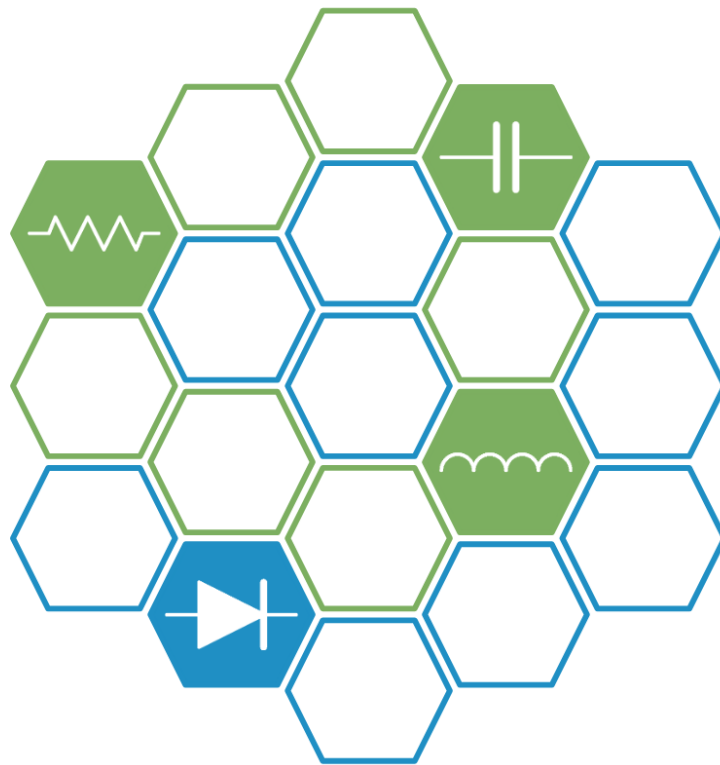




LabsLand

Electronics Hive



HIVE NODE REFERENCE DOCUMENTATION

Version 1.0

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1. Introduction

1.1. What is the LabsLand Hive?

Hive is an advanced remote electronics laboratory created by LabsLand. This online platform allows users to conduct electronics experiments and tests using equipment and devices that are remotely accessible over the internet. This capability facilitates learning and research in the field of electronics without the necessity of physical presence in a traditional laboratory.

Hive features a complex and diverse range of hardware components and devices. This online environment provides a variety of tools needed to conduct electronics experiments and tests, including a multimeter, an oscilloscope, a function generator, and a power supply. The lab's design offers considerable versatility in creating circuits.

To take advantage of this advanced technology and service, please contact us at hive@labsland.com.

1.2. Hive and Hive nodes

The LabsLand Electronics Laboratory serves as a comprehensive remote laboratory, housing equipment located across various institutions, including universities, companies, and LabsLand itself.

Each institution hosts its own "**LabsLand Hive**", a cluster composed of individual "**LabsLand Hive Nodes**", or "**LERN: LabsLand Electronics Remotified Nodes**". A LabsLand Hive Node represents a standalone unit equipped with all necessary components and instruments, capable of independent operation from other nodes.



Figure 1.1: LabsLand Hive Node

Typically, universities maintain a **LabsLand Hive** comprised of two identical **LabsLand Hive Nodes**. This redundancy ensures that if one node undergoes maintenance, the other can continue processing student requests. Future advancements aim to diversify node capabilities, supporting different types of measurements, such as slow and fast measurements.

A Hive can also accommodate multiple nodes tailored for various circuit types. For instance, a university may establish a **LabsLand Hive** of four **LabsLand Hive Nodes**, with two nodes possessing one configuration and the remaining two equipped with a different setup.

1.3. About this document

This document is focused on how to set up and manipulate each Hive node. If you are looking for other type of documentation (such as using the LabsLand Electronics Laboratory itself, what circuits are available by default, or similar), please go to:

- <https://labsland.com/web/hive>

1.4. Using the LabsLand Electronics Remote Laboratory without purchasing hardware

LabsLand is a remote laboratory company that provides both the equipment (Hives) but also remote access to the remote laboratory network by purchasing licenses. If you are interested, please refer to this link:

- <https://labsland.com/web/hive>

2. Installation guide

As previously highlighted, a typical LabsLand Hive deployment includes two LabsLand Hive Nodes. While these nodes are designed to work together to expand their collective capabilities, they are usually delivered and installed individually. This installation guide provides information for receiving and setting up a single node.

2.1. Introduction

As a Hive node is a delicate and costly piece of equipment, it is shipped with extensive protective packaging to prevent damage. Consequently, you may spend some time unpacking it upon receipt.

Once you've removed all the outer wrapping, you will find a transparent methacrylate lid that slides vertically and another one that slides horizontally. Open the vertically sliding lid first and carefully remove the packaging material from inside the box. Please be careful not to damage the web cameras located at the top interior of the box.

Within the packing material, you will find two cables essential for starting your Hive node. After you have retrieved these cables, you can close the box by sliding the methacrylate lid down along its rails.

2.2. Prerequisites before you install it

Each Hive node includes two structures like this one:

- Dimensions: 46 cm x 37 cm x 40 cm

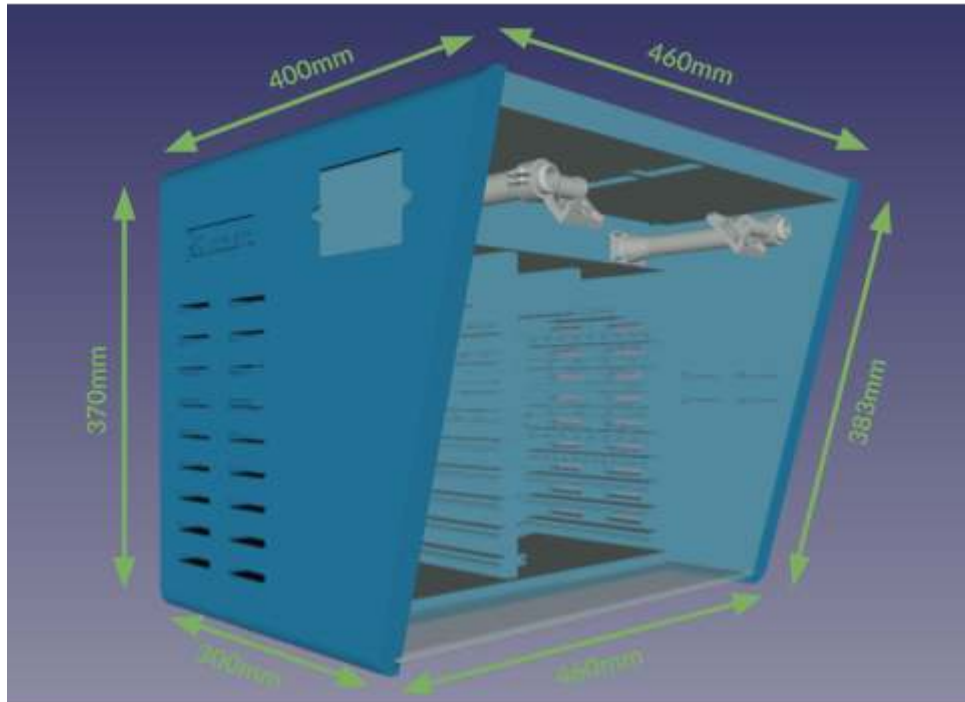


Figure 2.1: Hive dimensions.

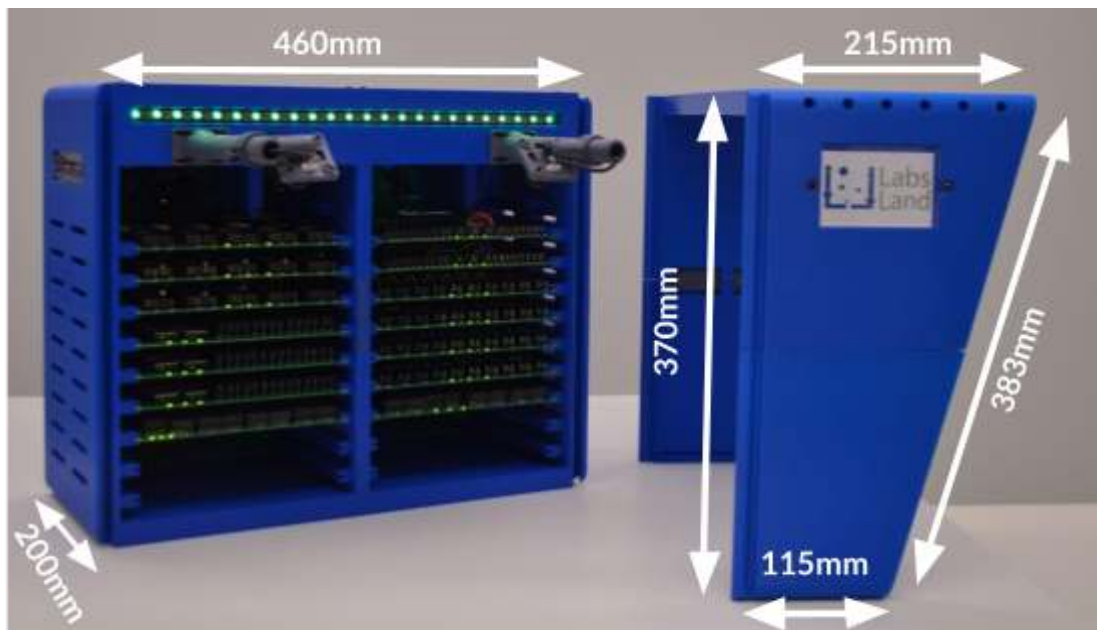


Figure 2.2: Unmounted Hive node dimensions.

- Weight (of each structure): 14 kg
- Energy:
 - Can operate with either 110V or 220, with a 4A maximum current.
- Networking:
 - DHCP is required by default (contact us at hive@labsland.com if only static IPs are available).

- TCP ports 80 (HTTP) and 443 (HTTPS) must be open outwardly.
- UDP port 51820 (WireGuard) must be open too.
- This setup allows us to remotely access the Hive node for initialization and necessary modifications.
- A public IP address is not required for the installation of this software.
- The Hive node can operate within a DMZ environment that has DNS and Internet access.
- You do not need a public IP address for installing this software.
- If you need questions or need help regarding your network architecture and its suitability, please contact security@labsland.com.
- Computing:
 - No server is needed for using the Hive node. The LabsLand Cloud Service is provided.



Figure 2.3: Fully assembled Hive.

2.3. Package contents

The package includes the following items:

- The Hive node itself.
- A power cable (the specific type of cable included will depend on the customer's country or their specific request).

- An Ethernet cable.

The cables may be found inside the Hive node. If that is the case, to access them, simply slide the methacrylate lid upwards. Once you've retrieved the cables, ensure to slide the lid back down to its original position.



Figure 2.4: Packaging of the Hive.

2.4. Setting up the Hive node

The Hive node box arrives fully assembled and no additional parts are required. However, it needs to be connected to the power and Internet to operate.

The cables provided inside are for the power supply and Internet connectivity. On the back of the box (refer to Figure 3), you will find connectors for each cable. Plug one end of the power cable into the connector on the left and the other end into a power socket. Similarly, connect one end of the Ethernet cable into the connector on the right and the other end into an Ethernet port or socket.

Please note that the Ethernet connection should provide Internet access to the device.

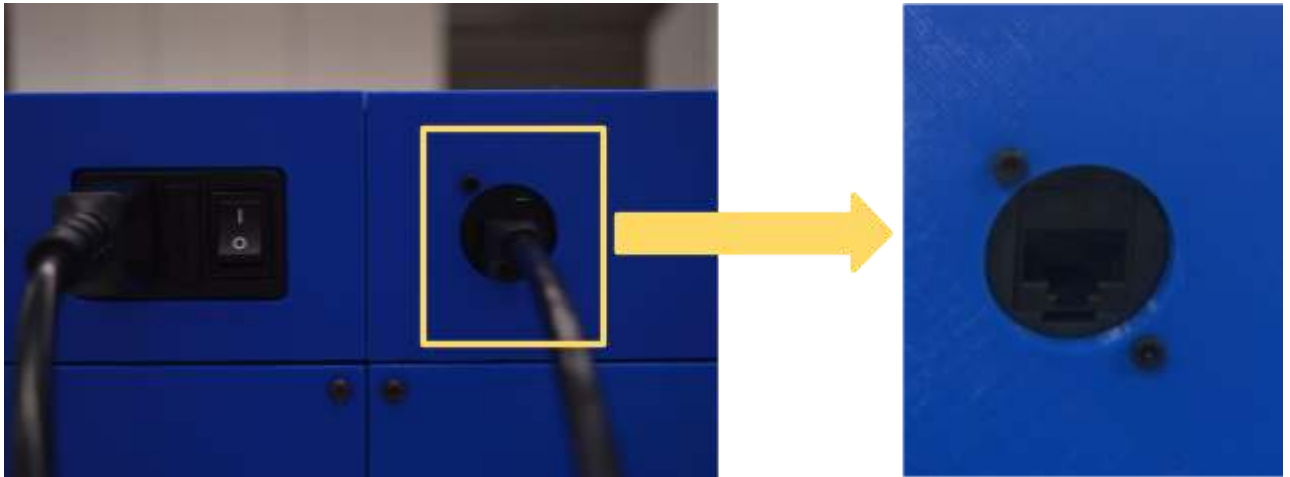


Figure 2.5: Back side of the Hive. Power and ethernet.

