مدينة زويل للعلوم والتكنولوجيا
Zewail City of Science and Technology
COMMUNICATION AND INFORMATION ENGINEERING

CIE 314
Embedded Systems Fundamentals

Lecture #2
Design Constraints

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Agenda

The Life Cycle of Embedded Designs

Design Constraints

- Functionality - Cost
- Performance - Power and Energy
- Time-to-Market - Reliability and Maintainability

1.4 THE LIFE CYCLE OF EMBEDDED DESIGNS

- Birth
- Design
- Growth
- Maturity
- Decline

EMBEDDED DESIGN LIFE CYCLE

- Birth
  - Need & opportunity
  - Specifications
- Design
  - Proof-of-concept
  - Manufacturing design
- Growth
  - Production & deployment
- Maturity
  - Maintenance & upgrade
- Decline
  - System disposal

Fig. 1.11: Life cycle of an embedded design

DESIGN ENDURANCE

- Embedded Design Goal
  - Design must successfully complete all pertinent stages
  - Not all designs go through all stages
- Plan for Each Stage
  - Designer's vision and planning needed for success
  - Good designs do not happen by chance

1.5 DESIGN CONSTRAINTS

- Functionality
- Cost
- Performance
- Power and Energy
- Time-to-Market
- Reliability and Maintainability

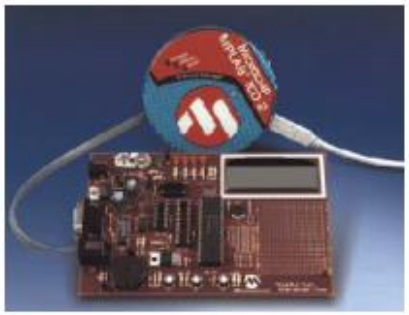
DESIGN CONSTRAINTS

- Functionality
  - System ability to perform the function it was designed for (REQ)
- Cost
  - Amount of resources needed to conceive, design, and produce an embedded system
- Performance
  - System ability to perform its function in time.
  - Affected by both HW & SW factors
- Size
  - Physical space taken by a system solution.
- Power and Energy
  - Energy required by a system to perform its function.
- Time to Market
  - The time it takes from system conception to deployment.
- Maintainability
  - System ability to be kept functional during its mature life.

FUNCTIONALITY (1/2)

- Functional verification is a difficult task
  - Can consume up to 70% of development time
- Verification Methods
  - Simulation Techniques
    - Behavioral (HDL-based)
    - Logic (Circuit Modeling)
    - Processor (Software)
  - JTAG Debugger
    - Hardware supported through dedicated ports
    - Used also for testing (boundary scan test)
    - Cost effective

MSP430 FET Tool
Courtesy of Texas Instruments Inc.



PIC In-circuit Debugger
Courtesy of Microchip Corporation

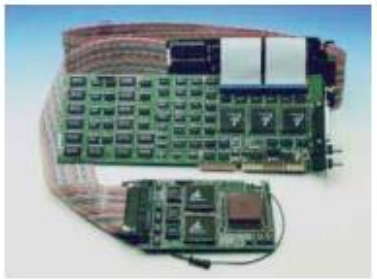
FUNCTIONALITY (2/2)

- In-Circuit Emulators
  - Replace MCU in target system
  - A powerful debugger
  - Expensive
- ROM Monitors
  - Monitor functions in ROM
  - Status sent via serial port

68HC11 In-circuit Emulator
Courtesy of Nohau Systems

8051 In-circuit Emulator
Courtesy of Signum Systems

ICE Test Pod
Courtesy of Signum Systems



8086 In-circuit Emulator
Courtesy of Nohau Systems

SYSTEM COST

- The cost of a given Volume (V) of units:

$$C_T = NRE + (RP \cdot V) \therefore$$

$$U_C = \frac{C_T}{V} = \frac{NRE}{V} + RP$$

- NRE = Non-Recurrent Engineering costs (Fixed)
  - Investment to complete all design aspects
  - Very large and independent of volume in CT
  - Include man-hours, infrastructure, and R&D
- RP = Recurrent Production costs (Variable)
  - Expenses in producing each unit of a given volume
  - Small but affected by V in CT
  - Include components, boards, packages, and testing

