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LOW COST WEATHER STATION FOR THE COLOMBIAN GEOGRAPHY IMPLEMENTED WITH PSoC5LP

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ABSTRACT

This paper presents the design and implementation of the prototype of a low-cost weather station, which allows the measurement of meteorological variables by sensors of various characteristics. The measured data is presented through a simple application hosted on a Smartphone, adaptable to any mobile device and with public access. The document initially presents some theoretical foundations, then characteristics of each of the sensors used, then details of handling, configuration and programming of the internal blocks of the PSoC5LP, to finalize showing the final result and conclusions.

Keywords: weather station, bluetooth, atmospheric pressure, relative humidity, pluviometer.

1. INTRODUCTION

Meteorology and climatology are sciences that are dedicated to the study of the processes that occur in the atmosphere, as well as the interaction of these processes with other systems. The measurement of physical variables that affect the atmospheric and climatic processes, is a key piece in the studies and investigations that correspond to these sciences. From this fact arises the need to design and develop measurement instruments, i.e. meteorological stations, to obtain the necessary data that after being processed by the experts, will be translated into invaluable information, which can be used for prevention and attention of disasters, besides benefiting the agricultural and livestock sector and also being useful in predicting and modeling climate change.

In Colombia there is a large number of climates due to its geographical location, this allows the generation of micro-scale and meso-scale meteorological processes that directly affect the country's socioeconomic activities, such as agriculture and livestock [1]. The need to protect themselves from the effects of these phenomena and the intention to prevent catastrophes has caused the Colombian population to demand more information (of quality and immediacy) about meteorological processes and phenomena.

In the Colombian geography the IDEAM (Instituto de Hidrología, Meteorología y Estudios Ambientales for its acronym in Spanish) is responsible for obtaining, analyzing, studying, processing and disseminating basic information on hydrology, hydrogeology and meteorology, has a network of observation, measurement and registration stations that is distributed throughout the country [2], this network is formed mostly by stations that need a person to record the measured data, that is, they are not autonomous. Currently a very low percentage (12%) of weather stations in the country have the ability to transmit their information in real time, this makes the information that serves as a basis for the modeling of climate forecasts arrive with delays to the central, which generates late reports and unsuccessful forecasts [3].

Today, many of the crops and crops are greatly affected by the limited capacity to foresee and cover the risks associated with abnormal climatic events such as hail, frost, excessive rainfall and high winds [4]. Only for the year 2010 there were losses of 89.004 million pesos in the country's crops due to these abnormal phenomena in the climate [5]. This is largely due to the lack of information obtained by small and medium producers and the lack of access to adequate forecasts. Through the design of a low-cost autonomous modular weather station that provides information in real time and can be adapted to small environments to create networks of stations, the producer or small business owner will have the possibility of accessing climate data without delays. They allow you to adopt early prevention strategies in your crops to mitigate some of the possible effects due to drastic climate changes.

Some works carried out in Spanish-speaking countries show developments of weather stations that can transmit their information in real time through a communication system, either SMS, Wi-Fi, Ethernet or Satellite [6] - [10], however, there is no low-cost system that allows its adaptation to the different measurement conditions (specifically to the conditions of the Colombian geography) according to the parameters desired by the user.

2. THEORETICAL FUNDAMENT

2.1 Meteorology

Meteorology is the science responsible for the study of the atmosphere, its properties and the phenomena that take place in it, the so-called meteors. The study of the atmosphere is based on the knowledge of a series of magnitudes, or meteorological variables, such as temperature, atmospheric pressure or humidity, which vary both in space and time.

When atmospheric conditions are described at a specific time and place, weather is being talked about. The weather is one of the main conditions of the activities that the human being performs, especially those that are performed outdoors, such as agriculture. Meteorological information appears daily in the media and, although this is sometimes the reason for the most trivial conversations, it is known that the understanding of time involves knowing a good number of scientific concepts, not all of them simple.

Since time immemorial, men have admired atmospheric phenomena and have tried to explain their causes. While there were no instruments or great scientific knowledge, magic and religion served as an explanation for most of the meteorological phenomena. But today, meteorology is a tremendously advanced science, based on knowledge of physics and the use of the most modern technologies. Meteorologists are even able to predict the time up to a week in advance without hardly failing [11].

2.2 Types of Weather Stations

The WMO (World Meteorological Organization) classifies meteorological stations based on different criteria [12].

