TTK 4155
Industrial and Embedded Computer Systems Design

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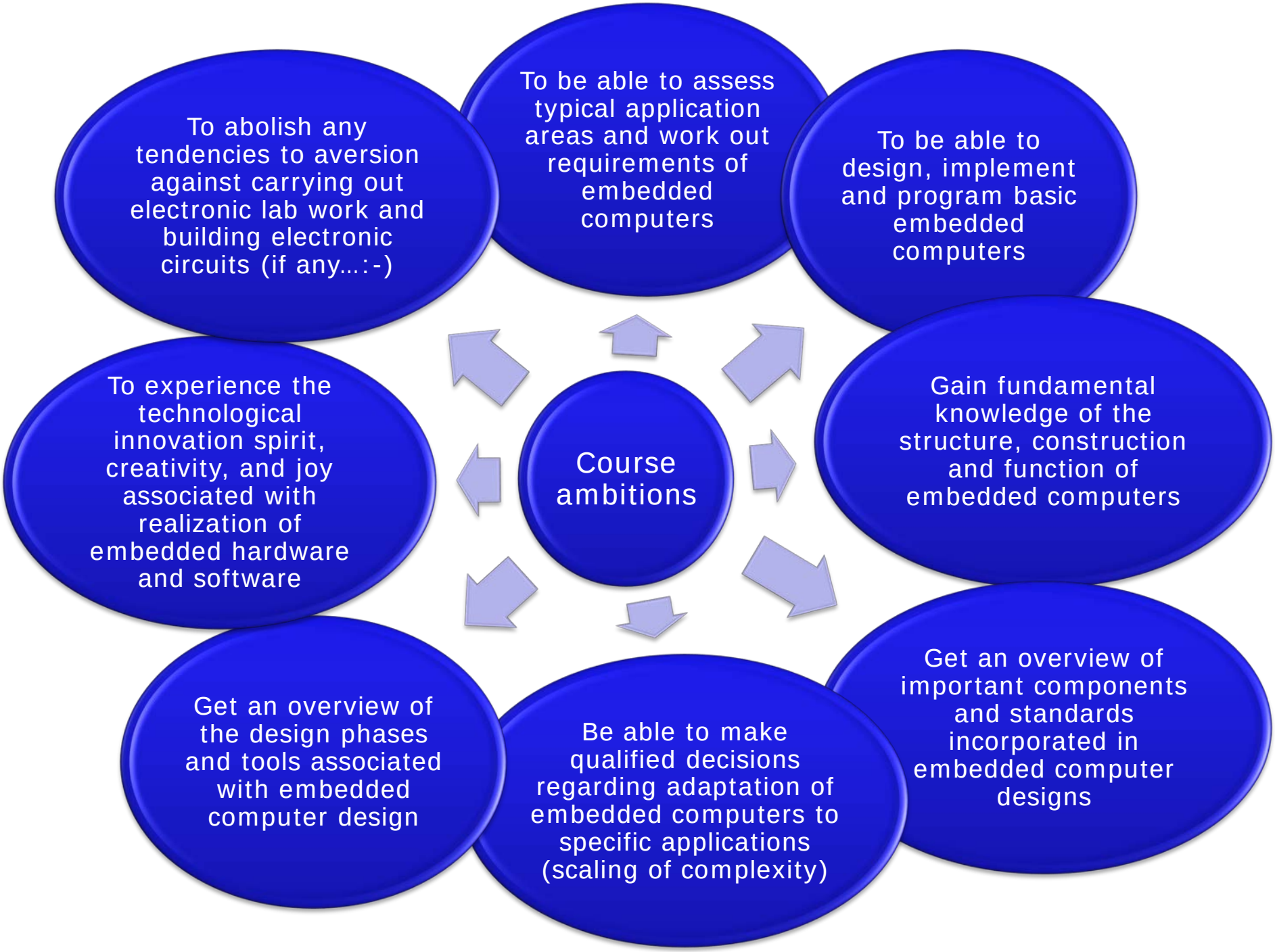
Faculty of Information Technology and Electrical Engineering
August 2019

CONTENTS

- Introduction
- Course information
- Embedded systems:
  - Definitions
  - Some historical perspectives
  - Properties and requirements
- Brush-up of some useful concepts in electronics

Significance of embedded computers

- Embedded computers completely *pervade our lives*!
- They are now so *ever-present* in all aspects of industry, society and life in general that they are almost invisible and taken for granted
- ... and most people are relatively unaware of their great significance for maintaining a modern society and lifestyle
- Billions of microprocessors are manufactured and sold each year, but only a small fraction of them are intended for general purpose computers like PCs and workstations – the rest goes to the myriad of embedded computer systems


Course ambitions
To abolish any tendencies to aversion against carrying out electronic lab work and building electronic circuits (if any…:-)
To be able to assess typical application areas and work out requirements of embedded computers
To be able to design, implement and program basic embedded computers
To experience the technological innovation spirit, creativity, and joy associated with realization of embedded hardware and software
Gain fundamental knowledge of the structure, construction and function of embedded computers
Get an overview of the design phases and tools associated with embedded computer design
Be able to make qualified decisions regarding adaptation of embedded computers to specific applications (scaling of complexity)
Get an overview of important components and standards incorporated in embedded computer designs

Course information

- Lectures:
  - 14 x 2 hours regular/guest lectures
  - Mondays 16:15 - 18:00, H3

Guest lectures:
- Silicon Labs
- Nordic Semi
- Others…

- Term project:
  - Design and implement a mechatronic ”Ping-Pong” machine with a distributed embedded control system
  - Group work (three students/group)
  - Work load: 5 - 10 hours/week throughout the semester
  - Divided into eight exercises that must be approved individually
    - Approval by teaching assistants in lab
  - Time:
    - **Start-up:** **Week 35, mandatory intro-lecture (time/place TBD)**
    - Lab lectures: Thursdays 08:15, S8
    - Lab days: Wednesday,Thursday and Friday, Real-time lab (G203, G204)

- Evaluation
  - Written exam: Saturday 9th Dec., 09:00 – 13:00. Support option D
  - Term project evaluation: **Last week of semester** (details to follow later)
  - Term project counts 50% of final grade

Supervision

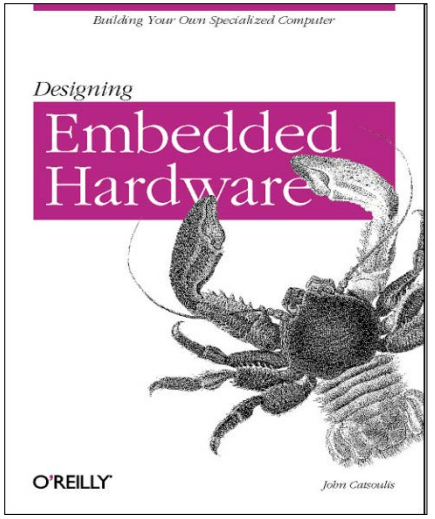
- Course leader:
  - Jo Arve Alfredsen (D-131)
- Head of lab:
  - Waseem Hassan, (D-351A)
- Six teaching assistants
  - 2 assistants present during lab hours
  - Queuing system to facilitate fair access to assistants

