Physics 124: Lecture 2

Topics and Techniques for Week 1 Lab

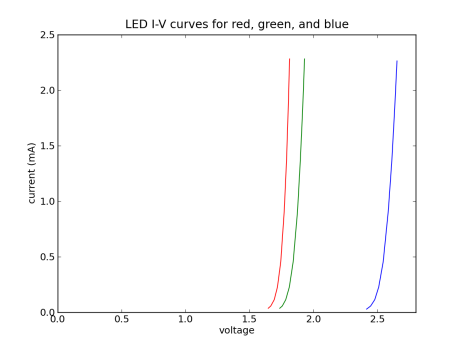
Week 1 Lab has 4 Exercises

- Blinking an LED in a Morse Code pattern
- Modulating LED brightness via PWM
- Using a switch to toggle LED and set brightness
- Analog input, reading a photocell
  - and possibly doing something about it

- Note that the last two constitute miniature versions of the final project
  - sense something in the real world; make some decisions accordingly; manipulate something in the real world in response
- These tasks largely follow from the *Getting Started* book

LED hookup

- The output of Arduino digital I/O pins will be either 0 or 5 volts
- An LED has a diode-like I-V curve
- Can't just put 5 V across
  - it'll blow, unless current is limited
- Put resistor in series, so ~2.5 V drop across each
  - 250 Ω would mean 10 mA
  - 10 mA is pretty bright



Blink Function (Subroutine)

- For complex blink patterns, it pays to consolidate blink operation into a function

```
void blink(int ontime, int offtime)
{
  // turns on LED (externally defined) for ontime ms
  // then off for offtime ms before returning
  digitalWrite(LED, HIGH);
  delay(ontime);
  digitalWrite(LED, LOW);
  delay(offtime);
}
```

- Now call with, e.g., `blink(600,300)`
- Note function definition expects two integer arguments
- LED is assumed to be global variable (defined outside of loop)

Blink Constructs

- For something like Morse Code, could imagine building functions on functions, like

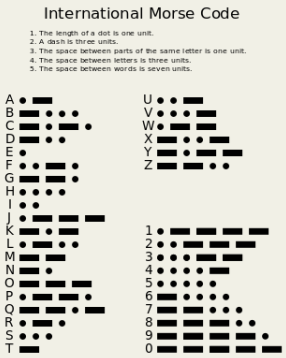
```
#define DOTDUR 200

void dot()              // dot, plus gap
{ blink(DOTDUR,DOTDUR); }

void dash()             // dash, plus gap
{ blink(3*DOTDUR,DOTDUR); }

void letterspace()      // aim for gap of 3
{ delay(2*DOTDUR); }    // already have one

void wordspace()        // aim for gap of 7
{ delay(4*DOTDUR); }    // already have three
```



- Note use of `#define` to specify duration of dot
  - and therefore overall cadence: change in one place!

Morse, continued

- And then perhaps letter functions:

```
void morse_s()
{ dot(); dot(); dot(); letterspace(); }

void morse_o()
{ dash(); dash(); dash(); letterspace(); }
```

- You could then spell out a word pretty easily like:

```
morse_s();
morse_o();
morse_s();
wordspace();
```

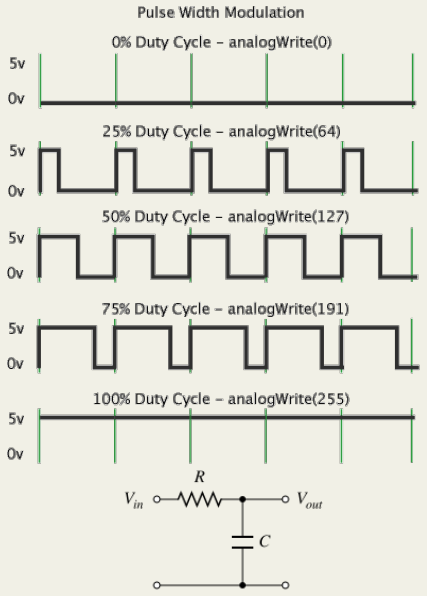
- Once you have a library of all the letters, it would be very simple to blink out anything you wanted
  - could even cleverly Morse-out string, like “HELLO”

Pulse Width Modulation

- A "poor man's" analog output can be synthesized out of a digital (0–5 V) signal by pulsing at variable *duty cycle*
  - the *time average* voltage can then be anything between 0 and 5 V
- Arduino provides `analogWrite`(*pin*, *value*), valid for 6 of the 14 digital I/O pins on the Uno
  - *value* is a number from 0 to 255 (one byte)
- For controlling LED brightness, the fraction of time in the ON state determines perceived brightness
- For other applications, may want capacitor to average (smooth) out the frenzied pulse sequence

