Designing Embedded Systems

Jin-Soo Kim (jinsookim@skku.edu)
Computer Systems Laboratory
Sungkyunkwan University
http://csl.skku.edu
Basic Architectures
Control Unit

- Custom logic
- FPGAs (Field-Programmable Gate Arrays)
- Microcontrollers
- Microprocessors
- DSPs (Digital Signal Processors)
- ASIPs (Application Specific Instruction-set Processors)
- Multicore? (symmetric vs. asymmetric)
- Typical word size: 8/16/32-bit
Why Microprocessors?

▪ Microprocessors
  • ARM, MIPS, PowerPC, SuperH, Cell, Atom, ...
  • Mostly less than 1GHz

▪ Microprocessors are often very efficient:
  • Can use same logic to perform many different functions

▪ Microprocessors simplify the design of families of products
The Performance Paradox

- Microprocessors use much more logic to implement a function than does custom logic
- But microprocessors are often at least as fast:
  - Heavily pipelined
  - Large design teams
  - Aggressive VLSI technology, ...
Power

- Custom logic uses less power, but CPUs have advantages:
  - Modern microprocessors offer features to help control power consumption
  - Software design techniques can help reduce power consumption
- Heterogeneous systems
  - Some custom logic for well-defined functions, CPUs + software for everything else
RAM

- SRAM
  - Easier to integrate on the same chip as processor
- DRAM
  - SDRAM (Synchronous DRAM): SDR/DDR/DDR2/DDR3
  - Mobile SDR/DDR SDRAM
  - RDRAM (Rambus DRAM)
- NVRAM (Non-Volatile RAM)
- Future NVRAMs: PRAM, MRAM, FeRAM
- Cache memory
- SPM (Scratch Pad Memory)
ROM

- Mask-programmed
  - Connections programmed at fabrication
- OTP (One-time programmable) ROM
  - Connections programmed after manufacture by use
- EPROM (Erasable programmable ROM)
- EEPROM (Electrically erasable programmable ROM)
Flash Memory

- NOR Flash
- NAND Flash
- Fusion memory: OneNAND Flash
- e-MMC: MoviNAND, iNAND
- Cards (MMC, SD, CF, ...)

ICE3028: Embedded Systems Design (Spring 2011) – Jin-Soo Kim (jinsookim@scku.edu)
Interfacing

- ARM AMBA (Advanced Microcontroller Bus Architecture)
- ISA (Industry Standard Architecture)
- PCI (Peripheral Component Interconnect)
- I²C (Inter-IC) bus
- USB
Common Peripheral Devices

▪ Interrupt controller
▪ DMA controller
▪ Timer/Counter
▪ Real-time clock
▪ Watchdog timer
▪ UART (Universal Asynchronous Receiver Transmitter)
▪ IrDA (Infrared)
▪ Ethernet (wired/wireless)
▪ Bluetooth
Recent Trends

- Increasing computation demands
- Increasingly networked
- Increasing need for flexibility

- Getting complex
- Increasingly platform-based
  - Hardware architecture + associated software
Design Process
Design Methodologies

- A procedure for designing a system
- Understanding your methodology helps you ensure you didn’t skip anything
- Compilers, software engineering tools, computer-aided design (CAD) tools, etc., can be used to
  - Help automate methodology steps
  - Keep track of the methodology itself
Design Goals

- **Performance**
  - Overall speed
  - Deadlines
- **Functionality and user interface**
- **Manufacturing cost**
- **Power consumption**
- **Other requirements (physical size, etc.)**
Design Process

- Requirements
- Specification
- Architecture
- Component design
- System integration
Approaches

▪ **Top-down design**
  • Start from most abstract description
  • Work to most detailed

▪ **Bottom-up design**
  • Work from small components to big system

▪ **Real design uses both techniques**
GPS Moving Map (GPS-MM)

- Moving map obtains position from GPS, paints map from local database
Requirements (1)

▪ Plain language description of what the user wants and expects to get

▪ May be developed in several ways:
  • Talking directly to customers
  • Talking to marketing representatives
  • Providing prototypes to users for comment
Requirements (2)

- Functional requirements
  - Output as a function of input
- Non-functional requirements
  - Time required to compute output
  - Cost
  - Physical size and weight
  - Power consumption
  - Reliability, ...
GPS-MM Requirements (1)

▪ **Functionality**
  - For automotive use
  - Show major roads and landmarks

▪ **User interface**
  - At least 400x600 pixel screen
  - Three buttons max.
  - Pop-up menu

▪ **Cost**
  - Street price: around $100
GPS-MM Requirements (2)

- **Performance**
  - Map should scroll smoothly
  - No more than 1 sec power-up
  - Lock onto GPS within 15 seconds

- **Physical size/weight**
  - Should fit in hand

- **Power consumption**
  - Should run for 8 hours on four AA batteries
## GPS-MM Requirements (3)

<table>
<thead>
<tr>
<th>Name</th>
<th>GPS moving map</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>Consumer-grade moving map for driving use</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td>Power button, two control buttons</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td>Back-lit LCD display 400x600</td>
</tr>
<tr>
<td><strong>Functions</strong></td>
<td>Uses 5-receiver GPS system</td>
</tr>
<tr>
<td></td>
<td>Three user-selectable resolutions</td>
</tr>
<tr>
<td></td>
<td>Always displays current latitude and longitude</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Updates screen within 0.25 seconds upon movement</td>
</tr>
<tr>
<td><strong>Manufacturing cost</strong></td>
<td>$30</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>100mW</td>
</tr>
<tr>
<td><strong>Physical size and weight</strong></td>
<td>No more than 2” x 6”, 12 ounces</td>
</tr>
</tbody>
</table>
Specification

- A more precise description of the system
  - Should not imply a particular architecture
  - Provides input to the architecture design process
- May include functional and non-functional elements
- UML (Unified Modeling Language)
GPS-MM Specification

▪ Should include
  • What is received from GPS
  • Map data
  • User interface
  • Operations required to satisfy user requests
  • Background operations needed to keep the system running
Architecture Design

- What major components go satisfying the specification?
- Hardware components:
  - CPUs, peripherals, etc.
- Software components:
  - Major programs and their operations
- Must take into account functional and non-functional specifications
GPS-MM Block Diagram

- GPS receiver
- Search engine
- Renderer
- Display
- Database
- User interface
GPS-MM HW Architecture

display

frame buffer

CPU

GPS receiver

memory

panel I/O
GPS-MM SW Architecture

position ⟷ database search ⟷ renderer ⟷ pixels

user interface ⟷ timer
Component Design

- Hardware and software components
- Must spend time architecting the system before you start coding
- Some components are ready-made, some can be modified from existing designs, others must be designed from scratch
System Integration

- Put together the components
  - Many bugs appear only at this stage

- Have a plan for integrating components to uncover bugs quickly, test as much functionality as early as possible