

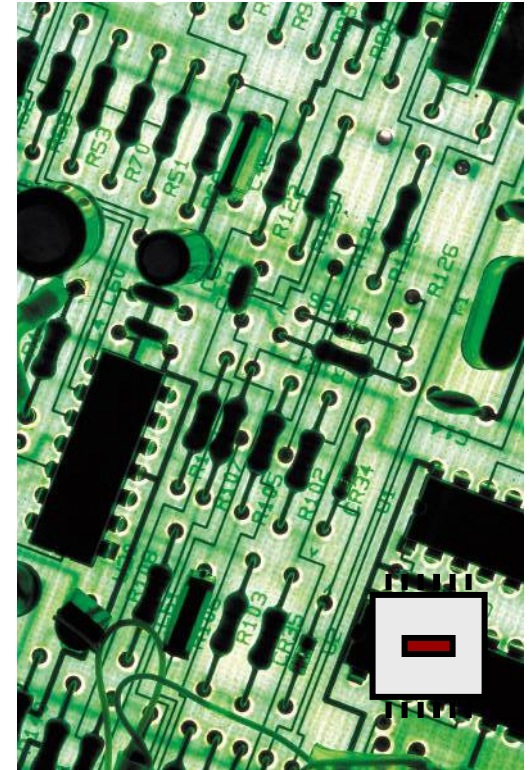
Embedded Systems

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Electronics Perspective

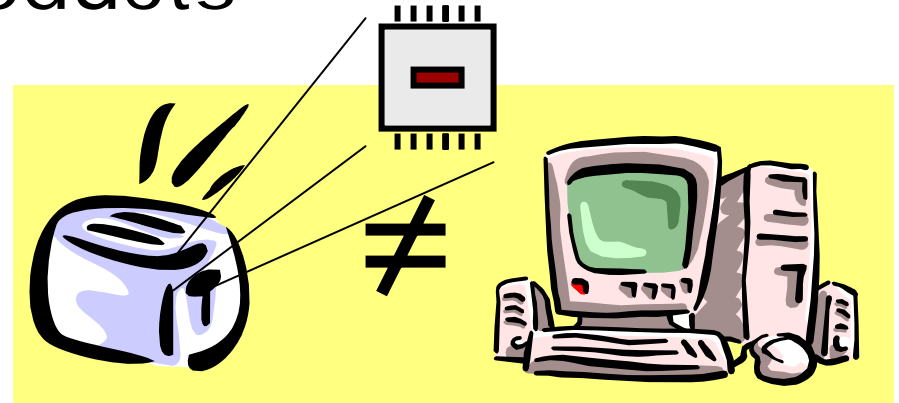
- A product that contains a programmable processor
- Software programming is part of the design of the product





Computer Perspective

- “A computer that doesn’t look like a computer”
- Interacts with world
- Primitive or no user interface
- Part of other products



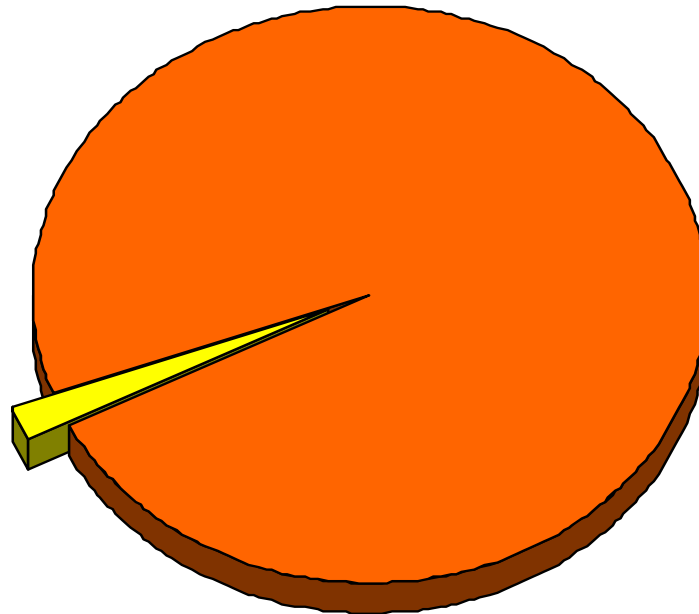


Dominant species

- Embedded = most processors!
 - ✱ 200 million PC and server
 - ✱ 8000 million embedded



