LOGIC BOOLE 16

Sixteen channels at 200 MS/s over USB 3, through 1 MΩ inputs for 1.2 to 5 V logic. It runs from one USB-C cable on a computer, or mounted on a Raspberry Pi 4 or 5 as a HAT+. Open source: the board, the FPGA design, the firmware and the software.

PRELIMINARY

Datasheet **rev C**
2026-11-18
Board **revision C**

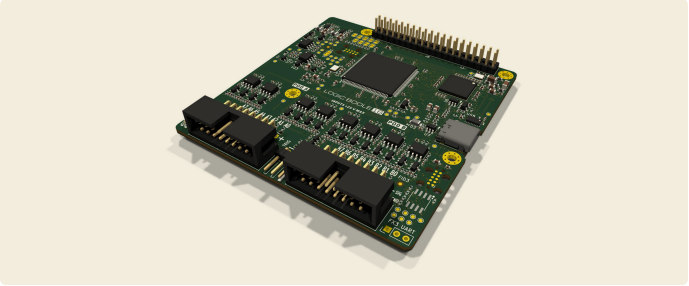
16 channels	**200** MS/s	**85** MHz	**Open** source
Two pods of 8, each with its own threshold	*On all 16 channels: one sample every 5 ns*	*Clocks captured whole, on each of the 16 inputs*	*Board, FPGA design, firmware and software*

OVERVIEW

Logic Boole 16 is a 16-channel digital logic analyzer on one 82 × 86 mm board. Signals come in on two keyed pods, pass through sixteen identical protected inputs to an FPGA that samples and triggers on them, and leave over USB 3 to the host: a computer, or the Raspberry Pi the board is mounted on. The host runs the software and holds the capture. The whole design is published under open licenses (section 12).

FEATURES

- **16 channels at 200 MS/s**, in two pods of 8: a sample every 5 ns.
- **Streams to the host over USB 3**: all 16 channels at 100 MS/s for any signal, and at 200 MS/s for signals that change in up to 96 million samples a second.
- **Triggers in the FPGA**, on every sample: levels, edges, pulses by their length and up to four stages in turn, with trigger in and out for other instruments.
- **A glitch filter for each channel**, up to 1.25 µs, and capture on the circuit's own clock up to 50 MHz.
- **1.2 to 5 V logic.** One threshold for each pod, set from 0.3 to 3 V.
- **1 MΩ inputs** with 10 pF at the probe pin, a comparator with hysteresis on every channel, and protection rated for ±25 V.
- **One USB-C cable** for power and data: about 1 W, USB 3 in either plug orientation, USB 2.0 as a fallback.
- **Raspberry Pi HAT+** for the Pi 4 and Pi 5: stackable, 16 mm above the Pi, room for the Pi 5 Active Cooler.
- **Nothing to brick**: the host loads the board each time it connects.
- **Open source**: the KiCad project, the FPGA design, the firmware and the host software, with an app, a command line, sigrok's decoders and a server for AI agents.



Main parts	Spartan-6 XC6SLX9 FPGA, EZ-USB FX3 USB controller, 16 fast comparators
Power	5 V from USB-C or the Pi's header, about 1 W
Host link	USB-C: USB 3 at 5 Gbit/s, or USB 2.0
Probing	2 × keyed 16-pin pods, 3-pin trigger header
Size	82.0 × 86.0 mm (3.23 × 3.39 in)
Design files	Open source, on GitHub (section 12)
In the box	1 × board, assembled. No USB cable, spacers, screws or leads: section 7 lists what to get

TYPICAL APPLICATIONS (section 8)

- I²C, SPI and UART buses
- Parallel buses with their clock
- Two logic levels in one capture
- Timing between signals
- Rare faults in long captures
- Glitches and runt pulses
- Triggering a scope
- Started by another instrument
- Scripts and AI agents
- Unattended capture on a Pi

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2 SPECIFICATIONS

For the revision C board. Input figures are at the probe pin of the pod connector. Figures are at room temperature. Section 13 says what was measured, and on which boards.

CAPTURE

Parameter	Min	Typ	Max	Unit	Notes
Channels		16			Digital. Two pods of 8: A0–A7 and B0–B7
Sample rate			200	MS/s	On all 16 channels: 5 ns between samples, 4.95 to 5.05 ns measured. Lower rates are 200 MS/s divided by a whole number
Streaming over USB 3, any signal			100	MS/s	All 16 channels in the raw format: two samples in each 32-bit word, 200 MB/s
Streaming over USB 3, run-length			200	MS/s	All 16 channels, for signals that change in up to 96 million samples a second: one word for each sample that differs from the one before. A 48 MHz clock streamed whole for 1 s
Any signal at 200 MS/s		0.89 M		samples	A signal that changes in 100 million samples a second or more fills the board's buffers. The capture ends there, after 4.5 ms, whole to its last sample
Streaming over USB 2.0			22	MS/s	All 16 channels in the raw format, any signal: 44 MB/s. Run-length at 200 MS/s for signals that change in up to 11 million samples a second
Kept from before the trigger			8184	words	16,368 samples in the raw format. In the run-length format 8184 changes, however long they took
Capture length					Limited by the host's memory. The longest so far is 600 million samples
Input signal frequency		85		MHz	Every period of a clock was seen at 50, 70, 80 and 85 MHz on each of the 16 inputs of one board, and on the five inputs tried of a second
Input pulse length	6			ns	A half period at 85 MHz is 5.9 ns. A pulse shorter than the 5 ns between samples can be missed
Pulse length error		±0.6		ns	At 85 MHz pod A reads a clock high for 51 to 53 % of the time and pod B for 45 to 48 %: the first boards have a different comparator on each pod (section 14)
Capture clock			50	MHz	The circuit's own clock on any input: a sample at its rising edges, its falling edges or both. The data must be steady 15 ns before the edge
Trigger output delay		75–80		ns	From the trigger sample at the inputs to TRIG OUT. A glitch filter adds its own time and 20 ns
Trigger input delay			5	ns	The trigger sample is the sample in which an input shows the same edge, or the one after it. Tried from 100 kHz to 50 MHz
Glitch filter	off		1.25	µs	For each channel, in 5 ns steps. A 25 MHz clock passes at 15 ns and is removed at 25 ns
Timebase accuracy			±50	ppm	The 24 MHz oscillator over temperature and five years

INPUTS

Parameter	Min	Typ	Max	Unit	Notes
Logic level	1.2		5	V	
Threshold range	0.3		3.0	V	Set separately for pod A and pod B. All 16 inputs read a 3.3 V pattern right at every setting from 0.2 to 3.0 V

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Parameter	Min	Typ	Max	Unit	Notes
Threshold step		0.75		mV	A 12-bit setting
Threshold voltage		±10		mV	The voltage the board makes against the setting, as seen from the probe: read at 0.30, 1.56 and 3.00 V on both pods of one board
Threshold accuracy			±100	mV	With the input divider's and the comparator's errors: at any setting, without calibration, on 99.7 % of channels
Hysteresis	25	60–80	100	mV	At every threshold setting
Input resistance	1.0	1.08		MΩ	To ground: the divider's two resistors
Input capacitance		8.6	10	pF	To ground
Channel-to-channel skew		1.4	5	ns	Between the earliest and the latest of the 16 inputs of one board. Pod B is 0.2 to 0.6 ns ahead of pod A. The 5 ns is one sample
Input voltage, continuous	−25		+25	V	On any channel, with the board powered or not

PI BUS LINES

Nine of the Raspberry Pi's header pins, through the bus jumpers of section 5.

