Electronic Design Laboratory

Facility

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Center for Human Technologies
Via Enrico Melen 83
Genova, Italy

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Center for Human Technologies (CHT)

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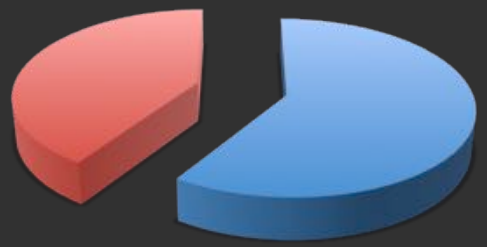
Administrative: 4%
Technicians: 18%
Ph.D. Students: 26%
Scientists: 52%



Men: 59%
Women: 41%

98 people (May 2017)

The **Center for Human Technologies (CHT)** started in July 4° 2016. Up to Dec. 2017, the center comprises four research lines and a facility. The CHT is devoted to the study and the development of human centered social, cognitive, rehabilitative and diagnostic technologies, including the interaction between human and humanoid robots.

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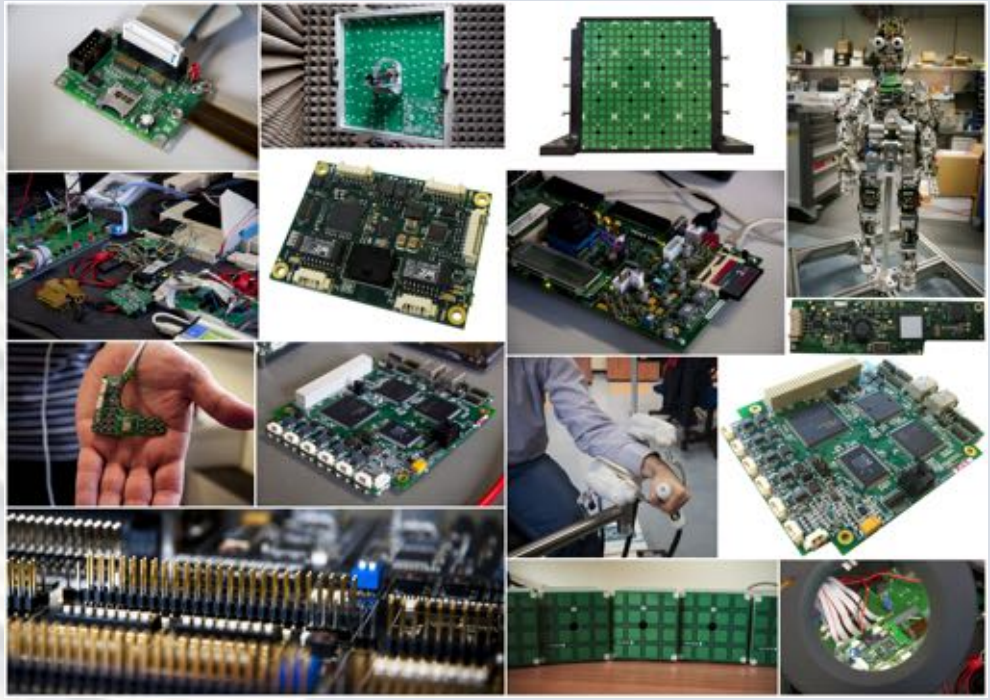

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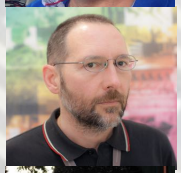
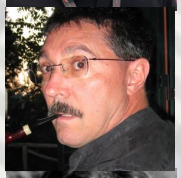
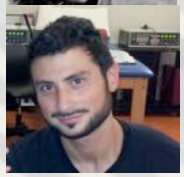
Electronics Design Laboratory

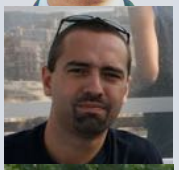
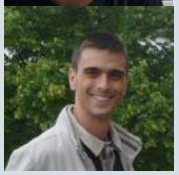
- An IIT **facility** providing both design service and research for the IIT network.
- Our mission regards both 1) **electronics design service** to meet research applications, 2) technical support and small batch projects, 3) **research** in electronics and microelectronics design to favor multidisciplinary research applications.
- Our business is **design**.

The EDL Group





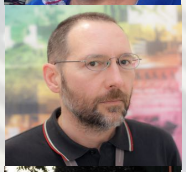




Collaborators at PoliTO (Co. coordinated w. Danilo Demarchi)

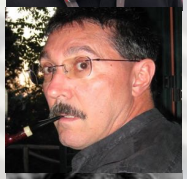
Paolo Motto Ros (PoliTo)

The EDL Group

Giorgio Zini
Low-power Embedded Systems
Microprogrammed Architectures
Low-Power Radio Systems

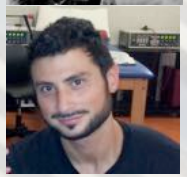


Claudio Lorini
Motor Control Systems
Power Electronics Systems
Comm. Systems for Industrial Automation



Antonio Maviglia
Hardware and Software Design
Short-Term Physical PCB Design
Microprogrammed architectures

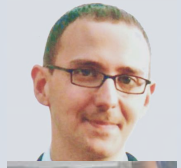
Marco Crepaldi
Mixed Signal Integrated Circuit Design
Ultra-low Power Integrated Radio Systems
Modeling and Design Methodologies



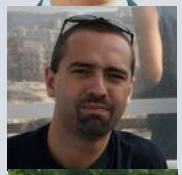
Alessandro Barcellona
Hardware Design
Reworking And Assembly Management
Short-Term Electrical/Physical Design

Francesco Diotalevi
Digital FPGA Design/ASIC Digital Design
Embedded Systems Design
Hardware/Software Design

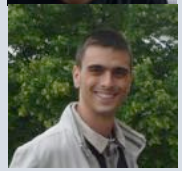
Andrea Merello
Application Software Engineering
Hardware/Software Firmware Design
Operating Systems Engineering



Davide Dellepiane
Mechanical Components Integration
Assembly, Small PCB and Connectivity Design
Reworking and Assembly Management



Luca Rivano
Supply Chain Procedure Management
Internal Warehouse Control
Component Entry EDA Control



Mirco Di Salvo
Application Software Engineering
Hardware/Software Firmware Design
Software Algorithm Design

Collaborators at PoliTO (Co. coordinated w. Danilo Demarchi)

Paolo Motto Ros (PoliTO)

Neuromorphic Circuits & Systems
Design
Integrated Circuits Design

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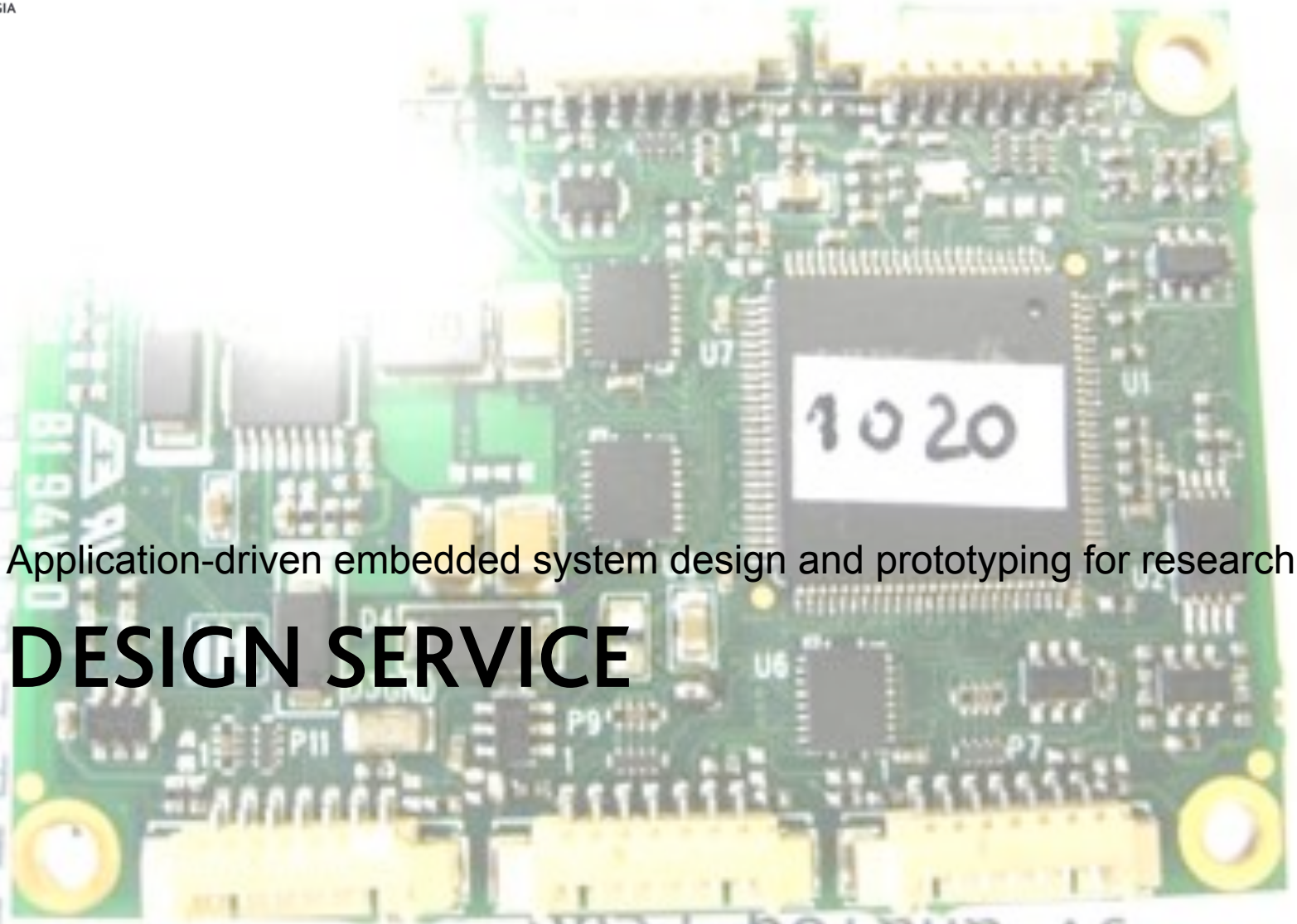

Application-driven embedded system design and prototyping for research.

DESIGN SERVICE

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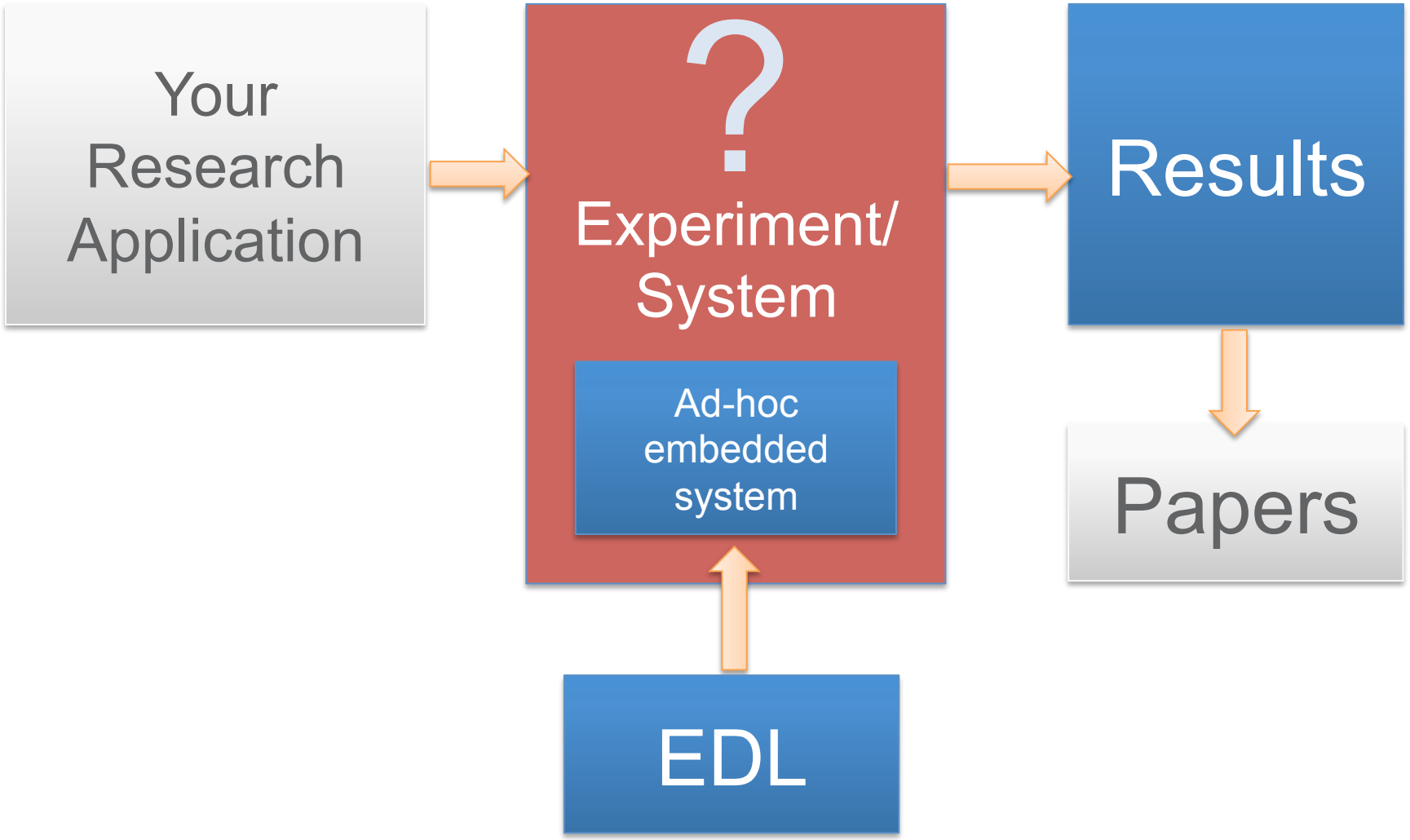
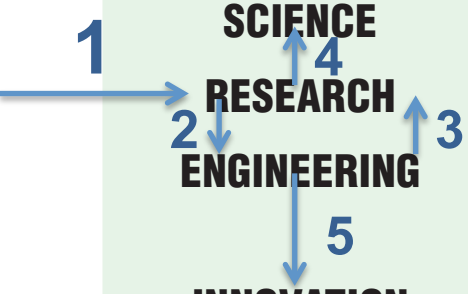
What do you want to (re)search?



