E11 Lecture 3: Welcome to the World of Mudduino

Prof. David Money Harris
Fall 2014
Outline

- Logistics
- Arduino
  - Power Supply
  - Microcontroller
  - Inputs/Outputs
  - Host Interface
- Mudduino
  - Features
  - Schematic
  - I/O Pins
- Board Assembly
Logistics

- Problem Set 1 – due next Tuesday (9/16) before class
  - More programming in Thursday’s lecture
  - Tutoring hours: LAC, Sunday, 2-5 pm
  - Bring board home with you at the end of lab!
Arduino

- Open-source microcontroller platform
- Started by an Italian team in 2005, but it has spread world-wide
- Makes hardware/software solutions inexpensive & simple
- Popular with universities and hobbyists
- Mudduino is a custom version of the Arduino platform
Official Arduino Boards

Uno

Mega

Nano

Mini

Source: www.Arsuino.cc
# Official Arduino Boards

<table>
<thead>
<tr>
<th>Version</th>
<th>Digital I/Os</th>
<th>Analog Inputs</th>
<th>Price</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uno</td>
<td>14</td>
<td>6</td>
<td>$28</td>
<td>Very popular</td>
</tr>
<tr>
<td>Mega</td>
<td>54</td>
<td>16</td>
<td>$65</td>
<td>More memory and I/Os</td>
</tr>
<tr>
<td>Nano</td>
<td>14</td>
<td>8</td>
<td>$35</td>
<td>0.73” x 1.70”, fits on a breadboard</td>
</tr>
<tr>
<td>Mini</td>
<td>14</td>
<td>8</td>
<td>$25</td>
<td>Smallest (0.7” x 1.3”), fits on a breadboard, requires Mini USB adapter for programming</td>
</tr>
</tbody>
</table>
The Arduino system includes:

- Power supply
- Microcontroller
- Analog and digital inputs and outputs
- Host interface: a way to interface with a host computer
Power Supply

Two options:

- Powered by USB port (5 V)
- Powered by external power (DC Jack) that’s connected to, either:
  - Battery (7-12 V) or
  - Wall transformer (transforms 120 VAC to 7-12 V DC)
  - On-board voltage regulator drops this to 5 V
Microcontroller

- Microprocessor with controls for outside world

- Arduino system uses Atmel Microcontrollers
  - Operate on 8-bit data
  - Operating on 32-bit data requires 4 instructions

- Mudduino uses Atmega328 Microcontroller
  - Costs $2.32 (quantities >2000)
  - Some competing microcontrollers cost ~ $0.50
Atmega328 Features

- 16 MHz clock
- Executes 1 instruction / clock cycle
- Analog and Digital input/output pins
- Built-in A/D converter

On-chip memory:
- Program memory: 32 KB of Flash Memory (retains value when powered off)
- Data memory: 2 KB of static random access memory (SRAM) (loses value when powered off)
Atmega328 Features (cont.)

- Multiple timers/counters
  - measuring elapsed time
  - generate periodic signals

- Universal Asynchronous Receiver and Transmitter (UART) serial port controller

- Interrupts

For more information, look up the ATmega328 datasheet on the web:

Inputs and Outputs

- At least 14 digital pins
  - Configured as inputs or outputs
  - HIGH, 5 V
  - LOW, 0 V
  - Some can use PWM to simulate analog voltage

- Some pins can be configured as analog inputs
  - Connected to 10-bit A/D (analog-to-digital) converter
  - A/D converts voltage to value between 0-1023
  - Value is proportional to voltage (0 = 0 V, 1023 = 5 V)
  - 100 µs / conversion (so at most 10,000 samples/second)
## Digital Inputs and Outputs

<table>
<thead>
<tr>
<th>Level</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIL</td>
<td>1.5</td>
<td>Maximum input voltage recognized as a 0</td>
</tr>
<tr>
<td>VIH</td>
<td>3.5</td>
<td>Minimum input voltage recognized as a 1</td>
</tr>
<tr>
<td>VOL</td>
<td>0.9</td>
<td>Maximum output voltage produced for a 0</td>
</tr>
<tr>
<td>VOH</td>
<td>4.2</td>
<td>Minimum output voltage produced for a 1</td>
</tr>
</tbody>
</table>
Host Interface

- Arduino communicates with host computer using USB

- Internally Arduino uses RS232 serial communication

- Converter chip converts data back and forth from USB to RS232 standards
  - Sends 8 bits of data at a time
  - Requires start and stop bit for each 8 bits of data
  - 9600 baud = 9600 bits/second = 960 bytes / second

- Host and computer must agree on data rate
  - 9600 – 115,200 baud
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  - Schematic
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Mudduino
Mudduino – Overall Description

- Designed by E11 students during spring 2011 (v 1.3)

- Similar to Uno, except:
  - Uses through-hole components
    - easier to solder
    - can assemble your own board
  - Has connectors customized to robotics applications
  - Has form factor designed for your vehicle
  - Includes a blank portion - can add your own circuitry
Mudduino – Features

- Atmega328 microcontroller
  - 32 KB of Flash program memory, 2 KB of RAM data memory, 16 MHz
Mudduino – Features

- Atmega328 microcontroller
  - 32 KB of Flash program memory, 2 KB of RAM data memory, 16 MHz
- H Bridge for driving two high-current motors
Mudduino – Features

- Atmega328 microcontroller
  - 32 KB of Flash program memory, 2 KB of RAM data memory, 16 MHz
- H Bridge for driving two high-current motors
- Two indicator LEDs (red, green)
Mudduino – Features

- Atmega328 microcontroller
  - 32 KB of Flash program memory, 2 KB of RAM data memory, 16 MHz
- H Bridge for driving two high-current motors
- Two indicator LEDs (red, green)
- Two team LEDs (white, green)
  - glows white (looks yellow)
  - glows green (looks white)
Mudduino – Features (cont.)

