

COMPREHENSIVE SERVICES

We offer competitive repair and calibration services, as well as easily accessible documentation and free downloadable resources.

SELL YOUR SURPLUS

We buy new, used, decommissioned, and surplus parts from every NI series. We work out the best solution to suit your individual needs.

 Sell For Cash  Get Credit  Receive a Trade-In Deal

OBSOLETE NI HARDWARE IN STOCK & READY TO SHIP

We stock **New**, **New Surplus**, **Refurbished**, and **Reconditioned** NI Hardware.



Bridging the gap between the manufacturer and your legacy test system.

 1-800-915-6216

 www.apexwaves.com

 sales@apexwaves.com

All trademarks, brands, and brand names are the property of their respective owners.

Request a Quote

 **CLICK HERE**

sbRIO-9505

sbRIO-9687

General Purpose Inverter Controller Universal Interface Board

This document describes the features of the sbRIO-9687 and contains information about connecting, configuring, and operating the device.

Contents

Overview.....	2
Features.....	3
Connectors.....	4
Switch and Resistor Configuration.....	5
Power Considerations.....	6
System Power and Grounding Recommendations.....	7
Power Input.....	8
GPIC Signals.....	8
Inverter Signals.....	9
Inverter CAN Bus Configuration.....	12
Inverter Analog Output Configuration.....	13
Inverter Driving Signals.....	14
Analog Input.....	14
Simultaneous Sampled Analog Input.....	15
Scanned Analog Input.....	24
Analog Output.....	27
Analog Output Configuration.....	27
Over-Range Comparators.....	28
Over-Range Comparator Input Configuration.....	28
Setting the Over-Range Threshold.....	29
Sourcing Digital Input.....	30
Sourcing Digital Input Connector.....	31
Sourcing Digital Input Configuration.....	32
Sinking Digital Output.....	33
Sinking DO Connector.....	34
Sinking Digital Output Configuration.....	34
Inverter Digital Signals.....	35
Halt Signals.....	36
GPIO Signals.....	37
LVTTL Lines.....	38

Expansion Board.....	40
Expansion Board Connectors.....	40
Expansion Board Power.....	42
Expansion Board Dimensions.....	42
Feedback Input.....	42
Feedback Connectors.....	42
RS485 Input Signals.....	44
Hall Sensor Input Signals.....	44
+5 V Output.....	44
Debug LEDs.....	44
Thermistor.....	45
Thermistor Connector.....	45
Thermistor Reading.....	46
Relative Humidity Sensor.....	46
Relay Connector.....	47
Display Connector.....	48
Inverter Connectors.....	48
Worldwide Support and Services.....	54

Overview

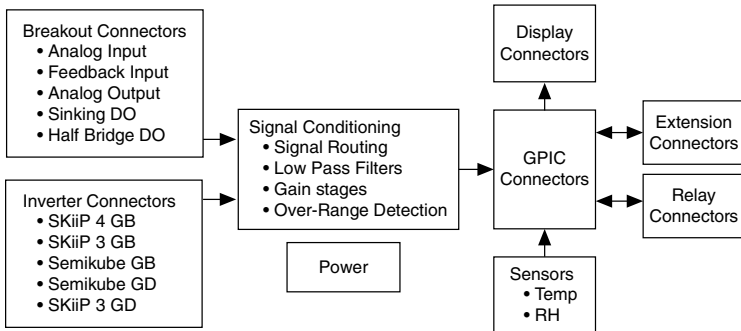
Overview of the sbRIO-9687 interface board.

The sbRIO-9687 interface board is an addition to the sbRIO-9683 or sbRIO-9684 General Purpose Inverter Controller stacked with the sbRIO-9607 CompactRIO Single-Board Controller. The sbRIO-9687 implements functionality required to control a variety of power conversion cabinets based on Semikron insulated-gate bipolar transistor (IGBT) modules.

The interface board supports signal inputs from inverter connectors and external connectors, and it can accommodate many configuration options for a wide spectrum of applications. Aside from handling all inverter signals, the sbRIO-9687 interface board provides additional functionality required for more complex systems implementation.

The following figure is a simplified block diagram of the sbRIO-9687 interface board.

Figure 1. sbRIO-9687 Block Diagram



Features

The sbRIO-9687 interface board provides a wide variety of input/output connectors, breakout connectors for onboard signals, expansion connectors for add-in boards, debugging LEDs, and options for configuration.

Inverter connectors

- 7 Semikron SKiiP 4 connectors
- 7 Semikron SKiiP 3 connectors
- 6 Semikron Semikube connectors
- 2 Semikron SKiiP 3 GD connectors
- 2 Semikron Semikube GD connectors

Analog inputs and outputs

- 16 simultaneous analog inputs¹
- 8 over-range detection circuits for simultaneous analog inputs or inverter inputs
- 7 scanned analog inputs²
- 8 analog outputs

Thermal control inputs and outputs

- Onboard RH and temperature sensor
- 2 thermistor inputs
- 4 relay control switches

Serial connector

- RS232 connector
- +5 V connector for remote device

Breakout connectors for onboard signals

- 28 lines of high voltage digital inputs (DI)
- 24 lines of high voltage digital outputs (DO)
- 14 digital lines for inverter control (HB)

Expansion connectors for add-in boards

- 32 low voltage TTL lines (LVTTTL)
- +3.3 V rail
- +5 V rail

¹ Current-sensing resistors, low pass filters, and gain stage for each simultaneous analog input.

² Bipolar/unipolar selection for each scanned analog input.

Debugging LEDs

- 3 debugging LEDs
- 1 power LED

Configuration options

- Onboard DIP switches for configuration
- 0 Ω resistors for configuration
- Pads for current-sensing resistors on analog inputs
- Easy access for changing low pass filter components

Connectors

The following table lists the sbRIO-9687 connectors and recommended mating connectors. Refer to the manufacturer for information about using and matching these connectors.

Table 1. sbRIO-9687 Connector Types

sbRIO-9687 Connector	Reference Designator	Description	Recommended Mating Connector
24 V power	J35	2-pin header	Weidmuller (1930050000)
SKiiP 3 (x7)	J36, J37, J38, J39, J40, J41, J42	14-pin header	On-Shore Technology, Inc. (101-146)
SKiiP 4 (x7)	J16, J17, J18, J19, J20, J21, J22	25-pin Dsub header	Kycon (K85X-BA-25S-30)
Semikube GB (x6)	J29, J30, J31, J32, J33, J34	20-pin header	On-Shore Technology, Inc. (101-206)
Semikube GD (x2)	J24, J25	34-pin header	On-Shore Technology, Inc. (101-346)
SKiiP 3 GD (x2)	J26, J27	26-pin header	On-Shore Technology, Inc. (101-266)
Simultaneous AI (x2)	J5, J11	26-pin header	Weidmuller (B2CF 3.50/26/180LH SN BK BX)
Feedback input (x2)	J6, J10	24-pin header	Weidmuller (B2CF 3.50/24/180LH SN BK BX)
Scanned AI, AO	J14	26-pin header	Weidmuller (B2CF 3.50/26/180LH SN BK BX)

Table 1. sbRIO-9687 Connector Types (Continued)

sbRIO-9687 Connector	Reference Designator	Description	Recommended Mating Connector
Thermistor	J28	6-pin header	Weidmuller (B2CF 3.50/6/180LH SN BK BX)
Relay output	J4	12-pin header	Weidmuller (B2CF 3.50/12/180LH SN BK BX)
Half-bridge DO	J13	24-pin header	Weidmuller (B2CF 3.50/24/180LH SN BK BX)
Sourcing DI	J12	36-pin header	Weidmuller (B2CF 3.50/36/180LH SN BK BX)
Sinking DO	J9	36-pin header	Weidmuller (B2CF 3.50/36/180LH SN BK BX)
LVTTL expansion (x2)	J7, J8	26-pin header	On-Shore Technology, Inc. (SH2-26G-PT)
RS232 display interface	J23	9-pin header	Kycon (K85X-EA-9S-30)
Display power	J15	2-pin header	Sauro (CBF020D8)

Switch and Resistor Configuration

The sbRIO-9687 utilizes a flexible design and can be configured to integrate with most inverter-based applications and circuit topologies for power conversion, motor driving, and so on.

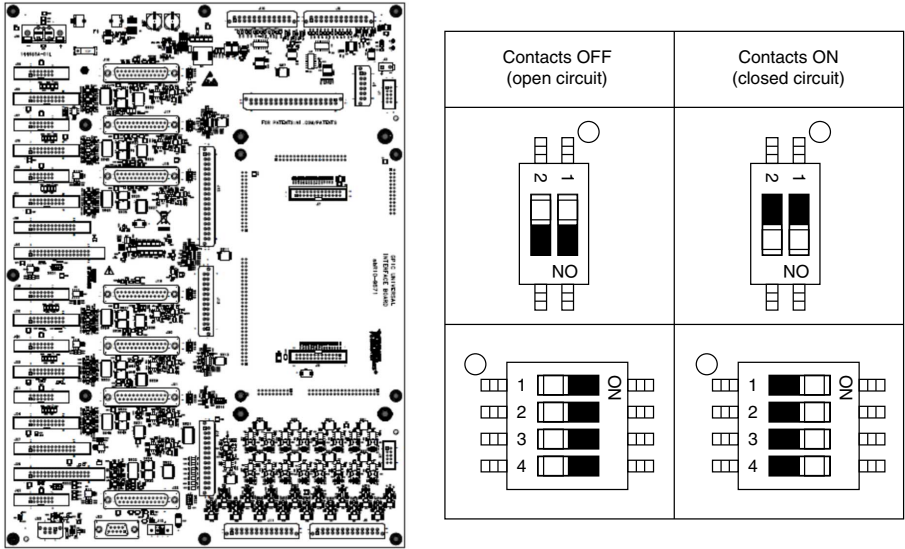
The sbRIO-9687 must be configured before it can be used. The board configuration can be set by toggling the onboard DIP switches. Alternatively, the spare resistors in parallel with the switches can be populated with 0 Ω .



Notice On a new board, all switch contacts are open by default. The sbRIO-9687 will not work as expected until switch contacts are configured as described in this manual.

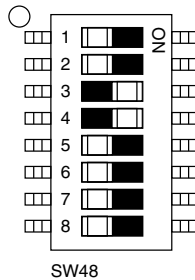
When a DIP switch actuator is moved to the ON position, the switch contacts are closed (input selected). All the DIP switches are oriented so that the closing position is to the right or down. The following figure shows board and DIP switch orientation.

Figure 2. Board and DIP Switch Orientation



Contacts are referenced by the switch reference designator. As an example, the following figure shows SW48 configured with contacts 3 and 4 closed.

Figure 3. Contact Configuration



Tip Use a sharp tool to toggle the contacts.

Power Considerations

It is recommended that you perform all resistor changes and switch configurations before the sbRIO-9687 is placed in its final location.

Before you fix the sbRIO-9687 in the final position, ensure that the mounting plate is grounded and that there is enough airflow around the board stack.



Note Exercise caution when placing the sbRIO-9687 inside an enclosure. Auxiliary cooling may be necessary to keep the device under the maximum ambient temperature rating for the sbRIO-9687. Refer to the *sbRIO-9687 Specifications* for more information about the maximum ambient temperature rating. For information and examples regarding factors that can affect thermal performance, visit ni.com/info and enter the Info Code `sbriocooling`.

