LAN Industrial HAT

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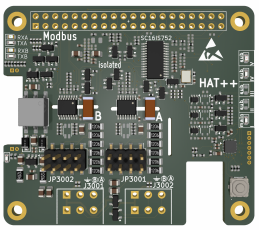

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Modbus over RS-485 enables robust long-distance multi-drop communication and is a well-established, future-proof industrial communication standard.

This HAT provides two fully independent RS-485 interfaces with galvanic isolation and automatic direction detection.

Key Features

- Dual Modbus (RS-485) HAT
- SC16IS752 dual I2C to UART controller
- Isolated RS-485 transceiver
- up to 1.15MBit/s
- Galvanically isolated Interfaces
- Configurable 120 Ω bus termination
- RSP HAT+ compliant (2024)
- Stackable HAT (BE-IIS-HAT++)
- Configurable addressing and IRQ routing
- RoHS compliant
- Quality component suppliers

Product Description

The MODBUS Industrial HAT is a Raspberry Pi HAT+ compliant interface board supporting Modbus RTU/ASCII over RS-485 in accordance with TIA/EIA-485-A.
It integrates an SC16IS752 dual UART controller and an isolated ISO1500 RS-485 transceiver, providing galvanic isolation between the logic domain and the field bus interface.

Applications

- MODBUS network evaluation
- Embedded system prototyping
- Education and training
- Gateway and protocol converter development
- Industrial communication testing

Contents

1 Introduction

The BE-IIS HAT++ Modbus Industrial HAT is a Raspberry Pi HAT+ compliant interface board providing Modbus RTU communication over RS-485 for industrial and laboratory environments.

The board integrates two fully independent RS-485 interfaces with galvanic isolation, ensuring electrical separation from the host system and between the channels. Each interface features automatic direction detection, eliminating the need for manual DE/RE control via software.

Modbus over RS-485 enables robust long-distance multi-drop communication and represents a mature and future-proof industrial standard.

The HAT can be used for evaluation, prototyping, industrial network integration, and educational purposes.

Optionally, the HAT can be combined with other BE-IIS HAT++ boards to extend functionality, such as additional communication interfaces or power supply modules.

The HAT is fully compatible with the Raspberry Pi Foundation HAT+ specification as well as the BE-IIS HAT++ system for advanced functionality such as stacking.

2 Hardware Configuration

2.1 Main Features

The BE-IIS-HAT++MODBUS-I2C enables Modbus RTU communication over RS-485 on Raspberry Pi platforms. It allows a standard Raspberry Pi platform (e.g. Raspberry Pi Zero or Raspberry Pi 3/4/5, excluding Compute Module variants) to operate as a Modbus node.

Communication between the Raspberry Pi and the onboard RS-485 interfaces is implemented via an I²C-connected UART bridge, providing two independent serial channels. The RS-485 transceivers feature automatic direction detection, eliminating the need for manual DE/RE control.

