INTERNSHIPS AND RESEARCH PROJECTS

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Addressed to: Any R&D-performing academic institution or industrial company

1. APPLIED PROJECTS IN POWER ELECTRONICS

CONTROL OF A DOUBLY-FED INDUCTION GENERATOR (DFIG) FOR WIND TURBINES

Motivations: Imperix wishes to develop application examples that demonstrate the capabilities of its digital controllers in various types of applications. This also contributes to grow the company's expertise in the field and provide detailed performance validation for specific cases and conditions.

Objectives: Implement with the B-Box RCP a working example of a complete closed-loop vector control for an DFIG. This includes the coding of the converter control as well as its practical validation on a Hardware-In-the-Loop (HIL) simulator.

Skills: A solid knowledge of power electronics and drives is required.

Level: This project is best addressed by a master-level student.

DESIGN AND EXPERIMENTAL VALIDATION OF A LOW-VOLTAGE GAN-BASED INVERTER

Motivations: Imperix wishes to continuously broaden its power module portfolio with recent silicon devices. In this context, it is proposed to design a three-phase inverter based on GaN silicon that will allow the intern to face the challenges raised by the high-speed switching devices.

Objectives: Design and test a GaN-based inverter, including the gate drivers, protections as well as high-bandwidth sensors.

Skills: Previous experience with power electronic design is mandatory.
Previous experience with Altium Designer is recommended.

Level: This project is accessible to a master-level student only.

DESIGN OF AN ISOLATED DC POWER SUPPLY USING IMPERIX POWER MODULES

Motivations: Imperix wishes to extend its set of available application examples. In this context, the design, implementation and validation of a controllable DC power supply, similar to a conventional laboratory power supply is proposed.

Objectives: Design, implement and validate the control for a variable DC voltage source using imperix products. The project covers both the control implementation as well as the experimental validation in the laboratory. A medium-frequency isolation stage is considered between the controlled rectifier and the DC/DC step-down stage.

Skills: A good general knowledge of power electronics is necessary.

Level: This project should be handled by a master-level student.

MODEL-PREDICTIVE CONTROL (MPC) OF A NEUTRAL-POINT-CLAMPED (NPC) INVERTER

Motivations: The fast advance of power electronics imposes imperix to continuously confront its hardware and software to the evolution of control techniques. This contributes to grow its expertise in the field as well as provide detailed performance validation for specific cases and conditions.

Objectives: Implement with the B-Box RCP a working converter control using Model Predictive Control techniques (MPC). A basic three-phase grid-tied inverter can be considered, as well as a three-level Neutral-Point-Clamped topology (NPC). This project can be done either in C/C++ or Simulink, and be implemented to Hardware-In-the-Loop (HIL) simulation or a low-power prototype (2kW), or both.

Skills: Prior knowledge of Model-Predictive Control (MPC) highly recommended.
A solid general knowledge of power electronics is also required.

Level: This project is best addressed at the end of master-level studies.

DESIGN OF PLANAR INDUCTORS FOR A HIGH-DENSITY POWER MODULE

Motivations: Imperix power modules embed power semiconductors as well as measurements and protections circuits directly onboard. However, they do not embed any inductive elements, as their design and sizing is heavily dependent on the selection of the switching frequency, which can vary in a broad range. Nevertheless, the company would be interested to develop an extension of these modules, comprising a planar inductor and EMC filter, target a narrow range of operating conditions.

Objectives: Design, implement and test a planar inductor and filter that can be used together with the newest power module PEB8024 (based on Silicon Carbide).

Skills: Some theoretical knowledge of magnetics design is indispensable.

Level: This project is should preferentially be addressed by a master student.

MODELING AND CHARACTERIZATION OF IMPERIX POWER MODULES

Motivations: Imperix would like to develop accurate simulation models of its power modules, which the company could provide to its customers. To this end, it is necessary to develop a first-order model of the parasitic elements comprised within the power modules, as well as accurately account for both conduction and switching losses.

