The B-Box RCP accelerates the development and experimental validation of converter control techniques in a laboratory environment.
TAILORED DESIGN
The B-Box RCP is entirely and exclusively tailored to be a rapid prototyping controller. It notably distinguishes by the very high flexibility of its analog front-end and specialized I/O interfaces.
Also, B-Box RCP has been designed for synchronous sampling applications and a strict management of timings, from analog inputs to PWM outputs, including in stacked configurations.

HIGH-END DESIGN
B-Box RCP embeds the latest processing devices, including a dual-core ARM processor and Kintex-grade FPGA.
Together with an ultra-light and specialized operating system, this guarantees state-of-the-art performance for all closed-loop control applications. Running a converter control algorithm in the hundreds of kHz range becomes no longer a challenge!

ELECTRICAL INPUTS
Connector A
- 8x General Purpose Inputs (GPI 0-7)
- 16x Fault inputs (e.g. driver feedback)
- 1x SPI/I2C link

Connector B
- 8x General Purpose Inputs (GPI 8-15)
- 36x User-configurable I/Os

ANALOG OUTPUTS
- 4 channels
- ±5V full-scale outputs
- Real-time configurable from the BB Control utility software
SCALABLE DESIGN

Multiple B-Box units can be stacked together to build up larger controllers. Up to 64 boxes can be combined, extending up to thousands of I/Os!

This brings high flexibility in time and across multiple projects. It is always possible to combine (or separate) units depending on the varying needs of their applications.

FUTURE-PROOF DESIGN

The B-Box RCP is built over a strong hardware abstraction layer, which guarantees the stability of its operation – as a platform – over time and across the evolution of its own hardware.

This way, it is guaranteed that a code that works today will still work in the future, even though the hardware will most certainly have changed in-between.

ANALOG INPUTS

- 16 channels
- ±10V full-scale inputs
- High-Z full diff. or Low-Z single-ended
- Programmable gains
- Programmable low-pass filters (+ bypass)

ELECTRICAL OUTPUTS

- Connector C
  - 8x General Purpose Outputs (GPO 0-7)
  - 16x PWM outputs (PWM 0-15)

- Connector D
  - 8x General Purpose Outputs (GPO 8-15)
  - 16x PWM outputs (PWM 16-31)

OPTICAL OUTPUTS

- 16x PWM outputs (PWM 0-15)
- Rigorous pairs or independent signals
- Plastic optical fiber (650nm)

INTERLOCK

- Inter-systems shared fault line
- Electrical and optical signalling

SFP+ INTERCONNECT

- I/O extension for inter-B-Box communication
- 5 Gbps RealSync™ link

ANALOG INPUTS

- 16 channels
- ±10V full-scale inputs
- High-Z full diff. or Low-Z single-ended
- Programmable gains
- Programmable low-pass filters (+ bypass)
KEY SPECIFICATIONS

- **NEW DSP**
  - 2x ARM 1GHz
  - 4 ns PWM resolution

- **NEW FPGA**
  - 134 user I/Os

- **MORE I/Os**

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>System on chip</td>
<td>Zynq XC7Z030-3</td>
<td>x1</td>
</tr>
<tr>
<td>Processor</td>
<td>ARM Cortex A9 1GHz</td>
<td>x2</td>
</tr>
<tr>
<td></td>
<td>1GB DDR3</td>
<td></td>
</tr>
<tr>
<td>FPGAs</td>
<td>Kintex 7 125K (main)</td>
<td>x1</td>
</tr>
<tr>
<td></td>
<td>Artix 7 35T (auxiliary)</td>
<td>x1</td>
</tr>
<tr>
<td>Analog inputs</td>
<td>16 bits @ 500ksps</td>
<td>x16</td>
</tr>
<tr>
<td>Incremental decoder inputs</td>
<td>3-pins (A,B,Z)</td>
<td>x4</td>
</tr>
<tr>
<td></td>
<td>(shared with GPI inputs)</td>
<td></td>
</tr>
<tr>
<td>PWM outputs</td>
<td>Optical</td>
<td>x16</td>
</tr>
<tr>
<td></td>
<td>Electrical (3.3V)</td>
<td>x32</td>
</tr>
</tbody>
</table>

**User I/Os**
- **(high-speed)**
  - Electrical (3.3V) (bi-directional)
  - x36

**General-purpose I/Os**
- IN, electrical (3.3V / 5.0V)
  - x16
- OUT, electrical (3.3V / 5.0V)
  - x16

**Fault inputs**
- Electrical (3.3V)
  - x16
- Electrical interlock
  - x1
- Optical interlock
  - x1

**Communication**
- CAN
  - x1
- Ethernet 1 Gbps
  - x1
- SFP+ 5Gbps (RealSync)
  - x3

BENEFITS

**SWITCH FROM SIMULATION TO EXPERIMENTATION IN NO TIME**

The B-Box RCP can be **programmed in just one click** directly from Simulink™. Besides, everything can be accurately simulated first, ensuring that everything that works in simulation also works in the real world!