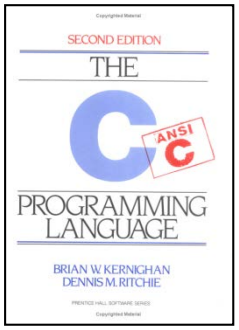
Tentative lecture plan TTK4155, autumn 2019:

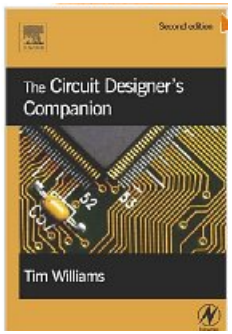
WEEK	SUBJECT
34	Course info, introduction and motivation. Brush-up on some basic and useful concepts in electronics. Power supply and voltage regulators. Preview serial comms. Prototyping techniques and production of electronic circuits.
35	Processors and architectures Examples of processors for embedded computers, microcontrollers Memory, memory access, address decoding, memory-mapped I/O
36	Interrupts, I/O and bus systems, MCU peripheral modules, functions and infrastructure
37	Communication and networks: Inter-IC, point-to-point
38	Communication and networks: Continued...
39	Communication and networks: Continued...
40	Wireless communication, ISM, ZigBee, 802.11, BlueTooth, IrDA
41	Digital/Analog interfaces Signal conditioning, AD/DA conversion principles, design techniques, examples
42	Digital/Analog interfaces Sensors and actuators, examples
43	Low-power design principles and battery powered systems (Industrial) Internet of Things (IoT).
44	High performance processors for embedded systems (AVR32, ARM Cortex M), Industrial PCs, examples
45	Digital signal processors (DSP) Properties and applications
46	Advanced topics: Parallelism, pipelining, multiprocessors, optimizations.
47	Summary

Course literature

- Book:
  - Designing Embedded Hardware (2nd ed.)
    Catsoulis, J. 2005/2009. O'Reilly,
    ISBN 0-596-00755-8.
- Other books (optional):

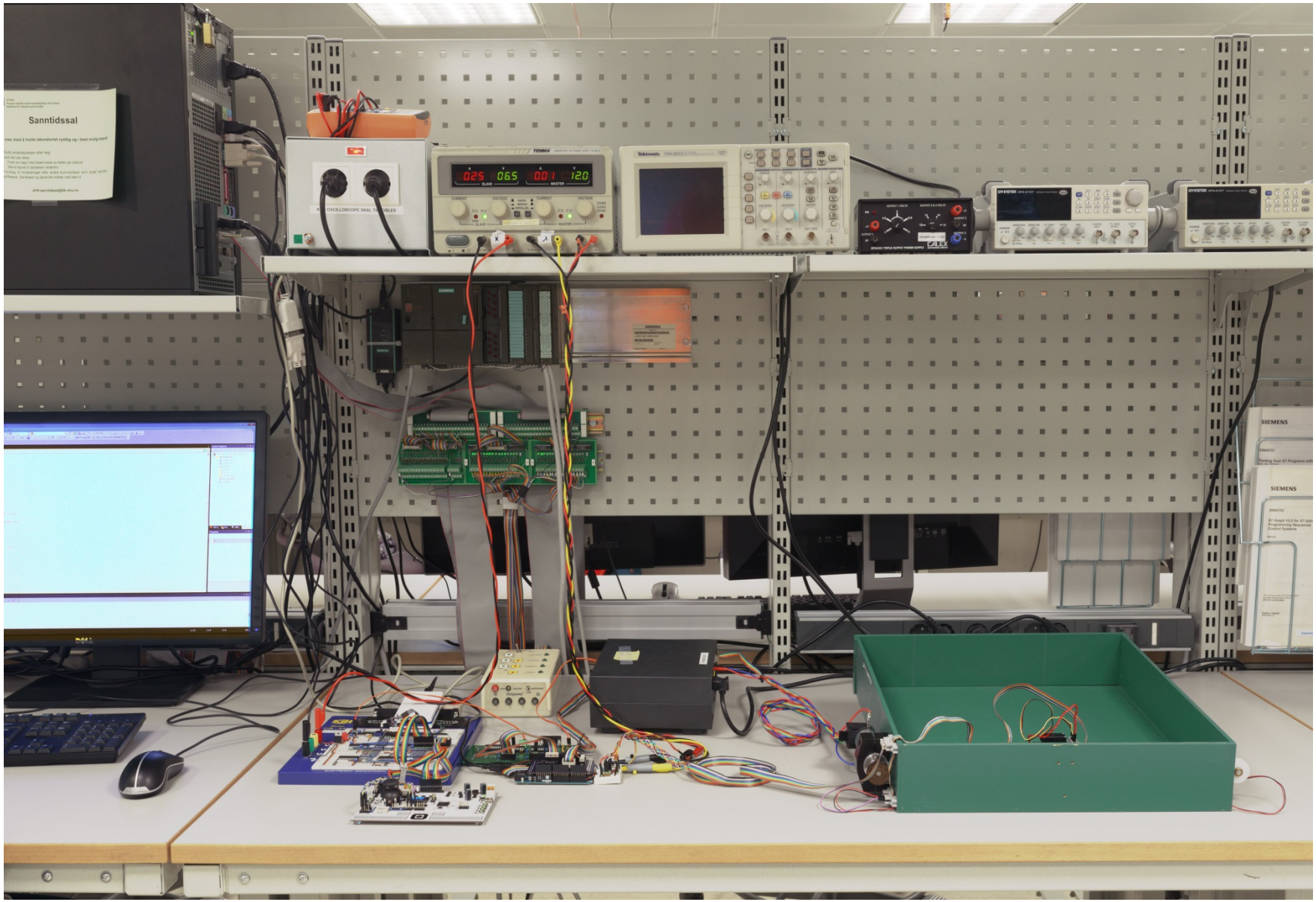






- Some selected articles and other documentation (made available at Blackboard)
- Documents related to the term project assignment (made available at Blackboard)
- Complete list of literature will be compiled at end of the term

