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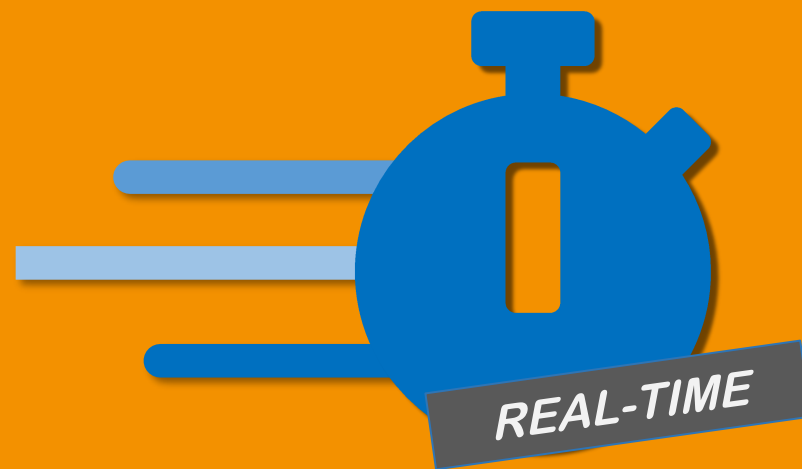**Rosenheim**
Technical University of Applied Sciences

Prof. Dr. Florian Künzner

Technical University of Applied Sciences Rosenheim, Computer Science

ERTS - Embedded real-time systems

ERTS 1 – Intro

REAL-TIME

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Real-time

What is real-time?

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Real-time system

What is a real-time system (RTS)?

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Real-time operating system

What is a real-time operating system (RTOS)?

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Real-time operating system

Which real-time operating systems do you know?

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Goal

Know and **feel** the **real-time requirements**, and be able to **implement** **real-time systems**, with and without a real-time operating system.

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Goal

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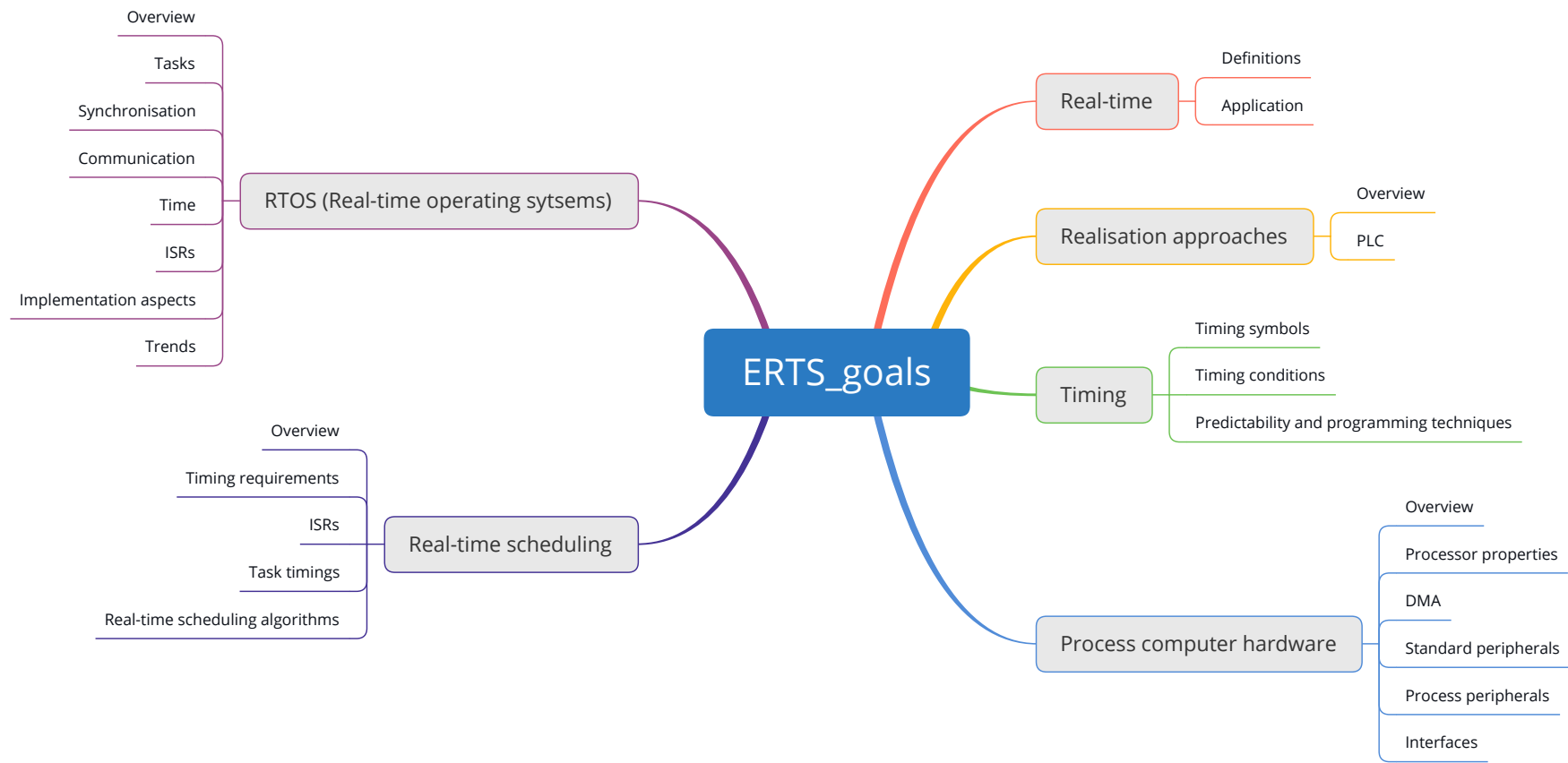
Material

