DEVELOPMENT OF A DIDACTIC TOOL FOR THE TEACHING OF BASIC CONCEPTS IN EMBEDDED SYSTEMS (ES)

DESARROLLO DE UNA HERRAMIENTA DIDÁCTICA PARA LA ENSEÑANZA DE CONCEPTOS BÁSICOS EN SISTEMAS EMBEBIDOS (SE)

José Araque-Gallardo*
José Luis López Prado*
Carlos Yeneris**

DOI: https://doi.org/10.18041/1909-2458/ingeniare.26.6568

ABSTRACT

Didactic tools in the classroom are a very important element in the teaching-learning process. In the embedded systems topic, these tools offer to teachers and students a fast way to apply the concepts and knowledge through rapid prototyping using the concept of modularity. In this paper, the development of a didactic tool for the teaching of basic concepts in embedded systems is presented. First, the study and selection of the most used peripherals in the teaching of embedded systems was made. Then, by using CAD tools, the Printed Circuit Boards (PCB's) of the didactic tool were designed based on Arduino compatible layout. Afterward, a functional prototype was built. Finally, a laboratory guide handbook and a user manual were elaborated. A prototype of a didactic module for the teaching of basic concepts in embedded systems was implemented and tested. Also, the related documentation with this didactic module was developed. The developed tool can be considered as a classroom technology innovation because of it can be used as a support tool in embedded systems related course, since its modular concept permit that students do not spend money and extra time implementing the necessary circuits to test the algorithms developed in the classroom.

Keywords:
Embedded system; Development kit; Didactic tools; Arduino; Microcontroller.

RESUMEN

Las herramientas didácticas en el aula son un elemento muy importante en el proceso de enseñanza-aprendizaje. En el tema de sistemas integrados, estas herramientas ofrecen a profesores y estudiantes una forma rápida de aplicar conceptos y conocimiento a través de prototipos rápidos utilizando el concepto de modularidad. En este artículo, se presenta el desarrollo de una herramienta didáctica para la enseñanza de conceptos básicos en sistemas embebidos. Primero, se realizó el estudio y selección de los periféricos más utilizados en la enseñanza de sistemas embebidos. Luego, mediante el uso de herramientas CAD, las placas de circuito impreso (PCB) de la herramienta se diseñaron compatibles con Arduino. Posteriormente, se construyó un prototipo funcional. Finalmente, se elaboró un manual de guía de laboratorio y un manual de usuario. Se implementó y probó un prototipo de un módulo didáctico para la enseñanza de conceptos básicos en sistemas embebidos. Además, se desarrolló la documentación relacionada con este módulo didáctico. La herramienta se puede considerar como una innovación tecnológica en el aula debido a que se puede utilizar como una herramienta de apoyo en un curso relacionado con sistemas integrados, ya que su concepto modular permite que los estudiantes no gasten dinero y tiempo extra implementando los circuitos necesarios para probar los algoritmos desarrollados en el aula.

Palabras Clave:
Sistema integrado; Kit de desarrollo; Herramientas didácticas; Arduino; Microcontrolador.

Cómo citar este artículo:
J. Araque-Gallardo, J. L. López Prado & C. Yeneris. Development of a didactic tool for the teaching of basic concepts in Embedded Systems (ES). Ingeniare, Año 15, No. 26, Junio 2019. pp. 89 - 98.

*Datos de contacto de los autores
Doctorado en Ingeniería Industrial. Departamento de Ingeniería Electrónica, Universidad de Sucre. Correos: jose.araque@unisucre.edu.co,, jose.lopez@unisucre.edu.co
**Tecnólogo en electrónica Industrial. Departamento de Ingeniería Electrónica. Universidad de Sucre, correo: cyeneris06@hotmail.com

Fecha de recepción: 17 de mayo de 2019 • Fecha de aceptación: 18 de junio de 2019

1. INTRODUCTION

Nowadays embedded systems are found everywhere: A car has more than twenty embedded systems inside for motor, brake, speed, air conditioner, lock and so on. Inside a home, practically every appliance operates thanks to embedded systems: washing machines, microwave oven, printers, T.V. sets, multimedia and so on[1]. For this reason, Embedded Systems based on microcontrollers is one of the most relevant topics in undergraduate electronics and computer engineering curricula [2]. In recent years, the use of didactic modules in the classroom for teaching digital electronics and related areas has been increased, due to the need of count with tools that allow to speed up and facilitate the teaching-learning process. Today, there are many commercial educational kits available in the market but, unfortunately, they are often expensive or inaccessible in some areas or countries.

