ADVANCED PROTOTYPING CONTROLLERS

HIGH-PERFORMANCE SOLUTIONS FOR
CONTROL DEVELOPMENT AND TESTING

imperix

THE MOST ADVANCED RCP CONTROLLER

B-Box 4

HIGH PROCESSING POWER

» Fast CPUs 4x 1.5GHz – Up to 500kHz operation
» Large FPGA Kintex 504T – User-programmable
» Extensive memory 8GB RAM – 500GB SSD

ADVANCED MONITORING

» Oversampling at full ADC speed
» Real-time logging & parameter tuning
» Live performance analysis
» OPC-UA connectivity

4x **ARM** 1.5 GHz — **NEW** CPU

1x **Kintex** 504 K — **NEW** FPGA

20 Msps sampling — **NEW** ADC

250 ps resolution — **NEW** PWM

ULTRA-FAST ANALOG INPUTS

» High bandwidth 2.7MHz
» Ultra-fast sampling up to 20Msps
» Wideband CMRR >80 dB at 1MHz
» Low noise / offset <1mV / <6nV/√Hz
» High accuracy 0.1% typ.

HARDWARE PROTECTIONS

» Configurable thresholds -10V...+10V
» Ultra-fast reaction 800 ns
» Simple configuration in Cockpit
» Software-independent operation

System on chip	AMD ZynQ Ultrascale+ 7EV	x1
Processors	ARM Cortex A53 1.5 GHz 8 GB DDR3	x4
FGPA	Kintex US+ 504K	x1
Internal storage	500GB SSD	x1
Analog inputs	16bits @ 20 Msps	x24
Analog outputs	12bits @ 500ksps	x24
Digital inputs	Electrical (3.3V)	x16
Digital outputs	Electrical (3.3V)	x16

PWM outputs	Optical Electrical (3.3V)	x24 x48
User I/Os (bidir.)	Electrical (3.3V)	x36
Encoder inputs	BiSS-C / EnDat / SSI	x2
Fault inputs	Electrical interlock Digital inputs (shared)	x1 x16
Communication	Ethernet 1 Gbps (RJ45) CAN-FD / CAN 2.0B USB 3.0 QSFP+ 4x10 Gbps	x1 x2 x1 x4

HOW DOES IT COMPARE TO B-BOX 3?

SUPERIOR PERFORMANCE

» More I/Os +50%
» Faster sampling x40
» Higher PWM resolution x16
» Increased processing power +50%
» Larger FPGA x4

IDENTICAL WORKFLOW

» Identical software (SDKs)
» Identical libraries
» Identical connectivity (RJ45, VHDCI, etc.)
» Identical licensing policy

ADDITIONAL CAPABILITIES

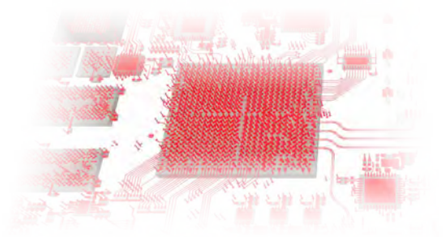
» Oversampling of ADC and PWM
» Remote configuration of analog I/Os
» Auto sensor configuration
» Extended protocol support: CAN-FD / CAN 2.0B
BiSS-C / EnDat / SSI
Modbus TCP

CROSS-COMPATIBLE WITH GEN.3

» Cross-compatible Simulink/PLECS models
» Cross-compatible RealSync connectivity
» Cross-compatible VHDCI pinout
» Compatible with all generations of power modules and sensors