COTS-BASED NRE COSTS

- Commercial off-the-shelf parts-based design
  - Traditional methodology for Embedded Systems
  - Minimizes Hardware costs
  - Increases design & verification costs
- NREs in UC are diluted by a large production volume
- Balance between technology choice and production volume

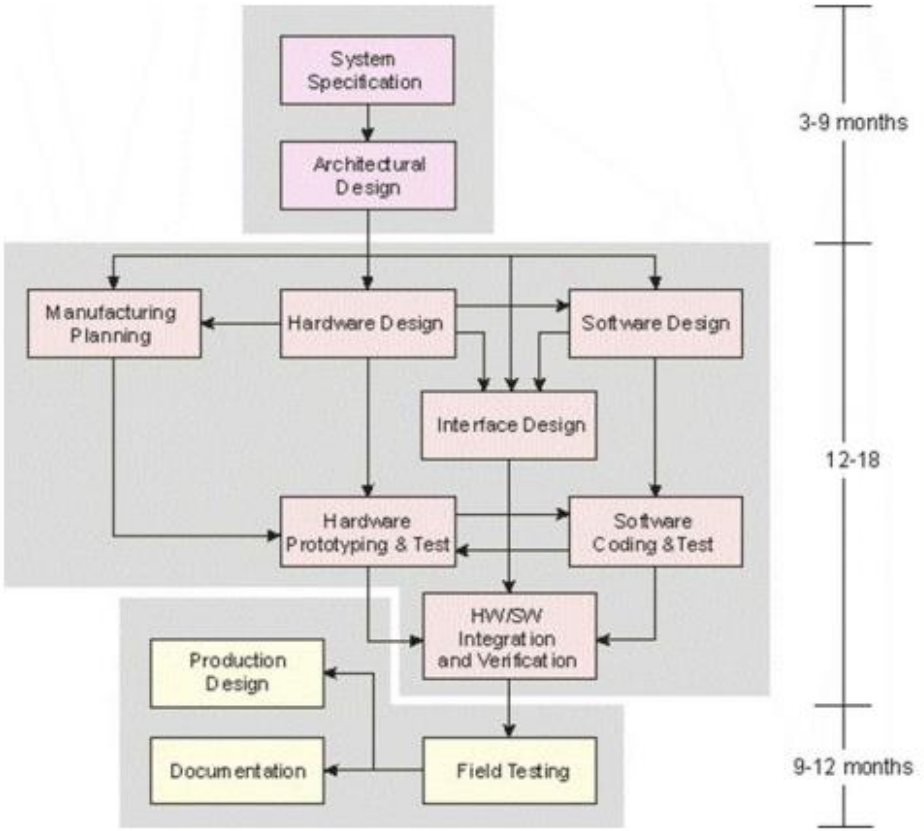


Fig. 1.12 Embedded systems design flow model based on COTS parts

PERFORMANCE: HW FACTORS

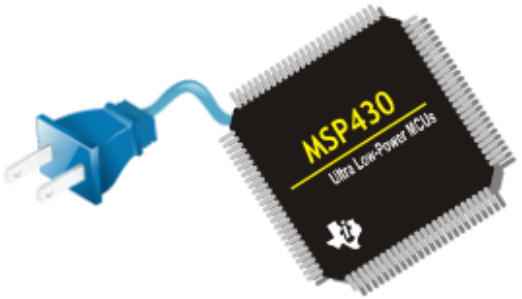
- Clock Frequency
  - System clock speed: not an absolute performance metric
- Architecture
  - Determines how clock cycles are used
- Component Speed
  - Response time and access time
- Handshaking
  - Signalization required to complete a transaction
- Low-power Modes
  - Wake-up times might affect application speed
- High speed is expensive!!!
  - Use it wisely

PERFORMANCE: SW FACTORS

- Algorithm Complexity
  - Steps and resources needed to complete a task
- Task Scheduling
  - Affects waiting time in multitasking system
- Inter-task Communication
  - Time taken by tasks to exchange information
- Level of Parallelism
  - Software usage of system hardware resources

POWER & ENERGY (1/2)

- Critical Parameter
  - A long chain of design events depend on it
- System reliability
  - Stress, noise, and heat
- Cooling Costs
  - High power = lot of heat to remove
- Power Supply Requirements
  - Larger batteries of power supply
- Size, Weight, and Form
  - Mechanical system parameters affected by heat density



POWER & ENERGY (2/2)

- Environmental Impact of Embedded Systems
  - Average individual uses 60 microprocessors per day
  - Household electronics accounts for 11% of all energy consumed in the USA
    - 147,000,000,000 KWh (147TWh) per year
  - Excludes digital TVs and large appliances
  - Excludes industry, schools, hospitals, etc
  - Trend continues to grow… Is there a limit?

