HW4 Recap

• Seemed the right length and difficulty for most
• Underspecified in assignment, but don’t forget: the PCBs have to be fastened to the shell somehow.
HARDWARE PWM
Hobby Servo Motors

- Feedback system and gearbox
- dc motor
- Pot
- Control circuitry
Hobby Servo Motors: PWM revisited

A typical servo-control signal and shaft-position response
Controlling Servos

- Naïve method: toggle pin high, wait $x$ ms, toggle pint low, wait $(20-x)$ ms
- Busy-waiting; can write asynchronously, but hard to interleave with other code and no timing guarantees
- Better: use hardware timers on chip
Hardware PWM

Period: want 20ms
Control by setting TOP/ICR

TCNT1

PWM signal

Duty:
want 1-2ms
Control by setting OCR

ICR1

OCR1A

TCNT: Counter
ICR: Input Compare Register
OCR: Output Compare Register
Hardware PWM

- To get right frequency: set *prescaler* and TOP of count based on system clock:

\[ f_{PWM} = \frac{f_{clk}}{2 \cdot N \cdot TOP} \]

\[ 50Hz = \frac{16000000Hz}{2 \cdot N \cdot TOP} \]

\[ N \cdot TOP = 160000 \]

- N is (1, 8, 64, 256 or 1024), TOP is 16bit
- Use N=8 and TOP = 20000 to get clean microsecond resolution
Hardware PWM

• To get desired duty cycle, set output compare register:
  • For 1ms, set OCR = 1000, for 2ms, set OCR = 2000
  • Output pin is pin 9 for OC1 (or can trigger internal interrupt)
SWITCHING
NPN Transistors

NPN transistor basics
- To start the flow of current from collector to emitter, apply a relatively positive voltage to the base.
- In the schematic symbol, the arrow points from base to emitter and shows the direction of positive current.
- The base must be at least 0.6 volts “more positive” than the emitter, to start the flow.
- The collector must be “more positive” than the emitter.

Illustrations: Platt, Make Electronics
NPN Voltages

Somewhere in between

More positive

More negative
PNP Transistors

PNP transistor basics
- To start the flow of current from emitter to collector, apply a relatively negative voltage to the base.
- In the schematic symbol, the arrow points from emitter to base and shows the direction of positive current.
- The base must be at least 0.6 volts “more negative” than the emitter, to start the flow.
- The emitter must be “more positive” than the collector.
Transistor Considerations

- Use NPN transistors to switch higher-voltage loads
- Determine $V_{\text{load}}$, $I_{\text{load max}}$ of your load
- Transistor’s maximum collector current: $I_{c\text{ (max)}} < I_{\text{load max}}$
- Transistor’s max collector-emitter voltage: $V_{\text{ceo (max)}} < V_{\text{load}}$
- Current gain: Supply base current from microcontroller must not exceed max $h_{FE} < 5x \left( \frac{I_{\text{load max}}}{I_{\text{uC max}}} \right)$
- Pick base resistor
TIP120: Darlington Pair

- Why use a TIP120 in the example circuit?
- TIP120 is a Darlington pair, with high current gain: $h_{FE} = h_{FE1} \times h_{FE2}$
Switching AC safely
<table>
<thead>
<tr>
<th>Type of load</th>
<th>Percent of rated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistive</td>
<td>75</td>
</tr>
<tr>
<td>Inductive</td>
<td>40</td>
</tr>
<tr>
<td>Capacitive</td>
<td>75</td>
</tr>
<tr>
<td>Motor</td>
<td>20</td>
</tr>
<tr>
<td>Incandescent</td>
<td>10</td>
</tr>
</tbody>
</table>

WIRELESS COMMUNICATION
Conceptual Framework

Serial over USB (virtual com port)
Conceptual Framework

Mechanisms and Enclosures

- Actuators
- Sensors

Circuits

- Embedded Code

Micro-Controller

PC or Phone

- Code

Wireless Serial?
XBee Radios

- 2.4GHz, up to 250kbps
- 3.3V (level shifters!)
- Optimistic: 100m range. Reasonable inside: 20m
- On-board A2D, GPIO
- Simple serial AT command set on top of 802.15.4 (Zigbee)
- ~ 50mA draw
Simple case: Serial cable replacement

