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Wireless Portable Microcontroller based Weather Monitoring Station

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ABSTRACT

Weather monitoring and its forecasting has become vital part of day-to-day life because of its numerous applications in agriculture, farming, fishery, shipping and military operations. Measuring the weather using conventional or manually operated Weather Monitoring Stations requires skilled labor for operation and demands regular maintenance which invariably increases the life cycle cost of the Weather Monitoring Station. To address these issues, the authors of this paper have attempted to design and implement inexpensive Wireless Portable Weather Monitoring Station using PIC16F887 microcontroller. The implemented Weather Monitoring Station is equipped with sensors to measure weather variables such as relative humidity, atmospheric pressure, rainfall, solar radiation, wind speed, wind direction, surface and ambient temperature. Besides of these capabilities, the designed Weather Monitoring station also includes some unique features like Modbus communication protocol, which provides seamlessly communication of real time weather measurements to the base station (PC\Laptop) over both wired (RS serial) and wireless (Xbee Pro modules) interfaces. Further, at the base station, the received data is logged and uploaded to an online data server to enable worldwide ubiquitous access to the weather measurements.

1. Introduction

In India, weather monitoring can be traced back to Vedic period literature, which presents extensive discussions about the seasonal cycles caused due to the movement of earth around the Sun, formation of clouds and rainfall [1]. Weather changes at its normal conditions greatly influence the daily moods [2] and activities of man such as agriculture, farming, fishing, entertainment, shipping and military operations [3–5]. But over the years, many events have made significant impact on mankind by destroying valuable property and took away many lives, in the form of floods, storms and hurricanes. Again, the weather conditions after twentieth century is even more worst due to population explosion, over migration, deforestation, global warming and other activities. Hence, in order to monitor and track weather changes, Weather Monitoring Stations are employed worldwide [6].

A typical modern Weather Monitoring Station uses multiple meteorological sensors to monitor weather changes by sensing weather variables such as temperature, relative humidity, dew point, atmospheric pressure, wind direction and wind speed. These meteorological sensors may not be limited to mechanical but also derived from advanced technologies such as Solid State and

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Micro-Electromechanical System (MEMS) [7,8]. Interfacing these meteorological sensors to microcontroller is easy and inexpensive using simple electronic circuits to acquire accurate weather measurements automatically without any interruption and maintenance [9–11]. Thus, the overall lifecycle cost of Weather Monitoring Station can be minimized.

In this paper, an attempt has been made to design and implement the Wireless Portable Weather Monitoring Station to measure relative humidity, atmospheric pressure, rainfall, solar radiation, wind speed, wind direction, surface and ambient temperature by interfacing meteorological grade sensors to PIC16F887 microcontroller. Further, industrial standard Modbus communication protocols has been implemented to acquire data from Weather Monitoring Station and communicated to base station (PC\Laptop) over Zigbee wireless (XBee-Pro radio modules) and serial interfaces (RS232\RS485) seamlessly. At the base station, the acquired data from Weather Monitoring Station is logged and uploaded to online MYSQL data server to provide ubiquitous sharing of the acquired weather data.

2. Related work

Author of [9] has presents a implementation of weather station which consists of TEMT600 luminosity sensor, SCP1000 pressure sensor and SHT15 temperature cum humidity sensor interfaced to ATmega328 microcontroller using SEN-08311 USB Weather Board, along with GSM module. The station can be controlled through the SMS service of mobile phones. Authors of [10] has implemented low cost distributed monitoring system for collecting environmental parameters like temperature, humidity and wind direction using TINI microcontroller card. TCP/IP protocol is used for data transmission and GUI has been developed to observe environmental parameters. Authors of [11] have designed a prototype of low-cost microcontroller based system for continuous and automated monitoring of crop conditions using inexpensive electronic components and solid-state sensors. This system designed to monitor soil moisture, soil temperature, air temperature, and canopy-temperature levels in cropped fields. Authors of [12] have implemented an Intelligent Transportation System (ITS) employing TxDOT Environmental System. TxDOT Environmental System includes sensors such as roadway water depth, rainfall gauge, wind speed, wind direction, temperature, stream velocity along with pavement temperature and moisture sensors. The values from these sensors are sent to local flood control agency using low frequency radios to alert the motorist during severe weather conditions. Authors of [13] have implemented a Multi-Tiered Portable Wireless System to monitor forest fires. The local area weather conditions such as relative humidity, wind direction, wind speed and temperature are acquired using Mica2 sensor nodes. A webcam is provided to monitor live video of the regions affected by forest fires. The acquired data is communicated to local base station through multi-hop technique. Authors of [14] have implemented On-site dynamic wireless sensor monitoring system to optimize energy consumption and to improve user comforts within the building. The system includes Zigbee devices to acquire parameters such as light intensity, temperature, relative humidity and air quality within the building. Further, Zigbee devices measures battery and building electrical power consumption through a current/ammeter sensor interfaced to the sensor nodes. A software tool called Building Monitoring System receives sensor values and updates its database through well established wireless sensor network and performs controlling, monitoring and reporting operations.

The rest of the paper is organized as follows Section 3 and Section 4 describes the block diagram of the implemented system and software architecture. Section 5 outlines the testing procedure and its results. Section 6 concludes the paper.

3. Hardware implementation

The block diagram of Wireless Portable Microcontroller based Weather Monitoring Station is shown in the Fig. 1. The implemented station consists of temperature and humidity sensor, wind speed and wind direction sensor, rain gauge sensor, solar radiation sensor, pressure sensor, surface and ambient temperature sensors along with TLV2543 serial ADC, PIC16F887 microcontroller and control switches. The XBee-Pro module provides wireless communication, MAX-232 and MAX-485 modules are provided for serial communication.

3.1. Relative humidity and temperature sensor (SHT11)

The Relative Humidity (RH) is defined as the ratio of the amount of water vapor in the air at any given temperature to the maximum amount of water vapor that the air can hold. In general RH is expressed in terms of percentage (%). Similarly, the atmospheric temperature is defined as the measure of temperature at different levels of Earth's atmosphere which is expressed in degree Celsius (°C).

