

Embedded board development with Analog Inputs and IoT features.

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Abstract— This research introduces the development of a system adapted to perform data communication between analog sensors and the Firebase database service, a platform that allows collecting information in a NoSQL model. Using a V-model methodology, a PCB design was developed to minimize the materials usage and reduce the physical space of the prototype. The achieved results were able to evidence that the use of Wi-Fi communication is effective in sending data to the database used.

Keywords— *Firestore, NoSQL, Database, IoT, Wi-Fi Module, PIC, Serial.*

1. INTRODUCTION

The use of sensors is one of the most useful tools when working with machines that need to be constantly monitoring their status. Normally these sensors are read locally, without having a backup for later reading in case of failures or if you want to know the behavior of a machine in a certain period of time. An alternative that seeks to solve this problem is the implementation of devices that can store these data and communicate them in real time, ensuring that the data will not only be communicated effectively, but will be stored permanently and securely. This research aims to contribute to the development of such technologies, proposing a prototype design with the ability to connect to an online database service, using a Wi-Fi connection following the guidelines of IoT technology to store information from analog sensory elements. The challenge of IoT is the creation of a bridge between the physical world and the world of information for the processing of data obtained from electronic equipment through interfaces between the user and the equipment [1]. One of the most neglected parts and one that is less and less taken into account when designing and implementing these systems is the tracking and storage of this data in some support. The result of IoT technology is the reduction of the main cost of transactions performed by companies, the growth of labor productivity and the increase in the efficient use of resources by companies and organizations [2]. It is a fact that the reduction of operating costs is and will be the goal of large industries, but they always seek quality and excellence in each of the products they offer to their customers. Therefore, implementing technologies that facilitate this process is a point of interest for organizations. The development of this research allows not only to facilitate the collection of sensory information, but also to be able to monitor this information effectively and safely in the shortest possible time from anywhere in the world. These characteristics are increasingly required by the different control systems, in order to provide companies with the current status of production

plants, identify the origin of a failure or even foresee an accident caused by a malfunction of equipment, reducing with the latter possible occupational accidents so that the safety of operators can be guaranteed.

2. CONTEXT

1. Databases and Cloud Storage

The idea of cloud computing dates to 1960 by Joseph Carl and John McCarthy and was limited to the processing of census data and financial transactions [3]. This was due to various limitations in the form of media storage, which will determine the level of speed and ease of access to data [4]. This shows that the greater the accessibility required, the more the database model to be used must be considered. When relational databases are implemented, each data is stored in the form of interconnected tables formed by rows and columns where the data is stored.

Normalizing tables causes queries to generate a high load on the systems when the data request involves many tables. Firestore, which is one of the NoSQL databases, where the construction of data structures is stored in JSON format, provides a high level of efficiency and speed in data processing. If they are compared with MySQL databases that have disadvantages compared to these, clearly they can be considered better, but that does not mean that MySQL databases are obsolete, depending directly on the type of application that is required should be critically analyzed between a model or another. A MySQL Database model consists of storing information in the form of tables, presenting the problem that each data to be stored must be perfectly identified. Firestore is a NoSQL cloud-based database, which synchronizes data between all clients in real time and is available when there is no network connectivity thanks to the local cache [5]. Each of these features have been implemented to be compatible with Android, iOS, Web model, Unity and even C++ features, as highlighted by Google in the official Firestore documentation where it shows its SDKs.

2. Wifi communication module Wemos D1 Mini

The Wi-Fi module transmits the data obtained by the board to the database where it will be stored. The chosen module is the ESP-12F, which has multiple advantages, such as being able to connect to networks with WPA and WPA2 security, has 4 MB flash memory and has different Wi-Fi modes. It can communicate via UART interface, where it communicates with microcontrollers or devices that use this protocol, which gives it versatility in data exchange.