Parameter	Min	Typ	Max	Unit	Notes
Lines		9			I²C1, the UART and SPI0. Each takes the place of one channel, A0 to A7 and B0, so a capture still has 16
Sample rate			200	MS/s	The capture's rate. A line is sampled, filtered and triggered on like the channel it replaces
Logic level		3.3		V	No threshold setting: low below 0.8 V, high above 2.0 V
Input resistance	7		17.5	kΩ	To ground: 1 kΩ in series and the FPGA pin's pull-down, which draws 0.2 to 0.55 mA from a line at 3.3 V
Input capacitance			10	pF	The FPGA pin, behind the 1 kΩ. The board's track adds to it
I²C high level, jumper closed	2.6		3.0	V	At the Pi's pin: the Pi's 1.8 kΩ pull-up against the FPGA's pull-down. 3.3 V with the jumper open
Input voltage	0		3.6	V	3.3 V logic only. Not 5 V tolerant, and no protection beyond the 1 kΩ

TRIGGER HEADER

Parameter	Min	Typ	Max	Unit	Notes
Trigger output level		3.3		V	CMOS output through 33 Ω. High from the trigger to the capture's last sample
Trigger input level		3.3	5	V	Schmitt-trigger input for 3.3 V logic, 100 kΩ to ground. It tolerates 5 V logic

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USB LINK AND POWER

Parameter	Min	Typ	Max	Unit	Notes
USB 3 link rate		5		Gbit/s	USB-C, in either plug orientation
Data to the host, USB 3		384		MB/s	96 million words a second in a capture. 391 MB/s for 10 minutes on a Raspberry Pi 5 with an earlier test design, every word checked
USB 2.0 link rate		480		Mbit/s	The fallback on a USB 2.0 cable, port or host: 44 MB/s to the host
Supply voltage		5.0	5.5	V	From USB-C, from the Pi's 5 V pins, or from both
Supply current		0.18	0.5	A	One board: 0.05 A before the host has loaded it, 0.14 A loaded and idle, 0.18 A streaming at 393 MB/s with an earlier test design. Any USB port can supply it. No USB Power Delivery
Power		0.95	2.5	W	

> **WHICH CABLE AND PORT?**
> Use a cable rated for USB 3 (5 Gbit/s) with a USB-C plug for the board, into a USB 3 port. On a charge-only or USB 2.0 cable, or on a USB 2.0 port, the board still works, at USB 2.0 rates. Any USB port can power it.

BOARD

Size	82.0 × 86.0 mm (3.23 × 3.39 in), 1.6 mm thick. Section 10 has the drawing
Mounting holes	4 × Ø2.7 mm for M2.5 screws, on the Raspberry Pi's 58 × 49 mm pattern. Joined to ground
PCB	4 layers, gold (ENIG) finish, green solder mask
Tallest parts	The pod connectors, about 11 mm above the board. The 40-pin header's pins stand 8.2 mm above it
Back	Only the stacking header's body, 13.5 mm. Nothing else is fitted underneath
Raspberry Pi	HAT+ with ID EEPROM, stackable class, for the Pi 4 and Pi 5. 16 mm between the Pi and the board
Use	Indoors, at 0 to 40 °C

3 ABSOLUTE MAXIMUM RATINGS

Beyond these limits the board may be damaged. Inside them, the specifications of section 2 say what it does.

Parameter	Min	Max	Unit	Notes
Pod inputs A0–A7 and B0–B7	−25	+25	V	To ground, continuously, powered or not
Trigger input	0	5.5	V	
Trigger output				An output: do not drive it
Supply, USB-C or the Pi's 5 V pins		5.5	V	
Pi bus lines, jumpers closed	0	3.6	V	3.3 V logic only. They do not tolerate 5 V
Electrostatic discharge		±8	kV	Contact, IEC 61000-4-2, on the USB-C, pod and trigger pins
Ambient temperature, operating	0	40	°C	Indoors

The inputs are not isolated. Their ground is the USB cable's ground and the Raspberry Pi's ground: see **section 9, Probing and safety**.

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4 BOARD LAYOUT

Everything you plug into is on an edge: the pods and the trigger header on the front edge, USB-C on the right, the 40-pin header along the back. Signals run from the pods through the input channels to the FPGA in the middle and the FX3 at the back right. Positions are as seen from the component side, with the pods nearest you.

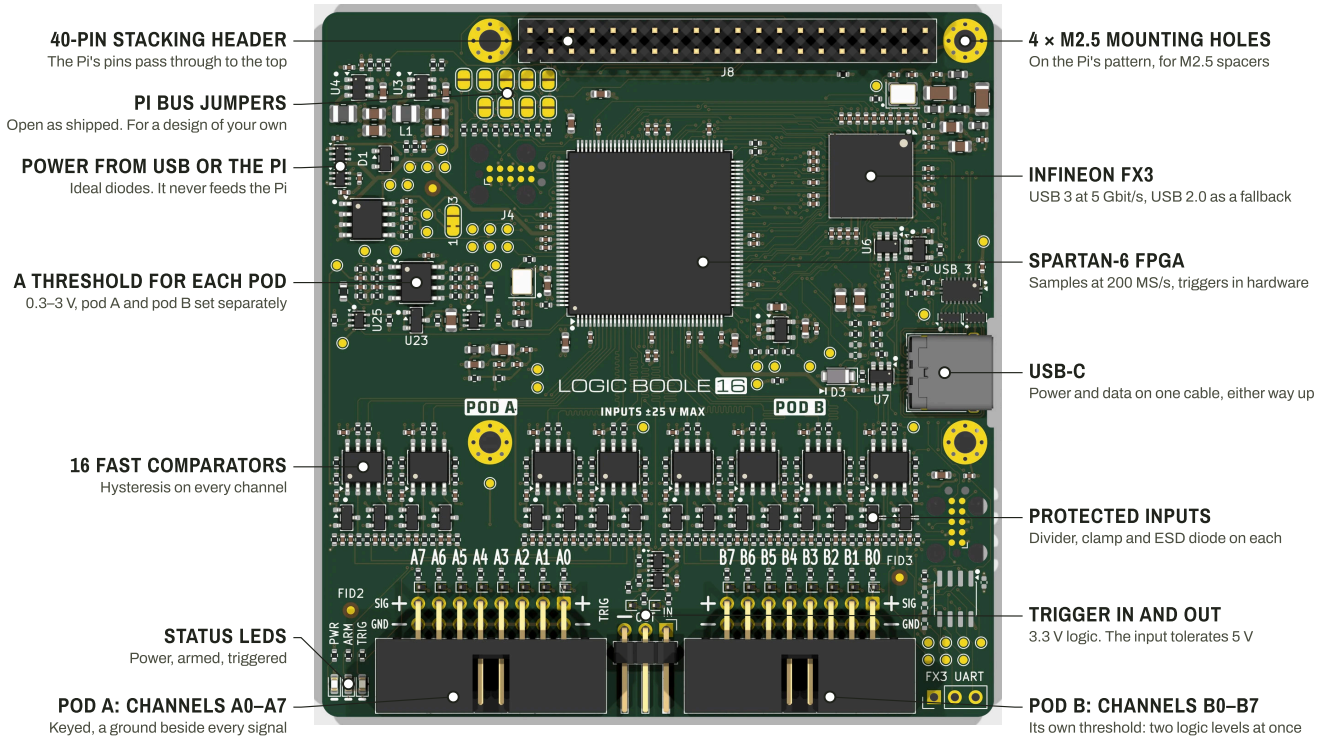


Figure 1. *Front (component side), labeled. Render of the revision C design.*

FRONT

Where	What	Notes
Front edge, left	**Pod A**	Channels A0–A7. Keyed 2 × 8 box header, with each channel's name printed above its pin
Front edge, middle	**Trigger header**	3 pins, marked TRIG: IN, OUT and – (ground)
Front edge, right	**Pod B**	Channels B0–B7, with their own threshold
Behind the pods	**16 input channels**	An ESD diode, a divider and a clamp for each channel, then eight dual comparators
Left edge	**Thresholds**	A 2.5 V reference and one threshold circuit for each pod
Middle	**Spartan-6 FPGA**	Samples, triggers, filters and buffers, on a 100 MHz clock made from a 24 MHz oscillator
Back right	**FX3 USB controller**	Carries the samples to the host
Right edge	**USB-C**	Power and data, marked USB 3. The plug goes in from the right
Back edge	**40-pin stacking header**	Fitted from underneath. Its pins come through the top for a second HAT
In front of the header, left	**Pi bus jumpers**	Nine solder jumpers, open as shipped, and the ID address jumper. See section 5
Back left	**Power**	Two ideal diodes take 5 V from USB or from the Pi. Regulators make 3.3 V, 1.8 V and 1.2 V
Front left corner	**Status LEDs**	PWR, ARM and TRIG, named on the board. See section 6
Left of the FPGA, right edge	**Programming pads**	FPGA JTAG and FX3 JTAG, for a Tag-Connect cable. Nothing is fitted. See section 11
Back and middle	**4 × M2.5 holes**	On the Raspberry Pi's pattern, joined to ground