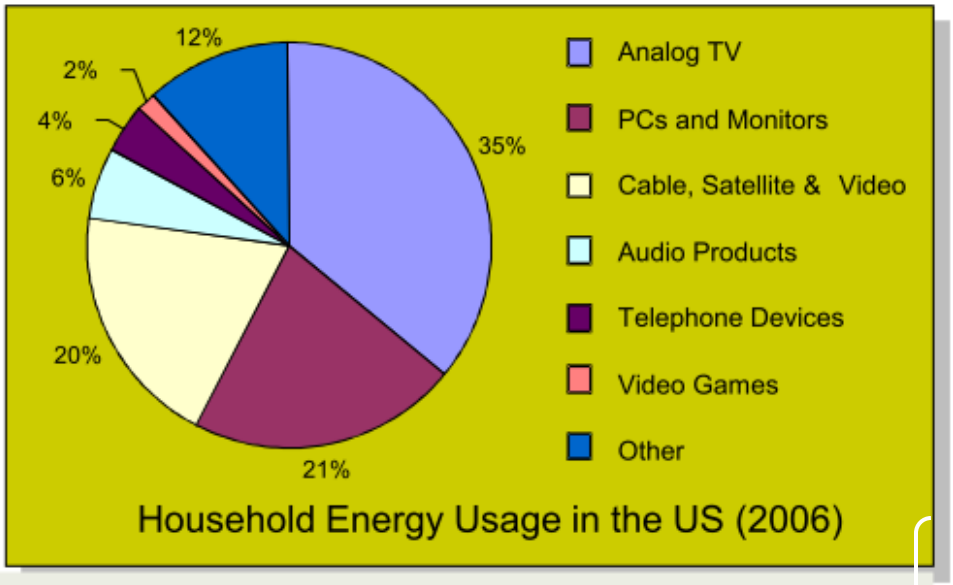


Fig. 1.13 Distribution of U.S. residential consumer electronics (CE) energy consumption in one year *(Source Consumer Electronics Association)*

TIPS FOR LOW-POWER DESIGNS

- Use low-power MCUs and Peripherals
  - Activate CPU standby and sleep modes
  - Let peripherals do the work while the CPU is off
- Stop the Energy Waste
  - Turn off unused peripherals
- Write power efficient code
  - Every wasted CPU cycle is energy that will never come back
- Use power management techniques
  - Power and clock gating plus efficient coding techniques

TIME-TO-MARKET (1/2)

- Critical Constraint for Applications with a Narrow Market Window (W)

