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SLSC 8-Channel VDT/Resolver Simulation Module

Installation Instructions and Reference Manual

Revision –
February 29, 2018

Revision History

Rev.	Date	Description
pre.	1/31/2017	Initial version.
pre.	4/10/2017	Corrected J1/J2 pinouts. (H/T Anders!) Added DCR for 400Hz variant. Added 0.1 factor to basic transfer function.
pre.	6/26/2017	Fixed RTI I/F pinout.
pre.	8/7/2017	Fixed transformer ratios for -01 variant.
–	2/29/2018	Added transformer ratios for -02 variant.

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1.0 Overview

These operating instructions describe how to install and use the Bloomy 1200-00019 SLSC 8-Channel VDT/Resolver Simulation Module into a National Instruments Switch/Load/Signal Conditioning (SLSC) system. For information about installing, configuring, and programming the system, refer to the system's documentation.

Note: The safety guidelines and specifications in this document are specific to this module. The other components in your system may not meet the same ratings and specifications. Refer to the documentation for each component in your system to determine the ratings and specifications for the entire system.

1.1 Regulatory

Refer to the product Declaration of Conformity for additional regulatory compliance information. To obtain product certifications and declarations of conformity for this product, see www.bloomy.com/support.

2.0 Module Description

The Bloomy SLSC VDT/Resolver Simulator Module provides eight channels of LVDT, RVDT or resolver simulation for the National Instruments SLSC family of products. Each channel can be connected as one four, five or six wire simulation, or two four-wire simulations with common excitation. It conforms to the NI SLSC Module Development Kit v1.1, occupies a single slot of a standard SLSC chassis and requires no external power.

2.1 Features

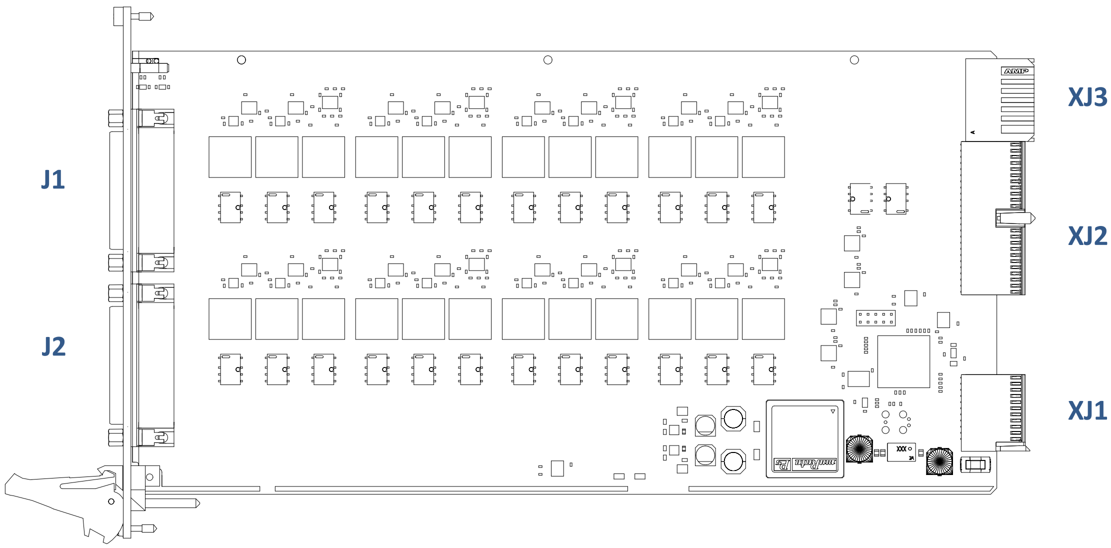
The SLSC VDT/Resolver Simulator Module has the following features:

- Each channel can simulate either an LVDT, an RVDT or a resolver independently of the other channels.
- Each channel can be wired as an independent 4-wire, 5-wire or 6-wire simulation without affecting the other channels.
- Each channel can simulate two four-wire devices as long as the excitation source is common for both simulations.
- Independent control of the two returns for each channel allow simulation of both nominal as well as non-nominal devices.
- Excitation for each channel's simulation can be provided through the module's front panel connectors or can be selectively provided from an SLSC-wide system bus for UUTs which do not supply their own excitation.
- Calibration relays on each channel provide both calibration and open-circuit fault/disconnect capability for the channel. The calibration relays connect the channel to the system-wide instrumentation bus allowing system instrumentation resources to calibrate each channel's transfer function.

