# Easy Way to Learn Robotic Using Microcontrollers

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***Abstract***— This paper presents a work to improve microprocessor and microcontroller education for robotic master students at the (BMAU) Badji Mokhtar Annaba University.. The paper examines the hardware and software used for microprocessor/microcontroller learning in robotic field, Examples are given for the PIC16F876 microcontroller and the different evaluation boards used for (a) code generation and development; (b) embedded systems applications. Then, attention is given to the software used in microcontroller education. The MPLAB comprehensive simulation and interfacing software is described. Finally, the paper discusses the interfacing between the microcontroller and the various electro-mechanical sensing and actuation components used in a mobile robot applications or project. The use of functional modules for teaching interfacing skills to EE students is described. We finish the paper with a conclusion and pointing further work.

***Keywords***— Microcontroller education; PIC16F876; Evaluation boards; Embedded applications; Interfacing software, Simulation; Electro-mechanical; Sensing;

## I . INTRODUCTION

Due to the accelerated growth of electronics, computers, and information technology industries, a gap has emerged between the traditional methods of teaching Electrical Engineering courses (e.g., robotic Engineering, biomedical Engineering, instrumentation engineering, etc.) and the skills expected of EE graduates entering the job market. A deluge of embedded systems, sensors, microcontrollers, wireless transmission, actuators have emerged present-day society. Microcontroller-based devices and appliances (in embedded systems) are found in all aspects of our everyday life. Even the automobile industry, a traditional Electro-mechanical engineering field, is putting tens of microcontrollers in a modern automobile, and plans to increase this number multifold as new technologies for security and comfort are being introduced.

New automobile technology using, hybrid propulsion, 42-Volts wiring bus, ‘‘steer-by-wire’’, ‘‘brake-by-wire’’, collision avoidance, autopilot, etc. are being currently developed, and automobiles with such capabilities will hit the market in the near future.

However, traditional EE education of students covers only minimal electrical, electronics, and information technology instruction. The ‘‘high-tech’’ components of a EE education are much below expectations, in spite of clear demand. Because of this demand in the job field, the EE engineering graduates entering the job market are at a considerable handicap. To acquire the high-tech skills required in the job market, some Robotic and Automatic Master or engineering students try to register in upper-division advanced electronic courses. However, lacking the proper lower-division background, this practice puts them at a disadvantage, and negatively aff ects their GPA and course load. In response to this situation, an interdisciplinary engineering branch, that spans robotic engineering, electronics, embedded microcontrollers/digital signal processing, controls, and information technology, has emerged under the name of mobile robotic. Nationwide, eff orts to introduce robotics in university education have sprung in over ten Algerian universities, and several worldwide [1..8].

### 1.1. The need for robotics education in Algeria

At our University BMAU, the EE engineering and Master students also have an acute need for education in the interdisciplinary field of mecatronics/microcontrollers. The Algerian government is going through an intense economical development eff ort focused on high-tech businesses and companies. This eff ort is aimed at bridging the technological divide that has placed Algeria among the last in the nation in a high-tech economy. Critical to this statewide eff ort, is the development of an adequate cadre of well trained personnel that can ‘‘hit the ground running’’ in the growing technology-oriented job market. Akin to similar eff orts going on in other places (e.g., France Italy ), this will permit the building of ‘‘a critical mass of talent that local companies can draw from’’ [1]. Because of that, many universities in Algeria are introducing the course of microcontrollers and programmable circuits in their Master program for different disciplines such as: automatic, telecommunication, biomedical, mechatronics, and instrumentation.

### 1.2. Microcontroller education in the department of EE

The Department of EE Engineering at the BMAU Annaba is well positioned to participate in promoting and developing this emerging engineering education field. EE department at BMAU established many courses for teaching microcontrollers to Master students in Robotics, Automatic, Biomedical and instrumentation Engineering students. The course consists of four major components:

(a) courses and exercises at classroom ; (b) homework; (c) laboratory; (d) project. The classroom work is focused on instilling in students the basic knowledge related to programming and using the microcontroller. Part of the

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classroom instruction is performed in a computer laboratory, where the students interact with simulation software on a one-on-one basis. The homework is focused on the students_ understanding and retention of the concepts in a self-teaching style, and it consists of examples that students follow and exercises that the students perform and return to the Teaching Assistants via email. The laboratory consists of nine sessions that gradually take the students from simple microcontroller programming through the usage of its various functions such as parallel ports, serial communication, internal timer programming (detection and generation), Analog-to-Digital Conversion, DC motor and stepper motor control, internal EEPROM read and write, and Digital to Analog conversion. The capstone of the course is a three-month project in which the students work in pairs to achieve the development, design, coding and programming, construction of PCB and wiring components, and demonstration of an embedded system project of their own choice.