Micro-Controller

Embedded Code

UART pins (0, 1)

Serial over USB

PC or Phone

Code

Demo this.
What happens with $N>2$ radios?
Star Networks
It is not possible to tell which sensor sent what data.
Peer-to-peer
Peer-to-peer networks

- Require firmware configuration:
  - PAN ID: Radios within same network can address each other
  - Radio ID2: Own, destination (default: 0)
XBEE PROJECT DEMO
BACK TO WIRELESS...
Other wireless approaches

- Many other RF transceiver available
- Infrared
- Audio
- WiFi? Later…
Smule Sonic Lighter

- **Speaker**: put near **mic** to ignite
- **Flame**: tilt/touch to play with fire, double tap to see map of flames
- **Flints**: strike to ignite
- **Valve**: hold on **both** phones to ignite
- **Mic**: blow to extinguish, put near **speaker** to ignite

Mitch Altman’s TV-B-Gone
IR Sniffing

Example from Tom Igoe, Making Things Talk
Infrared Example: NEC Protocol

Pulse Distance Modulation
Infrared Example: NEC Protocol

8 bit address, 8 bit command
Transmitted twice for error checking
Initial gain control burst
GETTING ON THE NET
Conceptual Framework

Micro-Controller

Embedded Code

PC or Phone

Code
Conceptual Framework

Micro-Controller
Embedded Code

Internet

Ethernet/Wifi?
Sparkfun WizNet breakout
$25
Ethernet Shield

- Based on Wiznet W5100 Serial/SPI-to-Ethernet
- POE available (but pricey)
- Limitations (remember LCD screens?):
  - Serial still order of magnitude slower
  - Received packets or even outgoing messages may not fit into Arduino RAM
    (Forget about nice XML parsing – JSON OK)
  - Single thread, slow as server
- Relatively easy to connect when you’re in control of the network, harder when someone else is running infrastructure (MAC filtering)
WiFi

Arduino WiFi Shield ~$80

Roving Networks WiFly ~$30
WiFi gotchas

• Until recently, fairly power hungry

• Authentication:
  – WEP, WPA, WPA2, … managing authentication can be messy
  – Worse: Browser-based authentication (e.g., AirBears!) impossible or very hard.

• Firewalls, NAT etc.: May be hard to serve to the outside world
Some Frequent Workarounds

- Microcontroller
- Ethernet/Wifi
- PC Server
- Internet
- Serial, Xbee, ...
Some Frequent Workarounds

- Micro-Controller
- PC Server
- Remote Client
- Internet
- Serial, Xbee, ...
- Ethernet/Wifi
Some Frequent Workarounds

Micro-Controller

PC Gateway

Remote Server

Remote Client

Internet

Serial, Xbee, …

Ethernet/Wifi
Serving Data

• Most likely, people will consume data through HTML in a Browser
• Standard Web 1.0 model: Client requests URL, Server constructs page using server-side logic, sends HTML+JS back to client
• Problem: Could you do a game controller this way?
FORM GROUPS
Form Groups

- Your project will be completed in groups of three. Other group sizes (2-4) are possible for MEng or dissertation projects, but are discouraged.
- **Project technology requirements:**
  - Must include custom 3D printed case or mechanism for your device
  - Must be interactive: include sensing and/or actuation circuitry
  - Must have some graphical user interface somewhere (doesn't have to be on the device)
  - Must communicate: either with your Phone, PC, tablet or the rest of the Internet - wireless preferred.
- **Project design requirements:**
  - Must pick a concrete user group
  - Must solve a real problem or improve their life in some meaningful way (more fun is ok)
- Project groups are self-paired: you decide who you'll work with.
- Use this [Google Form](https://example.com) to submit project groups.
- One submission per team is enough.
- To assist you in finding the right group, look at the wiki page on [Project Ideas](https://example.com).
- You'll submit your group name and member list as part of the [[P 1 - Project Brainstorm and Storyboard] assignment].