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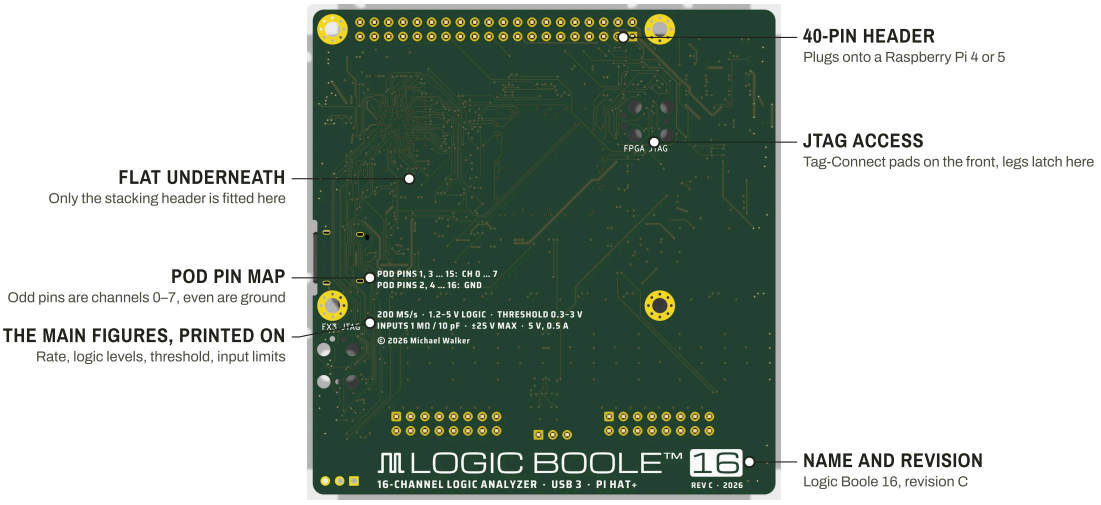


Figure 2. *Back, seen from behind, so left and right are swapped. The stacking header's socket is fitted here; it is not drawn.*

BACK

Only the stacking header's socket is fitted here. The rest is print.

What	Notes
Stacking header socket	13.5 mm tall. It plugs onto the Raspberry Pi's 40 pins and sets the 16 mm spacing
Pod pin map	Odd pins are channels 0–7, even pins are ground
Main figures	Sample rate, logic levels, threshold range and input limits
JTAG labels	FPGA JTAG and FX3 JTAG, where the Tag-Connect cable's legs latch
Name and revision	Logic Boole 16, revision C

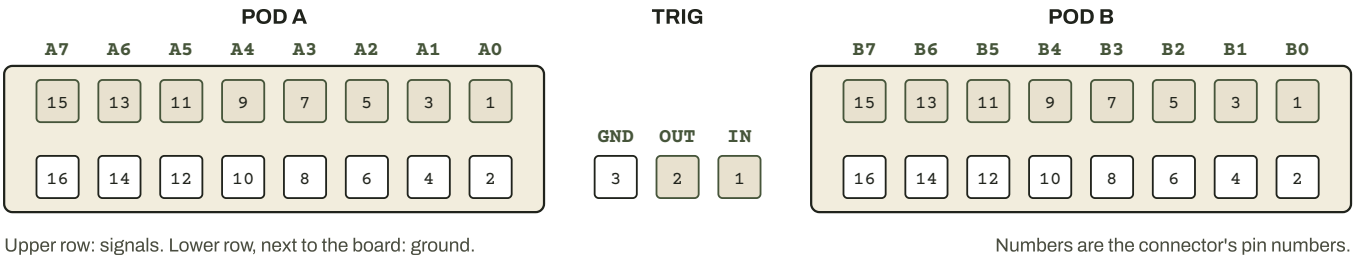
TEST POINTS

39 pads of 1 mm on the front bring out every supply rail, the 2.5 V reference, both thresholds, channel 0 of each pod, the FPGA's configuration lines and its 24 MHz clock. They are not named on the board.

5 CONNECTIONS

PODS A AND B: 2 × 8 BOX HEADERS, 2.54 mm

- **Odd pins are the channels**: pin 1 is channel 0 and pin 15 is channel 7. **Every even pin is ground.**
- The shroud is keyed, so a cable cannot go in reversed or offset. A standard 16-way ribbon cable puts a ground wire between every two signal wires.
- The board's print names every pin: the channel above each signal pin, and + and – (SIG and GND) at the ends of the two rows.



Upper row: signals. Lower row, next to the board: ground.

Numbers are the connector's pin numbers.

Figure 3. *Looking into the connectors from the front edge, parts facing up.*

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Pin	Name	Type	What it does
1, 3, 5 … 15	**A0–A7, B0–B7**	Input	Logic inputs for 1.2 to 5 V signals: 1 MΩ and 10 pF to ground, ±25 V at most. Any input can also take the circuit's own clock as the capture clock (section 6)
2, 4, 6 … 16	**GND**	Ground	One beside every signal pin. All sixteen are the board's ground

TRIGGER HEADER: 3 PINS, 2.54 mm

Pin	Name	Type	What it does
1	**TRIG IN**	Input	An edge here can be a stage of the trigger, so another instrument can start a capture. 3.3 V logic, and it tolerates 5 V. Schmitt-trigger input behind 100 Ω, with 100 kΩ to ground
2	**TRIG OUT**	Output	Goes high 75 to 80 ns after the trigger sample and stays high to the capture's last sample, to start a scope or a second analyzer. 3.3 V CMOS through 33 Ω
3	**GND**	Ground	Marked –

USB-C: POWER AND DATA

- One cable carries both, and the plug works either way up.
- Use a cable rated for USB 3 (5 Gbit/s). A charge-only or USB 2.0 cable links at USB 2.0 speed.
- The board draws about 0.2 A, 0.5 A at most, and never supplies power to the cable.

40-PIN HEADER

A stacking header in the Raspberry Pi's pinout. All 40 pins pass through to the top of the board for a second HAT. The board itself connects only to these:

Pins	Name	Type	What it does
2, 4	**5 V**	Power in	Power from the Pi. The board never feeds power back into these pins
1, 17	**3.3 V**	Power in	Supplies the ID EEPROM and tells the board that the Pi is running. In the Pi's standby state, with no USB host attached, the board switches itself off
27, 28	**ID_SD, ID_SC**	I²C	HAT+ ID EEPROM, at address 0x51
6, 9, 14, 20, 25, 30, 34, 39	**GND**	Ground	
3, 5, 8, 10, 19, 21, 23, 24, 26	**GPIO**	Optional	Only through the Pi bus jumpers below, which are open as shipped

PI BUS JUMPERS

Nine solder jumpers beside the 40-pin header, open as shipped. Closing one connects a Pi pin to a pin of the FPGA through 1 kΩ, and a capture can then take that line in place of the pod channel in the table, with no leads (section 6). The lines are the Pi's I²C1, UART and SPI0. The FPGA's pins are inputs with a pull-down, so an open jumper reads low.

Jumper	Pin	Line	Channel
JP2	3	**GPIO2 · SDA**	**A0**
JP3	5	**GPIO3 · SCL**	**A1**
JP9	8	**GPIO14 · TXD**	**A2**
JP10	10	**GPIO15 · RXD**	**A3**
JP7	19	**GPIO10 · MOSI**	**A4**

Jumper	Pin	Line	Channel
JP6	21	**GPIO9 · MISO**	**A5**
JP8	23	**GPIO11 · SCLK**	**A6**
JP5	24	**GPIO8 · CE0**	**A7**
JP4	26	**GPIO7 · CE1**	**B0**
JP1		ID address: 0x51, or 0x50	

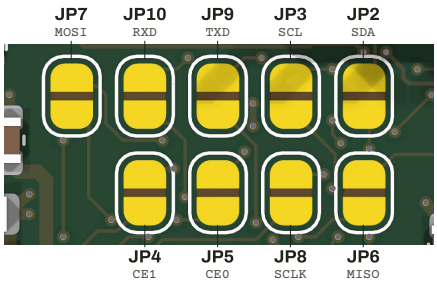


Figure 4. *The bus jumpers, below the left end of the 40-pin header. To close one, bridge its two pads with solder.*

IF YOU CLOSE A BUS JUMPER

With any of JP2 to JP10 closed the board uses GPIO pins, so it is no longer a stackable HAT+. Move JP1 to 0x50 as well, which tells the Pi that it is a standard HAT+. A second HAT on top must then not use the same pins.