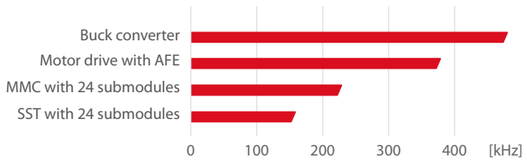
THE MOST ADVANCED RCP CONTROLLER

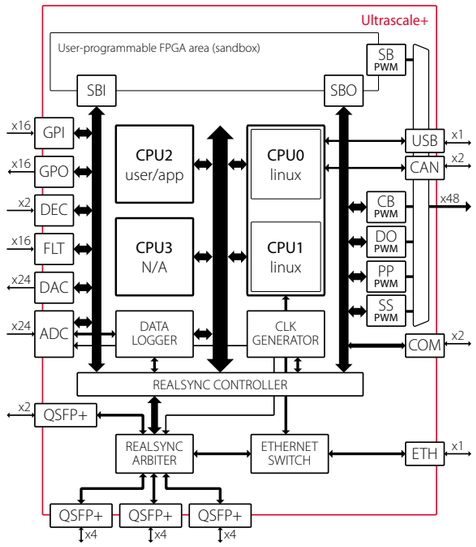
B-Box 4



HIGH-PERFORMANCE COMPUTING

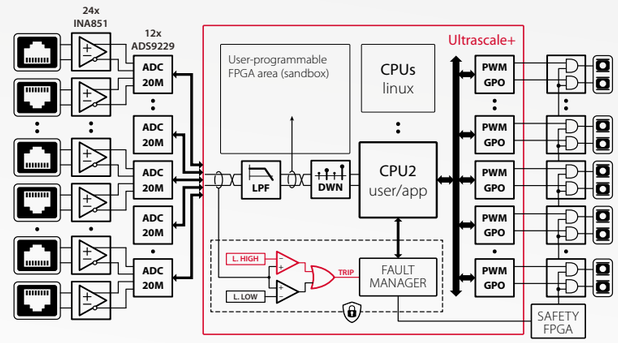
The B-Box 4 is the fastest CPU-based controller available, achieving closed-loop controls up to 500 kHz. This is enabled by its industry-leading SoC, fully leveraged through optimized bare-metal execution and maximum hardware acceleration. The result is a controller that delivers FPGA-level performance with the ease of CPU programming, ideal for today's most demanding applications and ready for tomorrow's next-generation systems.

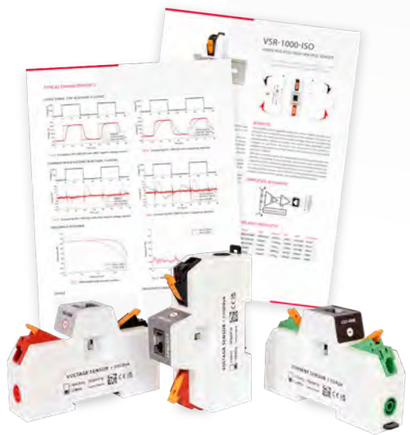




CUTTING-EDGE I/O PERIPHERALS

The B-Box 4 is the flagship of RCP systems, with best-in-class ADC and PWM circuits, featuring 20 Msps acquisition and 250 ps PWM resolution. To fully leverage this performance, the analog frontend has been rigorously designed for high-fidelity acquisition over the full bandwidth, without compromising on precision, EMI performance, or noise.



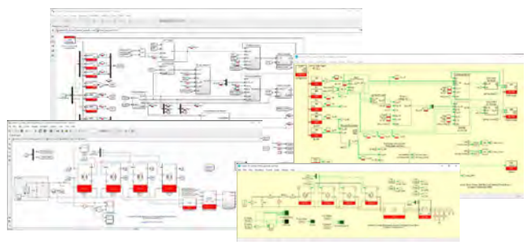


PLUG&PLAY HIGH-PERFORMANCE SENSORS

Even though the B-Box 4 can be used with virtually any sensor, imperix also offers high-performance, plug-and-play sensors for the B-Box 4, matching the performance of its analog inputs. These sensors feature automatic identification, simplifying configuration and saving setup time:

- **±500V 3 MHz differential voltage sensors**
- **±50 1.5 MHz isolated current sensors**
- **±1000V 100 kHz isolated voltage sensors**

These meticulously designed and benchmarked sensors offer outstanding common-mode voltage rejection, even in high dV/dt situations, allowing their placement virtually anywhere in the circuit, thus truly meeting the needs of rapid control prototyping.

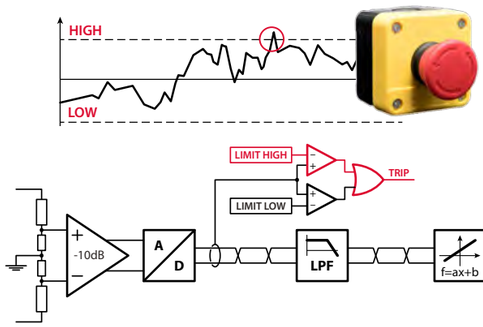


DIRECT INTEGRATION IN SIMULINK/PLECS

The B-Box 4 is the simplest controller to program, allowing automated code generation from Simulink or PLECS in just one click. What is so special is that the same model can be used for both simulating the system offline and generating the runtime code. This unified workflow, along with accurate simulation models of both the control- and the plant-side components, allows for easy control code validation or parameters tuning before any line of code is generated.

