Hello World
Agenda

• Introduction to ARM

• mbed
  – Introduction to mbed
  – Lab 1: mbed registration and Hello World demo
  – Lab 2: Other IO
  – Lab 3: Interfacing with sensors
  – Lab 4: Output devices, a TextLCD
  – Lab 5: Rapid prototyping, Build a datalogger
What does ARM do?

- ARM designs technology that lies at the heart of advanced digital products
ARM Overview

- ARM is the world’s leading semiconductor IP company and The Architecture for the Digital World ®
  - Over 15 billion ARM technology based chips shipped to date
  - Unrivalled Partner ecosystem
    - Over 640 processor licenses sold to more than 200 companies
    - Millions of developers; billions of users
  - ARM has the right technology – optimized for a mobilizing world
  - We’re customer-focused – listening harder and responding faster
mbed
Hello World!

Introduction to mbed
What’s happening in Microcontrollers?

• Microcontrollers are getting cheap
  – 32-bit ARM Cortex-M3 Microcontrollers @ $1

• Microcontrollers are getting powerful
  – Lots of processing, memory, I/O in one package

• Microcontrollers are getting interactive
  – Internet connectivity, new sensors and actuators

• Creates new opportunities for microcontrollers
Opportunities for Microcontrollers

• Before 1980 computers were used and applied by computer scientists

• now they are:
  – Applied across all industries
  – Widely used in the home
  – Used by almost anybody

• Currently microcontroller technology is mainly applied by the embedded professional

• Microcontrollers interact with “the real world”
  – Sensors, actuators and communication, define their application
  – Their potential is greater than the home computer
Barriers for Microcontrollers

• What prevents microcontrollers from being designed in?
• Conceptually simple things can be hard to prototype
  – I want to send an SMS when my cat comes through the cat flap
• Repetition of choices to make:
  – Microcontroller
  – Tool chain
  – Dev board
  – Sensors
  – It’s not difficult, but can be tedious and time consuming
• Overhead for starting a new project
  – Fine for a long complex projects
  – A deterrent for quick experiments and tests
Rapid Prototyping helps industries create new products
- Control, communication and interaction increasingly define products
- Development cycles for microelectronics have not kept pace

3D Moulding  3D Printing  2D/3D Design  Web Frameworks
mbed.org - Rapid Prototyping for MCUs

• Fastest way to get started with ARM microcontrollers
  – Plug ‘n’ Play Hardware, Online Compiler
  – Get setup and run “Hello World!” in 60 seconds
  – Removes entry barriers to MCU technology

• Focused on rapid prototyping for a diverse audience
  – DIP form-factor, High-level APIs, Developer website
  – Technology and tradeoffs to enable fast experiments
  – Creates new applications for MCU technology

• Launched at ESC Boston with live demo
  – Internet-enabled “Twittering Billy” read out tweets
  – An embedded internet device, prototyped in ½ day
  – Over ¼ million video views in first week!
mbed Approach

• Focus on tools supporting the earliest stage of design
  – Point of entry and Getting Started
  – Experimentation and Rapid Prototyping

• Apply technology and trade-offs that support this goal

• What mbed is not trying to do:
  – Replace Keil MDK or other professional tools
  – Replace development or evaluation boards
mbed Rapid Prototyping Platform

- Complete Hardware, Software and Web 2.0 Solution

Dedicated Developer Website

Lightweight Online Compiler

High-level Peripheral APIs

Prototyping Form-Factor

http://mbed.org | Rapid Prototyping for Microcontrollers
mbed Website

- Dedicated Developer Web Platform
  - Custom Web 2.0 tools and environment focused on developers
  - Simple route to get started, comprehensive resources and support

http://mbed.org
mbed Compiler

• Lightweight Online Compiler
  – Web 2.0 browser-based IDE with personal workspace “in the cloud”
  – Nothing to install or configure, login from anywhere
  – Industry leading RVCT 4.1 back end. It is a real tool!
mbed Library

