Physics 124: Lecture 1

Course Structure
Crash Course for Arduino
Crash Course in C

Course Structure

- MWF Lecture, at least for first 5 weeks
  - 7% of course grade on participation/attendance
- Structured Labs first 4 weeks (building blocks)
  - demonstrated performance is 36% of grade
  - must adhere to due dates to prevent falling behind
- Midterm to demonstrate simple coding, 7% of grade
- Creative project second half of quarter (50% of grade)
  - final demonstration Friday March 19 (with spectators)
- Work in teams of 2 (with few exceptions)
- Primary Lab periods: T/W 2–6
  - at least 2/3 of "help" will be on hand
  - will have access to lab space 24/7
- 2 Profs & 2 TAs:
  - Tom Murphy, Julio Barreiro, Clayton Anderson, Paul Lauria

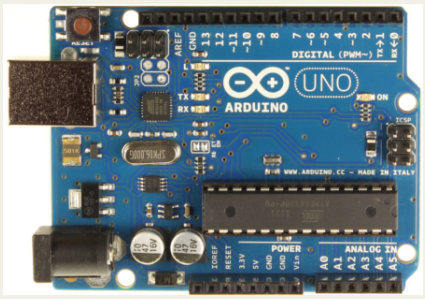
Project Rubric

- Three principal ingredients
  - Measure/Sense/Perceive
    - the most physics-related component
  - Process/Calculate/Think
    - usually via microcontroller
  - Act/React/Do
    - motors, lights, sound, display
- Examples from past (inadequately small sample)
  - remote-control type car parallel parks itself
  - automatic shifting on bike
  - rotating LED sphere changes color/intensity to music
  - see http://www.physics.ucsd.edu/~tmurphy/phys124/projects/projects.html for more

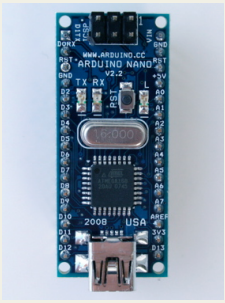
Why is this a Physics Course?

- What about this is physics? Why do we bother?
- True that this is not front/center in physics research
- BUT…
  - has been useful in research (mine and former students)
  - learn about sensors
  - proficiency with a tool that can help control experiments
  - learn some coding in C (well-used language in physics)
  - more familiar with practical electronics
  - learn team dynamics/communication
  - deadlines
  - gain confidence in ability to do something unique
- Goal is fun enough to motivate real investment
  - a necessary ingredient to *real* learning

Arduino: This is our Brain in Phys124



Arduino Uno



Arduino Nano

- Packaged Microcontroller (ATMega 328)
  - lots of varieties; we'll primarily use Uno and Nano
  - USB interface; breakout to pins for easy connections
  - Cross-platform, Java-based IDE, C-based language
  - Provides higher-level interface to guts of device

Arduino Core Capabilities

- Arduino makes it easy to:
  - have digital input/output (I/O) (14 channels on Uno)
  - analog input (6 channels on Uno; 8 on Nano)
  - "analog" (PWM) output (6 of the digital channels)
  - communicate data via serial (over USB makes easy)
- Libraries available for:
  - motor control; LCD display; ethernet; SPI; serial; SD cards, and lots more
- "Shields" for hardware augmentation
  - stepper motor drivers
  - LCD display
  - GPS receiver
  - bluetooth, SD card, ethernet, wireless, and lots more

Why Arduino?

- Previous incarnations of this course used the PIC microcontroller from Microchip Technology
- Why switch to something new?
- Arduino allows Mac/Linux users to have fun
  - many students are smart enough to avoid Windows
- Arduino is cheap ($25–$35 range is typical)
  - so students can afford to play on their own (encouraged!)
- Arduino programming usefully transfers to research
  - C rather than assembly code
- High-level functions mean less time at register/bit level
  - more time to learn about sensors, put amazing projects together, rather than dwell on computer engineering
- Yet loss of low-level understanding is unfortunate cost

Mission: Get up to Speed Fast

- We're going to do a crash course this first week to get you going super-fast
- Involves some hardware proficiency
  - hooking up elements in breadboard, e.g.
- But mostly it's about coding and understanding how to access Arduino functions
- Emphasis will be on *doing* first, *understanding* later
  - not always my natural approach, but four weeks is short
- Monday lecture will often focus on upcoming lab
- Wed. will elaborate and show in-class examples
- Friday may often provide context/background