2.5. Turning ON the Hive node

Next to the power connector (refer to Figure 3), you'll find a power switch. This switch controls the power supply to the device. Once both cables are securely connected, press the switch to power on the device.

WARNING: It is very important that you do not turn off the equipment using this button. Refer to Section [2.7. Turning OFF the Hive node](#) for proper shutdown procedures.

Upon powering up, you should observe the following:

- On the top part:
 - The fan starts.
 - The button's LED lights up in blue. This might take a few seconds.
 - The LED strip illuminates.
- On the front part:
 - The boards should have three LEDs lit. These LEDs should remain steady. Any blinking LEDs may indicate something is not correctly connected.
 - The LED strip illuminates.



Figure 2.6: Hive node's front side.



Figure 2.7: Hive node's top side.

2.6. Parts of the Hive node

The protective casing of the Hive node is designed in modular sections for easier access and handling. The sections of this casing include:

- Main Methacrylate Cover:
 - This clear cover allows visibility of all the components within the Hive node. It can be removed for direct access or adjustment of the components or cameras by sliding it upwards.
- Secondary Methacrylate Cover:
 - Situated beneath the main cover, this acts as a base and provides structural support. This should be installed before the main cover.
- Protective Trapezoid:
 - This 3D printed part serves to protect and encapsulate the cameras (see Figure 6). It can be disassembled by first removing the methacrylate pieces and then carefully sliding the piece upwards. To reinstall, simply follow the disassembly steps in reverse order.
- Upper Methacrylate Covers:
 - These are located on the top of the Hive node, providing protection to the equipment and electronic components inside. To remove these covers, an Allen key will be necessary.



Figure 2.8: Hive node with the trapezoid detached.



Figure 2.9: Hive node with the main and secondary methacrylate covers detached. (Supported on the sides).



Figure 2.10: Fully mounted Hive node.

2.7. Turning OFF the Hive node

The process of powering down the Hive node requires care to avoid damage to the controlling Raspberry Pi 4. For safe shutdown, there's a button equipped with a blue light located on the top (refer to Figure 9). To initiate shutdown, press and hold this button for at least one second. Upon release, you'll observe the LED strip change to a yellow light, then switch off, followed by the button's LED light extinguishing. Once the lights are no longer visible, you may then safely turn off the power switch located on the back (refer to Figure 3).

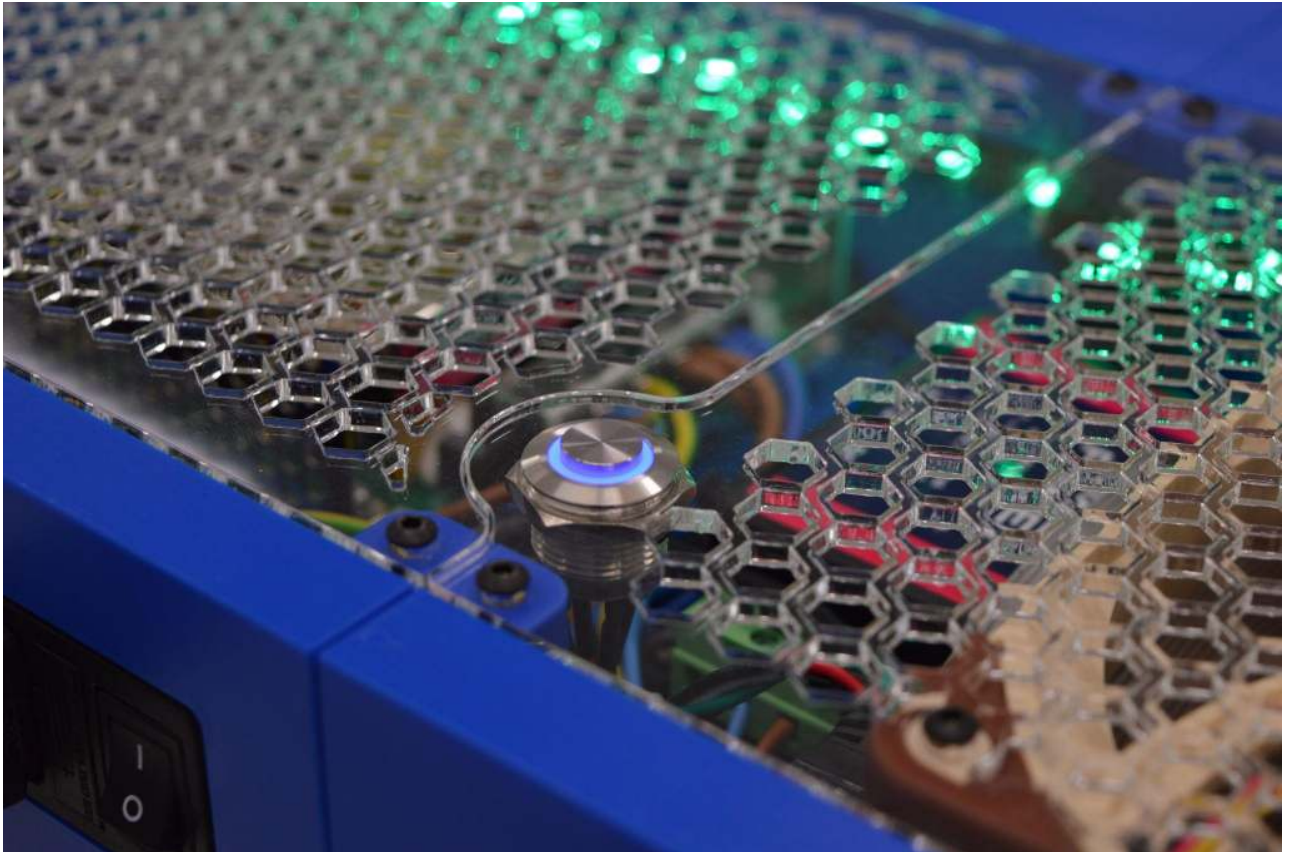


Figure 2.11: Turn off-safely button.

2.8. LEDs

The Hive node incorporates a color-changing LED strip that visually represents the device's current status. For practical purposes, the primary color patterns to be aware of are as follows:

- A single green LED circulating around the strip: This indicates that the equipment is powered on and ready to perform measurements.



Figure 2.12: Hive node ready.

- The entire strip illuminated in yellow: This signifies that the equipment is in the process of shutting down.



Figure 2.13: Hive node turning off.

- The entire strip is off after displaying yellow: This indicates that the equipment is fully shut down and safe to power off.



Figure 2.14: Hive node turned off.

- Other patterns: See Section [5. Troubleshooting](#).

3. Boards included in the node

3.1. Introduction

Each Hive node houses multiple boards that form the backbone of its functionality. There are seven distinct types of boards, each purpose-built for specific tasks, and these can be grouped into two main categories: User Boards and System Boards. Together, these printed circuit boards (PCBs) facilitate the building and interconnection of circuits. With their design, these boards are not only easy to connect but also to modify, allowing separate configuration adjustments for each board.

The boards are arranged in a particular order. As depicted in Figure 3.1, the design accommodates up to 18 boards:

Boards on the left side		Boards on the right side	
#	Board description	#	Board description
9	5 components with discharge network board	18	Protoboard board
8	5 components with discharge network board	17	Protoboard board
7	5 components with discharge network board	16	10 components board
6	Shortcuts 3 board	15	10 components board
5	Shortcuts 2 board	14	10 components board
4	Shortcuts 1 board	13	10 components board
3	Oscilloscope board	12	Digital Multimeter board
2	<i>Empty (for additional boards)</i>	11	<i>Empty (for additional boards)</i>
1	<i>Empty (for additional boards)</i>	10	<i>Empty (for additional boards)</i>



Figure 3.1: Board slots.

All the boards share 3 LEDs in common:

- 5 Volts LED: If the 5 Volt supply is faltering, this LED will be off.
- 3.3 Volts LED: If the 3.3 Volt supply is faltering, this LED will be off.
- Board status LED: This LED's blinking pattern provides information about the board's status.
 - If the boards are inserted in an incorrect slot, this LED will blink at a frequency of 1 Hz.
 - If the board controller is programmed for a different type of board (for instance, if the board was in the wrong slot during a Hive node upgrade), the LED will blink at a frequency of 2 Hz.



Figure 3.2: Status LEDs off.

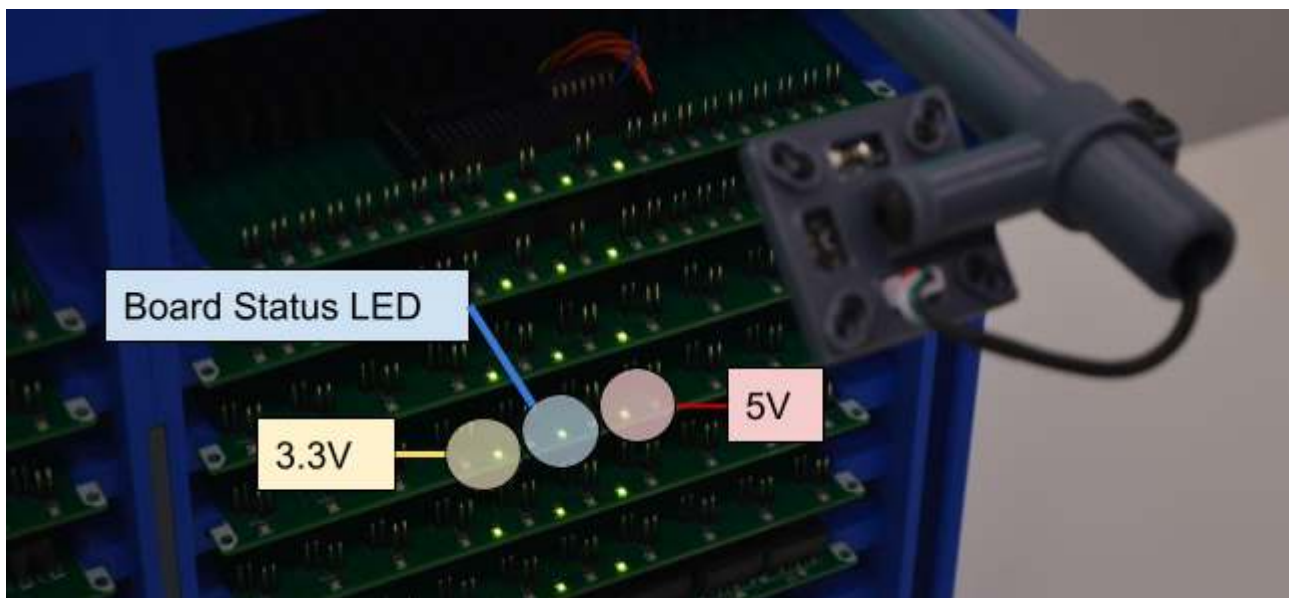


Figure 3.3: Status LEDs on.

3.2 User boards

3.2.1. Introduction

All user boards serve the same purpose: to connect an electronic component between two or more points. There are three types of user boards:

- 10-component board
- 5-component board with discharge network
- Protoboard

In each type of board, a different component is accommodated, as detailed in the subsequent sections. Jumpers are utilized to connect these components between the designated points.

The boards feature several rows of male connectors (refer to Figure 4). Each pair of pins in these rows is associated with a point ranging from A to Z, as well as other points such as +5V, +15V, -5V, -15V, COM, WF1, WF2, and GND.

If you wish to connect a component between point A and point B, a jumper should be placed in the row corresponding to one end of the component on the pair of pins labeled 'A', and similarly, at the row corresponding to the other end of the component on the pair of pins labeled 'B'. **It is critical to never place two jumpers in the same column.**

The sequence in which these points are arranged begins with 5V, followed by the letters A to Z, and then the points +5V, +15V, -5V, -15V, COM, WF1, WF2, and GND. Thus, the left-most component in the entire arrangement is situated between points A and B.

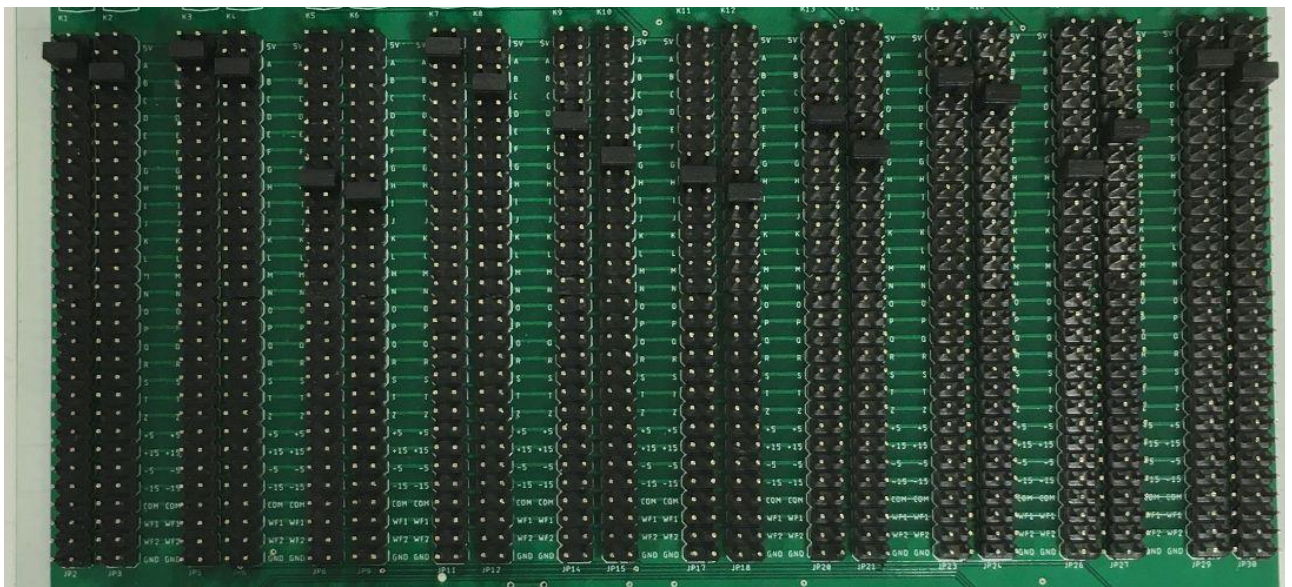


Figure 3.4: Rows for jumpers.