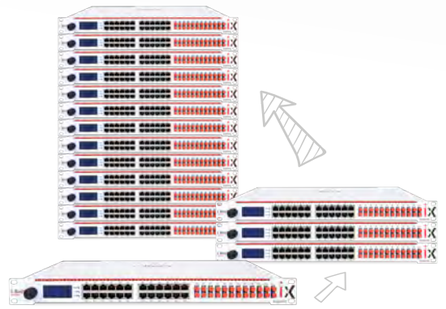
INTEGRATED SCOPING

The B-Box 4 comes with the most capable companion, Cockpit, a software application that runs independently on the host PC and provides remote access to the controller's measurements and internal variables. Cockpit combines advanced scoping functionalities with data analysis modules (FFT, THD, RMS, etc.), enabling rapid debugging and in-depth analysis directly on the live system. Its intuitive and customizable interface significantly simplifies experimentation and makes lab work more efficient.



HARDWARE PROTECTIONS

The B-Box 4 is the safest RCP controller, thanks to highly reliable hardware protection mechanisms. Acting as analog comparators with thresholds set by the user in the Cockpit software, these safeguards instantly detect unsafe conditions and immediately halt operation, completely independently of the user's application, be it running in CPU or FPGA. Combined with rigorous PWM generation that strictly prevents harmful output states, this makes the B-Box 4 a unique solution, purpose-built for power electronics.



INSTANT SCALABILITY

The B-Box 4 is the most easily scalable control system, thanks to an architecture that enables multiple units to operate in unison. A single fiber connection provides ±2 ns synchronization and operation with ultra-low latency, enabling instant expansion for I/O demanding applications or distributed control applications. With up to 64 units groupable, the system scales seamlessly to meet growing project requirements and ambitions. What's more, operating slave units requires no additional license.

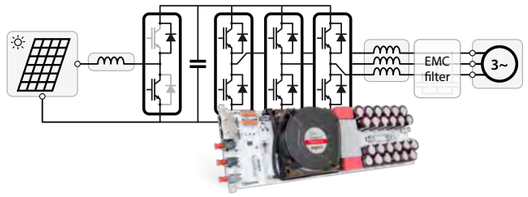
OFF-THE-SHELF APPLICATIONS

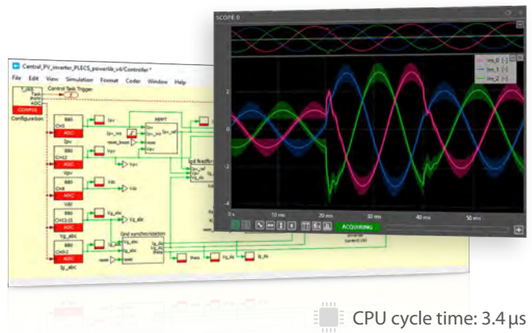
Plug-&-play examples from imperix's online knowledge base

Imperix provides a broad range of application examples on its website, which can serve as readily available starting points for further development. This covers conventional power electronic applications but also more advanced topics. In every instance, relevant technical details are provided and source files are made freely accessible. Learn more at imperix.com/doc.

GRID-TIED SOLAR INVERTER

Three-phase inverter with boost DC/DC





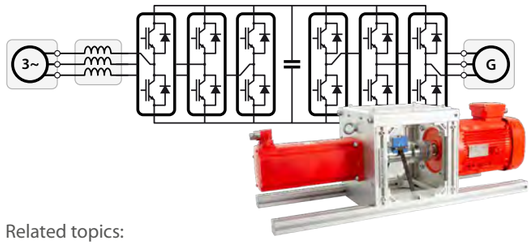
CPU cycle time: 3.4 µs

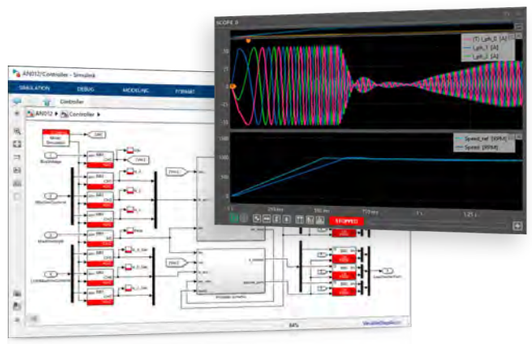
Related topics:

- Vector current control
- MPPT algorithm
- Islanding detection
- Grid-forming control