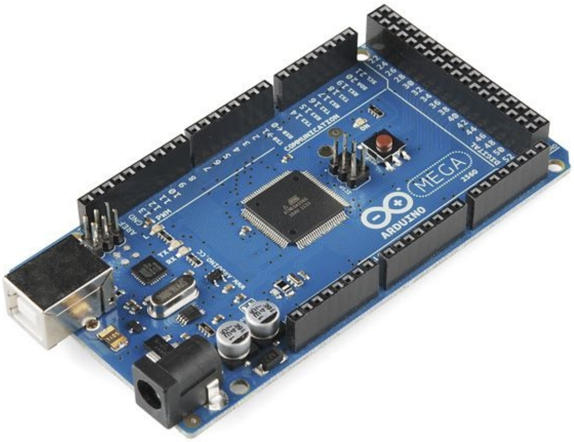
As an alternative to commercial development kits, there are a lot of works reported in the literature related to support the teaching of embedded systems. Kelemen et al present diverse didactic tools for the teaching of embedded systems based on of microcontroller family Basic Atom [3]. Belal et al propose a project-based methodology to enhance teaching Embedded Systems, allowing to expose students to real-world problems and give them the chance to apply what they learn in the classroom [4]. García and Cano developed a constructionist platform for embedded systems and wireless communications teaching, using a methodology based on the constructionist theory, establishing a framework divided into three phases: planning, implementing and learning about the project[5]. Shurui et al present a critical review of the diverse teaching methods for the embedded systems course [6]. A training module for teaching of microcontroller AVR was developed by Pilatásig et al who presents a training module mounted on a PCB that contains several peripherals like LCD screen, keyboard, seven-segment display, led matrix, among others [7]. An interesting approach can be seen in the work of Hsiung et al. Authors describe a low-cost microcontroller training system for hands-on distance and campus-based classes[8]. Rodriguez et al used a project-based learning (PBL) combined with collaborative learning (CL) in a microcontroller and embedded systems engineering Master's course employing the Arduino open-source platform [9]. Other authors have contributed to the development of methodologies, strategies and development kits for teaching embedded systems as can be seen in [10–14].

2. METODOLOGY

2.1 Embedded system concept

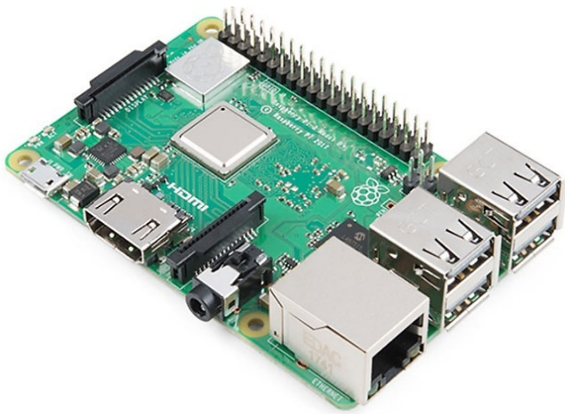
An embedded system can be defined as a microcontroller-based combination of hardware and software and some additional parts, either mechanical or electronic- designed to perform a dedicated function [15]. An embedded system is built to control a function or range of functions [1]. Between most known available embedded systems in the current market we can find the open-source Arduino platform (Figure 1), raspberry pi (Figure 2), Texas Instruments Tiva TI development kit (Figure 3) and PSoC4 pioneer kit (Figure 4), although there are many other development boards like these.