Every Arduino "Sketch"

- Each "sketch" (code) has these common elements

```
// variable declarations, like
const int LED=13;

void setup()
{
  // configuration of pins, etc.
}

void loop()
{
  // what the program does, in a continuous loop
}
```

- Other subroutines can be added, and the internals can get pretty big/complex

Rudimentary C Syntax

- Things to immediately know
  - anything after // on a line is ignored as a comment
  - braces { } encapsulate blocks
  - semicolons ; must appear *after every command*
    - exceptions are conditionals, loop invocations, subroutine titles, precompiler things like `#include`, `#define`, and a few others
  - every variable used in the program needs to be declared
    - common options are `int`, `float`, `char`, `long`, `unsigned long`, `void`
    - conventionally happens at the top of the program, or within subroutine if confined to { } block
  - Formatting (spaces, indentation) are irrelevant in C
    - but it is to your great benefit to adopt a rigid, readable format
    - much easier to read/debug if indentation follows consistent rules

Example Arduino Code

```
// blink_LED. . . . . . . slow blink of LED on pin 13
const int LED = 13;     // LED connected to pin 13
                        // const: will not change in prog.

void setup()            // obligatory; void->returns nada
{
  pinMode(LED, OUTPUT); // pin 13 as output (Arduino cmd)
}

void loop()             // obligatory; returns nothing
{
  digitalWrite(LED, HIGH); // turn LED ON (Arduino cmd)
  delay(1000);             // wait 1000 ms (Arduino cmd)
  digitalWrite(LED, LOW);  // turn LED OFF
  delay(1000);             // wait another second
}
```


Comments on Code

- Good practice to start code with descriptive comment
  - include name of sketch so easy to relate print-out to source
- Most lines commented: also great practice
- Only one integer variable used, and does not vary
  - so can declare as `const`
- `pinMode()`, `digitalWrite()`, and `delay()` are Arduino commands
- `OUTPUT`, `HIGH`, `LOW` are Arduino-defined constants
  - just map to integers: 1, 1, 0, respectively
- Could have hard-coded `digitalWrite(13,1)`
  - but less human-readable than `digitalWrite(LED, HIGH)`
  - also makes harder to change output pins (have to hunt for each instance of 13 and replace, while maybe not every 13 should be)

Arduino-Specific Commands

- Command reference: http://arduino.cc/en/Reference/HomePage
  - Also abbr. version in Appendix C of *Getting Started* book (2nd ed.)
- In first week, we'll see:
  - `pinMode`(*pin*, [INPUT | OUTPUT])
  - `digitalWrite`(*pin*, [LOW | HIGH])
  - `digitalRead`(*pin*) → `int`
  - `analogWrite`(*pin*, [0…255])
  - `analogRead`(*pin*) → `int` in range [0..1023]
  - `delay`(*integer milliseconds*)
  - `millis()` → `unsigned long` (ms elapsed since reset)

Arduino Serial Commands

- Also we'll use serial communications in week 1:
  - `Serial.begin`(*baud*): in `setup`; 9600 is common choice
  - `Serial.print`(*string*): *string* → `"example text "`
  - `Serial.print`(*data*): prints *data* value (default encoding)
  - `Serial.print`(*data*,*encoding*)
    - *encoding* is DEC, HEX, OCT, BIN, BYTE for format
  - `Serial.println()`: just like `print`, but CR & LF (`\r\n`) appended
  - `Serial.available()` → `int` (how many bytes waiting)
  - `Serial.read()` → `char` (one byte of serial buffer)
  - `Serial.flush()`: empty out pending serial buffer

Types in C

- We are likely to deal with the following types

```
char c;          // single byte
int i;           // typical integer
unsigned long j; // long positive integer
float x;         // floating point (single precision)
double y;        // double precision

c = 'A';
i = 356;
j = 230948935;
x = 3.1415927;
y = 3.14159265358979;
```

- Note that the variable `c='A'` is just an 8-bit value, which happens to be 65 in decimal, 0x41 in hex, 01000001
  - could say `c = 65`; or `c = 0x41`; with equivalent results
- Not much call for double precision in Arduino, but good to know about for other C endeavors

Changing Types (Casting)

- Don't try to send float values to pins, and watch out when dividing integers for unexpected results
- Sometimes, we need to compute something as a floating point, then change it to an integer
  - `ival = (int) fval;`
  - `ival = int(fval);  // works in Arduino, anyhow`
- Beware of integer math:
  - 1/4 = 0; 8/9 = 0; 37/19 = 1
  - so sometimes want `fval = ((float) ival1)/ival2`
  - or `fval = float(ival1)/ival2 //okay in Arduino`

