A Novel Design and Implementation of Electronic Weather Station and Weather Data Transmission System Using GSM Network

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Abstract: - The purpose of this project is to design and implement a cost effective, portable weather station to measure and display different weather parameters. Conventional weather stations are larger in size and incur a huge cost of installment, which is a limiting factor for developing countries. Although low cost miniature systems are also available but they are of poor precision. The goal of the project is to introduce an economical system that ensures flexibility, portability, scalability and user friendly operations. The design incorporates sensors and equipments to assess temperature, humidity, atmospheric pressure, wind speed, precipitation, presence of rain, UV index, dust density, ambient light intensity and presence of different gas in the atmosphere. To measure wind speed and precipitation, conducive mechanical structures are designed which can be made from locally available materials. The system utilizes solar energy which makes it a stand-alone system. Measured data through the developed system can be uploaded to the web server and sent to the user through web page or through text messages.

Key-Words: - Weather station, Microcontroller, Anemometer, GSM, Hall Effect sensor, MPL115A1, UV, TEMT6000, Dust density .

1 Introduction

Weather has always been a major force of nature that influenced mankind in a very authoritative approach for an elongated period of time. According to the National Center for Atmospheric Research, Americans check the weather 3.8 times a day. We are obliged by this force of nature because it is one of the few things that humans left untouched and out of their grasp of control. Over a couple of centuries humans has been trying to understand the weather and tried to forecast the weather correctly. For this purpose a lot of knowledge and data has been gathered which helped researcher extrapolating methods of measuring weather phenomena and even forecasting the hazardous incidents of weather. "Meteorology" is the part of science which is solely devoted to this field. In this modern era many new technologies and methods have been developed for accurate monitoring of weather.

Hygrometer was the first weather measuring instrument invented. It was invented by Nicholas Cusa in the mid-fifteenth century. Later in 1592 Galileo Galilei invented thermometer for measuring temperature. In 1643 after about 50 years of Galileo Evangelista Torricelli invented the barometer for measuring atmospheric pressure. For the next three centuries, these meteorological instruments were being refined and new instruments were being invented. All the observational, theoretical and technological development through centuries contributed to our knowledge of the atmosphere and individuals at scattered location began to make and record atmospheric measurements. [1]

A weather monitoring station is a collection of different instruments and apparatus used to measure many different weather variables like temperature, humidity, wind speed, rainfall, atmospheric pressure, UV index and many others. Not all weather stations has same instrument collection, the use of instruments depends on the weather condition of certain regions. In this modern time there are many different types of weather stations. Some are analog, where the humans physically collect the weather data from instruments and records the data.

But most of the weather stations now a day are operated digitally.

A weather monitoring station which gives digital data usually consists of several weather phenomena sensing sensors and a processor unit which integrates all of the monitoring systems altogether. This paper will discuss on the self sustainable weather station which have the option to recharge the power source to prolong operation time. Also the design is a standalone wireless weather station module so no external power source will be needed and data will be extracted by wireless means.

Digital weather stations can be categorized into personal stations and professional stations. The personal weather stations are characterized to have relatively low cost with limited capabilities. The equipped sensors are less sensitive and usually they don't have the capabilities of logging data or transmitting them. On the other hand professional stations are more costly. They usually are wireless and standalone stations with capability of logging data autonomously and transmit them by wireless means to a nearly situated base station/computer. Personal weather stations lack self sustainability, precision and reliability. On the other hand, professional weather stations are too expensive for public use[2]. The aim of this research is to develop a less costly, user friendly portable weather measuring device which can transmit the data to remote server for later viewing and analysis. Figure 1 shows a picture of the full implemented system.

Fig. 1 Implementation of portable weather station

2 Relevant works

Numerous low cost portable weather station projects have been proposed and implemented in many countries over the past years. In their economical weather monitoring system proposal, the author Kulkarni et al [3] developed a similar system like ours but did not measure pressure and precipitation parameters. Similar issues have arisen in the system mentioned by Sutar [4].Precipitation measurement was not taken into account in the system proposed by Popa et al [5]. Optimization of cost and power has been prioritized in the system design of Ghosh et al [6], but lacks wind speed measurement. However it offers measurement of solar radiation level which can be easily deployed in our structure with light sensor.

Author Fang et al [7] presented a micro weather station based on MEMS technology. The concept of a micro station does not incorporate rain measurement which is a key criterion in climatic conditions of the rural area. The tipping buckets deployed in our static station offer accurate precipitation measurement along with portability. Authors Pengfei et al and Singh et al both have proposed wireless temperature monitoring system using ZigBee technology in their respective papers[8][9]. ZigBee Technology is a popular choice for data transmission however it will require substantial amount of work to execute it in small or medium sized applications. Bazydlo et al [10] presented a model of wireless, distributed temperature measurement system based on the IQRF platform using IQMESH protocol. Seflova et al [11], in his paper described advantages, limitations and specifics of IQRF wireless technology. IQRF technology requires a setup of IQRF wireless mesh network as a prerequisite which then can transmit data through gateways like Wi-Fi/LAN/GSM. But GSM module incorporated in our setup simply uses the available cellular network.

A GSM based weather monitoring system for solar and wind energy generation has been designed by author Gaurav et al [12] considering aspects like low cost, portability and durability. The lightweight system is floatable and recoverable with the help of a simple Hydrogen balloon. The embedded system proposed by Sankar et al [13] also uses a hydrogen balloon for monitoring weather conditions, but for both the cases, the setup is not suitable for implementation in countries like Bangladesh since the flight support includes considerable amount of cost.

The paper presented by author Shaout [14] proposes a low cost embedded design with intelligent system to measure wind speed, wind direction and temperature parameters. The intelligent system is developed by planting small scale neural network in the microcontroller for post processing. Neural network can be applicable to dynamic systems but has both advantages and limitations of its own over conventional computing. Back Propagation (BP) learning algorithm in Artificial Neural Network (ANN) is widely used to solve various complex classifications and forecasting problems. The convergence is slow but it is assured. However, ANN is black box learning approach, cannot interpret relationship between input and output and unable to deal with uncertainties due to differences between signal and calibration samples.
Surussavadee et al [15] presented a method for evaluating weather forecasts via weather satellite. Weather satellites are being used for a long time in different countries and have contributed to improved weather analysis and weather predictions. But this concept is quite impractical to be implemented in developing countries. Many countries like Bangladesh do not have satellites of its own and setting up satellites is not feasible considering their economic condition .Besides satellites have trouble measuring some ground phenomenon such as precipitation whereas ground stations offer higher accuracy. Satellites do allow greater coverage of various parameters over a landscape but the precipitation ground measurements are more precise. Satellites undoubtedly provide more promising measures of weather variables however ground stations are more preferable in the rural area especially for precipitation measurement and cost-effectiveness.