The SHT11 sensor is employed to measure both relative humidity and atmospheric temperature. SHT11 incorporates a capacitive sensor element to measure relative humidity and band gap sensor to measure temperature. These sensors are connected internally to serial interface through high precision 14 bit Analog to Digital Converter (ADC). On the request of the host microcontroller, the SHT11 communicates the relative humidity (SO_{RH}) and temperature (SO_T) readouts through serial interface using I2C protocols [15]. The interfacing schematic for SHT11 sensor to PIC16F887 is shown in Fig. 2.

The readouts SO_{RH} is converted to true relative humidity and SO_T is converted to true temperature using Eqs. (1) and (2) respectively. The Eqs. (1) and (2) are referred from the SHT1x datasheet [15]. The coefficients C_1, C_2, C_3 in Eq. (1) and d_1, d_2 in Eq. (2) are selected from Tables 1 and 2 respectively based upon the conversion bit length of SO_{RH} and voltage (V_{DD}) applied to sensor.

$$\text{Relative humidity} = C_1 + C_2 \times SO_{RH} + C_3 \times SO_{RH}^2 \% \tag{1}$$

$$\text{Temperature} = d_1 + d_2 \times SO_T \ ^\circ\text{C} \tag{2}$$

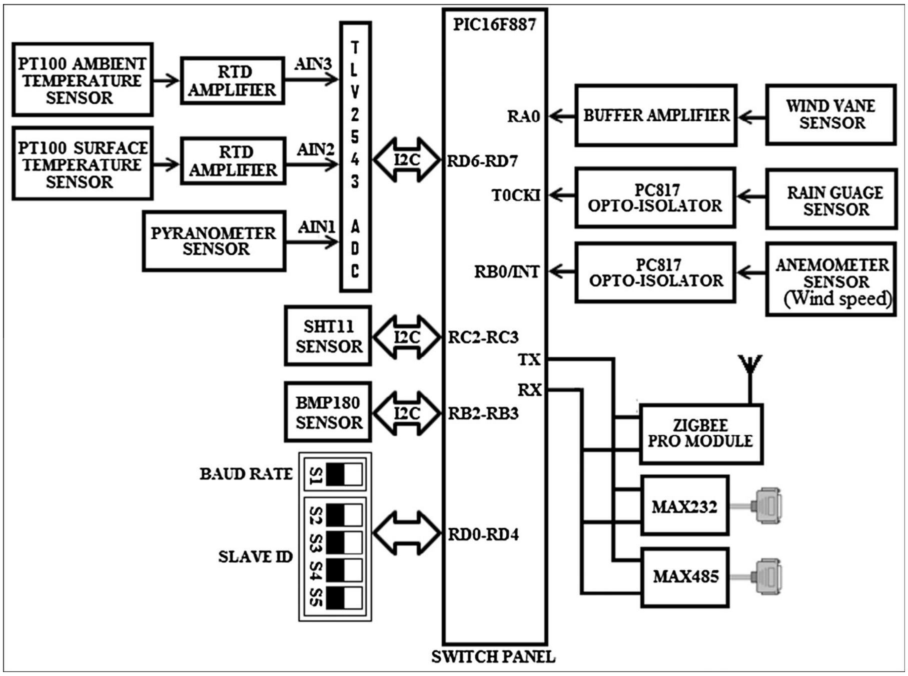

Fig. 1. The Block diagram of Wireless Portable Microcontroller based Weather Monitoring Station.

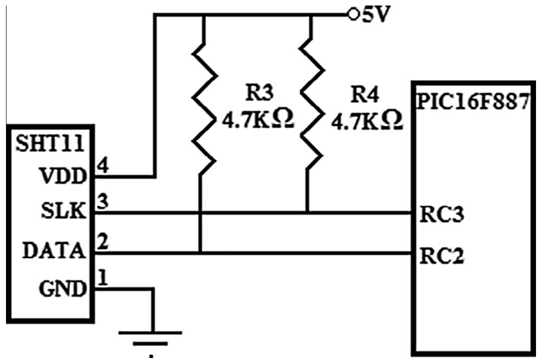

Fig. 2. The interfacing schematic for SHT11 to PIC16F887 microcontroller.

3.2. Wind direction and wind speed sensors (Wind Vane and anemometer sensor)

The wind is the perceptible natural movement of air in the form of current in a particular direction. The wind direction and speed are the two factors which are necessary to define the movement of the wind. The wind direction is defined as an angle measured in clock wise direction between the true North direction and direction of the wind movement. Wind Direction is often expressed in degrees (°). Similarly, the wind speed is defined as the speed at which air particles moves in the atmosphere measured in kilometers per hour (kmph).

The wind vane sensor consists of conventional vane or a pointer system and its shaft is attached to the continuous free rotating potentiometer. As the wind changes its direction forces the wind vane to change its direction which in turn changes the resistance and output voltage of the potentiometer coupled with the wind vane. Thus, by measuring the change in output voltage of the wind vane the direction of the wind is estimated. In this design, Davis Instruments-6410 anemometer sensor (Fig. 3) is been employed to measure wind direction, which produces 0–5 V for 0–360° angle of rotation [16]. The output of the wind vane sensor is connected to internal 10bit ADC (R_{A0}) of the PIC16F887 microcontroller through two-stage buffer amplifier constructed using TLV2472 (Fig. 4). The readout from the ADC (R_{A0}) is converted to wind direction using Eq. (3).

$$\text{Wind direction} = \frac{360 \times R_{A0}}{1023}\,\text{degrees} \tag{3}$$

Table 1
Humidity conversion coefficients.

SO_{RH}	C_1	C_2	C_3
12 bit	−2.0468	0.0367	−1.5955E−6
8 bit	−2.0468	0.5872	−4.0845E−4

Table 2
Temperature conversion coefficients.

VDD (V)	d_1 (°C)	d_1 (°F)	SO_T	d_2 (°C)	d_2 (°F)
5	−40.1	−40.2	14 bit	0.01	0.018
4	−39.8	−39.6	12 bit	0.04	0.072
3.5	−39.7	−39.5			
3	−39.6	−39.3			
2.5	−39.4	−38.9			

Fig. 3. Davis Instruments-6410 anemometer sensor.

