EMBEDDEDCI

BenchPod

Hardware-in-the-loop test instrument for embedded boards

Datasheet · Rev A · November 2026 · Digital board v3r3 with analog module v3-r4

Overview

BenchPod sits next to the embedded board under test (the DUT) and does what an engineer does at the bench: it powers the DUT, flashes its firmware, reads its console, and measures and drives its signals. Tests run on real hardware, started from a laptop, a CI pipeline or an AI agent, over Ethernet, USB or the EmbeddedCI cloud.

It is built from two stacked boards: a **digital board** (power, flashing, logic analyzer, network) and an **analog module** (ADC, DAC, 4-20 mA). It is professional lab equipment for electronics developers, supplied as a bare board assembly. The earlier single-board BenchPod (silkscreen BenchPod v3-r1 or v3-r2) has its own datasheet, the BenchPod v3 datasheet.

Typical uses

- Flash and boot test in CI, asserting on the boot log
- Firmware tests that toggle, read and decode the DUT's pins
- Sensor emulation over I2C, GPS emulation over UART
- Recording a real analog signal and replaying it into the DUT
- Power cycling and current measurement of the DUT

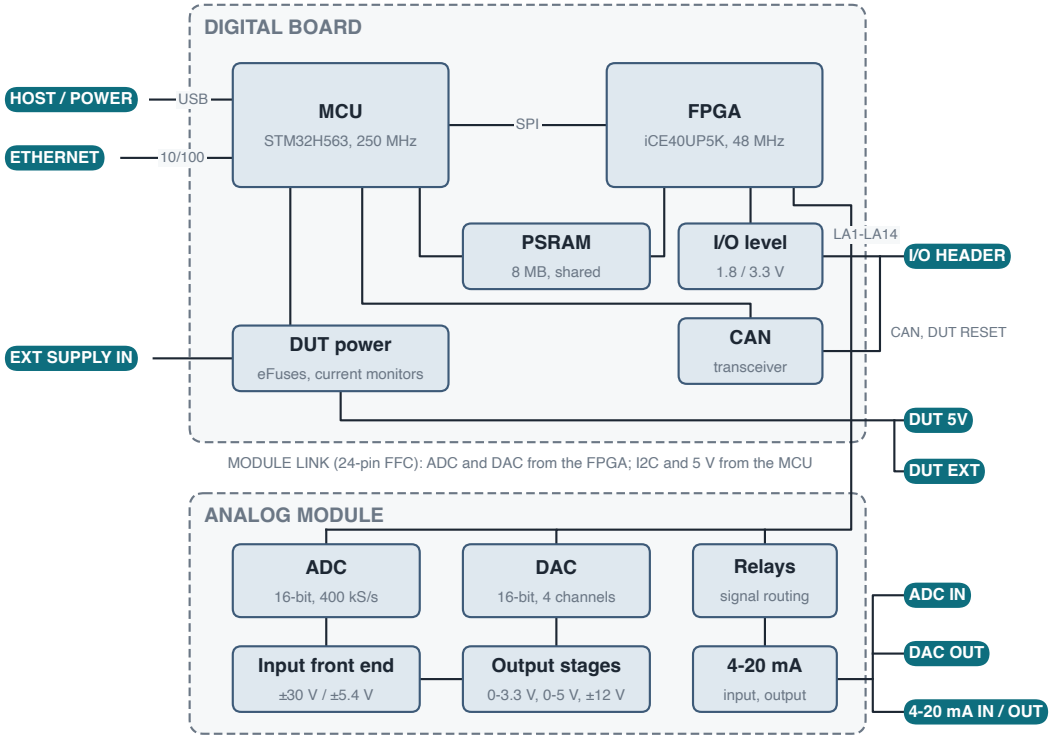
Key features

- **DUT power**: switched 5 V and external supply outputs, current monitoring
- **Flash and debug**: on-board CMSIS-DAP probe (SWD), works with OpenOCD targets
- **14-channel logic analyzer / GPIO** at 1.8 V or 3.3 V
- **Protocols**: UART, I2C (sensor emulation), SPI, CAN and CAN FD
- **16-bit ADC**, 400 kS/s, ±30 V, BNC input
- **16-bit DAC**, outputs 0-3.3 V, 0-5 V and ±12 V
- **4-20 mA** input and output
- **Network**: Ethernet, USB, optional Wi-Fi bridge, EmbeddedCI cloud
- **Software**: Python SDK with pytest, CLI, MCP server for AI agents, web app

