# DEVELOPMENT OF ELECTRONIC WEATHER STATION FOR USE IN FARMHOUSE AND NURSERY

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BY

**MR. S. R. CHAUDHARI**

UNDER THE GUIDENCE OF

DR. (MRS) S.A. DEUSKAR

DEPARTMENT OF ELECTRONIC SCIENCE,
UNIVERSITY OF PUNE,
GANESHKHIND ROAD, PUNE – 411 007 (INDIA).

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# CERTIFICATE

This is to certify that the dissertation entitled " **DEVELOPMENT OF ELECTRONIC WEATHER STATION FOR USE IN FARMHOUSE AND NURSERY"** Which is being submitted herewith for the award of Degree of **Master of Philosophy in Electronic Science,** of University of Pune, Pune , is the result of the original research work completed by Mr. S.R. Chaudhari under my supervision and guidance. To the best of knowledge and belief the work embodied in this dissertation has not formed earlier the basis for the award of any degree or similar title of this or any other University or examining body.

PLACE: PUNE

DATE: 11-08-06

**Dr. (Mrs.) S.A.Deuskar**
(Research Guide)
Reader,
Dept. of Electronic Science,
Modern College,
Pune – 411 005.

# DECLARATION

I hereby declare that the dissertation entitled **"DEVELOPMENT OF ELECTRONIC WEATHER STATION FOR USE IN FARMHOUSE AND NURSERY"** Completed and written by me has not previously formed the thesis for the award of any degree or Diploma or similar title of this or any other University or examining body.

Place: PUNE

Date: 11-08-06

Research student

(S. R. CHAUDHARI)

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## PAPER PUBLISHED IN NATIONAL JOURNALS

1. "Development of an instrument for soil moisture measurement"

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## RESEARCH PAPERS PRESENTED AT NATIONAL SEMINAR / CONFERENCES

1. National Seminar on Advanced Instrumentation (NSAI-2001), organized by CSIO, Chandigarh. January 29-31, 2001.
   Presented the research paper " Development of thermister based soil moisture meter for use in mobile weather station"
2. 8th National Seminar on Physics and technology of Sensors (NSPTS-8), Organized by Indira Gandhi Center for Atomic Research , Kalpakkam, 27th Feb-1st March 2001.
   Presented the research paper "Development of Humidity meter for use in mobile weather station".
3. National Seminar arranged by Instrument Society of India NSI-26 at IRDE Dehradun on 31st Oct to 2nd Nov. 2001.
   Presented the research paper " Development of an instrument for soil moisture measurement"
4. 16th I.A.P.T. National Convention 2001 at Yavatmal. (23 to 25 Nov. 2001)
   Presented the research paper "Development of software model for thermal Conductivity to develop soil moisture sensor."

5. National Seminar arranged by Instrument Society of India NSI-27 at Dept. of Physics, Bharathiar University, Coimbatore, Tamil Nadu on 27$^{th}$ Nov to 29$^{th}$ Nov. 2002.

   Presented the research paper " Design and development of soil moisture sensor for its use in indigenously developed automated drip irrigation system"

6. National Seminar arranged by Instrument Society of India NSI-28 at Pantnagar, Uttaranchal Pradesh on 03$^{rd}$ Nov to 05$^{th}$ Nov. 2003.

   Presented the research paper "Development of soil moisture sensor along with instrumentation".

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# Development of Automatic electronic weather station for use in farmhouse and nurseries.

## INDEX

Chapter 1. Introduction .................................................... (1-10)

1.1 Role of Agrielectronics in agriculture ........................... 01
1.2 Recent developments ........................... 03
1.3 Thrust areas in Agrielectronics ........................... 06
1.4 Aim and objectives ........................... 08
1.5 Organization of the thesis ........................... 09

References

Chapter 2. Automatic Weather Stations for Agricultural and Other Applications ................................................ (11-32)

2.1 Automatic Weather Station ........................... 11
2.2 Classification of Automatic Weather Stations ............... 19
2.3 A new approach to Automatic Weather Station ............. 21

References

Chapter 3. Development of soil moisture sensor and soil moisture measurement ................................................ (33-60)

3.1 Different methods used for soil moisture measurement ... 34
3.2 Basic idea for soil moisture sensor under development ... 35
3.3 Modeling for soil moisture sensor ........................ 37

3.4 Design and fabrication of soil moisture sensor .............. 40
3.5 Calibration of the sensor .......................................... 42
3.6 Development of instrumentation for soil moisture sensor ..... 45
3.7 Final assembly of the sensor .................................... 48
3.8 Optimization ............................................................ 52
3.9 Application in automated irrigation system ...................... 57
References
Chapter 4. Humidity measurement .......................................... (61-70)
4.1 Dry and wet bulb method ............................................ 63
4.2 Designing of the Stevenson's screen ............................ 65
4.3 Experimental set up for calibration .............................. 67
4.4 Observations ........................................................... 68
References
Chapter 5. Temperature and Light intensity measurement ........... (71-81)
5.1 Temperature measurement ........................................ 71
5.1.1 Different methods for temperature measurements .................................... 72
5.1.2 Temperature measurement using Pt 100 ... 72
5.1.3 Observations .................................... 74
5.2 Light intensity measurement .................................... 75
5.2.1 Method used for measurement ............ 75
5.2.2 Experimental measurements for light intensity .................................... 79
5.2.3 Calibration ........................................ 80
References
Chapter 6. Results and discussion ....................................... (82-88)
6.1 Results ............................................. 82
6.2 Automatic Electronic weather station : a practical approach ............................................ 85
6.3 Future Scope of the work ....................................... 88

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# Chapter 1

# INTRODUCTION

## 1.1 Role of Electronics In Agriculture:

Electrical and electronics systems play an important role in measurement and control system now days. The electrical and electronics era involving large scale use of electronic devices and computer, are also applicable for field of agriculture, field of weather station and field of industries. This has led to a new branch of science termed, as "Agro physics and Agrielectronics", Tests and Measurements are its challenges. New measurement techniques and novel approaches to instrumentation and control systems based on the latest development in the fields of electronics and computer science have helped to improve this new emerging field of agro physics and agrielectronics. In fact large number of measurement which, in the past were being done with simple mechanical or electromechanical gadgets are now possible to be made more speedily and accurately with the help of electronics instruments and instrumentation system using suitable sensor and signal processing integrated circuits in the form of microchips.

The field of transducers, sensors for the various parameters in physics and electronics consist of a very wide application in the agriculture and agrobased industries. Similarly instrumentation, control systems, actuators, computer based instrumentation is valuable for agro based industries [1.1].

All these phenomena that are severely affecting the developing countries in particular, need of careful analysis through accurate methods of estimation and measurement techniques. For all these problems electronic and electrical development techniques have proved to be very useful. Some of the techniques that are very useful in the field of agriculture are shown in table 1.1.

| |
|---|
| Equipment automation and Robotics. |
| Tractors with sophisticated electronics control. |
| Automatic harvesters with electronic tachometer and transmission control. |
| Grain loss and moisture content monitors. |
| Planter monitors. |
| New sensors for agricultural measurements and control based on silicon devices and oxides. |
| Micro-irrigation and programmed irrigation techniques based on new silicon moisture sensors. |
| Automatic Weather Stations (AWS). |
| Controlled environments through green house for optimum growth of plants. |
| Analysis and improvements in photosynthetic efficiency of plants. |
| Computerized dairy operations and electronic systems including controlled feeding and growth of livestock, milk analysis, cream separators etc. |
| Automatic grain grinding with predetermined consistency and preservation of vitamins and other nutrients. |
| Automatic sealing and sorting out the sealed canned food products. |
| Computerized cooperate planning of agricultural operations. |
| Reliable sensors, preferably non-contact type sensors. |

Table 1.1 Techniques useful in agriculture field

From table 1.1 it is clear that there is a lot of scope to apply electronics and instrumentation in the agricultural discipline. Further the field of agriculture is progressively becoming more multidisciplinary, with the increasing role of the applications of electrical, electronics and computer science; and simultaneously new scientific disciplines and area like bio-electronics, bio-physics, bio-engineering have already been recognized as separate field in themselves. With the increasing application of automation and robotic techniques, more emphasis is being given to the whole new range of 'sensors' which can measure the parameters encountered in modem agriculture and agro processing. However the challenges lies in the field test of such prototypes. The instruments or systems should be rugged, solar energy, battery operated and easy to use.

Along with the electronics instrumentation one has to make use of simulations, modeling, programming techniques for agricultural processes .The pioneering work in the field is carried out at various institutes in India as listed in table 1.2.

| |
|---|
| Indian Council for Agricultural Research, New Delhi |
| Central Electronics Engineering Research Institute, Pilani |
| Vasantdada Sugar Institute, Manjari (BK) Pune. |
| India Meteorological Department, Pune |
| Center of Advanced Studies in Agricultural Meteorology, College of Agriculture, Pune -5 |
| Central Scientific Instruments Organization, Chandigarh |

Table 1.2 Trendsetters in Agrielectronics

## 1.2 Recent Developments:

Agricultural activities in the world have now entered electrical and electronic era involving the use of electronic equipment on a large scale. New measurement techniques, latest control systems, use of GPS and GIS have changed the face of agriculture and Agro based Industries. Electronics has helped to reduce the bad effects of natural calamity on the agricultural production. The concept of precision farming used nowadays is good example of the electronic revolution in agricultural field. [1.2]

**Agri Electronics: World Scenario**

Agricultural activities in the world have passed through the mechanical and chemical era and have not only entered electronics era, (involving the use of electronic devices, sensors and computers) but also sailing very well through it. Countries like Canada, USA, China, Australia, Israel, European countries are using computerized controls for many of the agricultural and related activities such as harvesting, pest control, irrigation etc. they have also developed new type of farming e.g. dry farming, floriculture, nursery, market gardening etc. Use of sophisticated process control system and sensors have turned Agriculture into big Industry.

Very recently, Israel has staked its claim in developing high technology methods and modules for Agriculture, especially for irrigation and water management. The country has adopted dry farming technique to increase yield and also to convert a desert into a cultivating land. In most of the developed countries, electronics is being used in the major fields as listed in table 1.3.

| |
|---|
| Sensors and computers |
| Computerized controls for many of the agricultural activities Such as harvesting, pest control, Irrigation etc |
| Electronically controlled Green houses and storage beans |
| Dry farming, floriculture, nursery etc |
| Sophisticated process control system |
| Smart Sensors and ASICS |
| Precision farming – Use of GPS |

Table 1.3 Use of electronics in agricultural field in advanced countries

From table 1.3, India had tough challenges in the field of agriculture, a few of which are explained as below.

**Indian Scene: Issues related to Agri Electronics**

To understand the Indian scene, I am quoting some of the thoughts Prime Minister Dr. Man Mohan Singh sigh expressed very recently.

Long ago, Jawaharlal Nehru once said, "Everything else can wait but agriculture cannot wait." And I should begin by stating that our Government attaches the highest importance to achieve a four per cent average growth rate in agricultural production

Agriculture continues to play a vital role in our economy, although its share in our GDP has been declining over the years. Today, the contribution of agriculture to our GDP is only about 22% but the proportion of our population dependent on agriculture has not declined in a similar manner and even now, almost 65 % of our population relies on agriculture for its sustenance

As I have said on so many occasions, we need to usher in a second green revolution. The agricultural sciences would have therefore to work towards providing the technological basis for new breakthroughs

All advanced agricultural economies are knowledge-based economies. Hence, there is a need to make all out efforts to broaden the knowledge base of our farmers to enable them to make the optimum use of new technologies.

The last quote from the Prime Minister's speech [1.3] is very important from Agrielectronics point of view. The end user specifically the farmer should be benefited in terms of knowledge and technology for getting good rates for his produce. He has already started adopting some packaging skills to improve life of the produce. He will be enthusiastic if some developments in this field take place.

Agriculture and agro based industries are backbone of Indian economy and also are a major export potential. Irrigation and control over pests and use of modem methods of farming has brought a green revolution in Indian Agriculture. This facilitates India's self-sufficiency on food in spite of the growing population.

The demands of agricultural technology are now changing and diversifying. However for large-scale use of hi-tech methods in instrumentation, managements and process control automation Indian agriculture has a long way to go. In this context agrielectronics needs a national attention for efficiency in crop production and post harvest management. The technology requirements for Indian agriculture are location specific and hence the old methods of generalized (blanket approach) are not profitable. Here electronics due to its flexible and adoptable features can now play a major role. We have to develop farmer friendly gadgets for tests, measurements and control.

## 1.3 Thrust areas in Agrielectronics:

All these facts in agriculture need of careful analysis through accurate methods of estimation and measurement techniques. For all these problems electronic and electrical development techniques have proved to be very useful. Some of the techniques that are very useful in the field of agriculture are shown in table 1.4 below.

| |
|---|
| Equipment automation and Robotics. |
| Tractors with sophisticated electronics control. |
| Automatic harvesters with electronic tachometer and transmission control. |
| Grain loss and moisture content monitors. |
| Planter monitors. |
| New sensors for agricultural measurements and control based on silicon devices and oxides. |
| Micro-irrigation and programmed irrigation techniques based on new silicon moisture sensors. |
| Automatic Weather Stations (AWS). |
| Controlled environments through green house for optimum growth of plants. |
| Analysis and improvements in photosynthetic efficiency of plants. |
| Computerized dairy operations and electronic systems including controlled feeding and growth of livestock, milk analysis, cream separators etc. |
| Automatic grain grinding with predetermined consistency and preservation of vitamins and other nutrients. |
| Automatic sealing and sorting out the sealed canned food products. |
| Computerized cooperate planning of agricultural operations. |
| Reliable sensors, preferably non-contact type sensors. |

Table 1.4 Advanced techniques used in Agriculture

From table 1.4 we see that almost all the modern advanced techniques are used in agriculture and agrobased industries.

Also advances in microelectronics leading to microcomputers using CMOS technology. New display system and custom based integrated circuits and hybrid microcircuits, which can help to revolutionize agricultural operations.

This list cannot be comprehensive, and it's only an indication of the modern research activities leading to new techniques in agricultural production. All the incoming new technologies are being complemented by new sensor technologies such as silicon transducers, piezoelectric sensors, variable reluctance and capacitance transducers, ferromagnetic transducers, optical systems, nuclear radiation devices, laser, fiber optic sensors etc.

The various applications that are challenges in agricultural area and needs to be developed indigenously are listed in table 1.5.

| |
|---|
| Measuring devices for micronutrient planting |
| Bird scaring units |
| Solar cell based bell orchids |
| Test kits for tobacco |
| Environment control measures for poultry. |
| Fruit pressure tester |
| Fiber fineness measurement kits for jute and cotton |
| Portable gas analyzer, pH meter, Grain Moisture meter etc. |
| Grading systems for fruits and vegetation |
| Colour sorter |
| Sensors for spongy tissues in mango |
| Insect traps, rodent detection and control. |
| Water softener |

Table 1.5 Challenges in Agriculture field need to be developed

From Electronics point of view, the applications in the list require simple circuitry or devices. However the challenge lies in the field test of such prototypes. The instruments or systems should be rugged, solar energy / battery backup operated and easy to use. [1.4]

Another important factor is the use of simulations, modeling, programming techniques for agricultural processes. It is a first step towards development of prototype. Only few localized attempts can be seen in this area. The pioneering work in the field is carried out at CEERI Pillani, then at VSI Pune. CSIO Chandigarh is now taking lead, which is a good sign. More and more academicians should come together and work for this National cause.

Department of Electronic Science University of Pune, Pune had contributed toward this research by conducting projects, practical at postgraduate and research levels.

Department of Electronic Science, of Modern college of Arts, Science & Commerce, Pune-5, is the first college in to begin Agrielectronics as a subject at under graduate level. The Department had completed three minor research schemes on the subject agrielectronics [1.5] and presented 13 research papers at various national seminars and conferences, out of which three are published in journals.

With this background we have decided to develop an Automatic electronic Weather Station, which can measure microclimate in farmhouse, nursery and greenhouse. With the measurement of microclimate, the parameters can be controlled to get better yield.

## 1.4 AIM AND OBJECTIVES

The aim of the present work is to develop a electronic weather station .To achive this aim it has been planned to divide the work into following objectives.

1. Study of role of electronics in agriculture.
2. Surevey of Commercially available Automatic Weather Stations.
3. Design and development of thermal conductivity based soil moisture sensor.
4. Measurement of soil moisture using developed sensor.
5. Design and development of Stevenson screen for measurement of humidity.

6. Design and development of signal conditioning circuits for measurement temperature and light intensity.
7. Integrating the various circuits to develop Electronic weather station.
8. Use of microcontroller system for the control of drip irrigation using the soil moisture measurement system.
9. Field testing of Electronic Weather Station.
10. Modification from the results of field testing.

## 1.5 ORGANIZATION OF THESIS

The dissertation is divided into six chapters.

The work presented in this dissertation deals with the development of electronic weather station for use in farmhouse and nursery. Role of electronics in agriculture, recent developments in this area at world and Indian level, aim and objectives are outlined in the first chapter.

In chapter two concept of automatic weather station and some issues while installing it are described. The idea of automatic electronic weather station that is to be developed, its instrumentation and use in farmhouse, nursery is discussed. The various parameters influencing the growth of plants that are to be measured and monitored by the developed weather station are also discussed.

In chapter three development of soil moisture sensor, its use to measurement soil moisture, modeling and simulation used in design, instrumentation developed for it, and ultimate fully developed soil moisture sensor for which all the necessary optimization tests carried out are discussed. The literature for the developed soil moisture sensor is mentioned. Also the autoirrigation system using developed soil moisture sensor is also explained.

In chapter four talks about development of instrumentation, Stevenson screen needed for humidity measurement. The conventional dry and wet bulb method is used to measure humidity, where the dry and wet bulb temperatures are measured by using RTD and electronic instrumentation.

In chapter five instrumentation to measure temperature and light intensity is explained. The effect of temperature and light intensity on plant growth is also mentioned in this chapter.

The last chapter six summarizes the efforts and achievements of the work by giving the results and discussions about the project work. The cultivation under controlled parameters in green house with the corresponding parameters is briefly discussed. Practical approach towards the designed electronic automatic weather station and the existing commercially available weather station are discussed. The future scope is specified at the end.

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[1.2] Dr. Sulabha Deuskar " Role of Agrielectronics: Issues and Challenges ", Modem college of Arts, Science and Commerce, Shivajinagar, Pune 411 005, lead talk at National Conference, Chopda.

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c) B.B. Yenage , A.V. Kamble , Modem College of Arts , Science and Commerce, Pune-5,"Low cost Instrumentation for Chemical Analysis", minor research scheme sanctioned by U.G.C ( 2002-2003)

# CHAPTER 2
## Automatic Weather Stations for Agricultural and Other Applications

### INTRODCTION

A weather monitoring system, which can measure and display or record in site or remotely meteorological parameters without the help of observer is referred as an automatic weather station, Such weather stations are in common use wherever round the clock observations are required from inaccessible areas like mountains, river, remote islands, touchdown/takeoff areas in airports etc. Depending on the location and specific data requirements, the parameters monitored differ.

In this chapter the concept of automatic weather station , facors to be considered for installing it , cost , maintenance are discussed. The performance of conventional automatic weather station is compared with automatic electronic weather Station that can be used in farm house and nursury .

### 2.1 Automatic Weather Station

An AWS system typically consists of a set of sensors mounted outdoors to measure the various weather parameters, a console unit, usually located indoors, to collate and display the weather readings and optionally a data logger to link the system to a PC. The number and type of outside sensors will obviously vary with the purpose and sophistication of the AWS system.

Automatic Weather Stations (AWS) have a number of advantages over conventional manual recording. They are more consistent in their measurement, provide data at a significantly greater frequency (some provide data every minute), provide data in all weather, day and night, 365 days per year, AWS can be installed in far-off populated areas.