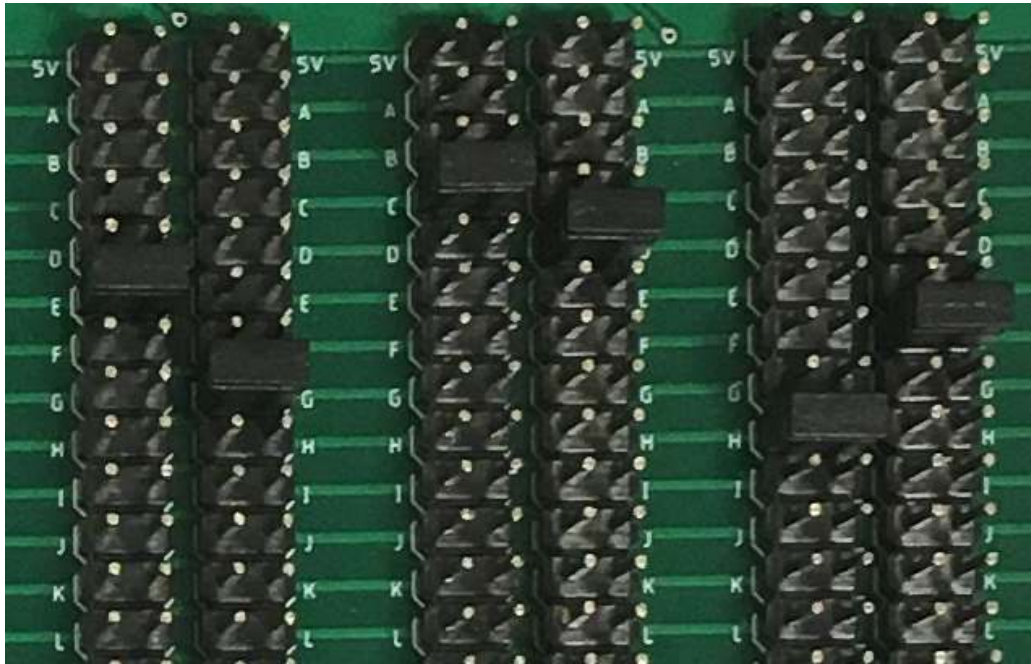


Figure 3.5: Detailed row, part 1.

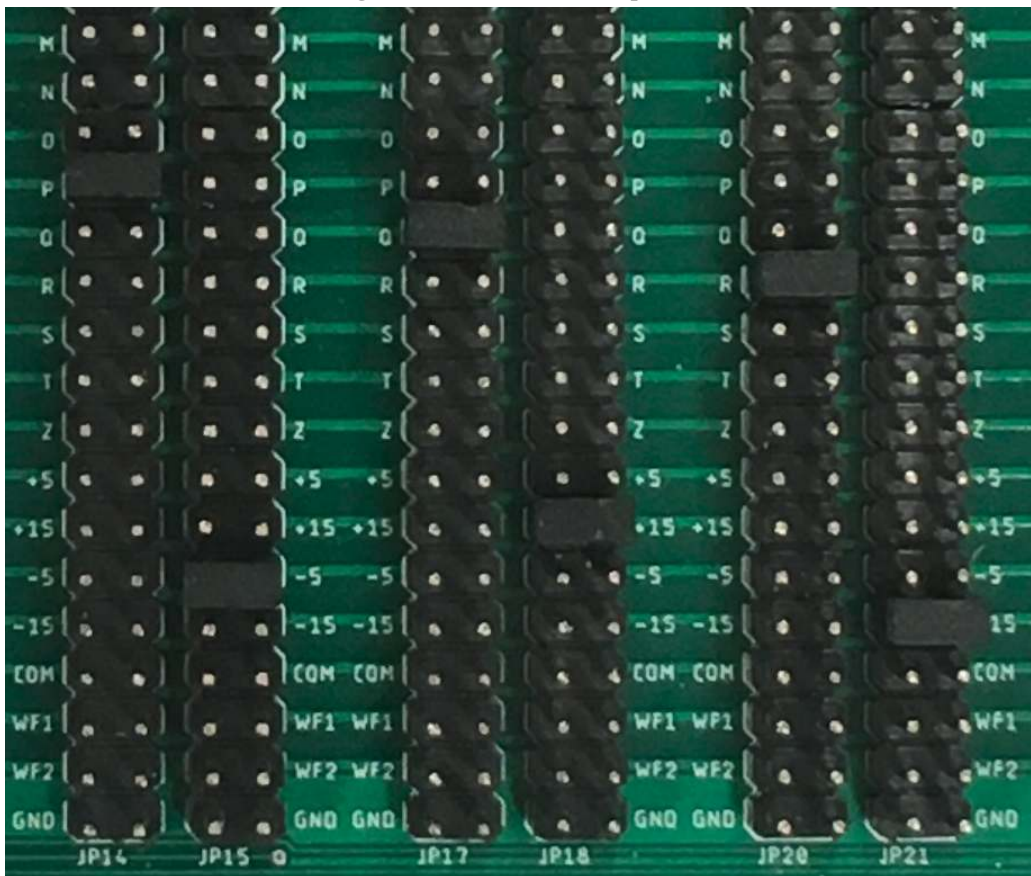


Figure 3.6: Detailed row, part 2.

Each component is connected to, and disconnected from, the circuit thanks to two relays present on the 10-component and 5-component boards with discharge networks, and a single relay on the Protoboard boards. A status LED remains active for as long as the component is connected.

If you wish to check the condition of a relay, there are 4 test points located at the edge of the board, opposite each component. To check for functionality, simply use a multimeter in continuity mode to test if the relay is conducting.

3.2.2. 10 components board

This board facilitates the connection of two-pin components, specifically those that do not store energy, across two points. It is capable of connecting up to 10 components at a time, which is reflected in its name. The appearance of these boards is as follows:

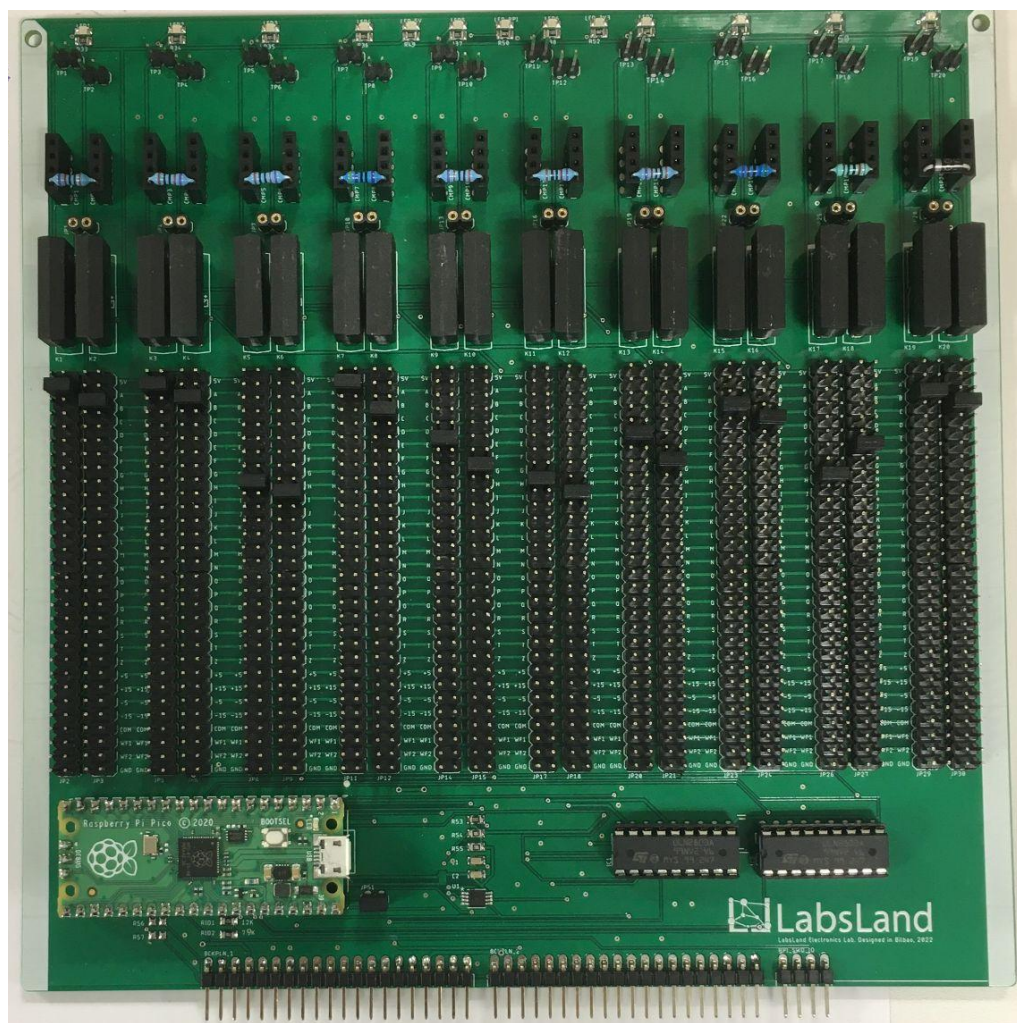


Figure 3.7: 10 components board.

Components that can be connected:

- Resistors
- Diodes
- Cables (for instance, making a connection between one point and ground).

Components that shouldn't be connected:

- Capacitors
- Coils
- Components with three or more legs

The schematic in Figure 3.8 shows how the sockets are interconnected. There are 2 ways of connecting a component:

1. By placing one leg in one of the sockets in the left column and the other leg in a socket in the right column (See Figure 3.8).
2. By connecting each leg in the small sockets at the bottom.

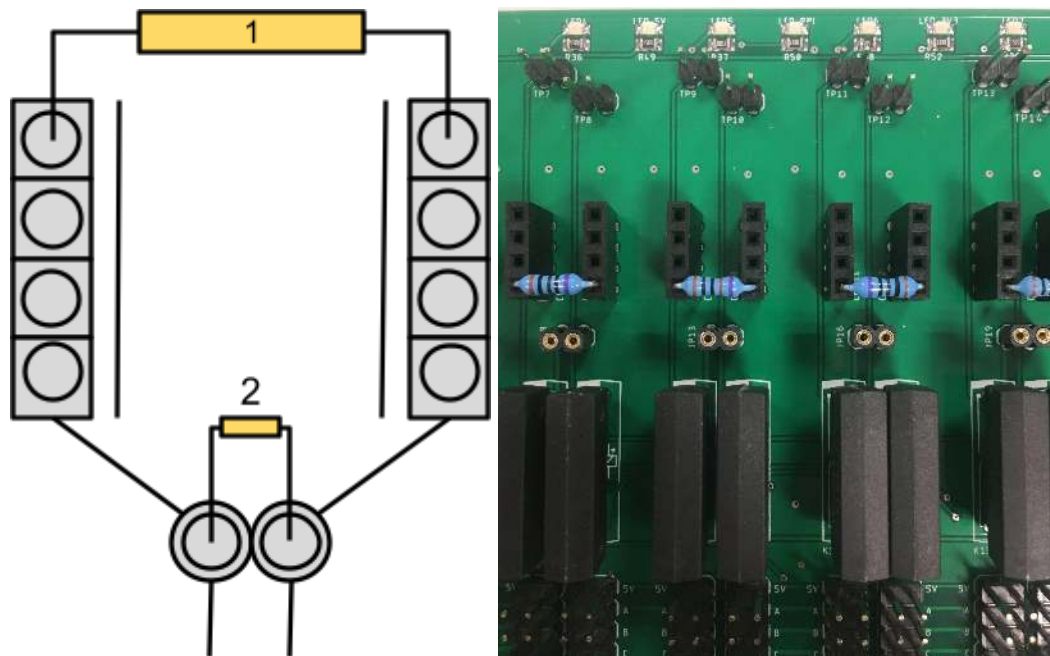


Figure 3.8: Connections in the 10 components board.

3.2.3. 5 component boards (with discharge network)

This board facilitates the connection of two-pin components that store energy between two points. It accommodates 5 components, each with a corresponding discharge network, which lends it its name.

When energy-storing components like a capacitor or a coil are energized, they retain a charge. Therefore, to perform a measurement with the component discharged, this residual energy must be safely dissipated. To achieve this, each component has an associated discharge network that

ensures the component can be safely discharged within a short period. For capacitors, this discharge network comprises a resistor, while for coils, it includes both a resistor and a bidirectional TVS diode.

