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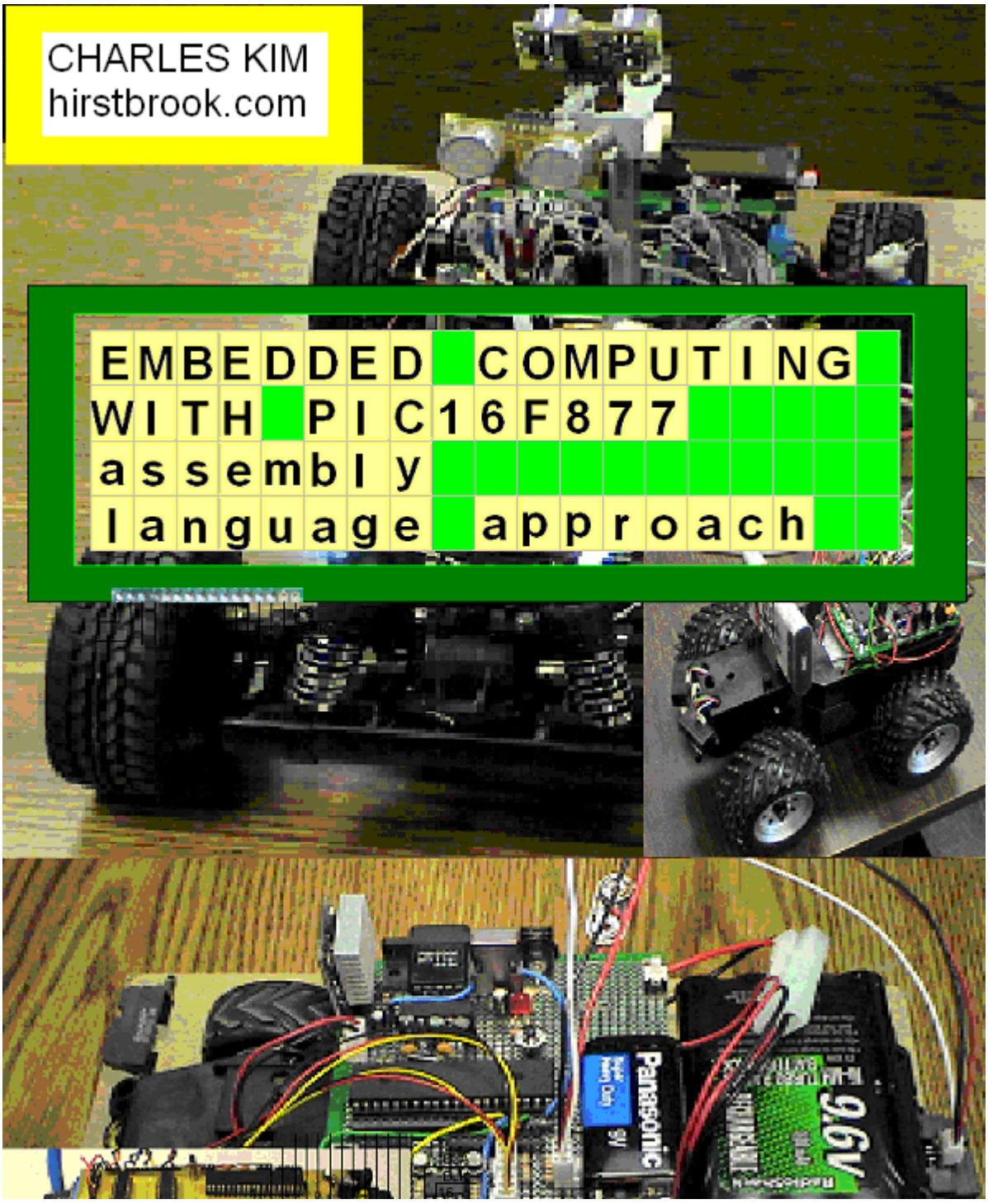
EMBEDDED COMPUTING WITH PIC16F877
- Assembly Language Approach



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About the author

Dr. Charles Kim is a professor in the Department of Electrical and Computer Engineering at Howard University in Washington, DC, USA. He has taught for years both for undergraduate and graduate students at many universities including Texas A&M University, University of Suwon, and Howard University. Dr. Kim wrote this book originally for his Microcomputer course and Embedded Computing course, and currently this book is used as the refernece of Embedded Computing, which is basically project-based robot building course. It will be also adopted for the Microcomputer course for assembly language programming. His approach in the book is simple: code in assembly language, which is free, instead of using C which costs you with cross compiler. Dr. Kim is active in embedded computing, smart sensor network, and AI and expert systems. His most recent award is the "professor of the year" award in April 2006 by the College of Engineering, Architecture, and Computer Sciences of Howard University Student Assembly.

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Most of the photos, diagrams, figures are my own and my product, however, I freely adopted numerous diagrams to explain the modules of PIC16F877 from the following two materials published by Microchip Technology Inc:

- PIC16F87X 28/40-pin 8-Bit CMOS FlASH Microcontroller, 1999. DS30292B.
- PICmicro Mid-Range MCU Family Reference Manual, 1997. DS33023A

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Preface

I have been teaching microcomputer application including embedded computing several years in both undergraduate and graduate classes. Teaching and learning microcomputers and microcontrollers in college classroom is challenging in that hardware development systems are usually not well equipped for installation of microcontroller systems. Also, software development systems for specific microcontrollers are too costly for an engineering department. My approach, to overcome the limitations, has been to use microcontrollers with easily installable IC package on breadboard, notably DIP, which comes with manufacturer provided freely available programming software. Another important criterion is if executable code downloading is also freely available.

