Microcontroller-Driven Hydrogen Fuel Cell Car

Hugo Queirós*, António Lafuente**, João Sepúlveda** and João Sena Esteves**
*Departamento de Engenharia Electrotécnica do Instituto Superior de Engenharia do Porto
Instituto Politécnico do Porto, R. Dr. A. B. de Almeida, 431, 4200-072 Porto, Portugal
**Department of Industrial Electronics
University of Minho, Campus of Azurém, 4800-058 Guimarães, Portugal
1081541@isep.ipp.pt, pedrolafuente@netcabo.pt, mjs@dei.uminho.pt, sena@dei.uminho.pt

Abstract. *This paper presents a fuel cell car with 8 minutes autonomy, capable of following a white line on a black track, using infrared sensors that detect white and black colors. A servomotor controls its direction. Guidelines to the servomotor are given by a system based on an 8051 microcontroller, according to the information it receives from the infrared sensors. The hydrogen needed by the fuel cell is produced by electrolysis, which requires an external power supply. The gas is retained on an isolated tank placed in the car. Then, it is used by the fuel cell to produce the electric energy required by the car motor.*

Keywords. Hydrogen Fuel Cell, Infrared Sensors, 8051 Microcontroller, Electrolysis.

1. Introduction

The project described in this paper shows the application of fuel cell technology [1, 2] and Electronics to a model car (Fig. 1). The *HyRunner* car – built by *h-tec, Wasserstoff-Energie-Systeme GmbH, Hydrogen Energy Systems* – was the starting point of the project. This model car is equipped with a reversible fuel cell. To control the vehicle, more conventional technologies were used. Infrared sensors and an 8051 microcontroller are some of the components integrated in the control system.

Since the fuel cell car is very suitable for science fair events, an oval track (Fig. 2, Fig. 3 and Fig. 4) was built for exhibition purposes. Over the black surface of the track, a white line was drawn. The car follows this line using its infrared sensors.

The fuel cell car has been showed in the University of Minho, in several schools and also appeared in the following events:

1. *Oficinas de Electricidade* (Electricity Workshops), integrating part of *Robótica*

2006 – Festival Nacional de Robótica (National Robotics Festival), Guimarães, Portugal, April 28 – May 1, 2006.

2. *Mostra Interactiva de Ciência e Tecnologia* (Interactive Exhibition of Science and Technology), Palácio Vila Flor, Guimarães, Portugal, April 14 – 20, 2008, integrating part of the *Projecto Ciência na Cidade de Guimarães* (Science in Guimarães City Project).

3. *Mostra Interactiva de Ciência e Tecnologia* (Interactive Exhibition of Science and Technology), *Museu de Alberto Sampaio* (Alberto Sampaio Museum), Guimarães, March 6 – May 15, 2009.

2. Key aspects of the project

These are the key aspects of the project, which will be emphasized:

- The use of fuel cells;
- The use of infrared sensors;
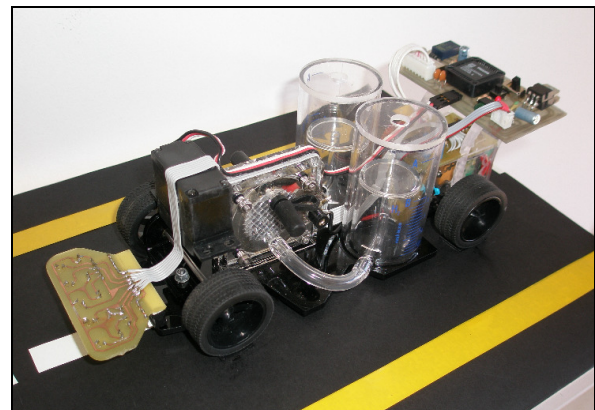- The use of an 8051 microcontroller.
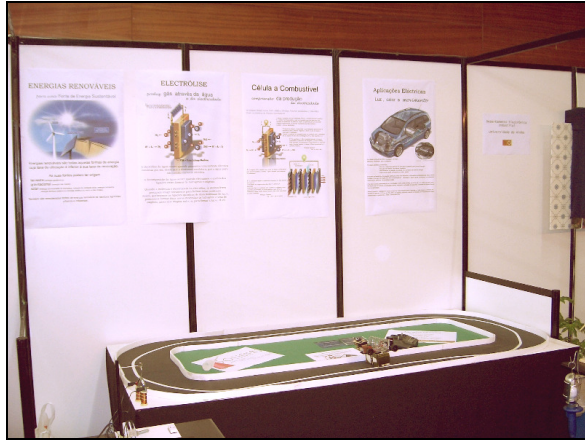

Figure 1. Hydrogen fuel cell car.

