

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, ...)

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

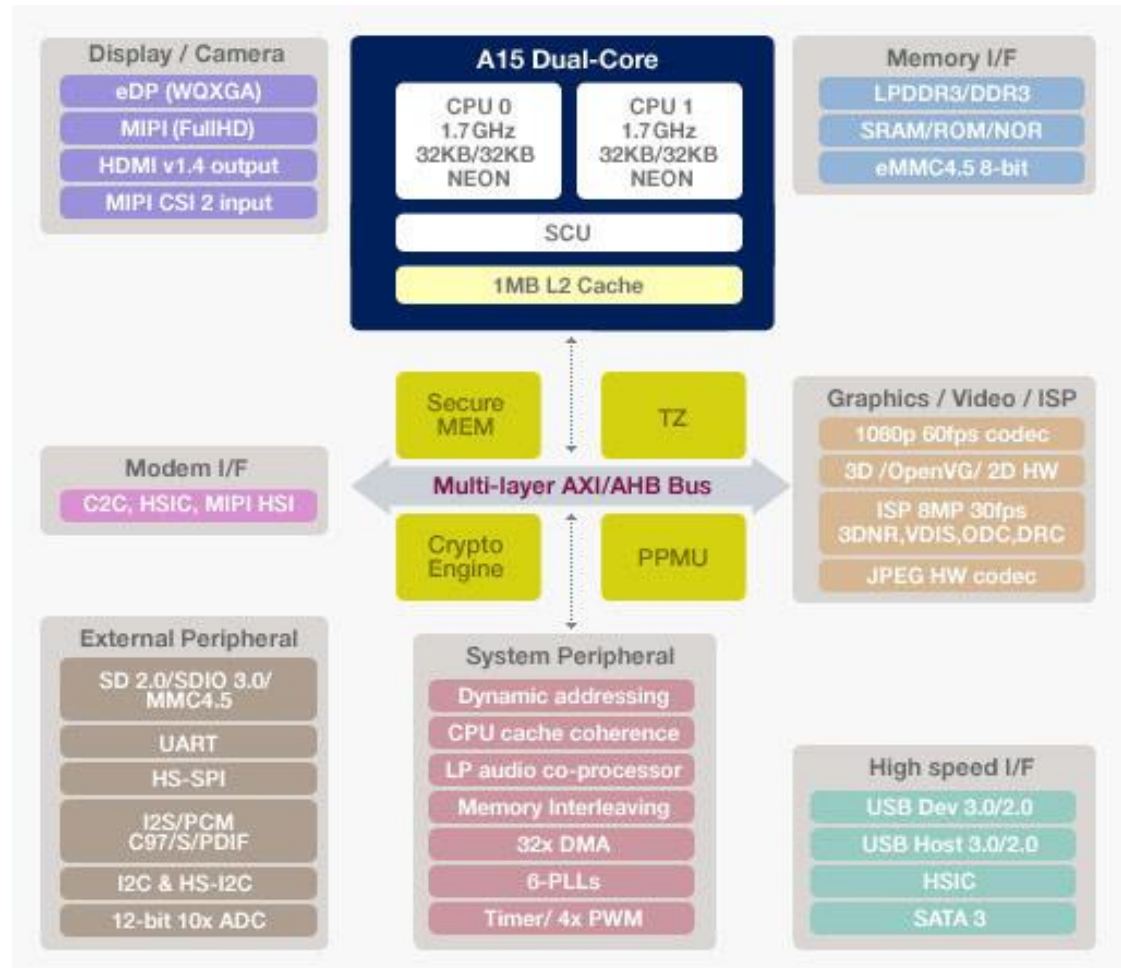
Recent Trends

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

- Getting complex
- Increasingly platform-based
 - Hardware architecture + associated software

SoC (System-On-a-Chip)