The result of the approach and criterion led me to choose the PIC16F877 microcontroller from Microchip. Microchip provides its own, free of course, development system called MPLAB which provides assembly language programming and simulation environment. Assembly language program takes a longer learning period than high-level language like C. However, once learned, assembly programming gives better control of the microcontroller, let alone better understanding of the internal structure and operation of it. There is a problem in assembly language programming of the PIC microcontroller: there is no book on the subject.

This book is the collection of my own lecture notes of last few years on assembly language programming of PIC16F877 and its application to autonomous robots, robot arm controllers, and other interesting projects. As clearly put in the cover, this electronic textbook is a beta edition and it is solely for internal use for the students who take my course, Embedded Computing. Since I am the only person worked for this edition, without help of editors or proof-readers, I do not expect this edition is without errors or typos. So I am asking your favor: if you find errors, typos, or spelling and grammar errors, please kindly send me your findings to me at ckimson@gmail.com or doc@hirstbrook.com

My objective of this book is to give students an independent and complete source of 16F877 programming. The source codes in whole in the book are accurate and tested by me, and I hope these source codes put you head start for your intended projects. Following my goal, I made this book self-learning and self-training manual. I added detailed explanation behind each code with illustration and diagram.

First three chapters cover the basic of 16F877 with architecture, memory, I/O ports, and instruction sets. Chapter 4 details about the coding environment, namely PIC Assembler. two versions of PIC Assembler, MPLAB, of Microchip Technology are thoroughly covered step by step. Then, hex code downloading is detailed. Also covered are the minimum hardware needed for hex code downloading to 16F877 and commercially available PIC board for 16F877. At the end, troubleshooting and connection tips are discussed followed by the first serious example of piezoelectric buzzer problem.

Chapter 5 discusses about asynchronous communication utilizing 16F877's built-in communication module. Serial communication between 16F877 and a PC is discussed with example code. Additionally and very importantly, serial communication without using the

module is discussed. This example is very important can find many applications, a few of them are discussed in Chapters 6, 10, and 11. Chapter 6 is the extension of serial communication with LCD displaying. Here infrared remote control protocols and applications are demonstrated.

Chapter 7 is for motor control and robot building. DC and stepper motors and their control using relays, H bridges, and other solid state control chips are discussed. Robot building schemes are also suggested along with code examples.

Chapter 8 is about analog-to-digital conversion using the A/D conversion module of 16F877. Infrared ranger for distance measurement and current measurement are demonstrated as parts of the A/D application.

Chapter 9 discusses about another built-in function of timer module in 16F877. Time delay using Timer 0 are thoroughly discussed and expanded to a digital clock project. Several version of digital clock codes are discussed. In the application of Timer 1, a color sensing scheme is illustrated.

Chapter 10 discusses synchronous serial communication and its application to keyboard reading. Many different aspects of keyboard reading and LCD displaying are detailed in the chapter.

Chapter 11 covers a voice synthesizer project in which we try to build a system which generates voice from the text typed in a keyboard. The text is also displayed on a LCD display. A long and complete code is provided for the readers.

Chapter 12 focuses on the subject of storing and retrieving data into/from the internal EEPROM of 16F877. The internal EEPROM has about 1/4 K Byte of memory space, and very valuable when you want to keep your data eve after you turn off your PIC board. Reading from and writing to the internal EEPROM are detailed with full explanation and full source code.

Chapter 13 deals with the CCP module of 16F877 but the focus is on the PWM mode operation of the module. PWM output example is discussed with source code.

Chapter 14 is about accessing external EEPROM access. In this chapter, we assume that we need more EEPROM space and want to read from and write to an external serial EEPROM. The serial EEPROM we selected as an example is Microchip's 24LC16B, which has 2KByte memory space. Since the control access is based on synchronous serial communication and I^2C (Inter-IC) bus protocol, a lengthy introduction precedes the main application part using 16F877 and 24LC16B. Hardware connection diagram is also included.

Chapter 15 controls a legacy robot called Armatron. The Armatron has several motors inside and its control is to turn motors according to the motion cotrol need. Detailed control scheme, which cannot be easily found even from Googling, is illustrated and relay control is discussed. Lastly, an example control project is described with diagrams and source code.

Chapter 16 tries to control using a PC, which gets signal from IR transmitter controlled by 16F877. Since control button is implemented as a window in the Windows operating system, a

Visual Basic code for Windows programming is included as well as the source code for 16F877.

The draft of this book was finished last summer and this year, I could merely revise, only slightly, because of my tight schedule. I regret that I could not finish the intended chapter on *projects* which would contain various application of 16F877 applying the knowledge you gained from the previous chapters. Fortunately, I have draft on the subject along with actual working code, but I do not have enough time to put all things together in to a very long chapter. I plan to take this summer to add this subject in to a final copy of the book.

I sincerely hope you enjoy this rough edition, and complete your project with a great success.

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