Objectives: Develop an experimental test-bench in order to characterize the power modules in terms of losses and first-order parasitics. Then, an extensive measurement campaign will allow establishing detailed simulation models, that can be further validated against complementary experimental results.

Skills: A good general knowledge of power electronics is recommended.

Level: This project is targeting a master student interested in experimental activities.

DESIGN AND IMPLEMENTATION OF A Z-SOURCE PHOTOVOLTAIC INVERTER PROTOTYPE

Motivations: Imperix power modules allow building most power converter topologies. However, a few of them cannot be directly implemented. Z-source converters constitute one of such families. Therefore, the company would like to explore the design and control of such converters using a more conventional prototyping approach.

Objectives: Design and implement a prototype circuit board (PCB) of a single-phase photovoltaic inverter as well as implement its control using Simulink or PLECS. The experimental validation of the system will also be covered by the project.

Skills: Some prior knowledge of power electronic control and design is required.

Level: This project is should preferentially be addressed by a master student.

EMBEDDED AUTONOMOUS CONTROL OF A GRID-CONNECTED INVERTER

Motivations: Imperix products are very easy to use in prototyping applications. However, some degree of human intervention is always required in order to power up and connect a power inverter to the grid. As such, we would like to develop suitable control firmware for having a 100 % standalone and automated operation.

Objectives: Based on existing converter control files (conventional control techniques), implement the necessary state machine for monitoring the relevant quantities and managing the complete operation cycle automatically.

Skills: Some prior knowledge of power electronic control and design is required.

Level: This project could be addressed by a bachelor student.

INTRODUCTORY VIDEOS FOR POWER ELECTRONICS

Motivations: Imperix provides several application examples on its website, which are a great help for its customers when working with the company's products for the first time. We would like to improve our getting-started documentation with additional content focused on basic power electronic setups, arranged as tutoring videos.

Objectives: Use imperix products for building elementary power converters (buck, boost, inverter, etc.) as typically done by students during teaching laboratories. Produce tutoring videos in order to help other students in a similar situation.

Skills: A strong interest and prior experience with video capture and production are essential. Some prior knowledge of power electronic control and design is a plus.

Level: This project could be addressed by a bachelor or master student.

2. EMBEDDED SOFTWARE PROJECTS

LONG-TERM, HIGH BITRATE DATALOGGING

Motivations: The B-Box RCP control platform possesses a large DDR memory that can be used for a long-term data recording or high bitrate datalogging. Enabling such a feature would be attractive for monitoring applications.

Objectives: Implement the complete firmware and software stack-up to use this memory, configure the logger and trigger it from the usual development environments. Test and validate the design. This project involves both DSP and FPGA programming (VHDL) as well as high-speed microelectronic.

Skills: Mastery of C++ and VHDL is mandatory.
Prior experience with multi-core systems is a plus.

Level: The project is accessible to the bachelor level, provided rock-solid FPGA skills.

MICROCHIP PIC32 BOOTLOADER FOR IN-FIELD FIRMWARE UPDATE USING SPI

Motivations: Imperix's power electronic controller (the B-Box RCP) has a frontpanel composed of an LCD display, a rotary button, LEDs and an USB port. This frontpanel mainly serves to display status information and configure the analog inputs of the controller (filters, gains, protection thresholds, etc.).
Imperix wishes to improve the code of the Microchip PIC32 microcontroller that controls this frontpanel, as well as to distribute such updates to its customers. In order to distribute such a firmware upgrade, the considered approach is to transfer the new code from a neighboring FPGA using SPI.

Objectives: Implement a bootloader for the PIC32 to support on-field firmware update through SPI. Improve the existing SPI communication with the main CPU.

Skills: C, C++, SPI. Prior experience with Microchip microcontrollers is a plus.

Level: This project can be addressed by a bachelor student.