"Desktop"
2%

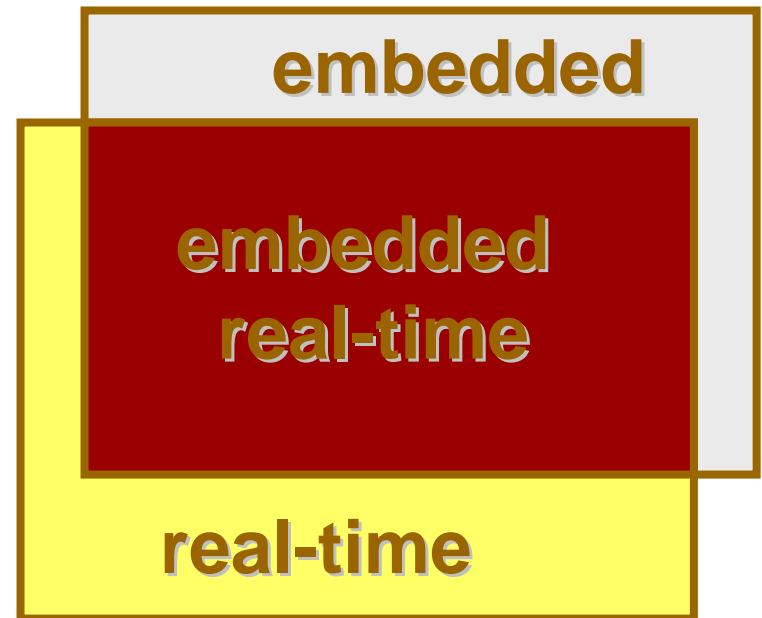


"Embedded"
98%



Real-Time Systems

- Embedded and Real-Time
 - ✱ Synonymous?
- Most embedded systems are real-time
- Most real-time systems are embedded





Embedded Systems

- Single purpose products
 - ✿ Not *general purpose* like desktop PCs
 - ✿ Do one thing very efficiently
- Software very important:
 - ✿ Gives character to product
 - Used to differentiate inside a “platform”
 - ✿ Can be changed late
 - ✿ Processor cheaper than special HW
 - ✿ Dominates HW development cost!



Processors used

- 4-bit:
 - ✿ Very simple & slow
 - ✿ 1970s pocket calculators
- 8-bit:
 - ✿ Simple, slow, low-power
 - ✿ Immensely popular (4 G/year)
 - ✿ Early 1980s home computers





Processors used

- 16-bit
 - ✿ More power than 8-bit
 - ✿ Mid-1980s home computers
 - ✿ Very popular: 2G/year





Processors used

- 32 & 64-bit
 - ✱ Old desktop & server chips
 - ✱ New desktop & server chips
 - ✱ Unique designs
 - ✱ 30 to 3000 MHz
 - ✱ About 1G units/year
 - Many more than PC & server market





