

# ALLIANCE SENSORS GROUP

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A DIVISION OF H.G. SCHAEVITZ LLC

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## **S1A** *Signal Conditioner for AC LVDTs, RVDTs, LVRTs, and Half-bridges*

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### **Set-up and Operating Instructions**

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## EC/EU Declaration of Conformity

The undersigned, representing **Alliance Sensors Group, a Div. of H.G. Schaevitz LLC,  
102 Commerce Drive, Unit 8,  
Moorestown, NJ 08057 USA,**

hereby declares that the product, **Model S1A LVDT Signal Conditioner,**

of the following category and type: **Measurement, Control Equipment, and Laboratory Use,**

is in conformity with the provisions  
of the following EC/EU directives: **EMC Directive 2004/108/EC; RoHS 2 Directive 2011/65/EU**

Testing was done to requirements  
as stated in harmonized standards **EN 61326-1: 2006 and CISPR 11, A-1: 2003**

using the methods noted hereafter: **IEC 61000-4-2: 2001, IEC 61000-4-3: 2002,  
IEC 61000-4-4: 2004, IEC 61000-4-5: 2001,  
IEC 61000-4-6: 2003, and CISPR 11 A-1: 2003.**

A TCF for the product is maintained  
for inspection at the location noted.

*Edward E. Herceg*  
Edward E. Herceg, VP, CTO

*March 1, 2014*  
Date of Issue

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## Product Warranty

Alliance Sensors Group warrants the Model S1A LVDT Signal Conditioner to be free from defects in workmanship and materials for a period of two (2) years from the date of shipment. In the event a valid claim is made under this warranty, the only obligation of Alliance Sensors Group is to repair or replace the unit. ***Under no circumstances will Alliance Sensors Group be liable for fitness of purpose by the user or any damages, direct, consequential, or otherwise, or for any damage to any sensor connected to the S1A LVDT Signal Conditioner, or for any damage to any electronic equipment connected to the inputs or outputs of the S1A LVDT Signal Conditioner.***

To submit a claim under the provisions of this warranty, the claimant must secure an RMA (Returned Material Authorization) number by contacting Alliance Sensors Group at: 856-727-0250, or by sending a letter, or by e-mailing [sales@alliancesensors.com](mailto:sales@alliancesensors.com). The defective unit must be returned freight prepaid to Alliance Sensors Group for inspection, accompanied by the RMA number and a letter of explanation of the purported defect. If the inspection and evaluation validates the warranty claim, the repaired or a replacement unit will be promptly returned to the claimant freight prepaid.

If inspection and evaluation of the device determines that it has been misused, abused, misapplied, or modified by the user; has been subjected to a fire, flood, or mishandling; or is damaged due to improper packing for the return shipment, no warranty claim will be allowed or accepted. Instead, the unit will be returned to the claimant freight collect, along with an invoice for the evaluation charge. Any questions about Alliance's warranty provisions can be answered by contacting Alliance Sensors Group at: 856-727-0250, or by sending an e-mail query to: [sales@alliancesensors.com](mailto:sales@alliancesensors.com).

## PREFACE

In this manual, you will find a chart on page 4 for quickly connecting your AC-LVDT, AC-RVDT, LVRT, or inductive half-bridge sensor to this model S1A DIN-rail mounting, 24 Volt DC-operated signal conditioning module, and a **Quick Start Guide** on page 5 for calibrating it with the two front-panel push buttons, which eliminate any need for external pot adjustments. The internal DSP (Digital Signal Processor) will lead you through the various calibration steps by means of the three green LEDs on the module's front panel, as illustrated on page 2. The term *LVDT* is used generically throughout these instructions for any low voltage audio frequency AC-operated position sensors, i.e. LVDTs, RVDTs, LVRTs, and inductive half-bridges.

You will also find the S1A specifications and a more detailed description of the advanced functions available for applications where you may wish to go beyond the basic features. Such possibilities include the master/slave synchronization of the excitation for multiple LVDTs, the open-collector failure warning switch output, the DC voltage null position indicator signal, and digital communications via the RS-485 addressable multi-drop port. The S1A LVDT Signal Conditioner is **CE** compliant for both EMI and RoHS. To assure long, maintenance-free life, all inputs and outputs are equipped with ESD protection, as well as protections against reverse voltage, overvoltage, and short circuits. Operating current and power-on inrush current are also limited by solid-state resettable fuses.

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# Identification of Front Panel LEDs and Switch Functions

(Use with **Quick Start Guide** on page 5)

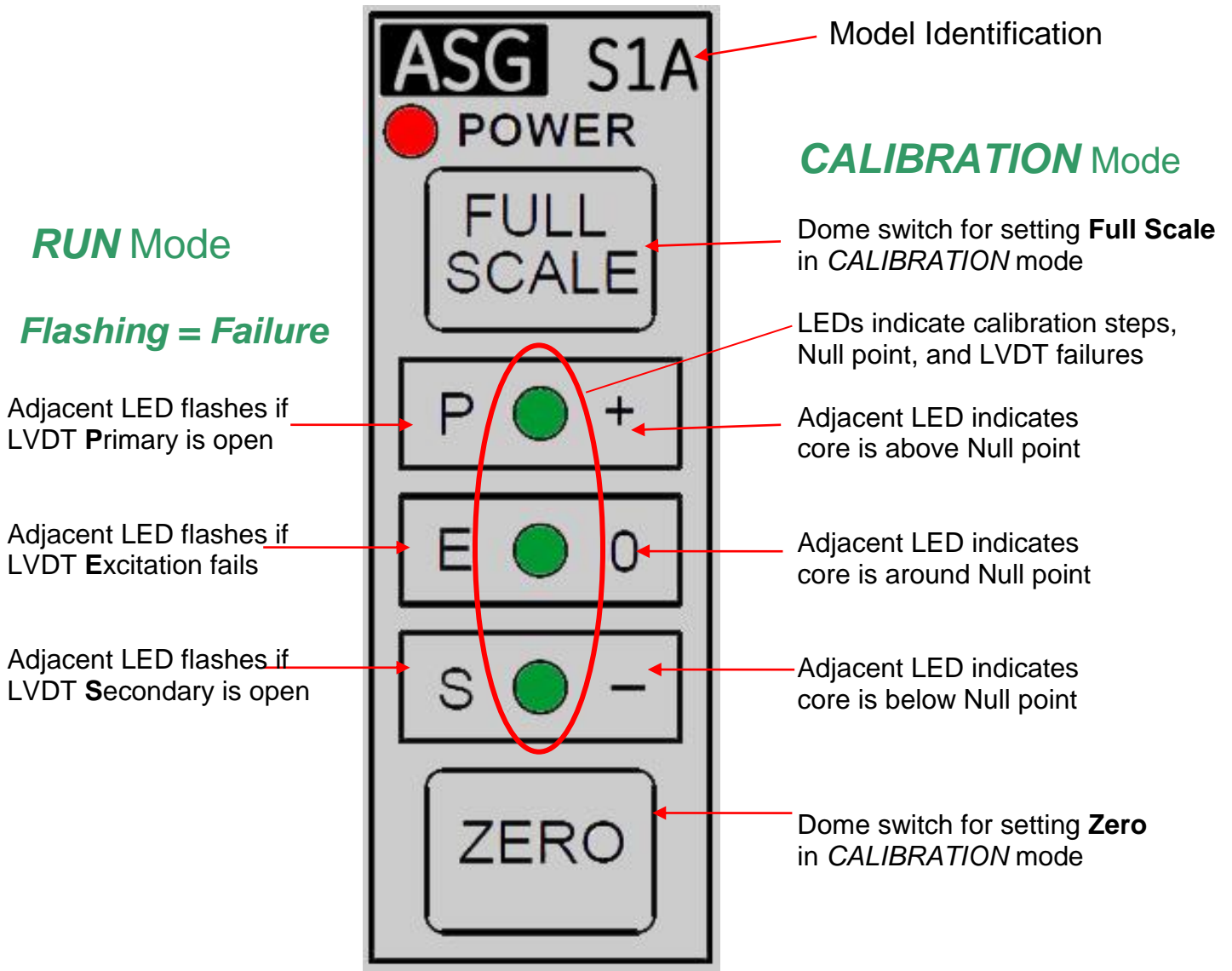
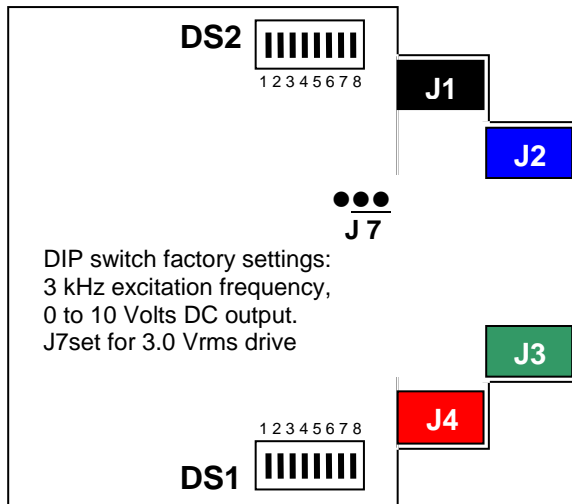