However, AWS suffer a number of disadvantages like some elements are difficult to automate, AWS require a large capital investment, possibility of breakdowns or malfunctioning of the instruments. AWS are less flexible than human observers. [2.1]

At present, automatic weather stations are run by microprocessors or microcomputers, which enable them to perform a great number of tasks with considerable flexibility nearly by modifying certain instructions in the command software. The present generation of stations represent a great leap forward compared with past installations, which were automated to deal with specified tasks and incapable of modification in their predetermined programs.

**THE BASIC REQUIREMENTS FOR AN AWS**

Different users have different requirements for AWS as below.

- Some AWS are installed for Short-term projects (e.g. animal health emergency monitoring or near wild fires), some are installed for long-term projects (e.g. studying climate change)
- Some AWS are required to provide data in real-time (e.g. for irrigation), some provide delayed reports (e.g. for climate monitoring)
- Some AWS are required to perform in all weather (e.g. for cyclone forecasting); some do not (e.g. crop disease monitoring).

One common set of conditions for all the above users is that the data must be representative of the area and time period under investigation, and that the data must continually meet the accuracy required. In addition, the data collection and storage systems must be cost effective.

## NEEDS TO BE CONSIDERED WHEN PLANNING FOR AN AWS

The factors like accuracy, collection, and storage are depends on the following issue listed in table 2.1 as below.

| | |
|---|---|
| 1 | Siting |
| 2 | Sensors |
| 3 | Algorithms |
| 4 | Maintenance |
| 5 | Documentation |
| 6 | Data formats and communications |
| 7 | Archiving and retrieval |
| 8 | Cost |

Table 2.1 Factors affecting performance of AWS

These issues are discussed in more detail as below.

### 1. SITING

a) Spatial Representative ness

The AWS should be sited so the variables measured are representative of the area of interest. Slight variations in exposure may mean that the data are not representative.

Three examples will be sufficient to explain this.

1. rainfall collection efficiency varies with height, due to wind turbulence effects. (e.g. rain measured at 1m above ground level is only 97% of rain measured at 300 mm)
2. Temperatures measured over a bitumen surface are significantly different to those measured over a grass surface.
3. Wind speed measured at 3m is significantly less than wind speed measured at 10m (the wind directions are also different).

b) Temporal Representative ness

In addition to difficulties with the correct exposure of instruments, thought has to be given to changes in the long-term exposure of the site. Buildings in close proximity to the instrument enclosure will result in the area of representative ness being reduced. It is important that the station be inspected regularly and any changes in the siting are properly documented.

## 2. SENSORS

The sensors used on an AWS are the heart and soul of the system. Therefore a great deal of care should be taken when choosing sensors appropriate to the user's requirements.

The Bureau's standard AWSs use sensors to monitor temperature, humidity, wind speed and direction, pressure and rainfall. Various advanced sensors are available for specialized applications. These sensors can monitor cloud height (ceilometer), visibility, present weather, thunderstorms, soil temperature (at a range of depths) and terrestrial temperature. Some of the sensors and their requirement of accuracy are listed in table 2.2.

| Sensor | Range | Accuracy | Unit |
|---|---|---|---|
| Air Pressure | 750 to 1060 | 0.3 | hPa |
| Air temperature | -25 to +60 | 0.3 | °C |
| Wet bulb temperature | -25 to +60 | 0.3 | °C |
| Relative Humidity | 2 to 100 | 3 | % |
| Wind Speed | 2 to 180 | 2 | knot |
| Wind Direction | 0 to 359 | 5 | degree |
| Rainfall | 0 to 999.8 | 2% | Mm |

Table 2.2 Accuracy of sensors needed for AWS

The quality of the final data received by the researcher or farmer can only be as good as the quality of the sensors used. No post analysis of the data can improve the accuracy or reliability of the information obtained.

There are a number of fundamental characteristics which make up the accuracy and precision of a sensor, like resolution, repeatability, response time, drift, Hysterisis, linearity etc. All of these factors go into defining the accuracy and precision of a sensor but some are more important in particular situations than others. For example, for monitoring climatic temperature changes a significant amount of data is collected over a long period therefore a sensor is required which has very little drift. However if you want to measure short-term wind gusts then the repeatability of the device and the response time become more important.

Another factor to consider is the robustness of the device. As a general rule, these devices are installed in harsh environments. This requires the sensors to be well designed and constructed, have strong waterproof housings for the electronics and be able the withstand extremes of climate variability. It is counterproductive to install a lightweight wind vane that will break the first time a sparrow sits on it or to use a sensing device that is designed for laboratory use (e.g. many humidity probes) in a dusty environment. Frequent replacement of lightweight or unreliable instruments can end up costing more than their more costly counterparts. The swapping of sensors can also have a significant effect on the quality of data, frequently introducing discontinuities into a data series.

The usefulness of the data obtained from a sensor is heavily dependent on the calibration of the sensor. For data to be comparable with other sites and networks, the calibration of sensors needs to be traceable back to common standards. This is often difficult to establish, particularly with cheaper sensors, but is of equal importance regardless of the quality of the sensor.

## 3. ALGORITHMS

The algorithms used to derive meteorological variables should be meaningful, documented, and comparable between networks.

For example, the maximum temperature derived from one second readings can be quite different to a maximum temperature derived from hourly readings, wind gusts based on one second readings will be significantly greater than gusts based on three second readings, and scalar averaging of wind direction generally produces meaningless results. Documenting the algorithms used, and all changes to those algorithms, is necessary for future users of the data.

## 4. MAINTENANCE

AWS should be chosen for their ease of maintenance. Maintenance should be able to be performed on an AWS without affecting the climatological record. For example, the temperature and humidity sensors should be able to be disabled before the instrument shelter is washed.

Many of the cheaper AWS cannot be adjusted in the field and need to be returned to the manufacturer for periodic calibration. In addition, many of these AWS lack robustness and require frequent maintenance visits to replace electronics and/or sensors. It is important to consider the lifetime costs of an AWS rather than simply the initial cost. Generally, the lower the initial cost, the higher the ongoing cost to maintain acceptable data.

## 5. DOCUMENTATION

One area of observational networks that is frequently overlooked is proper ongoing documentation of equipment and siting. In many weather stations, years of data have been rendered useless for climate-related research due to lack of metadata showing changes in the station's immediate surroundings or instrumentation.

The initial siting of the AWS should be documented with maps and photographs. In addition, all inspection and maintenance visits should be fully documented to record any changes or errors detected in the instrumentation.

## .6. DATA FORMATS AND COMMUNICATIONS

a) Output Format

Careful thought must be given to the output data format. Ideally, the format used should be-

- Flexible - so new sensors can be added without having to re-process all the stations records into the new format
- Simple - such that only simple programming is required to decode the data
- Preferably human-readable without reformatting - to assist in the quality monitoring of the data
- Independent of AWS manufacturer - to allow data to be easily exchanged between agencies and to encourage cost competitiveness between manufacturers
- Unambiguous - the use of features such as check-sums minimize the possibility of data corruption

The use of standard data formats permits easy exchange of data between agencies and for their processing with a minimum of reformatting.

Most AWS manufacturers use their own proprietary data formats. Their use reduces the user's ability to exchange data to/from other agencies and reduces the AWS owner's flexibility to add AWS of another manufacturer.

The Bureau of Meteorology AWS generates five standard data formats. They are the one-second format (for maintenance and real-time read-outs), one-minute format (data logging, display), ten-minute format (data logging), thirty-minute format (forecasting), and three hourly format (international exchange and archiving).

b) Communications

The communications between the AWS and the collection agency should be, reliable, inexpensive and follow standard protocols.

AWS reports observations by a variety of formats, including telephone lines, radio modems, mobile phone networks and satellite networks. Consideration must be given to the frequency of messages, cost (satellite telephone can be expensive) and availability of services.

## 7. ARCHIVING AND RETRIEVAL

The archival and retrieval of AWS data must be considered. Apart from, possibly, short-term projects AWS data should be kept permanently. This will require balancing the need to store high temporal resolution data against the large volumes generated. When deciding on a data storage system, consideration should be given to the ease of quality control and retrieval of the data. This applies as equally to data stored on hard copy as to data held in electronic form.

## 8. AWS COSTS

No definitive AWS costs can be given as each user has different requirements, as noted above. Each AWS purchase needs to be considered in the context of these requirements. As an analogy, definitive transport costs cannot be given as a user's requirements may vary from a bicycle to an aircraft.

As an indication of costs, an AWS with sensors for air temperature, humidity and rainfall, and conforming to Bureau standards, can be purchased for approximately $ 40000 (Rs. 1860000/-) or upto £ 1999 (Rs. 175912/-) to around £ 12000 (Rs .1044000/-) it is also important to consider costs beyond simply the installation. Regular inspection of the site, sensor performance testing, having sufficient spares in stock, retaining trained technical personal and monthly communications cost all contribute to keeping an AWS running smoothly. For a given quality of data, the general rule is: the cheaper the AWS, the less accurate the data, the more prone are the electronics and sensors to failure, and the higher the maintenance costs. [2.2]

## 2.2 CLASSIFICATION OF AUTOMATIC WEATHER STATIONS

Automatic weather stations may be classified in to two main categories, according to the manner in which the data they acquire are used.

Climatologic stations, whose data are used with a certain time delay and Synoptic stations whose data are used in real time. Stations are much the same, which ever of these two categories they belong to. The only difference is that in synoptic stations there is a system for real time transmission of data to the user. In climatology stations, though, a transmission system is not obligatory, as data may be stored in the station itself.

Stations may deal with the marine or terrestrial environment according to their location, and possible applications are in the field of aeronautics, microclimatology, and agrometeorology, early warning for example storms or floods and pollution monitoring.

## GENERAL FUNCTION:

The block diagram of automatic weather station is shown in the figure 2.1

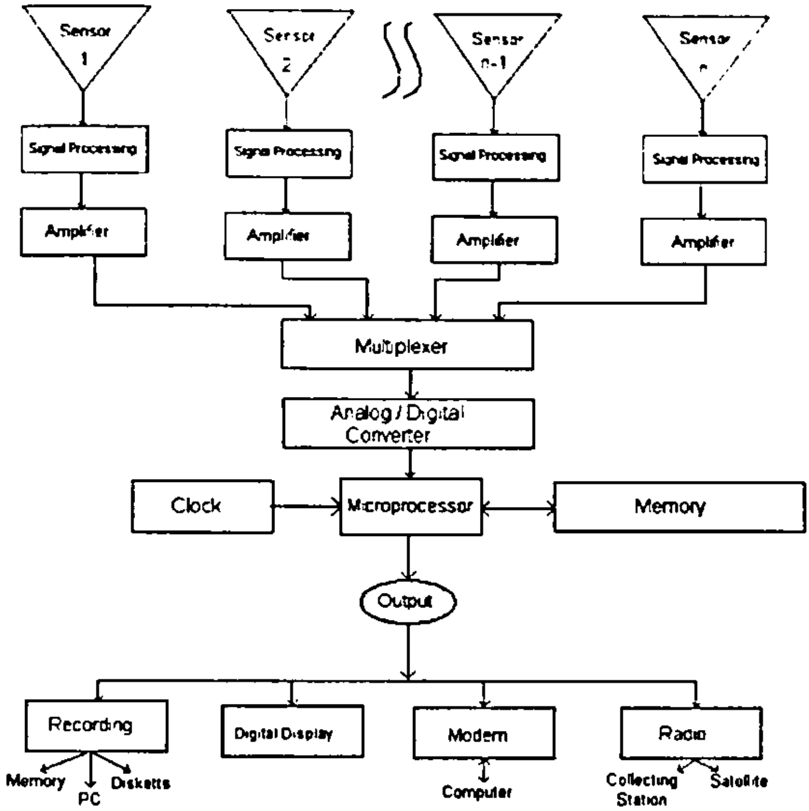



figure 2.1 Block diagram of Automatic weather station

The various sensors are linked through signal conditioning to MUX that enables each instruments to be read in sequence. The signal conditionings allow for the particular characteristics of each sensor or standardize its data.

MUX is connected to ADC and buffer memory. The microprocessor directs the reading of instruments according to a time reference provided by a clock and each sensors data are converted into meteorological quantities.

The data acquired are therefore available for outward transmission, to be used either in real time or at latter date if stored in situ in static internal memories or in microcomputer. A modem can access the station in order to consult data as they come in or from a memory.

To assume reliability in data acquisition, the station should incorporate it's own self-monitoring system, able to report any malfunction to the user.

Various application of Automatic Weather Station is like in Agriculture, Floriculture, Ecology, Environmental science, Pollution control, Sports centers, Tourists places, mental health, Marine observations etc. [2.3]

**2.3 A new approach to Automatic Weather Station**

In the present work, the project is undertaken to design an automatic electronic weather station to monitor the microclimate condition in a green house, farmhouse or a small nursery. This is to be done by using locally available and the developed sensors with related circuitry.

The focus in the present work is to measure and control the following parameters [2.4] shown in table 2.3.

| Parameter | Effect on plant in greenhouse | Control or upholding the conditions |
|---|---|---|
| Temperature | Night temperatures, nutrition activities | Air conditioning, fan, pad convective cooling |
| Relative Humidity | A transpiration loss from the leaves depends on humidity. High humidity causes fungus and mildew. | Allow outside air inside |
| Solar Energy | It is a source for energy growth, intensity, duration and quality are important for photosynthesis. | Artificial light of particular wavelength and power. |
| Soil Moisture | Temperature, Humidity inside Green house as well as growth of the plant | Auto irrigation system |
| Wind Velocity and Direction | Temperature, Humidity inside Green house. Pollination of plants in season. Mechanical support to plants | Controlled airflow through all possible directions. |

Table 2.3 parameters influencing plant growth

It was decided to develop an automatic electronic weather station system that can be installed for limited area of operations like farmhouse, nursery or greenhouse.

The steps in the development of proposed automatic electronic weather station were as below.

Step1 : Decide the beneficial parameters needed to be controlled for plant growth.

Step2 : Perform various initial experimentation for measurement of each parameter to choose a proper sensor and instrumentation system.
If necessary develop a sensor indigenously.

Step3 : Develop an instrumentation system for each parameter, calibrate it properly.

Step 4: Display the measured parameter on a common display with the help of manual switch .

Step 5 : Install whole the instrumentation in an assembly where the parameters are to be measured .

Step 6 : Cultivate small flower plants inside the small greenhouse model and try to control the parameters according to climatology of that plants.

Step 7: Once the above system works properly, it is to be automated using Microcontroller or a computer system.

Step 8 : Data can be generated for plants artificially cultivated in the greenhouse , nursery or farmhouse.

The parameters temperature, humidity, soil moisture, light intensity, and wind velocity are chosen for include in the automatic weather station.

Each parameter is measured by using electronic measurement system as shown in figure 2.2 below.

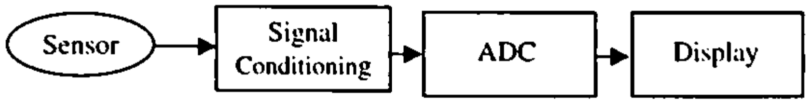



Figure 2.2 Block diagram of electronic measurement system

In any measurement system measurand (physical quantity under measurement) is detected by the first stage (sensor) as shown in fig 2.4 this quantity is detected as transuded into an electrical form output. This electrical signal corresponding to physical quantity is to be linearise with improved signal to noise ratio. Hence the second stage is signal conditioning and scaling of the signal. Then by using analog to digital converter the measured parameter is displayed in the digital form. There are various approaches of signal conditioning depending upon the type of transducer used. [2.5] In the present work the entire information adopted to measure the various parameters described in subsequent chapters.

Combining all these measurement units electronic weather station is to be formed. Figure 2. 3 shows block diagram of the proposed weather station.

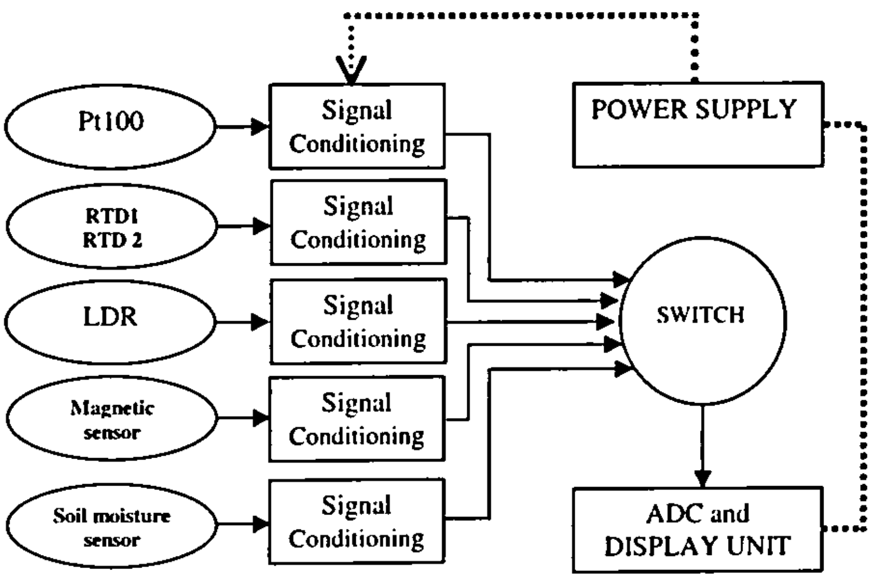
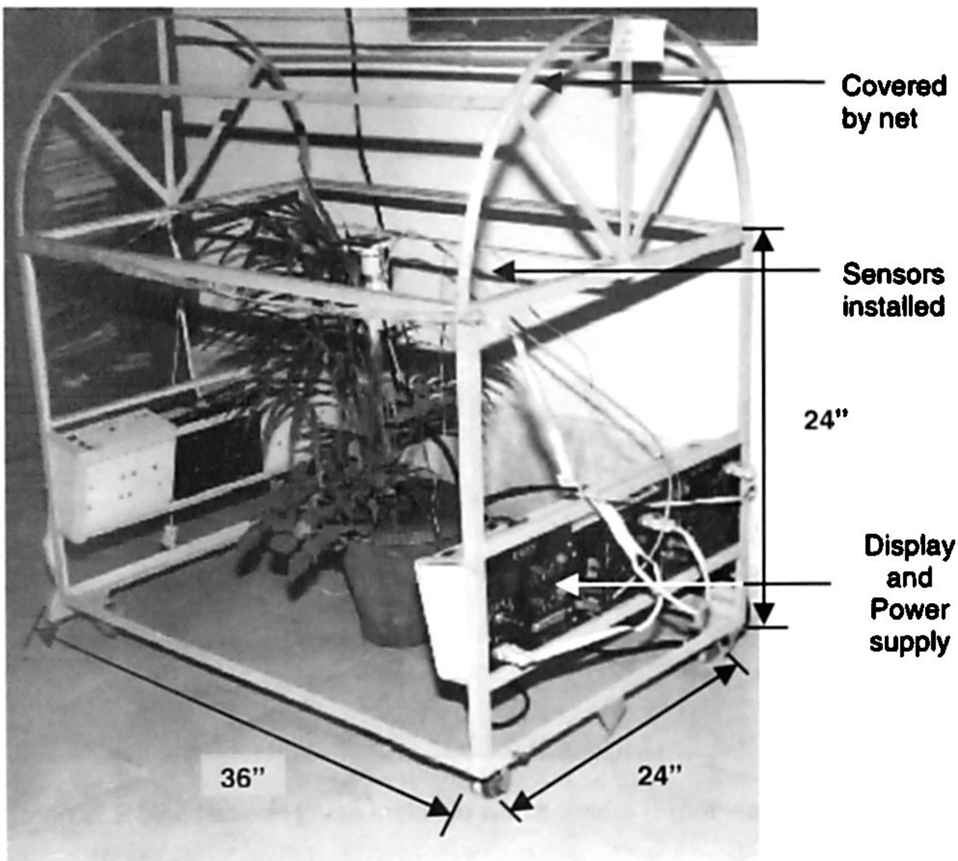
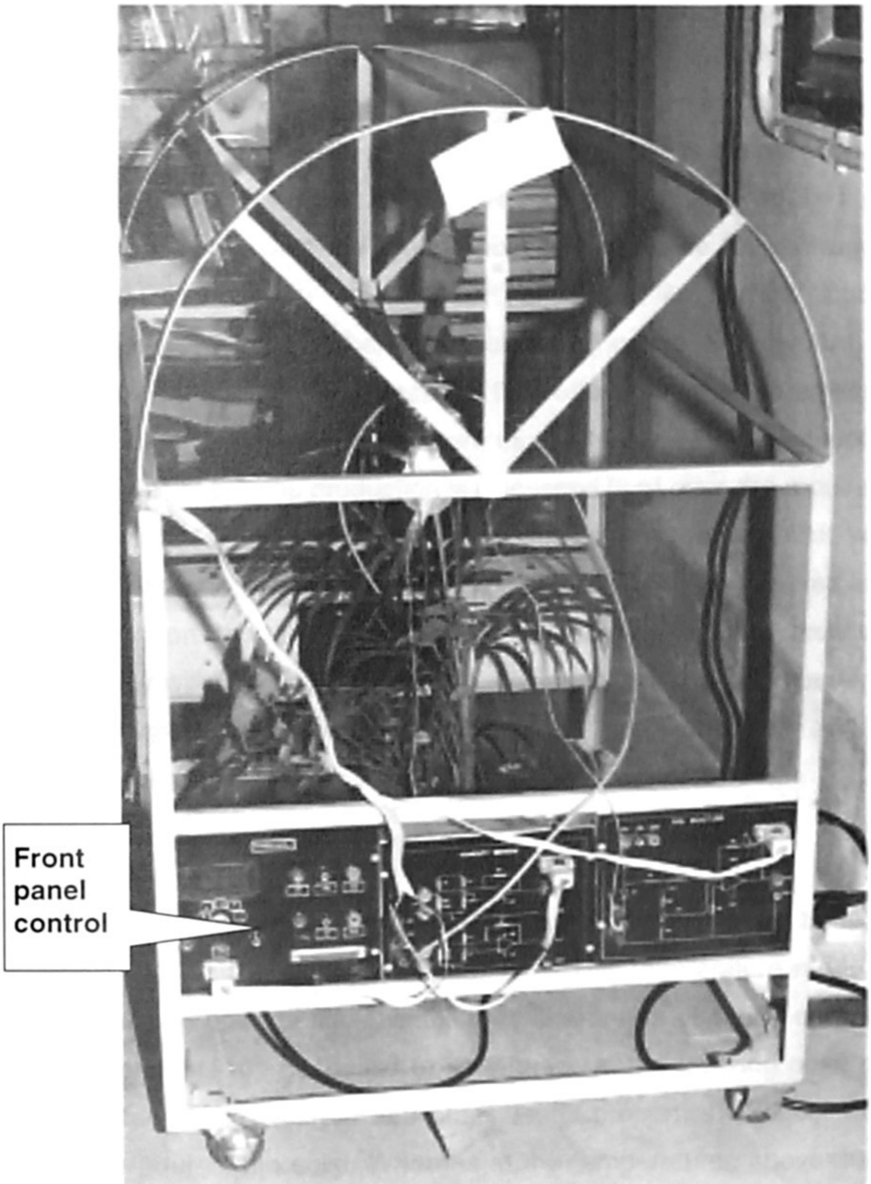