**GO EARLY TO THE LAB AND WORK STRAIGHT AHEAD WITH POWER**

With the hardware protections present in the B-Box RCP, engineers can **start testing early** and confront their models to real-world issues as soon as possible.

**GENERATE HIGH QUALITY AND IMPACTFUL EXPERIMENTAL RESULTS**

Thanks to the data logger embedded in the B-Box RCP, every signal can be observed, tuned and logged during run time. This allows to generate high quality measurements in the blink of an eye.
The B-Box RCP has been designed to be easily programmed using C/C++ code or using automated code generation toolbox for Simulink™. All it takes to flash a control code on the B-Box RCP is one click; code generation, compilation and upload on the device are fully automated. Besides, no particular skills are needed to program the B-Box RCP; complete block-set and code libraries are readily available to make programming as easy as possible.

B-Box RCP can be used alongside a computer or as a standalone device. In both cases, a Gigabit Ethernet connection provides a programming access and a direct insight into the code’s execution, thanks to the BB Control utility software. This way, B-Box RCP can be used as a desktop-based development platform, as well as an integrated controller within a larger system. This second scenario may be of interest in microgrids, where the focus is rather put on strategy-level aspects.

The BB Control utility software is the tool for the real time access to B-Box RCP and B-Board PRO controllers. It enables users to access, monitor and tune any variable in real time. This software also provides datalogging capabilities that are comparable to those of an oscilloscope combined with a signal generator. This allows to produce and observe various transient regimes, while logging every data point, thereby facilitating the tuning of control parameters.
Each B-Box RCP features no less than 2 FPGAs, a dual-core processor and several microcontrollers, enabling state-of-the-art performance and an unrivaled ease of use!

1. **PROCESSING BOARD**
   A high-performance embeddable controller at the heart of B-Box RCP.
   The B-Box RCP embeds a high-performance variant of B-Board PRO controller. It therefore ideally supports the very demanding needs of rapid control prototyping.

2. **FRONT DISPLAY**
   A direct access to all details and settings from the front panel.
   All configuration settings for the analog front-end can be directly modified from the LCD front panel. Status message are also immediately made available.

3. **AUXILIARY FPGA**
   The necessary hidden logic behind a highly flexible platform.
   The Artix 7 FPGA located on the motherboard hosts all of the resident features of the B-Box RCP such as protection, signal mapping and internal monitoring.

4. **ELECTRICAL I/Os**
   High-performance I/Os for demanding control applications.
   B-Box RCP offers hundreds of digital I/Os. Furthermore, thanks to their direct ties to FPGA logic, ultra-fast operation is possible with a bandwidth above 200 Mbps.

5. **ANALOG FRONT-END**
   A fully-configurable front-end within a power converter controller.
   With configurable impedance, gains and low-pass filter frequencies, the B-Box RCP is ready to accommodate any analog signal, with no additional interface board.

6. **OPTICAL I/Os**
   Plug-and-play compatibility with imperix power modules.
   With superior EMC performance, optical fibers are the preferred solution for conveying PWM signals, which are also 100% plug-and-play with power modules.
KEY FEATURES

USER-PROGRAMMABLE FPGA

Absolutely no expertise in FPGA-based development is needed to work with the B-Box RCP, as it operates readily with a highly flexible and highly configurable FPGA firmware.

Nevertheless, for those who require to implement specialized control logic inside the FPGA, a dedicated area is provided, with straightforward integration within the DSP software kernel.

HIGH PROCESSING POWER

The B-Box RCP uses a 1GHz dual-core processor. One core is dedicated to the closed-loop control tasks (bare metal, dedicated kernel), the other one to the supervision and monitoring (linux). Besides, most low-level tasks are shifted in FPGA.