At a glance

Power input	5 V DC, USB-C, from a computer or USB-C power source
DUT power	Switched 5 V (2 A) and external 2.7-20 V (3 A) outputs, current monitoring
Logic analyzer / GPIO	14 channels, 1.8 V or 3.3 V, up to 12 MS/s, 48 MS/s change capture
Protocols	SWD (CMSIS-DAP), UART, SPI, I2C sensor emulation, GPS emulation, CAN and CAN FD
ADC	16-bit, 400 kS/s, ±30 V, BNC
DAC	16-bit, 0-3.3 V, 0-5 V and ±12 V outputs, up to 889 kS/s
Current loop	4-20 mA input and two-wire 4-20 mA output
Network	Ethernet 10/100, USB, optional Wi-Fi bridge, EmbeddedCI cloud
Size	98.6 x 122.5 mm footprint, two stacked boards

How it works



Functional block diagram. Ports are shown with their names on the board edge.

Digital board

- **MCU** (STM32H563): runs the firmware. It handles the network (ETHERNET, the USB network adapter and the cloud connection) and executes the commands. It also switches and monitors DUT power, runs the CAN controller and drives DUT RESET. Over the MODULE LINK it sets the analog module's relays and reads its ID memory.
- **FPGA** (iCE40UP5K): every LA channel on the I/O HEADER goes straight to an FPGA pin, through a 330 Ω series resistor and an ESD clamp. No pin has a fixed function. The FPGA implements logic analyzer capture, GPIO, timed pulses, UART, SPI, the SWD debug probe, and I2C sensor and GPS emulation, on whichever channels the wiring profile assigns. It also drives the ADC and DAC on the analog module and the STATUS LED.
- **I/O level**: the FPGA's LA bank runs from a switched 1.8 V or 3.3 V supply. The channels are at the DUT's logic level directly, with no level shifters.
- **PSRAM** (8 MB): shared by the MCU and the FPGA. Deep captures stream into it, and recorded signals replay from it.
- **DUT power**: eFuses with current limits switch the DUT 5V and DUT EXT outputs. A monitor measures each output's current.

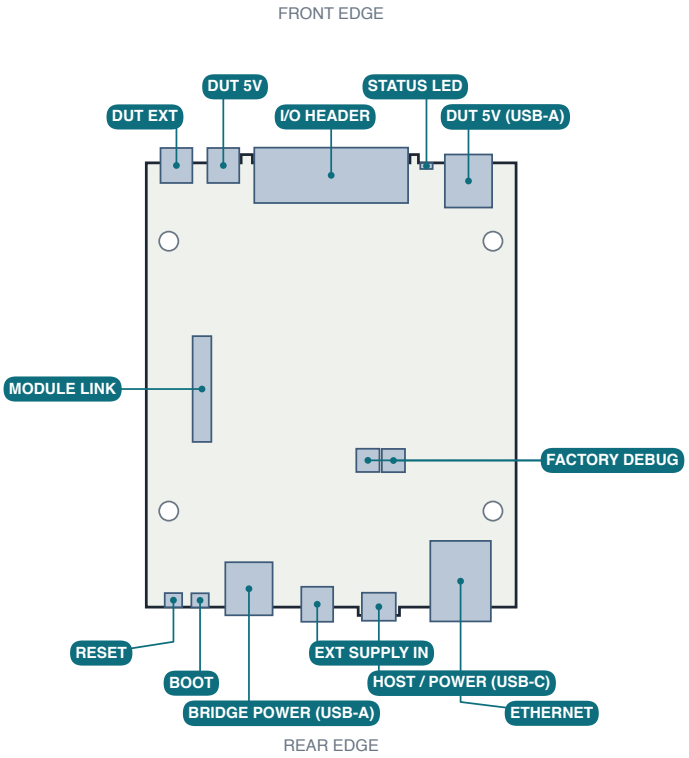
Analog module

The analog module has no processor. The FPGA reads the ADC and writes the DAC over the MODULE LINK, and the MCU sets the relays over I2C.