Figure 1

# Identification of the pc board-mounted DIP switch functions & I/O connections

(Use with **Quick Start Guide** on page 5)



**Figure 2** Internal DIP Switch Locations

DS2-1 and DS2-2 Switch positions	Excitation Frequency
DS2-1 & DS2-2 both OFF	1 kHz
DS2-1 ON & DS2-2 OFF	3 kHz
DS2-1 OFF & DS2-2 ON	5 kHz
DS2-1 & DS2-2 both ON	10 kHz

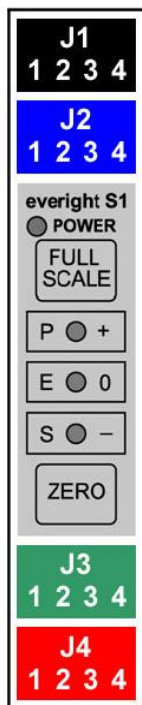
**Table 1** Excitation Frequency Settings

DS2 -	3	4	5	6	7	8
Switch ON	Invert Output	10 Hz	add 8	add 4	add 2	add 1

**Table 1a** Special Outputs and Unit Address

DS1 Position	1	2	3	4	5	6	7	8
Output with DS1-No. ON	0 to 5 Volts	1 to 5 Volts	0.5 to 4.5 Volts	0 to 10 Volts	-10 to +10 Volts	0.5 to 9.5 Volts	0 to 20 mA	4 to 20 mA