The project culminates with a written report including the assembly program, an oral presentation, and a hands-on demonstration with test on hardware design. The syllabus for this course has been discussed and presented to students , final grade is as follow:50% for the final exam, 15% for homework and 35% for project and lab work.

The masters students at the EE Department at BMAU, of which 40% are women and 10% are minority from Sub-Saharian Africa countries ( mainly : Niger, Mali and Senegal), are in need of support to expand and enhance the Robotics/microcontroller education. The project currently undertaken with some Laboratories support will empower the BMAU Master students with the knowledge and hands-on experience required for success in today's technologically competitive economy and market place.

## II ARDWARE FOR MICROCONTROLLER IN ROBOTIC EDUCATION

The hardware issue is also challenging because of the large variety of microcontroller options available on the market . Our objective in developing this course has been to find a microcontroller that is widely used and accepted in the industry and well documented in robotic applications ( Mobil robots, robot arm and robotic applications).

Another criterion in our selection was to choose a microcontroller that has the essential functions that need to be conveyed to the students ( internal memories, timers, converters, parallel and serial ports). The third selection criterion was cost, i.e., an inexpensive microcontroller. There are many microcontrollers available on the market today. However, none is better than the PIC series microcontrollers for the classroom atmosphere. Many OTP microcontrollers may give a better solution in a particular application, but their computer architectures and instruction set are not suitable to a general educational purpose, moreover the OTP controllers are one time programming they are not suited for education where the student can make many tests before succeeding in the realization of the project. The PIC16F876 off ers a powerful and easy-to-memorize instruction set and has been around for more than 8 years. Once you have built your solid foundation of PIC microcontroller expertise, you can easily apply the PIC16F876/628 knowledge to the more developed family of microchip PIC18F or DSPIC30 series or other family of microcontrollers in the future. Plus, there is a lot of application software that can be downloaded from the web and Electronic review. Therefore, the final choice was for the PIC16F876 from Microchip as microcontroller. Figure 1 illustrates the internal architecture of PIC16F628 witch is close in hardware and software to PIC16F876.

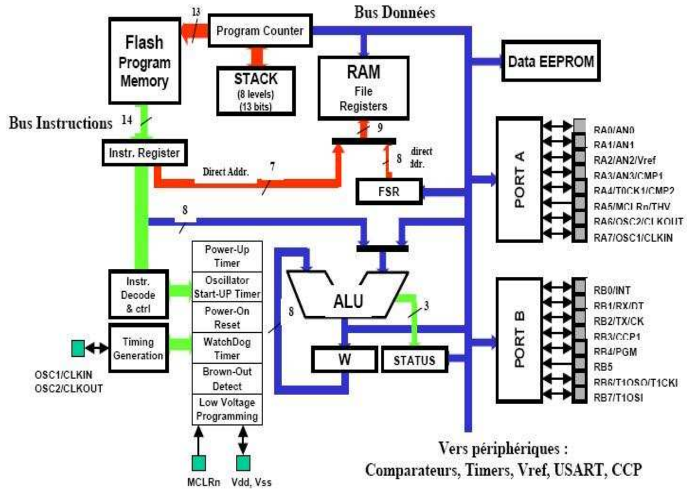


Figure 1 illustrates the internal architecture of PIC16F628

### *A.1. PIC-A microcontroller evaluation and development board*

For embedded applications, the microcontroller is usually used in single chip mode. In embedded applications, the microcontroller comes with the program already ''burned'' into its ROM or EEPROM memory. The user only has to place the microcontroller in its intended location, to power it up and initiate the program for the OTP type , however our type of microcontroller PIC16F876 has a Flash program memory of 8K bytes. Then, the microcontroller will run by itself. There are many types of evaluation and development board in the market, in would be better to have a solid , adapted and upgradable board from microchip company ( designer of PIC microcontrollers)