Figure 1. Arduino Mega 2560 development board



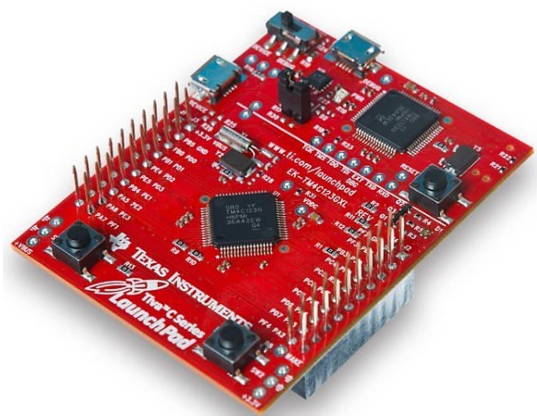
Source: ElectronicaEmbajadores.com

Figure 2. Raspberry Pi 3 development board



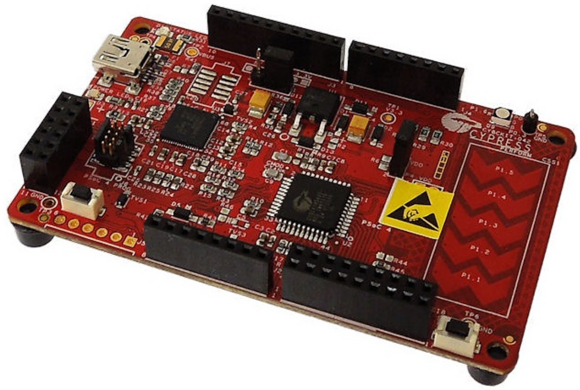
Source: SanDoRobotics.com

Figure 3. Texas Instruments Tiva development board



Source: electrokit.com

Figure 4. Cypress Semiconductor PSoC4 pioneer kit



Source: cypress.com

2.2 Proposed architecture

There are some important considerations for the embedded systems educational kit [2], such as:

-It must be easy to use, especially for novice students.

-It must be accompanied by a user manual, laboratory guides, and demonstration examples

-It must be generic and compatible with various embedded system boards.

-It must comprise a number of varied embedded systems topics and practical experiments.

Taking into account the previous considerations, Figure 5 shows a general block diagram of the proposed kit. It is composed of five principal stages:

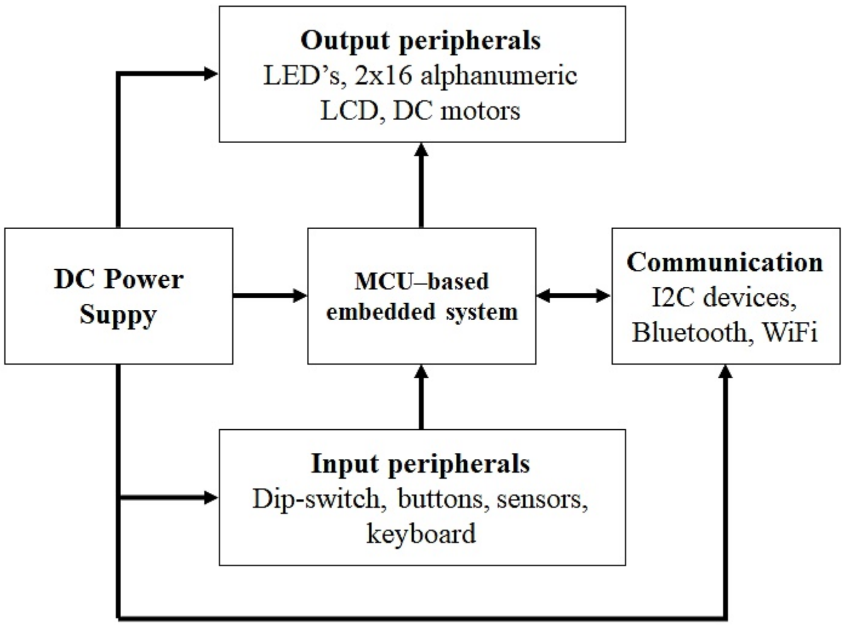
-Microcontroller-based embedded system like Arduino Uno, a DC power supply that feeds all the other blocks.

-Input peripherals block that contains the main input devices used in embedded systems teaching: dip-switch, matrix keyboard, buttons and sensors (potentiometer, gas, ultrasonic, temperature, humidity, color, hall effect).