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WIRING EXAMPLES

To do this	Connect
Capture signals at one logic level	The signals to odd pins of either pod, and at least one lead from an even pin to the circuit's ground
Capture two logic levels at once	One level on pod A and the other on pod B. Each pod has its own threshold
Sample on the circuit's own clock	The clock to any input, the data to the other channels
Trigger a scope from the analyzer	Trigger header pin 2 (OUT) to the scope's external trigger input, pin 3 to its ground
Start a capture from another instrument	Its 3.3 V or 5 V logic output to trigger header pin 1 (IN), its ground to pin 3
Add a second HAT	Plug it onto the pins on top. As shipped the board uses none of the Pi's GPIO

6 CAPTURE AND TRIGGERS

The board has no switches or trimmers: everything in this section is set from the host over USB. Samples go to the host as they are taken, so a capture can run for as long as the host has memory. The board keeps no capture of its own.

WHAT THE LINK CARRIES

Format and link	What it carries	Notes
Raw, USB 3	16 channels at up to 100 MS/s	For any signal, however busy the lines are: two samples in each 32-bit word, 200 MB/s at 100 MS/s
Run-length, USB 3	16 channels at 200 MS/s	For signals that change in up to 96 million samples a second: I²C, SPI, UART and most buses, and a clock up to 48 MHz. Lossless
Any signal at 200 MS/s	892,928 samples, 4.5 ms	Signals that change in every sample are more than the link carries. The capture ends when the board's buffers are full
USB 2.0	16 channels at up to 22 MS/s raw	On a USB 2.0 port or cable: 44 MB/s. Run-length at 200 MS/s for signals that change in up to 11 million samples a second

STREAMING

A capture has no gaps. If the samples come faster than the link and the host take them, the FPGA's buffer of 8192 words fills, sampling stops, and the capture says that it overflowed. What arrived is the capture's beginning, whole to its last sample.

All 16 channels at 200 MS/s are 3.2 Gbit/s of raw samples, more than the link carries. In the run-length format the FPGA sends a word only for a sample that differs from the one before, with the time the inputs then stayed as they were. Real buses have enough idle time to fit. A signal that changes in every sample does not: capture it at 100 MS/s, or take the 4.5 ms that fit.

BEFORE THE TRIGGER

While a capture waits for its trigger the FPGA keeps the newest 8184 words, so the capture also holds what came before: 16,368 samples in the raw format, and far more time on quiet signals in the run-length format. A trigger that comes soon after the start has less before it.

CAPTURE CLOCK

In place of a sample rate, the analyzer can keep one sample at each edge of a clock from the circuit under test, up to 50 MHz: its rising edges, its falling edges or both, on any input. The inputs are still looked at every 5 ns, and the sample kept is the one from just before the edge, so the data must be steady 15 ns before it.

TRIGGERS

The trigger is in the FPGA and looks at every sample, at any sample rate. It has up to four stages, met one after the other. A stage is one of:

- **Levels**: a mask and a value across all 16 channels.
- **Edges**: rising or falling, on any channels, with levels on others.
- **A pulse by its length**: levels that held for a set range of time and have ended.
- **Levels that have lasted** a set time, and still hold.
- **The trigger input**: a rising or a falling edge.

The trigger output goes high 75 to 80 ns after the trigger sample and stays high to the capture's last sample.

GLITCH FILTER

Each channel has a filter, off by default. With it set, a change counts once the channel has held its new level for the set time, from 5 ns to 1.25 µs. Shorter pulses are removed before the trigger and the capture. Every channel is delayed alike, so the edges that pass keep their places against each other.

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THRESHOLDS

Each pod has its own threshold. Set it to about half the logic level of the circuit that pod watches. The threshold is designed to land within ±100 mV of the setting, so the table gives the window in which a channel may switch, and the room that leaves above a low and below a high.

Logic	Threshold setting	Switches between	Room above 0 V	Room below the high level
1.2 V	0.60 V	0.50 – 0.70 V	0.50 V	0.50 V
1.5 V	0.75 V	0.65 – 0.85 V	0.65 V	0.65 V
1.8 V	0.90 V	0.80 – 1.00 V	0.80 V	0.80 V
2.5 V	1.25 V	1.15 – 1.35 V	1.15 V	1.15 V
3.3 V	1.65 V	1.55 – 1.75 V	1.55 V	1.55 V
5 V CMOS	2.50 V	2.40 – 2.60 V	2.40 V	2.40 V
5 V TTL levels	1.40 V	1.30 – 1.50 V	1.30 V	0.90 V, from TTL's 2.4 V high

The threshold stops at 3 V. That covers 5 V logic at its half-way point, but not a threshold near the top of a 5 V swing. On the first boards all 16 inputs read a 3.3 V pattern right at every setting from 0.2 to 3.0 V.

STATUS LEDS

LED	Color	It means
PWR	Green	The board has power
ARM	Yellow	Blinks once a second when the FPGA is loaded. On while a capture waits for its trigger
TRIG	Green	On from the trigger, or the first sample, to the capture's last sample

HOW IT IS SET

In the app, or from the command line. `./logicboole capture reset.sr --rate 200M --time 1ms --trigger "B0=f"` waits for B0 to fall and keeps the millisecond after it, with some of what came before. Section 11 has the software.

On a Raspberry Pi with the bus jumpers closed, `--pi i2c`, `uart`, `spi` or `all` puts the Pi's own lines in place of channels (section 5).

7 GETTING STARTED

You need a host (a Mac, a Linux computer, or a Raspberry Pi 4 or 5), a USB-C cable made for USB 3, and leads from the pods to your circuit. To mount the board on a Raspberry Pi you also need four M2.5 × 16 mm spacers and eight M2.5 × 6 mm screws. None of these comes with the board. The **quick start guide**, `docs/quick-start.pdf` in the repository, goes through these steps on two pages with what each command prints.

WITH A COMPUTER

1. **Read section 9, Probing and safety.** The analyzer's ground is the host's ground.
2. **Get the software**: download the repository (section 12) and open a terminal in its folder. It needs Python 3.9 or later and libusb. Nothing in it is built or installed.
3. **Set the board down on something that doesn't conduct**, or mount it on M2.5 standoffs.
4. **Plug the USB-C cable into the board and into a USB 3 port.** PWR lights.
5. **Run `./logicboole check`.** It checks the computer, loads the board, which the software does every time the board connects, and says what to do about anything that is missing. ARM then blinks. `./logicboole` opens the app in your browser.
6. **Connect ground first**: a lead from an even pin of each pod you use to the ground of the circuit under test. Then connect the signals to the odd pins.
7. **Set each pod's threshold** to half the logic level of the signals on it (section 6).
8. **Choose a sample rate and a trigger, and start the capture.** ARM is on while the analyzer waits for its trigger, and TRIG when it has fired.

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ON A RASPBERRY PI

The board follows the Raspberry Pi HAT+ specification, for the Pi 4 and Pi 5. Power comes from the Pi's header and the samples go over a short USB cable to one of the Pi's USB 3 ports.