Application-Driven Design for Research

TABLE 1. Knowledge, Science, Research, Engineering and Innovation Objectives



KNOWLEDGE	Familiarity, awareness, or *understanding*.
SCIENCE	*Build and organize* knowledge.
RESEARCH	*Increase* the stock of knowledge and use it to devise applications.
ENGINEERING	*Apply* knowledge to invent, design, build, maintain, research, and improve (solve problems and find solutions).
INNOVATION	*Apply* better solutions to meet new requirements and/or market needs.

M. Crepaldi, D. Demarchi, “Tackling Technical Research”, in IEEE Potentials, 2016.

Starting from research requirements we make an engineering prototype to enable getting scientific results and if possible towards innovation.

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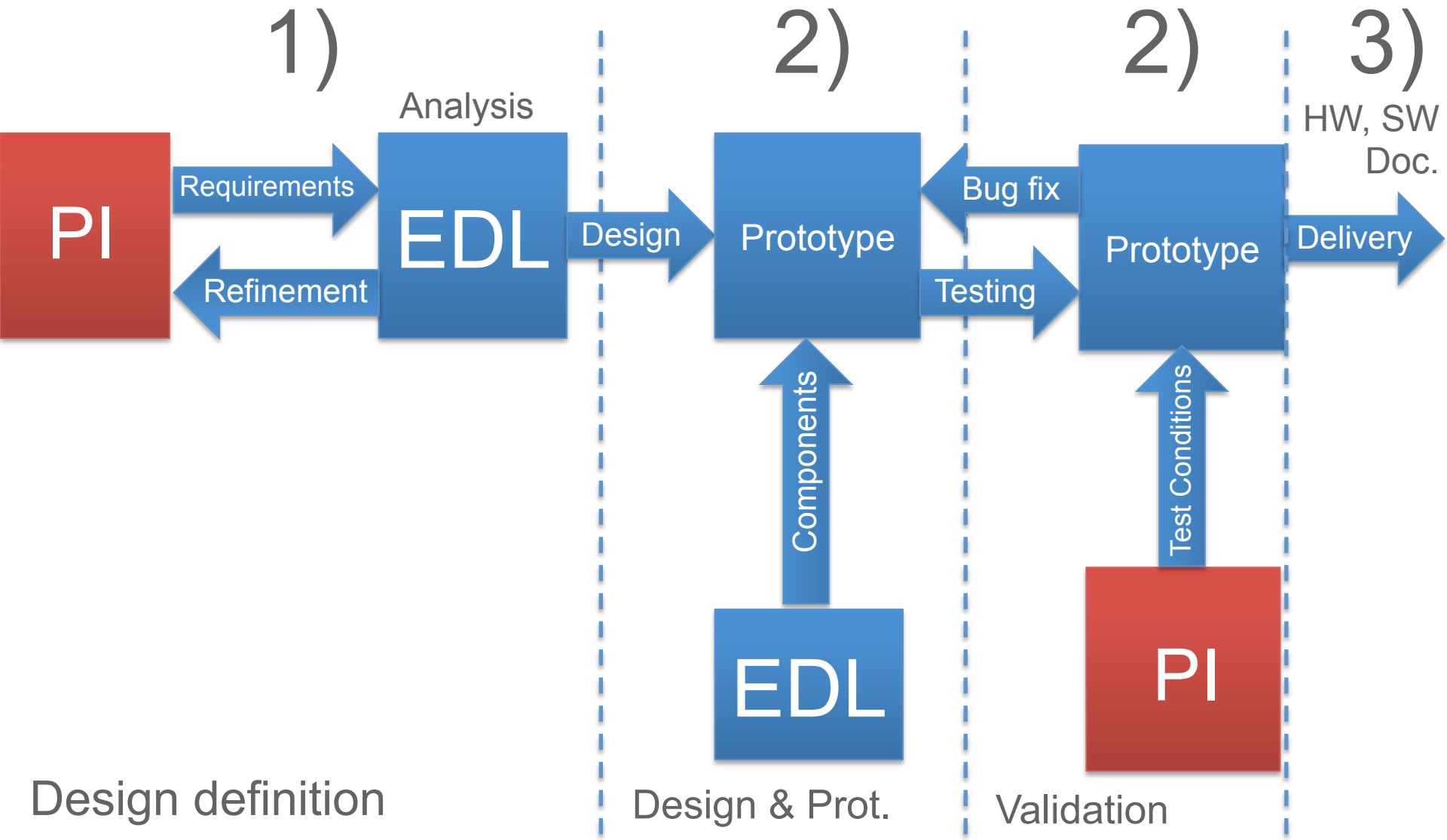
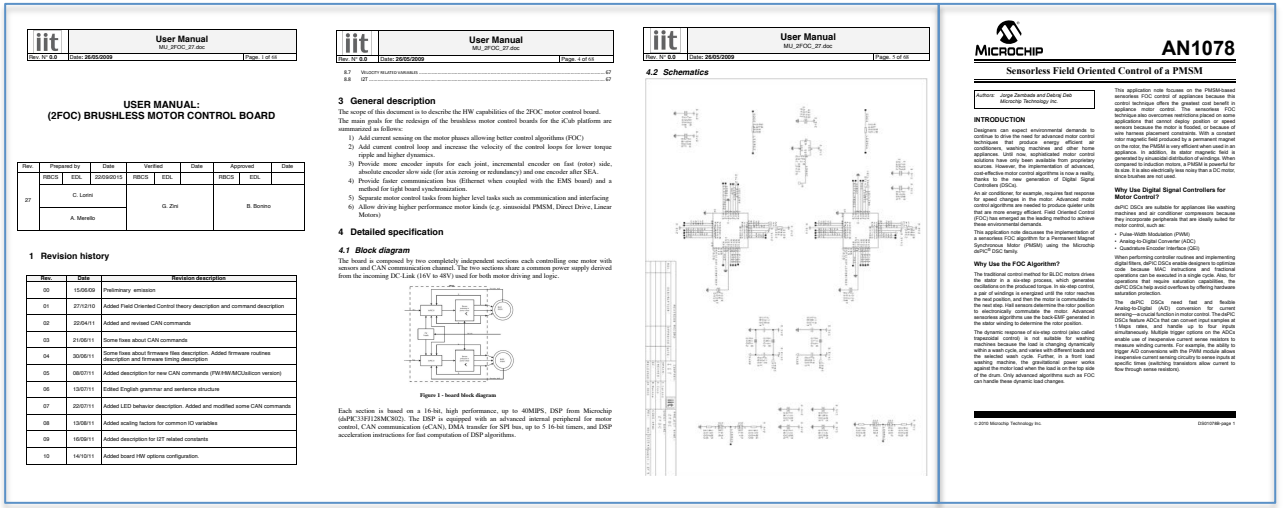
Your inputs, Our outputs, and Our Work Together

Activity	What	You	EDL	Together
Design	Object (embedded system)	**Input (definition)**	Analysis. Feasible?	If not feasible, we need to refine.
	Goals	**Input (definition)**	Analysis. Feasible?	If not feasible, we need to refine.
	Requirements	**Input (definition)**	Analysis. Feasible?	If not feasible, we need to refine.
	Environment	**Input (definition)**	Analysis. Feasible?	If not feasible, we need to refine.
	Primitive components		**Output**	
	Constraints		**Output**	
Prototyping			**Output**	
Validation & Test (regulations)			**Output**	Test conditions.
Follow-up			**Output**	Beta releases.

Application-Driven Design for Research

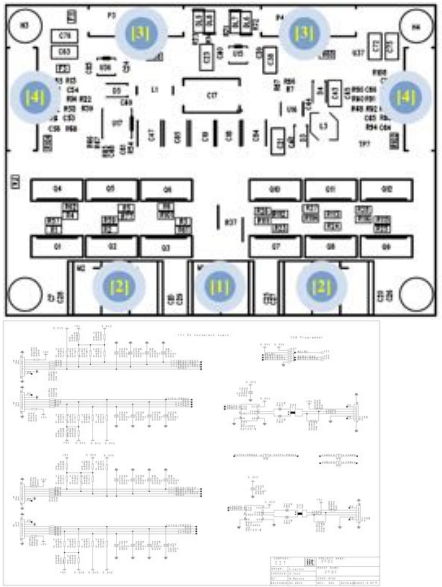


What do we deliver?



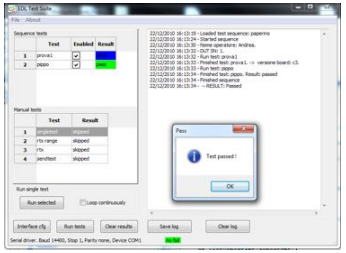
User manual of the IIT device/system

Components datasheets

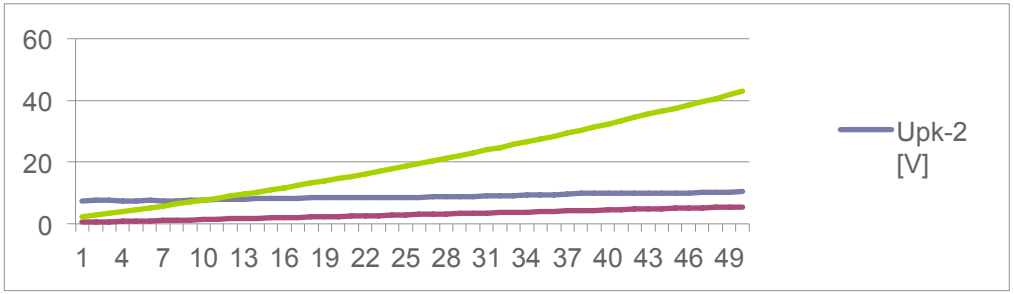


Technical documents

Hardware



Low-Level
Software/Firmware



Validation results

What do we deliver?

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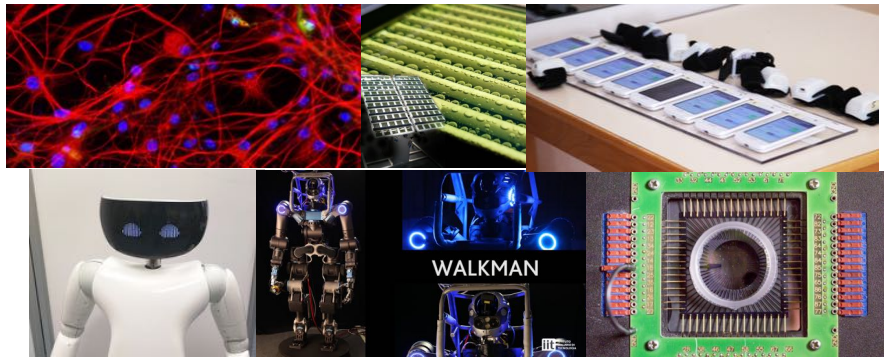
Constraints

PI

Application,
Embedded System,
Software, (Part of the) Solution



LDM

Low-level
Software/Firmware

Dev_read_Bluetooth();
Dev_send_WiFi();
Dev_read_sensor();
Dev_write_data();
...

Component/System
Sub-System
Hardware

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Full-custom/All-programmable/Full custom w/integrated circuits.