Before powering on the sbRIO-9687, make sure there are no wires or metal parts that could touch the surface of the sbRIO-9687.

To power the sbRIO-9687, use a +24 V supply capable of delivering the current required by the application. Inverter driver boards, the sbRIO-9607, and the GPIC are all powered through the sbRIO-9607. The total power consumption should be considered when choosing an external power supply. For information about sbRIO-9687 power consumption, refer to the *sbRIO-9687 Specifications*.

For information about connector type, see the [Connectors](#) on page 4 section. For details about wiring, see [Power Input](#) on page 8.

System Power and Grounding Recommendations

NI recommends making the following connections to power and ground your system. For the main sbRIO-9687 Power +24 VDC Power connection, make sure that the following recommendations are incorporated into the design.

- Connect the power supply to the sbRIO-9687 power connector with wires that can carry the current for the sbRIO-9687 as well as all of the attached peripheral hardware.
- If more power is needed for the inverters, consider disconnecting them from the sbRIO-9687 power and supplying them directly with +24 V from a separate power supply.
- Connect the inverter power supply ground to the inverter driver board; do not connect it to the sbRIO-9687 main power supply.
- If separate power supplies are used for sensors, connect the sensor supply ground with the sbRIO-9687 ground at the analog input connector.
- Power the sbRIO-9687 before, or at the same time as, other power supplies in the system.
- For lower earth connection impedance, add a low-gauge wire between one of the standoff fixing screws and the chassis. The sbRIO-9687 is connected to earth ground through the standoffs.
- If shielded wires are used, ground them at the inverter connectors or at one of the standoff fixing screws.
- Electrically isolate the thermistors from earth ground and from other rails in the system.

Power Input

The sbRIO-9687 interface board must be powered with a +24 V DC supply. The power supply should have a maximum output current higher than the current consumption of the interface board and all attached inverters. Refer to the *sbRIO-9687 Specifications* for maximum current consumption.

The sbRIO-9687 power input is protected against reverse polarity, and it uses a 10 A fuse to provide protection for overcurrent. Littlefuse Series 314 is recommended, but any compatible fuse can be used. Refer to the *sbRIO-9687 Specifications* for maximum fuse rating.



Caution Disconnect the main +24 V supply before replacing the fuse.

Connector Pin	Signal Name
1	GND
2	+24 V

GPIC Signals

The main function of the sbRIO-9687 is to provide an interface between the GPIC controller and different Semikron inverters. The GPIC controller utilizes the following signals. Refer to the sbRIO-9683 or sbRIO-9684 documentation for connector pinouts and detailed signal descriptions.

Table 2. GPIC Signals

Generic Name	Lines	Signal Name	Description
Half-Bridge DO	14	DO<0...13>	High voltage digital signals for inverter control.
Sourcing DI	28	DI_P0.<0...13> DI_P1.<0...13>	High voltage digital input with pull-up resistors.
Sinking DO	24	DO_<0...22 >	Open collector digital outputs.
Simultaneous AI	16×2	AI<0...15>±	Simultaneous sampled differential analog inputs.
Scanned AI	8	AI_<0...7>	Scanned analog inputs 0 V to 5 V.
Analog Output	8	AO<0...7>	Analog outputs 0 V to 5 V.
LVTTTL	32	DIO<0...31>	Low voltage TTL lines.
Relay Control	4×2	DO<0...3>±	Relay control lines.

Inverter Signals

One of the main functions of the sbRIO-9687 is to provide an interface between the sbRIO-9683 or sbRIO-9684 GPIC controller and up to seven single-phase Semikron inverters.

The following tables show the connections between inverter signals and the GPIC. Only one connector from each column of the following tables can be used at a time. Using two connectors from one column could result in unpredictable behavior or damage to the interface board or inverters.

Table 3. Signal Assignments, GPIC to SKiiP 4 (Single-Phase Inverter)

Signal	Inv. 0 (J16)	Inv. 1 (J17)	Inv. 2 (J18)	Inv. 3 (J19)	Inv. 4 (J20)	Inv. 5 (J21)	Inv. 6 (J22)
High Side IGBT	DO1	DO3	DO5	DO7	DO9	DO11	DO13
Low Side IGBT	DO0	DO2	DO4	DO6	DO8	DO10	DO12
Current Sensor	AI0±	AI1±	AI2±	AI3±	AI4±	AI5±	AI6±
DC Link Voltage	AI7± or AI_0	AI8± or AI_1	AI9± or AI_2	AI10± or AI_3	AI11± or AI_4	AI12± or AI_5	AI13± or AI_6
Temperature Sensor	AI_0	AI_1	AI_2	AI_3	AI_4	AI_5	AI_6
HALT	DO_0, DI_P0.0	DO_1, DI_P0.1	DO_2, DI_P0.2	DO_3, DI_P0.3	DO_4, DI_P0.4	DO_5, DI_P0.5	DO_6, DI_P0.6
GPIO	DI_P0.7	DI_P0.8	DI_P0.9	DI_P0.10	DI_P0.11	DI_P0.12	DI_P0.13

Table 4. Signal Assignments, GPIC to SKiiP 3 GB (Single-Phase Inverter)

Signal	Inv. 0 (J36)	Inv. 1 (J37)	Inv. 2 (J38)	Inv. 3 (J39)	Inv. 4 (J40)	Inv. 5 (J41)	Inv. 6 (J42)
High Side IGBT	DO1	DO3	DO5	DO7	DO9	DO11	DO13
Low Side IGBT	DO0	DO2	DO4	DO6	DO8	DO10	DO12

Table 4. Signal Assignments, GPIC to SKiiP 3 GB (Single-Phase Inverter) (Continued)

Signal	Inv. 0 (J36)	Inv. 1 (J37)	Inv. 2 (J38)	Inv. 3 (J39)	Inv. 4 (J40)	Inv. 5 (J41)	Inv. 6 (J42)
Current Sensor	AI0±	AI1±	AI2±	AI3±	AI4±	AI5±	AI6±
DC Link Voltage	AI7± or AI_0	AI8± or AI_1	AI9± or AI_2	AI10± or AI_3	AI11± or AI_4	AI12± or AI_5	AI13± or AI_6
Temperature Sensor	AI_0	AI_1	AI_2	AI_3	AI_4	AI_5	AI_6
HALT	DO_0, DI_P0.0	DO_1, DI_P0.1	DO_2, DI_P0.2	DO_3, DI_P0.3	DO_4, DI_P0.4	DO_5, DI_P0.5	DO_6, DI_P0.6
GPIO	DI_P0.7	DI_P0.8	DI_P0.9	DI_P0.10	DI_P0.11	DI_P0.12	DI_P0.13

Table 5. Signal Assignments, GPIC to Semikube GB (Single-Phase Inverter)

Signal	Inv. 0 (J29)	Inv. 1 (J30)	Inv. 2 (J31)	Inv. 3 (J32)	Inv. 4 (J33)	Inv. 5 (J34)
High Side IGBT	DO1	DO3	DO5	DO7	DO9	DO11
Low Side IGBT	DO0	DO2	DO4	DO6	DO8	DO10
Current Sensor	AI0±	AI1±	AI2±	AI3±	AI4±	AI5±
DC Link Voltage	AI7± or AI_0	AI8± or AI_1	AI9± or AI_2	AI10± or AI_3	AI11± or AI_4	AI12± or AI_5
Temperature Sensor	AI_0	AI_1	AI_2	AI_3	AI_4	AI_5
HALT	DO_0, DI_P0.0	DO_1, DI_P0.1	DO_2, DI_P0.2	DO_3, DI_P0.3	DO_4, DI_P0.4	DO_5, DI_P0.5
GPIO	DI_P0.7	DI_P0.8	DI_P0.9	DI_P0.10	DI_P0.11	DI_P0.12

Table 6. Signal Assignments, GPIC to SKiiP 3 GD (Three-Phase Inverter)

Signal	Inv. 0 (J26)			Inv. 1 (J27)		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
High Side IGBT	DO1	DO3	DO5	DO7	DO9	DO11
Low Side IGBT	DO0	DO2	DO4	DO6	DO8	DO10
Current Sensor	AI0±	AI1±	AI2±	AI3±	AI4±	AI5±
DC Link Voltage	AI7± or AI_0	—	—	—	—	AI12± or AI_5
Temperature Sensor	—	AI_1	—	—	AI_4	—
HALT	DO_0, DI_P0.0	DO_1, DI_P0.1	DO_2, DI_P0.2	DO_3, DI_P0.3	DO_4, DI_P0.4	DO_5, DI_P0.5
GPIO	DI_P0.7	—	—	—	—	DI_P0.12

Table 7. Signal Assignments, GPIC to Semikube GD (Three-Phase Inverter)

Signal	Inv. 0 (J24)			Inv. 1 (J25)		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
High Side IGBT	DO1	DO3	DO5	DO7	DO9	DO11
Low Side IGBT	DO0	DO2	DO4	DO6	DO8	DO10
Current Sensor	AI0±	AI1±	AI2±	AI3±	AI4±	AI5±
DC Link Voltage	AI7± or AI_0	—	—	—	—	AI12± or AI_5
Temperature Sensor	—	AI_1	—	—	AI_4	—
HALT	DO_0, DI_P0.0	—	—	—	—	DO_5, DI_P0.5
GPIO	DI_P0.7	—	—	—	—	DI_P0.12

The signals on connectors 0 to 6 for SKiiP 3 GB and SKiiP 4, and signals on connectors 1 and 2 of SKiiP 3 GD and Semikube GB are shared. The two full bridge connectors for SKiiP 3 GD and Semikube GD are also in parallel. One full bridge connector reuses signals from three half-bridge connectors.

Each signal can only be used by one inverter at a time. For example, if SKiiP 3 GB half-bridge inverter 0 is connected on J16, then connectors J36, J29, J26, and J24 cannot be used because all of these connectors share several lines with J16.

The DC link voltage output can be connected to either simultaneous scanned analog input or scanned analog input. Refer to the *Simultaneous Sampled Analog Input* on page 15 and *Scanned Analog Input* on page 24 sections for details about signal routing.



Note By default, the inverter analog outputs are not connected to the GPIC analog inputs. The onboard switches should be configured before using the sbRIO-9687 interface board.

Inverter CAN Bus Configuration

The SKiiP 4 inverters have a CAN port for easy diagnosis of the system. The inverters are connected to CAN bus in order, with inverter 0 closest to the GPIC. If one of the SKiiP 4 inverters is not used, the corresponding switch should be closed for CAN bus continuity. The switches should be open only when a SKiiP 4 inverter is connected to the corresponding connector.

