

Digital Control Protoshield

The basic objective of the Digital Control Protoshield is to simplify, minimize the noise, and make more student friendly, the design used in the Spring '10 EE470 course. The goal is to simplify both the hardware and the software.

[Software](#)

[Hardware - Unipolar ATmega ADC and Microchip MCP4921 DAC](#)

[Printed Circuit Board Design](#)

[PCB Design Fabrication](#)

[Protoshield Components](#)

[Appendix A Single Op-amp for Level Shifting and Gain Stage](#)

Software

The timer interrupt code would be limited to something like this.

```
void sample() {
    R = setpoint()           // generate set point clock
    dn_in = readADC();       // read bipolar ADC
    E1 = R - dn_in;          // summing junction
    // lead-compensation difference equation
    U1 = A*U0 + B*E1 + C*E0;
    // update variables for next iteration
    U0 = U1;                 // save current output as previous output
    E0 = E1;                 // save current error as previous error
    writeDAC(U1);           // write to bipolar DAC
}
```

Much of the software complexity would be hidden in an INCLUDE file containing `readADC` and `writeADC`.

Hardware - Unipolar ATmega ADC and Microchip MCP4921 DAC

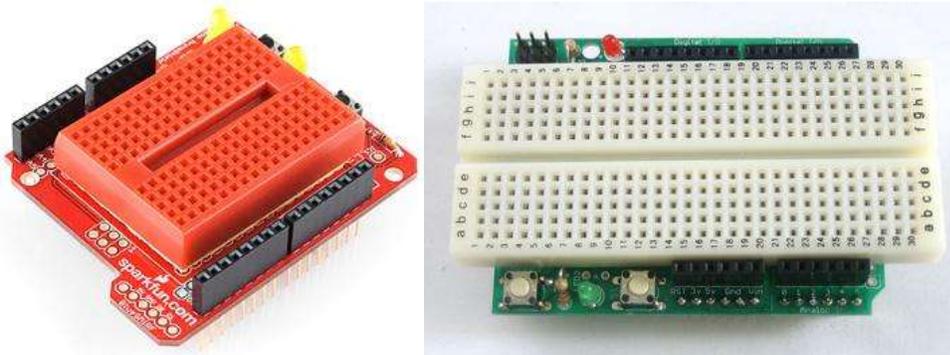
Printed Circuit Board Design

The PCB design begins with a custom “Digital Control” Shield which looks like the [Sparkfun Arduino Protoshield](#) when it is done is based on the [Adafruit Wave Shield](#). The Control Shield would be a dual-sided PCB having the ICs (DAC, Op Amps, Voltage Reference, Schottky

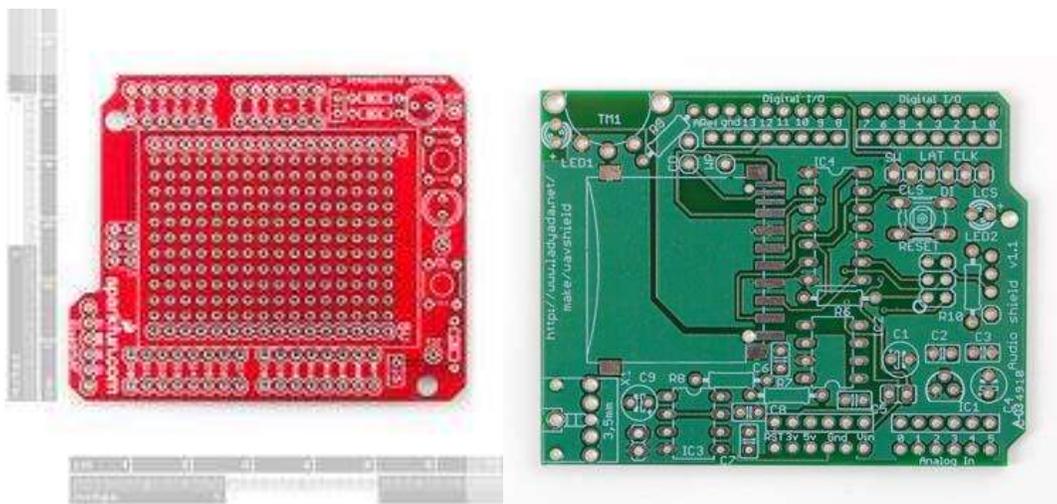
Diodes, etc.) mounted on one side of the board, with a mini or standard breadboard attached to the other.

The Top of the Control Shield would look like the Sparkfun Protoshield (see photos below). The side with the breadboard would also have a socket (*not shown*) allowing the DC/DC converter to be plugged in or provide easy access for jumper wires if the students wants to use lab supplies (*not recommended*).