DESIGN APPROACH

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Design Approach

- Full-custom design.
  - The design is based on commercial Hardware and Software components available on the market.
  - Less flexible, more optimized from an energy consumption viewpoint, fast/average prototyping.
- ***All-programmable.***
  - The design is mostly based on an FPGA running microprocessors, operating system and ad-hoc interfaces.
  - Very flexible solution, more power hungry, fast prototyping.
- Full-custom with integrated circuit design.
  - The design is mostly based on the design of a full-custom integrated circuit.
  - The most flexible and optimized solution, slow prototyping.

All-programmable Flow: an EDL Uniqueness

Computer

Real-time ad-hoc peripherals

Linux Operating System/drivers

Pin23U: Video? Audio? Ethernet? USB? PWM? Control? What?

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All-programmable Flow: an EDL Uniqueness

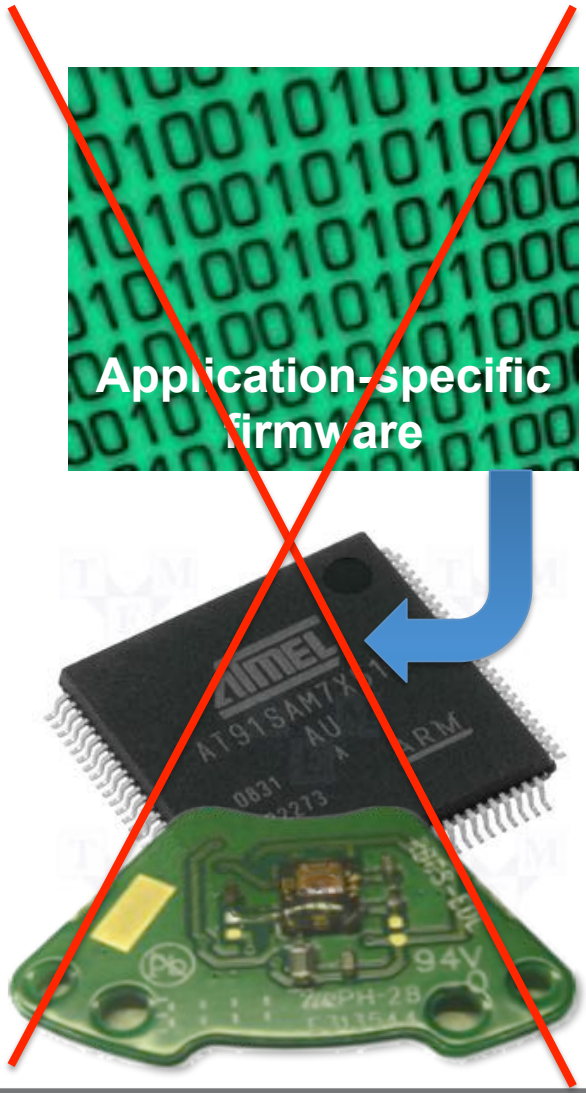
"A reconfigurable 2W embedded PC"

The embedded system comprises and FPGA (Field Programmable Gate Array), a reconfigurable Hardware in which we implement a PC with full custom hardware acceleration, real-time operating system and ad-hoc peripherals (depending on the applications).

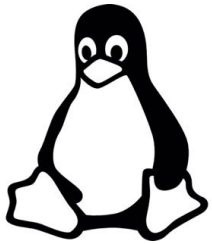
It is an "all-programmable" PC (both from an **Hardware** and **Software** point of view).

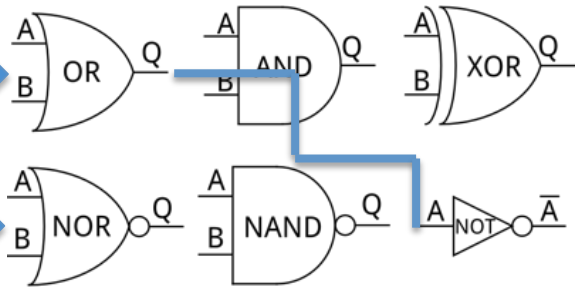
Research is a creative work in which flexibility and fast prototyping are highly demanded, also for an electronic "tool".

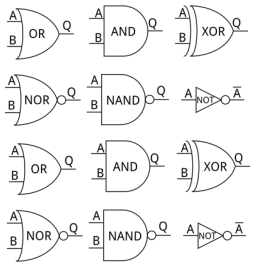
All-programmable Flow: an EDL Uniqueness

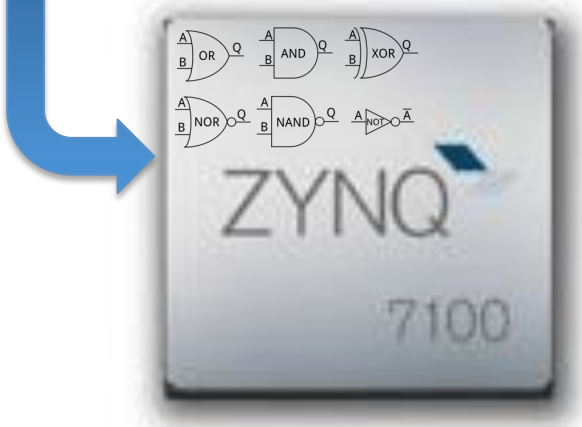


Cortex™
Intelligent Processors by ARM®









Application-specific Hardware

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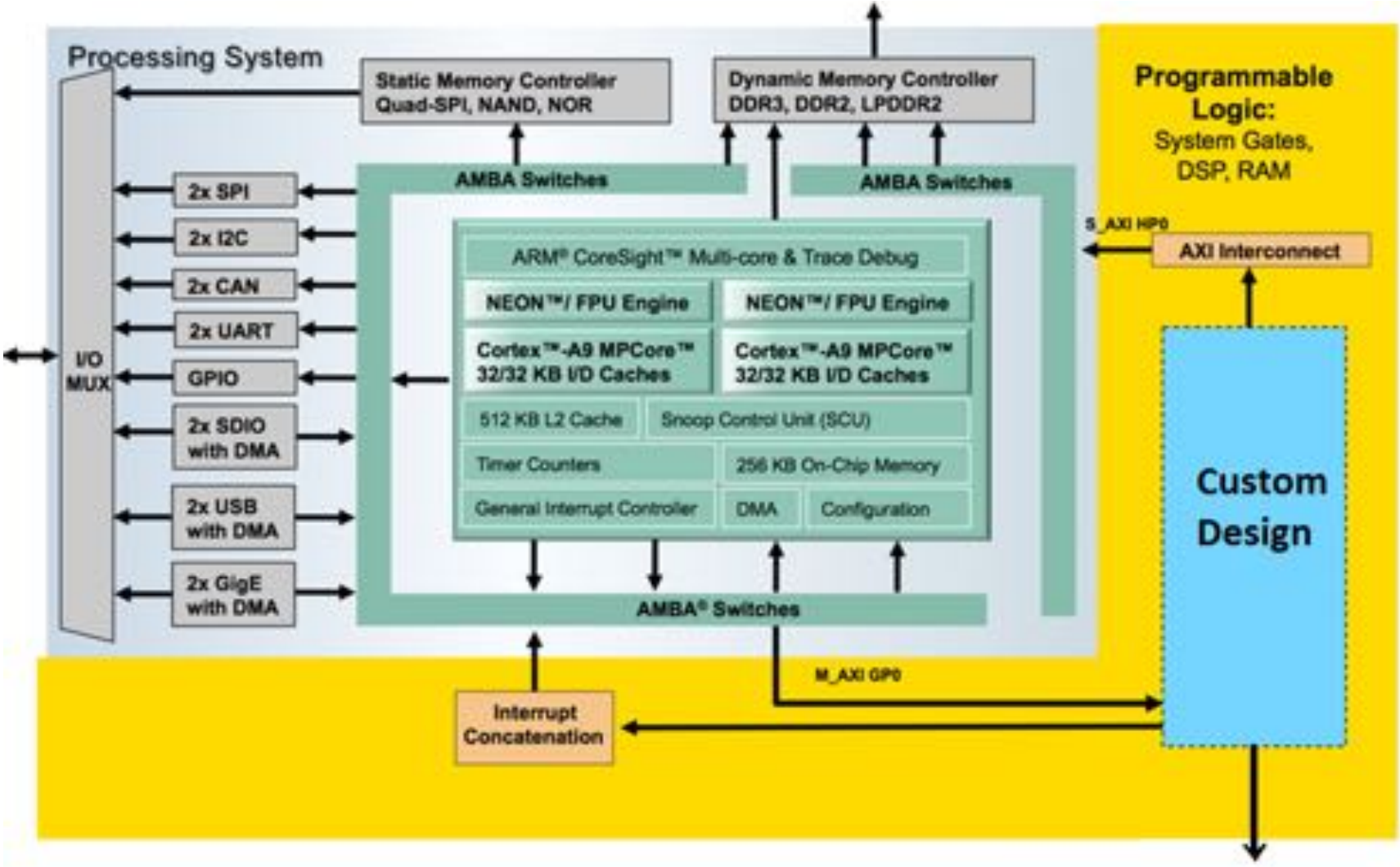
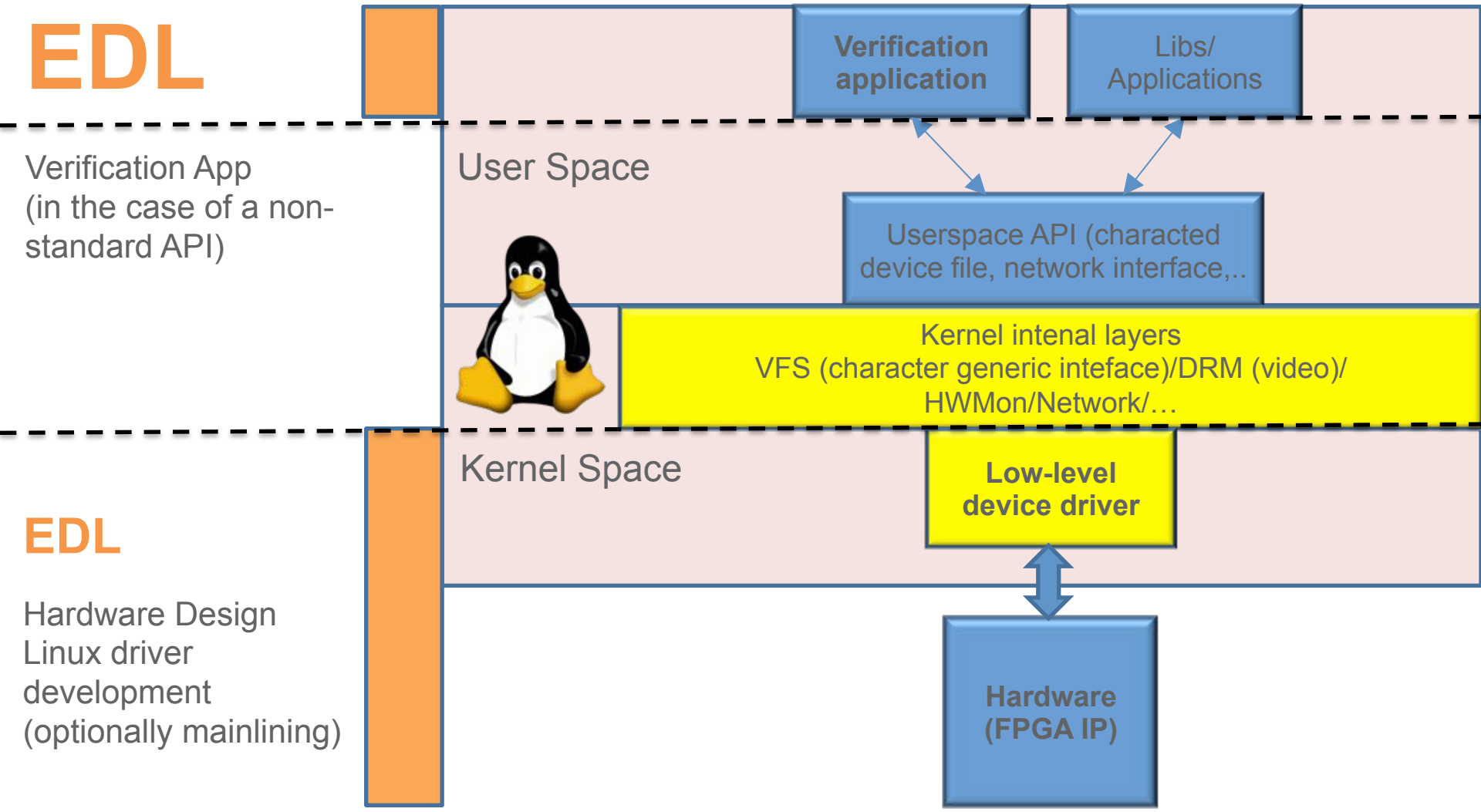
All-programmable Flow: an EDL Uniqueness



All-programmable Flow: an EDL Uniqueness



All-programmable Flow: an EDL Uniqueness

Processor: 2x ARM CORTEX A9 (32bit)
RAM: 1Gbyte DDR3 (External)
Disk: SD cards (up to 32Gbytes, External)
Hardware: all-programmable, including the peripherals, input, interfaces, etc.