Figure 2. Car track.

Figure 3. Track detail and the hydrogen fuel cell car (photo by Ana Luísa Pedrosa).

Figure 4. Track in its stand at the *Oficinas de Electricidade* (Electricity Workshops), in 2006.

2.1. The fuel cell

The objective of the project is to create an autonomous car, capable of circulating on a track, following a white line. To power its electric motor, a hydrogen fuel cell (Fig. 5 and Fig. 6) was used. This fuel cell can work in *electrolyzer mode* or in *fuel cell mode* [2]. These modes will be described with more detail.

2.1.1. Electrolyzer mode

In this mode, the fuel cell produces hydrogen and oxygen from water. This is a very useful capability, since it avoids the use of a refilling station.

The car has two separate and isolated tanks. First, both tanks are partially filled with water. Then, an external power supply is connected to the cell to perform the electrolysis of the water, which separates the hydrogen from the oxygen. One of the tanks is filled with hydrogen and the other is filled with oxygen. The chemical reactions are the following:

$$2H_2O \rightarrow 4H^+ + 4e^- + O_2 \qquad \text{(cathode side)}$$

$$4H^+ + 4e^- \rightarrow 2H_2 \qquad \text{(anode side)}$$
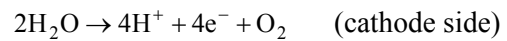
With a 1W power supply, the time required to fill the tanks with hydrogen and oxygen is about 2 minutes.

2.1.2. Fuel cell mode

After filling the car tanks with hydrogen and oxygen, the terminals of the external electric circuit (which includes all the electric circuits to be powered by the fuel cell) may be connected to the anode and cathode of the fuel cell.

Hydrogen flows from its tank to the fuel cell anode and oxygen flows from its tank to the fuel cell cathode.
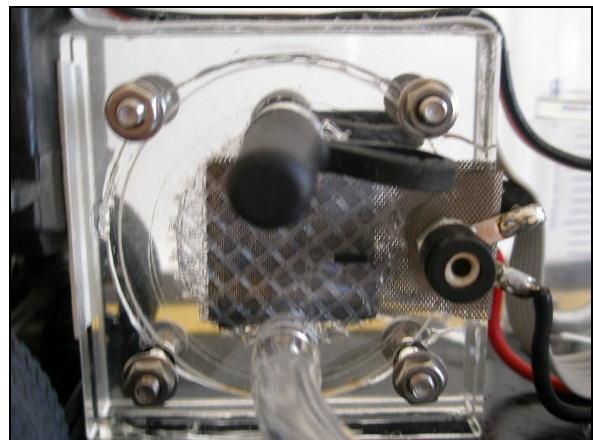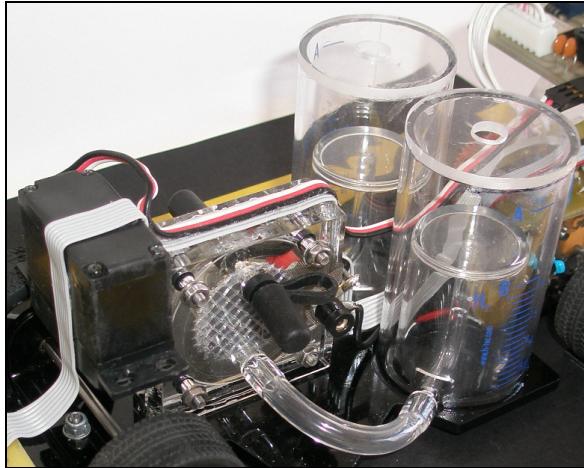

Figure 5. The fuel cell.

Figure 6. Fuel cell, between the servomotor (on the left) and the hydrogen and oxygen tanks (on the right).

- ***On the anode side of the cell***, a platinum catalyst separates the hydrogen into electrons and protons. The protons flow towards the cathode through a Proton Exchange Membrane (PEM). However, the electrons cannot pass this membrane. Instead, they go to the cathode through the external electric circuit, establishing an electric current in this circuit.

- ***On the cathode side of the cell***, the electrons are combined with the protons and oxygen, with the help of a platinum catalyst.

The chemical reactions are the following:

$$2H_2 \rightarrow 4H^+ + 4e^- \qquad \text{(anode side)}$$

$$4H^+ + 4e^- + O_2 \rightarrow 2H_2O \qquad \text{(cathode side)}$$
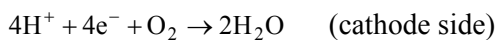
2.2. Infrared sensors

Five infrared sensors are placed in the front of the car, facing down (Fig. 7). They allow distinguishing white surfaces from black surfaces, so the car can follow a white line drawn on a black track.

