

Modular architecture with microcontroller for advanced electronic practices

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Abstract—The high level of complexity of integrated circuits is one of the main problems in modern electronic practices. These circuits can only be explained on a theoretical level or require expensive and specialized equipment. The traditional teaching of electronics based on discrete components or LSI integrated circuits as logic gates or flip-flops is being clearly outdated, and runs the risk of creating a gap between theory and practice that goes against the spirit of professional training. This article presents a hardware and software set of components designed for advanced electronic practices whose centerpiece is a microcontroller that connects different peripherals such as analog-to-digital converters, keyboards, displays of different technologies (including latest graphics LCD modules), power and different communications interfaces and protocols. This modular architecture can be used in basic training modules (such as analog and digital electronics) but also in more specific modules such as sound, home automation, robotics and industrial control. The components used are cheap and modules can be built in the schools to reduce its cost. The schematics and printed circuit boards are free to use and for their design has been used the open source program Kicad. The microcontroller programming environment is based on Eclipse-SDCC, which is also open source and multiplatform. This system can be used for demonstrations and school practices. The system can also be used as a platform for teaching C programming or assembler for microcontrollers. All the elements have been developed at the institute "Escolas Proval" of Nigrán (Pontevedra) by a team of electronics teachers and students. Over the last years have been designed and built some of the modules and it is planned to continue making new ones based on the training needs that will be detected and new professional qualifications currently under implementation.

Keywords—component; microcontrollers; electronics practices; programming

I. INTRODUCTION

The project described in this paper is the design and construction of a modular microprogrammable system (Fig. 1) that can be used on practices of electricity and electronics. The system uses free software and hardware to eliminate the dependence on technology from different manufacturers and can be modified to adapt to future needs of the new qualifications.

The system allows to carry on practices of different levels of difficulty, from the study of the most basic components to complex control units that simulate complete equipment for robotics, alarm or telephone.



Figure 1. Project general view

All items are low cost and easy construction so they can be implemented in as many schools as possible.

For the construction of the different elements it is planned to reuse available materials such as switched power supplies, transformers, computer power supplies, stepper motors from printers, hard drives or optical disk drives. These materials are thrown away in many cases, contributing to environmental pollution.

This system supports multiple methods of microcontroller programming, including commercial adaptors from Atmel or developed for the Arduino boards.

It is planned the design of practical activities for the study of digital integrated circuits, for programming modules (assembler, C), and practices associated with sensors, alarms, robotics, telephony and others. The system can also be useful in modules related to energy efficiency or renewable energy, in which control and data acquisition systems are fundamental.

One of the strengths of this project is the possibility of using different communication technologies, both wired (serial

port, USB, ethernet, Internet) and wireless (radiofrequency 433MHz, Bluetooth, wifi, wimax). This will allow adaptation to contents related to mobile communications and devices that use them.

II. PROJECT DESCRIPTION

This project, which we called SISDECEMI-51 (SYSTEM for DEvelopment of Circuits with Microcontrollers 8051) consists of a main board with a microcontroller of the 8051 family, a power supply and a communication interface, and a set of plug-in peripheral boards designed for different applications.

The main board can directly program AT89S microcontrollers [1] (In-System Programming or ISP) through the appropriate communication cable which is also part of the project. Other microcontrollers can also be used with programs recorded by external programmers.

Each peripheral board has its own set of application programs developed as part of the project.

The system serves also for the initial development and testing of specific applications which can then operate independently, even developing specific printed circuit boards.

III. PROJECT ELEMENTS

The system consists of the following elements and architecture:

A. Programming development environment Eclipse.

This environment that is widely used in technical and university teaching was created by IBM, can run on different platforms and allows the use of different programming languages (microcontrollers, c, c + +, java, php, etc).

B. Control unit with 8051 microcontroller.

This family consists of multiple devices from different manufacturers (Philips, Atmel, Siemens) and has extensive implementation and consolidation in the industry.

C. Microcontroller programming adapter

Admits different options: external programmer, ISP programming through serial, parallel and USB ports with different utilities like free program AVRDUDE. It is planned to develop an specific communications module for the project based on the serial-usb converter circuit FT232BL.

D. Educational units for practical activities.

Each unit consists of a hardware module and the documentation necessary for the completion and evaluation of the activity, which may be available in multimedia format. The set of documents can be easily integrated into a web environment or as part of a virtual classroom, opening the possibility of using the system in distance learning.