Here's what these boards look like:

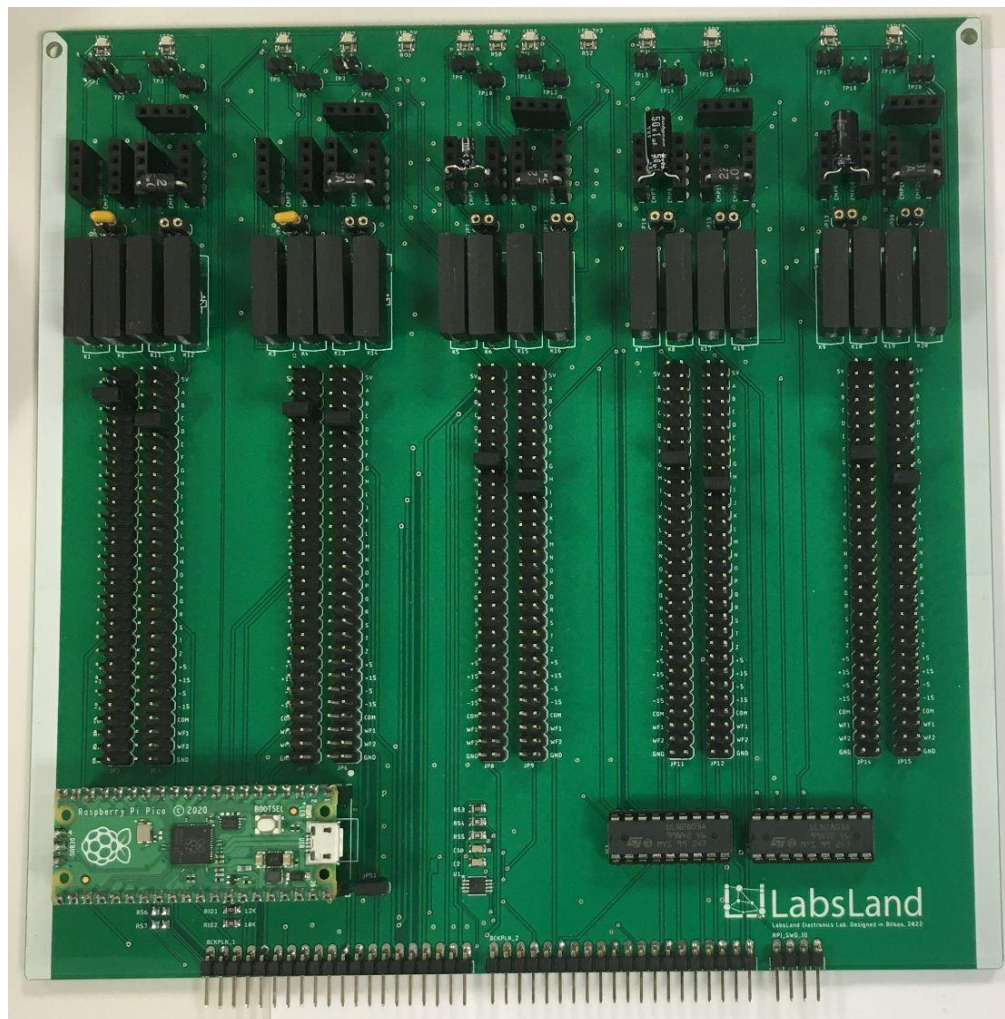


Figure 3.9: 5 components board with discharge network.

Components that can be connected:

- Capacitors
- Coils

Do not connect any other type of component to these boards (use the other types of boards).

The schematic reveals how the left column's sockets are interconnected, as well as connected to the bottom-left socket, and the same applies for the right side. There are two methods for connecting a component:

1. Insert one leg into a socket in the left column and the other leg into a socket in the right column.
2. Connect each leg into the smaller sockets located at the bottom (See Figure 3.10).

To connect components in the discharge network, they can be arranged either in series or in parallel with each other, while the entire circuit is in parallel to the main component.

To connect the components of the discharge network in series:

- Connect one leg into a socket in the left column and the other leg into a socket in the top row.
- Connect the other component similarly, but connect one leg to the top row and the other to the right column.

To connect them in parallel, follow the same process as with the sockets for the components under test.

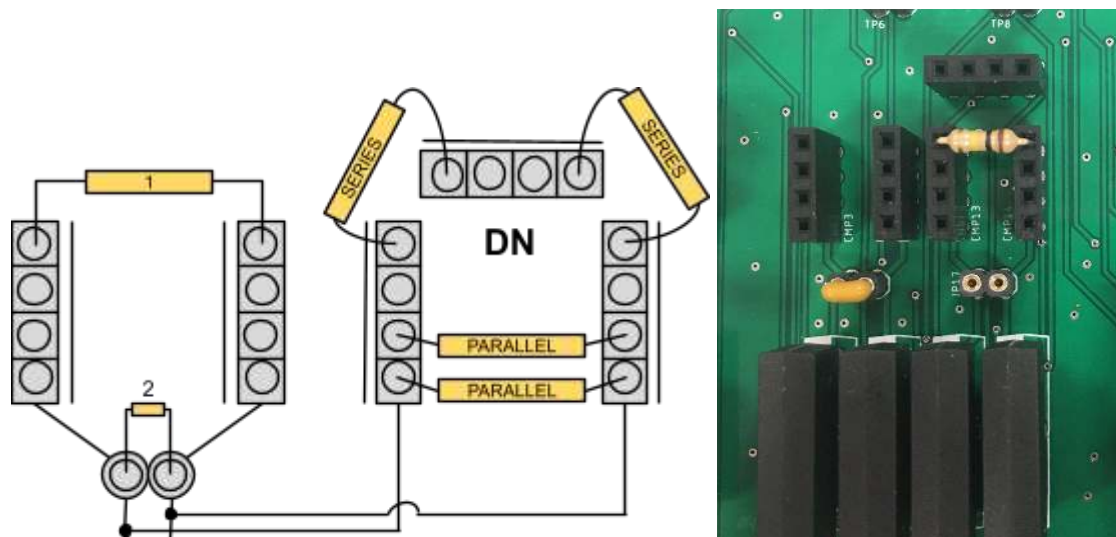


Figure 3.10: Connections in the 5 components board with discharge network.

As suggested by their name, these boards have a unique discharge network for each component. They can be categorized into two types:

- **Capacitor Discharge Network:** This configuration consists of a resistor connected in parallel with the capacitor. This resistor discharges the energy stored in the capacitor. The value of the resistor varies depending on the value of the capacitor.

Capacitor	Max voltage (mV)	Min voltage (mV)	Discharge time (ms)	Resistance (Ohms)	Initial power (W)	Initial current (mA)	Selected DN
2.2 nF	30,000	100	1.25	100,000	0.009	0.3	100k Ohms ¼ W

2.2 nF	15,000	100	1.25	100,000	0.009	0.2	100k Ohms ¼ W
0.1 uF	30,000	100	10	18,000	0.018	1.7	18k Ohms ¼ W
0.1 uF	15,000	100	10	18,000	0.018	0.8	18k Ohms ¼ W
1 uF	30,000	100	45	8,000	0.12	3.8	7.5k Ohms ¼ W
1 uF	15,000	100	45	8,000	0.12	1.9	7.5k Ohms ¼ W
10 uF	30,000	100	60	1,000	0.85	30	1k Ohms 2 W
10 uF	15,000	100	60	1,000	0.85	15	1k Ohms 2 W

Table 3.1: Analysis of a discharge network for capacitances.

- Coil Discharge Network:** This configuration consists of a resistor and a bidirectional TVS (Transient Voltage Suppressor) diode, both connected in parallel to the coil. This combination allows the energy to be discharged safely. The value of the resistor changes based on the inductance of the coil.

Inductor	Max voltage (mV)	Min voltage (mV)	Discharge time (ms)	Resistance (Ohms)	Initial power (W)	Initial current (mA)	Selected DN
10 mH	5,000	100	0.85	1,000	0.05	5	1k Ohms ¼ W & 5V TVS diode
100 mH	5,000	100	0.85	1,000	0.05	5	1k Ohms ¼ W & 5V TVS diode

Table 3.2: Analysis of a discharge network for inductors.

WARNING: If you wish to introduce new capacitor or coil values, do not use arbitrary discharge networks. The discharge networks we provide have been thoroughly tested in our laboratory. This testing involves monitoring the discharge over time using specialized measuring equipment, as shown in Figure 3.11. If you plan to introduce a new component that necessitates a discharge network, please reach out to us in advance at hive@labsland.com.

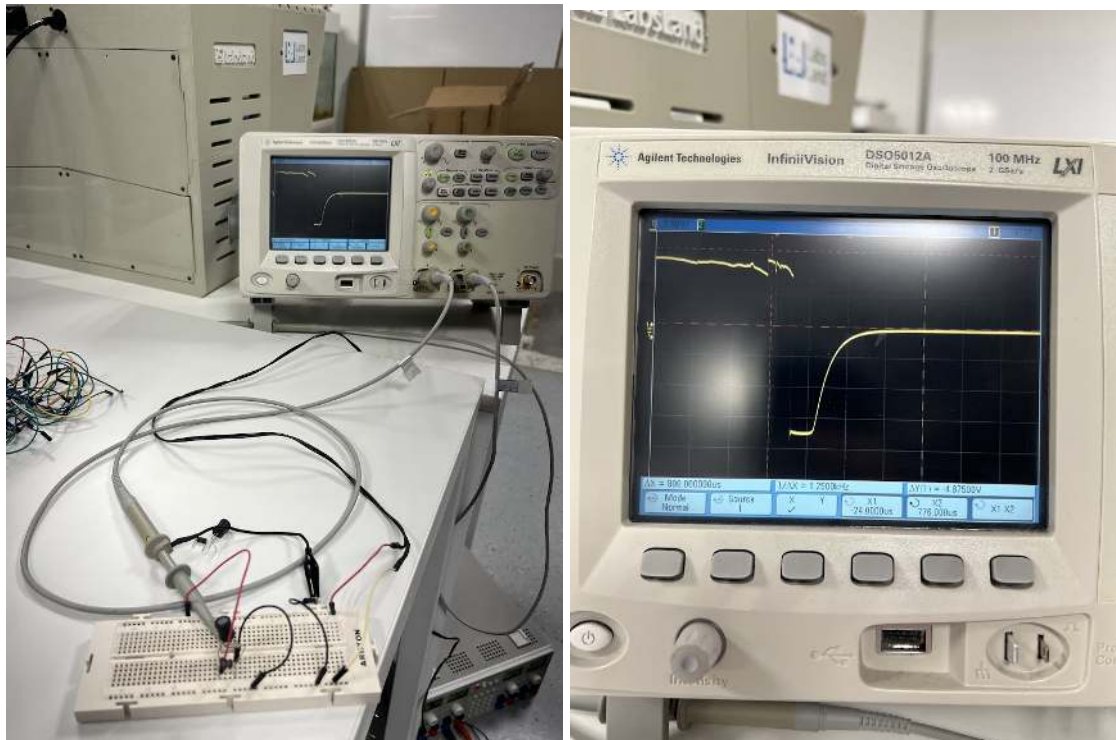


Figure 3.11: Lab test for a coil's discharging network.

3.2.4. Protoboard Boards

The Protoboard board is designed to facilitate the connection of components with 2 or more pins. It features a small breadboard that enables the connection of components that require more than two pins and are typically used with breadboards. With 20 relays available, up to 20 pins can be connected simultaneously.

They look as follows:

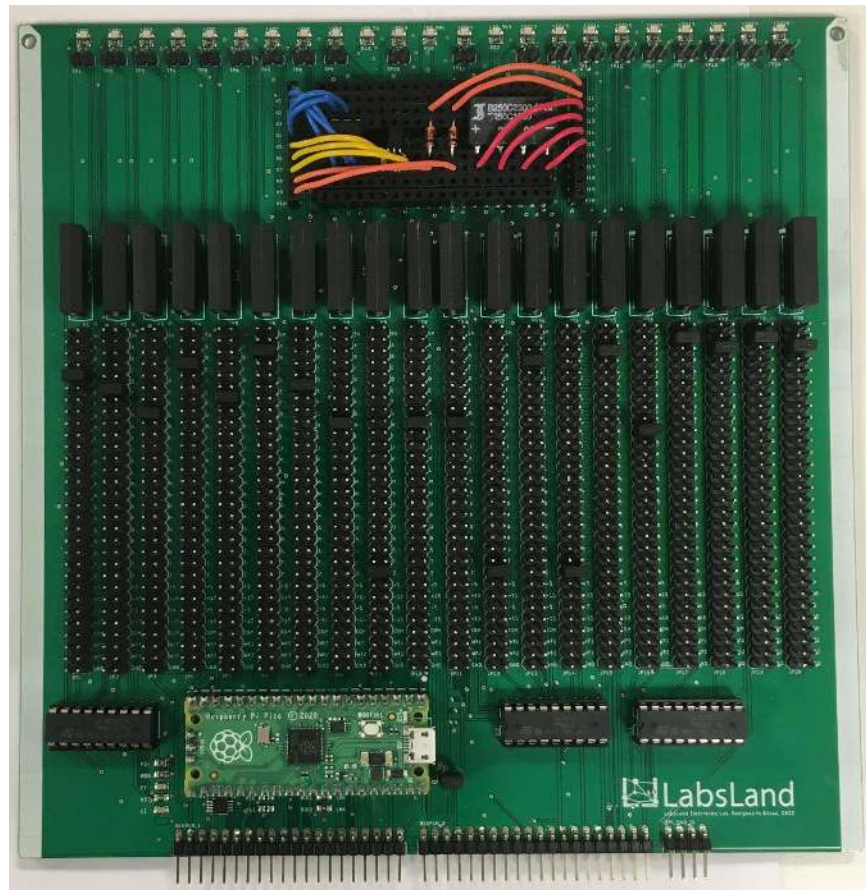


Figure 3.12: Protoboard board.

