Designing an Embedded Microcontroller Laboratory

Team 12
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Abstract

This document gives a brief overview of the designs for the embedded microcontroller laboratory.

The current design for the laboratory entails multiple lab benches configured to ease in the development of software systems for popular microcontroller and embedded systems. Included in the laboratory will also be a station for the fabrication of new custom embedded systems.

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1 Overview

2 Team Members

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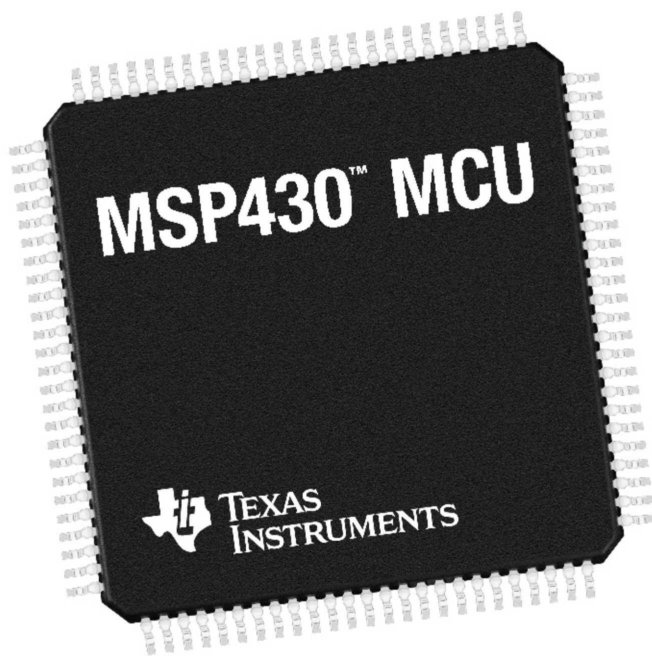
3 Embedded Devices

3.1 MSP430



3.1.1 Background

The MSP430™is a line of ultra-low-power 16-bit microcontrollers produced by Texas Instruments. The microcontroller comes in several different flavors, which are outlined below.

Name	Features
1 Series	General purpose
2 Series	General purpose (upgrade from the 1 Series)
Value Line	Low cost
4 Series with LCD	Integrated LCD controller
5 Series	Integrated USB connectivity
6 Series with LCD	Integrated USB connectivity and LCD controller
FRAM Series	Includes FRAM (low-power, fast memory)
Low Voltage Series	Low power
RF SoC Series	Integrated RF tranceiver and LCD controller
Fixed Function	Receives wireless power; pre-programmed
Automotive	Certified by the Automotive Electronics Council
Extended Temperature	Extended temperature range

3.1.2 Hardware

In order to be useful, a microcontroller development laboratory requires a method of programming, debugging, and testing the microcontrollers. In order to facilitate this, Texas Instruments has several off-the-shelf development board solutions for their MSP430™line of microcontrollers. Since the MSP430™microcontrollers do not all have the same number of pins, multiple development boards are needed to accommodate.

Name	Price
MSP-TS430PW14 - MSP430 14-Pin Target Board	$75.00
MSP-TS430PW28 - MSP430 28-Pin Socket Target Board	$75.00
MSP-TS430DA38 - MSP430 38-Pin Target Board	$75.00
MSP-TS430DL48 - MSP430 48-Pin Socket Target Board	$75.00
MSP-TS430PM64 - MSP430 64-Pin Target Board	$75.00
MSP-TS430PN80 - MSP430 80-Pin Target Board	$75.00
MSP-TS430PZ100 - MSP430 100-Pin Target Board	$75.00
MSP-TS430PZ100A - MSP430 100-Pin Target Board	$75.00

The Texas Instruments development boards also require a special flash emulation tool to program the device. This device is called the MSP-FET430UIF and in addition to providing programming capabilities, it also enables some debugging capabilities through the JTAG interface of the development boards. The cost of one MSP-FET430UIF is $99.00. The MSP-FET430UIF is pictured below.

3.1.3 Software

By their nature, embedded systems typically require user-defined code to be run on a microcontroller. In order to compile this user-defined code, program the microcontroller, and debug the system, software is required. Texas Instruments has a software package, Code Composer Studio^{TM}, that performs all of these functions. It includes:

- Grace^{TM}, a visual program to generate C code for interacting with peripherals
- SYS/BIOS, a real-time operating system for Texas Instruments microcontrollers
- A compiler tuned for the space limitations and performance characteristics of the MSP430
- Various system analysis and debugging tools

The above list is only a sample of some of the features of Code Composer Studio. The cost of this software package is $795.00 for one floating license. The floating license allows for Code Composer Studio^{TM}to be installed on multiple computers, but for only one user to use the application at any given time.

3.2 Pico M-505 FPGA Module

3.2.1 Description

FPGA module utilizing a Xilinx Kintex-7 K410T, the worlds first 28nm programmable logic device. Reasonably we can get twelve 505 modules and fully set up two ex-500 backplanes.