Krejcar [16] has also used temperature sensors in his proposed model that comes with a remote control but the construction of the entire setup is comparatively complex. Precipitation measurement has been proposed by Conti et al [17]; the system uses X-band weather radar. The radar monitors precipitation fields with high resolution in space and time and is supported by a rain gauges network of 18 tipping bucket gauges spread over the observed area, a weight rain gauge, an optical disdrometer, and a weather station. The setup is considerably complex and costly. Our proposed model allows measurement of various parameters in a cost effective and easily deployable structure.

3 System Design and Implementation

3.1 Temperature Measurement System

Temperature is a comparative measure of thermal state. Several scales and units exist for measuring temperature, the most common being Celsius (denoted by ºC), Fahrenheit (denoted by ºF) and Kelvin (denoted by K). Temperature is a very critical and widely measured variable. Measurement of this variable encompasses a wide variety of needs and applications. To fulfill this wide array of needs, a large number of sensors and devices have been developed. Temperature measurement can be done through many methods. In this proposed project, temperature has been monitored and controlled by the use of microcontroller based precision-integrated circuit temperature sensor. The sensor is of low cost, smaller in size, and is not subjected to oxidation. The sensor’s low output impedance, low self heating, linear output, and precise inherent calibration make interfacing to readout or control circuitry convenient. The use of these sensors ensures accuracy and wide range measurement. Moreover, this controller based system can send data to the web server without the requirement of any user input. All these reasons stated makes the choice of this particular method of measurement more preferable if compared to other available methods.

Components Used:

- Temperature sensor(LM35)
- Microcontroller
- Circuit elements

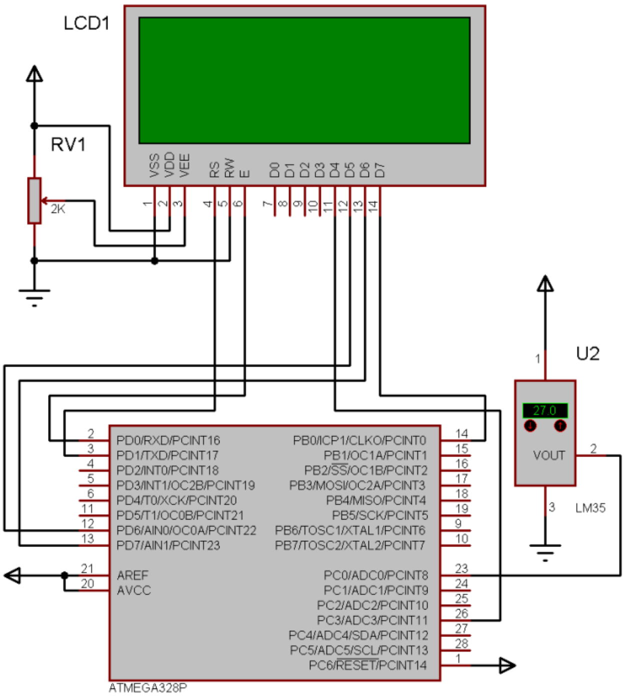

Fig. 2 Schematic for temperature measurement

Data Acquisition Process:
In this project to measure temperature, electronic sensor has been used. The sensor IC LM35 gives linear output voltage proportional to ambient temperature ranging from -55ºC to 150 ºC. For weather data this range is quite enough as temperature usually does not exceed this range. The output voltage is processed using ATMEGA328 microcontroller IC in such a way that the system displays temperature output in degree Celsius unit.

3.2 Humidity Measurement

The amount of water vapour which exists in the atmosphere at a certain time is known as humidity. Absolute humidity refers to the actual amount of water vapour present in a specified volume of air. Relative humidity is defined by the ratio of partial pressure of water vapour to the equilibrium vapour pressure at a given temperature. Relative humidity is expressed in percentage. The device which is used to measure relative humidity is highly dependent on temperature and pressure known as hygrometer. Hygrometers are of various types which uses change in different properties such as temperature, dimension, impedance, thermal conductivity, colour, acoustic transmission and so on. Measurement of relative humidity can be done both in digital and analog system. In this system HSM-20G sensor is used. This sensor converts relative humidity and provides voltage output that varies with relative humidity. The main reason for using this sensor is it enables high accuracy and range of measurement at very low cost. Moreover, this sensor allows continuous and convenient operation. The sensor is interfaced with the system microcontroller which measures the output voltage provided by the sensor and compute the corresponding relative humidity. The measurement is displayed via an LCD display connected with the system microcontroller.

Components Used:

- HSM-20G Sensor
- Microcontroller
- Circuit elements

Data Acquisition Process:
HSM-20G is the main component in the humidity sensing unit. The operating voltage input for this sensor is 5.0±0.2V. The maximum operating current rating of the sensor is rated at 2mA which ensures very low power consumption. Depending on the relative humidity of the surrounding atmosphere, the sensor output voltage range is 1.0-3.0VThe variation in output voltage corresponding to change in relative humidity is given by table 1 supplied by the manufacturer of the sensor:

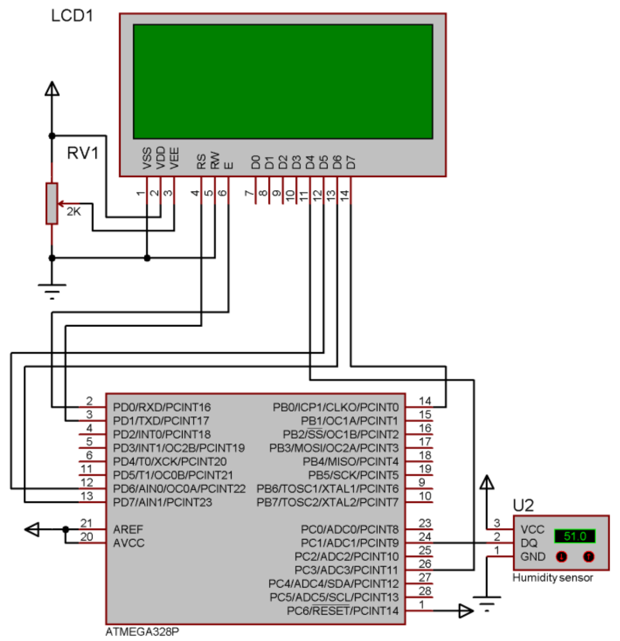

Fig. 3 Schematic for Humidity measurement

%RH	10	20	30	40	50	60	70	80	90
Output Voltage	0.74	0.95	1.31	1.68	2.02	2.37	2.69	2.99	3.19

Table 1 Humidity data provided by manufacturer

The above data was used to generate a 4th order equation. The equation is

$$\%RH = P_1 * V^4 + P_2 * V^3 + P_3 * V^2 + P_4 * V + P_5$$

Coefficients:

P_1 = 3.176e-08
P_2 = -9.8284e-06
P_3 = 0.0009064
P_4 = 0.0035786
P_5 = 0.61444

This equation converts the analog voltage measured by the microcontroller to accurate humidity data.