Figure 4. sbRIO-9687 CAN Bus Topology

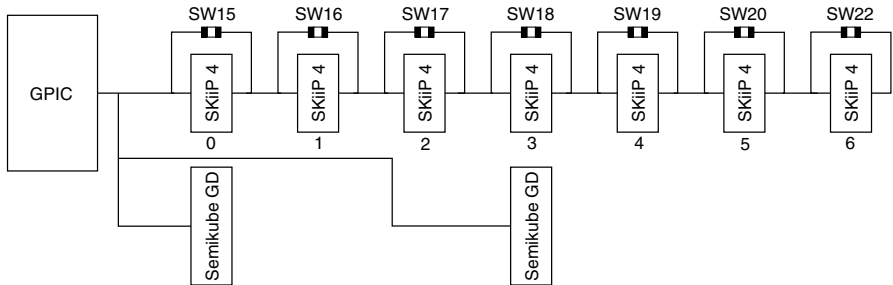


Table 8. SKiiP 4 Connector CAN Configuration

Inverter	Inverter Connector	CAN Switch	Contacts
0	J16	SW15	1, 2
1	J17	SW16	1, 2
2	J18	SW17	1, 2
3	J19	SW18	1, 2
4	J20	SW19	1, 2

Table 8. SKiiP 4 Connector CAN Configuration (Continued)

Inverter	Inverter Connector	CAN Switch	Contacts
5	J21	SW20	1, 2
6	J22	SW22	1, 2

Inverter Analog Output Configuration

SKiiP 3 GB inverters come in two variants: one with temperature output, another with voltage output on pin 12. The return for all analog signals is on pin 13. The interface board can be configured so that the signals are routed to the correct GPIC analog inputs. You can configure the signals by populating resistors on the sbRIO-9687. The options are listed below.

Table 9. SKiiP 3 Connector Output Type Selection

Inverter	Inverter Connector	Temperature Output ³	DC Link Voltage Output
0	J36	R865	R859
1	J37	R860	R852
2	J38	R861	R854
3	J39	R862	R855
4	J40	R863	R856
5	J41	R864	R858
6	J42	R818	R817

SKiiP 3 GD inverters do not have separate return paths for DC link voltage and temperature analog outputs. For accurate measurements, the returns for the signal that is used in the system should be connected to ground with the onboard switch. If both temperature and DC link voltage are used, close both circuits on the corresponding switch. The options are listed below.

Table 10. SKiiP 3 GD Connector Signal Ground Connections

Inverter	Inverter Connector	Temperature Ground	DC Link Voltage Ground
0	J26	SW51 contact 1	SW52 contact 1
1	J27	SW51 contact 2	SW52 contact 2

³ Temperature output is populated by default.

Inverter Driving Signals

Fast, high voltage digital signals are used to turn the high side and low side IGBT modules on and off. The connections between the inverter signals and the GPIC are described in [Inverter Signals](#) on page 9. The digital signals for SKiiP 3 GD and SKiiP 3 GB connectors are 15 V logic. For the other connectors, the signals are 24 V logic. All digital driving signals are available at breakout connector J13 with 24 V logic levels.

The following table shows the pin assignments for the J13 breakout connector.

Table 11. J13 Pin Assignments (HB Signals Breakout Connector)

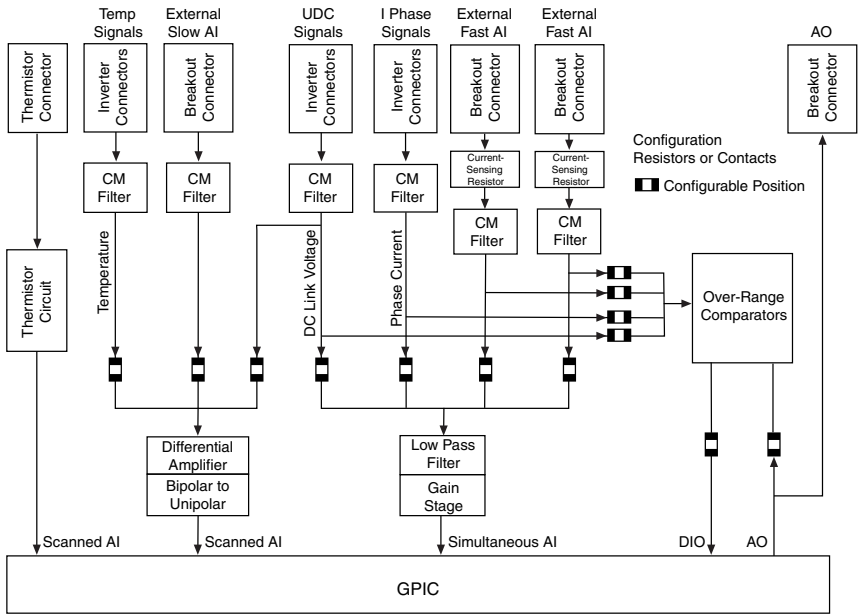
Pin	GPIC Signal	Inverter Signal	Pin	GPIC Signal	Inverter Signal
1	GND	—	13	GND	—
2	DO0	HB0_BOT	14	DO1	HB0_TOP
3	DO2	HB1_BOT	15	DO3	HB1_TOP
4	GND	—	16	GND	—
5	DO4	HB2_BOT	17	DO5	HB2_TOP
6	DO6	HB3_BOT	18	DO7	HB3_TOP
7	GND	—	19	GND	—
8	DO8	HB4_BOT	20	DO9	HB4_TOP
9	DO10	HB5_BOT	21	DO11	HB5_TOP
10	GND	—	22	GND	—
11	DO12	HB6_BOT	23	DO13	HB6_TOP
12	GND	—	24	GND	—

Analog Input

The sbRIO-9687 interface board can accept inputs from analog input connectors or from inverters. The analog input signals can be configured on the sbRIO-9687 in a variety of ways; as a result, it is possible to use the sbRIO-9687 to control most of the power conversion circuits without any additional wiring or circuitry.

The following figure shows a block diagram of the sbRIO-9687 analog input subsystem.

Figure 5. sbRIO-9687 Analog Input Subsystem



Simultaneous Sampled Analog Input

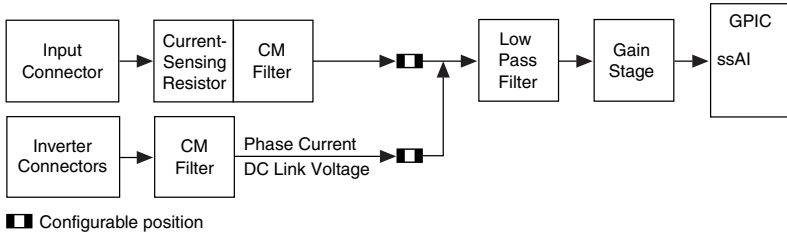
The General Purpose Inverter Controller (GPIC) has 16 simultaneous sampling analog inputs, which acquire samples at a rate of 180 kS/s per channel. Phase difference between channels is minimal due to the simultaneous sampling and high bandwidth of these signals. Each GPIC input is differential with a software-range of ± 10 V or ± 5 V. These inputs should be used for signals whose bandwidth and phase information is important for the control algorithm. Phase current and DC link voltage from inverters can be connected to simultaneous sampled AI.

The sbRIO-9687 has 16 external analog inputs that can be connected to the GPIC simultaneous sampling analog inputs. Other features of the analog input circuitry include:

- Pads for current-sensing resistor option on each input.
- Low pass filter and gain stage for each input.
- Eight configurable over-range comparators.

The following figure shows depicts a block diagram for simultaneous sampled analog input.

Figure 6. Simultaneous Sampled Analog Input



Simultaneous Analog Input Connectors

The sbRIO-9687 interface board includes 16 external simultaneous sampling analog inputs at two connectors, J5 and J11. The following tables provide pin assignment information for the J5 and J11 simultaneous AI breakout connectors.

Table 12. J5 Pin Assignments

Pin	Signal		Pin	Signal
1	GND		14	GND
2	ssAI0+		15	ssAI0-
3	ssAI1+		16	ssAI1-
4	GND		17	GND
5	ssAI2+		18	ssAI2-
6	ssAI3+		19	ssAI3-
7	GND		20	GND
8	ssAI4+		21	ssAI4-
9	ssAI5+		22	ssAI5-
10	GND		23	GND
11	ssAI6+		24	ssAI6-
12	ssAI7+		25	ssAI7-
13	GND		26	GND

Table 13. J11 Pin Assignments

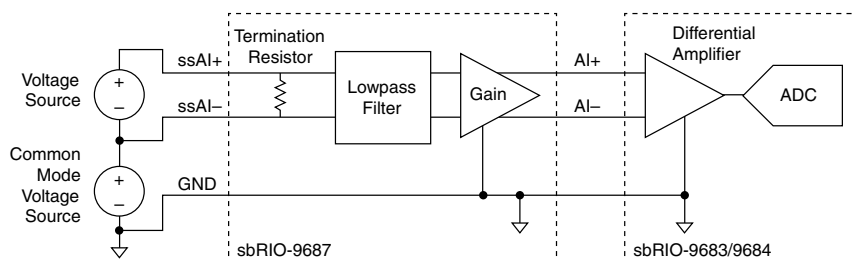
Pin	Signal	Pin	Signal
1	GND	14	GND
2	ssAI8+	15	ssAI8-
3	ssAI9+	16	ssAI9-
4	GND	17	GND
5	ssAI10+	18	ssAI10-
6	ssAI11+	19	ssAI11-
7	GND	20	GND
8	ssAI12+	21	ssAI12-
9	ssAI13+	22	ssAI13-
10	GND	23	GND
11	ssAI14+	24	ssAI14-
12	ssAI15+	25	ssAI15-
13	GND	26	GND

Connecting Voltage Sources to Simultaneous Analog Input

All sixteen inputs share a common ground that is the same as the digital and analog ground of the GPIC. The differential input signal and absolute voltage of each input should be within the input range of each channel. Refer to the *sbRIO-9687 Specifications* for details.

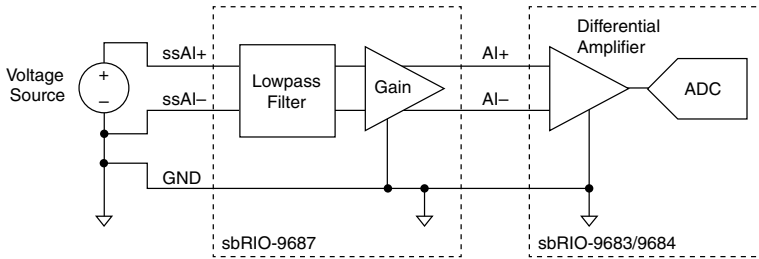
The simultaneous sampling analog inputs are differential, so the input measures the voltage between the positive and negative terminals.

Figure 7. Connecting a Differential Voltage Signal to Simultaneous AI



If single-ended signals are measured, one end of the signal source and one input terminal should be connected to ground, as in the following diagram.

Figure 8. Connecting a Single-Ended Voltage Signal to Simultaneous AI

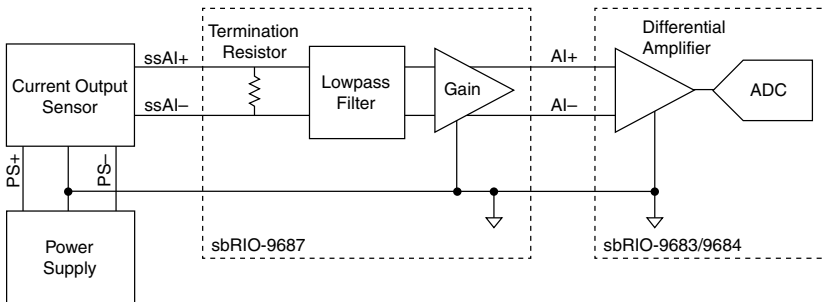


The gain stage of each input channel can be set as x1, x2, x3, or x4. See [Gain Stage](#) on page 22 for details.

Connecting Current Output Sensors to Simultaneous Analog Input

A large selection of current output sensors can be connected to the `sbRIO-9687`. For current measurements, a current-sensing resistor converts input current into voltage. The burden voltage of the resistor follows the same signal path as the voltage inputs.

