Abstract—A monitoring system for a battery powered electric vehicle (EV) has been implemented and tested. The system allows voltage and temperature monitoring of each one of the 24 batteries. Besides, the system will also allow monitoring the energy delivered by a photovoltaic cell which is being implemented on the roof of the vehicle. The monitoring method uses digital sensors with technology “One Wire”®, which allows transmitting data from all batteries through a serial bus. The information is shown in a LCD screen with 320x340 pixel resolution. The paper explains the main characteristics of the system and shows some photographs and some experimental results through the information given by the LCD screen.

I. INTRODUCTION

As the result of new developments on experimental battery-powered electric vehicles, the need for fast information related to different components and equipment emerges, especially data related to battery life and knowledge about the overall system efficiency. Also, the capability of preventing fires and explosions produced by the bad operation of individual batteries is required. Then, it becomes essential having specific data-monitoring and data-logging systems to acquire this information. Specially, in the case of batteries, individual voltages and temperatures are necessary to identify. Then becomes visible the problem of different voltage reference levels and the need for galvanic isolation. In this way, each battery can be replaced in case of failure and it is possible to view the conditions of the charging/discharging process.

The classical method to measure voltage and temperature in a battery pack inside an EV, is based on implementing voltage and temperature sensors for each one of the batteries [1]. These sensors (with an appropriate galvanic isolation for voltage measurements) produce analog signals which are individually transmitted to a central management system, then converted to digital signals and processed by a microprocessor. The microprocessor makes the appropriate calculations to show the information on a screen or store it for later analysis. However, two problems arise in the design of this monitoring method: electromagnetic interference (EMI), and the huge amount of wires required for its implementation. These problems become complicated because of difficulty in noise isolation and hardware management (too many shielding wires) [2]. Besides, the system obviously needs multiplexers to control every signal coming from each one of the individual batteries in the string.

This work presents a different approach: sequential monitoring with only “one wire”, using special integrated sensors designed with individual identifications. The system implemented does not allow a balanced charging/discharging of the batteries, but it can be the base of it.

II. THE VEHICLE

The vehicle used for the implementation of the “One Wire” [4], monitoring battery system, is a Chevrolet S-10 converted to EV by Solectria Corporation. Each one of its 24 batteries has a small module containing the sensors and connected to a single-wire net. Figure 1 shows a picture of the Chevrolet S-10 EV.

A. Batteries

The lead-acid 12 Volts batteries of this EV are located at the bottom of the pick up and also at the front, where normally the engine of an ICE (internal combustion engine) is placed. Each battery has a capacity of 55 Ah. Under normal conditions the batteries have near 5 degrees Celsius over ambient temperature and battery operation is between 0ºC to 40ºC. However, in case of abnormal operation, the temperature can reach 50ºC.
The voltage of the batteries is normally between 12 to 13 Volts. When the battery is in good conditions, but discharged, the voltage can be 11.5 Volts. If the battery gets out of this range it has a problem inside it. The location of the batteries inside the vehicle is displayed in Figures 2 and 3.

III. HARDWARE IMPLEMENTATION

Figure 4 shows a diagram of the monitoring and logging system.
As already mentioned, this paper presents a sequential monitoring system with just one wire, and digital data transmission instead of analog. This alternative asks for special semiconductors, capable of sending the captured information from each battery to the microprocessor. In this work, a special integrated sensor from Dallas Semiconductor, designed for monitoring purposes in small equipment has been used: the DS2436 [6].

A. The DS2436 sensor

The digital sensor DS2436 measures temperature and voltage. It has only three terminals: supply, ground and communication port. The communication port is common to all sensors, no matter the quantity. They are connected to the same wire and finally to a resistance-pulled-up driver. The bus has a master-slave configuration, where the master could be a computer or microprocessor, and the sensors are the slaves. Eventually different sensor types could be added to the bus, even actuators such as digital potentiometers. In this particular application only the DS2436 sensor was used. Each sensor has a unique identification number assigned by the manufacturer, which is used to send commands to a particular sensor. These commands include voltage or temperature conversion and storing or sending the associated data. The same bus is used to send commands and receiving data, as a bidirectional path. Each voltage or temperature conversion takes about 10 ms. Figure 5 shows a detail of the sensors in a couple of batteries.