TIMESTAMPING-BASED NETWORK FAILURE DETECTION FOR ETHERNET APPLICATIONS

Motivations: Imperix has developed a unique protocol for ultra-low-latency communication between digital controllers in power electronics applications. The existing fault detection mechanisms could be improved based on the various possible (multi-rate) sampling configurations. This would also offer attractive benefits at the HMI level, enabling to display and enforce a specific configuration.

Objectives: Design and implement an OSI layer 2 time-stamping mechanism as well as the corresponding processing and validation features.

Skills: Mastery of C++ and VHDL is mandatory.
Prior experience with multi-gigabit serial communication is a plus.

Level: The project is accessible to the bachelor level, provided rock-solid FPGA skills.

DESIGN AND IMPLEMENTATION OF CONFIGURABLE FPGA-BASED LOW-PASS FILTERS

Motivations: The B-Box RCP power electronic controller possesses 16 analog inputs, each featuring a LTC1065 programmable low-pass filter from Linear Technology (5th-order Bessel filter). For each input, the user can select between 12 cut-off frequencies ranging from 0.5kHz to 40kHz or decide not use any filtering. Imperix would like to explore the possibility to shift towards using digital filters, while keeping all the current features and capabilities.

Objectives: Design and implement, in C++, digital filters with characteristics as close as possible to the LTC1065. Once the filters validated, port them in the FPGA using VHDL.

Using I2C, interface the B-Box frontpanel (PIC32 microcontroller) with the FPGA to retrieve the user configuration.

Skills: Mastery of C++ and VHDL is required.

Level: This project is accessible to a master level student.

CONFIGURABLE ANALOG FRONT-END FOR POWER ELECTRONIC APPLICATIONS

Motivations: The B-Box RCP power electronic controller possesses 16 analog inputs, each with configurable impedance, gain, filter and protection thresholds. To this end, each analog input channel is managed by a small microcontroller, which receives its configuration from a basic HMI (LCD screen + button) on the hardware itself. We would like to make this configuration also available from the computer.

Objectives: In order to make the remote configuration of the front-end possible, configuration data must travel through the following path : Computer GUI -> OPC-UA protocol -> Embedded Linux -> FPGA soft core -> SPI -> ADC channel microcontroller. Each component must be studied and modified in order to add the remote configuration capability.

Skills: Interest for all parts of the stack is essential. Prior experience with most components is also important (PC software, Linux, FPGA, microcontrollers).

Level: This project is accessible to a master level student.

3. DESIGN PROJECTS IN ELECTRONICS

WIRELESS POWER SUPPLY FOR MEDIUM-VOLTAGE POWER CONVERTERS

Motivations: The series-connection of power converter modules up to medium-voltage (MV) levels requires that the power supply of the local gate drive units can withstand an isolation of several kilovolts. In this context, imperix wishes to develop new wireless power supplies for its products, which can support several hundreds to kilovolts of galvanic isolation.

Objectives: Design and implement a wireless power supply (10W at 10kV). This includes the complete circuit design (PCB), magnetics design and assembly as well as system testing.

Skills: Knowledge in analog circuit design required.
Prior experience with magnetics design recommended.

Level: This project is accessible to bachelor students with the required skills.

WIDE-BANDWIDTH HIGH-CMRR ANALOG FRONT-END FOR POWER ELECTRONICS

Motivations: Imperix is currently investigating several design options for the next generation of the B-Box RCP. In this context, the company is investigating how far the analog bandwidth can be pushed, while maintaining the very high common-mode rejection ratio (CMRR) that is required by harsh EMI environments. Typically, a bandwidth of several MHz must be guaranteed, as well as a CMRR of >65 dB from 0 Hz to 1 GHz, all this with a large signal swing.

Objectives: Contribute to the design and characterization of a new analog input chain, aiming to identify the best possible design trade-offs.