Figure 2.3 block diagram of manually operated weather station

Initially the parameters are selected to display on a common digital panel by using manual switch. When the system is completed working upto agreeable results. The mini Green house installed with electronic weather station is shown in photograph 2.1 (side view) and photograph 2.2 (Front view) .The sensors are placed at appropriate positions. The signal conditioning and calibration units, display are placed as shown in it.




Photograph 2.1 Mini Green House installed with sensors (Side view)




Photograph 2.2 Mini Green House installed with sensors (Front view)

The parameters are displayed on seven-segment display, where we have facility to check each parameter observation one by one. Thus with the measured quantities of temperature, humidity, light intensity, soil moisture level used for irrigation purpose, study of plants can be done. The same can be installed in a farmhouse or nursery to check out these parameters, in order to take some decisions regarding the cultivation of plants taking place there over.

**Environmental control in cultivation**

Now a days green house technology is enormously developed all over the world. In the artificially monitored weather the plantation of the crops is done and quality of the output production is maintained. A lot of experimentation is done in horticulture, tissue culture to find out the desired climate inside the green house or polyhouse for cultivation. The data is available for different sort of plants like tomato, cucumber, watermelon, and strawberry, Capsicum. Flowers like jerbera, roses, sunflowers etc. In this chapter the effect of the parameters like temperature, humidity, soil moisture m, wind velocity and its direction and light intensity on crop production is discussed [2.6]. Also the required value of the data for maintaining these parameters for the particular variety is given. Measurement of these parameters is crucial; the required accuracy depends on the different kind of plantations. Also the measurement accuracy will be vital while these parameters are controlled automatically by designing control system. Also the requirement of accuracy of measurement of these parameters is given.

**Temperature**

In general, the biochemical reactions within crop plants take place within very narrow range of temperature. This temperature range is from the freezing point of liquid water to temperatures at which enzymes and other proteins are despoiled or denatured. At the freezing point of water temperature the catalytic and other useful properties of liquid water are lost as it turns into solid. Whereas at the temperatures above 30 degree centigrade or above the molecular structure of the several enzyme and proteins is irretrievably altered. Thus the integrity of enzymes and protein system in crop plants is maintained only within narrow range of temperature this does not means that a constant temperature within this range produces the highest yield. This is because in different stages of the growth the temperature requirement is different. The knowledge of temperature influence on crop plant growth is classified as either favorable i.e. optimum temperature range or unfavorable for growth of the crop. Here favorable condition is the optimum temperature range within which maximum photosynthesis and normal respiration take place throughout the life cycle of the plant to get highest yield of the crop. The following table 2.4 shows the temperature range for some of the crops.

| Crops | Temperature range 7 to 13° C | Temperature range 13 to 18° C | Temperature range 18 to 24° C |
|---|---|---|---|
| Fruits | Apple, pear, plum, cherry, strawberry. | Peach, apricot, pecan, blackberry, viniferous grape | Banana, cacao, cashew, coffee, papaya |
| Vegetables | Spinach, pea, potato, the root crops, asparagus | Tomato, capsicum, pepper, bean, protepea | Sweet potato, sweet corn, cucurbits |
| Flowers and ornamental | Aster, vinca, calceolaria, cineraria | Gardenia, poinsettia, roses | Gloxinia, philodendron |

Table 2.4 Temperature requirements of horticulture crops

The temperature required to maintain for the cultivation in green house is of two types. One method is by heating and cooling, which also depends on the CO2 enrichment inside hit. There are three basic methods of green house cooling, natural ventilation, mechanical fan and pad cooling, fog cooling. Typically the range of the temperature is divided into different timings like Day minimum, Night minimum and Ventilation temperature. For example the recommended air temperatures in degree centigrade for tomato cropping are given in the table 2.5.

| Temperature (°C) | Low light | High Light | CO2 Enrichment |
|---|---|---|---|
| Night Minimum | 17 | 18 | 18 |
| Day Minimum | 19 | 21 | 21 |
| Ventilation | 21 | 24 | 26 |

Table 2.5 Temperature maintained in green house for tomato

From the above table we see that the accurate temperature measurement is necessary, but the error up to ±2% will not affect so much. Thus in the present work using RTD sensor Pt 100, the temperature measurement instrumentation is designed, to fulfill the essential requirement. [2.7]

**Humidity**

The amount of water vapor in the air compared with the amount when the air is saturated for any particular temperature is known as relative humidity. In general moist air contains relatively huge quantity of water vapor. It is found that with the temperature of the leaf of plant and that of the surrounding air is same; the rate of transpiration and photosynthesis is directly proportional to the differences in vapor pressure of the transpiring surface and that of the ambient temperature. It is inversely proportional to the relative humidity of ambient air.

It is not always clear what humidity levels are to be maintained in a green house for desirable plant growth, fruit set and disease prevention. Also humidity control is indirect and usually involves tradeoffs with air and leaf temperatures, CO2 and ventilation. The issue of vapor pressure deficits in green house is complicated. At low vapor pressure deficits plants are light colored with large soft leaves, weak growing points and low transpiration rates. On the other hand high humidity reduces the leaf area because of lack of calcium, increased stomata conductance, reduced final yield and reduced mean fruit weight. High relative humidity generally favors growth. However, reasonable growth can be achieved at medium or even low relative humidity. The most important reason of cropping under conditions of high relative humidity include the risk of water condensing on the plants and development of serious diseases [2.8]. Also diseases also spread more rapidly under conditions of high relative humidity, especially if leaf surfaces are also wet from dripping on condensate. The devices used to maintain humidity level include venting the humid air by replacing it with cooler, driver outside air. Thus in the present work using RTD sensor, the temperature measurement instrumentation is designed, which is used to measure Dry bulb and Wet bulb method of humidity measurement. In the different cropping stages the note can be taken about the humidity. Also it can be maintained to a particular value for particular species.

**Light Intensity**

Light intensity refers to the number of photons impinging on a given area or to the total amount of light which plants receive. For any given location the intensity varies with the day, with the seasons and with the distance from the equator. The effect of optimum light intensity range on the plant growth is on photosynthesis, respiration, and carbohydrate availability for growth. With the other factors favorable the rate of photosynthesis is high, the rate of respiration is normal and as a result carbohydrate available for the growth of the plant are enough. The optimum range of light intensity range is not same for all crops. This range of light intensity for many crops is not definitely known, but from the experience, particularly with patterned plants indicates that the plant are classified as shade plants, partial shade plants, partial sun plant and sun plants.

The following table 2.6 shows the examples with various light intensity requirements for some of the crops.

| Crops | Shade only 500-1000 foot-candle | Shade and Direct sun for small duration 1000-3000 foot-candle | Direct sun mostly 3000-8000 foot-candle | Slight shade 2000-8000 foot-candle |
|---|---|---|---|---|
| Fruits | ---- | Cacao, coffee, tea | Banana, coconut, date, papaya | Apple, pear, peach, rubber tree |
| Herbaceous crops | Ginseng Tobacco | Vanilla, pepper | Capsicum, cotton, corn, rice, Pineapple, sweet potato | Cabbage, Peanut, Potato |
| Ornamentals | African violet, ferns, Aspidistra | Calladium, dogwood, orchids | Caranation, gladiolus, lily, rose | Abelia, berberis, mangolia |

Table 2.6 Light intensity requirement for crops

Beside an intensity of the light, its quality, quantity, duration, direction and periodicity are the important aspects that are significant in the crop growth. For various kinds of plants the condition of light is different. [2.9]

**Wind velocity and direction**

The major aspect of wind velocity and direction is the pollination in the plants. The mechanical strength of the plant root system, humidity, temperature, and soil moisture level, and respiration are affected by the wind velocity and direction. In the controlled environment natural ventilation or electric air blower or fans are used to keep desired air circulation of the air around the cultivation plant.

**Soil Moisture**

The plant gets the water through capillary action, hygroscopic water, free water, gravitational water and chemically composed water. Although sufficient water is available to the plant growth, It is very important scheduling of the watering i.e. irrigation to the crop at its various growing stages. This can done by applying auto irrigation system. For controlling the irrigation system and precise irrigation at a particular growing stage of the plant soil moisture level determination is very important. Also the consumption of the minerals from the soil along with water by the plant is very important. Sufficient quantity of water is necessary to execute this action. Also the water deficiency across the leaves of the plant due to transpiration is recovered through the soil water only, hence soil moisture level maintenance is very much necessary.

Thus with these five parameters it was decided to develop an automatic weather station which can be installed in a green house, farm house and nurseries. The soil moisture parameter is focused essentially in order to install automatic irrigation system. The soil moisture sensor along with the automation instrumentation is developed which is described in the next chapter 3.

## References


[2.1] Gerard Guyot, " PHYSICS OF THE ENVIRONMENT AND CLIMATE ", (1998), JOHN WILEY & SONS pp 592-593.

[2.2] Australian Government bureau of Meteorology, website.

[2.3] Gerard Guyot, " PHYSICS OF THE ENVIRONMENT AND CLIMATE ", (1998), JOHN WILEY & SONS pp 593-598.

[2.4] Treatise on Agrophysics and Agrielectronics: Dr.G.N. Acharya & Dr. D.G. Hapse, Vasantdada Sugar Institute, Manjari (B.K), Pune 412 307, (1993), pp 28.11

[2.5] Abert D. Helfrick, William D. Cooper," Modem Electronic Instrumentation and measurement techniques", Prentice-Hall of India, (1996), pp 337-377.

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[2.8] 8 West Sunrise PR NW Benton City, WA 99320, website on lights for green house and temperature control

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# Chapter 3
# Development of soil moisture sensor and soil moisture measurement

**Introduction**

Water is necessary as a food in a cultivation of crops. The principle source of water is rain that varies from region to region. Soil is a storehouse of plant nutrients, a habitat for bacteria, a port and reservoir that holds water needed for plant growth. The water absorption, transpiration stream refers to the path that the water flows. Water enters into the plant through finer portions of the root system and transported through stem towards leaves for photosynthesis process. The transpiration stream is a continuous throughout the plant body from the region of absorption to the region of vaporization. In crop plants most of the water is lost through leaves. Water has great solvent properties due to which the water in the soil (soil moisture) contains many substances in solution form. The various minerals are supplied through the water from soil to the plants, also in the photosynthesis and transpiration process water is vital factor. The water supply to the crops i.e. irrigation is also important in various stages of the cultivation like seeding, germination, stemming, flowering, fruiting, reproductive phase etc. Thus the soil moisture measurement and accordingly irrigation becomes mandatory in the agriculture.

In the present work soil moisture sensor is developed and included in the electronic weather station. The output of the soil moisture sensor is available in a voltage that corresponds to percentage soil moisture. Using this sensor soil moisture can be monitored and controlled when used in an automatic drip irrigation system.

The principle of thermal conductivity is used to develop the soil moisture sensor. It is inserted in the soil up to 6 cms level and heated for predetermined time, depending on the moisture level the degree of temperature rise varies. The relation between the temperature gradient in the vicinity of moisture level is found out. Results for different moisture levels are calibrated using the standard thermo-gravimetric method. The reproducibility of the results has been confirmed by several trials.

## 3.1 Different methods used for soil moisture measurement

There are basically two types of methods to determine the soil moisture level. One is the direct method in which one can estimate the soil moisture level. These methods cannot be used ON line for moisture control. The other methods are indirect method in which the thermal properties, electrical resistively, capillary tension and radioactivity or radiation properties of the soil are incorporated. The advantage of the indirect measurement method of soil moisture level is that it can be used to estimate ON line soil moisture measurement and can be combined with auto irrigation system. Table 3.1 lists the different soil measurement sensors available and used.

| Method | Soil moisture sensor | Remark |
|---|---|---|
| Gravimetric | Loss / Gain of weight of soil due to moisture | Time consuming, need to take proper soil sample |
| Thermal | Thermal conductivity probe | Needs calibration for every soil |
| Electrical Conductivity of soil | Capacitive<br><br>Gypsum block | Corrosive<br><br>In Freezing condition does not work, conductivity of soil changes with salinity. |
| Capillary tension | Tensiometer | At saturation water level can not work<br>Micro irrigation can be monitored |
| Radioactive method | Neutron probe<br>Gamma ray probe | Corrosive, costly |
| Time Domain Reflectometry | Pair of metallic rod with specific dielectric constant | Long distance transmission of measurement is possible |

Table 3.1 various sensors used to measure soil moisture

From table 3.1 it is seen that each sensor has its own limitation. Hence it was decided to develop a thermal conductivity based sensor .In the following section a detailed account of the development of soil moisture sensor [3.1] is given.

### 3.2 Basic idea for soil moisture sensor under development

The thermal properties of the soil are strongly dependent on soil moisture content. Hence to measure soil moisture, the temperature gradient calibrated at various soil moisture levels is used. Soil thermal conductivity measurements describe the soil properties, which govern the flow of heat through the soil. [3.2] The thermal conductivity is defined as the quantity of heat that flows through a unit area in a unit time under a unit temperature gradient.

In the beginning as shown in figure 3.1 aluminum rod of length 7 cm and diameter of 2 cm is tapered inside to fix a NTC thermister (82 Kohm) and a wire wound resistor (6.2 ohm, 5 W). They are sealed together by using wax.

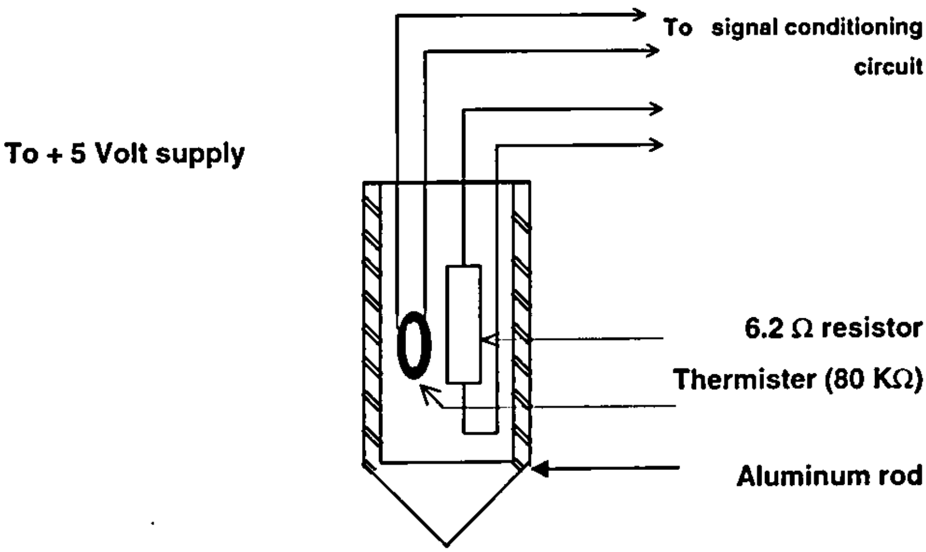



Figure 3.1 Thermister based sensor

In the sensor heat is generated using 6.2 Ohm wire wound resistor 5 watt enclosed in an aluminum rod, where the temperature is measured by placing thermister nearby to the resistor. The rod, which is now soil moisture sensor, is to be placed inside the soil 4-5 cm inside, then by passing the current through the heater for predetermined time the flow of the heat from the sensor towards the soil is measured .The thermister is connected to the signal conditioning circuit which is current to voltage converter circuit.

The heater is turned off after 120 seconds. The thermal gradient (mV/sec) is calculated at particular moisture percentage. Thus we can calibrate and measure soil moisture using thermister based probe. Here, after repetitive experimentation, time period for heating the sensor is decided to be 2 minutes. Then the calibration curve is obtained to determine soil moisture. The thermal conductivity is measured by using transient heat flow, which is considered more accurate than steady state method. Transient methods minimize effects of water movement due to temperature gradients and do not require long time for the temperature gradient to stabilize. In the designing of this sensor the theory of heat transfer is considered. The heat transfer from a body "Q" of area "A" is given by

$$\frac{Q}{A} \propto \frac{\partial T}{\partial x}$$

When the proportionality constant is inserted,

$$Q = -kA\frac{\partial T}{\partial X}$$

Where Q is the heat-transfer rate and $\partial T/\partial x$ is the temperature gradient the direction of heat flow. The constant k is called the thermal conductivity of the material, and the minus sign indicates the heat flow according to second law of thermodynamics. (k =202 W/m°C for Aluminum, and k = .556 W/m°C for water.) [3.3]

In this sensor, the assembly of aluminum rod with the thermister is inserted in the soil sample so as to ensure firm contact. Hence the heat transfer is only by conduction at the surface of sensor. From the above equation the heat transferred is determined, and we can use the thermal gradient to measure soil moisture. In the present work the rate of flow of heat is measured as temperature per second, and is calibrated for different moisture levels.

