How to choose between imperix controllers

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This article outlines the various controllers in the imperix ecosystem and explains how each is optimized for specific niches in the power electronics domain, ensuring that first-time users can select the appropriate controller correctly.

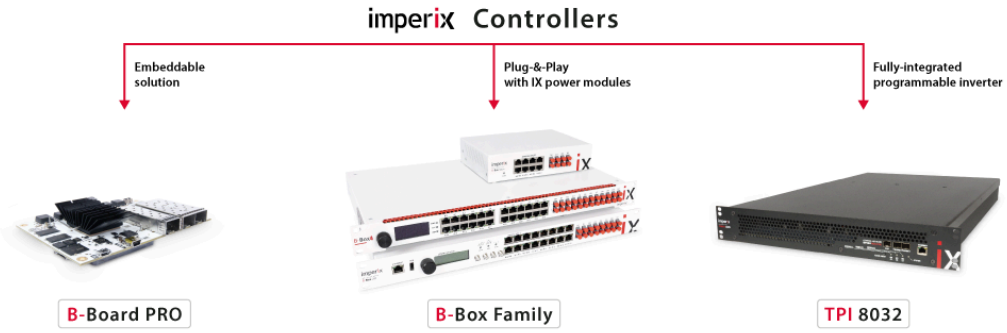
Products presentation

All imperix controllers are based on a DSP + FPGA architecture that is fully programmable by the user. This common architecture is the foundational layer for extensive hardware abstraction, which in turn authorizes excellent interoperability and compatibility across devices and generations.

From a software perspective, all controllers are identical in the sense that they can be programmed from the same Simulink/PLECS control model, with only a few parameter changes. They also support the same workflow and provide the same runtime monitoring and tuning capabilities via Cockpit. At the hardware level,

however, the controllers may present rather different characteristics, notably linked to their I/O resources, each being specifically optimized for a particular use case.

Overall, imperix offers three distinct types of controllers, as shown below:



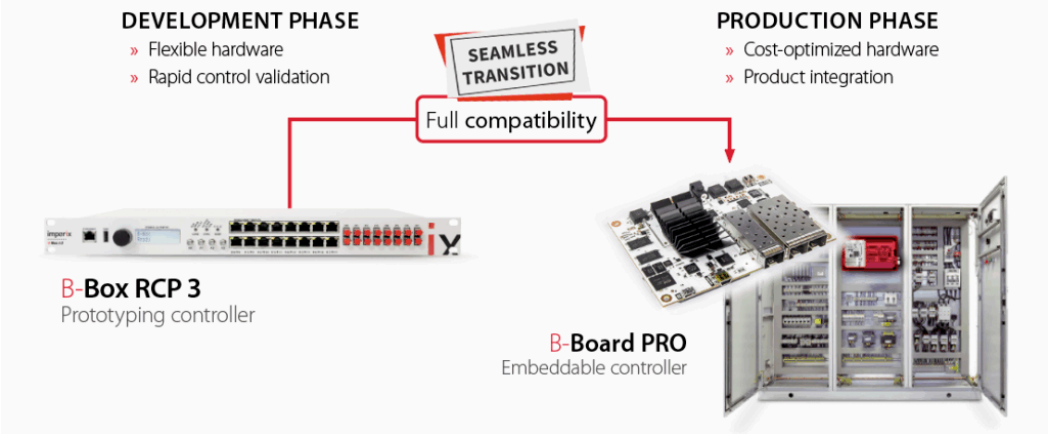
B-Box family

The B-Box family comprises controllers designed for laboratory applications, where performance and flexibility are the main priorities. B-Box controllers are designed to be plug-&-play with imperix power modules (example) but are also flexible enough to be easily used with custom power hardware.

The differences between B-Box controllers are summarized below. Further details on their analog input stages are given in PN105 (B-Box RCP$^{3.0}$), PN106 (B-Box micro), and PN252 (B-Box 4). Differences regarding user-programmable safety thresholds are given in PN257.

B-Board PRO

The B-Board PRO is the control board present inside B-Box RCP and B-Box micro, but is also available as a standalone control board. Its typical applications include industrial use or research, where the controller needs to be embedded directly in the power converter itself. In such a case, the main benefit of using B-Board PRO resides in the way it facilitates the transition between the development phase and the production phase, thanks to immediate portability from the B-Box RCP 3.



