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Hello World!

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

- 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: SMS Alerts
  - Lab 6: Mobile data with websockets
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Introduction to mbed
What’s happening in Microcontrollers?

• Microcontrollers are getting cheap
  – 32-bit ARM Cortex-M3 Microcontrollers @ $1
  – 32-bit ARM Cortex-M0+ Microcontrollers @ $0.50

• 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

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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 existing professional tools
  – Replace development or evaluation boards

Proof of Concept  Specification  Implementation

http://mbed.org | Rapid Prototyping for Microcontrollers
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
Dedicated Developer Web Platform

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

Welcome to mbed!

mbed is a tool for Rapid Prototyping with Microcontrollers. Microcontrollers are getting cheaper, more powerful and more flexible, but there remains a barrier to a host of new applications. Someone has to build the first prototypes! With mbed, we've focused on getting you there as quickly as possible.

Check out the video to see how you get started.

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!

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

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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!
Over to you...

http://mbed.org/cookbook/SprintUSBModem

This presentation and the rest of the notes are published as a PDF
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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 using and Analog input.
What IO is there?
mbed application board

1. 128x32 Graphics LCD
2. 5 way joystick
3. 2 x Potentiometers
4. 3.5mm Audio jack (Analog Out)
5. Speaker, PWM Connected
6. 3 Axis +/- 1.5g Accelerometer
7. 3.5mm Audio jack (Analog In)
8. 2 x Servo motor headers
9. RGB LED, PWM connected
10. USB-B Connector
11. Temperature sensor
12. Socket for Xbee (Zigbee) or RN-XV (Wifi)
13. USB-A Connector
14. RJ45 Ethernet connector
15. 1.3mm DC Jack input

http://mbed.org/cookbook/mbed-application-board
The AnalogIn object returns a normalised float between 0.0 (0.0v) and 1.0 (3.3v)

Pot1 is wired between GND (0v) and Vout (3.3v), and is connected to pin “p19” – an AnalogIn
Challenge: DigitalOut and Analog Input

• Write a program to give the LED in the first blinky program a delay of 0.1-1.1 seconds.

```cpp
#include "mbed.h"

DigitalOut myled(LED1);
AnalogIn pot(p19);

int main()
{
    while(1)
    {
        myled = !myled;
        wait(0.1 + pot.read());
    }
}
```

• 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

• Hint: Look at BusOut in the mbed Handbook!
Lab 3
Rapid Prototyping: Interfacing a sensor

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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 show how to implement a simple temperature sensor.

• The sensor in question is the LM75B which has a digital interface using the I2C bus.
Connecting a Sensor

- mbed keeps I2C simple, and a library and example exists
  - I2C handbook page - [http://mbed.org/handbook/I2C](http://mbed.org/handbook/I2C)
  - Cookbook - [http://mbed.org/cookbook/LM75B-Temperature-Sensor](http://mbed.org/cookbook/LM75B-Temperature-Sensor)

```cpp
#include "mbed.h"
#include "LM75B.h"

LM75B temp(p28,p27,0x90);

int main() {
    while(1) {
        printf("Temperature : %f\n", temp.read());
        wait(5);
    }
}
```
Challenge: Interfacing with sensors

• Write a program that turns LED1 on at 26°C, LED2 at 27°C, LED3 and 28°C and LED4 at 29°C.

• As an extended challenge, add Min/Max recordings to the program.
Lab 4
Rapid Prototyping: Output device, Text LCD
Output device, LCD

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

- This example shows an LCD connected to mbed and be driven simply from software.
Connecting up the TextLCD

- The LCD module has an SPI interface and a few digital outputs for reset, chips select and so on

- mbed keeps it simple
  - Standard C/C++ interface via printf
Challenge: Digital Thermometer

- Make a digital thermometer that displays the current temperature.

- If you have time, you could also add Min/Max to the display too

Lab 5
Rapid Prototyping: SMS alerts
SMS Alerts

• Some applications need to include an element of communication

• Taking the previous example of registering Min/Max temperatures, it may be desirable to communicate if limits are exceeded

• This example shows how the SprintUSBModem can be used to achieve mobile communication,
Hardware

• Simple hardware:
  – mbed NXP LPC1768 microcontroller
  – mbed application board
  – Sprint Mobile Broadband
  – DC adaptor
Example Program : SMS Send

• An example program of how to send SMS messages using the USB Modem can be found here

http://mbed.org/users/donatien/code/SprintUSBModemSMSTest/

• Experiments :
  – Use the example program to send your self a message
  – Using “ssprintf” send yourself a over temperature alert message
Challenge: SMS Receive

Once you have successfully sent SMS messages to your cell, try this:

Challenge

- Set the minimum and maximum alert points by SMS
  - Receive a reply message from your cell back to the mbed
  - Use "sscanf" to retrieve the new minimum and maximum values for your thermometer
  - Trigger alert SMS messages when these new limits are exceeded
  - Include the temperature reading in the alert message
Lab 6
Rapid Prototyping: Mobile data logging

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Mobile data logging

• This example shows how the Sprint Mobile Broadband can be used to achieve remote data logging, where the data is sent live to online storage.

• The driver is now providing a socket interface over which various protocol APIs and. For this example, we are using HTML5 web sockets.

• Take 5 minutes to familiarise yourself with web sockets:
  – [http://mbed.org/cookbook/Websockets](http://mbed.org/cookbook/Websockets)
Websocket server channels

The mbed.org websocket uses “channels”, with “demo” as the default. To avoid conflict during a workshop, create your own channel by substituting “demo” with your own channel name.

In mbed code:

```c
Websocket ws("ws://sockets.mbed.org:443/ws/demo/rw");
Becomes
Websocket ws("ws://sockets.mbed.org:443/ws/<your_channel>/rw");
```

In browser URLs:

```
http://sockets.mbed.org/demo/viewer
```

becomes

```
http://sockets.mbed.org/<your_channel>/viewer
```
Hardware

• Simple hardware :
  – mbed NXP LPC1768 microcontroller
  – mbed application board
  – Consumer USB Modem
  – DC adaptor
**HTML5 and Websockets**

- New feature of HTML5 (RFC 6455) providing:
  - Full-duplex communication
  - Over a single TCP socket
  - Standard and secure connections (ws:// and wss://)

- Motivation:
  - Replace existing polling techniques (AJAX) used in modern websites
  - Provide a two-way communication without multiple HTTP connections
  - Enable new classes of application

- Other notable HTML5 features:
  - HTML5 Canvas Element – For dynamic, scriptable 2D rendering
Example Program: Web sockets

• An example program of how to send the current temperature as a web socket message to the mbed web socket server using the Sprint USB Modem can be found here

http://mbed.org/users/chris/code/SprintUSBModemWebsocketTest-Temp/

See the output here:

http://sockets.mbed.org/demo/viewer

Experiments:

– Trigger a web socket message using navigation switch
Challenge: Web sockets

- The previous example was write-only (“wo”) and sent data to the socket server.

- Try making a connection that is read-only “ro”
  - To see how to receive web socket messages refer to: [http://mbed.org/users/donatien/code/SprintUSBModemWebsocketTest/](http://mbed.org/users/donatien/code/SprintUSBModemWebsocketTest/)
  - Display received messages on the LCD, for examples see: [http://mbed.org/cookbook/mbed-application-board](http://mbed.org/cookbook/mbed-application-board)
  - To send messages, use the “sender” [http://sockets.mbed.org/demo/sender](http://sockets.mbed.org/demo/sender)

- If you get stuck... But try to do it yourself first!
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
Q&A