-Output peripherals block that allows developing exercises related to control tasks: Light emitting diodes (LED), alphanumeric LCD 2x16 and DC motors with its respective drivers.
-Communication section that supports the basic protocols like I2C bus, Bluetooth and Wi-Fi.

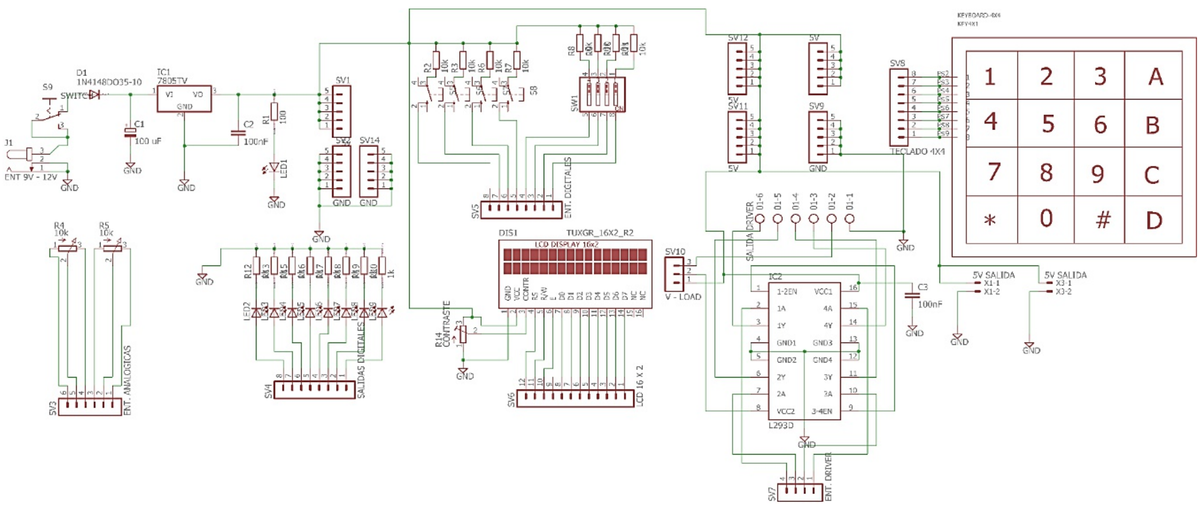
Figure 6 shows the schematic diagram of the main board. In Figure 7 we can see the schematic diagram of the auxiliary board. Figure 8 and Figure 9 displays the printed circuit board designs for both, the principal and the auxiliary boards.