3.3 Pressure Measurement

Atmospheric pressure can be measured in several techniques. Some of the older technique includes using liquid column and using bourdon tubes, which are bulky way to implement measurement of pressure. Due to the advancement of microelectronics, so many small size sensors can be made which measures the pressure effectively without that bulk. One of the common microelectronic pressure measurement techniques is using the Piezoresistive effect of semiconductor materials. For a semiconductor material, when mechanical stress is applied, resistivity of the material varies. When atmospheric pressure

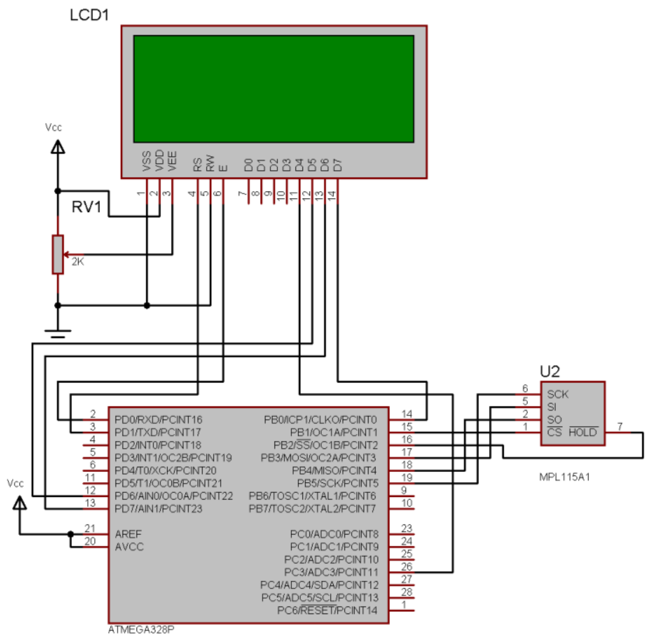

Fig. 4 Schematic for pressure measurement

increases, the stress on semiconductor material also increases. Electronic circuit can be used to measure the resistivity of material and hence the pressure

Components Used:

- MPL115A1
- Microcontroller
- LCD Display
- Circuit elements

Data Acquisition Procedure:

MPL115A1 is a digitized pressure sensor which converts the data measured by its Piezoresistive portion into digital data. As MPL115A1 is factory calibrated, there is no need to calibrate the sensor during use. The pressure sensor MPL115A1 provides pressure data in digital SPI interface. When requested by microcontroller, MPL115A1 sends proper bits of data which is then converted to pressure data by the equation provided by the manufacturer.

According to manufacturer the pressure measurements are accurate to 1kPa and can measure pressure from 50kPa to 115kPa absolute pressure.

3.4 Wind Measurement

There are two different component of wind, wind speed and wind direction. As the main target of this research is to implement a system that is cost effective, wind direction measurement was skipped. Wind speed can be measured in several different methods. Some of the popular methods include using momentum transfer sensor, heat transfer sensors, and Doppler Effect sensors. The instrument used to measure wind speed is called anemometer. By mechanical design most popular anemometer used are cup anemometer, propeller anemometer and sonic anemometer.

In this project cup anemometer was used, mainly because it is easier to build, it has a linear response to wind and direct measurement of wind speed can be possible. Cup anemometers provide instantaneous speed of wind.

A cup anemometer has three or four cups mounted symmetrically around a freewheeling vertical axis. The difference in the wind pressure between the concave side and the convex side of the cup causes it to turn in the direction from the convex side to the concave side of next cup. The revolution speed is proportional to the wind speed irrespective of wind direction. In our design a three cup anemometer was designed and was build with brass stator base and stainless steel cups with stainless steel rotating base, as shown in figure 6. A magnet was added in base. A Hall Effect sensor was used to generate the rotation signal for use of microcontroller for further processing. The full working procedure is depicted in figure 5 below.

Components Used:

- Mechanical body
- Hall effect sensor A6851
- Microcontroller
- LCD Display
- Circuit elements

Working Principle block diagram:

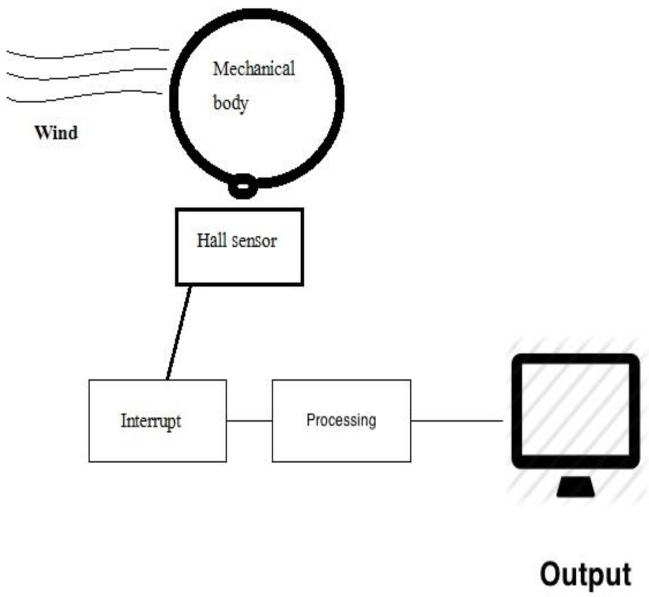

Fig. 5 Block diagram of anemometer

Fig. 6 Implemented anemometer

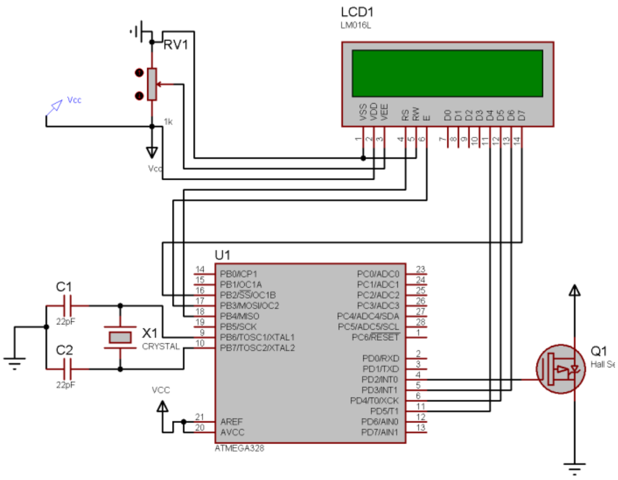

Fig. 7 Schematic for anemometer and precipitation measurement

Data Acquisition Procedure:
When the anemometer base moves due to wind, for every rotation the magnet crosses the Hall Effect sensor. The Hall Effect sensor creates a voltage level transition. Microcontroller interrupt is used to detect this change. A counter in microcontroller is used to count the number of rotation per 4 second. This rotation per four second data can be used to measure rotation per minute. This in turn gives the speed of wind.