## 3.3 Modeling for soil moisture sensor

Initial experiments for soil moisture measurements were carried using this sensor and results were compared. They were not as per expectation. The causes were large recovery time, calibration and it was useful only few centimeters below the soil surface. To overcome these difficulties software simulation is used and model is developed [3.4]

### Model for sensor

In the development of the software model for thermal conductivity beside above theory, other factors are also considered. These are like type of metal, its specific heat, its property of corrosion to moisture and soil salts, heater used, the power consumption and stability to produce heat with respect to time, sealing material used to enclose the assembly etc. Since this assembly is to be used as soil moisture sensor the properties of the soil that affects thermal conductivity of soil are also considered like soil texture, Type of the soil, organic matter inside soil and compaction of the soil particles. [3.5]

By considering all above factors in designing the soil moisture sensor the, C program model is very useful. Since one can have different possibilities of the above factors which are to be selected. The values generated by the model are also be confirmed whether they are feasible in practice, Hence this is the limitation while referring a model for a developing a sensor.

The software model developed based on Newton's law of cooling. The equation of which is

$$\frac{DT}{dt} = \frac{(P - L)}{m_T}$$

Where P = power excited inside sensor ( $i^2R$ since resistive heater)

L = conductive + convection + radial loss , where as the sensor is dipped inside the soil only conductive loses accounts in it.

The heat loss is directly proportional to T – Ts. The temperature rise across soil depends on Thermal mass or thermal load. As the thermal load increases the time rate of heat transfer increases. The more compact the soil, and the larger the water content, the greater its thermal conductivity. [3.6]

Hence we can calibrate the soil moisture sensor as shown in figure 3.2.

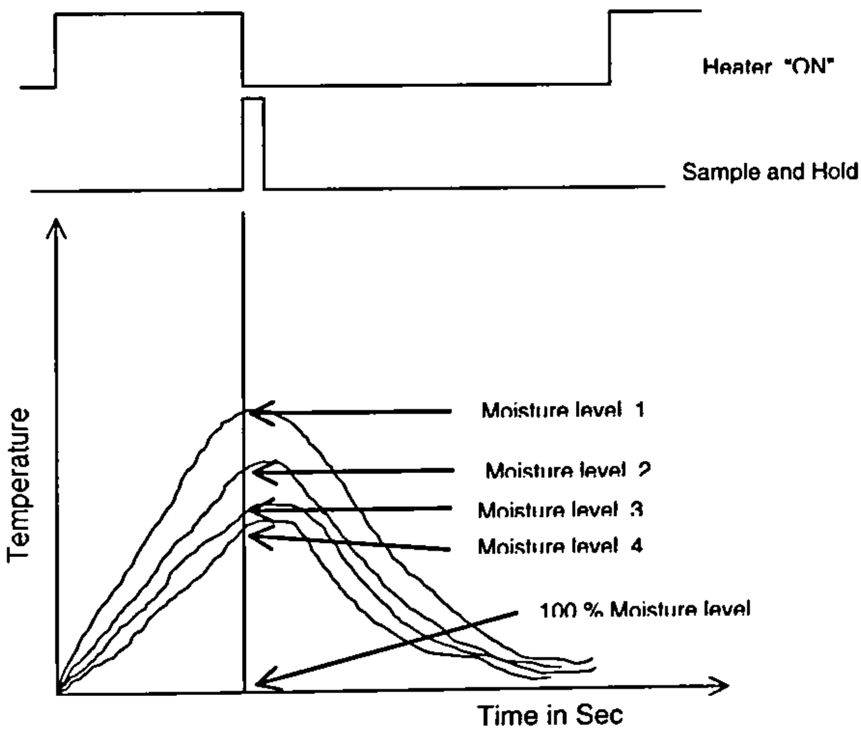



Figure 3.2 Data acquisition and calibration for soil moisture sensor

As seen from figure 3.2 sensor is exited for heat radiation for fixed duration, the rise in temperature is detected as soon as the heater is made OFF. The rate of increasing temperature depends on soil moisture content in the soil. More the soil moisture the rise in temperature is less, where as in dry soil the temperature rise is fast having higher value. Using this phenomenon the soil moisture sensor is calibrated.

In the present work model is developed to optimize to excitation and recovery time as shown in figure 3.3.

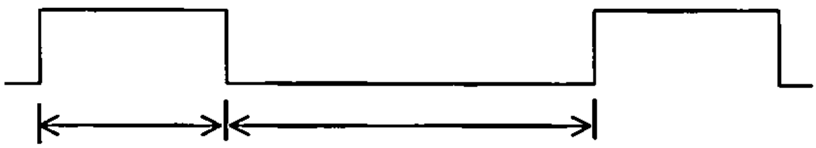



Figure 3.3 Optimization of excitation and recovery time for soil moisture sensor

From the model it was seen that if we keep excitation time low, very small amount of heat is transferred into soil. If the excitation time is high the heat transfer is excessive and the recovery time increases widely. Hence both the excitation and recovery time are optimized as the minimum time for excitation and desirable time for recovery. It was decided to keep 180 seconds as excitation time and 420 seconds as recovery time. Thus after each ten minutes the soil moisture is measured. The temperature is measured by using NTC thermister .The instrumentation designed for signal conditioning for thermister provides the output of soil moisture sensor in miliivolts.

Astable Multivibrator using Timer IC 555 is used as timing circuit to make the heater ON for 120 seconds and Keep it OFF for 420 seconds. duration in which there is equilibrium of heat transfer between sensor and soil. Here the sufficient amount of heat is transferred into soil in adequate time and sensor comes to its initial condition in the next measurement cycle. This time is optimized using heat transfer curve is graphically displayed on the computer screen.

The size of the sensor is kept small to avoid radiation losses or loss of heat generated by the resistor heater. The metal Aluminum is selected because of its physical no corrosive properties. To measure the soil moisture at various depths it was decided the length of the sensor is to be increased by using nonconductive materials like an ebonite rod of nearly 1 foot in length.

Hence from the software model, we get the design parameters for thermister based soil moisture sensor. Due to software model the trial and error values with all possibilities are taken in to consideration.

**3.4 Design and fabrication of soil moisture sensor**

The design of the sensor was based on the following inputs derived after initial experimentation and results of simulation.

Referring to the figure 3.1 the various parameters in designing of soil moisture sensors are listed in table 3.2.

| Sr. No | Parameter | Design |
|---|---|---|
| 1 | Material / metal | Aluminum, ebonite |
| 2 | Type | Rod with 3" height and 1" bore with tapering.<br>Ebonite rod as an extension to sensor 9" in height |
| 3 | Heater assembly | Wire wound resistor |
| 4 | Temperature sensor | NTC Thermister with signal conditioning circuit |
| 5 | Package | Heater and thermister are packed by using wax |
| 6 | Power supply | DC power supply for fixed time using timer circuit |
| 7 | Output | Volts in digital readout after signal conditioning |

Table 3.2 Design parameters of soil moisture sensor

In the signal conditioning circuit proper adjustments are done to set output in mV corresponding to change in resistor of thermister. The calibration range is for 80 Kohm thermister. Figure 3.4 shows the signal conditioning for thermister.

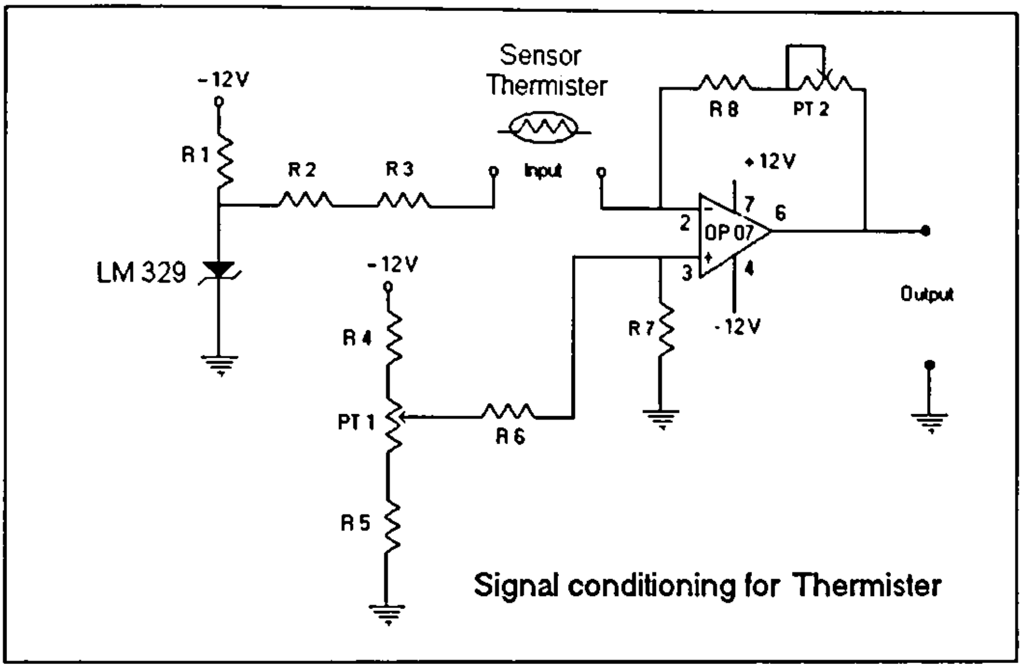



Figure 3.4 Signal conditioning for thermister

In this circuit NTC thermister of 80 Kohm is used as temperature sensor. A zener diode maintains a constant voltage drop across it. The trip Pot PT1 is used for removing initial offsets and thus adjusting the initial value of output as 0 mV. The trim pot PT2 is used for span adjustment. . Here the span is from zero degree to hundred degrees centigrade.

The output is displayed on LCD display using 7109 ADC interface, the temperature is displayed in millivolts corresponding to degree centigrade. The advantage in this calibration is that change of 1mV at the output corresponds to 1°C of change of temperature. The +5 volt dc supply is connected through switch to the 6.2 ohm resistor, which is used as a heater. Switching of the supply is done manually.

**3.5 Calibration of the sensor**

The soil moisture sensor as described above is now calibrated for the soil moisture measurement. The objective was to display a voltage output corresponding to various soil moisture levels. Various experiments were carried out with the experimental set up as described below.

AS shown in Figure 3.5 the output of the sensor is connected to the signal conditioning circuit, ADC, Display circuit and power supply used for the unit.

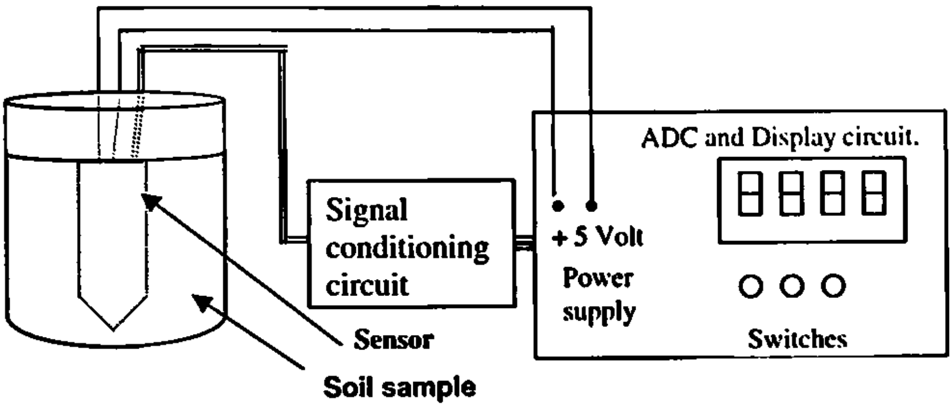



Figure. 3.5 Block diagram of the unit

**Characteristic of the sensor**

First the characteristic of the sensor is studied. For this, sensor is heated in air medium for 2 minutes and cooled for 10 minutes, and then the thermal conductivity is studied. Same procedure is repeated by inserting the sensor in water, and dry soil. Hence thermal conductivity characteristic is found out as shown in figure 3.5 .The slope of the curve for air, water and soil is calculated. It is found that the thermal gradient changes from 0.51 mV/sec to 0.40 mV/sec from dry soil to water. This shown in figure 3.6. Hence we can use the sensor for measurement of soil moisture, which is defined as the quantity of water content in a soil, measured as percentage moisture.

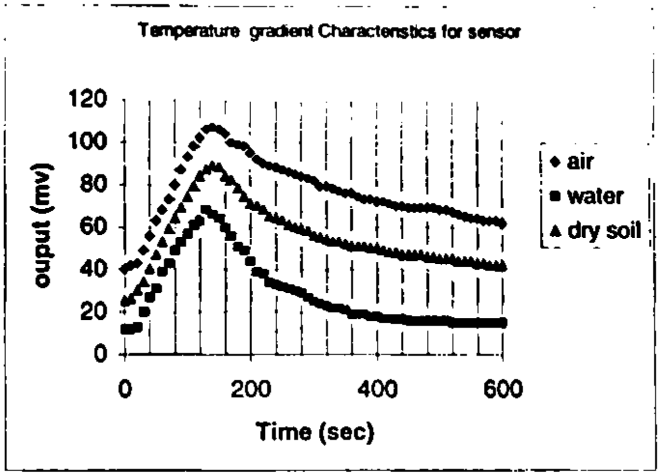



Figure. 3.6 Sensor Characteristics

**Experimental Work**

To measure soil moisture, first the complete dry soil is prepared. 120 gm of soil is heated at 105° C for 24 hours. Weighing and drying repeatedly in oven up to .1 gm accuracy confirmed the dryness. [3.7][3.8] The soil is kept in desiccators so as to protect it from humidity. Then 100 gm of the dry soil is taken into sample pot, which is used as 0% soil moisture level sample. The sensor is dipped into it and heated for 2 minutes, cooled for 10 minutes; in this process the temperature is noted in terms of millivolts at 10 seconds time interval. Then by adding 10 ml of water into the sample and stirring it well, soil moisture level is raised to 10 percent. After allowing it to settle the cycle of heating and cooling is completed. The whole procedure is repeated for 20%, 30%, 40% likewise up to 80% and the corresponding thermal transfer curves are plotted as shown in figure (3.7 a) and (3.7 b).

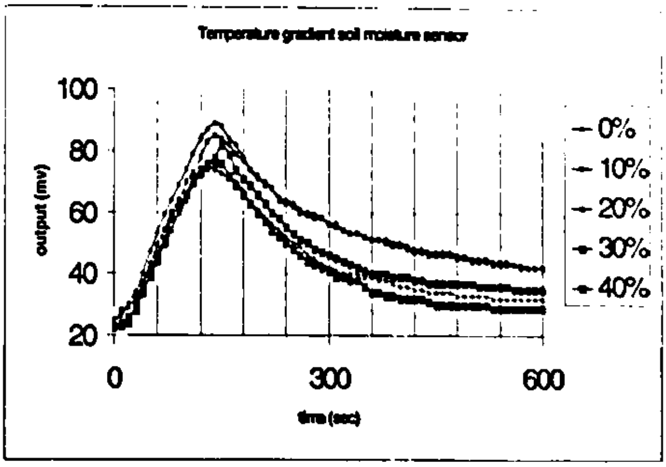



Figure 3.7 (a) Temperature Gradient

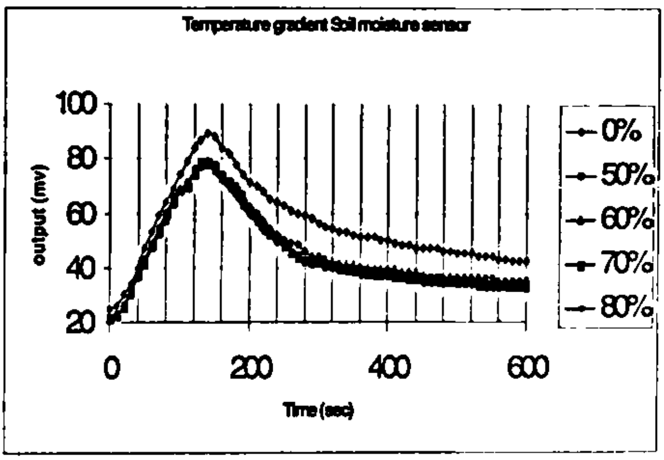



Figure 3.7 (b) Temperature Gradient

From these graphs the soil moisture content is calibrated corresponding to output in milivolts corresponding to percentage moisture as shown in graph. Figure 3.8.

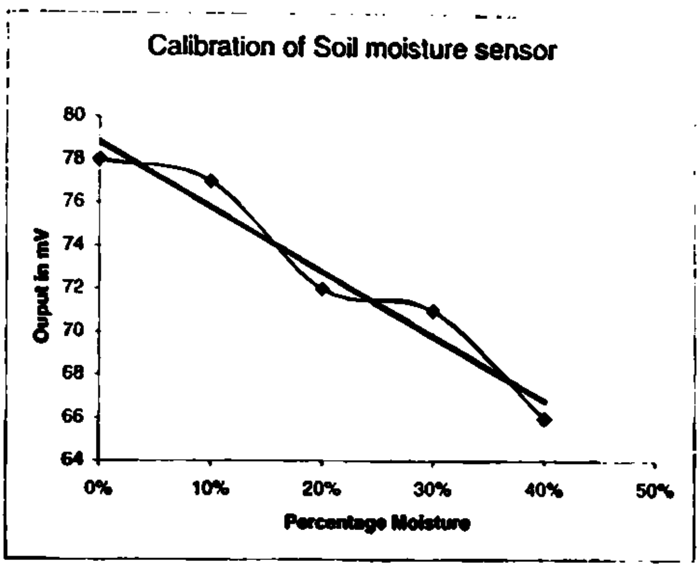



Figure 3.8 Calibration Curve for soil moisture sensor.

It is observed that while heating the sensor up to 2 minutes it gives sensible response at different soil moisture levels. Hence taking this into consideration, heating of sensor up to 2 minutes is decided for the calibration. From graph 3.7 we see that from 0% soil moisture level 40% soil moisture level the corresponding output voltage of spoil moisture sensor varies from 64 mV to 78 mV.

The results are verified by taking the actual sample from the soil, and the soil moisture content determined by thermister based sensor and gravimetric method [3.9].

### 3.6 Development of instrumentation for soil moisture sensor

This soil moisture sensor is used to design an instrument for the measurement of soil moisture. [3.10] The sensor is dipped into the soil where the moisture is to be estimated; the soil moisture level is displayed on the front panel LCD display. The provision for the automatic irrigation control is made. The details are described as below.

The development of instrumentation for soil moisture measurement is designed as shown in the functional diagram shown in Figure 3.9.