Figure 5. Block diagram of the development kit proposed



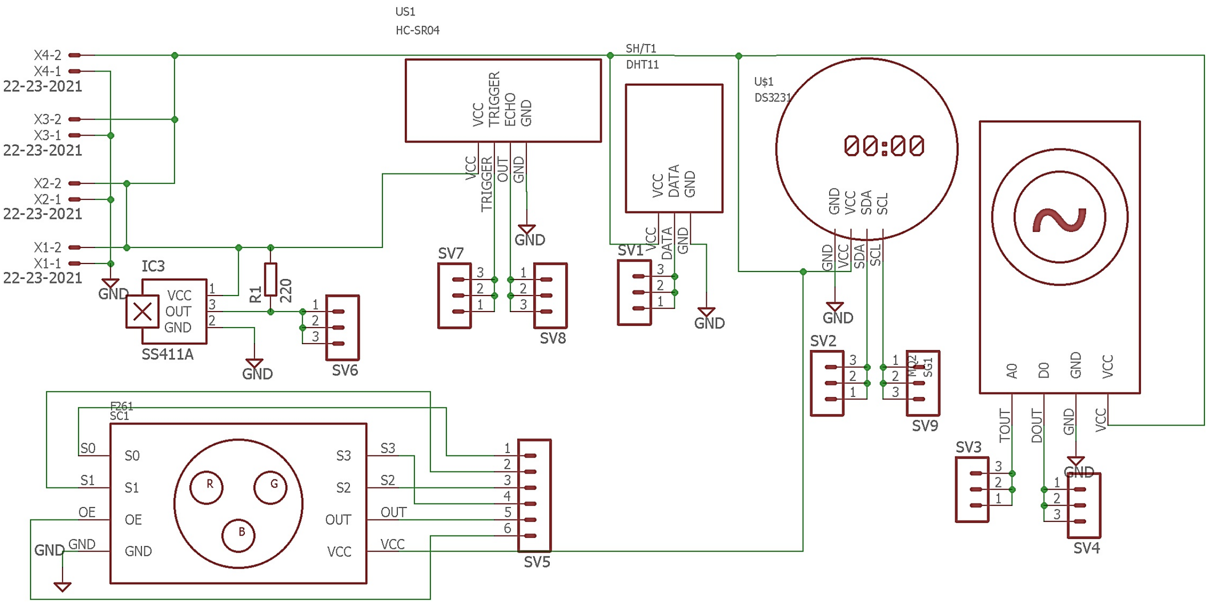
Source: The authors

Figure 6. Schematic diagram of main board



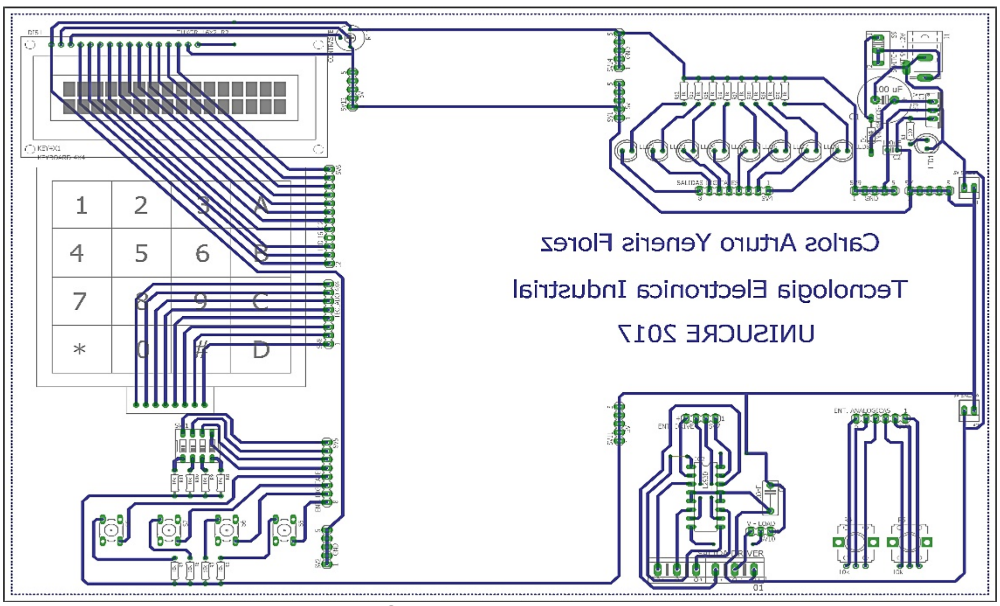
Source: The authors

Figure 7. Schematic diagram of auxiliary board



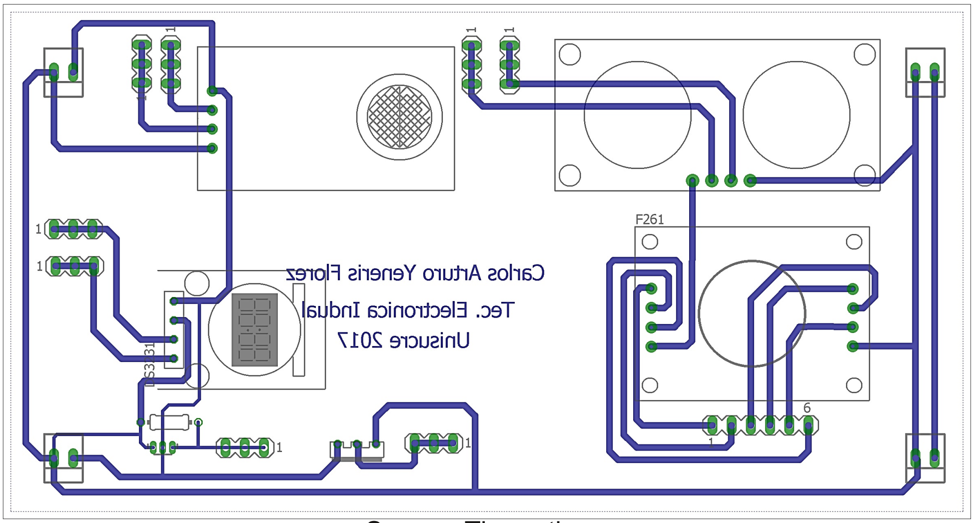
Source: The authors

Figure 8. Printed circuit board design for main board



Source: The authors

Figure 9. Printed circuit board design for auxiliary board



Source: The authors

2.3 Learning Material

Two learning documents were made with the aim to give to students a support material for a convenient use of the development kit. These learning documents were based on Arduino Uno board and Arduino IDE as a study case. The documents are a user manual and a laboratory classroom guide. The user manual is a technical document that introduces to the student the physical features of the development kit, as well as the different hardware modules, its ubication, and connections. The laboratory