**Table 2** S1A Analog Output Settings

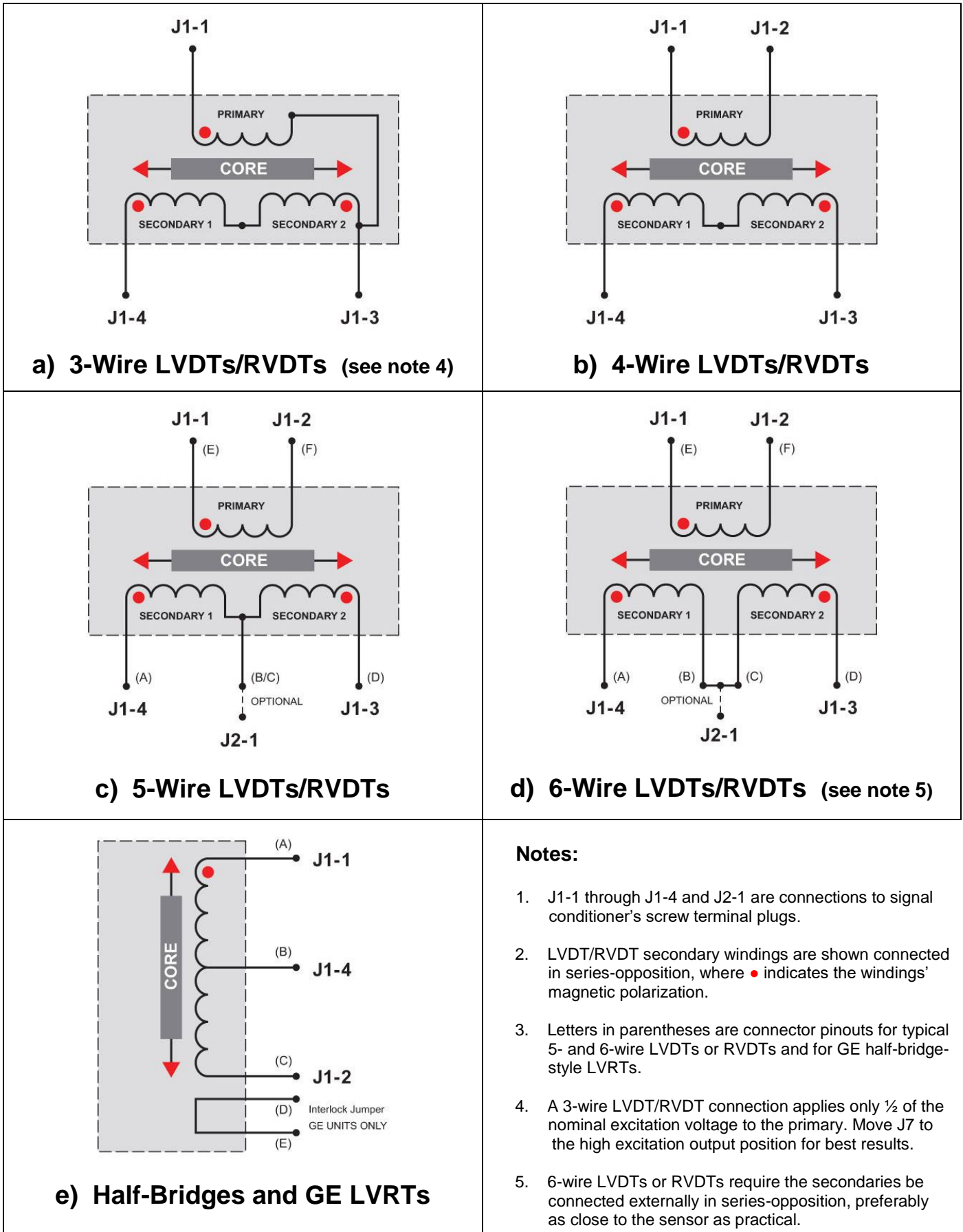


**Figure 3**  
Front View

J1-1	Black	LVDT Primary High <i>or</i> Half-bridge High End
J1-2	Black	LVDT Primary Low <i>or</i> Half-bridge Low End
J1-3	Black	LVDT Secondary Low; Sensor Cable Shield Ground
J1-4	Black	LVDT Secondary High <i>or</i> Half-bridge Mid-tap
J2-1	Blue	LVDT "Center Tap" Junction Point ( <i>No internal connection</i> )
J2-2	Blue	Failure Warning Output ( <i>Open Collector, 50 mA max.</i> )
J2-3	Blue	-15 V DC input for $\pm 10$ V DC output
J2-4	Blue	Sync Input / Output ( <i>Master / Slave Bus</i> )
J3-1	Green	RS-485 Data Line B ( <i>D+</i> )
J3-2	Green	RS-485 Data Line A ( <i>D-</i> )
J3-3	Green	Analog Output Ground ( <b>Common Ground</b> )
J3-4	Green	Analog Output (+) ( <i>Voltage or Current, as selected by DS1</i> )
J4-1	Red	Null Indicator Differential DC Output (floating)
J4-2	Red	Null Indicator Differential DC Output (floating)
J4-3	Red	Power Ground ( <b>Common Ground</b> )
J4-4	Red	Power Input (+) ( <i>+15 to +30 V DC</i> )

**Table 3** S1A LVDT Signal Conditioner Module I/O Connections

**Note:** *J3-3 and J4-3 share the same Common Ground, so use only one ground connection to prevent potential ground loops*



**Figure 4** LVDT or RVDT and Half-Bridge (LVRT) Wiring Connections to S1A Signal Conditioner

## Quick Start Guide

**1. If you are able to utilize the factory default settings for DC output and excitation frequency, skip to Step 3.** Otherwise, open the S1A module's case by pushing the locking tab inward on both of the thin sides and sliding the case rearward to expose the two circuit-board-mounted DIP switches.

**2. Set the pcb-mounted DIP switches:** The factory default LVDT excitation frequency is 3 kHz, which is suitable for most LVDTs, but it can be changed by setting DS2-1 and DS2-2 according to Table 1. The DC output is factory set at 0 to 10 V DC, but it can be changed by setting DS1 (indicated as OUT on the pc board) according to Table 2. When DIP switch changes, if any, are finished, slide the pc board back into the module's case on its internal tracks and snap the front and rear sections of the case back together.

**3. Mount the module:** Remove the color-coded plugs from the S1A module and install the module on the DIN rail by hooking the bottom of the module's rear edge under the bottom edge of the rail, and then pressing the module back against the rail until the module's spring-loaded rail catch engages the top edge of the rail. To remove the module from the DIN rail, insert a flat-bladed screwdriver into the slot in the metal catch at the back of the module, lift the catch, and disengage the module from the rail.

**4. Make the I/O connections:** Following Table 3 and the schematics on page 4, connect the color-coded screw-terminal plugs to the LVDT primary and secondaries (and the "center tap pair" junction point if needed), DC power, and to the analog output to the system or indicator, as set in Step 2. When finished, insert the colored plugs completely back into the corresponding colored jacks on the module.

**5. Calibrate the LVDT's core positions:** Turn on the DC power and allow the module to warm up for at least 15 minutes before beginning the calibration procedure. The red **POWER** LED should glow steadily and the green LEDs should be off, except the **P** LED will be steady on if the module is a master (page 6) or in stand-alone operation. If any of the green LEDs are flashing, check the LVDT connections: **P** indicates open primary; **S** indicates open secondary; **E** indicates loss of excitation. With power applied and the red **POWER** LED on, calibration can proceed. **Note:** *The LVDT's core must not protrude from the LVDT at any point during the calibration process or erroneous calibration will result.*

▶ Shift the module into *CALIBRATION* mode by depressing both the **FULL SCALE** and **ZERO** buttons simultaneously for about 3 seconds, until the red **POWER** LED flashes. The module is now functioning in the *CALIBRATION* mode

▶ One of the green LEDs will be illuminated, indicating that the LVDT's core is on one side or the other of null, or at null. As the LVDT's core is moved inward, that LED will go out and the middle LED will come on (showing the LVDT is at null), then the middle LED will go out and the LED on the opposite end (compared to the first green LED that was on) will come on. Adjust the LVDT core's position until the middle green LED is on. The LVDT's core is now approximately at its null position.

▶ Move the workpiece whose position is being measured so that it is located at the middle of its range of motion when the LVDT's core is at its null position. Mechanically couple the LVDT core to the workpiece in this position. Now, move the workpiece to the desired Full Scale (maximum travel) position and depress the **FULL SCALE** pushbutton until the green (+) LED flashes once and the (-) LED lights up.

▶ Next, move the workpiece, still coupled to the LVDT's core, to the Zero (start of travel) position at the other end of its range of motion and depress the **ZERO** pushbutton until the green (-) LED flashes once.

▶ If one (or both) of the green LEDs is still flashing, rerun the calibration procedure by moving the workpiece and the coupled core to the end position indicated by the flashing LED and depressing its nearby button. The red LED should be flashing, showing that the module is in *CALIBRATION* mode. To return to *RUN* mode, depress both the **FULL SCALE** and the **ZERO** buttons simultaneously for about 3 seconds until the green LEDs go out and the red **POWER** LED turns on steady. Verify that the analog output and its direction (slope) is that which was desired. If the output is reversed, switch DS2-3 to *on*.



## Functional Description of the S1A LVDT Signal Conditioner

The S1A LVDT Signal Conditioner is an intelligent module which uses a DSP (digital signal processor) chip to sequence and control the various functions of the module. The following descriptions are provided to assist the user in setting up and applying this module.

### DC Power Input

The input power range of +15 to +30 V DC covers the common +24 V DC industrial power supply and the older +15 V DC. If the input voltage rises above 32 V, a Zener diode conducts and a PTC resettable fuse will open if the current becomes too high. After cooling, the fuse will reclose to allow normal functioning to resume. The S1A module avoids a high inrush current with an NTC current limiting device in series with the power circuitry. The module's input is also protected against reverse polarity connection and ESD. For  $\pm 10$  Volt output, +15 V DC is input to J4-4, -15 V DC is connected to J2-3, and ground connects to J4-3.

### LVDT Primary Excitation

The AC-LVDT's primary is excited by a digitally synthesized low distortion sine wave signal. The nominal excitation frequency selections are 1, 3, 5, or 10 kHz. The sine wave synthesizer operates from a crystal oscillator, so the resulting frequencies will be very stable. 3 kHz is chosen as the factory default setting, since most commercial LVDTs specify 2500 to 3300 Hz excitation and will operate very satisfactorily at this frequency. To select another of the excitation frequencies, it is necessary to open the S1A module's case and change the setting of DIP switches DS2-1 and DS2-2 according to Table 1 or the left side label.

The amplitude of the excitation sine wave is very stable because of the digital synthesis process. The excitation driver operates in push-pull mode to provide about 3 Volts ACrms to the LVDT's primary, but for unusual cases, the drive voltage can be increased by 50% by removing internal jumper J7, or decreased by 50% by exciting the primary single ended to ground (J1-1 to J1-3). A fault detector in the S1A's LVDT excitation circuitry detects if the LVDT's primary is open-circuited or disconnected. If so, the green **P** LED on the front panel flashes, a failure warning is output at J2-2, and an error code shows on the RS-485 bus.