Communication between microprocessor can be achieved connecting directly the processor to the bus and respecting One Wire protocol timing or through the processor’s serial port using a bus driver. The integrated circuit DS2480 is a bus driver that converts One Wire protocol into RS232 and vice versa at speeds up to 115200 bps. In this case the bus driver was used.

B. Other system requirements

The sensor itself is not enough to capture data from series-connected batteries, because ground of every sensor must be connected together as the bus’s reference. Hence an isolation circuit must be added between the sensor and battery terminals, to modules installed in each battery. This isolation can be achieved via signal transformers, voltage LEMs or optocouples. The third option was selected because of the easier implementation and lower space requirements[3]. The circuit used for galvanic isolation is shown in Fig. 6.

![Galvanic isolation with optocouples](image)

Nevertheless, the optocouple must be linearized, so the analog voltage transmitted is properly measured. The SLC800 optocouple, from **Solid State Optronics**, is an appropriated element that can be easily linearized via feedback circuit. It has two application modes: photoconductive or photovoltaic operation. In this case it was more appropriate to use it in the photovoltaic mode.

It is also desirable that data can be stored in a memory so it can be analyzed afterwards. The ideal case would be the possibility to store voltage and temperature data from a complete charge and drive cycle, at small time intervals.

C. Specific Characteristics

The particular implementation consists of 24 sensor modules, each with DS2436 sensor, a SLC800 optocouple for galvanic isolation; these modules are connected to a One Wire bus, which is interfaced to a microprocessor PIC 16F877A by a DS2480B bus driver [5]. The microprocessor sends commands to the sensors and receives data from them [4]. The bus driver translates commands and data to and from RS232 to One Wire protocol. Figure 7 shows the sensors arrangement over the batteries of Fig. 3, and Fig. 8 displays the printed board with the microprocessor.

![Sensors arrangement at the back of EV.](image)
The processor shows data on a 7” screen in real time and interacts with the user through a touch-screen, which are shown in Figs. 9a) and 9b).

The vehicle also has a solar-cell group, which’s energy contribution is measured and shown on screen. This information is measured by the microprocessor via the A/D converter.

Voltage, temperature and solar cell data is stored every 10 seconds. All of this information is stored in a 1 MB flash memory BQ4016Y, which is also controlled by the PIC microprocessor.

IV. EXPERIMENTAL RESULTS

The experimental results obtained fulfills with the requirements of the system. The objective of the implementation is the behavior of each battery of the EV. The communications of the system works well, without errors. The tests done to the system guarantees an error rate of one in a million.

The refresh speed of the measures satisfies the requirements of a monitoring system. The driver can see each five second the behavior of each battery, but this speed is not enough if a control system is required. In this case, the solutions are operating with a higher speed in the One Wire bus and use a faster microcontroller.

The next figures show some experimental results obtained with the LCD screen installed inside the vehicle. Once activated, the touch-screen displays five options: Battery Voltage (Voltaje), Battery Temperature (Temperatura), power and energy delivered by the solar cells (Celdas), Record Data (Grabar), and screen contrast (Contraste).

Figure 10 shows the screen related with the photovoltaic cells. This screen gives information of the instantaneous power delivered and the energy stored in the batteries after a defined period of time (in Spanish: Tiempo transcurrido aproximado). The grey button at the right of the touch-screen (Reiniciar Tiempo) allows resetting the energy data.

Figure 11 shows information related with the individual voltage in each one of the 24 batteries of the EV. The range of measuring is 10 to 15 Volts. The green columns allow the
comparison between battery voltages. Numerical value of each voltage can be read at the bottom of the screen. It can be appreciated in the figure that battery number two is low in voltage related to the other batteries and probably it needs to be revised.

Finally, Figure 12 shows a similar bar information for the battery temperatures. The range of measure is 0 to 50 °C.

V. CONCLUSIONS

A monitoring system for a battery powered electric vehicle (EV) was implemented and tested. The system allows voltage and temperature monitoring of each one of the 24 batteries, which allows to detect early problems or failures in individual batteries. Besides, the system will also allow monitoring the energy delivered by a photovoltaic cell which is being implemented on the roof of the vehicle. The monitoring method uses digital sensors with technology “one wire”, which allows transmitting data from all batteries through a serial bus. The information is shown in a LCD screen with 320x340 pixel resolution. The paper showed the main characteristics of the system, some photographs, and some experimental results through the information given by the LCD screen.

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VII. REFERENCES