



EMBEDDED SYSTEM DESIGN

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AGENDA

- Embedded System –
 - Introduction, components, classification
 - Hardware, software, applications
 - Market
 - Designing Embedded System

EMBEDDED SYSTEMS: AN INTRODUCTION

- What is an embedded system?
 - More than just a computer
- What makes embedded systems different?
 - Real-time operation
 - Many sets of constraints on designs
 - size
 - cost
 - time
 - reliability
 - safety
 - energy
 - security
- What embedded system designers need to know?
 - The "big" picture
 - Skills required to be an "expert" in this area

WHAT IS AN EMBEDDED SYSTEM?

- Computer purchased as part of some *other* piece of equipment
 - Typically dedicated software (may be user customizable)
 - Often replaces previously electromechanical components
 - Often no “real” keyboard
 - Often limited display or no general purpose display device
- But, every system is unique there are always exceptions

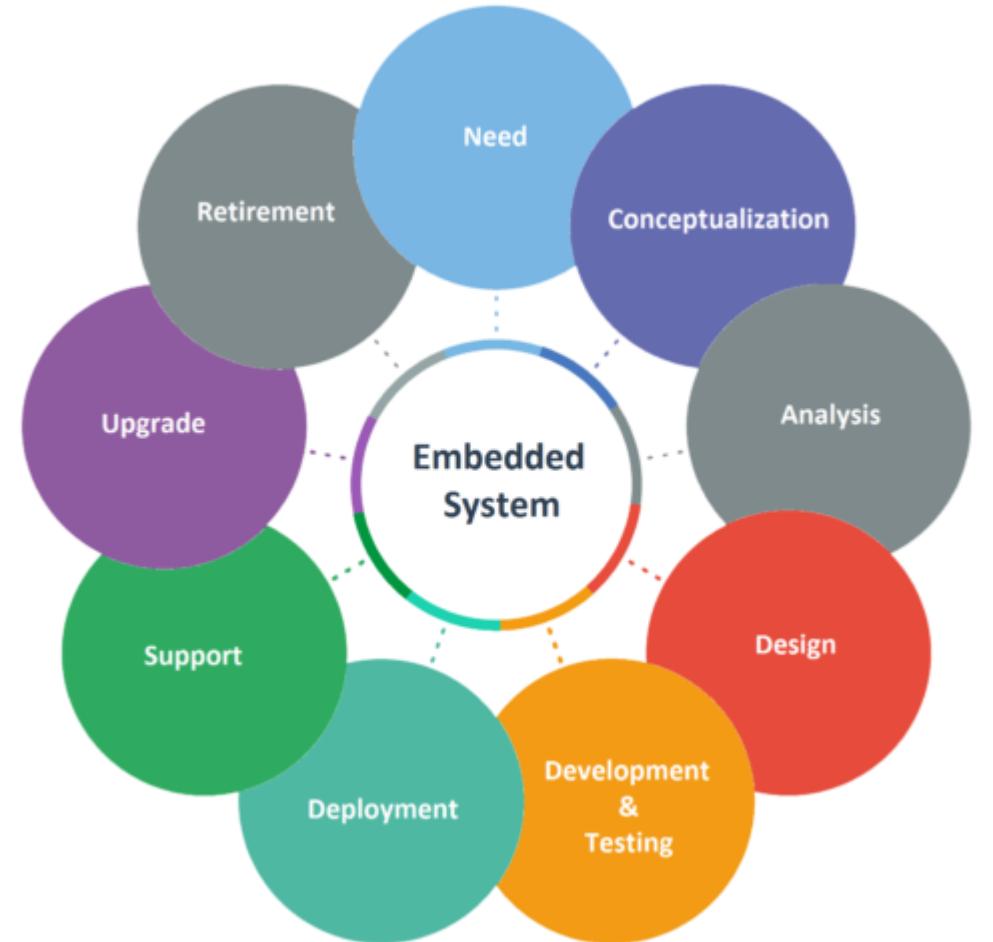


SIMPLE PRODUCT VS EMBEDDED PRODUCT

A typical simple product contains 5 phases-

- Requirement analysis
- Design
- Development and test
- Deployment
- Maintenance

Embedded product life cycle model



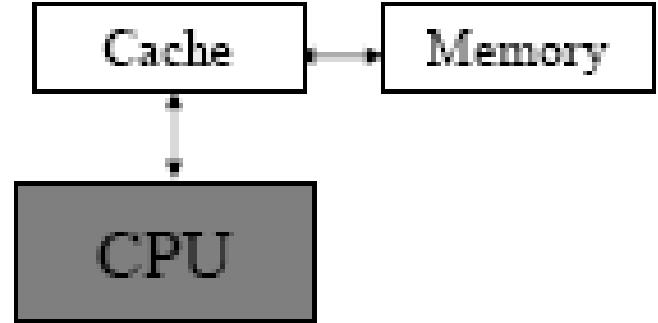
CPU: AN ALL-TOO-COMMON VIEW OF COMPUTING

