Home Compatible Labs Concept in Erasmus+ Conn'Cor Project

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***Abstract*—This paper describes and discusses the concept of home-compatible lab exercises that are designed so that students of electrical engineering can do them on their own, at the leisure of their homes. The requirements for these labs are different than for the classical sets of lab exercises that are conducted in the laboratory environment. On the other hand, the labs have advantages over the remotely run lab exercises, and are more useful for the students, in comparison. A set of lab exercises has been developed within the framework of Erasmus+ Conn'Cor project, and evaluated by each of the partner institutions. The feedback received shows that the concept is a promising one, being embraced in special circumstances, but also as the general concept for specific courses.**

***Keywords*—Home-compatible labs, lab exercises, electrical engineering education.**

I. Introduction

Laboratory work is widely recognized as a cornerstone of engineering education, often considered the main distinction between engineering and applied mathematics degrees [1]. It is also emphasized in accreditation and curriculum standards, as it promotes active learning and deeper knowledge retention.

In digital design courses, lab activities have traditionally relied on in-person sessions, which demand significant infrastructure and staff time. New technological tools now allow alternative approaches, such as simulation-based learning [2] or remote access to equipment. While simulations are useful, they fail to capture the practical challenges of hardware implementation. Remote labs [3], [4] can offer valuable experiences, but they are complex to set up, may obscure technical details for beginners, and are best suited for advanced or resource-intensive courses.

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A more accessible option is the use of take-home labs [5], [6]. Initially emerging with PCs and later with microprocessor kits, this approach expanded to digital design through low-cost programmable logic devices and free software. These portable kits give students authentic, hands-on experience while also supporting flexible, distance-friendly learning.

Also, there are HomeLab kits with micro controller hardware, for self-educating of learners at home or for utilizing them in classes in the frame of face-to-face education. The kits are combined with specific modules for different domains. There can also be blended in comprehensive learning [7].

The initiative described here is based on lending hardware kits to students throughout the semester. This method combines the benefits of traditional lab practice with the scalability of modern teaching tools. The project's design, course restructuring, and teaching experience highlight its effectiveness in meeting learning objectives and its adaptability to other contexts.

The aim of this paper is to propose a laboratory support that can be applied across various educational levels, ensuring high-quality education even under constrained conditions such as lockdowns, natural disasters, limited mobility of students and teaching staff, limited funding, and other challenges. Some of the home compatible labs are suggested by the authors and their realization is described here. All suggested labs have been developed in the frame of joint EU project Conn'Cor [8].

II. Proposed Labs

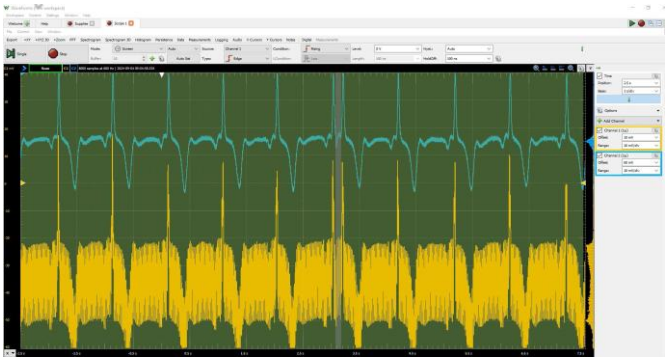
During the implementation of Conn'Cor project, we have proposed a set of laboratory exercises that includes:

- Design of an Electrocardiogram (ECG) circuit
- Introduction to Arduino
- DC motors synchronization with Arduino
- Air quality monitoring
- Iot Control of RGB ring using mobile phone

These topics cover a wide range of skills in the field of electrical engineering education: analog circuits design digital circuits and microcontrollers, automatic control, sensors and displays, IoT concept and remote control of devices over the Internet.