2.2 Hardware Overview

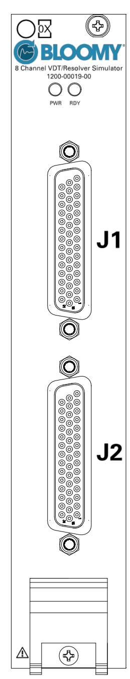
Side and front views of the module are shown below with connector designators. Pinouts for the connectors are shown in Appendix A.

Right Side View:



J1 and J2 are user connections for the VDT/resolver simulations. XJ1 connects to the SLSC backplane, while XJ2 and XJ3 connect to the rear transition interface and then to the rest of the system. XJ2 is the analog/digital I/O connector, and XJ3 is the system-wide fault/instrumentation bus.

Front View:



J1 and J2 are 44-pin high-density female D-shell connectors. The PWR and RDY indicators show the status of the module according to the table below.

Indicator	Behavior	Status
PWR	Off	The module is not properly powered.
	Solid Green	The module is powered correctly.
	Blinking Red	Module fault.
RDY	Off	Module is not powered or is not ready.
	Solid Green	Module is in default condition and ready for use.
	Blinking Yellow	Module is active, but in a non-default condition.

2.3 Specifications

Conforms to National Instruments SLSC Module Development Kit v2.0

Parameter	Value	Notes
Supply power	24VDC	Supplied through SLSC backplane connector XJ1 Measured with all relays energized
Supply power	3.3VDC	Supplied through SLSC backplane connector XJ1
$V_{EXC, MAX}$	$11V_{peak}$	1200-00019-00
	$20V_{peak}$	1200-00019-01
	$40V_{peak}$	1200-00019-02
f_{EXC}	1kHz-10kHz	1200-00019-00
	400Hz-1kHz	1200-00019-01
	400Hz-1kHz	1200-00019-02
DCR, input	38Ω±15%	1200-00019-00
	44Ω±15%	1200-00019-01
	40Ω±15%	1200-00019-02
DCR, output	41Ω±15%	1200-00019-00
	52Ω±15%	1200-00019-01
	52Ω±15%	1200-00019-02

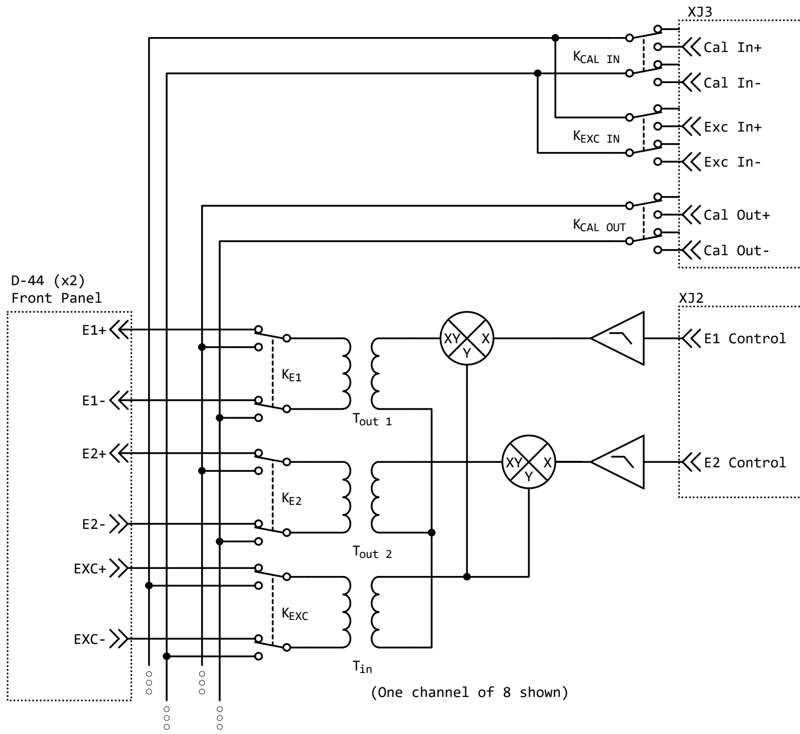
2.4 Software Overview

A LabVIEW VI is provided which converts engineering units (displacement) to voltages to drive the D/A converters. This VI also connects the calibration and shared excitation buses. Instructions for these VIs are included with the VI. The transfer functions of the VI and module is discussed further below.