Figure 1: Pico

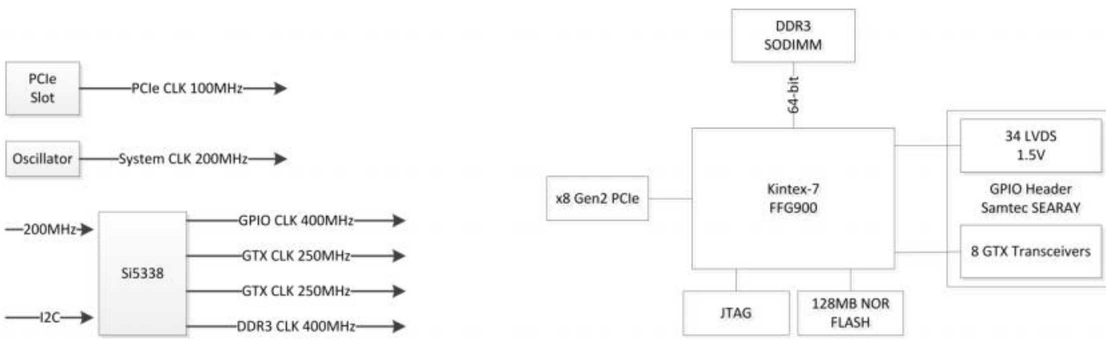


Figure 2: Pico diagram

3.2.2 Cost

Not cheap, couldn't find any info online, will call Pico for more info.

3.2.3 Why we need it

Our lab needs a high performance FPGA setup for cryptography and bioinformatic projects

3.2.4 Sensors

None at the moment since we would be using our FPGA cluster for raw computing power

3.2.5 Software

Provided by Pico Computing with purchase.

3.2.6 Additional Info

Given a large enough budget, we could add a SC-5 SuperCluster with 48 Xilinx Kinetx-7's.

Figure 3: SC-5 SuperCluster

3.3 Papilio Pro FPGA Board

3.3.1 Description

Essentially a cheap FPGA for hobbyists, the papilio has lots of add- ons aka wings that make prototyping simple projects super easy. More of a beginner/learning tool, its still pretty neat. Uses the Xilinx Spartan 3E FPGA

3.4 PIC18 Series

There are quite a few of the PIC18 devices, and any would really do for a learning setting and are all relatively inexpensive and flexible for a variety of tasks be it communication, ADC, or integration. All of the pic18f have internal oscillators so there wouldn't be a need for external crystals or anything else of the sort that would cut down on the total cost of development. We think that from a learning perspective, doing all of the work on a breadboard is essential to really understanding how every pin of the PIC18. So, we dont believe a development kit would be very necessary, however depending on the size and/or quality of lab we are looking at, may be a decent option, so we will also discuss them.

3.4.1 PIC18LF4550-I/P

The PIC we would choose for a setting such as a university would be the PIC18LF4550-I/P

The pic18lf4550-I/P is an 8-bit microcontroller with three serial ports for usb, I2C, and SPI communication. It can also be easily programmed for USART/UART communication it has 2048 bytes of ram and a CPU speed of 12 MIPS (so 48MHz). The memory type of this microcontroller is flash, and has an available 32 KB to be programmed. It has a

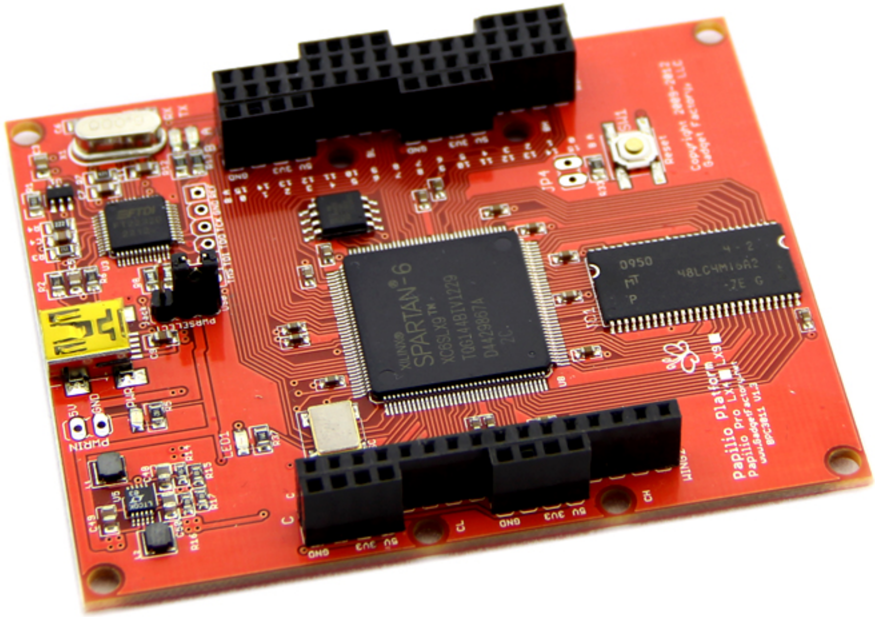


Figure 4: SC-5 SuperCluster

Figure 5: PIC18LF4550-I/P

total of 40 pins, and is easily worked into a breadboard for development because of its large pins. Some of the neat features on this particular pic are its power saving modes, on-the-fly- mode switching, multiple idle modes (can disable core of CPU and allow peripherals to continue to reduce power consumption to about 4It has four crystal modes, four external clock modes, and two internal clocks, so timing considerations should really never be an issue for learning/development. Also, new to the pic18 series is full USB communications (only up to usb 2.0 however).