Material for lecture and exercises:

`https://inf-git.th-rosenheim.de/Lectures/ERTS_exercises.git`

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Lectures

Weekly, on **Monday** 08:00 - 09:30
With small, mostly theoretical exercises included

Exercises

Due to the complexity and the HW requirements, the exercises are held as block courses.

Exercise dates:

- Friday, 27.05.2022, 08:00 - 17:00, Ball drop exercise
- Friday, 03.06.2022, 08:00 - 17:00, Response times, signal sampling
- Friday, 10.06.2022, 08:00 - 17:00, Robot (Linux, ROS2)

Equipment:

- All hardware is in the lab (A0.06)
- We have 6 pre-installed notebooks

Exam

Planned is:

- Written exam
- 90 minutes
- Date: 04.07.2021, 08:00 - 09:30

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Application of real-time systems

Used in technical processes to support humans, to:

- automate
- facilitate heavy, complex, or repetitive work
- support very precise requirements: time, quality

Risks:

- Damage in or through the technical process
- Blind trust in real-time systems
- Lack of verifiability

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Technical process

Definitions:

Process   Transformation, storage, or transport of material, energy, or information

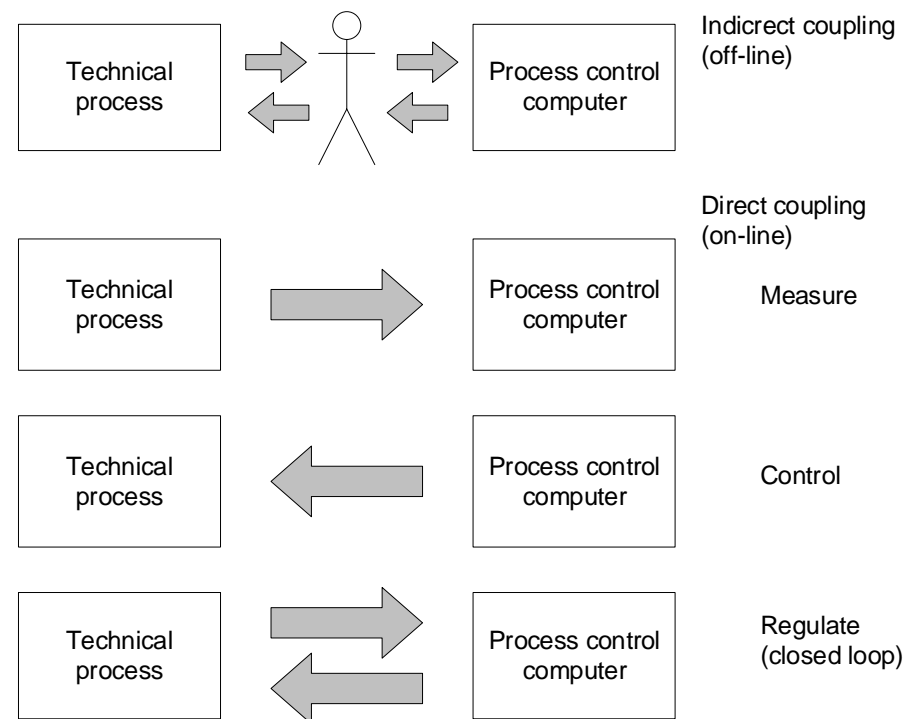Technical process   Process whose state variables can be measured, controlled, or regulated by technical means

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Real-time data processing (1/2)

Definition: Measure, control, and regulate technical processes with a process control computer hardware.

