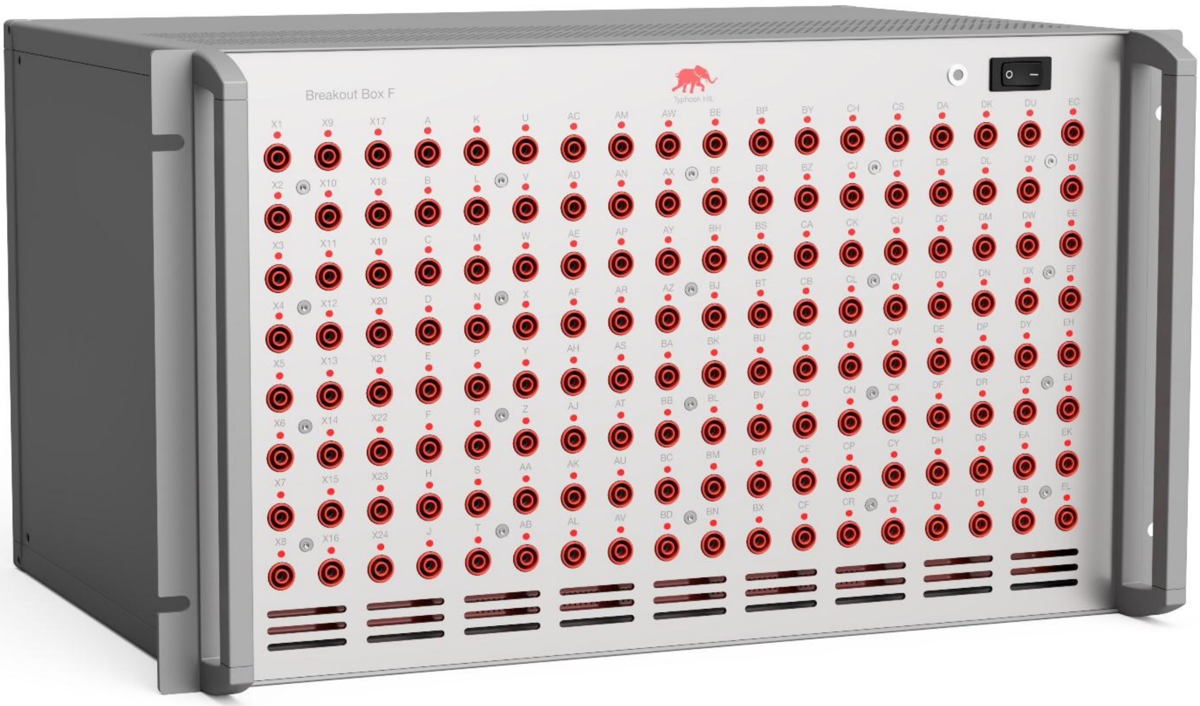
Breakout Box F Datasheet



Version: 1.1

Contents

1 Overview

This document serves as the official datasheet for the Breakout Box F, designed and manufactured by Typhoon HIL Inc. It provides detailed information on the device's electrical, mechanical, and software characteristics to support proper integration, operation, and use.

2 Introduction

The Breakout Box F is a 19-inch, 6U device designed for controlled fault insertion and direct signal access across 150 independent channels. Of these, 144 channels are available for convenient front panel probing via 4 mm banana jacks.

The device supports both open-circuit and short-circuit fault conditions. Short circuits may be introduced between channels or to externally supplied voltage levels applied through the fault input connectors (e.g., GND, IGN, BATT). Up to three independent fault lines can be connected to enable flexible test scenarios.

The Breakout Box F is suitable for both desktop and rack-mounted installations and may be operated as a standalone unit or integrated with HIL and HIL Connect systems. Device control and configuration are performed via the CAN communication interface.

3 Applications

- Stand-alone device for fault insertion and signal probing
- Engine Control Unit (ECU) HIL Testing
- Battery Management System (BMS) HIL Testing
- On-Board Charger (OBC) HIL Testing

4 Features

- Total of 150 channels
- 120 channels available via EDAC (ELCO) connector for general purpose applications
- 30 channels available via D-Sub connectors dedicated for more sensitive applications
- Part of the dedicated D-Sub channels are arranged to support direct interfacing with four CAN and two resolver signals with two extra connectors for monitoring resolver EXC signals.
- Independent entry of physical faults for each channel individually
- Option to supply up to three independent fault lines (GND, BATT, IGN...)
- Ability to create a short circuit between channels (If one of the fault lines is not used.)
- The possibility of creating an open circuit for all channels
- Choice of feeding the fault lines to banana jacks or to a dedicated connector on the back of the device
- Front panel signal probing via 4 mm banana jacks for the first 144 channels
- LED status indicator above each of the 144 channels
- Each channel rated at 30 VDC, 2 A
- Device controlled over CAN communication protocol
- Configurable CAN bus ID from 0 to 15
- Integrated CAN splitter on the rear panel for the HIL CANs
- Each channel on the CAN splitter has a 120 Ω termination controlled by a switch
- Powered via universal C14 mains power input 90 – 240 V, 50 – 60 Hz
- An output C13 connector for mains power extension available on the back of the device

5 Specification

The following specifications describe the electrical, mechanical, environmental, and communication characteristics of the Breakout Box F. These parameters define the device's operating conditions and performance capabilities for reliable integration into test environments.

5.1 Electrical Characteristics

Parameter	Condition	Min	Typ	Max	Unit
Number of Channels	Total	–	150	–	–
Front-Panel Probing Channels	Banana jacks	–	144	–	–
Number of Fault Lines per Channel	Open wire, short to three fault buses	–	4	–	–
Fault Line Voltage	Continuous	0	–	30	VDC
Fault Line Current	Continuous	–	–	1	A
Max Fault Line Current	Duration of 1800 sec.	–	–	2	A
Static Contact Resistance (EDAC IN → OUT)	1 A test current	–	0.58	–	Ω
Static Contact Resistance (EDAC IN → Banana)	1 A test current	–	1.68	–	Ω
Propagation Delay (EDAC IN → OUT)	–	–	20	–	ns
Propagation Delay (EDAC OUT → Banana)	–	6	–	–	ns
Propagation Delay (EDAC IN → Banana)	–	–	26	–	ns
Analog Bandwidth (-3 dB)	Typical channel	8.8	9.5	10	MHz
Signal-to-Noise Ratio	10 Vpp input	–	64	–	dB

Table 5.1 Electrical characteristics

5.2 Power Requirements

Parameter	Condition	Min	Typ	Max	Unit
Input Voltage	AC mains	90	–	240	VAC
Input Frequency	–	50	–	60	Hz
Power Consumption	Idle	–	3	–	W
Power Consumption	Full Load	–	–	37	W
Fuse Rating (Factory Installed)	–	–	250 V, 3.15 A	–	Fast blow
Maximum Supported Fuse	Optional replacement	–	250 V, 8 A	–	Slow blow

Table 5.2 Power requirements

5.3 Communication Interface

Parameter	Value
Interface Type	CAN (ISO 11898)
Bitrate	1 Mbps
CAN Identifier	0x00 – 0x0F (hardware selectable)
Frame Type	Standard 11-bit
Payload Length	6 bytes (DLC = 6)

Table 5.3 Communication interface

5.4 Mechanical Characteristics

Parameter	Value
Form Factor	19-inch rack mount
Height	6U
Mounting	Rack or desktop
Front Interface	4 mm banana jacks
General Purpose Connector	EDAC 120-pin
Dedicated Connectors	D-Sub (DE9)
Fault Connector	8-pin terminal + 4 mm banana
Dimensions	485 x 265 x 355 (W x H x D) mm
Weight	12.1 kg ±0.2

Table 5.4 Mechanical characteristics

5.5 Switching Specifications

Parameter	Value
Relay Type	Hermetically Sealed Electro-Mechanical SPST (1 form A)
Magnetic system	Monostable
Contact Type	Cross bar twin; Ag-Alloy and Au plating
Total number of relays	600
Minimum Switching Voltage	100 μV
Max Switching Voltage	60 VAC; 30 VDC
Rated Current	2 A
Limiting Continuous Current	1 A
Max Power	60 W; 62.5 VA
Initial contact resistance	<50 mΩ at 10 mA/30 mV
Initial insulation resistance	$>1^9$ Ω
Typical Operate Time	10 ms max
Durability - Mechanical	20 x10^6 min.
Durability - Electrical	100,000 min. (Resistive and Inductive load) @ 2A; 30VDC

Table 5.5 Switching specification

5.6 Power Consumption

The device was evaluated across 110 VAC and 230 VAC mains inputs under minimum, typical, and maximum loading conditions.

Loading Cond.	Input Voltage	Input Current	Input Power
Min.	110 V	27.2 mA	3.03 W
Nom.	110 V	101.3 mA	11.25 W
Max.	110 V	247.7 mA	36.68 W
Min.	230 V	38.6 mA	6.99 W
Nom.	230 V	59.8 mA	13.69 W
Max.	230 V	159.9 mA	36.79 W

Table 5.6 Power consumption

6 Device Overview

The Breakout Box F is a device that utilizes 150 independent signal channels, 144 of which have front-facing jacks for signal probing, as well as an LED indicator above each jack to indicate channel status. On each channel, the device has the ability to introduce an open-circuit fault or to connect the channel to one of three user-defined fault lines. The fault lines are common to all channels and are externally fed to the device via dedicated connectors. For all channels, input and output connections can be accessed on the rear panel via EDAC (ELCO) and D-Sub (DE9) connectors.

6.1 Functional Block Diagram

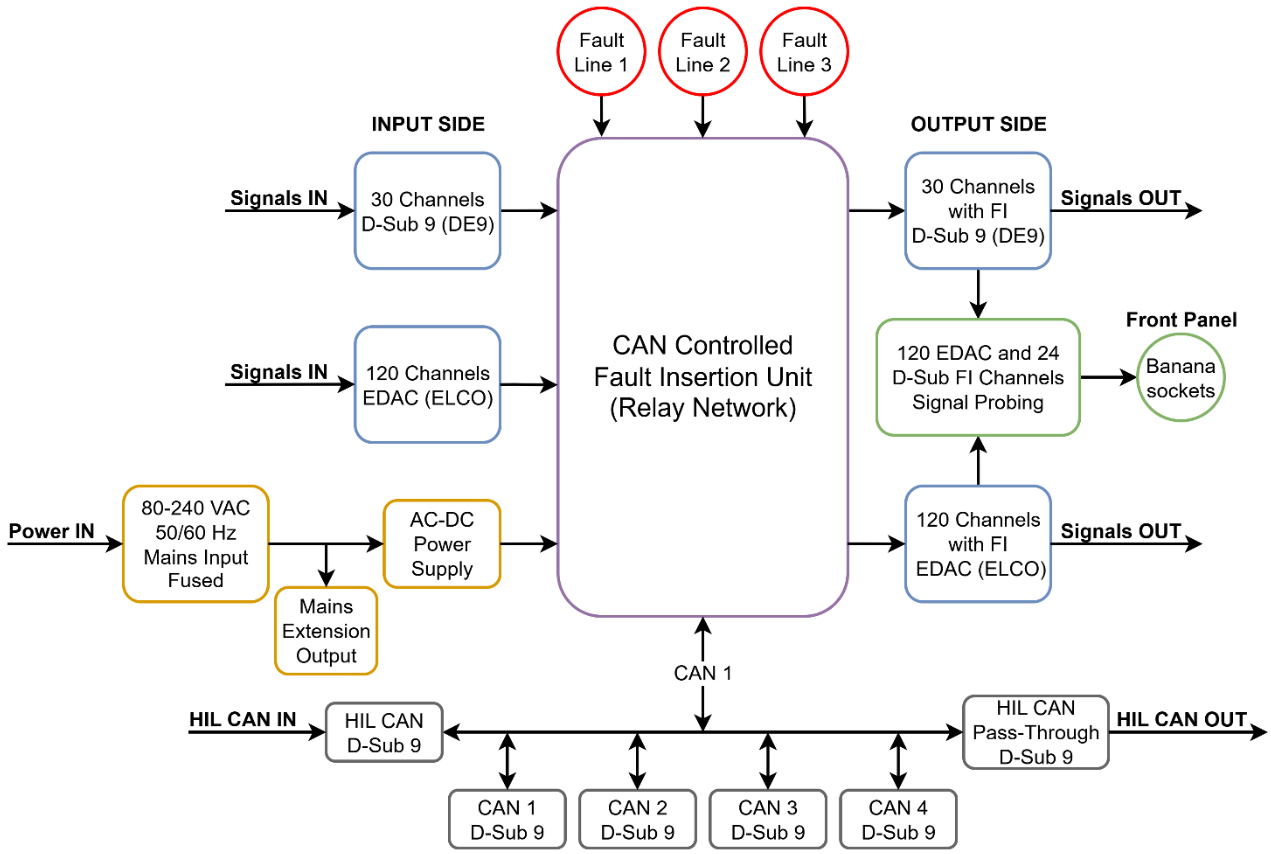


Figure 6.1 Breakout Box F Functional Block Diagram

6.2 Front Panel

The front panel of the Breakout Box F device consists of a mains power switch, a device power status LED indicator, 144 banana jacks, and an channel status LED above each jack.

6.2.1 Power Switch

The power switch is used to turn the device on and off, it directly disconnects the device from the mains. It is located on the front panel in the upper right corner.

The device's power status is indicated by a white LED which is located next to the power switch. When the device is turned off, the LED indicator remains on for a few more seconds.

6.2.2 Banana Jacks

Front panel 4 mm banana jacks are used for direct signal probing of 144 of the 150 channels available in the device. They are evenly distributed throughout the front panel. 120 of them are marked with letters of the alphabet and are used to probe the general purpose channels that are fed via the EDAC connector, and 22 of them are marked with the letter X plus number and are used to probe the dedicated channels that are fed via the D-Sub connectors also on the rear of the device.