According to its purpose:

- Climatological
- Agricultural
- Specials
- Aeronautics
- Satellite

According to the magnitude of the observations:

- Main
- Ordinary
- Auxiliaries

According to the place of observation:

- Terrestrial
- Air
- Maritime

2.3 Weather Stations in Colombia

The meteorological network of the IDEAM is composed of a set of observation, measurement and recording stations that are classified depending on their function [2].

- **Pluviometric Station (PS):** meteorological station equipped with a rain gauge or container that allows to measure the amount of rainfall during a given period of time.
- **Pluviographic Station (PS):** station equipped with a rainfall recorder that records precipitation continuously in a graph that allows knowing the amount, duration, intensity and period in which the rain has occurred.
- **Main Climatological Station (MCS):** observations are made of precipitation, temperature and humidity of the air, wind, radiation and/or solar brightness, evaporation and special phenomena. Three daily observations are made: at 07, 13 and 19 hours.
- **Ordinary Climatological Station (OCS):** in them there is at least one rain gauge, a pluviograph and a psychrometric. Three daily observations are made: at 07, 13 and 19 hours.
- **Main Synoptic Station (MSS):** observations are made of the main meteorological elements at internationally agreed times. The data correspond to cloudiness, direction and speed of the wind, atmospheric pressure, air temperature, type and height of clouds, visibility, special phenomena, humidity, precipitation extreme temperatures and sequence of atmospheric phenomena.
- **Supplementary Synoptic Station (SSS):** as in the previous station, the observations are made at internationally agreed hours and the data commonly correspond to visibility, special phenomena, weather, cloudiness, soil condition, precipitation, air temperature, humidity of air and wind speed and direction.
- **Agrometeorological Station (AS):** meteorological observations are made to help determine the relationships between weather and climate, on the one hand, and the development of agricultural and animal crops, on the other. It includes the same program of observations of the CP station, plus records of temperature and possibly humidity, at various depths (up to one meter) and in the layer near the ground (0, 10 and 20 cm above the ground).
- **Radiosonde Station (RS):** its purpose is the observation of temperature, pressure, humidity and wind in the upper layers of the atmosphere (troposphere and low stratosphere), by tracking, by electronic or radar, the trajectory of a Meteorological balloon that rises freely.
- **Special Meteorological Station (SMS):** its purpose is the observation of a particular phenomenon; the IDEAM uses it specifically for observing frosts (minimum temperatures equal to or lower than 0° C).

3. DESIGN AND SENSORS USED

In Figure-1 it shows the block diagram with the solution proposed for the design of the low cost weather station.

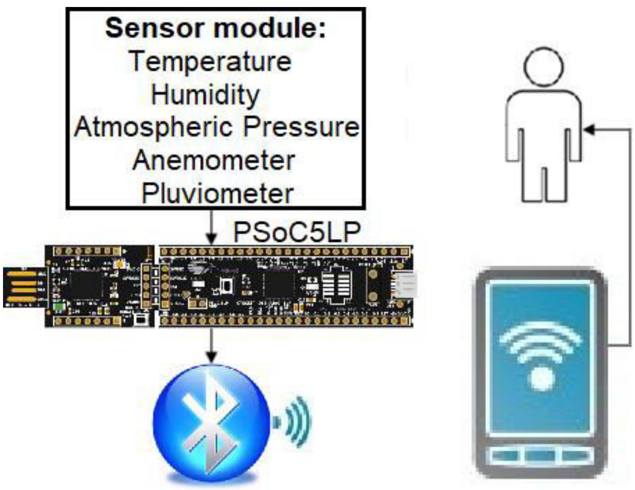

Figure-1. Block diagram of the proposed solution.

3.1 Humidity Sensor HIH-4000

It is a sensor manufactured by the American company Honeywell, by reviewing the user's manual is obtained the response curve (which relates the relative

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humidity with the voltage generated by the sensor) presented by this sensor in Figure-2. As it is observed the output is linear, but it presents a variation in the slope of the line which depends on the ambient temperature on which the sensor is located.

