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SYSTEM OF ACQUISITION AND TREATMENT OF TEMPERATURE DATA STORED IN iBUTTON SENSORS THROUGH Wi-Fi

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ABSTRACT

This paper presents the development of an information acquisition and processing system through Wi-Fi wireless communication that allows the programming, capture and sending of data stored in an iButton sensor, to later centralize and store this information in a Web server. The design of the system was structured in three modules and a hardware interface based on the ESP 8266 chip, which was responsible for sensor control and communication. An application for mobile phones was developed to capture the data coming from the hardware application, this application has the option to serve as the programming interface for the iButton sensors and the interface for capturing the data recorded in the internal memory of the same device.

Keywords: serial communication, iButton, Wi-Fi, ESP8266, 1-Wire.

1. INTRODUCTION

In various processes such as floriculture, storage and transportation of food, storage of biomedical material, among others, it is essential to measure the temperature of the work environment and / or the products, in order to guarantee the quality of the final product, this is known as the cold chain [1], [2]. These processes eventually develop over extensive physical areas (greenhouses, crops, ports, and food transport) that force the industry to implement complex monitoring and temperature recording systems in servers linked to WAN/LAN networks.

In addition, industrial processes with specific purposes that were previously implemented on complex data platforms have been replaced by new applications developed for mobile devices such as smartphones and tablets. These mobile solutions have been successful due to the constant innovation in data processing capacity, storage and improvements in communication technologies in wireless networks for mobile devices.

The complex systems of monitoring, recording and storage of temperature data, currently existing in the industry, can be replaced by a system that, using a specific sensor, captures the temperature in a predetermined period of time, stores said measurement in a memory and subsequently, it is sent, that measurement, through a mobile device in order to centralize said information in a Web server.

The process of capturing the temperature in a period of time and the storage of this measurement is achieved through a sensor belonging to the iButton family called Thermochron, the way to program and collect the information stored in the Thermochron with smartphone and the process to centralize and store this information on a Web server is what is intended to be presented in this article.

2. DESCRIPTION OF iBUTTON

For the development of the application we used DS1921G Thermochon from Maxim Integrated which is a rugged, self-sufficient system that measures temperature and records the result in a protected memory section. The recording is done at a user-defined rate, both as a direct storage of temperature values as well as in the form of a histogram. Up to 2048 temperature values taken at equidistant intervals ranging from 1 to 255min can be stored.

The histogram provides 63 data bins with a resolution of 2.0°C. If the temperature leaves a user-programmable range, the DS1921G also records when this happened, for how long the temperature stayed outside the permitted range, and if the temperature was too high or too low. An additional 512 bytes of battery-backed SRAM allow storing information pertaining to the object to which the DS1921G is associated. Data is transferred serially through the 1-Wire protocol, which requires only a single data lead and a ground return. Every DS1921G is factory lasered with a guaranteed unique, electrically readable, 64-bit registration number that allows for absolute traceability. The durable stainless steel package is highly resistant to environmental hazards such as dirt, moisture, and shock. Accessories allow the DS1921G to be mounted on almost any object including containers, pallets, and bags [3].

2.1 Key Features

High accuracy, full-featured digital temperature logger simplifies temperature data collection and dissemination of electronic temperature record:

- Accuracy ±1°C from -30°C to +70°C
- Digital thermometer measures temperature in 0.5°C increments
- Built-In Real-Time Clock (RTC) and timer has accuracy of ±2 minutes per month from 0°C to +45°C
- Automatically wakes up and measures temperature at user-programmable intervals from 1 minute to 255 minutes
- Logs consecutive temperature measurements in 2kB of data log memory
- Records a Long-Term temperature histogram with 2.0°C resolution

- Programmable temperature high and temperature low alarm trip points
- Records up to 24 timestamps and durations when temperature leaves the range specified by the trip points
- Individually calibrated in a NIST-Traceable Chamber
- Complies to standard EN12830
- 512 Bytes of general purpose battery backed SRAM

Rugged construction survives harsh environments:

- Water resistant enclosure (IP56) or waterproof if placed inside DS9107 iButton capsule (exceeds water resistant 3 ATM requirements)
- CE, FCC, and UL913 Certifications

Simple serial port interfaces to most microcontrollers for rapid data transfer:

- Communicates to host with a single digital signal up to 15.4kbps at standard speed or up to 125kbps in overdrive mode using 1-Wire Protocol [3].