2.5 Theory of Operation

The module simulates VDTs and resolvers by using an analog four-quadrant multiplier under external control to vary the amplitude and sign of two return outputs for each excitation input. Both the excitation and the returns are transformer coupled for isolation and to provide the unit under test with an inductive load. The external control is provided by an analog signal from a digital to analog converter, such as a National Instruments PXI or Compact RIO module.

A simplified block diagram of one channel of the module is shown below. (All relays are shown in their default states.)



As shown in the diagram, excitation is received through the front panel "EXC" connections. The excitation is isolated by an input transformer, T_{IN}, and is distributed to two analog multipliers. The multipliers create the product of the excitation signal and the two control signals received from the rear XJ2 connector. The output of each multiplier is isolated by an output transformer, T_{OUT}, which is connected to the front panel. Because the multiplier is a four-quadrant device, the sign of the products can be the inverse of the excitation.

Some units under test do not supply their own excitation but rather source excitation for the connected sensors from an external source. Relays K_{EXC} and $K_{EXC\ IN}$ allow a system-wide excitation signal to be brought into the module through the rear fault/instrumentation connector, XJ3.

For calibration of the transfer function, K_{EXC} and $K_{CAL\ IN}$ are closed thus connecting a source of AC to the excitation input of the channel. $K_{CAL\ OUT}$ is closed which connects a measurement device, such as a National Instruments PXI-based DMM, to the on-board calibration bus. K_{E1} or K_{E2} is then closed to complete the output signal path to the DMM. The control signals are then swept from -10V to +10V and the transfer function of the channel can be analyzed for calibration purposes. Each channel is calibrated in turn.

If the excitation source is uncalibrated, $K_{CAL\ IN}$ may also be connected during this process, though the circuit to the DMM must be completed by a switch matrix elsewhere.

While $K_{CAL\ IN}$, $K_{CAL\ OUT}$ and $K_{EXC\ IN}$ are all in their open positions, K_{E1}, K_{E2}, and K_{EXC} may be opened individually or as a group to simulate open-circuit faults.

Note: $K_{EXC\ IN}$ is not present on modules produced prior to 2017.

2.6 Transfer Function

The basic transfer function for each channel of the module is defined by the formulas below:

$$E_1 = V_{EXC} \times T_{in} \times \frac{V_{control,1}}{10} \times T_{out}$$

$$E_2 = V_{EXC} \times T_{in} \times \frac{V_{control,2}}{10} \times T_{out}$$

The transformation ratios (T_{in} and T_{out}) are dependent on the module configuration per the following table:

Part number	T_{in}	T_{out}
1200-00019-00	0.909	1.2
1200-00019-01	0.5	2.1
1200-00019-02	0.25	2.1

The supplied VI automatically detects the module type and uses the transformation ratios to set $V_{control,n}$ based on the chosen simulation type as detailed below.

V_{EXC} is bandwidth limited and has a -3dB corner frequency of 20kHz.

2.6.1 4-Wire VDT Simulation

Because the output E of a four-wire VDT is the sum of the two return coils, E_1 and E_2, the output may be expressed by the following equation:

$$E = V_{EXC} \times S \times d$$

where

V_{EXC} is the RMS, peak or instantaneous voltage,

S is the sensitivity of the VDT in units of $\frac{mV}{V*mm}$ or similar, and

d is the displacement of the VDT from its null position in units of corresponding length or rotation.

Note that because the displacement can be positive or negative that the return voltage can be in phase or inverted relative to the excitation.

Because the module has the capability of providing inverted outputs, each channel can be used to simulate two 4-wire VDTs.

VI Inputs

The VI for the 4-wire simulation requires the following inputs:

d_1, d_2: displacement for each return in units of length (e.g., mm or in.) or rotation (°)

$d_{1,E}$, $d_{2,E}$: displacement error for each return in the same units as the displacement; default value of 0

S: the sensitivity of the VDT expressed in units of mV/V/length or mV/V/°.