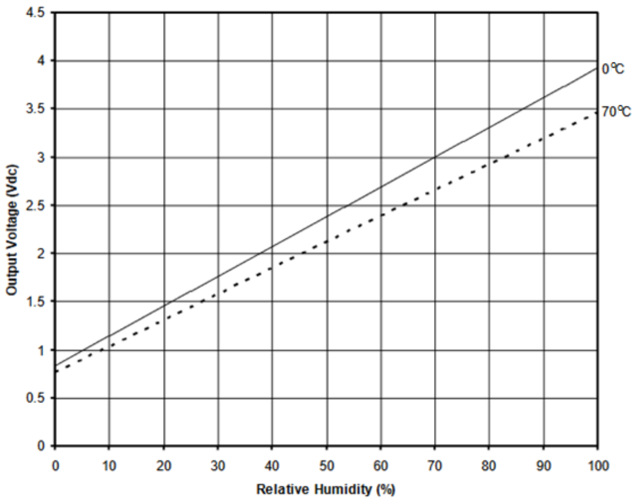

Figure-2. Humidity sensor response HIH-4000 [13].

The CEM-DT8820 Digital Multifunction Environmental Meter, which measures between 25% RH to 95% RH with 0.1% RH resolution and fast time response, was used to make an optimal characterization of the sensor response.

Then it proceeded to perform the respective measurement of the ambient humidity present in the place where the characterization was being done. Once the measurement was stabilized, the measurement given by the standard equipment which marked 58% of relative humidity was noted, on the other hand, the output voltage of the sensor was measured, which gave a value of 2.27V.

This would be a point of the line, but to be able to generate the respective equation, it is necessary to have 2 points. For the other point, the 0% humidity value was taken as reference, which is almost the same for the different temperatures and which according to the user manual is 0.826V.

Now, with the two points it can be find the equation of the line, but before using the equation inside the PSoC, the voltage values have to be passed to their value in bits. As the ADC was set to 10 bits and from 0 to 5V this gives a value of 4.8828mV per bit.

3.2 Anemometer

It is an instrument that is used to measure the wind speed in a certain geographic location, the unit of measurement is indicated in meters per second (m/s). There are different types of anemometers that are characterized by their precision and therefore the technology with which it is built, among the most basic is the windmill anemometer (Figure-3), which is a kind of mill with three blades that are responsible for put resistance to the passage of the wind to be moved and thus register a movement, there are also the ultrasonic anemometer, laser anemometer and cup anemometer [9].

Figure-3. Anemometer used in the weather station.

For this, a windmill anemometer coupled to a DC motor was used, operating as a voltage generator whose generated value is measured by the ADC of the PSoC5LP.

3.3 Pluviometer

A rain gauge is a meteorological instrument which gives a metric measure of the rainfall or precipitation that falls at a certain point and in a specific time space. With it the rain or fallen snow is measured, this measurement is done in mm or in l/m2.

The rain gauge is a simple instrument to build, especially its totalizing version, and that is why it is one of the oldest meteorological instruments and thanks to which it allows us to have longer pluviometric series.

There are several models of rain gauges according to their design and functionality. The first classification is between analog gauges and digital rain gauges. Secondly, the totalizing models and the models that are going to measure precipitation intensity [14].

The rain sensor or rain gauge used in the implemented station is a double tilt bucket of digital type, each 0.2794 mm of rain causes a momentary contact closure. The switch is connected to the two wires with RJ11 output cable (Figure-4.).

Figure-4. Pluviometer.

3.4 Atmospheric pressure and temperature (BMP280)

A barometer is an instrument that measures atmospheric pressure, atmospheric pressure is the weight per unit area exerted by the atmosphere and its units are the hectoPascal (hPa) [15].

The sensor used to measure the barometric pressure at the station was the BMP280 manufactured by Bosch. This sensor uses the I^{2}C and SPI communication protocols, it also incorporates a temperature sensor that was also used in the implementation of the weather station.

The main characteristics of this sensor are summarized in Table-1.

Table-1. Sensor characteristics of atmospheric pressure and temperature BMP280 [16].

Measuring range	
Pressure	300 hPa a 1100 hPa
Temperature	-40 a +85°C
Measurement resolution	
Pressure	0.16 hPa
Temperature	0.01 °C
Supply voltage	1.71 a 3.6V (VDD)
Resolution	16 -20 bits
Current consumption (Max.)	4.2 µA
Filter options	Five bandwidths

4. METHODOLOGY

For the design of the meteorological station, the process was divided into multiple stages that would facilitate this process and its subsequent analysis.

4.1 Capture of Analog Signals

The ADC_SAR block is responsible for receiving the data measured by the wind speed and relative humidity sensors, which are inputs of analog type, through the use of two pins of the PSoC5LP. The module was configured with a resolution of 12 bits, a voltage range from Vss to Vdd, single conversion and internal clock with frequency of 1MHz.