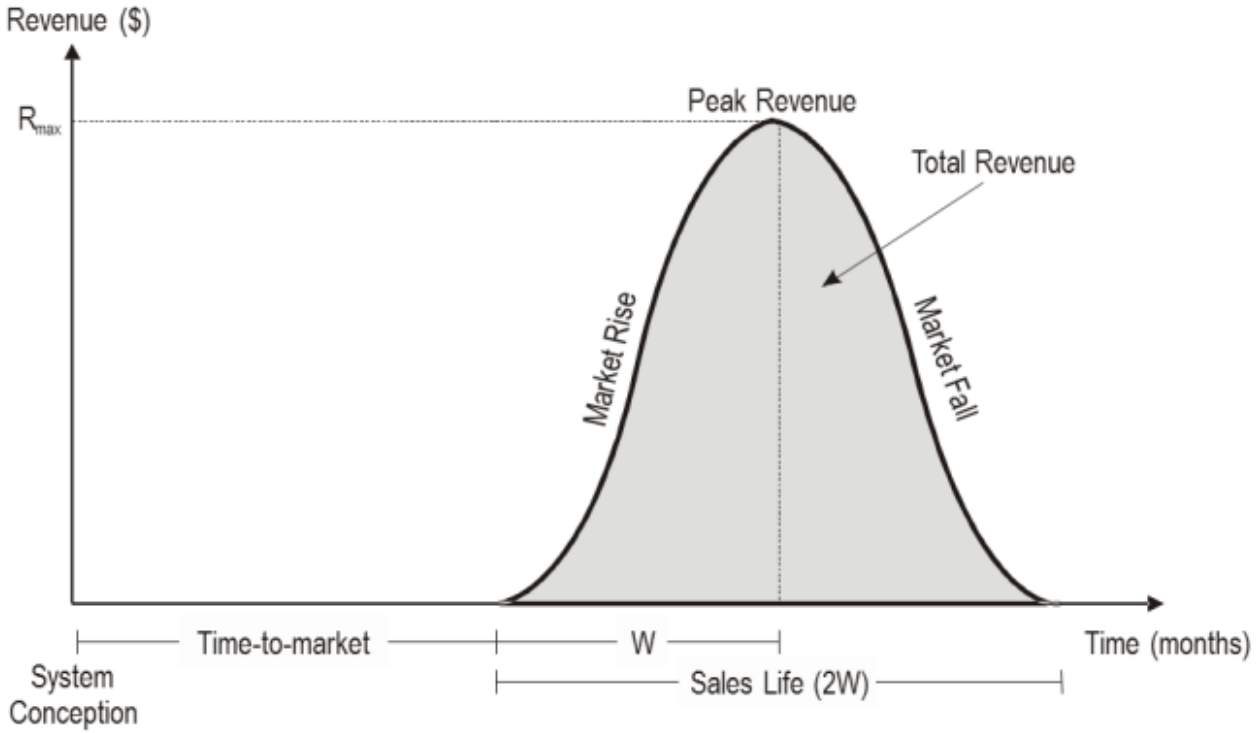
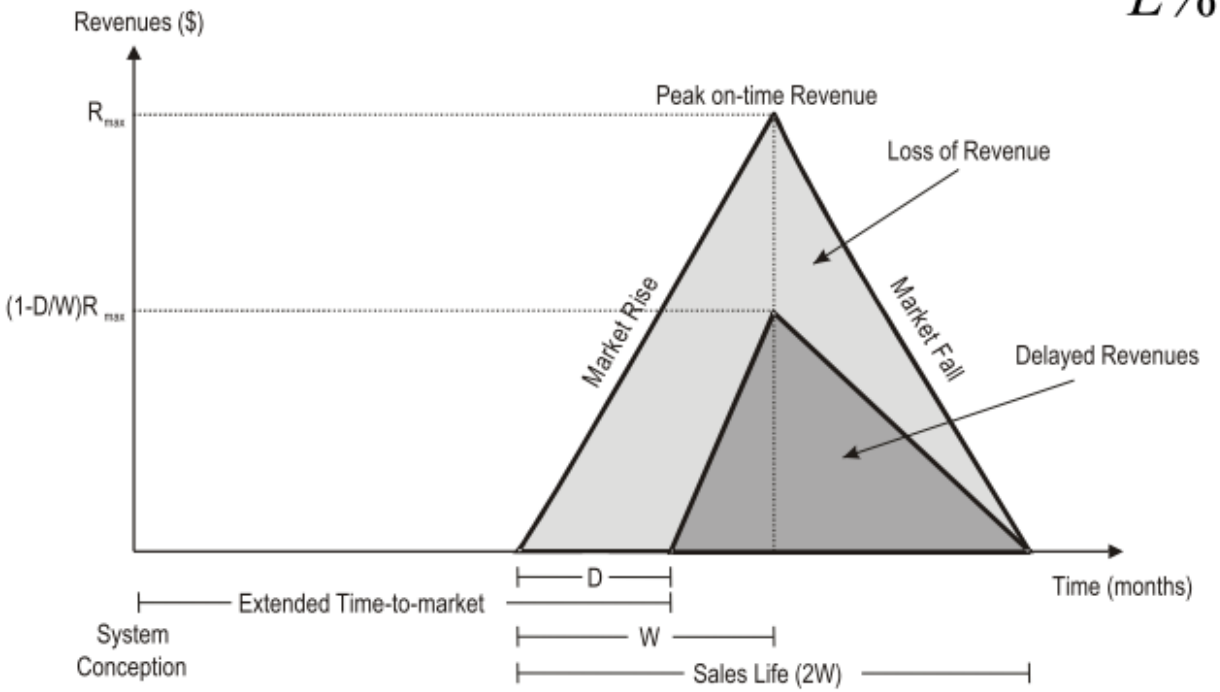


