DSP Research Project

The digital signal processing (DSP) research project is a core component of the Physics 351 digital electronics course. The research project component is structured as design, construction, and presentation competition.

I. Objectives

The objective of the project is to teach you how to plan, design, construct, and debug a working DSP device based on an FPGA with Physics research applications.

An important secondary objective is to teach the following experimental research skills:

- Team research work
- Device design
- Project budgeting
- Project proposal writing
- Finding, selecting, and purchasing device components
- Device construction
- Device debugging
- Oral and web presentations of work

II. Schedule

The DSP projects will follow the schedule below:

September 8, 2009: DSP design competition launch (this document is released).

October 9, 2009: Formal project proposals are due.

October 14, 2009: Project proposals are graded and returned.
(or sooner) Project funds are released (you should start buying ASAP so that you will have your components by the next lab).

October 26 – November 29, 2009:
Project construction.

November 23-29, 2009:
Project debugging.

November 30, 2009: Oral presentations and website launch.

December 1-2, 2009: Official device performance testing and review.

III. Project Proposal

The project proposal is a request for funding from the instructor. The proposal should contain the following sections:

Introduction

The introduction introduces what the proposal is proposing … and also motivates and explains in general terms what the device can do.

Device design

This section explains the device design. It should indicate the overall design and what types of components are to be used. If possible it should indicate specific components (model#). For soft-hardware design (i.e. FPGA code), you should explain your FPGA design and where possible provide specific schematics and/or Verilog HDL code.

You will probably not have determined every last detail of the project design by the time the proposal is due (especially since we will have barely covered ADCs and DACs), but you have to convince the instructor that your design can work, even if some specific details still have to be worked out (hardware and software). You should include diagrams and figures to explain your design.

You should provide a detailed budget and a construction time-line for the project.

Conclusion

In this section you will briefly recap the previous two sections and explain how the device can be uniquely used to make specific measurement relevant to experimental Physics.

Note: only one project proposal per research team is required.

IV. Budgeting and Electronics Components

You have a budget of $250, which you cannot exceed. In principle you should be able to construct the project for about $100-$150. The excess funds should be used to buy several copies of the same part (in case you have a circuit construction malfunction) or to try different parts out to see which ones work best. If the components are relatively cheap, then you should buy several extra in case you break some. You should keep in mind that components take several days (even up to a week, if you are unlucky) to arrive after you order them.

Internet shopping is a great way to purchase electronics components. The sites with the largest and most diverse inventories are the following (the university is also set-up to buy things quickly from these companies):

www.newark.com
www.digikey.com
www.mouser.com

In the past, digikey.com has provided the quickest and most reliable service.

The following companies are the primary manufacturers of both analog and digital ICs and will sometimes provide free samples (good for the budget, but sometimes a little slower on the delivery):

Analog Devices
Texas Instruments
National Semiconductor

ON Semiconductor (formerly Motorola)
FreeScale Semiconductor (also formerly Motorola)
Linear Technologies
Fairchild Semiconductor

Lab components and ICs

You may NOT use any lab components in your final device, with the exception of wire. You are free to use any components in the lab for prototypes on breadboard. You must supply all components that you solder.

V. General Design Considerations

Your design and construction will strongly influence the performance of your device and determine whether it works or not. Here are a few suggestions that will help improve your design:

Inputs and Outputs

- All analog inputs and outputs on your device should go through an op-amp, even if it is just a buffer (i.e. a 1-to-1 amplifier).

Wires

- All wires should be color coded and, ideally, labeled.
- You should use heatshrink to cover bare wire as much as possible.
- All connections should be soldered.
- Input and output wires should be in the form a twisted pair (one wire carries the signal, the other is at ground), this will limit cross talk between signal lines and limit noise from external sources.

ICs (i.e. chips)

- Use sockets for ICs so that they are easy to replace if you accidentally break them.
- Use a ~100 nF capacitor across the supply inputs of any IC. Make sure that the capacitor is a close as possible to the IC. If noise is still an issue, an additional 1 nF capacitor in parallel with the 100 nF can help.
- Gold-plated sockets are preferable to tin, since they will not oxidize with time (and then lose the electrical connection).

PC boards

Most electronics components are wired together on a printed circuit board (PC board). For high frequency (i.e. 1 MHz and higher) analog circuits, a custom PC board is essential. A digital circuit can function fairly well with just wires up to much higher frequencies, since they are less susceptible to noise.

Unfortunately, custom PC boards are very time consuming to make using layout software such as the Eagle prototyping software that we briefly used in Physics 252. Furthermore, there is also the risk with prototyping software that you do not get what you thought you should get: either you specified the circuit incorrectly, you accidentally made wires too thin for the current they need to support, or two wires are so close together that they actually touch in places. While custom PC boards are good for production purposes and when you have a lot of experience, they can use up a lot of your time.

