Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2006
Advisors	Prof. Meyer, Johnson, and Nyenhuis
Team Number	10
Project Title	RFID Xpress

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Jennifer Tietz	ECE	Software design and debugging, Schematic design, PCB population	May, 2006
Jared Suttles	ECE	Software and Hardware design and debugging, PCB layout, PCB population	May, 2006
Jonathan Chen	ECE	PCB layout, LCD software design	May, 2006
Joshua D. Chapman	ECE	Ethernet and server software, Packaging	May, 2006

Project Description: Provide a brief (two or more page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

RFID Xpress is a self-checkout system designed for use in grocery and retail stores. The purpose of this project was to improve upon the current UPC technology and develop a better system for retailers and shoppers. RFID technology improves upon UPC labels by allowing the customer to scan and detect items from a reasonable radial distance from the RFID reader. The item does not have to be oriented in a particular fashion in order to read a label, as with UPC. Also, RFID tags provide each item with a unique serial number, embedded in the tag, which help retailers maintain more accurate knowledge of individual product arrivals and departures. Finally, due to radial scanning of RFID tags, added security measures can be easily implemented in order to prevent shop-lifters from carrying items out of the store undetected.

The RFID Xpress system is controlled by a Freescale MC9S12NE64 microcontroller and consists of a slim profile external RFID reader, a graphical LCD, a PIN entry keypad, and a thermal receipt printer. Additionally, the customer and item information are stored in an external database which is interfaced via a Java UDP server.

Once the customer is finished shopping, he or she initiates the check-out process by swiping a key fob with an embedded RFID tag within a few inches of the mouse pad-like receiver. The unique serial number on the key fob is used to query the external database and obtain the customer name, email address, and PIN number. The customer is then prompted to input his or her PIN on the 16-key keypad as an added security measure. Once authenticated, the customer can begin scanning products past the receiver. The serial number stored on each item's RFID tag is used to retrieve the product's name and price from the external database. As products are scanned, their information and other cart statistics (i.e., the number of items scanned and total) are displayed on the LCD screen for

the customer to view. After all of the customer's products are scanned, the customer chooses whether to print a receipt or to just receive one via e-mail.

The intended purchaser of the RFID Xpress system is the owner of a grocery or large retail operation where item tracking can be improved. It is also intended that customer self-checkout lanes are already implemented, as our system is meant as a bolt-on solution to existing checkout lanes. The design approach included consideration of realistic design constraints, as well as retail owner applications, customer ease-of-use, and overall customer satisfaction.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The development of RFID Xpress relied heavily on knowledge and skills obtained through previous ECE courses. The microcontroller was programmed mainly in C, so our experience in ECE264 gave us the advanced C programming knowledge required to successfully write the 1,700 lines of embedded code. Assembly language programming knowledge from ECE362 also proved very helpful for understanding the auto-generated code from CodeWarrior, debugging the system, implementing timing and serial communication interrupts, and setting internal registers for the proper operation of the peripherals. This class also provided us with general embedded system design knowledge that was very useful. During the hardware design, course notes for ECE270 were consulted numerous times to remind us of basic digital system design principles. They were helpful for debugging techniques for the keypad using a 7-segment LED, for understanding sinking and sourcing current considerations, for datasheet comprehension, and for providing insight on general state machine design considerations.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Many new technical skills were acquired or improved during the design process of RFID Xpress. We all had previous experience with reading and understanding schematics, but for this project we were faced with the task of actually designing one from start to finish. No members of our team had any experience with PCB layout, but after the project was complete, we were able to understand the process of PCB design as well as identify key considerations for part placement and routing. Finally, few members of our team had experience with PCB population or soldering in general. While everyone's soldering skills improved throughout the semester, we minimized the number of individuals actually soldering the final PCB to maintain quality and consistency.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

At the beginning of the semester, the team identified the following five Project Specific Success Criteria for RFID Xpress:

1. An ability to identify an item (and look up data on that item) based on its RFID tag.
2. An ability to identify a customer based on a key ring transponder and PIN code (entered on a keypad).
3. An ability to display status information (e.g., item being scanned/price) on an LCD.
4. An ability to print and/or E-mail receipt, based on customer selection (via keypad).