- Measured by:
 - Performance



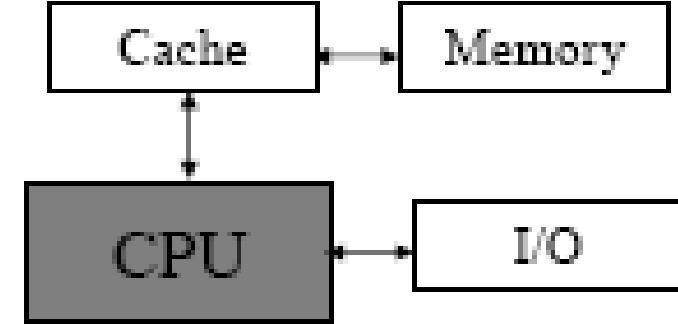
AN ADVANCED COMPUTER ENGINEER'S VIEW

- Measured by: Performance
 - Compilers matter too...



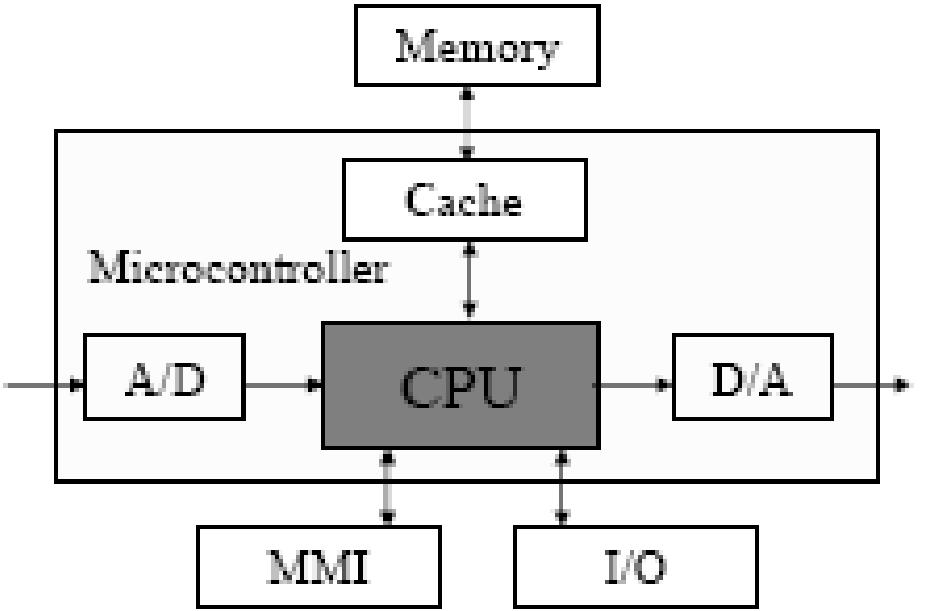
AN ENLIGHTENED COMPUTER ENGINEER'S VIEW

- Measured by: Performance, Cost
Compilers & OS matters



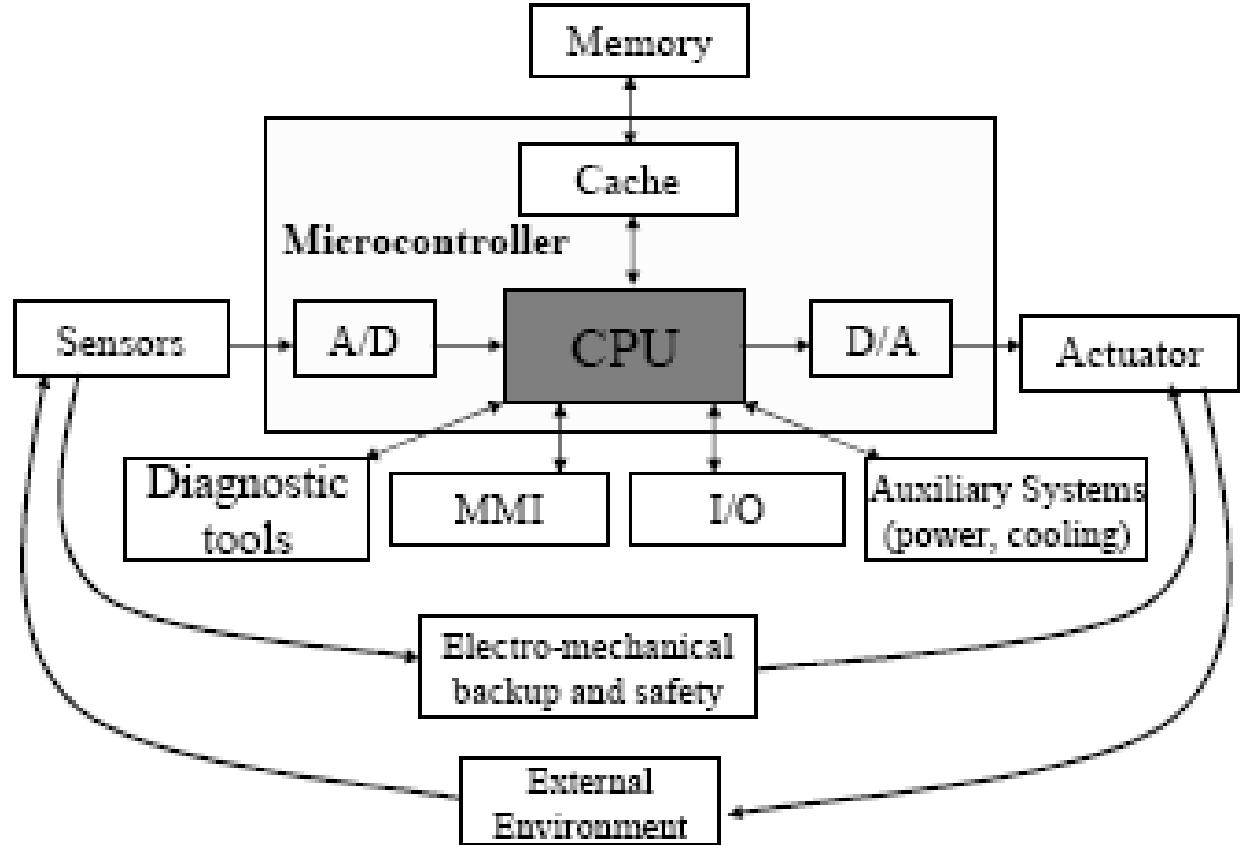
AN EMBEDDED COMPUTER DESIGNER'S VIEW

- Measured by: Cost, I/O connections, Memory Size, Performance



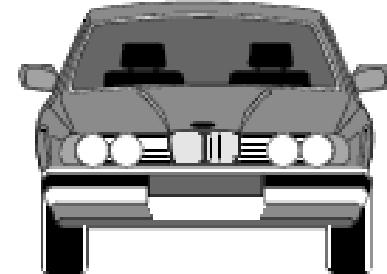
AN EMBEDDED CONTROL SYSTEM DESIGNER'S VIEW

- Measured by:
Cost, Time to market, Cost, Functionality, Cost & Cost.



A CUSTOMER VIEW

- Reduced Cost
- Increased Functionality
- Improved Performance
- Increased Overall Dependability



SOME EMBEDDED SYSTEM EXAMPLES

- Pocket remote control RF transmitter
 - 100 KIPS, water/crushproof, fits in pocket, 5year battery life
 - Software handcrafted for small size (less than 1 KB)
- Industrial equipment controller (e.g., elevator; jet engine)
 - 110 MIPS for 1 to 10 CPUs, 1 8MB memory
 - Safety critical software; real time control loops
- Military signal processing (e.g., Radar/Sonar)
 - 1 GFLOPS, 1 GB/sec I/O, 32 MB memory
 - Software handcrafted for extremely high performance



An example of:	Signal Processing	Mission Critical	Distributed	Small
Computing speed	1 GFLOPS	10 - 100 MIPS	1-10 MIPS	100,000 IPS