Figure 9. Connecting a Current Output Sensor to Simultaneous AI



If the sensor is powered, the sensor power supply ground should be connected to the ground pin on the simultaneous AI connector. The common mode and differential input signal on the burden resistor should stay within the limits listed in the *Simultaneous Sampled Analog Input* section of the *sbRIO-9687 Specifications*.

Current-Sensing Resistor

By default, the current-sensing resistor is not populated. The current-sensing resistor pads accommodate a resistor footprint of 2512, with a maximum dissipated power of 1 W. For lower power applications, the `sbRIO-9687` includes a 1206 footprint (0.25 W) in parallel with the current-sensing resistor.

Select the current-sensing resistor value so that the power dissipation is minimized while as much of the GPIC input range as possible is used. The current-sensing resistor value should be less than or equal to the lesser of the values obtained from the following equations:

$$R_{CSR_max} \leq \frac{P_{CSR}}{I_{in_rms}^2}$$

$$R_{CSR_max} \leq \frac{GPIC_{range}}{AI_{gain} \times I_{in_max}}$$

where

P_{CSR} = Current-sensing resistor power (1 W for 2512 footprint, 0.25 W for 1206 footprint).

R_{CSR_max} = Maximum resistance of the current-sensing resistor (in Ohms).

I_{in_rms} = RMS value of the input current (in Amps).

I_{in_max} = Maximum input current (DC or $\frac{pk - pk}{2}$) (in Amps).

$GPIC_{range}$ = Input range set for the GPIC (10 V or 5 V).

AI_{gain} = Gain of the interface board amplifier (x1, x2, x3, x4).



Note Use the maximum gain for simultaneous sampled analog input to get a lower power dissipation from the current-sensing resistor.

Table 14. Simultaneous Sampled AI Current-Sensing Resistors

Simultaneous AI	2 W Current-Sensing Resistor	0.25 W Current-Sensing Resistor
ssAI0±	R141	R140
ssAI1±	R121	R120
ssAI2±	R91	R90
ssAI3±	R60	R59
ssAI4±	R46	R45
ssAI5±	R30	R29
ssAI6±	R17	R16
ssAI7±	R5	R4
ssAI8±	R304	R303
ssAI9±	R266	R265

Table 14. Simultaneous Sampled AI Current-Sensing Resistors (Continued)

Simultaneous AI	2 W Current-Sensing Resistor	0.25 W Current-Sensing Resistor
ssAI10±	R243	R242
ssAI11±	R232	R231
ssAI12±	R213	R212
ssAI13±	R198	R197
ssAI14±	R186	R185
ssAI15±	R161	R160

Common Mode Filters

The sbRIO-9687 uses a high frequency common mode filter for each analog input from external connectors and from Semikron modules. The common mode filter attenuates the inverters' high frequency switching noise, which can interfere with the input signal.

Simultaneous Analog Input Configuration

The signal source for each GPIC simultaneous analog input is selected with a series of DIP switches. Because all input signals are differential, a pair of contacts should be closed to select one signal source. Refer to the following table for information about selecting simultaneous sampled analog input signal source.

Table 15. Simultaneous Sampled Analog Input Signal Source Selection

GPIC Input	Input 1 (Inverters)			Input 2 (AI Connector)		
	Name	Switch	Contact Pair	Name	Switch	Contact Pair
AI0±	I Phase 0	SW42	3, 4	ssAI0±	SW42	1, 2
AI1±	I Phase 1	SW34	3, 4	ssAI1±	SW34	1, 2
AI2±	I Phase 2	SW36	3, 4	ssAI2±	SW36	1, 2
AI3±	I Phase 3	SW38	3, 4	ssAI3±	SW38	1, 2
AI4±	I Phase 4	SW44	3, 4	ssAI4±	SW44	1, 2
AI5±	I Phase 5	SW40	3, 4	ssAI5±	SW40	1, 2
AI6±	I Phase 6	SW25	3, 4	ssAI6±	SW25	1, 2
AI7±	U DC 0	SW41	3, 4	ssAI7±	SW41	1, 2
AI8±	U DC 1	SW33	3, 4	ssAI8±	SW33	1, 2

Table 15. Simultaneous Sampled Analog Input Signal Source Selection (Continued)

GPIC Input	Input 1 (Inverters)			Input 2 (AI Connector)		
	Name	Switch	Contact Pair	Name	Switch	Contact Pair
AI9±	U DC 2	SW35	3, 4	ssAI9±	SW35	1, 2
AI10±	U DC 3	SW37	3, 4	ssAI10±	SW37	1, 2
AI11±	U DC 4	SW43	3, 4	ssAI11±	SW43	1, 2
AI12±	U DC 5	SW39	3, 4	ssAI12±	SW39	1, 2
AI13±	U DC 6	SW24	3, 4	ssAI13±	SW24	1, 2
AI14±	—	—	—	ssAI14±	connected	—
AI15±	—	—	—	ssAI15±	connected	—



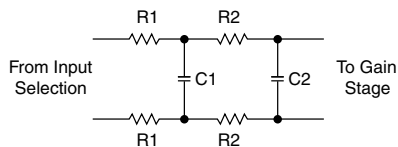
Notice Only one signal source should be connected to each GPIC analog input at one time. Connecting two signal sources in parallel can produce unexpected results.

Analog inputs from inverters are shared between the half-bridge modules and the full-bridge modules. For proper operation, each analog line should be driven by only one inverter. Refer to [Inverter Signals](#) on page 9 for more information.

Low Pass Filters

The sbRIO-9687 provides a low pass filter for each analog input. The filter has two stages that are populated by default with 10 kΩ resistors and 3.3 nF capacitors. Refer to the *sbRIO-9687 Specifications* for details about the filter characteristics.

Figure 10. Simultaneous Sampled AI Input Low Pass Filter



The first two filter resistors (R1) have a second functionality on the board and have a value of 10 kΩ. Other filter elements can be changed to set filter characteristics as required by the application. The R2 has a default value of 10 kΩ (0603 footprint), and C1 and C2 have a default value of 3.3 nF (0805 footprint).

Table 16. Filter Component Reference Designators

GPIC Input	R2	C1	C2
AI0±	R195, R207	C122	C121
AI1±	R219, R227	C142	C141
AI2±	R219, R226	C140	C139
AI3±	R194, R206	C120	C119
AI4±	R183, R170	C105	C104
AI5±	R138, R153	C88	C87
AI6±	R169, R182	C103	C102
AI7±	R137, R152	C86	C85
AI8±	R68, R75	C47	C46
AI9±	R107, R118	C70	C69
AI10±	R99, R116	C66	C65
AI11±	R80, R66	C50	C49
AI12±	R38, R50	C31	C30
AI13±	R12, R24	C14	C13
AI14±	R49, R37	C29	C28
AI15±	R23, R11	C12	C11



Note For a different cut-off frequency, change only the filter capacitors while keeping C1 and C2 of equal value.

Gain Stage

Each analog input channel has a gain stage immediately after the low pass filter. Gain can be set as x1, x2, x3, and x4. The output of the gain stage will work correctly only if the input voltage at the simultaneous AI connector is within the common mode and differential range listed in the *sbRIO-9687 Specifications* for each selected gain.

The gain should be set to use as much of the GPIC input range as possible. When current signals are converted to voltage with onboard current-sensing resistors, it is preferable to set the gain to the maximum value so that power dissipation from resistors is minimized.

Refer to the following tables for information regarding simultaneous sampled AI gain configuration and related DIP switch reference designators and contact assignments.

Table 17. Simultaneous Sampled AI Gain Configuration

Gain_A Contact	Gain_B Contact	Gain	Input Range
open	open	x1	±10 V
closed	open	x2	±5 V
open	closed	x3	±3.33 V
closed	closed	x4	±2.5 V

Table 18. DIP Switch Reference Designators and Contact Assignments

GPIC Input	Switch Reference Designator	Gain_A Contact	Gain_B Contact
AI0±	SW9	3	4
AI1±	SW9	1	2
AI2±	SW8	3	4
AI3±	SW8	1	2
AI4±	SW6	3	4
AI5±	SW6	1	2
AI6±	SW5	3	4
AI7±	SW5	1	2
AI8±	SW4	3	4
AI9±	SW4	1	2
AI10±	SW3	3	4
AI11±	SW3	1	2
AI12±	SW2	3	4
AI13±	SW2	1	2
AI14±	SW1	3	4
AI15±	SW1	1	2



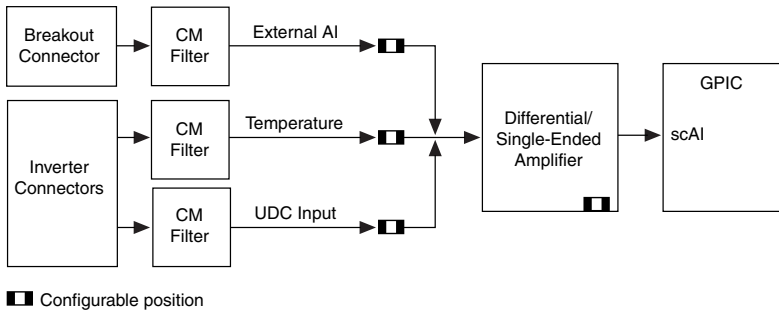
Note For analog inputs that are connected to inverter current or voltage outputs, the gain should be set to x1.

Scanned Analog Input

The sbRIO-9683 or sbRIO-9684 GPIC controller has eight scanned analog inputs with an input range of 0 V to 5 V. These inputs have limited bandwidth, and each input is read at a slightly different time as it is scanned. These inputs should be used for slow analog signals as temperature or DC voltages.

The sbRIO-9687 interface board connects slow analog inputs from inverter and breakout connectors to the GPIC scanned AI. The signals are conditioned. The input range on the sbRIO-9687 is 0 V to 10 V or -5 V to 5 V.

Figure 11. Scanned AI Block Diagram



Scanned Analog Input Connectors

The sbRIO-9687 interface board has seven external scanned analog inputs that are available at breakout connector J14. The following table provides pinout information for the breakout connector.

Table 19. J14 Pin Assignments

Pin	Signal	Pin	Signal
1	GND	14	GND
2	AO0	15	AO1
3	AO2	16	AO3
4	GND	17	GND
5	AO4	18	AO5
6	AO6	19	AO7
7	scAI0	20	scAI0 GND

Table 19. J14 Pin Assignments (Continued)

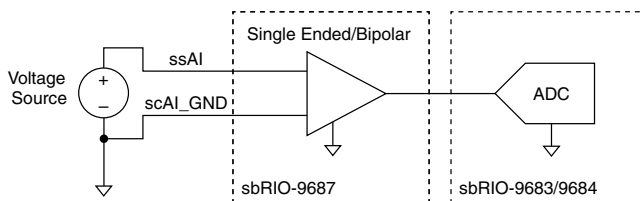
Pin	Signal	Pin	Signal
8	scAI1 GND	21	scAI1
9	scAI2	22	scAI2 GND
10	scAI3 GND	23	scAI3
11	scAI4	24	scAI4 GND
12	scAI5 GND	25	scAI5
13	scAI6	26	scAI6 GND

The sbRIO-9687 uses scanned analog input 7 for thermistor measurement; it is not available on the breakout connector.

Connecting Voltage Sources to Scanned Analog Input

The scanned analog inputs are single ended. One of the input pins is always ground. It is recommended to connect the signal source to the ground pin assigned to each analog input.