Components that can be connected:

- Integrated circuits.
- Transistors.
- Resistor or diode bridges.
- Resistors.
- Diodes.

Components that should not be connected:

- Capacitors.
- Coils.

The schematic illustrates the available connections provided by the breadboard. It functions similarly to a traditional breadboard, where components can be connected using wires. To connect a leg of a component to the circuit, you need to attach a wire to one of the pins located on the sides

of the Protoboard board. This allows for easy integration of components into the circuit.

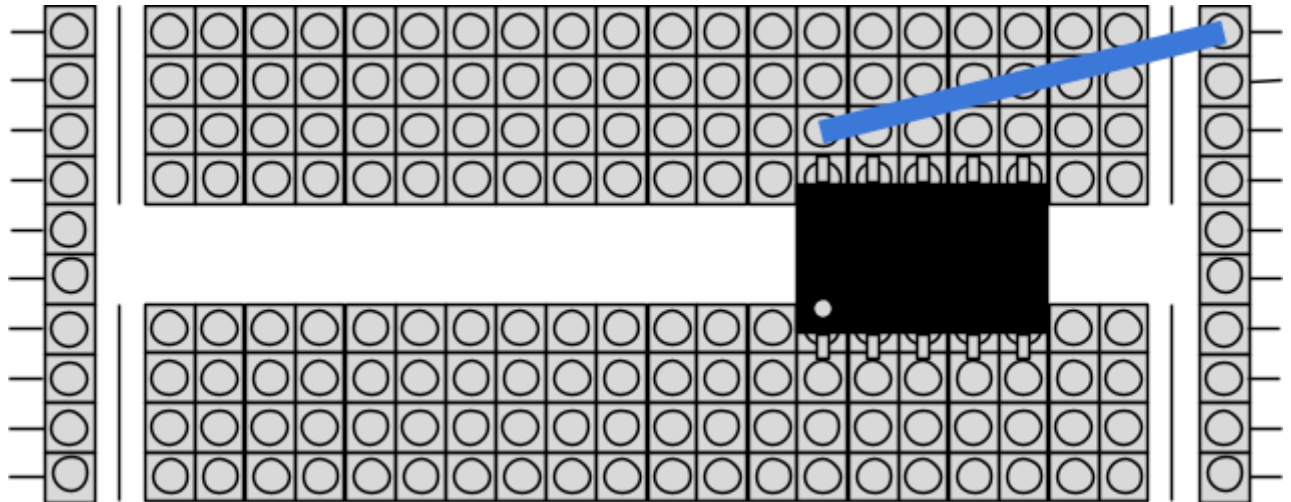


Figure 3.13: Protoboard schematic.

3.2.5. Test points

All user boards have test points which are located on the top of the board in the form of a male connector pointing upwards. These test points are linked to the relays directly to make it easier to check. Each relay has a pair of pins (see Figure 3.14). These are the features for the 10 components and protoboard boards:

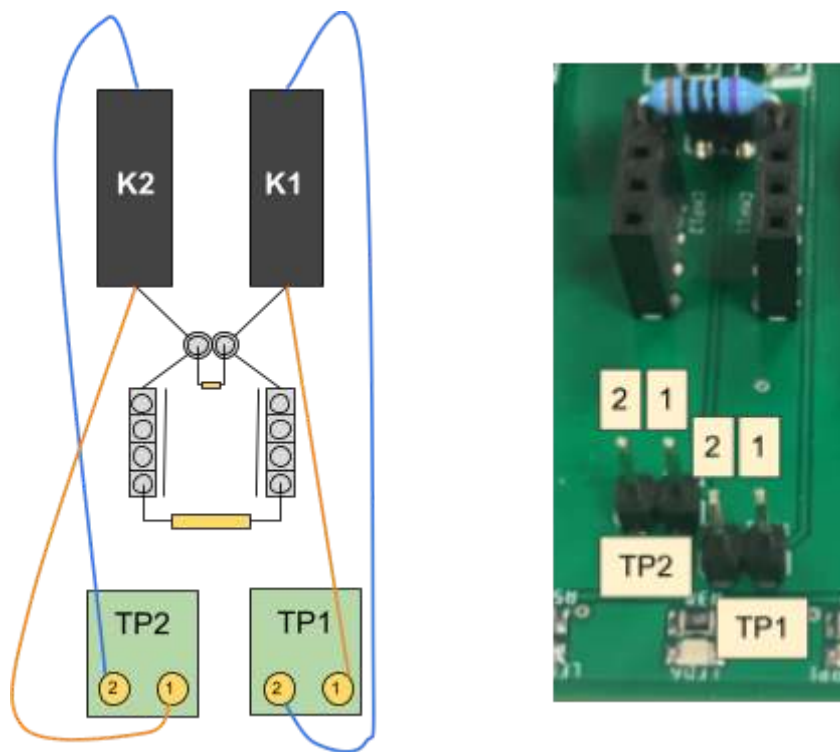


Figure 3.14: Test points from the "10 components" board.

Testing the relays:

Relay under test	Multimeter probes	Multimeter mode	When idle	When testing a circuit that uses that component
Right relay (K1)	TP1-1 with TP1-2	Continuity	No sound / no continuity	Short beep when the LED of the relay turns on
Left relay (K2)	TP2-1 with TP2-2	Continuity	No sound / no continuity	Short beep when the LED of the relay turns on

Table 3.3: Using Testing Points to diagnose relays

Measuring the components:

Component under test	Multimeter probes	Multimeter mode	When idle
Resistor	TP1-1 with TP2-1	Ohmmeter	Value of the resistor

Table 3.4: Using Testing Points to measure components

Additionally, for advanced tests, the TP1-2 and TP2-2 are connected to the nodes of the matrix, so it becomes possible to use the multimeter between those two points in certain circuits.

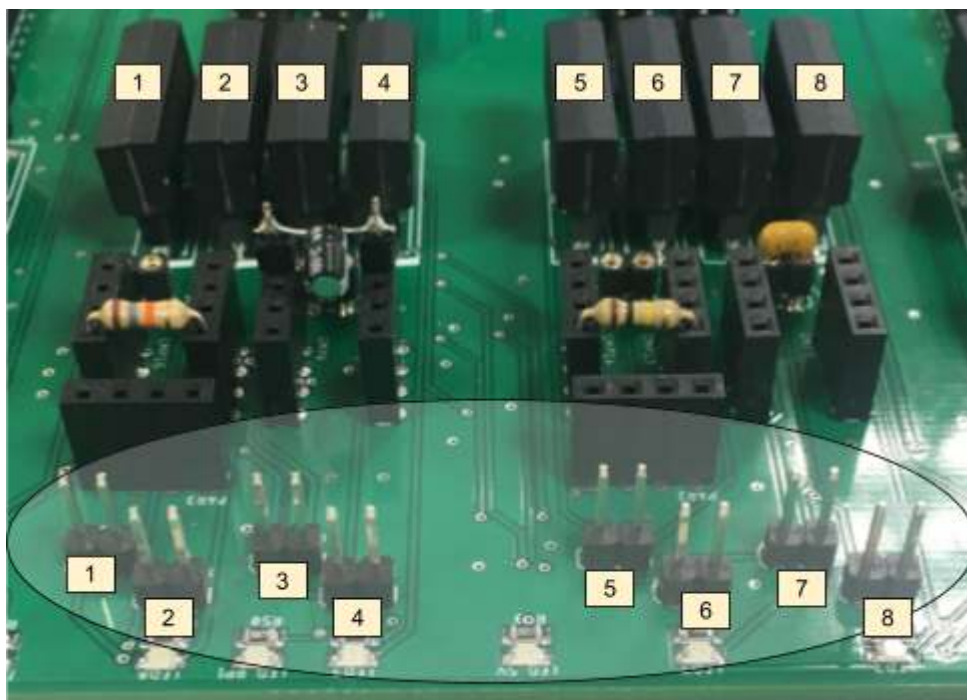


Figure 3.15: Test points from the “5 components with discharge network” board.

3.3. System boards

3.3.1. Introduction

System boards are diverse, each serving a unique purpose. They can be classified into four types: Oscilloscope and PSU, DMM, Shortcuts, and Motherboard.

The Oscilloscope and PSU, along with the DMM, primarily perform measurements and facilitate connections between electronic instruments and circuits. On the other hand, the Shortcuts and Motherboard types mainly focus on interconnection and communication between various points and boards.

Unlike the other boards mentioned earlier, system boards are not user-configurable. These boards are fixed and have a predetermined setup designed to execute tasks that do not pertain to the selection of components for the Hive node.

3.3.2. Oscilloscope and PSU board

The Oscilloscope and PSU Board serves as a nexus, connecting the oscilloscope, function generator, and power supply to the matrix. It operates through a network of relays that can open and close circuits, ensuring the appropriate connection point is linked to the desired channels.

Specifically, it can connect a chosen point to one of the two channels on either the oscilloscope or the function generator. It can also link to the programmable power supplies, providing +5V and -5V outputs, as well as the non-programmable power supplies, which deliver +15V and -15V outputs.



Figure 3.16: Oscilloscope and PSU board

3.3.3. DMM board

The DMM board is equipped to carry out the common measurements typical of a multimeter. Its components include a voltmeter, capable of measuring both AC and DC currents; an ammeter, designed for DC currents (AC currents will be supported in 2023 with a different board); an ohmmeter for measuring electrical resistance; and a capacitance meter for assessing the capacitance in a circuit.



Figure 3.17: DMM board.

3.3.4. Shortcuts boards

The Shortcuts Board serves as a comprehensive relay network that connects all points together. Although there are three types of Shortcuts Boards, they are visually identical, distinguished only by the identifier located at the top right of each board.

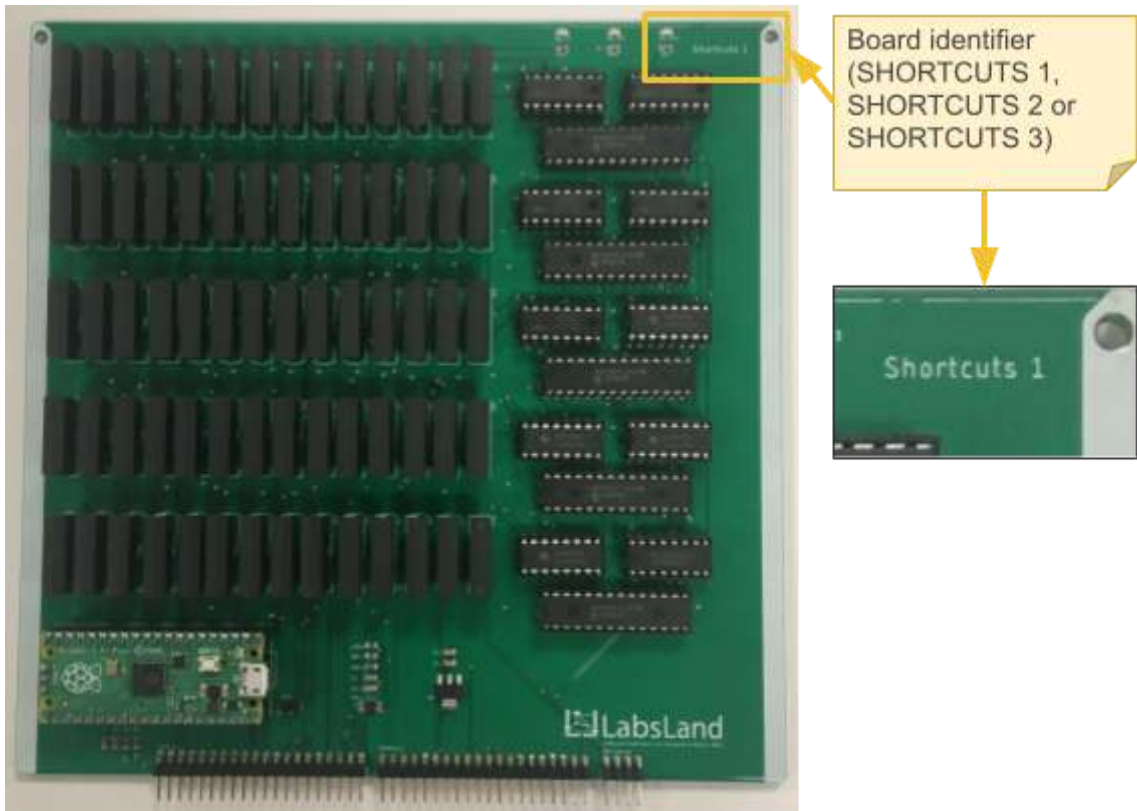


Figure 3.18: Shortcuts 1 board.

3.3.5. Motherboard

Serving as the core component, the Motherboard connects all the other boards together. It is the largest board in the system, with two of them needed in conjunction to support all the boards in the matrix that constitutes the Hive node. Beyond facilitating interconnections, the Motherboard also provides power to the rest of the boards. Moreover, the electronic instruments are directly connected to it, enabling the other boards to use them effectively.



Figure 3.19: Motherboard.

