EIT Digital Master School

Embedded Systems

What can I study at the entry and exit points?

eit Digital

FOR A STRONG
DIGITAL EUROPE

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Entry - 1st year, common courses

KTH Royal Institute of Technology (KTH), Sweden

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- Programme homepage

Contact: Matthias Becker, mabecker@kth.se”

Students going to exits TU Berlin and TU Eindhoven do only have mandatory courses in year 1. Other exits can choose more freely.

Compulsory courses:

ID2202 Compilers and Execution Environments Mandatory for INSY exit Aalto, TU Berlin, TU Eindhoven. Elective for others.	7.5	Q2
IL2206 Embedded Systems	7.5	Q1
IL2212 Embedded Software Mandatory for INSY exit Aalto, TU Berlin, TU Eindhoven. Elective for others.	7.5	Q3
IS2202 Computer Systems Architecture Mandatory for INSY exit Aalto, TU Berlin, TU Eindhoven. Elective for others.	7.5	Q4

Electives courses:

AK2036 Theory and Methodology of Science with Applications (Natural and Technological Science) One of II2202, AK2036 shall be chosen	7.5	Q1, Q2, Q3 or Q4
ID2218 Design of Fault-tolerant Systems Elective for INSY exit UNITN, UTU, BME	7.5	Q4
II2202 Research Methodology and Scientific Writing One of II2202, AK2036 shall be chosen	7.5	Q1
II2302 Sensor Based Systems Elective for INSY exit UNITN, UTU, BME	7.5	Q1, and Q2
IL2203 Digital Design and Validation with HDL Elective for INSY exit UNITN, UTU, BME	9	Q1
IL2225 Embedded Hardware Design in ASIC and FPGA Elective for INSY exit UNITN, UTU, BME	7.5	Q2
IL2237 Electronic Systems Design Elective for INSY exit UNITN, UTU, BME	7.5	Q4
IL2238 Fundamentals of Integrated Electronics Elective for INSY exit UNITN, UTU, BME	7.5	Q2
IL2239 Analog-Digital Interfaces Elective for INSY exit UNITN, UTU, BME	7.5	Q4

ME2062 Technology-based Entrepreneurship One of ME2062, ME2094, ME2095 shall be chosen	7.5	Q3
ME2094 Internet Marketing One of ME2062, ME2094, ME2095 shall be chosen	7.5	Q2
ME2095 e-Business Strategies One of ME2062, ME2094, ME2095 shall be chosen	7.5	Q4

I&E

ME2072 Entrepreneurship for Engineers	6.0
ME2073 Business Development Lab of Entrepreneurship Engineers	9.0
ME2078 Summer Course- Entrepreneurship for Engineers	4.0

University of Bologna (UNIBO), Italy

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Compulsory courses:

- Business Models - (6 ECTS)
- Fundamentals of Corporate Finance - (6 ECTS)
- Organization, Teams and Digital Leadership - (6 ECTS)
- Cybersecurity - (6 ECTS)
- Software Engineering for Intelligent Distributed Systems - (6 ECTS)

- Lab. of Network Programmability and Automation - (6 ECTS)
- EIT Summer School - (4 ECTS)
- EIT lab. - (2 ECTS)

Electives – 6 ECTS to be chosen

- Embedded Systems and Internet of Things - (6 ECTS)
- Pervasive Computing - (6 ECTS)

Electives – 12 ECTS to be chosen

- Pervasive Computing - (6 ECTS)
- Intelligent Robotic Systems - (6 ECTS)
- Smart Vehicular Systems - (6 ECTS)

University of Turku (UTU), Finland

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Contact: Dr Tomi Westerlund, tomi.westerlund@utu.fi

TECHNICAL MODULE	(25 ECTS)
System Modelling and Synthesis with HDL	(5 ECTS)
Hardware Accelerators for Robotics and AI	(5 ECTS)
Robotics and Autonomous Systems	(5 ECTS)
Perception and Navigation in Robotics	(5 ECTS)
Autonomous Systems Architectures	(5 ECTS)
I&E MODULE	(25 ECTS)

Enterprise Architecture	(6 ECTS)
Introduction to Innovation and Business	(5 ECTS)
Business Development Laboratory	(7 ECTS)
Business Management of Startups	(3 ECTS)
EIT Digital Summer School	(4 ECTS) during the summer between the entry and exit years

Also, at least 10 ECTS of elective studies need to be taken during the entry year to obtain at least 60 ECTS in total. For example, Data Analysis and Knowledge Discovery (5 ECTS), Algorithm Design (5 ECTS), or Machine Learning and Algorithmics Seminar (5 ECTS)

Exit - 2nd year, specialisation

Budapest University of Technology and Economics, Hungary

Visit:

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Contact: **Tamás Dabóczi**, daboczi@mit.bme.hu

Specialisation: Critical Embedded Systems

BME offers a specialisation on embedded system for which the safety, reliability, fault tolerance, availability and reaction time are crucial. Among many fields this includes automotive industry (engine management, safety systems, advanced driver assistance systems etc.), railway control, aerospace industry, medical instrumentation. The specialisation provides skills for designing complex systems, designing components of the systems, for verification and validation, and also for operation and maintenance of the system.

