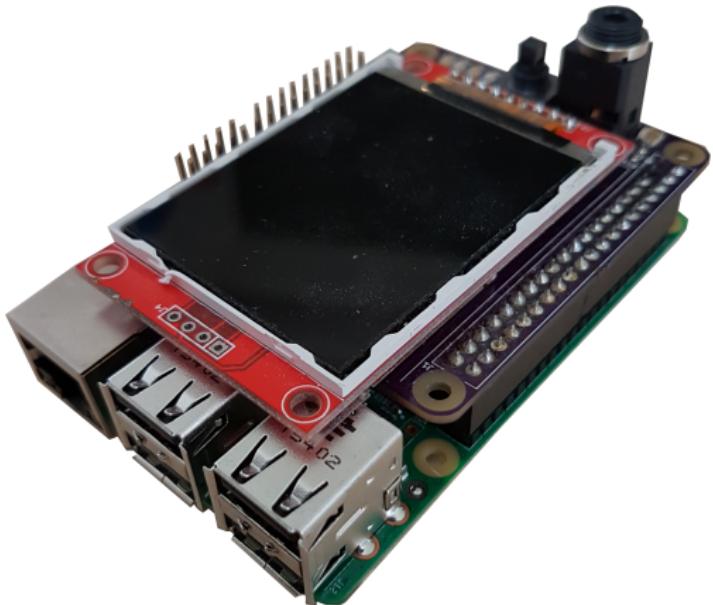


# Embedded Systems Hands-On 1: Design and Implementation of Hardware/Software Systems

## Introduction



# Embedded System

- ▶ Hidden in many devices
- ▶ Small processor
- ▶ Sensors to measure environment
- ▶ Actors to influence environment

# Learning Goals



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- ▶ Electrical engineering basics
- ▶ Usage of laboratory equipment
- ▶ Design and implementation of electronic circuits
- ▶ Acquisition and processing of sensor data
- ▶ Communication buses in embedded systems
- ▶ Programming and debugging heterogeneous embedded systems
- ▶ Linux kernel in embedded systems