As long as the unit of displacement matches the unit of the sensitivity, the simulation will work for both linear as well as rotary VDTs.

The VI simulates an ideal VDT and does not simulate the nonlinearities of the ends of the range of a real VDT. In this mode, as in a real 4-wire VDT, a minimal residual voltage will be present at the null position; this null voltage cannot be calibrated out though it can be quantified through the system instrumentation. The Advanced Mode of the VI can be used to control all aspects of the simulation through direct control of the D/A outputs to the module.

Note: A four-wire VDT simulation may also be created by wiring a channel's return coils in series and by using the 5-wire/6-wire simulation mode.

2.6.2 5- and 6-wire VDT Simulation

Each channel of the module simulates a 6-wire VDT in its normal configuration. Connecting the channel's returns in series as shown in the following diagram yields a 5-wire configuration.

The normal transfer function of a variable differential transformer can be expressed by the following equations:

$$E_1 = (V_{EXC} \times N) + (V_{EXC} \times S \times d)$$
$$E_2 = (V_{EXC} \times N) - (V_{EXC} \times S \times d)$$

where

V_{EXC} is the RMS, peak or instantaneous voltage,

S is the sensitivity of each return in units of $\frac{mV}{V*mm}$ or similar,

d is the displacement of the VDT from its null position in units of corresponding length or rotation, and

N is the nominal transformation ratio of the VDT, the ratio of the VDT when the VDT's displacement is 0.

Notes:

When obtained from a datasheet, sensitivity (S) is typically expressed based on the sensitivity of the VDT (that is, the sensitivity of the difference between E_1 and E_2), and thus must be divided by 2 for use in the equations above. When in doubt, the sensitivity can be derived using the following equation:

$$S = \frac{V_{max} - V_{min}}{V_{EXC} \times D}$$

where

V_{max}, V_{min} are the outputs of one of the returns at opposite ends of the VDT's displacement,

V_{EXC} is the excitation voltage, and

D is the total stroke (end-to-end displacement) of the VDT.

N is rarely available from the VDT data sheet but is necessary for this type of simulation. It may be derived using the following equation:

$$N = \frac{V_{max} + V_{min}}{2 \times V_{EXC}}$$

where

V_{max}, V_{min} are the outputs of one of the returns at opposite ends of the VDT's displacement, and

V_{EXC} is the excitation voltage.

Also note that in a 5- or 6-wire configuration, E_1 and E_2 are never inverted in polarity from the excitation; their difference will be inverted, however, for negative displacements.

VI Inputs

The VI for the 5- or 6-wire simulation requires the following inputs:

d: displacement for the VDT in units of length (e.g., mm or in.) or rotation (°)

$d_{1,E}$, $d_{2,E}$: displacement error for each return in the same units as the displacement; default value of 0

S: the sensitivity of the VDT expressed in units of mV/V/length or mV/V/°.

N: the nominal transformation ratio of the VDT.

As long as the unit of displacement matches the unit of the sensitivity, the simulation will work for both linear as well as rotary VDTs.

The VI simulates an ideal VDT and does not simulate the nonlinearities of the ends of the range of a real VDT. The Advanced Mode of the VI can be used to control all aspects of the simulation through direct control of the D/A outputs to the module.

2.6.3 Resolver Simulation

Resolver simulation has two different implementations depending on what the resolver receiver (unit under test, resolver meter, etc.) requires. If the device requires static updates or updates only as frequently as a model updates it, then the static simulation can be used. If the device is a tracking device and requires updates at >10x the excitation frequency, the dynamic implementation should be used instead. Each simulation technique is described below.

2.6.3.1 Static Resolver Simulation

The static resolver simulation works nearly identically to the 6-wire VDT simulation described above. The normal transfer function of a resolver can be expressed with the following equations:

$$S_{24} = R_{13} \times TR \times \sin(\mathrm{N}\Theta + \Phi)$$

$$S_{13} = R_{13} \times TR \times \cos(\mathrm{N}\Theta + \Phi)$$

where

S_{24} is the sine return, provided by the E1 return of a channel

S_{13} is the cosine return, provided by the E2 return of a channel

R_{13} is the excitation voltage, provided by the V_{EXC} input of a channel

TR is the nominal transformation ratio

N is the number of poles (or "speed") of the device

Θ is the angle of the rotor, and

Φ is the phase shift of the resolver.

