Microprocessor Interfacing Laboratory

Derek B. Gottlieb, Nicholas P. Carter
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
Urbana, IL 61801
{dgottlie, npcarter}@crhc.uiuc.edu

Abstract

This paper summarizes the rationale behind the revision of a microcomputer laboratory course involving hardware-software co-design and the integration of microcontroller-based systems with a general-purpose microprocessor system. The revised course replaces aging custom hardware with a high-performance PDA running Linux and a feature-rich FPGA prototyping board. The resulting course objectives and content as well as early experiences are highlighted.

1. Introduction

One of the long-running technical electives at the University of Illinois recently underwent a major revision in an effort to take advantage of more current technology. This course, Microprocessor Interfacing Laboratory (ECE 311) [1], is one of several senior-level design courses offered by the department. Previously, the course focused on interfacing several custom boards to an embedded Intel 80386EX microprocessor. This approach suffered from a few significant problems, which were primarily due to the extensive use of custom hardware in the lab. Over time, this hardware became increasingly difficult to maintain, especially since several of the chips used were no longer readily available. In addition, the limited versatility of this custom hardware prevented the offering of an open-ended design project.

To address these issues, the course was revised to use more modern hardware with a focus on flexibility. To this end, the embedded Intel 80386EX board was replaced by a HP iPAQ PDA running Linux. Linux was selected over the pre-installed Microsoft Pocket PC OS for a variety of reasons. First, Linux is open-source and, therefore, source code is easily obtained for any portions of the OS used in the course. Second, our students have previous experience with the Unix platform making it much easier for them to program for Linux than it would be to teach them how to program for the Microsoft Windows GUI.

Similarly, all of the custom hardware was replaced by an XESS XSV-300 FPGA prototyping board [3], which addressed several of the previously mentioned problems. Since it is a commercial product, the option exists to easily purchase replacements if repairs are not feasible. The board also supports a wide array of functions that are not all used during the structured labs, allowing the addition of an open-ended design project to the curriculum. This flexibility combined with the inherent flexibility of a powerful PDA running Linux provides students with a great amount of freedom in their design projects.

2. Course objectives

The course objectives focus on several key elements of embedded system design. In particular, they are:

- Understand the tradeoffs in system design across the hardware-software barrier
- Understand common techniques such as I/O and interrupts
- Perform a major design project

3. Course content

This course is intended for senior undergraduate students in electrical or computer engineering who have completed introductory digital logic design and microprocessor interfacing courses.

The main task of the course is to complete four Machine Problems (MPs) consisting of the following:

1. Introduction to VHDL
2. PCMCIA and interrupts
3. Video and the NTSC standard
4. Design Project

In the first MP, students familiarize themselves with the available tools (CAD software and lab equipment) and develop a simple PS/2 keyboard interface using the XSV-300. This MP also includes a brief open-ended segment in which students develop their own designs using the hardware they have used up to that point. As time permits, similar sections are included in the other structured labs for the course. In the second MP, students develop a PCMCIA device interface on the XSV-300 and a simple driver for the iPAQ to support communication between the iPAQ and XSV-300. In the third MP, students develop a system that grabs video data from an NTSC webcam and displays it on the iPAQ's LCD screen and a VGA monitor. The fourth MP is left as an open-ended design project in which students develop a hardware-software design that makes use of any of the equipment available to them.

4. Laboratory support

The laboratory is configured with 7 lab stations, each consisting of an XESS XSV-300 FPGA prototyping board and a HP iPAQ H3600-series PDA running Linux (Figure 1). The XSV-300 combines an NTSC video decoder, VGA RAMDAC, ethernet PHY, and a 20-bit stereo codec with a powerful Xilinx Virtex FPGA [2]. In addition, the board provides USB, PS/2, serial and parallel interfaces to the FPGA. The board also includes two expansion headers, one of which we use to connect to the PCMCIA slot of the iPAQ.

The iPAQ provides an impressive amount of flexibility with a 206MHz StrongARM processor running Linux, 32MB of RAM, 16MB of Flash ROM, and a 320x240 color LCD display. The iPAQ also features an expansion connector that is used to add additional functionality by way of expansion packs. This course uses a dual PCMCIA expansion pack to add two PCMCIA slots to the iPAQ. A PCMCIA breakout board is used in one of these slots to support communication with the XSV-300. The other slot contains an ethernet adapter, which allows students to interact with the iPAQ using a desktop PC.

In addition, a wide array of supplementary hardware is supplied for students to use in their projects. This equipment includes VGA displays, NTSC webcams, assorted audio equipment, and network hardware.

5. Experiences

So far, the revised course has been offered twice, first in Spring 2002 and again in Fall 2002. During that time, there have been some issues with the reliability of the equipment. The iPAQs have stood up well to lab use, but the XSV-300s have not fared as well. Over the course of two semesters, a handful of iPAQs have reqiured software reinstallation, which is a trivial task since we have developed a

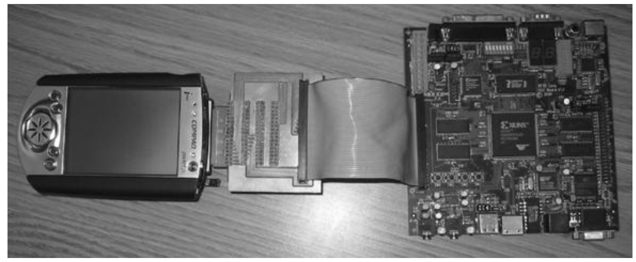

Figure 1. iPAQ and XSV-300

filesystem image that is easily reloaded when necessary. On the other hand, the XSV-300s are fairly complicated boards which makes troubleshooting and repairing failures a difficult task. Many of these failures seem to be caused by overheating or incorrect signal values on the SRAM enable lines. A new enclosure for the board is in development that should alleviate the overheating problem and students will receive greater guidance when developing their interface to the SRAM chips in future semesters.

Despite these issues, the revised course has been well received by students as demonstrated by the variety and complexity of their design projects. Students have developed designs ranging from audio applications to games and 3-D video. The course has generated enough enthusiasm in the students that many of them have gone beyond the hardware we provide by using additional special hardware in their projects such as custom amplifiers and targeting equipment. Clearly, the advantages of newer, more versatile equipment is not lost on the students as illustrated by the variety and creativity of their projects.

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References

[1] *ECE 311 Course Web Site*. University of Illinois, http://courses.ece.uiuc.edu/ece311/.

[2] X Engineering Software Systems Corporation. *XSV Board V1.1 Manual*, September 2001.

[3] *XESS Web Site*. X Engineering Software Systems Corporation, http://www.xess.com/.