3.4. How to manipulate the boards

All boards, with the sole exception of the Motherboard, are designed for easy removal from the Hive node. The user-friendly design facilitates straightforward plugging and unplugging of any board. If you need to remove a board, please follow these steps:

1. Preferably, turn off the equipment first. Although it is possible to unplug and plug in boards with the equipment powered on, we recommend turning it off to avoid potential issues.
2. Lift the front cover.
3. Gently pull out the desired board.

When you're ready to reinstall the board, follow these steps:

1. Slide the board back into the same slot from which it was removed.
2. Close the front cover.
3. Power on the Hive node.

To confirm that the board has been properly connected, check the status LEDs. All three should be lit and steady, with no blinking.

Below is a series of photos demonstrating these steps, performed without powering off the Hive node:

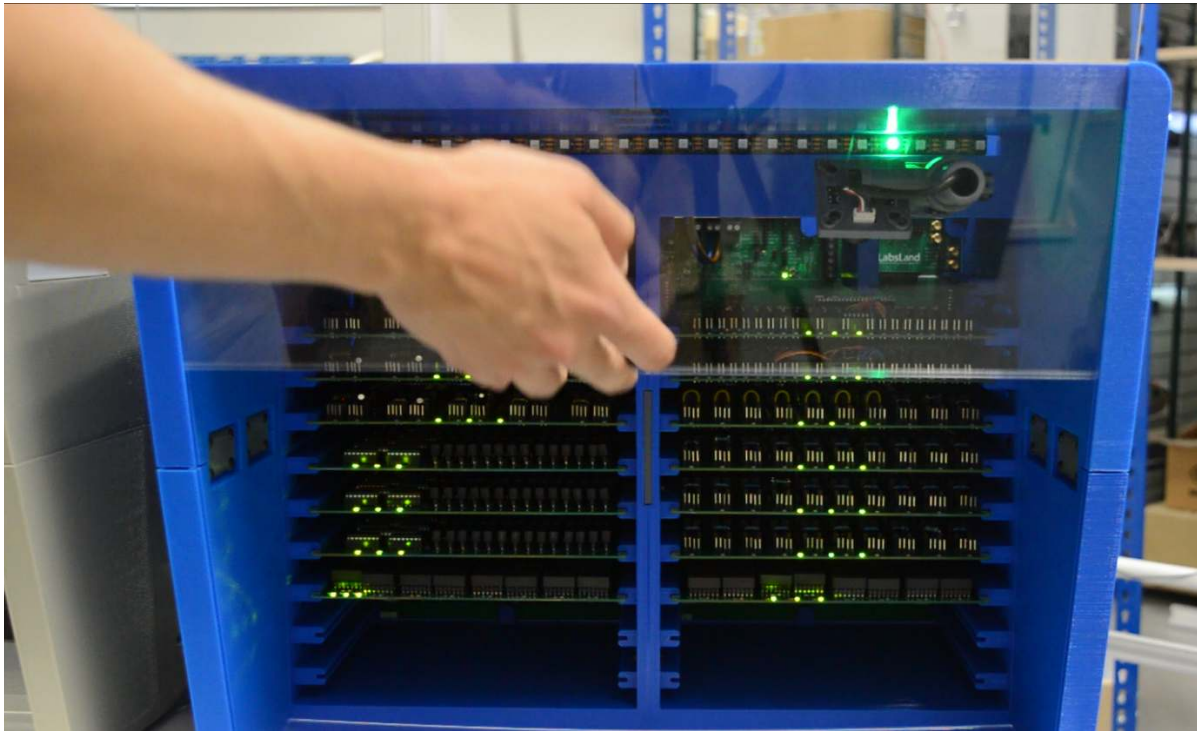


Figure 3.20: Lift the front cover.

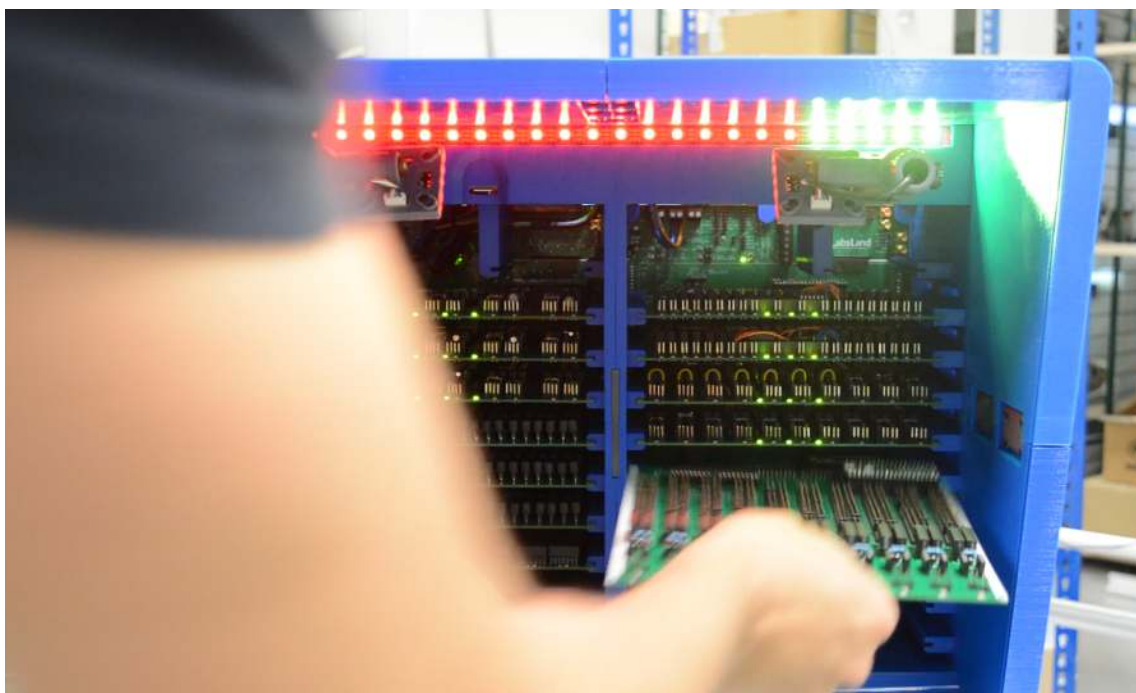


Figure 3.21: Pulling out the desired board.

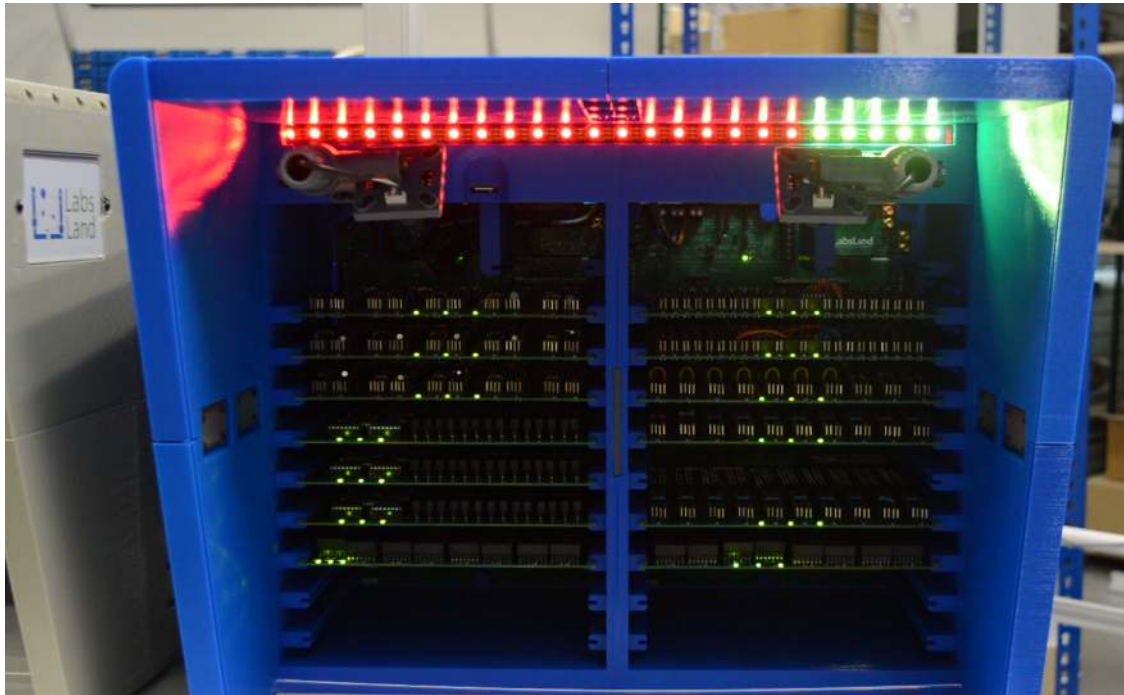


Figure 3.22: The Hive node without 1 board. In this instance, the fifth board from the right has been taken out. Consequently, five LEDs on the right side light up in yellow, while the remaining LEDs display a red color.

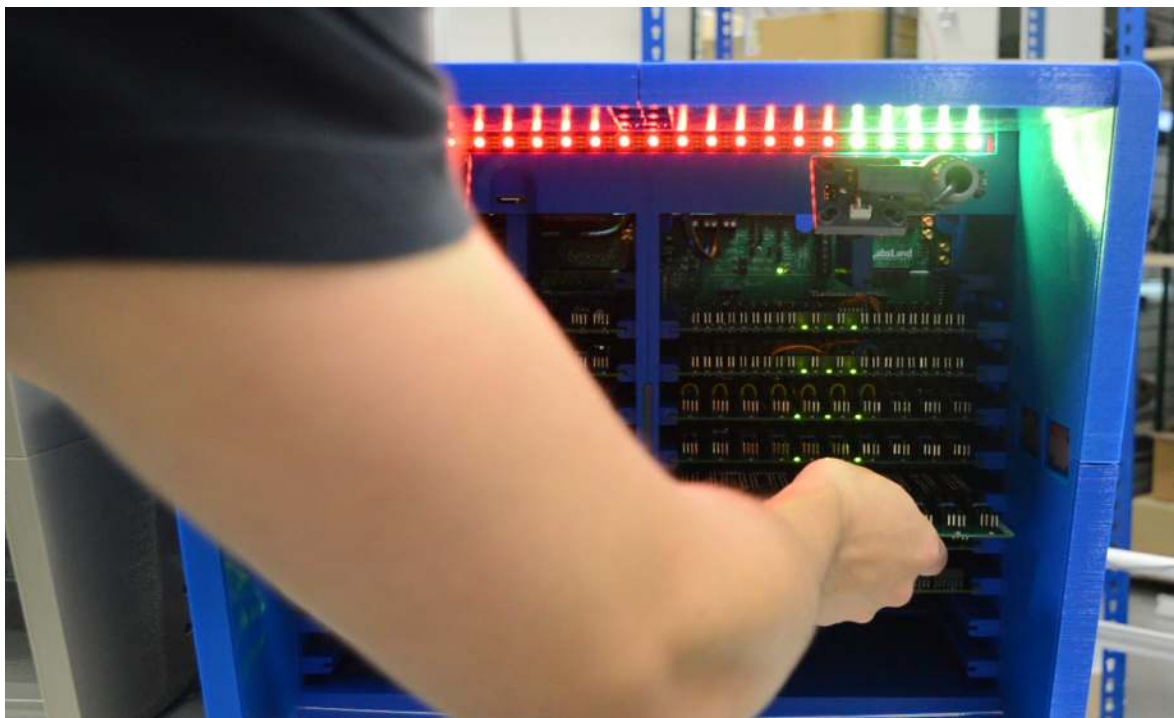


Figure 3.23: Pushing the board into the same slot from which it was removed.

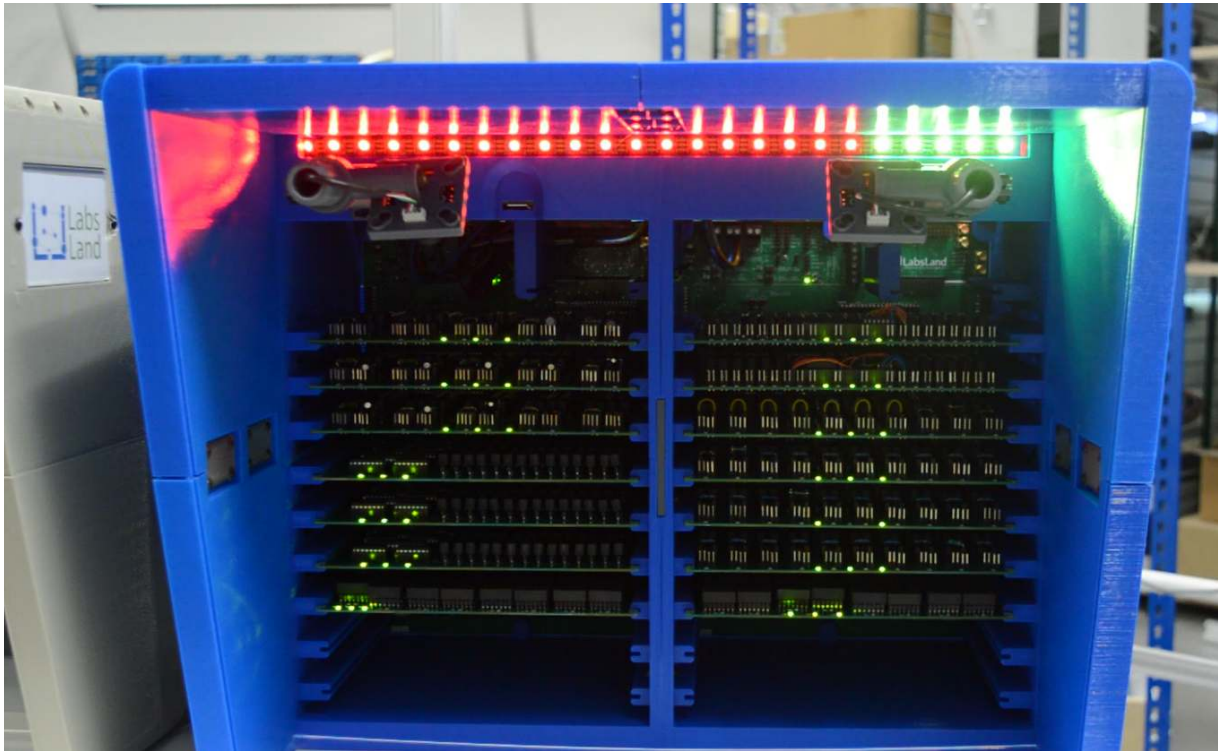


Figure 3.24: The Hive node takes a few seconds to verify the board has been correctly inserted.