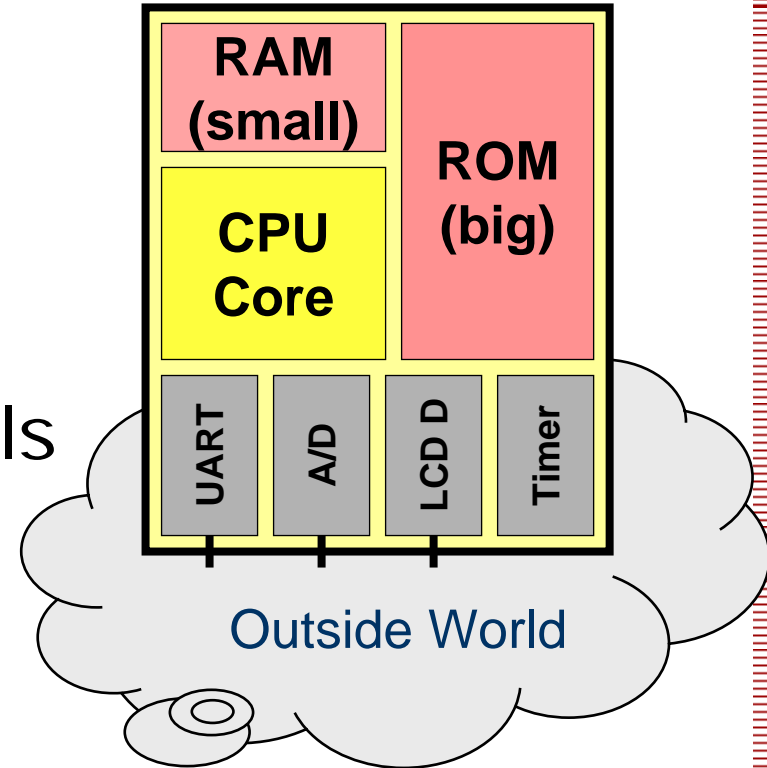
Processors used

- DSP: Digital Signal Processor
 - ✿ Specialized for signal processing
 - Not very good at general computing
 - ✿ High performance on DSP tasks
 - Low power, low price compared to 32- and 64-bit processors of same capability



Integration

- A single chip:
 - ✱ CPU Core
 - ✱ Integrated memory
 - ✱ Integrated peripherals
 - ✱ Integrated services
- Goal:
 - ✱ System on one chip
 - ✱ No external HW
 - ✱ Fit application “perfectly”





Devices on the Chip

- Interface with the world
 - ✱ Digital I/O
 - ✱ Analog/Digital conversion
 - ✱ Digital/Analog conversion
- Communications
 - ✱ CAN networks
 - ✱ Ethernet networks
 - ✱ Radio
 - ✱ Serial ports (UART, USART)
 - ✱ USB, FireWire, ...



Devices on the Chip

■ Timers

- ✿ Trigger interrupts
- ✿ Watchdogs

■ Graphics

- ✿ LCD drivers
- ✿ 2D/3D graphics acceleration

■ Buses

- ✿ On-chip: between devices: AMBA, ...
- ✿ Off-chip: PCI, HyperTransport, RapidIO ...





Trends

- Software dominates development
 - ✿ Hardware used to dominate
 - ✿ Software is now up to 75% of effort
 - ✿ Even when product is “full custom”
 - ✿ Especially in telecomm & datacomm
- Hardware is “under control”
 - ✿ Increasing use of standard components
 - ✿ Functionality moves to software



