EMBEDDED MICROPROCESSORS IN A PROJECT LABORATORY

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Introduction

Electrical and Computer Engineering students have a need to be able to design and build systems with embedded microprocessors. They also need to be able to become familiar with different processors. There are many different ways to teach microprocessors and their applications. At Texas Tech University this goal is accomplished through a number of laboratories and courses. Students first encounter microprocessors in a first semester, sophomore level course on microprocessors, using a Motorola 68HC12. They also use this processor in their first project laboratory, also in the sophomore year. The objective in the second project laboratory, in the first semester of the junior year, is to have the students design and develop a system using a microprocessor they have not seen before. In this way, students learn that their basic knowledge can be carried over to other devices and systems.

Project Laboratories

The laboratory structure in the ECE department at TTU is somewhat different than most university laboratories.[1-10] There are 5, 3 hour credit required laboratory classes. Although all of the laboratories have pre-requisites, they are not associated with any one class. All of the laboratories require students to work in teams on long term projects. The student teams each have a project advisor, separate from the lab instructor and teaching assistant associated with each lab. All of the teams report on their progress and answer questions on their projects in a weekly 3 hour lab meeting with all of the groups.

In this case, in the second project laboratory, EE 3332, the students were given a semester long project to design and develop a system incorporating a low power, RISC microprocessor, the Texas Instruments' MSP430. The students were divided into teams of 3 to 4 members. Although each team had a different embedded microprocessor project, they were all using the same microprocessor. This enables increased peer learning and support. All of the figures in this paper came from student presentations or reports.

Project Assignment

The topics of the projects, in this case, varied considerably from a multiprocessor battery pack monitoring system to a hail stone measuring system to a blood pressure monitor. In all cases, they were required to provide a PC interface to down load data and possibly up load parameters. Otherwise, the systems had to be stand alone systems. A few of the specific projects are described along with the students' results. The project statements are given below.

EE 3332

Your group has been chosen to develop new applications for the TI MSP430 micro controller. The MSP430 is a small, very low power RISC type processor. The objective of this project is to design and develop the application, verify the application through construction and measurements, prepare a paper and a presentation describing the project.

1. *A microprocessor based power controller for a remote battery operated lighting system. The system should consist of, at least, a photovoltaic cell, a battery, a light bulb and a controller. The light is to be on at night at whatever energy level is available from the battery. The light will be off and the battery recharged during*

the day. The system must be able to communicate to a PC to transfer data and provide status and self diagnostic information.

2. *A microprocessor based, battery operated non-invasive blood oxygen monitor. The system should be able to display the time of day and oxygen level of the individual wearing the system. The system should also be able to indicate the average oxygen level, minimum and the maximum oxygen level over a specific time period. The system must be able to communicate to a PC to transfer data and provide status and self diagnostic information.*

3. *A microprocessor based battery pack monitoring system. The system should be able to monitor multiple batteries in a series chain with electrical isolation. Individual monitoring devices should be able to communicate through serial communication. The system must be able to communicate to a PC to transfer data and provide status and self diagnostic information.*

Example Project: Remote Lighting

A block diagram for the Remote Lighting Project is shown in Figure 1. An excerpt from the conclusions in one of the student's final report is given below.

"A remote lighting system was designed with the following characteristics. The system was battery powered to provide for maximum portability. The system is able to detect if it is day or night using a photoresistor. The system time stamps the sunrise and sunset times of each day and determines the length of the night. At night the system test the battery level and illuminates a light at a brightness that will last the entire night. During the day a solar panel is used to recharge the battery. The system is also able to transfer data every 5 seconds to a PC using Hyper Terminal. A visual basic program was also written to retrieve stored data from the MSP and graph the battery levels of 14 days. The system was accomplished using Texas Instrument lower power MSP-430 microcontroller. The lower power microcontroller allows the system to run on battery life for a much longer time period than a conventional microcontroller. The system was designed, built and tested during one semester that lasted about three mounts."[11]