I/O Transfer Rates	1 Gb/sec	10 Mb/sec	100 Kb/sec	1 Kb/sec
Memory Size	32 - 128 MB	16 - 32 MB	1 - 16 MB	1 KB
Units Sold	10 - 500	100 - 1000	100 - 10,000	1,000,000+
Development Cost	\$20M - \$100M	\$10M - \$50M	\$1M - \$10M	\$100K - \$1M
Lifetime	15 - 30 years	20 - 30 years	25 - 50 years	10 - 15 years
Environment	Vibration, Heat	Heat, Vibration, Lightning	Dirt, Fire	Over-voltage, Heat, Vibration
Cost Sensitivity	\$1000	\$100	\$10	\$0.05
Other Constraints	Size, weight, power	Size, weight	Size	Size, weight, power
Safety	—	Redundancy	Mechanical Safety	—
Maintenance	Frequent repairs	Aggressive fault detection/ maintenance	Scheduled maintenance	"Never" breaks
Digital content	Digital except for signal I/O	~½ Digital	~½ Digital	Single digital chip; rest is analog/power
Certification authorities	Customer	Federal Government	Development team	Customer; Federal Government
Repair time goal	1-12 hours	30 minutes	4 min - 12 hours	1-4 hours
Initial cycle time	3-5 years	4-10 years	2-4 years	0.1-4 years
Product variants	1-5	5-20	10-10,000	3-10
Engineering allocation method	Per-product budget	Per-product budget	Allocation from large pool	Demand-driven daily from small pool
Other possible examples in this category:	Radar/Sonar Video Medical imaging	Jet engines Manned spacecraft Nuclear power	High-rise elevators Trains/trams/subways Air conditioning	Automotive auxiliaries Consumer electronics "Smart" I/O