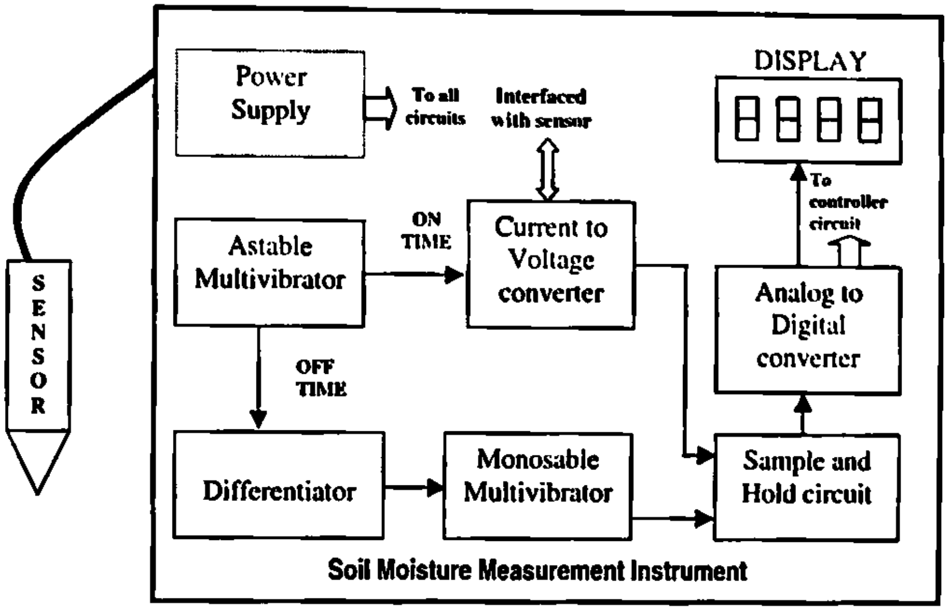



Figure. 3.9 Functional diagram of the instrument

The inbuilt power supply is used to drive the circuits like astable multivibrator, monostable multivibrator using IC 555, Current to Voltage converter using IC OP07, Sample and Hold circuit LF398 and ADC 7109.

The thermister embedded inside the sensor is used in current to voltage circuit where the moisture level is directly correlated with output voltage. An astable multivibrator using IC 555 monitors the heating period of the sensor and cooling time of it up to the initial temperature. The ON time of the astable multivibrator is designed, to make heater ON and conduct the heat through sensor into the soil, when heater is made OFF, i.e. output of astable multivibrator in OFF time the pulse is generated by using differentiator, which drives the sample and hold circuit.

The astable multivibrator is designed having ON time adjustable in the range 60 seconds to 180 seconds and OFF time can be adjusted from 300 seconds to 480 seconds as shown in figure 3.10

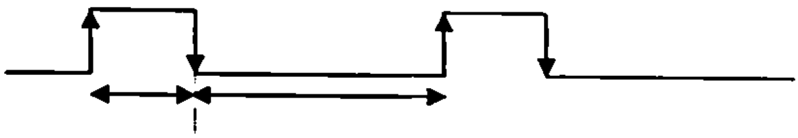



Figure. 3.10 Monitoring the timing for sensor and S/H circuit

As shown in Figure 3.9 During On time the heater is on and the heat generated is transferred to the soil, As soon as the output of astable multivibrator goes into OFF state a negative pulse is generated using differentiator, through which sample and hold circuit is triggered, This holds the output voltage value of the current to voltage converter which is related with the moisture level in the soil. This value of the output voltage is displayed on seven-segment display using Analog to digital converter. During the off period the sensor cools to its initial temperature and again the cycle repeats.

The sample and hold circuit holds the value of the output voltage of current to voltage converter. Since the thermister is used in feedback path of the current to voltage converter, the heat-transferred rate in predetermined time is measured in terms of voltage. The transfer of heat into the soil is strongly dependent on soil moisture content. Hence the soil moisture level can be determined in terms of output voltage. Using Analog to digital converter circuit the voltage is displayed on seven-segment display. This voltage with proper difference amplifier directly indicates the moisture level of the soil. Also this voltage is compared with comparator circuit, with preset value as per required for irrigation schedule and the irrigation solenoid valve can be controlled properly.

The output from the Analog to digital converter is compared with comparator .The comparator is preset at a reference voltage level as per requirement of the irrigation control solenoid valve. Hence this instrument can be used in automatic irrigation system. The facilities are provided to the instrument to adjust the timings according to the different soil type, crop etc. The sensor is provided with four-pin connector. The back panel view of the instrument is shown in figure 3.11.

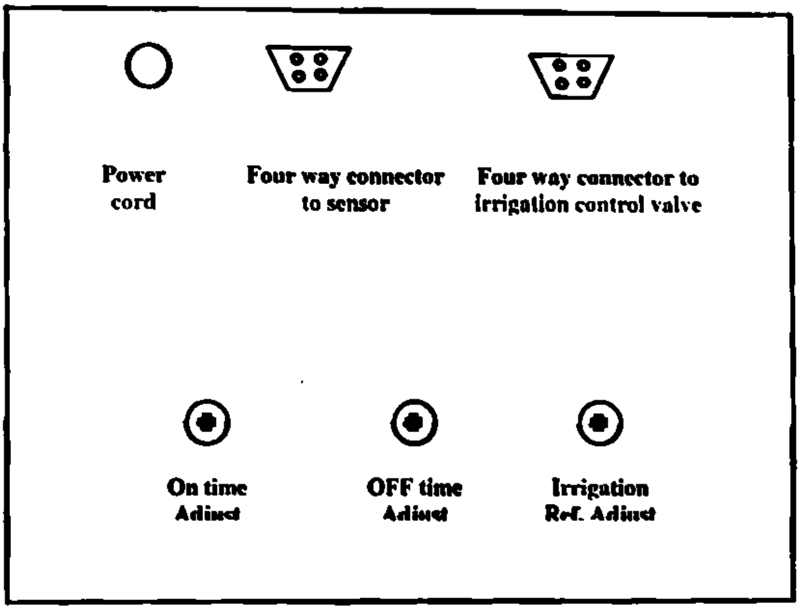



Figure 3.11 the back panel view of the instrument

Following the same experimentation procedure as in soil moisture sensor calibration experiments were carried out and the calibration curve for soil obtain measuring instrument as shown figure 3.12 below.

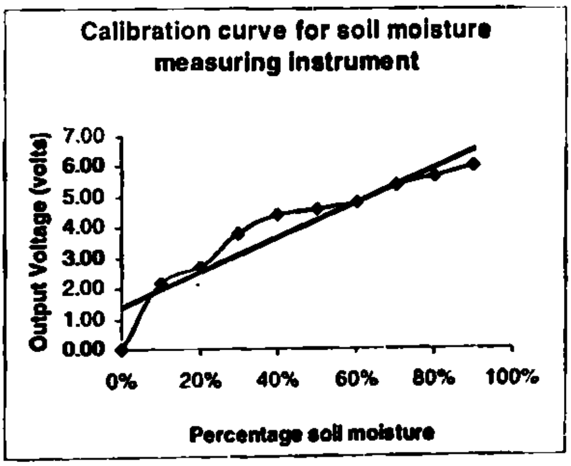



Figure. 3.12 Calibration Curve for Soil moisture measuring instrument

### 3.7 Final sensor assembly of the sensor

This soil moisture sensor described in above sections is used to design along with its instrumentation circuit enclosed in a weather protector assembly for the measurement of soil moisture [3.11]. It is optimized and tested for various parameters.

As shown in figure 3.13 aluminum rod of length 10 cm and diameter of 2 cm is tapered inside to fix a NTC thermister (80 Kohm) acts for temperature sensor, a wire wound resistor (6.2 ohm) used as a heater. They are sealed together by using wax.

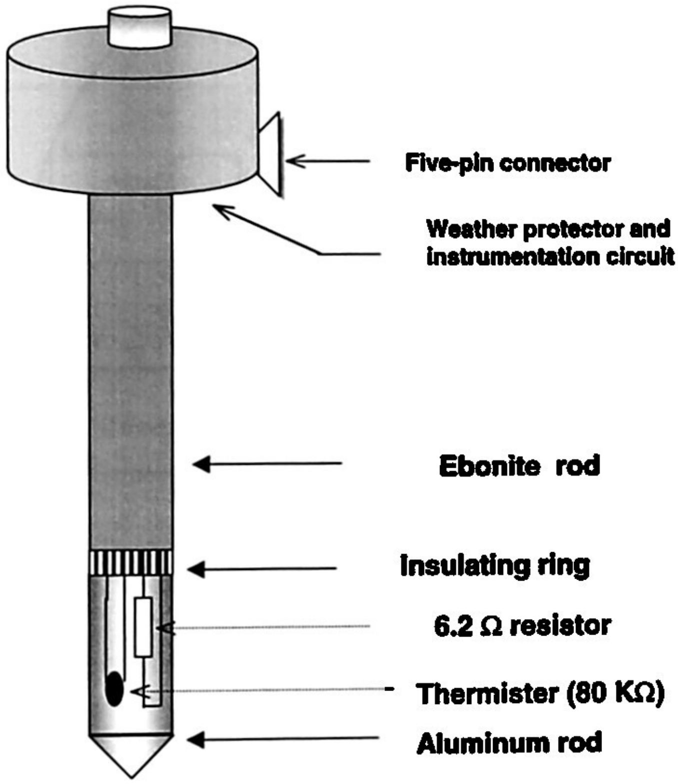



Figure 3.13 fully developed soil moisture sensor assembly

The parameters like size of Aluminum rod, heater dimensions, and its value are optimized after much experimentation and also by using a computer model program. The necessary instrumentation circuit is enclosed in a weather protector box. A five-pin connector is provided to provide power supply to sensor and to get out put from the sensor. The necessary instrumentation for soil moisture measurement sensor is designed as shown in the functional diagram shown in Figure 3.14.

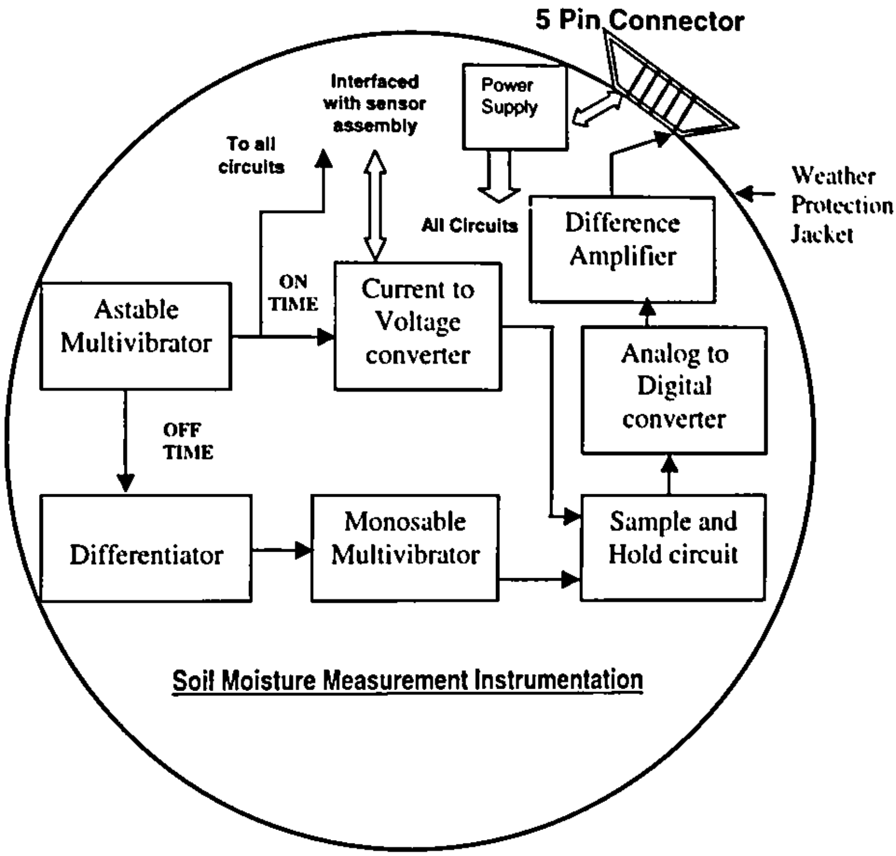
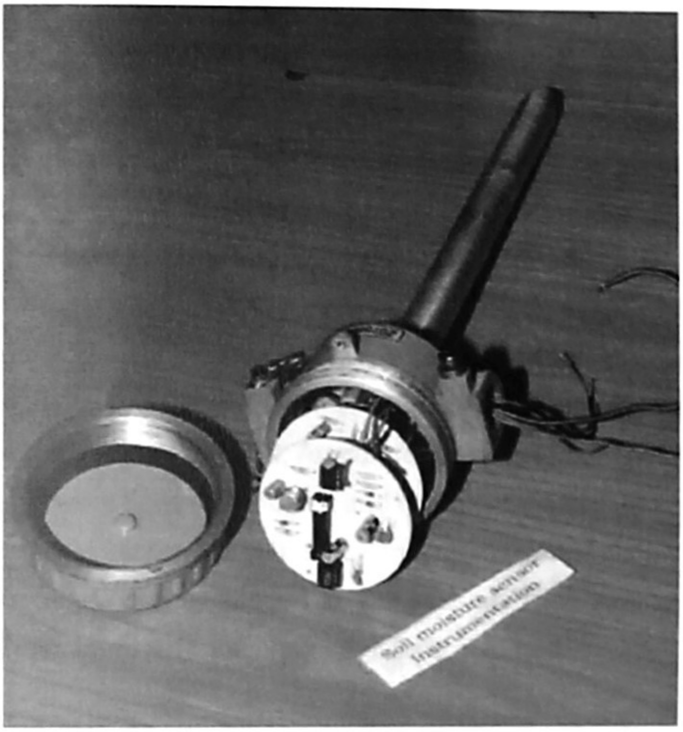



Figure 3.14 Circuit Assembly inside weather protected Jacket

The power supply is provided through 5 pin connector to drive the circuits like astable multivibrator, monostable multivibrator using IC 555, Current to Voltage converter using IC OP07, Sample and Hold circuit LF398 and difference Amplifier.

The total assembly is fitted in a weatherproof jacket as shown in Photograph 3.1 and Photograph 3.2 below. The length of the sensor rod is 1 foot in long 10cm Aluminum rod plus 20 cm ebonite rod, all the circuitrary is enclosed inside the jacket and the connecting wires for power supply and output are available at the five-pin connector at the top of the sensor jacket. The power supply and digital meter is to be connected from outside.



Photograph 3.1 Soil Moisture sensor assembly Circuit (side view)

Photograph 3.2 Soil Moisture sensor assembly bottom (side view)

## 3.8 Optimization

In developing this sensor first the thermister based soil moisture detection is optimized. Then the sensor is tested for its measurement characteristics like linearity, repeatability, recovery time [3.12] and possibility for output to be used in auto irrigation system.

### i) To decide the power supply for the operation

Heat transferred from the sensor towards soil is decided by factors how much time the heater is ON, Amount of heat generated by the heater depends on current flowing through it and of course the soil moisture level, The experiment is carried out with 5 volt and 12 volt power supply, with the heat transfer time from 10 second to 120 second. Then as shown in the following graph figure 3.15 the characteristic is obtained.

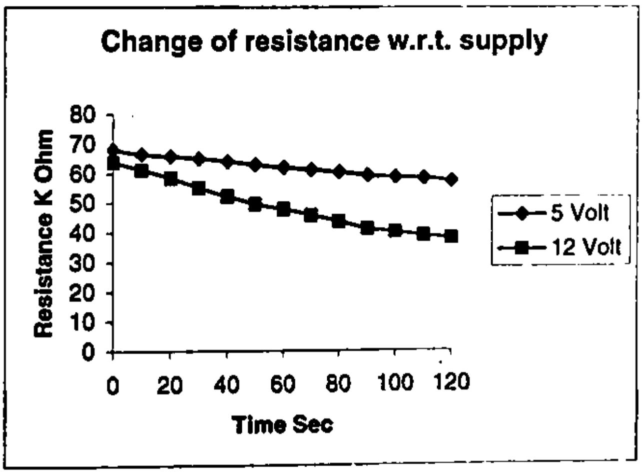



Figure 3.15 Change of resistance for two different supplies

Here we see that for 12 volt power supply (1Amp) we get the variation of the resistance of sensor 64 Ohm to 38 Ohm a large span with the heating time of 120 seconds, The another reason to choose the 12 volt power supply is the soil moisture sensor unit can be operated on 12 volt dc battery source on the Field.

**ii) To decide recovery time for the sensor**

Now after heat transfer up to 120 seconds, for the next observation the sensor must be retain to its initial stage. Thus the experiments were carried with 10 % and 80 % soil moisture samples and the characteristics graph is figure 3.16 obtained as below.

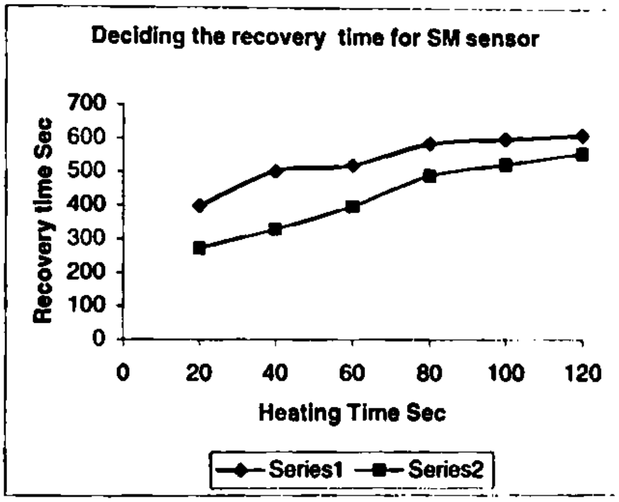



Figure 3.16 Recovery time for SM sensor

It is observed that while heating the sensor up to 2 minutes it gives sensible response at different soil moisture levels. Hence taking this into consideration, heating of sensor up to 120 seconds is decided for the calibration. Also the cooling time to retain the initialization of the sensor for next observation is optimized for 480 seconds. Thus totally 10 minutes are required to acquire the soil moisture level data by the sensor.

**iii Repeatability of the sensor** When the sensor ready with all the designing point of view, it is important to verify the repeatability for the results. The repeatability for the different soil samples from zero percent to eighty percent soil moisture is tested with e developed soil moisture sensor. The graph below figure 3.17 shows the repeatability for the sensor.

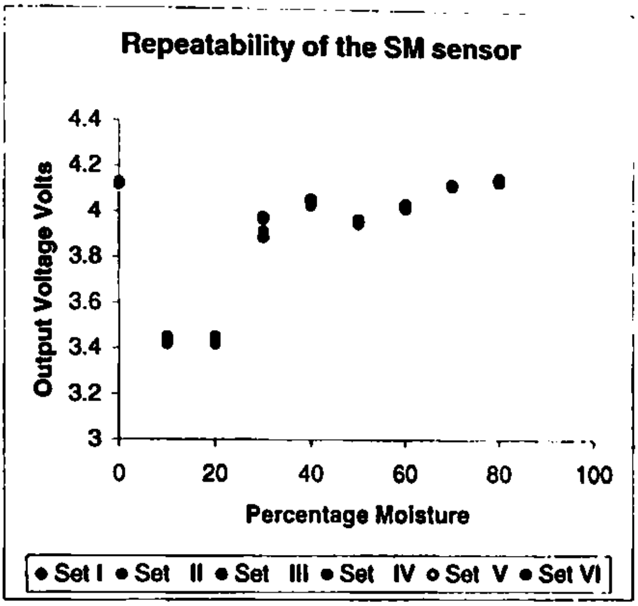



Figure 3.17 Repeatability for SM sensor

Here we see that there is quite acceptable repeatability in the measurement of soil moisture by the sensor.

**iv) Continuous response of soil moisture sensor**

In the calibration process, by finding the recovery time the measurements by the sensor were recorded continuously. This had also helped in finding the repeatability of the sensor. The graph below shows figure 3.18 continuous response of the sensor at various soil moisture levels.