More information on the B-Board PRO can be found on the related product page.

TPI 8032

The TPI 8032 is the only product in the imperix portfolio that combines the power and control stages into a single product. Standing for Three-Phase Inverter, the TPI 8032 is a fully programmable inverter optimized for maximum flexibility on the software side, but in experiments where the topology remains constant. Typical applications include grid-connected inverters and the emulation of DERs in lab-scale microgrid applications.

More information on the TPI 8032 can be found on the product page.

	B-Box controllers	**B-Board PRO**	**TPI 8032**
Application target	Modular power electronic systems	Integration inside converters or custom controllers	Easy-to-use programmable inverter
Plug-&-play with imperix modules and sensors	YES	NO	YES, but only sensors: 4x analog inputs (RJ45)
Processing	B-Box 4: 4×1.5GHz + 504K FPGA	2×1.0GHz + 125K FPGA	2×1.0GHz + 125K FPGA
Product datasheet	**B-Box 4** **B-Box RCP 3.0** **B-Box micro 3.0**	**B-Board PRO 3.0**	**TPI8032**

	B-Box controllers	B-Board PRO	TPI 8032
	Gen. 3: 2×1.0GHz + 125K FPGA		
Analog I/Os	RJ45 for analog inputs	On high-density connectors (bottom side)	4x analog inputs on RJ45
Digital I/Os	Optical fibers for PWM signals VHDCI connectors for other digital I/Os	On high-density connectors (bottom side)	8x GPIO as 5/12V electrical signals.
Software environments	ACG SDK or CPP SDK Free FPGA programming	ACG SDK or CPP SDK Free FPGA programming	ACG SDK or CPP SDK Free FPGA programming
SW-independent protections	YES	NO	YES (not configurable)
Product datasheet	**B-Box 4** **B-Box RCP 3.0** **B-Box micro 3.0**	**B-Board PRO 3.0**	**TPI8032**

B-Box devices

Within the B-Box family, imperix controllers essentially share the same type of I/O interfaces, namely RJ45 connectors for analog inputs, and plastic optical fibers (POF) for PWM outputs. Cross-compatible digital I/Os are also available at the rear side of the devices in electrical form.

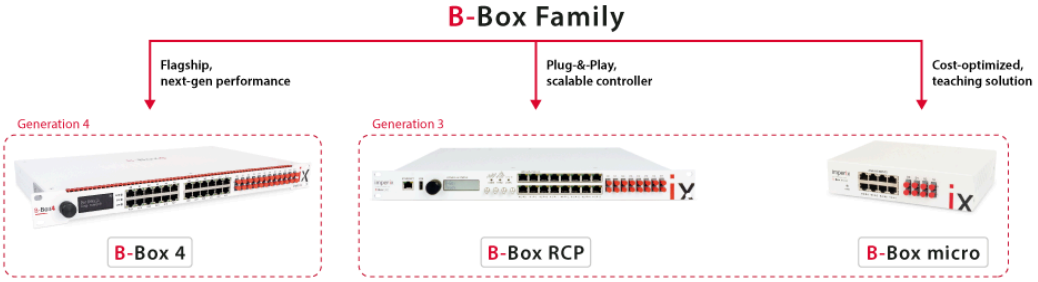
On the other hand, differences among units offer freedom of choice, notably regarding:

- **I/O count and related performance**. The bandwidth and sampling rate of analog inputs, as well as the PWM resolution of digital outputs, differ significantly across devices.

- **Computing performance**. The B-Box 4 embeds a significantly more powerful processing system.
- **Oscilloscoping capabilities**. The B-Box 4 supports the so-called oversampling technology.
- **Networking options**. The B-Boxes 4 and 3 can be stacked for high-performance I/O extension, unlike the B-Box micro.

This results in the following product positioning:

- **B-Box 4**: Flagship controller with the largest set of capabilities and highest performance. Commercialized since 2026.
- **B-Box RCP 3**: High-performance controller with full support for networked control and direct portability to B-Board PRO. Commercialized since 2019.
- **B-Box micro**: Cost-optimized, teaching-oriented system with limited I/Os. Networked control is not supported.



