Computing in Physics Education

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Introduction

Most of today's physics experiments are based on sensors converting physical parameters into electronic signals, which are then converted into binary numbers and read out by computers. Computers are not only used to collect the data but also to analyze and display them in easily understandable tables, plots etc.

For this reason every Physics curriculum should contain courses allowing the students to acquire at least basic electronics and computing skills, including programming.

Physics Education and the Internet of Things

The technological development of micro-processors has changed everybody's life probably more than any other technological advance. None of today's TV sets, hand phones, cars, coffee machines … could work without micro-processors. This lead to mass production of these devices and a massive drop in prices, such that you can buy a micro-processor with much higher computer power than the processor used in the lunar lander, for just a few cents.

Of course micro-processors are also everywhere in Physics, but electronic and programming courses are still in their infancy in Africa. In order to employ micro-controllers in Physics experiments practical experience with them are of utmost importance. This means that we need computing courses in our Physics education that are heavily biased in hands-on experience.

Modern micro-controllers usually have a large number of interfaces already implemented on their chip. These interfaces range from simple general purpose I/O modules allowing to read or write a single digital data line to Analogue to Digital and Digital to Analogue converters or interfaces to serial instrumentation buses. Some of them also have BlueTooth and WiFi interfaces on chip. Such micro-controllers not only allow to acquire data or control processes and treat the corresponding data, but they can also transfer the results onto the Internet where they can be seen by anybody interested.

A course on Micro-controllers in Physics for Africa

In 2017 the University of Cape Coast (UCC), Ghana, has offered a course on "Embedded Systems" to their computer science and Physics students. The goal was to set up a simple micro-processor laboratory, where the students can play with sensors and actuators and control them with a micro-controller. In 2020 this course was remodeled to include network functionality, making it a course on "the Internet of Things". While the first course used Raspberry Pi computers and the C programming language, the new course employs the cheaper ESP32 processor and is based on Python for programming. All course documentation is available on a Twiki server located in Accra and accessible to anyone interested: https://afnog.iotworkshop.africa/do/view

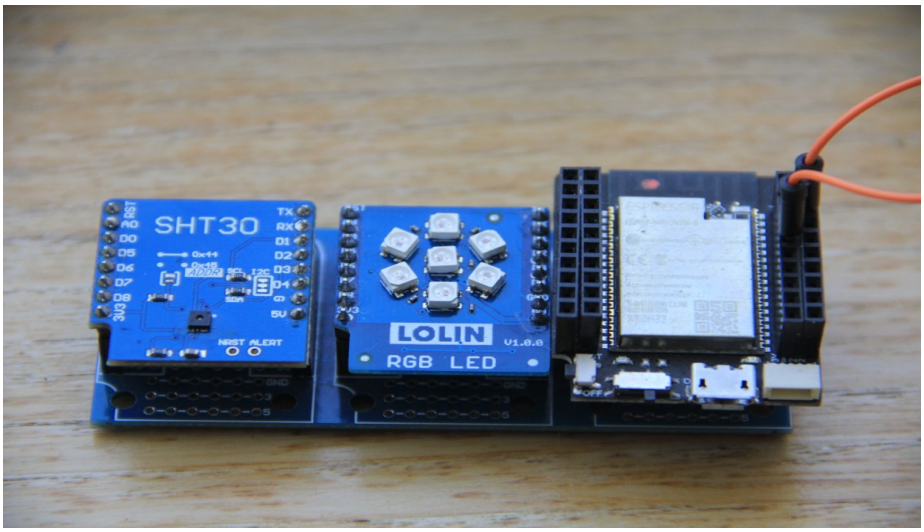
Contents of the current Micro-controller course

The course requires the setup of a cross-compilation environment, some knowledge in electronics and good programming skills. At many universities in Africa it is not easy to find a lecturer having all these required skills. For this reason we propose a basic, standardized set of sensors, actuators and micro-controller, which is fully described on the Twiki site. The procedure of setting up the development environment is also explained.

The equipment allows a number of experiments on

- LEDs, relays and switches
- Motor control: DC, servo and stepping motors
- Temperature and humidity measurement
- The I2C serial bus
- Digital to Analogue and Analogue to Digital conversion
- Data transfer to the Internet through the MQTT protocol and implementation of a WEB server

When using a standardized set of hardware, collaborations between universities providing a data acquisition course for Physics would be eased. At UCC a simple bus system was used onto which the processor and the sensors/actuator can simply be plugged making all the necessary connections.



The bus system with an SHT30 I2C sensor, an LED chain and the processor

The programs needed to perform the above experiments are all OpenSource and can be downloaded from github.

Of course the number of experiments can easily be extended and lecturers proposing new projects can upload their code to github and describe them on the Twiki site. Quite a few are already available on the site.