2.2 Main Features

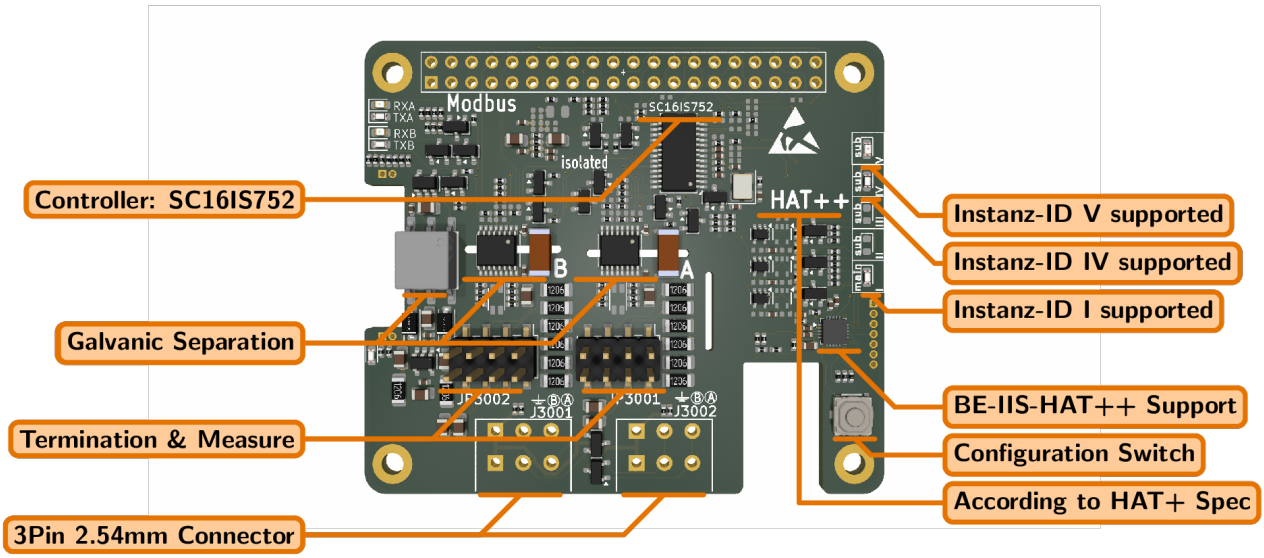


Figure 1: BE-IIS-MODBUS-I2C top view with annotations

Device

- Supplier: NXP
- SC16IS752I dual UART controller
- Supplier: Texas Instruments
- ISO1500 isolated RS-485 transceiver

I2C Interface

- 0x9A, 0x98, and 0x92 Device Address supported
- Persistent selection via push button

Isolation

- Galvanically seperated Interface
- Isolator rated up to 3KV

Protocol Support

- Supports Modbus RTU and ASCII protocols
- Half-duplex RS-485 interface
- Compliant with TIA/EIA-485-A standard

Direction Control (DIR)

- Automatic RS-485 direction control (DE/RE)
- Modbus RTU: configurable 15 ms turnaround timeout

subsectionBlock Diagram

The block diagram shown in Figure 2 is simplified. It illustrates the power domains, isolation barriers, main functional blocks, and principal signal paths.

The interrupt signal routing is not shown.