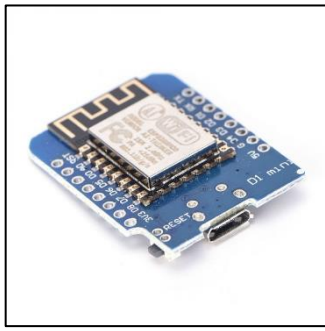


Figure 1. Wemos D1 Mini

1. RESULTS

First proceeded to make each of the parts separately, where it is possible to ensure the correct functioning of the prototype. Pins were added to be able to make the sensor change as deemed appropriate. And a way of transferring the data obtained by the microcontroller to the database was implemented, making use of the Wi-Fi module.

3. Softwares

The techniques and tools must be identified in order to optimally develop the prototype design. In the case of this research, use is made of Electronic Systems Design and PCB's software, such as Proteus, which is used to develop these systems in a professional manner and presents multiple tools for design, another software that is implemented is the use of MCAD's or Mechanical Computer Aided Design Software, software used to develop mechanical elements or 3D designs, which allows 3D designs of plates using software such as SolidWorks. The use of one software or another depends directly on the environment and user comfort, this means that it does not directly affect the use of one or the other to successfully develop the PCB design or board simulations.

4. PCB Design and Manufacturing.

The expectation when manufacturing PCBs is to obtain the minimum number of defects and errors possible, being the engraving the one that represents the most important and critical part of the process, being 70% of the manufacturing cost. Inspection should be done at an early stage of the process and not have defective PCBs discarded due to detections at late stages of the manufacturing process [6]. Applying simulation technologies can not only reduce existing experimental risks, but it also reduces teaching costs, efficiency, and revisions that can lead to corrections before showing the final prototype. Experimenting and testing become a very important role when developing new technologies in the electrical and electronics industry, but due to lack of resources they are often not completed successfully. This is where simulation technology is born. In electronics and electrical experiments, it is necessary to perform the electrified experiment. High resistance voltage and current has some danger. If the circuit design is incorrect or the operation is incorrect, the experimenter may run the risk of suffering an electric shock [7].

3. METHODOLOGY

The V model is based on following stages ranging from Design to implementation, in many cases you can return in the stages to finish details and thus create viable and safe prototypes. whenever a problem is found or a change is required, you can return to one of the previous stages to make the corresponding changes.

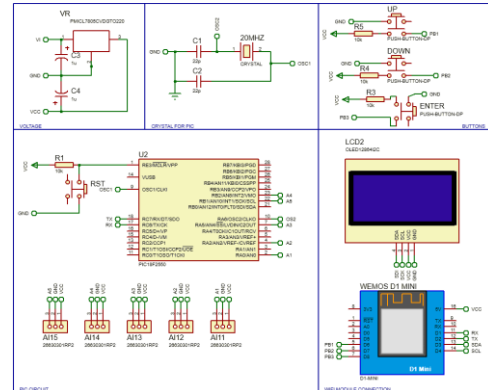


Figure 2. Schematic of the Prototype

The schematic presented in Figure 2 shows the components used in the final prototype, including the power supply.

1. Sensory subsystem.

The plate has the terminals to be able to make the sensor change as deemed appropriate. The analog inputs are thought to use a maximum of 5 volts sensor and are measured by a PIC18F2550 microcontroller. ADC functions are used, which allow the measurement of sensors by means of analog pins.

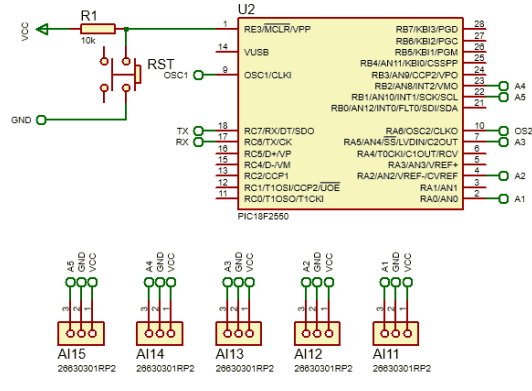


Figure 3. Schematic of Sensory subsystem

2. Communications Subsystem

For the communication subsystem, the UART protocol was used, which uses the RX and TX pins and is the direct way to transfer the data to the ESP module, this is the only function that is given to this protocol. This module connects to the Wi-Fi network and after that proceeds to check the status of the database, checking the access and permissions to read and write data.