To measure wind speed, Davis Instuments-6410 anemometer sensor (Fig. 3) has been employed. The anemometer consists of free rotating vertical spindle mounted on friction less ball bearing to which three equally spaced horizontal arms are attached. For each arm, hemispherical-shaped cup is mounted with the meridian plane vertical. When anemometer sensor is placed in airstream, a differential pressure is set up between the concave and convex faces of the cups which lead to rotational torque on vertical spindle. The magnetic switch coupled with the vertical spindle generates the output pulses proportional to rotational frequency of the anemometer. The magnetic reed switch coupled inside the anemometer generates 0–60 Hz pulse for the wind speed of 0–217 kmph respectively [16]. The output pulses of the anemometer are fed to the external interrupt pin (RB0/INT) of the PIC16F887 microcontroller through PC817 opto-isolator (Fig. 5).

In order to estimate the wind speed, the time period and thereby frequency of anemometer output pulses are calculated by configuring Timer1 to count internal clock pulses (N) between the successive external interrupts which are caused due to anemometer magnetic reed switch pulses. Later, Timer1 count (N) is converted to wind speed using Eq. (4).

$$\text{Wind speed} = \left(\frac{217}{60}\right)\left(\frac{F_{osc}}{4 \times N}\right)\text{kmph} \quad (4)$$

where F_{osc} is the operating frequency of microcontroller. In PIC family microcontroller internal Timer1 is incremented by one for every 4 clock pulses.

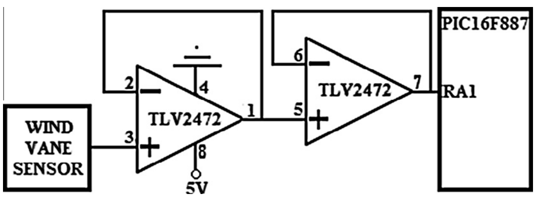

Fig. 4. The interfacing schematic for wind vane sensor to PIC16F887 microcontroller.

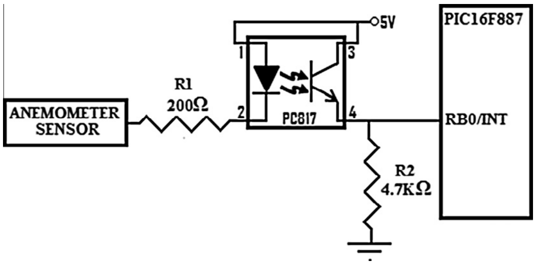

Fig. 5. The interfacing schematic for anemometer sensor to PIC16F887 Microcontroller.

3.3. Rain gauge sensor

Rain is liquid water in the form of droplets that have condensed from atmospheric water vapor and then precipitated enough to fall under gravity. The rain gauge is a sensor which measures the amount of rainfall in a give place within a specific time interval and its measurements are expressed in millimetres or inches.

The Rain gauge sensor consists of collecting funnel, two chamber tipping bucket connected in a see-saw arrangement to which magnetic reed switch is coupled (Fig. 6). The rain water enters the collecting funnel and passes through a debris filtering screen then accumulates into one of the tipping bucket chamber placed at the collecting position. After collecting the specified volume of water, the tipping bucket switches to drain position. Simultaneously, second tipping bucket will be moved to collecting position and the rain water from previous tipping bucket drains out immediately. This process continues and the magnetic reed switch coupled with the tipping buckets generate the output pulses. In this design, Davis Instruments-7852 rain collector is employed to measure rainfall, which generates an output pulse for every 2 mm volume of rainfall [17]. The output pulses from the rain collector are fed to external clock input of Timer0 (T0CI) of the microcontroller through PC817 Optoisolator (Fig. 7). The Timer0 is configured as counter for counting the number of pluses (RF_c)

Fig. 6. Davis Instuments-7852 rain collector.

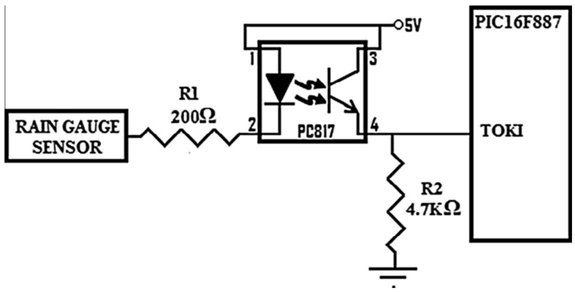

Fig. 7. The interfacing schematic for rain gauge sensor to PIC16F887 microcontroller.

on TOCI pin which is converted to rainfall measurement using Eq. (5).

$$\text{Rainfall} = 0.2 \times RF_c \text{ mm} \tag{5}$$

3.4. Pyranometer sensor

The solar radiation is an instantaneous energy emitted by the Sun in the form of electromagnetic radiation that reaches the earth surface measured in Watts per meter square (Wm^{-2}). The pyranometer\solar radiation sensor is employed to measure the solar radiation, which consists of wide spectral range silicon photo diode transducer to convert incident solar radiation into electrical current. The output of the photo diode is connected to internal amplifiers which further boost its output signal strength. Both the transducer and amplifier are kept inside the air-tight covering and the airflow path is provided for convection cooling of the body to minimize the heating of the sensor interior. Further, sensor includes cut-off ring for cosine response, a level indicator and fins to aid in aligning the sensor with the direction of Sun rays. In this design, Davis Instruments-6450 pyranometer sensor (Fig. 8) is employed which is capable of measuring 0–1800 Wm^{-2} solar radiation [18]. The output of the pyranometer is connected to AIN1 channel of TLV2543 serial ADC through buffer amplifier constructed using TLV2472 as shown in Fig. 9.