Term project



Term project

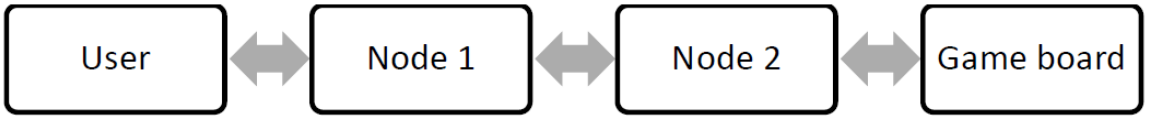


Figure 1 – system overview

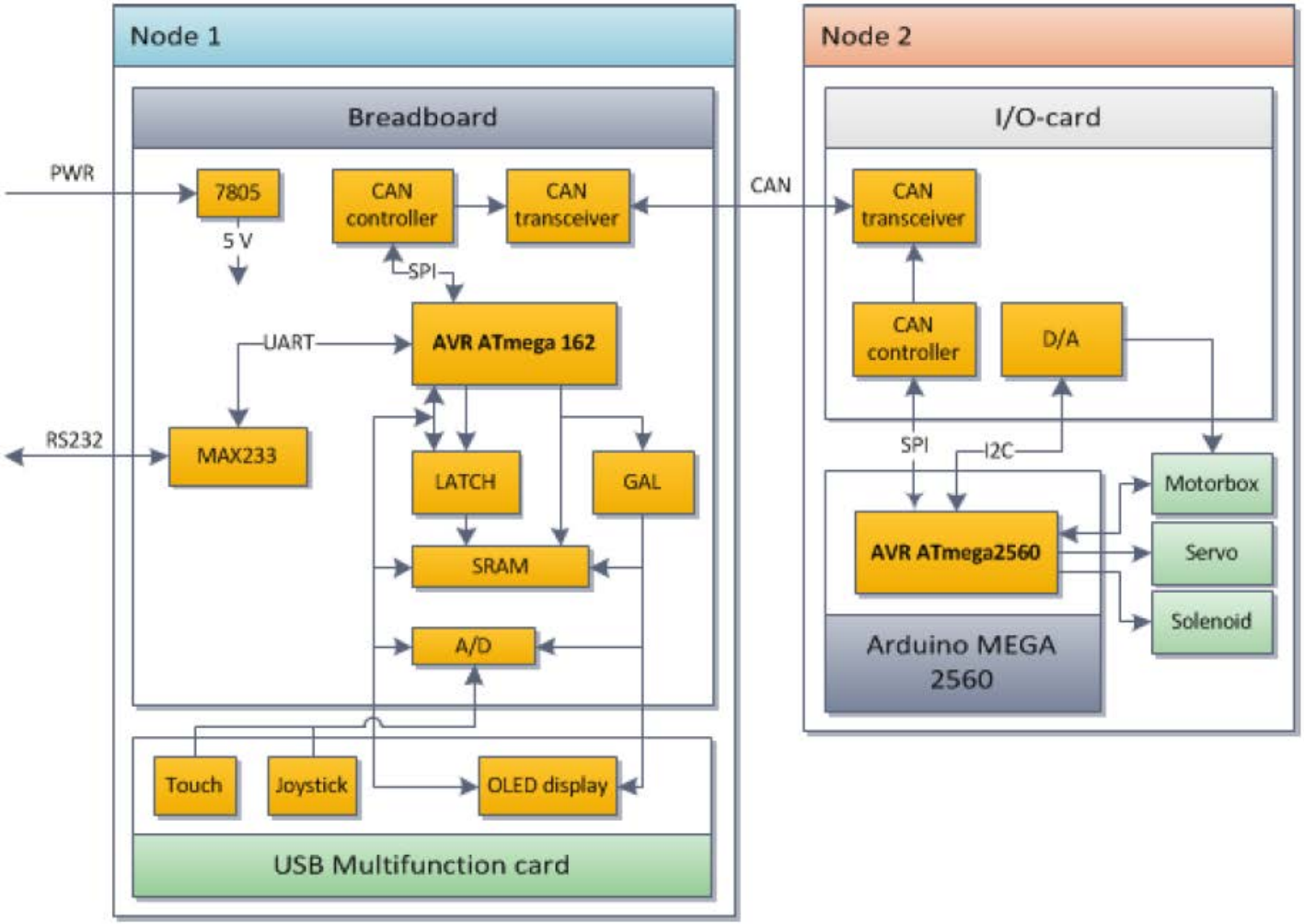
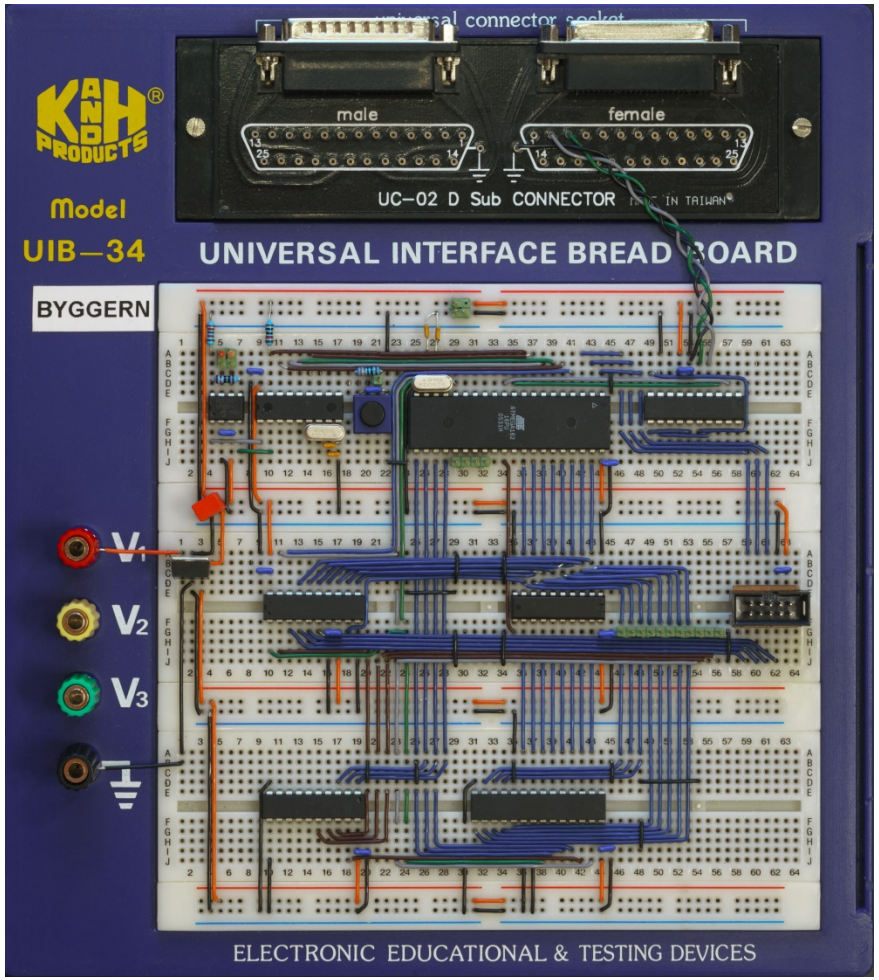
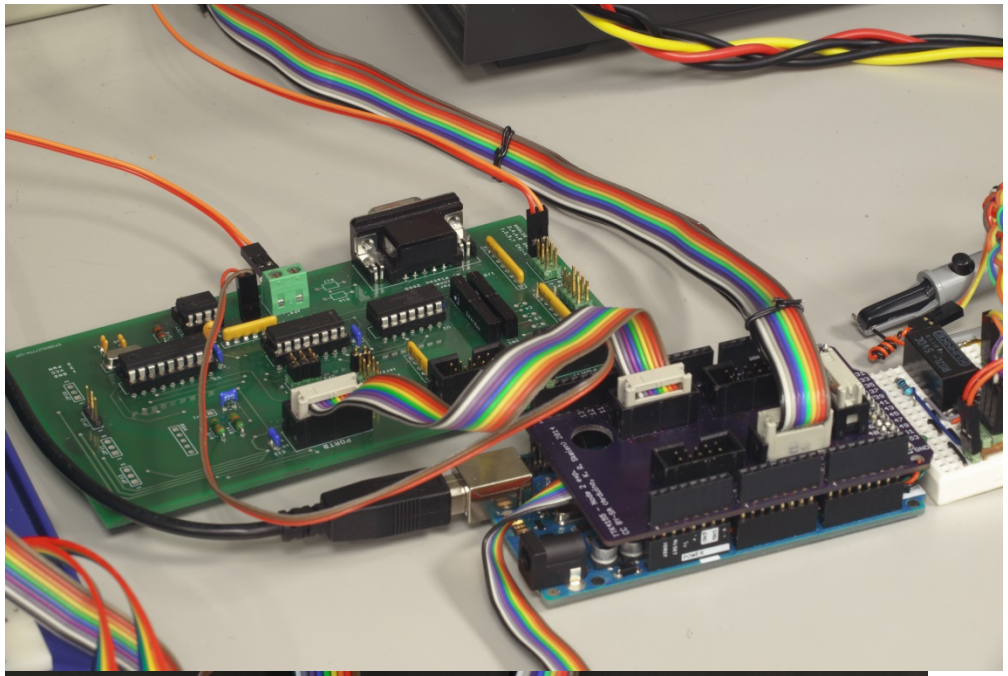
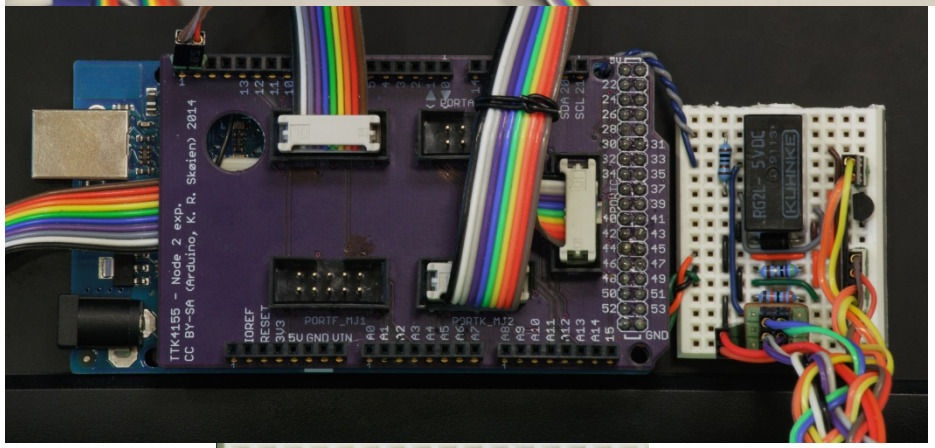