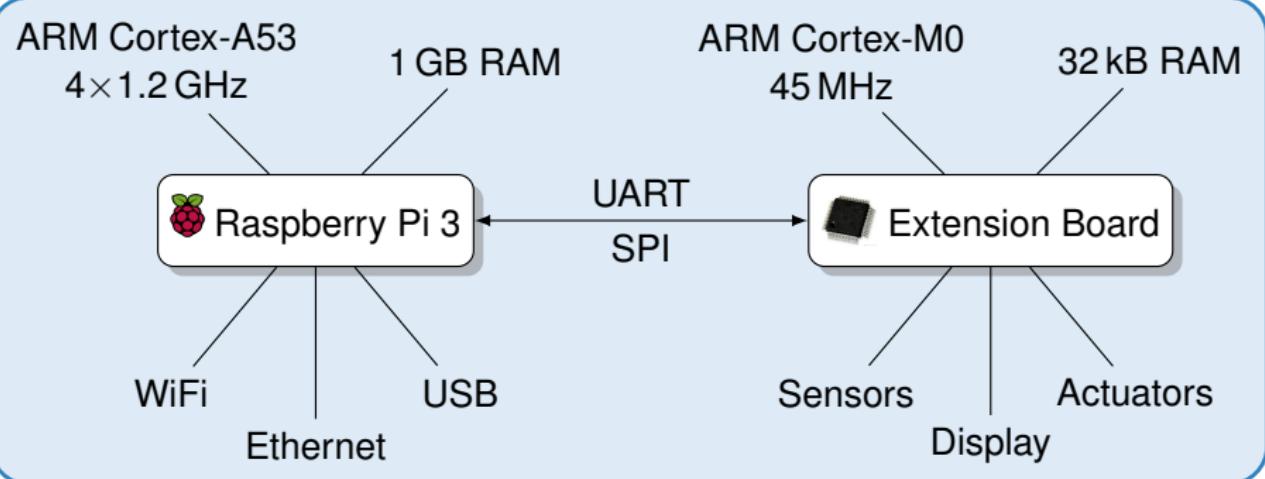
# Hardware Toolkit



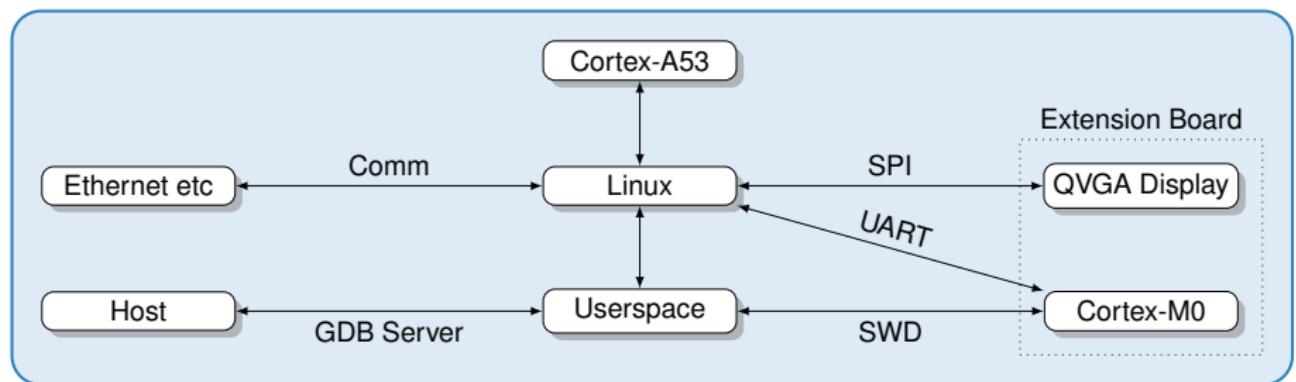
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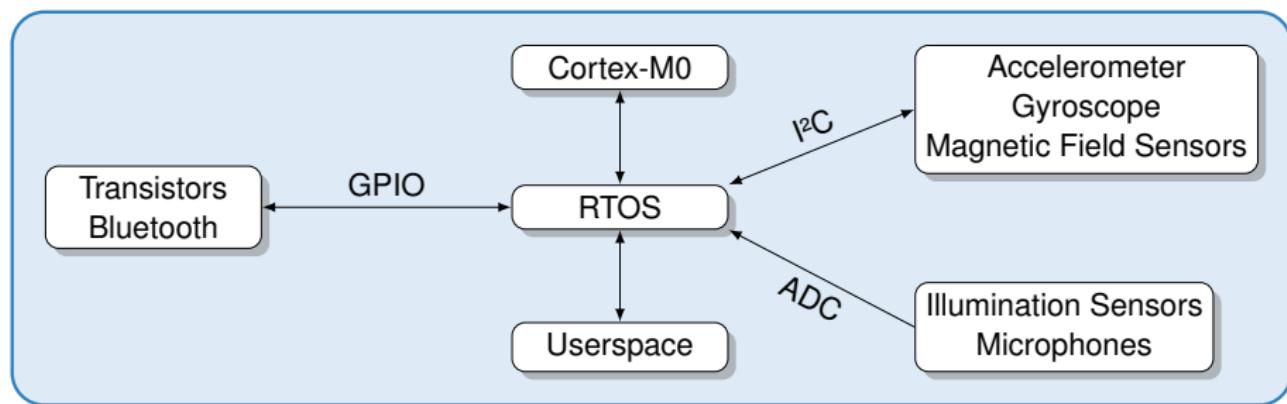
# Heterogeneous Processing System



# Raspberry Pi 3



# Extension Board



# Electrical Engineering Basics

- ▶ Required for interfacing the analog world

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- ▶ (analog) signal conditioning
  - ▶ Amplify
  - ▶ Shift
  - ▶ Frequency-specific filtering

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- ▶ Supporting Software
  - ▶ Circuit simulators
  - ▶ PCB design