Figure 3.25: The board has been correctly inserted.



Figure 3.26: Close the front cover.

Full video in the next link: <https://www.youtube.com/watch?v=33T5k5JKM4s&t=4s>

WARNING: It is important to ensure that the jumper next to each Raspberry Pi Pico on the boards is in the 'on' position. Without this, the board will not function correctly.

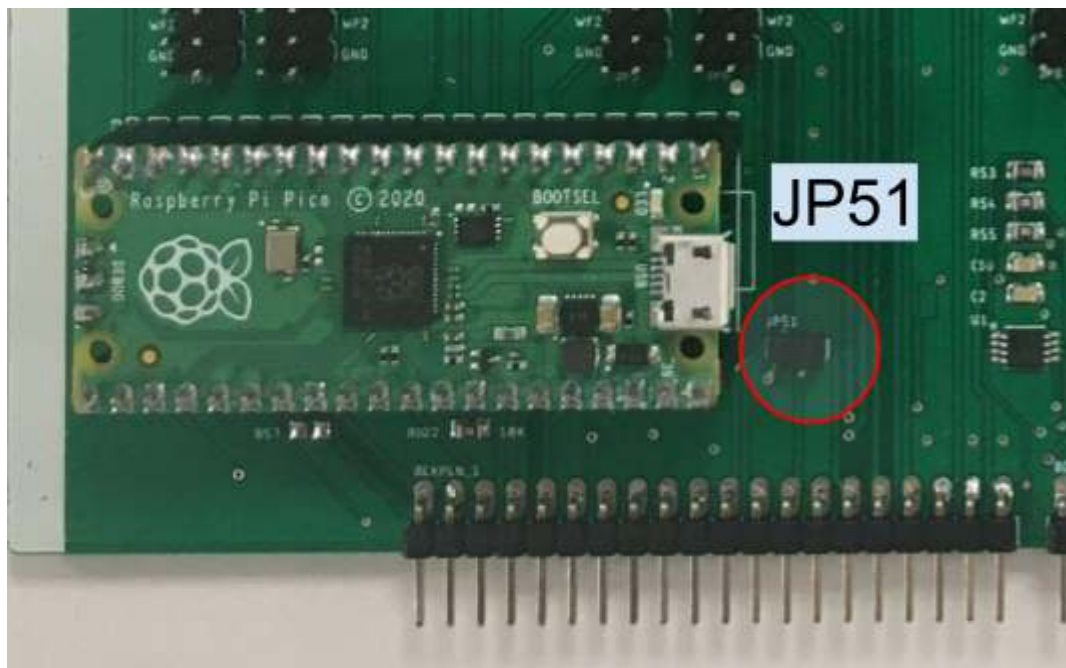


Figure 3.27: Raspberry Pi Pico 3.3 voltage supply.

4. Technical specifications

4.1. Equipment specifications

4.1.1. General

- When switching off the device make sure you follow the instructions at [2.7. Turning OFF the Hive node](#).

4.1.2. Designing your own circuits

The LabsLand Hive node offers the capability for you to design and add your own circuits to the boards. However, undertaking such modifications comes with certain responsibilities:

Please note, **if you decide to design your own circuits, you do so at your own risk**. Any damage to the equipment resulting from your modifications **voids the LabsLand liability and warranty**. Ensure that you have a complete understanding of what you are doing.

Follow these guidelines to minimize the risk of potential damage:

- Make sure that the potential circuits can never draw more than 200 mA.
- Avoid designing circuits that involve a direct short to ground or a very low resistance path (< 50 Ohms).
- Do not create circuits that could cause a short circuit between one power supply and another, or between the two channels of the function generator.
- The equipment includes 200mA resettable polyfuses on each rail of each power supply. If a short-circuit situation occurs, the performance of the affected power supplies may be temporarily impaired. Should this situation persist and remain uncorrected, please contact us at hive@labsland.com.
- Before integrating your hardware changes into the Hive node, ensure they do not create any of the dangerous situations outlined above. Test and measure the current outside the Hive node prior to integration.
- Please let the Hive node maintenance team know about these changes by contacting them at: hive@labsland.com.

4.1.3. Relay management

- It is necessary to take into account that the commutation matrix of the equipment is based on relays that may add extra resistance to the circuit, which may, in some cases, lead to small discrepancies between the expected theoretical values and the measured values.
- <https://www.digikey.es/es/products/detail/littelfuse-inc/HE3621A0500/133255>
- https://www.littelfuse.com/~media/electronics/datasheets/reed_relays/littelfuse_reed_relay_s_he3600_datasheet.pdf.pdf

4.1.4. Ammeter

- Precision: of 7.5 μ A.
- It introduces a 1.5 Ohm series resistor to the measured circuit.
- AC ammeter functionality is not supported currently, but anticipated in 2023 with a new board.
- DC ammeter measures only positive power supplies, not to be used with -15V or -5V. Maximum range: 50mA.

4.1.5. Capacimeter

- Capacitance measurement range: it can't measure below 0.001 μ F (1nF) or above 2.2 μ F. Currently, it only supports one capacitor at a time.
- Given its dependency on the measurement of a resonant circuit and usage of an internal precision power supply, it can't be used concurrently with power supplies or function generators in the circuit.

4.1.6. Ohmmeter

- Because the ohmmeter is based on Ohm's law and uses an internal precision power supply, it cannot be used while power supplies or function generators are present in the circuit.

4.1.7. Oscilloscope

The oscilloscope operates through an internal Analog Discovery 2 device by Digilent, and its capabilities align closely with this device's specifications.

- Channels: 2.
- Internal accuracy (scale \leq 0.5V/div, $V_{inCM} = 0V$): ± 10 mV \pm 0.5%.
- Internal accuracy (scale \geq 1V/div, $V_{inCM} = 0V$): ± 100 mV \pm 0.5%.
- CMMR (typical): $\pm 0.5\%$.
- Max sample rate in user interface: 2 MS/s.
- Input impedance: 1M Ω | 24pF.
- Scope scales in user interface: 1mV to 5V/div.
- Input range: $\pm 5V$ ($\pm 10V$ diff).
- Input protected to: $\pm 50V$.
- Triggering in user interface: edge
- Multiple math channels with complex functions.
- Captured data files can be exported in CSV.

4.1.8. Function generator

- Channels: 2.
- Channel type: single ended.

- Internal absolute Resolution (amplitude $\leq 1V$): $166\mu V$.
- Internal absolute Resolution (amplitude $> 1V$): $665\mu V$.
- Internal accuracy - typical ($|V_{out}| \leq 1V$): $\pm 10mV \pm 0.5\%$.
- Internal accuracy - typical ($|V_{out}| > 1V$): $\pm 25mV \pm 0.5\%$.
- AC amplitude (max): $\pm 5 V$.
- DC Offset (max): $\pm 5 V$.
- Standard waveforms: sine, square, triangle.
- The sum between the offset and the signal must always be 5 or less than 5, otherwise the circuit will not be possible.

4.1.9. +5V/-5V Programmable Power Supply

- Voltage range: $0.5V \dots 5V$ and $-0.5V \dots -5V$.
- 200mA for each supply.
- Accuracy (no load): $\pm 10mV$.
- Both can be used at the same time.

4.1.10. +15V/-15V Fixed Power Supply

- Fixed power supplies of +15V and -15V
- Do not use it with coils.

4.2. Response times

So as to measure how long it takes to take a measurement in the Hive node, it is important to specify two concepts, as depicted in Figure 4.1:

- **User perspective request time (UPRT):** How long it takes for a user to obtain one result. This typically does not include disconnecting everything properly (e.g., when using capacitors activating the discharge network, waiting for the capacitor to be discharged, etc.).
- **Hive perspective request time (HPRT):** How long it takes for a hive node to process one user request. This does include all the cleanup process.

The UPRT depends on the user network, the network of the institution hosting the Hive node, and the availability of Hives nodes. If there are more users concurrently requesting measurements than Hive nodes in the LabsLand network, the user will have to wait an additional queuing time.

The HPRT depends on the performance of the Hive and the complexity of the circuits built (the more relays involved, and discharging elements like coils or capacitors, the longer it will take).

When there is a single user performing requests (technically, when there are less concurrent users than hive nodes performing measurement requests), UPRT is independent of the HPRT and might be faster or slower of the HPRT depending on the particular network.

However, if there are more concurrent users than hive nodes, then some students will have to wait in a queue for the Hive nodes to process their request. In that case, the UPRT highly depends on the queuing time, which depends on the HPRT.

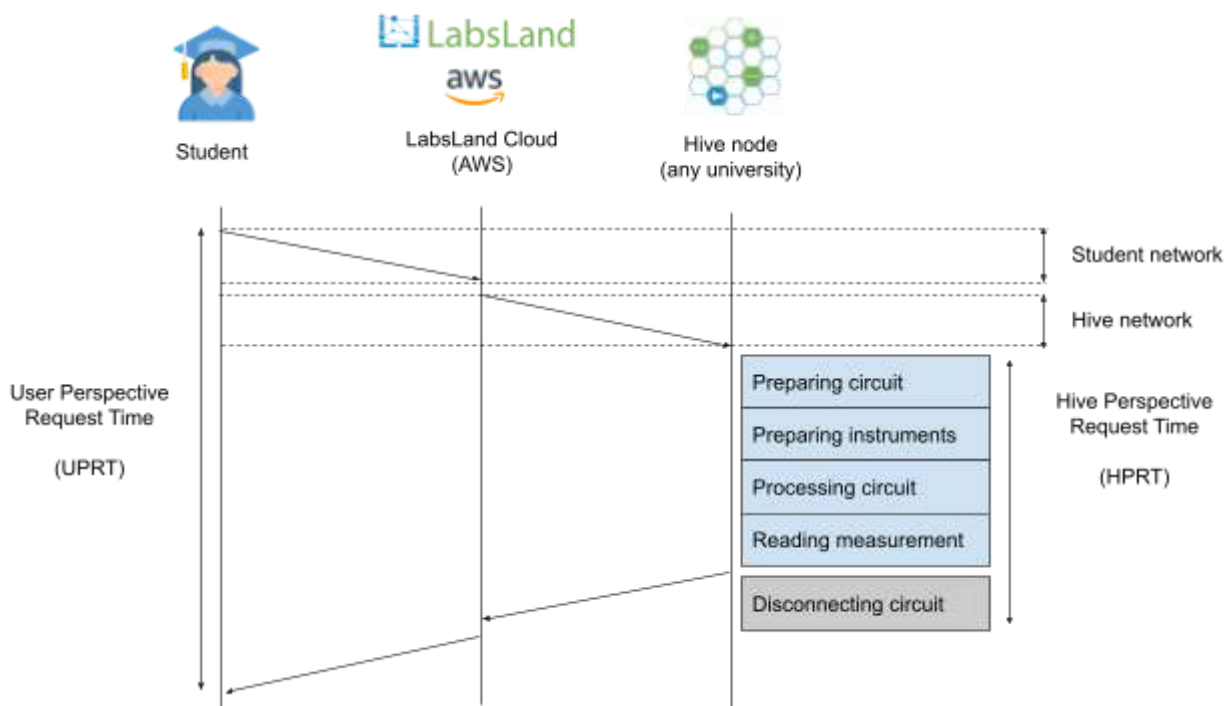


Figure 4.1: User Perspective Request Time and Hive Perspective Request Time

In Table 4.1, the UPRT is measured by performing 100 measurements sequentially of each type of circuit. The tests were made in the LabsLand Cloud, therefore virtually eliminating the Student network variable to pursue more reliable results.

	UPRT in milliseconds						
	min	max	mean	std	median	p90	p99
Resistors	319	829	401	55	424	440	538
Ohm's law	220	557	358	517	330	433	496
Diodes	225	549	374	54	341	437	477
RC	321	538	392	55	424	442	527
RL	321	632	379	57	347	439	480
RLC	321	449	366	47	339	432	443
OpAmp	225	549	374	54	341	437	477

Table 4.1: Measurements per circuit type with a single user performing the measurement (UPRT)

In Table 4.2, the HPRT is measured by using 2 nodes and simulating 5 concurrent students sending continuously circuits of each type to the system, balancing the load between both hive nodes. This way, there was always a queue of measurements and it allows us to analyze the HPRT.