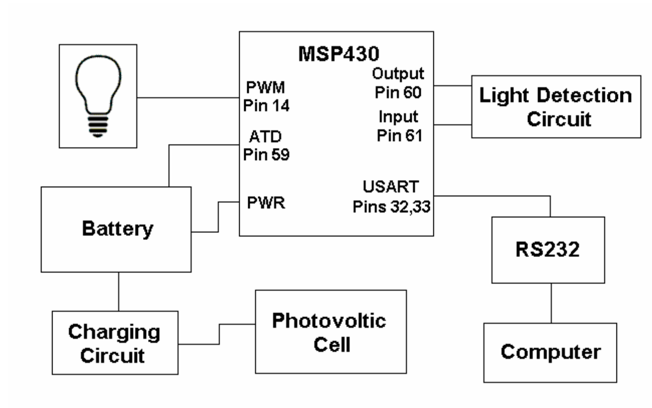

Figure 1. Remote Lighting Block Diagram.[12]

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Is it day or night: Day  14:3:5
The battery level is 80%
The Charging Circuit duty cycle is 511/511
Time of sunrise 7:0

Is it day or night: Day  14:3:15
The battery level is 80%
The Charging Circuit duty cycle is 511/511
Time of sunrise 7:0

Is it day or night: Night  14:3:25
The battery level is 80%
The Light duty cycle is 383/511
Time of sunset 14:3
Length of Night 7hr 3min

Is it day or night: Night  14:3:35
The battery level is 79%
The Light duty cycle is 381/511
Time of sunset 14:3
Length of Night 7hr 3min
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Figure 2. Remote Lighting Computer Output.[12]

Figure 2 shows a typical output from the visual basic program. In Figure 3 the budget for the project is given. Students were required to keep track of all expenses including assumed labor charges and overhead.

Budget Prices			
Labor			
Number of people		3.5	
Est. hours per week		12	
Number of weeks		13	
Hourly wage		$15.00	
Total		**$8,190.00**	
Equipement	Cost	# of Units	Total
Battery	$6.00	1	$6.00
Solar Battery Charger	$38.00	1	$38.00
MSP 430	$99.00	1	$99.00
Misc. Components	$30.00	1	$30.00
Total			**$173.00**
Total			$8,363.00
Overhead (75%)			$6,272.25
Grand Total			**$14,635.25**

Figure 3. Remote Lighting Budget.[12]

Example Project: Blood-Oxygen Monitor

The block diagram for the Blood-Oxygen Monitor is shown in Figure 4. The monitor utilizes the fact that oxygenated blood absorbs certain frequencies of light. By shinning 2 different frequency LEDs through the skin on a finger to a photo diode and a current to frequency convert, the relative absorption can be measured. This relative absorption is a measure of the oxygen content of the blood. The outputs of the system are a LCD display, for stand alone operation, and a PC interface through a transceiver, MAX 3325.

Figure 5 shows some of the LCD display outputs for the Blood Oxygen Monitor. The SpO2 indicates the percent oxygen saturation in the blood. The time of day is also indicted. The interval used to compute the average reading is indicated under the INT area. The intervals have a number of settings from 5 minutes to 12 hours. The RTime setting is for real time and provides a running average. The maximum and minimum oxygen levels over the interval are indicated in the other display in Figure 5.

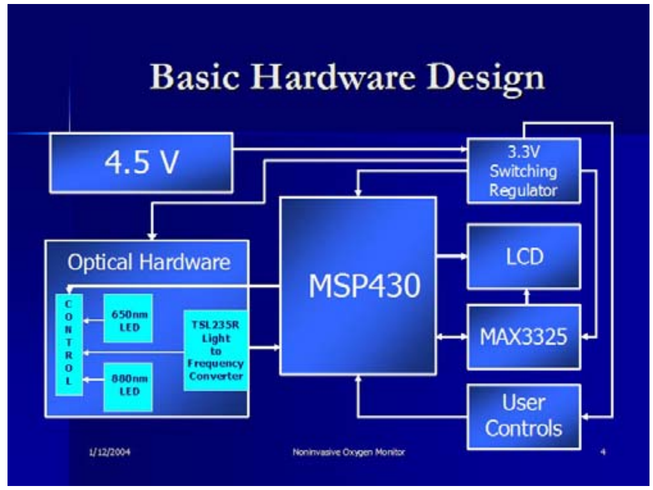

Figure 4. Blood Oxygen Monitor Block Diagram.[13]

Figure 5. Blood Oxygen Monitor Displays.[13]