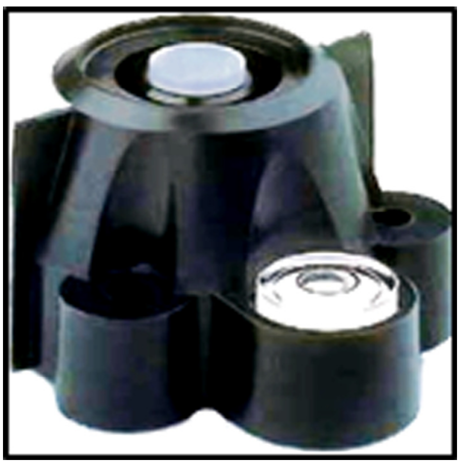

Fig. 8. Davis Instruments-6450 pyranometer sensor.

The TLV2543 is a serial ADC with 14 multiplexed inputs channels and conversion 12bit readouts are communicated to microcontroller using I2C protocol. The solar radiation readout (R_{SR}) from TLV2472 is converted to solar radiation using Eq. (6).

$$\text{Solar radiation} = \frac{R_{SR} \times 1800}{4095} \text{ Wm}^{-2} \tag{6}$$

3.5. Ambient and surface temperature

Ambient temperature is the temperature of the surrounding environment and surface temperature is the measure temperature of air near the earth surface. The Resistance Temperature Detectors (RTDs) are used to measure both ambient and surface temperatures in degree Celsius (°C). Typically, RTDs consist of temperature sensing element made up of long metal wire wounded on ceramic or glass rod and placed inside the protective jacket for which wires are connected to provide external connection. At any given time resistance of the RTDs are proportional to its surrounding environmental temperature, therefore by correlating the RTD resistance the surrounding environmental temperature can be estimated.

In this design, the maximum temperature to be measured is less than 100 °C thus PT100 sensor is employed. The PT100 sensor provides linear change in resistance from 100 to 138.50 Ω for 0–100 °C temperature [19]. In order to avoid self heating, current through PT100 is limited to 1 mA. Therefore, the voltage across the PT100 sensor increases by 0.385 mV for every degree rise in temperature. The low level output voltage of RTD is amplified using RTD amplifier (Fig. 10) constructed using LM358 dual operational amplifier. The RTD amplifier is designed to provide 4–20 mA of output current for 0–100 °C temperature range, which is in turn produces the voltage drop of 0.5–2.5 V across series resistance R5 (125 Ω).

To measure surface and ambient temperatures, two PT100 sensors with RTD amplifiers are employed and outputs of RTD amplifiers are connected to AIN1 and AIN2 channels of the TLV2543 serial ADC respectively (Fig. 1). The readouts from the AIN1 (T_{ST}) and AIN2 (T_{AT}) channels of ADC are converted to surface and ambient temperatures using Eqs. (7) and (8) respectively.

$$\text{Surface temperature} = \left(\frac{1000}{3276}\right) \times (T_{ST} - 819)\ ^{\circ}\text{C} \tag{7}$$

$$\text{Ambient temperature} = \left(\frac{1000}{3276}\right) \times (T_{AT} - 819)\ ^{\circ}\text{C} \tag{8}$$

3.6. Atmospheric pressure

The atmospheric pressure is defined as the force exerted on unit surface area on the earth by the weight of earth's atmospheric air above its surface which is often expressed in milli-bar (mbar). In this design BMP180 sensor is employed to measure atmospheric pressure. To measure atmospheric pressure, BMP180 high precision digital pressure sensor has been employed. The BMP180 is based on piezo-resistive technology and capable of measuring

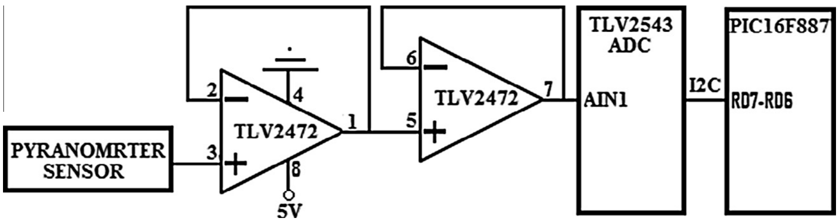

Fig. 9. The interfacing schematic for pyranometer sensor to PIC16F887 microcontroller.

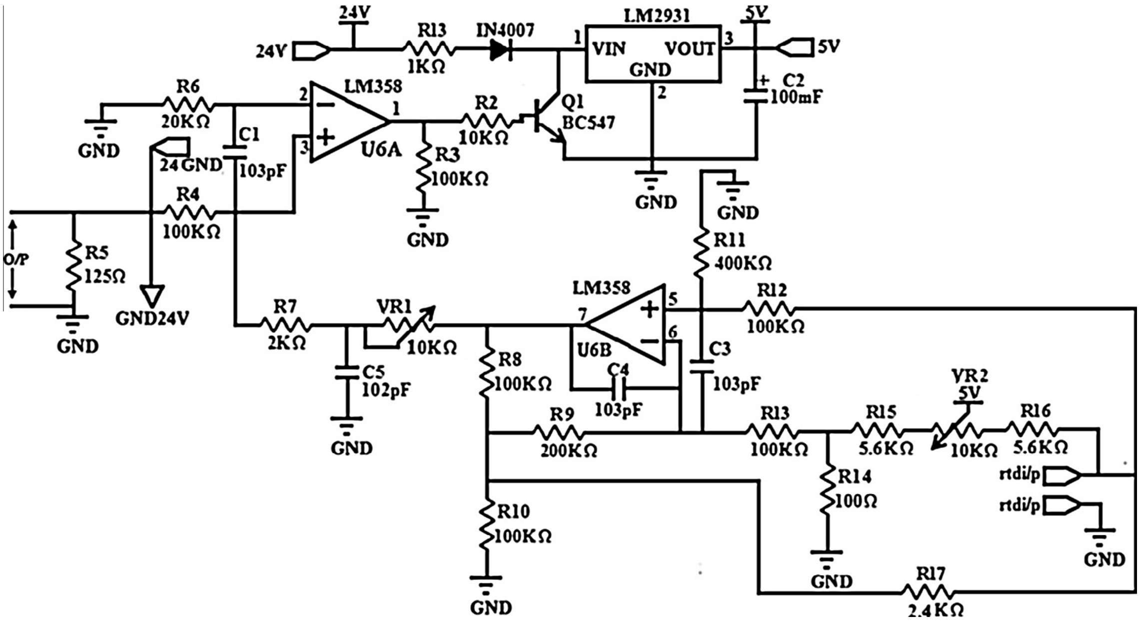

Fig. 10. The circuit schematic of RTD amplifier.