The module does not simulate four-wire rotor resolvers.

VI Inputs

The VI for the static resolver simulation requires the following inputs:

TR: the nominal transformation ratio

N: the number of poles (or "speed") of the device (default is 1)

Θ: the angle of the rotor

Φ: the nominal phase shift of the resolver (default is 0)

$\Theta_{ERR,SIN}$, $\Theta_{ERR,COS}$: angle error of each return (default is 0)

2.6.3.2 Dynamic Resolver Simulation

When the angle of the resolver is being converted using a tracking converter and the required update rate exceeds the ability of the static simulation to update the position, the dynamic resolver simulation should be used. This simulation has two components, a VI which runs in a real-time or non-real-time host environment, and a VI which is compiled and deployed to a target consisting of a National Instruments R-Series Multifunction I/O PXI module or to a similar solution in the Compact RIO system.

In this simulation, the target emulates the rotating machinery at the update rate of the on-board FPGA. The host environment does not maintain the state of the rotating machinery, but rather gives the target commands to set initial position and accelerate or decelerate. The target responds to these commands and provides the host with current state (position and speed) when the host requests the state.

Emulation of the resolver is the same as with the static simulation. Note that the first-order filter applied to the control voltages has its cutoff frequency set to 20kHz. The practical limit for the electrical rotational velocity is therefore 2kHz, or 120,000 RPM. For a single-pole resolver, the electrical speed is the same as the mechanical speed. Multipole resolvers will reduce the mechanical speed by a factor of $1/N$, so a 2-pole resolver has a maximum mechanical speed of 60,000RPM, etc.

Host VI Inputs and Outputs

TR: the nominal transformation ratio

N: the number of poles (or "speed") of the device (default is 1)

Φ: the nominal phase shift of the resolver (default is 0, changes take effect immediately)

$\Theta_{ERR,SIN}$, $\Theta_{ERR,COS}$: angle error of each return (default is 0, changes take effect immediately)

Target VI: a reference to the target VI

RPM command: a structure which performs one of the following actions:

sets the target to a desired RPM

commands the target to accelerate from the current RPM at an acceleration rate (in RPM/s) for a set length of time, or

commands the target to accelerate from the current RPM to a target RPM in a set length of time.

The VI outputs the current position and RPM of the simulation.

The host VI maintains the connection to the target VI, so no user VI interaction is required.

2.6.4 Advanced Mode

Advanced mode allows full control of each channel per the transfer function listed in *Transfer Function,* above.

In this mode, $V_{control,1}$ and $V_{control,2}$ are under direct user control. Other parameters are set by the VI based on the board configuration.

VI Inputs

$V_{control,1}$ and $V_{control,2}$: control voltages sent to the controlling channel's D/A converters, ±10V range.

2.7 Routing Control

The module provides the capability to set up various routes and faults through the SLSC switch routing topology standard. The following table shows the various route names, their functionality, and the relays which are energized. Note that the block diagram in "Theory of Operation" shows the relays for a single channel, but the relays are the same for each channel. Only the relays with "1" (energized) or "0" (de-energized) are affected unless otherwise noted.

Route	Relay States						Function
	$K_{EXC,CHn}$	$K_{E1,CHn}$	$K_{E2,CHn}$	$K_{CAL\ IN}$	$K_{EXC\ IN}$	$K_{CAL\ OUT}$	
DEFAULT	0	0	0	0	0	0	Normal state of the module with no faults or calibration routes engaged.
CAL_CH_*n*_E1	1	1	0	1	0	1	Connects excitation of channel *n* to CAL IN, E1 of channel *n* to CAL OUT.
CAL_CH_*n*_E2	1	0	1	1	0	1	Connects excitation of channel *n* to CAL IN, E1 of channel *n* to CAL OUT.
CAL_CH_*n*_E1_EXT	1	1	0	1	1	1	Connects external excitation of channel *n* to CAL IN, E1 of channel *n* to CAL OUT.
CAL_CH_*n*_E2_EXT	1	0	1	1	1	1	Connects external excitation of channel *n* to CAL IN, E1 of channel *n* to CAL OUT.
EXT_EXC_CH_*n*	1			0	1		Connects excitation of channel *n* to the external excitation source. Route must be re-connected after a calibration operation.
OPEN_EXC_CH_*n*	1			0	0	0	Opens channel *n* excitation relay. All other relays are unaffected.
OPEN_E1_CH_*n*		1		0	0	0	Opens channel *n* E1 relay. All other relays are unaffected.
OPEN_E2_CH_*n*			1	0	0	0	Opens channel *n* E2 relay. All other relays are unaffected.