### Inductive Half-Bridge Connections

An AC inductive half-bridge sensor, or LVRT, is similar to an LVDT, but combines an LVDT's primary winding with a center-tapped secondary winding. AC excitation is applied to the ends of the winding and the output signal is taken from the mid-tap. To hook up a half-bridge or LVRT sensor to the S1A signal conditioner, connect the high end of the half-bridge winding to terminal J1-1, the low end of the winding to terminal J1-2, and the mid-tap to terminal J1-4. See page 4e. The module will function the same as it does for an LVDT and will demonstrate the same fault indications as for a failure of the windings of an LVDT.

### Master/Slave Synchronization

When multiple LVDTs and their interconnecting wiring operate in close proximity, beat frequencies or heterodyning could occur if slight differences exist in the excitation frequencies of the modules. If a beat frequency develops, it will be observed as very low frequency amplitude modulation of the modules' DC output. The best way to avoid such interaction is to synchronize each module's excitation to exactly the same frequency so that beating cannot occur. Typically, one module is chosen as master and the other modules are slaves connected synchronously to the master, using the built-in auto-master sync system.

The S1A modules' auto-master syncing can be implemented as follows: First, all modules must have their excitation DIP switches DS2-1 and DS2-2 set for the same nominal excitation frequency. Second, each module must have a different unit address, which can be set from 00 through 15 by DIP switches DS2-5, DS2-6, DS2-7, and DS2-8 in accordance with Table 1a on page 3. No duplicate addresses are allowed. The factory default address, 00, is usually applied to the master module. Finally, module terminal J2-4 of the master module is connected to terminal J2-4 of up to fifteen slave modules. All the sync connections are protected against ESD or erroneous connections. If the master oscillator were to fail, a new master would be automatically developed to control the excitation oscillator frequency, providing true fail/safe operation. If all of the modules are not powered up at the same time, the module with the lowest numerical address at initial power up will become the master, as indicated by its **P** LED being steady *on*.



## LVDT Output Signal

The two secondaries of the LVDT are connected together in series-opposing to develop a differential signal. This LVDT output circuit also has a built-in fault detector to warn if the secondaries are open-circuited, not connected together, or the cable is disconnected. Any fault or wiring failure in the secondaries flashes the green **S** LED on the module's front panel, triggers a failure warning output at J2-2, and shows an error code on the RS-485 bus.

The differential signal from the LVDT's secondaries is demodulated, buffered, and then sent to a 13-bit analog-to-digital converter (A/D) built into the DSP. The amplitude of full scale LVDT output signals accepted extends from 50 mVrms to 5 Vrms, a 40 dB dynamic range. The DSP scales the digital data as needed for the output type that is selected. The digital data are converted back to an analog signal by a digital-to-analog converter (DAC). This analog signal is passed to a buffer/driver stage from which the signal is then delivered as one of the eight user-selectable analog DC outputs: 0 to 5 V, 1 to 5 V, 0.5 to 4.5 V, 0.5 to 9.5 V, 0 to 10 V, -10 to +10 V, 0 to 20 mA, and 4 to 20 mA. All unipolar analog outputs feature a "live" zero, whereby the output can go below zero, so a user can establish a true zero point.

The analog output is selected by setting one position of 8-section DIP switch DS-1 inside the module to *on*, in accordance with Table 2. The factory default analog output is 0 to 10 Volts (DS1-4 *on*). Besides selecting a specific analog output signal using DS-1, a user can invert the output signal by setting DIP switch DS2-3 to *on*, effectively reversing the slope of the output signal. For example, inverting the 4-to-20 mA output changes it to 20-to-4 mA over exactly the same range of motion for the LVDT's core.

## DC Output Filtering

Within the DSP, the digitized demodulated LVDT signal goes through some digital filtering before being input to the DAC. The DAC's analog output is first sent to a single-pole low pass R/C filter having a -3 dB cutoff frequency of at least 10% of the excitation frequency set by DS2-1 and DS2-2, and then on to the output terminals. For applications requiring very low noise and ripple, the analog output can further filtered by turning DIP switch DS2-4 *on*, which engages an additional single-pole low pass filter with a -3 dB cutoff frequency that can be programmed between 0.1 to 10 Hz (default) by using the **Set LF** RS-485 command.

## Failure and Fault Indicators

The green front panel LEDs will flash to indicate failures in the cases of an open LVDT primary (**P**), an open LVDT secondary (**S**), or a loss of excitation (**E**). The DSP determines a loss-of-excitation condition exists if anything causes the digital signal to the sine wave synthesizer to be lost. Any of these faults will trigger the failure warning output, an open collector transistor switch that pulls the failure warning output terminal J2-2 either low or high (NO or NC) for any case where the DSP detects a fault or failure. The failure warning output terminal includes protections against overcurrent, overvoltage, and ESD. Page 10 and Table 6 offer more detailed explanations of the LED indications and the failure warning outputs.

## RS-485 Communications

The S1A incorporates an RS-485 two-wire multi-drop serial communications interface for up to 16 devices. This port enables half-duplex serial communications to implement specific ASCII commands listed later in this manual by which a module can be set up and calibrated and system data can be read and stored on a PC. The PC should be running an ASCII terminal program such as Hyper Terminal and using a 2-wire RS-485 converter for a serial or USB port to connect to S1A module terminals J3-1 and J3-2. See page 12 for detailed information about setting up the RS-485 communications link and the ASCII commands available.

A Graphic User Interface (GUI) program that communicates with an S1A via the RS-485 multi-drop com link is available for download from the following website: [www.alliancesensors.com](http://www.alliancesensors.com). The GUI facilitates setting up, calibrating, and monitoring any S1A on the 2-wire RS-485 multi-drop network from a remote computer or terminal. It also facilitates saving system-specific configuration data in files which could be reloaded into another S1A module during a hot swap. If all the S1A signal conditioners for a particular application (up to 16) were to be connected in an RS-485 multi-drop configuration, that network could be connected to a wireless interface with appropriate third party hardware and software, which would permit remote calibration or configuration from a location at some distance from that of the modules themselves.

# Expanded Version of the Calibration Procedure

## Terminology and Definitions

To provide a clear explanation of the operation of this product, it is necessary to properly define the following words: *program*, *setup*, and *calibration*. To understand this manual and module, the word *program* is used to describe the operating system resident within the DSP, which is factory loaded and is not accessible to the user. The word *setup* is used to describe the settings chosen by the factory or the user for the LVDT's excitation frequency, analog DC output, and other parameters that can be selected either by the internal DIP switches or via commands using the RS-485 communications port. *Setup* should be done in accordance with the **Quick Start Guide** and the DIP switch settings on page 3. Besides the switches for excitation frequency and analog output, there are choices for additional low pass filtering to improve signal-to-noise ratio, inversion of output slope, and up to 16 individual RS-485 digital addresses.