For code development applications, the microcontroller must be used in connection with a host computer (PC) and/or a terminal. The programmer can develop the program on the host computer and then test it on the microcontroller. Alternatively, the programmer can develop the program directly on the microcontroller using the terminal interface. The electronic circuitry and IC chips associated with this process are placed on an evaluation board (EVB). The EVB contains expanded memory chips, a port replacement unit, as well as IC chips for servicing the connection to the host computer and/or a terminal. The EVB is essential for program development, since it allows the software programmer to develop and test the microcontroller application software. Once the microcontroller application software is developed and tested, then it will be ''Flashed'' into the program memory of the mass production microcontrollers. By using the EVB expanded system containing an PIC16F876/8777 and aPC, the user can develop software intended for either single-chip mode or expanded mode microcontroller applications. Several microcontroller evaluation boards are commercially available. They range from the simplest to the most complex. For our lab, we have selected two types, one for code development (Easypic http://www.docshut.com/ikvmmn/easypic2-manual.html), the other for embedded applications (PIA-A microcontroller DVB,

*B. PIC-A microcontroller evaluation and development board*

PIC-A development board is a new type designed to develop good e-multifunctional PIC microcontroller development platform. MCU integrates commonly used external devices, such as, DS1302 clock chip, DS18B20 temperature sensor, an external EEPROM chip 24C02, MAX232, beep horn, matrix keyboard, separate keyboard, dynamic digital control, marquees, LCD1602, LCD12864, 2003 motor drive, etc. The PIC microcontroller development platform provides a great deal of learning materials, including routines, instructions, e-books, user's examples. PIC-A development board uses typically the most widely used chip PIC16F877A.

To easily study and develop all series of PIC Microcontroller's, only a set of PIC-A demo system and a computer are needed. Based on programming functions, abundant on-board hardware resources, flexible expansion, free resource distribution, and ICSP download function for customer target board, PIC-A can not only satisfy the demands of a beginner in Microcontroller study, but also meet the requirements of engineers in development of Microcontroller. In addition to a study & experimental board, PIC-A is also a demo board of Microcontroller integrated with multiple resources.

Characteristics:
Abundant on-board resources: LED, digital tube, key-press, keyboard matrix, character LCD, A/D converter, D/A converter,, USART serial communication
Open modular design: All I/O ports are open externally with output socket. Expansion is easily accomplished..

1. 8 LED lights
2. 6 Clock digital tube (do counter, voltmeter, stopwatch, electronic clock, frequency counter, etc. display);
3. 4 Independent keys (do button scanning);
4. 4 * 4 ranks of the keyboard (buttons do scan);
5. MAX232 serial port (RS232 and Computer Communication can do experiments);
6. AT24C02 (EEPROM can do experiments);
7. Buzzer sound output (do music-related sound experiments);
8. DS18B20 temperature sensor (temperature measurement do thermometers and other related experiments);
9. DS1302 real time clock circuit (tube or LCD display can be used to do digital electronic clock);
10. 1602 LCD display interface (2 lines of 16 characters per line, with backlight); (not including lcd)
11. 128 * 64 LCD display interface (4 lines of 16 characters per line, with backlight); (not including lcd)
12. Stepper motor interface (do stepper motor Reversible experimental) (not including motor)
13. All the way 10-bit A / D converter (DAC testing DC voltage, tube or LCD display with digital display);
14. DC power input (DC voltage :6-15V);
15. USB power input interface (direct access to computer power supply);
16.40 PIN Block the programming (which can replace the chip);
include: - a development board; - USB cable; - serial line; - PIC16F877A

*C. . EasyPic-2 development board*

Presented in figure 2, the hardware system supports 8,14, 18, 28, and40-pin microcontrollers Each jumper, element and pins clearly marked on the board. Most of the industrial applications can be tested on the board: temperature controllers, counters, timers etc. EasyPIC2 also includes practical examples in PASCAL, BASIC, C, and assembly. Port A is connected to the resistor network, if switch is not in ON position, the appropriate pin has neither pull-up or pull-down resistor attached. This is very important, because it enables using A port in Analog mode as AD Converter, and yet it can be used as ordinary digital I/O port. Setting PORT jumper to the upper position sets the pins of the appropriate port to logical one(pull-up). If jumper is set to the lower position, pins are set to logical zero (pull-down). It is very important to put pin on pull-up if you expect logical zero on input and vice versa. Prototype area in which we can place our additional components. The back side of the board has pin marks to make the connectingeasier.32 buttons allows us to control every pin on the microcontroller. we can chose how pressing the button will affect the pin, high state or low state. See all the signals - each pin has LEDs. Seven segment digits in multiplex mode for displaying the results.