Synonyms:

- Real-time data processing
- Industrial data processing
- Cyber physical system

A suitable **process periphery** is required for direct coupling to the technical process!

Technical process	→ ←	Process control computer	Indirect coupling (off-line)
Technical process	→	Process control computer	Direct coupling (on-line) — Measure
Technical process	←	Process control computer	Control
Technical process	→ ←	Process control computer	Regulate (closed loop)

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Real-time data processing (2/2)

Main task: Knowing the **actual values** (sensors) of the measured variables and their **desired (specified) values**, the actors should **control** (regulate) and the operators should be **informed**, such that the **technical process runs** in the desired manner.

Resulting tasks:

- Determine: **Measure**, **control**, and **regulate** task
    - Mathematical control algorithms and models
    - PID, Fuzzy, …
- Design of the process computer system (requires: experience, enough buffer)
- Connecting the process periphery (modules, interfaces, signal transmission)
- Mapping the structure of the technical process to a programme structure (modularisation, concurrent and distributed algorithms, synchronisation and communication)
- Guarantee real-time requirements
- Guarantee fault-tolerant operation
- Project tasks: cost/benefit analysis, impact assessment (safety, security)

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Real-time system

Definition: A real-time system has to be able to keep up with the time specified by the technical process—always!

Synonyms:

- Real-time system
- Process control computer

Time constraints:

- **Hard**: missing a deadline is a **total system failure** typically related to system-user interactions
- ⇒ Typically safety-critical systems, and related to sensing, actuation, and control activities
- **Firm**: missing a deadline causes **useless results** for the system, but does not cause any damage.
- ⇒ Networked applications and multimedia systems (skip a packet vs process later)
- **Soft**: missing a deadline has **still some utility** for the system (may degrading the system's quality)
- ⇒ Typically related to system-user interactions

source: [2, Buttazzo, p. 9]

Timeliness

The **results** have to be **on-time** depending of the technical process.

Timeliness (time period):

- **Short term**: micro, milli, seconds, minutes
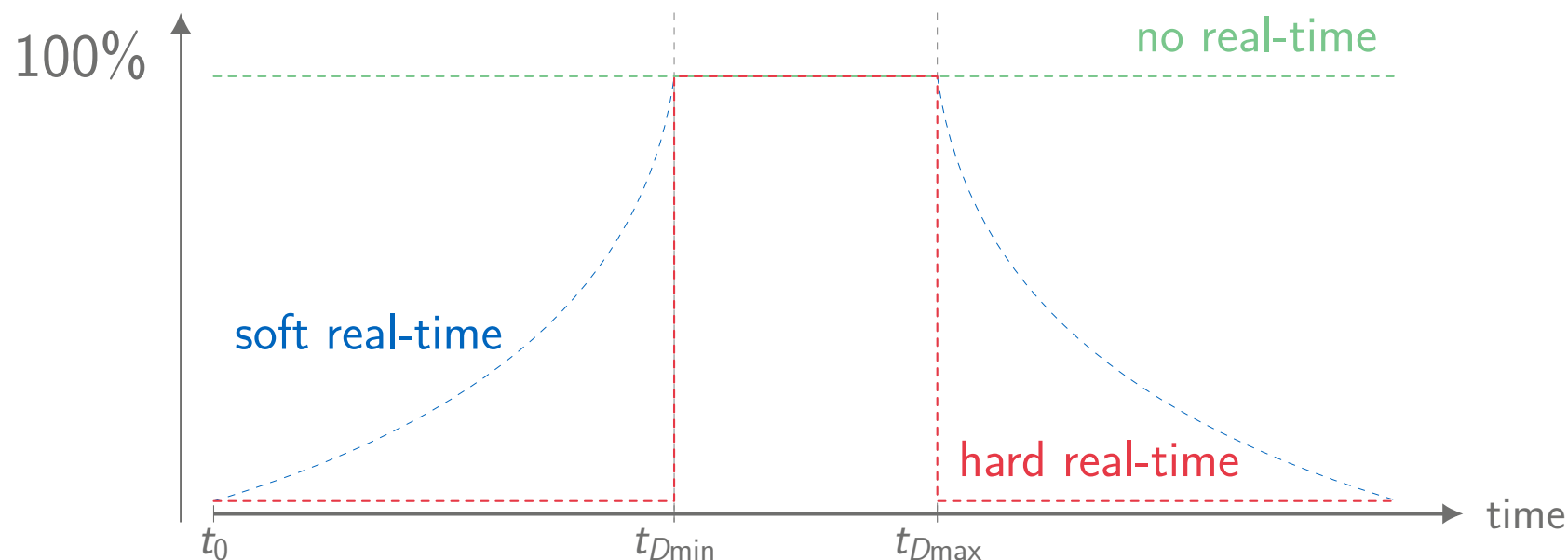- **Long term**: seconds, minutes, hours, days