The word *calibration* is used to describe a process or sequence of actions by which the range of motion of the workpiece is matched to the range of motion of the LVDT to produce the desired electrical output from the system. To begin, the LVDT's body is clamped in place. Next, the LVDT's core is moved to find its Null point or mid-range position. The LVDT's null point is the only repeatable unique position of the core; for most LVDTs, there is no definable *full scale* or *zero* position. The workpiece is moved to the middle of its range of motion and then, without changing the core's position, the two are mechanically coupled to each other. The LVDT core and connected workpiece are moved to the Full Scale or maximum travel position so the module's *Full Scale Output* can be set. Finally, the LVDT core and connected workpiece are moved to the Zero or starting point (minimum) position, where the module's *Zero Output* is set. The result of this process is a typical end-point calibration for the LVDT-based position measuring system.

## Calibration Procedure

Before beginning the calibration procedure, allow the module to warm up for at least 15 minutes. On the front panel, there are three green LEDs positioned vertically and a red LED for power indication. The **POWER** LED normally glows steadily when power is applied and the signal conditioner module is in its *RUN* mode. When the module is in its *RUN* mode (not in *CALIBRATION* mode), the green LEDs flash only to indicate failures, and in master/slave or standalone operation, the **P** LED on the master module will glow steadily. When in *CALIBRATION* mode, the green LEDs indicate the position of the LVDT's core in relation to its null point. To enter *CALIBRATION* mode, depress the **FULL SCALE** and **ZERO** buttons simultaneously until the red **POWER** LED flashes, indicating the signal conditioner is in *CALIBRATION* mode. The module can also be put into *CALIBRATION* mode by sending the **Cal** command via the RS-485 port. (See page 12 for a listing of the RS-485 commands).

## Null Point Location

After entering *CALIBRATION* mode from *RUN* mode, as described above, it is possible to find the LVDT's null point by moving the core and watching the green LEDs. In *CALIBRATION* mode, the three green LEDs operate according to Table 4 below as followings: if the core is far into LVDT's positive side (above null), only the uppermost (+) LED will glow. This means the core should be moved in the direction expected to be toward null. As the core approaches the null point, the center (0) LED will light (at null). If the movement of the core is continued (below null) in the same direction, then the bottom (-) LED will glow. In this way, an LVDT's core can be positioned sufficiently close to the LVDT sensor's mid-range position for reasonably accurate calibration. **Note:** *The LVDT's core must not protrude from the LVDT during any null point measurement or else false null indications can result.*

Above Null +	At Null 0	Below Null -
●	○	○
○	●	○
○	○	●

**Table 4** Finding an LVDT's null in *CALIBRATION* mode: LED state vs. LVDT core position

## Null Indicator Output

During *CALIBRATION*, the green front-panel LEDs are used to show the position of the LVDT's core in relation to its Null point. To find the Null point with better resolution, or for a continuous Null indication, connect an ungrounded DC voltmeter between terminals J4-1 and J4-2, the Null Indicator output. With the LVDT's core at Null, each terminal is floating at about 1.5 V DC above common ground, so the voltmeter will read zero volts between the terminals. As the LVDT's core is moved off Null, one terminal's voltage increases toward +3 V as the other terminal's voltage goes toward 0 V or vice versa when moving the core in the other direction, for a maximum voltmeter reading of approximately  $\pm 3$  Volts DC. *The LVDT's core must not protrude from the LVDT during any null point measurement or false null readings can result.*

## Setting the Full Scale Output Point

Once the LVDT core's Null position has been found and the core has been mechanically connected to the object whose motion is being measured, the next step is to calibrate the Full Scale output of the measuring system. This step assumes that the range of motion will be symmetrical with respect to the LVDT's null point, but the process also works for asymmetrical measuring ranges, as long as the FULL SCALE and ZERO points are no closer to each other than 20% of the sensor's full scale. This step also assumes the Full Scale output was already selected by accepting the factory default of 0-to-10 Volts DC or by setting DIP switch DS1 during the initial *setup* for another analog output using the settings of Table 2.

The red **POWER** LED should be flashing, indicating the unit is still in *CALIBRATION* mode. The core with its attached workpiece must be moved to the desired Full Scale (maximum travel) position. Once the core is in the Full Scale position, depress the **FULL SCALE** button on the front panel until the upper green LED below the **FULL SCALE** button flashes once, or send an **FS** command via the RS-485 port. The LED flash indicates that the Full Scale position calibration has been accepted. If an error occurred and it is desired to set the Full Scale again, depress the **FULL SCALE** button again and the Full Scale calibration will be updated with this new position as indicated by another flash of the upper green LED.

## Setting the Zero Output Point

When the Full Scale calibration is complete, the lower green LED above the **ZERO** push button will start flashing. Move the core with its attached workpiece to the Zero (travel start) position. Then depress the **ZERO** button until the lower green LED flashes once, or send a **Z** command via the RS-485 port. The flash of the LED indicates that the Zero position calibration has been accepted. If an error occurred and it is desired to set the Zero point again, depress the **ZERO** button again and the Zero point calibration will be updated with the new position as indicated by another flash of the lower green LED.

Full Scale is set	Full Scale set required	Zero set required	Zero is set
●	☼	○	○
○	○	○	○
○	○	☼	●

**Table 5** LEDs in *CALIBRATION* mode. LEDs flash if Full Scale reset or Zero reset is required.

If the LVDT's calibration was successful and the DSP was able to be properly scaled, then the green LEDs will not be blinking. In the event that something unusual has caused the calibration to be rejected (such as a very high or very low output LVDT), either the upper (FULL SCALE) or lower (ZERO) LED, or both, may be flashing again. This means that the core must be moved to that particular position again, and re-scaled or re-zeroed by repeating the original Full Scale and/or Zero calibration procedures. Normally, repeating the calibration process one time will remedy any problems that have developed during the DSP's auto-scaling operations.

When the calibration is completed, exit the *CALIBRATION* mode by depressing both the **FULL SCALE** and **ZERO** buttons simultaneously until the red **POWER** LED stops flashing and glows steadily. There is also an RS-485 command for exiting the *CALIBRATION* mode. After exiting *CALIBRATION* mode, the module will return to normal operation in *RUN* mode, the red **POWER** LED will glow steady, and the green LEDs (except for the master module in a master/slave configuration) will not be glowing.

### Alternative Calibration Procedure

For some specific applications, there is an alternative calibration procedure that can often save time by establishing the mechanical relationship of the LVDT's core to the workpiece whose motion is being measured without going through the process of actually finding the LVDT's null point. This process can work well in cases where the nominal range of the LVDT is at least 10% larger than the range of motion of the workpiece to be measured. It works by connecting an ungrounded DC voltmeter with a range of 0 to  $\pm 3$  Volts to terminals J4-1 and J4-2, the Null Indicator Output. (Refer to **Null Indicator Output** on page 9)

Mechanically connect the LVDT core to the workpiece at about the middle of its range of motion. Move the workpiece to each end of its range of motion, noting the voltage indicated on the meter. Adjust the core's position relative to the workpiece so that the magnitude of the output of the voltmeter at each end of the range of motion is approximately the same, which establishes that the LVDT is operating in a symmetrical manner within its nominal range of measurement. Proceed to calibrate the system's Zero and Full Scale as noted on page 9. *The LVDT's core must not protrude from the LVDT during any of the measurements or calibration errors will result*

