AC 2008-1976: EMBEDDED SYSTEM DESIGN WITH MICROCHIP'S 16F88 MICROCONTROLLER

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Embedded System Design with Microchip's 16F88 Microcontroller

Abstract

The paper expounds the course material that is developed dealing with Embedded System Design. The course is designed for offering in Electrical, Electrical and Computer or Mechatronics types of Engineering Technology or Engineering Programs.

The paper examines the pedagogical aspects of the course which determines the successful learning that is achieved in this course. First and foremost the course utilizes the C programming which is the industry standard. It is based on 16F88[1] PIC Microchip microcontroller. 16F88 is chosen since it is a powerhouse of functionality and hence ideal for industrial, automotive and consumer applications. The laboratory exercises that brings into focus most of the features and functions associated with 16F88. The laboratory exercises are performed using an open architecture Design and the Development Board. This development platform is designed and developed by the department. During the course students learn the architectural details of system design around this development board. The paper describes the development platform in detail. The paper elaborates the integration of CCS[2] C compiler and an open source Programmer WinPic[3]. The trio: the Development platform, CCS C Compiler and WinPic Programmer provides the ideal integrated development environment for Embedded System Design.

Introduction

Traditionally the first course in microcontrollers or microprocessors has been in the past taught with assembly language, this trend is both wasteful in terms of classroom learning curve and is not efficient in terms of software development after the advent of efficient C compilers. This practice has been abandoned for decades by the industry. Somehow the only patron of this approach has been the academia. This practice has been particularly harsh in student's performance in subject matter content mastery as well as raising the learning curve to the level of not able to achieve any meaningful fulfillment in a single semester course offering. The paper presents here the practice followed by the authors in the Department of Electrical and Computer Engineering Technology at Purdue University Calumet for over a decade of successful course delivery that translate into interactive learning from the students perspective.

We have selected 16F88 Microcontroller because it provides a very rich collection of functions. Based on the following functions a number of laboratories can be created that address and prepares student to become a successful Embedded System Designer. 16F88 has 8 MHz internal oscillator, thereby eliminating the need for any external clock source. 16 discrete I/Os, provides ample digital discrete interface and control for the system. Two 8 bits and one 16 bits Timers / Counters, provides for background time reference and related time function control. One external interrupt, coupled with discrete I/Os allowfor monitoring of external events. Flash programmability, provides for ease and repeated usage in a laboratory setting. Capture/compare - PWM, is ideal for speed control applications. Addressable USART, a synchronous serial port that can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I^2C™) bus, provides for serial communication capabilities to the system. The 7 channels of 10-bit Analog-to-Digital (A/D) converter and 2 Comparators, further eliminates the need of external A/D device thereby simplifying the system design. Further Program Memory Size of 7 Kbytes, is ample enough for laboratory usage.

Course Audience

The course is designed and is being offered as an introductory course. It is aimed at students interested in majoring in one of the following disciplines: Electrical, Electrical and Computer, Mechatronics types of Engineering Technology or Engineering Programs and Computer Science.

Corse Format

This course is offered on a semester basis consisting of 16 weeks. The course has 3 hours of lecture and 3 hours of laboratory / week and has 4 credit hours allocated at its completion. The course could also be offered as a Seminar course that would have these two components: 1) Lecture part will be offered in a Distance Learning mode and 2) Laboratory portion of the course will be completed on an open lab bases. The authors have offered the course in both the formats.

In the second format, with lectures delivered through distance learning requires a lot more preparation time. Lectures were recorded, in the form of voice along with continuous video in the form of screen. The lectures were taped and delivered in Windows Media Player format. This was possible with a commercially available recorder Huelix[4] - Screen Play and Screen Recorder, that Captures, Records, and broadcasts screen video in real-time.

Course Software Development Tools

The course utilized C language for all the software development of 16F88 microcontroller. The compiler for the course that we utilized is Custom Computer Service's CCS v-4 C compiler. This could be invoked from the MPLAB, the Integrated Development Environment (IDE) that is freely available from Microchip Technologies. The students could do the software development in MPLAB IDE and also could perform the simulation of the software as well. The other commercially available C Compilers are: 1) HI-Tech PICC v.9.50. 2) IAR Embedded Workbench v.2.21. 3) Forest Electronics C Compiler v.14. 4) B Knudsen CC5X and CC8E C Compiler and 5) Source boost C Compiler.

Course Hardware Design and Development Tools

The authors have designed an in house hardware development platform, whose schematic is provided in Figure 1. The development board provides headers for accessing all the ports along with VDD and VSS. It has also a Serial port interface to access the PC and communicate via Rs232 port for down loading the program. By adding another serial port interface (not in the schematic), the development board could utilize the monitor display of PC as its extension. It has on board opto-isolators to protect the ports inputs and outputs. There are 2 seven segment displays, eight dip switches and eight toggle switches and eight LEDS for immediate interfacing.