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Examples

| Example	Time constraints	Timeliness
1. Payroll (Gehaltsabrechnung) until the end of the month	soft	long term
2. The command interpreter of the user interface	soft	short term
3. Weather forecast until 20:14 o'clock	hard/firm	long term
4. Audio/video encoding and decoding for a video conference	firm	short term
5. Control the landing of the space shuttle	hard	short term
6. A robot detects a opening of a security barrier or an end switch	hard	short term
7. Self-driving car drives automatically to its target	hard	short term

more examples: [2, Buttazzo, p. 9–10]

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Real-time system: utility function

- $t_{D\text{min}}$ $\rightarrow$ Minimum allowable deadline (reaction time)
- $t_{D\text{max}}$ $\rightarrow$ Maximum allowable deadline (reaction time)

source: [1, Quade, p. 21]

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Real-time system: timing basics
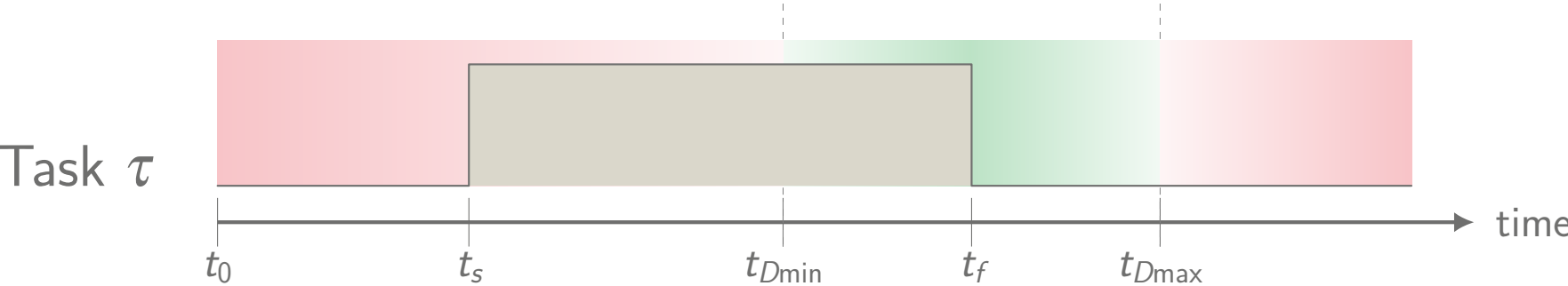
- $t_s \rightarrow$ Start time of task τ
- $t_f \rightarrow$ Finish time of task τ
- $t_{D\mathrm{min}} \rightarrow$ Minimum allowable deadline (reaction time)
- $t_{D\mathrm{max}} \rightarrow$ Maximum allowable deadline (reaction time)

source: [1, Quade, p. 20] and [2, Buttazzo, p. 27]

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Real-time

Real-time means **not** as fast as possible.

Instead, it has to be **predictable** (**deterministic**) and fast enough.

Computers are deterministic
But this can introduce non-deterministic behaviour:

- Abstractions and algorithms (e.g. scheduling mechanisms depending on input parameter)

- Internal characteristics of the processor (e.g. instruction prefetch: pipelining)

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Process computer hardware

The process computer hardware is:

- suitable to process technical process data
- satisfy real-time requirements

Usually, **every computer** can be used as a process computer hardware, **but** this has to be taken into account:

- Vibration-proof and robust (e.g. special buses, industry PC)
- Reliability (cheap Arduino vs more expensive STMicroelectronics)
- Coupling the technical process may require special periphery and interfaces
- Use of real-time operating systems (RTOS) and real-time programming languages