WIND-TURBINE GENERATOR CONTROL

Variable-speed drive with grid-tied front-end





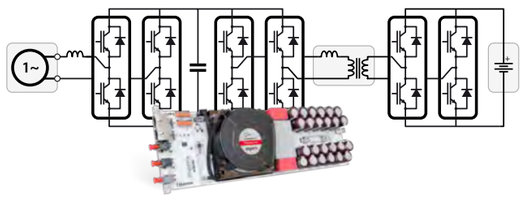
CPU cycle time: 3.0 µs

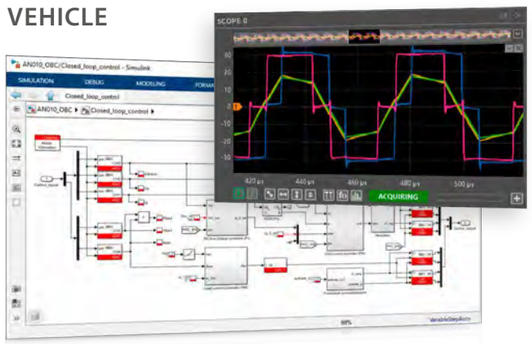
Related topics:

- Field-oriented control
- Sensorless position estimation
- Weak grid stability
- Harmonic mitigation

ON-BOARD BATTERY CHARGER FOR ELECTRIC VEHICLE

Single-phase rectifier and dual active bridge DC/DC





CPU cycle time: 3.2 µs

Related topics:

- Active damping
- DAB modulation schemes
- Vehicle-to-Grid operation
- Grid code compliance

KEY PERFORMING AREAS

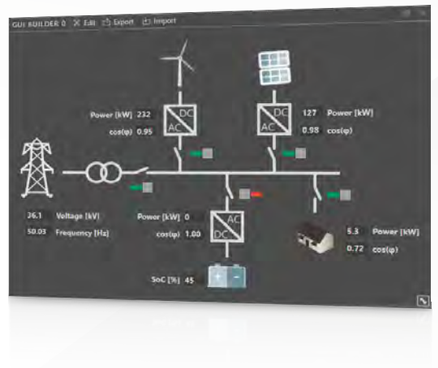
Applications benefiting most from the capabilities of B-Box 4

GAN-BASED CONVERTERS

The enhanced resolution of CB-PWM modulators enables precise control of the fastest GaN or SiC semiconductors and allows for deadtime duration as low as a few nanoseconds. For applications demanding ultra-high control bandwidth (>500 kHz), full control loops can be offloaded to the programmable FPGA for maximum performance.

MICRO-GRID CONVERTER SYSTEMS

The high processing power of B-Box 4 allows for the centralized control of multiple converters, providing enough CPU capacity for grid-level coordination strategies. Alternatively,RealSync also permits hierarchical or fully distributed control implementations across multiple units.



RESONANT CONVERTERS

The controller's substantial analog bandwidth and low-latency peripherals enable the implementation of ultra-fast responses to measurement stimuli. This capacity, further augmented by FPGA programmability, facilitates specialized applications such as synchronous rectification and hysteresis control, previously unattainable with rapid prototyping systems.

MODULAR MULTI-LEVEL CONVERTERS

With 24 analog inputs and 48 digital PWM outputs per device, the B-Box 4 is perfectly suited for controlling MMC, CHB, or SST converters. Various controller arrangements are feasible, depending on the total number of required I/Os and the desired control hierarchy. From a software perspective, the implementation efforts are greatly reduced due to pre-implemented sort-and-select or carrier-based modulators.

IMPERIX COCKPIT

The companion software of imperix controllers

Imperix Cockpit is a powerful monitoring software designed to facilitate the experimental testing of power electronics systems by leveraging the hardware capabilities of imperix controllers.

The software provides a set of non-intrusive tools that support the monitoring and tuning of any control variable in real time, allowing fast and easy validation of the control algorithm.