I/O specifications

	B-Box 4	B-Box RCP	B-Box micro
Analog inputs	**24x RJ45 ports** – Resolution: 16-bit – Simult. Fs: 20Msps – Bandwidth: 2.7MHz – Impedance: 5kΩ[1] – Auto-ID: YES – Pre-amp gain: 1x – LPF: digital (++ precision)	**16x RJ45 ports** – Resolution: 16-bit – Simult. Fs: 0.5Msps – Bandwidth: 0.41MHz – Impedance: 3kΩ/100Ω – Auto-ID: NO – Pre-amp gain: 1x,2x,4x,8x – LPF: analog	**8x RJ45 ports** – Resolution: 16-bit – Simult. Fs: 2Msps – Bandwidth: 1.3MHz – Impedance: 20kΩ – Auto-ID: NO – Pre-amp gain: 2x – LPF: NO
Product datasheet	B-Box 4	B-Box RCP[3.0]	B-Box micro[3.0]

	B-Box 4	B-Box RCP	B-Box micro
	– Oversampling: YES	– Oversampling: NO	– Oversampling: NO
PWM outputs	**48x fiber + VHDCI outputs** – 24x optic./elec. + 24x elec. – 250ps resolution – Oversampling: YES	**32x fiber + VHDCI outputs** – 16x optic./elec. + 16x elec. – 4ns resolution – Oversampling: NO	**8x fiber outputs** – 8x optical only – 4ns resolution – Oversampling: NO
Analog outputs	**24x RJ45 ports** – Resolution: 12-bit – Update rate: 500 ksps – Shared with inputs	**4x SMA ports** – Resolution: 16-bit – Update rate: 50 kHz spaceholder	**Unavailable** spaceholder spaceholder spaceholder
GPO	**24x VHDCI outputs** – Logic level: 3.3V/5V	**16x VHDCI outputs** – Logic level: 3.3V/5V	**8x PCB header outputs** – Logic level: 5V
GPI	**24x VHDCI inputs** – Logic level: 3.3V/5V	**16x VHDCI inputs** – Logic level: 3.3V/5V	**8x PCB header inputs** – Logic level: 5V
USR	**36x VHDCI pins** – Logic level: 3.3V	**36x VHDCI pins** – Logic level: 3.3V	**36x VHDCI pins** – Logic level: 3.3V
Product datasheet	B-Box 4	B-Box RCP[3.0]	B-Box micro[3.0]

[1] Low-impedance adapter available for purchase

The B-Box 4 and B-Box 3 controllers are capable of expanding their I/O count, thanks to master-slave operation. However, the B-Box micro cannot be further expanded due to it not being compatible with optical fiber networking.

Computational capability

Computational capability differs only across generations. While Generation 3 controllers are powerful enough for most typical applications, with achievable maximum control frequencies in the range of 250 kHz in CPU, the B-Box 4 is considerably more powerful and capable to run 4x more complex code at a given control frequency.

	Generation 4	Generation 3
SoC architecture	Zynq Ultrascale+	Zynq 7000
Processing system	– 4x 1.5GHz AMD Cortex A53 -3 – 8GB DDR4	– 2x 1.0GHz AMD Cortex A9 -3 – 1GB DDR3
FPGA	Kintex US+ 504K – 350K programmable logic cells	Kintex 7 125K – 62K programmable logic cells
Product datasheet	B-Box 4	B-Box RCP 3.0 B-Box micro 3.0

Supported communication protocols

Each controller supports various communication protocols. The more research-oriented devices (B-Box 4 and B-Box RCP) support many more protocols than the teaching-oriented device (B-Box micro).

	B-Box 4	B-Box RCP	B-Box micro
Ethernet-based	**1x Ethernet port** – UDP/IP – OPC-UA – Modbus TCP	**1x Ethernet port** – UDP/IP – OPC-UA spaceholder	**1x Ethernet port** – UDP/IP – OPC-UA spaceholder
High-performance	**4x QSFP+ 40Gbit/s** – RealSync – Aurora – Custom protocol	**3x SFP+ 10Gbit/s** – RealSync – Aurora – Custom protocol	**Unavailable** spaceholder spaceholder spaceholder
Product datasheet	B-Box 4	B-Box RCP 3.0	B-Box micro 3.0

	B-Box 4	B-Box RCP	B-Box micro
CANBUS	**2x CANBUS ports** – CAN-FD – CAN-2.0B	**1x CANBUS ports** – CAN 1.0 spaceholder	**Unavailable** spaceholder spaceholder
Serial communication	**2x serial ports** – RS422/RS485 – BISS-C – SSI – EnDat 2.0	**Unavailable** spaceholder spaceholder spaceholder spaceholder	**Unavailable** spaceholder spaceholder spaceholder spaceholder
Product datasheet	**B-Box 4**	**B-Box RCP 3.0**	**B-Box micro 3.0**

The third-generation controllers and fourth-generation controllers are cross-compatible in distributed control and modulation implementations using RealSync. When mixing multiple generations of controllers, the master of the tree must be a B-Box 4.

