first part of the project the look-up table can be generated from actual solar readings instead of readings from the lamp with dimmer circuit. This will help in precise measurements as the dimmer circuit contributes to changing wavelength of incident light which might alter the characteristics of the LDRs used. Further, LDRs of bigger diameter if available should be used as they would have more reproducible characteristics. Entirely replacing the LDRs with even more precise devices like photo-diodes or PV cells can also be considered for accurately reproducible results.

2. The circuit designed can be enhanced with communication ability so that it can talk to circuits similar to itself and also to air-borne sensor nodes. Depending on the intensity of light detected by various nodes, information about cloud-movement can be formulated. These will be stationed on the earth.

3. The Crossbow nodes can be mounted on air-borne balloons forming a wireless sensor network powered by PV arrays. They can be used there to find ambient atmosphere parameters. This circuit will derive information about the maximum efficient operation from the earth-stationed light measurement devices designed above.

4. The PV panel response can be characterized with the help of the data about diffused light and direct light and standard charts prepared for different technologies of PV arrays.

References:

[1] *Datasheet of ADC0808/ADC0809 8-Bit µP Compatible A/D Converters with 8-Channel Multiplexer* from www.national.com. © National Semiconductor Corporation, September 1980.

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[4] Kenneth J. Ayala, *The 8051 Microcontroller Architecture, Programming & Applications second edition*, Penram International Publishing (India) Pvt. Ltd., 1996.