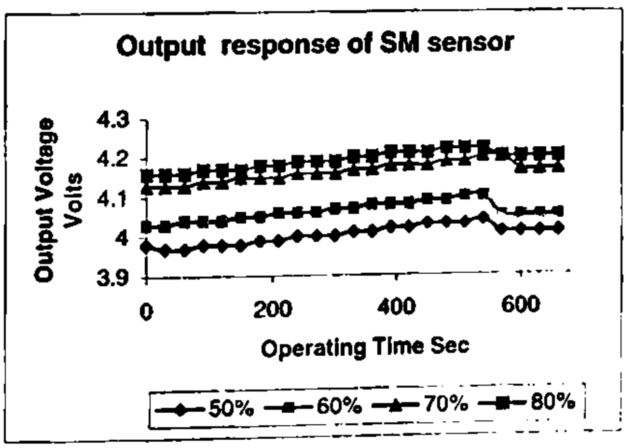



Figure 3.18 Continuous response of SM sensor

Here we see that after 600 second (10 minutes) the initialization of the sensor come about. Hence in the next cycle the observation is initialized properly.

### v) Calibration

The output of the soil moisture sensor is in volts. For various soil moisture levels ranging from 10 percent to 90 percent is obtained as shown in the graph figure 3.19 below. In the calibration process soil samples of known values of moisture were used as stated in 3.5 in this chapter.

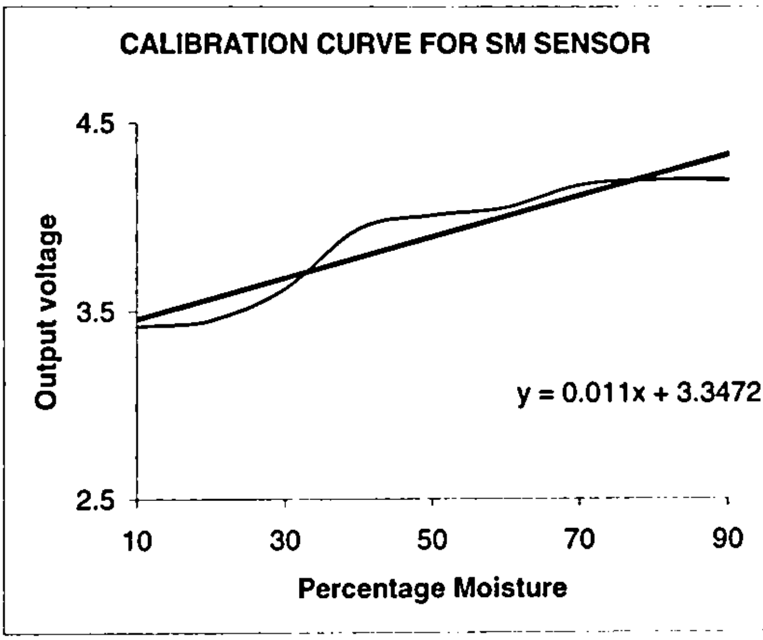



Figure 3.19 Calibration curve for SM sensor

Here we see that the output voltage varies with the soil moisture by factor 0.011 (Volts per % soil moisture). The intersection of 3.3472 is compensated to zero initialization by using a difference circuit with opamp. The zero percent soil moisture is actually meaningless, and in the auto irrigation system it is to be operated from 10 percent to 50 percent of soil moisture level.

However this result is obtained only for a particular sample of the soil. By taking different types of the soils, of different texture also the sensor of another dimensions these timing may vary accordingly. Though the data acquisition is very slow, it is sufficient to determine soil moisture level in order to maintain irrigation schedule.

The soil moisture measurement by using this type of sensor is verified by other well known gravimetric process.

The results obtained may require a correction factor to account for the dimensions of the probe. The state of water in soils varies from that which is free to flow to that which is adsorbed firmly the surfaces of particles i.e. hygroscopic water. Also it must be remembered that thermal diffusivity of a soil is parabolic function of moisture content, and the thermal conductivity of soil also depends on type of the soil, soil texture, organic matters in soil and compaction of soil molecules. [3.13] Hence the calibration for moisture measurement sensor may be slightly modified according to these parameters related to the soil properties.

**Literature of sensor developed for users application**

The specifications of the soil moisture sensor developed are as in table 3.3 below.

| Specification | Typical values |
|---|---|
| Operating Voltage | 12 volt dual Supply, 1 Amp |
| Output Display | Digital Voltmeter |
| Acquisition Time | One Minute |
| Recovery time | 10 Minutes |
| Sensitivity | 0.011 volts per percentage soil moisture |
| Dimensions | Height 14 inch, Diameter 1 inch |
| Protection | Weather Protection Jacket assembly |
| Application area | Automated Drip Irrigation System |
| Cost | 1900/- Rs. Excluding power supply |

Table 3.3 Specifications for the SM sensor

### 3.9 Application in automated irrigation system.

The soil moisture sensor developed is tested with the micro controller base automatic irrigation system at the college garden [3.14]. The working of the Automatic Drip System with its diagram is discussed below.

The controller is made to checks the need for the irrigation system by reading the output voltage of the signal conditioning system through ADC. Micro controller compares this value with the data stored in lookup table, then it activate the relay to change the state of valve. Micro controller (89C51) is used in this application other hardware components such as ADC, Relay, LCD display, Push Button switches are interfaced to it as shown in Figure 3.20

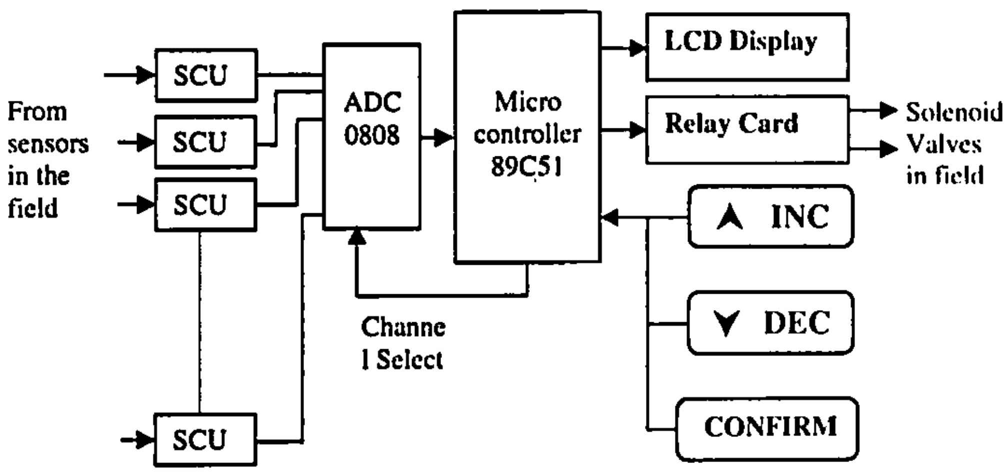



Figure 3.20 Block diagram of Micro controller based Irrigation system

Soil moisture sensors are dipped into different regions of the field. ADC data is acquired by software and stored in RAM as processes variable. Desired set point is selected by selecting the crop from the table. The system has a LCD display (1X16), This display enables the user to see menu lines. Three push buttons are also interfaced with the micro controller. These are used to select type of crop. INC, DEC, Confirm keys along with LCD display is used to select crop. Mode of operation also selected in similar manner. In auto mode of operation software checks the process variable with set points provided in lookup table. According to value of processes variable it activates the relay, which in turn open/close the valve. Multiplex ADC facilities use of more number of sensors that can be connected. Channel is selected through software. Valve corresponds to the same channel is activated by software. Thus all channels are scanned serially in continuous loop.

The system is installed in the college garden and tested for auto irrigation. The basic aim of developing a soil moisture sensor and a low cost prototype for auto irrigation mainly for study purpose has been achieved. The prototype is working satisfactorily.

The developed soil moisture sensor gives fast response to the measurement. Once it is calibrated it can be varied easily when used in fieldwork. The calibration agrees with the gravimetric results with the same soil samples. The life of the sensor is more since it is sealed in an aluminum rod, which is less corrosive, packed with wax. which has very high melting point. This sensor is being dipped permanently in the field and the corresponding soil moisture is measured online, which is used for automated drip irrigation system.

The results are encouraging. The sensor can be used in green houses along with other facilities such as controls for temperature, humidity, radiation etc.

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So many of the Websites related soil moisture measurement .

# Chapter 4
## Humidity measurement

**Introduction**

Water vapor present in the atmosphere is known as humidity. There are numerous sources of water vapor in the atmosphere. These are evaporation of water from ocean, sea, lake, river, soil moisture, respiration plant and trees and vegetation on the earth. Also with evaporation, convection, diffusion and wind also influence the water content in the atmosphere. The percentage of water in the atmosphere is extremely variable. It varies with mainly on temperature. Humidity in the atmosphere is expressed by different terms. When water vapor mixes with other gases of atmosphere, it exerts a pressure in all directions. This partial pressure is known as the vapor pressure, which is the contribution of water vapor made to the total atmospheric pressure. Another concept is of dew point. It is defined as the temperature at which the actual mass of water vapor present in a certain volume of air is just able to saturate to condense into visible water droplets. At a given temperature air holds only a certain amount of water vapor, which is given by vapor pressure at that temperature. When air contains all the moisture that it can hold to its highest limit that is called as saturated air. The vapor pressure excreted at this temperature is then called as saturated vapor pressure of air. Humidity is represented by different ways; like Relative humidity, Absolute humidity and Specific humidity.

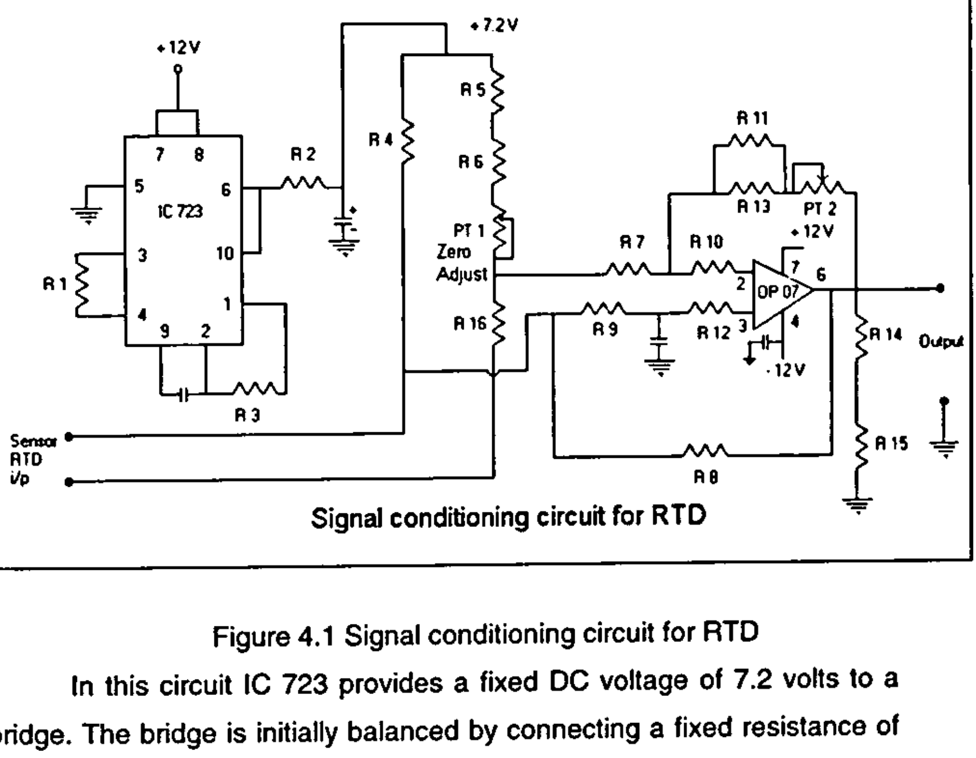
Relative humidity is defined as the ratio of actual quantity of water vapor pressure in a given volume of air to maximum amount of water vapor in the same volume of air. Relative humidity is represented by percentage and indicates degree of saturation of air at a given temperature with water vapor.

Absolute humidity is the actual mass of water present in the given volume of air. The unit is grams per cubic meter. Specific humidity is the mass of water vapor in the given mass of air containing the moisture .The unit for specific humidity is grams of water vapor per kilogram of air.

The instrument used to measure moisture present in the air i.e. humidity are known as hygrometers.

The conventional Dry bulb and wet bulb hygrometers cannot be used directly in automatic weather station. Hence electronic instrumentations are developed for humidity measurement. [4.1]

In the present work relative humidity is measured by using electronic Dry bulb and Wet bulb thermometer measurement. The temperature measurement using RTD sensor with proper signal conditioning circuit is used as an electronic thermometer. Figure 4.1 shows the signal conditioning circuit for RTD.




Signal conditioning circuit for RTD

Figure 4.1 Signal conditioning circuit for RTD

In this circuit IC 723 provides a fixed DC voltage of 7.2 volts to a bridge. The bridge is initially balanced by connecting a fixed resistance of 100 ohm in place of RTD and trim pot PT1 is to be adjusted to get initial output as 0 mV. Any change in the resistance of a sensor makes the bridge imbalance. The imbalance voltage is given to a difference amplifier, whose gain can be set by trim pot PT2. The pot PT2 is used for span adjustments. Here the span is from zero degree to hundred degrees centigrade.

The dry and wet thermometers are installed in a Stevenson screen, designed for use in the Electronic Weather Station. Here one of the modules among the several ones in the proposed weather station is described for measurement of relative humidity.

In the present work wet and dry bulb thermometer configuration is adopted. To measure the temperatures RTD temperature sensors with signal conditioning circuit, ADC and LCD display are used. The temperatures are measured in millivolts calibrated in degree centigrade. The two RTD's are placed nearby in portable assembly, where one of them is kept continuously in wet condition in water reservoir and other is in atmosphere. The RTD sensor kept wet is blown with constant airflow, by using handy dryer. Hence this relative humidity measurement assembly becomes portable which can be placed in green house or on field. Noting the dry and wet temperatures and using appropriate equations the relative humidity is estimated. This may be done through a computer program or ready recognizer table. Results for different relative humidity levels are verified by standard hygrometer. The reproducibility of results has been confirmed by several trials.

### 4.1 Dry and Wet Bulb method

In the present work relative humidity is measured by using dry bulb and wet bulb method. The partial pressure of water vapor in air is usually called water vapor tension, and its symbol is "e". The atmospheric pressure ($P_A$) can be considered as the sum of partial pressure of dry air ($P_a$) and water vapor ($P_v$). For water to pass from liquid state to the gaseous, a certain amount of heat L calories per unit mass is necessary where L is the latent heat of vaporization. It has been shown that vapor tension in equilibrium with liquid water or saturation vapor pressure depends on temperature alone, of which it is an increasing function. It does not depend on the presence of another gas, for example dry air. Different formulae have been suggested to represent the variation in saturation water vapor pressure as a function of temperature.

The formula given by equation (1) developed by scientist ALT in 1978, which is valid for whole range of temperatures relevant to meteorology is adopted in the present work for estimating relative humidity.

$$e(T) = 6.1070[\,1+\sqrt{2}\,\sin(T/3)]^{8.827} \qquad \text{-----------------------------(1)}$$

Where T is expressed in ° centigrade, T/3 is expressed in degrees ,e is given by hPa.

If we consider humid air characterized by water vapor pressure $e_a$ and temperature $T_a$, and if the saturation vapor pressure at temperature $T_a$ is called $e_s$ ($T_a$), relative humidity $H_r$ is defined as the ratio of ea to $e_s$ ($T_a$) expressed as percentage, given by equation (2).

$$H_r = e_a / e_s(Ta) \times 100 \quad \% \qquad \text{-----------------------------(2)}$$

In dry air $H_r$ = 0% [since ($e_a$ =0)] ,and if air is saturated $H_r$ = 100% [since ($e_a$ =$e_s$ ($T_a$)]

The psychrometer i.e. dry bulb and wet bulb thermometer is used with this theoretical background to determine air relative humidity. One of it indicates, the atmospheric temperature called as dry bulb, and the other has a muslin jacket, which stands in a reservoir of water in such a way as to ensure constant humiditification by capillary action known as wet bulb. Evaporation of water from the muslin consumes certain amount of energy, evidenced by the lower temperature of the wet bulb thermometer than of the air. This basic assembly consisting of the two thermometers is shown in Figure 4.2 below.

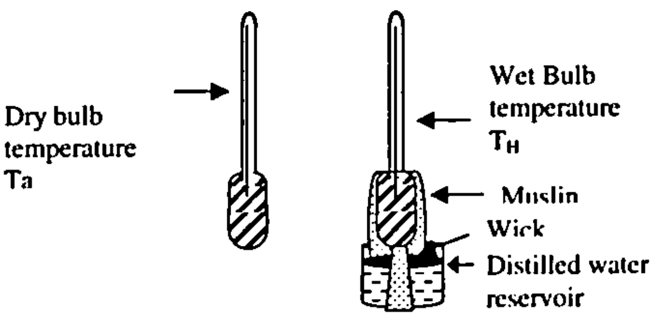



Figure 4.2 Basic diagram of psychrometer.

The relation between these two thermometer readings is established by considering thermal equilibrium. The psychometric equation is obtained as below.

$$e_a = e(T_H) - \gamma (T_a - T_H) \qquad \text{-----------------------------(3)}$$

Where $\gamma$ is psychometric constant.

Now if we know the dry bulb temperature using equation (1) we can estimate $e_s(T_a)$ , and with wet bulb temperature using equation (1) calculate $e(T_H)$ then using (3) $e_a$. Finally using equation (2) we calculate the percentage relative humidity.[4.2]

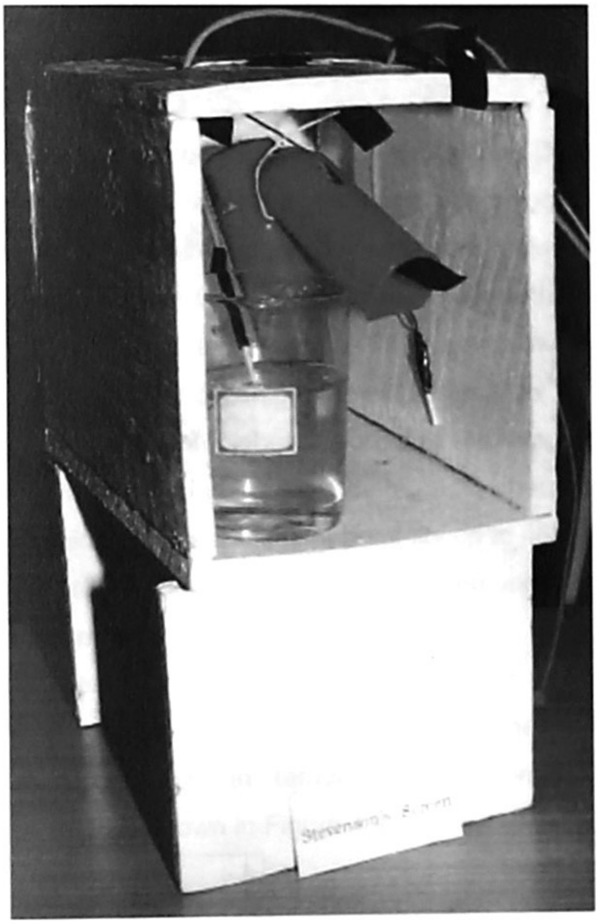
## 4.2 Designing of the Stevenson's screen

Stevenson screen is a wooden rectangular box of dimensions 2'x2.5'x2.75' feet and having louvered walls to permit free movement of air. The aim of it is to protect the instrument placed inside from sunshine, rain and snow. A conventional Stevenson screen is shown in photograph 4. 1 below.

Photograph 4.1 Conventional Stevenson Screen

It has double roof structure and lower roof is horizontal. In between these roofs air can move freely. There is isolation between the two roofs due to airflow inside it. The box is place at about 4 feet height from the ground to prevent the radiation from the earth to reach towards the thermometers. [4.3]

For the Automatic Electronic Weather station Stevenson screen is designed as shown in photograph 4.2 below.