Students can select a branch from a set of different areas of critical systems, based on their interest. This includes hardware and software verification and validation, design paradigms for safety critical applications like automotive embedded systems or medical applications.

Compulsory courses (52 ECTS):

Third semester:

- Critical Embedded Systems (VIMIMA16, 4 ECTS)
- Design and Integration of Embedded Systems (VIMIMA11, 4 ECTS)
- Diploma Thesis Design 1 (VIMIMT00, 10 ECTS)
- Innovation & Entrepreneurship Study (VIMIMT06, 6 ECTS)

Fourth semester:

- ARM Cortex Core Microcontrollers (VIMIAV07, 4 ECTS)

- Software Technology for Embedded Systems (VIMIMA09, 4 ECTS)
- Diploma Thesis Design 2 (VIMIMT01, 20 ECTS)

Electives courses (two from the following set, min. 8 ECTS):

- Artificial Intelligence Based Control (VIIIMA09, 4 ECTS)
- Computer Vision Systems (VIIMA07, 4 ECTS)
- Development of Software Applications (VIAUMA09, 4 ECTS)
- Communication Technologies of Autonomous Vehicles (VIHIM008, 4 ECTS)
- ... and possible others, depending on the semester and the number of applicants.

Total credits for the whole exit year: 60 ECTS.

There is a strong cooperation with the industry in the field of dependable embedded systems. The most appropriate link to this cooperation is the thesis work at industrial partners. Many large automotive research centres reside in Budapest (thyssenkrupp, Bosch, Knorr-Bremse, Continental), and also other embedded system developers like Ericsson.

Prof. Tamás Dabóczi is Head of the Department of Measurement and Information Systems, Budapest University of Technology and Economics, Budapest, Hungary. Besides coordinating the EIT Digital Master School Critical Embedded Systems specialisation, he has been involved in developing four new Embedded Systems (ES) specialisations both at BSc and MSc level in the past years. He teaches Real-time systems, Embedded and ambient systems, and Information processing within ES tracks.

His research area is embedded systems, with special emphasis on information processing and numerical correction of distortions. He has published around 80 papers in areas of signal processing, embedded systems, and cyber-physical systems. He has been visiting scientist at Swiss Federal Institute of Technology (ETH, Zürich, Switzerland), at Technical University of Karlsruhe (Karlsruhe, Germany), and at National Institute of Standards and Technology (NIST, Gaithersburg, MD, USA). He cooperates with the leading international R&D companies in Budapest like thyssenkrupp, Bosch and Ericsson. Tamás has led many national and international research- and industrial development projects.

KTH Royal Institute of Technology (KTH), Sweden

Visit University homepage

Contact: **Matthias Becker**, mabecker@kth.se

Specialisation: Embedded Platforms

Compulsory courses:

Degree project 30 credits advanced level is mandatory during the spring term.

In accordance with KTH's regulations, a mandatory course in Research Methodology and Scientific Writing 7,5 credits needs to be included. This course can be taken anytime during the studies. Currently, the following courses are offered:

- II2202 Research Methodology and Scientific Writing - 7,5 credits (P1 only)
- AK2036 Theory and Methodology of Science with Applications (Natural and Technological Science) - 7,5 credits

Compulsory courses:	**ECTS cr.**	**Study period**
IL2217 Digital Design with HDL *Students that have studied VHDL before, can apply for replacing this course with an elective one instead*	7.5	This course will not be given anymore
IL2203 Digital Design and Validation using HDLs	9	Q1

Conditionally elective courses:	**ECTS cr.**	**Study period**
AK2036 Theory and Methodology of Science with Applications (Natural and Technological Science) *One of II2202, AK2036 shall be choosen*	7.5	Q1, Q2, Q3 or Q4

II2202 Research Methodology and Scientific Writing *One of II2202, AK2036 shall be choosen*	7.5	Q1

Electives courses:

Optional	ECTS cr.	Study period
II2300 Product Realization Processes I	7.5	Q2
II2302 Sensor Based Systems	7.5	Q3
IL2225 Embedded Hardware Design in ASIC and FPGA	7.5	Q2
IL2232 Embedded Systems Design Project	15	
IL2236 Embedded Many-Core Architectures	7.5	Q4
IL2452 System Design Languages	7.5	This course will not be given in 2019/2020
IS2500 RFID Systems	7.5	Q1

I&E

ME2096 ICT Innovation Study Project	6.0	Q1

Dr. Matthias Becker is Assistant Professor at KTH Royal Institute of Technology since November 2019. Since 2020, he is the coordinator of the Embedded Platform Track of the EIT Digital Master School program. His main research interests are the design and analysis of real-time and embedded systems. In this area, Matthias has co-authored over 50 publications in peer-reviewed international journals, conferences and workshops. He received his B.Eng. degree in Mechatronics/Automation Systems from the University of

Applied Sciences Esslingen, Germany in 2011. In the year 2013 he got his M.Sc. degree in Computer Science specializing in embedded computing from the University of Applied Sciences Munich, Germany. He received his Licentiate and PhD degree in Computer Science and Engineering from Mälardalen University in 2015 and 2017 respectively. Matthias has been a visiting researcher at CISTER - Research Centre in Real-Time and Embedded Computing Systems in Porto, Portugal for two months in 2015 and for three months in 2016 and he has been postdoctoral researcher at KTH Royal Institute of Technology in 2018 and 2019.

University of Trento (UniTN), Italy

Visit:

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- Programme homepage

Contact: **Prof Luigi Palopoli**; luigi.palopoli@unitn.it

Specialisation: Real-Time Systems and Design of Cyber-Physical Systems

UNITN provides a specialisation on real-time systems, a particular class of embedded systems that are required to operate in close connection with the environment. The prominent issue for a successful design of a real-time system is its predictability: the system has to be bug free to the maximum degree allowed by the current industrial practice, it has to react to external stimuli in a predictable time and has to optimize resource utilization. Students will be exposed to the most recent trends on safety critical systems, embedded control systems and sensor networks.

Track 1: Real-Time Embedded Systems
Real-time systems are a particular class of embedded systems that are required to operate in close connection with the environment. The prominent issue for a successful design of a real-time system is its predictability: the system has to be bug free to the maximum degree allowed by the current industrial practice, it has to react to external stimuli in a predictable time and has to optimize resource utilization. To be able to develop a real-time system, a student has to be in command of several foundational disciplines on software development, computing architecture, model-based design. In addition, he/she will be exposed to the most

recent trends on safety critical systems, embedded control systems and sensor networks. This rich basis of knowledge is constructed through the mandatory courses and elective courses, while a wide choice of optional courses enable the students to enrich their expertise in areas that are tightly related to embedded systems (e.g., distributed systems, security, software technologies). Laboratory experiences in which the students are required to operate on robotic and multimedia application contribute to the construction of practical skills that prove essential in the daily work experience on embedded real-time systems.

Compulsory courses (24 ECTS):

- Laboratory of Applied Robotics (6 ECTS)
- Real-Time Operating Systems (6 ECTS)
- Laboratory of Sensor Networks (6 ECTS)
- Advanced Computing Architectures (6 ECTS)

Electives:

- Distributed Algorithms (6 ECTS)
- Network Security (6 ECTS)
- Nomadic Communication (6 ECTS)
- Formal Methods (12 ECTS)
- Simulation and Performance Evaluation (6 ECTS)
- Research Project in Embedded Systems (12 ECTS)

Track 2: Methodologies for Cyber-Physical Systems Design

Cyber-physical systems are a new generation of systems with integrated computational and physical abilities that interact with humans through a number of new modalities and operate in open environments. The potential applications of cyber-physical systems are beyond count; a few examples are next-generation airplanes and space vehicles, hybrid gas-electric vehicles, fully autonomous urban driving, and prostheses that allow brain signals to control physical objects. Over the years engineering disciplines have defined powerful methods to design systems able to operate in the environment (e.g., frequency domain techniques, optimal control, stochastic control etc.). Meanwhile, research in computing systems has produced a wealth of innovative ideas on how to exploit modern computing architectures to their full extent (e.g., using reconfigurable hardware and optimised compilers). The challenges posed by the design of cyber-physical systems call for new ideas and methods that stay at the confluence between once separate disciplines (Engineering and Computer Science). Additional contributions can arrive from social sciences through the establishment

of Human Machine Interaction as a new science in its own right. Receiving exposure to these disciplines is crucial for a study programme tailored for future professional operating in this area, but the complex expertise required can be constructed only through hands-on experience on a real-life design problems of cyber-physical systems. This is the objective of this specialisation track.