2.2 Common Features of iButton

In Figure-1 you can see an image of the pin distribution, size and general characteristics of an iButton DS1921G. There are other features that are common to iButton:

- Contains a unique digital identification and information through momentary contact.
- Multipoint control (2 contacts) for the 1-Wire network.
- It contains a data storage chip where it stores information in a compact way.
- The packaging type of iButton and its factory reader are easily aligned to read it.
- Stainless steel case engraved with a resistant registration number in industrial environments.
- Easy installation with self-stick adhesive, retained by ties, or with a closed pressure ring provided by the manufacturer.
- Detects presence when the reader applies voltage for the first time.

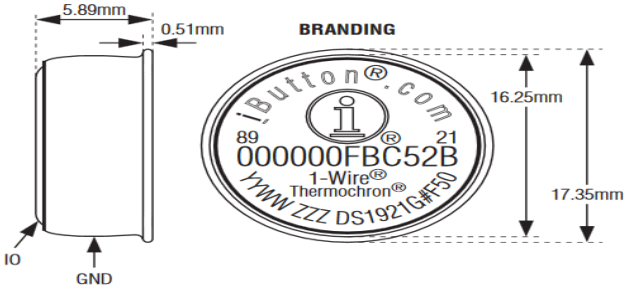

Figure-1. Characteristics of the iButton DS1921G [4].

2.3 Block Diagram of the iButton DS1921G

The block diagram shown in Figure-2 shows the relationships between the main control and the memory sections of the DS1921. The device has seven main data components: 64-bit lasered ROM; 256-bit scratchpad; 4096-bit general-purpose SRAM; 256-bit register page of timekeeping, control and counter registers; 96 bytes of alarm time-stamp and duration logging memory; 126 bytes of histogram memory; and 2048 bytes of data-log memory. Except for the ROM and the scratchpad, all other memory is arranged in a single linear address space. All memory reserved for logging purposes, including counter registers and several other registers, is read only for the user. The timekeeping and control registers are write protected while the device is programmed for a mission [4].

Figure-2 also shows the parasite-powered circuitry. This circuitry "steals" power whenever the IO input is high. IO provides sufficient power as long as the specified timing and voltage requirements are met.

Each DS1921G contains a unique ROM code that is 64 bits long. The first 8 bits are a 1-Wire family code. The next 48 bits are a unique serial number. The last 8 bits are a cyclic redundancy check (CRC) of the first 56 bits.

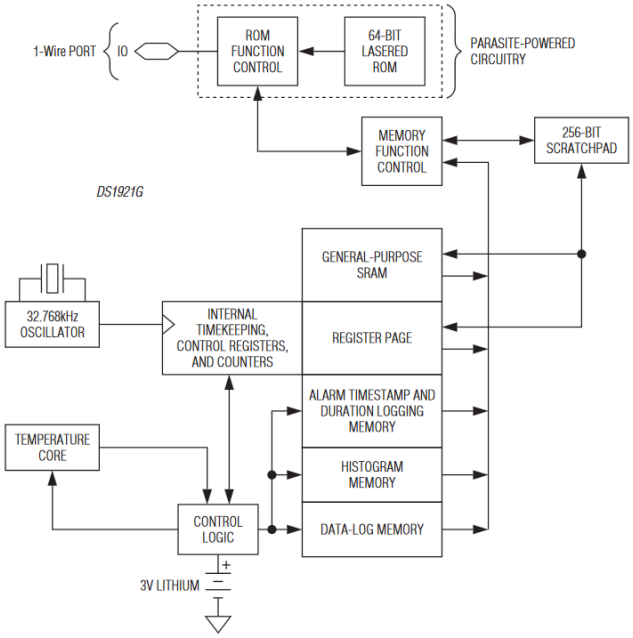

Figure-2. Block diagram of the iButton DS1921G [4].

Figure-3 shows the DS1921G memory map. The 4096-bit general-purpose SRAM makes up pages 0 to 15. The timekeeping, control, and counter registers fill page 16, called register page. Pages 17, 18, and 19 are assigned to storing the alarm timestamps and durations. The temperature histogram bins begin at page 64 and use up to four pages. The data-log memory covers pages 128 to 191. Memory pages 20 to 63, 68 to 127, and 192 to 255 are reserved for future extensions [4].