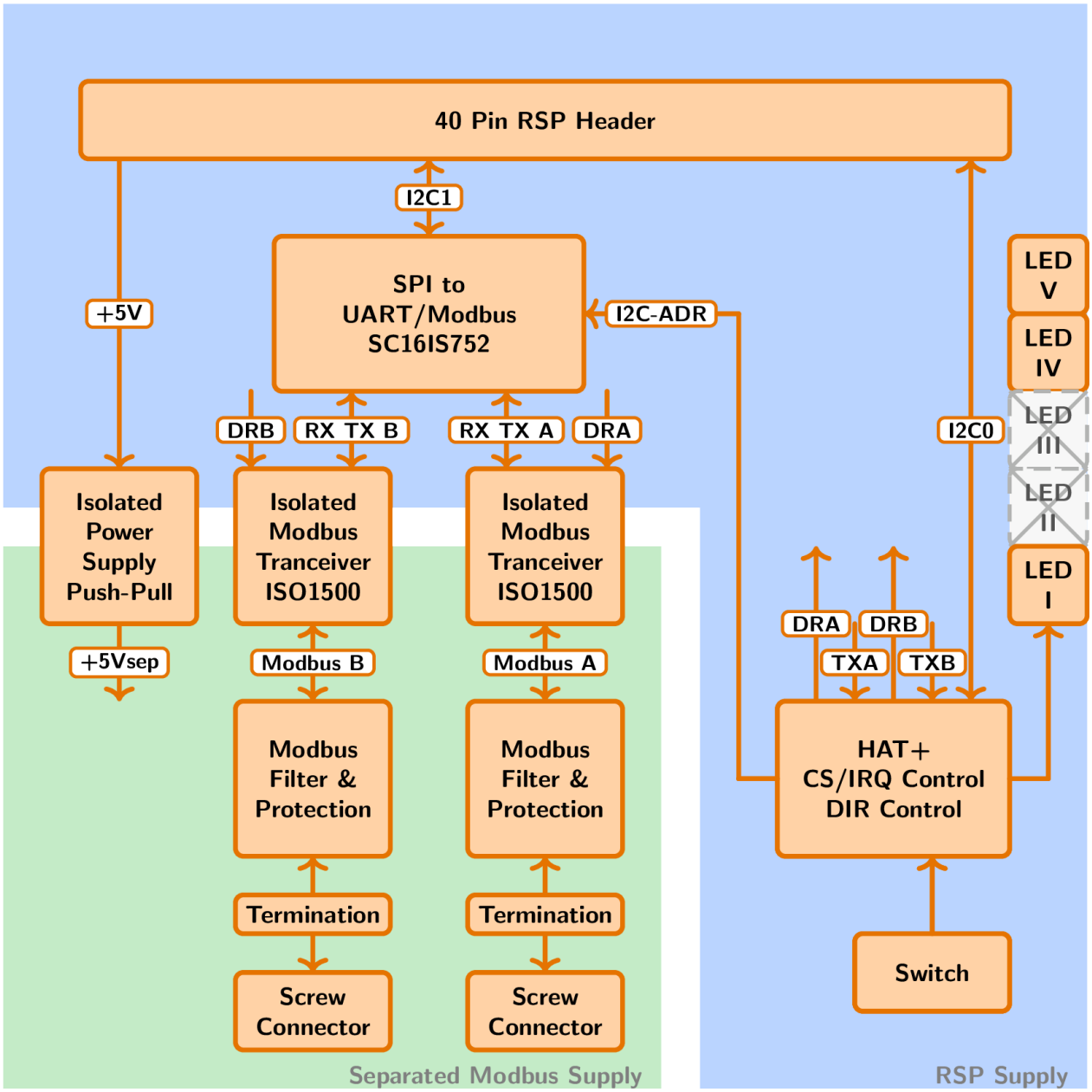


Figure 2: Simplified block diagram

2.3 HAT Configuration

The BE-IIS-HAT++ system is fully compliant with the Raspberry Pi HAT+ specification.

The HAT automatically provides its device tree overlay via the onboard EEPROM. As a result, no manual configuration through the bootloader or user-space tools is required. The device tree overlay defines the software configuration of the HAT hardware.

In addition, the BE-IIS-HAT++ system extends the standard HAT+ functionality by supporting multiple hardware configurations on a single HAT.

Up to three predefined configurations can be stored and selected. Each configuration is referred to as an **instance mode**. An instance mode defines the assignment and usage of interfaces such as SPI, I^{2}C, GPIO, and interrupt lines.

This enables:

- Operation of multiple identical HATs within one system
- Combination of several BE-IIS-HAT++ modules
- Flexible interface mapping without manual reconfiguration

2.4 Instance Modes and System Constraints

Instance Mode I corresponds to the primary Raspberry Pi HAT+ configuration. A HAT operating in this mode enables the I^{2}C pull-ups and participates in the HAT+ EEPROM detection mechanism.

For proper system operation, exactly one HAT must be configured in Instance Mode I.

In stacked configurations:

- One HAT must operate in Instance Mode I
- Additional HATs must use alternative instance modes
- No two HATs may use the same instance mode simultaneously

The BE-IIS-HAT++ system supports stacking of up to five HATs, depending on the selected instance modes and system configuration.

This HAT supports Instance-Mode I, IV and V

2.5 Interfaces

The board interfaces with the host system via the I²C bus (I²C1) and a dedicated interrupt (IRQ) signal.

The I²C bus is used for communication between the Raspberry Pi (I²C master) and the onboard interface controller (I²C slave). An interrupt line is used for event-driven communication.

The supported instance modes define the assignment of the I²C target address and the interrupt (IRQ) signal, as shown in Table 1.

Instance Mode	Target Address	IRQ
I	0x9A	GP6
IV	0x98	GP14
V	0x92	GP25

Table 1: Exclusive HW resources

Instance Mode	Signal	Pin
I, II, III, IV, V	RESET	GP13
I, II, III, IV, V	SCL0	GP1
I, II, III, IV, V	SDA0	GP0

Table 2: Shared HW resources

The I²C target address and IRQ signals are exclusively occupied by the HAT in each instance mode.

The I²C bus signals (SDA, SCL) are shared across all instance modes and may also be shared with additional HATs, provided that proper address separation is ensured.

HAT+ / HAT++ functionality

The I²C bus **I2C0** (SDA0 / SCL0) is reserved for HAT identification and configuration purposes.

An onboard controller connected to I2C0 provides standard HAT+ identification data as well as extended HAT++ metadata. This includes, for example, device tree overlay references and configuration parameters used for automatic system integration.

The EEPROM content can be evaluated by the bootloader or by user-space software to dynamically apply device tree overlays and configure the system.

All other GPIO signals remain available for user applications, unless otherwise specified.