IV. PROGRAMMING ENVIRONMENT

For this project we have chosen Eclipse [3] that is a multiplatform and free software development environment. This IDE allows to use multiple complements for different languages. To program in C/C++ it must be installed Eclipse-CDT [8]. In the case of series 8051 microcontrollers there is a specific complement called SDCC (Small Devices C Compiler) [4]. To transfer programs to the main board we have chosen AVRDUDE program [5]. This program can be integrated into the Eclipse environment and allows transfer of code through the serial port, parallel or USB.

The set of applications described above form a compact programming environment for 8051 microcontrollers in C and assembler with direct recording capability of the microcontroller circuit (ISP), allowing rapid development and debugging of both hardware and software. Fig. 2 shows an example of the main screen of the environment.

Also for the project was used as an alternative communication program Adam Dybkowski's ISP Programmer [6], which uses the parallel port and is also free software.

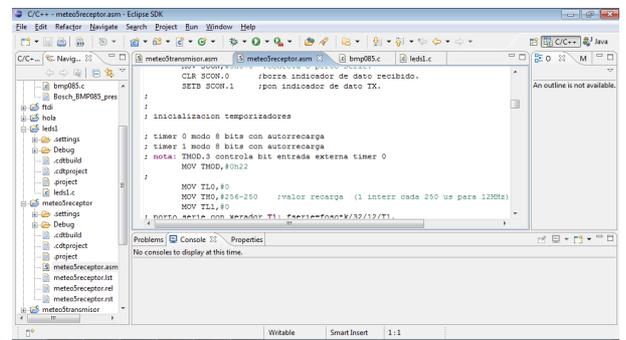


Figure 2. Eclipse IDE screen

V. MAIN BOARD

In the first phase was designed and built the main board with the following characteristics:

- Switching power supply of +5 V, 1A.
- Supports the 8051 family microcontrollers with 40 or 20 pins (89S2051/89S4051 models [2]).
- ISP programming capability via 10-pin IDC connector (2x5).
- Reset circuit with three options: at the start (power-on), pushbutton, or remotely via ISP connector.
- Serial port connector.
- 4 connectors 10-pin IDC for the microcontroller ports with power and ground connections.
- 5V power supply connectors for peripherals.
- Input connector for low voltage external power supply (max 25V) with diode bridge for AC or DC input of

either polarity. This configuration allows the use of almost any ac adapter or charger available.

- Mounted on plastic base

The main board includes a 40-pin socket for the microcontroller. The solution adopted for use of 20-pin microcontrollers is an adapter board with a 20-pin socket and pin strips that are inserted into the socket on the main board. Fig. 3 shows the appearance of the main board and Fig. 4 the 20-pin microcontroller adapter.

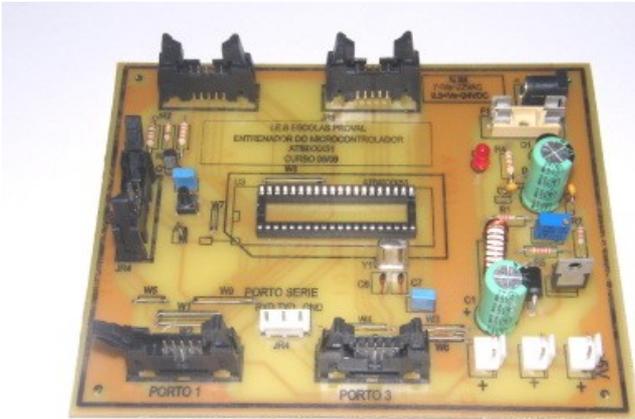


Figure 3. Microcontroller Board

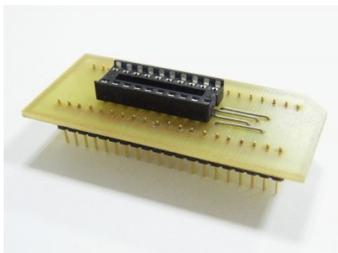


Figure 4. 20-pin microcontroller adapter

VI. POWER SUPPLY

The power supply of the main board provides a voltage of +5 V, stabilized and protected against short circuit, with a maximum current of 1A.

