PRESCRIBED EMBEDDED SYSTEM's APPROACH TO PREVENTING METEOROLOGICAL DROUGHT IN NIGERIA.

O. S Bolaji[1], E. E Nymphas[2], T.O Aluko[3]
[1,3] *Department of Physics, University of Lagos, Akoka, Lagos state,* [2]*Department of Physics, University of Ibadan, Oyo State*
[1]oloriebimpjch2002@yahoo.co.uk, [2]efnda@yahoo.co.uk, [3]toluwisdom@gmail.com

***Abstract*— Drought indices based on weather information have been developed by different researchers over the years. Drought predictions are expected to be based on reliable weather data collected on continuous basis which could assist in planning and putting up various preventive measures. Nigeria as a country has been acknowledged to have inadequate, unsystematic, not reliable and inconsistent weather data and information by several climate change authors making it difficult to study and making predictions impossible. Over the scanty, ill-equipped, and sometimes non-functional weather measuring instruments in the country, this research prescribes a portable, low energy consuming embedded system. It was fabricated using the AVR microcontroller with the Atmel ATmega 328p chip, available in 28-pin DIP that fits into available IC sockets. Other features such as having a 23 general purpose I/O lines made sensor interfacing easy. Three sensors were interfaced and direct data acquisition from the sensors- MPX 4115, HIH 4000 and LM 35 for pressure, humidity and temperature was displayed on a Liquid Crystal Display, logged on to a scan disk memory and sent to the server via sim 800. Designed embedded system was calibrated with standard instrument and gave a correlation coefficient of 0.999, 0.998 and 0.997 for pressure, humidity and temperature sensors respectively. With well deployed embedded weather monitoring systems on a citywide or regional wide level, sufficient weather data will be available for accurate weather forecast and predictions which will help prevent meteorological drought and other weather-related disasters through early warning and effective preventive measures.**

***Keywords*— Drought, Embedded System, Sensors, Predictions, Microcontroller.**

I. INTRODUCTION

Regular availability of meteorological parameter data is very important, especially in relation to the current global environmental issues like climate change, drought and global warming, which are transforming the world's ecosystem on an extraordinary scale and pace. Report from a study conducted by [1] indicated that damages from climate change may be the highest for low latitude countries such as Nigeria. Unfortunately, low latitude countries are difficult to study because of the absence of complete information about them. Nigeria as a country has been acknowledged to have inadequate, unsystematic, not reliable and inconsistent weather data and information by several climate change authors [5].

For a developing nation like Nigeria and particularly a densely populated city like Lagos to survive the adverse effects of climate change, there is the need to establish better-equipped, easy to maintain, automatic weather stations on a citywide or regional wide level as against the scanty and ill-equipped, and sometimes non-functional ones that are currently present in the country. With enough weather monitoring systems, sufficient weather data will be available for accurate weather forecast and predictions and this will help prevent weather-related disasters through early warning and effective response system.

A. EMBEDDED SYSTEMS AND CHARACTERISTICS

An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real time computing constraints. It typically engages in data processing. Majority of embedded systems gather data from one or more sensors, subject the data to some form of conditioning and provides it directly, or via a buffer or multiplexing stage in cases involving large amounts of data, to a central processing unit (CPU), which processes the incoming data and typically outputs commands to the output conditioning phase [3]. For many embedded applications, microcontrollers are used in place of application-specific integrated circuit (ASICs), which significantly lowers cost and increases flexibility [13]. There are different types of microcontrollers and several works have been done over the years using them. Among others are: the implementation of a multisensory system using programmable systems on chip (PSOC) by [11], the design of a weather monitoring system using PIC16F877A microcontroller by [4], the development of an embedded system or industrial weather monitoring using the LPC1768 microcontroller by [12], a proposal of a weather monitoring system based on 8051 microcontroller by [2] and the design of a data logger and remote monitoring system or multiple parameter measurement using the Atmega 32 microcontroller by [8].