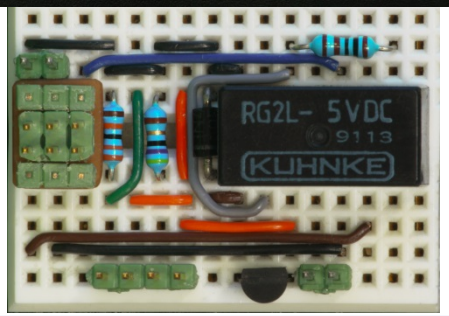
Figure 2 – Node 1 and 2 with their main components

Term project









Week	Assignment to be completed
35	1: Initial assembly of microcontroller and RS-232
36	2: Address decoding and external RAM
37	3: A/D converting and joystick/touch input
38	4: OLED display and user interface
39	
40	5: SPI and CAN controller
41	6: CAN-bus and communication between nodes
42	*Catch up week*
43	7: Controlling servo and IR
44	8: Controlling motor and solenoid
45	9: Completion of the project and extras
46	*Catch up week*
47	*Evaluation*

- Video clip TTK4155 lab

Definitions: Embedded computer system

Any device that contains a programmable computer which introduce some degree of intelligence to the system, but which itself is not a general purpose computer (such as PCs, workstations, laptops, tablets)

Definitions: Embedded computer system

A computer system:

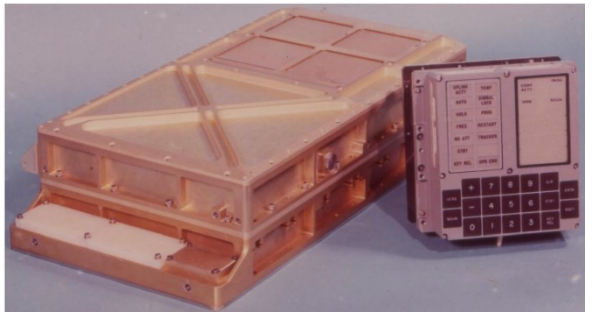
- that is designed and optimized to execute a dedicated task
- that is embedded as a part of a larger system, which typically consists other types of components (mechanical, electrical) than computers
- where the computer itself is not necessarily the “purpose” of the system
- where hard or soft real-time requirements often are part of the specification

Types of computer systems

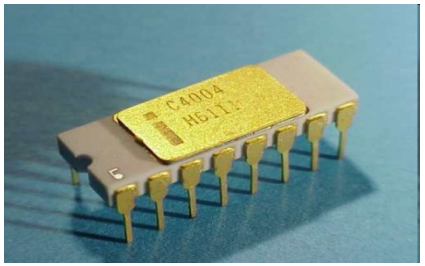
- Open systems
  - General purpose computing
  - Purpose-loaded functions
  - Flexible, high performance, no limitations on energy
- Embedded systems
  - Fixed-function, optimized, high/low performance
  - Part of larger system
  - Computer not the «purpose» of the system
- Deeply embedded systems
  - Devices of a single purpose
  - Not «visible», highly optimized wrt. application
  - Typically sense -> process -> act

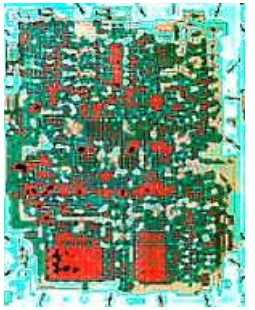
Embedded systems - A historical perspective