3.5 Precipitation measurement

A rain gauge is a type of instrument which is used to gather and measure the amount of rainfall for a period of time. The unit of measurement for precipitation measurement varies from system to system. Some design measure the precipitation in millimeters which is equivalent to liters per square meter. Sometimes the level is measured in inches or centimeters. Rainfall can be measured automatically or manually. There are many methods of measuring rainfall but all the methods donot merge with automatic weather station because for automation the system has to measure the rainfall automatically. For this reason tipping bucket concept is used. This concept is convenient and offers high accuracy.

The tipping bucket system consists of a funnel which collects the water; the channel guiding the water in a seesaw-like container. After a preset amount of water is stored in the container, lever tips, dumping the collected water and an electrical signal is transmitted to the controlling unit.

Components Used:

- Microcontroller
- Funnel
- Bucket
- Jar
- Hall effect sensor
- Circuitry Elements
- Magnet

Hall Effect Sensor:
In this system A6851 hall effect sensor is used. It is an integrated Hall latched sensor which has a output pull high resistor driver for electrical communication with brushless DC motor application and contactless switch. It has an on-chip voltage generator for magnetic sensing and it has a comparator which amplifies the Hall voltage. It has 3 pins one two pins for vcc and ground and the other one is for hall sensing output. When magnet passes the sensor this pin turned high. This sensor's rated temperature range is -20^{0}C to 100^{0}C and it has a voltage range of 3.5V to 28V. It works for unlimited magnetic flux density. Power dissipation is only 20mW and maximum junction temperature is 175^{0}C.A funnel was used to collect water from rainfall. A bucket was added in a way that every turn is equivalent to 1mm rainfall.

Data Acquisition Procedure:
A plastic jar was used to seal the bucket so that there is no external effect and to direct the water from funnel to bucket directly. The bucket used is portrayed on figure 8.

Fig. 8 Implemented rain measurement system

In this system a funnel is designed to collect water and measure the area of the funnel. A channel guides the water in a bucket. According to the area of funnel the bucket is made which will trip when 1mm precipitation is measured. The tips of the bucket are measured using a magnet and a Hall Effect sensor. The magnet is attached to the center of the bucket and the hall effect sensor is attached to the base of the bucket in a way that the bucket trips whenever the magnet passes the sensor. As a result, for every tip the Hall Effect sensor will send a 5V signal to the main circuit. Measuring each signal the system will display the total mm of rain within a certain time.

3.6 Water Sensing

To get information about rainfall during specific time of the day a simple PCB with trace similar to the structure as shown in Fig. 9 was designed where actual board inter trace distance was kept small and all the traces were tinned and checked for oxide layer. The board was washed with salt water and was dried so that there were some salt crystals on the traces. When water falls in the traces the salt layer gets mixed with water and the resistance between the traces is decreased. This decrease in resistance was measured using a pull up voltage divider as shown in the schematic in Fig. 10. The major drawback in the design is that the PCB get damaged over time and hence maintenance is necessary from time to time.

Fig. 9 PCB for water sensor

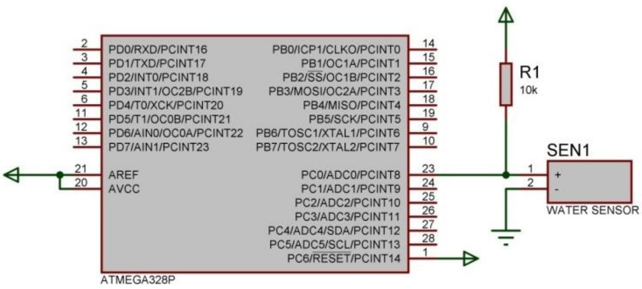

Fig. 10 Water sensing schematic

Components Used:

- Water sensing PCB
- Microcontroller
- Resistor

Data Acquisition Process:

The analog pin connected with the sensor pin is routinely checked by the microcontroller. If there is no water in the traces the voltage across the analog pin is close to 5 volt. The voltage across this analog pin decreases to close to 0 volt when there is water in the traces. If the measured voltage is higher than 3 volt the microcontroller considers this as no water in the trace and if the voltage is less than 3 volt the microcontroller considers this as presence of water.

3.7 UV index Measurement

Ultraviolet is harmful for human skin and eyes. It is very helpful for end users to know about the current intensity of UV in the atmosphere. For measuring UV index GUVA-S12SD photodiode is used. This photodiode is made of gallium nitride based material and operates in photovoltaic mode. It has a good responsivity for UV range in the electromagnetic spectrum. This photodiode is commonly used in UV lamp monitoring and UV index monitoring. The graph in Fig. 11 shows the photocurrent vs UV index curve for GUVA-S12SD, provided by the manufacturer [18]. As the current is small, an op-amp is used to amplify the signal to get good voltage reading. The circuit schematic is given in the Fig. 12.

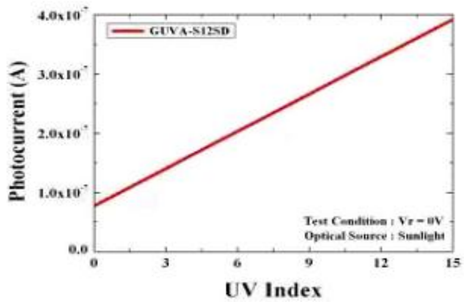

Fig. 11 Photocurrent Vs UV index curve for GUVA-S12SD

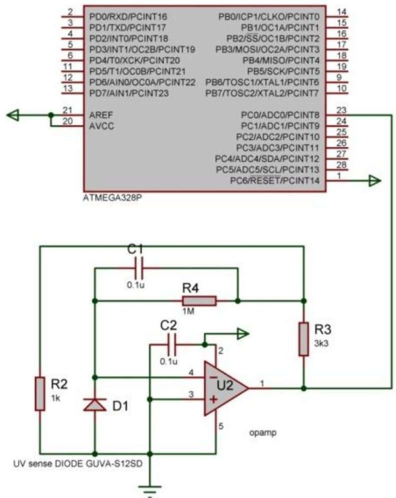

Fig. 12 Schematic for UV index measurement

Components Used:
- GUVA-S12SD photodiode
- Operational amplifier
- Microcontroller
- Resistor
- Capacitor

Data Acquisition Process:
The output voltage from the experimental setup was measured routinely using a microcontroller. From the graph provided in Fig. 11 a relationship was established between the produced photocurrent and corresponding UV index. Since an operational amplifier is used to amplify the sensors output signal another relationship was established between the measured voltage and produced photocurrent. The UV index can be measured from these two relationships. The output voltage of the sensor goes high with the increasing amount of UV ray detected by the photodiode.