In the design of the power supply has been taken into account the possibility of using the system as a portable battery-powered equipment, or in autonomous vehicles, so it does not include a 230Vac transformer. The power input accepts a wide range of AC or DC voltages of either polarity, for which a bridge rectifier circuit with diodes and capacitor is placed at the entrance, and protection elements have also been added like a diac and fuse.

The power supply uses a switching regulator LT1074 [7] in step-down configuration (buck). This circuit has been replaced in a later design by the LM2576 [8], with similar performance

and lower cost. The use of switching regulators improves system efficiency, reduces heat generation and allows a wider range of input voltages.

Although the LT1074 maximum input voltage can reach up to 41V, this value has been reduced to 22Vac or 24Vdc to ease the design of the source.

VII. USB COMMUNICATIONS INTERFACE

The USB bus has become in recent years the usual method of communication between computers and their peripherals. This type of bus has major advantages such as its speed, ease of connection and the ability to directly power low-consumption devices. On the other way programming and hardware-level management were complicated in the early years of use. The emergence of low-cost adapter circuits as FTDI FT232BL [9] that also supplied free to use drivers significantly reduced the level of complexity in the use of this bus.

The development of this project required a good knowledge of the characteristics of usb bus for data transfer and in-system microcontroller programming (ISP). Previous projects like the automation of the weather station of the centre [11] helped to acquire the necessary experience.

One of the objectives of the project was the use of in-system programming of the microcontroller (ISP) which required an specific printer port (parallel) cable or an usb converter. As the parallel port is rapidly falling into disuse, for this project has been chosen to develop a serial-usb converter independent board. In a first version the integrated circuit FT232BL was used [9] In a newer version this circuit was changed by FT232R [10], which eliminated the need of an external eeprom memory and other components.

Fig. 5 shows the converters that were used for initial testing (Elektor USBPROG and FTDI EVAL232R). Fig. 6 shows the board developed for the project that is currently in use.

Besides ISP programming, these boards can be used as general purpose serial-usb converters for data transfer via the microcontroller's serial port or other applications.



Figure 5. USBPROG and EVAL232R

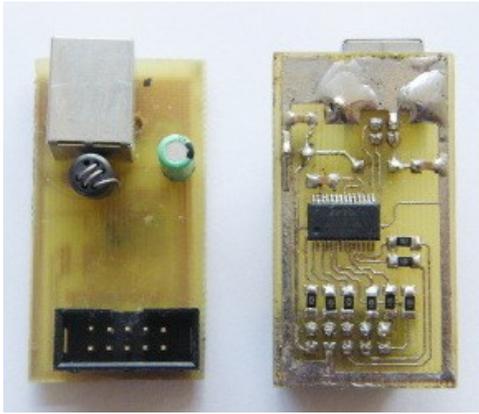


Figure 6. USB-ISP Converter Board

VIII. PERIPHERALS

For the second phase of the project it was originally scheduled the construction of the following peripheral boards:

- Board with LED diode display
- 7-segment static and dynamic display
- Board with 2x16 character LCD display
- Graphic LCD monochrome or color.
- Keyboards (row and matrix)
- Board with analog-to-digital and digital-to-analog converters
- Control circuit for motors (stepper or dc) with MOSFET transistors.
- Power control circuit with triacs and thyristors
- Circuit for Serial-USB conversion
- Serial-Ethernet/WIFI conversion circuit
- RS232-485 serial bus converter for home automation.
- Wireless transmission Modules 433/868MHz or bluetooth for remote control.
- Plates and ultrasonic sensors for infrared remote control and mobile robotics applications. (obstacle detection)
- Boards with different types of sensors (temperature, humidity, pressure, position, acceleration, movement).

During the 2009-2010 academic year have been designed and built the following boards:

- Logical indicator with switches to simulate inputs and led diodes to view the status of the outputs of two ports.
- 7-segment display: This plate has 4 multiplexed digits with decimal point.

- Port Monitor: This board is inserted between the output of a port and other peripherals, allowing to check the status of the data lines with leds.

The Fig. 7 and Fig. 8 show some of the peripheral boards already made. In the following courses another peripherals will be assembled until completion of the whole set of practices.