- Late 40s: Whirlwind was developed at MIT
  - Originally designed to control a flight simulator
- 50s and 60s: First ”mainframes” used in process control
- 60s: Apollo Guidance Computer (AGC)
  - The first modern embedded computer?
  - Implemented using discrete logic ICs (4100 NOR-gates)
  - f_{osc} = 2.048 MHz, 2K RAM, 36K ROM

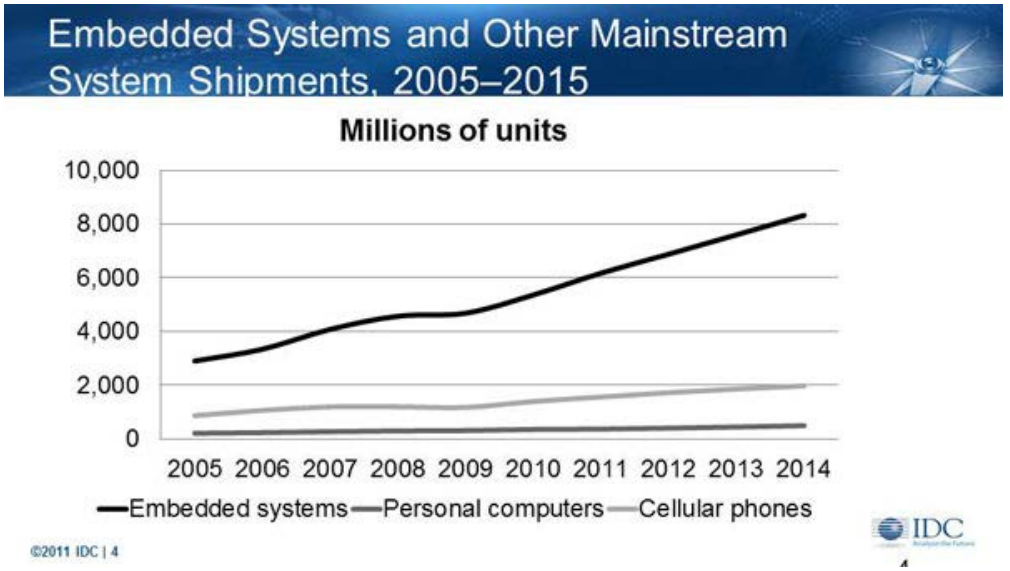


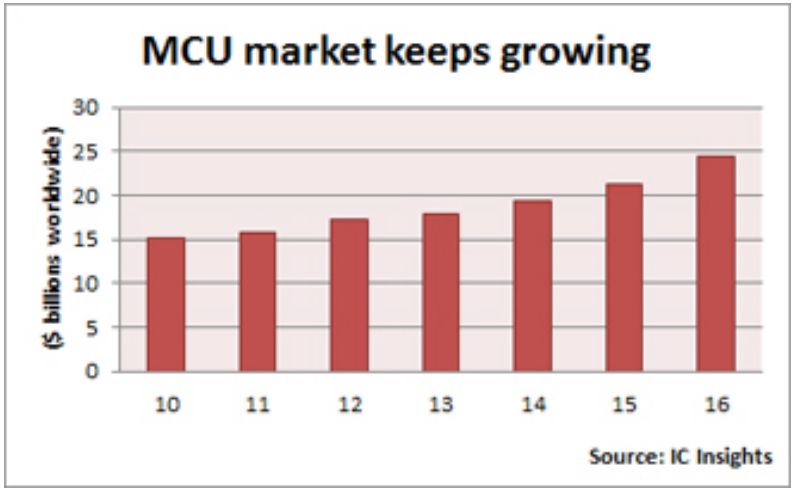
- Early 70s: First ”single chip” microprocessor:
  - Integrated Electronics 4004
  - 4-bit, 4K data, 1K program, 108 kHz
  - Developed for use in a calculator, but…
  - A new era was started!