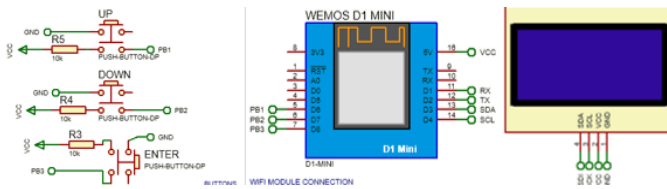


Figure 4. Schematic of Communications subsystem

An Adafruit OLED I2C screen is also connected to the Wemos module, which makes it easier to monitor the status of the connection and the levels of the sensors coming from the microcontroller, also adding greater functionality to the design and the origin of the data can be modified without altering the operation of the project. Firebase is used for data storage since it has a JSON record design, which makes the records can be read and written more simply and quickly. Another advantage is the small amount of storage required by a single piece of data. A JSON record was exported from the database, inside it contains the text: "159", according to the data obtained, a file can have a maximum size of 40 bytes of storage if there is enough information to store.

Once the work of each of the parts is completed separately, the design of the electronic board where the components are mounted is carried out, 3 plates of approximately 5 centimeters by 5 centimeters were designed. In each one, the connections to be made to join each plate are taken into consideration, as well as the quartz crystal required by the microcontroller to regulate its frequency, the buttons, and other connections between components. The objective of making this number of plates is to optimize the space to be used, the consumption of materials and a better handling if it is seen as an almost finished product.

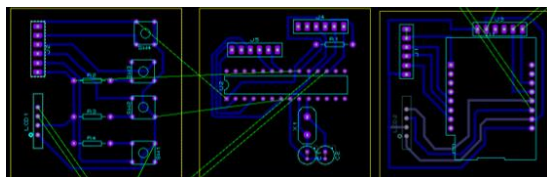


Figure 5. PCB design.

The final prototype of the PCB to be used is developed and the 3D design is made in SolidWorks to have a preview of the board and its final appearance, after having made multiple manufacturing methods it can also be extracted, which of these techniques is the one that is more economical, fast and of the highest quality, using the IPC-A-610 design standard the prototype allows reparations and massive production. To begin with the validation, 5 values of the analog sensors sent to Firebase are taken. With these values it can be concluded that there is no loss of data between obtaining information and communicating it. Since there was no loss of connectivity at the time of making the measurements, it is said that the effectiveness is 100%. In terms of database usage, the metrics provided by Firebase are obtained, in which it can be concluded that the bandwidth consumption is very small.

Firebase as a platform returns the value of Data downloaded by connected clients in intervals of one minute, the division of the KB used in one minute by 60 is made to obtain the result of a required bandwidth of 15.79 KB / s, something insignificant for the networks of 10 to 100 MB residential available in the country. As most database service providers calculate the prices to charge their customers based on the storage used, it is an important aspect to consider.

In this cases e use only 19.4KB of disk storage to save the sampling values. This makes it easy to export it into a file where the tree of all the data received by the platform is located and reduce data storage costs.

For the manufacture of the PCB different methods can be used, the most common being the method of etching in acid or by removal of material that is carried out in a CNC. For the manufacture of the first PCB board of the prototype the acid engraving method was used but implementing the use of Voltera, a device designed for the manufacture of PCB plates through an innovative technique, which consists of drawing the tracks with special conductive ink that when baked solidifies and becomes the tracks where welding can be performed, This machine is designed for educational environments so that students learn to manufacture their own boards with a more automated process but given the high cost of materials it becomes an unviable alternative when making many electronic boards.