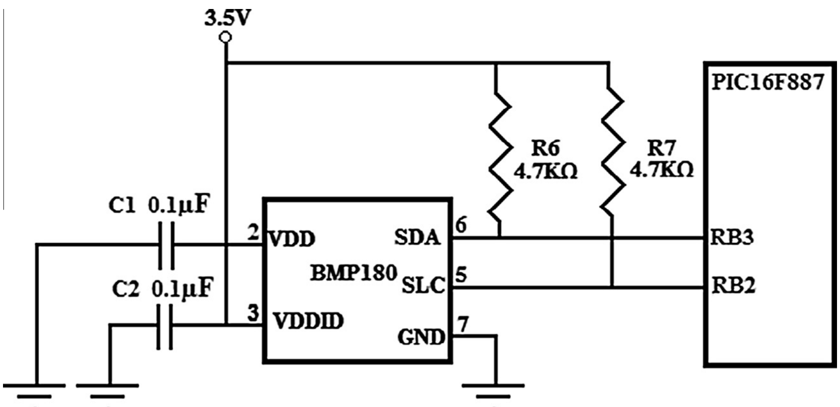

Fig. 11. The interfacing circuit for BMP 180 pressure sensor.

pressure in range of 300–1100 mbar [20]. The measured readouts form BMP180 is communicated to host microcontroller using I2C protocol. The readouts from BMP180 are later converted to true pressure by following the flow chart given by the manufacturer in the datasheet [20]. The interfacing circuit of BMP180 sensor to PIC16F887 microcontroller is shown in Fig. 11.

3.7. Communication to base station

In this design, provisions for both wired and wireless interfaces are provided to communicate with the base station. The RS-232 and RS-485 standards serial connections are implemented by employing MAX-232 and MAX-485 modules respectively. At any given time, either one of

Fig. 12. XBee-PRO module.

them can be used for data transmission. Further, wireless connectivity between Weather Monitoring Station and Base Station is provided by employing XBee-Pro RF module (Fig. 12). The Xbee-Pro module [21] is based on IEEE802.15.4 standard which providing 256 kbps bandwidth over 2.4 Ghz frequency bands and has transmission range of 1 km line of sight (as specified by manufacturer). Hence, for low data rate communications XBee-Pro RF modules along with Zigbee protocol serves as an ideal platform to establish reliable wireless interface as compared with other wireless technologies such as Bluetooth and Wifi.

3.8. PIC16F887 microcontroller

The PIC is a family of modified Harvard architecture microcontrollers from Microchip Technology. PIC microcontrollers are popular because of their wide availability, extensive collection of application notes and inexpensive programmers. The PIC16F887 is a CMOS based general purpose 40 pin microcontroller with 35 input and output pins. It has inbuilt software selectable clock frequency (31 kHz to 8 MHz range), three Timer\Counters, 10 bit internal Analog to Digital Converter ADC and Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) to support both RS-485 and RS-232 serial communication standards [22].

3.9. Control switches

The Control Switches includes five dip switches (DS1–DS5) which are interfaced to RD0–RD4 pins of the microcontroller respectively (Fig. 1). The dip switch DS1 is

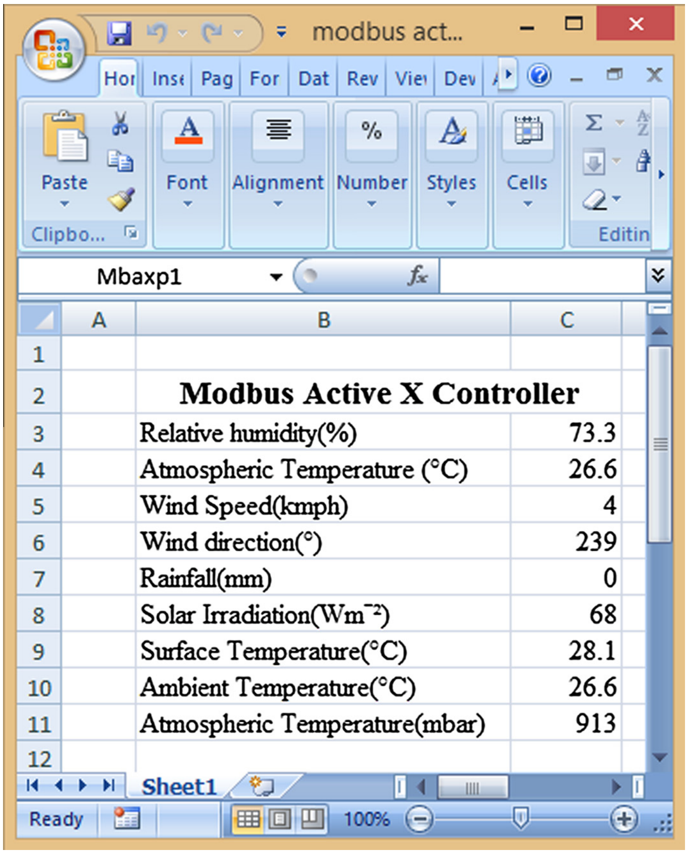

Fig. 13. Modbus Active X controller displaying acquiring data from slave Weather Monitoring Station.

