Designing Embedded Systems

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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 1 GHz

- 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 user
- 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 2012) – Jin-Soo Kim (jinsookim@skku.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

- Requirements
- Specification
- Architecture
- Component design
- System integration
Solid State Drives (SSDs)
HDDs vs. SSDs (1)

2.5” HDD    Flash SSD
(101x70x9.3mm)

1.8” HDD    Flash SSD
(78.5x54x4.15mm)
## HDDs vs. SSDs (2)

<table>
<thead>
<tr>
<th>Feature</th>
<th>SSD (Samsung)</th>
<th>HDD (Seagate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>MMDOE56G5MXP (PM800)</td>
<td>ST9500420AS (Momentus 7200.4)</td>
</tr>
<tr>
<td>Capacity</td>
<td>256GB (16Gb MLC x 128, 8 channels)</td>
<td>500GB (2 Discs, 4 Heads, 7200RPM)</td>
</tr>
<tr>
<td>Form factor</td>
<td>2.5” Weight: 84g</td>
<td>2.5” Weight: 110g</td>
</tr>
<tr>
<td>Host interface</td>
<td>Serial ATA-2 (3.0 Gbps)</td>
<td>Serial ATA-2 (3.0 Gbps)</td>
</tr>
<tr>
<td></td>
<td>Host transfer rate: 300MB</td>
<td>Host transfer rate: 300MB</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Active: 0.26W</td>
<td>Active: 2.1W (Read), 2.2W (Write)</td>
</tr>
<tr>
<td></td>
<td>Idle/Standby/Sleep: 0.15W</td>
<td>Idle: 0.69W, Standby/Sleep: 0.2W</td>
</tr>
<tr>
<td>Performance</td>
<td>Sequential read: Up to 220 MB/s</td>
<td>Power-on to ready: 4.5 sec</td>
</tr>
<tr>
<td></td>
<td>Sequential write: Up to 185 MB/s</td>
<td>Average latency: 4.17 msec</td>
</tr>
<tr>
<td>Measured performance</td>
<td>Sequential read: 176.73 MB/s</td>
<td>Sequential read: 86.07 MB/s</td>
</tr>
<tr>
<td></td>
<td>Sequential write: 159.98 MB/s</td>
<td>Sequential write: 84.64 MB/s</td>
</tr>
<tr>
<td></td>
<td>Random read: 10.56 MB/s</td>
<td>Random read: 0.61 MB/s</td>
</tr>
<tr>
<td></td>
<td>Random write: 2.93 MB/s</td>
<td>Random write: 1.28 MB/s</td>
</tr>
<tr>
<td>Price</td>
<td>539,190 won</td>
<td>80,400 won</td>
</tr>
</tbody>
</table>


1$-per-GB?

Outlook

SSD Per-GB Cost to Fall Below $1 in Second Half of 2012 - Market Observers.

SSDs to Gain Considerable Market Share This Year, Says DRAMeXchange

[03/07/2012 08:53 PM]
by Anton Shilov

The $1-per-GB price has been for a long time considered as a holy grail for solid-state drives as it is widely believed that at such price points SSDs will start to be adopted by mainstream users.

According to DRAMeXchange, a division of TrendForce market research firm, the price per GB will be even lower than $1 in the second half of the year, which will unleash growth potential for SSDs.

After SSDs based on NAND flash memory manufactured using the latest - 19nm, 20nm and similar - process technologies enter mass production in the second half of 2012, unit cost may fall below $1-per-GB, the pricing sweet spot the market has been anticipating. When this occurs, DRAMeXchange expects ultrabook/thin notebook makers will transition from adopting hybrid HDD solutions to pure SSD solutions, and mainstream capacity will increase to 128GB.

SSD Internals