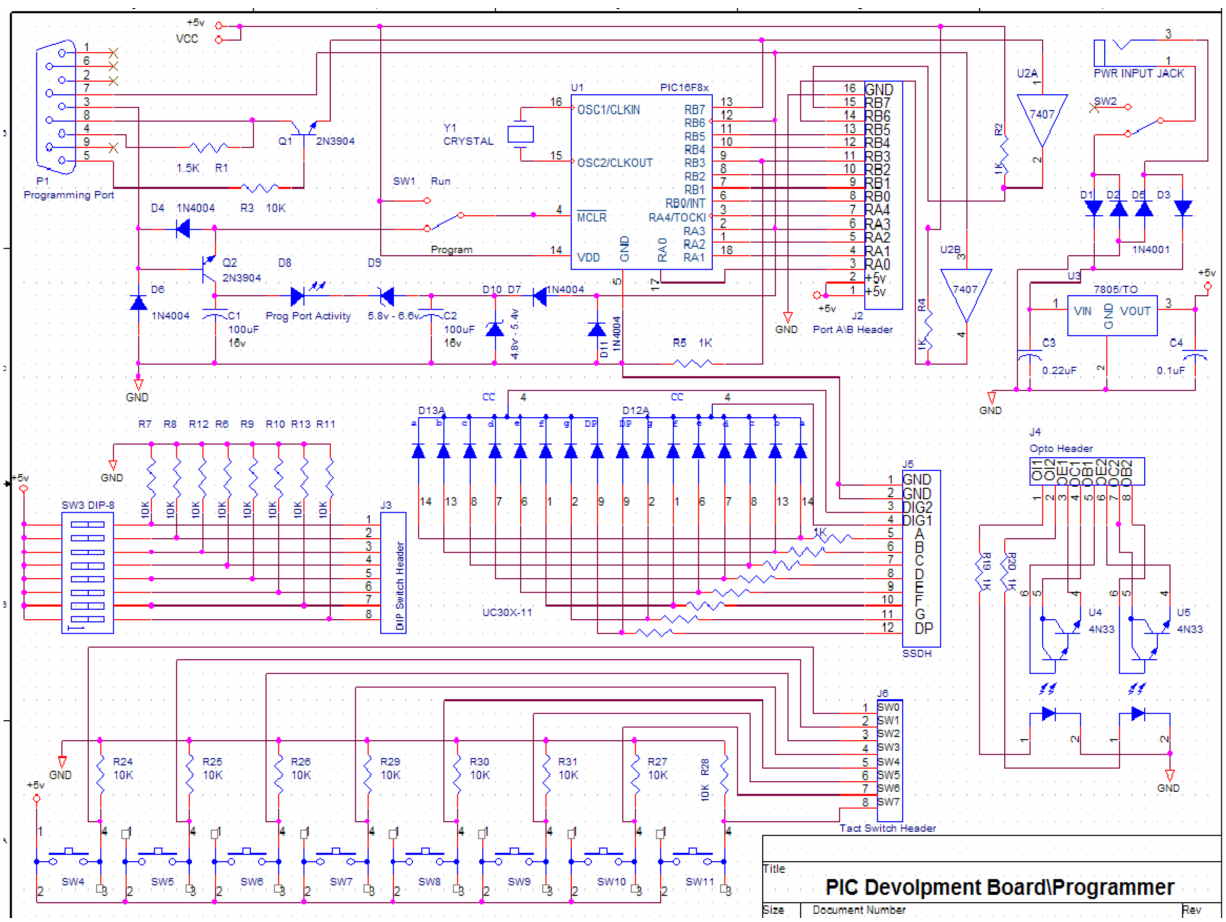

Figure 1. PIC 16F88 Design and Development Platform

The Embedded System Hardware – Software Development Platform

The MPLAB IDE v7.61 by Microchip is the core development platform for the software. MPLAB is a freely down load from Microchip's website. The MPLAB IDE provides an integrated development platform in which we can do software development, which consist of an editor with all its functionality. The C compiler (in our case CCS v-4 C compiler) is invoked from within the MPLAB. After the compilation the MPLAB also provides a simulation mode that allows the simulation and testability of the code that allow us to monitor data, variables and all the special Purpose registers of the subject microcontroller. After satisfying with the simulation the next step is to down load the source code file which is the Standard Intel Hex Format. The PIC 16F88 Design and Development Platform (Figure 1) along with the respective interface circuitry which forms our respective Embedded System is connected to PC. The designed software file in the form of Standard Intel Hex Format is then down loaded using the WinPic, open source programmer which is again free download. Thus the whole development platform described here with the exception of the compiler is open architecture and utilizes open or free software.