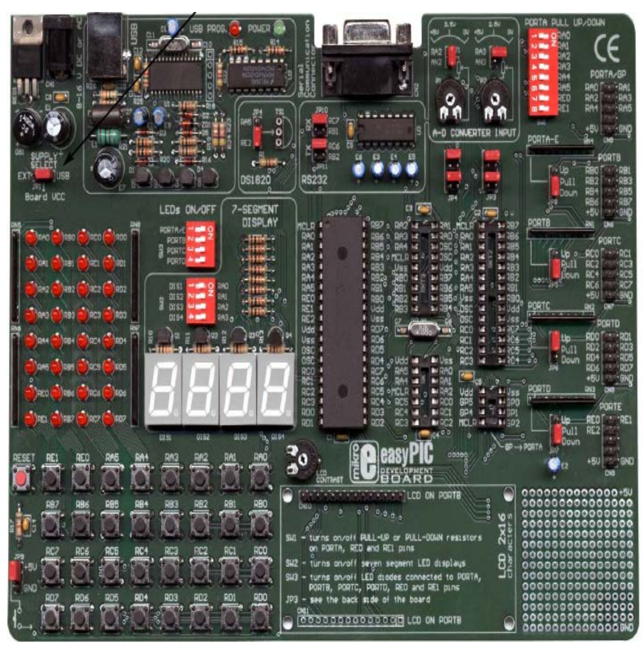


Fig. 2. Easy Pic -2 development board
http://www.docshut.com/ikvmmn/easypic2-manual.html

### III Software for Microcontroller Education in Robotics

The software issue is particularly challenging since the robotic master students receive instruction in high level programming without getting involved in assembly programming until they enter the microcontroller course. Today, most of the programming education of EE students is done in visual languages such as MathLab and LabView, for which the EE department and some laboratories at BMAU have licenses. Hence, the teaching of a script language such as Assembly or C++ for programming the microcontroller has to done from basic principles. We found that the use of microcontroller simulation software greatly enhances the students ability to climb this steep learning curve. We selected an inexpensive microcontroller simulation software based on the assembly language, MPLAB by microchip[13],[14], http://www.microchip.com.
And at
http://ww1.microchip.com/downloads/en/DeviceDoc/MPLAB_User_Guide_51519c.pdf
MPLAB Integrated Development Environment (IDE), as presented in figure 3, is a free, integrated toolset for the development of embedded applications employing Microchip's PIC® and dsPIC® microcontrollers. MPLAB IDE runs as a 32-bit application on MS Windows®, is easy to use and includes a host of free software components for fast application development and super-charged debugging. MPLAB IDE also serves as a single, unified graphical user interface for additional Microchip and third party software and hardware development tools. Moving between tools is a snap, and upgrading from the free software simulator to hardware debug and programming tools is done in a flash because MPLAB IDE has the same user interface for all tools.

MPLAB IDE supports many language Toolsuites. Integrated into MPLAB IDE is the Microchip MPASM Toolsuite, but many others can be used, including the Microchip C18, C30 and C32 Toolsuites, as well as language tools from HI-TECH, IAR, CCS, Micro Engineering Labs and Byte Craft. These are integrated into MPLAB IDE in two ways: using “plug-ins” designed by the manufacturer, and by older style “.MTC” files that can be customized for any language Toolsuite.

#### A. *STEPS for Program development*

In order to create code that is executable by the target PIC MCU, source files need to be put into a project. The code can then be built into executable code using selected language tools (assemblers, compilers, linkers, etc.). In MPLAB IDE, the project manager controls this process. All projects will have these basic steps:
a) Select Device: The capabilities of MPLAB IDE vary according to which device is selected. Device selection should be completed before starting a project.
b) Create Project : MPLAB IDE Project Wizard will be used to Create a Project.
c) Select Language Tools : In the Project Wizard the language tools will be selected. For this tutorial, the built-in assembler and linker will be used. For other projects, one of the Microchip compilers or other third party tools might be selected.
d) Put Files in Project : Two files will be put into the project, a template file and a linker script. Both of these files exist in sub-folders within the MPLAB IDE folder. It is easy to get started using these two files.
e) Create Code : Some code will be added to the template file to send an incrementing value out an I/O port.
f) Build Project : The project will be built – causing the source files to be assembled and linked into machine code that can run on the selected PIC MCU.
g) Test Code with Simulator :Finally, the code will be tested with the simulator.