PWM, Visually

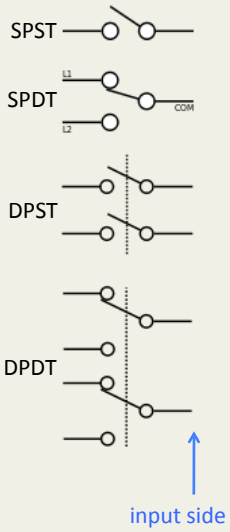
- At right, pulse period denoted by green markers
- Can go from always LOW (0% duty cycle) to always HIGH (100% duty cycle)
  - or anything in between, in 255 steps
- Can change period, if needed
  - though only among limited selection of options



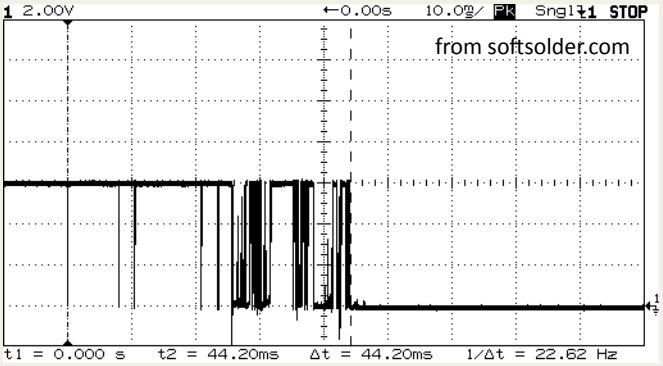
low pass filter can smooth out

Switches & Debouncing

- Switches come in a dizzying variety
  - normally open (NO), normally closed (NC)
    - applies to single throw, typically
  - single pole (SP), double pole (DP), etc.
    - how many inputs to the switch
  - single throw (ST), double throw (DT), etc.
    - how many contacts each input may make
    - DT can also come in CO variety: center open
- The Arduino kit button is NO, SPST
  - it is normally open, one input (shared two pins), one output (shared two pins)
- But switches are not as simple as you think
  - transition from open to closed can be erratic, random, fast oscillation, bouncing many times between states before settling



Typical Bounce



- On the tens of milliseconds timescale, a switch can actually go through any number of transitions
- Each time will look completely different
- Idea is to catch first transition, then hold off until you're sure things have settled out

Delay Can Save the Day

- A fast microprocessor looking for switch transitions can catch all these bounces, as if you had pressed the button many times in fast succession
  - this is seldom the behavior we want
- Inserting a delay gives the physical switch time to settle out
  - something like 50−100 ms is usually good; faster than you can intentionally press twice (see dt_pair)
- Often use hardware solution too, with flip-flops
  - lock in first edge
- Will also be relevant when we get to interrupts

Thinking Through Complex Logic

- In the dimmer exercise, it's tough to keep track of the states
- Tendency to want to grasp entire scheme at once
- Brains don't often work that way
  - break it down to pieces you understand: divide & conquer
  - ask yourself questions *throughout the process*
    - Do I just need to know the state of the button, or catch change?
    - If catching a change, what am I comparing against?
    - Do I need a variable to keep track of a previous state?
    - If so, when do I store the "old" value?
    - If the button has just been pressed, what should I do?
    - Does the answer depend on the LED state?
    - Then do I need a variable to track this? (and the list goes on!)

Analog to Digital Conversion (ADC)

- Computers are digital, while the physical world is analog
- Converting voltage (analog value expressed electrically) into a digital number is a fundamental task in computer/world interface
- Internally, the processor is doing a "guess and check" approach from most significant bit (MSB) to LSB
- Arduino Uno has six analog inputs, turning each into a 10-bit number, 0..1023
  - measure 0−5 V range to 0.1%, or 5 mV precision
- This is your key portal into using sensors

Assignments/Announcements

- First week exercises due Tue/Wed, 1-11/12 by 2PM
  - depends on whether you are in Tue or Wed lab session
  - can drop in slot on TA room in back of MHA 3544
  - expect code printout (can be common to group), and some paragraphs *from each group member* as to contribution: how do we know you did something and *learned*?
- TA office hours:
  - Clayton M 3-4 PM; Tu 1-2 PM
  - Paul F 2-3 PM; M 2-3 PM