ADDRESS	32-BYTE INTERMEDIATE STORAGE SCRATCHPAD	
0000h to 01FFh	GENERAL-PURPOSE SRAM (16 PAGES)	PAGES 0 to 15
0200h to 021Fh	32-BYTE REGISTER PAGE	PAGE 16
0220h to 027Fh	ALARM TIMESTAMPS AND DURATIONS	PAGES 17 to 19
0280h to 07FFh	(RESERVED FOR FUTURE EXTENSIONS)	PAGES 20 to 63
0800h to 087Fh	TEMPERATURE HISTOGRAM MEMORY	PAGES 64 to 67
0880h to 0FFFh	(RESERVED FOR FUTURE EXTENSIONS)	PAGES 68 to 127
1000h to 17FFh	DATA-LOG MEMORY (64 PAGES)	PAGES128 to 191
1800h to 1FFFh	(RESERVED FOR FUTURE EXTENSIONS)	PAGES 192 to 255

Figure-3. Memory map [4].

Thermochrons are recyclable and under normal conditions record data for up to 10 years or 1 million temperature measurements. The iButton can be easily attached to cold or frozen food containers, blood products, chemical products or drug reagents, recording the time and temperature during transport and storage, can apply in environmental measurements to monitor areas such as greenhouses and some mission critical sites such as data centers. By registering this information of the material sensitive to temperature, preventive and / or corrective actions can be taken that allow the normal occurrence of the supervised processes.

The configuration of the iButton can be carried out using a PC or a portable device. The iButton is connected to a Blue Dot receiver (low cost serial or USB reader), like the one shown in Figure-4 and then with the configuration software the parameters are selected: Alarm, Internal clock, Sampling rate, Selection of the time at which the sampling will begin and Define what to do if the memory runs out (stop or rewrite) [5].

Figure-4. iButton reading cable [6].

2.4 1-Wire Bus

1-Wire is a communications protocol designed by Dallas Semiconductor. It is based on a bus, where there is a master and there may be several slaves in a single line of data. The data line requires a pull-up resistor connected to the power supply. A 1-Wire device network consists of a master and one or more slaves that have a single "open drive" data pin, to which a "Start" resistor is connected, normally anchored to + 5VDC. One of the characteristics of the 1-Wire technology is that each slave device has a unique and unrepeatable identification recorded in its ROM memory at the time of its manufacture.

The networks of 1-Wire devices can easily have a length of 200m and contain about 100 devices. Each 1-Wire device has an internal oscillator that synchronizes with the master each time a falling edge appears on the data line [7]. Figure-5 shows the typical connection between the iButton (slave) and the master device that handles all communication control.

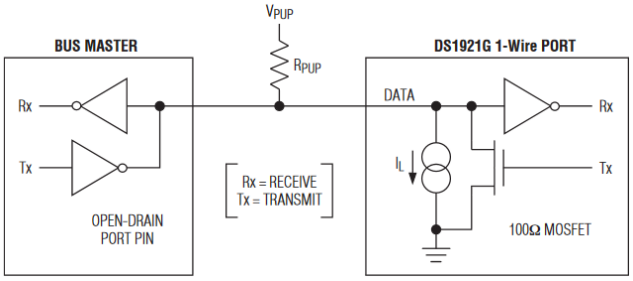

Figure-5. Slave master connection of the iButton [4].

The communication in the 1-Wire protocol consists of a sequence of transactions developed with the steps of Initialization, commands and ROM functions, commands and control functions, data transfer, which will be described below:

- **Initialization:** All communication on the bus is initiated with a reset pulse, this down pulse synchronizes all the slave devices that are on the bus, this pulse in low logic state lasts 480µs.
- **ROM commands and functions:** Once a microcontroller or master device receives the presence pulse of the slave devices, a ROM command can be sent. The ROM commands are common to all 1-Wire devices, basically they are related to the search, reading and use of the ROM ID of the slave devices connected to the bus for their corresponding identification.
- **Control and memory commands and functions:** These are the commands used to read / write in valid memory locations, read scratchpad memory segment (high speed internal memory for temporary storage of preliminary information), control the start of the conversion operation of an ADC, initiate the measurement of a temperature or manipulate the state of an output bit, among other cases. Each device defines its own set of commands.
- **Data transfer:** The reading and writing of data on the 1-Wire bus is done through Slots (insert, enter), the generation of these is the responsibility of the master (downstream generator that synchronizes the bus and leaves it ready to start communication). For the present case corresponds to the hardware interface set and the commands sent by the mobile device. When the master reads information from the bus, you must force the data line to a low state for at least 1 microsecond and wait for about 15 microseconds to read the status of it. The logical state of the line at that moment will be determined by the slave device.

3. METHODOLOGY

The design of the system for acquiring, sending and processing temperature measurement data stored in iButton Thermochron sensors is structured in three modules (Data processing and visualization module, Information administration module and Information management module) and a Connection hardware interface (Hardware module).

