Embedded Systems
Lecture 1: Introduction

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Overview

• Definitions, Motivation

• Examples of Embedded Systems

• Characteristics of Embedded Systems

• Course Overview

• Coursework
Definition of an Embedded System

- “Embedded Systems are information processing systems embedded into a larger product” (Peter Marwedel, TU Dortmund)

- “Embedded software is software integrated with physical processes. The technical problem is managing time and concurrency in computational systems.” (Edward Lee, Berkeley)

- “Cyber-Physical (cy-phy) Systems (CPS) are integrations of computation with physical processes” (Edward Lee, Berkeley)

- Cyber-physical system (CPS) = Embedded System (ES) + physical environment
Example of an Embedded System

- Automotive electronics
  - ABS: Anti-lock braking systems
  - ESP: Electronic stability control
  - Airbags
  - Efficient automatic gearboxes
  - Theft prevention with smart keys
  - Blind-angle alert systems
  - In-car entertainment systems
  - ... etc ...

- Multiple networks
- Multiple networked processors
Another Example

- Avionics
  - Flight control systems,
  - anti-collision systems,
  - pilot information systems,
  - power supply system,
  - flap control system,
  - entertainment system,
  - …

Dependability is of utmost importance.
Motivation for Studying Embedded Systems

• Trend in Information Processing Systems towards
  - Ubiquitous computing, Pervasive computing, Ambient intelligence
  - Post-PC era

• Requires holistic approach involving embedded software, embedded hardware and physical environment

• Additional constraints and challenges: Power/Energy, Cost, Dependability, Real-Time Processing, ...

• Underrepresented in teaching
Importance of Embedded Systems

• $6bn embedded processors market in 2012, 12-15% growth in the next two years

• 49.7% of Americans own smartphones [www.itfacts.biz, March 31, 2012]

• Average car has about 15 microprocessors in it. S-class has 63 microprocessors; a 1999 BMW 7-series has 65 [Microprocessor Report 2009]

• Average middle-class household has about 40 to 50 microprocessors in it [Microprocessor Report 2009]

• ..., the market for remote home health monitoring is expected to generate $225 mln revenue in 2011, up from less than $70 mln in 2006, according to Parks Associates. [www.itfacts.biz, Sep. 4th, 2007]
Embedded Hardware

• **Domain/application-specific**: Optimised for one fixed domain/application

• **Energy-efficiency** often more important than raw performance, especially for battery operated devices

• **Power constraints**: Cooling, power supply, ...

• **Cost**: Low cost for large volume device vs Non-recurring engineering cost

• **Programmability**: ASIC (no flexibility), ASIP, CPU, FPGA (lots of flexibility)

• **Design Complexity**: Composed of individual building blocks (IP blocks)
Example

TI OMAP5430 SoC

Dynamic memory manager

L2 cache

ARM Cortex-M4

ARM Cortex-A15 MCore (up to 2 GHz)

POWERVR SGX544 MPx 3D graphics

C64x DSP

IVA-HD video accelerator

Image signal processor

L3 Network-on-chip interconnect

Timers, Int Controller, Mailboxes, System DMA

Boot/Secure ROM, L3 RAM

Audio processor

M-Shield system security technology: SHA-1/SHA-2/MD5, DES/3DES, RC4, AES, PKA, secure WDT, keys, crypto DMA

Multi-pipe display sub-system (DSS)

L4 peripherals

Debug & trace

UART, GPIO, Keypad, PC/SPI

HDMI 1.4a

Emulator pod

Trace analyzer

Fast IrDA

GPIO, Keypad

Touch screen controller

HDMI 1.4a

Up to four displays

3D HDTV

2x MIPI HSI

MIPI LLI

TI C2C

USB/HSIC

UART/SPI

SDIO

McbSP

PC/SPI

SDIO

UART

McbSP

Main battery

Power Monitor

Clocks

Serial devices

HDO/1-Wire

REF/CLK

(4) UARTs

TWL

Power

Monitor

WiLink wireless connectivity

3G/4G modem

USB SS/HS

host/target

USB 3.0 OTG

3x USB 2.0 host

(ULPI/TLI/HSIC)

MIPI LLI/ UniPort™-M

MIPI CSI-3

3x MIPI CSI-2 + CPI

Camera control

DIG MIC

TWL6040

Audio

Headset

Speakers

Vibrators

Amplifiers

HF speakers

Handset microphone

32 kHz Crystal

In/Out

LCD

PDM

SLIMbus®

McbSP

MIPI DSI

MIPI DSI

MIPI DBI-B/DPI

LCD

Up to four displays

3D HDTV

L2 cache

ARM Cortex-M4

ARM Cortex-A15 MCore (up to 2 GHz)

PowerVR SGX544 MPx 3D graphics

C64x DSP

IVA-HD video accelerator

Image signal processor

L3 Network-on-chip interconnect

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Up to four displays

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2x MIPI HSI

MIPI LLI

TI C2C

USB/HSIC

UART/SPI

SDIO

McbSP

PC/SPI

SDIO

UART

McbSP

Main battery

Power Monitor

Clocks

Serial devices

HDO/1-Wire

REF/CLK

(4) UARTs

TWL

Power

Monitor

WiLink wireless connectivity

3G/4G modem
Another Example
Embedded Software

- **Real-time:** Timing constraints set by physical environment
- **Reactive:** Response to physical environment
- **Concurrency:** Physical environment is not sequential
- **Dependability:** Impact on physical environment, safety-critical
- **Reliability:** Fixing bugs in the field may be costly/impossible
- **Efficiency:** Manual optimisation required
- **(Lack of) Abstraction:** Exposure of underlying hardware to the programmer
Preliminary Course Overview

1. Introduction
2. Interfacing with the Environment
3. Coursework Session
4. Models of Computation 1 & 2
5. Imperative Programming Languages
6. Embedded Hardware
7. Power/Energy/Faults
8. Scheduling Theory
9. Real-Time Operating Systems
10. Guest Lecture
11. Worst-Case Execution Time
12. Mapping & Scheduling for Multi-Core 1
13. Mapping & Scheduling for Multi-Core 2
14. Mapping & Scheduling for Multi-Core 3
15. HW & SW Optimisations 1
16. HW & SW Optimisations 2
17. Dynamic Voltage Scaling/Dynamic Frequency Scaling
18. Revision
Coursework Overview

• Two parts of individual coursework

• Accompanied by lab sessions (and demonstrator support)

• Coursework 25% of total course mark

• 50/50 split of marks

• Networked home alarm system

• Freescale Kinetis K70 Tower Module (ARM Cortex-M4)
Textbook and Course Website

• Recommended textbook:
  Peter Marwedel
  “Embedded System Design”
  ISBN 13 978 94 007 0256 1

• Other textbooks:
  Alan Shaw, Real-Time Systems and Software, John Wiley & Sons

• Course website:
  www.inf.ed.ac.uk/teaching/courses/es
Summary

• Examples of Embedded Systems

• Embedded Hardware and Software

• Course Overview
Preview

• Next Lecture: Interfacing with the Environment

• Input (Sensors), Output (Actors)

• Analog-Digital Conversion, Digital-Analog Conversion
PhD in Pervasive Parallelism

http://pervasiveparallelism.inf.ed.ac.uk