- **ADC IN**: a divider, buffer and differential driver feed a 16-bit SAR ADC with a 4.096 V reference. A relay selects the ±30 V or the ±5.4 V range.
- **DAC OUT**: a quad 16-bit DAC with one channel per output: 0-3.3 V, 0-5 V, ±12 V, plus the channel for the 4-20 mA output.
- **4-20 mA**: the input is a 249 Ω sense resistor read by the ADC. The output is a two-wire loop transmitter set by the DAC.
- **Relays** route the inputs and loop the outputs back to the ADC, for self-test and calibration.
- **ID memory**: identifies the module to the firmware.

Ports

Digital board

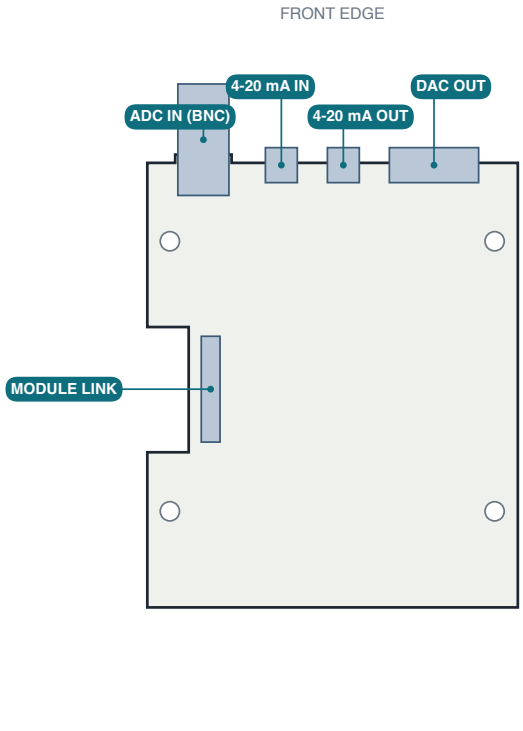


Digital board, top view, front edge up.

Port	Connector	Function
HOST / POWER	USB-C	5 V power input and USB connection to the computer (network adapter, console, firmware update)
ETHERNET	RJ45, 10/100 Mbit/s	Network connection to the LAN or the EmbeddedCI cloud
I/O HEADER	2x13, 2.54 mm	14 logic analyzer / GPIO channels, CAN, DUT reset, reference voltages
DUT 5V	2-pin terminal block, 3.81 mm	Switched 5 V supply for the DUT
DUT 5V (USB-A)	USB-A	Same switched 5 V supply as DUT 5V, power only
EXT SUPPLY IN	2-pin terminal block, 3.81 mm	External DUT supply input, 2.7-20 V
DUT EXT	2-pin terminal block, 3.81 mm	Switched external supply for the DUT
BRIDGE POWER	USB-A	5 V for the optional Wi-Fi bridge, power only
STATUS LED	RGB LED	Pod status
RESET, BOOT	Push buttons	Restart the pod; enter firmware update mode
MODULE LINK	24-pin FFC	Connection to the analog module
FACTORY DEBUG	Two 2x2 footprints	Production use only

Analog module

The analog module stacks on top of the digital board, on the same mounting holes, with its front edge on the same side.



Analog module, top view, front edge up.

Port	Connector	Function
ADC IN	BNC	Analog input, ±30 V
DAC OUT	6-pin terminal block, 3.81 mm	Three analog outputs: 0-3.3 V, 0-5 V, ±12 V
4-20 mA IN	2-pin terminal block, 3.81 mm	Current loop measurement input
4-20 mA OUT	2-pin terminal block, 3.81 mm	Two-wire 4-20 mA transmitter output
MODULE LINK	24-pin FFC	Connection to the digital board

Pin assignments

I/O HEADER

The I/O HEADER is a keyed, shrouded 2x13 right-angle header with 2.54 mm pitch, on the front edge of the digital board. A triangle on the shroud marks pin 1. Odd pins are in one row and even pins in the other.