Figure-6 shows the block diagram that represents the proposed system with each of the modules indicated above. The coupling between the modules is done by structuring the way in which the data is delivered.

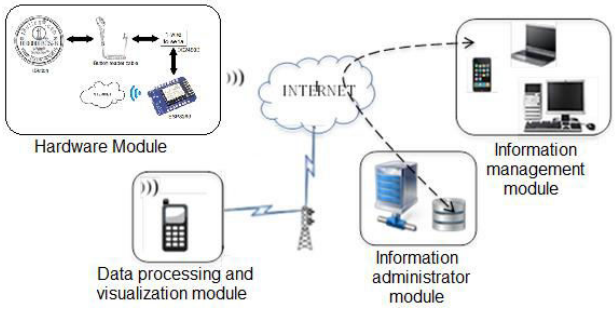

Figure-6. Block diagram of the proposed solution.

3.1 Hardware Module

The configuration shown in Figure-7 was used for the hardware module.

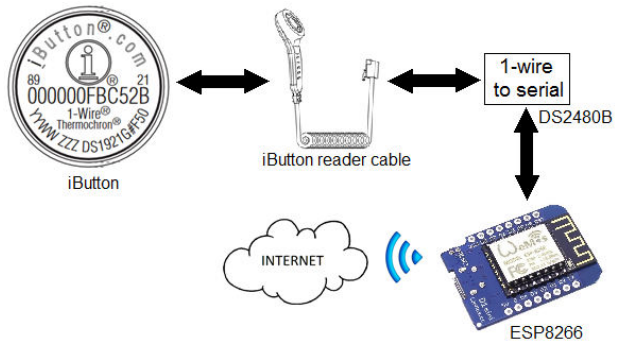

Figure-7. Block diagram of the hardware module.

The operation of this module is described below: the temperature information acquired in the time period configured by the user is stored in the iButton when the user requests the data through the mobile application on the smartphone (described in the following numeral of this document), this requirement is served by the module ESP8266 [8] (which internally includes a microcontroller where the entire application was programmed) responsible for Wi-Fi communication and serial communication with the protocol converter 1-Wire to asynchronous serial (DS2480B) [9], which is responsible for controlling the proper functioning of the 1-Wire bus.

3.2 Data Processing and Visualization Module

This module contains a mobile application developed specifically for the processing and visualization of the data obtained from iButton. The integrated development environment (IDE) aims to improve the productivity of the developer by offering a set of tools that are fully cohesive with each other, through a graphical user interface. The IDE that was used for the development of the application was NETBEANS. In Figure-8 you can see one of the windows of the mobile application.

Figure-8. Mobile application presentation window.

The mobile application was developed taking into account two modes of use:

- **Programmer mode:** It is the mode responsible for writing the data in the Termochron sensor, programming the sampling rate, programming the upper alarm and programming the lower alarm.
- **Capture mode:** It is the mode responsible for reading the data of the Termochron sensor, temperature measurement data in the preset times and alarm activation data. In this mode, during the development of the application, the way of sending the data and the timing of sending them was implemented.

3.3 Information Administration Module

The information management module is formed by the information storage and processing equipment together with the applications and computing tools responsible for managing the correct flow of information among all the components of the loading system and processing said information according to the operating rules [10].

The implementation of the System on a standard Web platform allows the access of authorized third parties to consult or load information in real time without requiring additional communication applications. Through the use of authentication and security technologies widely used and tested on the Internet, the validity of the information transmitted to and from the module for capturing, processing and sending data to the information management module is guaranteed.

The design and implementation of the database will define the methods, logical means and information storage technologies, as well as the relationships established within it and towards other data sources [11]. In Figure-9 you can see one of the working windows of the Web application implemented.