Operating systems:
Standard Linux 4.4 (Debian)
Real-time Linux 4.4 RT-PREEMPT
Real-time Linux 4.4 Xenomai
FreeRTOS

Power consumption:

0.200A @ 5V = 1.0W	Board in reset state
0.385A @ 5V = 1.9W	Linux running, 100/1000 network
0.42A @ 5V = 2.1W	Linux running, 100/1000 network, 1 core 100%
0.45A @ 5V = 2.25W	Linux running, 100/1000 network, 2 core 100%
0.36A @ 5V = 1.8W	Linux running, 100/1000 network, with 8 CAN bus IP not clocked

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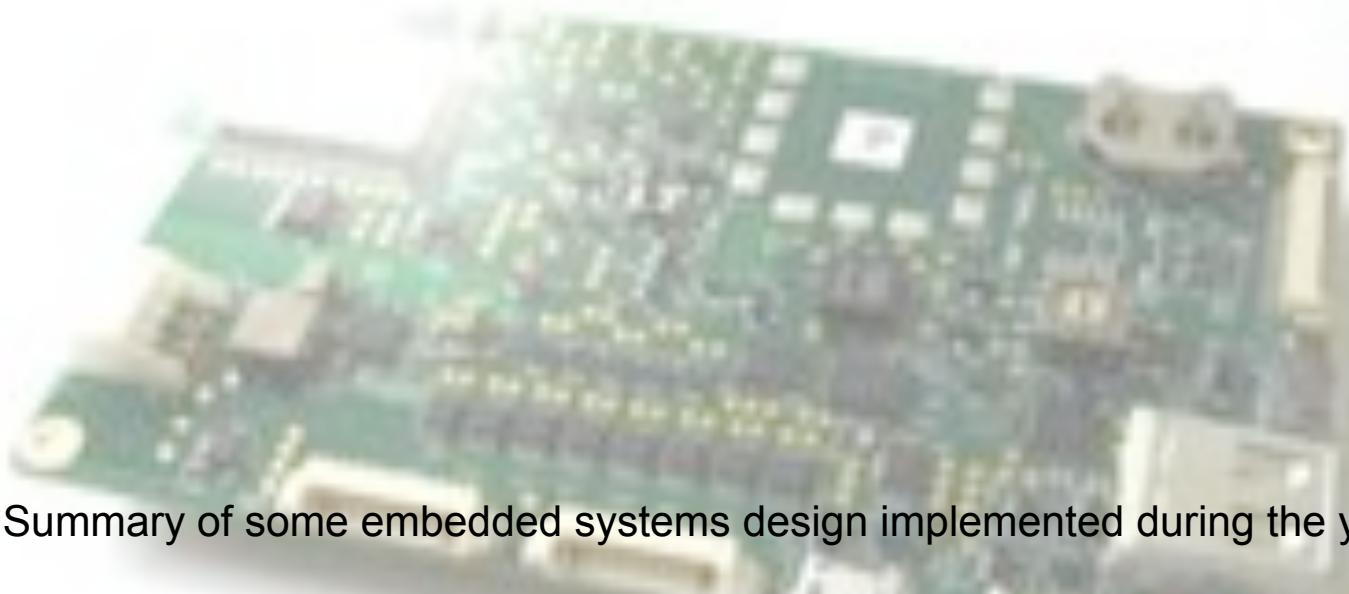
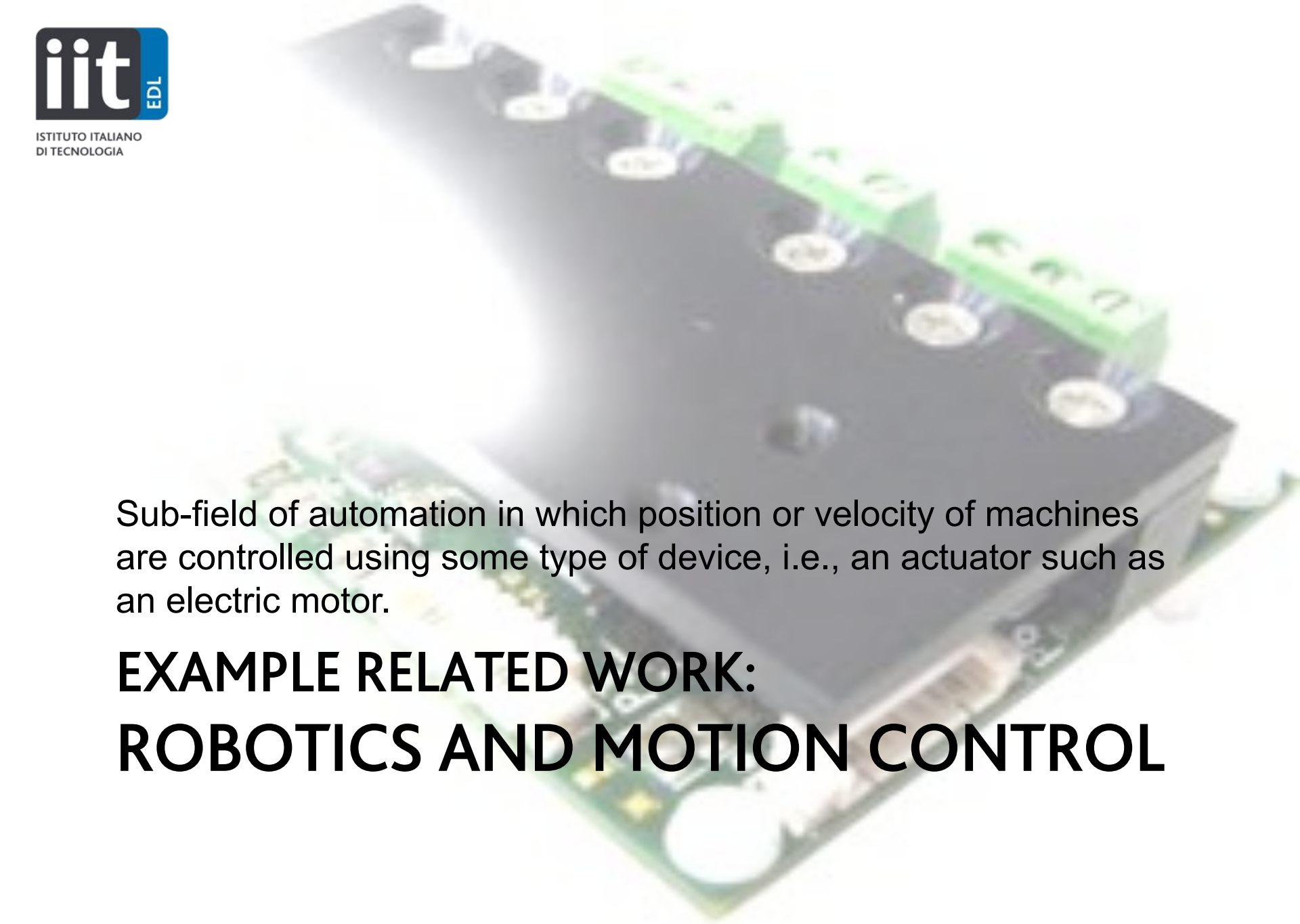


Summary of some embedded systems design implemented during the years.

DESIGN SERVICE: CONCLUDED PROJECTS



Sub-field of automation in which position or velocity of machines are controlled using some type of device, i.e., an actuator such as an electric motor.

EXAMPLE RELATED WORK:

ROBOTICS AND MOTION CONTROL

Robotic Motion Control

Dual Channel Brushless Motor Controller with CAN Bus Interface (2FOC) (Project: **G. Metta** iCub Facility, **G. Sandini,** RBCS)

Problem solved:

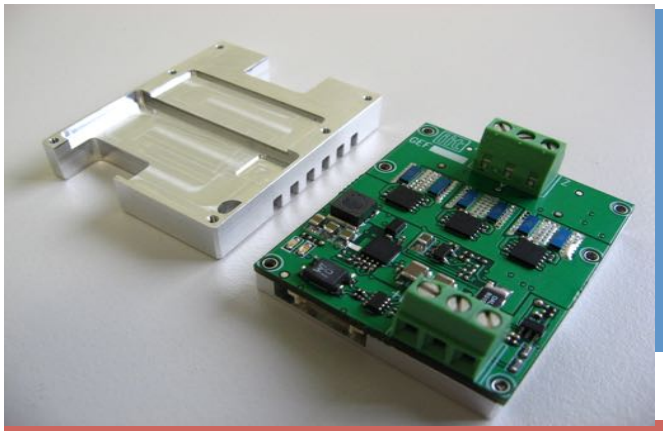
Improve accuracy, reduce motion noise, size and power consumption of previous generation iCub motor control modules.

Features:

- Dual channel 500W motor controller.
- Dual CAN bus communication.
- Reduction of size and price by a factor 2 prices w.r.t. previous controllers (BLL-BLP).
- Motor feedback form Hall effect sensors and absolute or incremental encoders.
- Field-oriented control algorithms for torque and speed control at 40KHz rate.
- Applicable to biomedical applications thanks to HW and FW safety mechanisms and fault tolerance.

Robotic Motion Control

Brushless Motor Controller with GaN Transistors Power Stage (Project: **G. Sandini**, RBCS)



Problem solved:

Improve power/volume ratio, efficiency levels and speed of operation (at present close to maximum achievable levels) of MOSFET power stages.

Features:

- Miniature single channel, 500W, high efficiency motor controller with GaN power stage.
- CAN bus communication.
- Motor feedback form Hall effect sensors and absolute or incremental encoders.
- Field-oriented control algorithms for torque or speed control at 40KHz.

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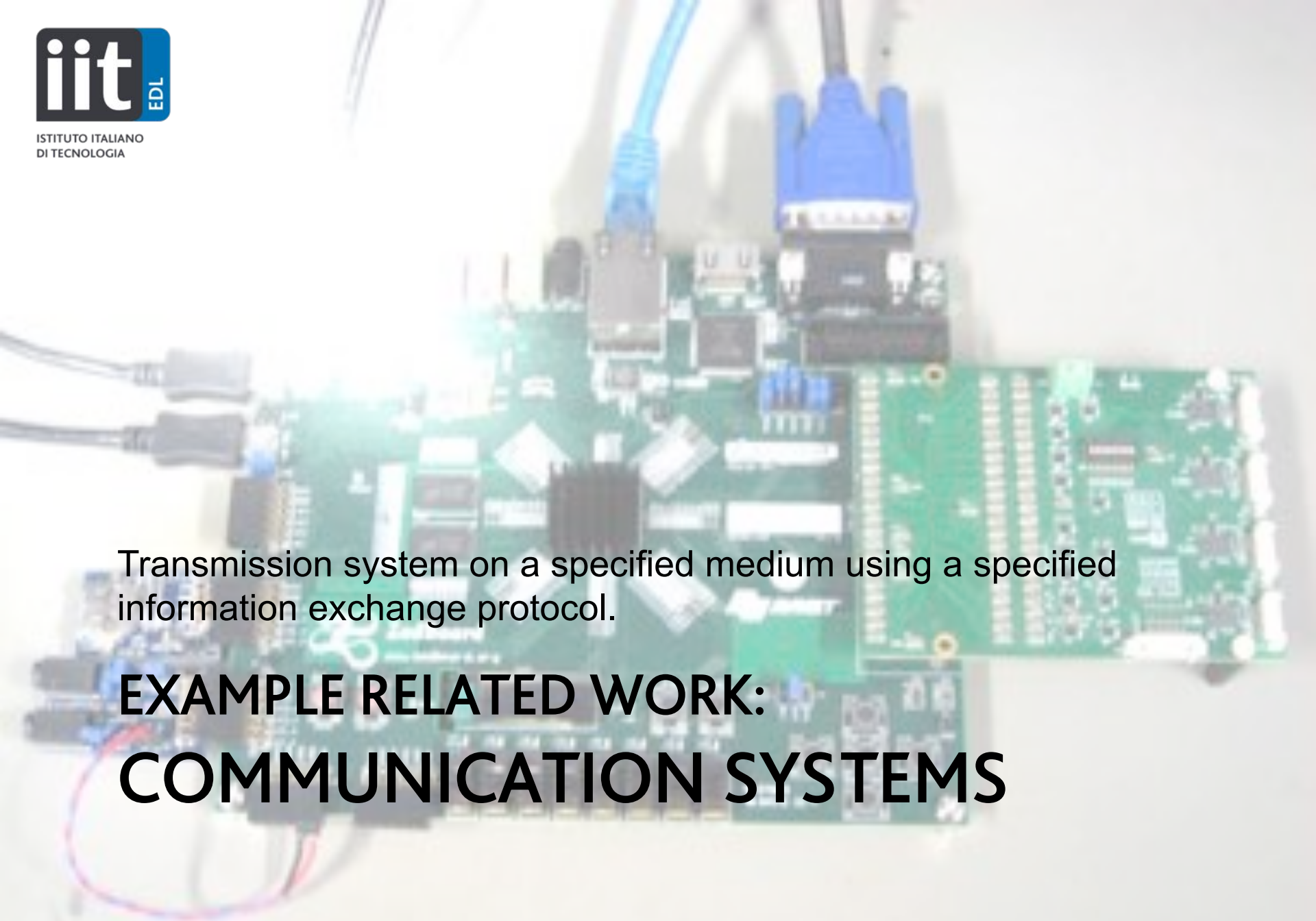

Transmission system on a specified medium using a specified information exchange protocol.