Figure 12. Connecting a Voltage Signal to Scanned AI



Scanned Analog Input Configuration

The input source for scanned analog inputs 0 to 6 is selected with the onboard DIP switches. The signal source can be inverter temperature, inverter DC link voltage, or external voltage from the input breakout connector. Refer to the following table for information about selecting scanned analog input signal source.

Table 20. Scanned Analog Input Signal Source Selection

GPIC Input	Input 1			Input 2			Input 3		
	Name	Switch	Contact Pair	Name	Switch	Contact Pair	Name	Switch	Contact Pair
AI_0	UDC 0	SW30	1, 2	Temp0	SW30	3, 4	scAI0	SW30	5, 6
AI_1	UDC 1	SW26	1, 2	Temp1	SW26	3, 4	scAI1	SW26	5, 6
AI_2	UDC 2	SW27	1, 2	Temp2	SW27	3, 4	scAI2	SW27	5, 6
AI_3	UDC 3	SW28	1, 2	Temp3	SW28	3, 4	scAI3	SW28	5, 6
AI_4	UDC 4	SW29	1, 2	Temp4	SW29	3, 4	scAI4	SW29	5, 6
AI_5	UDC 5	SW31	1, 2	Temp5	SW31	3, 4	scAI5	SW31	5, 6
AI_6	UDC 6	SW23	1, 2	Temp6	SW23	3, 4	scAI6	SW23	5, 6

Unipolar/Bipolar Mode Configuration

Each scanned analog input can be configured to accept unipolar or bipolar input voltages. Refer to the *sbRIO-9687 Specifications* for details about the input range and accuracy for each setting. Refer to the following table for information about configuring unipolar and bipolar input voltages.

Table 21. Scanned Analog Input Unipolar/Bipolar Configuration

GPIC Input	Unipolar Input (0 V to 10 V)		Bipolar Input (-5 V to 5 V)	
	Switch Reference Designator	Contact	Switch Reference Designator	Contact
AI0	SW12	1	SW12	2
AI1	SW12	3	SW12	4
AI2	SW11	1	SW11	2
AI3	SW11	3	SW11	4
AI4	SW13	1	SW13	2
AI5	SW13	3	SW13	4
AI6	SW14	1	SW14	2



Notice Only one configuration should be selected for each scanned analog input. Selecting both unipolar/bipolar configuration at the same time will produce unexpected results.

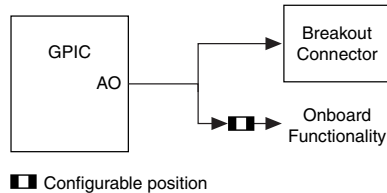


Note Scanned analog inputs connected to inverters should be set to unipolar mode.

Analog Output

The analog outputs of the GPIC are connected directly to the breakout connector. See [Scanned Analog Input Connectors](#) on page 24 for details. The following figure shows a block diagram for analog output subsystem.

Figure 13. Analog Output Block Diagram



Analog output can be used on the sbRIO-9687 to set over-range thresholds. See [Over-Range Comparators](#) on page 28 for details about onboard functionality.

The analog output lines have the same specifications as the AO lines of the GPIC. For more information, refer to *NI 9683 User Manual and Specifications* and *NI 9684 User Manual and Specifications*.

Analog Output Configuration

Analog outputs can be disconnected from the onboard functionality by changing the corresponding DIP switch to the OFF position. Refer to the following table for information about analog output configuration.

Table 22. Analog Output Configuration

GPIC Analog Output	SW21 Contact
AO0	1
AO1	2
AO2	3
AO3	4
AO4	5
AO5	6

Table 22. Analog Output Configuration (Continued)

GPIC Analog Output	SW21 Contact
AO6	7
AO7	8



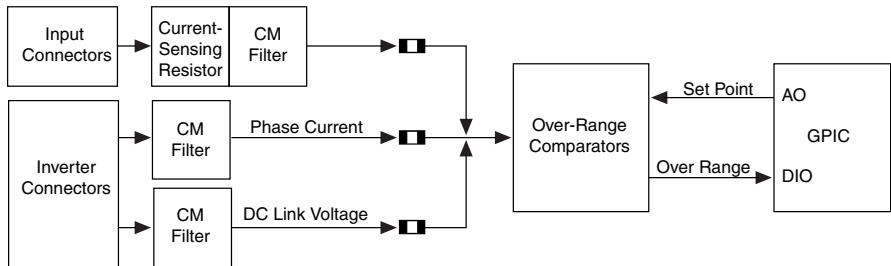
Note Analog outputs that are used outside the sbRIO-9687 should be disconnected from onboard functionality.

Over-Range Comparators

The sbRIO-9687 interface board has eight over-range comparators that can be connected to analog input signals. The over-range comparators are triggered if the absolute value of the input is over the set voltage. For example, if the threshold is set at 7 V, then the over range is triggered if the input is over 7 V or under -7 V.

The following figure is a block diagram for the over-range circuits.

Figure 14. Over-Range Circuit Block Diagram



■ Configurable position

The eight over-range comparators can be connected to inverter phase current, inverter DC link voltage, or to one of the 16 simultaneous sampled analog inputs. The over-range threshold can be set using one of the GPIC analog outputs or by populating a resistor divider on the board. The over-range output is an active low digital signal connected to the GPIC low voltage TTL inputs.



Note If any of the DIO lines (DIO0 to DIO7) are to be used for the extension board, they should be disconnected from the onboard functionality by depopulating the corresponding 0 Ω resistor. See [LVTTL Lines](#) on page 38 for details.

Over-Range Comparator Input Configuration

Over-range comparators are connected to the input source with a series of DIP switches. Because all input signals are differential, a pair of contacts should be closed to select one

signal source. Refer to the following tables for information about selecting over-range comparator input signal source.

Table 23. Over-Range Comparator Input Selection, Inputs 1 and 2

Circuit	Input 1	Switch	Contacts	Input 2	Switch	Contacts
O-Ra 0	I Phase Inv. 0	SW47	5, 6	UDC Inv. 0	SW47	1, 2
O-Ra 1	I Phase Inv. 1	SW45	5, 6	UDC Inv. 1	SW45	1, 2
O-Ra 2	I Phase Inv. 2	SW48	5, 6	UDC Inv. 2	SW48	1, 2
O-Ra 3	I Phase Inv. 3	SW49	5, 6	UDC Inv. 3	SW49	1, 2
O-Ra 4	I Phase Inv. 4	SW50	5, 6	UDC Inv. 4	SW50	1, 2
O-Ra 5	I Phase Inv. 5	SW46	5, 6	UDC Inv. 5	SW46	1, 2
O-Ra 6	I Phase Inv. 6	SW32	5, 6	UDC Inv. 6	SW32	1, 2
O-Ra 7	—	—	—	—	—	—

Table 24. Over-Range Comparator Input Selection, Inputs 3 and 4

Circuit	Input 3	Switch	Contacts	Input 4	Switch	Contacts
O-Ra 0	ssAI0±	SW47	7, 8	ssAI7±	SW47	3, 4
O-Ra 1	ssAI1±	SW45	7, 8	ssAI8±	SW45	3, 4
O-Ra 2	ssAI2±	SW48	7, 8	ssAI9±	SW48	3, 4
O-Ra 3	ssAI3±	SW49	7, 8	ssAI10±	SW49	3, 4
O-Ra 4	ssAI4±	SW50	7, 8	ssAI11±	SW50	3, 4
O-Ra 5	ssAI5±	SW46	7, 8	ssAI12±	SW46	3, 4
O-Ra 6	ssAI6±	SW32	7, 8	ssAI13±	SW32	3, 4
O-Ra 7	ssAI14±	SW10	3, 4	ssAI15±	SW10	1, 2

Setting the Over-Range Threshold

Analog input signals are connected to the over-range comparators before the gain stage, so the threshold should be set in accordance with the signal level at the sbRIO-9687 input, which is the breakout connector or inverter connector. The over-range circuit has a gain of 0.5 that should be considered when setting the threshold.

The over-range threshold can be set by using the GPIC analog outputs or by populating an onboard resistive divider.

To use the GPIC analog output for the set point, configure AO for onboard use; see [Analog Output Configuration](#) on page 27 for details. For each over-range comparator, set the

corresponding AO channel to the appropriate DC value. The comparator threshold is twice the set AO voltage and acts for both positive and negative input voltages.

$$V_{AO} = \frac{V_{threshold}}{2}$$



Note If GPIC analog outputs are used for the over-range comparator set point, the corresponding contact on switch SW21 should be turned ON.

If using the onboard resistors to set the over-range threshold, the analog outputs should be disconnected from the onboard functionality. See [Analog Output Configuration](#) on page 27 for configuration information. The set point is established by populating the corresponding resistor for each channel. To calculate the resistor value, use the following formula:

$$R_{threshold} = \frac{V_{threshold}}{10V - V_{threshold}} \times 100k\Omega$$

The following table provides threshold settings for the sbRIO-9687 over-range comparators.

Table 25. Over-Range Comparator Threshold Setting

Circuit	Set Point 1	Set Point 2	Over-Range OUT
O-Ra 0	AO0	R381	DIO0
O-Ra 1	AO1	R383	DIO1
O-Ra 2	AO2	R373	DIO2
O-Ra 3	AO3	R386	DIO3
O-Ra 4	AO4	R394	DIO4
O-Ra 5	AO5	R396	DIO5
O-Ra 6	AO6	R403	DIO6
O-Ra 7	AO7	R244	DIO7



Note If any of the lines DIO0 to DIO7 are to be used for the extension board, they should be disconnected from the onboard functionality by depopulating the corresponding 0 Ω resistor. See [LVTTL Lines](#) on page 38 for details.

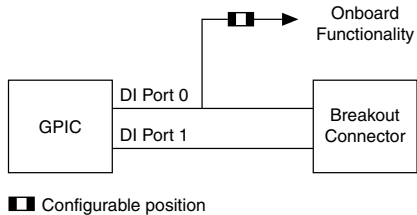
Sourcing Digital Input

The GPIC has 28 sourcing digital inputs grouped in two ports. Each of the sourcing digital inputs is connected to a breakout connector on the sbRIO-9687 interface board. The DI lines


used onboard can be disconnected from the sbRIO-9687 circuitry by depopulating the 0 Ω resistors.

The following figure shows a block diagram for the sourcing digital input circuitry.

Figure 15. Sourcing Digital Input Block Diagram



The sourcing DI lines have the same specifications as the sourcing DI lines of the GPIC. Port 1 should be powered at the VI_P1 pin for proper operation. The digital input operates in the low range or high range based on the VI_P1 voltage.

 **Note** If no device is connected to the sourcing digital input, the channel registers as OFF. If the input is connected to ground, the channel registers as ON.

Sourcing Digital Input Connector

Sourcing digital inputs are available at breakout connector J12. Refer to the following table for pinout information.