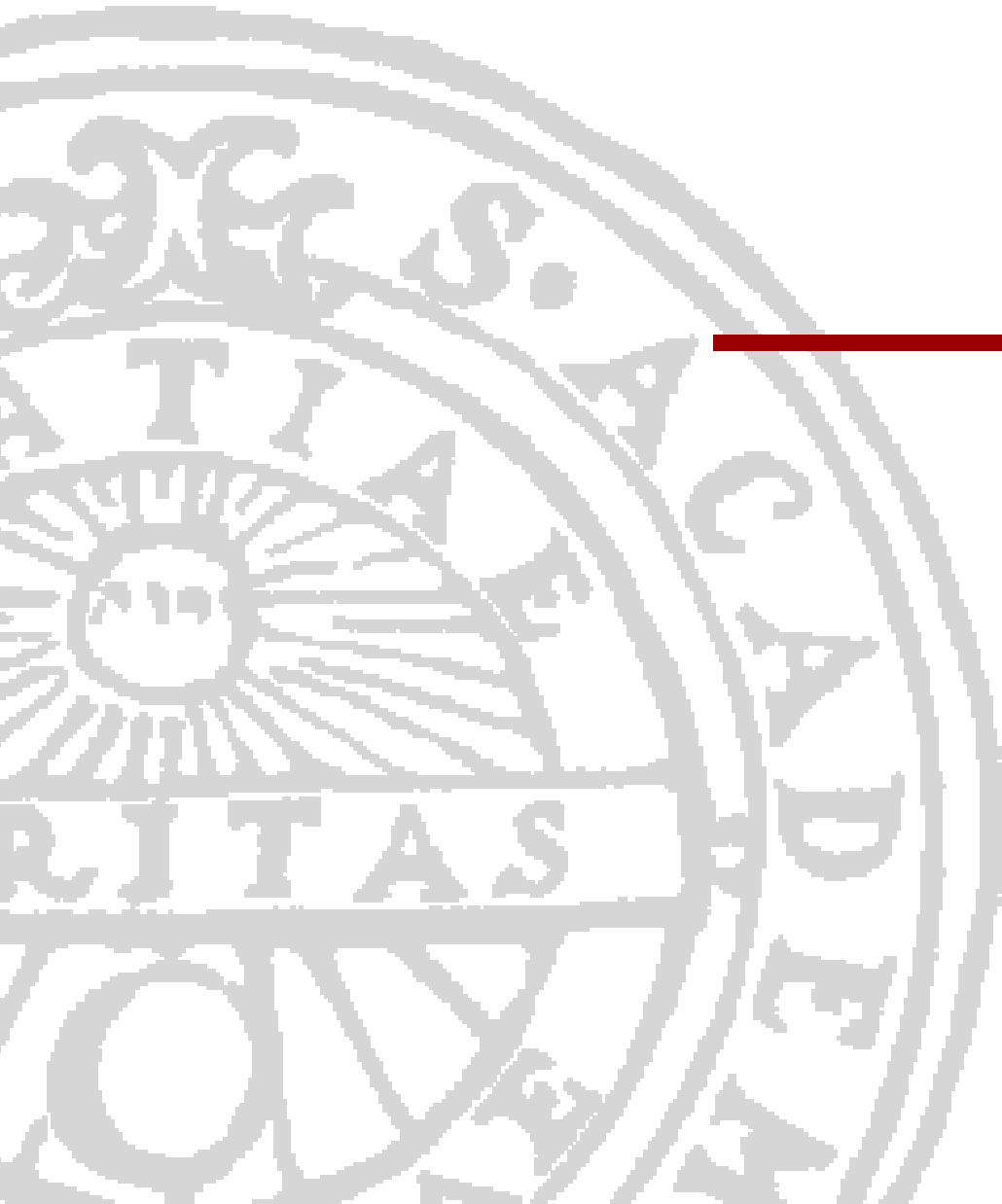
Trends

- Talk by Lars Philipsson, LTH, 2004
 - ✿ What is the future of electrical engineering in Sweden?
- Answer:
 - ✿ Software work
 - Software replacing logic design
 - ✿ Some analog design work
 - Circuit-board design, high-speed circuits
 - ✿ Measuring technology



Trends

- Non-stop miniaturization and integration of computers
 - ✿ From one processor in a fridge
 - ✿ To thousands of processors on a chip
 - ✿ Steady trend over time
- One chip = one system
 - ✿ Processors, memories, electronics
 - Can be 100s of processors
 - ✿ "SoC": System-on-a-Chip