3.8 Ambient Light Intensity
Combining the data from ambient light sensor and real time clock, estimation about the sky cloudiness is possible. For measuring ambient light Temt6000 phototransistor is used. Temt6000 is a phototransistor with high sensitivity to visible light much like human eye. The photocurrent in the photo transistor varies with different light intensity as shown in the Fig. 13[19]. A resistor is used for pulling the collector pin to ground such that the output voltage at the collector pin varies from 16mV to 1.6 V for 10 Lux to 1000 Lux respectively. The connection is shown in Fig. 14.

Components Used:
- Temt6000 phototransistor
- Microcontroller
- Resistor

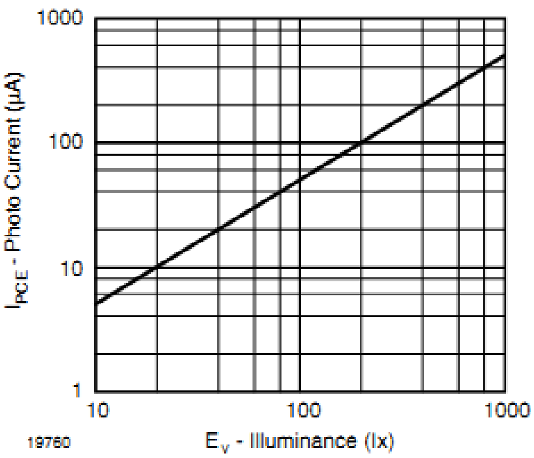

Fig. 13 Characteristics curve of Temt6000

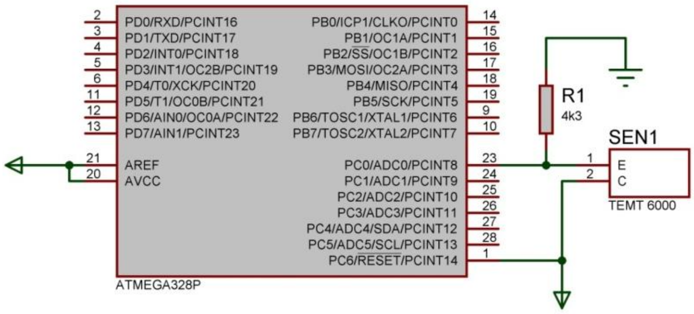

Fig. 14 Schematic for measuring ambient light

Data Acquisition Process:
The output voltage from the experimental setup was measured routinely using a microcontroller. For measuring the ambient light intensity in Lux from the measured voltage a relationship was established using the graph in Fig. 13. The measured voltage was fed into the relationship to find the corresponding ambient light. The higher the voltage measured by the controller the higher the ambient light intensity.

3.9 Dust density Measurement
GP2Y1010AU dust sensor is used to measure the dust density in air. GP2Y1010AU senses dust by optical sensing means. The sensor consists of an Infra-Red emitting diode and a phototransistor which are arranged diagonally. The sensor detects the amount of reflected light from dust in the air. There is a hole in the sensor where the air needs to flow and a small fan is used to serve this purpose. The output voltage from the sensor represents the amount of dust in the air. A linear relationship between the output voltage and the amount of dust (for low dust density) is observed in the graph in Fig. 15, provided by the [20].

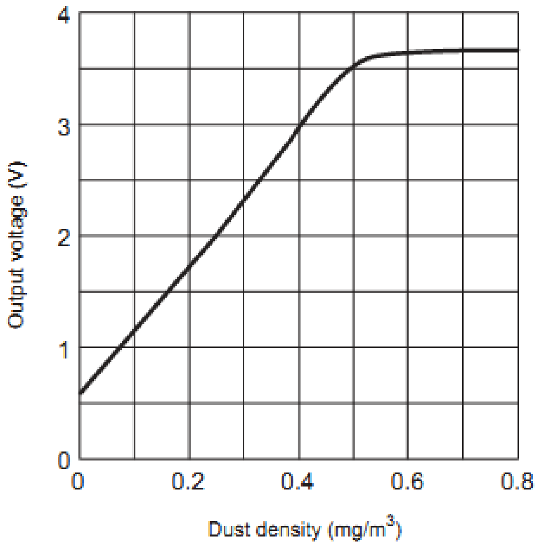

Fig. 15 Y1010AU characteristics curve

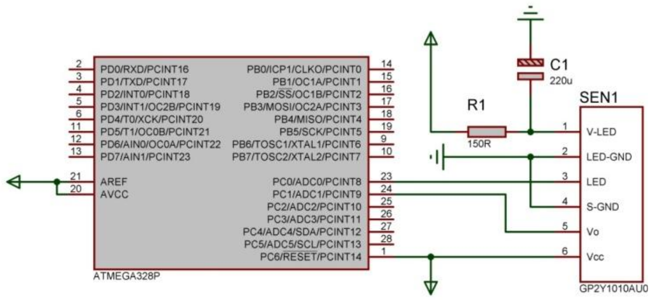

Fig. 16 Dust sensing schematic

Components Used:

- GP2Y1010AU dust sensor
- Microcontroller
- Resistor
- Capacitor
- Fan

Data Acquisition Process:

For measuring the amount of dust in air, the IR LED in the sensor is powered on and a small time is taken by the microcontroller to sample the result. After the sampling delay, the voltage from the output of the sensor is read by the microcontroller. The IR LED in the sensor then powered off and after some time the dust density is found from the relationship established using the characteristics curve of the sensor. The circuit used for measuring dust density is depicted in Fig. 16.