2.6 Isolation

Galvanic separation is implemented between the MDI signaling domain and the Raspberry Pi domain.

The separation barrier isolates the field-side interface from the logic-side circuitry, improving robustness against ground potential differences.

The separation is implemented using a transformer in the MDI path.

The implemented separation provides functional galvanic decoupling between domains. It is not specified or certified as a safety isolation barrier in its standard configuration.

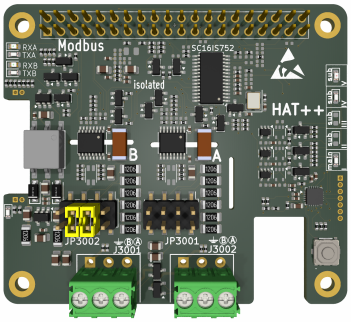
The required isolation performance depends on the specific application and corresponding safety requirements. If such requirements are defined, application-specific evaluation, testing, and certification may be supported. Upon request, variants with validated isolation performance, including testing, labeling and certification, can be provided.

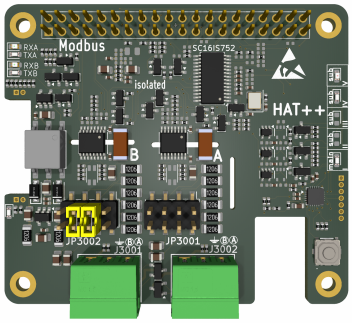
In the default configuration, the board provides functional separation only.

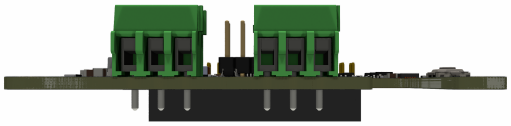
2.7 Connectors

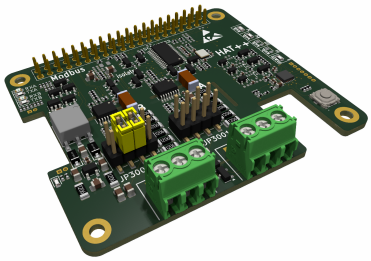
Connectors J3001 and J3002 provide the physical RS-485 bus interfaces.

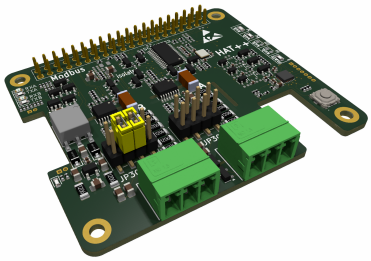
- **J3001**: Interface B
- **J3002**: Interface A











Supplier: Phoenix Contact
MPN: PT 1,5/3-3,5-H
Order Code: 1984620 [5]
Description: 3-pin 3.5 mm screw terminal block
Note: This connector is included in the delivery

Supplier: Phoenix Contact
MPN: MC 1,5/ 3-G-3,5 - PCB header
Order Code: 1844223 [6]
Description: 3-pin 3.5m mm PCB header

2.8 Jumper Configuration JP3001 / JP3002

Jumpers **JP3001** and **JP3002** configure the RS-485 bus termination and optional external biasing networks for Interface 1 and Interface 2, respectively.
For proper Modbus operation, the 120 Ω termination resistor must only be enabled at the two physical end nodes of each RS-485 bus segment.

Bus topology requirements

- **End nodes:** 120 Ω termination enabled
- **Intermediate nodes:** No termination

The RS-485 transceiver (ISO1500DBQR) provides integrated fail-safe biasing to ensure a defined idle bus state.
In addition, optional external biasing networks are available on the board:

- Line A pulled up to +5 V via 5 kΩ
- Line B pulled down to GND via 5 kΩ

External biasing is typically not required due to the integrated fail-safe functionality of the transceiver. However, it may be enabled if required by specific system configurations or network conditions.
If used, external biasing should be enabled at only one node per RS-485 segment.

Point-to-point operation
In point-to-point configurations, both connected devices are considered end nodes. Therefore, termination must be enabled on both sides.
Figures 3 illustrate valid end-node configurations:

- Right: Termination enabled, bias disabled
- Left: Termination and external bias enabled

If additional nodes are present between the endpoints, these intermediate nodes must remain unterminated and without external biasing, as shown in Figure 4 (left).
Normally, external biasing is enabled at one end node only. The configuration shown in Figure 4 (right) is electrically valid but uncommon.