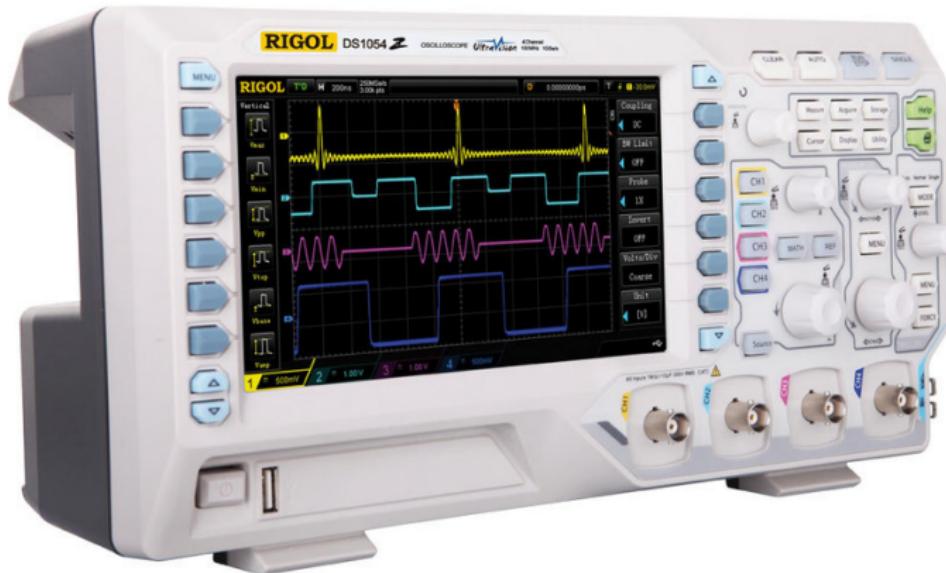
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  - ▶ Frequency-specific filtering
- ▶ Supporting Software
  - ▶ Circuit simulators
  - ▶ PCB design
- ▶ Hands on hardware
  - ▶ Using laboratory measurement systems
  - ▶ Prototyping electronic circuits

# Electrical Engineering Basics



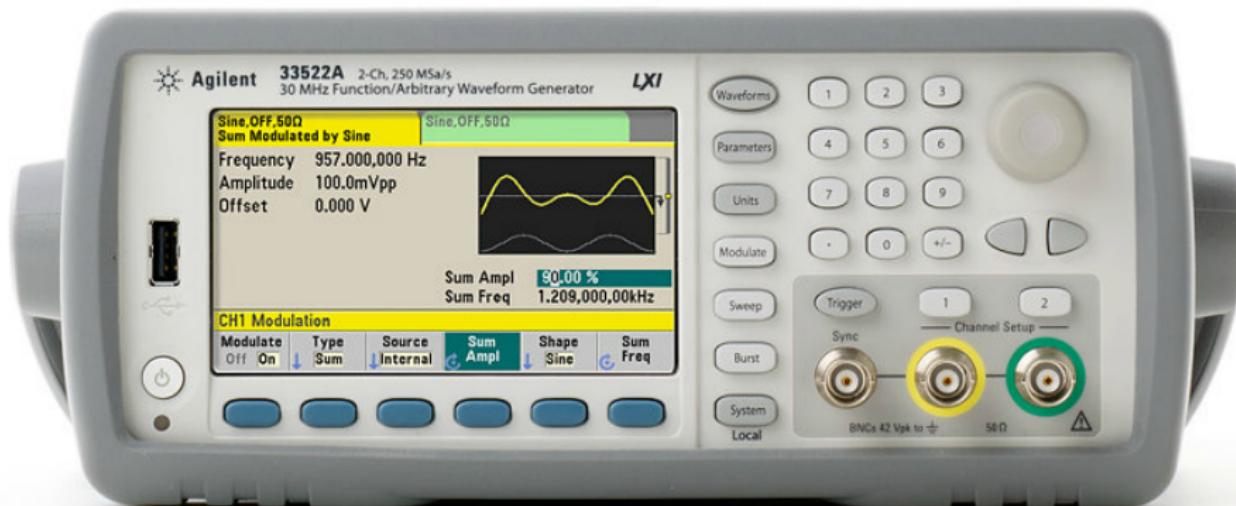
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# Electrical Engineering Basics