After receiving the data and storing it in a variable, the necessary conversions are made for each measurement so that the data can be sent correctly to the Smartphone. In Figure-5 you can see an ADC image and its connection to the sensors.

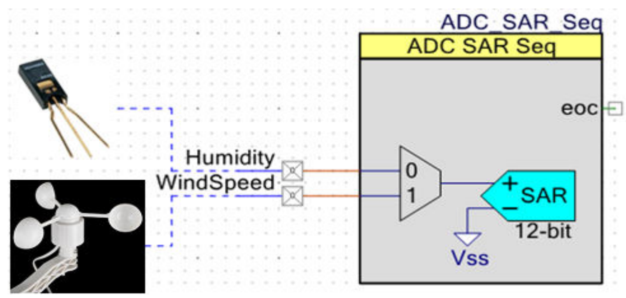

Figure-5. Connection of the ADC_SAR block to the analog sensors.

The code used in the PSoC5LP is shown in Figure-6, where the operations performed to calculate the value of relative humidity and wind speed are shown.

```
ADC_SAR_Seq_StartConvert();
ADC_SAR_Seq_IsEndConversion(ADC_SAR_Seq_WAIT_FOR_RESULT);
anemo= ADC_SAR_Seq_GetResult16(0);
humed= ADC_SAR_Seq_GetResult16(1);
humed=humed-715;
humed=humed*0.03866;
anemo=(anemo*0.028);
```

Figure-6. Code implemented for the measurement of humidity and wind speed.

4.2 Measuring the Amount of Rain

The Timer module, in conjunction with a digital input pin and its respective interruptions take the rain gauge (rain fall sensor) measurement. For this, the data is taken just when the sensor sends the pulse, which generates the interruption in the input pin. While this occurs, the Timer module is configured with a determined period of 3 seconds, and as it is previously known the volume that has the instrument which has a capacity of 0.2794mm, the measure of the time it takes to fill is obtained, obtaining thus a measurement in terms of mm/s (Figure-7).

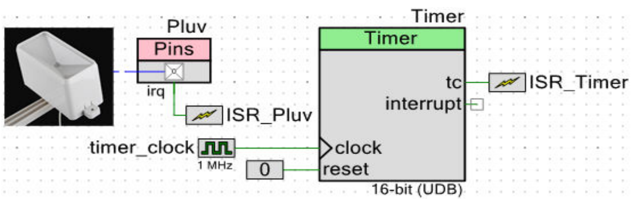

Figure-7. Connection of the Timer block to the rain sensor.

4.3 Temperature and Atmospheric Pressure

The I^{2}C block of the PSoC5LP allows the reading of the data obtained by the BMP280 sensor for both atmospheric pressure and temperature. It requires a series of previous readings and operations supplied by the datasheet and must be coded so that this sensor works correctly.

The first thing to do is to indicate the direction of the sensor, define the seven parameters of initial calibration for the measurement define the records corresponding to pressure and control and ID of the same. Figure-8 shows the connection of the I^{2}C block with the BMP280 sensor.

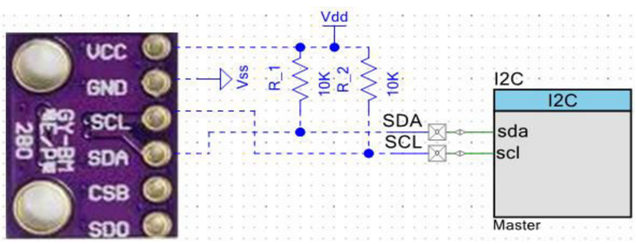

Figure-8. Connection of the I^{2}C block with the BMP280 sensor.