EXAMPLE RELATED WORK:
COMMUNICATION SYSTEMS

Communication Systems

CANOpen and Ethercat Communication Protocol Integration
(Project: **G. Sandini**, RBCS)

Problem solved:

Enlarge the applicability of the devised robotic motion control solutions in applications out of the IIT network.

Features:

- Integration of the open source Ethercat master on Linux OS.
- Ethercat and CANOpen protocols for multi-axis motor control EDL modules, compatible with commercial Ethercat controllers such as Beckhoff Twincat.

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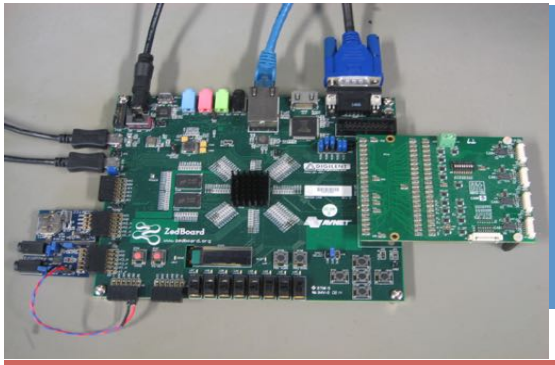
Communication Systems

CAN Bus Communication FPGA IP
(Project: **G. Sandini**, RBCS)



Problem solved:

Integrate CAN bus with a large number of ports in existing microcontrollers (e.g. those in the Xilinx ZinQ platform).

Features:

- Any number of CAN bus peripherals can be added.
- The FPGA design is compatible with Philips SJA1000.
- Compatible with the SJA1000 Linux driver.

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Design & development of technological solutions to problems confronted by individuals with disabilities.

Assistive, adaptive and rehabilitative devices for people with disabilities (including use, selection and locating them).

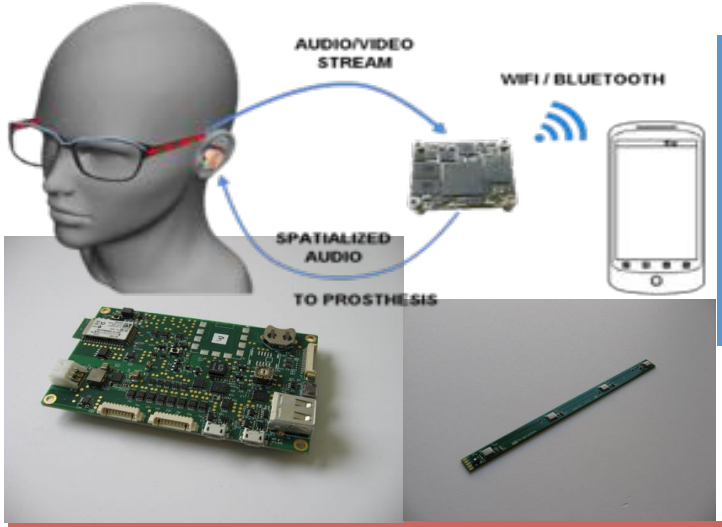
EXAMPLE PROJECT:

REHABILITATION AND ASSISTIVE TECHNOLOGIES

Rehabilitation and Assistive Technologies

FPGA system for the "acoustical lens" *Glassense* using a MYIR Z-Turn platform (Project: **Luca Brayda**, RBCS)

https://www.youtube.com/watch?v=b7uxrT10wxA



Problem solved:

1. Complementary audio prosthesis for sensorineural hearing loss ("acoustic lens")
2. Helping camera for visually impaired people.

Giuliani, et al "Compensating cocktail party noise with binaural spatial segregation on a novel device targeting partial hearing loss" ICCHP 2016
Oliveira et al "Spatial Discrimination of Vibrotactile stimuli around the head" Haptics Symposium 2016

Features:

- Linux OS, 32 bit dual core processor (ARM A9 series).
- 1GB DRAM, USB-OTG, HDMI, SDCard, ETH, BlueTooth low energy, RTC.
- Beamformers with 8 MEMS microphones, audio amplifiers, headsets and speakers.
- 9 axis IMU device, vibromotors driver.
- Standard visible and IR thermo cameras.

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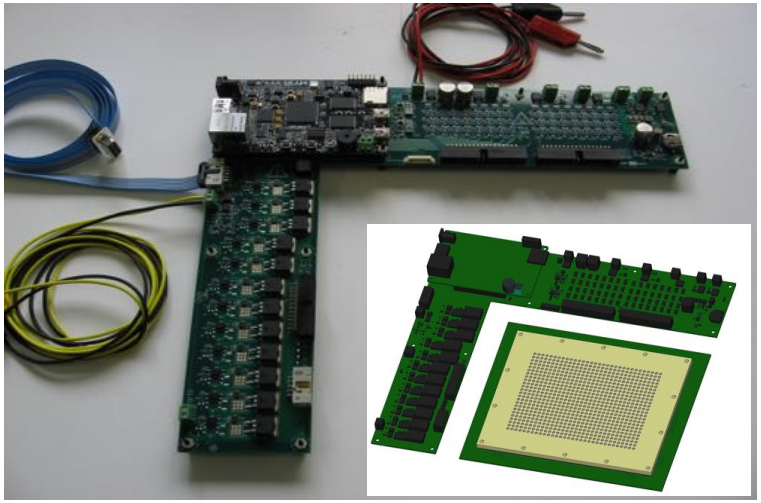
Rehabilitation and Assistive Technologies

Design and development of an FPGA module for *BlindPAD* (Project: **Luca Brayda**, RBCS)

https://www.blindpad.eu



Problem solved:

Powering bistable, refresheable, deformable array of tactile stimulators for blind persons
Fast, high voltage, high current warming and taxel reshaping (Shape Memory Polymers), to be completed as fast as possible.

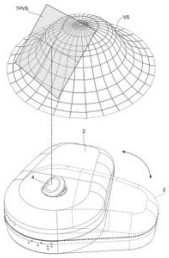
Features:

- Linux OS, 32 bit dual core processor (ARM A9 series).
- 1GB DRAM, USB, HDMI, SDCard, ETH.
- FPGA hardware protection.
- GaN transistors drivers.

Rehabilitation and Assistive Technologies

Design and development of the *TActile MOuse*
(Project: **Luca Brayda**, RBCS) **https://www.youtube.com/watch?v=FS7j0qIeL4k**






L. Brayda, et al., "Predicting Successful Tactile Mapping of Virtual Objects", IEEE Trans. on Haptics, 2013
L. Brayda et al., "The importance of visual experience […] in the assessment of an assistive tactile mouse" IEEE Transaction on Haptics, 2015"

Problem solved:

Studies on the mental representation of shapes and maps in visually impaired persons, by means of haptic stimulation.

Features:

- 32 bit ARM-Cortex M3 microcontroller.
- Low power: 4 AA-size batteries.
- 3 motors for controlling the Z-axis elevation and inclination of the tactile stick.
- Inductive coils for position and orientation measurement over a commercial drawing tablet.
- Bluetooth or Zigbee communication.
- Audio speaker for synthetizing sounds.
- Haptic vibro-motor.

Rehabilitation and Assistive Technologies

ABBI: An Audio Bracelet for Blind people Interaction

(Project: **Monica Gori UVIP, Gabriel Baud-Bovy,** RBCS)

https://www.abbiproject.eu

Problem solved: Fit a full 9 DOF IMU system with sophisticated audio and radio communication capabilities in a device small enough to be wore by babies.

Research objective: Studies on spatial consciousness of blind persons.

Features:

- 32 bit ARM Cortex M3 microcontroller.
- 16MB flash memory.
- 0.8W audio speaker, 24 bit microphone.
- 9 DOF MEMS IMU: accelerometer, gyroscope, magnetometer.
- Bluetooth communication.
- USB interface.
- Lithium rechargable battery.

The designed system is directly used in an experiment.

EXPERIMENTAL SETUP

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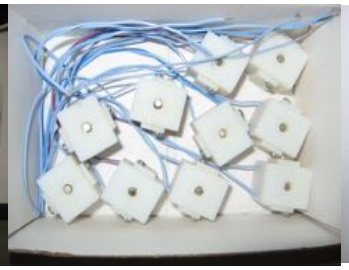
Experimental Setups

Tactile sensor
and actuator

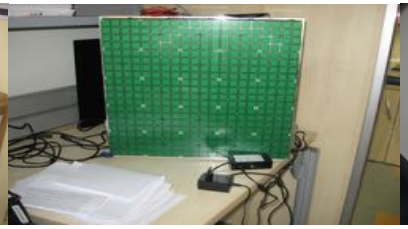


Electromagnetic
stimulator

Dual capacitive sensor

ABBI2
Test & Calibration

Arena audio/video



Arena with sound, touch,
accelerometer, light sensors

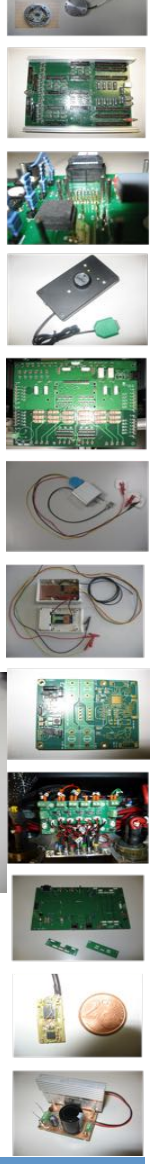
Tactile Stimulator

Brain Machine
Interface

Visio-Haptic perception
tactile stimulator

Wrist accelerometer with sound

Full-custom modules and system-level design for ad-hoc research experimental setups



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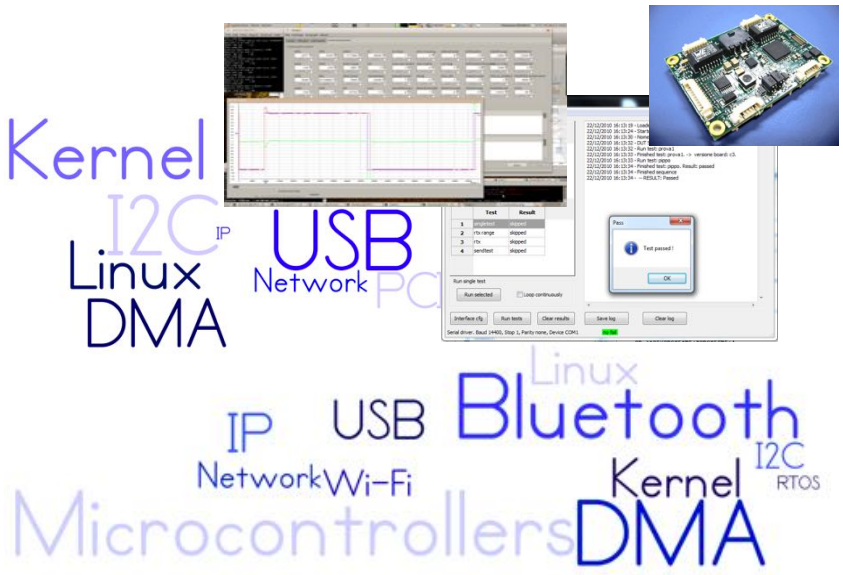
Linux Embedded Systems, driver development, interfaces.

SOFTWARE AND FIRMWARE

Software/Firmware Design



- Linux drivers development (ad-hoc or mainstream kernel).
- Embedded PC peripherals drivers development.
- Bare-metal microcontroller firmware.
- RTOS firmware development for ARM-based microcontrollers.

- Maintenance and update activities.

CFW002 CAN iCub module.

Sigma-Delta Zedboard module.

Wi-Fi chipsets.

CER robot display.

Example drivers

Xilinx DMA, Analog Devices HDMI, OCFB (VGA frame buffer), Xilinx I2C, Myir devicetree, audio codecs, Raspberry-II IRQ controller.