Pin	Signal	Pin	Signal
1	5 kΩ Pull-up (A to +5 V)	2	A
3	120 Ω (A–B termination)	4	A
5	120 Ω (A–B termination)	6	B
7	5 kΩ Pull-down (B to GND)	8	B

Table 3: JP3001 / JP3002 pin assignment for termination control and biasing.

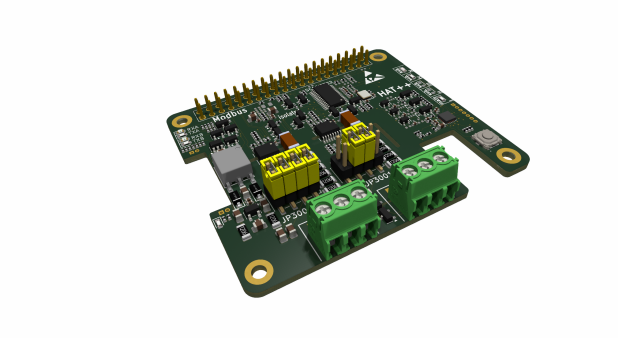


Figure 3: JP3001 / JP3002 RS-485 end-node configuration. Left: 120 Ω termination enabled, bias disabled. Right: 120 Ω termination and 5 kΩ bias enabled.

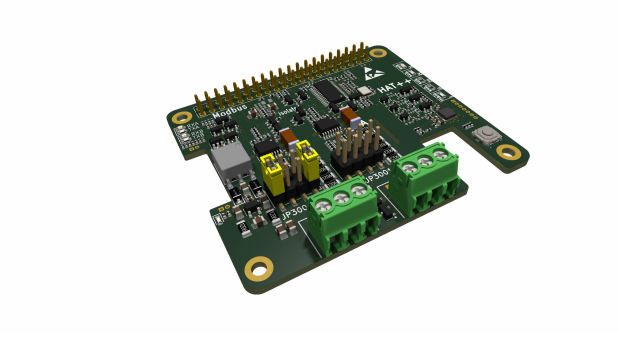


Figure 4: JP3001 / JP3002 intermediate-node configuration. Left: No jumpers installed. Right: Bias enabled only (termination disabled) – uncommon but valid.

Configuration summary

- Enable termination without biasing at one bus endpoint (Figure 3, right
- Intermediate nodes must remain unterminated and without biasing (Figure 4, right)
- If needed, enable termination with biasing at the opposite endpoint (Figure 3, left)

2.9 Indicators (LEDs)

In addition to the LED status bar on the side, which indicates the selected instance mode, additional status LEDs are located on the opposite side of the HAT:

- **Interface 1 RX/TX**: Bus activity of RS-485 Interface Bus A
  - *Green*: Receive activity (RX)
  - *Red*: Transmit activity (TX)
- **Interface 2 RX/TX**: Bus activity of RS-485 Interface Bus B
  - *Green*: Receive activity (RX)
  - *Red*: Transmit activity (TX)

2.10 Signal Polarity and Wiring Orientation

The RS-485 interface uses differential signaling with lines A and B.

The pinning of both connectors is identical and follows the PCB marking:

- **Pin 0**: Isolated GND
- **Pin 1**: Line B (inverting)
- **Pin 2**: Line A (non-inverting)

Correct polarity shall be observed when connecting the bus. Line A must be connected to line A and line B to line B across all nodes.

Both interfaces share a common isolated ground reference. This ground is galvanically separated from the Raspberry Pi (host) ground.

3 Software and System Configuration

The BE-IIS-HAT++ system provides a unified platform for fast system integration.

- Predefined drivers and kernel modules
- Support for prebuilt modules and custom kernel builds
- Ready-to-use build and configuration scripts
- Centralized software repository [TODO]
- Typical setup time below a few minutes

After installation, the system can be used without further software modification.