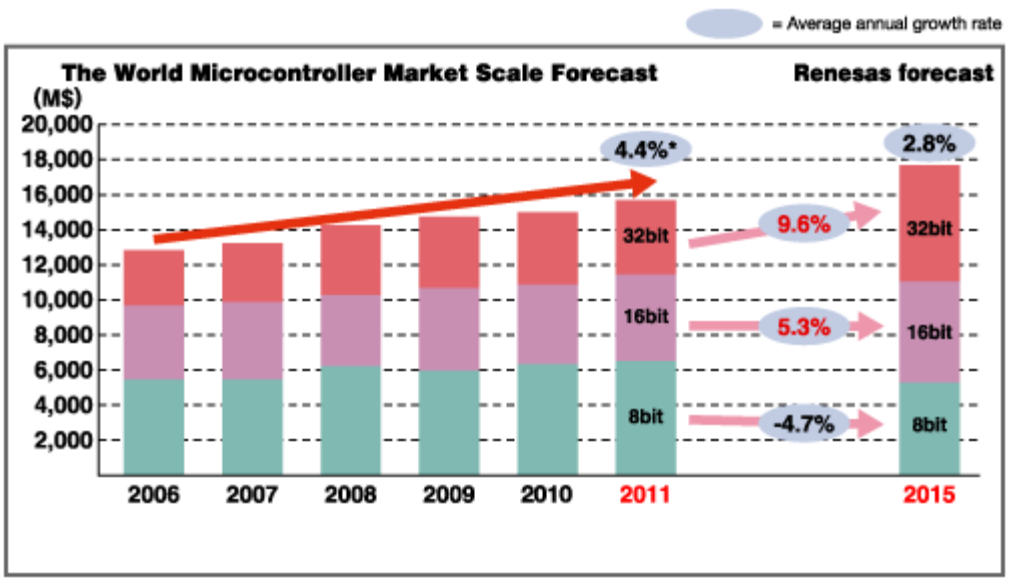


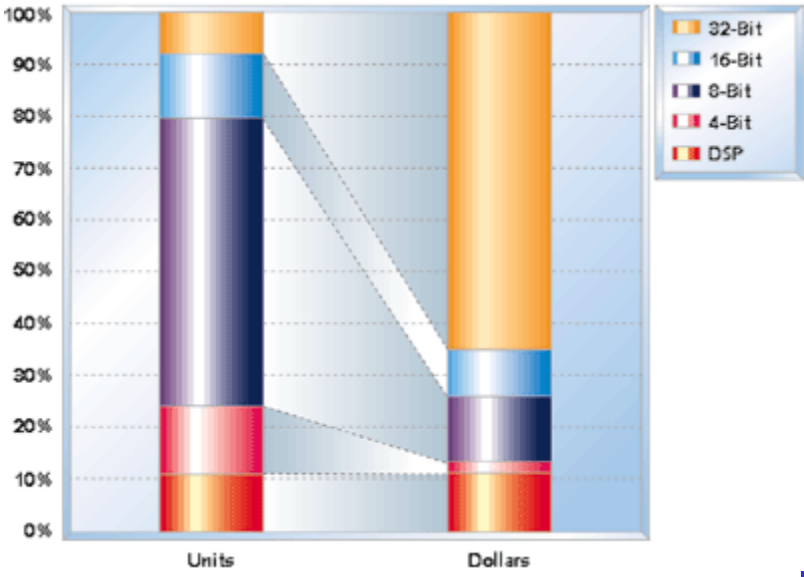


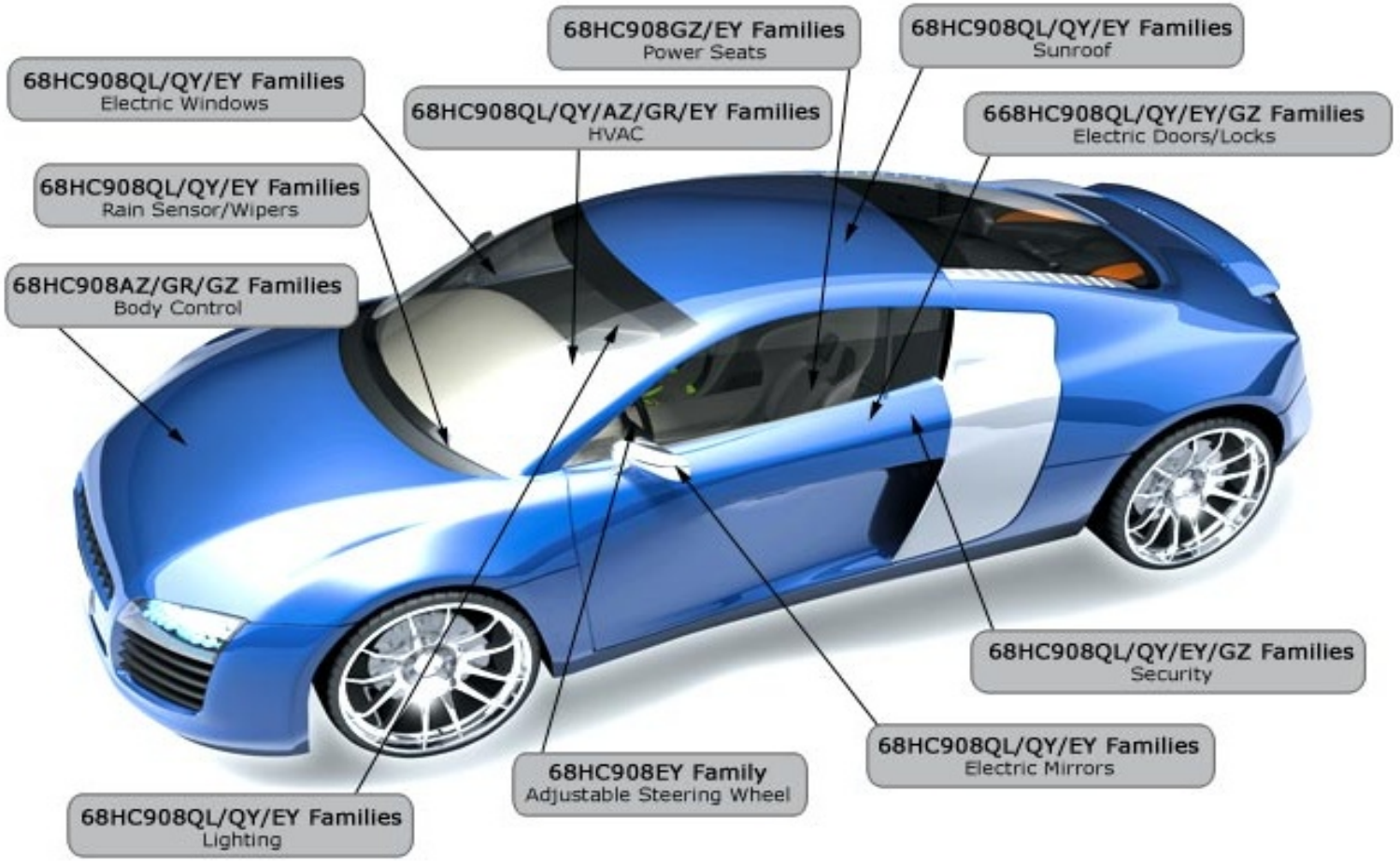
- The automotive and aerospace industry adopted the microprocessor fully in the 70s:
  - Fuel monitoring, motor timing, guidance/control etc.
  - 1974 – first microcontroller: TI TMS1000


Embedded Systems and Other Mainstream System Shipments, 2005–2015
Millions of units
10,000
8,000
6,000
4,000
2,000
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Embedded systems
Personal computers
Cellular phones
©2011 IDC | 4
IDC