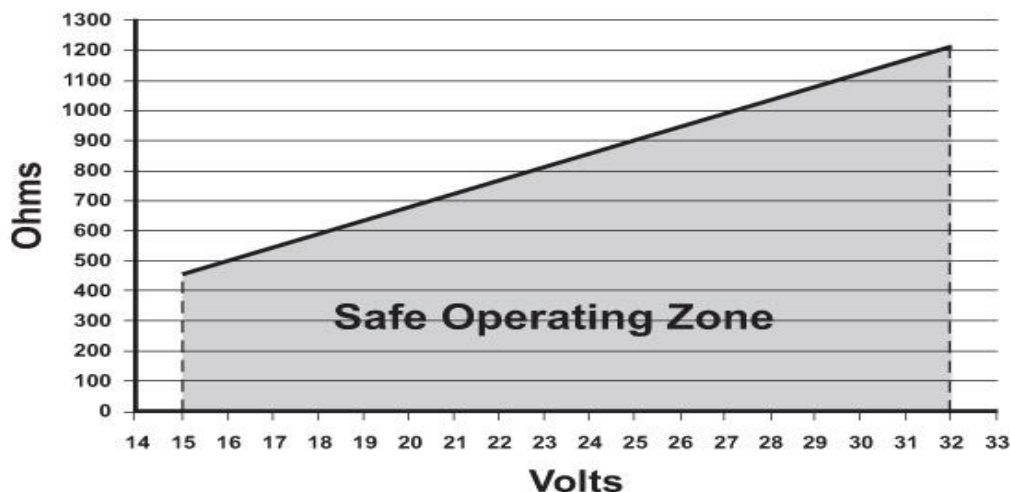
### Live Zero and Extra-range Output

When a unipolar DC output range is selected, the Full Scale and Zero positions correspond exactly to that range. But to have a "live zero output", the DC output is capable of going higher and lower than these points by 2.5 to 3%. So, for example, with a 0 - to -10 V full scale output, the output continues to respond past the Full Scale and Zero calibration points, going up to about 10.3 V or down to about -0.3 V. For current loop output, the output continues from 0.4 mA to 0.6 mA past the calibration points. For a 4-to-20 mA output (span = 16 mA), it continues to respond up to 20.6 mA and down to about 3.6 mA. These limit values can vary somewhat from module to module, depending on circuit and component tolerances.

### Using the Voltage and Current Outputs

When using the module in any voltage output mode, the output current to the load resistor is normally just a fraction of one mA, but should always be less than 5 mA. The recommended minimum load resistance across terminals J3-4 (+ output) and J3-3 (- ground) for any of the voltage outputs is 10,000 Ohms.

When using the module's current loop output, either 0 to 20 mA or 4 to 20 mA, the maximum permissible loop load resistance depends on the power supply voltage, as shown in Figure 5 below. If the module is powered by the recommended 24 Volt DC supply, the maximum loop load resistance is about 850 Ohms. Typical loop loads are 250 or 500 Ohms, so the module has adequate capacity for long connecting lines.



**Figure 5** Maximum Loop Load Resistance vs. Supply Voltage

### Failure Diagnostics

The S1A module incorporates diagnostics to identify internal failures, mistakes made during the setup, and operational failures due to external causes, and provides a failure indication both visually and electrically.



When the S1A is in *RUN* mode, the front-panel LEDs indicate specific operational failures by flashing at a rate of 0.1 second on and 0.1 second off, according to Table 6. Setup errors are typically indicated by steady *on* LEDs, and multiple failures are indicated by an LED that alternates between blinking and steady *on*. When indicating a "general failure" in *RUN* mode, the red **POWER** LED will flash at the same rate of 0.1 second on and 0.1 second off. (It flashes at the slower rate of 0.5 second on and 0.5 second off while indicating that the S1A is in *CALIBRATION* mode.)

<i>RUN</i> <i>MODE</i>	Normal Operation	Master Operation	Primary Open	Secondary Open	LVDT not Connected	Excitation Error	Shorted Sync Line	Frequency Set Error	General Failure
<b>POWER</b>	●	●	●	●	●	●	●	●	⊗
<b>P</b>	○	●	⊗	○	⊗	○	○	○	○
<b>E</b>	○	○	○	○	○	⊗	●	○	○
<b>S</b>	○	○	○	⊗	⊗	○	○	●	○

**Table 6** ⊗ indicates a flashing LED. Most failure modes flash the LEDs, but some are steady on

In addition to the local visual indication of a failure or fault by the LEDs as illustrated by Table 6, the S1A also provides electrical outputs that allow the failure warning to be transmitted to a remote indicator, system controller, or other device. The electrical outputs include a failure output using an open collector switch, out-of-range analog output, and numerical error codes accessible via the RS-485 digital bus. A matrix table identifying the meaning of these digital error codes is listed in **Appendix A** on page 16.

Failures identified by the diagnostics incorporated in the S1A can be classified either as errors in setting up the module during installation that should be corrected before the S1A module is brought online, or operational failures that occur sometime after the module has been properly installed and put into service. The module will produce different error outputs for each of these two different classes of failures, as can be seen in the matrix table in **Appendix A** on page 16.

If an error code or failure is presented, it usually requires a "soft" reset to clear it, but occasionally might require powering the module down and back up ("hard" reset) to clear it. To initiate a soft reset on an S1A, depress the **FULL SCALE** button three times in a row for at least half a second each time, or enter the **Reset** command for that particular module's digital address via the RS-485 bus.

### Failure Warning Output Signals

When any of the operational failures shown in Table 6 occur, the DSP activates the continuous output failure warning signal via an open-collector transistor switch that can operate a relay, alarm, or use a pull-up resistor for a TTL output pulse. This switch is configured normally open (NO), but can be changed to normally closed (NC) via an RS-485 command. The failure warning signal has a short, programmable delay (200 ms default) before activation to eliminate trips due to momentary effects such as power line noise spikes, nearby lightning strikes, and similar transients. If the set up errors shown in Table 6 occur, the failure warning output may not be activated, because all set up errors must be corrected before the S1A module can function properly, including its ability to send the continuous output failure warning signal.

Besides the continuous output failure warning signal, the S1A module also offers another form of electrical failure notification by driving the analog output to an out-of-range value of voltage or current. This out-of-range value is usually a slightly negative output, although in the case of the ±10 V DC output, it goes to an output of about -11 Volts DC, and for the 4-20 mA output, the out-of-range output value is around -2.3 mA.

Unlike the open collector failure output, the out-of-range output has no built-in delay so that it can react to some transient effects. This is because many DCS applications that utilize an S1A module with redundant sensors incorporate either a voting scheme to assess the fidelity of the multiple readings, or average the readings from the multiple sensors to derive some acceptable value. Typically the DCS controllers for redundant systems sample the sensors' outputs at high speeds, but have built-in diagnostic software that rejects an output value that either goes out of range or that deviates too sharply from an expected value. A very fast fault or failure response that shifts the S1A's analog output out of range works well with such software to prevent an erroneous output from being averaged or accepted by the DCS's voting scheme.

## Troubleshooting LVDT Connections

Table 6 on the previous page shows that the S1A's front panel LEDs indicate most common LVDT wiring failures. If a front panel LED indicates an open winding, turn off the DC power and troubleshoot the LVDT wiring with an ohmmeter. Double check the LVDT's lead wire colors or connector pinouts against the specifications for that LVDT to be sure that all of the wires are correctly identified and properly connected.