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This sensor has developed a C library that facilitates the configuration of it, which is provided by the manufacturer, however, it must be adapted to the embedded system that is being used. In this way, functions were created to read data from registers of different sizes, 8, 16, or 24. With this data reading, it is possible to obtain the initial calibration values that this sensor has by default and it is possible to initialize it for start the measurement. Figure-9 shows a part of the code implemented in the PSoC for the operation of the BMP280, specifically the code for sensor calibration.

```
void Leer_Coeficientes_Calibracion(){
    datos_cal.dig_P1 = Leer_Datos_U16_LE(BME280_DIG_P1_REG);
    datos_cal.dig_P2 = (int16)Leer_Datos_U16_LE(BME280_DIG_P2_REG);
    datos_cal.dig_P3 = (int16)Leer_Datos_U16_LE(BME280_DIG_P3_REG);
    datos_cal.dig_P4 = (int16)Leer_Datos_U16_LE(BME280_DIG_P4_REG);
    datos_cal.dig_P5 = (int16)Leer_Datos_U16_LE(BME280_DIG_P5_REG);
    datos_cal.dig_P6 = (int16)Leer_Datos_U16_LE(BME280_DIG_P6_REG);
    datos_cal.dig_P7 = (int16)Leer_Datos_U16_LE(BME280_DIG_P7_REG);
    datos_cal.dig_P8 = (int16)Leer_Datos_U16_LE(BME280_DIG_P8_REG);
    datos_cal.dig_P9 = (int16)Leer_Datos_U16_LE(BME280_DIG_P9_REG);

}
```

Figure-9. Code for sensor calibration BMP280.

4.4 Communication and Application on the Smartphone

The UART block is in charge of making the communication between the PSoC and a reference Bluetooth module KC-21 (Figure-10). As it is necessary that the communication is bidirectional, the block is configured in Full UART mode (Tx+Rx), at a speed equal to the speed programmed by the Bluetooth module of 115200 bps.

Figure-10. Bluetooth module KC-21.

In order to store and manipulate the data obtained by the serial port, it was necessary to enable the reception interrupt, which takes the received data and stores it in a vector of 4 positions, and then performs the corresponding concatenation to obtain the real value that is sends from the mobile application, this value will be stored in a variable which will aim to update the delay value that will have the sending of data from the PSoC to the Smartphone.

For the development of the mobile application for the weather station an existing application was used in the Google Play Store called Bluetooth Electronics. This application allows to program in a very simple way sub-internal applications that make use of the Bluetooth of the phone.

Initially the application developed allows you to configure the connection between the Bluetooth module KC-21 and the smartphone, once the Smartphone is connected to the Bluetooth device you can advance to the menu that contains the different display windows of the sensors as shown in Figure-11.

Figure-11. Data windows of sensor data.

Figure-12 shows in detail each of the windows that can be selected in the application developed in the smartphone. The detail of the temperature measurement design, which uses an LM35 analog sensor, was omitted in this document.

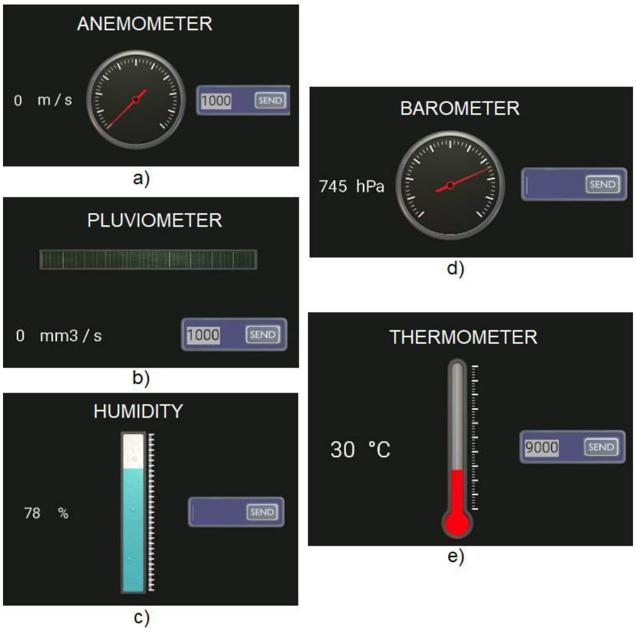

Figure-12. Detail of each window of the application for the weather station.

5. CONCLUSIONS

A functional prototype of a modular, low-cost meteorological station was reached, which has great advantages over commercial systems, since according to the variables that need to be measured, the system can be adapted to incorporate the necessary sensors.

According to the research and guidelines presented by the WMO, the priority variables for meteorological conditions measurement in the meteorological station prototype design were defined, also, based on the investigated requirements, the appropriate sensors were selected for the collection of data and the measurement methodology recommended by WMO.

The design obtained from weather station allows adapting a wide range of communication modules for data transmission, which offers an advantage over commercial systems, since according to the measurement environment and distance, modules can be adapted from a lower price and thus reduce implementation costs.

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