Above each banana jack there is a red LED indicator, it gives feedback to the user about the state of the channel. The LED indicator has several states that will be described in more detail in the next chapter.

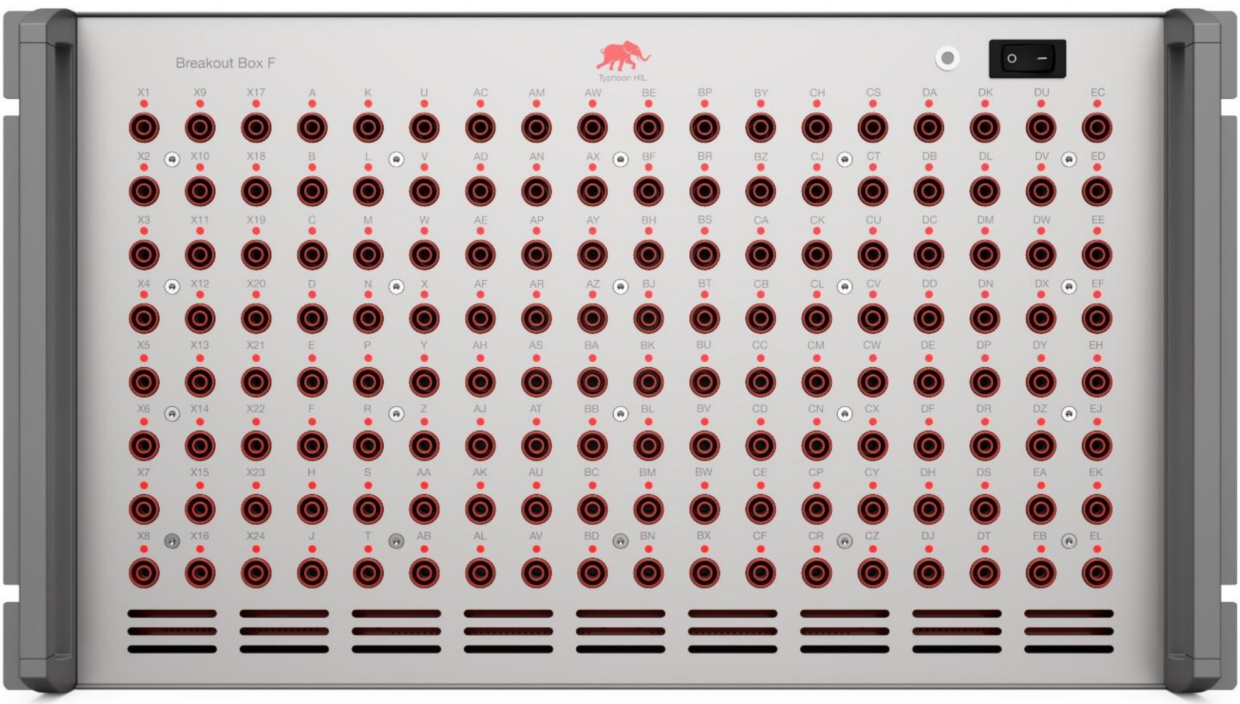


Figure 6.2 Breakout Box F Front Panel

6.3 Rear Panel

The rear panel of the Breakout Box F device consists of mains input and extension sockets, male and female EDAC connectors for 120 general purpose channels, D-Sub connectors for 30 dedicated channels, supply connectors for fault lines and CAN splitter connectors.

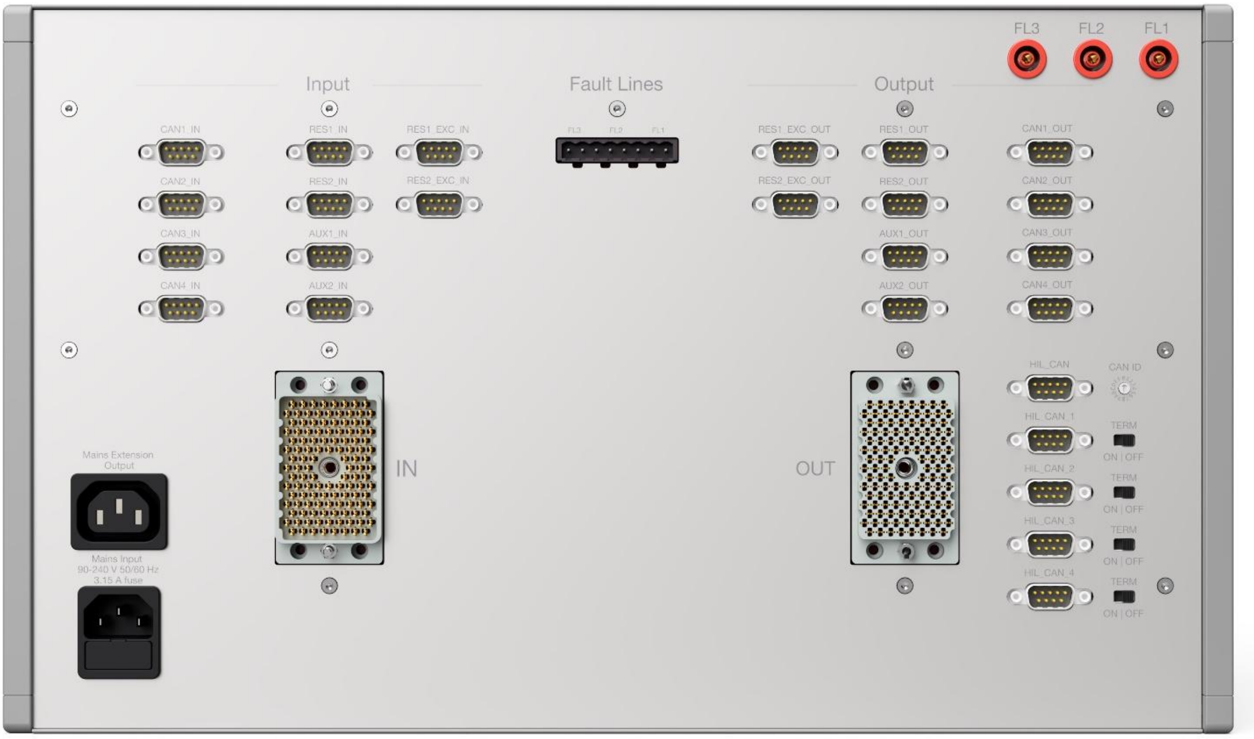


Figure 6.3 Breakout Box F Back Panel

6.3.1 Mains Sockets

Mains AC power is supplied to the device via the C14 socket located in the bottom left corner. The device contains a universal AC mains input and accepts everything between 90 V and 240 V, as well as frequencies between 50 Hz and 60 Hz. Beneath the C14 socket is a pull-out fuse holder containing two slots for a standard 5x20 mm fuse.

The device is supplied with both slots occupied by a 250V 3.15A fast blow fuses, the first one is for circuit protection, and the second one is spare.

When operating the Breakout Box F in regions with a 110 V AC mains supply, special care must be taken to ensure that the total load current does not exceed the rating of the installed fuse.

Alternatively, the factory-installed fuse may be replaced with a 250 V, 8 A slow-blow (T) fuse, provided that the replacement complies with local electrical regulations and safety standards.

Above the C14 mains AC power socket is a C13 mains extension output socket which, as the name suggests, extends the fuse protected side of the AC mains supply to an additional C13 socket to which additional devices can be connected. The device plugged into the mains extension output must not exceed the specified power consumption limits.

6.3.2 General Purpose Channels Connectors

The group of 120 channels routed through the EDAC 120-pin connectors are designated as general purpose channels. These channels are intended for signals that do not require dedicated shielding or enhanced noise immunity, as all lines are combined within a single high-density connector that does not provide ground or shield terminals.

Channel naming follows the EDAC connector pinout, ensuring that channel identifiers correspond directly to the connector pin designations. This alignment simplifies cable assembly and reduces the risk of wiring errors.

Signals enter the device through the male EDAC connector located on the left side of the rear panel. After passing through the internal fault insertion stage, the signals are routed to the corresponding pins of the female EDAC connector on the right side.

Following the fault insertion stage, all channels are additionally routed to front-panel banana jacks, enabling convenient signal probing and measurement.

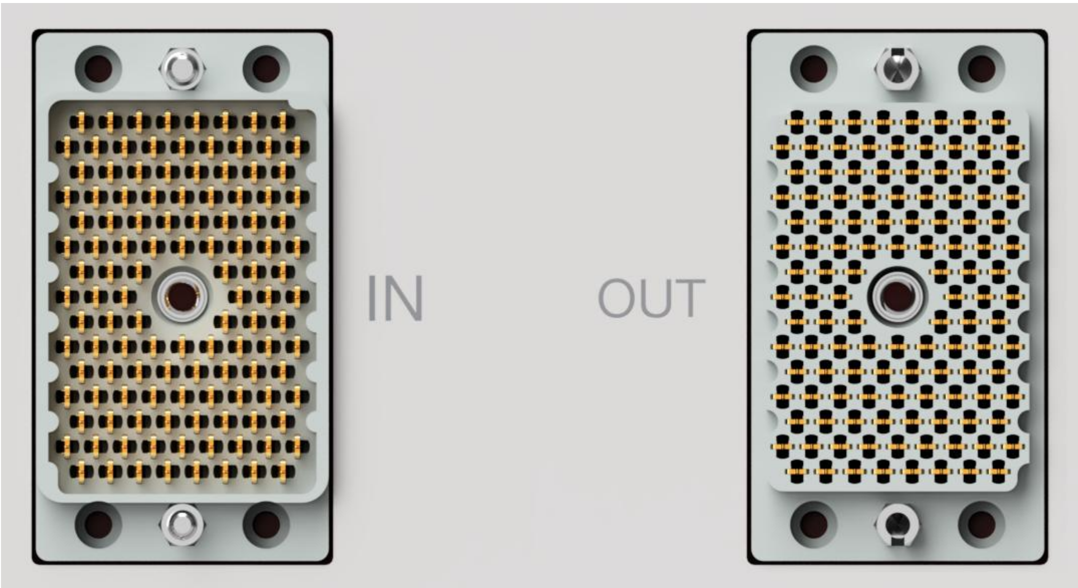


Figure 6.4 IN and OUT EDAC connectors for 120 general purpose channels

6.3.3 Dedicated Channels Connectors

Dedicated channels are implemented on D-Sub connectors and are optimized for interfacing with CAN and resolver signals, as well as other signal types that benefit from standardized pin assignments and type of connector. There are in total 30 dedicated channels of which 24 are available on the front panel for signal probing.

Dedicated channels share the same fault insertion architecture and operational behavior as the general purpose channels. The only difference is the physical interface, with dedicated channels implemented on D-Sub connectors featuring standardized pin assignments for four CAN networks, two resolver interfaces and two auxiliary connections.

Although the channels are labeled and pin-assigned for CAN, resolver, and similar signals, they may be used with any signal type that benefits from improved noise immunity and standardized connector interfaces.

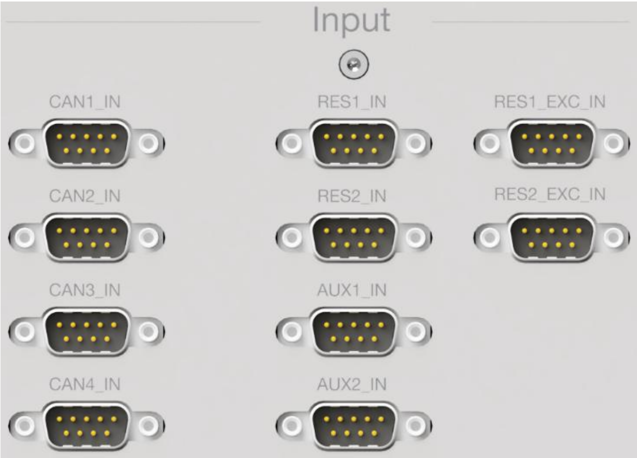


Figure 6.5 Dedicated channels D-Sub input side

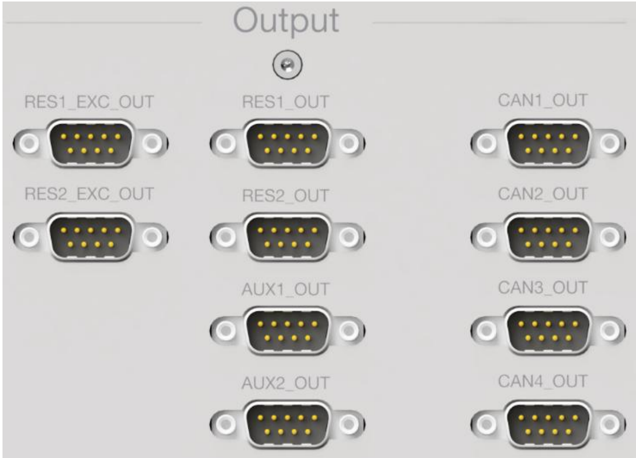


Figure 6.6 Dedicated channels D-Sub output side

6.3.4 Fault Line Connectors

Fault line connectors are located on the rear panel and provide access to the internal fault insertion network for applying externally generated fault voltages.

The device supports three independent fault channels. These channels are normally disconnected and can be activated individually via CAN communication or through the THCC software interface.

External fault signals may be connected using one of the following interfaces:

- 4 mm Banana Jacks – Three red banana jacks, each corresponding to one fault channel, allow quick connection of laboratory power supplies or other external signal sources.
- 8-Pin Connector – A dedicated multi-pin connector enables wiring of all three fault channels through a single interface for permanent or harness-based installations.

Electrical limits for the fault lines are specified in the Electrical Specifications section.