Sensors are a major source of data generation to most embedded systems. They are hardware devices that produce measurable response to a physical condition like temperature, pressure, humidity etcetera. They also sense physical data of the area to be measured. The continual analog signal sensed by the sensors is digitized by an analog to digital converter and sent to microcontrollers for further processing. They are small in size; consume extremely low energy, operate in high volumetric densities and possess adaptability to the environment [8].

II. RELATED WORKS

Reference [6] designed and constructed a weather station with modern sensors, a four-pin digital sensor DHTII, Motorola MPX4250A sensor and a 12-V brushless DC motor to measure four weather elements: temperature, relative humidity, atmospheric pressure and wind speed respectively. An 8-bit microcontroller, ATtiny 48/88 from Atmel Corporation was embedded in the sensors bank and TLP 315 radio frequency (RF) transmitter was used for data transmission. Data transmitted was logged periodically to a database.

The Temperature, Pressure, Relative-Humidity and Dew-point (TPHD) Microcontroller based Weather Sensor, measuring Temperature, Pressure, Dew point and Relative Humidity of the environment every two seconds and made them visually available in useful form through an LCD was designed by [10] for Trans-Africa Hydro-Meteorological Observatory (TAHMO) project. It utilized 4 major components: Microcontroller (PIC16F877A), Pressure transducer (MPX4115A), Relative Humidity and Temperature sensing transducer (SHT11) and a 16x4 LCD (LM041L). It automatically reads the variable of the environment upon power on and requires no human intervention or maintenance for years.

III. MATERIALS AND METHODS

All Temperature sensor LM35, Pressure sensor MPX 4115 and humidity sensor HIH 4000 were interfaced with AVR microcontroller for data acquisition and processing, data storage was done on an SD card and data transmission was through sim800 to the server, though first displayed on the LCD.

The system schematics as shown in figure 1 consist of Atmel Atmega chip 328P. The three sensors used were connected to the chip through port [C]. Port [C][1] was used for the temperature sensor, port [C][2] was used for the humidity sensor and port [C][3] for the pressure sensor and the three sensors formed a major part of the input stage. After processing the temperature, humidity and pressure data measured by the sensors (input data), the digitized output readings were displayed on an LCD connected to port [B][1-2] and port [D][5-2] of the ATmega chip.

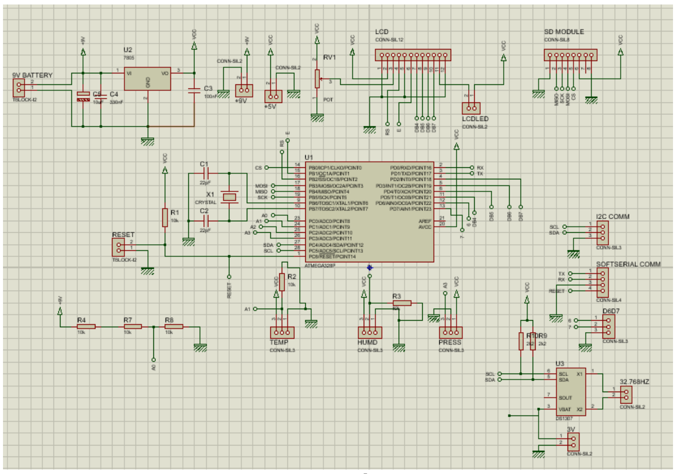

Figure 1: System Schematics

A. SENSORS USED

The sensors used for this system design are: LM35 - the temperature sensor, MPX 4115 – pressure sensor and HIH 4000 -humidity sensor.

LM35 is a precision IC temperature sensor. It has an output voltage proportional to temperature (in

°C), a sealed sensor circuitry therefore not subjected to oxidation and other processes. Its temperature range is from 55°C to 150°C and its accuracy is 0.01V/°C. Reference [9],[8] used this sensor for their system design.