When running cables between LVDTs and signal conditioners, a common wiring error is failure to properly connect the two secondaries together, separate from the other connections. For the S1A, the secondaries of the LVDT are connected together in a series-opposing configuration, so the module can operate on the net differential AC output that results from this winding connection. It is strongly recommended that the interconnection of the secondaries be done at the LVDT itself, before any cabling or wiring is attached, especially with a long cable run between the LVDT and the module. Normally the junction of the two secondaries is not connected to the LVDT signal conditioner, but if an S1A is to be hooked up in close proximity to a leaded LVDT, the secondary interconnection may be hooked up to J2-1, which is merely a convenient tie point that is not connected to anything within the signal conditioner.

## Grounding and Shielding

The most common problem encountered with grounding and shielding of a sensor circuit is current flow in the ground circuit, called a ground loop. To avoid ground loops, a circuit must have only one common ground point. An S1A module's terminals J3-3 and J4-3 share the same common ground, so, to avoid ground loops, a single wire should be run to the system ground from just one of these ground terminals.

Furthermore, do not connect any sensor cable shield to the LVDT sensor's housing or to any separate or intermediate system ground point. Connect any sensor cable shields, acting as simple Faraday shields, only to the S1A's signal input ground point at J1-3. If an additional cable shield ground point is needed for an S1A operating from unipolar DC voltage, (not  $\pm 15$  V DC), a 2-pole shunt jumper inserted over J8 (located on the pc board next to J2) can convert J2-3 into an additional ground for sensor cable shields.

## Commands for the RS-485 port

Commands for transmission via the RS-485 communications link can be sent to an S1A from a PC using an ASCII terminal program like Hyper Terminal and a 2-wire RS-485 adapter from a serial or USB port. Check that the port adapter is connected with the proper polarity: (*D+*) to J3-1 and (*D-*) to J3-2. Communication parameters are: 9600 bps, no parity, 8 data bits, 1 stop bit (9600, NP, 8, 1) with echo on and no flow control. Note that all commands must be preceded by a module address in the format: **Uxx**(space), where **xx** is the number from 00 to 15 of the module's decimal digital address, as set with DS2 using Table 1a or referencing the left side label.

*Note: Commands in **Bold Italics** only function with S1A modules having firmware Version 2.00 or later.*

**Analog** In *RUN* mode, returns nominal analog output value scaled in electrical units that depend on the setting of DS1.

**Cal** Enters *CALIBRATION* mode; command is same as pressing the FULL SCALE and ZERO pushbuttons simultaneously.

**Config** Lists the module's setup data and displays DIP switch settings and current EEPROM values. Specifically, it shows the module's digital address (00-15), date stamp, serial number, firmware version, any error code, analog output switch setting (1-8), excitation frequency switch settings (1-4), excitation drive jumper (J7) position, output inversion switch *off* or *on*, low frequency filter switch (LF) *off* or *on* and filter cutoff frequency, failure output delay time (FD) and polarity (FOP) *NC* or *NO*, and stored EEPROM values for ADC Lo, ADC Hi, Input pot, and Gain pot. (Log and store all "Config" data names and values by digital address to be able to reconfigure a hot swapped module at a later time).

**Exit** Required to exit any command, and to write any reconfiguration value to the module's EEPROM in *RUN* mode.

**FS** In *CAL* mode, sets the module's full scale output point at the maximum position of the LVDT's core; function is the same as pressing the FULL SCALE pushbutton. Occasionally it may require setting a second time after using **Z** command.

**Help** Lists all user commands available for operation over the RS-485 bus, including some factory-use-only commands.

**LEDs** In *RUN* and *CAL* modes, outputs the status of the 3 green LEDs, displayed in Z-C-F (zero, center, full scale) order, e.g.: - \* 0 means the **S** LED is off, the **E** LED is flashing, and the **P** LED is on.

**Null** In *RUN* mode, displays the Null Output voltage at any core position. This command is typically used to verify the null position of an LVDT.

**Read Error** In *RUN* mode, displays any setup or operations error code(s); for multiple errors, error code sum is displayed.

**Read LF** In *RUN* mode, when DS2-4 is *ON*, shows the status and frequency setting of the supplemental low pass filter.

**Recal FS** In *RUN* mode, after a calibration has been completed, if the actual full scale output value is within  $\pm 5\%$  of the span of the output chosen by DS-1, this command trims the actual full scale output value to match the nominal full scale output value. This command may need to be repeated a second time to get the most precise full scale output value.

**Recal Z** In *RUN* mode, after a calibration has been completed, if the actual zero output value is within  $\pm 5\%$  of the span of the output chosen by DS-1, this command trims the actual zero output value to match the nominal zero output value. This command may need to be repeated a second time to get the most precise zero output value.

**Reset** In *RUN* mode, produces a "soft" reset of the module's processor so the module restarts as if it is powering on. This command works the same as pressing the FULL SCALE pushbutton for at least one-half of a second three times in a row.

**Reset All** In *RUN* mode, using prefix **U90** instead of **Uxx**, performs a simultaneous "soft" reset on all modules connected to the RS-485 bus. Each module on the RS-485 bus then restarts itself as if it is powering on.

**Set ADC Hi** In *RUN* mode, writes a high value for the A / D converter input into module's EEPROM. Command is normally used during a hot swap module reconfiguration to enter ADC Hi value logged from the original module's "Config" command.

**Set ADC Lo** In *RUN* mode, writes a low value for the A / D converter input into module's EEPROM. Command is normally used during a hot swap module reconfiguration to enter ADC Lo value logged from the original module's "Config" command.

**Set FD** In *RUN* mode, sets the delay time from 0 to 900 ms in 100 ms increments before failure warning output activation.

**Set FOP** In *RUN* mode, sets the failure warning output polarity to either Normally Open (default) or Normally Closed.

**Set Gain** In *RUN* mode, writes a Gain pot value into module's EEPROM. Command is normally used during a hot swap module reconfiguration to enter the Gain pot value logged from the original module's "Config" command.

**Set In Pot** In *RUN* mode, writes an Input Pot value into module's EEPROM. Command is normally used during a hot swap module reconfiguration to enter the Input Pot value logged from the original module's "Config" command.

**Set LF** In *RUN* mode, when DS2-4 is *ON*, sets the frequency of the supplemental low pass filter between 0.1 Hz and 10 Hz.

**Ver** In *RUN* mode, returns the version number of the unit's firmware to determine whether certain commands will work.

**Z** In *CAL* mode, sets the module's zero output point at the minimum position of the LVDT's core; function is the same as pressing the ZERO pushbutton. Occasionally it may require setting a second time after using the **FS** command.



## Endpoint Recalibration Process

In certain circumstances, it may be desirable to perform a "hot" recalibration on a module. Typically this need arises from the effects of thermal expansion and/or contraction on a mechanical system when the initial calibration was done at room temperature, but the workpiece and its LVDTs are now operating at elevated temperature and the normal calibration process cannot be repeated under these new conditions.

Anticipating this problem, a recalibration feature has been incorporated into any S1A module with firmware version 2.0 or higher. A pair of RS-485 commands, **Recal FS** and **Recal Z**, permit trimming of either end point's analog output in a system that has already been calibrated, provided that the actual output values from the module are within  $\pm 5\%$  of the full span of the output chosen by the setting of DS-1. Recalibration can be used to trim either end point's analog output independent of the other and is done while the module is operational. As a result, these commands have immediate effect upon the system's analog output.