Table 26. J12 Sourcing Digital Input Connector Pinout

Pin	Signal		Pin	Signal
1	GND		19	GND
2	DI_P0.0		20	DI_P0.1
3	DI_P0.2		21	DI_P0.3
4	DI_P0.4		22	DI_P0.5
5	DI_P0.6		23	DI_P0.7
6	DI_P0.8		24	DI_P0.9
7	DI_P0.10		25	DI_P0.11
8	DI_P0.12		26	DI_P0.13
9	+24 V		27	+24 V
10	GND		28	GND

Table 26. J12 Sourcing Digital Input Connector Pinout (Continued)

Pin	Signal		Pin	Signal
11	DI_P1.2		29	DI_P1.3
12	DI_P1.4		30	DI_P1.5
13	DI_P1.6		31	DI_P1.7
14	DI_P1.8		32	DI_P1.9
15	DI_P1.10		33	DI_P1.11
16	DI_P1.12		34	DI_P1.13
17	GND		35	VI_P1
18	Not Connected		36	Not Connected

Sourcing Digital Input Configuration

Port 0 of the sourcing digital input is powered at +24 V through the sbRIO-9687 interface board. This power is available at the DI connector on pins 9 and 27. The +24 V can be used to power external circuits or port 1.

Port 1 is not powered from sbRIO-9687 interface board; it should be powered externally at a voltage that matches the voltage levels of the application. Power for port 1 is connected at pins 18 and 36 of J12 connector.

Port 0 DI lines are used on the sbRIO-9687 interface board. For details, refer to [Halt Signals](#) on page 36 and [GPIO Signals](#) on page 37. If Port 0 DI lines are not used for the application, they can be disconnected from onboard functionality by depopulating the corresponding resistor.



Note If port 0 sinking DI lines are used outside the sbRIO-9687, they should be disconnected from onboard functionality.

The following table provides information about the onboard function and corresponding resistor for sourcing DI signals.

Table 27. Sourcing Digital Input Signals

GPIC DI Signal	Onboard Function	Disconnecting Resistor
DI_P0.0	HALT0	R550
DI_P0.1	HALT1	R570
DI_P0.2	HALT2	R554

Table 27. Sourcing Digital Input Signals (Continued)

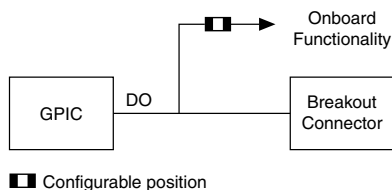
GPIC DI Signal	Onboard Function	Disconnecting Resistor
DI_P0.3	HALT3	R535
DI_P0.4	HALT4	R516
DI_P0.5	HALT5	R633
DI_P0.6	HALT6	R566
DI_P0.7	GPIO0	R500
DI_P0.8	GPIO1	R501
DI_P0.9	GPIO2	R497
DI_P0.10	GPIO3	R498
DI_P0.11	GPIO4	R572
DI_P0.12	GPIO5	R499
DI_P0.13	GPIO6	R573

Sinking Digital Output

The GPIC has 24 sinking digital outputs. Each sinking DO is connected to the breakout connector. The sbRIO-9687 interface board uses some of the DO lines, which can be disconnected from sbRIO-9687 circuitry by depopulating 0 Ω resistors.

The sinking DO lines have the same electrical specifications as the DO lines of the GPIC. For more information, refer to the *NI 9683 User Manual and Specifications* or the *NI 9684 User Manual and Specifications*. The GPIC has current sinking digital outputs, which means that the output pin is driven to ground (GND) when the channel is ON.

The following figure is a block diagram of the sinking digital output.

Figure 16. Sinking Digital Output Block Diagram

Sinking DO Connector

Sinking digital outputs are available at breakout connector J9. The following table contains pinout information for the sinking DO connector.

Table 28. J9 Sinking Digital Output Pinout

Pin	Signal		Pin	Signal
1	GND		19	GND
2	DO_0		20	DO_1
3	DO_2		21	DO_3
4	DO_4		22	DO_5
5	DO_6		23	DO_7
6	DO_8		24	DO_9
7	DO_10		25	DO_11
8	DO_12		26	DO_13
9	—		27	—
10	GND		28	GND
11	DO_14		29	DO_15
12	DO_16		30	DO_17
13	DO_18		31	DO_19
14	DO_20		32	DO_21
15	DO_22		33	DO_23
16	GND		34	GND
17	GND		35	GND
18	—		36	—

Sinking Digital Output Configuration

The first seven digital output lines are used on the sbRIO-9687 interface board for inverter signals. See [Inverter Digital Signals](#) on page 35 for more details. If sinking digital outputs need to be used externally, they can be disconnected from onboard functionality by depopulating the corresponding resistors. The following table provides information about the onboard function and corresponding resistor for sinking DO signals.

Table 29. Sinking Digital Output Signals

GPIC DO Signal	Onboard Function	Resistor
DO_0	HALT0	R524
DO_1	HALT1	R552
DO_2	HALT2	R508
DO_3	HALT3	R534
DO_4	HALT4	R517
DO_5	HALT5	R632
DO_6	HALT6	R567

Inverter Digital Signals

Semikron inverters have several digital signals that can be read by and in some case written by the GPIC. The functionality of the digital signals depends on the inverter type and is described in Semikron documentation. The following tables provide information about the Semikron inverter digital signal connections.

Table 30. Semikron Inverter Digital Signal Connections (Single-Phase Inverters)

Inverter Connector	Signal (Semikron)	R/W	Inv. 0	Inv. 1	Inv. 2	Inv. 3	Inv. 4	Inv. 5	Inv. 6
SKiiP 4	CMM_HALT	R/W	HALT0	HALT1	HALT2	HALT3	HALT4	HALT5	HALT6
	CMM_GPIO	R	GPIO0	GPIO1	GPIO2	GPIO3	GPIO4	GPIO5	GPIO6
	CMM_GPIO2	R	—	—	—	—	—	—	—
SKiiP 3 GB	ERROR out	R	HALT0	HALT1	HALT2	HALT3	HALT4	HALT5	HALT6
	Overtemp out	R	GPIO0	GPIO1	GPIO2	GPIO3	GPIO4	GPIO5	GPIO6
Semikube GB	IF_CMN_nHALT	R/W	HALT0	HALT1	HALT2	HALT3	HALT4	HALT5	HALT6
	IF_CMN_GPIO	R/W	GPIO0	GPIO1	GPIO2	GPIO3	GPIO4	GPIO5	GPIO6

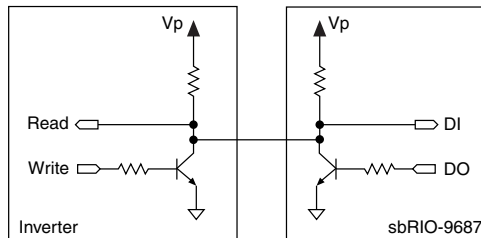
Table 31. Semikron Inverter Digital Signal Connections (Three-Phase Inverters)

Inverter Connector	Signal (Semikron)	Read/Write	Inv. 0	Inv. 1
SKiiP 3 GD	ERROR HB1 out	R	HALT0	HALT3
	ERROR HB2 out	R	HALT1	HALT4
	ERROR HB3 out	R	HALT2	HALT5
	Overtemp out	R	GPIO0	GPIO5
Semikube SL GD	IF_CMN_nHALT	R/W	HALT0	HALT5
	IF_CMN_GPIO	R	GPIO0	GPIO5
Semikube GD	IF_CMN_nHALT	R/W	HALT0	HALT5
	Reserved	R/W	GPIO0	GPIO5

Halt Signals

The sbRIO-9687 HALT signals are bidirectional. Both ends of the signal line use a pull-up resistor and a transistor for pull-down functionality. Both the controller and the inverter can set or read the status of the signal line. The following diagram shows the HALT signal schematic.

Figure 17. HALT Signal Schematic



To read the line status, set the corresponding sinking digital output to high; the logic level will be read on the corresponding sourcing digital input. To write to the line, set the sinking digital output to low or high.

The following table shows the mapping between inverter HALT signals and GPIC sourcing DO and sinking DI.

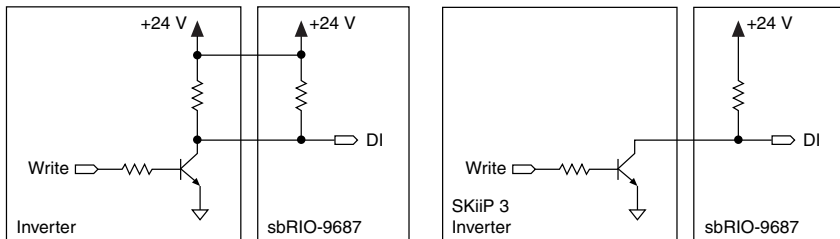
Table 32. Mapping for HALT, Sourcing DO, and Sinking DI Signals

HALT Lines	GPIC DI Line	GPIC DO Line
HALT0	DI_P0.0	DO_0
HALT1	DI_P0.1	DO_1
HALT2	DI_P0.2	DO_2
HALT3	DI_P0.3	DO_3
HALT4	DI_P0.4	DO_4
HALT5	DI_P0.5	DO_5
HALT6	DI_P0.6	DO_6

GPIO Signals

The sbRIO-9687 GPIO signals are unidirectional. The signals can only be read by the GPIC. On the inverter side, the signal has a pull-up to 24 V for SKiiP 4, Semikube GB, Semikube GD, Semikube SL GD inverters, and it is open collector for SKiiP 3 GB and SKiiP 3 GD inverters. The following figure is a schematic diagram of the GPIO signals.

Figure 18. GPIO Signal Schematic



The GPIO signals can be read on one of the sourcing digital input lines. The following table shows the mapping between inverter GPIO signals and GPIC sinking digital input.

Table 33. Mapping Between GPIO Signals and Sinking Digital Input

GPIO Line (Inverters)	DI Line (GPIC)
GPIO0	DI_P0.7
GPIO1	DI_P0.8
GPIO2	DI_P0.9
GPIO3	DI_P0.10

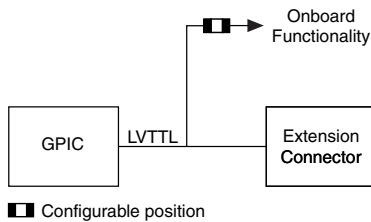
Table 33. Mapping Between GPIO Signals and Sinking Digital Input (Continued)

GPIO Line (Inverters)	DI Line (GPIC)
GPIO4	DI_P0.11
GPIO5	DI_P0.12
GPIO6	DI_P0.13

LVTTL Lines

The sbRIO-9683 or sbRIO-9684 GPIC has 32 LVTTL digital signals. These signals are high speed bidirectional lines with 3.3 V logical levels. All LVTTL lines are used for onboard functions on the sbRIO-9687. All LVTTL signals are available at the two expansion board connectors. The LVTTL signals are connected directly to the expansion board connectors and have 0 Ω resistors to onboard functions.

The following figure shows a block diagram for the LVTTL lines.

Figure 19. LVTTL Lines Block Diagram

The following table provides information about the onboard function and corresponding resistor for the LVTTL lines.



Note It is highly recommended to disconnect the LVTTL signals from sbRIO-9687 functionality when they are being used with an expansion board.