2.8 Manual Relay Control

The VIs which are provided with the module provide direct control of the on-board relays through the SLSC API "Property" function.

Caution! Improper use of the relays could lead to damage to the module, system or unit under test.

3.0 Installation

3.1 System Requirements

This module requires:

- an open slot in a National Instruments SLSC-12001 chassis
- a single-ended analog rear transition interface (RTI) module installed into the open slot
- a National Instruments PXI or Compact RIO D/A converter (two D/As per simulation channel)
- a cable which mates the RTI to the D/A converters
- LabVIEW 2015 or later.

Note: Install the latest software drivers for this module before plugging the module into the target SLSC chassis. The latest version of the software may be obtained from www.bloomy.com/support.

3.2 External Connections

The module is designed to be used with the National Instruments Mil/Aero HIL SLSC standard system of components such as the Bloomy ThroughPoint™ Interface Panel. As such, most connections can be made using the off-the-shelf D-shell cables which are part of this system. When necessary, connections to the module may be made using custom D-shell cables per the pinouts shown in Appendix A.

Appendix A: Module Pinouts

J1: Simulation I/O Channels 0-3

Connector type: HD44F
Mates with: HD44M, e.g., AMP/TE Connectivity P/N 1757823-9

Pin	Function	Pin	Function
1	Channel 0 E1+/S2	9	Channel 2 E1+/S2
16	Channel 0 E1-/S4	24	Channel 2 E1-/S4
2	Channel 0 E2+/S1	10	Channel 2 E2+/S1
17	Channel 0 E2-/S3	25	Channel 2 E2-/S3
31	Channel 0 EXC+/R1	39	Channel 2 EXC+/R1
32	Channel 0 EXC-/R3	40	Channel 2 EXC-/R3
5	Channel 1 E1+/S2	13	Channel 3 E1+/S2
20	Channel 1 E1-/S4	28	Channel 3 E1-/S4
6	Channel 1 E2+/S1	14	Channel 3 E2+/S1
21	Channel 1 E2-/S3	29	Channel 3 E2-/S3
35	Channel 1 EXC+/R1	43	Channel 3 EXC+/R1
36	Channel 1 EXC-/R3	44	Channel 3 EXC-/R3

J2: Simulation I/O Channels 4-7

Connector type: HD44F
Mates with: HD44M, e.g., AMP/TE Connectivity P/N 1757823-9

Pin	Function	Pin	Function
1	Channel 4 E1+/S2	9	Channel 6 E1+/S2
16	Channel 4 E1-/S4	24	Channel 6 E1-/S4
2	Channel 4 E2+/S1	10	Channel 6 E2+/S1
17	Channel 4 E2-/S3	25	Channel 6 E2-/S3
31	Channel 4 EXC+/R1	39	Channel 6 EXC+/R1
32	Channel 4 EXC-/R3	40	Channel 6 EXC-/R3
5	Channel 5 E1+/S2	13	Channel 7 E1+/S2
20	Channel 5 E1-/S4	28	Channel 7 E1-/S4
6	Channel 5 E2+/S1	14	Channel 7 E2+/S1
21	Channel 5 E2-/S3	29	Channel 7 E2-/S3
35	Channel 5 EXC+/R1	43	Channel 7 EXC+/R1
36	Channel 5 EXC-/R3	44	Channel 7 EXC-/R3

XJ1: SLSC Backplane

Reserved for SLSC use.