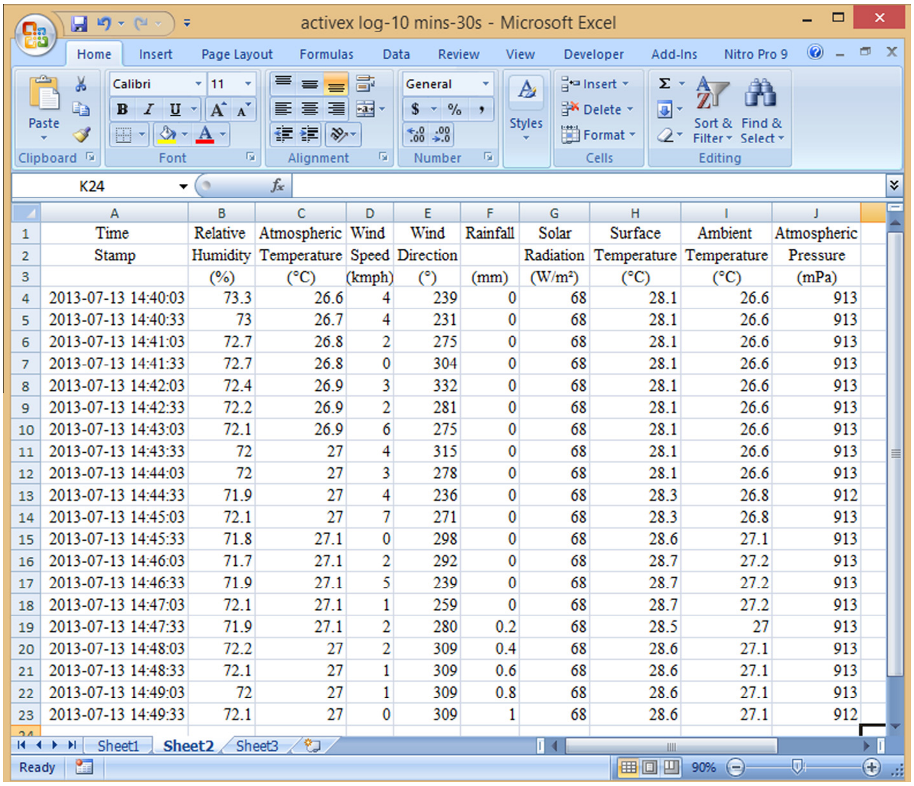

Fig. 14. Data logged in Microsoft Excel using ActiveX controller.

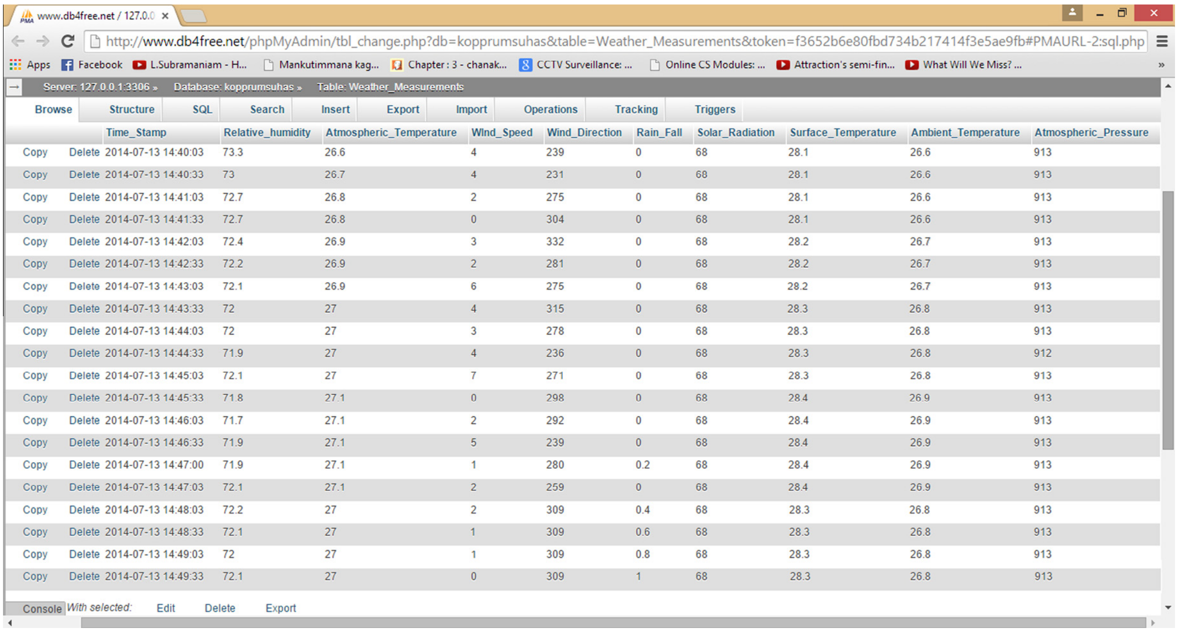

Fig. 15. Online MYSQL Data server storing wether parameters.

employed to select the baud rate for serial communication between 9600 and 19200. The rest of the switches (DS2–DS5) are provided to set the four bit Slave ID of the Weather Monitoring Station.

3.10. Modbus protocol

The Modbus is simple Master–Slave protocol used to communicate data on serial communication standards.

Each device in the network acts as Modbus slave for which Modbus address is assigned, but within the entire network only one device is assigned as Modbus master which can initiate Modbus commands. A Modbus command contains the Modbus slave address and some intended purpose. When the command is initiated by Master all the devices in network might receive the same command but only the intended device will respond to the master to fulfill the request and all other devices in the network will remain silent [23]. In this designl Weather Monitoring Station is programmed to operate has Modbus slave and Base Station is programmed to operate has Modbus Master.

4. Software architecture

The software of Weather Monitoring Station consists of firmware and application software. The firmware is developed using Embedded C language to direct the operations of the Weather Monitoring Station. The Modbus slave protocol is implemented within firmware of Weather Monitoring Station to acquire data from Weather Monitoring Station and to communicate serially through Xbee Pro radio module or RS serial interfaces. When Base Station request for weather measurements, following operations are carried out in Weather Monitoring Station. The channel0 of internal ADC of the microcontroller is programmed to read the output of the wind vane sensor and its readout is converted to wind direction. The external interrupt of RB0/INT pin is enabled and Timer1 is programmed to count the internal clock pulses between successive external interrupts. Also, Timer1 overflow interrupt is enabled and overflow of Timer1 between successive external interrupts is counted using interrupt service routine. The overflow count and Timer1 count is used to estimate the wind speed. The Timer0 is programmed to count the output pulses from rain gauge and its readout is converted to amount of rainfall. The I2C protocol is implemented to get the readouts from AIN 1, 2 and 3 of the TLV2543 serial ADC and converted into surface temperature, ambient temperature and solar radiation measurements respectively. The Pressure readouts are obtained from BMP180 sensor using I2C protocol and converted to atmospheric pressure. Similarly, humidity and temperature readouts are obtained from SHT11 sensor using I2C protocol, which are converted to relative humidity and atmospheric temperature respectively. After measuring all weather parameters and its corresponding measurements are placed in Modbus hold registers and transferred to Modbus Master.