classroom guide provides to the students an easy step-by-step guide of examples that involves most of the modules and devices in the development kit. This guide includes:

-Introductory example: A "hello world" example with detailed explanation of the development process, from hardware connections to software programming. This laboratory practice is accompanied by a demonstration video that allows students to become familiar with the kit and the development process.

-Basic output peripherals: Controlling LEDs.

-Basic input peripherals: Dip Switch and push-buttons

-Data visualization with alphanumeric LCD.

-The matrix Keyboard.

-Fundaments of analog inputs: Reading analog voltages through a potentiometer.

-Controlling DC motors with PWM.

-Playing with sensors I: Ultrasonic meter and hall effect.

-Playing with sensors II: Color Detector.

-Playing with sensors III: Measuring temperature and humidity.

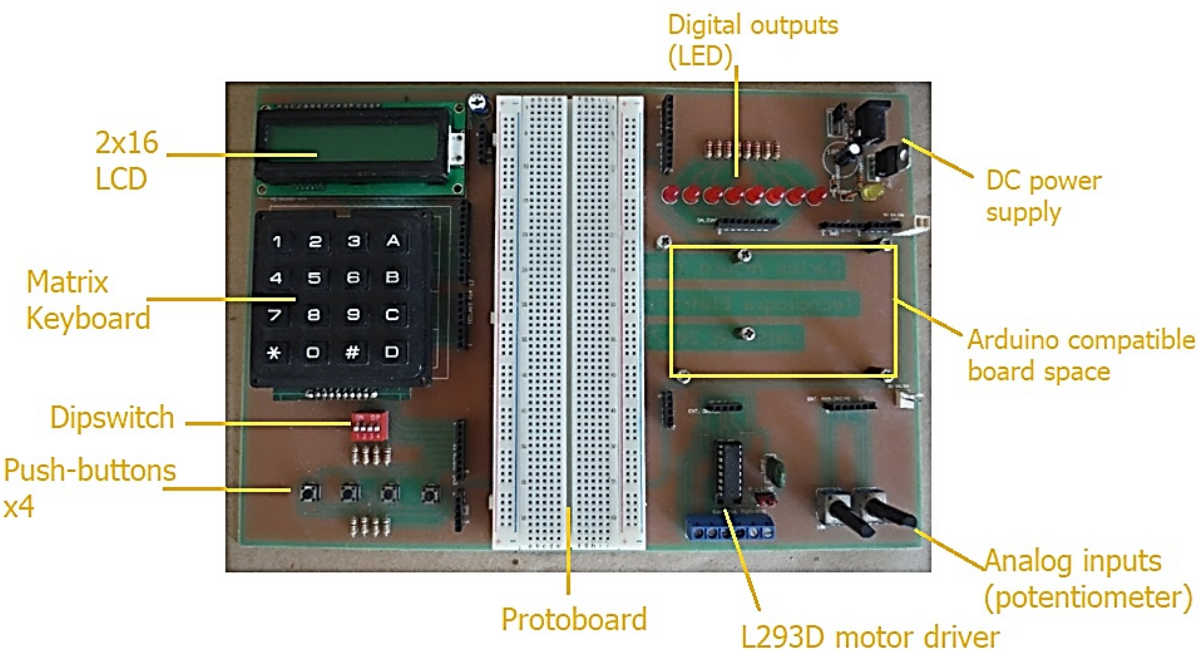
-Playing with sensors IV: Detecting CO2 emissions.