Software-independent protections

The software-independent protections available on most imperix controllers have slightly different characteristics, which are summarized in the table below. Further details are given in PN257.

	B-Box 4	B-Box RCP	B-Box micro
Implementation	Protected FPGA firmware	Hardware comparators	Protected FPGA firmware
Scaling	Identified sensor: true value Third-party sensor: ADC value	ADC value	ADC value
Response speed	Ultra: <800ns Fast: 1.6µs	Fast: 1.6µs	Fast: 1.5µs
Product datasheet	**B-Box 4**	**B-Box RCP3.0**	**B-Box micro 3.0**

	B-Box 4	B-Box RCP	B-Box micro
Configuration	In Cockpit	with Front panel[1]	in Cockpit
Product datasheet	**B-Box 4**	**B-Box RCP 3.0**	**B-Box micro 3.0**

[1] Saving/restoring the protection configuration requires a USB key on the B-Box RCP3.0, as it's entirely independent of Cockpit.

Application-based selection guide

Every imperix controller can run most control algorithms with excellent closed-loop performance. However, even in the specific scope of the power electronics domain, applications can be tackled from various perspectives, and imperix's controller portfolio aims to provide a solution optimized for each use case.

When to select a B-Box family controller

The primary reasons to go for a B-Box family controller are to maintain the plug-&-play compatibility with imperix power modules, and be able to change the controlled topology in a couple of minutes by simply rewiring the power stage and changing the I/O mapping. This type of flexibility is often required in research laboratory settings. The selection of the specific B-Box controller depends on user requirements:

Selecting the B-Box 4

The B-Box 4 is imperix's flagship controller. Apart from offering the largest number of I/Os, it also offers access to oversampled ADC and PWM data, enabling their scoping directly in Cockpit. This makes it the first-choice controller for easily researching and debugging high-performance applications, down to the modulation, from one device. Examples where this would prove particularly useful include:

- Quick start guide PE bundle (PN171)
- Single-phase PV inverter (AN003)
- Onboard battery charger for electric vehicles (AN010)

All the examples on the imperix knowledge base, initially written for third-generation controllers, are compatible with the B-Box 4 with minimal modifications.

Selecting the B-Box RCP

As the previous flagship of the imperix controller portfolio, the B-Box RCP is a perfectly capable device that can perform well in a wide variety of applications (examples shown below). Its only limitations are the comparatively lower performance of processing and peripherals, and the missing oversampling feature.

- Three-phase PV inverter (AN006)
- Wind turbine generator control (AN012)
- NPC multilevel inverter (TN132)

Selecting the B-box micro

The B-Box micro is as computationally capable as the B-Box RCP 3.0 but is more limited in I/Os (and cost!). This makes it the ideal controller for teaching various concepts in power electronics that do not require a large number of I/Os:

- Interleaved buck converter (TN122)
- DAB converter control (TN115)
- Single-phase totem pole PFC (TN113)

When to select the TPI8032

The TPI8032 is the preferred controller/converter for lab-scale microgrid and distributed generation modelling, as it combines the programmability of the B-Board PRO with an all-in-one integrated 2-level 3-phase inverter with grid connection filters included.

This makes it the perfect solution for when flexibility in topology is not required, but flexibility in the number of modelled DERs is. The inverter can be programmed in various ways, as can be seen below, and can also be paralleled if the total power output needs to be scaled up:

- Grid-Forming Inverter (TN168)
- Grid-Following Inverter (TN167)
- Active Front End (TN166)

When to select the B-Board PRO

The B-Board PRO is specifically designed to be embedded onto a pre-implemented or custom-designed power stage. It optimizes for better packaging at the expense of the high-end front-ends of the B-Box family controllers. These front-ends are normally not required for such embedded applications because the analog chain is implemented on the custom converter itself.

The two examples below give two examples of the types of applications that the B-Board PRO is optimized for:

- Control of a Sinamics S120
- Mersen power stack-up