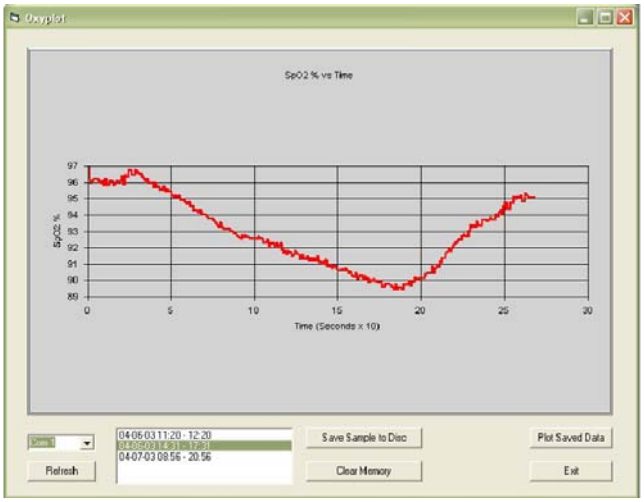

Figure 6. Blood Oxygen Monitor Computer Output.[13]

Figure 6 shows the output from the Blood-Oxygen Monitor displayed on a PC versus time. The data in this chart was obtained by having a student hold his breath for a short time interval and then begin breathing again.

Conclusions from one of the student's final report are "The Blood Oxygen Monitor does many functions extremely well. The data is taken and can be viewed using a PC or the display. The different display modes along with the user interface buttons let the user choose a variety of functions and give him control of the system. Power consumption is held extremely low by constantly turning off ICs or putting them in sleep modes. This is also accomplished by keeping the MSP430 at low power mode three whenever possible. Almost everything worked as initially planned. The LCD problem was easily solved, and everything in software was debugged quickly."[14]

Example Project: Battery Monitoring System

This project was different in that it was a continuing project. Some projects that are too complex to be completed in one semester are continued on to other semesters. This gives the students the experience of working on more complex projects and learning the importance of proper documentation. It is common for practicing engineers to start work on projects that are on going. This specific project has been carried over for 3 semesters. The block diagram for the system is shown in Figure 7. Figure 8 shows the battery pack with the 38 slave printed circuit boards attached. The basic circuit diagram for the system is shown in Figure 9. The system is interfaced to a PC through National Instruments LabVIEW program. The LabView display is shown in Figure 10.

The slave, multiplexer and master boards were designed and prototype boards were built and tested. The boards were layed out and sent out for manufacturing. Test software and hardware was developed to allow testing of the individual boards. System software and PC interface software were also developed. The boards were constructed, tested and wired to the system for final test. An excerpt from the conclusions in one of the student's final report is given below.

"The whole system has been designed and tested and meets the project criteria for monitoring the battery voltage. From reading in the voltage from individual modules, to interpreting, processing, and displaying the data to computer, the system works to satisfaction. There are a few issues in the design of this system that could be improved upon".[16]

Conclusions

As is always the case, some projects faired better than others. However, in all the students enjoyed the projects and felt they got a lot out of using a different processor. As another indicator, we use a number of different processors through out our course work and laboratories. In the senior labs the students have a choice of what they use on their projects. Many of the seniors this year have requested to use the MSP430 on their senior projects.