Samsung
Exynos 5
Dual



Design Process

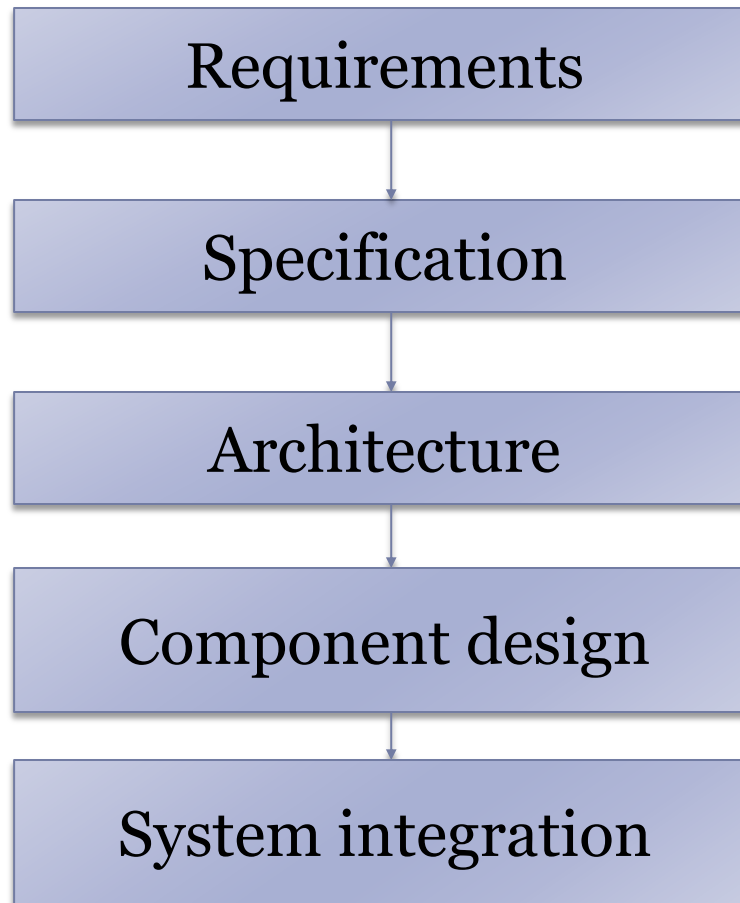
Design Methodologies

- 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

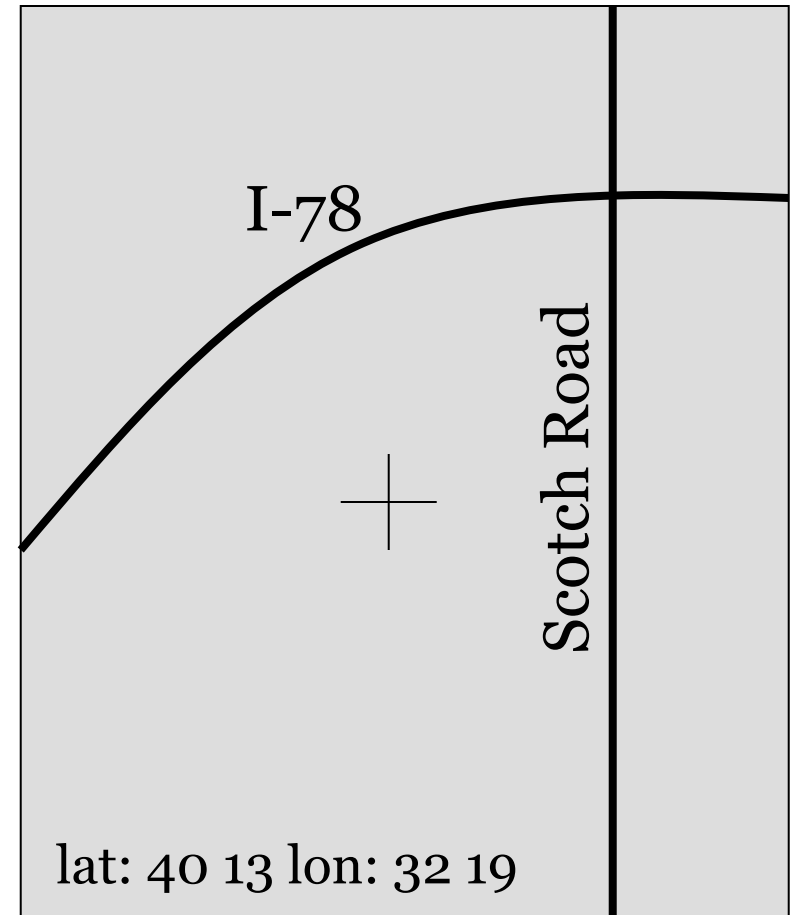


Approaches

- 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)

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

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)