3.10 Gas Sensing

For measuring different gas concentration in the air MQ series of gas sensors are used. A small heater along with an electrochemical sensor is used inside the sensor. The electrical connection is shown in the Fig. 17. These electrochemical cells contain electrode where the gas particle can get diffused and the working electrode gets oxidized or reduced. Current is produced due to these electrochemical reactions which passes through the external resistor and can be measured with microcontroller. Different MQ sensor has different electrodes and different responsivity. Three MQ sensors namely MQ4, MQ7 and MQ135 were used in our design. MQ4 gas sensors are sensitive to combustible gas like natural gas; The MQ7 gas sensor is sensitive to carbon monoxide; MQ135 is sensitive to carbon dioxide, smoke and ammonia. The datasheet of each sensor provides Rs/Ro Vs ppm curve for any specified gas where Rs is resistance of sensor for any concentration and Ro is the resistance of the sensor at 100 ppm of specified gas. Figures 18 to 20 shows the sensitivity characteristics for MQ4, MQ7 and MQ135 sensors respectively [21-23].

Components Used:

- MQ4
- MQ7
- MQ135
- Operational amplifier
- Microcontroller
- Resistor

Data Acquisition Process:

For all three sensors the data extraction from the sensor is same. The sensor is first powered on and after some delay the resistance of the sensor Rs is measured using the voltage divider. Then using the equation formed from Rs/Ro Vs ppm curve of that gas, concentration of gas can be found. If the controller finds gas concentration crosses certain limit the controller treats it as polluted air.

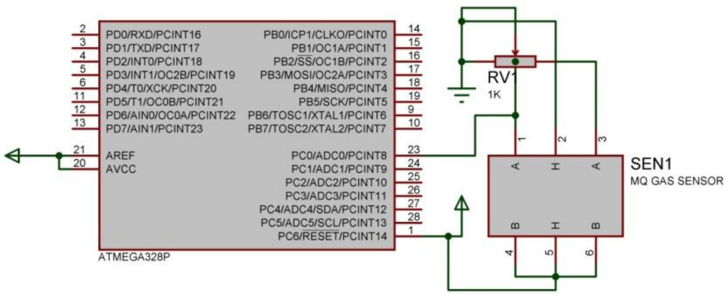

Fig. 17 schematic for gas concentration measurement

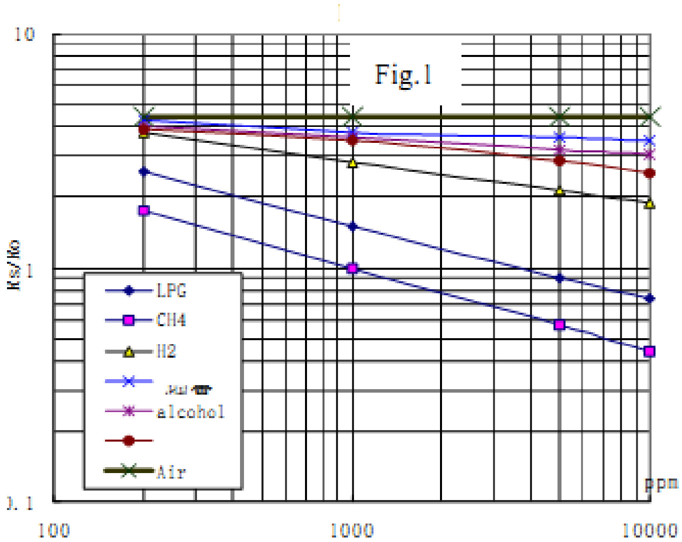

Fig. 18 Sensitivity characteristics for MQ4 sensor

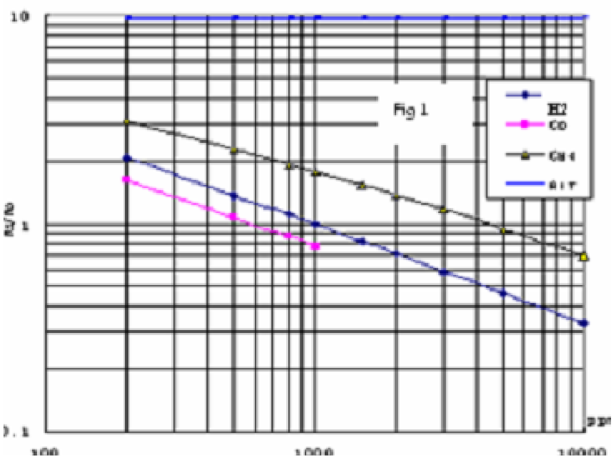

Fig. 19 Sensitivity characteristics for MQ7 gas sensor

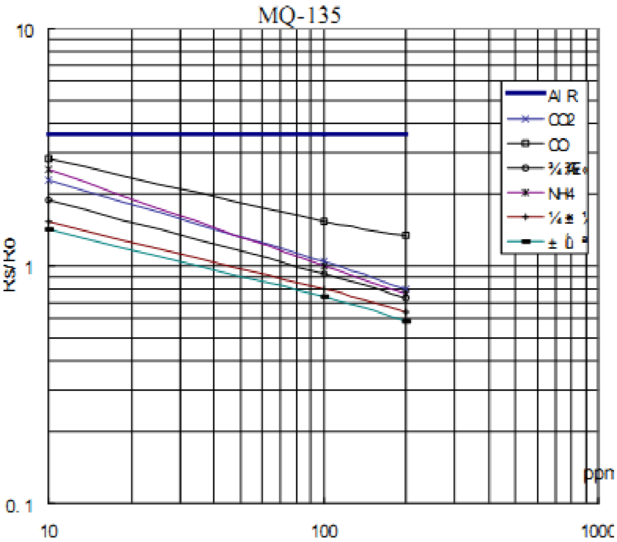

Fig. 20 Sensitivity characteristics of MQ135 gas sensor

3.11 GSM interfacing

To facilitate the creation of a network of weather stations, communication is necessary. There are many ways of communication. GSM communication is used mainly because of its severe advantages over others. As GSM network penetration in Bangladesh is very high, the chances of finding a GSM network in any rural area is very high. So the portability issue is greatly attained in sense of communication. At the same time there is absolutely no cost related to creation of network. The maintenance cost for using GSM is not so high. Also using GSM communication means we can set our weather station in any place in the GSM network coverage.

For the purpose of this research SIM900 GSM module was used. SIM is a series of mobile communication System on Chips (SOCs) specifically designed for experimentation and design purpose. SIM900 module has quad band GSM/GPRS functionality. For this project, we explored the SMS and GPRS functionality of SIM900 module. The GPRS modem inside SIM900 module supports GPRS class10 internet capability, which is enough for updating data to the server.