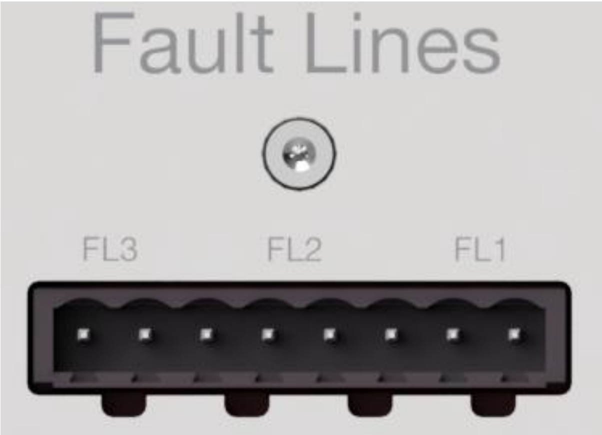


Figure 6.7 8-Pin Connector

Figure 6.8 4 mm Banana Jacks

6.3.5 CAN Splitter Connectors

The CAN splitter connectors are located on the rear panel and provide a convenient interface for distributing CAN communications from the HIL device to multiple external connections.

A single HIL_CAN connector serves as the input through which four independent CAN communication lines are fed into the device: two standard CAN channels and two CAN FD channels. These communications are internally routed to four dedicated output connectors labeled HIL_CAN_1, HIL_CAN_2, HIL_CAN_3, and HIL_CAN_4.

Each output connector is equipped with a termination switch that allows the user to enable or disable the integrated 120 Ω termination resistor, ensuring proper bus termination and simplifying network configuration.

Connector allocation is organized as follows:

- HIL_CAN_1 – CAN 1
- HIL_CAN_2 – CAN 2
- HIL_CAN_3 – CAN3 (CAN FD 1)
- HIL_CAN_4 – CAN4 (CAN FD 2)

For all four output connectors, CAN High is assigned to pin 7, while CAN Low is assigned to pin 2.

The pinout of the HIL_CAN input connector is defined as follows:

- CAN 1: pins 2 (CAN Low) and 7 (CAN High)
- CAN 2: pins 4 (CAN Low) and 8 (CAN High)
- CAN 3 (CAN FD 1): pins 6 (CAN Low) and 1 (CAN High)
- CAN4 (CAN FD 2): pins 5 (CAN Low) and 9 (CAN High)

This splitter architecture enables flexible CAN network deployment while maintaining signal integrity and reducing the need for external distribution hardware.

It should be noted that the Breakout Box F device is controlled via the CAN 1 network and is internally connected to this communication line. Therefore, **for the device to work properly**, the termination next to the **HIL_CAN_1** connector must be set to the **ON position**.

A rotary switch labeled CAN ID is positioned to the right of the HIL_CAN connector and allows configuration of the device CAN identifier. The switch supports selectable addresses ranging from ID 0 to ID 15, enabling straightforward integration into multi-device CAN networks while preventing address conflicts.

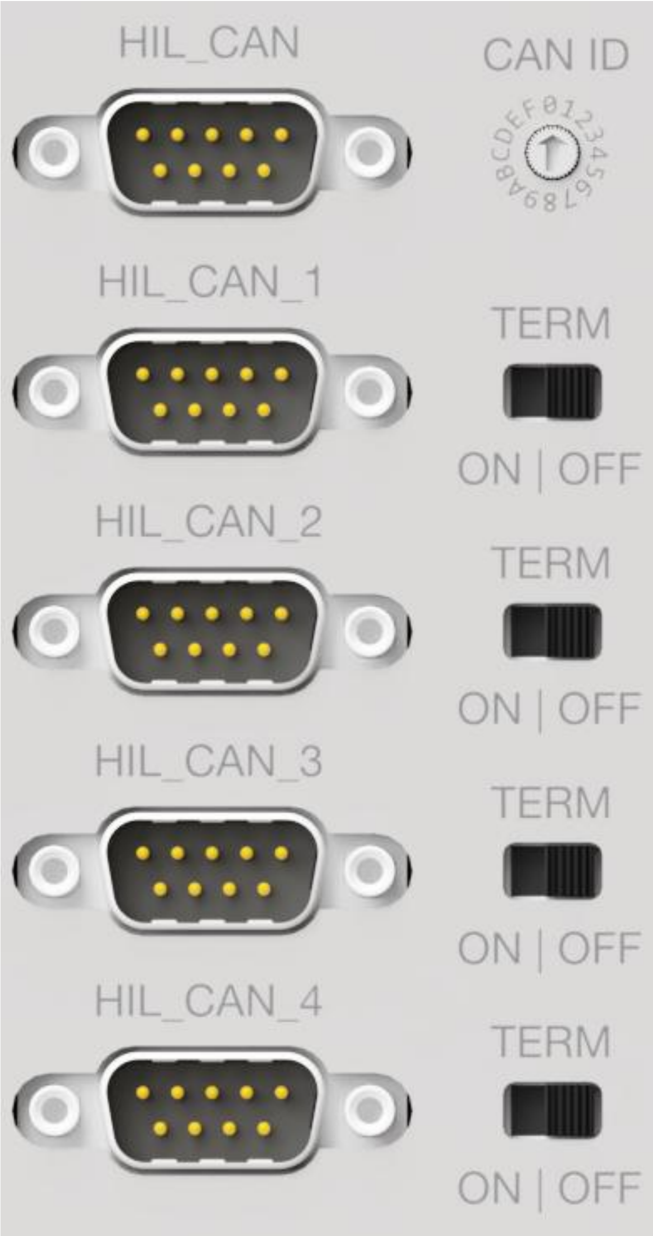


Figure 6.9 CAN splitter

7 Detailed Description

This chapter describes the internal architecture and functional operation of the Breakout Box F, including the fault insertion mechanism, channel routing structure, signal probing implementation and integrated fault protection system.

7.1 General Purpose Channels

General purpose channels comprise a group of 120 signal paths implemented across four of the five relay boards located inside the device, with each board supporting 30 channels. These channels are accessible through the EDAC connectors on the rear panel and are intended for signals that do not require dedicated shielding or enhanced noise immunity.

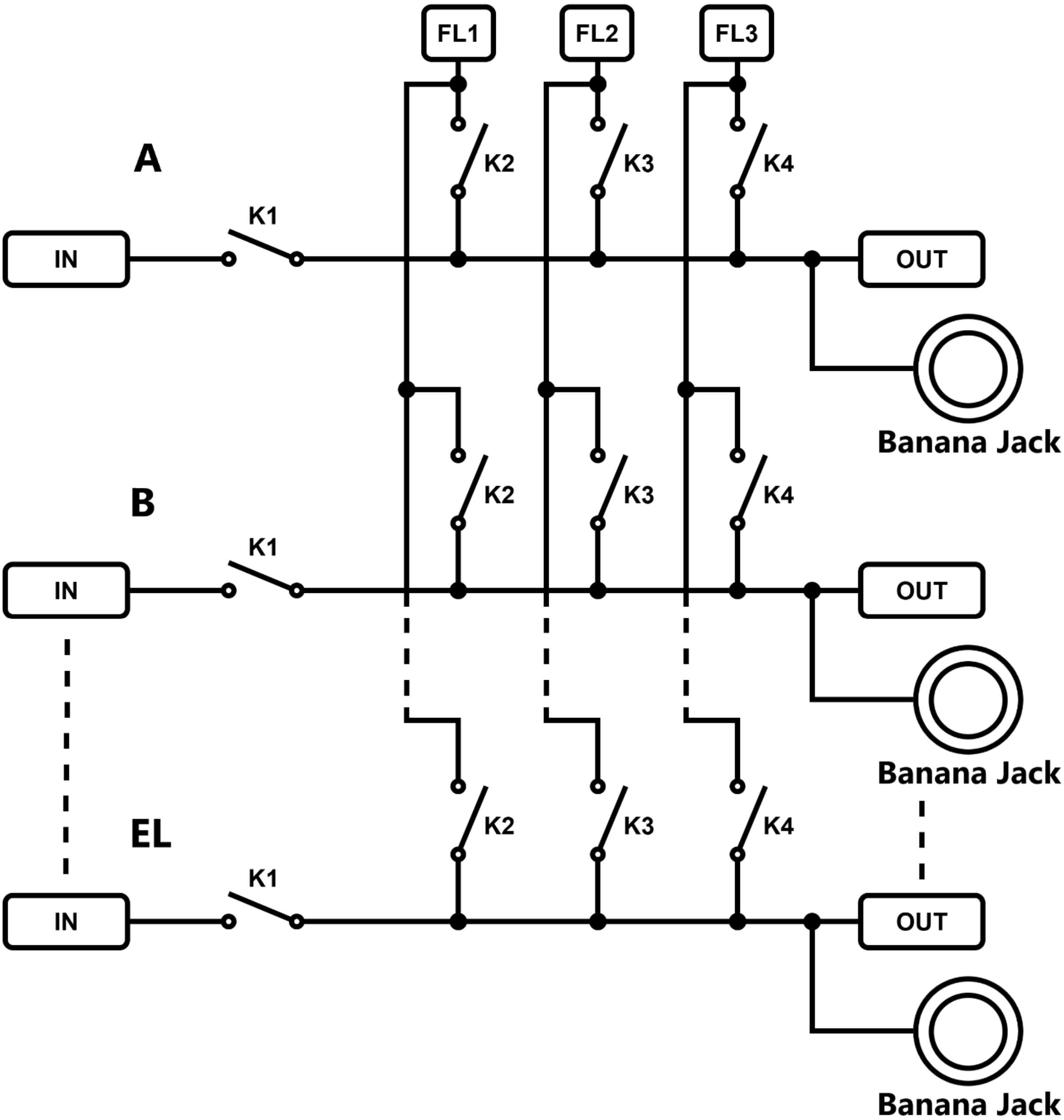


Figure 7.1 Schematic diagram of the general purpose channels

Signal entry is provided through the male EDAC connector positioned on the left side of the device, while the corresponding outputs are routed to the female EDAC connector on the right side. Internally, each channel consists of an input node, an output node, four electromechanical relays, and a front-panel banana jack used for monitoring.

7.1.1 Channel Architecture

Each channel integrates four relays labeled K1 through K4:

K1 — Open-Circuit Relay

Relay K1 is responsible for creating an open-circuit condition by interrupting the signal path between the input and output. In addition to enabling fault simulation, K1 plays an important protective role. When a fault condition is introduced via the fault relays, K1 automatically isolates the HIL side of the system from the external environment, preventing unintended voltage from reaching sensitive equipment.

K2, K3, K4 — Fault Relays

Relays K2 through K4 independently connect the channel to one of the three shared fault lines. If multiple channels are connected to the same fault line, they become electrically common, effectively creating a short circuit between them. This behavior can be intentionally utilized when test scenarios require shorting two or more channels together.

When performing channel-to-channel shorting, care must be taken to ensure that no external voltage source (such as a supply rail or ground potential) is simultaneously connected to the selected fault line unless such a condition is explicitly required by the test.

7.1.2 Front-Panel Monitoring

Every general purpose channel supports external measurement and monitoring via a red 4 mm banana jack located on the front panel. Channels can be easily identified by their alphabetical naming convention, ranging from A to EL. Channels labeled with the prefix X correspond to dedicated channels and are not part of the general purpose group.

The banana jack is permanently connected to the channel output, independent of relay state and regardless of whether the device is powered. This ensures continuous measurement access during both active testing and system setup.

7.1.3 Status Indication

A red LED indicator positioned above each banana jack provides immediate visual feedback regarding channel status:

- Steady illumination indicates that relay K1 is closed and that the signal path between input and output is continuous.
- Flashing illumination indicates that one or more fault relays (K2–K4) are active. When a fault relay is engaged, K1 is automatically opened to isolate the HIL interface, regardless of its previous state.

This behavior helps prevent unsafe electrical conditions while clearly signaling that a fault has been inserted.

7.1.4 Electrical Rating and Grounding Considerations

Each channel is rated for a maximum continuous voltage of 30 V and a maximum current of 2 A, representing the limits within which the relays can operate reliably without risk of degradation or failure.

General purpose channels do not share a common device ground or reference potential. The EDAC connector does not provide dedicated ground or shielding terminals; therefore, if a signal requires a reference potential, it must be routed together with its corresponding ground through an adjacent channel.

7.1.5 Internal Routing and Signal Integrity

During PCB layout, special attention was given to channel routing to minimize parallel trace paths and reduce the likelihood of crosstalk or unintended signal coupling. This design approach improves overall signal integrity across the connector despite the high channel density.

7.1.6 Recommended Usage

General purpose channels are best suited for:

- Low-frequency analog signals
- Slow digital signals
- Status and control lines
- Non-noise-critical interfaces

Signals known to generate significant electromagnetic noise should not be routed alongside sensitive signals through the same EDAC connector. Logical signal grouping and physical separation are strongly recommended to maintain measurement accuracy and system stability.

7.1.7 Connector Advantages

A key advantage of the EDAC-based implementation is its high connection density combined with a connector design that supports straightforward cable assembly. This simplifies harness fabrication while maintaining strong mechanical reliability and broad compatibility with industry-standard wiring practices.

7.2 Dedicated Channels

Dedicated channels provide enhanced signal interfacing capabilities through industry-standard D-Sub 9 connectors and are arranged to support communication, resolver, and other signal types requiring improved grounding and physical separation. These channels share the same internal relay architecture and fault insertion capabilities as general purpose channels but offer optimized connector layout and grounding features to support higher signal integrity requirements.