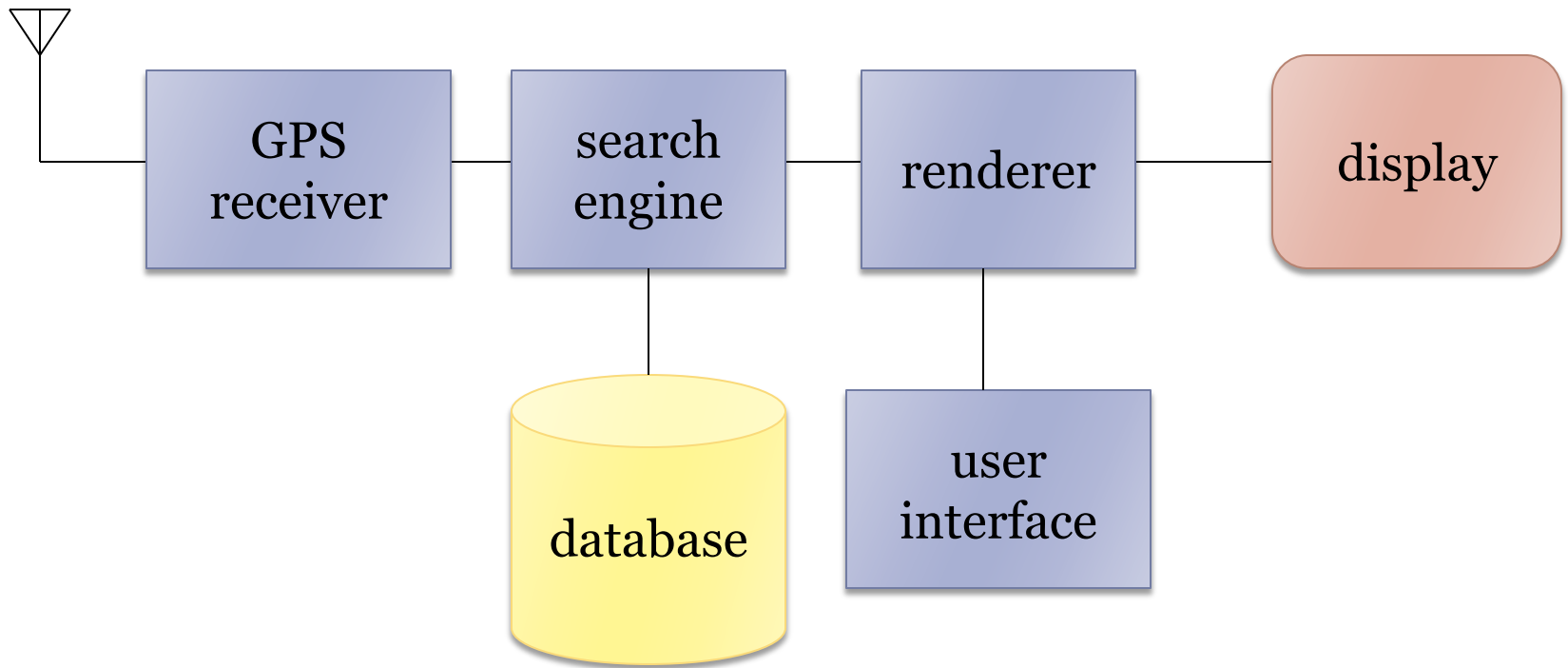
GPS-MM Specification

- **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

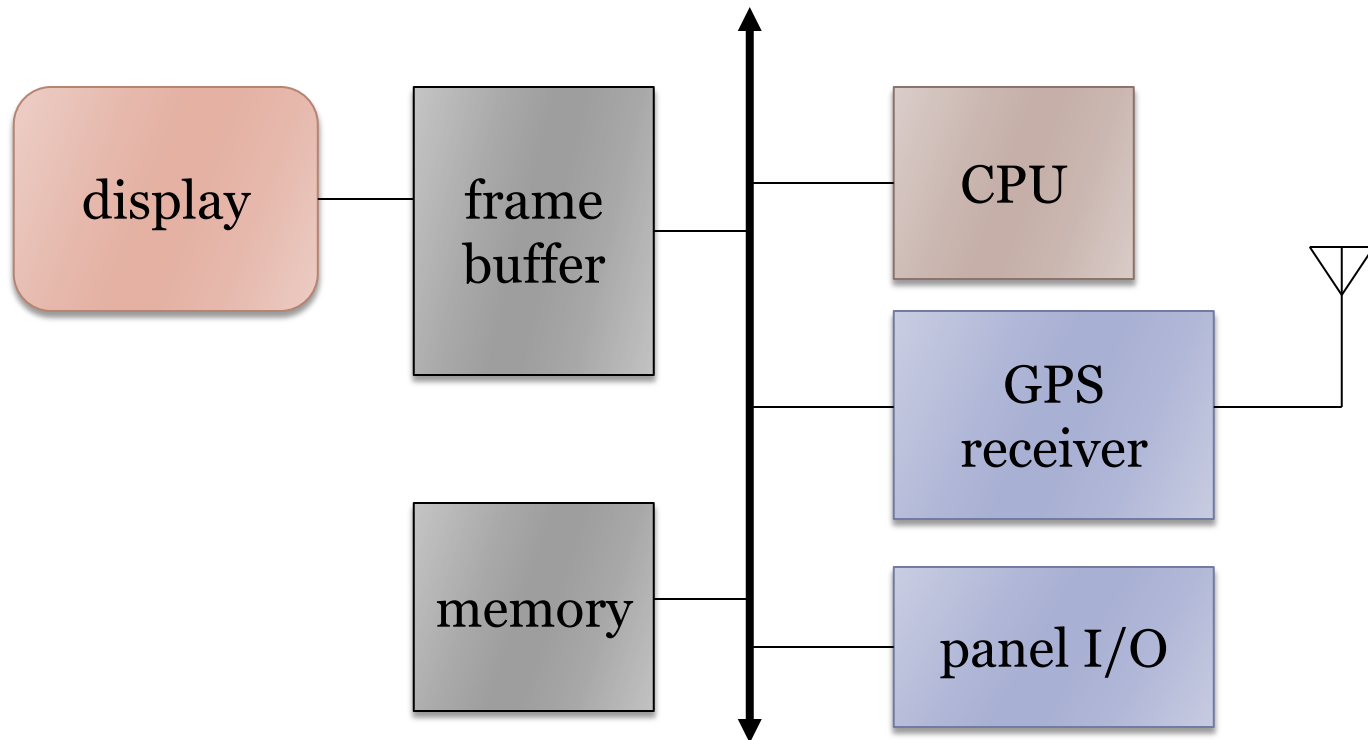
Architecture Design