3.4.2 Why do we need it?

The pic series of microcontrollers, from my perspective are used very frequently in industry and it would be a good idea for students to get experience with this particular microcontroller architecture so they are more prepared for work in a professional setting. The PIC microcontrollers are easyto learn, have great additional software and compilers, and a large support network. Due to being manufactured my microchip, there is a high probability of receiving a quality product, with a technical support back-up for any problems that may arise. The PIC18LF4550 is very versatile and could be used for a lot of tasks, which we think is important for a school setting as it could allow the biggest bang-for-the-buck, given that it can be used and re-used for many different projects. The PIC18LF4550 would be a good fit for our lab because it is also low cost and has quite a bit of free development tools which would help cut costs for our lab as a whole. Seeing as, honestly, all one needs to start programming the pic microcontrollers is the PIC18LF4550, a breadboard, and a programmer (as well as some free software). Overall, the PIC18LF4550 is a cheap, easy to learn, useful, and supported microcontroller which would be beneficial for students to learn before they graduate from school.

3.4.3 Extra components

As we said before, there are really no need for extra components when programming with the pic18lf4550 as long as one has a pic, and a programmer. So first up is the programmer: The programmerthat we think would be best for the PIC18LF4550 is the PICKit2. The PICkit2 is also developed by microchip, so compatibility is guaranteed. It is a cheap, fast, and useful programmer with a couple of nice features.

1. It is an in-circuit debugger, so it works well with a breadboard. Just plug it into your circuit, connect the power and programming pins to the PIC18LF4550.
2. It has an on-the-fly programming method that allows the pickit to reprogram a device with the press of a single button.
3. The PICKit2 is open., meaning that its hardware and firmware are open to the public and as such, has the availability to be used on linux machines.
4. Local UART tool (no need to use a hyperterminal to test uart) When the PICKit2 is ordered it comes with driver software, an adapting usb cable, and Mplab IDE software(also available free online).

3.4.4 Cost

Thankfully, the microcontrollers and the programming/debugging hardware run very inexpensive, The cost per MC is

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Figure 6: Pickit 2

Unit Quantity	Price
1-25	4.47
26-99	4.36
100+	4.26
Unit Quantity	Price
1000-4999	3.92
5000+	3.72

The cost for the pickit2 programmer/debugger with usb cable and software is 34.99 per unit. As we am not entirely sure the scope of the lab and the number of lab machines to be equipped with their own pickit2 (although they are very small and compact and could be moved from machine to machine, and the software is free) we do not know how to add up the total costs for everything involved. However, as a rough estimate of three pickit2's in the lab, and a base order of 100 PIC18LF4550, the total would come to 460.99 for a complete lab set up.

3.4.5 Software Needed

As stated before, if we do infact decide upon the pickit2, the software is already available in the package in the form of microchip's MPLab. This software is simply an IDE based off of netbeans(so also works great on linux) that allows the user to write code, simulate that code, and add breakpoints.

3.4.6 Other considerations

There are a few other things that must be addressed for these pic microcontrollers. The compilers used to program the PIC18LF4550 vary from company to company, or student to student. There a a few free compilers such as MikroC, but we feel that sticking with Microchip's free compiler XC16 would be a good choice, just to keep consistent with the company that most of my suggested parts are coming from. The XC compilers that microchip offers for free for download off of their website are not as fully featured as their paid C30 compiler, or offer as much code optimization, but as I said, is free. So, we suggest we use the XC16 compiler on any lab machine that would be used to program PIC microcontrollers. There are many additional things that would be useful for developing with pic18lf4550 such as rs232 cables, USB cables, LED's, motors, and other such devices, but we did not include those in the above description because they are really add-ons for projects that can be done with the pic18lf4550. I am assuming here that every student that were to use these machines would have their own breadboards (as are standard issue at michigan tech) . But for the prototyping of any microcontroller or circuit, oscilloscopes are EXTREMELY useful. We know we have not yet discussed oscilloscopes yet or if they will be a part of the lab, but maybe that is something to discuss at a later date.

4 Todo

- Generate list of supported microcontrollers
- Generate gantt chart for project timeline
- For each microcontroller determine:
  - Cost
  - Necessary Software
  - Necessary Adapters and Plugs
  - Necessary equipment (shields/modules/dongles...)
- Design lab bench for fabrication of custom embedded devices