**Photograph 4.2 Designed Stevenson Screen**

The cross sectional view of the Stevenson screen used in the present work is shown in figure 4.3 below.

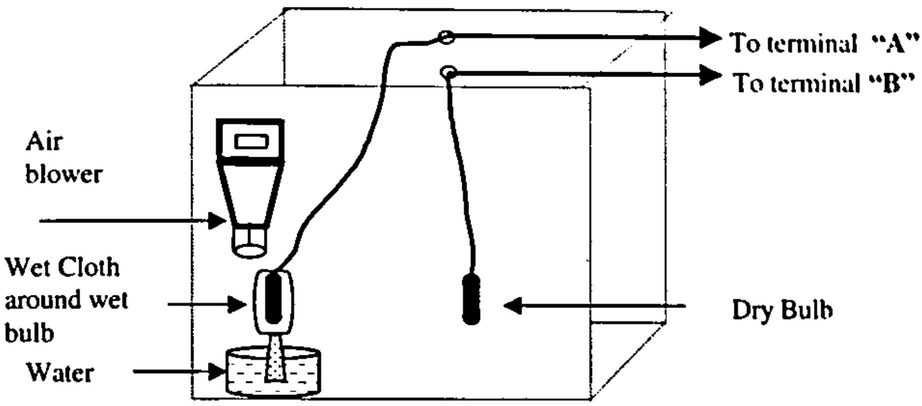



Figure 4. 3 Detailed Assembly of the Wet and Dry bulb unit

The Stevenson's screen is designed according to meteorological consideration. The container is painted with white color to avoid any heat absorption. The wet bulb is wound by a thin cloth and inserted in distilled water reservoir as shown in the figure 4.3 The air blower is DC operated, for which the wind speed can be adjusted as 2 to 3 m/sec, which is standard in the psychometric observation. The two temperatures are noted by keeping the developed unit inside the humidity chamber. It is saturated up to 90 % humidity then set to fall of humidity up to 45% the observations are noted with standard hygrometer and designed unit.

### 4.3 Experimental set up for calibration

In the present work, the two thermometers are built using RTD sensors. With proper signal conditioning circuit and, ADC on DPM the temperature is displayed in terms of corresponding millivolts. The experimental setup is shown in Figure 4.4

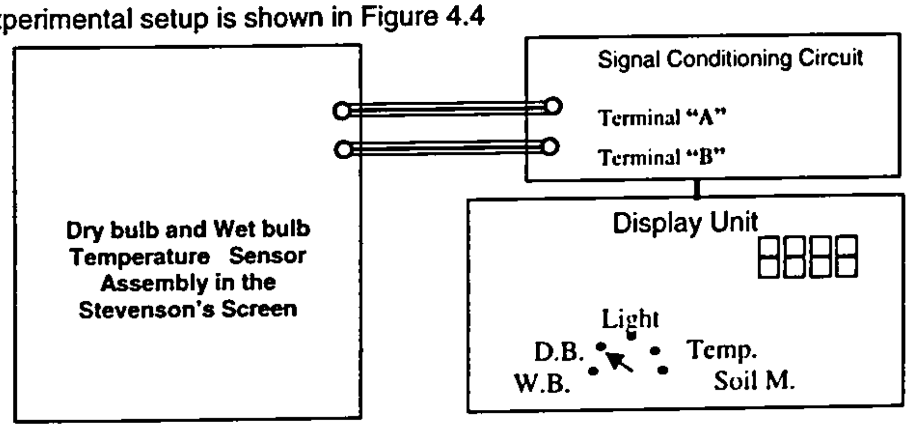



FIGURE 4.4 SET UP FOR HUMIDITY MEASUREMENT

The dry bulb and wet bulb assembly inside the Stevenson screen is placed in a glass dome. A standard hygrometer (Sansui) on which the humidity can be recorded is placed near to the Stevenson screen. A locally available vaporization machine, electrically operated is placed inside the glass dome. This was the setup like humidity chambers. [4.4]
The schematic of this is shown in figure 4.5 below.

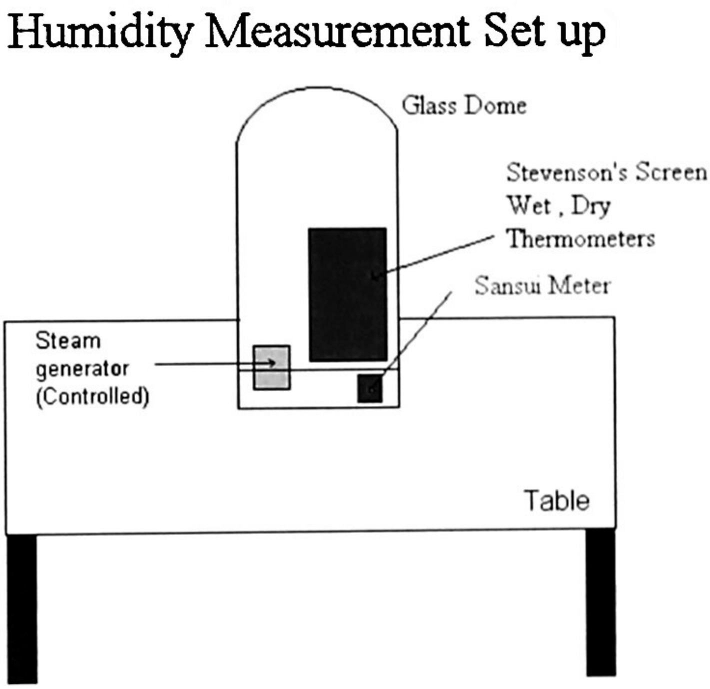



Figure 4.5 Schematic diagram for humidity measurement unit calibration

The vaporization of the water due to steaming of water can be controlled by the power given to the vaporization machine. In this way the humidity shown by the standard hygrometer and relative humidity found out by using dry and wet bulb temperatures wet compared and calibrated.

## 4.4 Observations

The observations are repeated for four times and then calibration curve is obtained. The relationship of the measurement is shown in figure 4.6 graph, where we see that the measured relative humidity agrees with that measured by Sansui hygrometer.

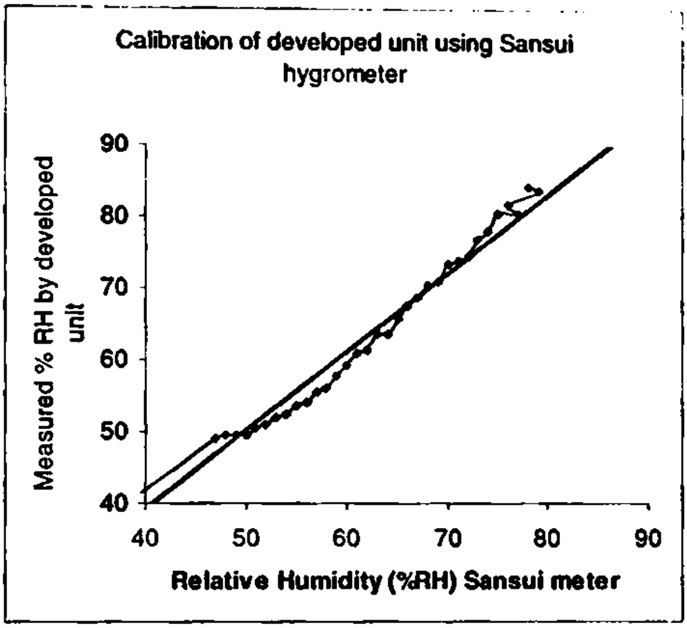



Figure 4.6 Calibration Curve for humidity measurement

From fig 4.6 we see that the calibration of the dry and wet thermometers to estimate relative humidity agrees with the standard hygrometer. The range obtained is from 45% to 80% of relative humidity measurement, which is well suitable for the green house or nursery humidity measurements.

Other methods are also available for measuring relative humidity, but considering the life of the instrument, maintenance, simplicity in use, availability of electrical signals for control, sturdy for installing in field, dry and wet bulb scheme is selected. By a lot of reference work the Stevenson's screen is designed of suitable size, which becomes portable and gives the desired results for wet temperature measurement by adjusting the airflow. Since the assembly is portable and compact satisfying all climatically design considerations it can be fixed in automatic weather station. Using mains driven power supply operates the unit and in case of power failure 12 Volt batteries can drive it. The assembly with the Stevenson screen is installed in the Electronic weather station.

## References


[4.1] "Development of Humidity meter for use in mobile weather Station". 8th National Seminar on Physics and technology of Sensors (NSPTS-8), Organized by Indira Gandhi Center for Atomic Research, Kalpakkam, 27th Feb-1st March 2001.

[4.2] Gerard Guyot, " PHYSICS OF THE ENVIRONMENT AND CLIMATE ", (1998), JOHN WILEY & SONS pp 138-147.

[4.3] Dr. S.R. Ghadekar, "METEOROLOGY", Nagpur , (2001), pp27-29. Agromet Publishers

[4.4] " Standard Temperature/ Humidity Chambers", website http://www.envirotronics.com/stsh.html

# Chapter 5

## Temperature and Light intensity measurement

**Introduction**

In this chapter measurement of air temperature and light intensity is described which is to be engaged in automatic weather station.

The degree of hotness is known as temperature. Atmosphere receives the heat energy from the sun and its temperature increases. Due to different amount of heat energy reception at different places the air temperatures at different places also varies. This variation of temperature results air motion on the earth, change of humidity and overall on the life cycle on the earth. Thus temperature is the most important parameter affecting the weather. In the present work it is decided to design electronic thermometer using proper temperature sensor .The temperature range required to cultivate the plants have certain range between low temperature, moderate temperature and a high temperatures. Thus moderate accuracy in the measurement is sufficient for temperature measurement. This temperature measurement system is installed in the electronic weather station. The other advantage of electronic thermometer is we can have control signal for automation, as well as we can have Data acquisition system to record the temperatures for the particular crop cycle.

### 5.1 Temperature Measurement

Temperature measurement by using temperature sensor Pt100 is described here. Before designing this electronic thermometer, the usual method of recording atmospheric temperature by the observatory was referred. Information about the different methods for temperature measurements was collected. Importance of temperature in agriculture in point view of green house and nurseries was collected. Hence with the aim of electronic thermometer, it was also planned to use this parameter for other controls like auto irrigation, humidity measurement or a data acquisition system in which the temperature data for the weak, month can be recorded.

### 5.1.1 Different methods for temperature measurements

To measure the temperature there are numbers of types of thermometers are available listed in table 5.1 as below.

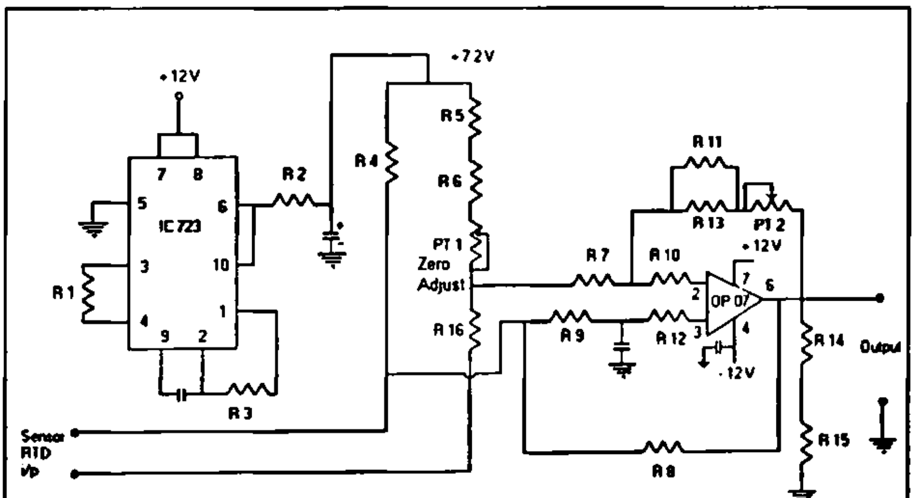
| | |
|---|---|
| 1 | Liquid in glass thermometer |
| 2 | Bimetallic thermometer |
| 3 | Gas thermometer |
| 4 | Thermograph |
| 5 | Sling thermometer |
| 6 | Infra red thermometers |
| 7 | Electrical Thermometers such as thermister, thermocouple, RTD etc. |
| 8 | Semiconductor sensors like AD 590, LM35 etc. |

Table 5.1 various temperature measurement thermometers

In the ambient temperature measurement the thermometer is installed in Stevenson's screen described in chapter 4. Thus a thermometer is protected from sunshine, rain and snow. The temperature measurement records are kept as mean temperature, average temperature, maximum temperature and minimum temperature etc. The readings are taken at 7:00 am, 09:00 am 2:00 pm and 09:00 pm. The mean of these observations gives mean temperature. The average of maximum and minimum temperature is also calculated. The maximum temperature is recorded between 02:00 pm to 04:00 pm. This is because in this time interval the energy given out by the earth exceeds the energy gained from the solar heat. In the present work it is decided the continuous measurement of temperature throughout the experimentation process in green house or nursery.

### 5.1.2 Temperature measurement using Pt 100

Resistance transducers are widely used in temperature measurement. Resistive temperature detectors are thermally sensitive resistive elements that exhibit an increase in resistance as the temperature increases. Thus these devices have a positive temperature coefficient, and they are constructed of platinum, nickel, copper, tungsten or nickel-iron etc. The change of resistance of RTD is a function of temperature. The resistivity of the metal like platinum shows markable temperature dependence that is very linear. Thus it is used in many high accuracy resistance thermometers. Platinum is especially suited this purpose, as it can withstand high temperatures while maintaining excellent stability. It shows limited susceptibility to contamination and also for measurement integrity, platinum is obvious choice. The common values of resistance for a platinum RTD range from 10 ohms to several thousands ohm for the film RTD. The single most common value is 100 ohms at 100 o centigrade. The standard temperature coefficient of platinum wire is $\alpha$ = 0.00392. For 100 ohm wire this corresponds to + 0.385 ohms/°C. The resistance of Pt 100 at 0°C is 100 ohms and 138.5 ohms at 100°C. [5.1] The signal conditioning circuit for Pt 100 sensor, in temperature measuring unit is shown in figure 5.1 below.



Signal conditioning circuit for Pt 100

Figure 5.1 Signal conditioning for Pt 100

In this circuit IC 723 provides a fixed DC voltage of 7.2 volts to a bridge. The bridge is initially balanced by connecting a fixed resistance of 100 ohm in place of RTD and trim pot PT1 is to be adjusted to get initial output as 0 mV. Any change in the resistance of a sensor makes the bridge imbalance. The imbalance voltage is given to a difference amplifier, whose gain can be set by trim pot PT2. The pot PT2 is used for span adjustments. Here the span is from zero degree to hundred degrees centigrade.

### 5.1.3 Observations

In the calibration off this electronic thermometer, a variable trim pot of 200 ohms is used. The value of the trim pot is adjusted to 100 ohms and it is connected at the place of Pt 100. The POT P1 is adjusted for 0 mV output. This corresponds to zero degrees initialization for the thermometer. Then the pot PT 1 is adjusted at 138.5 ohms and connected at the place of Pt 100. Now the pot PT 2 is adjusted to give out put display of 100 mV. This corresponds to the span range for measurement. Thus the thermometer is set for the range from zero degree to hundred degrees centigrade. Then by referring the standard RTD tables as given in appendix II the simulated resistance using trim pot of 200 ohms, change of output voltage in millivolts corresponding to change of resistance is obtained. This characteristic is as shown in figure 5.2 below.

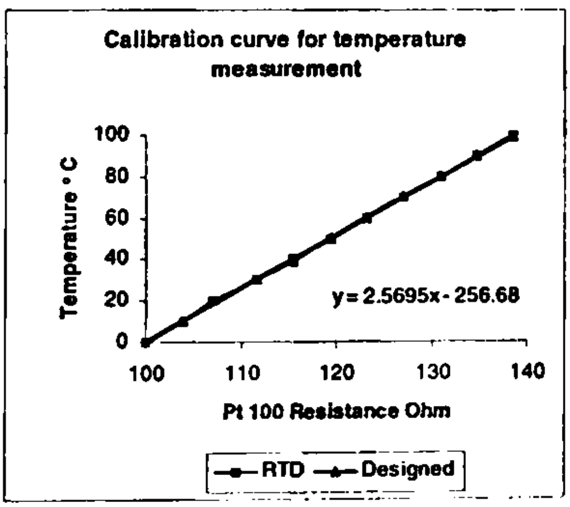



Figure 5.2 Calibration for temperature measurement

From Figure 5.2 it is seen that the calibration for temperature is reasonably linear and can be used to measure temperature for electronic weather station.

## 5.2 Light intensity measurement

### Introduction

Light intensity is also very much important in agriculture. The various physical processes, biological, biochemical and geological process are depending on light energy received from the sun to the earth. An intensity, quality, quantity, duration, direction and periodicity of the sun energy received on the earth are the important aspects that are biologically important. In the agriculture crop-plant scientists measure the amount of light in terms of foot-candles or thermal units. Light intensity refers to the number of photons impinging on a given area or to the total amount of light which plant receives. A lot of experimentation is done to find out effect of light intensity on plant growth. Since it is the one of the most important factor in photosynthesis process and has very critical effects on time of flower bud formation, developments of plant organs like bulbs of onion, tubers of potato etc. Light is the ultimate source of energy used by plants in photosynthesis. Light also serves as a signal to plants, allowing them respond to changing environmental conditions. Light used by plants, called photosynthetically active radiation (PAR), is in 0.4-0.7 micron waveband. This is within the range of the visible spectrum. Light intensity is a critical environmental gradient, having significant effects on both specious composition and plant development. The amount of light is critical for green plants in an ecosystem. The available light will also influence the types of plants that grow in an area, as well as the moisture content of the soil.

### 5.2.1 Methods used for measurement

The radiation from the sun is propagated in the form of electromagnetic waves. The wavelength $\lambda$ of the electromagnetic wave is given by $\lambda = cv$, where c is the velocity of light and v is frequency of radiation. The complete set of possible electromagnetic waves is known as spectrum these are short wave radiation, long wave radiation, photosynthetically active region (PAR) or visible radiation, Infrared radiation, UV radiation, x-ray radiation and gamma ray radiation. Each of these varies with their wavelength .The measurement of the solar radiation is of different types [5.2]

1. Radiant flux density: - It is amount of radiant energy crossing a unit area in unit time, Measured as Watt/ Square meter. This is related to the frequency or wavelength of radiation and describes quality of radiation.

2. Intensity of illumination: - It is the density of the luminous flux incident at a point on a surface. Luminous flux is the amount of radiation transmitted from the source per unit time, evaluated in terms of standard visual response. The common unit is lux or Klux.

3. Quantum: - This is equal to the number of photons crossing a unit area in unit time. The unit is µmol/square meter per second.

4. Quality of radiation: - this depends on energy content i.e. frequency or wavelength of the light.

5. Duration of the radiation: - Duration of the sun radiation is measured with bright sunshine hours, astronomical day length or day length for plant activity at various light intensities.