EMBEDDED COMPUTERS *RULE THE MARKETPLACE*

- ~80 Million PCs vs. ~3 Billion Embedded CPUs annually
 - Embedded market growing; PC market *mostly* saturated

WHY ARE EMBEDDED SYSTEMS DIFFERENT?

Four General Categories of Embedded Systems

- General Computing
 - Applications *similar* to desktop computing, but in an embedded package
 - Video games, set top boxes, wearable computers, automatic tellers
- Control Systems
 - Closed loop feedback control of real time system
 - Vehicle engines, chemical processes, nuclear power, flight control
- Signal Processing
 - Computations involving large data streams
 - Radar, Sonar, video compression
- Communication & Networking
 - Switching and information transmission
 - Telephone system, Internet



THE PATRIOT MISSILE FAILURE

- <http://www-users.math.umn.edu/~arnold/disasters/patriot.html>



APPLICATION AREAS

- TV
- stereo
- remote control
- phone / mobile phone
- refrigerator
- microwave
- washing machine
- electric tooth brush
- oven / rice or bread cooker
- watch
- alarm clock
- electronic musical instruments
- electronic toys (stuffed animals, handheld toys, pinballs, etc.)
- medical home equipment (e.g. blood pressure, thermometer)

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Medical Systems

pace maker, patient monitoring systems, injection systems, intensive care units, ...

Office Equipment : printer, copier, fax, ...

Tools : multimeter, oscilloscope, line tester, GPS, ...

Banking : ATMs, statement printers, ...

Transportation

(Planes/Trains/[Automobiles] and Boats)
radar, traffic lights, signalling systems, ...

Automobiles

engine management, trip computer, cruise control, immobilizer, car alarm, airbag, ABS, ESP, ...

Building Systems

elevator, heater, air conditioning, lighting, key card entries, locks, alarm systems, ...

Agriculture feeding systems, milking systems, ...

Space satellite systems, ...

APPLICATION AREAS

- **Facts:**

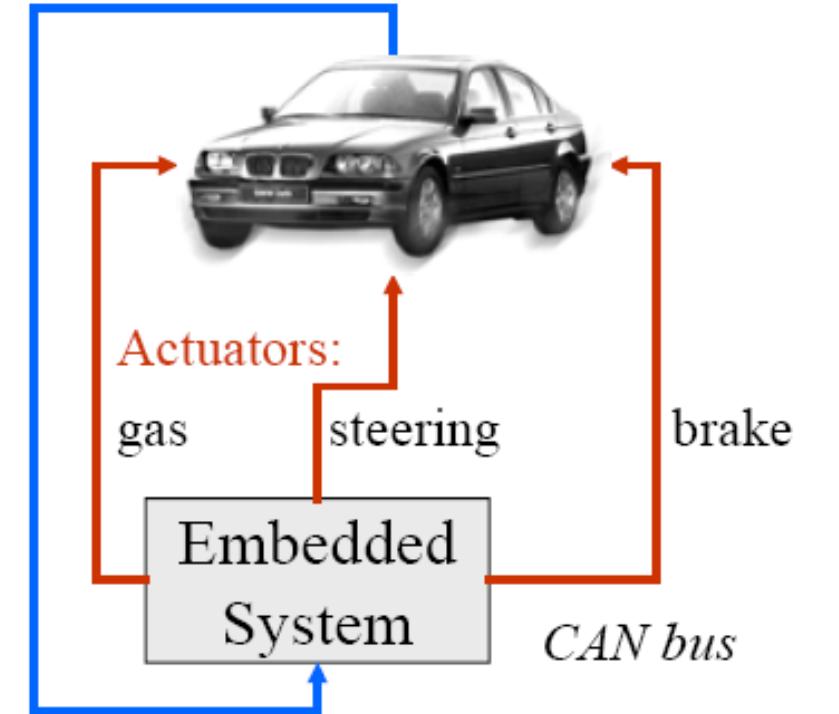
- 1997: The average U.S. household has over 10 embedded computers
(source: www.it.dtu.dk/~jan)
- 1998: 90% Embedded Systems vs. 10% Computers
 - (source: Frautschi, www.caliberlearning.com)
- 2001: The Volvo S80 has 18 embedded controllers and 2 busses (source: Volvo)