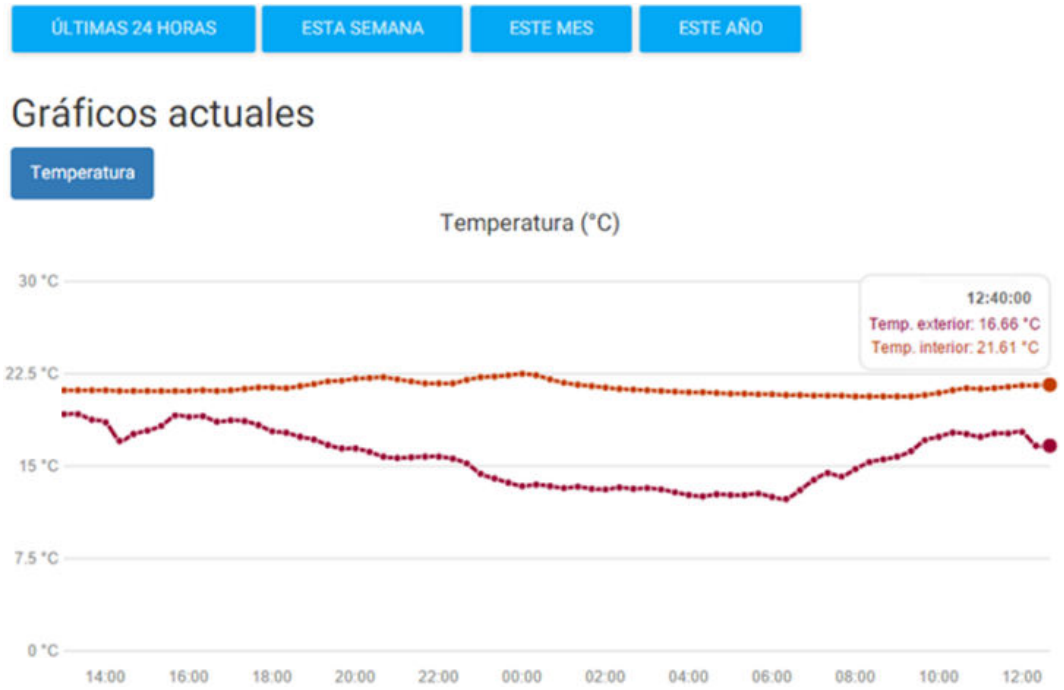

Figure-9. Web application interface.

3.4 Information Management Module

In this module we designed and implemented a Web portal (Web server) accessible from browsers based on Windows, Android and OSX operating systems, allowing system users to manage the information stored in the Information Manager Module.

This Web management portal allows the administration, management and monitoring of the system, admitting the entry of registered and enabled Web users, according to the user profile granted. The profiles delimit the Web user the ability to execute one or more processes from the Web portal, generating what is known as Roles.

Two types of Web users are managed: user administrator and user of monitoring, which can enter the management portal through their user name, an access password of 8 digits and a CAPTCHA code generated by the server. The following describes the users and the roles that each one of them can execute in the Web management portal [12].

Administrator user

This user will be able to execute the following roles:

- **Role of roles:** Manages the process responsible for creating and editing data of the roles, which are the processes that can be executed from the Web management portal. Each role is linked to a single PHP file of the information management module and is presented in the Web management portal as a Submenu.
- **Role of modules:** Manages the process responsible for creating and editing data of Management Modules. The Management Modules may have related one or more work roles, they are presented in the Web management portal as a Menu.
- **Access role:** Manage the process responsible for creating the monitoring users, edit their data and grant the management modules for each of them. In the procedure for creating the monitoring users, the data of the User, Name, Address, Telephone, Associated Management Modules, Email and Observations will be minimally related. After the creation procedure, the new registered user will receive an email to his registered email account, with the user's data and password.

Monitoring user

This user will be able to execute the following roles:

- **Record role of the Termochron sensor:** Manages the process of relating the ID of the iButton Termochron with the Monitoring User. In this role you can include the data of the specific location and the work that the Termochron sensor will accomplish.
- **Role of statistics:** Manages the process of visualizing, through graphics, the behavior of one or several Termochron sensors in a predetermined time range.
- **Role of reports:** Manages the process of downloading a CSV file with information on the behavior of one or more Thermochron sensors in a predetermined time range.

- **Role of alerts:** Manages the process of registering one or more emails associated with the Termochron sensors, in order to generate alerts to these emails with the information of the activated alarms of the Termochron sensors at the moment they enter the administrator module information.

4. CONCLUSIONS

The multiplicity of applications in which the iButton Thermochron can intervene, versatility of packaging and its small cost in the DS1921 version guarantees a broad portfolio of clients with diverse applications that may be interested in acquiring the services that this application offers.

The development of this application is the gateway to design mobile applications for the transmission of other sensors of the Maxim family, such as temperature and humidity sensors (hygrometers) with high-capacity customers such as pharmaceutical supply chains, where said variable must be measured and controlled, in several countries of the world the relevant regulations already exist.

The development of the Web application is modular and scalable, allowing it to grow completely, thus managing to meet the market's demands

The tests carried out were only of functionality, another type of tests such as stress tests, where data base capacity is measured, capacity of communication channel were not made, remain pending for the case of continuing the process of implementation of business with this type of products.

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