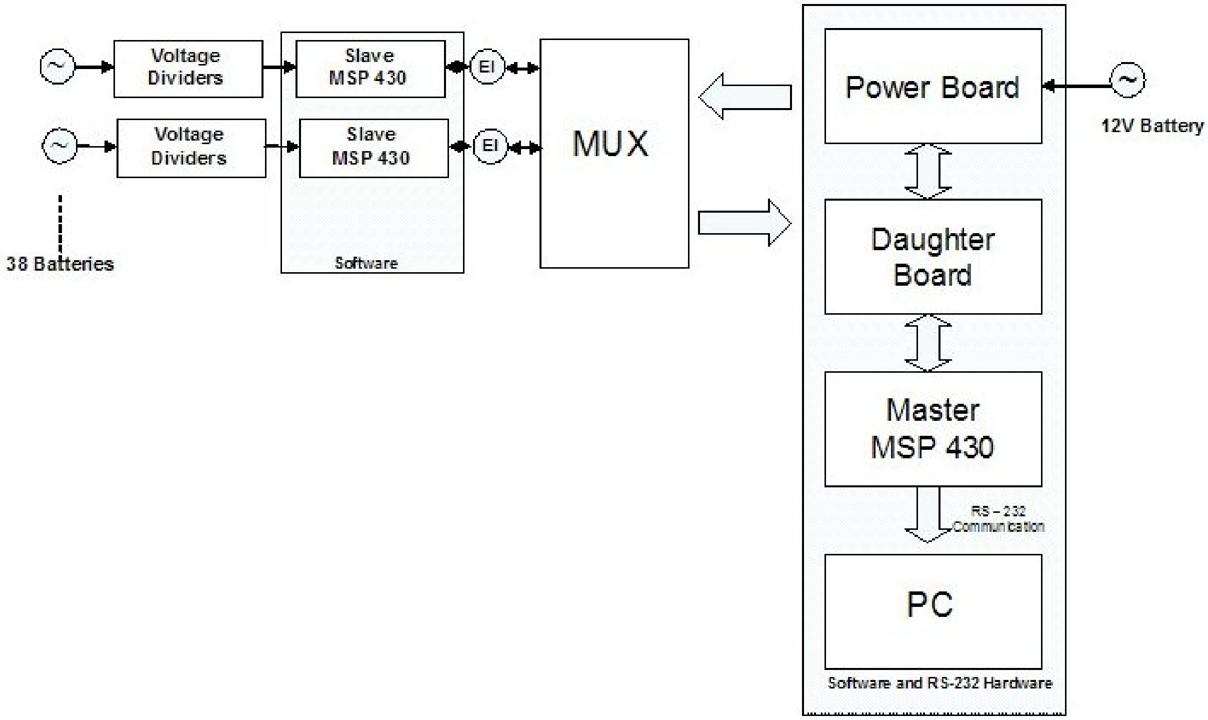

Figure 7. Battery Monitoring System Block Diagram.[15]

Figure 8. Battery Pack and Slave Boards.[15]

Some of the projects were power related type projects. Three of the papers competed in a local IEEE Power Engineering Society (PES) contest. The winning paper went on to compete at the PES Transmission and Distribution Conference and Exposition in Dallas, Texas in September, 2003. The student paper contest at the PES T&D conference is an international contest and is open to all students, including graduate students. Michael Graham presented his teams' paper on a Battery Monitoring System and placed third in the competition, which we feel, is very good considering a PhD candidate won the contest.

In all, our experience with using a different processor has been very favorable. The easy of use and short learning curve of this particular processor were useful for quick projects. The low operating power allowed for more interesting portable applications in the projects. We plan to continue using a processor, other than the one used in our basic course, in our first junior project laboratory to allow our students to gain confidence in their ability to apply basic knowledge to new systems.