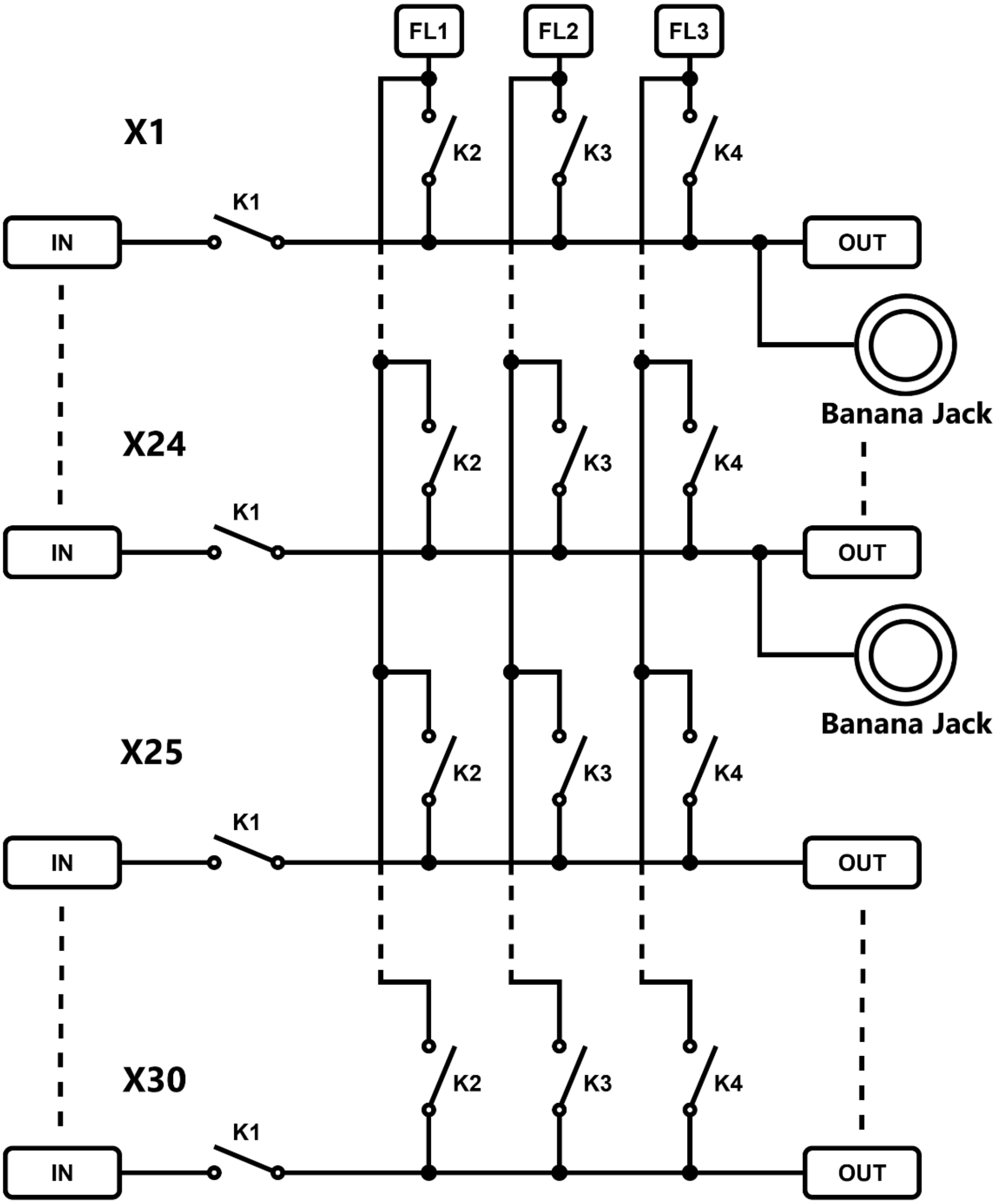


Figure 7.2 Schematic diagram of the dedicated channels

7.2.1 Channel Architecture and Physical Implementation

The dedicated channel group consists of 30 channels, all located on the fifth internal relay board. These channels are accessed through eight male D-Sub 9 input connectors located on the left side of the device, while the corresponding outputs are available on the right side using the same connector type and pin layout.

On the front panel, dedicated channels are identified using the naming convention X1 through X30, clearly distinguishing them from general purpose channels labeled A through EL.

Each dedicated channel contains the same internal functional elements as general purpose channels:

- Input
- Output
- Four relays (K1–K4) for signal interruption and fault insertion
- Front-panel monitoring interface (where available)
- Status LED indicator

The internal relay operation, fault insertion behavior, protection logic, and electrical ratings are identical to those described for general purpose channels.

7.2.2 Front-Panel Monitoring and Status Indication

Front-panel monitoring access is available for the first 24 dedicated channels (X1–X24) via red 4 mm banana jacks. These monitoring points are connected directly to the channel output node, independent of relay state and regardless of device power status, allowing continuous measurement access.

The remaining six channels (X25–X30) do not provide front-panel banana jack access and are accessible only through the rear D-Sub connectors.

Status indication for all dedicated channels is provided by LED indicators positioned above the corresponding banana jacks or channel labels, using the same behavior as general purpose channels:

- Steady LED illumination indicates that relay K1 is closed and the signal path is continuous.
- Flashing LED illumination indicates that one or more fault relays (K2–K4) are active. When a fault relay is engaged, relay K1 is automatically opened to isolate the HIL interface.

7.2.3 Connector Assignment and Functional Grouping

Dedicated channels are distributed across eight D-Sub 9 connectors according to their intended primary application, enabling direct interfacing with common industrial signal types without requiring custom cable modifications.

CAN Communication Connectors

Four connectors are designated for CAN communication signals:

- CAN1_IN / CAN1_OUT
- CAN2_IN / CAN2_OUT
- CAN3_IN / CAN3_OUT
- CAN4_IN / CAN4_OUT

Each of these connectors provides access to two channels located on pins 2 and 7, which correspond to the industry-standard pinout for CAN communication interfaces. This arrangement allows direct insertion of faults into CAN communication lines without requiring specialized wiring.

Resolver Interface Connectors

Two connectors are dedicated to resolver signal interfacing:

- RES1_IN / RES1_OUT
- RES2_IN / RES2_OUT

Each resolver connector provides access to six channels, arranged according to standard resolver signal assignments, including: SIN+, SIN-, COS+, COS-, EXC+ and EXC-.

This layout enables direct integration with resolver sensors while supporting fault insertion and monitoring capabilities.

Resolver Excitation Access Connectors

Two additional connectors provide supplementary access to resolver excitation signals:

- RES1_EXC_IN / RES1_EXC_OUT
- RES2_EXC_IN / RES2_EXC_OUT

These connectors provide parallel electrical access to the resolver excitation channels available on RES1 and RES2 connectors. Internally, the corresponding channels are electrically common, enabling flexible connection configurations and additional measurement access without requiring signal splitting outside the device.

Auxiliary Connectors

Two additional connectors are designated for general-purpose use:

- AUX1_IN / AUX1_OUT
- AUX2_IN / AUX2_OUT

Each AUX connector provides access to five dedicated channels, enabling flexible integration of additional signals requiring improved grounding or connector robustness.

7.2.4 Grounding and Signal Integrity Advantages

Unlike general purpose channels, dedicated channels provide direct access to device ground through the metal shell of the D-Sub connectors. This allows cable shielding to be properly referenced to the device chassis ground, significantly improving electromagnetic compatibility and reducing susceptibility to noise and interference.

This grounding feature makes dedicated channels particularly suitable for:

- High-speed digital signals
- PWM signals
- Communication interfaces such as CAN
- Resolver sensor signals
- Noise-sensitive analog signals when properly separated

When using dedicated channels for sensitive analog signals, care should still be taken to avoid routing them adjacent to signals capable of generating significant electromagnetic interference.

7.2.5 Signal Direction and Connector Identification

All dedicated channel input connectors are located on the left side of the device and are identified using the suffix: _IN

Corresponding output connectors are located on the right side of the device and use the suffix: _OUT

This consistent naming convention ensures clear identification of signal flow direction and simplifies system integration.

7.2.6 Functional Flexibility

Although dedicated channels are physically arranged to support specific signal types such as CAN and resolver interfaces, they are not electrically restricted to those applications. Any dedicated channel may be used for general signal routing and fault insertion as required by the test scenario.

This flexibility allows users to leverage the improved grounding and connector characteristics of dedicated channels for a wide range of signal types beyond their primary intended use.

7.3 Fault Insertion System

The Breakout Box F implements a relay-based fault insertion system that enables controlled simulation of electrical fault conditions across all 150 channels. This system allows users to introduce open-circuit faults, short circuits between channels, and short circuits to externally applied fault voltages in a safe, deterministic, and repeatable manner.

The fault insertion architecture is fully integrated into each channel and is controlled either through the CAN communication interface or via the THCC software environment.

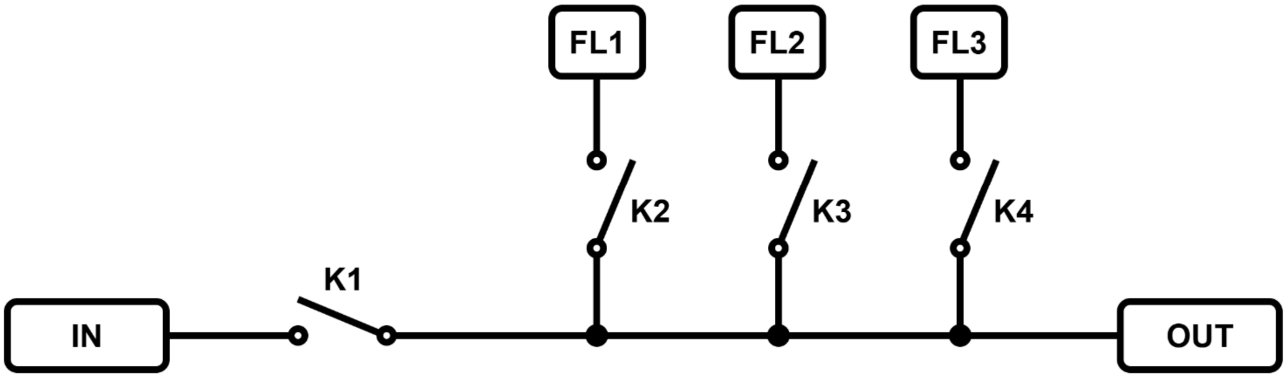


Figure 7.3 BOB-F Fault Insertion System

7.3.1 Channel Fault Insertion Architecture

Each channel contains four electromechanical relays labeled K1 through K4, which together provide complete fault insertion functionality.

Relay K1 — Signal Path Relay (Open-Circuit Fault)

Relay K1 controls the primary signal path between the channel input and output. When closed, the signal passes normally through the device. When opened, the signal path is interrupted, creating an open-circuit fault condition equivalent to disconnecting the cable or signal line.

Relay K1 also performs a protective function. When any fault relay (K2–K4) is activated, K1 is automatically opened to isolate the HIL interface from external fault voltages, preventing unintended stress or damage to connected equipment.

Relays K2, K3, and K4 — Fault Routing Relays

Relays K2, K3, and K4 independently connect the channel to one of the three shared fault lines: FL1, FL2, or FL3. These fault lines are available through rear-panel connectors and allow externally supplied fault voltages or signals to be introduced into the channel.

When one of these relays is closed, the channel becomes electrically connected to the corresponding fault line, allowing the applied fault signal to propagate into the channel.

7.3.2 Fault Line Sharing and Channel-to-Channel Faults

Because each fault line is shared across all channels, multiple channels connected to the same fault line become electrically common. This behavior enables the simulation of short circuits between two or more channels by connecting them to the same fault line without applying an external voltage source.

This capability allows realistic simulation of wiring faults such as:

- Short circuits between signal lines
- Crosstalk faults
- Connector failures
- Intermittent or permanent electrical coupling

When using this feature, care must be taken to ensure that external fault voltages are not simultaneously applied unless required by the intended test condition.

7.3.3 External Fault Signal Injection

Fault signals may be introduced through dedicated rear-panel connectors using either:

- Individual 4 mm banana jack connectors (one per fault line), or
- A 8-pin fault connector providing access to all fault lines in a single interface. (MPN: BLF 5.08HC/08/180 SN BK BX)

These inputs allow connection of external voltage sources such as:

- Ground potential (GND)
- Battery voltage (VBAT)
- Ignition voltage (IGN)
- Arbitrary test voltages
- Function generator outputs

This enables simulation of a wide range of fault conditions including:

- Short to ground
- Short to supply voltage
- Short between signal lines
- Injection of external test signals

The maximum allowed continuous fault line voltage is 30 V, with a maximum current of 2 A per channel.

7.3.4 Fault Isolation and Protection Behavior

To ensure safe operation, the fault insertion system is designed so that the primary signal path relay (K1) is automatically opened whenever a fault routing relay (K2–K4) is activated. This prevents unintended electrical coupling between the HIL system and externally applied fault voltages.

This architecture ensures that:

- External fault voltages cannot propagate back into the HIL device unless explicitly intended.
- Channel fault conditions remain fully controlled and isolated.
- Equipment safety is maintained even in complex fault configurations.

Fault insertion and removal occur under full software control, allowing precise timing and repeatable fault simulation during automated testing.

7.3.5 Fault Insertion Control

Fault insertion is controlled through the internal relay control system using either:

- Direct CAN communication, or
- THCC software interface

Each relay can be individually controlled, allowing independent configuration of fault conditions for every channel.

This enables simulation of both static and dynamic fault scenarios, including:

- Permanent faults
- Intermittent faults
- Sequential fault injection
- Automated fault testing sequences

The relay-based implementation ensures deterministic switching behavior and high reliability over extended operation.

7.3.6 Operational Summary

The fault insertion system enables simulation of realistic electrical fault conditions while maintaining full isolation and protection of connected equipment. By combining independent relay control, shared fault line architecture, and integrated protection mechanisms, the Breakout Box F provides a flexible and safe platform for advanced fault injection testing in Hardware-in-the-Loop environments.

7.4 Fault Protection System

The Breakout Box F incorporates an internal fault protection mechanism designed to prevent relay configurations that could expose connected equipment to hazardous voltage levels.

Under certain conditions, externally applied fault signals (FL1, FL2, FL3) may exceed the safe operating limits of the connected HIL Analog/Digital I/O. If relay K1 (IN) is simultaneously activated while a high fault voltage is present, voltages greater than ±24 VDC could be routed toward the HIL interface, potentially causing permanent damage.