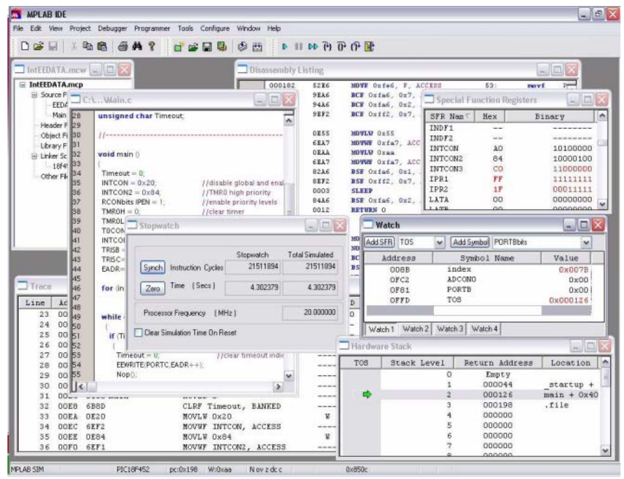


Fig. 3. Screen capture of the MPLAB IDE simulation and emulation software for PIC16F876/877 microcontroller.

#### B. *Simulation and Debugging*

The simulator visualizes the CPU, Flash memory for program, RAM, EEPROM and all memory mapped I/O ports (Figure 3). It also simulates the on board peripherals such as :
- timer (including pulse accumulator),
- analog to digital converter,
- parallel ports (including handshake),
- serial port,
- I/O pins (including analog and interrupt pins).

While debugging, the graphical user interface makes it possible to view and control every register (CPU registers and I/O registers), memory location (data, program, and stack), and pin of the simulated microcontroller. Even when the program is running! It is possible to stop the simulation at any combination of events. For example, stop when stack calls function 1 and RAM location $003F contains $BD or I/O register TCNT is greater than $2578.
A number of (simulated) external components can be connected to the pins of the simulated PIC16F876 while debugging. For example:
• LED’s, • switches, • analog sliders (variable voltage potential), • serial transmitter and receiver,
The MPLAB can communicate with the EasyPIC Development Boards and different tools for emulation and

programming developed by Micronchip. This MPLAB program can be downloaded (for free) from the microchip website. When the assembly program is compiled it produces a HEX file which is loaded into the target board the graphical user interface makes it possible to view and control every register (CPU registers and I/O registers) and memory location (data, program, and stack) of the real microcontroller. It is possible to stop the execution at any address and inspect or change the registers and memory.

## IV. Interfacing of ROBOT microcontroller projects

Finally, we are addressing the interfacing between the microcontroller and the various electro-mechanical sensing and actuation components used in a Mobil robot or robot arm project as in figure 4. These issues are very important, especially with EE engineering students that have little or no previous experience with interfacing electronics with mechanical engineering hardware. We treated this aspect using a suite of functional modules. These functional modules are used for teaching hands-on skills related to the interfacing of mechanical, electrical, and electronic components of a Mobil robot design.

EE engineering students have the need for hands-on experience to increase their ability and confidance in tackling mechanical, electrical and electronics concepts, especially during the realization phase of a Mobil robot project. To address this need, we started developing a suite of functional teaching modules. These functional modules are intended as bolt-on building blocks with clearly defined inputs and outputs, and an explanation of the underlying operational principles. The students are expected to use the functional modules as a learning tool. After understanding their functionality, they are expected to duplicate the circuitry on their own breadboards to be incorporated into their robots and automatic class projects, as well as into other hands-on projects, as appropriate. The modules that have been developed include:

- Opto-electronic sensor,
- temperature sensor LM135,
- humidity sensor,
- H-bridge for DC motor (relay and transistor),
- Stepper motor controller, stepper motor drive unit
- pulse-width modulation dc motor drive unit,
- open collector buffer, latches and LED's
- Relay and transistor commutation module.
- Ultra-sonic sensor ( MSU-08).