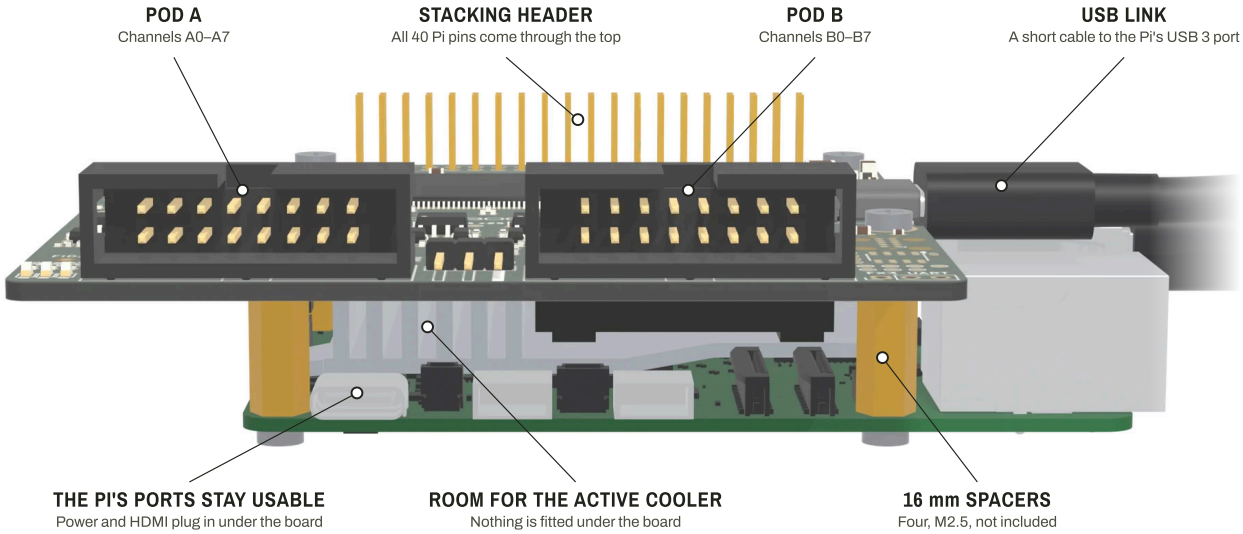


Figure 5. *On a Raspberry Pi 5 with its Active Cooler, seen from the pod edge.*

1. Plug in any camera, display or PCIe flat cables first. They pass under the board.
2. Screw four M2.5 × 16 mm spacers onto the Pi's mounting holes, from underneath, with four M2.5 × 6 mm screws.
3. Press the board's header onto the Pi's 40 pins until the board sits on the spacers, and fit four more screws from the top.
4. Connect a USB 3 cable, USB-C to USB-A and about 20 cm long, from the board to one of the Pi's blue USB 3 ports.
5. Go on from step 5 above, with the software on the Pi.

Power. The board runs from the Pi's 5 V pins, from USB-C, or from both at once. Ideal diodes keep each source from feeding the other, so the board never powers the Pi. When the Pi goes to standby and no USB host is powering the board, it switches itself off.

What stays free on the Pi

- **All of GPIO 2 to 27.** As shipped the board connects to none of them, and all 40 pins come through the top for a second HAT.
- **The Pi 5 Active Cooler** fits underneath, with 4 mm between its fan and the board.
- **The PoE header and the camera, display and PCIe connectors** are not blocked.
- **The Pi's power and HDMI sockets**: their plugs go in under the board's overhang, with 9 mm to spare.

`Pi 5`	Each USB 3 port has its own 5 Gbit/s controller. Any USB-C plug fits
`Pi 4`	Fits. Its USB ports share one link. Use a link cable whose USB-C plug body is no thicker than 6.4 mm, because the plug sits over the Pi 4's USB sockets
`Older 40-pin Pis`	Fit, at USB 2.0 rates

The stackable HAT+ class needs current Raspberry Pi firmware.

WHAT HAS RUN ON A PI

One board on a Pi 5's header, on the spacers, powered from the header and from USB-C at once: test data at 391 MB/s for 10 minutes with every word right, and captures from the command line with an earlier version of the software.

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8 TYPICAL APPLICATIONS

Settings to start from for common jobs. Every one needs a host, wired as in A or B.

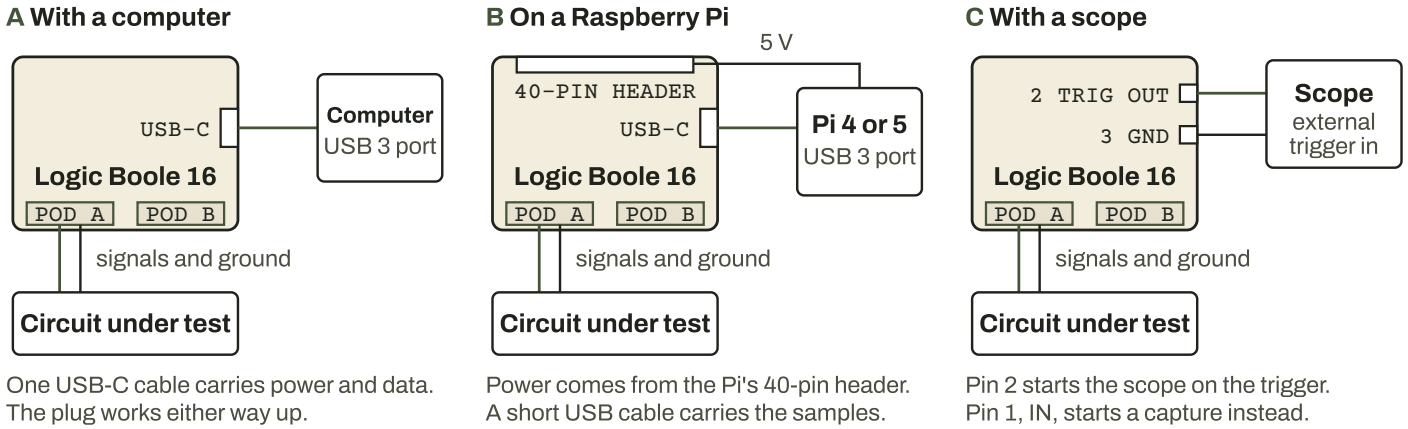


Figure 6. *Typical application wiring. A and B are the two hosts; C adds the trigger header (section 5) to either.*

Use	Start from	How
I²C bus	Threshold at half the bus voltage. Run-length format at 200 MS/s	SDA and SCL on one pod, with a ground lead. Trigger on SDA falling while SCL is high, the start of a message
SPI bus	Threshold at half the logic level. Trigger on chip select falling	Clock, data and chip select on one pod. Sample at four or more times the clock rate: 200 MS/s suits clocks up to 50 MHz
UART	Threshold at half the logic level. Trigger on a falling edge	One channel for each direction. The falling edge is the start bit
Parallel bus with its clock	Capture clock, on any input	The data on the other channels. The analyzer keeps one sample for each edge of the bus's own clock, up to 50 MHz
Two logic levels in one capture	Pod A at 0.90 V for 1.8 V logic, pod B at 1.65 V for 3.3 V	For a level shifter, or a processor with two I/O voltages: put each side on its own pod
Timing between signals	200 MS/s	Each sample is 5 ns. The 16 inputs of one board matched within 1.4 ns
A rare fault	A trigger on levels, edges or a pulse's length	The capture waits in the board for as long as it takes, and keeps what came just before the trigger
Glitches and runt pulses	A pulse-length trigger, glitch filter off	Pulses down to 6 ns are captured. With the filter set, shorter ones are removed instead
Triggering a scope	Trigger header pin 2 to the scope's external trigger (C)	The scope then shows the analog signal around the logic event that the analyzer found
Started by another instrument	Its 3.3 V output to trigger header pin 1, and the trigger input as a stage	The capture triggers when the other instrument fires
The Pi's own buses	Board on a Pi (B), bus jumpers closed	`--pi i2c`, `uart` or `spi`: the Pi's lines in place of channels, with no leads (section 5)
Decoding a bus	A saved capture, and `sigrok-cli` installed	`./logicboole decode bus.lb16 i2c scl=A1 sda=A0` lists what one of sigrok's decoders finds
Unattended capture on a Pi	Board on a Pi (B), with no screen	Captures from the command line over SSH, with JSON results for a script, or the app opened from another computer
Scripts and AI agents	`import logicboole`, or `./logicboole mcp`	A Python package for scripts. For AI agents, a Model Context Protocol server and a skill file

WHICH FORMAT?