To eliminate this risk, the device firmware continuously monitors commanded relay states received via CAN and blocks unsafe combinations before they can be applied. This protection is implemented within the BOB microcontroller and operates automatically without requiring user intervention.

When an invalid relay configuration is requested, the command is ignored and the relays remain in a safe state.

Allowed Relay Configurations

The following table defines the valid relay states permitted by the protection system. Any combination not listed above is automatically rejected by the protection logic.

Status	K1 – IN1	K2 – FL1	K3 – FL2	K4 – FL3
Allowed	Closed	Open	Open	Open
Allowed	Open	Closed	Open	Open
Allowed	Open	Open	Closed	Open
Allowed	Open	Open	Open	Closed

Table 7.1 Allowed relay configurations

8 Device Control via THCC Software

The Breakout Box F supports device control through the Typhoon HIL Control Center (THCC), enabling both manual operations and fully automated Hardware-in-the-Loop testing. THCC provides a straightforward method for configuring channel relays and fault conditions directly from the simulation environment, eliminating the need for detailed knowledge of the device's internal communication structure.

To further simplify deployment, Typhoon HIL provides the e-Drive THCC package, which includes a standardized Breakout Box F component together with a dedicated SCADA interface for intuitive device control. This preconfigured implementation reduces setup effort and enables rapid integration into test models without requiring manual component construction, allowing the device to be deployed quickly while maintaining consistent system behavior.

8.1 Component Description

The following section describes the component, its architecture and highlights the key configuration elements required for proper device operation.

8.1.1 Schematic Editor

Within the Schematic Editor, the Breakout Box F is available as a dedicated control component. Its properties panel allows users to fully configure communication with the device, as well as import channel names from a file or enter them manually.

Configuration parameters accessible from the properties panel include:

- Json or xlsx file – Supports import of .json or .xlsx files containing channel assignments and corresponding channel identifiers. The supported channel range covers both EDAC connector channels and dedicated DB9 channels, ensuring full coverage of all device interfaces.
- Place CAN Setup – Automatically inserts and configures the required CAN communication component if it is not already present in the schematic.
- CAN TX time-step – Defines the execution rate of the CAN messages. This parameter is named Ts_slow and is defined in the initialization script, with a default value of 1 ms.
- TX pause – Specifies the delay between consecutive CAN transmissions, allowing the bus utilization and update timing to be adjusted. The default value is 50 time-step units, and the allowable range is 0 to 100. Example is provided below.
- BOB CAN ID – Specifies the real device address that must match the rotary switch configuration on the rear panel of the device.
- Type in signals – Opens the Signal Editor configuration interface for manual entry or modification of all channel names.
- Build Signals – Automatically generates the required SCADA inputs and communication structure from file or dialog for all 150 channels.

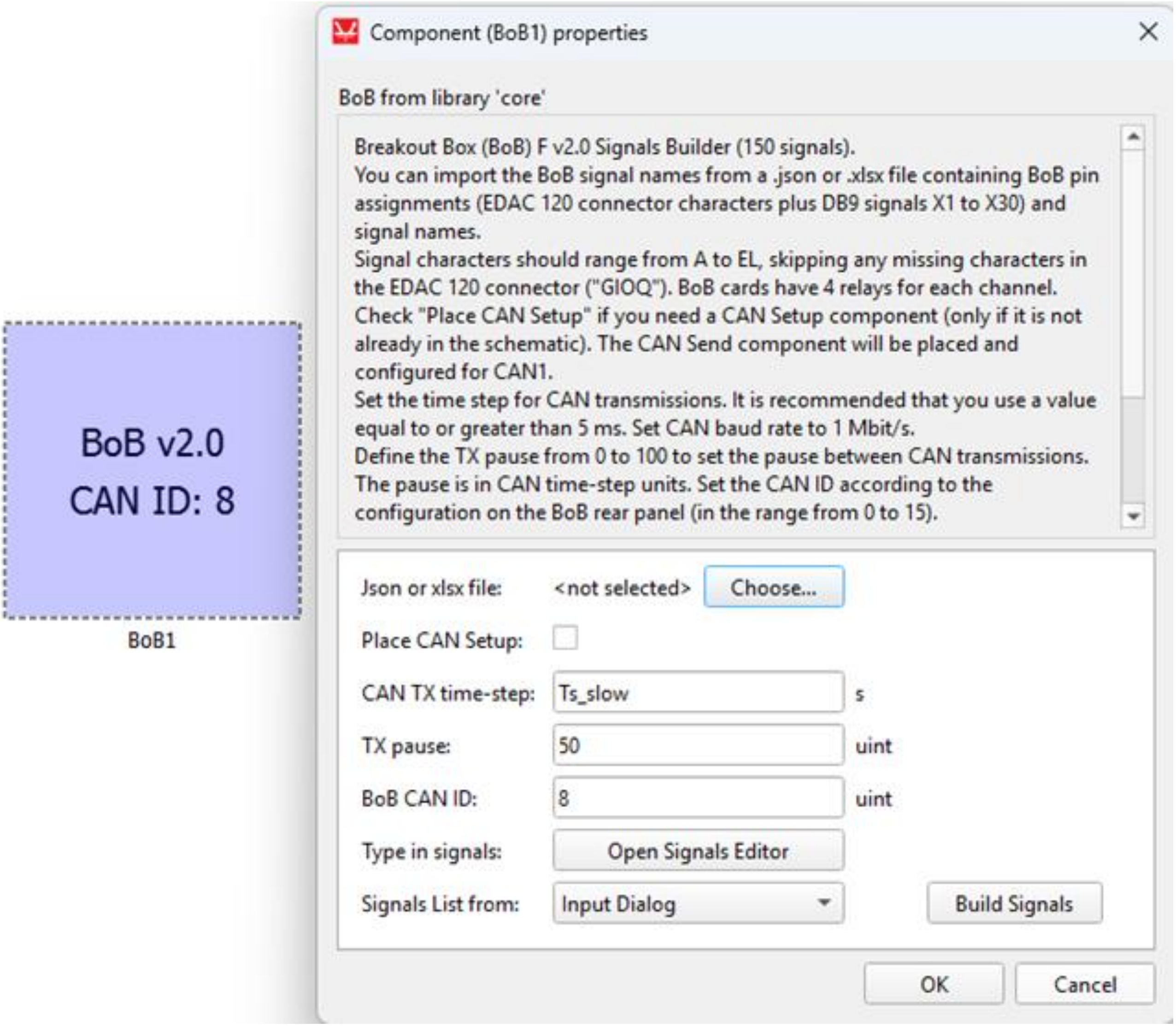


Figure 8.1 BOB-F component in the THCC schematic editor

Example:

For example, if the execution rate Ts_slow is 1 ms and the delay between consecutive transmissions (TX pause) is set to 50, the system will wait 50 ms after completing one transmission before initiating the next cycle.

The achievable execution rate is limited by the mechanical switching speed of the relays, i.e. how quickly they can change state, and is constrained to a minimum cycle time of 5 ms between consecutive cycles.

8.1.2 SCADA Panel

When deployed within the SCADA environment, the Breakout Box F component provides an interactive control interface for monitoring and commanding relay states in real time.

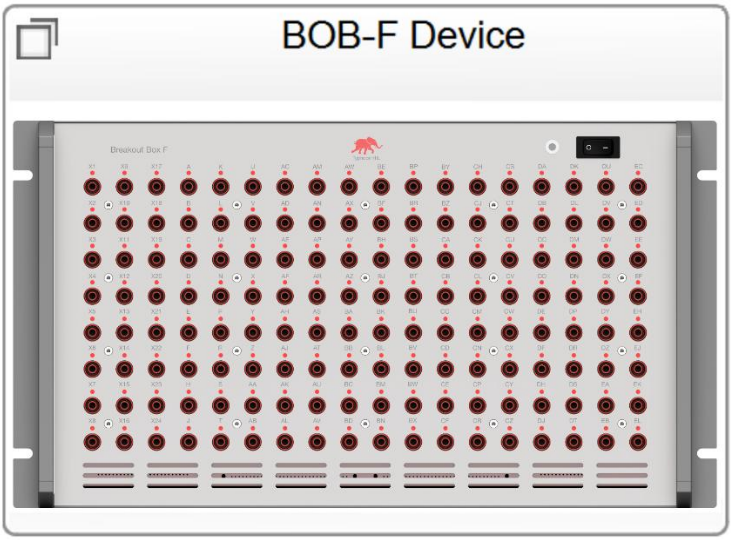


Figure 8.2 Component look in the SCADA Panel

The SCADA panel presents a graphical representation of the device together with grouped control elements that allow immediate access to channel behavior.

Key control features include:

- Global Relay Commands – Controls such as *Open All Relays* and *Close All K1 Relays* enable rapid system initialization and safe-state configuration during test preparation.
- Individual Channel Relay Control – Individual checkboxes for relays K1 through K4 allow precise configuration of the signal path and fault insertion behavior for the selected channel.
- Channel Selection – A signal selector combined with a channel indicator provides clear identification of the active channel being controlled.

Using these configuration buttons as an example, users can create a custom initialization script to configure and control the relay channels according to their requirements.

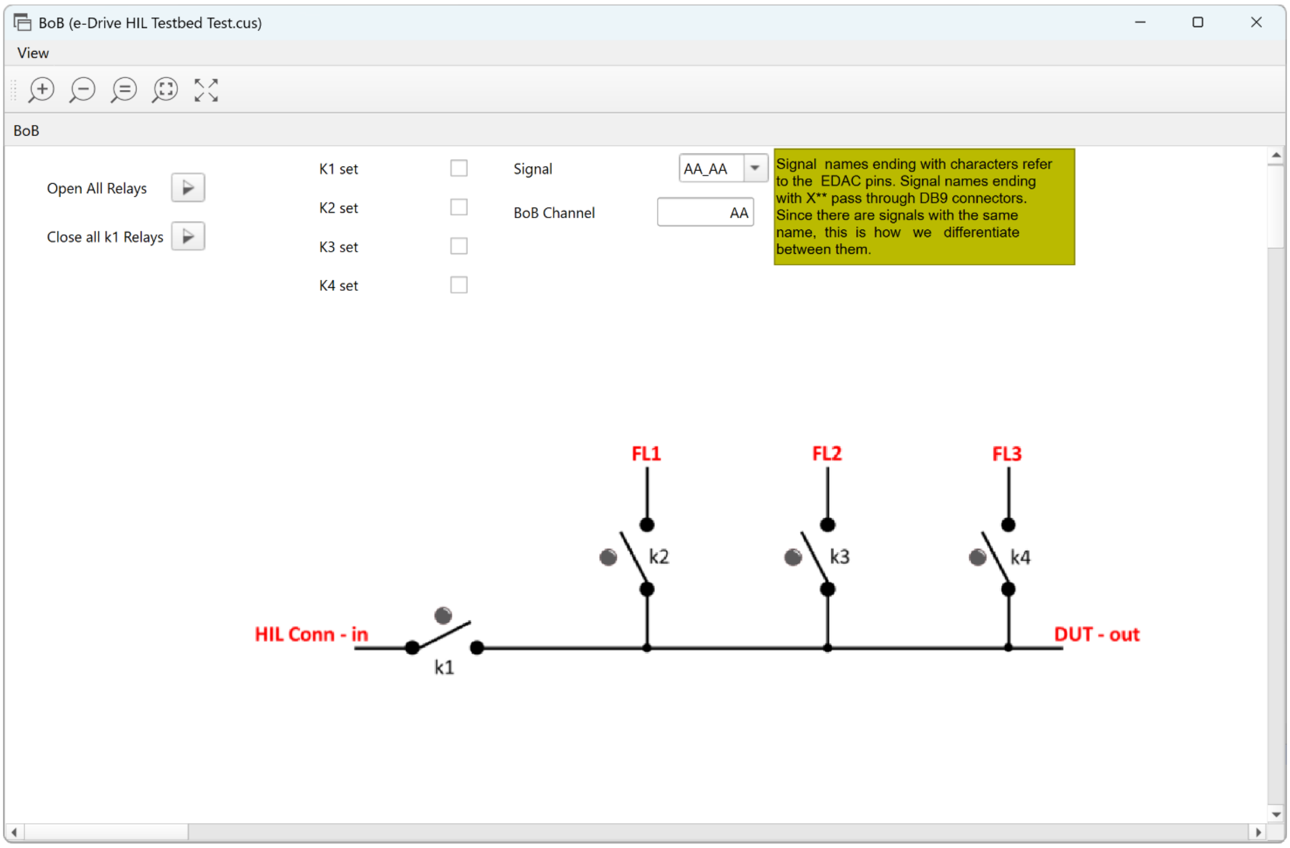


Figure 8.3 BOB-F SCADA Panel widget

Channel names ending with alphabetical characters correspond to EDAC connector pins, while signals labeled with the X suffix are routed through DB9 connectors. This naming structure helps differentiate channels that may otherwise share similar identifiers.

8.1.3 Control Architecture

Within the Schematic Editor environment, each relay is controlled using an individual SCADA Input component. Since the device contains 150 channels with four relays per channel, a total of 600 SCADA inputs are required to define all relay states.

Each SCADA input represents a binary control signal that determines whether a relay is open or closed. Updating the complete relay configuration requires transmission of 75 bytes of control data over the CAN communication interface.

The Breakout Box F CAN interface is internally hard-wired to the HIL CAN 1 channel, ensuring a direct and deterministic communication path between the simulation model and the device.

8.1.4 CAN Send Component and Signal Organization

Relay control data is transmitted using a dedicated CAN Send component within the BOB F component in the Schematic Editor.

The input *signal0* acts as a switching control used to select groups of relay control signals during transmission. To send the full set of 600 relay control bits, the switching signal cycles through values 1 to 15, with each value selecting a corresponding 40-bit signal group (10 channels) mapped to inputs *signal1* through *signal5* of the CAN Send component.