Each sensor has an emitter and a receiver. The emitter sends to the track an infrared beam that is reflected back to the receiver if the white line is detected.

If the leftmost sensors detect the white line, the car turns left; if the rightmost sensors detect the white line, the car turns right. This way, the car follows the white line.
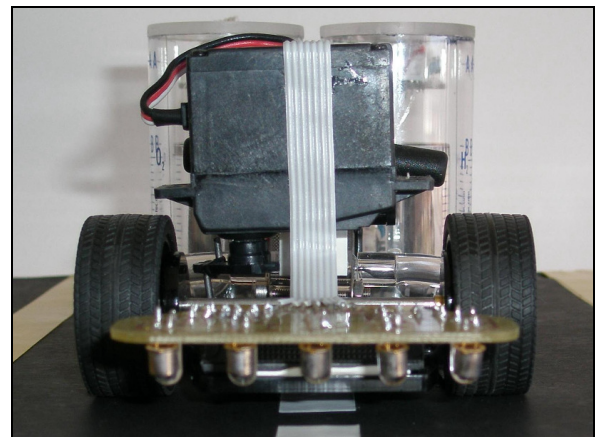
2.3. The 8051 microcontroller circuit

A circuit that contains an 8051 microcontroller (Fig. 8) was designed to receive and process the information sent by the infrared sensors [3] and then send the correct information to the servomotor that controls the direction of the car.

The program installed on the 8051 microcontroller [4, 5] has two functions:
1. controlling the direction of the car;
2. switching on and off the car motor.

The source code was written in C [5]. This task offered the authors the opportunity to practice this programming language.

The microcontroller requires a 5V power supply. This is provided by a 9V battery, which also supplies the servomotor and the infrared sensors.

Figure 7. Due to five infrared sensors placed in the front of the car, facing down, the car is able to follow a white line drawn on a black track.
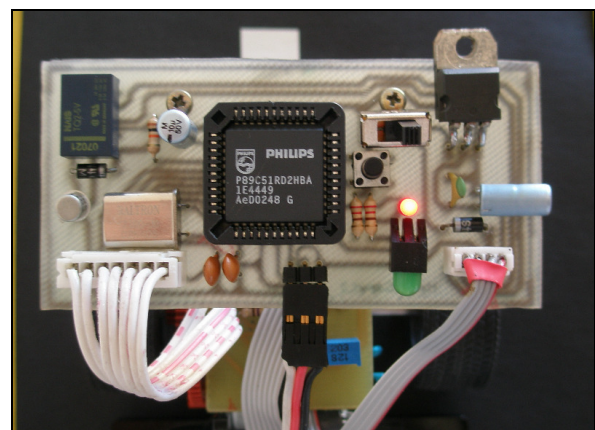
Figure 8. The 8051 microcontroller circuit.

3. Car operation

Before starting the car, the tanks located near the fuel cell must be partially filled with water.

Then, an external power supply is attached to the anode and cathode of the fuel cell, so it can produce hydrogen and oxygen from the water in the tanks.

Once the tanks are filled with hydrogen and oxygen the car may be started, which requires turning on a switch and pressing a key. After this, the car will automatically run on the track, following a white line.

When a horizontal line appears, the car stops for a few minutes to refill. This only takes place after the car completes three or four laps.

With the tanks initially filled with hydrogen and oxygen, the autonomy of the car is up to 8 minutes.

4. Conclusions

A hydrogen-powered car with 8 minutes autonomy has been presented.

The hydrogen, produced by electrolysis, is used by a fuel cell to generate the electric current supplied to the car motor.

The car follows a white line on a black track using infrared sensors that detect white and black colors.

A system based on an 8051 microcontroller has been developed. It receives information from the infrared sensors, controls a servomotor that steers the car and switches on and off the car motor.

The car is very suitable for science fair events. Seeing a fuel cell working arouses the interest for this technology. The project offered the authors the opportunity of learning more about fuel cells, practicing electronics and improving programming skills.

5. Acknowledgements

6. References

[1] Voight, C., Hoeller, S., Kueter, U., Fuel Cell Technology for Classroom Instruction, Books on Demand GmBh, Norderstedt, 2005.

[2] FuelCellStore
www.fuelcellstore.com

[3] Rocha, José Gerardo Vieira, MOSFETS e Amplificadores Operacionais, Netmove Comunicação Global, Lda Editora, 2005.

[4] Nicolosi, Denys E.C., Microcontrolador 8051 Detalhado (6th ed.), Érica, 2005.

[5] Nicolosi, Denys E.C., Rodrigo B. Bronzery Microcontrolador com Limguagem C, Érica, 2005.