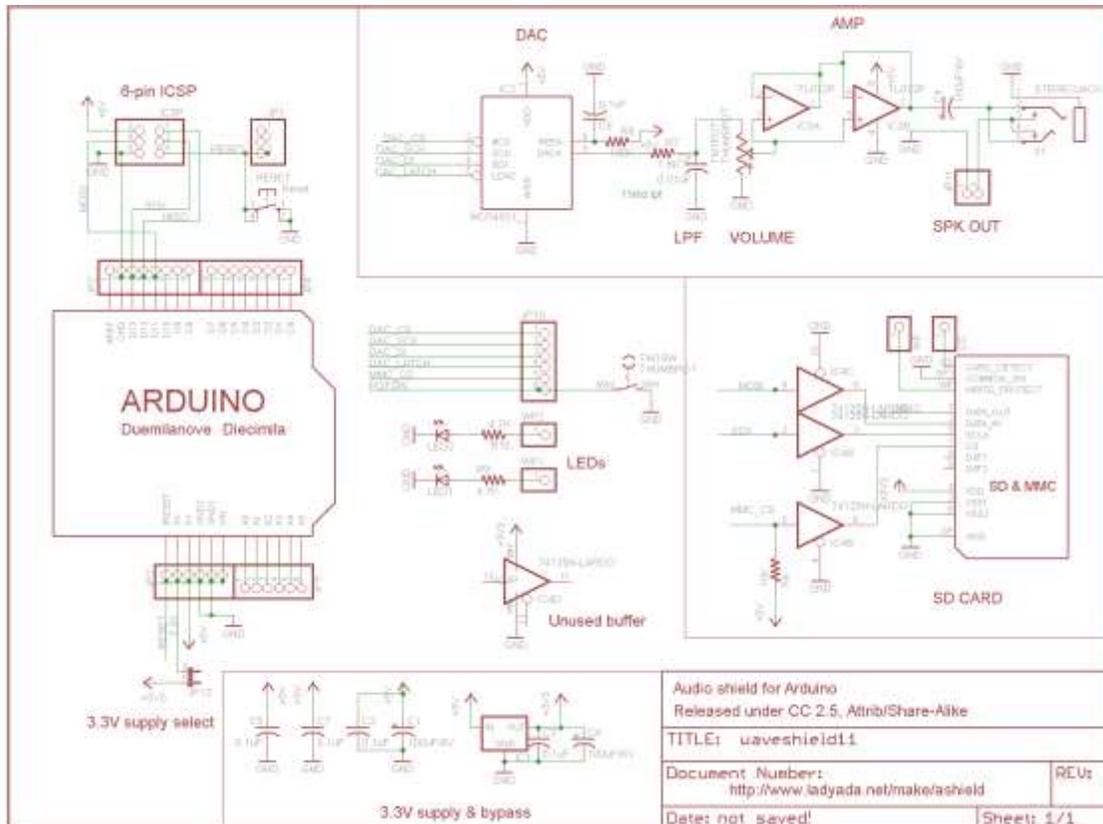
When completed the student only needs to wire their "plants" and jump over to the ADC/DAC header pins as needed.



Shown below, is a picture of the unpopulated PCB for the Sparkfun Arduino Protoshield (surface mount version) or [Adafruit Wave Shield](#) (through-hole version).



To start the design process I would download the [v1.1 Schematics](#) and [board layout](#) in EagleCAD format for the Adafruit Wave Shield.



This comes with most of the parts already laid out on the board (no looking for an Eagle version of a part). Notice that they also use the [12-bit MCP4921 DAC](#). For our variable gain stage they also include a variable resistor.

PCB Design Fabrication

- [Advanced Circuits](#)
- [Imagineering, Inc.](#) 5 days \$25.00
- [BatchPCB](#)
- [Gold Phoenix](#)
- [Coastal Circuits](#)

Protoshield Components

- The [Sparkfun Arduino Protoshield Kit](#) includes:
 - 2x [Stackable Headers 6-pin](#)
 - 2x [Stackable Headers 8-pin](#)
 - 2x [5mm Basic Yellow LEDs](#)
 - 2x [330 Ohm resistors](#)

- 1x [10k resistor](#)
- 3x [0.1uF Ceramic Capacitors](#)
- 2x [Momentary push buttons](#)



- 1x [Mini Breadboard](#)



- We would use the on-board ADC of the Arduino MCU. The input to the ATmega328P ADC would be protected with schottky diodes and a limiting resistor as shown in the S'10 Design. Eagle file for the Arduino Uno: <http://arduino.cc/en/Main/arduinoBoardUno>
- The proposed DAC is the [12-bit MCP4921 DAC](#) (S'10 Design) in an 8-MSOP package. MCU communication is implemented using the SPI serial interface. The output swings between 0 to 5v rail-to-rail with a single 5 v supply voltage. [Digi-key](#) has them in stock at \$2.34.



- TDK CC1R5-0512DF-E DC/DC Converters 5v to +/- 12v or +/-15v. [Digi-key](#) has them in stock at \$9.60.



- [MCP1525T-I/TT](#) (SOT-23) [MCP1525-I/TO](#) (TO-92-3) 2.5v Voltage reference eliminates the op-amp voltage divider circuit. [Digi-key](#) has them in stock for \$0.92



- Quad Bipolar TL034ACDR Op-amp in a 14 pin SOIC package using a standard Quad Op-Amp pinout.



- The output of the DAC goes to a level shifter and then to a gain stage bringing the analog output to +/- 12v. This would be the input to the Plant.
- The Output of the Plant goes to a gain stage and then to a level shift. The gain of this stage would need to be set by resistor(s) on the breadboard or a variable resistor pre-soldered on the board.
- [BAS40-04-V-GS08 Schottky Diodes](#) - Dual. [Digi-key](#) has them in stock for \$0.48



Appendix A Single Op-amp for Level Shifting and Gain Stage

- My current thoughts are that the added complexity of debugging an Op-amp that integrates two functions is not worth the savings of a few cents for the Op-amp saved so am moving away from this design option. I would however like to hear your thoughts on this subject. The best source on this subject, that I have found are here:

[Analog Devices, Optimizing Data Converter Interfaces, High Speed System, Part 2 of 4](#)

Section 6.5 "Bipolar Operation," Microchip Technology Inc. MCP4921/MCP4922, 12-Bit DAC with SPI™ Interface, [Microchip Technology document DS21897B](#)