A Repeating Sequence Discrete component ("*z sequence*") is used to generate the switching signal. This sequence also controls a multiport signal switch responsible for selecting which relay group is transmitted during each CAN cycle.

This multiplexed transmission method reduces CAN bus utilization while maintaining predictable update behavior suitable for real-time Hardware-in-the-Loop applications.

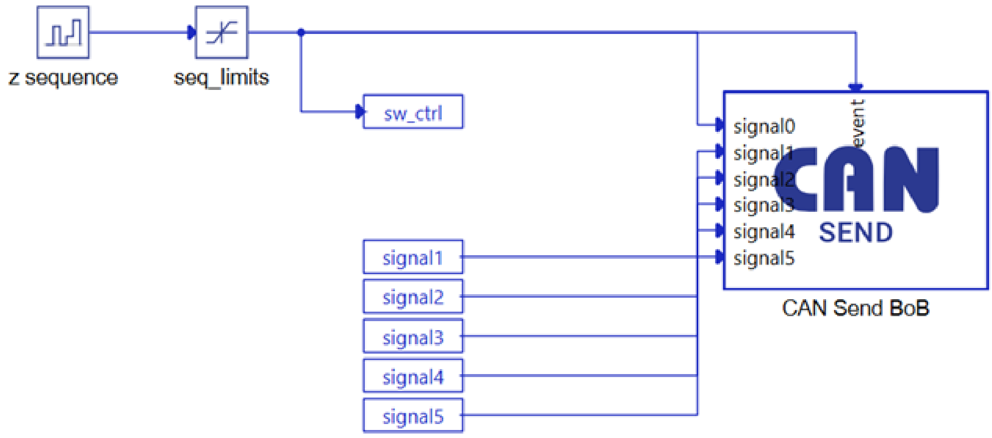


Figure 8.4 CAN Send BOB-F component

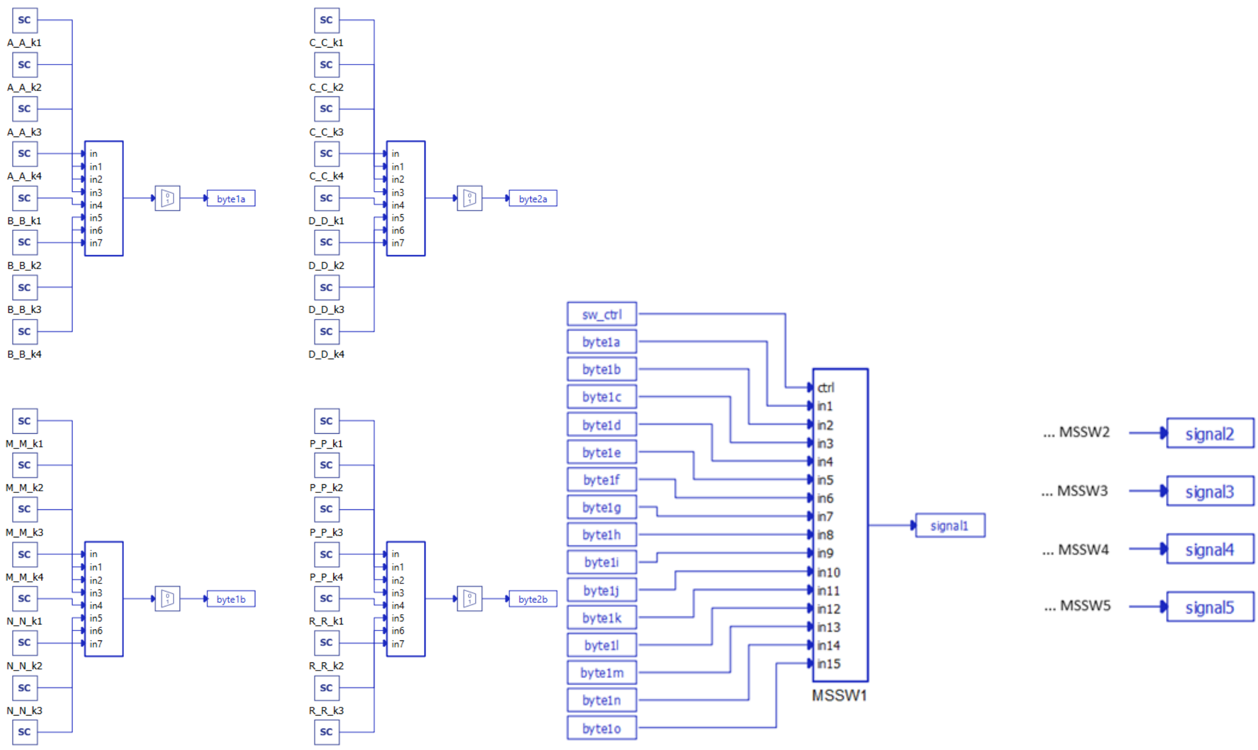


Figure 8.5 BOB-F channels multiplexing

8.1.5 Signals Builder Interface

To simplify channel naming, the component provides a dedicated Signals Builder interface that automates the assignment of channel names within the Schematic Editor.

The interface includes a script capable of generating SCADA inputs based on channels name definitions imported from either a structured .json file or a predefined .xlsx spreadsheet template.

The JSON structure must contain paired entries consisting of the signal identifier (for example A, B, … AB, AC) and its corresponding user-defined name. Spreadsheet-based imports must follow the predefined format supplied with the e-Drive package.

```
{
    "A": "5V_S",
    "B": "15V_GD",
    "C": "5V_GD",
    "D": "",
    "E": "",
    "F": "GND",
    "H": "CRT_W",
    "J": "CRT_U",
    "K": "CRT_V",
    "L": "CRT_DC",
    "M": "HV_VDC1",
    "N": "5V_Buck",
    "P": "",
          .
          .
          .
```

Figure 8.6 BOB-F JSON file structure

This automated generation approach significantly reduces configuration time while minimizing the risk of naming inconsistencies or mapping errors.

9 Pinout

This section defines the pin assignments for all external connectors of the Breakout Box F. The provided information enables accurate system integration and reliable electrical interfacing.

9.1 General Purpose Channels Pinout

This section defines the pin assignments for the general purpose channels available on the IN and OUT connectors.

Signals applied to the IN connector are routed through the internal fault insertion network and forwarded to the corresponding pins on the OUT connector. Pin naming follows the EDAC connector convention to ensure straightforward cable assembly and system integration.

All channels present on the OUT connector are additionally routed to the corresponding front panel banana jacks, allowing direct and convenient channel probing via the 4 mm banana jacks.

The types of connectors used for general purpose channels are:

- IN connector: EDAC 120 Plug (516-120-520-302)
- OUT connector: EDAC 120 Receptacle (516-120-520-402)

Refer to the tables below for detailed pin mappings.

9.1.1 Connector IN Pinout Table

No.	Connector Pin	BOB Channel Name	Front Panel Probing
I1	A	A	NO
I2	B	B	NO
I3	C	C	NO
I4	D	D	NO
I5	E	E	NO
I6	F	F	NO
I7	H	H	NO
I8	J	J	NO
I9	K	K	NO
I10	L	L	NO
I11	M	M	NO
I12	N	N	NO
I13	P	P	NO
I14	R	R	NO
I15	S	S	NO
I16	T	T	NO
I17	U	U	NO
I18	V	V	NO
I19	W	W	NO
I20	X	X	NO
I21	Y	Y	NO
I22	Z	Z	NO
I23	AA	AA	NO
I24	AB	AB	NO
I25	AC	AC	NO
I26	AD	AD	NO
I27	AE	AE	NO
I28	AF	AF	NO
I29	AH	AH	NO
I30	AJ	AJ	NO
I31	AK	AK	NO
I32	AL	AL	NO
I33	AM	AM	NO
I34	AN	AN	NO
I35	AP	AP	NO
I36	AR	AR	NO
I37	AS	AS	NO
I38	AT	AT	NO
I39	AU	AU	NO
I40	AV	AV	NO
I41	AW	AW	NO
I42	AX	AX	NO
I43	AY	AY	NO
I44	AZ	AZ	NO
I45	BA	BA	NO
I46	BB	BB	NO
I47	BC	BC	NO
I48	BD	BD	NO
I49	BE	BE	NO
I50	BF	BF	NO
I51	BH	BH	NO
I52	BJ	BJ	NO
I53	BK	BK	NO
I54	BL	BL	NO
I55	BM	BM	NO
I56	BN	BN	NO
I57	BP	BP	NO
I58	BR	BR	NO
I59	BS	BS	NO
I60	BT	BT	NO
I61	BU	BU	NO
I62	BV	BV	NO
I63	BW	BW	NO
I64	BX	BX	NO
I65	BY	BY	NO
I66	BZ	BZ	NO
I67	CA	CA	NO
I68	CB	CB	NO
I69	CC	CC	NO
I70	CD	CD	NO
I71	CE	CE	NO
I72	CF	CF	NO
I73	CH	CH	NO
I74	CJ	CJ	NO
I75	CK	CK	NO
I76	CL	CL	NO
I77	CM	CM	NO
I78	CN	CN	NO
I79	CP	CP	NO
I80	CR	CR	NO
I81	CS	CS	NO
I82	CT	CT	NO
I83	CU	CU	NO
I84	CV	CV	NO
I85	CW	CW	NO
I86	CX	CX	NO
I87	CY	CY	NO
I88	CZ	CZ	NO
I89	DA	DA	NO
I90	DB	DB	NO
I91	DC	DC	NO
I92	DD	DD	NO
I93	DE	DE	NO
I94	DF	DF	NO
I95	DH	DH	NO
I96	DJ	DJ	NO
I97	DK	DK	NO
I98	DL	DL	NO
I99	DM	DM	NO
I100	DN	DN	NO
I101	DP	DP	NO
I102	DR	DR	NO
I103	DS	DS	NO
I104	DT	DT	NO
I105	DU	DU	NO
I106	DV	DV	NO
I107	DW	DW	NO
I108	DX	DX	NO
I109	DY	DY	NO
I110	DZ	DZ	NO
I111	EA	EA	NO
I112	EB	EB	NO
I113	EC	EC	NO
I114	ED	ED	NO
I115	EE	EE	NO
I116	EF	EF	NO
I117	EH	EH	NO
I118	EJ	EJ	NO
I119	EK	EK	NO
I120	EL	EL	NO

Table 9.1 Connector EDAC IN pinout

9.1.2 Connector OUT Pinout Table

No.	Connector Pin	BOB Channel Name	Front Panel Probing
O1	A	A	YES
O2	B	B	YES
O3	C	C	YES
O4	D	D	YES
O5	E	E	YES
O6	F	F	YES
O7	H	H	YES
O8	J	J	YES
O9	K	K	YES
O10	L	L	YES
O11	M	M	YES
O12	N	N	YES
O13	P	P	YES
O14	R	R	YES
O15	S	S	YES
O16	T	T	YES
O17	U	U	YES
O18	V	V	YES
O19	W	W	YES
O20	X	X	YES
O21	Y	Y	YES
O22	Z	Z	YES
O23	AA	AA	YES
O24	AB	AB	YES
O25	AC	AC	YES
O26	AD	AD	YES
O27	AE	AE	YES
O28	AF	AF	YES
O29	AH	AH	YES
O30	AJ	AJ	YES
O31	AK	AK	YES
O32	AL	AL	YES
O33	AM	AM	YES
O34	AN	AN	YES
O35	AP	AP	YES
O36	AR	AR	YES
O37	AS	AS	YES
O38	AT	AT	YES
O39	AU	AU	YES
O40	AV	AV	YES
O41	AW	AW	YES
O42	AX	AX	YES
O43	AY	AY	YES
O44	AZ	AZ	YES
O45	BA	BA	YES
O46	BB	BB	YES
O47	BC	BC	YES
O48	BD	BD	YES
O49	BE	BE	YES
O50	BF	BF	YES
O51	BH	BH	YES
O52	BJ	BJ	YES
O53	BK	BK	YES
O54	BL	BL	YES
O55	BM	BM	YES
O56	BN	BN	YES
O57	BP	BP	YES
O58	BR	BR	YES
O59	BS	BS	YES
O60	BT	BT	YES
O61	BU	BU	YES
O62	BV	BV	YES
O63	BW	BW	YES
O64	BX	BX	YES
O65	BY	BY	YES
O66	BZ	BZ	YES
O67	CA	CA	YES
O68	CB	CB	YES
O69	CC	CC	YES
O70	CD	CD	YES
O71	CE	CE	YES
O72	CF	CF	YES
O73	CH	CH	YES
O74	CJ	CJ	YES
O75	CK	CK	YES
O76	CL	CL	YES
O77	CM	CM	YES
O78	CN	CN	YES
O79	CP	CP	YES
O80	CR	CR	YES
O81	CS	CS	YES
O82	CT	CT	YES
O83	CU	CU	YES
O84	CV	CV	YES
O85	CW	CW	YES
O86	CX	CX	YES
O87	CY	CY	YES
O88	CZ	CZ	YES
O89	DA	DA	YES
O90	DB	DB	YES
O91	DC	DC	YES
O92	DD	DD	YES
O93	DE	DE	YES
O94	DF	DF	YES
O95	DH	DH	YES
O96	DJ	DJ	YES
O97	DK	DK	YES
O98	DL	DL	YES
O99	DM	DM	YES
O100	DN	DN	YES
O101	DP	DP	YES
O102	DR	DR	YES
O103	DS	DS	YES
O104	DT	DT	YES
O105	DU	DU	YES
O106	DV	DV	YES
O107	DW	DW	YES
O108	DX	DX	YES
O109	DY	DY	YES
O110	DZ	DZ	YES
O111	EA	EA	YES
O112	EB	EB	YES
O113	EC	EC	YES
O114	ED	ED	YES
O115	EE	EE	YES
O116	EF	EF	YES
O117	EH	EH	YES
O118	EJ	EJ	YES
O119	EK	EK	YES
O120	EL	EL	YES

Table 9.2 Connector EDAC OUT Pinout

9.2 Dedicated Channels Pinout

This section provides the pin assignments for the dedicated channels implemented on the back panel input and output sides. Both sides utilize the DSub9 Plug (163A16259X) connectors.