Conditionals

- The if statement is a workhorse of coding
  - `if (i < 2)`
  - `if (i <= 2)`
  - `if (i >= -1)`
  - `if (i == 4)// note difference between == and =`
  - `if (x == 1.0)`
  - `if (fabs(x) < 10.0)`
  - `if (i < 8 && i > -5)  // && = and`
  - `if (x > 10.0 || x < -10.0)  // || = or`
- Don't use assignment (=) in test clauses
  - Remember to double up ==, &&, ||
- Will execute single following command, or next { } block
  - wise to form { } block even if only one line, for readability/ expansion
- Can combine with else statements for more complex behavior

If..else construction

- Snippet from code to switch LED ON/OFF by listening to a button

```
void loop()
{
  val = digitalRead(BUTTON);
  if (val == HIGH){
    digitalWrite(LED, HIGH);
  } else {
    digitalWrite(LED, LOW);
  }
}
```

- BUTTON and LED are simply constant integers defined at the program start
- Note the use of braces
  - exact placement/arrangement unnec., but be consistent

For loops

- Most common form of loop in C
  - also `while`, `do..while` loops
  - associated action encapsulated by braces

```
int k,count;

count = 0;
for (k=0; k < 10; k++)
{
  count += 1;
  count %= 4;
}
```

- `k` is iterated
  - assigned to zero at beginning
  - confined to be less than 10
  - incremented by one after each loop (could do `k += 1`)
- `for(;;)` makes infinite loop (no conditions)
- `x += 1` means `x = x + 1`; `x %= 4` means `x = x % 4`
  - `count` will go 1, 2, 3, 0, 1, 2, 3, 0, 1, 2 then end loop

`#define` to ease the coding

```
#define NPOINTS 10
#define HIGHSTATE 1
```

- `#define` comes in the "preamble" of the code
  - note no semi-colons
  - just a text replacement process: any appearance of NPOINTS in the source code is replaced by 10
  - Convention to use all CAPs to differentiate from normal variables or commands
  - Now to change the number of points processed by that program, only have to modify one line
  - Arduino.h defines handy things like HIGH = 0x1, LOW = 0x0, INPUT = 0x0, OUTPUT = 0x1, INPUT_PULLUP = 0x2, PI, HALF_PI, TWO_PI, DEG_TO_RAD, RAD_TO_DEG, etc. to make programming easier to read/code

Voices from the Past

- avoid magnets in projects (2013)
- heat sinks are there for a reason (2013)
- make circuit diagrams & update changes (2013)
- robots are **stupid** (2013, 2014)
- use the oscilloscope (2013)
- **save often**, and different versions (2013, 2014, 2015)
- some lectures are boring, but boring ≠ useless (2013)
- start early (2014)
- comment your code (2014)
- take more time to think than to code (2014)
- don't use perf-board unless you rock at soldering (2014)

Voices, Continued

- Listen to Prof. Murphy and TAs (2014)
- Use Serial Monitor and DVM for debugging (2014, 2015)
- Pin conflicts are real! (2014)
- Know what pins are used by your shield (2014)
- Read the data sheets (2014)
- Walk away if something doesn't work (2014)
- Know the purpose of every line of code (2015)
- A simple concept might not be so simple (2015)
- Pick a project that can be scaled up or down (2015)
- Get your own Arduino & practice/explore (2015)
- Batteries can be a real pain (2015)
- Make a set schedule with partner (2015)

Announcements

- Can go to lab right after class to start on kits
  - otherwise Tue. or Wed. lab at normal 2PM start time
- Late labs (even by an hour) incur grade-point penalty
  - very important (for project) to avoid slippage
  - can accelerate by jumping through labs ahead of schedule
- Will have midterm to check basic coding proficiency
- Grading scheme:
  - 50% project (proposal, implementation, success, report)
  - 36% weekly lab (4 installments: success/demo, write-up)
  - 7% midterm (coding example)
  - 7% participation/attendance of lecture

Course Website

- Visit http://www.physics.ucsd.edu/~tmurphy/phys124/
  - Assignments
  - Lab Exercises
  - Useful Links
  - Contact Info & Logistics
- May want to look at Lecture 2 for Week 1 Lab
  - especially you Tuesday folks…