XJ2: Control Voltage Input

Connector type: 110-pin hard metric connector, ERNI Electronics P/N 354142

Pin	Function	Pin	Function
a1	Channel 0 $V_{in,1}$	a7	Channel 4 $V_{in,1}$
b1	Channel 0 $V_{in,1}$ RTN	b7	Channel 4 $V_{in,1}$ RTN
d1	Channel 0 $V_{in,2}$	d7	Channel 4 $V_{in,2}$
e1	Channel 0 $V_{in,2}$ RTN	e7	Channel 4 $V_{in,2}$ RTN
a2	Channel 1 $V_{in,1}$	a8	Channel 5 $V_{in,1}$
b2	Channel 1 $V_{in,1}$ RTN	b8	Channel 5 $V_{in,1}$ RTN
d2	Channel 1 $V_{in,2}$	d8	Channel 5 $V_{in,2}$
e2	Channel 1 $V_{in,2}$ RTN	e8	Channel 5 $V_{in,2}$ RTN
a4	Channel 2 $V_{in,1}$	a10	Channel 6 $V_{in,1}$
b4	Channel 2 $V_{in,1}$ RTN	b10	Channel 6 $V_{in,1}$ RTN
d4	Channel 2 $V_{in,1}$	d10	Channel 6 $V_{in,1}$
e4	Channel 2 $V_{in,1}$ RTN	e10	Channel 6 $V_{in,1}$ RTN
a5	Channel 3 $V_{in,1}$	a11	Channel 7 $V_{in,1}$
b5	Channel 3 $V_{in,1}$ RTN	b11	Channel 7 $V_{in,1}$ RTN
d5	Channel 3 $V_{in,1}$	d11	Channel 7 $V_{in,1}$
e5	Channel 3 $V_{in,1}$ RTN	e11	Channel 7 $V_{in,1}$ RTN

XJ3: Instrumentation/Fault Bus

Connector: 8-position power connector, TE Connectivity P/N 5646958-2

Pin	Function	Pin	Function
A	CAL OUT +	E	reserved
B	CAL OUT –	F	reserved
C	CAL IN +	G	EXC IN +
D	CAL IN –	H	EXC IN –

Appendix B: Module Memory Map

Address	Bitmask	Function
0x000		ID Demux
0x001	0000 0001	LED1_RED
	0000 0010	LED2_RED
	0000 0100	LED1_GREEN
	0000 1000	LED2_GREEN
0x100	0000 0001	CH0_EXC_TO_CAL1
	0000 0010	CH0_OUT1_TO_CAL2
	0000 0100	CH0_OUT2_TO_CAL2
	0001 0000	CH1_EXC_TO_CAL1
	0010 0000	CH1_OUT1_TO_CAL2
	0100 0000	CH1_OUT2_TO_CAL2
0x101	0000 0001	CH2_EXC_TO_CAL1
	0000 0010	CH2_OUT1_TO_CAL2
	0000 0100	CH2_OUT2_TO_CAL2
	0001 0000	CH3_EXC_TO_CAL1
	0010 0000	CH3_OUT1_TO_CAL2
	0100 0000	CH3_OUT2_TO_CAL2
0x102	0000 0001	CH4_EXC_TO_CAL1
	0000 0010	CH4_OUT1_TO_CAL2
	0000 0100	CH4_OUT2_TO_CAL2
	0001 0000	CH5_EXC_TO_CAL1
	0010 0000	CH5_OUT1_TO_CAL2
	0100 0000	CH5_OUT2_TO_CAL2
0x103	0000 0001	CH6_EXC_TO_CAL1
	0000 0010	CH6_OUT1_TO_CAL2
	0000 0100	CH6_OUT2_TO_CAL2
	0001 0000	CH7_EXC_TO_CAL1
	0010 0000	CH7_OUT1_TO_CAL2
	0100 0000	CH7_OUT2_TO_CAL2
0x104	0000 0001	CAL1_ENABLE (Connects CAL1 to XJ3-CD)
	0000 0010	CAL2_ENABLE (Connects CAL2 to XJ3-AB)
0x200		Temperature #1 (low-order byte)
0x201		Temperature #1 (high-order byte)
0x202		Temperature #2 (low-order byte)
0x203		Temperature #2 (high-order byte)
0x300	0000 0001	DC_DC_ENABLE
0x400		CPLD Version (low-order byte)
0x401		CPLD Version
0x402		CPLD Version
0x403		CPLD Version (high-order byte)