4 Electrical Characteristics

4.1 Supply Voltage

Parameter	Min	Typ	Max
3.3 V Input [V]	3.0	3.30	3.6
5 V Input [V]	4.5	5	5.5

Table 4: Voltage supply

4.2 Current Consumption

Parameter	Typ	Unit
Current @ 5 V	200	mA
Current @ 3.3 V	15	mA

Table 5: Current consumption

5 Environmental Conditions

5.1 Conditions

Condition	Min	Max
Operating Temperature [°C]	-40	+85
Storage Temperature [°C]	-40	+105
Relative humidity [%]	5	95

Table 6: Operating conditions

5.2 Usage

Condition	Parameter
Usage	indoor
Pollution degree	2
Operating altitude	up to 2000 m

Table 7: Operating usage

5.3 EMC and Environmental Compliance (Preliminary)

The standard version of the board is provided without formal EMC or safety certification.

The hardware design is developed with consideration of commonly applied IEC standards, including:

- **ESD immunity:** IEC 61000-4-2
- **Electrical fast transient (EFT/Burst):** IEC 61000-4-4
- **Surge immunity:** IEC 61000-4-5
- **Conducted RF immunity:** IEC 61000-4-6
- **Radiated RF immunity:** IEC 61000-4-3
- **EMC immunity (industrial):** IEC 61000-6-2
- **EMC emission (industrial):** IEC 61000-6-4
- **Safety / isolation reference:** IEC 62368-1

These standards are not verified for the standard product variant.

Compliance with specific standards, test levels, or safety requirements is not guaranteed unless explicitly specified.

If defined EMC or isolation requirements are provided, application-specific validation, testing, and certification can be supported. Upon request, product variants with validated performance, including labeling, certification, and test reports (e.g. Hi-Pot testing), can be delivered.

6 Delivery

The product is delivered as a partially assembled kit intended for final user assembly. Mechanical accessories and connector components required for standard evaluation and stacked operation are included.

Order Code	BE-IIS-HPP-MODBUS-REV.B
Condition	Assembly kit
Status	Partially assembled
Included Items	1× HAT 4× 15 mm spacers 1× 2×20 pin stackable header 4x Jumper 2x 3-pin skew connector
REACH & RoHS	Compliant with EU Directive 2011/65/EU and REACH Regulation (EC) No 1907/2006

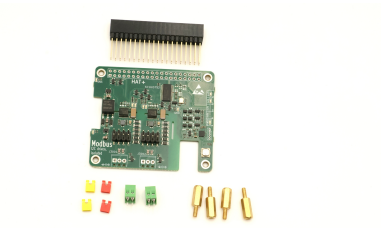


Figure 5: Delivery condition

7 Mechanical

7.1 Board Format

- Form factor: Raspberry Pi HAT+
- Mechanical dimensions: Raspberry Pi HAT compatible [4]
- Mounting hole pattern: Raspberry Pi HAT compatible [4]
- Stackszize: 15mm

7.2 Connectors and Assembly Height

- Host connector: 40-pin Raspberry Pi header
- Field connector: J6000, updated connector option
- Assembly height: [TODO]

7.3 Board Views

Figure 6: Mechanical overview

8 Assembly

This product is delivered as a kit and requires basic soldering and mechanical assembly.

8.1 2x20-Pin Main Connector

The 2x20-pin connector provides the interface to the Raspberry Pi. For proper HAT functionality, the connector must be assembled carefully.

A stackable 2x20-pin header is included in the delivery and is recommended for most applications, especially when using the BE-IIS HAT++ stacking system.

- Mount the header on the top side of the PCB (component side)
- The socket side faces down towards the Raspberry Pi

Alternatively, a standard (non-stackable) pin header may be used if stacking is not required.

Soldering instructions:

- Use a suitable soldering iron with adequate temperature control
- Ensure good ventilation and avoid inhaling solder fumes
- Heat both the pad and the pin simultaneously, then apply solder
- Solder each pin individually and ensure proper wetting
- Avoid excessive solder to prevent large solder cones, which may affect stacking capability

Proper alignment of the connector is important to ensure mechanical compatibility with the Raspberry Pi and other HATs.

8.2 Spacer

To ensure mechanical stability and correct stacking height, spacers must be installed.

- Recommended spacer height: 15 mm
- Fix the PCB using appropriate screws and spacers
- Ensure stable mechanical mounting to avoid stress on the connector

The spacers define the stacking distance and provide mechanical fixation of the HAT.

8.3 3.5 mm Terminal Block Connector

Two suitable screw terminal blocks are typically included in the delivery. Alternatively, a compatible PCB header (plug or socket variant) may be used, depending on the application. Refer to the corresponding product section for supported connector types.