The MPX4115 pressure is designed to sense absolute air pressure in an altimeter or barometer (BAP) applications. It gives an analogue output voltage which is proportional to the prevailing atmospheric pressure. The effective operation range is 15 to 115 kPa (2.18 to 16.7 psi) which corresponds to an output voltage range of 0.2 to 4.8 Volts. The transfer function of the barometric pressure sensor as given by the manufacturer is :

$$Vout = Vs(0.009*P-0.095) \pm Error$$

where *Vout* is the sensor output voltage and *P* is the applied pressure. The sensor error is negligible when operating within the temperature range of 0 to 85°C. Reference [6],[10] used this sensor for their system design.

HIH4000 has a molded thermoset plastic housing with cover. It has the following features: linear voltage output vs %RH, laser trimmed interchangeability, low power design, high accuracy, fast response time, stable low drift performance and it is chemically resistant.

B. THE AVR MICROCONTROLLER

The AVR microcontroller used for the design has a basic structure comprising a CPU employed to fetch data, decode it and at the end complete the assigned task successfully. It also possesses a memory chip which stores all programs and data. On the chip are Input and output ports which are basically employed to interface or drive different appliances and the Serial Ports give serial interfaces amid microcontroller and various other peripherals such as parallel port. The Timers or counters are in-built to control all counting and timing operations within the microcontroller.

The Atmel ATmega328P is a member of the Atmel 8-bit microcontroller family. It is available in 28-pin DIP (dual-inline package) that fits into available IC sockets. It has the following features - 32K bytes of In-System Programmable Flash with Read-While-Write capabilities, 1K bytes EEPROM, 2K bytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable Watchdog Timer with internal Oscillator, and five software selectable power saving modes. This allows very fast start-up combined with low power consumption.

C. SIM 800 WITH WEATHER SYSTEM

SIM800 is a complete GSM/GPRS solution in a Surface Mount Technology (SMT) module which is used for embedded applications. It is designed with a very powerful single-chip processor integrating ARM926EJ-S core based processor which is capable of supporting all Operating System such as Linux, Windows CE, and Symbian). It has an embedded TCP/IP (Transmission Control Protocol/Internet Protocol) stack for communication.

The communication between the designed weather system and the server is through GTP (GPRS Tunneling Protocol) used to transfer data via GPRS(General Packet Radio Service). SIM800 has an interface for external SIM (smart card for user identification) for internet access through ISP (Internet Service Provider). It was interfaced with the embedded SOC (System on Chip) through the serial port on pin 7 and pin 8 of the AVR microcontroller for receiver and transmitter respectively and the AT command syntax was used to pass instructions to the microcontroller through codes. AT commands is a set of instruction syntax (in String) developed by SIMCom- the manufacturer of SIM800.ATMega328P write the GPRS syntax to SIM800 to enable communication for weather data transfer. This transfer is accomplished through HTTP protocol. Each time a weather data is measured by ATMega328P, the data is sent to the server over GPRS through a URL (Universal Resource Location) written in string syntax, and it is included in AT command codes for HTTP. The measured data by the sensors are usually in form of a float variable, this variable is concatenated (concatenation is a method of embedding variables in string syntax) with string because SIM800 AT command can only be written in String syntax. The concatenated String – Variable is added to the URL provided as hypertext which is sent through HTTP to the server.

Power was supplied to the system through a regulated 5V dc source backed up with an inverter to prevent any loss of data as a result of power outage. The system could also be powered using solar energy source hence, a flexibility of the system design to fit into any form of power supply, whether AC or DC.

D. DESCRIPTION OF SYSTEM OPERATION

At first power, the entire system becomes energized. The input and output peripherals are set by the microcontroller as instructed through the processor from the assigned codes. According to the codes, after setting the global variables, it should run through the void set up enabling other peripherals such as the SPI, I2C, LCD and sim800 to the serial port of the system. The void set up is to run once then it goes on to the void loop instruction. This is to run repeatedly, sampling all the sensors connected to the system, probe them for data and convert them from analog to digital values based on the transfer function of the sensors. To save power and not to over flood us with every second data, the processor was instructed to display sampled values once every other minute and store them in an Sd card after which should proceed to sleep mode every other minute alternately with the sampling timing.