Automobiles

Autonomous cars:

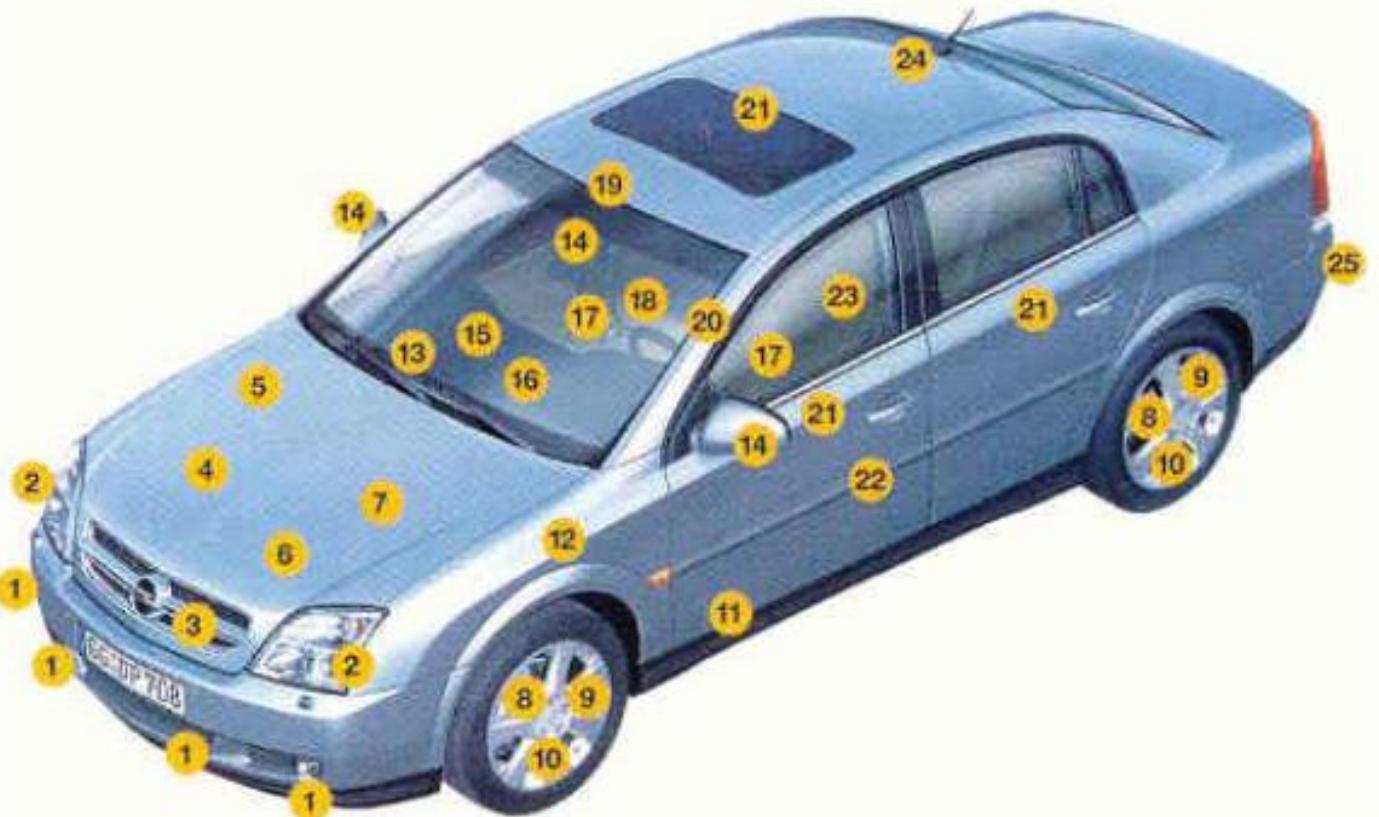
- Electronic gas
- Electronic brake
- Electronic steering

See: The Daimler Story



Sensors: Stereo-cameras, speedometer, accelerometers, signalling

Automobiles



2002: Opel Vectra has over 40 sensors (25 types)