-Basic communication protocols: I2C and Bluetooth.

3 RESULTS

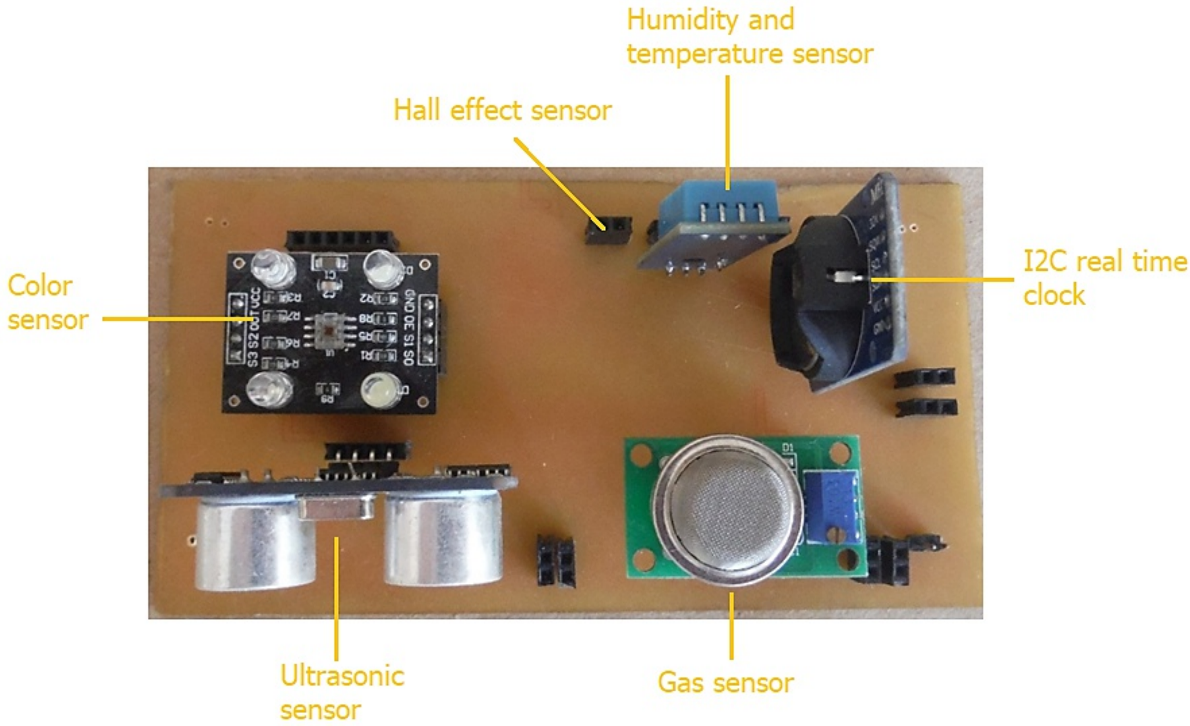
Figure 10 shows the development kit mainboard with its principal parts, whereas Figure 11 displays the auxiliary board. As can be seen, the module was designed to facilitate the interaction with the students, allowing easy access to different peripherals through connectors and the general purpose built-in protoboard. Every peripheral and module was tested and each one of the demo examples and laboratory guides was implemented using an Arduino Uno board. An introductory demonstration video was developed with the aim to allow students to become familiar with the kit and the development process. The schematic circuits, the PCB designs, the user manual, and the laboratory guide are available for free access by e-mail request.