Fig. 1.14 Typical revenue-time curve for embedded products, denoting the time-to-market and market window

TIME-TO-MARKET (2/2)

- A Moderate Market Entry Delay Could Cause a Large Loss of Revenue

$$L\% = \frac{D(3W - D)}{2W^2} \times 100\%$$



Assume:

- 2W = 24 months
- D = 4 months

Estimated Revenue Loss:

- L% = 50%

Fig. 1.15 Linear revenue model with a delayed system deployment

MAINTAINABILITY

- Maintenance enables reliable system operation throughout entire useful life
- Relevance of maintenance depends on application
  - Expected lifespan
  - Application criticality
- Maintainability is a design requirement
  - Must be included among system specifications
- Must consider both aspects:
  - Hardware Maintenance
  - Software Maintenance

- Four maintenance dimensions
  - Corrective: Fixes faults
  - Adaptive: Copes with a changing environment
  - Perfective: Adds enhancements
  - Preventive: Anticipates events

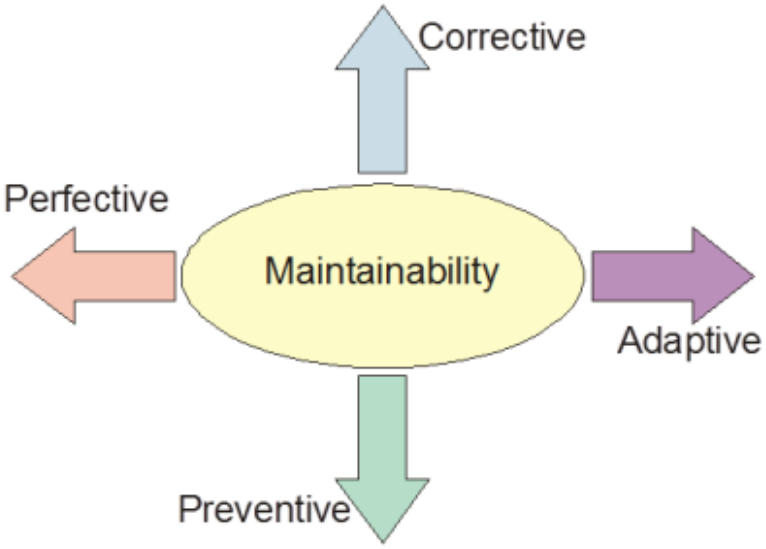


Fig. 1.16 The four actions supporting system maintainability

HARDWARE MAINTENANCE ISSUES

- Increased NREs
  - Design overhead to support HW maintenance
- Time-to-market Impact
  - Additional development time
- Increases Recurrent Cost
  - More components in system
- Component Obsolescence
  - Limit system useful life span

SOFTWARE MAINTENANCE ISSUES

- Hardware Constraints
  - Stringent HW constraints leave little room for support functions
- Cost of Verification
  - Undiscovered software bugs become maintenance headaches
- Inadequate Code Documentation
  - Meaningful and up-to-date
- Technology Changes
  - Compatibility with tool newer versions
- Ripple Effect of Changes
  - Identifying effect down the code
- Qualified Personnel
  - Everybody wants to design

Assignment#1

- Choose any application around you that contains an embedded system, then answer the following:
  1. Why did you consider it as an embedded system?
  2. Mention its main hardware and input output components.
  3. Analyze its software components and mention its main services/resources and its main tasks.
  4. State the class of this embedded systems application and why did you classify it in this category/
  5. State the main design constraints that is applied to that application.

- Deadline:
  - due next Wednesday, 22 Feb.

- For more details, refer to:
  - Chapter 1 at **Introduction to Embedded Systems,** Springer 2014 by Manuel Jiménez et al.

- The lecture is available online at:
  - *http://bu.edu.eg/staff/ahmad.elbanna-courses/14130*

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