A reasonable alternative is the use of generic PC boards with a few wire traces. They are generally about the same price as a custom PC board, but they are more likely to work the way you expect them to. You can also do you some of your circuit layout on the fly. *RadioShack* sells generic through-hole PC boards. *Futurlec.com* also sells PC boards and multi-position switches, but has very long delivery times. Here are a few on-line manufacturers which sell generic PC boards for surface-mount chips chips:

twinind.com , *smt-adapter.com* , and *www.schmartboard.com*

FPGA

You should connect your project device to the DE2 FPGA development kit with ribbon wire and header connectors. If you are really enthusiastic, you can buy an FPGA, EPCS configuration device, and Schmartboard, and make your entire project from scratch. While this is favorably looked upon, it is a significant amount of extra work and should only be attempted by those willing to invest a large fraction of their waking hours.

The DE2 can only be used for the FPGA itself. You should not use the HEX displays, LEDs, microphone input, USB, VGA output, etc … This means that you can only use the header I/Os and the external clock input of the DE2.

Power Supplies

- Use the MC79xx and MC78xx series voltage regulators to further regulate the power you receive from your plug-in power supply. Watch out! On some of these regulators the case will have positive or negative voltage on it, which can make heat-sinking a little more difficult. If voltages below 5 V are required, the following regulators can also be useful: LD1117Axx series by STMicroelectronics and the PQxxxEF1SZ by Sharp.
- Generally, a 60 Hz transformer-based power supply is preferable to a high-frequency switching supply (though this must be weighed against cost). A battery is another option.

Heat sinking

- Some components can get hot. They should be heat-sunk well – ideally, to the device case. You can also use metal fins and a fan.
- Hot components should be avoided where possible, since they do not last as long. Heat can also lead to the deterioration of neighboring devices (i.e. wire insulation can deteriorate, ICs work differently when the device is first turned on than in steady-state).

Device Box

- A metal box is preferable (though a little more expensive) to a plastic box, since it can be used for heat sinking and provide some protection against external electromagnetic noise.
- The device box is generally grounded (either hard or soft ground).
- The device box should include a circuit diagram on the inside.

Knobs, Switches, and Displays

- Ideally, knobs are multi-turn potentiometers which give you a fine degree of control.

- A selector knob with a few positions can be used for coarse selection of values.
- Switches should be made of metal.
- Displays are nice, but are generally very time consuming to implement.

Warning: ***The user interface can frequently be the most time consuming part in the development of an electronics device (much like in a computer program). It is generally easy to implement (at least in the abstract), but can be very time consuming, especially if you add lots of special features. In the past, the groups that have won the competition or made the most progress on their project were also the ones that had the simplest user interfaces.***

User Manual

Your device should include operating instructions or a manual. You should be able to compile a manual from the oral and web presentations which will take place at the end of the semester.

VI. Design, Construction, and Testing

While ideally your design will work exactly as you conceived it, you are encouraged to construct a prototype of your final device using components in the lab, including the DE2 board, breadboard, op-amps, ADCs, DACs, miscellaneous ICs, resistors, capacitors, transistors, etc … Once you have settled on a design that you are confident will work, you can start constructing the final device.

Since it can take time to order and receive parts, you should buy ahead of time all the components that you can, and especially those that do not depend on the exact details of the design (i.e. FPGAs, ADCs, DACs, possibly op-amps, etc …). This will reduce the probability that you are just waiting for your parts to arrive with nothing else to do.

VII. Team Lab Book and Wiki

Each team will maintain a group lab book and a wiki "lab book" webpage. The lab book and the wiki can complement each other (i.e. not everything that is on the wiki has to be in the lab book, and vice versa). You may certainly keep records in your own lab book, but these should be photocopied into the team lab book.

A wiki is a great way for a group of people to collaborate on a project, especially one that involves lots of electronics files (plots, tables, images, Quartus II files, etc…). It allows several collaborators to share information from separate locations. There are many wiki webpage services on-line. You can create a wiki at wiki.wm.edu, but it will not be private. In other words, the whole world will have access to it. Several on-line services offer free wiki webpages with private access and limited storage space (e.g. pbwiki.com).

VIII. Oral and Web Presentations of Device

During the last lecture period of the semester each team will make a 15 minute presentation of their device. All team members must participate in the presentation. The presentation will cover the design, budget, difficulties, highlights, and final performance of the device.

The webpage for the device must be posted before the last lecture period and will cover the same topics as the oral presentation.