Table 34. LVTTL Lines

GPIC Signal	Onboard Function	Direction (to GPIC)	Active State	Disconnecting Resistor
DIO0	Over Range 0	Input	Low	R165
DIO1	Over Range 1	Input	Low	R156
DIO2	Over Range 2	Input	Low	R155

Table 34. LVTTTL Lines (Continued)

GPIC Signal	Onboard Function	Direction (to GPIC)	Active State	Disconnecting Resistor
DIO3	Over Range 3	Input	Low	R150
DIO4	Over Range 4	Input	Low	R142
DIO5	Over Range 5	Input	Low	R134
DIO6	Over Range 6	Input	Low	R133
DIO7	Over Range 7	Input	Low	R129
DIO8	Feedback_0.0	Input	Low/High	R123
DIO9	Feedback_0.1	Input	Low/High	R114
DIO10	Feedback_0.2	Input	Low/High	R113
DIO11	Feedback_0.3	Input	Low/High	R104
DIO12	Feedback_0.4	Input	Low/High	R96
DIO13	Feedback_0.5	Input	Low/High	R95
DIO14	Hall_0.0	Input	Low	R86
DIO15	Hall_0.1	Input	Low	R78
DIO16	Hall_0.2	Input	Low	R65
DIO17	Feedback_1.0	Input	Low/High	R72
DIO18	Feedback_1.1	Input	Low/High	R73
DIO19	Feedback_1.2	Input	Low/High	R79
DIO20	Feedback_1.3	Input	Low/High	R87
DIO21	Feedback_1.4	Input	Low/High	R97
DIO22	Feedback_1.5	Input	Low/High	R98
DIO23	Hall_1.0	Input	Low	R105
DIO24	Hall_1.1	Input	Low	R115
DIO25	Hall_1.2	Input	Low	R124
DIO26	SCL (I ² C RH sensor)	Input/Output	—	R125
DIO27	SDA (I ² C RH sensor)	Input/Output	—	R130

Table 34. LVTTTL Lines (Continued)

GPIC Signal	Onboard Function	Direction (to GPIC)	Active State	Disconnecting Resistor
DIO28	MUX A0 (TC Input)	Output	Low/High	R135
DIO29	DS3 (Green LED)	Output	Low	R136
DIO30	DS2 (Green LED)	Output	Low	R143
DIO31	DS1 (Red LED)	Output	Low	R151

The sbRIO-9683 LVTTTL DIO lines connect directly to the FPGA DIO on the sbRIO-9505/9506/9507 and are unbuffered and unprotected.



Caution Operating the LVTTTL DIO outside the rated specifications may result in permanent damage to the FPGA on the sbRIO-9605/9606/9607.

If overshoot, undershoot, and signal integrity are concerns for your application, use a single load per line that does not exceed 25 pF.

The LVTTTL DIO channels on the sbRIO-9687 are routed with a 50 Ω impedance trace. It is recommended to route all external circuitry with a similar impedance to ensure the best signal quality.

Expansion Board

LVTTTL lines are available at two expansion connectors that allow a custom expansion board to be placed on top of the sbRIO-9687 interface board.

Expansion Board Connectors

Each expansion board connector (J7 and J8) consists of a 26-pin header. For information about mating connectors, refer to the [Connectors](#) on page 4 section. The following tables provide pinout information for the expansion board connectors.

Table 35. LVTTTL Expansion Connector Pinout (J7)

Pin	Signal		Pin	Signal
1	DIO0		2	DIO1
3	DIO2		4	GND
5	DIO3		6	DIO4
7	GND		8	DIO5

Table 35. LVTTTL Expansion Connector Pinout (J7) (Continued)

Pin	Signal		Pin	Signal
9	DIO6		10	DIO7
11	DIO8		12	GND
13	DIO9		14	DIO10
15	GND		16	DIO11
17	DIO12		18	DIO13
19	DIO14		20	GND
21	GND		22	DIO15
23	+3.3 V		24	+3.3 V
25	+5 V		26	+5 V

Table 36. LVTTTL Expansion Connector Pinout (J8)

Pin	Signal		Pin	Signal
1	DIO16		2	DIO17
3	DIO18		4	GND
5	DIO19		6	DIO20
7	GND		8	DIO21
9	DIO22		10	DIO23
11	DIO24		12	GND
13	DIO25		14	DIO26
15	GND		16	DIO27
17	DIO28		18	DIO29
19	DIO30		20	GND
21	GND		22	DIO31
23	+3.3 V		24	+3.3 V
25	+5 V		26	+5 V

Expansion Board Power

The expansion board connectors have pins for +3.3 V and a +5 V power.

The +3.3 V is supplied directly by the GPIC, and the power is provided at the same time as the sbRIO-9607 FPGA power. The current on the +3.3 V rail should not exceed 330 mA. For details, refer to the *NI sbRIO-9607 Specifications*.

The +5 V pin is connected to the sbRIO-9687 internal rail and can supply up to 1 A for both connectors.

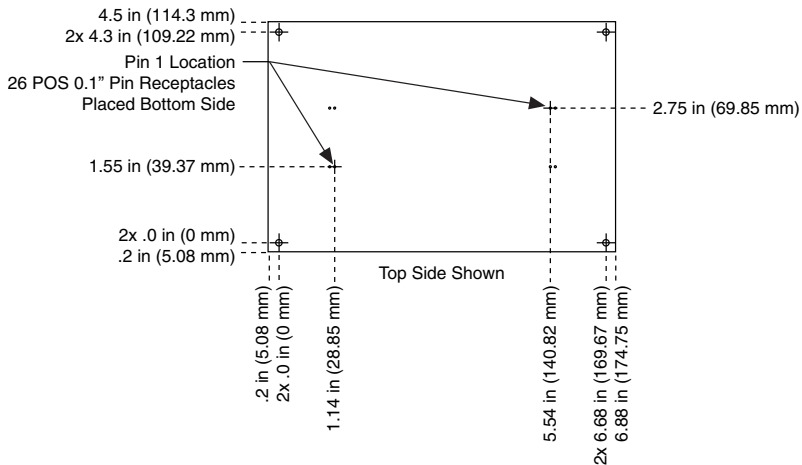


Note A short circuit on the +5 V rail could shut down the sbRIO-9687 and may require cycling the +24 V input.

Expansion Board Dimensions

An expansion board must have two mating connectors on the secondary side, each with pin 1 located as shown in the following figure.

Figure 20. Expansion Board Dimensions



Feedback Input

The sbRIO-9687 interface board includes two connectors for feedback signals. Each connector has six RS485 digital inputs for quadrature encoders, named *Feedback_x.x_x*, and three inputs for open collector Hall sensors, named *Hall_x.x*.

Feedback Connectors

The following tables provide pinout information for the J6 and J10 feedback connectors.

Table 37. J6 Feedback Connector Pinout

Pin	Signal	Pin	Signal
1	GND	13	GND
2	Feedback_0.0_A	14	Feedback_0.0_B
3	Feedback_0.1_A	15	Feedback_0.1_B
4	Feedback_0.2_A	16	Feedback_0.2_B
5	GND	17	GND
6	Feedback_0.3_A	18	Feedback_0.3_B
7	Feedback_0.4_A	19	Feedback_0.4_B
8	Feedback_0.5_A	20	Feedback_0.5_B
9	GND	21	GND
10	Hall_0.0	22	Hall_0.1
11	Hall_0.2	23	GND
12	+5 V	24	+5 V

Table 38. J10 Feedback Connector Pinout

Pin	Signal	Pin	Signal
1	GND	13	GND
2	Feedback_1.0_A	14	Feedback_1.0_B
3	Feedback_1.1_A	15	Feedback_1.1_B
4	Feedback_1.2_A	16	Feedback_1.2_B
5	GND	17	GND
6	Feedback_1.3_A	18	Feedback_1.3_B
7	Feedback_1.4_A	19	Feedback_1.4_B
8	Feedback_1.5_A	20	Feedback_1.5_B
9	GND	21	GND
10	Hall_1.0	22	Hall_1.1

Table 38. J10 Feedback Connector Pinout (Continued)

Pin	Signal	Pin	Signal
11	Hall_1.2	23	GND
12	+5 V	24	+5 V

See the [LVTTT Lines](#) on page 38 section for more information on how feedback signals are connected to the GPIC digital lines.

RS485 Input Signals

RS485 input signals are used for interfacing with a large selection of encoders. Differential RS485 signals are connected between the Feedback_x.x_A and Feedback_x.x_B lines. Each input line can support up to ± 25 V fault voltage. In normal operating mode, the input voltage should be kept within the RS485 specifications.

The outputs of the RS485 receivers are directed to the LVTTT lines. The name of the corresponding LVTTT signal is *Feedback_x.x*. For details, refer to [LVTTT Lines](#) on page 38.

Hall Sensor Input Signals

Each of the six Hall sensor inputs are designed for open collector driving outputs. Each input has a 10 k Ω pull-up resistor connected to +5 V. The inputs have a Schmitt trigger input circuit that reduces the false transitions for a noisy input signal. The output of the Schmitt trigger circuit is connected to the LVTTT signals. For details, refer to [LVTTT Lines](#) on page 38.

+5 V Output

The feedback connectors have an +5 V output that can be used for powering encoders. The +5 V output is connected to the sbRIO-9687 internal rail and can supply up to 0.5 A for each connector.



Note A short circuit on the +5 V rail could shut down the sbRIO-9687 and may require cycling the +24 V input.

Debug LEDs

The sbRIO-9687 interface board provides four LEDs for debugging purposes. One LED is powered by the 5 V rails, and the others are driven by the LVTTT lines. The LED turns ON when the corresponding LVTTT line is low. The following table provides information for each LED, including reference indicator, color and LVTTT command line.

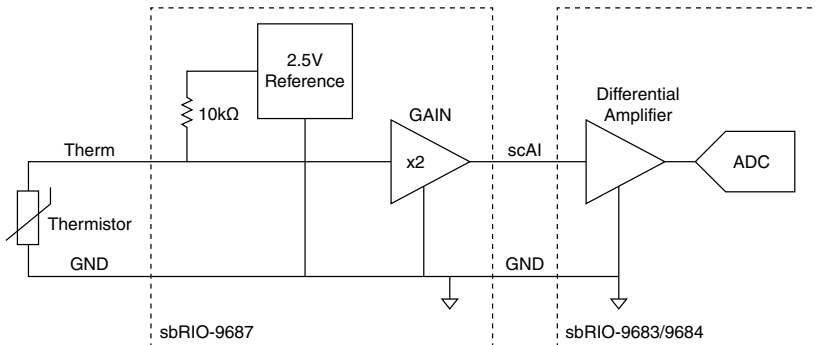
Table 39. LED Command Lines

LED Reference Indicator	LED Color	LVTTTL Command Line
DS1	RED	DIO31
DS2	GREEN	DIO30
DS3	GREEN	DIO29
DS4	GREEN	Always On

Thermistor

The sbRIO-9687 has support for two 10 kΩ thermistors for temperature measurement. The sensors are connected to a 2.5 V reference through a 10 kΩ precision resistor. The thermistor voltage is amplified by a factor of 2 on a gain stage, and then directed to the GPIC scanned analog inputs.

Figure 21. Thermistor Measurement Circuit



The thermistors should be connected between the two available terminals, Therm and Therm_GND.



Caution Do not electrically connect the thermistor body to the chassis ground or to high voltage lines in the cabinet. Such a connection could permanently damage the sbRIO-9687.

Thermistor Connector

The following table provides pinout information for the thermistor connector. If a shielded cable is used for the thermistor, connect the shield to the CHASSIS GND pins.

Table 40. J28 Thermistor Input

Pin	Signal	Pin	Signal
1	Therm1	4	Therm0
2	Therm1_GND	5	Therm0_GND
3	CHASSIS GND	6	CHASSIS GND

Thermistor Reading

The two thermistor outputs are multiplexed into the GPIC scanned AI_7 with the help of one LVTTL line. When the LVTTL line is 0, the Therm0 signal is connected to AI_7. When the LVTTL line is 1, the Therm1 signal is connected to AI_7.