At the base station, Modbus Master is been implemented by using Modbus ActiveX Controller within Microsoft Excel for acquiring data from Weather Monitoring Station. The Base Station (Modbus master) sends the request to Weather Monitoring Station (Modbus slave) for regular intervals of time and waits for updates from the Weather Monitoring Station. If the Base Station is successful in receiving the data from Weather Monitoring Station, then the received data is displayed (Fig. 13) and (Fig. 14) logged into Microsoft Excel by Modbus ActiveX controller. If the Base Station fails to receive data then error message is displayed. The logged data from Excel is uploaded to online MySQL server (Fig. 15) hosted by db4free.net [24] using Visual Basic form application (Fig. 16). The flow chart of firmware for Weather Monitoring Station and Application software for Base Station are shown in Figs. 17 and 18 respectively.

5. Testing and results

In order to validate the proper functioning of Weather Monitoring Station, following test procedures have been applied. The ambient and surface temperature readings acquired from PT100 sensors are compared with the readings of conventional thermometer and was found that both the readings were consistent. To test the rain gauge sensor, its tipping bucket states were manually toggled to generating a known number of output pulses. In each case, theoretical value of rainfall is calculated and compared with the equivalent practical readings obtained from Weather Monitoring Station and results were found consistent with each other. Similarly to test wind direction module, the

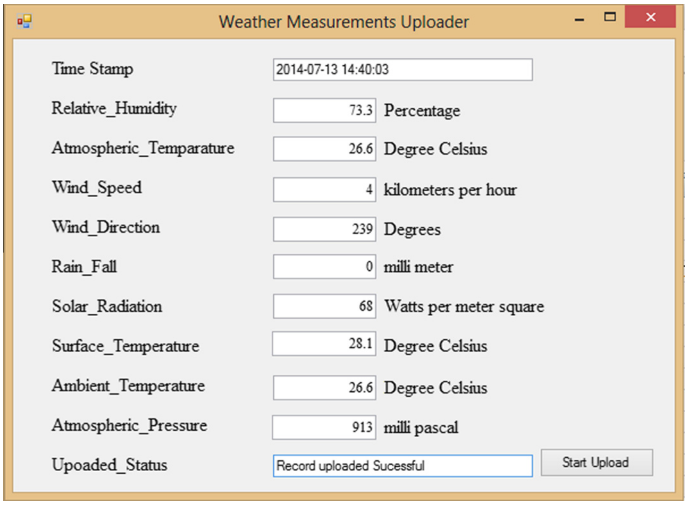

Fig. 16. Visual Basic form application uploading data to online MySQL dataserver.

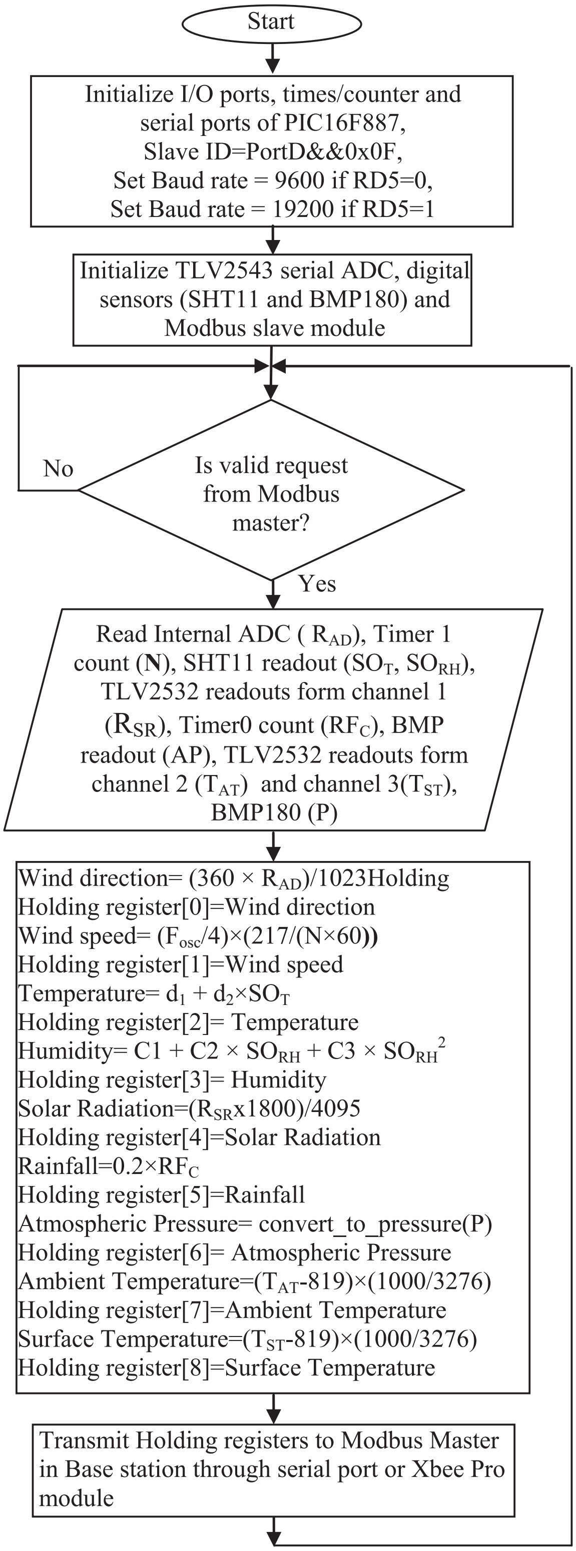

Fig. 17. Flow chart of Firmware.