GUI EDITION

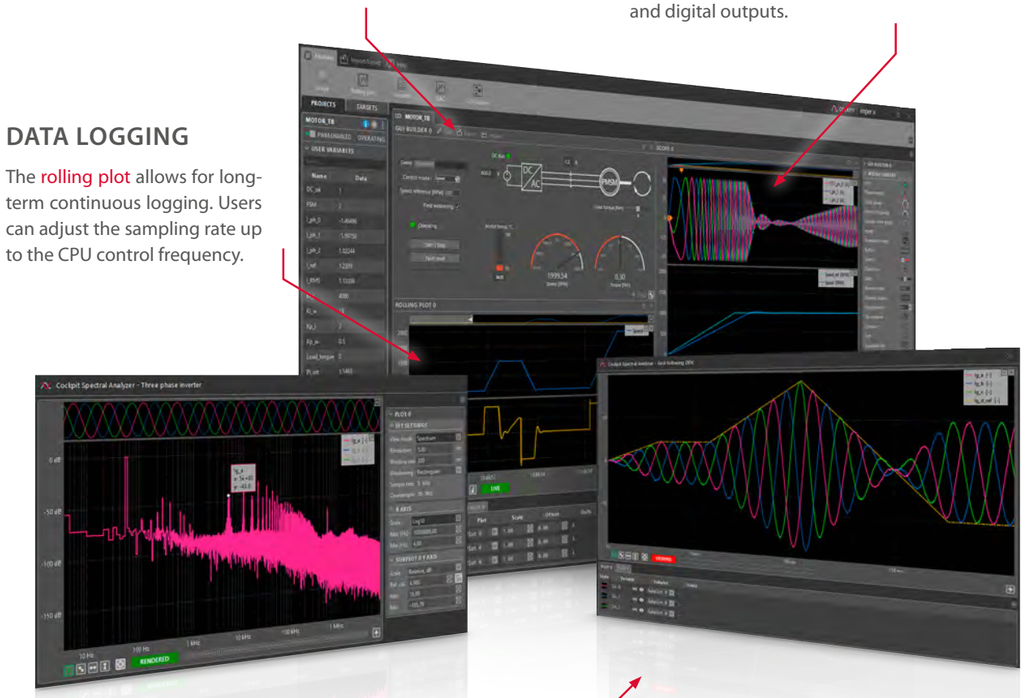
The GUI builder enables users to build custom interfaces thanks to numerous widgets to ease the interaction with the controller.

TRIGGERED SCOPING

Similar to a digital oscilloscope, the scope module allows for trigger-based data acquisition. With B-Box 4, it can even display over-sampled analog inputs and digital outputs.

DATA LOGGING

The rolling plot allows for long-term continuous logging. Users can adjust the sampling rate up to the CPU control frequency.



SPECTRAL ANALYSIS

The spectral analyzer can compute and display the FFT of any scoped variables. This includes all user variables, mathematical formulas and over-sampled signals.

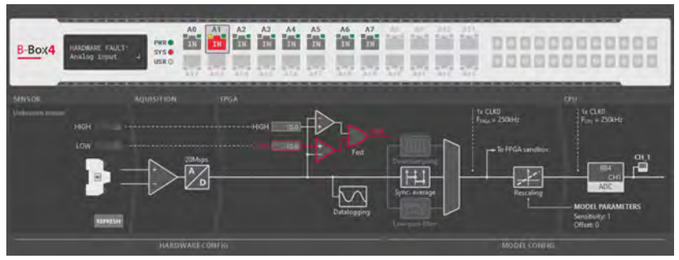
TRANSIENT GENERATION

The performance of the control algorithm can be easily assessed by applying custom test sequences with the transient generator.

REMOTE CONFIGURATION

B-Box4

With B-Box 4, a detailed remote view of the front panel is provided in Cockpit, enabling users to validate or edit the analog I/O configuration in real-time. This also includes the visualization and acknowledgment of faults. Furthermore, the auto. sensor identification makes it easy to configure the protection limits and leverage sensor calibration.



ADC OVERSAMPLING

B-Box4

Taking advantage of the B-Box 4's ultra-fast acquisition, Cockpit can help visualize complex waveforms, revealing dynamics that are invisible at the control rate. This distinctive feature allows for precise observation of what the controller perceives at no extra cost or effort.

PWM OUTPUTS CAPTURE

B-Box4

With B-Box 4, the scoping capabilities are not limited to analog signals, as PWM outputs and other digital signals can also be captured, making an external logic analyzer dispensable.

Plug-&-play compatible, high-bandwidth sensors available at imperix.com

THE GAME-CHANGING DIFFERENCE

Cockpit features exclusive to B-Box 4

See real signals, sampled at 20 MHz !

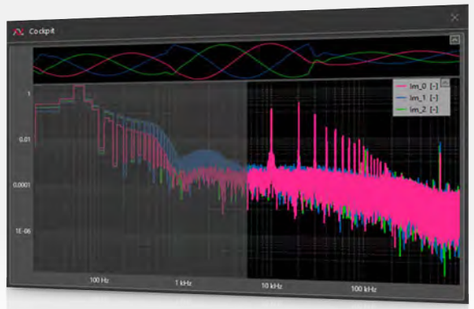
This enables observing switching ripple, or medium-frequency waveforms together with their imperfections for easy validation of the sampling strategy, or debugging.

Observe PWMs, captured at 250 MHz !

This makes it straightforward to validate the modulation, and is applicable to both standard and custom modulators implemented in the FPGA sandbox.

Measure harmonics, up to 10 MHz !

This makes switching harmonics and even low-end EMI components clearly visible. These components are then fully accounted for in the THD and WTHD computation.