Buses with idle time stream on all 16 channels at 200 MS/s in the run-length format. For signals that never rest, use the raw format at 100 MS/s or less, or take the 4.5 ms that fit at 200 MS/s (section 6). Section 13 says what each of these uses has been tried with.

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9 PROBING AND SAFETY

⚠ WARNINGS

- **Ground is common.** The pods' ground pins, the USB cable's ground and the Raspberry Pi's ground are one net. The inputs are not isolated: connect the analyzer's ground only to the ground of the circuit under test, never to a point at another voltage.
- **±25 V at most on any input.** Do not probe mains wiring, or any circuit that is not isolated from the mains.
- **It is a bare board.** Keep loose wires, tools and metal off it while it is powered.

THE INPUT CIRCUIT

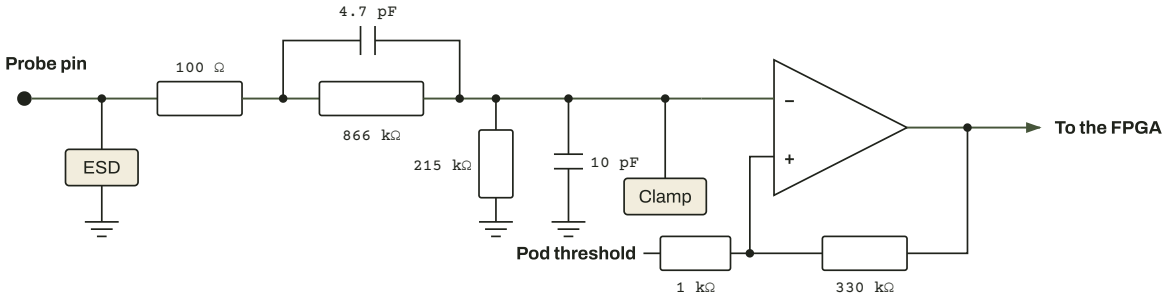


Figure 7. *One input channel, simplified. The 330 kΩ from the comparator's output to its + input gives the hysteresis.*

Every channel is the same circuit. An ESD diode at the connector is rated for discharges of ±8 kV. A compensated divider of 866 kΩ and 215 kΩ scales the signal by 5 and sets the 1 MΩ load. A clamp holds the divided signal in range when the input is far above the logic level or below ground, which is how an input is designed to stand ±25 V for as long as you like, with the board powered or not. A fast comparator then compares the signal with the pod's threshold. Feedback around the comparator gives the hysteresis: once an input has crossed the threshold it must come back by 25 to 100 mV to switch again, so a slow or noisy edge is recorded once.

LOADING

Each input looks like 1 MΩ in parallel with about 9 pF to ground, at the pod connector. A cable and its leads add their own capacitance. On a line with a weak pull-up the extra capacitance slows the rising edge a little: 10 pF on a 10 kΩ pull-up adds 0.1 µs to its time constant.

GROUNDS

Every signal pin has a ground pin beside it. Connect at least one ground lead per pod, close to the signals, and more for fast signals: a long ground return adds ringing that the analyzer then records.

SLOW EDGES BESIDE BUSY CHANNELS

The signal pins of a pod stand side by side in the connector, so a little of each channel's edges couples into its neighbors. Normally that is far below the hysteresis. One case can show extra edges: a line that is only pulled up weakly and has little capacitance of its own, about 20 pF or less, such as a short line on a microcontroller's internal pull-up, next to channels switching fast at 5 V. As it crosses the threshold slowly it can be recorded as a burst of edges.

- Put such a line on a channel whose neighbors are quiet, or leave the channels beside it unused.
- Or set that channel's glitch filter to 25 ns or more.

An ordinary I²C bus has enough capacitance that it is not affected.

USE

- Indoors and dry, at 0 to 40 °C.
- Handle it like any development board. The inputs are protected; the rest of the board is open electronics.
- Not for safety-critical or medical use.
- Revision C is a prototype. It has not been tested for FCC or CE compliance.

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10 DIMENSIONS

In millimeters. Positions are measured from the **top left corner of the board seen from the component side**, with the 40-pin header at the top: x to the right and y down.

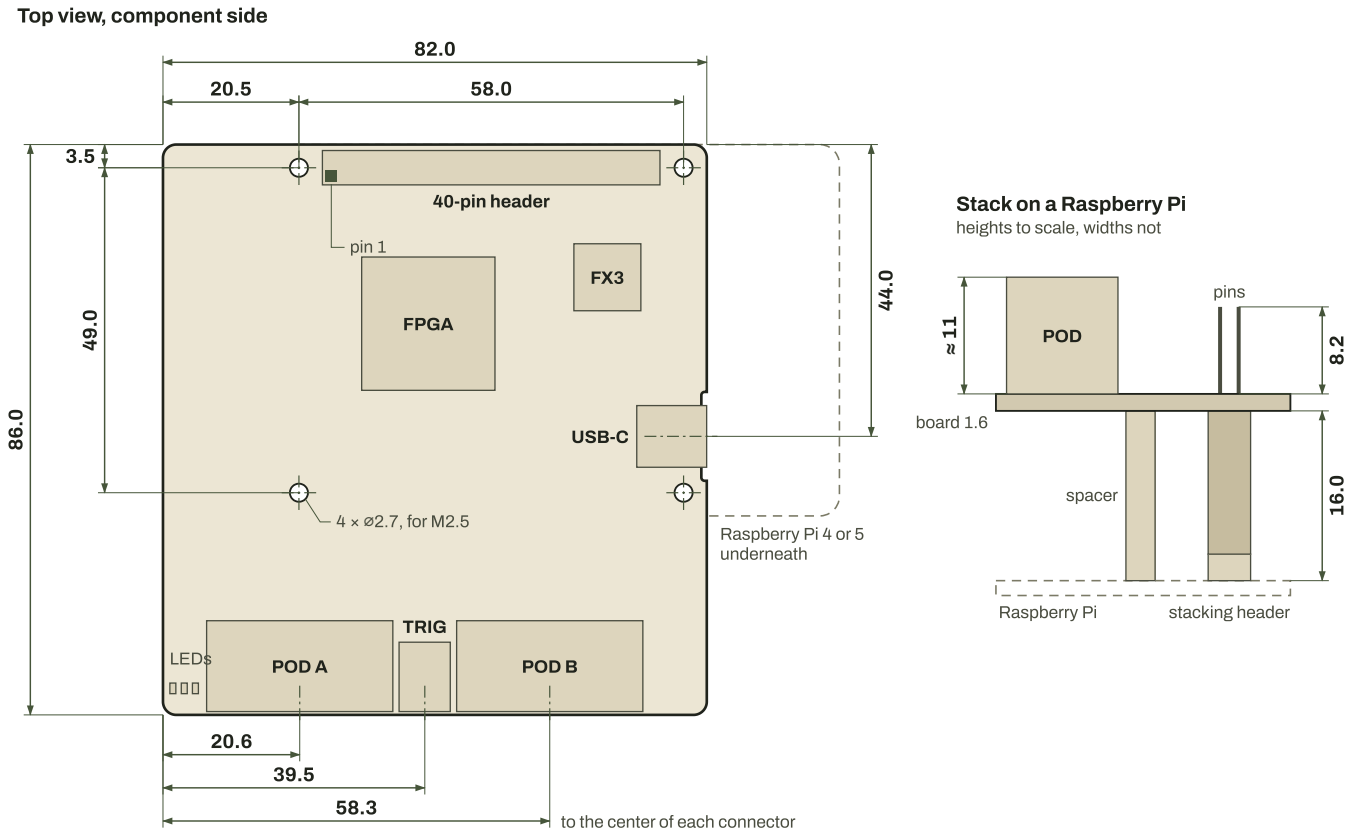


Figure 8. *Board outline, mounting holes and connectors, and the stack on a Raspberry Pi. The dashed outline is the Pi underneath.*

Feature	X	Y	Notes
Board	82.0	86.0	Overall size. 2 mm corner radius, 1.6 mm thick
Mounting holes	20.5, 78.5	3.5, 52.5	Four holes of 2.7 mm for M2.5, 58.0 × 49.0 mm apart
40-pin header, pin 1	25.37	4.77	2 × 20 at 2.54 mm. The header's center is at 49.5, 3.5
USB-C, center	right edge	44.0	The plug goes in from the right. The receptacle's face is 0.8 mm out from a notch in the edge
Pod A, center	20.62	front edge	The connector's body is 28.1 mm wide. Its face is 0.5 mm inside the edge
Trigger header, center	39.47	front edge	Pin 1, trigger in, is the right-hand pin
Pod B, center	58.31	front edge	As pod A
Above the board			Pod connectors about 11 mm. The 40-pin header's pins 8.2 mm
Below the board			The stacking header's body, 13.5 mm. Nothing else
On a Raspberry Pi			16.0 mm from the top of the Pi's board to the underside of this one, on M2.5 × 16 mm spacers. The board reaches 17 mm past the Pi's microSD end and 30 mm past its HDMI edge, and stops 20 mm short of its USB and Ethernet end

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11 FIRMWARE AND SOFTWARE

The board keeps no firmware of its own, so there is nothing to program before you use it. You only need the pads in this section for development.