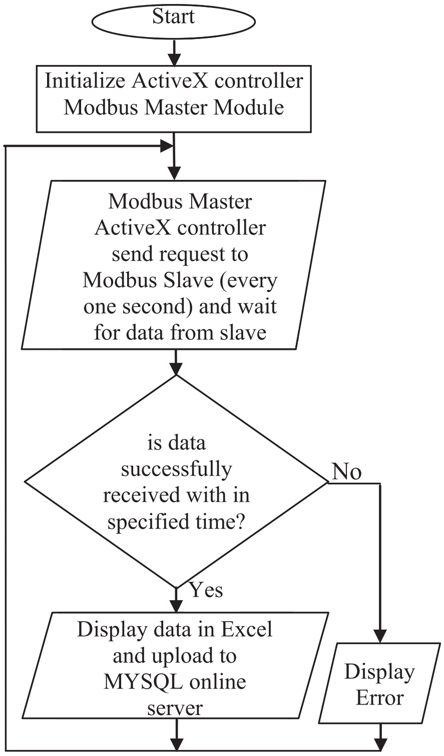

Fig. 18. Flow chart of application software.

Table 3
Theoretical and practical measurements from wind vane sensor.

Voltage in volts	Wind direction in degrees	
	Practical	Theoretical
0.5	035	036
1.0	072	072
2.0	145	144
3.0	215	216
4.0	287	288
5.0	359	360

Table 4
Theoretical and practical measurements from anemometer sensor.

Frequency in Hz	Wind speed in kmph	
	Practical	Theoretical
1	3	03.61
5	18	18.00
10	36	36.16
20	72	72.32
30	108	108.48
40	145	144.64
50	180	180.80
60	217	217.00

wind vane sensor is replaced with potentiometer and its output voltage of is varied in steps of 0.5 V. In each case, the wind direction measurements are recorded and compared with its theoretical measurements as shown in Table 3 and its results are found consistent. Likewise for testing the wind speed module, the anemometer sensor is replaced with function generator. The output frequency of the function generator is set to a known value of frequency as shown in Table 4. For each set value of frequency both theoretical and practical values were found and consistent with each other. Further, to test SHT11, BMP180

Table 5
Weather measurements acquired from implemented Weather Monitoring Station.

Time stamp	Relative humidity (%)	Atmospheric temperature (°C)	Wind speed (kmph)	Wind direction (°)	Rainfall (mm)	Solar radiation (Wm^{-2})	Surface temperature (°C)	Ambient temperature (°C)	Atmospheric pressure (mbar)
2014-07-13 14:40:03	73.3	26.6	4	239	0.0	68	28.1	26.6	913
2014-07-13 14:40:33	73.0	26.7	4	231	0.0	68	28.1	26.6	913
2014-07-13 14:41:03	72.7	26.8	2	275	0.0	68	28.1	26.6	913
2014-07-13 14:41:33	72.7	26.8	0	304	0.0	68	28.1	26.6	913
2014-07-13 14:42:03	72.4	26.9	3	332	0.0	68	28.2	26.7	913
2014-07-13 14:42:33	72.0	26.9	2	281	0.0	68	28.2	26.7	913
2014-07-13 14:43:03	72.1	26.9	6	275	0.0	68	28.2	26.7	913
2014-07-13 14:43:33	72.0	27.0	4	315	0.0	68	28.3	26.8	913
2014-07-13 14:44:03	72.0	27.0	3	278	0.0	68	28.3	26.8	913
2014-07-13 14:44:33	71.9	27.0	4	236	0.0	68	28.3	26.8	912
2014-07-13 14:45:03	72.1	27.0	7	271	0.0	68	28.3	26.8	913
2014-07-13 14:45:33	71.8	27.1	0	298	0.0	68	28.4	26.9	913
2014-07-13 14:46:03	71.7	27.1	2	292	0.0	68	28.4	26.9	913
2014-07-13 14:46:33	71.9	27.1	5	239	0.0	68	28.4	26.9	913
2014-07-13 14:47:03	72.1	27.1	1	259	0.0	68	28.4	26.9	913
2014-07-13 14:47:33	71.9	27.1	2	280	0.2	68	28.4	26.9	913
2014-07-13 14:48:03	72.2	27.0	2	309	0.4	68	28.3	26.8	913
2014-07-13 14:48:33	72.1	27.0	1	309	0.6	68	28.3	26.8	913
2014-07-13 14:49:03	72.0	27.0	1	309	0.8	68	28.3	26.8	913
2014-07-13 14:49:33	72.1	27.0	0	309	1.0	68	28.3	26.8	912

Fig. 19. Photograph of installed wireless Weather Monitoring Station.

and pyranometer sensors the measured outputs are compared with outputs of the corresponding standard meteorological reports and its results were found match with the reports [25].

The Weather Monitoring Station has been setup to acquire weather measurements for every 30 s and its corresponding measurements are shown in Table 5. The rainfall measurement shown in Table 5 is obtained by manually toggling the state of tipping bucket to generate known number of output pulses.

The photograph of installed Weather Monitoring Station is shown in Fig. 19. From the photograph it is clear that the implemented weather monitoring station is portable and adaptable for rapid installation on any type of terrains including building roof top.

6. Conclusion

The Wireless Portable Weather Monitoring Station is implemented by designing and developing hardware and software. The hardware consists of standard meteorological sensors which are interfaced to PIC16F887 microcontroller for measuring multiple weather variables. In particular, measured weather variables are acquired using Modbus protocol and communicated to base station over RS serial standard for wired interface and Xbee Pro radios wireless connections. At the base station, the application software has been developed using Modbus ActiveX controller which log the received data from Weather Monitoring Station into Microsoft Excel and uploads to online MySQL server using Visual Basic form application. The implemented Weather Monitoring Station provide high degree of portability and serve as an ideal platform to share the acquired weather data worldwide using online MYSQL server which is unique feature of this work.

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