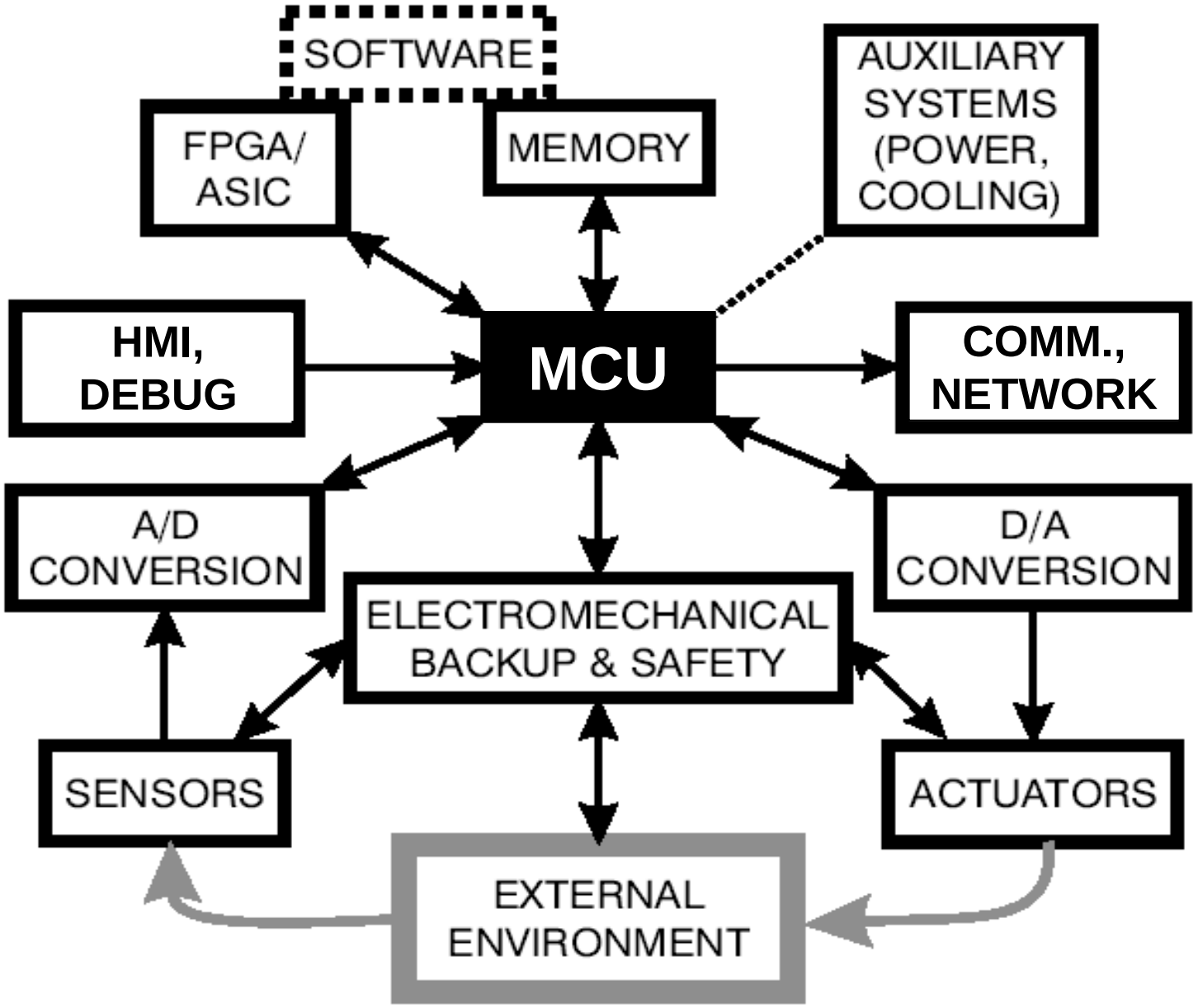

MCU market keeps growing
($ billions worldwide)
30
25
20
15
10
5
0
10 11 12 13 14 15 16
Source: IC Insights


= Average annual growth rate
The World Microcontroller Market Scale Forecast
Renesas forecast
(M$)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
4.4%*
2.8%
32bit
16bit
8bit
9.6%
5.3%
-4.7%
2006 2007 2008 2009 2010 2011 2015


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
32-Bit
16-Bit
8-Bit
4-Bit
DSP
Units
Dollars

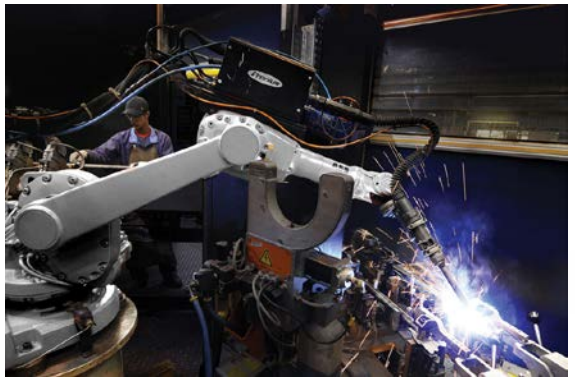

68HC908GZ/EY Families
Power Seats
68HC908QL/QY/EY Families
Sunroof
68HC908QL/QY/EY Families
Electric Windows
68HC908QL/QY/AZ/GR/EY Families
HVAC
668HC908QL/QY/EY/GZ Families
Electric Doors/Locks
68HC908QL/QY/EY Families
Rain Sensor/Wipers
68HC908AZ/GR/GZ Families
Body Control
68HC908QL/QY/EY/GZ Families
Security
68HC908QL/QY/EY Families
Electric Mirrors
68HC908EY Family
Adjustable Steering Wheel
68HC908QL/QY/EY Families
Lighting

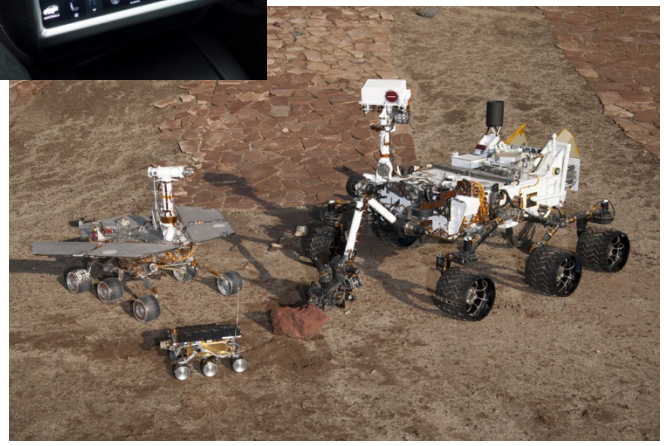
Industrial embedded system, typical components



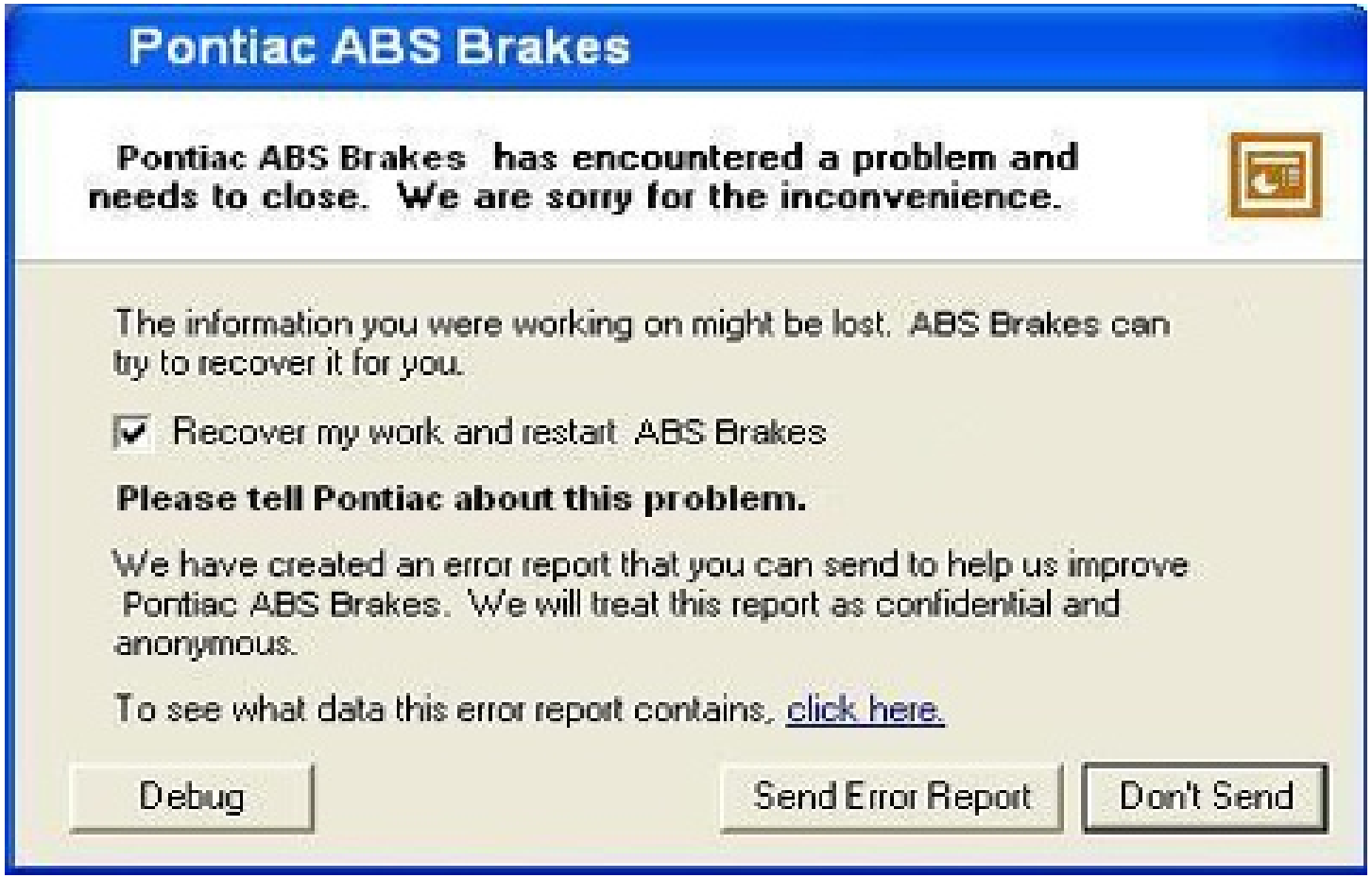
Embedded systems development – a diversity of requirements