LOADED BY THE HOST

Each time the board connects, the host software loads the FX3's firmware over USB, and the FX3 then configures the FPGA, which takes 0.7 s. An update is a new file on the host, and nothing you load can leave the board unusable: unplug it and plug it in again.

Thresholds, triggers, glitch filters and everything else the FPGA controls are set over the same USB link.

The firmware image is not in the repository. The software downloads it once, about 110 kB, checks it and keeps it, so the host needs the internet that one time.

On USB the board has the IDs of Infineon's SDK examples, `04B4:00F1`, the name Logic Boole 16 and a serial number of its own.

A footprint for an SPI flash, not fitted, would let the FX3 start on its own.

macOS	Runs: the current software was tested from a Mac laptop
Raspberry Pi OS	Supported: 64-bit, on a Raspberry Pi 4 or 5
Linux on a PC	Supported
Windows	Not supported

HOST SOFTWARE

One Python package that needs Python 3.9 or later and libusb, and nothing else. It runs from its folder: nothing is built or installed.

- **The app**: `./logicboole` opens it in a browser, with the waveforms, each pod's threshold, the trigger and the decoders.
- **The command line**: `check`, `capture`, `decode`, `measure`, `selftest` and more, with JSON output for scripts.
- **A Python package**: `import logicboole`.
- **Files**: `.sr` for PulseView and sigrok-cli, `.vcd`, `.csv`, and its own `.lb16`.
- **Decoders**: sigrok's, more than a hundred, through `sigrok-cli` if it is installed.
- **For AI agents**: `./logicboole mcp`, a Model Context Protocol server, and a skill file.
- **With no board**: `--fake` runs all of it on a stand-in.

`./logicboole selftest` checks the whole path from the FPGA to the host: 34 captures of a test pattern, with every word compared.

PROGRAMMING AND DEBUG PADS

Nothing is fitted. Both JTAG ports are Tag-Connect TC2050 pad patterns for the cable with locking legs (TC2050-IDC), at 3.3 V.

Marked	Where	For	Pins 1 to 10
FPGA JTAG	Left of the FPGA	The FPGA, in Tag-Connect's Xilinx order	**3V3, TMS, GND, TCK, GND, TDO, GND, TDI, GND, not connected**
FX3 JTAG	Right edge, towards the front	The FX3, in ARM's 10-pin order. JTAG only, no SWD	**3V3, TMS, GND, TCK, GND, TDO, key, TDI, GND, RESET**
FX3 UART	Front right corner	The FX3's serial port: 3 holes at 2.54 mm, no header fitted	**GND, RX, TX**

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12 OPEN SOURCE

Logic Boole 16 is open hardware with open software. Everything needed to study the board, to change it and to have it made is in one repository: **github.com/mgwalkerjr95/logic-boole-16**.

Part	What is published	Folder	License
The board	The KiCad 10 project, the schematic as a PDF, the parts list, the Gerber files and placement files that revision C was made from, a 3D model	`hardware/`	CERN-OHL-S v2
The FPGA design	The Verilog source, a test bench that checks itself, the build script, and the bitstream the software loads	`gateware/`	CERN-OHL-S v2
The firmware	The FX3's firmware in C	`firmware/`	MIT
The host software	The app, the command line, the Python package, the server and the skill file for AI agents, with their tests	`software/`	GPL-3.0-or-later
The documents	This datasheet and its source, the quick start guide, the USB requests, the FPGA's registers and the format of the sample stream	`docs/`	CERN-OHL-S v2

WHAT YOU MAY DO

Under the CERN-OHL-S v2 you may use, study, change and share the design, and make and sell boards from it. Whoever passes on the design, or boards made from it, changed or not, passes on the complete source under the same license and keeps its notices. The host software is under the GNU General Public License, version 3 or later, on the same principle. The firmware's source is under the MIT license.

These lines are a summary. The licenses' own texts decide: `LICENSE`, `software/LICENSE` and `firmware/LICENSE` in the repository. The design is distributed without any express or implied warranty, including of merchantability, satisfactory quality and fitness for a particular purpose.

CHANGING IT

`./logicboole load --gateware FILE.bin --firmware FILE.img` runs your own build on the board, and `./logicboole selftest` then checks it. The software is plain Python and JavaScript with no build step. JTAG pads for both chips are on the board (section 11), and the Pi bus jumpers bring nine of the Pi's pins to the FPGA. The published design fills 92 % of the FPGA's logic, so a large addition has to take something out.

WHAT IS NOT OPEN

- **Infineon's code in the firmware image.** The image is built from the published source with Infineon's EZ-USB FX3 SDK and also holds code of the SDK's libraries, which is Infineon's and stays under the license of its SDK. The image is a file of the repository's releases, for use on a Logic Boole 16. `firmware/README.md` says how to build it yourself.
- **Two of the tools.** The FPGA is built with AMD's ISE 14.7, whose free WebPACK license covers it, and the firmware with Infineon's SDK. The simulation needs only Icarus Verilog, which is open.
- **The name.** Logic Boole and its logo are not part of the licenses.

HAVING BOARDS MADE

The fabrication files are the ones the first boards were made from at JLCPCB: four layers on the stack-up JLC04161H-3313, ENIG, parts on the top side only. The repository's `README.md` lists the order options, and the stacking header that is soldered by hand afterwards.

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13 STATUS AND KNOWN LIMITS

Revision C is the first build: five boards, of which two have been brought up so far. This is what has been measured on them, and what we know about them. None of it is a safety problem.

WHAT HAS BEEN MEASURED

What	On	Result
Supplies and start-up	Boards 1 and 2	Every rail right. The firmware and the FPGA load over USB, and the two boards give different serial numbers
The path to the host	Boards 1 and 2	The self-test passes over USB 3 and over USB 2.0: 34 captures of a test pattern with every word compared, 600 million samples at 200 MS/s among them
Sampling	Board 1	Clocks of 1 MHz and 100 kHz at 200 MS/s: every half period of the 1 MHz clock is 99 to 101 samples, and the two samples of a cycle are 4.95 to 5.05 ns apart
Inputs at speed	Board 1: all 16. Board 2: 5	A clock on one input at a time at 50, 70, 80 and 85 MHz: every period seen, the other inputs quiet. At 90 MHz some inputs miss up to 2 % of the periods
Thresholds	Board 1	The threshold voltage is within 10 mV of its setting, seen from the probe, at 0.30, 1.56 and 3.00 V. All 16 inputs read a 3.3 V pattern right from 0.2 to 3.0 V
Skew and 5 V logic	Board 1	1.4 ns between the earliest and the latest of the 16 inputs. 5 V logic reads right on four inputs of pod A beside 3.3 V logic on four more
Trigger, glitch filter, capture clock	Board 1, three or four inputs	In 50 captures the trigger sample was the one a model picked, sample by sample. The capture clock at 10, 25 and 50 MHz gave one sample for each edge. The filter is as in section 2
Trigger header	Board 1	TRIG OUT in 600 captures and TRIG IN in 2,000, from 100 kHz to 50 MHz
USB	Board 1	5 Gbit/s with the plug either way up. 384 MB/s in a capture, and 44 MB/s over USB 2.0 for 20 s
Current	Board 1	0.18 A while streaming, with an earlier test design. Before they are loaded, boards 1 and 2 both draw 0.05 A
On a Raspberry Pi 5	Board 1	On the header and the spacers, powered from the header and from USB-C: 391 MB/s for 10 minutes with every word right, with an earlier test design