Figure 6. Adapted Voltera working with Permanent Marker.

After many attempts to integrate the use of Voltera in the research it was concluded that it can be used to be able to make the drawing of the electronic board using a permanent Marker, although it is a functional method I do not recommend implementing since it would be wasting the potential of this device and is a method that consumes too much time. But if it becomes an alternative use for this device if you have difficulties in obtaining its recommended materials. For the first prototype, a board is designed on which all the components are mounted temporarily, since it was used only for connectivity tests and data communication. Once the internet connection tests are finished, the operation of the sensor communication and its correct sending of data to the Firebase platform is reviewed, a redesign is carried out to correct and improve possible design errors that could cause problems in the future.

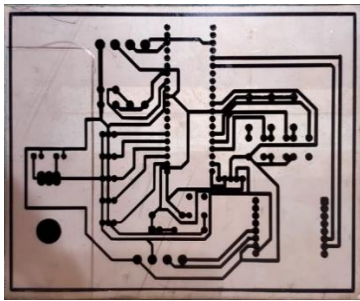


Figure 7. First Plate Design for Testing and Evaluation.

The final prototype of the PCB to be used is developed and the 3D design is made in SolidWorks to have a preview of the board and its final appearance, which is optimized both in space and in quantity of material to be used, using only the components required for the correct operation of the circuit.



Figure 8. Final Prototype Design and Electrical Circuits.

For the second design and which is considered final design, a system of multiple interconnected plates using pins is proposed. The approximate size of these plates is 5 cm per side.

Subsequently, the performance tests of the complete system were carried out.

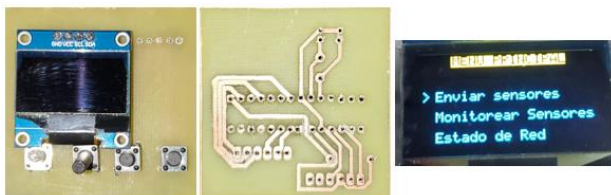


Figure 9. Final PCB Design and Working Display

As visualized in the 3D rendering, the separators that are normally used in drones are used to ensure that the plates were made firmly enough to withstand the pressure made by the users on the buttons. This can be considered as the final prototype of the research, where it is possible to create an innovative design and that allows to use a modular type of plate without using cables. Which allows you to be sure that it will not fail due to a bad connection of any of these.

The System follows the operating diagram presented. The process follows 4 stages:

1. Reading of Physical Data from sensors, the Microcontroller obtains the external data, scale these values from 0-1024 to 0-255.
2. The Microcontroller shares the values concatenated in a long string format to the Wi-Fi Module using the UART protocol, for subsequent transmission to the cloud.
3. The cloud in this case Firebase, receives, collects, and stores the data in real time, allowing the monitoring of this values in the real time console of the database



Figure 10. Operating diagram

The module checks the status of the Wi-Fi network, if it is not available, the system is kept waiting for one. The status of the database is checked, user authentication is performed and in case these fail, an error screen is displayed. Finally, it is checked if there is data from the microcontroller for later sending and storing them.

4. CONCLUSION

- It was possible to develop an embedded system that collects the reading of 5 analog sensors, providing their measurements for subsequent sending to the Internet, allowing real-time and remote monitoring of the operation of this type of sensors, using a modular type design was achieved by reducing the space required to 5 cm³ of area.
- Google's Firebase service was implemented to store and monitor sensor data in real time, verifying their transmission in extreme cases of bandwidth drops or connection loss, using a transmission speed of approximately 20 KB/s and a storage used of less than 100 Kilobytes.
- Additionally, a low-cost alternative for Voltera is implemented, reducing errors in copying the circuit to Bakelite and shortening the time of this process to 15 minutes when compared to the heat transfer method. In this way, the cost of the ink is reduced by being drawn by a low-cost marker and not the conductive ink by Voltera.

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