µLAB
A remote laboratory to teach and learn the ATMega328p µC

Ricardo Costa
IPP/ISEP/CIETI/LABORIS
Porto, PORTUGAL
rjc@isep.ipp.pt

Francisco Pérola
IPP/ISEP/CIETI/LABORIS
Porto, PORTUGAL
1111491@isep.ipp.pt

Carlos Felgueiras
IPP/ISEP/CIETI/LABORIS
Porto, PORTUGAL
mcf@isep.ipp.pt

***Abstract*- Remote laboratories, also known as weblabs, are presently widely adopted in engineering education, since they provide more flexibility to access a real laboratory. As a contribution to teach and learn µCs, this paper presents a remote laboratory based on the ATMega328p µC. The laboratory allows students and teachers to remotely program a hardware infrastructure based on the ATMega328p µC and control/observe a set of attached experiments.**

Keywords - Remote lab, µCs, ATMega328p µC, Engineering education, Digital Systems.

I. Introduction

In modern technology, µCs are a commonplace. They have become the universal solution in electronics design, mainly because of their low-cost, high performance and easy programmability [1]. This means that the µCs thematic is vital to be included in the curricula of any electronics engineering course [2]. Besides a previous theoretical presentation about µCs, a practical experimentation is mandatory in any well-design course, and the laboratory experiments play an important role [3]. However, the typical, and still more adopted solution, is the use of traditional hands-on laboratories, where students and teachers should attend a common laboratory to interact with real equipment and, in particular, with the µC under test. However, hands-on laboratories are known for their high costs, associated with the required equipment, space, and maintenance staff. For this reason, sharing resources via the Internet, is a good option to address the previous limitations, and this is typically made through the denominated remote laboratories (also known as weblabs). Depending on how remote labs are deployed, they can increase the amount of time students and teachers have to access the lab equipment, eventually with fewer resources and at lower costs. The experiments can be available 24 hours per day, 7 days per week, promoting an autonomous learning by using a single and sharable infrastructure. Moreover, the traditional damages to the equipment are prevented, as well as the safety of teachers and students, in particular when dangerous experiments are considered [4][5].

Therefore, this paper presentes a remote laboratory, denominated µLAB, designed to enable the remote programming of a ATMega328p µC. The remote lab includes several peripherals that forms a set of experiments able to remotely control and observe.

II. µLAB

The µLAB is a remote laboratory designed to complement the work developed in engineering classes. Available 24 hours per day, 7 days per week, this lab enables remote programming the ATMega328p µC allowing students the control and the observation of a set of experiments implemented by a set of peripherals. In addition, this lab is accessed through a standard web browser, thereby eliminating the need of additional software.

A. Overall Architecture

The adopted architecture follows the same generic approach of a traditional remote lab, comprising the weblab infrastructure supported by a server and by the underlying experiments able to remotely access. As illustrated in figure 1, the experiments include a set of peripherals able to control according to a program remotely uploaded to the ATmega 328p µC.

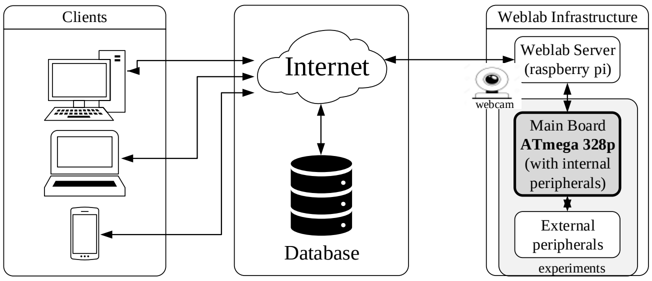

Fig. 1. Adopted µLAB architecture.

This remote lab includes several hardware and software modules to provide to any user, with a device connected to the Internet, the control and monitor functionalities of the experiments under test. In order to emphasize the reality of the experiments, there's also a webcam that allows users to see the results of the actions applied to those experiments. The weblab server consists on a single-board computer, namely a Raspberry Pi, connected to the network available in the research lab Laboris[1]. To store authentication data and the users' files used to program the µC, the weblab server is able to access a cloud database.

B. The weblab infrastructure

The weblab infrastructure is the main board that has several digital and analogue components and a set of peripherals that all together implement the experiments. In order to deliver a system as versatile and as comprehensive as possible, the choice for the ATmega328p µC was made due to its widely adoption and acceptance by the industry and by hobbyists, especially because it is the adopted processor in the well-known Arduino platform. Additionally its choice also took into account that currently some courses running at ISEP adopted this µC as its basis, which

[1] Weblab access webpage: http://www.laboris.isep.ipp.pt:8090/

predictively make this a possible solution to be adopted as a complement to some traditional laboratory classes.

As illustrated in picture of figure 2, the remote laboratory infrastructure has peripherals available in the same µC board (7 segment displays, a DAC and communication peripherals as USART, SPI and I2C), and others external to that board (stepper motor, a DC motor). To make the experiments as rich and as broad as possible using the maximum of the µC features and possibilities, all peripherals are connected by a set of multiplexers. Additionally, connected to each µC IO there are LEDs that, through the webcam, are useful to give a visual feedback of the remote actions applied by the users.