Example Software maintenance and integration

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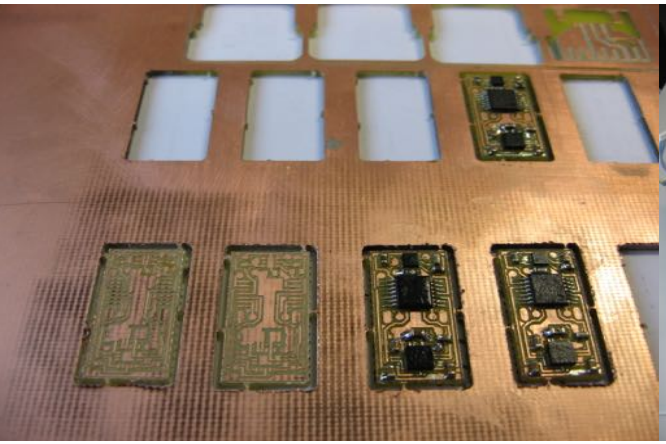
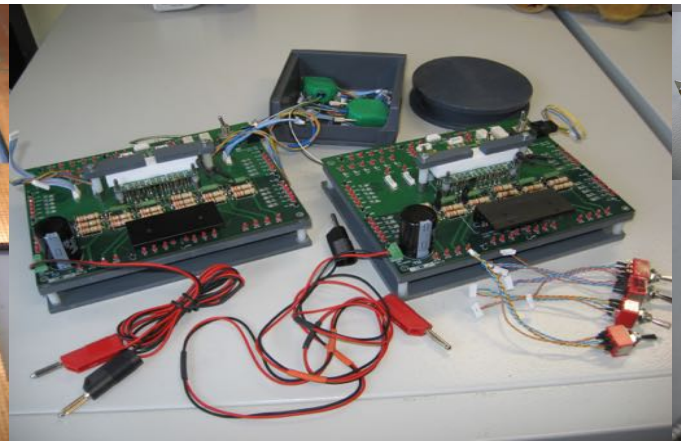
Rapid prototyping (milling machine), ad-hoc cabling and wiring, experimental setup preparation, components substitution and assembly, fast ad-hoc soldering.

TECHNICAL SUPPORT

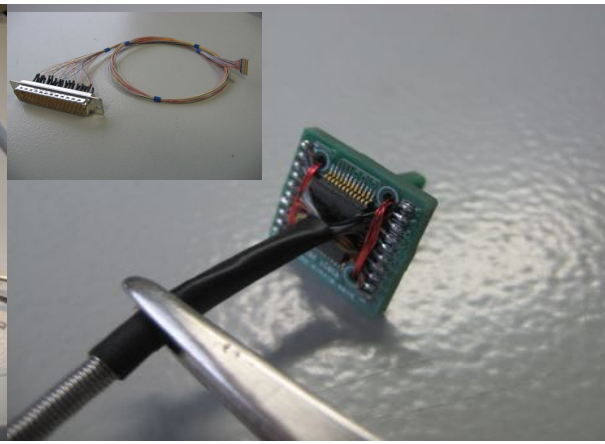
Technical support



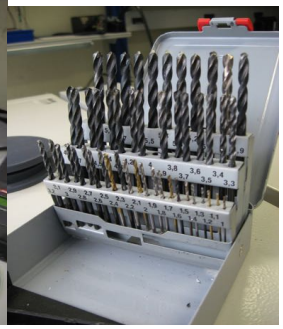
Rapid prototyping
(milling machine)



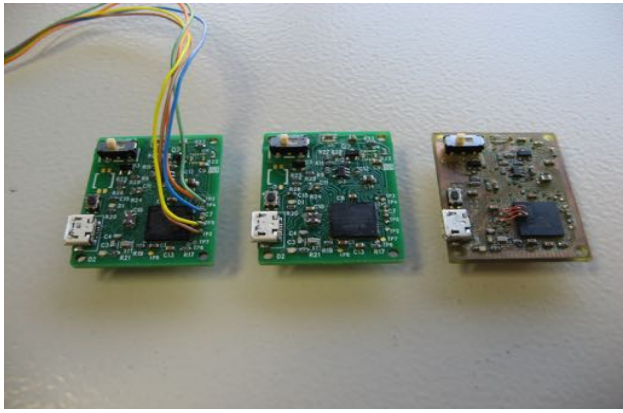
PCB design validation and test



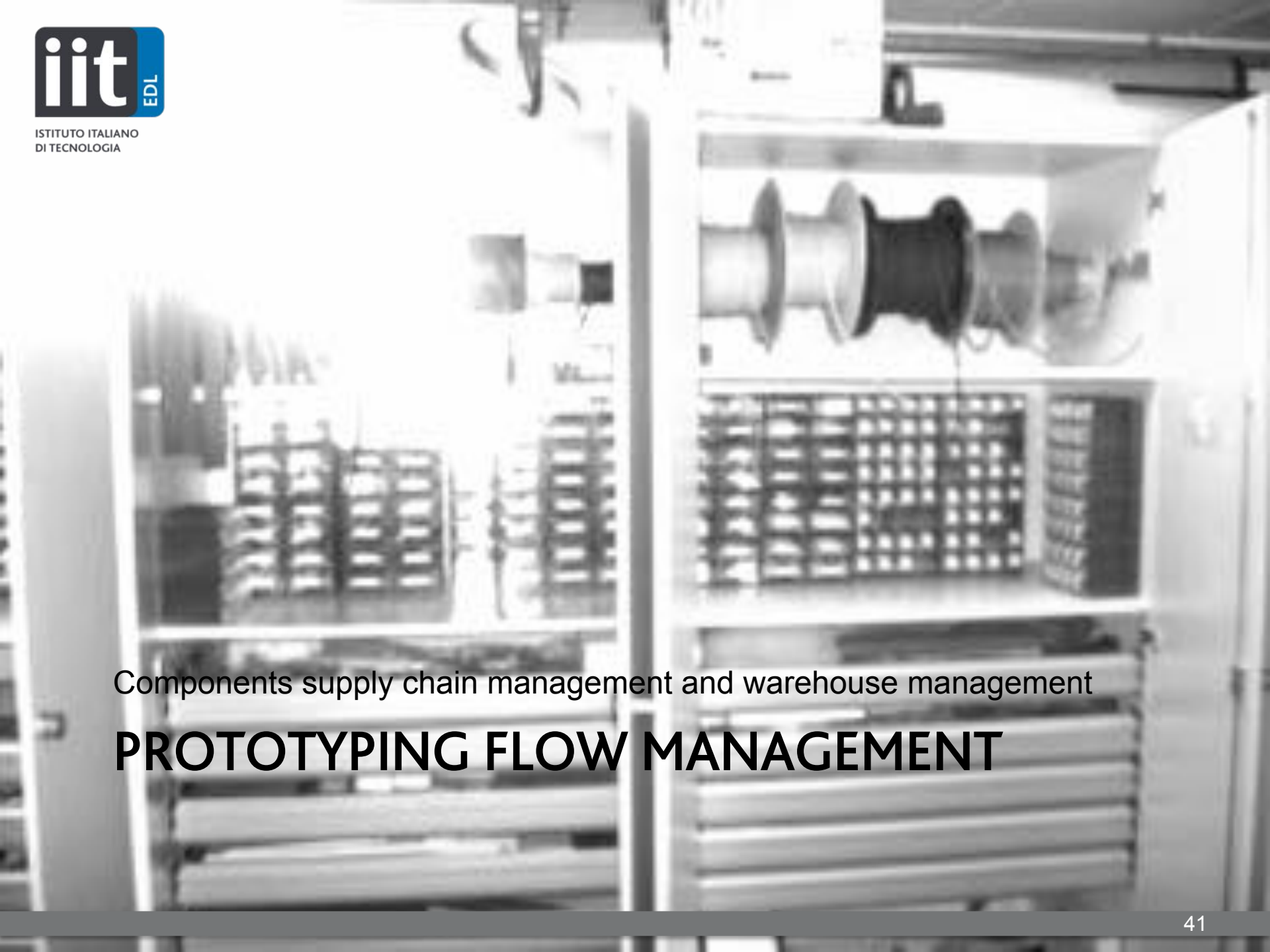
Wiring and cabling/PCB design
co-optimization



Components substitution,
ad-hoc assembly/soldering



Rapid prototyping
(from rapid prototype to
industrial-level PCB)



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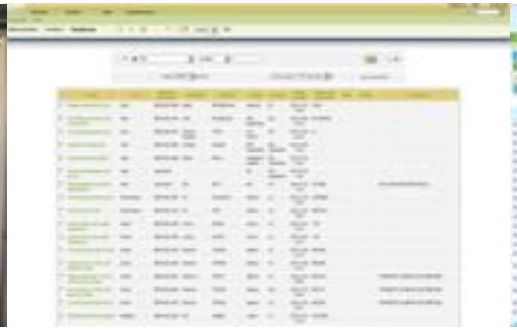
Components supply chain management and warehouse management

PROTOTYPING FLOW MANAGEMENT

Prototyping Flow Management

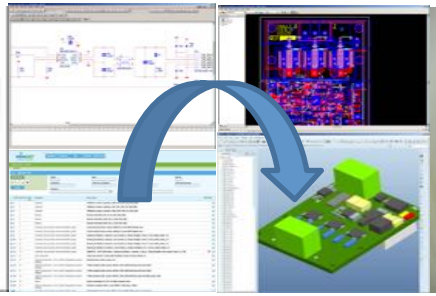
Components and assembly materials standardization.



Technical instruments management and maintenance.

Time-to-prototyping simplification through part lists import.

Pre-orders arrangement.



Electronics and Mechanics CAD integration.

Purchasing process monitoring.

Components supply chain control.

Encoding and standardization.

Overall codes arranged and managed: **10000**.

Overall technical instruments managed: **190**.

Average orders managed per year: **100**.

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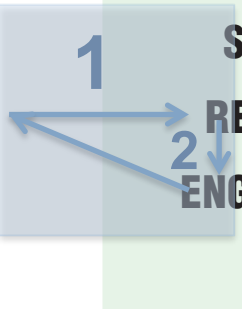
Stock of knowledge increase in circuits and systems, and integrated systems.

ELECTRONIC DESIGN RESEARCH

Application-Driven Research

TABLE 1. Knowledge, Science, Research, Engineering and Innovation Objectives

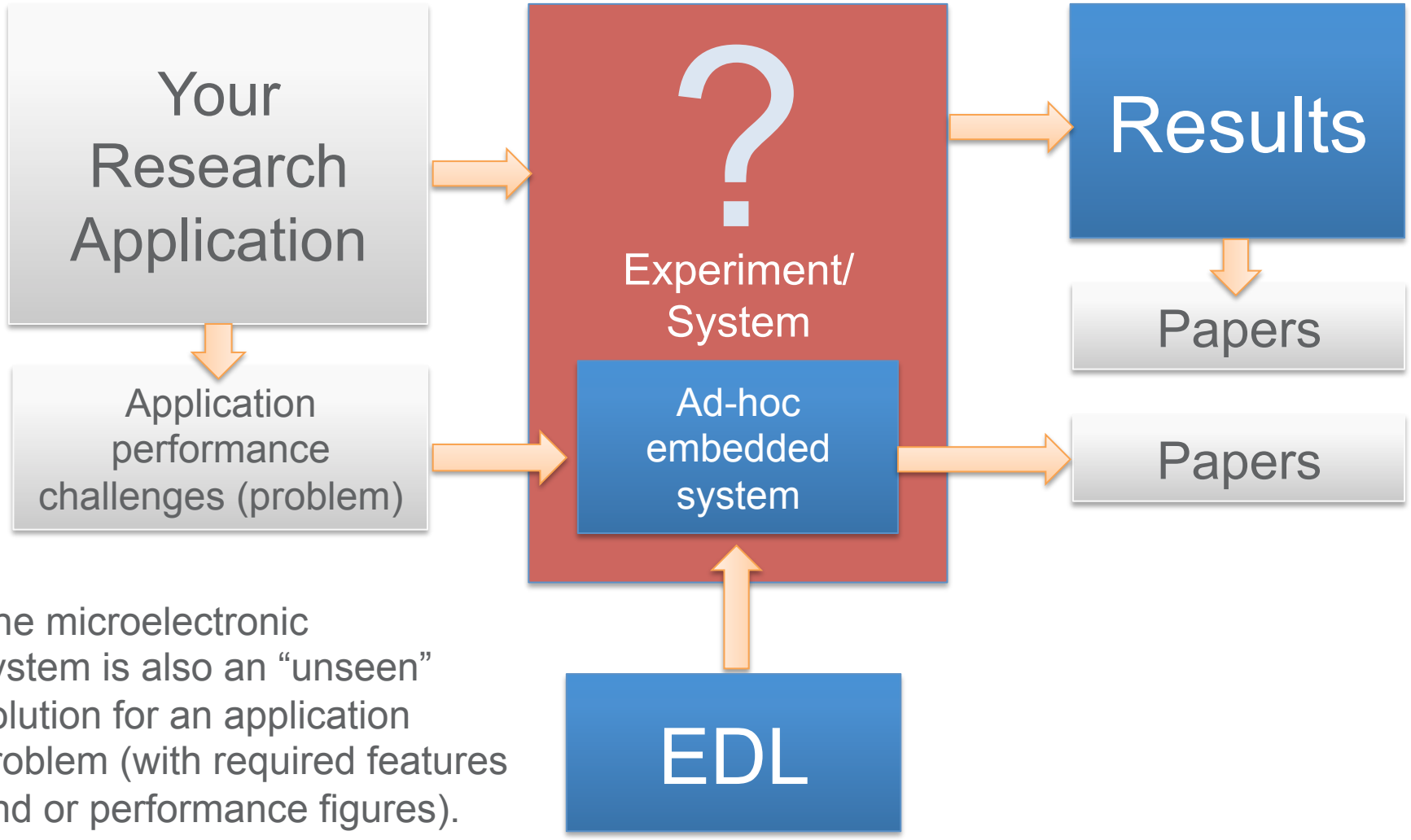


KNOWLEDGE	Familiarity, awareness, or *understanding*.
SCIENCE	*Build and organize* knowledge.
RESEARCH	*Increase* the stock of knowledge and use it to devise applications.
ENGINEERING	*Apply* knowledge to invent, design, build, maintain, research, and improve (solve problems and find solutions).
INNOVATION	*Apply* better solutions to meet new requirements and/or market needs.