KNOWN LIMITS

Limit	What you see	What to do
It needs a host	On its own the board does nothing: a computer or a Raspberry Pi loads it and holds the capture	None needed
Digital only	No analog channels and no pattern generator	Use the trigger output to start a scope
200 MS/s needs idle time to stream	A signal that changes in 100 million samples a second or more overflows: the capture ends after 4.5 ms, whole up to there	Use the raw format at 100 MS/s, or take the 4.5 ms
USB 2.0 carries a ninth as much	Captures that make more than 11 million words a second overflow	Use a USB 3 cable and port
Signals above 85 MHz	At 90 MHz some inputs miss pulses	Keep to 85 MHz, or 6 ns pulses
Two comparator types on the first boards	At 85 MHz pod A reads a high up to 0.4 ns long and pod B up to 0.6 ns short. Pod B's edges come 0.2 to 0.6 ns before pod A's	Put signals whose timing you compare on one pod
Capture clock: data set-up	Data that changes about 5 ns before the clock's edge is read old in some samples and new in others	Have the data steady 15 ns before the edge
Thresholds stop at 3 V	No threshold near the top of a 5 V swing	Use 2.5 V for 5 V CMOS, or 1.4 V for TTL levels (section 6)

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Limit	What you see	What to do
A threshold close to a logic level, on pod A	With the threshold within 8 % of the swing of the low or the high level, an edge that follows a level held for 4 µs or longer is read 0.1 to 0.4 µs late. Pod B does not show it	Set the threshold near the middle of the swing
Slow edges beside busy channels	A weakly pulled-up line next to channels switching fast at 5 V can record extra edges	Quiet neighbors, or a glitch filter of 25 ns or more (section 9)
The first load needs the internet	The software downloads the firmware image once	Or put the file in place by hand: `software/README.md`
A Mac laptop asks first	macOS asks whether to allow the accessory when a board's firmware first starts there	Choose Allow, and run the command again if it had stopped waiting
No Windows	The software does not run on Windows	macOS or Linux
Pi 4: a slim USB-C plug	The link cable's plug sits over the Pi 4's USB sockets	Use a plug body no thicker than 6.4 mm (section 7)

STILL TO BE DECIDED

- The probe lead set.
- Which of the two comparators later boards carry on both pods.

14 REVISIONS AND DOCUMENTS

HOW IT WORKS

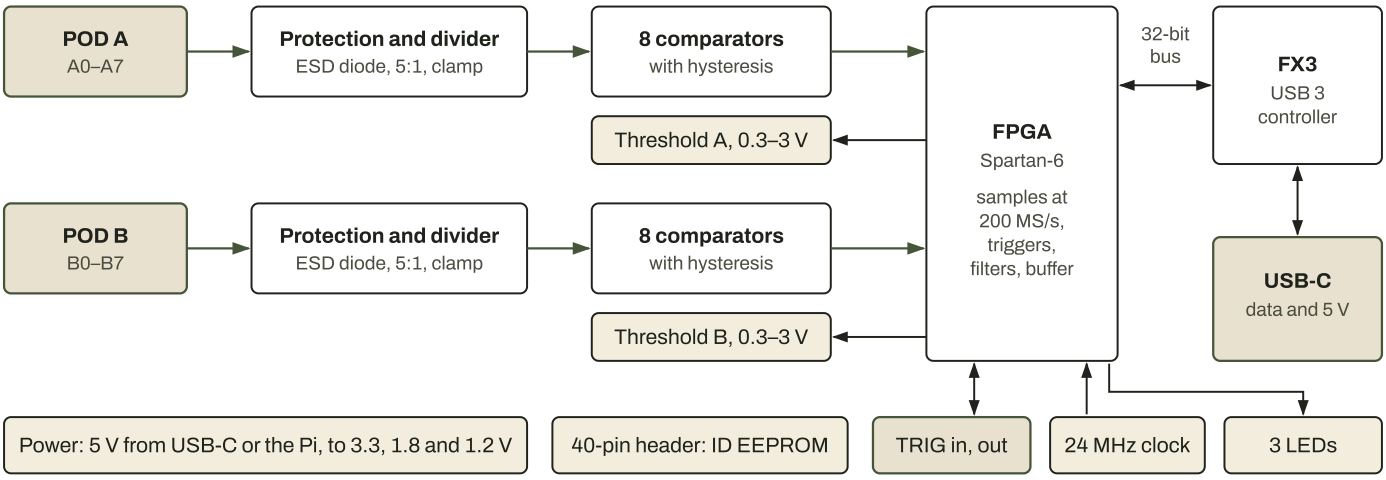


Figure 9. *Signal path. Olive marks the connectors and the path of the signals you probe.*

Inputs. Sixteen identical channels: an ESD diode, a 5:1 divider, a clamp and a fast comparator with hysteresis. There is no buffer or level shifter in the path. Section 9 has the circuit (figure 7).

Thresholds. Each pod has its own threshold, made from a 2.5 V reference under the FPGA's control and set from the host. Two pods with two thresholds let one capture mix two logic levels.

Sampling and the link. The FPGA samples all 16 comparator outputs at up to 200 MS/s, runs the glitch filters and the trigger on every sample, and passes the samples through a buffer of 8192 words to an Infineon FX3, which carries them to the host over USB 3.

BOARD REVISIONS

Revision	Date	Notes
C	November 2026	The first build, five boards, ordered in October 2026. This datasheet. "Logic Boole 16" and the revision are printed on the back

DATASHEET REVISIONS

Version	Date	Changes
A	2026-11-13	First issue, for board revision C. Preliminary

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Version	Date	Changes
B	2026-11-17	Figures measured on the first boards in place of design figures. Capture, triggers, glitch filter and capture clock as built: revision A's burst buffer is not built and is gone; capture of the Pi's bus lines is in the FPGA design, in place of pod channels. The software, and the open-source release (section 12)
C	2026-11-18	Only the board is in the box: a USB cable, and spacers and screws for a Raspberry Pi, are the customer's to get (sections 1 and 7). A new look, in the typefaces and colors of the shop pages

MAIN PARTS

Part	Maker	Number	LCSC
FPGA, Spartan-6	AMD	XC6SLX9-2TQG144C	C27408
USB 3 controller, EZ-USB FX3	Infineon	CYUSB3014-BZXI	C57294
Comparators, dual, 8 a board	Texas Instruments, Maxinmicro	TLV3502AIDR, MX3502S	C131165, C19269867
Input ESD diodes	Texas Instruments	ESD701DPYR	C42409125
Input clamp diodes	Nexperia	BAV199	C40919
Threshold reference, 2.5 V	Texas Instruments	TL431BIDBZR	C41283
USB-C plug-orientation switch	Texas Instruments	HD3SS3212IRKSR	C544517
Oscillator, 24 MHz	YXC	OT2EL4C4JI-111OLP-24M	C5203548
3.3 V and 1.2 V regulators	Texas Instruments	TPS62A02PDDCR	C22445521
1.8 V regulator	Diodes Inc.	AP2112K-1.8TRG1	C176944
Ideal diodes on the two supplies	Texas Instruments	LM66100DCKR	C2869734
HAT+ ID EEPROM	STMicroelectronics	M24C64-RMN6TP	C79988

On the first boards pod A has the MX3502S and pod B the TLV3502AIDR. The two are pin-compatible. The full parts list is `hardware/bom.csv` in the repository.

Design files, source and the latest revision of this datasheet: github.com/mgwalkerjr95/logic-boole-16. Product page: nearfieldsupply.com/boards/logic-boole-16. Logic Boole 16 · © 2026 Michael Walker. Designed in Texas. This document is licensed under the CERN-OHL-S v2. Preliminary: figures may change. Raspberry Pi is a trademark of Raspberry Pi Ltd. Other names belong to their owners.

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