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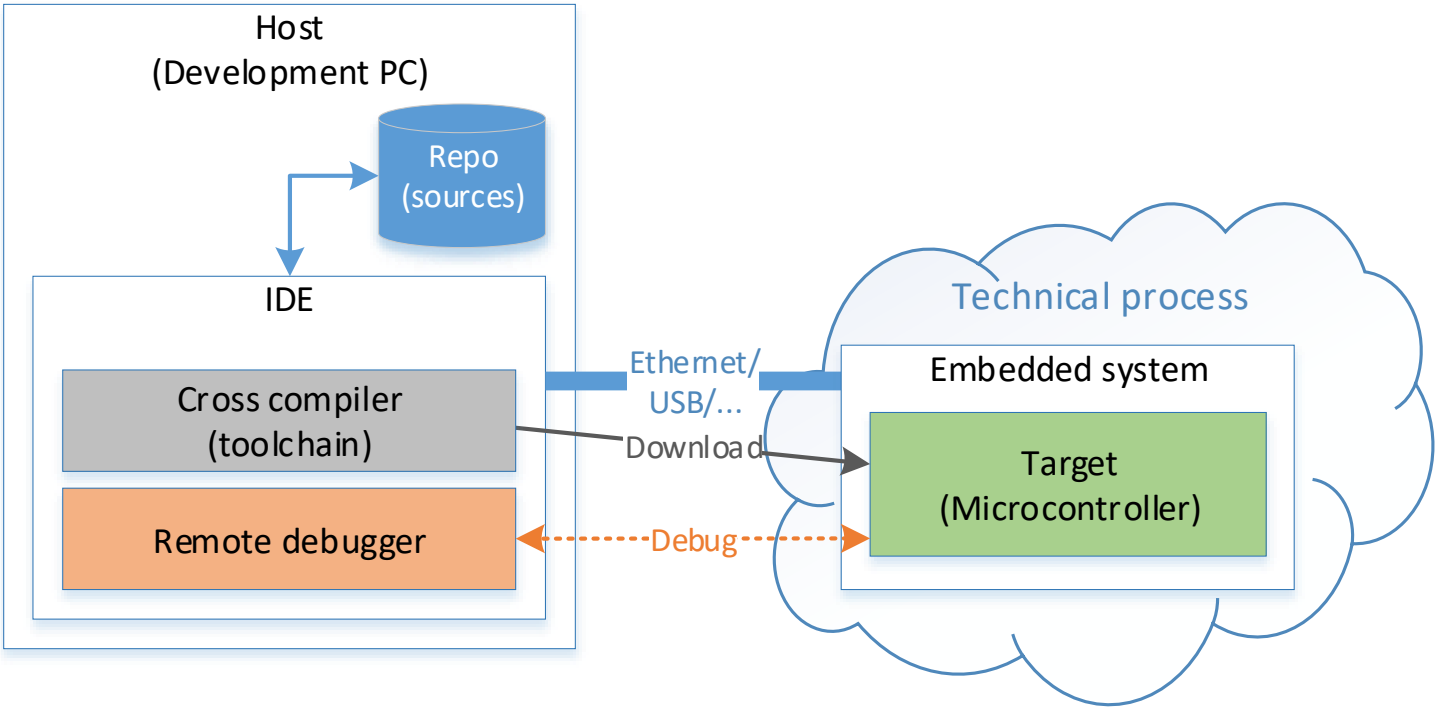
Embedded systems

Embedded systems are often real-time systems (and vice versa).

Special kind of a process computer hardware:

- Embedded into the technical device
- Usually, without standard PC peripheral: mouse, keyboard, ...
- ⇒ Control of an Airbus, washing machine, or ABS control unit
- Sometimes, also with standard PC peripheral
- ⇒ Computer tomograph, CNC control terminal

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Embedded systems
Development environment:

Safety

Embedded systems are often safety critical systems.

Discussion:

Safety vs Security

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Literature (1) - Realzeitsysteme

Moderne Realzeitsysteme kompakt: Eine Einführung mit Embedded Linux

Author(s)	Jürgen Quade, Michael Mächtel
Date	01. October 2012
Edition	1. edition
Language	German
ISBN	978-3898648301
Reference	[1, Quade]

[source: amazon.de]

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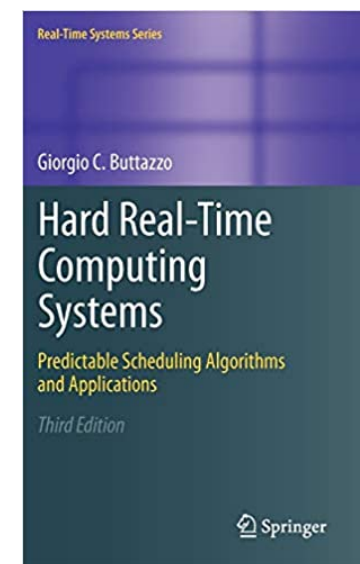
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Literature (2) - Real-time systems

Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications

Author(s)	Giorgio C. Buttazzo
Date	15. September 2011
Edition	3. edition
Language	English
ISBN	978-1461406754
Reference	[2, Buttazzo]

[source: amazon.de]

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Summary and outlook

Summary

- Real-time data processing

- Real-time

- Technical process

Outlook

- Realisation approaches

- PLC