E. CALIBRATION OF SYSTEM

The calibration of the sensors that make up the system was done at the Nigerian Meteorological Agency (NIMET) using a barometer, dehumidifier and thermometer for pressure, humidity and temperature sensor calibrations respectively. The comparison of the readings from the designed system and the standard ones using Microsoft excel package gave a correlation coefficient of 0.999, 0.998 and 0.997 respectively.

IV. RESULT

The sensors were calibrated with standard sensors used at the Nigerian Meteorological Agency (NIMET) Oshodi, Lagos and gave the following plots as shown on figure 2, figure 3 and figure 4. This comparison was done using Microsoft excel tool. Figure 5 is the final outlook of the embedded weather monitoring system designed.

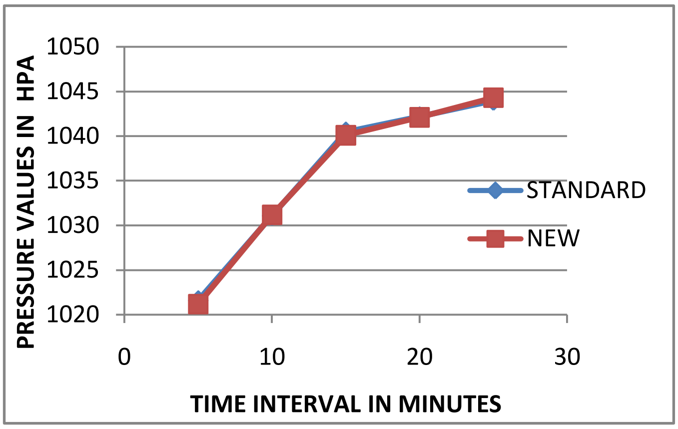

Figure 2: Pressure Sensor Calibration Profile

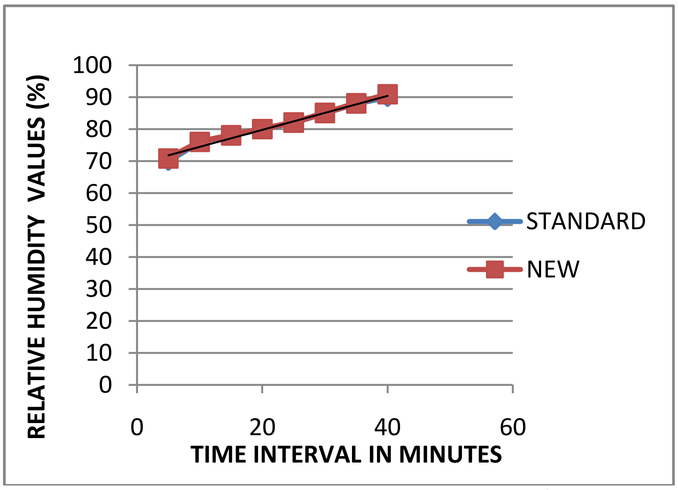

Figure 3: Relative Humidity Sensor Calibration Profile

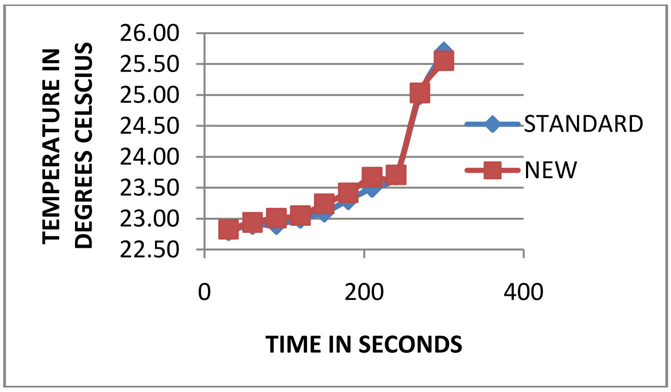

Figure 4: Temperature Sensor Calibration Profile

Figure 5: Final Outlook of Prescribed Weather Monitoring System

V. DISCUSSION

The correlation coefficient of the sensors; 0.999, 0.998 and 0.997 for pressure, relative humidity and temperature respectively is an indication of good instrument performance. Also, the advent of solid state physics has made sensors available to measure meteorological variables which can be integrated in microcontrollers to achieve this. For this embedded system designed, the three basic meteorological parameters were taken care of and the technology behind the design has given room for as many combinations of sensors as possible making availability of meteorological data possible. Reproducing and installing this system all over will help as recommended by the Nigerian Meteorological Agency CEO who warned that the availability of timely and accurate information from weather measurement data about impending severe weather phenomena is the first and critical step in weather disaster risk reduction by any country [1]. Knowing fully that “we are faced with drought in the country” stated by senator Ali Ndume in the senate meeting of may 7, 2015 reported by Omololu Ogunmade in Abuja titled “Senate bill seeks to end desertification, drought in Nigeria” [14], it is expedient since all droughts originate from meteorological drought, to harness the flexibility and ease of design created by microcontrollers to solve part of this meteorological problems.

VI. CONCLUSION

Designing this portable embedded system for some weather parameter measurements as seen in figure 5 and installing it in different parts of the state and nation with the communication system (sim800), measured data from all over can be collected and saved on the server as a database and archive for weather data over time. These data can be further analysed to form the basis for drought predictions for different parts of Nigeria and encourage early preparations to advert or control it.