M. Crepaldi, D. Demarchi, "Tackling Technical Research", in IEEE Potentials, 2016.

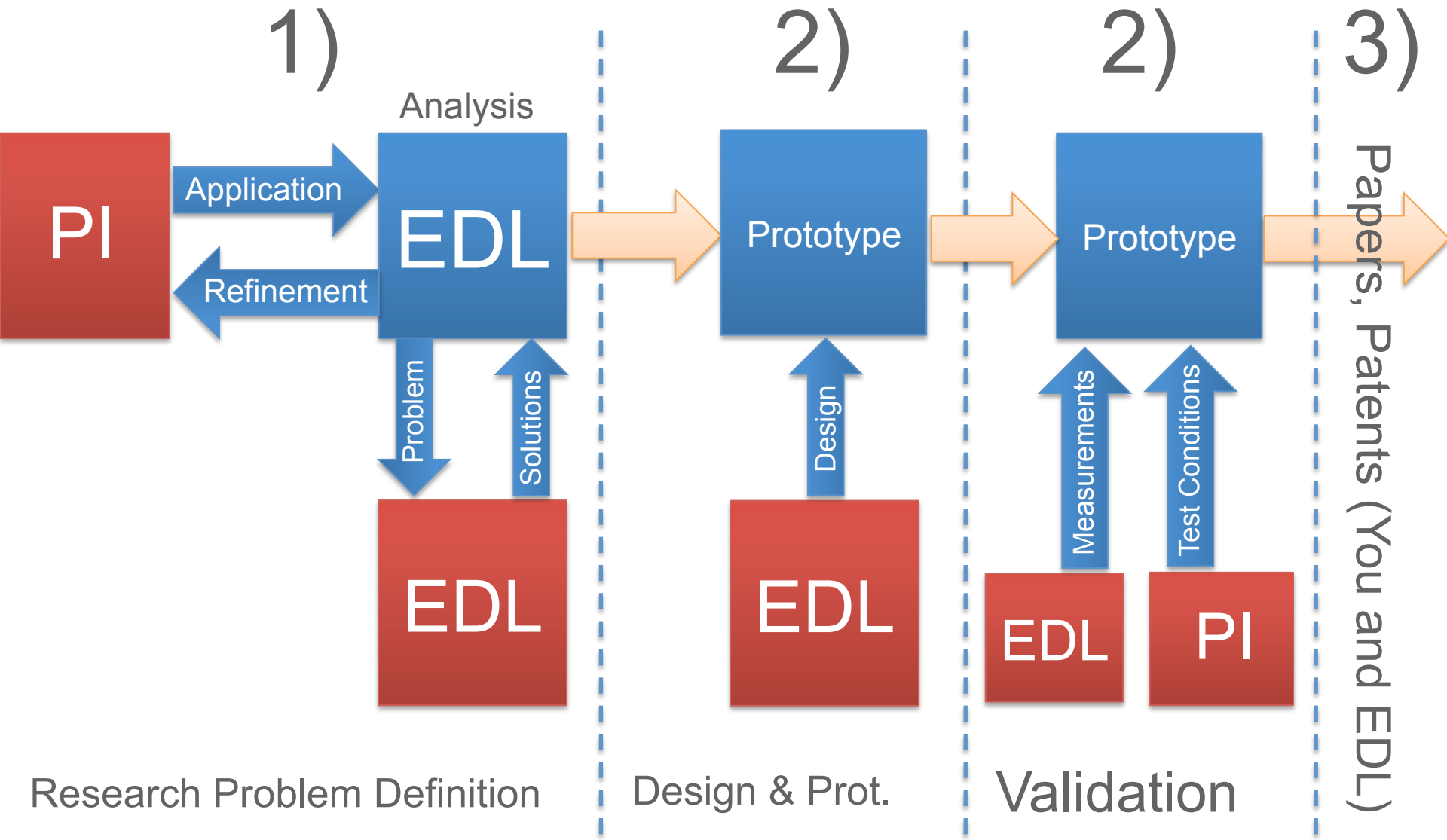
Not a permutation, not a "combination", but the obtained circuit or system is really an "unseen" contribution to the state-of-the-art **to solve a particular problem (features)** or **to meet performance figures defined by a research application**.

What do *we* want to (re)search?



The microelectronic system is also an “unseen” solution for an application problem (with required features and or performance figures).

Application-Driven Research



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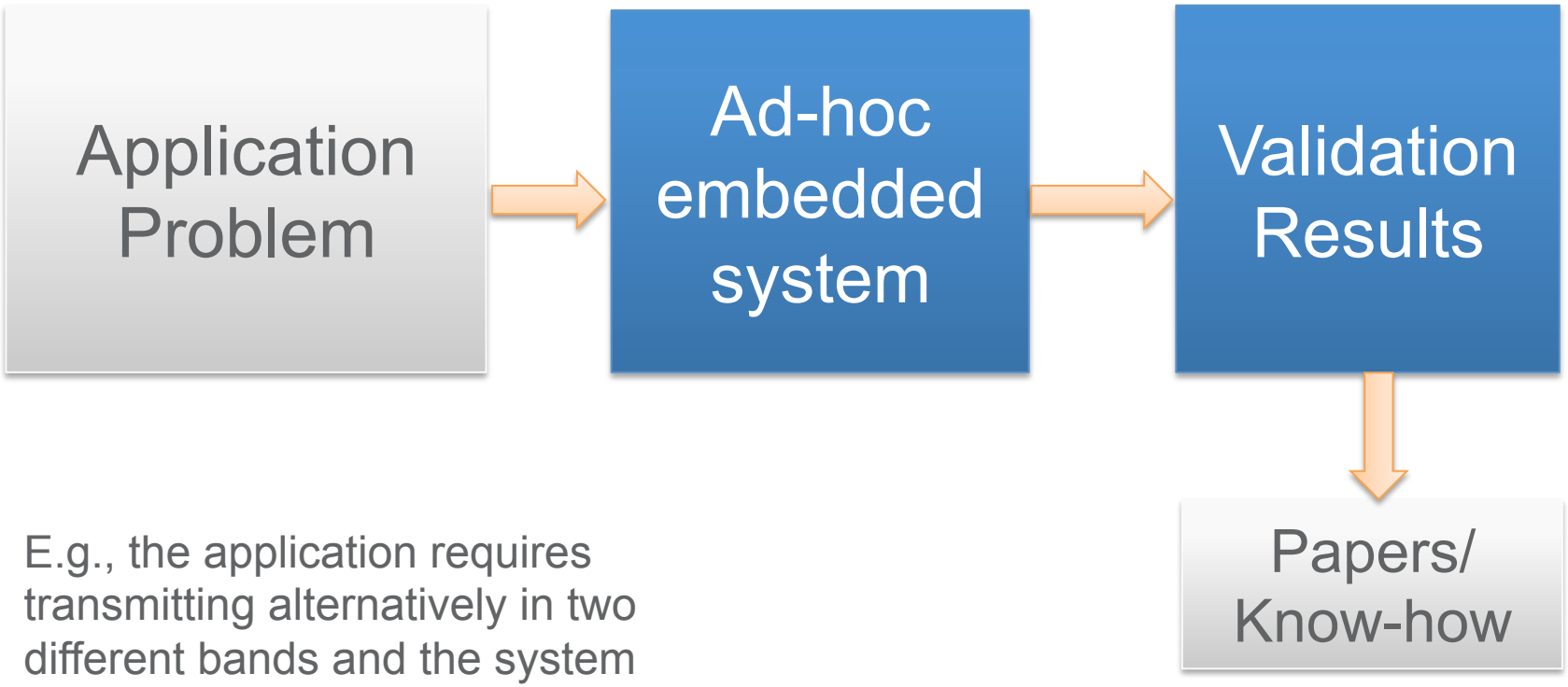
What does EDL want to (re)search?



E.g., the application requires transmitting alternatively in two different bands and the system needs to hop from 3GHz to 300kHz. The prototype solves this problem.

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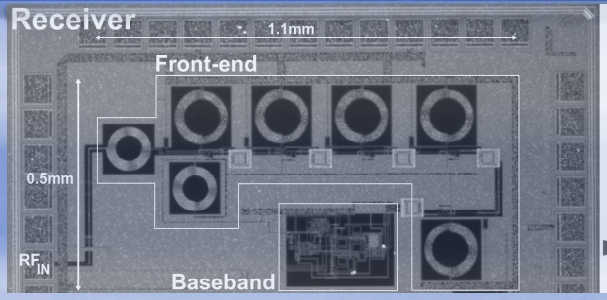

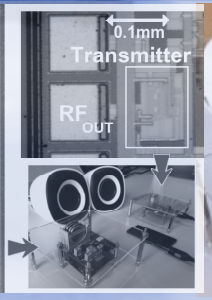

Research in the field of RF integrated circuits, Impulse-Radio Ultra-Wide Band transceivers, IoT and electronics design in general.

The research problem is circuits and systems and integrated circuits design.

ELECTRONIC DESIGN RESEARCH

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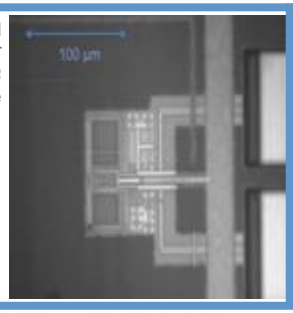
Integrated Systems Research

Nanodevices sensing & Harvesting

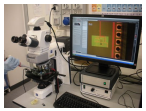
Operational Schmitt-Trigger 100k-1GΩ dynamic range

CMOS Read-Out Circuits (M4N)

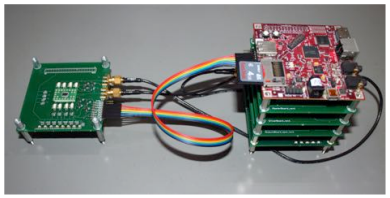


CMOS Micro-electrodes

130nm RFCMOS process

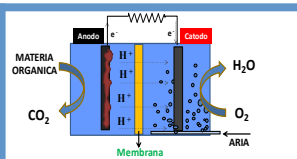


M4N chip nanowire deposition and monitoring with an optical microscope

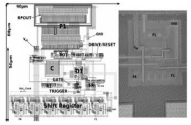


Modular system for the batch fabricarion and characterization of nanogaps (embedded Linux)

CMOS Micro & Nano Probing with Read-Out (M4N)



Microbial Fuel Cell (MFC)

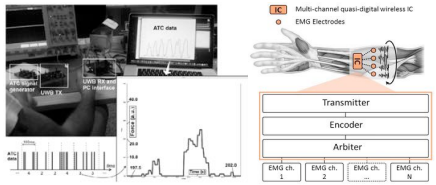


All-digital 400MHz self-calibrating transmitter for Wireless Body Area Networks

Piezoresistive material

MFC-powered Pulsed TX + Piezo—resistor and Read-Out Circuit

Ultra-Low Power (Bio-Inspired) Wireless Communication



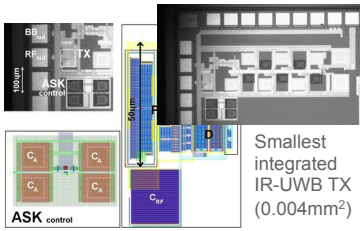
Neural Amplifier interfaced to IR-UWB (Torino-Genova)

Average Threshold Crossing (ATC) (spike encoding of EMG muscle force)