- FTDI connector to communicate with a host
Mudduino – Features (cont.)

- FTDI connector to communicate with a host
- Power supply circuitry
Mudduino – Features (cont.)

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- Power supply circuitry
- Battery connector for untethered operation
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- Switches:
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- Switches:
  - power (USB / BAT - battery)
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- Power supply circuitry
- Battery connector for untethered operation
- Switches:
  - power (USB / BAT - battery)
  - motors (on/off)
Mudduino – Features (cont.)

- FTDI connector to communicate with a host
- Power supply circuitry
- Battery connector for untethered operation
- Switches:
  - power (USB / BAT - battery)
  - motors (on/off)
  - team (white, green)
  - Center position: no selection (careful!)
Mudduino – Features (cont.)

- FTDI connector to communicate with a host
- Power supply circuitry
- Battery connector for untethered operation
- Switches:
  - power (USB / BAT - battery)
  - motors (on/off)
  - team (white, green)
  - Center position: no selection (careful!)
- Expansion area for soldering on custom hardware
Mudduino – more parts!

- Reset button
  - When push button, uploaded program restarts
Mudduino – more parts!

- **Reset button**
  - When push button, uploaded program restarts

- **Clock Oscillator (16 MHz)**
Mudduino – more parts!

- Reset button
  - When push button, uploaded program restarts
- Clock Oscillator (16 MHz)
- Speaker (Buzzer)
Mudduino – more parts!

- Reset button
  - When push button, uploaded program restarts
- Clock Oscillator (16 MHz)
- Speaker (Buzzer)
- Capacitors and resistors
Mudduino – FTDI connector

- Important: Make sure black wire on FTDI cable is connected to pin labeled “GND” on board header
Mudduino – Settings

- **Switches:**
  - **Power:**
    - USB
    - to the right
  - **Team:**
    - white or green
    - left or right
    - but not in the middle!
    - indicates board has power
Mudduino – Pins

- Header pins for connecting:
  - 5 digital ports
  - 5 analog ports
  - 2 motor ports
  - Sensors:
    - Distance
    - Phototransistor
    - Reflectance
  - 5 V and GND
  - 20 expansion pins
Mudduino – Pins

- Header pins for connecting:
  - 5 digital ports
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  - 2 motor ports
- Sensors:
  - Distance
  - Phototransistor
  - Reflectance
- 5 V and GND
- 20 expansion pins
Mudduino – Pins
<table>
<thead>
<tr>
<th>Digital Pin #</th>
<th>Analog Pin #</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>Serial TXD – don’t use</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Serial RXI – don’t use</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Header D2</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Team (0 = green / 1 = white) read only</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Header D4, Buzzer</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Header D5 / green LED / programming indicator</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Left Motor Enable</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Right Motor +</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Left Motor -</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Left Motor +</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Header D10 / Servo (use servo.write)</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Right Motor Enable</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Right Motor -</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Header D13 / red LED</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>Distance Sensor</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>Header A1</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>Header A2</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>Header A3</td>
</tr>
<tr>
<td>18</td>
<td>4</td>
<td>Header A4, Reflectance Sensor</td>
</tr>
<tr>
<td>19</td>
<td>5</td>
<td>Header A5, Phototransistor</td>
</tr>
</tbody>
</table>
Mudduino Schematic
Mudduino Schematic

Reset switch

Header pins

Oscillator
Arduino Bootloader

- Your Atmega328 preprogrammed with Arduino bootloader
  - Occupies part of flash memory
  - Initializes chip at powerup or reset
  - Monitors serial port (USB port), waiting for program to be uploaded
Mudduino Assembly

- You will all assemble (build) your own Mudduino in lab this week

- Start with a bare printed circuit board (PCB)
  - PCB has 4 conducting layers (sandwiched between insulator – called FR4):
    - Two inner layers for power and ground
    - Two outer layers for carrying signals

- Solder parts using a soldering iron and solder
  - Parts must have good electrical and mechanical connection to board!
Bare PCB

Holes through which parts are placed
PCB Drawing - Traces
Through-hole Assembly

- Place pins of part through the hole
- Solder on opposite side of board
Place parts

- Oscillator
- Reset
- Pushbutton
- Speaker
- Voltage regulator
- Sockets
- Capacitors
- Header pins
- Resistors
- LEDs
- 49
Voila! – your very own Mudduino
Voila! – your very own Mudduino

Test & Debug!