This results in the complete dedication of a fast floating-point processor core to real time control tasks, with best-in-class performance, ranging up to 250 kHz closed-loop control frequencies.

HARDWARE-LEVEL PROTECTION

In case of dangerous operating conditions, the B-Box RCP instantly blocks all its PWM signals, thanks to a dedicated hardware protection circuit. This guarantees a high level of protection, entirely independently from both the DSP cores and the FPGA.

The B-Box RCP is also self-protected against inappropriate software conditions such as excessive computational burden or critical algorithmic errors.

HIGHERLY FLEXIBLE FRONT-END

Each B-Box RCP possesses 16 highly configurable analog inputs. This obviates the burden of repeatedly developing analog signal conditioning interfaces for each project.

Each input channel features:
- 3kΩ full-differential voltage-type input or 100Ω single-ended current-type input
- Programmable safety thresholds
- Programmable gain amplifier and low-pass filter

![Diagram of B-Box RCP hardware](image)
A HARDWARE FOR POWER ELECTRONICS
Tailored peripherals for best-in-class performance and convenience

READY FOR ANY SENSOR
Highly flexible analog front-end
The B-Box distinguishes from other RCP platforms by its highly configurable and high-performance front-end. This allows to easily adapt to existing prototypes and/or allow to switch easily across several projects.

READY FOR ANY MISTAKE
Software-independent protections
Each analog input channel features programmable safety thresholds which allow to block the generation of PWM signals in less than 1 μs in case of an overvalue (e.g. over-voltage or overcurrent).

This mechanism is implemented at the hardware level, so that it is entirely independent from the operation of both the CPU and the FPGA. It is hence guaranteed to be effective even when the user application is still under debugging and not sufficiently reliable on its own.

READY FOR EXPANSION
Transparent I/O extension
B-Box RCP can be used in stacked configurations up to 64 units. Communication uses 5 Gbps optical fibers and the RealSync™ technology, which simultaneously guarantees an extremely low latency and extremely high synchronization accuracy (see later). Moreover, this is absolutely transparent to the user so that nothing needs to be configured at any point in time. Slave I/Os simply work as if they belonged to the master.
READY FOR WIDE BANDGAP SEMICONDUCTORS

High performance modulators

The newest B-Box RCP hardware supports a ultra-high time resolution of 4 ns (250 MHz) on all its PWM signal generation processes. This guarantees a high angular resolution even in very fast-switching applications such as with Silicon Carbide (SiC) semiconductors.

Very-low jitter on all PWM signals is also guaranteed such that the overall temporal accuracy of all edges is also maintained up to the gate drivers. This way, very low dead times (typ. < 50ns) can be configured, hence minimizing distortion sources in very fast switching applications.

What's more, this is also guaranteed across several B-Boxes, thanks to the imperix RealSync™ technology!

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>16</td>
<td></td>
<td></td>
<td>bits</td>
</tr>
<tr>
<td>Operating frequency range</td>
<td>0.001</td>
<td>2'500</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>(with 1 % angular resolution)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output jitter/skew</td>
<td>±4.5</td>
<td>±13</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>(single B-Box)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(across B-Boxes)</td>
<td>±6.5</td>
<td>±15</td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

READY FOR ANY MODULATION ALGORITHM

Pre-implemented modulators

B-Box RCP supports a broad range of PWM techniques, thanks to dedicated modulators that are pre-implemented inside the FPGA.

This guarantees a safe and sound behavior and relieves users from the burden of implementing and testing their own peripherals.

By default, B-Box RCP provides carrier-based and space-vector modulators, programmed pulse patterns (e.g. for selective harmonic elimination), direct output access (e.g. for model-predictive control) and sort-and-select balancing and modulation for Modular Multilevel Converters (MMC).

READY FOR ANY PROJECT

Multiple I/O expansion options

By default, B-Box RCP is designed to operate with RJ45 analog inputs and fiber optical outputs. This is what is directly plug-and-play with imperix power modules.

Furthermore, numerous electrical I/Os are also available for other projects or interfacing additional equipment. Fast bidirectional I/Os are also available for custom-implemented FPGA firmware.
PROGRAMMING

Software Development Kits (SDK)

ACG SDK

The Automated Code Generation (ACG) SDK enables engineers to program B-Box RCP and B-Board PRO controllers directly from MATLAB™ Simulink™. The provided toolchain handles fully automated code generation, compilation and upload, in just one click.