Along with the referred devices, there is the STM32F302 ARM µC in the board. This µC is the responsible to establish the interface between the server and the peripherals used by the experiments. It receives commands from the remote, user sent through the webserver, and actuates on the peripherals accordingly. It has connections the each µC IO, as well as to the peripherals interface pins. This µC communicates with the weblab server through a serial port using a protocol with specific frames designed for this particular application.

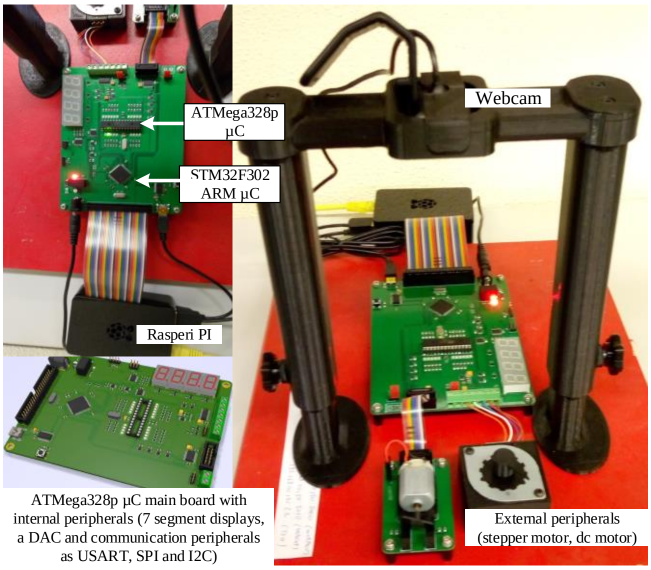

Fig. 2. Experiment Platform.

C. User Interface

The user interface is a set of webpages that provide users access the experiments. These webpages were developed using HTML and Javascript, together with some CSS frameworks, which result in a modern and responsive design allowing the access to the remote lab using all types of devices. Since the server includes two types of user accounts, namely administrator and student accounts, there are also different types of user interfaces. The difference is in the user management options, and in the system overview.

Figure 3 illustrates some screenshots of the available webpages that together with the login and user registration webpages make the full user interface. Figure 3a), represents the main control/monitor webpage used by a student to control the IO pinout of the µC, send and receive data from the available protocols and interact with the connected peripherals. Figure 3b) shows the booking webpage so users may reserve timeslots to get full control over the remote experimentS. Figure 3c) shows the webpage where users can upload & flash the hexadecimal files obtained after compiling the code using the Atmel studio software used to create programs for the µC. Figure 3d) illustrates the webpage available for administrators accounts, that provided the resources to manage users' accounts (e.g. delete users, change settings, etc.).

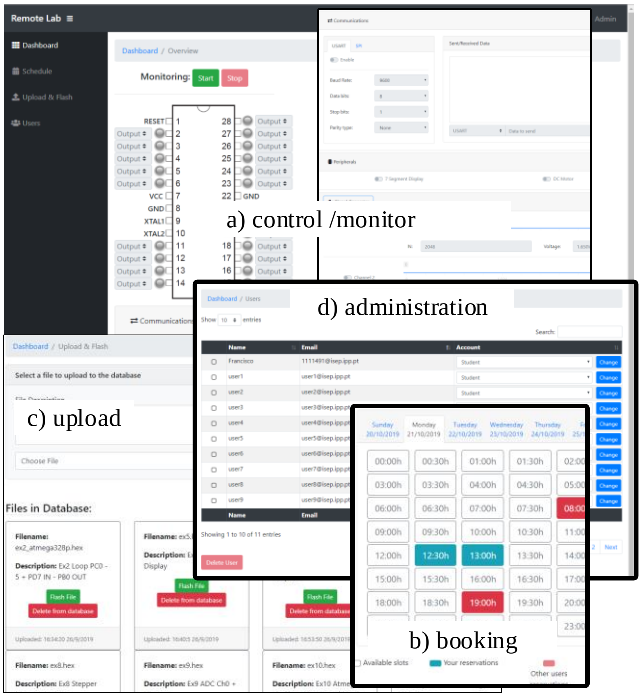

Fig. 3. (a) Control/monitor webpage. (b) Booking webpage. (c) Upload & Flash webpage. (d) Administration webpage.

III. Conclusions

Currently µCs are one of the key device in most of the available electronic products. This evidence emphasize their importance in electronics engineering courses, requiring the adoption of modern educational methodologies to facilitate their teaching and learning, such as the use of remote laboratories. Thus, this paper described a remote lab named µLAB used to support the learning of the ATMega328p µC. An overview on the system construction and functionalities has been provided. A validation of this remote lab would be expected to be made in the future through course trial sessions, along with surveys, to evaluate its acceptance in a real education scenario.

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