Pin	Signal	Pin	Signal
1	LA1	2	LA2
3	LA3	4	LA4
5	LA5	6	LA6
7	LA7	8	LA8
9	LA9	10	LA10
11	LA11	12	LA12
13	LA13	14	LA14

Pin	Signal	Pin	Signal
15	GND	16	GND
17	+3.3 V out	18	+1.8 V out
19	CAN high	20	CAN low
21	LA_REF	22	DUT RESET
23	GND	24	GND
25	GND	26	GND

- **LA1-LA14**: logic analyzer and GPIO channels. Any channel can carry UART, SWD, SPI, I2C or a GPIO; the wiring profile in the web app records which signal is on which channel.
- **LA_REF**: reference output at the selected I/O voltage (1.8 V or 3.3 V).
- **DUT RESET**: dedicated reset line to the DUT, used when flashing and by reset commands.
- **CAN high / CAN low**: CAN or CAN FD bus through an on-board transceiver, with a switchable termination.

Terminal blocks

All terminal blocks are pluggable, 3.81 mm pitch. Pins are listed left to right, looking at the connector from outside the board.

Port	Left to right
DUT EXT	+ , GND
DUT 5V	+ , GND
EXT SUPPLY IN	+ (2.7-20 V), GND
4-20 mA IN	+ (input), GND
4-20 mA OUT	+ (to loop supply plus), - (loop return)
DAC OUT	0-3.3 V, GND, 0-5 V, GND, ±12 V, GND

> The 4-20 mA OUT minus terminal is not ground. The loop needs its own floating supply, and nothing in the loop may connect to the pod's ground.

Electrical characteristics

Typical values at 25 °C, with the pod powered from a 5 V USB-C supply.

Power

Parameter	Value
Supply input	5 V DC via HOST / POWER (USB-C), protected by an eFuse. No power adapter is included: BenchPod runs from the computer's USB-C port
Current consumption	About 0.26 A idle; under 0.5 A with all functions running (DUT power not included). Measured on the previous board revision
DUT 5V output	5 V from the input, switched, current limit about 2 A, shared with DUT 5V (USB-A). Together with the pod's own draw, limited by what the computer's USB-C port supplies (often 1.5 A or 3 A)
EXT SUPPLY IN	2.7-20 V DC, for example 3.3 V, 12 V or 19 V. Below about 2.5 V the output stays off, so it cannot pass 1.8 V. Above about 21.8 V the output switches off
DUT EXT output	Switched EXT SUPPLY IN, current limit about 3 A
DUT current monitoring	On both DUT outputs: about 83 µA resolution on DUT 5V, 125 µA on DUT EXT
BRIDGE POWER output	5 V, current limit about 1 A

Logic analyzer and GPIO

Parameter	Value
Channels	14
I/O voltage	1.8 V or 3.3 V, selectable
Channel protection	330 Ω series resistor and ESD clamp on each channel
Pull resistors (switchable, 3.3 V I/O)	LA1-LA2 4.7 kΩ up; LA3-LA4 2.2 kΩ up; LA5-LA6 10 kΩ up; LA7-LA8 10 kΩ down; LA9-LA14 none
Sample rate	Up to 12 MS/s; change capture up to 48 MS/s (20.8 ns resolution)
Capture depth	Up to 4 M samples (8 MB PSRAM)
GPIO pulses	FPGA-timed, 4 µs to 65.5 ms wide

Protocols

Protocol	Value
SWD	On-board CMSIS-DAP probe, clock up to 6 MHz, dedicated DUT RESET line
UART	Default 115200 baud, interactive console and boot log capture
SPI	Master, modes 0-3, up to 6 MHz
I2C	Sensor emulation: BMP280, BME280, SHT4x, MPU-6050
GPS	NMEA 0183 emulation over UART, up to 10 Hz
CAN	Classic CAN and CAN FD: 10 kbit/s to 1 Mbit/s arbitration, CAN FD data phase up to 8 Mbit/s (for example 2 or 5 Mbit/s) with up to 64-byte frames, switchable termination

ADC IN

Parameter	Value
Resolution	16-bit
Sample rate	Up to 400 kS/s
Input range	±30 V (about 1 mV per count); low range ±5.4 V
Input impedance	About 1 MΩ (±30 V range), 1.8 MΩ (low range)
Capture depth	32 k samples; deep capture up to 2 M samples (about 5 s at 400 kS/s)
Connector	BNC

DAC OUT

Parameter	Value
Resolution	16-bit, one DAC channel per output
Outputs	0-3.3 V, 0-5 V, ±12 V
Output impedance	49.9 Ω series resistor on each output
Update rate	Up to 889 kS/s
Waveforms	Sine, square, sawtooth, arbitrary; replay of recorded signals up to 4 M samples