Assembly instructions:

- Ensure correct orientation before soldering: the cable entry openings must face outwards from the PCB edge
- Insert the connector fully into the PCB to ensure proper mechanical alignment
- Solder all pins carefully with sufficient wetting

Important notes:

- Avoid direct contact between the soldering iron and the plastic housing of the connector, as this may cause visible damage or deformation
- Ensure clean solder joints without excessive solder to maintain proper mechanical fit

Correct assembly ensures reliable electrical contact and proper usability of the terminal interface.

8.4 Board Overview

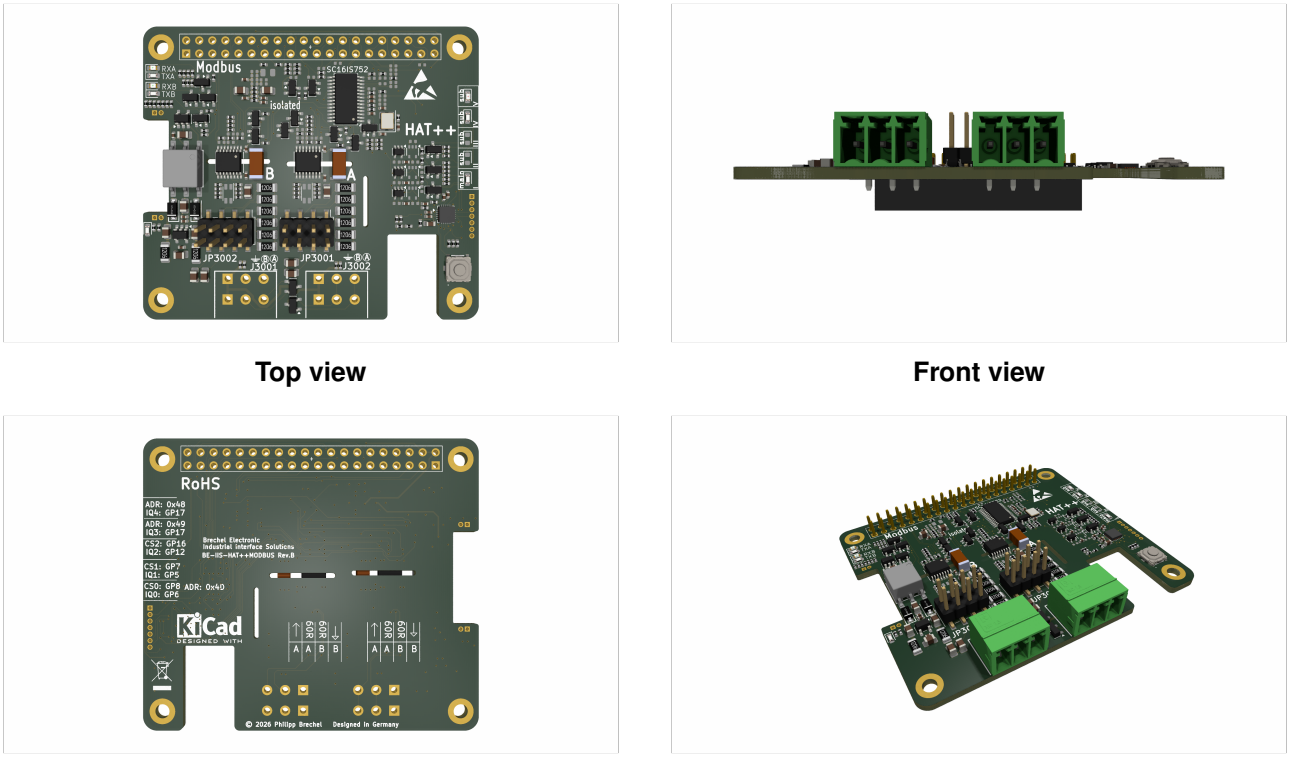


Figure 7: BE-IIS-HAT++MODBUS-I2C – mechanical overview

9 References

1. SC16IS752IPW Product Webside
2. ISO1500 Product Webside
3. BE-IIS Installer (Software and Setup Tools)
4. Raspberry Pi HAT+ Specification
5. PhoenixContact PT 1,5/ 3-3,5-H - PCB terminal block
6. PhoenixContact MC 1,5/ 3-G-3,5 - PCB header
7. [TODO: PCB layout and assembly documentation]