Compulsory courses (18 ECTS):

- Capstone Project Module (18 ECTS):
    - Includes an industry-driven multidisciplinary design project (12 ECTS) and a project-oriented course (6 ECTS) selected from: Laboratory of Applied Robotics, Digital Image Processing, HW/SW Co-Design, Laboratory of Sensor Networks

Electives (min. 6 ECTS):

- Real-Time Operating Systems (6 ECTS)
- Advanced Computer Architectures (6 ECTS)
- Simulation and Performance Evaluation (6 ECTS)

Prof Luigi Palopoli is the coordinator of Embedded Systems major at Trento University, Italy. He is associate professor and received his PhD degree from the Scuola Superiore S. Anna, Pisa, Italy, which is one of the most active university sites worldwide in real-time systems. He has a strong network of collaborations with several institutions working on real-time scheduling, control and robotics. He is the coordinator of an EU project on assistive robotics (www.ict-dali.eu). The research on embedded system in Trento is carried within the EECS research program at the DISI department. Research activities in embedded systems are on sensor networks, design methodologies, real-time control and robotics.

University of Turku (UTU), Finland

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Contact: **Dr Tomi Westerlund**, tomi.westerlund@utu.fi

Specialisation: Smart Systems

In the Smart Systems specialisation, students will get a strong knowledge base for designing and implementing autonomous and intelligent systems. For example, the programme focuses on various hardware and software architectures, hardware accelerators, reconfigurable circuits, and device-specific programming, with preference to integrate intelligence and sensors into actuators. Individual and group assignment projects are related to several courses and are an integral part of the courses. Graduate students will be able to meet the new challenges posed by the increasing complexity of the systems.

Specialisation electives (choose 25 ECTS):

- Capstone Project (10 ECTS)

Which is an Industry-driven multidisciplinary design project in the field of Autonomous Systems and Robotics. Other elective courses at UTU are:

- Perception and Navigation in Robotics (5 ECTS)
- System Modelling and Synthesis with HDL (5 ECTS)
- Hardware Accelerators for Robotics and AI (5 ECTS)
- Robotics and Autonomous Systems (5 ECTS)
- Autonomous Systems Architectures (5 ECTS)
- Data Analysis and Knowledge Discovery (5 ECTS)
- Algorithm Design (5 ECTS)
- Machine Learning and Algorithmics Seminar (5 ECTS)
- Analytics for Industrial Internet (5 ECTS)
- System Architecture of IoT (5 ECTS)
- Multidimensional Sensing Techniques (5 ECTS)

- System and Application Security (5 ECTS)

The preference is to select the elective courses from the above list, but depending on the time of the internship, a student should discuss with Tomi Westerlund before enrolling the course. The mandatory specialisation studies include a **Master's Thesis** (30 ECTS) and **I&E Study** (6 ECTS).

Upon completion of the Smart Systems specialisation, students will be able to design and implement hardware accelerators and embedded systems for different sets of sensors and data processing approaches. A student will understand the basic concepts of robotic perception, mapping and navigation and acquire data from different sensors and convert it for visualization and analysis to be used with real robots. Students will be able to utilise different approaches for the design of control systems in robotics.

The local coordinator for the specialisation, **Dr Tomi Westerlund**, is the leader of the Turku Intelligent Embedded and Robotic Systems (https://tiers.utu.fi) research group at the University of Turku. He has a long experience in education and research in the field. His main research interest is in Multi-robot Systems and Autonomous Robots. Specifically focusing on the collaborative operation of heterogenous robots and UAVs/UGVs, localization and mapping in dense urban and unstructured environments by utilizing artificial intelligence at the edge (embedded and distributed intelligence).

EIT Digital

We believe in making and shaping a competitive digital Europe that is inclusive, fair and sustainable and aim at global impact through European innovation fueled by entrepreneurial talent and digital technology.

We embody the future of innovation by mobilizing a pan-European multi-stakeholder open-innovation ecosystem of top European corporations, SMEs, startups, universities and research institutes, where students, researchers, engineers, business developers and investors address the technology, talent, skills, business and capital needs of digital entrepreneurship.

We build the next generation of digital ventures, digital products and services, and breed digital entrepreneurial talent, helping business We build the next generation of digital ventures, digital products and services, and breed digital entrepreneurial talent, helping business and entrepreneurs to be at the frontier of digital innovation by providing them with technology, talent, and growth support:

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