REFERENCES

[1] Anforom Anthony (2016), “*NIMET advocates accurate information for Weather Risk Reduction”* The Guardian Nigeria, May 7, 2016.

[2] Dev, G, Dishant, M, Bhavya,V and Jimmy, M (2014), “*A GSM Based low cost Weather Monitoring System for Solar and Wind Energy Generation”* Institute of Electrical and Electronics Engineers, fifth International conference on the applications of digital information and web technologies (ICADIWT) Chennai, India.

[3] Edward, H.C and David, V.E (2010), PSoC 3/5 Reference Book, Cypress Semi-Conductor Corporation ,USA, pp 65-70.

[4] Ekejiuba, C.O and Kolawole, M.O (2014), “*An Automated Data logging system for Soil moisture and Temperature Determination”* International Journal of Innovative Science, Engineering and technology, vol. 1, Issue 9, ISSN 2348-7968, 729-737.

[5] Eludoyin, O. M and Adelekan, I.O (2009), “*The Physiologic climate of Nigeria”* International Journal of Biometeorology 57(2), 241-264

[6] Lanre, J.O and Umoru, S. A (2012), “*Design and Construction of a low cost Digital Weather Station*” Assumption University Journal of Technology (AUJ.T),16 (2), 125-132.

[7] Mendelsohn, R (2009), “*Climate change and Economic growth”* The commission on growth and development, Washington, U.S.A

[8] Nhivekar, G.S, Mudholker, R.R (2011), “*Data logger and remote monitoring system for multiple parameter measurement application”* E-journal of science and technology, pages 55-62.

[9] Noordin, K.A, Onn, C.C and Ismail, M.F (2006), “*A low-cost microcontroller-based weather monitoring system”* Chiang Mai University (CMU) journal vol.5

[10] Oduguwa, A.O and Akinfenwa, O.O (2013), “*Design of a Temperature, Pressure, Relative Humidity and Dew-point (TPHD) Microcontroller Based Weather Sensor”* Trans-African Hydro-Meteorological Observatory (TAHMO) Project.

[11] Priyanka, D.P, Patil,R.D, Nikita, N.S and Vishal, P.P(2015), "*PSoC multisensory for Temperature, Humidity and Light Intensity"* International Journal of Engineering Science Invention Research and Development, Vol.1

[12] Susmitha, P and Sowmyabala, G (2014), "*Design and Implementation of Weather monitoring and controlling System"* International journal of Computer Applications, vol. 97-No 3, 19-22.

[13] Titzer, B. L and Palsberg, J, (2005), "*Non Intrusive Precision Instrumentation of Microcontroller Software"* Proceedings. of the 2005 Conference on Languages, Compilers, and tools for Embedded Systems (LCTES) Chicago, USA.

[14] THISDAY, May 7, 2015. Senate bill seeks to end desertification, drought in Nigeria.