DIO29	AI_7 Input
0	Thermocouple 0 input (Therm0)
1	Thermocouple 1 input (Therm1)

The following formula describes how the thermistor value can be obtained from the scanned AI voltage:

$$R_{Thermistor} = \frac{V_{AI_7}}{5V - V_{AI_7}} \times 10 \text{ k}\Omega$$

where

$R_{Thermistor}$ = Thermistor resistance.

V_{AI_7} = Voltage reading at the GPIC scanned AI_7.

To obtain the temperature, the thermistor value must be converted into temperature units based on the typical thermistor characteristics obtained from thermistor manufacturer.

Relative Humidity Sensor

For safety, a high voltage system should not be operated when condensation conditions are present. The sbRIO-9687 interface board has a built-in environmental sensor that measures temperature and relative humidity (RH) on the board.

Use the following formula to determine the RH on a different point of the cabinet:

$$RH_{cabinet} = RH_{board} \times e^{\left(\frac{17.502 \times T_{board}}{240.97 + T_{board}} - \frac{17.502 \times T_{cabinet}}{240.97 + T_{cabinet}} \right)}$$

where

RH_{cabinet} = RH value at a given point inside the cabinet (%).

T_{cabinet} = Temperature at the point where we want to determine the RH (°C).

RH_{board} = RH value read from the onboard RH sensor (%).

T_{board} = Temperature read from the onboard RH sensor (°C).

The RH sensor type is HDC1080 (Texas Instruments). It communicates with the GPIC through an I²C bus connected to the LVTTL lines. The following table shows the signal assignments for the RH sensor. Consult the Texas Instruments Web site for a full description of the RH sensor communication protocol.

Table 41. RH Sensor I²C Lines

I ² C Signal	LVTTL Line
SCL	DIO26
SDA	DIO27

Relay Connector

The sbRIO-9687 provides connections for four relay control outputs. Each output has a relay control DO+ and a current return pin, relay control DO-. The sbRIO-9683 and sbRIO-9684 have current sinking outputs, which means that the relay control DO+ is driven to relay control DO- when the channel is ON.

The following table provides pinout information for the relay connector.

Table 42. J4 Relay Connector Pinout

Pin	Signal		Pin	Signal
1	+24 V		7	+24 V
2	DO0-		8	DO0+
3	DO1-		9	DO1+
4	DO2-		10	DO2+
5	DO3-		11	DO3+
6	GND		12	GND

The relay control lines are directly connected to the GPIC relay control connector. For further details regarding best practices for relay connections, refer to the *NI 9683 User Manual and Specifications* and the *NI 9684 User Manual and Specifications*.

Display Connector

The sbRIO-9687 interface board includes support to drive an Amulet Technologies display⁴ that connects to sbRIO using an RS232 interface. The sbRIO-9687 provides power for the display on a separate connector.

The following tables provide pinout information for the RS232 and power connectors.

Table 43. J23 RS232 Serial Communication Connector

Connector Pin	Signal Name
1	DCD
2	RXD
3	TXD
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

Table 44. J15 Display Power Connector

Connector Pin	Signal Name
1	+5 V
2	GND

The maximum current available at the display power connector is 0.5 A.



Note The RS232 connector has a standard pinout and could be used for other needs inside the system.

Inverter Connectors

The following tables provide pinout information for the inverter connectors.

⁴ NI part numbers 783304-01 (display), 783306-01 (power board), and 157570-01 (cable).

Table 45. SKiiP 4 Connector (Dsub 25 Header)

Pin	Signal Name	Description
1	+24 V	Power for inverter
2	+24 V	Power for inverter
3	+24 V	Power for inverter
4	CMN_rsvd	Digital output signal from inverter (reserved)
5	HALT	Halt signal
6	Temp	Temperature (analog signal)
7	UDC	DC link voltage (analog output)
8	HB_TOP	Driving signal for high side IGBT
9	Rsvd	Reserved
10	HB_I	Phase current (analog output)
11	CAN_H	CAN high
12	CAN_H	CAN high
13	GND	Ground
14	GND	Ground
15	GND	Ground
16	GND	Ground
17	GND	Ground
18	GPIOx	General purpose digital output (open collector)
19	Temp_GND	Return for temperature output
20	UDC_GND	Return for DC link voltage
21	HB_BOT	Driving signal for low side IGBT
22	GND	Ground
23	HB_I_GND	Return for Phase current output
24	CAN_L	CAN low

Table 45. SKiiP 4 Connector (Dsub 25 Header) (Continued)

Pin	Signal Name	Description
25	CAN_L	CAN low
Shell	Earth	Earth ground

Table 46. Semikube GB Connector (20-pin DIN Header)

Pin	Signal Name	Description
1	+24 V	Power for inverter
2	GND	Ground
3	+24 V	Power for inverter
4	GND	Ground
5	+24 V	Power for inverter
6	GND	Ground
7	CMN_rsvd	Digital output signal from inverter (reserved)
8	GND	Ground
9	HALT	Halt signal
10	GPIO	General purpose digital output (open collector)
11	Temp	Temperature (analog signal)
12	Temp_GND	Return for temperature output
13	UDC	DC link voltage (analog output)
14	UDC_GND	Return for DC link voltage
15	HB_TOP	Driving signal for high side IGBT
16	HB_BOT	Driving signal for low side IGBT
17	Rsvd	Reserved
18	GND	Ground
19	HB_I	Phase current (analog output)
20	HB_I_GND	Return for phase current output

Table 47. SKiiP 3 GB Connector (14-pin DIN Header)

Pin	Signal Name	Description
1	Earth	Earth Ground
2	HB_BOT	Driving signal for low side IGBT
3	HALT	Halt signal
4	HB_TOP	Driving signal for high side IGBT
5	GPIO	General purpose digital output (open collector)
6	+24 V	Power for inverter
7	+24 V	Power for inverter
8	—	Not connected
9	—	Not connected
10	GND	Ground
11	GND	Ground
12	Temp/UDC	Temperature or DC link voltage analog output (default to temperature)
13	AO_GND	Return for phase current/temperature/DC link voltage output
14	HB_I	Phase current (analog output)

Table 48. Semikube GD and Semikube SL GD Connector (34-pin DIN Header)

Pin	Signal Name	Description
1	+24 V	Power for inverter
2	GND	Ground
3	+24 V	Power for inverter
4	GND	Ground
5	+24 V	Power for inverter
6	GND	Ground
7	CMN_rsvd	Digital output signal from inverter (reserved)
8	GND	Ground
9	HALT	Halt signal

Table 48. Semikube GD and Semikube SL GD Connector (34-pin DIN Header) (Continued)

Pin	Signal Name	Description
10	GPIO	General purpose digital output (open collector)
11	Temp	Temperature (analog signal)
12	Temp_GND	Return for temperature output
13	UDC	DC link voltage (analog output)
14	UDC_GND	Return for DC link voltage
15	HB0_TOP	Driving signal for high side IGBT (Half-Bridge 0)
16	HB0_BOT	Driving signal for low side IGBT (Half-Bridge 0)
17	Rsvd	Reserved
18	GND	Ground
19	HB0_I	Phase current output (Half-Bridge 0)
20	HB0_I_GND	Return for phase current (Half-Bridge 0)
21	HB1_TOP	Driving signal for high side IGBT (Half-Bridge 1)
22	HB1_BOT	Driving signal for low side IGBT (Half-Bridge 1)
23	Rsvd	Reserved
24	GND	Ground
25	HB1_I	Phase current output (Half-Bridge 1)
26	HB1_I_GND	Return for phase current (Half-Bridge 1)
27	HB2_TOP	Driving signal for high side IGBT (Half-Bridge 2)
28	HB2_BOT	Driving signal for low side IGBT (Half-Bridge 2)
29	Rsvd	Reserved
30	GND	Ground
31	HB2_I	Phase current output (Half-Bridge 2)
32	HB2_I_GND	Return for phase current (Half-Bridge 2)
33	CAN_H	CAN high
34	CAN_L	CAN low

Table 49. SKiiP 3 GD Connector (34-pin DIN Header)

Pin	Signal Name	Description
1	Earth	Earth Ground
2	HB0_BOT	Driving signal for low side IGBT (Half-Bridge 0)
3	HALT0	Halt signal (Half-Bridge 0)
4	HB0_TOP	Driving signal for high side IGBT (Half-Bridge 0)
5	HB1_BOT	Driving signal for low side IGBT (Half-Bridge 1)
6	HALT1	Halt signal (Half-Bridge 1)
7	HB1_TOP	Driving signal for high side IGBT (Half-Bridge 1)
8	HB2_BOT	Driving signal for low side IGBT (Half-Bridge 2)
9	HALT2	Halt signal (Half-Bridge 2)
10	HB2_TOP	Driving signal for high side IGBT (Half-Bridge 2)
11	GPIO	General purpose digital output (open collector)
12	—	Not connected
13	UDC	DC link voltage (analog output)
14	+24 V	Power for inverter
15	+24 V	Power for inverter
16	—	Not connected
17	—	Not connected
18	GND	Ground
19	GND	Ground
20	Temp	Temperature (analog signal)
21	HB0_I_GND	Return for phase current (Half-Bridge 0)
22	HB0_I	Phase current output (Half-Bridge 0)
23	HB1_I_GND	Return for phase current (Half-Bridge 1)
24	HB1_I	Phase current output (Half-Bridge 1)

Table 49. SKiIP 3 GD Connector (34-pin DIN Header) (Continued)

Pin	Signal Name	Description
25	HB2_I_GND	Return for phase current (Half-Bridge 2)
26	HB2_I	Phase current output (Half-Bridge 2)

Worldwide Support and Services

The NI website is your complete resource for technical support. At ni.com/support, you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

Visit ni.com/services for information about the services NI offers.

Visit ni.com/register to register your NI product. Product registration facilitates technical support and ensures that you receive important information updates from NI.

A Declaration of Conformity (DoC) is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electromagnetic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting ni.com/certification. If your product supports calibration, you can obtain the calibration certificate for your product at ni.com/calibration.

NI corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. NI also has offices located around the world. For support in the United States, create your service request at ni.com/support or dial 1 866 ASK MYNI (275 6964). For support outside the United States, visit the *Worldwide Offices* section of ni.com/niglobal to access the branch office websites, which provide up-to-date contact information.

Information is subject to change without notice. Refer to the *NI Trademarks and Logo Guidelines* at ni.com/trademarks for information on NI trademarks. Other product and company names mentioned herein are trademarks or trade names of their respective companies. For patents covering NI products/technology, refer to the appropriate location: **Help»Patents** in your software, the `patents.txt` file on your media, or the *National Instruments Patent Notice* at ni.com/patents. You can find information about end-user license agreements (EULAs) and third-party legal notices in the `readme` file for your NI product. Refer to the *Export Compliance Information* at ni.com/legal/export-compliance for the NI global trade compliance policy and how to obtain relevant HTS codes, ECCNs, and other import/export data. NI MAKES NO EXPRESS OR IMPLIED WARRANTIES AS TO THE ACCURACY OF THE INFORMATION CONTAINED HEREIN AND SHALL NOT BE LIABLE FOR ANY ERRORS. U.S. Government Customers: The data contained in this manual was developed at private expense and is subject to the applicable limited rights and restricted data rights as set forth in FAR 52.227-14, DFAR 252.227-7014, and DFAR 252.227-7015.