- 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

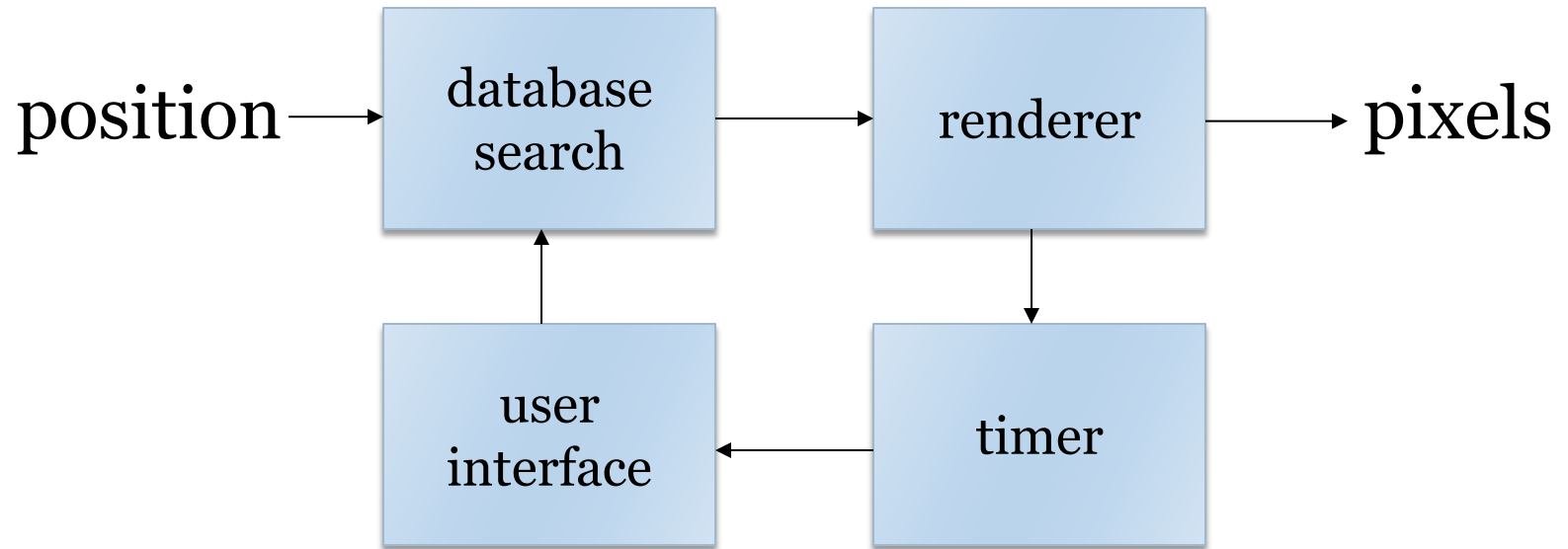
GPS-MM Block Diagram



GPS-MM HW Architecture



GPS-MM SW Architecture



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