Figure 7. Input-output board

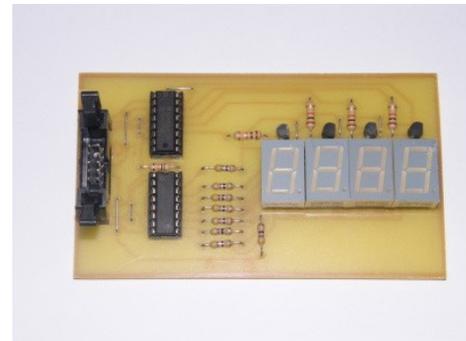


Figure 8. 7-segments display board

IX. PROGRAM OF PRACTICES

Each peripheral board developed in this project is accompanied by an educational unit designed for use in the classroom. Each hardware module is associated with one or more application programs and the documentation necessary for the completion and evaluation of activities. The set of documents can be easily integrated into a web environment or as part of a virtual classroom, opening the possibility of using the system for in-site and distance learning.

Units will be grouped by courses and levels, like digital or analog basic electronics, home automation, radio, power, robotics.

For each of the activities objectives, contents and methodologies are specified for further evaluation.

X. OTHER APPLICATIONS OF THE PROJECT

The circuits developed for this project have served to make improvements in other projects of the authors, as an example in Fig. 9 can be seen the new board of the automatic weather station with ISP programming connector (left, top).

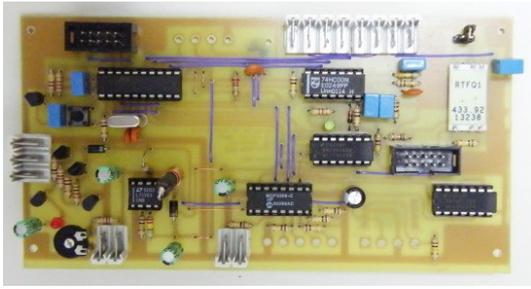


Figure 9. PCB with ISP connector

We have also developed some boards with power MOSFET transistors (Fig. 10) to control stepper motors on a robotic vehicle or a drilling machine for printed circuits.

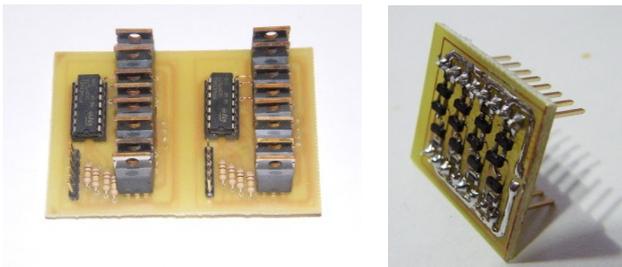


Figure 10. MOSFET power boards

A smaller version of the control board with 89S4051 microcontroller and USB interface integrated has been used for infrared and ultrasonic sensor reading in a robotics project (Fig. 11). This board is being used as a prototype for the usb oscilloscope of the virtual instrumentation system we are developing.

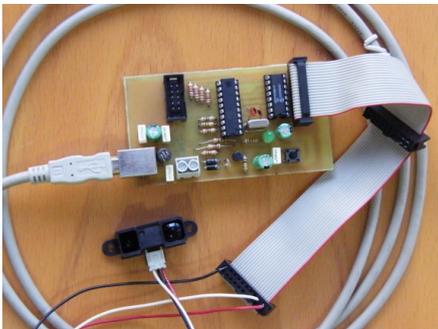


Figure 11. AT89S4051 board with IR sensor

XI. COMPARISON WITH ANOTHER TEACHING STRATEGIES

In recent years there have been developed many strategies for electronics teaching both in universities and professional training. There are commercial systems based on different microcontroller families such as Microchip PIC [15] and others developed by universities [13]. They are based on the MPLAB-IDE environment provided by the manufacturer. The system presented in this article is an open source alternative with much lower cost. Other systems are based on computer simulation combined with self-developed hardware elements [12], and there are higher-level systems based on FPGAs [14] whose

development is difficult for a professional training center for technical and economic reasons. Finally, the Arduino system [16] based on microcontrollers from Atmel ATMEGA is widely used for educational applications for its ease of use, although it is more focused to non technical users and is less suitable for technical education.

XII. CONCLUSIONS

In this paper we have presented a modular system with microcontroller for teaching of electronics. The system is self-developed, low cost and open source. Over the last years it has been verified with many students that have participated in its design and construction, and has also been used for basic digital electronics practices and more complex practices of communications and home automation. The good results obtained have encouraged the continuation of the project with the design of new elements, a process that is expected to continue in the coming years.

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