- Simple/complex algorithms
- Simple/complex interfaces
- Multi-rate systems
- Real-time requirements
- Safety requirements
- Requirements to operating environment
- Requirements to energy consumption
- Requirements to physical size/shape
- Cost sensitivity
- Typically small development teams and tight deadlines
- Complex development tools and test requirements

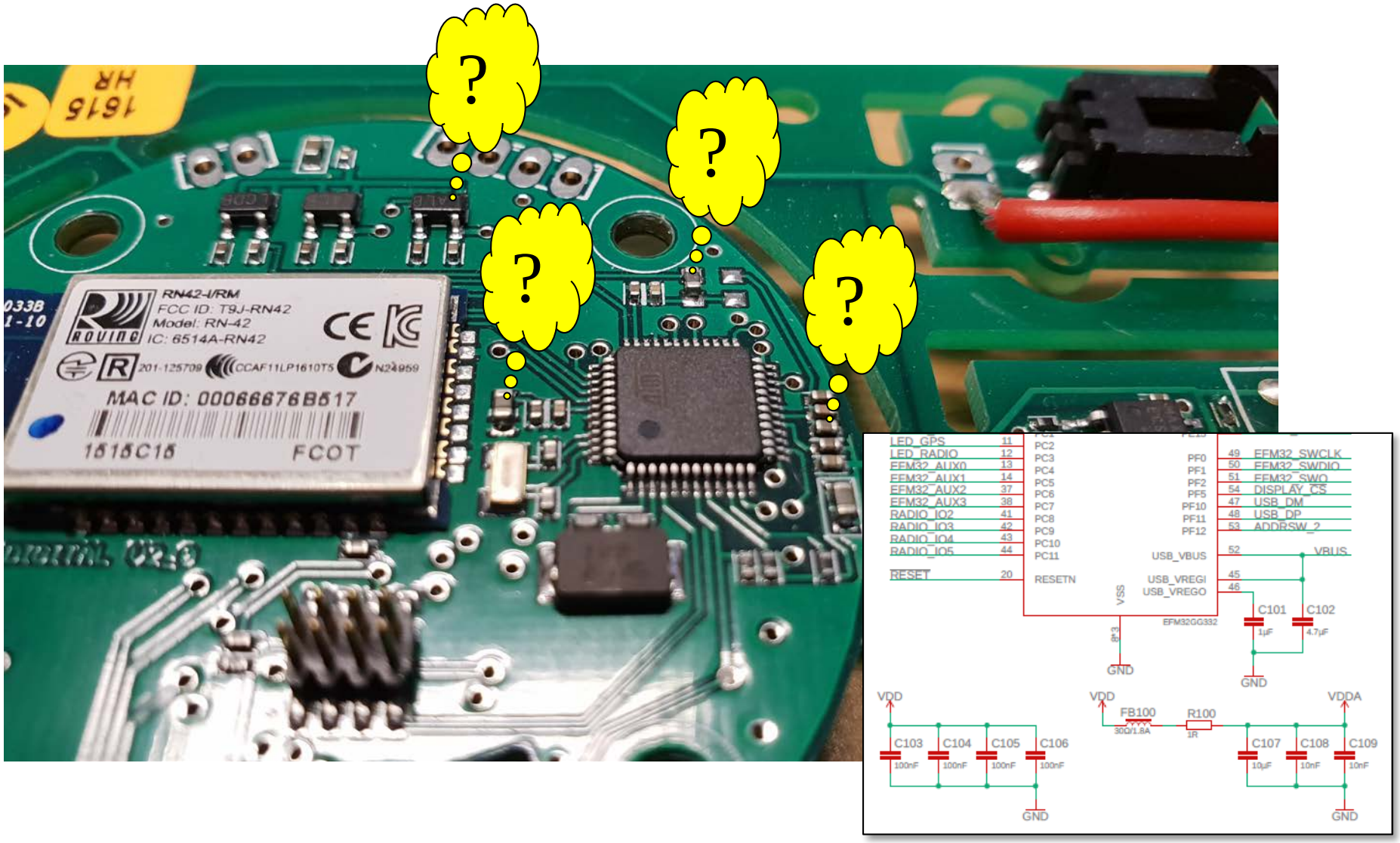




Desktops and embedded computers: Different requirements…

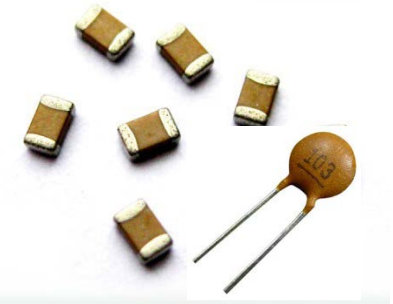


Brush-up of some useful concepts in electronics…



Decoupling of digital circuits: recommendations

- One 22uF bulk electrolyte per board
- One 1uF tantalum per 10 SSI/MSI
- One 1uF tantalum per 2-3 LSI
- One 10-100nF ceramic per supply pin per LSI
- One 10-100nF ceramic per octal IC/MSI
- One 10-100nF ceramic per 4 SSI logic Ics



(T. Williams, *The Circuit Designer's Companion*)