A. Design of an Electrocardiogram circuit

During this labwork session, the students are engaged in the design of a complete acquisition circuit to observe the bioelectric activity of the heart. Students will use electronic



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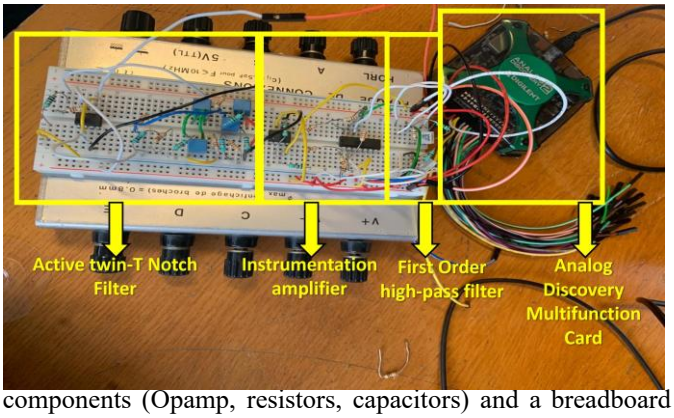


components (Opamp, resistors, capacitors) and a breadboard to create a "homemade" ECG device. If successful, they will be able to observe the different segments of their own cardiac activity as presented in Fig. 1 a) before (yellow) and after (blue) the 50 Hz noise removal.

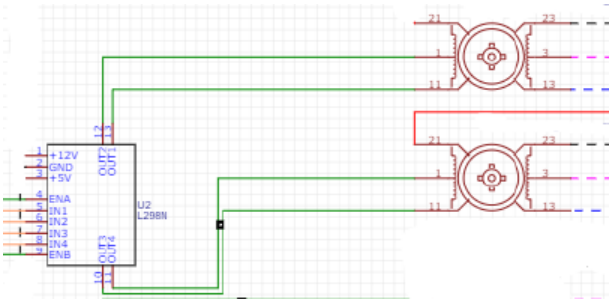
An ECG signal has voltage amplitude between 0.5 mV up to 4 mV [9]. The heartbeat is comprised into the range [60 bpm – 120 bpm]. Useful frequency range is [0.01 – 250 Hz]. A 50 Hz signal coming from the surrounding electrical network will be present in the ECG signal and need to be removed. A baseline wander due to physiological reasons also appears in ECG signal [10] and can be compensated by many techniques, in this labwork it will be removed by a high-pass filter.

This labwork will be done with a multifunction card, a breadboard and electronic components form the lab (Opamp OP482, LF356, resistors, capacitors). The voltage supply and scope are provided by a multifunction card. The multifunction card used is an Agilent card “Analog Discovery 2” (Fig. 1 b), and it is a complete kit for mini-lab which can provide:

• Voltage supply (up to +/- 5V)
• Different kind of programmable waveforms
• Scope functionality

B. *Introduction to Arduino*

In order to fully exploit the capabilities of a microcontroller, it is necessary to have sound knowledge of its internal functioning (registers, timers, etc.). However, there are rapid prototyping tools that make it possible to reach a satisfactory (although non-optimized) result very quickly. Among these tools, the "Arduino" family includes development boards (hardware) and a development environment and many libraries (software).



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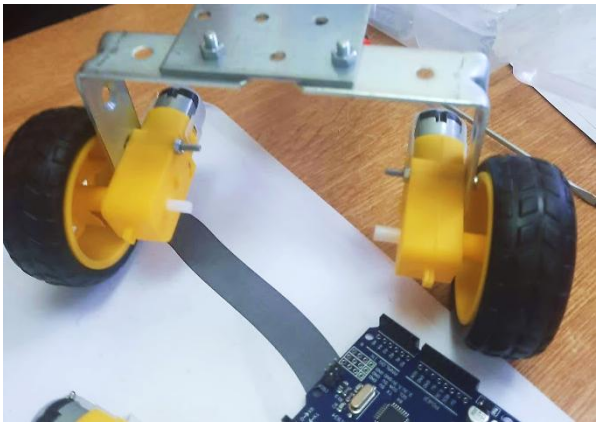


b)

Fig. 2. Motor driver schematic and a test chassis with two wheels mounted

The objective of this activity is to allow you to discover the world of microcontroller-based development using a development board created specifically for this, as well as a series of progressive exercises.