4-20 mA

Parameter	Value
4-20 mA IN	249 Ω sense resistor (0.1 %), measured by the ADC
4-20 mA OUT	Two-wire transmitter, about 4 to 20 mA, 0.25 µA steps
Loop supply for 4-20 mA OUT	External, floating, 30 V maximum

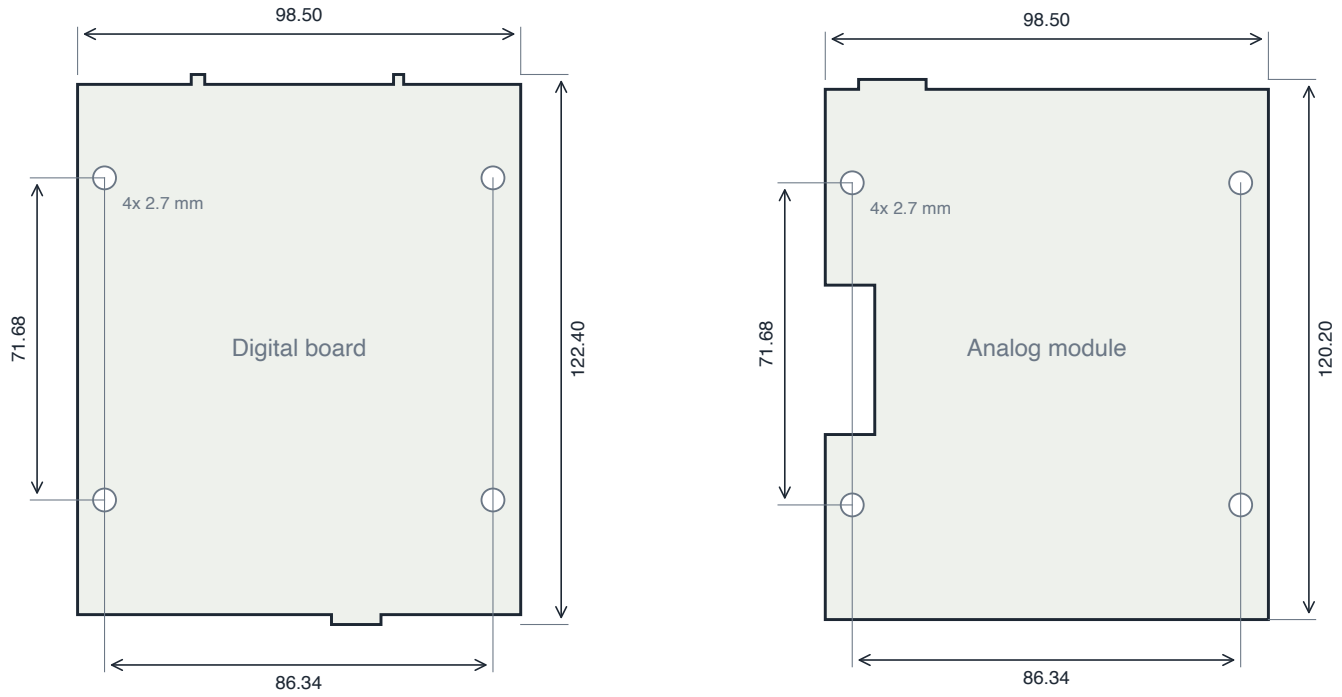
Processing and network

Parameter	Value
Processor	STM32H563 Arm Cortex-M33, 250 MHz, 1 MB flash
FPGA	Lattice iCE40UP5K, captures and signal generation
Memory	8 MB PSRAM for deep captures and replay
ETHERNET	10/100 Mbit/s, RJ45 with magnetics, no PoE
USB	USB 2.0 full speed device: network adapter, console, firmware update
Cloud	Secure WebSocket (TLS) connection to embeddedci.com
Firmware update	Over the network or the cloud (SHA-256 checked images) or over USB

STATUS LED

Color	Meaning
Three green blinks	Started up normally
Green	DUT power on
Short cyan flash	A command ran
Blue	Deep capture or replay running
Magenta	Firmware update in progress
Blinking red	DUT power fault (current limit or overvoltage)
Solid red	Self-test failed, or safe mode
Off	Idle

Mechanical



Board outlines and mounting holes, top view, dimensions in mm. The analog module stacks on the digital board on the same four mounting holes.