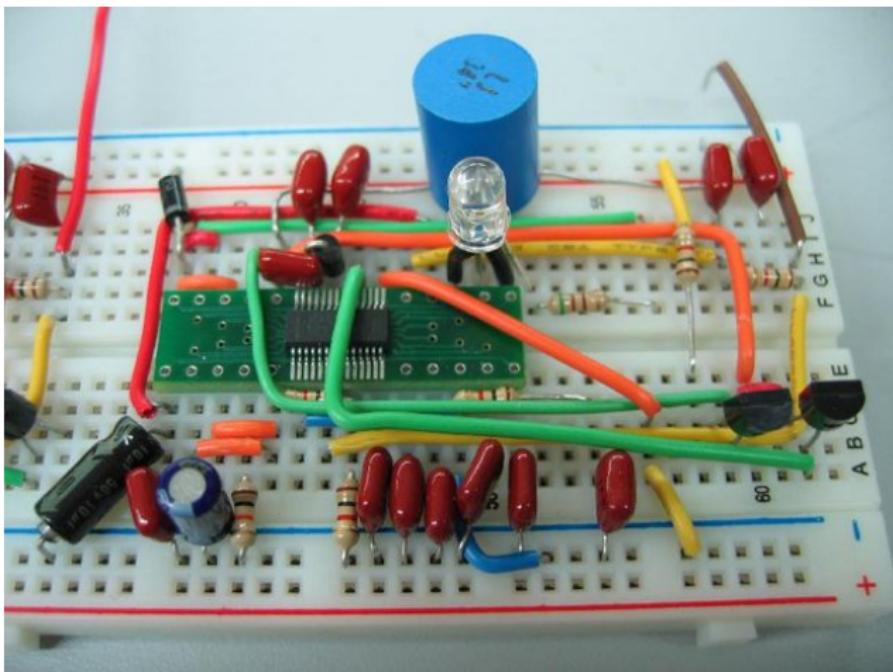
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# Electrical Engineering Basics



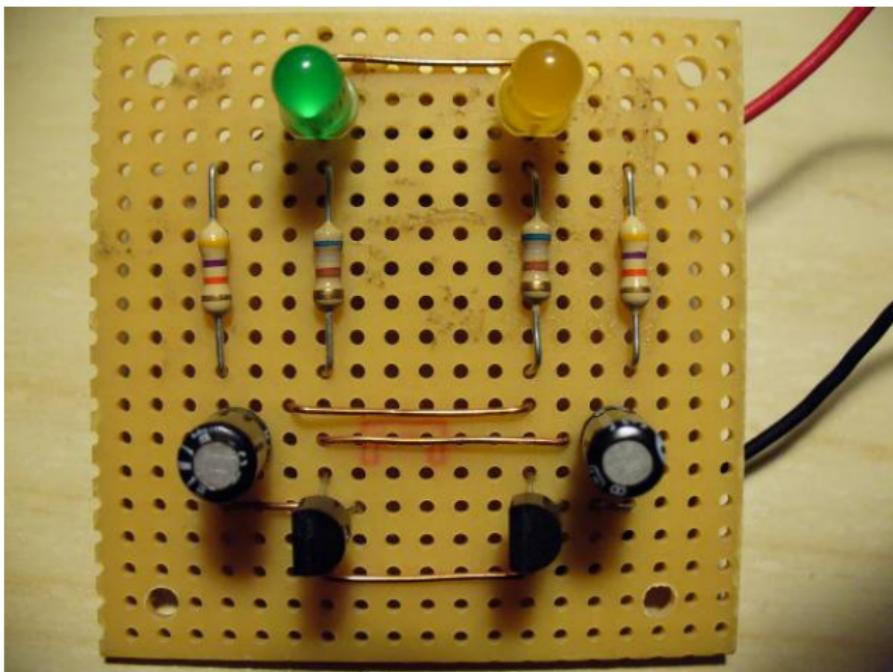
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# Electrical Engineering Basics



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# Electrical Engineering Basics



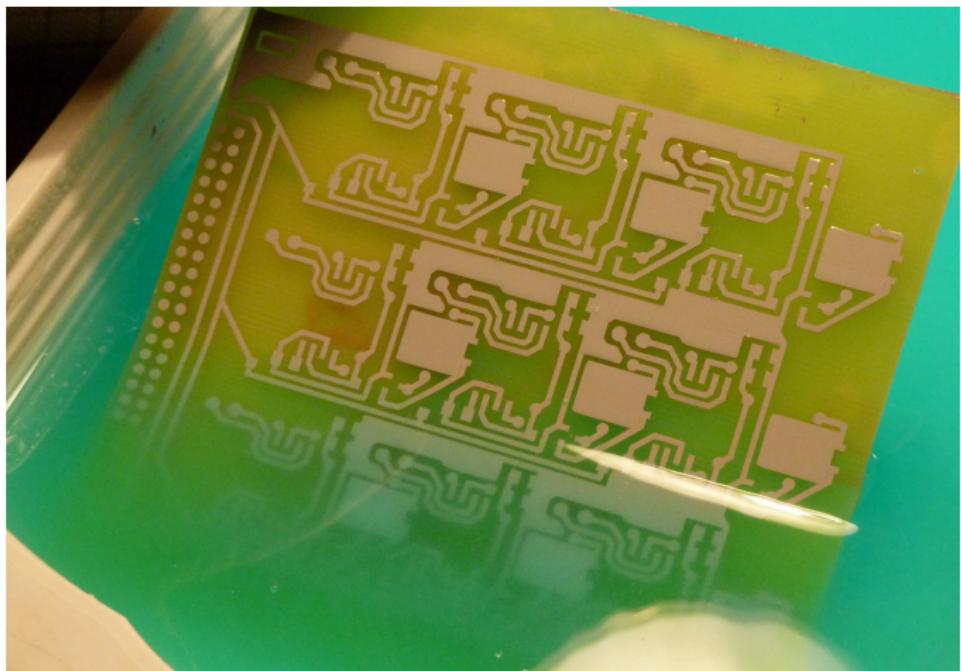
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# Electrical Engineering Basics