Effect of the sunlight on plant growth with respect to quality of radiation [5.3] is shown in table 5. 2.

| Wavelength Of light | Effect on Plant growth |
|---|---|
| 200 – 280 nm | UVC ultraviolet range that is extremely harmful to plants because it is highly toxic. |
| 280 – 315 nm | Includes harmful UVB ultraviolet light that causes plants colors to fade. |
| 315 – 380 nm | Range of UVA an ultraviolet light that is neither harmful nor beneficial to plant growth. |
| 380 – 400 nm | Start of visible light spectrum. Process of chlorophyll absorption begins. UV protected plastics ideally block out any light below this range. |
| 400 - 520 nm | This range includes violet, blue, and green bands. Peak absorption by chlorophyll occurs, and a strong influence on photosynthesis. (Promotes vegetative growth) |
| 520 - 610 nm | This range includes the green, yellow, and orange bands and has less absorption by pigments. |
| 610 - 720 nm | This is the red band. Large amount of absorption by chlorophyll occurs, and most significant influence on photosynthesis. (Promotes flowering and budding) |
| 720 - 1000 nm | There is little absorption by chlorophyll here. Flowering and germination is influenced. At the high end of the band is infrared, which is heat. |
| 1000+ nm | Totally infrared range. All energy absorbed at this point is converted to heat. |

Table 5.2 Effect of sunlight on plant growth with respect to quality of light

The sensors used in radiation measurement are shown in table 5.3.

| Characteristic phenomenon | Types of sensor |
|---|---|
| Photo voltaic effect | Silicon solar cells |
| Photometric effect | Silicon photodiode |
| Variable conductivity | Light Dependent Resistor (LDR) |
| Thermoelectric effect | Thermopile |
| Pyroelectric effect | Blackened silver disk |
| Differential thermal expansion | Bimetallic strip |

Table 5.3 Sensors used in radiation measurement

Different instruments used to measure radiation flux [5.4] are listed in table 5.4.

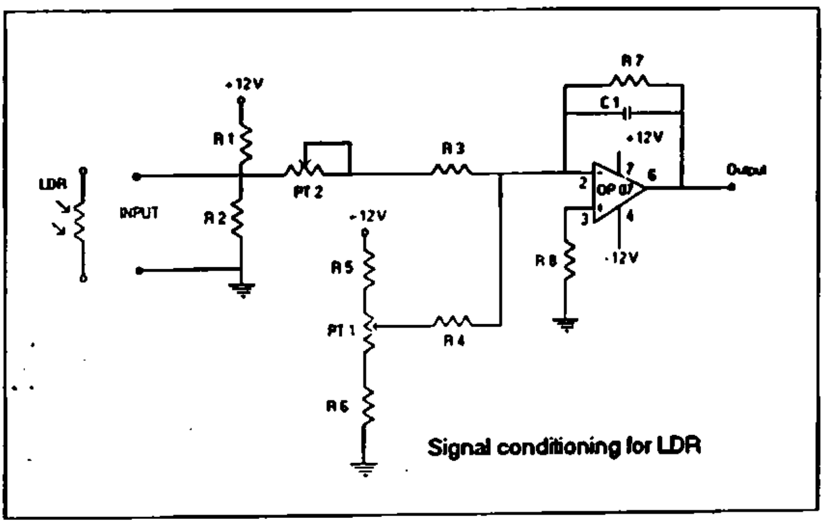
| Sr. No. | Instrument | Radiation Flux measured |
|---|---|---|
| 1 | Pyrheliometer | Direct solar beam on a plane surface at normal incidence |
| 2 | Pyranometer | Total Short Wave radiation on a horizontal plane surface from hemispheric sky |
| 3 | Pyrradiometer | Global radiation on a horizontal plane surface from a hemispheric sky |
| 4 | Pyrgeometer | Net atmospheric IR radiation |
| 5 | Diffuse Pyranometer | Diffuse short-wave radiation |
| 6 | Net Pyrradiometer | Net short wave and long wave radiation |
| 7 | Quantum sensor | Visible light radiation |
| 8 | Lux meters | Intensity of visible light radiation |

Table 5.4 Instruments used to measure radiation flux

### 5.2.2 Experimental measurements for light intensity

In the light intensity measurement sensor used is LDR. It is a photoconductive transducer of which there is a change in electrical conductivity when a variation of light energy incident on it varies. This device are also called as photo resistive, since their resistance varies in inverse proportion to their conductivity. The Cadmium sulphide cell is a common type of photoconductive cell (LDR). When it is exposed to varying light intensities of visible light, it changes its own resistance. An increase in light energy falling onto its surface will increase the conductivity of LDR. It is very sensitive to variation of the light. The dark resistance of LDR is maximum (in the range of Mohms) and light resistance is in Ohms range. Thus resistance of LDR decreases with increase in intensity of light falling it. Using this property of LDR it is selected to measure the intensity of ambient light.

The signal conditioning circuit used to linearise the output with respect to variation in light intensity incident on LDR is shown in figure 5.3 below.




Signal conditioning for LDR

Figure 5.3 Signal conditioning for LDR

The signal conditioning circuit provides output in Millivolts corresponding to incident light intensity. An opamp is used in inverting amplifier configuration. As the resistance of LDR decreases the output voltage increases. The trim pot PT1 is used to set initial output as 0 mV. The trim pot PT2 is used for span adjustment. The resistance of the LDR increases with lowering of the light intensity the output voltage decreases, indicating poor light intensity of the light. Whereas the light intensity increases the LDR resistance decreases, causing increase in output voltage, indicating rise in light intensity.

The LDR used in the present work LDR is used with its dark resistance 20 K ohm. The light resistance is assumed to be zero ohms. Then by using 47 K ohm trimpot the simulated resistance of 20 k ohm (dark resistance of LDR) is connected at he place of LDR. Trimpot PT1 is adjusted to provide output of the signal conditioning circuit equal to zero. This indicates the light intensity is zero. Then the input where the LDR is connected is shorted (Light resistance of LDR is zero) .At this situation variable potentiometer PT 2 is adjusted such that output of the circuit shows 100 mV output. This corresponds to 100 percent light intensity.

### 5.2.3 Calibration

In this calibration the light intensity is calibrated for dark room corresponding to out put 0 mV, and the sensor fully illuminated by light producing 100 mV. Hence with the light source available for application we can have the light intensity measurement from zero to maximum corresponding to output in mV. Using light intensity power meter of Newport Company, where the input light intensity is measured in watts, does this calibration. However by using the relation of 1 watt = 683 lumen we can have calibration curve as luminous intensity versus millivolt output. This is necessary because for most of the agricultural plants the data available for photosynthesis, and light intensity is in lumens.

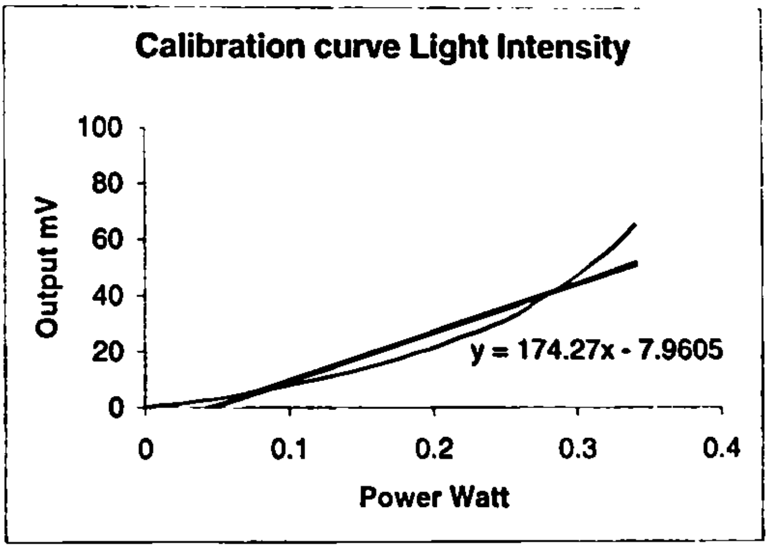



Figure 5.4 Calibration curve for light intensity

From Figure 5.4 It is seen that the calibration for light intensity is reasonably linear and can be used to measure light intensity to be used in automatic electronic weather station.

**References**

[5.1] C S RANGAN , G R SARMA , V S V MANI , " Instrumentation Devices & Systems , second Edition,Tata Mcgraw-Hill Publishing Company, (1997), pp191-195.

[5.2] Website of company, " 8 W Sunrise Lane PR NW, Benton City, WA 99320"

[5.3] Gerard Guyot, " PHYSICS OF THE ENVIRONMENT AND CLIMATE ", (1998), JOHN WILEY & SONS pp 37-50.

[5.4] Dr. S.R. Ghadekar, "METEOROLOGY" ,Agromet Publishers, Nagpur, (2001), pp99-100

# Chapter 6

# Results and discussion

## 6.1 Results

In the present work it was proposed to design Automatic Electronic Weather station for use in Farmhouse and nursery. It was decided to measure electronically the parameters temperature, humidity, and soil moisture, light intensity, wind velocity and wind direction. The aim was to measure these parameters for the purpose of cultivation of plants in farmhouse, nursery and the greenhouse. The measured parameters can be used to set the desired value of the parameter proper for better growth of plants.

When we measure agro meteorological parameters like temperature, humidity, light intensity, wind velocity and soil moisture, it was recognize that the most important factor to be controlled is soil moisture level. Efforts were taken to construct an automatic drip irrigation system using the thermo conductive-based developed sensor. The operation of automation of irrigation system can be correlated with other agro meteorological local parameters like temperature, humidity, and light intensity, wind velocity. Because all the parameters are interrelated with each other and the irrigation cycle is important in the field.

At the beginning the subject Agrielectronics was studied. The role of electronics in agriculture and agrobased industries was understood. This was done by referring to books, websites, attending seminars related with the subject and visiting the institutes like India Meteorological Department Pune, Vasantdada Sugar Institute Manjari in Pune, Center of Advanced Studies in Agricultural Meteorology, College of Agriculture, Pune –5, Department of Electronic Science University of Pune. It was observed that the number of websites giving into about Agrielectronics in increasing at a stupendous rate day by day. As the subject is comparatively new, most of the information about automatic weather station such as its working, applications was obtained form websites.

Various experiments were carried out as described in chapter 3 and finally soil moisture sensor is developed upto a commercial level. The developed sensor was also tested successfully in microcontroller based drip irrigation system installed in our college garden. Five research papers were presented at national conferences and two of them published in Journal of Instrumentation society of India.

For the measurement of humidity, it was necessary to have Stevenson screen. With the support of India Meteorological Department, Pune, a Stevenson screen is designed and used while measuring humidity. With the measurement of humidity, one research paper is presented at national level conference.

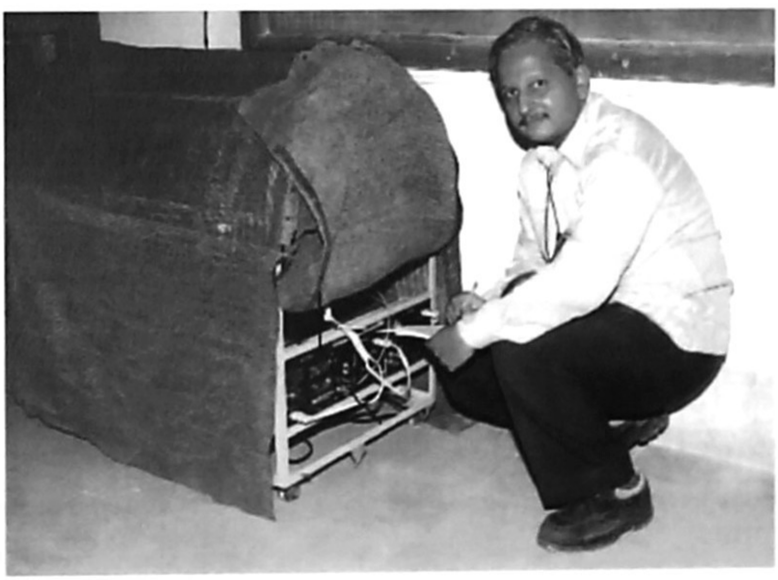
The other parameters light intensity and temperatures were measured by using LDR, Pt 100 respectively. The necessary signal condition circuitry was developed. The parameters were measured and included in electronic weather station.

Sensor for wind velocity and wind direction was designed but due to mechanical design was in the initial stage. It could not be finalized within stipulated time.

The four parameters measured were integrated through a switch. With the help of switch the desired parameter can be selected and displayed on common digital front panel of electronic weather station.

The field-testing of electronic weather station in the green house model was carried out on laboratory level.

The actual system photograph is as shown in photograph 6.1 below.



Photograph 6.1 EWS installed in Small green house model

It is observed that measuring and calibrating individual parameter is simple, but when these parameters are measured inside a green house where live plants are maintained the correlation between the parameter becomes significant. Only the soil moisture parameter was used to manage irrigation system "ON" with the response of soil moisture sensor.

The other important issues regarding installation, operation and maintenance of Automatic Electronic weather station are similar to any measurement system. Here we have to take care of measurement of various parameters, their co-relation and accordingly take the action. For example in some cases if there is increase of temperature, vaporization of water from the soil takes place and humidity may increase.

The measurement specifications of the Electronic Weather Station developed are as shown in table 6.1

| Sr, No. | Parameter | Range | Accuracy |
|---|---|---|---|
| 1 | Temperature | 0 to 100 °C | ± 2% |
| 2 | Humidity | 40 to 90 % | ± 5 to 8% |
| 3 | Soil Moisture | 0 to 40 % | ± 10 % |
| 4 | Light intensity | 50 mW to 350 mW | ± 10% |
| 5 | Wind velocity, wind direction | Not included | |

Table 6.1 Measurement specifications of Electronic Weather Station

The operating specifications of the Electronic Weather Station developed are as shown in table 6.2

| Sr. No. | Description | Remark |
|---|---|---|
| 1 | Operating voltage | 12 volt Dual power supply or 12 volt DC battery |
| 2 | Dimensions | 24"x 24" x 36" Metallic body, Covered by nylon net |
| 3 | Irrigation system | Autoirrigation system using soil moisture sensor |
| 4 | Display | 4 digit seven segment display |

Table 6.2 Operating specifications of Electronic Weather Station

The developed electronic weather station is acceptable for agricultural microclimate measurements.

## 6.2 Automatic Electronic weather station: a practical approach

Temperature is the most important parameter regarding green house climate. In Indian climatic conditions the temperature inside the green house is 8 to 10°C greater than the atmospheric temperature. Hence to maintain the temperature suitable for cultivation of plants is to be maintained by installing cooling systems. The various methods used for temperature maintenance inside greenhouse are roof shading, water film on greenhouse glass, evaporative cooling and fan-pad for air circulation etc. Also the methods like high-pressure mist, low-pressure mist systems are used carefully to cool the green house temperature. On the other hand if it is required to increase the temperature inside the greenhouse artificial using hot water, electric heater, oil lamps etc provides heating. Also heating system based on alternate energy sources are used. The examples are geothermal heat, biogas, solar energy etc.

For light intensity control shading is installed to reduce light intensity or incandescent, fluorescent; amps are lighted to provide required light quality. The parameters to be considered to control light intensity are response of the plants to light, other factors influencing the plants, type, quality, duration of light, methods and instruments available to provide light and lastly the cost factor is also to be considered.

For the maintenance of relative humidity inside green house other factors like temperature, wind velocity are also to be considered. While controlling the temperature using like high-pressure mist, low-pressure mist systems humidity factor can be controlled.

Control of Carbon Dioxide is also important Plant growth is mainly depends on carbon dioxide, light intensity needed for photosynthesis. The level of carbon dioxide can be maintained using solid carbon dioxide, liquid carbon dioxide or by burning paraphin materials.

In our work the soil moisture sensor is developed and is applied for autoirrigation inside the greenhouse crops.

The crops cultivated in greenhouse are like tomato, cucumber, various colored capsicums bringle, ladies finger and various types of flowers like rose, gladiola, coronation, gerbera etc. The suitable climatical parameters to cultivate some of the plants are listed in table 6.3.

| Plant | Temperature Day | Night | Light | Humidity | Wind velocity | $CO_2$ level |
|---|---|---|---|---|---|---|
| Tomato | 25 °C | 18 to 20 °C | 760 foot candle | < 90% | 1 km/s | 1000 ppm |
| Cucumis | 23 to 25 °C | 20 °C | less than 25% of sunlight | < 80% | 500 m/s | 1000 ppm |
| Capsicum | 20 to 24 °C | 21 to 23 °C | Lower level | 70 to 80% | 500 m/s | 1000 ppm |
| Cornation | 15 to 16 °C | 12.2 °C | 10 foot candle upto 4 hours late night | 70 to 80% | 500 m/s | 500 ppm |

Table 6.3 Climatical parameters suitable inside green house for various plants

The nursery computerized controllers are readily available in the market. For example one of the weather monitoring station is shown in photograph 6.2.

**The RWMS-8** is a stand-alone weather station, which measures, displays and stores temperature, humidity wind speed, wind direction, rain, solar radiation and barometric pressure. The RWMS-8 equipped with three keys and three-digit display.

It can independently transfer the sensed data to other controllers directly or through central PC.

***Features:***

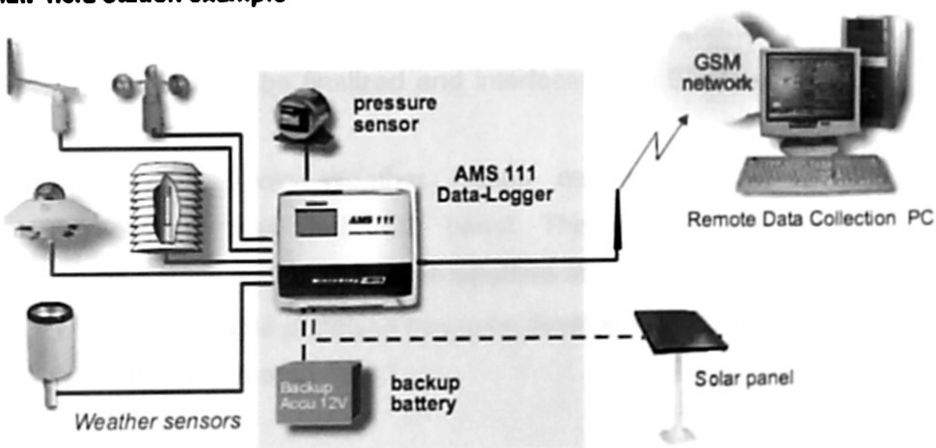
- 3 digits easy-to-read display.
- Guide light indicate display status
- 8Temperature display in F or C.
- Conversion to metric or inch units of measure.
- Water and dust resistant.
- Unerasable memory.
- Simple installation.
- 115/230 VAC operation.
- Power surge protection.
- Water and dust resistant enclosure.

Photograph 6.2 Commercial available Weather Monitoring Station

The company, "ROTEM & OEC", 2/32 Billabong Street, Stafford, BRISBANE, QLD 4053, supplies this model. AUSTRALIA.

The company "MicroStep-MIS " Monitoring and Information Systems Cavojskeho 1, 84104 Bratislava 4, Slovakia supplies the weather station as shown in Photograph 6.3.

**Small field station example**




Photograph 6.3 Commercial available Weather Monitoring Station

The MicroStep-MIS AMS-111 system is designed for mobile, temporary or standard meteorological stations, as well as for the applications in areas where the commercial power or communication networks are limited or non-exist. The AMS 111 interfaces with a various sensors and telecommunication devices in order to communicate the weather data.

The price and maintenance of such type of Weather Station is costly. It is not locally made hence the problem of maintenance arises.

Indian versions of Automatic Weather stations are also available with Metos Instruments India Pvt. Ltd, METOS HOUSED-213, Vivek Vihar - I New Delhi - 110095 (India), SVI Biomedical Pvt. Ltd. New Delhi. The Indian companies also sells weather stations in collaboration of foreign companies.

Thus the developed electronic Weather Station is cost effective and easy to maintain because all the instrumentation designed is known, the sensors used are readily available.

### 6.3 Future Scope of the work

- Using available climatic data for cultivation of a particular crop, computer controlled cultivation and growth of that crop is possible using Electronic Weather Station.
- The design and development of wind velocity and wind direction sensor is to be finalized and interfaced with Electronic Weather station.
- The Electronic Weather station can be automated using Microcontroller and LCD panel. The display time for each parameter may be preset ~~or repetitive~~ after certain interval.
- A Comparable prototype has to be developed and filed testing has to be carried out.

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