• High-level Peripheral APIs
  – Trading memory and CPU performance for ease of use
  – Abstract software interfaces for controlling microcontroller hardware
  – Intuitive peripheral access, encapsulation of implementation details
  – Treat hardware and software the same

http://mbed.org | Rapid Prototyping for Microcontrollers
mbed Microcontroller

- Cortex-M3 MCU in a Prototyping Form-Factor
  - 0.1” pitch DIP with “USB Disk” interface and support components
  - Nothing to install or configure, practical for breadboard and PCBs
Lab 1

mbed registration and hello world!
Registration

- mbed microcontroller enumerates as a Mass Storage Device (USB disk)
- Double-click the mbed.htm file on the mbed USB disk
- Log in or sign up for a new account
- The mbed microcontroller contains your license to the compiler
Getting Started

• Useful resources linked from the first page, including very clear links to “Hello World” and the Getting Started guide

• Compiler linked from front page
Getting Started

• Create or open a project in the Program Workspace
• Develop code in the text editor
• Save and compile
• Compiler outputs
  – Errors and warnings
  – -or-
  – A downloadable binary
• Save to the USB flash disk
Getting Started

• Once the file has saved to the flash disk, it needs to be programmed into the microcontroller
• Press the button on the mbed module
• Your code will start running!
Hello World

Lab 2
Rapid Prototyping: Other IO
DigitalOut and Analog Input

- In the hello world session, we simply compiled the default program – blinky, but we didn't take too much notice of the code.
- It was simple, it set up a digital output (DigitalOut) called “myled” and run a loop forever turning it on and off.
- Let's see if we can begin to influence this.
What IO is there?

- Take another look at your compiler window. In your default project there the mbed library with a “+” box. Try expanding this, and exploring the libraries.

- Note that these are libraries that relate to the microcontroller on chip hardware.

- We’ll be using the AnalogIn object, so take time to have a look at it’s API.
DigitalOut and Analog Input

- The AnalogIn object returns a normalised float between 0.0 (0.0v) and 1.0 (3.3v)

- Wire your potentiometer between GND (0v) and Vout (3.3v), and connect the wiper (the middle pin) to pin “p20” – an AnalogIn

http://mbed.org | Rapid Prototyping for Microcontrollers
Challenge: DigitalOut and Analog Input

- Write a program to give the LED in the first blinky program a delay of 1-5 seconds.

```c
#include "mbed.h"

DigitalOut myled(LED1);
AnalogIn pot(p20);

int main () {
    while(1) {
        myled = !myled;                  // toggle
        wait (1.0 + (4.0 * pot.read())); // 1.0s - 5.0s
    }
}
```

- Write a program that turns LED1 on at 0.66v, LED2 on at 1.32v, LED3 on at 1.98v and LED4 at 2.64v
Lab 3
Rapid Prototyping: Interfacing a sensor
Example: Interfacing with sensors

- A good deal of microcontroller applications require some form of sensors to detect events or conditions in the immediate environment.

- This experiment shows how to implement a simple temperature sensor.

- The sensor in question is the TMP102 which has a digital interface using the I2C bus.
Connecting up the sensor

• The TMP102 has just four pins, Vcc, Gnd for the power, and SCL, SDA for the I2C interface.

  Vcc (Vout)
  SDA (p9)
  SCL (p10)
  GND

• As before, mbed keeps I2C simple
  – http://mbed.org/handbook/I2C
  – http://mbed.org/cookbook/TMP102-Temperature-Sensor
Challenge: Interfacing with sensors

- Using the Cookbook as a resource, write a program that turns LED1 on at 26°C, LED2 at 27°C, LED3 and 28°C and LED4 at 29°C.
Lab 4
Rapid Prototyping: Output device, Text LCD

Hello World
Example: Output device, Text LCD

- It is not uncommon for devices that are embedded to have some form of user interface, or display output.

- This example shows how a Text LCD can be connected to mbed and be driven simply from software.
Connecting up the TextLCD

- Text LCD modules have almost standardised, although they still have their quirks.