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# Task 1: Embedded Linux for the Cortex-A53

- ▶ Operating the Raspberry Pi
- ▶ Starting up an embedded Linux
- ▶ OpenOCD communication with the microcontroller
- ▶ Compiling the Linux kernel with a TFT driver
- ▶ Device tree and kernel modules

## Task 2: Serial Wire Debugging of the Cortex-M0

- ▶ Understanding and implementing SWD
- ▶ Connecting the Cortex-M0 via SWD with a GDB server on the Cortex-A53
- ▶ Remote debugging with Eclipse

# Task 3: Cortex-M0 Bare-metal Programming

- ▶ Controlling GPIO and timers via CMSIS
- ▶ Event-based control with polling and interrupts

## Task 4: Cortex-M0 Connected to External Components

- ▶ Using the ChibiOS HAL
- ▶ UART communication between the Cortex-A53 and the Cortex-M0
- ▶ Sensor control via I<sup>2</sup>C and ADC

# Task 5:

## Analog and Digital Filters

- ▶ Simulation of analog filters with Qucs
- ▶ Observing the behavior of analog filters with waveform generator and oscilloscope
- ▶ Simulation and implementation of digital filters

# Task 6:

## Analog Output

- ▶ Generating and filtering PWM signals
- ▶ Controlling bipolar transistors

# Task 7: Project Application

- ▶ Designed by the participants ⇒ **select ASAP**
- ▶ Peripheral control and data processing
  - ▶ Sensors for acceleration, position, magnetic field, temperature, illumination
  - ▶ TFT displays
  - ▶ Bluetooth transceivers
  - ▶ Ultrasonic transceivers
  - ▶ DCF77 receivers
  - ▶ Speakers
  - ▶ CCD cameras
  - ▶ Solar and thermoelectric modules
  - ▶ 6-DOF robotic arm
  - ▶ may be extended on request
- ▶ Focus on hardware or software possible

# Completion

- ▶ Colloquia
- ▶ Demo day
  - ▶ Present your projects

# Organization

- ▶ Max. 10 groups of three persons ⇒ **Provide feedback until 30.04.2020**
  - ▶ Send email with name, TU-ID to [heinz@esa.tu-darmstadt.de](mailto:heinz@esa.tu-darmstadt.de)

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  - ▶ in lab room E104 (5 work stations)
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  - ▶ Discussion forum: **GitLab instead of Moodle**
- ▶ Two submission deadlines:
  - ▶ T1-T6 by beginning of August
  - ▶ T7 by end of October

# Organization - Changes

- ▶ Distribution of Toolkits

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  - ▶ Try out different options!
  - ▶ Find solution that works for you
- ▶ Start of Task 5-7 adapted to circumstances

# GitLab used as Central Communication Platform



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- ▶ Material, submissions, issues with discussion forum