Figure 10. Main board of the educational development kit



Source: The authors

Figure 11. Auxiliary board of the educational development kit



Source: The authors

4 CONCLUSION

In this work, the development of an educational development kit for embedded systems was presented. The kit is composed of a variety of input and output peripherals that allows students to apply the basic concepts on embedded systems, in a simple, convenient and flexible platform. The user manual and laboratory guides were designed for allowing the independent student work, and it is an ideal platform for test new designs and develops in embedded systems area. The effectiveness of the educational development kit in the classroom was not covered in this paper, so it will be done in a future work.

ACKNOWLEDGEMENT

This work was supported by Electronic engineering Department, University of Sucre-Colombia.

REFERENCES

[1] L. M. Liu, A Survey for Concept of Embedded Systems, Appl. Mech. Mater., vol. 63–64, pp. 73–76, 2011.

[2] W. Balid, M. Abdulwahed, and I. Alrouh, Development of an educationally oriented open-source embedded systems laboratory kit: A hybrid hands-on and virtual experimentation approach, Int. J. Electr. Eng. Educ., vol. 51, no. 4, pp. 340–353, 2014.

[3] M. Kelemen, T. Kelemenová, I. Virgala, Ľ. Miková, T. Lipták, and V. Maxim, Didactic Tools for Education of Embedded Systems, Am. J. Mech. Eng., vol. 2, no. 7, pp. 204–208, 2014.

[4] B. H. Sababha, Y. A. Alqudah, A. Abualbasal, and E. A. Q. Al, Project-based learning to enhance teaching embedded systems, Eurasia J. Math. Sci. Technol. Educ., vol. 12, no. 9, pp. 2575–2585, 2016.

[5] I. A. Garcia and E. M. Cano, Designing and implementing a constructionist approach for improving the teaching-learning process in the embedded systems and wireless communications areas, Comput. Appl. Eng. Educ., vol. 22, no. 3, pp. 481–493, 2014.

[6] S. Fan, J. Liu, and Y. Zhao, Investigate on the Teaching Method for the Course‘Embedded System, Creat. Educ., vol. 03, no. 07, pp. 141–144, 2012.

[7] M. Pilatasig et al., Implementation a training module for teaching of microcontroller AVR, in 2016 IEEE International Conference on Automatica (ICA-ACCA), 2016, pp. 1–7.

[8] B. S. Hsiung, J. Ritz, R. Jones, and J. Eiland, Training System for Hands-on Distance and Campus-Based Classes, J. Ind. Technol., vol. 26, no. 3, p. 10, 2010.

[9] M. C. Rodriguez-Sanchez, A. Torrado-Carvajal, J. Vaquero, S. Borromeo, and J. A. Hernandez-Tamames, An Embedded Systems Course for Engineering Students Using Open-Source Platforms in Wireless Scenarios, IEEE Trans. Educ., vol. 59, no. 4, pp. 248–254, 2016.

[10] E. A. Vakhtina and A. V Vostrukhin, Formation of Training Environment by Means of Didactic Design, Int. J. Eng. Pedagog., vol. 3, no. 1, pp. 4–11, 2013.

[11] D. Ibrahim, A New Approach for Teaching Microcontroller Courses to Undergraduate Students, Procedia - Soc. Behav. Sci., vol. 131, pp. 411–414, 2014.

[12] M. A. Koslowski, G. B. Borba, and R. A. De Faria, An Easy-To-Use Development Kit For A Microcontroller Course Based On The 8051, in XIII International Conference on Engineering and Technology Education, 2014, pp. 99–103.

[13] L. A.Ajao, O. M.Olaniyi, J. G.Kolo, and A. O.Ajao, Project-Based Microcontroller System Laboratory Using BK300 Development Board With PIC16F887 Chip, Int. J. Embed. Syst. Appl., vol. 5, no. 3, pp. 15–28, 2015.

[14] Y. F. Fung, S. Ren, and M. F. Ercan, A system to assist the learning of embedded microprocessor programming, in Proceedings of IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2012, 2012, pp. 2–4.

[15] M. Barr, Programming Embedded Systems Second Edition Programming Embedded Systems, Second Edition with C and GNU Development Tools. Cambridge: O’Reilly, 2006.