5. An ability to gather product and customer data by querying an external database (using Ethernet).

These minimal design objectives guided our progress throughout the semester and provided a basis for evaluation of our progress.

We analyzed the specific needs of our project to select the most appropriate components. For example, it was essential that the microcontroller have Ethernet capability in order to communicate with the external database, as well as have at least two serial communication ports for the RFID reader and receipt printer. Several voltage regulators and converters were needed to generate the 3.3, 5.0, and 12.0 V requirements for all of the components. The packaging needs were also modified several times as we added components to our design. We also analyzed existing similar products on the market to identify points of parity and points of difference for our product.

In order to verify functionality of different modules of our design, we built isolated prototype circuits for the major components and gradually combined them into one large prototype of the whole system. We simultaneously developed and modified our schematic and PCB layout to meet the needs of our project. After the PCB was fabricated and all of the components were acquired, the PCB was populated in modules to make debugging easier. Throughout the whole design process, we developed software on one of three development boards we had acquired. This made for easy testing of software functionality, and easy porting over to our prototype. The software development was also completed in modules to verify functionality of the individual blocks. Eventually, the hardware and software were synthesized and simultaneous debugging of the hardware and software continued. The packaging for the system was constructed to fit the proportions of our major components, and the board and components were placed inside. Finally, the system was continually tested for various usage situations and any bugs were fixed. The system performance was evaluated to determine if it met the objectives laid out in the Project Specific Success Criteria.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Many design constraints were considered throughout the development process of RFID Xpress. Prior to the start of the project, we conducted thorough research into the expected costs of the prototype system as well as large-scale manufacturing. It was essential to lower the cost of production as much as possible to increase the mass marketability of our product. Ethical implications were also considered, as our project involved the use of personal customer identification information which, when in the wrong hands, could lead to identity theft. Thus, we included an added security feature of a PIN entry keypad. Health and safety considerations were examined carefully, as our product will be used by the general public on a regular basis. Much research has been conducted into the effects of long-term exposure to RF radiation, and the results strongly support the design of our system. Environmental considerations included the decision to use passive RFID tags rather than active, which contain low power lithium batteries which are hazardous to the environment. Social considerations were a large factor, as the use of RFID has yet to become accepted by mainstream society as a practical or safe method of product identification. Finally, the sustainability of the product was thoroughly analyzed to ensure long-lasting customer satisfaction and customer safety.

(f) Description of the multidisciplinary nature of the project.

The development of RFID Xpress incorporated knowledge from many disciplines. Electrical engineering skills were required in the power supply and other circuit design process, while computer engineering skills helped in digital system design and software development. A fair amount of mechanical knowledge was necessary to properly select and modify the product packaging to meet the specific needs of the project. Marketing knowledge helped showcase the appeal of the product in the introduction of the User Manual. Finally, technical writing skills were utilized throughout the design process to professionally document our progress.

(g) Description of project deliverables.

The semester culminated in the delivery of a complete self-checkout system, controlled by a microcontroller. It includes an RFID reader external to the product casing, which includes a keypad for user PIN entry, an LCD to display the shopping cart and other pertinent information to the user, and a thermal receipt printer. Additionally, the system utilizes an Ethernet connection to synchronize the internal clock, send email receipts to the user, and query an external database for customer and product information. The project satisfies and surpasses all five of the Project Specific Success Criteria identified at the beginning of the semester.

The system accurately detects a user key fob and queries a database for the user information related to the fob serial number. If the customer is located in the database, the LCD greets the user and prompts them for their PIN. The digits are properly stored and compared against the correct PIN, and valid users are authenticated. As items are scanned, the RFID serial number is queried in the database and the correct product name and price are returned. The user can remove items from the shopping cart, cancel the shopping session, or complete the shopping session by pressing specific buttons on the keypad. After the session is ended, the user can chose to receive a printed receipt in addition to the email receipt. The LCD provides visual confirmation to the user after each decision. The components are packaged in an appealing and user-friendly casing designed to be bolted onto existing check-out lanes.