Skills: Prior experience with analog circuit design is recommended.

Level: This project can be addressed by a bachelor with the requied skills.

DESIGN OF A LOW-COST MODULE FOR DISTRIBUTED MODULATION AND ACQUISITION

Motivations: Imperix has developed a special communication technology that allows distributed control implementations. In addition to its current controllers that embed RealSync technology, imperix wants to develop an FPGA-based (instead of SoC-based) module usable as a RealSync interface in cost-sensitive power applications.

Objectives: Design and validate a low-cost FPGA-based board compatible with the RealSync protocol (5Gb/s). Port the existing VHDL IPs to the chosen FPGA device. Run performance tests as well as cost analysis.

Skills: Schematic capture and PCB design with Altium Designer, VHDL. Prior experience with Xilinx Vivado is a plus.

Level: This project is accessible to a bachelor student (with reduced scope) or at the master level.

4. SOFTWARE DEVELOPEMENT PROJECTS

USER-CUSTOMIZABLE HUMAN MACHINE INTERFACE (HMI) FOR A DIGITAL CONTROLLER

Motivations: Imperix is developing a new version of its real-time monitoring software BB Control, which is a desktop application that grants remote access to the hardware controllers. This new version of BB control will offer improved performance and flexibility, follow our controller's evolution as to guarantee the best possible experience to our customers.

Objectives: Develop a user interface for a specific module of BB control using Qt. This feature offers a graphical view of the B-Box and the B-Board peripherals. It displays how the B-Box or B-Board are configured (what I/O are used, how the ADCs and PWMs are configured etc). The user would also be able to configure the peripherals in real-time (enable and configure the ADCs and PWMs, assign a hardware scope to ADCs and PWMs, etc).

Skills: C++ , Qt framework, System architecture.

Level: This project can be addressed by a bachelor student.

IN-HOUSE DATA VISUALIZATION LIBRARY FOR AN OSCILLOSCOPE-LIKE SOFTWARE

Motivations: Imperix is developing the future revision of its real-time monitoring software for power electronic applications. It is a desktop application that grants remote access to the company's digital controllers, the B-Box RCP and the B-Board PRO. An essential part of this software is the oscilloscope-like interface, which allows the user to monitor the status of control variables, PWM signals, and much more.

The associated challenge is that these data contain signals of very different sampling rates, ranging from few kHz to hundreds of MHz. This requires a careful handling in order to allow real-time update and manipulation, while respecting the strict time-coherence of data samples.

Objectives: Design and implement, in C++, a data visualization library suitable for the proposed special purpose. This library will be separated into two main features.

1) The data optimization part of the library will ensure a fluid visualization of the data retrieved from the digital controllers (e.g optimize the number of displayed points regarding the desired refresh rate, the number of displayed signals, etc.).

2) The second part of the library will manage the data visualization itself. The goal is to develop a customized plotting library tailored to the utmost demanding needs of the visualization software.

Skills: C++, QT framework, boost C++ Libraries.

Level: This project is best addressed by a master-level student.

XML-RPC SERVER TO MANAGE A REAL-TIME CONTROLLER USING PYTHON

Motivations: Imperix controllers (B-Box RCP and B-Board PRO) have a CPU running Linux for system monitoring and Ethernet communication with the PC. The PC utility software (BB Control) allows the user to read the controller status, update its firmware, monitor and modify variables of running code in real-time. Imperix wishes to explore the possibility for the user to monitor and manage the controllers from Python scripts instead of the BB Control utility software. XML-RPC is considered in this context (see also *https://docs.python.org/3.0/library/xmlrpc.client.html*).

Objectives: The objective is to implement an XML-RPC server on the controller as well as an associated API on the computer side, so that the user could interact with the controllers using Python scripts instead of the BB Control utility software.

Skills: C++, Python, Embedded Linux, HTTP/HTTPS.

Level: This project is accessible to bachelor students with the required skills.