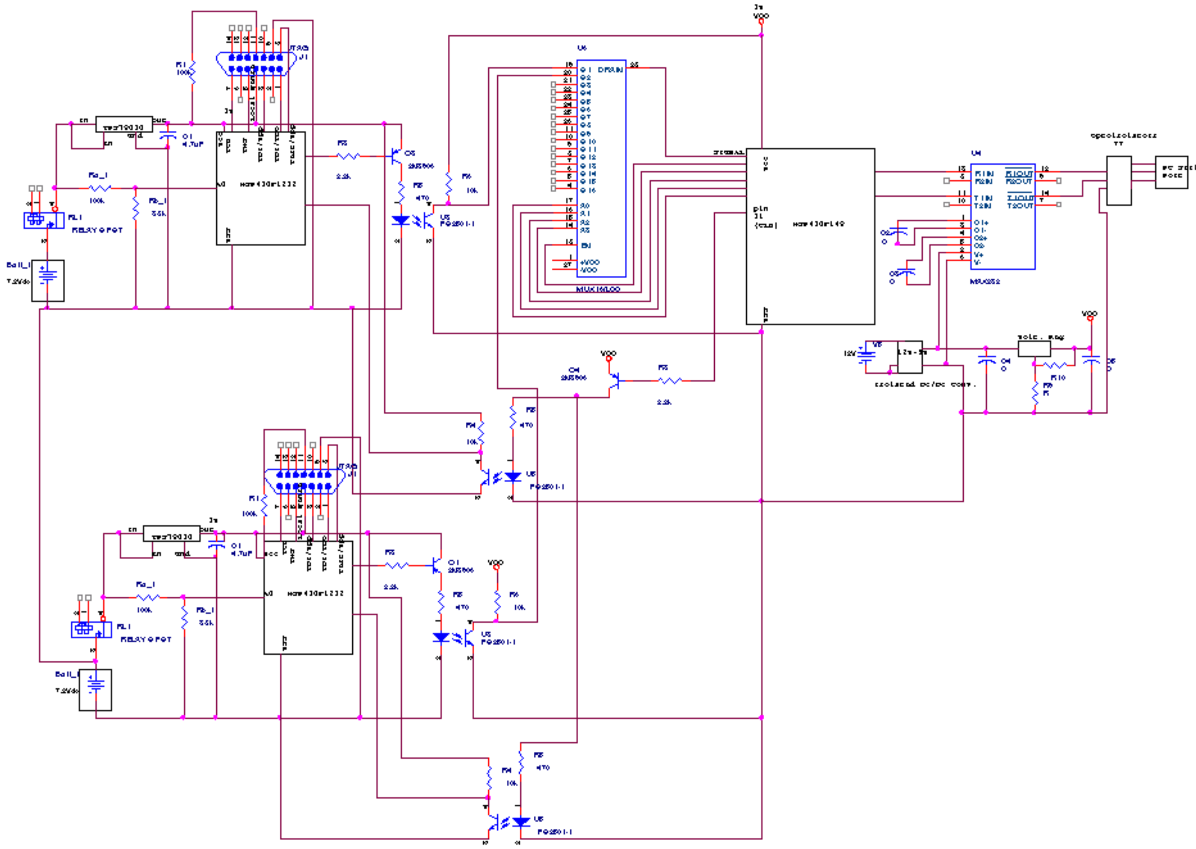

Figure 9. Battery Monitoring System Circuit Diagram.[17]

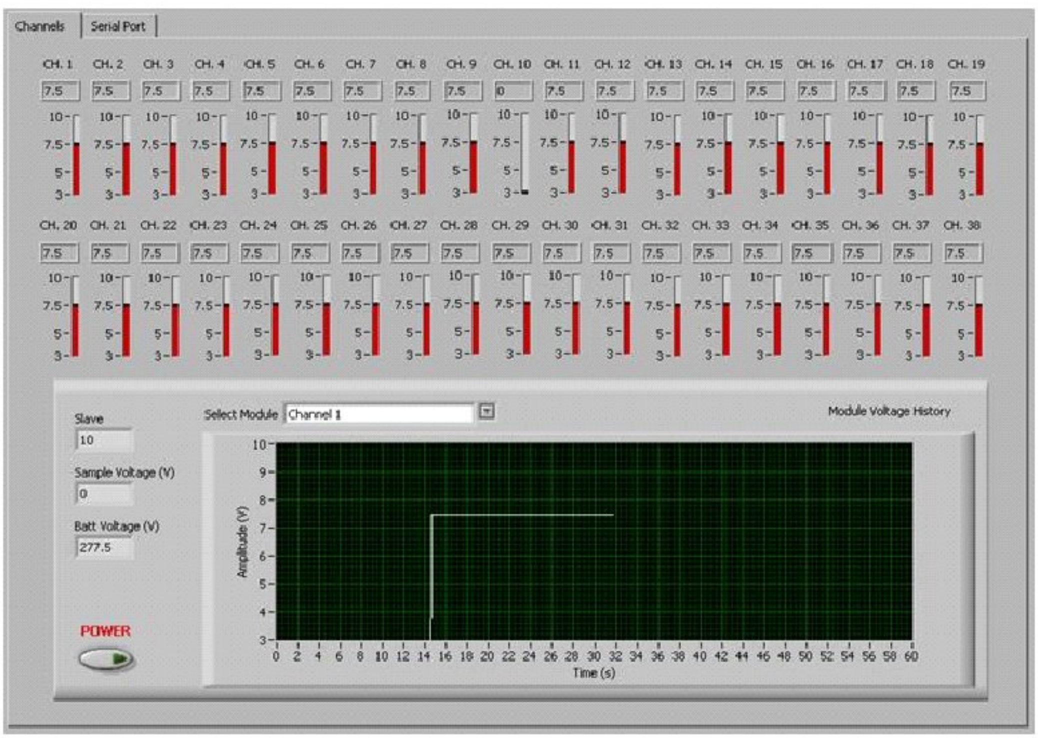

Figure 10. Battery Monitoring System LabVIEW Display.[15]

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Biographical Information

Micheal E. Parten is a Professor of Electrical Engineering at Texas Tech University. Dr. Parten has conducted research and published in the areas of instrumentation, control, modeling and simulation of a variety of systems, including hybrid electric vehicles. Dr. Parten has served for over eighteen years as the Director of the Undergraduate Laboratories in Electrical Engineering.