Accompanying the functional modules are full reports containing electrical and component schematics, applicable equations, and a full experimental results during calibration tests results. These reports play an important role in the functional modules education. Several graduate students and undergraduate students composed these reports for every functional module when they first built these modules. The goals of these reports are helping the readers to understand the functional module component and facilitating repairing these functional modules. The students are provided with a bag of components and asked to reproduce the functional module circuit following the circuit diagram and observing the physical realization in the functional module box. Using this approach, the students know what to expect when using the functional module by reading the report, and acquire the hands-on experience by building the physical object. As an example, Fig. 5 shows the appearance of port information using LED's circuit containing LED's to simulates ports and Fig. 6 presents the Mobil robot project using POB-Bot that include a module called "Pob-Proto", this module uses PIC16F877 as microcontroller to interface actuators and sensors which are presented in the functional module report[19]. Machine Science in www.machinescience.com,Offers an expandable metal robot base, which includes motors, wheels,microcontroller, and other electronics. were presented in site [8] ,Giurgiutiu and Liu presented other modules for michatronics [9].

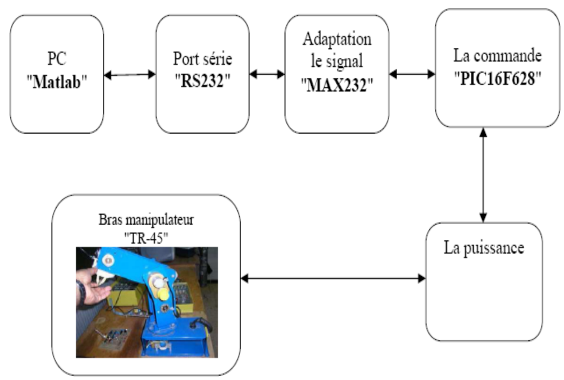


Fig.4. : synoptic of realized as project: robot arm control via Pc through microcontroller PIC16F628.

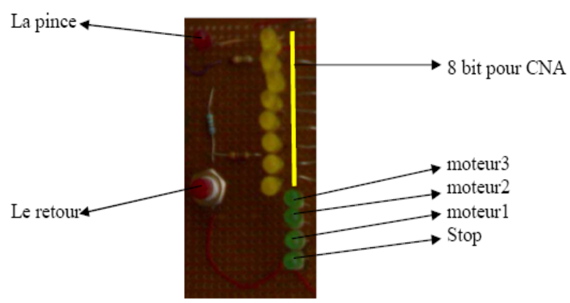


figure5.6 : carte émulation.

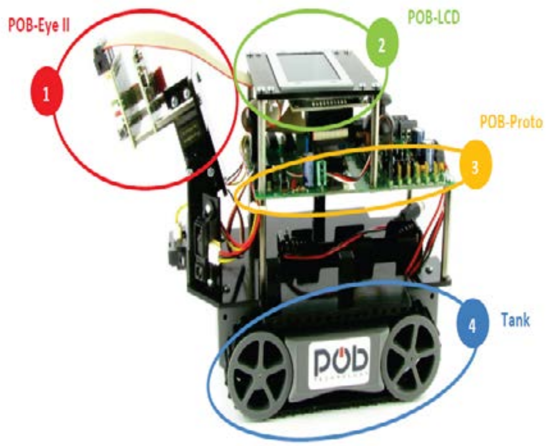


Fig 6. Pob-Bot robot with sensors for navigation, I/O interfaces are controlled via PIC16F877.

## V. Conclusions

Many universities have started disposing courses on robotics to undergraduate and graduate students. Such courses, cutting across departmental boundaries and combining theory, hands-on experiments, and technology applications, greatly benefit the undergraduate students, graduate students, and even faculty. They propel the curriculum towards the forefront of engineering education and directly answer the training and education challenges of the coming years.

The Department of EE at BMAU Algeria has embarked upon a project to enhance the robotic and mechanic education of EE engineer and master students. This project is to prepare these students for jobs in industrial factory at Annaba city. Annaba City is a big industrial area with companies like ARCELOR MITAl and FERTIAL. Our approach will help expand the students understand microcontrollers from both analysis and hands-on viewpoints. Our instruction has focused on using the microcontroller in various applications in robotic sensors network and automatic, rather then how the microcontroller is built inside. This is considered most applicable for electrical engineering and other non-electrical engineering students. The work on this project is continuing. Further developments will be reported in future publications.

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