In addition, the SDK contains simulation models of each controller peripheral, so that the exact system behavior can be simulated – and hence easily anticipated – before code is generated.

C/C++ SDK

The C/C++ SDK provides a direct way to implement converter control techniques without requiring any simulation software. This approach also offers superior performance and flexibility over automatically-generated code.

The SDK contains extensive libraries, specifically developed to make the coding experience as simple as possible, while granting users direct access to each and every system parameter.

FEATURE

<table>
<thead>
<tr>
<th>ACG SDK</th>
<th>C/C++ SDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBOS operating system</td>
<td>✔</td>
</tr>
<tr>
<td>Blockset for Simulink™</td>
<td>✔</td>
</tr>
<tr>
<td>C/C++ coding environment</td>
<td>✔</td>
</tr>
<tr>
<td>BB Control monitoring software</td>
<td>✔</td>
</tr>
<tr>
<td>Code examples</td>
<td>✔</td>
</tr>
<tr>
<td>User-editable FPGA area</td>
<td>✔</td>
</tr>
<tr>
<td>Multi B-Box operation (I/O extension)</td>
<td>✔</td>
</tr>
</tbody>
</table>

* Requires a valid MATLAB™ license issued by MathWorks™ and the following toolboxes: Embedded Coder, MATLAB™ Coder and Simulink™ Coder.

MULTIPLE HARDWARE

The very same software can be used for programming either the B-Box RCP or the B-Board PRO. Besides, thanks to the strict equivalence between both devices, user-level control software is also guaranteed to behave identically.

OPEN FRAMEWORK

Imperix SDKs being only a set of tools, engineers remain in complete control of their control software. Everything can be tuned or edited down to the duty cycle! Furthermore, the FPGA firmware can also be modified for even more flexibility.

SOFTWARE FOR EVERYONE

Irrespective of the level of expertise or field of use, the very same software can be used for teaching purposes, R&D activities or industrial applications. Everything is kept simple, allowing to accelerate any development.
REAL TIME MONITORING AND TUNING

With the BB Control utility software, the execution of the control code can be fully supervised from a PC. The software allows to both visualize and modify any variable in real-time. It is then the perfect tool for the easy debugging of any control algorithm.

What’s more, thanks to the full dedication of a separate CPU core for the data logging, the monitoring and tuning and logging of variables is guaranteed not to interfere with the real-time execution of the main control code.

DATA LOGGING AND PROCESSING

The datalogging capabilities of B-Box RCP and B-Board PRO are directly accessible from the BB Control utility, allowing to see exactly what the code sees and does at every sample. The latest hardware enhancements enable access to 32 channels of 200,000 pts.

The datalogging can observe any variable and can be triggered from any signal, offering maximum flexibility. Also, thanks to the associated transient generator, testing the transient response of control loops and tuning them has never been so easy!

FRONTPANEL CONFIGURATION

Each of the 16 analog inputs channels of the B-Box RCP can be configured visually, directly from within the BB Control utility.

This way, all hardware parameters can be stored together with other software and recalled instantly when moving to the lab. This also enables several users to share the same control hardware and carry with them their individual configurations.
SOLUITIONS FOR THE INDUSTRY

From the lab to the field!
BRIDGE THE GAP BETWEEN PROTOTYPES AND PRODUCTS!

What if you could simply take the result of your research and put it into an affordable controller, directly embedded inside your own products?

DEVELOPMENT PHASE
• Flexible hardware
• Rapid control validation

PRODUCTION PHASE
• Cost-optimized hardware
• Pre-validated control

FULL BITFILE COMPATIBILITY!

B-Box RCP
Prototyping controller

B-Board PRO
Embeddable controller

The exact compatibility between B-Box RCP and B-Board PRO allows to benefit from the increased flexibility of the prototyping controller during developments, while using a lower-cost product-embeddable variant during series production.

BITFILE COMPATIBILITY
The FPGA-based abstraction layer present in B-Box RCP and B-Board PRO guarantees the exact same performance (especially timings) on both devices.

SMALL FORM FACTOR
Despite its numerous I/Os, the B-board measures only 86x124 mm. It is therefore small enough to be mounted within most industrial control systems.