Course Content

The course consists of Lectures that spans over the topics that are described below. Furthermore there are 15 Laboratory exercises are hierarchically build, upon and reinforce the topics that are learned during the lectures.

Course Topics

This is an introductory course. No Prior knowledge of the subject is needed. A programming course in C^{++} is desirable.

The course would comprise of the following topics[5]:

1) A Tutorial to the C Language and the Use of the C Compiler
   - Introduction to C
   - Types, Operators, and Expressions
   - Program Flow Control
   - Inputs and Outputs
   - Functions and Program Structure
   - Pointers, Arrays, Structures, and Unions
   - Compiler Specific Library Functions
   - Mixing C and Assembly (toward the end of the semester optional)

2) PIC16 Development Tools and 16F88
   - Software Tools
   - Hardware Tools
   - Using MPLAB IDE

- Using the MPLAB SIM in Debugging PIC16 Applications
- Development board from commercially available sources
- Authour's own Development board

3) Parallel Ports
   - I/O Addressing
   - Overview of the PIC16 Parallel Ports
   - Interfacing with DIP Switches
   - Interfacing with a Keypad
   - Interfacing with Simple Output Devices, LEDs, Seven Segment Displays
   - Interfacing with LCD Controller
   - Interfacing with driver circuits, Opto Isolators, Power Transistors

4) The PIC16 Interrupts
   - PIC16 Interrupt Operation
   - PIC16 Interrupt Programming
   - The PIC16 Resets

5) Timers and CCP Modules
   - Overview of PIC16 Timer Counter Functions
   - Use of Timer Counter Interrupts
   - Capture/Compare/PWM Modules
   - CCP in Capture Mode and Compare Mode
   - CCP in PWM Mode

6) Analog-to-Digital Converter
   - Basics of A/D Conversion
   - The PIC16 A/D Converter
   - Procedure for Performing A/D Conversion and C Library Functions

7) Addressable Universal Synchronous Asynchronous Receiver Transceiver
   - Overview of Serial Communication
   - The EIA232 Standard
   - The PIC16 Serial Communication Interface and C Library Functions

Course Laboratory Exercises

The following exercises are performed during the course offering.

Laboratory 1. Orientation of MPLAB and CCS compiler and use of simulation of code.

Laboratory 2. Orientation of the PIC 16F88 Development system and WinPic Programmer.

Laboratory 3. Discrete Data input –output with I/O ports. Input with switches setting and data output with LEDs.

Laboratory 4. Data output with I/O ports and interfacing of seven segment display. Use of multiple seven segment display and multiplexing of output data.

Laboratory 5. Embedded System serial interface using RS 232. With PC. Displaying of data on PC monitor.

Laboratory 6. Registering / monitoring of external events with hardware interrupts.

Laboratory 7. Use of Timer / Counters and their respective interrupts.

Laboratory 8. Using 16F88 A/D converter and monitoring of and displaying of voltage with LCD panel.

Laboratory 9. Mid Semester Embedded System Design "Digital Home Thermostat.

Laboratory 10. Designing a DC Motor speed controller system, using PWM.

Laboratory 11. Designing a DC Motor speed and direction controller system, using PWM. Status of the system is communicated to PC monitor via RS232.

Laboratory 12. Establishing I^2C communication, with the embedded system.

Laboratory 13. Designing a Temperature monitoring system using I^2C communication with Dallas Semiconductor DS1631A Digtal thermometer.

Laboratory 14. Independently Researched and faculty approved team Final Project.

Laboratory 15. Independently Researched and faculty approved team Final Project.

Course Assignments

The course requires a weekly position paper that expounds the conceptual understanding of the subject matter content and inferences drawn from the laboratory performance. The course assignments are submitted on line. Each student maintains an online portfolio of the work.

Pedagogy of the Course

The pedagogy of the course is based on Outcome Based Education[6], and utilizes the interactive model of learning. All the students maintain an online portfolio of their work. The system designed in the laboratory to perform a specific task is the core measurement as the learning outcome of the course. The laboratory performance of the course is performed in teams of three students. This mode provides a platform for horizontal learning through active and engaged discourse and discussion. Students are empowered to charter their learning and feed their curiosity. The course culminates in a Final Project which is assessed based upon its comprehensiveness and originality. Students are required to master the soft skills of comprehensive report writing on a weekly basis and of Technical Project Report writing and project oral presentation based upon the Team's Final Project. These classroom practices and laboratory environment provides a challenging and invigorating environment that prepares them for a lifelong learning process and career path.

Bibliography

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[3] http://freenet-homepage.de/dl4yhf/winpicpr.html

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