Since the health crisis and the difficulty of sharing equipment, we now use an emulator.

The lab exercise will make it possible to gradually reach the full use of the development board. It has four parts:

1. Installation and first contact with the framework
2. Basic structure of Arduino programs
3. Basic programs
4. Advanced programs

To adapt to both those who discover the environment and those who have already used it, the subject is voluntarily long. The goal is not to finish the tutorial in the allotted time but to go as far as possible.

C. *DC motors synchronization with Arduino*

The aim of this work is to characterize two DC motors that will activate two wheels in an autonomous vehicle in order to control its speed and ensure a rectilinear trajectory for the vehicle. The project stages are as follows:

1. Connect the motors to the boards.
2. Test manually each motor behaviour
3. Automatically test the motors to obtain a speed response curve
4. Model the drive-speed relationship of each motor
5. Write a direct motor control program to compensate for the nonlinear speed/command characteristics.

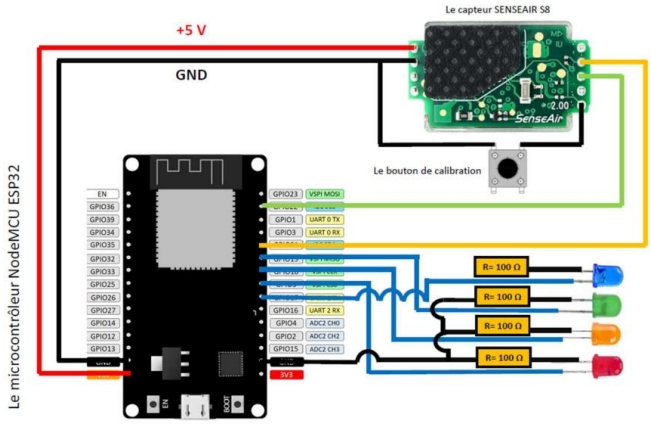


Fig. 3. Schematic of the connections between ESP32 and CO2 sensor

We assume that at this point, the operation of Arduino boards is known, we will now move on to a practical aspect. The material used for this labwork is not expensive and can be brought home: one Arduino Uno, one H-Bridge, two little motors with encoders, cables, potentiometer, breadboard and one DC supply which could be provided by the Analog Discovery card presented in II.A.

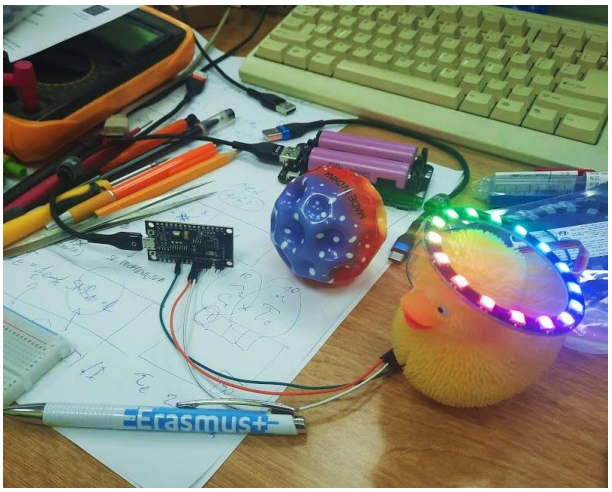
D. Air quality monitoring

In this lab, students will create a smart CO2 monitoring system using an ESP32 development board. The sensor readings will be visualized through RGB LEDs (green/yellow/red), and sent to a smartphone via Bluetooth. Regarding the learning objectives of this exercise, at the end of the session, students will be able to:

- Interface a CO2 sensor with a microcontroller (ESP32)
- Display sensor status using colored LEDs or a small display
- Set up Bluetooth communication to send live data to a smartphone

E. Iot Control of RGB ring using mobile phone

This lab exercise concerns the IoT concept and ability to control the internet-connected devices using other devices that are themselves connected to the internet. First part of the exercise is to realize an actuator device and ensure the hardware is functional. For this part, we have chosen Neopixel ring as light source that can be controlled in terms of colour and brightness (Fig 4.a). The hardware interface is a simple one, and the focus of the exercise is not on the hardware, nor is it on the controlling software that actuates the ring using the microcontroller. The focus is on the second part, which consists of connecting the device to the internet, and providing a secure communication with publicly available server. The concept of IoT communication is then demonstrated, providing the students with hands-on approach to learning its details. The students are invited to create their accounts on an IoT platform that provides free access option, and make an app (Fig 4.b) that is connected with the device controlling the ring. So far as all goes well, the students will be able to control the colour and brightness of the ring.



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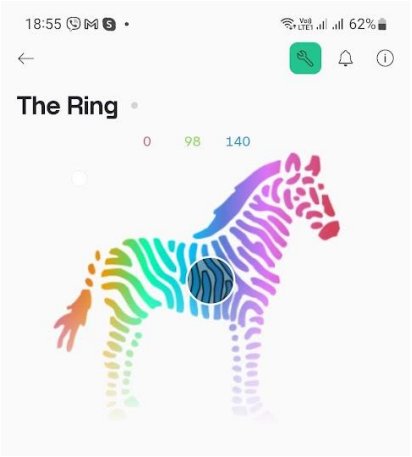

b)

Fig. 4. Functional Neopixel ring a), and screenshot from mobile IoT control application b)

III. SUMMARY

The exercises are envisioned as increasing in complexity, while at the same time they follow established concepts in the electrical engineering education. First lab concerns analog electronics concepts and instrumentation. The second lab introduces digital electronics and microprocessor concepts using the popular Arduino paradigm. The next lab relates to the previous ones and expands into automation and control areas while also introducing the mathematical tools for analyzing the practical results. The following exercise introduces sensors, displays and communication concepts with the aim of integrating these concepts into a functional and controllable device. And finally, the last exercise builds on the previous labs and demonstrates the concept of IoT applications, enabling the remote control of the devices over the internet, regardless of the geographical location of the users.

Fig 5. Illustrates the sequence of the proposed labs, together with the traditional fields to which they relate, also showing the increasing complexity.

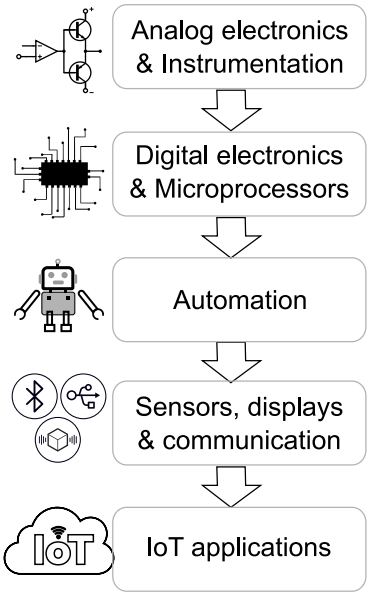

Fig. 5. Sequence of the proposed home-compatible labs.

IV. Conclusion

The home compatible lab exercises are designed so that they can be used by students as self-learning aids that boost the interest and practical skills. Although the labs themselves may seem quite straightforward, they are designed to illustrate various key concepts in different electrical engineering specialties and enable the students' better understanding of the underlining subjects. The labs are envisioned as a cost-effective supplement to regular/mandatory lab exercises, but with the advantage that the students can work with them without the standard class-related time limit, and in the leisure of their own familiar environment, this reducing the teacher-students barrier and recognizing individual preferences of the students.

Acknowledgement

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