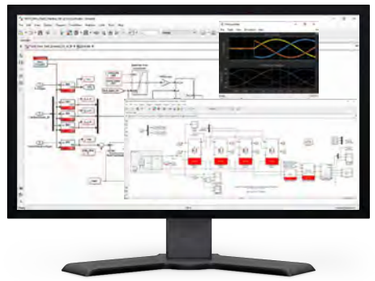
CONTROL ALGORITHM DEVELOPMENT

The imperix workflow for easy transition from the PC to the lab

#1

KNOWLEDGE BASE EXAMPLES

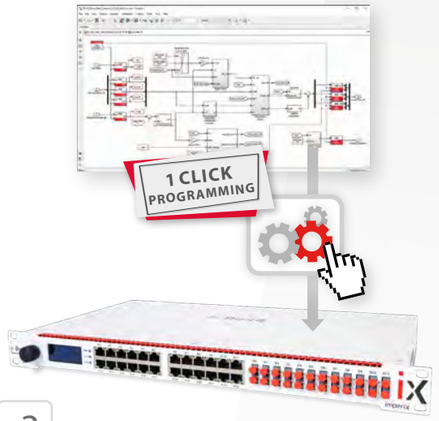
Start from an example from the online knowledge base, which offers over 200 pages of comprehensive examples and guides. It is highly probable that a relevant example for the specific topic in question has already been addressed, making it the ideal starting point for the development of your own control algorithms.



#2

OFFLINE SIMULATION

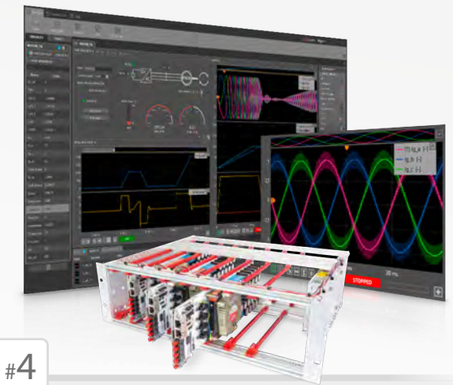
Run offline simulations to refine and validate your control algorithms on a simulated plant, which can be easily modeled with elements from the imperix Power Library. On the controller side, library blocks already integrate accurate models that truthfully replicate the actual behavior, including sampling and various delays.



#3

AUTOMATED CODE GENERATION

Automatically generate a run-time executable for imperix controllers from the same Simulink / PLECS file. All blocks used in the simulation, along with the control algorithms, are automatically translated into code. The programming process, from code compilation to deployment onto the controller, occurs fully automatically with a single click.



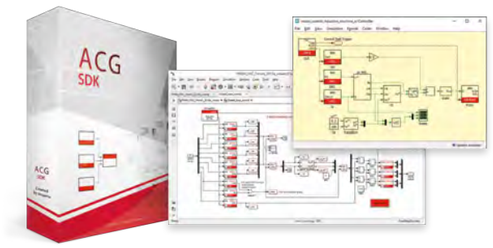
#4

EXPERIMENTAL VALIDATION

Validate experimentally the proper operation of the system using the visualization and analysis tools in Cockpit. Users can fine-tune control parameters in real time and evaluate the resulting dynamics using the transient generator or spectral analyzer. Upon achieving satisfactory results, graphs can be readily exported for subsequent use.

CPU PROGRAMMING plecs

Control development made simple



ACG SDK

The Automated Code Generation (ACG) SDK is the software package that includes all necessary tools to simulate, program and operate imperix controllers. It contains both Simulink and PLECS blocksets for offline simulation and code deployment, as well as the Cockpit monitoring software.

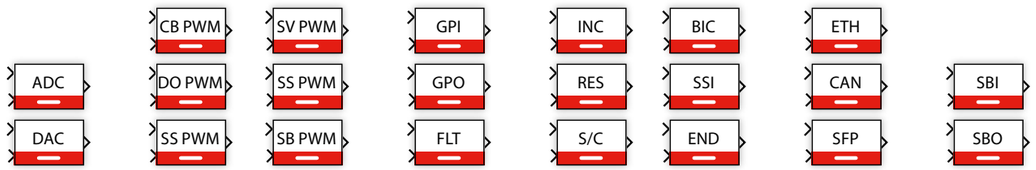
LICENSING POLICY

Imperix software is covered by a lifetime license that includes free maintenance and permits unlimited PC installations. All slave units operate license-free.