Interfacing the SIM900 module

SIM900 module supports communication in many protocols. For simplicity, we used the serial communication protocol to communicate with the module. Furthermore, this module supports standard AT cellular command interface. The communication consists of three-wire communication between the controller and the GSM module. One for ground as reference and other two wires for two transmit receive connection for serial communication protocol.

Using SIM900 module

As GSM modules are power hungry and our use needs the GSM module to work only for sending data, keeping the module powered on for longer time means wastage of energy. Moreover, a portable system like this needs to save energy as much as possible. Therefore, our target was to keep the GSM module powered on for only when data transmission is required. A real-time clock facilitates this need. Using a real-time clock means, we can power on the GSM module in a certain predetermined time and power-off the module after sending the data to the server.

Data sending

The GSM module can be used to send data in mainly two ways. SMS based system and Server based system. For SMS based system the system sends SMS to predetermined phone numbers using the GSM network and for the server-based system, the system sends weather data using GPRS modem to a server, which is then displayed the data to end users.

SMS

For the SMS based system the system uses the measured data from sensors to create a string with the measured data and necessary units. The GSM module sends an SMS with the created string to SMS enabled mobile phone numbers. This feature can be implemented in many ways. One way is to send SMS to predetermined phone numbers and another way is to send SMS with current data to any number, who calls the phone number used in the GSM module.

Website

The data sent by the weather station with the help of GSM module can be stored in a database on a Linux based server. The backend of the website is the SQL database, which can store all the data send by the weather station. The processor used in the weather station sends the raw data captured from the sensors to the server with the help of GSM module. Three different sorts of benefits can be extracted in this way. First, as only raw data are sent, the processor does not need to process the data. As a result, the working load of the controller of the weather station is decreased. Second, the size of the raw data is less than the processed data. Therefore, the internet charge involved in sending the data from the weather system to server is less, thus reducing the running cost of the system. Third, if the system requires to be calibrated to transmit the data the older data can be reprocessed to get the accurate data

For showing weather data to users, the front-end can fetch the data from this SQL database. The frontend of the website is designed with HTML, CSS and PHP. CSS is used for styling in the pages in the website.

When an user requests for a page, the PHP code pulls weather data from the SQL database and after necessary processing the data are organised in the page created by HTML mark-up.

The GSM module sends data to server by connecting to a page in the server. The PHP code receives the data send by GSM module and after doing necessary processing, it enters the data to SQL database.

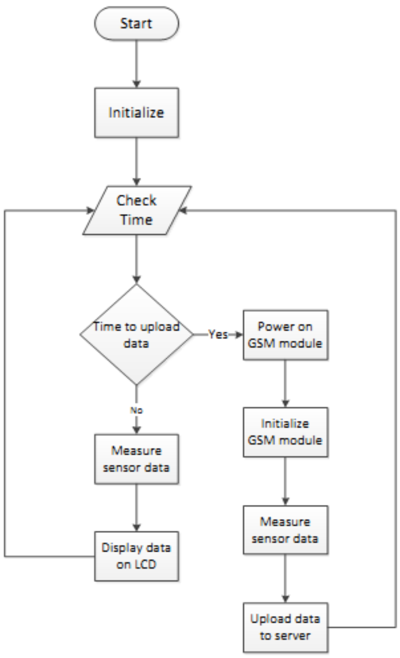

Fig. 21 System Workflow

As the number of types of devices that browses websites increases, there are many display sizes in devices. A fixed web site is not ideal for viewing a page in all different display sizes. CSS was used to make the page layout of the website fit to the display size of the end user.

3.12 System Block Diagram

The flow of work is shown in Fig. 21. And the block diagram of the designed system is depicted in Fig. 22

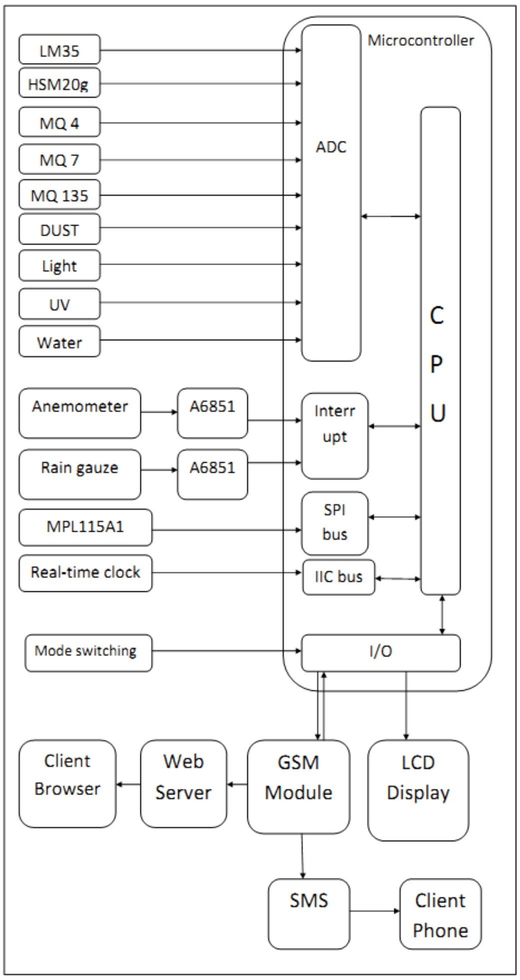

Fig. 22 System Block diagram

4 Research contributions

The project was designed considering the environmental factors and weather condition in Bangladesh. The implemented device is to be used outdoor and can withstand certain level of abuse from weather and human interference. The circuit is fully enclosed inside water tight box, so that the system will not be affected by rain or storm. The implemented device is portable. There are four screws in the feet of the stand. To move from one place to another the system can be unscrewed from one place and screwed in new place.

Considering the perspective of countries like Bangladesh, the most important design consideration for any electronic based system is reliable power options. In countries where load shedding is an everyday issue, continuous operation is not possible without backup power source. To combat this issue the full system is designed to operate over the battery. And the system is capable of charging the battery from mains supply if necessary. But for most of the time the system will charge the battery from the embedded solar panel in the system. The operating voltage of the system is 5 V DC. All the circuitry except the GSM module needs around 300mA maximum current with idle current of around 50mA whereas The GSM module alone needs around 1A current. As discussed earlier the GSM module is kept on for small amount of time to save power. Considering full load for the control and sensor segment running 24 hour, the system needs 36 Watt-hour of energy. The GSM module is switched on for merely less than 30 minutes in 24 hours for which energy consumption is 2.5 Watt-hour. The battery used in this design has a rating of 12 v 7Ah. So the total energy available when the device is fully charged is 84 Watt-hour.