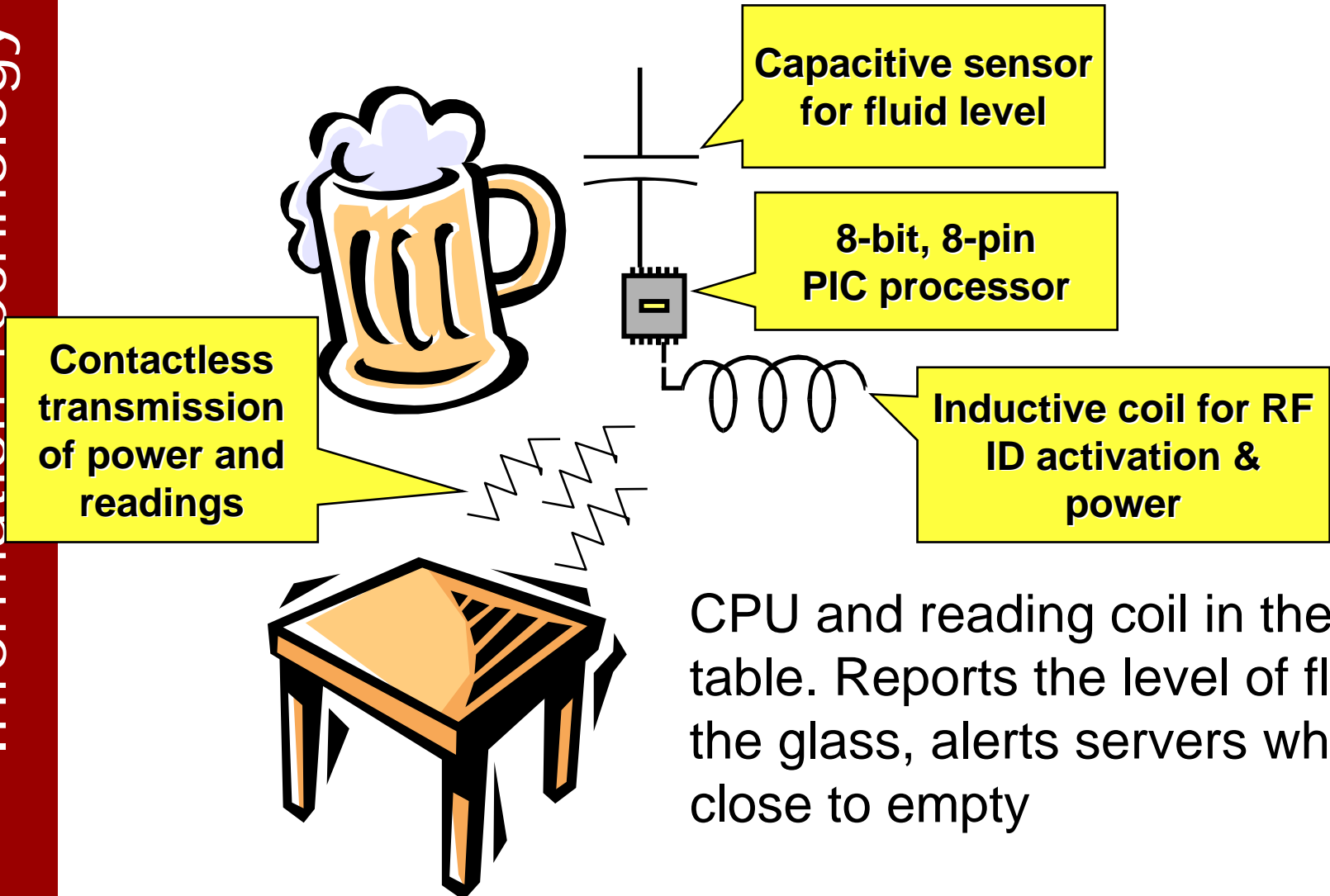


Examples

Some embedded systems from real life



Smart Beer Glass





Smart Beer Glass

- Typical embedded solution
- Integrates several technologies:
 - ✱ Radio transmissions
 - ✱ Sensor technology
 - ✱ Magnetic inductance for power
 - ✱ Computer used for calibration
- Impossible without the computer
- Meaningless without the electronics



Pedometer

- Obvious computer work:
 - ✿ Count steps
 - ✿ Keep time
 - ✿ Averages
 - ✿ etc.
- Hard computer work:
 - ✿ Actually identify when a step is taken
 - ✿ Sensor feels motion of device, not of user feet





Mobile phones

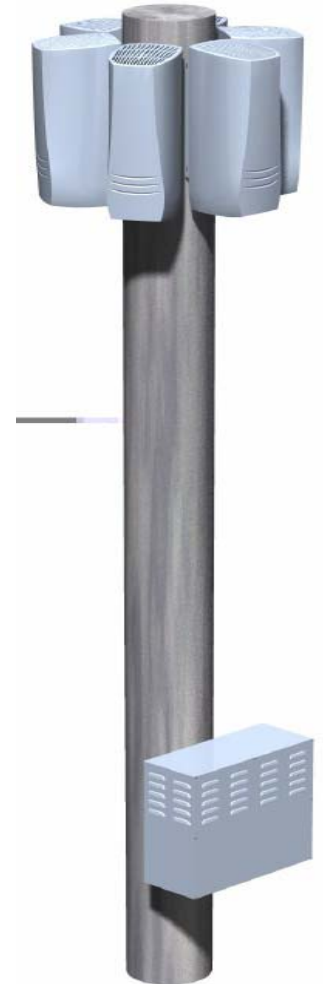


- Multiprocessor
 - ✱ 8-bit/32-bit for UI
 - ✱ DSP for signals
 - ✱ 32-bit in IR port
 - ✱ 32-bit in Bluetooth
- 8-100 MB of memory
- All custom chips
- Power consumption & battery life depends on software