Parameter	Value
Digital board	98.55 x 122.45 mm including connector overhang, 1.6 mm, 4 layers
Analog module	98.60 x 120.30 mm including connector overhang, 1.6 mm, 4 layers
Mounting holes	4x M2.5 (2.7 mm), 86.34 x 71.69 mm spacing, same on both boards
Board link	24-pin FFC, 1.0 mm pitch
Enclosure (optional)	Hammond 1455N1201BK, 120 x 103 x 53 mm, with custom end panels

Wi-Fi bridge (optional accessory)

The Wi-Fi bridge connects BenchPod to a Wi-Fi network. It plugs into the pod's ETHERNET port with a patch cord and takes 5 V from the pod's BRIDGE POWER port. The pod reaches the network through the bridge as if it were wired.

Parameter	Value
Radio module	Espressif ESP32-WROOM-32E-N8, module antenna
Radio	Wi-Fi 2.4 GHz
Size	About 70 x 52 mm, bare board
Firmware	Updated through the pod, signed images

Full specifications: the BenchPod Wi-Fi bridge datasheet.

Software

Tool	Use
Web app (embeddedci.com)	Live capture, generator, terminal, flashing and wiring setup in the browser
Python SDK	`pip install embeddedci`: drive the pod from Python, with pytest fixtures
CLI	`benchpod`: discover, flash, capture, firmware update from the command line
MCP server	Lets AI agents (Claude, Codex and others) drive the pod
GitHub Action	Run hardware tests from a CI workflow through the EmbeddedCI cloud

Documentation: embeddedci.com/docs

Getting started

1. Connect and set up

Plug HOST / POWER into a computer with a USB-C cable, and ETHERNET into the network (or set up Wi-Fi with the optional bridge). Install the CLI and run the guided setup. It finds the pod, waits for its network address, asks for the DUT's I/O voltage (1.8 V or 3.3 V) and registers the pod to your account.

```
brew trust embeddedci-com/tap
brew install --cask embeddedci-com/tap/benchpod
benchpod setup
```

Linux and Windows downloads: embeddedci.com/downloads. `benchpod discover` shows every pod it finds on USB and on the network.

2. Wire the DUT

For a first flash, three wires on the I/O HEADER are enough:

I/O HEADER pin	Signal	DUT
11	LA11	SWCLK
12	LA12	SWDIO
15	GND	GND

Add the DUT's UART on two more channels to see its console, and power it from DUT 5V or DUT EXT. Record which signal is on which channel once, in the wiring profile in the web app; tests and tools read it from there.

3. Run a first test

```
pip install "embeddedci[pytest]"
pytest --benchpod-connection=usb
```

```
def test_pod_is_alive(benchpod):
    assert benchpod.ping()

def test_target_flashes_and_boots(benchpod_target, firmware):
    assert benchpod_target.flash(file=firmware, target="target/stm32f4x.cfg").ok
    boot = benchpod_target.power_cycle_and_capture(duration=5.0, until="APP_OK")
    assert boot.matched, boot.text
```

The connection can be `usb`, the pod's network address, or `embeddedci:<name>` through the cloud (for CI).

Usage notes

- **Indoor use, short cables.** BenchPod is for indoor use. Keep every cable under 3 m, except ETHERNET: up to 30 m, indoors, to a switch or router in the same building.
- **Set the I/O voltage first.** The pod refuses flashing, UART, logic analyzer captures, pull resistors and I2C emulation until the I/O voltage matches the DUT (1.8 V or 3.3 V). Never connect an LA channel to a signal above the selected I/O voltage.
- **One owner per channel.** A channel used as GPIO must be released before UART, flashing or I2C emulation can use it; the error message names the command that frees it.
- **Pull resistors** on LA1-LA8 work at 3.3 V I/O. For I2C, use LA1-LA6 (pull-ups), or add external pull-ups on LA9-LA14.
- **DUT EXT** passes the voltage on EXT SUPPLY IN (2.7-20 V) to the DUT. Use DUT 5V when the DUT runs from 5 V.
- **DAC OUT**: connect the DUT to the one output its pin tolerates. A 3.3 V MCU pin belongs on 0-3.3 V; the 0-5 V and ±12 V outputs can exceed it.
- **4-20 mA OUT** needs its own floating 12-30 V loop supply. Nothing in the loop may connect to the pod's ground, so it cannot loop back into 4-20 mA IN or be powered from the pod's own outputs.
- **ADC IN** readings within a few millivolts of 0 V show a small step of about 3 counts. This comes from the ADC and is not removed by calibration.