PROCESSING POWER
The 3rd generation of controllers rely on dual-core processors and modern FPGAs for best overall performance in demanding applications.
HIGH-END INTERCONNECT

Imperix RealSync™ technology

PERFECT SYNCHRONIZATION

Imperix’s patent-pending RealSync™ technology guarantees an unrivaled synchronization accuracy across multiple units, down to ±2.0 ns! This is achieved through advanced clock dissemination through the optical fibers, enabling multiple B-Box to operate as if they were one single unit!

HIGH-SPEED COMMUNICATION

The 5 Gbps SFP+ links can be configured to form a tree-shaped network, achieving superior data bandwidth and lower latency over daisy-chain or ring topologies. This guarantees sub-microsecond data transfers in many configurations with up to 8 controllers!

MAXIMUM I/O CAPABILITIES

<table>
<thead>
<tr>
<th>Component</th>
<th>Single (1 unit)</th>
<th>Stacked (64 units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog inputs</td>
<td>16x</td>
<td>1024x</td>
</tr>
<tr>
<td>PWM outputs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical</td>
<td>16x</td>
<td>1024x</td>
</tr>
<tr>
<td>Electrical</td>
<td>32x</td>
<td>2048x</td>
</tr>
<tr>
<td>General-Purpose digital Outputs (GPO)</td>
<td>16x</td>
<td>1024x</td>
</tr>
<tr>
<td>General-Purpose digital Inputs (GPI)</td>
<td>16x</td>
<td>1024x</td>
</tr>
</tbody>
</table>

The synchronization between B-Boxes is achieved without the user even knowing it! The guaranteed accuracy is ±2.0 ns.

Ultra-low latency is achieved even with a high number of ADC or PWM channels. This allows closed-loop control frequencies up to 250 kHz.
POWER ELECTRONICS PROTOTYPING

STARTER KITS
DEVELOP AND BUILD UP
SYSTEM PROTOTYPES WITHIN MINUTES!

Combined together, imperix products are ideally suited for laboratory and teaching applications. They indeed possess all the features – ranging from ease-of-use to robustness – to be safely put in the hands of engineers and even students.

Starting kits and specialized bundles are now available on imperix.ch/products/bundles, which allow to start working in the lab straight away, with almost no start up time.

INTEGRATION LEVELS
Imperix products can be delivered as bare and independent products, fully turnkey systems, or anything in-between.

POWER RATINGS
Imperix products are well suited for the implementation of power converter prototypes ranging from 100 W to 100 kW.

INTER-OPERABILITY
Imperix products are plug-and-play when used together, but can also be used with any other controller or power stage.

PLUG-AND-PLAY SOLUTIONS
By combining imperix control and power hardware with dedicated software and accessories, users benefit from a broad range of prototyping equipment, suitable for everyone’s need and ambition.

ACCESSORIES
Imperix provides several accessories that also contribute to facilitate the implementation of laboratory-scale converters.

SOFTWARE EXAMPLES
Imperix is currently building a complete knowledge base of control code and software examples, available free of use.
BUNDLES EXAMPLES

In order to accelerate as much as possible the prototyping of power converters, imperix provides several bundles including hardware, software and all the necessary accessories to start working as soon as products are delivered.

**LIGHT MMC BUNDLE**
**REACH WORLD-CLASS RESULTS IN NO TIME!**

The MMC bundle is a typical example of a ready-to-use system. Dedicated to Modular Multilevel Converters it allows engineers to focus on converter control techniques rather than hardware implementation.

* HARDWARE + SOFTWARE
  - 3x B-Box RCP + ACG SDK
  - 3x open chassis with 24x PEH 2015
  - 6x inductors
  - Grid-side panel
  - 4x voltage sensors
  - 6x current sensors
  - All needed cables

OPTIONS
- Without ACG SDK (Simulink™ blockset)

VARIANTS
- PEB4046 for increased power

**MICROGRID BUNDLE**
**EXPERIMENT IN THE REAL WORLD!**

The microgrid test bench is a multi-purpose test bench for power electronics. It is able to support both HIL simulation and low-voltage experimentation with an easy-to-use reconfigurable hardware.

* HARDWARE + SOFTWARE
  - B-Box RCP + ACG SDK
  - Interface for Opal-RT simulators
  - Opal-RT OP4510
  - PowerTrench with 6x PEB SiC 8024
  - Passives filters box
  - All needed cables

OPTIONS
- Without ACG SDK (Simulink™ blockset)
- Grid connection box
- Power amplifier for PHIL

VARIANTS
- Other configuration

* All current prices are available on www.imperix.ch