Dedicated channels are intended for signals that require improved noise immunity or standardized connector layouts, such as CAN and resolver communication interfaces. Each input pin is internally routed through the fault insertion stage and connected to the corresponding output pin.

The first 24 channels present on the OUT connector are additionally routed to the corresponding front panel banana jacks, allowing direct and convenient channel probing via the 4 mm banana jacks. The last 6 channels are not present on the front panel.

Detailed pin descriptions are listed in the following tables.

9.2.1 CANx_IN Pinout Table

No.	Connector Name	Connector Pin	BOB Channel Name	Front Panel Probing
NC	CAN1_IN	1	NA	NA
I121	CAN1_IN	2	X1	YES
NC	CAN1_IN	3	NA	NA
NC	CAN1_IN	4	NA	NA
NC	CAN1_IN	5	NA	NA
NC	CAN1_IN	6	NA	NA
I122	CAN1_IN	7	X2	YES
NC	CAN1_IN	8	NA	NA
NC	CAN1_IN	9	NA	NA
NC	CAN2_IN	1	NA	NA
I123	CAN2_IN	2	X3	YES
NC	CAN2_IN	3	NA	NA
NC	CAN2_IN	4	NA	NA
NC	CAN2_IN	5	NA	NA
NC	CAN2_IN	6	NA	NA
I124	CAN2_IN	7	X4	YES
NC	CAN2_IN	8	NA	NA
NC	CAN2_IN	9	NA	NA
NC	CAN3_IN	1	NA	NA
I125	CAN3_IN	2	X5	YES
NC	CAN3_IN	3	NA	NA
NC	CAN3_IN	4	NA	NA
NC	CAN3_IN	5	NA	NA
NC	CAN3_IN	6	NA	NA
I126	CAN3_IN	7	X6	YES
NC	CAN3_IN	8	NA	NA
NC	CAN3_IN	9	NA	NA
NC	CAN4_IN	1	NA	NA
I127	CAN4_IN	2	X7	YES
NC	CAN4_IN	3	NA	NA
NC	CAN4_IN	4	NA	NA
NC	CAN4_IN	5	NA	NA
NC	CAN4_IN	6	NA	NA
I128	CAN4_IN	7	X8	YES
NC	CAN4_IN	8	NA	NA
NC	CAN4_IN	9	NA	NA

Table 9.3 Pinout of the input side on the dedicated channels

9.2.2 RESx_IN and AUXx_IN Pinout Table

No.	Connector Name	Connector Pin	BOB Channel Name	Front Panel Probing
NC	RES1_IN	1	NA	NA
NC	RES1_IN	2	NA	NA
I130	RES1_IN	3	X10	YES
I132	RES1_IN	4	X12	YES
I134	RES1_IN	5	X14	YES
NC	RES1_IN	6	NA	NA
I129	RES1_IN	7	X9	YES
I131	RES1_IN	8	X11	YES
I133	RES1_IN	9	X13	YES
NC	RES1_EXC_IN	1	NA	NA
NC	RES1_EXC_IN	2	NA	NA
NC	RES1_EXC_IN	3	NA	NA
NC	RES1_EXC_IN	4	NA	NA
I134	RES1_EXC_IN	5	X14	YES
NC	RES1_EXC_IN	6	NA	NA
NC	RES1_EXC_IN	7	NA	NA
NC	RES1_EXC_IN	8	NA	NA
I133	RES1_EXC_IN	9	X13	YES
NC	RES2_IN	1	NA	NA
NC	RES2_IN	2	NA	NA
I136	RES2_IN	3	X16	YES
I138	RES2_IN	4	X18	YES
I140	RES2_IN	5	X20	YES
NC	RES2_IN	6	NA	NA
I135	RES2_IN	7	X15	YES
I137	RES2_IN	8	X17	YES
I139	RES2_IN	9	X19	YES
NC	RES2_EXC_IN	1	NA	NA
NC	RES2_EXC_IN	2	NA	NA
NC	RES2_EXC_IN	3	NA	NA
NC	RES2_EXC_IN	4	NA	NA
I140	RES2_EXC_IN	5	X20	YES
NC	RES2_EXC_IN	6	NA	NA
NC	RES2_EXC_IN	7	NA	NA
NC	RES2_EXC_IN	8	NA	NA
I139	RES2_EXC_IN	9	X19	YES
NC	AUX1_IN	1	NA	NA
I141	AUX1_IN	2	X21	YES
NC	AUX1_IN	3	NA	NA
I144	AUX1_IN	4	X26	NO
NC	AUX1_IN	5	NA	NA
NC	AUX1_IN	6	NA	NA
I142	AUX1_IN	7	X22	YES
I143	AUX1_IN	8	X25	NO
I145	AUX1_IN	9	X27	NO
NC	AUX2_IN	1	NA	NA
I146	AUX2_IN	2	X23	YES
NC	AUX2_IN	3	NA	NA
I149	AUX2_IN	4	X29	NO
NC	AUX2_IN	5	NA	NA
NC	AUX2_IN	6	NA	NA
I147	AUX2_IN	7	X24	YES
I148	AUX2_IN	8	X28	NO
I150	AUX2_IN	9	X30	NO

Table 9.4 Pinout of the input side on the dedicated channels – continued

9.2.1 CANx_OUT Pinout Table

No.	Connector Name	Connector Pin	BOB Channel Name	Front Panel Probing
NC	CAN1_OUT	1	NA	NA
O121	CAN1_OUT	2	X1	YES
NC	CAN1_OUT	3	NA	NA
NC	CAN1_OUT	4	NA	NA
NC	CAN1_OUT	5	NA	NA
NC	CAN1_OUT	6	NA	NA
O122	CAN1_OUT	7	X2	YES
NC	CAN1_OUT	8	NA	NA
NC	CAN1_OUT	9	NA	NA
NC	CAN2_OUT	1	NA	NA
O123	CAN2_OUT	2	X3	YES
NC	CAN2_OUT	3	NA	NA
NC	CAN2_OUT	4	NA	NA
NC	CAN2_OUT	5	NA	NA
NC	CAN2_OUT	6	NA	NA
O124	CAN2_OUT	7	X4	YES
NC	CAN2_OUT	8	NA	NA
NC	CAN2_OUT	9	NA	NA
NC	CAN3_OUT	1	NA	NA
O125	CAN3_OUT	2	X5	YES
NC	CAN3_OUT	3	NA	NA
NC	CAN3_OUT	4	NA	NA
NC	CAN3_OUT	5	NA	NA
NC	CAN3_OUT	6	NA	NA
O126	CAN3_OUT	7	X6	YES
NC	CAN3_OUT	8	NA	NA
NC	CAN3_OUT	9	NA	NA
NC	CAN4_OUT	1	NA	NA
O127	CAN4_OUT	2	X7	YES
NC	CAN4_OUT	3	NA	NA
NC	CAN4_OUT	4	NA	NA
NC	CAN4_OUT	5	NA	NA
NC	CAN4_OUT	6	NA	NA
O128	CAN4_OUT	7	X8	YES
NC	CAN4_OUT	8	NA	NA
NC	CAN4_OUT	9	NA	NA

Table 9.5 Pinout of the output side on the dedicated channels

9.2.2 RESx_OUT and AUXx_OUT Pinout Table

No.	Connector Name	Connector Pin	BOB Channel Name	Front Panel Probing
NC	RES1_OUT	1	NA	NA
NC	RES1_OUT	2	NA	NA
O130	RES1_OUT	3	X10	YES
O132	RES1_OUT	4	X12	YES
O134	RES1_OUT	5	X14	YES
NC	RES1_OUT	6	NA	NA
O129	RES1_OUT	7	X9	YES
O131	RES1_OUT	8	X11	YES
O133	RES1_OUT	9	X13	YES
NC	RES1_EXC_OUT	1	NA	NA
NC	RES1_EXC_OUT	2	NA	NA
NC	RES1_EXC_OUT	3	NA	NA
NC	RES1_EXC_OUT	4	NA	NA
O134	RES1_EXC_OUT	5	X14	YES
NC	RES1_EXC_OUT	6	NA	NA
NC	RES1_EXC_OUT	7	NA	NA
NC	RES1_EXC_OUT	8	NA	NA
O133	RES1_EXC_OUT	9	X13	YES
NC	RES2_OUT	1	NA	NA
NC	RES2_OUT	2	NA	NA
O136	RES2_OUT	3	X16	YES
O138	RES2_OUT	4	X18	YES
O140	RES2_OUT	5	X20	YES
NC	RES2_OUT	6	NA	NA
O135	RES2_OUT	7	X15	YES
O137	RES2_OUT	8	X17	YES
O139	RES2_OUT	9	X19	YES
NC	RES2_EXC_OUT	1	NA	NA
NC	RES2_EXC_OUT	2	NA	NA
NC	RES2_EXC_OUT	3	NA	NA
NC	RES2_EXC_OUT	4	NA	NA
O140	RES2_EXC_OUT	5	X20	YES
NC	RES2_EXC_OUT	6	NA	NA
NC	RES2_EXC_OUT	7	NA	NA
NC	RES2_EXC_OUT	8	NA	NA
O139	RES2_EXC_OUT	9	X19	YES
NC	AUX1_OUT	1	NA	NA
O141	AUX1_OUT	2	X21	YES
NC	AUX1_OUT	3	NA	NA
O144	AUX1_OUT	4	X26	NO
NC	AUX1_OUT	5	NA	NA
NC	AUX1_OUT	6	NA	NA
O142	AUX1_OUT	7	X22	YES
O143	AUX1_OUT	8	X25	NO
O145	AUX1_OUT	9	X27	NO
NC	AUX2_OUT	1	NA	NA
O146	AUX2_OUT	2	X23	YES
NC	AUX2_OUT	3	NA	NA
O149	AUX2_OUT	4	X29	NO
NC	AUX2_OUT	5	NA	NA
NC	AUX2_OUT	6	NA	NA
O147	AUX2_OUT	7	X24	YES
O148	AUX2_OUT	8	X28	NO
O150	AUX2_OUT	9	X30	NO

Table 9.6 Pinout of the input side on the dedicated channels - continued

9.3 Fault Channels Pinout

This section describes the pin assignments for the external fault line interfaces. Fault signals can be connected using either the SL 5.08HC/08/180G 3.2SN BK BX connector or the CT3149-2 4 mm banana jacks.

Both connection methods provide access to the same three independent fault channels, allowing flexible wiring depending on the application requirements. These inputs enable externally supplied voltage levels to be injected into the fault insertion network.

Refer to the tables below for complete pin allocation.

No.	Connector Name	Connector Pin	BOB Channel Name	Front Panel Probing	Assigned Relay
1	FAULT	1	FL1	NO	K2
2	FAULT	2	FL1	NO	K2
3	FAULT	3	NA	NO	NA
4	FAULT	4	FL2	NO	K3
5	FAULT	5	FL2	NO	K3
6	FAULT	6	NA	NO	Na
7	FAULT	7	FL3	NO	K4
8	FAULT	8	FL3	NO	K4

Table 9.7 Connector SL 5.08HC/08/180G 3.2SN BK BX pinout

No.	Connector Name	Connector Pin	BOB Channel Name	Front Panel Probing	Assigned Relay
1	FL1	1	FL1	NO	K1
2	FL2	2	FL2	NO	K2
3	FL3	3	FL3	NO	K3

Table 9.8 CT3149-2 4 mm banana jacks pinout

9.4 CAN Splitter Pinout

This section defines the pin assignments for the CAN splitter interfaces, including the HIL_CAN input connector and the HIL_CAN_1 through HIL_CAN_4 output connectors.

The splitter distributes two CAN and two CAN FD communication lines from the HIL device while preserving signal integrity and supporting configurable bus termination. In addition to external distribution, the splitter internally routes the HIL_CAN_1 connection within the Breakout Box F, enabling direct communication with the device.

Detailed pin mappings for each connector are provided in the following table.