CONTROLLER I/O BLOCKS

Control library (included in ACG SDK)

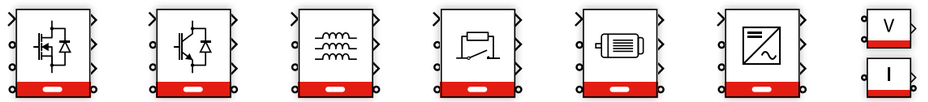
Peripheral blocks that serve as interface to hardware I/Os within the Simulink or PLECS model



PLANT SIMULATION BLOCKS

Power library (included in ACG SDK)

Simulation models of all imperix power products, which facilitate the development of plant models, including impedance parasitics, losses and thermal models.



FPGA PROGRAMMING (OPTIONAL)

LICENSE-FREE

When a microsecond is a challenge

Thanks to the high control rate achievable with sequential algorithms running inside the main CPU core, most engineers prefer not to edit the FPGA, and rather leverage the ease of use offered by the automated generation of code from Simulink or PLECS.

However, more advanced control applications can leverage the unused area available in the FPGA, which is fully customizable for implementing specialized control tasks, custom modulators, or extra means of communication. To this end, relying on all the Vivado Design Suite and IPs, working with imperix controllers is similar to programming any other AMD FPGA.

NETWORKED CONTROL

Imperix's solutions for maximum versatility and scalability

40Gbps QSFP+ optical links

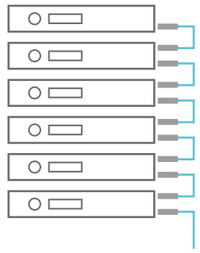
B-**Box 4**

Also compatible* with

B-**Box** RCP 3.0

B-**Board** PRO 3.0

TPI-**8032**



MAXIMUM I/O CAPABILITIES

Component		Single (1 unit)	Stacked (64 units)
Analog inputs		24x	1536x
PWM outputs	**Optical**	24x	1536x
	Electrical	48x	3072x

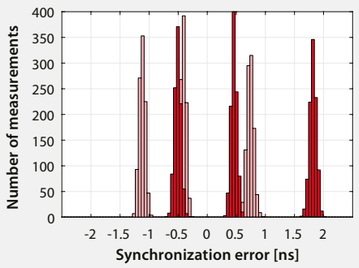
PERFECT SYNCHRONIZATION

Imperix's patented RealSync technology offers an unrivaled synchronization accuracy of ±2.0ns across all units by disseminating the clock throughout the control network, thereby allowing multiple controllers to operate as a single unit.

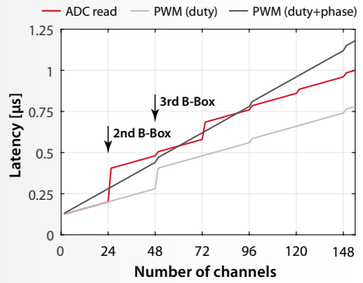
HIGH-SPEED COMMUNICATION

The optical fiber links can be configured to create a tree-shaped network, achieving superior bandwidth and lower latency when compared to daisy-chain or ring topologies. This typically offers sub-µs data transfers in configurations with up to 8 controllers!

The figures tell the story...



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

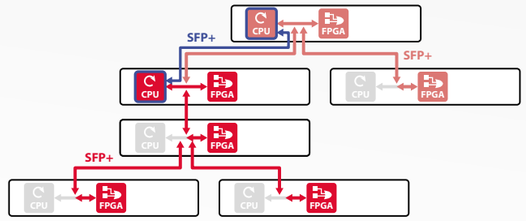


Ultra-low latency is achieved, even with a high number of ADC or PWM channels. This allows closed-loop control frequencies up to 500 kHz.

* at slower rates.

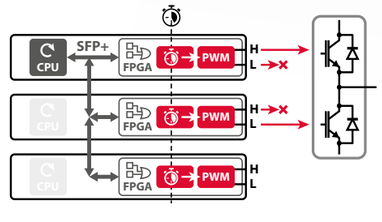
PLUG-&-PLAY I/O EXTENSION

The RealSync technology enables the operation of multiple controllers in a master-slave configuration, thereby extending their I/O capabilities. This expansion is entirely transparent from the user's perspective, such that the collective group of controllers functions and is programmed as a single, larger control unit.



DISTRIBUTED CONTROL

The same technology also supports distributed control strategies across the imperix controller network. Its ultra-low-latency communication allows both local and global control strategies to be implemented for any distributed converter architecture.



DISTRIBUTED MODULATION

The synchronization across the network is so precise that it enables the generation of time-coherent PWM signals across multiple units. This allows for complementary or parallel-connected semiconductors to be directly driven by distinct, geographically separated controllers.