Safety

Port	Rating	Never
ADC IN	±30 V	Mains, or any circuit connected to mains. The BNC shell is the pod's ground and connects to the computer through USB
EXT SUPPLY IN	2.7-20 V DC	More than 20 V (no 24 V supplies), or + and GND swapped
4-20 mA IN	Current input, up to 24 mA	A supply wired straight to it, with no transmitter in the loop
4-20 mA OUT	External floating loop supply, 12-30 V	More than 30 V, or anything in the loop tied to the pod's ground
DUT 5V, DUT EXT, BRIDGE POWER, DAC OUT	Outputs	A supply or voltage connected to an output
LA1-LA14	1.8 V or 3.3 V, as set	A signal above the I/O voltage set

- **DUT power can switch on at any time**, from tests, CI, AI agents or the web app. Unplug the DUT power plug before touching or reworking the DUT.
- Several terminal blocks take the same plug: check each plug before inserting it. Use wires rated for 2 A (DUT 5V) and 3 A (DUT EXT).
- Power from a computer or a CE or FCC marked USB-C power supply, 5 V, at least 1.5 A (3 A when DUT 5V is used).
- Indoor, dry, on a non-conductive surface (case, stand or standoffs). Not a toy: keep away from children.

Full safety rules: embeddedci.com/docs/benchpod-safety.

Firmware updates

New firmware is published on embeddedci.com/downloads. Update a pod from the web app (over the network or the cloud), or from the CLI:

```
benchpod flash-self --network     # over the network or the USB network adapter
benchpod flash-self --enter-dfu   # over USB, through the bootloader
```

Images are checked (SHA-256) before they are installed. To recover a pod that does not start, hold BOOT and tap RESET to enter the bootloader, run `benchpod flash-self`, then tap RESET again.

Support

Documentation: embeddedci.com/docs, including the full pin-out, the Python SDK and troubleshooting. Contact: hello@embeddedci.com.

Information for test labs

The EMC test plan, a separate document, describes the operating mode, monitoring and setup.

Port classification

Port	Type	Notes
HOST / POWER	DC power port and signal port	5 V in; USB 2.0 full speed
ETHERNET	Wired network port	10/100 Mbit/s, no PoE
EXT SUPPLY IN	DC power port (input)	2.7-20 V
DUT 5V, DUT 5V (USB-A), DUT EXT	DC power ports (output)	To the DUT
BRIDGE POWER	DC power port (output)	To the Wi-Fi bridge
I/O HEADER	Signal port	Logic level 1.8 / 3.3 V, CAN
ADC IN, DAC OUT, 4-20 mA IN, 4-20 mA OUT	Signal ports	Analog, ±30 V maximum

There is no mains port: BenchPod runs from 5 V USB-C. Indoor use only. Cables: 3 m maximum on every port except ETHERNET, which is up to 30 m, indoors, to a switch or router in the same building.

Internal frequencies

Source	Frequency
MCU core (PLL, VCO 500 MHz)	250 MHz
MCU crystal, Ethernet PHY crystal	25 MHz
Ethernet RMII reference	50 MHz
USB	48 MHz
MCU to PSRAM	50 MHz
FPGA oscillator (no PLL)	48 MHz; logic mostly at 24 MHz
ADC / DAC serial clocks	12 MHz / 24 MHz

Highest internal frequency: 250 MHz (500 MHz PLL VCO inside the MCU).

Switching converters

Part	Board	Function
TPS62130A	Digital board	5 V to 3.3 V buck
TLV61046A	Analog module	Boost for the analog supply
TPS65131	Analog module	±14 V rails
LM27761, LM7705	Analog module	Negative charge pumps
TLV62569	Wi-Fi bridge	5 V to 3.3 V buck

Compliance

In progress: EMC testing to FCC Part 15B Class B and EN 55032 / EN 55035, and the RoHS declaration. Current status: embeddedci.com/compliance.

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