No.	Connector Name	Connector Pin	Signal Name	Front Panel Probing
1	HIL_CAN	1	CANFD1_H	NO
2	HIL_CAN	2	CAN1_N	NO
3	HIL_CAN	3	GND	NO
4	HIL_CAN	4	CAN2_N	NO
5	HIL_CAN	5	CANFD2_N	NO
6	HIL_CAN	6	CANFD1_L	NO
7	HIL_CAN	7	CAN1_P	NO
8	HIL_CAN	8	CAN2_P	NO
9	HIL_CAN	9	CANFD2_P	NO
10	HIL_CAN_1	1	NC	NO
11	HIL_CAN_1	2	CAN1_N	NO
12	HIL_CAN_1	3	GND	NO
13	HIL_CAN_1	4	NC	NO
14	HIL_CAN_1	5	NC	NO
15	HIL_CAN_1	6	NC	NO
16	HIL_CAN_1	7	CAN1_P	NO
17	HIL_CAN_1	8	NC	NO
18	HIL_CAN_1	9	NC	NO
19	HIL_CAN_2	1	NC	NO
20	HIL_CAN_2	2	CAN2_N	NO
21	HIL_CAN_2	3	GND	NO
22	HIL_CAN_2	4	NC	NO
23	HIL_CAN_2	5	NC	NO
24	HIL_CAN_2	6	NC	NO
25	HIL_CAN_2	7	CAN2_P	NO
26	HIL_CAN_2	8	NC	NO
27	HIL_CAN_2	9	NC	NO
28	HIL_CAN_3	1	NC	NO
29	HIL_CAN_3	2	CANFD1_H	NO
30	HIL_CAN_3	3	GND	NO
31	HIL_CAN_3	4	NC	NO
32	HIL_CAN_3	5	NC	NO
33	HIL_CAN_3	6	NC	NO
34	HIL_CAN_3	7	CANFD1_L	NO
35	HIL_CAN_3	8	NC	NO
36	HIL_CAN_3	9	NC	NO
37	HIL_CAN_4	1	NC	NO
38	HIL_CAN_4	2	CANFD2_N	NO
39	HIL_CAN_4	3	GND	NO
40	HIL_CAN_4	4	NC	NO
41	HIL_CAN_4	5	NC	NO
42	HIL_CAN_4	6	NC	NO
43	HIL_CAN_4	7	CANFD2_P	NO
44	HIL_CAN_4	8	NC	NO
45	HIL_CAN_4	9	NC	NO

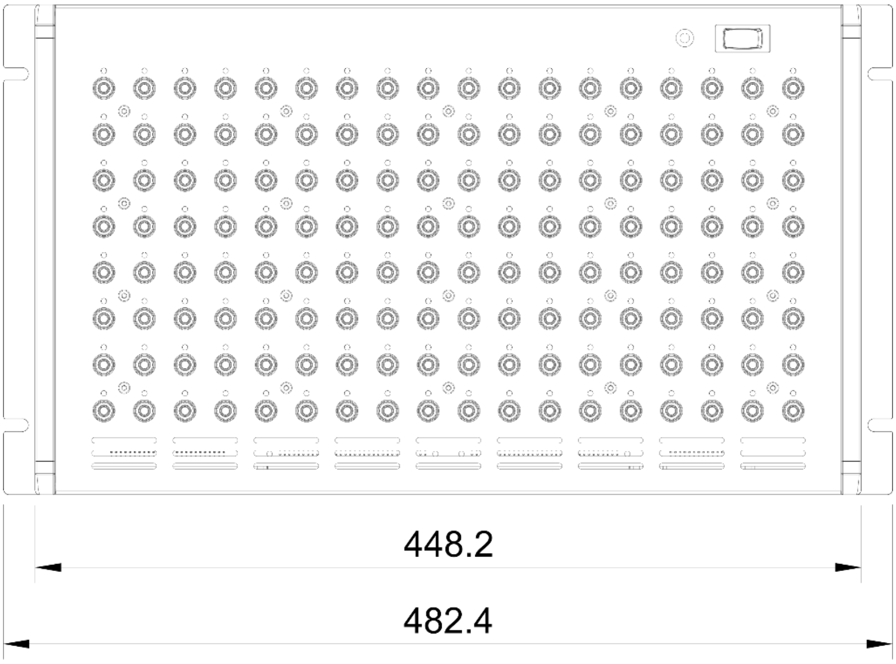
Table 9.9 CAN splitter pinout

10 Mechanical Characteristics

The Breakout Box F is housed in a robust 19-inch, 6U enclosure designed for both rack-mounted and desktop operation. The mechanical construction ensures high durability and stable operation in laboratory and industrial environments.

The overall device dimensions are provided in the mechanical drawing below. Adequate clearance should be ensured on the rear side of the device to allow proper cable routing and maintain the minimum bending radius of connected cables.

Integrated rack mounting points enable straightforward installation into standard 19-inch equipment racks without the need for additional adapters.



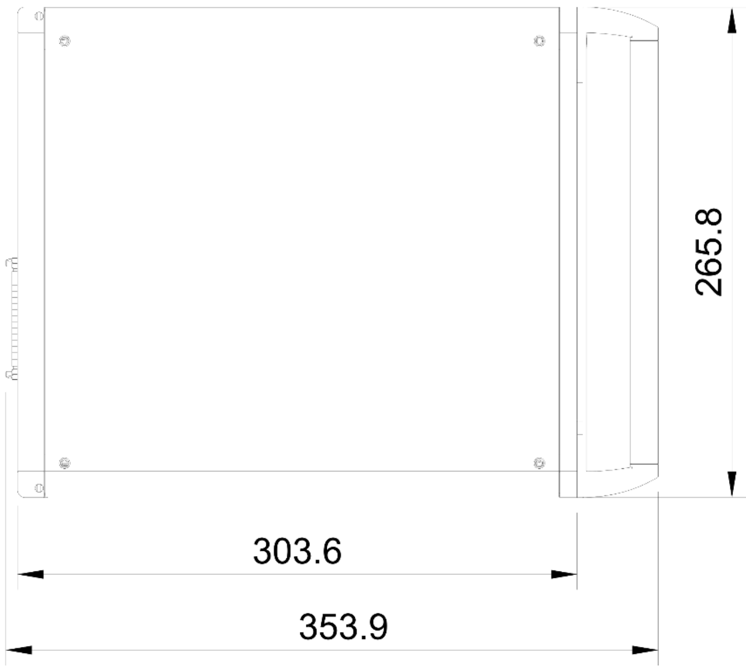


Figure 10.1 BOB-F Dimensions

10.1 Front and Rear Panels Print

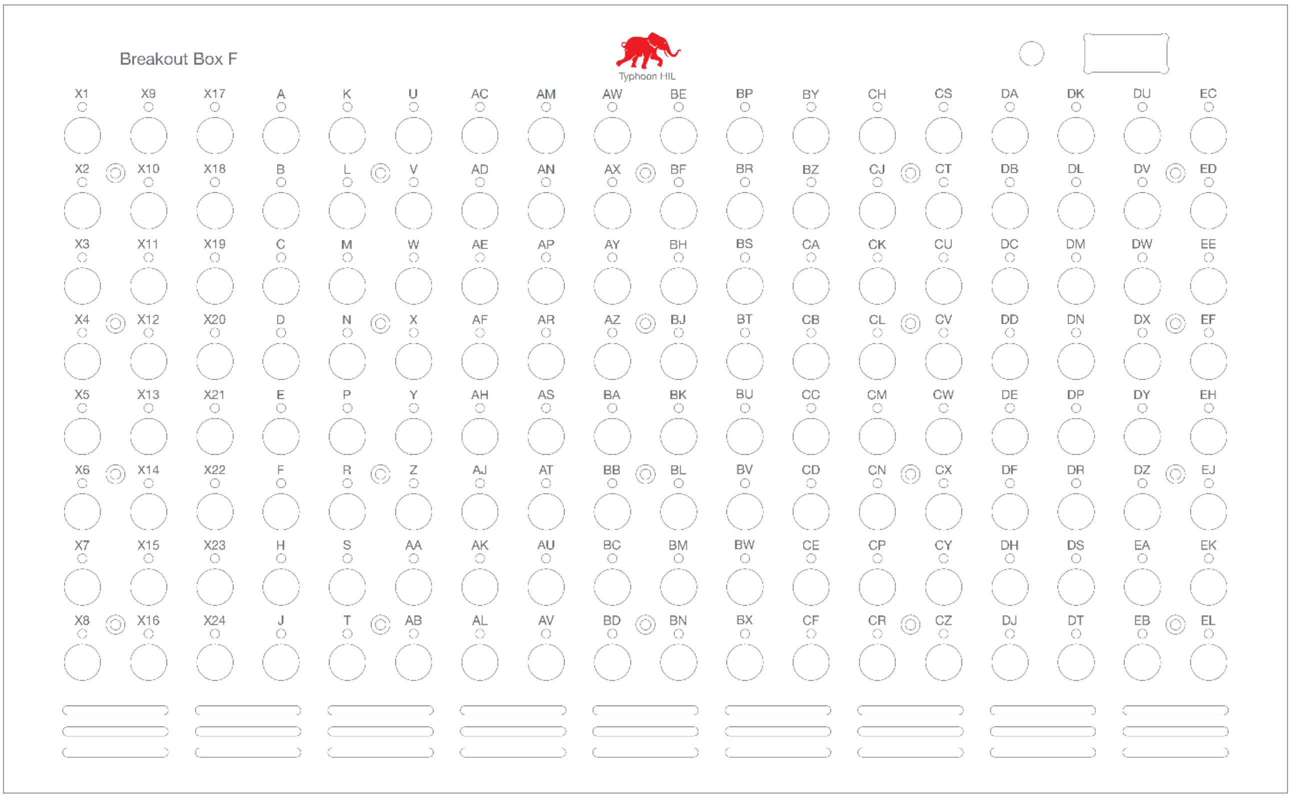


Table 10.1 Front panel print

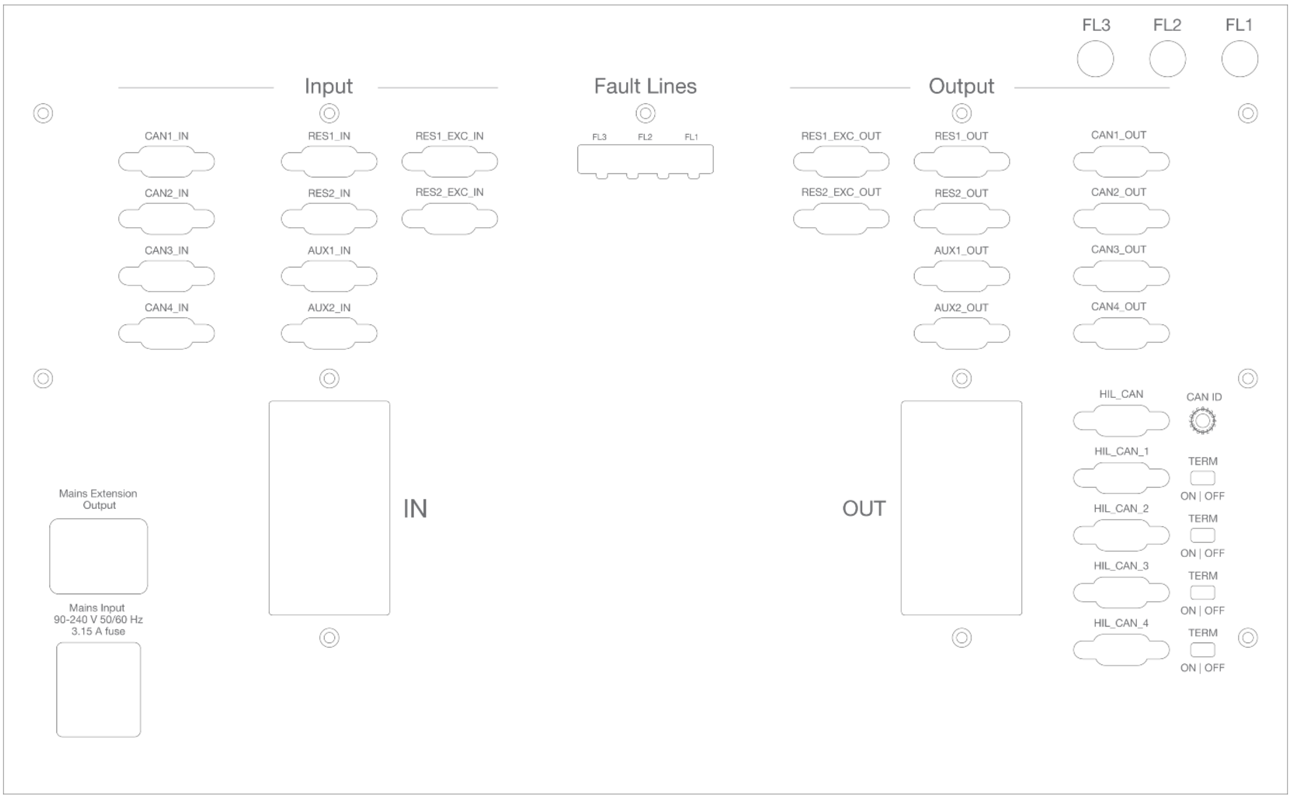


Table 10.2 Rear panel print

10.2 Mating Connectors and Tools

This chapter lists the recommended mating connectors, contacts, and tooling required for assembling wire harnesses compatible with the IN and OUT EDAC connectors used on the Breakout Box F device.

The EDAC 516 series connectors are rack and panel style interconnects available with various contact termination methods, including crimp contacts that can be ordered separately for cable assembly.

Required Tooling

The following tools are recommended for preparing and assembling crimp contacts used with the EDAC 516 connector system.

Tool	Manufacturer	Manufacturer Part Number	Description
Hand Crimper Tool	EDAC	516-280-201	Manual ratcheting hand crimper for 18–28 AWG wires used contacts.
Insertion / Removal Tool	EDAC	516-280-300	Tool for installing and extracting contacts in EDAC 516 connectors.
Contact Extraction Tool	EDAC	516-280-400	Tool used to safely remove crimped contacts from the connector housing.

Table 10.3 Required tooling for EDAC IN and OUT connectors

Mating Components

The following parts are required to assemble a complete mating harness.

Component	Manufacturer	Manufacturer Part Number	Description
120 Position Plug Housing	EDAC	516-120-000-301	120 position male housing with guide hardware for non-gendered contacts
120 Position Receptacle Housing	EDAC	516-120-000-401	120 position female housing with guide hardware for non-gendered contacts
Crimp Signal Contact	EDAC	516-290-590	Gold-plated non-gendered signal contact with crimp termination for 18–28 AWG wires.
Metal Cover Assembly	EDAC	516-230-612	Size-120 metal cover providing cable entry and mechanical protection.

Table 10.4 Mating components for EDAC IN and OUT connectors

For reliable operation, always use manufacturer-approved contacts and tooling when assembling cable harnesses. Proper crimping and contact installation help ensure stable electrical performance and reduce the risk of intermittent connections.

11 Scope of Delivery

Item	Typhoon HIL PN	Quantity
Breakout Box F	25419	1
Country-specific C14 power cord	20039 (EU), 20460 (US), 20044 (CH) or 20045 (UK)	1
HIL CAN cable - 2m	26319	1
Fault lines 8-pin connector BLF 5.08HC/08/180 SN BK BX	20920	1