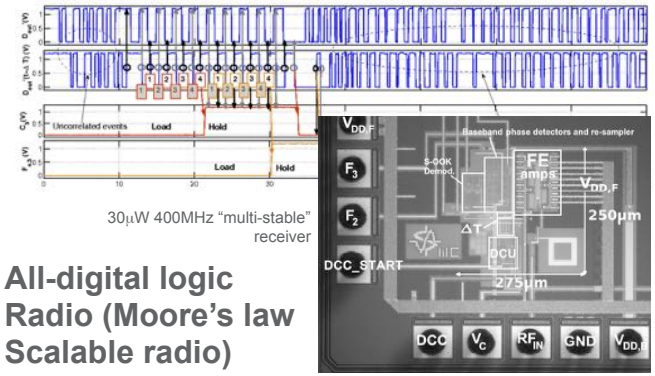
Event-driven Bio-signals Transmission

IR-UWB transceiver design

10mm precise short-distance ranging RX



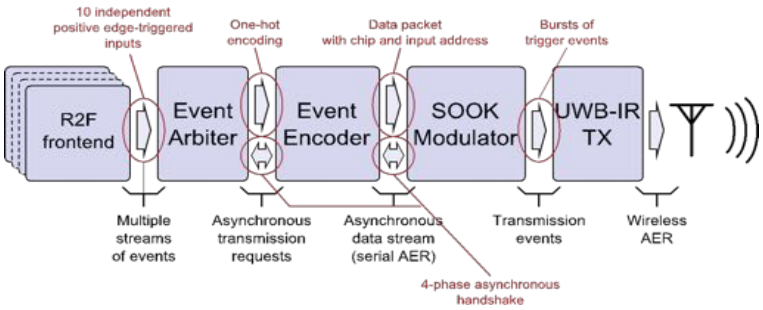
Smallest integrated IR-UWB TX (0.004mm²)



30µW 400MHz "multi-stable" receiver

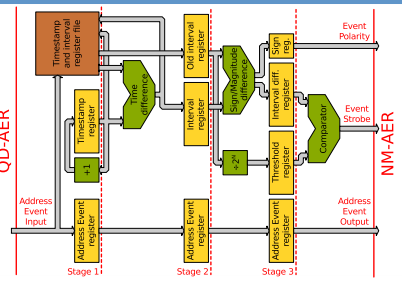
All-digital logic Radio (Moore's law Scalable radio)

Bio-Inspired Architectures for Robotics & Event-based Systems



Wireless Neuromorphic (AER) Event Transmitter and receiver (sensing glove)

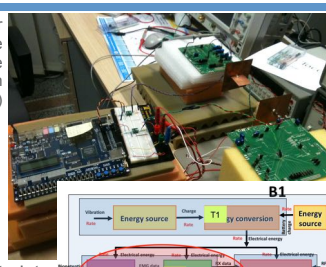
Event-arbiter modulator/demodulator, for wireless IR-UWB transmission of pressure sensors data



FPGA architecture for the integration of Quasi-Digital sensing systems in Neuromorphic applications

Quasi-Digital/Neuromorphic Event-based filter (iCub)

Hardware In the Design (HiD)



Constraint-driven methodology

Wireless Hardware-in-The Loop (HIL) & Smart Systems Constraint Management

Integrated Systems Research

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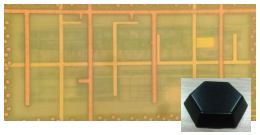
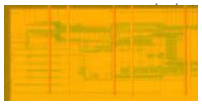
Nanodevices sensing & Integration

Process, Voltage and Temperature robust all-digital capacitive ROC for MW-CNT pressure sensors

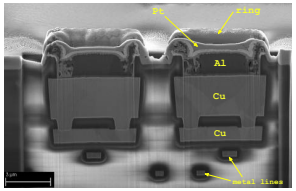


All-digital resistive and capacitive ROC for commercial sensors



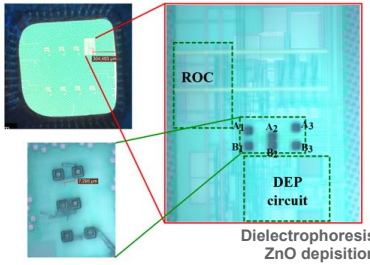
130nm RFCMOS process

All-digital, Modular & Integrated ROC for Robotics

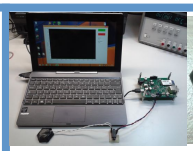


Gold plated CMOS micro-electrodes (on-chip post-processing)

CMOS Micro & Nano Probing with Read-Out (M4N)

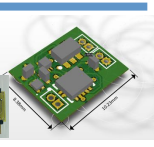


Dielectrophoresis ZnO depisition



Wireless read-out System based on IR-UWB

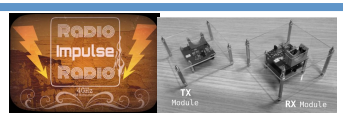
MW-CNT transducer



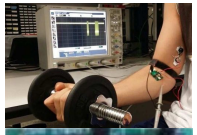
PCB Read-Out module incorporating front-end Power regulation and Level-translation

MW-CNT Quasi-digital ROC for Space Applications with Wireless TX

Ultra-Low Power (Bio-Inspired) Wireless Communication

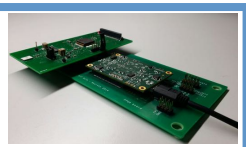


Lowest power *ever* analog wireless audio transmission system based on IR-UWB RF spikes (pulse-based FM modulation)

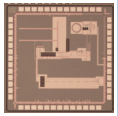


Spike-level EMG signals TX mini-module comprising integrated amplifier, interface and IR-UWB transmitter (Average Threshold Crossing)

Event-driven Bio-signals Data Transmission

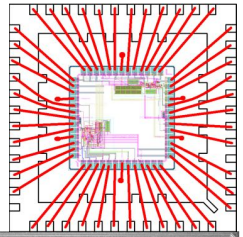


Cyberbrain project (IIT@PoliTo/IIT) Flexible biosignals recording platform with biosensing IC and IR-UWB transmission



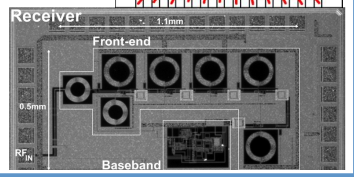
NMOS-based 100Mbit/s IR-UWB TX and RX

Duty Cycling controller for FM-based IR-UWB plus analog conditioning (in cooperation with Columbia University), under test (RFCMOS 130nm)

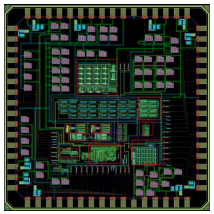


IR-UWB transceiver design

Interference Robutst 130nm IR-UWB receiver for analog/digital-mode Wireless links

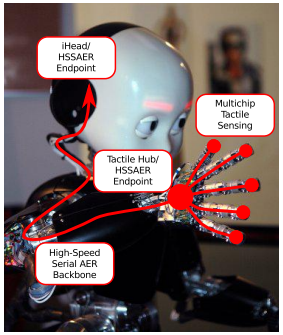


IEEE 802.15.6 compliant IR-UWB receiver (in cooperation with ESAT-MICAS, KULeuven and Polito), under test (65nm CMOS)



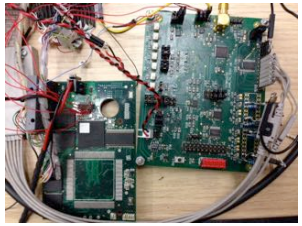
All-digital logic Radio (Moore's law Scalable radio)

Bio-Inspired Architectures for Robotics & Event-based Systems

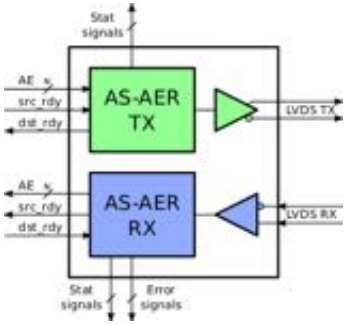


iCub neuromorphic interfacing concept

FPGA testbed for the protocol test (PC interfacing and error-rate validation)



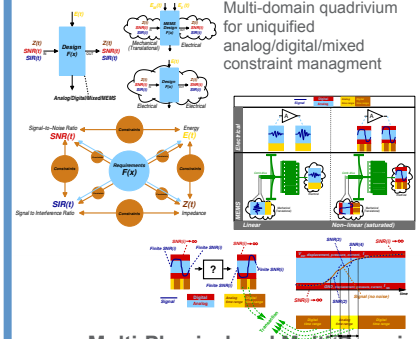
Quasi-digital read-out circuit IC (tactile sensing) connected to iHead



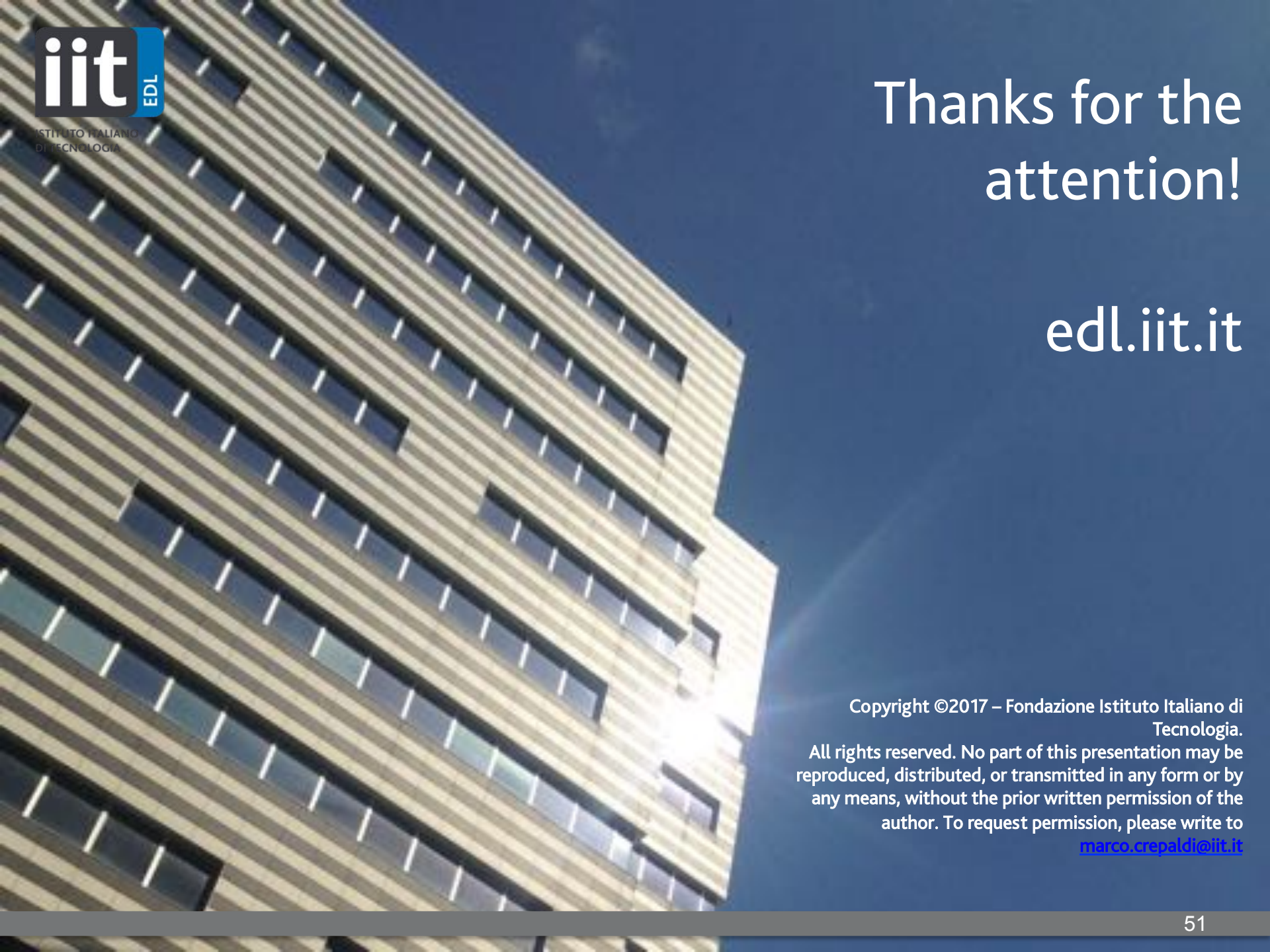
Block scheme of the AS-AER integrated interface

Neuromorphic asynchronous DC-Free Serial Protocol for Event-Based AER Systems (iCub, Torino-Genova)

Multi-domain quadrivium for uniquified analog/digital/mixed constraint managment



Multi-Physical and Multi-Domain Smart Systems Constraint Management



Thanks for the attention!

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