The designed system can measure temperature, humidity, pressure, wind speed, rainfall, UV indexing, Dust density, ambient light intensity. And can sense presence of rain and different gas. Scalability was another design parameter which was taken into consideration. Exclusion or inclusion of different weather parameter is possible. Therefore the system can be easily customized without making too much change to the system hardware and software. The custom scaled version of weather station is sometimes much better than a single way system. For example in a tea garden knowledge about when the rain starts is more important than knowledge about atmospheric pressure. Similarly the system can be used indoor with the rain and wind measurement stripped down from the system and adding some gas sensing modules which is very much helpful for industrial application.

Operation of this system is kept simple. As there is no need of calibration, switching on the power will start the weather data measurement procedure. The system can also store previous data which can be displayed at a later time if necessary. The cost to build our device is 20000 BDT(Equivalent to around 260 USD or 240 euro).

The weather stations used by the meteorological department are huge in size and incur huge cost of installation and operation. Thus these large weather stations are not installed in small city and towns. As our implemented design is not very costly it can be installed in small towns and villages which can provide enough accurate real data for small towns and villages. If needed, multiple weather stations can be installed in big cities to provide weather data of individual areas. As for the accuracy of measured data through the implemented system, temperature is accurate to ±0.5 ºC. Humidity is accurate to ±5% and atmospheric pressure is accurate to 1kPa for RTP condition. As for wind measurement the accuracy was not measured as no standard wind tunnel was found. The anemometer has a threshold of minimum 2 kmph speed. The rain measurement as calculated and compared with the readings from local meteorological department is accurate to 1mm rain for a measurement close to 50mm. Water sensing is used to find if it is raining at a particular time of the day whereas the precipitation measuring system measures the total amount of rain in a whole day. Gas sensing is used to estimate the quality of air. This is also applicable for the dust sensor. UV indexing system is used to find the amount of UV light in the atmosphere.

All the data measured by the system is transmitted wirelessly to a remote server. This is facilitated by the use of SIM 900 module which is a quad band GSM/GPRS module supporting industry standard AT commands making the data transmission easier. All the data are stored in a SQL database in a Linux based server, from which the data can be served to end user with pages created by PHP HTML and CSS on the designed website.

5 Conclusions

Our prime concern for this project was to construct an inexpensive mini weather station which can provide data of different weather variables including temperature, humidity, pressure, wind speed, precipitation, UV index, dust density, ambient light intensity and can determine the presence of different gas and water. The system can be easily installed in both urban and rural backdrop; able to withstand weather adversity to a certain extent. This can be very useful to everyone especially farmers to be acutely aware of the current weather conditions. The system is convenient for users as it does not require external calibration after installation. The data transmission setup through GSM module enables the data to reach out to the users in remote places.

Acknowledgement:

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Appendix

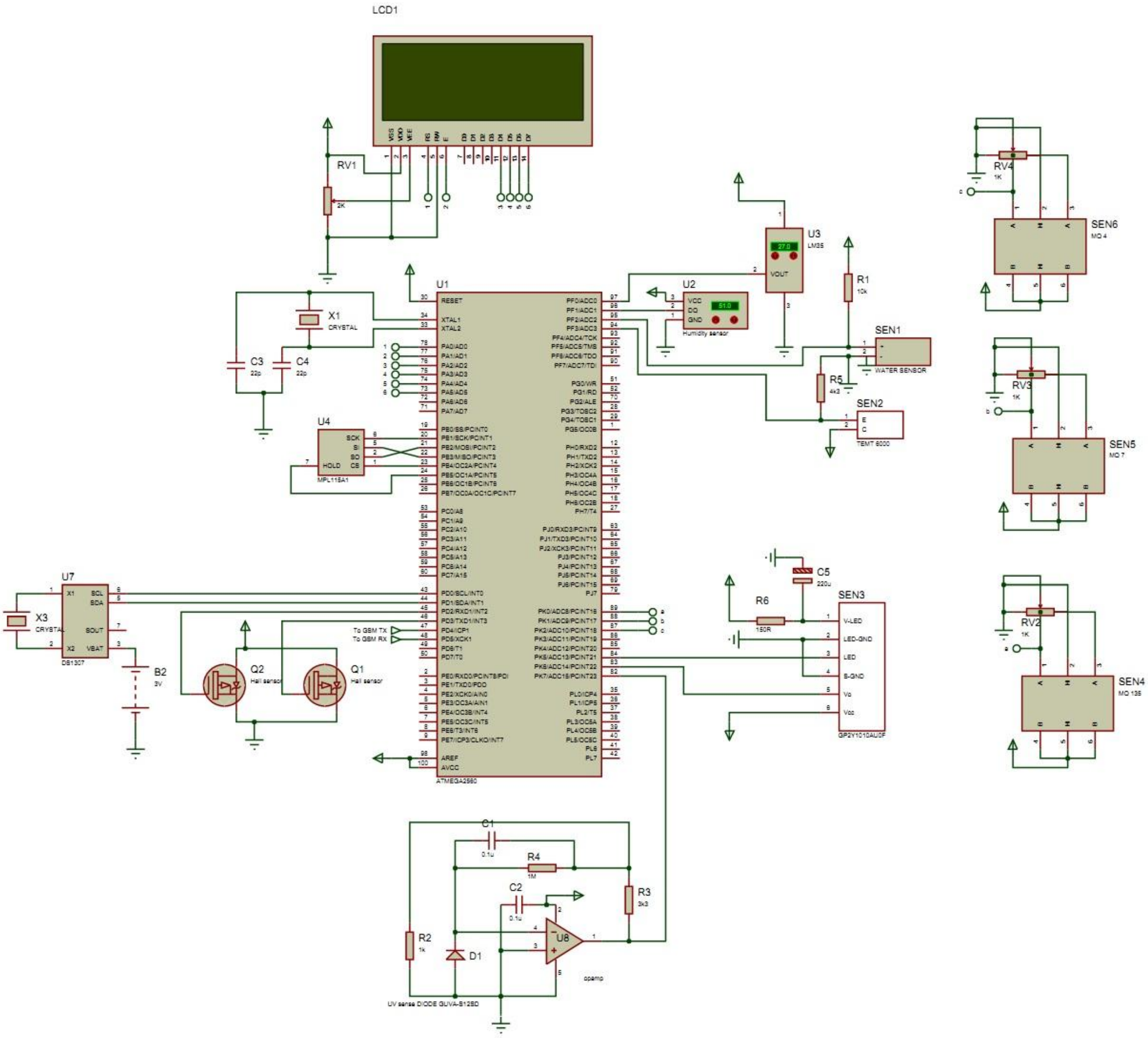

Fig. 23 Complete schematic of the implemented system