	Circuit per user	Users	Hive nodes	Total time (seconds)	Time per request (ms)	Time per request per hive node - HPRT (ms)	Request per second - 1 hive node	Request per second - 3 hive nodes (calculated)
Resistors	1,000	5	2	1,227.35	245	491	2.04	6.11
Ohm's law	200	5	2	237.99	238	476	2.10	6.30
Diodes	800	5	2	965.04	241	483	2.07	6.22
RC	300	5	2	385.43	257	514	1.95	5.84
RL	100	5	2	127.12	254	508	1.97	5.90
RLC	100	5	2	130.97	262	524	1.91	5.73
OpAmp	500	5	2	656.11	262	525	1.91	5.72

Table 4.2: Time per request and hive node throughput with two hive nodes depending on the circuit type

Times displayed in Table 4.1 and Table 4.2 were measured in May 2023 and are expected to be improved over time.

The reason why times are so important is because it allows us to calculate how many requests per second each Hive node can process and more importantly, how many requests per second the whole network can therefore support. In a single-node mode (e.g., if there was a single node, or in the VISIR system where each university had a single system and was not able to automatically send students to other systems when the queue was long), HPRT is that key number.

For example, if a system can process 2 requests per second and 50 students click on the “perform measurement” button at the same time, the first student will take UPRT time to get a result, but the second will depend on HPRT + UPRT, the third one 2xHPRT+UPRT, and the last one 49xHPRT+UPRT, and if, for the sake of simplicity, both UPRT=HPRT = 0.5 seconds, the last student will take 25 seconds to obtain a result.

However, the architecture of the LabsLand Electronics Laboratory is distributed, as explained in the article “LabsLand Electronics Laboratory: Distributed, Scalable and Reliable Remote Laboratory for Teaching Electronics”¹ and displayed in Figure 4.2. This means that every single measurement will go to the LabsLand Cloud and will be processed by any of the Hive nodes that can process that request, anywhere in the world.

¹ “LabsLand Electronics Laboratory: Distributed, Scalable and Reliable Remote Laboratory for Teaching Electronics”, Aitor Villar-Martinez et al. REV2023 Conference, March 2023. <https://labsland.com/pub/hidden/papers/rev2023-electronics.pdf>

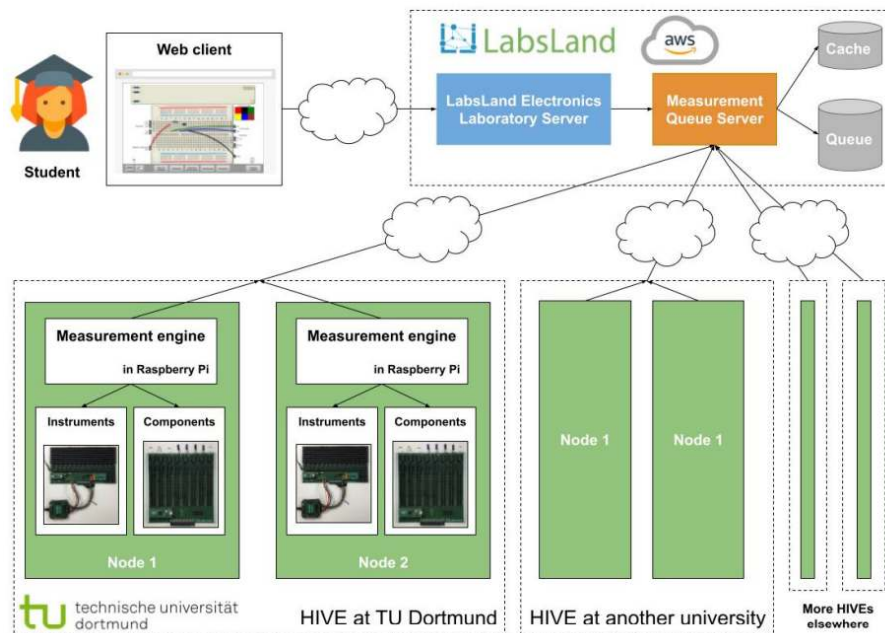


Figure 4.2: LabsLand Electronics Hive Architecture

This way, if there are 10 Hive nodes, the first 10 students will take UPRT time, the next 10 students HPRT+UPRT, the next 10 students 2xHPRT+UPRT and the last student will take 4xHPRT+UPRT, which in the same conditions as before (UPRT=HPRT = 0.5 seconds) will result in 2.5 seconds.

If 10 Hive nodes are distributed in 5 universities, it might happen that all of them have users using them at the same time. However, with our experience in LabsLand, we know that this does not happen so often. Even in a regular class, students will not click on the “perform measurement” that often, so classes of 200 students can easily be managed with 2 hive nodes.

In VISIR, there are reports in the literature measuring that the time to process a student is 10-100ms, but the time measured usually only measures the Equipment Server (and in VISIR, the equipment server does not disconnect the circuits, creating situations where the equipment can be damaged if a circuit was improperly managed), without counting network issues between the Measurement Server and the Equipment Server or the Measurement Server processing time itself. In our experience measuring the VISIR systems in the LabsLand network, the equivalent to UPRT was at minimum 300ms, making the system considerably slower than the Hive node in a class environment.

As the LabsLand network grows, the number of concurrent students with fast responses will keep increasing.

5. Troubleshooting

To identify Hive node’s status more easily, it has a strip of LEDs. These LEDs change the color pattern depending on the state it is in. In the following sections there is a set of tables showing all the possible states of the Hive node. There are some errors that are not easy to solve, therefore, as indicated in the table, you should contact our team to get Hive node up and running again.

5.1 Basic LED states

The basic LED states are described in Table 5.1, and previously detailed with photos in [2.8. LEDs](#).



Figure 5.1: The Hive node performing user measurement: all the LEDs are white to optimize for the cameras.
See video at: <https://www.youtube.com/watch?v=nGz2nR6Yy88>

Pattern	Description
All LEDs off but 2 separate green LEDs that are moving	Idle: everything is ready. Waiting for measurements.
White	Processing a user measurement
Yellow	Turning off the Raspberry Pi
All off after yellow	You can turn off the equipment
All green	Starting the Hive initialization

Table 5.1: Hive basic LED patterns.

5.2 Running automated tests (orange LEDs)

Periodically, LabsLand performs automated tests to confirm that all the equipment is working as expected. For example, for each shortcut it will check if it actually works as expected or not, and for each resistor if the value is correct, etc.

When doing so, the LEDs take a different pattern, indicating what board is being tested. While the test is ongoing, it will also be possible to hear the relays clicking very fast.



Figure 5.2: The Hive node performing automated tests. It has a yellow/orange color most of the LEDs except for 4 in this case that indicate that the board under test is the number 4.

Pattern	Description
Orange with 1 white LED (first from the left)	Performing a test in board 1
Orange with 2 white LED (2 from the left)	Performing a test in board 2
Orange with 3 white LED (3 from the left)	Performing a test in board 3
Orange with 4 white LED (4 from the left)	Performing a test in board 4
Orange with 5 white LED (5 from the left)	Performing a test in board 5
Orange with 6 white LED (6 from the left)	Performing a test in board 6
Orange with 7 white LED (7 from the left)	Performing a test in board 7

Orange with 8 white LED (8 from the left)	Performing a test in board 8
Orange with 9 white LED (9 from the left)	Performing a test in board 9
Orange with 1 white LED (1 from the right)	Performing a test in board 10
Orange with 2 white LED (2 from the right)	Performing a test in board 11
Orange with 3 white LED (3 from the right)	Performing a test in board 12
Orange with 4 white LED (4 from the right)	Performing a test in board 13
Orange with 5 white LED (5 from the right)	Performing a test in board 14
Orange with 6 white LED (6 from the right)	Performing a test in board 15
Orange with 7 white LED (7 from the right)	Performing a test in board 16
Orange with 8 white LED (8 from the right)	Performing a test in board 17
Orange with 9 white LED (9 from the right)	Performing a test in board 18

Table 5.2: LED patterns indicating automated tests.

5.3 Error with board connection (red LEDs with right or left LEDs of other color)

If one of the boards is incorrectly connected, then it will indicate it with red LEDs and a number of yellow LEDs on one side or the other indicating what board is failing. The most common reason is that the PCB board is not properly connected so try to reconnect it and make sure that the pins are properly aligned when connecting it. However, if the problem persists, this could also indicate that the board or the controller is damaged (in which case, contact LabsLand to do further tests).

Note: if multiple boards are failing, it will only show the error in one of the boards at a time.

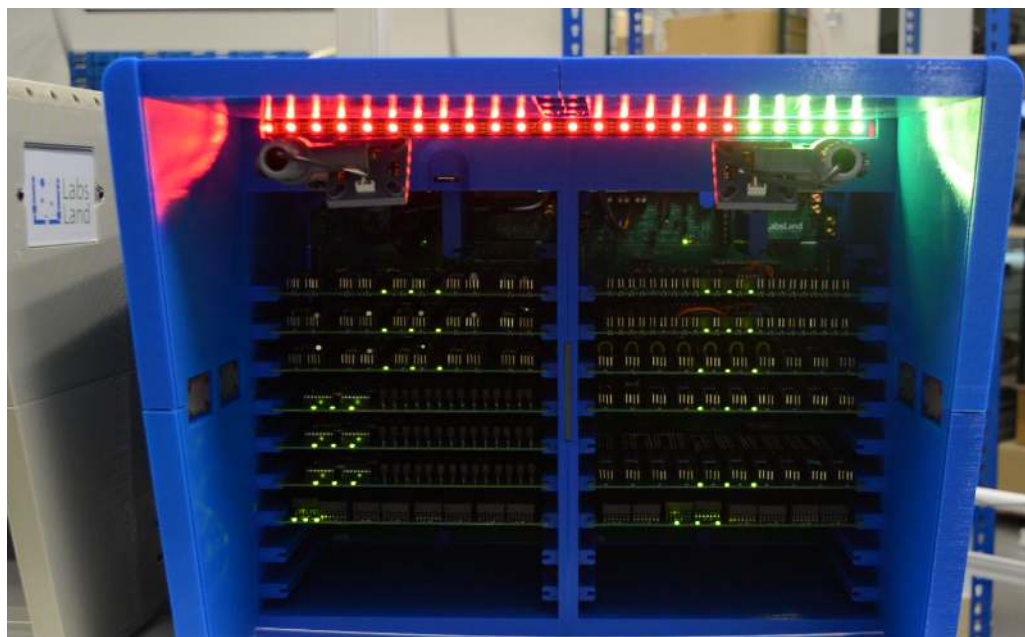


Figure 5.3: The Hive node without 1 board. As the board that has been removed is the fifth from the right, 5 LEDs light up yellow on the right side and the rest are red.

Pattern	Description
Red with 1 yellow LED (1 from the left)	Error: I2C issue on board 1
Red with 2 yellow LED (2 from the left)	Error: I2C issue on board 2
Red with 3 yellow LED (3 from the left)	Error: I2C issue on board 3
Red with 4 yellow LED (4 from the left)	Error: I2C issue on board 4
Red with 5 yellow LED (5 from the left)	Error: I2C issue on board 5
Red with 6 yellow LED (6 from the left)	Error: I2C issue on board 6
Red with 7 yellow LED (7 from the left)	Error: I2C issue on board 7
Red with 8 yellow LED (8 from the left)	Error: I2C issue on board 8
Red with 9 yellow LED (9 from the left)	Error: I2C issue on board 9
Red with 1 yellow LED (1 from the right)	Error: I2C issue on board 10
Red with 2 yellow LED (2 from the right)	Error: I2C issue on board 11
Red with 3 yellow LED (3 from the right)	Error: I2C issue on board 12
Red with 4 yellow LED (4 from the right)	Error: I2C issue on board 13
Red with 5 yellow LED (5 from the right)	Error: I2C issue on board 14
Red with 6 yellow LED (6 from the right)	Error: I2C issue on board 15

Red with 7 yellow LED (7 from the right)	Error: I2C issue on board 16
Red with 8 yellow LED (8 from the right)	Error: I2C issue on board 17
Red with 9 yellow LED (9 from the right)	Error: I2C issue on board 18

Table 5.3: Hive node status for board errors.

5.4 Other error states (red LEDs with white LEDs in the middle)

If there is another type of error, the Hive node will try to indicate what kind of problem there is by showing LEDs in the middle.



Figure 5.4: Hive node displaying a connection error to the server (4 white LEDs in the middle, all the rest are red).

Pattern	Description
Red with 1 white LED (1 in the middle)	Error: unexpected error in general: contact hive@labsland.com
Red with 2 white LED (2 in the middle)	Error: no internet (DHCP failed)
Red with 3 white LED (3 in the middle)	Error: no VPN (is port UDP 51820 up?)
Red with 4 white LED (4 in the middle)	Error: cannot reach LabsLand server (e.g., DNS is failing, no proper access to Internet, or server down)
Red with 5 white LED	Error: authentication error with LabsLand

(5 in the middle)	server (contact hive@labsland.com)
Red with 6 white LED (6 in the middle)	Error: Analog Discovery 2 failed (contact hive@labsland.com)
Red with 7 white LED (7 in the middle)	Error: unexpected error performing test failed (e.g., a resistor does not have the value is expected). Contact hive@labsland.com
Red with 8 white LED (8 in the middle)	Error: unexpected error performing measurement: contact hive@labsland.com

Table 5.5: Hive node status for other errors.