

# Advanced Robot Control

## Embedded system design

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**Presentation compiled for taking notes during lecture**



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- 1 Embedded system
  - What is it?
  - Features
- 2 System architecture
  - Software & Hardware
  - Sensors & Actuators
  - Communication
- 3 Tools
  - Data types
  - Code optimization
  - Computation acceleration
  - Parameters
  - Bootloader



# Embedded system

What is an embedded system?



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# Embedded system features (1/1)

- Feasibility
- Extendability
- Maintainability
- Longevity
- Repairable
- Modularity
- Power efficiency



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# Software (1/1)

System architecture for an embedded solution can be divided into a few groups depending on the nature of the process.



# Hardware (1/1)

Similarly to software requirements same can be applied to hardware ones. Depending on the system analysis in contrast to embedded system features. The most suitable platform should be selected.





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# Sensors (1/1)

Each embedded system is connected with sensors and/or actuators. The purpose of the embedded solution is to collect data from the sensors, process them in some degree, and act accordingly through actuators.



# Actuators (1/1)

Actuators are devices capable of influencing the environment when they are triggered with an external signal.



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# Communication (1/1)

Communication between peripherals, sensors and actuators can be either wired or wireless. Depending on requirements for an embedded system one or the other type of communication can be selected.



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# Data types in C language (1/1)

C language offers a variety of data types which differ in size and interpretation. Depending on the architecture the size of a variable can differ [3].



# Floating point operations (1/1)

Some MCUs are equipped with a specialized block called Floating Point Unit (FPU). This block is responsible for hardware acceleration of mathematical operations on floating point variables.





# Global variable initialization

If a global variable should be initialized with a zero value then there should be no initialization at all since it is done by the startup routine.



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# Code optimization in GCC (1/1)

Code optimization can be controlled with `-O` flag passed to `gcc` compiler [2].



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# Lookup table (LUT)

Lookup table is a technique commonly used to store pre calculated data in an array.



# Direct Memory Access (DMA)

DMA is a peripheral available in most of MCUs. It's main purpose is to allow for data transfer between memory regions (program memory, peripheral registers) without direct use of the CPU.



# CMSIS DSP Software Library

DSP library is a set of signal processing algorithms prepared for Cortex-M3 [1].



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# Configuration parameters

Depending on the embedded solution a need of storing configuration parameters can emerge.



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# Bootloader (1/1)

A bootloader is a piece of software which governs the process of loading target firmware. Also, it allows to **download**, **upload** and **verify** the integrity of the firmware. It is usually used to flash a new version of firmware through a common communication interface without a need of specialized hardware – a debugger/programmer.



## Quiz (1/1)

Calculate group number as the rest from dividing the Student ID number by 4.

**Example**

Student ID number is 123456, thus the group is 0.

Take last 2 digits from Student ID number (56) and calculate the rest from dividing by 4 ( $56 \% 4 = 0$ ).

Write down your name, Student ID number and group.



# Literature (1/1)



ARM.

*CMSIS DSP Software Library.*

, 2019.

<http://www.keil.com/pack/doc/CMSIS/DSP/html/index.html>.



R. M. Stallman and the GCC Developer Community.

*Using the GNU Compiler Collection.*

GNU Press, 2003.



J. Yiu.

*The Definitive Guide to ARM<sup>®</sup> Cortex<sup>®</sup>-M3 and Cortex<sup>®</sup>-M4 Processors.*

Newnes, 2013.



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