- Six wires and a resistor for contrast
- As before, mbed keeps it simple
  - Standard C/C++ interface via printf
  - http://mbed.org/cookbook/Text-LCD

http://mbed.org | Rapid Prototyping for Microcontrollers
Challenge: Digital Thermometer

- Using the cookbook TextLCD page and the temperature sensor page, make a thermometer that displays the current temperature.

- If you have time, you could also add Min/Max to the display too
Lab 5
Rapid Prototyping: Data Logging

mbed
Hello World
Example : Data Logging

• Applications often include data logging capabilities, and access to the data often involves bespoke software and interface cables.

• This example shows how standard methods and interfaces can be used to display, save and retrieve data from an application.

• For the purposes of the experiment, we will be displaying and logging noise from an unconnected ADC. Touching the pin will influence the noise, it is a demonstration, imagine it is real data!
Example: See the data

- The USB connection to mbed can also be used to provide a serial port
- Windows requires a driver, Linux and Mac “just work”
- http://mbed.org/handbook/SerialPC
- Standard C functions, printf and scanf
- This example displays 100 samples to a terminal application
Example: Data Logging

- The mbed Flash disk is accessible from user code using the LocalFilesystem object
- Standard C file handling techniques apply
- fscanf for runtime configuration
- fprintf for data logging purposes
- This example logs 100 samples to a CSV file
Data quickly visible to a PC

While the program executes the flash drive disappears from the PC, and returns when the file is closed

Logging to a CSV file means Excel can open the file and interpret, manipulate or plot the data.

http://mbed.org | Rapid Prototyping for Microcontrollers
Extend it to store lots of data

• Perhaps a final system might want to store lots of data
  – SD cards are ideal, ubiquitous and recognisable by everyone

  GND
  MISO – p6
  SCL – p7
  Vcc
  MOSI – p5
  nCS – p8

• Hardware for an SD Card is minimal
  – SPI Port connection using simple breakout

• As before, mbed keeps it simple

http://mbed.org | Rapid Prototyping for Microcontrollers
Extend it to store lots of data

- Import the SDFileSystem Library into the project
- Include the SDFileSystem header
- Swap LocalFileSystem for SDFileSystem
- Everything else remains the same
What about a USB drive?

- USB Host hardware is minimal; a USB A connector

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>Red</td>
<td>+5V</td>
</tr>
<tr>
<td>2</td>
<td>D-</td>
<td>White</td>
<td>Data -</td>
</tr>
<tr>
<td>3</td>
<td>D+</td>
<td>Green</td>
<td>Data +</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Black</td>
<td>Ground</td>
</tr>
</tbody>
</table>
What about a USB drive?

- On your project, right click -> Import Library -> MSCFileSystem
  
  - Add #include for MSCFileSystem
  
  - Call it “fs”, as before
  
  - The change in storage medium is transparent to the application

---

http://mbed.org | Rapid Prototyping for Microcontrollers
Challenge: Data Logging

• Use all you have learnt to build a digital thermometer that also data logs to a USB flash disk.

• Use a .csv file so that the file can be opened in Microsoft Excel, and a graph drawn.
mbed
Hello World

Summary

http://mbed.org | Rapid Prototyping for Microcontrollers
Summary

• There is huge opportunity for microcontroller applications
  – A major barrier to adoption is simple experimentation

• mbed helps with getting started and rapid prototyping
  – Fast turnaround of experiments and prototyping new ideas
  – Try out new technology and new ideas

• Makes the technology very accessible
  – Demo showed a start to finish prototyping example
  – From getting a user started to enabling an application experiment

• Use at as a tool when you need to experiment!
Summary

• A solution focused on prototyping has a broad appeal

• Engineers new to embedded applications
  – Enables experimentation and testing product ideas for the first time
  – Create designs where electronics and MCUs are not the focus

• Experienced engineers
  – Provides a way to be more productive in the proof-of-concept stages
  – Introduce 32 bit microcontroller technology to existing designs

• Marketing, distributors and application engineers
  – Provides a consistent platform for demonstration, evaluation, support
  – Make promotion of MCUs more effective and efficient