CENTRALIZED MONITORING

A major benefit of imperix's networked control technology is its capability to facilitate centralized monitoring and supervision of extensive, intricate systems from a single Cockpit instance. This is achievable as the monitoring link is integrated within the same physical RealSync connection.

OTHER COMMUNICATION OPTIONS

The communication capabilities of the B-Box RCP 4 goes far beyond RealSync and also extends to third-party devices. For maximum flexibility, a broad range of standard communication protocols is supported:

- Ethernet (TCP / UDP)
- OPC-UA
- CAN (regular / extended / FD)
- SSI / BiSS-C / EnDat
- Modbus TCP
- Aurora (SFP+ / QSFP+)

GENERATION 3.0 CONTROLLERS

Specialized controllers for special needs

While fundamentally similar to the flagship B-Box 4, third-generation controllers are tailored for distinct use-case scenarios and embed a slightly different system on chip (SoC). Nevertheless, the control development environment and workflow remain identical, ensuring portability across devices. This provides substantial flexibility for operating with mixed configurations or for porting developments to the B-Board PRO for deployment in a production environment.

B-**Board** PRO 3.0

The B-Board PRO is a fully programmable controller that can be directly embedded inside power converters. It features a flexible 5-15V power supply and the same system on chip (SoC) as B-Box RCP 3.0 and B-Box Micro. Its direct bitfile compatibility with B-Box RCP 3.0 makes it suitable for a seamless transition from the development phase to the production phase.

B-**Box** micro 3.0

The B-Box micro is a plug-and-play controller for teaching, compatible with imperix power modules and sensors. It supports the same Simulink- or PLECS-based programming experience as other controllers. Its firmware-based protection scheme allows for a safe and student-proof experience in laboratory setups.

B-**Box** RCP 3.0

The B-Box RCP 3.0 is the previous-generation Rapid Prototyping controller. Its continued support and networking compatibility with B-Box 4 makes it a cost-effective alternative with reduced features.

		B-**Box 4**	B-**Box** RCP 3.0	B-**Board** PRO 3.0	B-**Box** micro 3.0
HARDWARE	Processing	4x 1.5 GHz	2x 1.0 GHz		
	FPGA	Ultrascale+ 7EV 504T	ZynQ 7030 125T		
	Digital I/O (PWM)	118x (48x PWM)	118x (32x PWM)	118x (32x PWM)	54x (8x PWM)
	Analog I/O	24x in. 20 Msps 24x out. 250 ksps	16x in. 500 ksps 4x out. 50 ksps	8x in. 2 Msps 0x out.	8x in. 2 Msps 0x out.
	Networking	4x QSFP+ 40 Gbps	3x SFP+ 10 Gbps	3x SFP+ 10 Gbps	N/A
SOFTWARE	Imperix Cockpit	☑ Yes +oversampling	☑ Yes		
	Bare metal OS	☑ Yes			
	CPU programming	☑ Yes (license-based)			
	FPGA programming	☑ Yes (no extra license)			

POWER SOLUTIONS

A complete ecosystem for rapid prototyping in power electronics

Imperix power modules are ideal complements to the B-Box 4, acting as building blocks for the quick and easy development of power converter prototypes.

ASSEMBLE A CONVERTER IN UNDER AN HOUR

Power modules integrate all requisite components for building power converters, including semiconductors, gate drivers, sensors, cooling, and protection. Their deployment accelerates and simplifies the assembly of laboratory prototypes, requiring only a few connections. Plug-and-play compatibility with imperix controllers further streamlines the process.

The product lineup encompasses two-level and three-level phase legs, as well as full-bridge modules, suitable for building virtually any converter topology, ranging from a few watts to a few hundred kilowatts.

PEB-800-40 SIC HALF-BRIDGE

PEH 2015 / 4010 FULL-BRIDGE

PEB 8024 / 8038 SIC HALF-BRIDGE

PEN 8018 NPC PHASE-LEG

READY-TO-USE BUNDLES

LITE KIT

- Programmable controller (B-Box 4)
- Software tools for Simulink and PLECS
- 6x phase-leg modules
- 6x voltage sensors

POWER ELECTRONICS BUNDLE

- Programmable controller (B-Box 4)
- Software tools for Simulink and PLECS
- 6x phase-leg modules
- Passives filters box
- Grid-side panel
- 3x current sensors
- 6x high-bandwidth voltage sensors

MMC BUNDLE

- 2x Programmable controller (B-Box 4)
- Software tools for Simulink and PLECS
- 24x full bridge submodules
- 6x inductors
- Grid-side panel
- 4x voltage sensors
- 6x current sensors

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