# GitLab used as Central Communication Platform

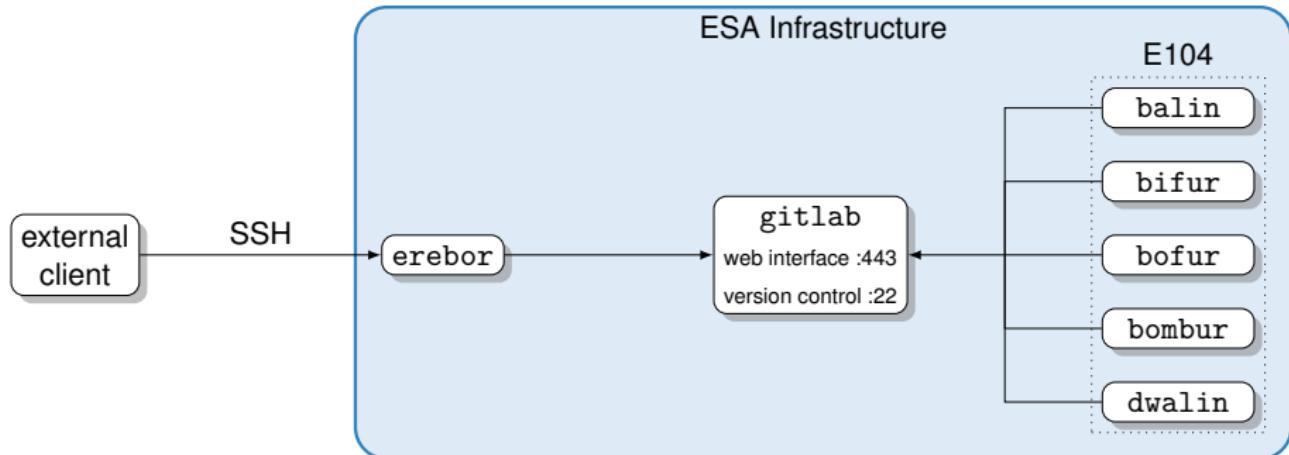


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- ▶ Material, submissions, issues with discussion forum
- ▶ Login-Accounts provided after groups are built

# GitLab used as Central Communication Platform

- ▶ Material, submissions, issues with discussion forum
- ▶ Login-Accounts provided after groups are built
- ▶ See setup notes on the lab homepage (`overview.pdf`)



# GitLab used as Central Communication Platform



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S ESHO1 / Materials · GitLab + https://gitlab.esa.informatik.tu-darmstadt.de/ESHO1\_2020/Materials

Projects Groups More Search or jump to... 22 19 2 0 0

M Materials ESHO1 > Materials > Details

**Materials** Project ID: 704 1 Commit 1 Branch 0 Tags 195 KB Files 195 KB Storage

master Materials / Clone

Add Readme Carsten Heinz authored 4 minutes ago 0813886f

README Add LICENSE Add CHANGELOG Add CONTRIBUTING Enable Auto DevOps

Add Kubernetes cluster Set up CI/CD

Name	Last commit	Last update
README.md	Add Readme	4 minutes ago

Collapsible sidebar README.md

# GitLab used as Central Communication Platform



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M Materials

Project overview

Details Activity Releases

Repository Issues 0 Merge Requests 0 CI / CD Operations Analytics Wiki

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https://gitlab.esa.informatik.tu-darmstadt.de/ESHO1\_2020/Materials

README.md

## Embedded Systems Hands-On 1: Design and Implementation of Hardware/Software Systems (summer term 2020)

All relevant materials and information will be provided in this area:

- Lab description
- Presentation slides
- Task presentations
- Task descriptions
- Source code libraries
- Meeting schedules and deadlines

Besides, the issues of this project will be used to discuss task-specific questions, and provide relevant information to all participants.

### Upcoming Events

Date	Time	Location	Info
		Gitlab	Deadline for task 6

# GitLab used as Central Communication Platform



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New Issue · ESHO1 / Mai x +

https://gitlab.esa.informatik.tu-darmstadt.de/ESHO1\_2020/Materials/-/issues/new

Projects Groups More Search or jump to... 22 19 ? ⚙

M Materials ESHO1 > Materials > Issues > New

Project overview Repository

Issues List Boards Labels Milestones 0

Merge Requests 0 CI / CD Operations Analytics

## New Issue

Title Title Add [description templates](#) to help your contributors communicate effectively!

Description Write Preview Write a comment or drag your files here...

Markdown and [quick actions](#) are supported Attach a file

This issue is confidential and should only be visible to team members with at least Reporter access.

Assignee Unassigned Due date Select due date

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# Embedded Systems Hands-On 1: Design and Implementation of Hardware/Software Systems

## Questions?



- ▶ By email [heinz@esa.tu-darmstadt.de](mailto:heinz@esa.tu-darmstadt.de)
- ▶ Consultation hour:
  - ▶ Tuesday, 28.4.2020 16:00
  - ▶ <https://zoom.us/j/96650339861>