Mobile base station

- Massive signal processing
 - ✿ Several processing tasks per connected mobile phone
- Based on DSPs
 - ✿ Standard or custom
 - ✿ 100s of processors





Telecom Switch



- Rack-based
 - ✱ Control cards
 - ✱ IO cards
 - ✱ DSP cards
 - ✱ ...
- Optical & copper connections
- Digital & analog signals



Smart Welding Machine

- Electronics control voltage & speed of wire feed
- Adjusts to operator
 - ✱ kHz sample rate
 - ✱ 1000s of decisions/second
- Perfect weld even for quite clumsy operators
- Easier-to-use product, but no obvious computer





Sewing Machine



- User interface
 - ✿ Embroidery patterns
 - ✿ Touch-screen control
- "Smart"
 - ✿ Sets pressure of foot depending on task
 - ✿ Raise foot when stopped
- New functions added by upgrading the software



UPPSALA
UNIVERSITET

Forestry Machines

Information Technology





Forestry Machines

- Networked computer system
 - ✿ Controlling arms & tools
 - ✿ Navigating the forest
 - ✿ Recording the trees harvested
 - ✿ Crucial to efficient work
- Processors
 - ✿ 16-bit processors in a network



Operator Panel



- Embedded PC
 - ✱ Graphical display
 - ✱ Touch panel
 - ✱ Joystick
 - ✱ Buttons
 - ✱ Keyboard
- But tough enough to be “out in the woods”



Cars

- Multiple processors
 - ✱ Up to 100
 - ✱ Networked together
- Multiple networks
 - ✱ Body, engine, telematics, media, safety





Cars

- Functions by embedded processing:
 - ✿ ABS: Anti-lock braking systems
 - ✿ ESP: Electronic stability control
 - ✿ Airbags
 - ✿ Efficient automatic gearboxes
 - ✿ Theft prevention with smart keys
 - ✿ Blind-angle alert systems
 - ✿ ... etc ...



Cars

- Large diversity in processor types:
 - ✿ 8-bit – door locks, lights, etc.
 - ✿ 16-bit – most functions
 - ✿ 32-bit – engine control, airbags
- Form follows function
 - ✿ Processing where the action is
 - ✿ Sensors and actuators distributed all over the vehicle



Extremely Large

- Functions requiring computers:
 - ✿ Radar
 - ✿ Weapons
 - ✿ Damage control
 - ✿ Navigation
 - ✿ basically everything
- Computers:
 - ✿ Large servers
 - ✿ 1000s of processors





Inside your PC

- Custom processors
 - ✿ Graphics, sound
- 32-bit processors
 - ✿ IR, Bluetooth
 - ✿ Network, WLAN
 - ✿ Harddisk
 - ✿ RAID controllers
- 8-bit processors
 - ✿ USB
 - ✿ Keyboard, mouse





If you want to play

- Lego mindstorms robotics kit
 - ✿ Standard controller
 - 8-bit processor
 - 64 kB of memory
 - ✿ Electronics to interface to motors and sensors
- Good way to learn embedded systems



THE RCX

Swedish Business Perspective





Very very important

- All advanced products contain embedded systems today
- Software is the key driver for new functions & special characteristics



End-Product Companies

- Core Swedish industry
- Very large companies
- Builds end-user products
- Ericsson
- ABB
- Volvo
- Volvo Cars
- Saab
- Scania
- SonyEricsson
- SKF
- Silva
- Huskvarna



Suppliers

- Tool providers
 - ✿ IAR Systems
 - ✿ Telelogic
 - ✿ Nohau
 - ✿ Virtutech
 - ✿ Volcano
 - ✿ Arcticus
- Solution providers
 - ✿ CC-Systems
 - ✿ ConnectBlue
- Component companies
 - ✿ Xelerated
- Consultants
 - ✿ TietoEnator
 - ✿ Teleca
 - ✿ ÅF
 - ✿ Saab Combitech
 - ✿ + many many more