Before attempting a recalibration on an S1A module, establish RS-485 communications with the module from an ASCII terminal as noted on page 12. Then invoke the **Ver** command to find out if the module is running firmware version 2.0 or higher. If it is not, the recalibration feature is not available.

If **Ver** shows the recalibration feature is available, before proceeding to perform a recalibration, verify that the difference between the actual output of the end point to be trimmed is within  $\pm 5\%$  of the span of the analog output for which the module was set, where the span is the difference between the maximum and minimum values of the selected analog output. Thus, the trimmable range of actual output at the system's Zero point is -5 to 5% of the span, and at the Full Scale point, it is 95 to 105% of the span. If the actual analog output of an end point is not within the limits noted, the attempt at recalibration will not be effective.

To perform a recalibration, move the workpiece to the endpoint to be recalibrated and invoke the **Recal** command for that endpoint over the RS-485 bus. Either **Recal** command may be repeated one time to achieve the most precise recalibration, but do not repeat the command more than one time.

## Hot Swapping Modules

Under the right conditions, an S1A module connected in a multi-module array can be "hot swapped" with another module having the same internal DIP switch settings and loaded with values in certain EEPROM locations that match those in the original module. Carefully done, this process can make the replacement module's characteristics match those of the module being taken out of service within approximately 1% and will also allow the remaining modules in the array to continue operating in a normal manner.

To prepare the replacement module for a hot swap, the configuration data of the original module, which should have been obtained previously and saved for a possible hot swap, is needed. If this data is not available, connect to the RS-485 port of the original module with a PC and terminal program, and use the **Config** command to get it. Using that data, set the internal DIP switches and jumpers of the new module to match, then power it up and use its RS-485 port as noted above to load the values of ADC HI, ADC Lo, In Pot, Gain, and, if needed, FOP, FD, and LF using the **Set** command for each value.

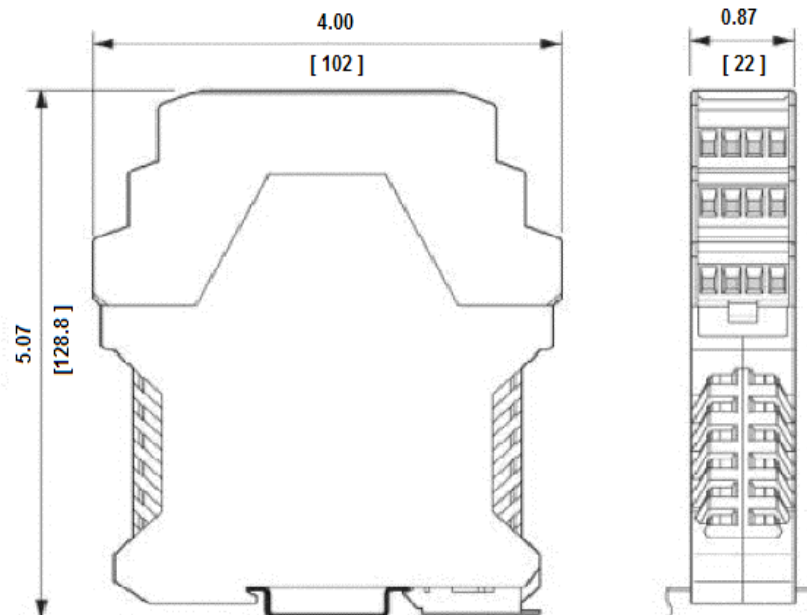
To do the hot swap, the first remove the positive power line for the original module connected to J4-4, the red plug. This may be done by loosening the screw terminal of J4-4 and carefully removing the wire, or by pulling the power fuse, or by tripping a circuit breaker, or switching it off the power switch for that module. Do not remove the red plug with any power present. Once the unit has been depowered, the plugs may be disconnected from the original module in order of J4 (red), J3 (green), J2 (blue), then J1 (black). The sequence for plugging back into the replacement module is J1 (black), J2 (blue), J3 (green), and last, J4, the red plug with no power positive connected. Finally, reconnect positive power to J4-4.

Although the system can be operated indefinitely with the replacement module in place, the module match may not be ideal, so for optimum performance, when a suitable opportunity presents itself, the system with the replacement module should be calibrated again in the normal manner.

## S1A Specifications

Operating power:	+15 to +30 V DC (+24 V DC nominal), 60 mA maximum at 24 V DC; +15 V DC and -15 V DC needed for $\pm 10$ V DC bipolar output
Excitation voltage:	3.0 Vrms (nominal) push-pull drive (factory default) 4.5 Vrms (nominal) push-pull drive (with shift of jumper J7 on pc board) 1.5 Vrms (nom) single-ended drive for low impedance (100 -150 $\Omega$ ) primary
Excitation frequencies:	1 kHz, 3 kHz, 5 kHz, 10 kHz (nominal)
Auto-master syncing:	Master output couples up to fifteen slave inputs; if original master fails, new master is automatically generated for fail-safe excitation control.
LVDT AC output range:	50 mVrms to 5000 mVrms at LVDT's full scale position
Analog DC outputs:	0 - 5 V, 1 - 5 V, 0.5 - 4.5 V, 0.5 - 9.5 V, 0 - 10 V, -10 to +10 V, 0 -20 mA 3-wire sourcing, 4 -20 mA 3-wire sourcing
Loop resistance:	850 Ohms maximum at 24 V DC supply
Output non-linearity:	$\leq 0.025\%$ of Full Span Output (FSO)
Frequency response:	-3 dB at 10% of excitation frequency (minimum) (standard: DS2-4 <i>off</i> ) -3 dB at 10 Hz (nominal) (low noise setting: DS2-4 <i>on</i> )
Noise and ripple:	$\leq 2$ mVrms (voltage output), or $\leq 4$ $\mu$ Arms (current loop output.)
Fault indication:	Loss of excitation, primary open, secondary open, LVDT disconnected
Fault output:	LED indicators, open collector output, 50 mA max.
Null detection:	Front panel LEDs, $\pm 30$ mV threshold out of about $\pm 1.6$ V signal level
Null output signal:	Up to $\pm 3$ V DC
Operating temperature:	0 $^{\circ}$ C to +75 $^{\circ}$ C
Temperature Coefficient	$\pm 0.002\%$ of FSO/ $^{\circ}$ C (combined span and zero shift)
Zero set:	Front panel push button or RS-485 ASCII command
Full Scale set:	Front panel push button or RS-485 ASCII command
Digital interface:	RS-485 2-wire half-duplex multi-drop network, 16 individual addresses

## S1A Module Outline Dimensions



## Appendix A, S1A Error Codes and Fault Matrix

LED display	Code	Error / Fault	Description / Diagnosis	Setup Errors		Operating Faults	
				Analog Fault Output	Failure Warning Output	Analog Fault Output	Failure Warning Output
<b>P, E, S,</b> and <b>POWER</b> LEDs in <i>RUN</i> Mode	RS-485 Error Code						
<b>P</b> blinks	1	LVDT primary circuit open	Open circuit in LVDT primary or its wiring	yes	no	yes	yes
<b>P</b> alternates blinking with steady on	1	Open LVDT primary circuit on master	Open LVDT primary circuit or wiring to master module	yes	no	yes	yes
<b>S</b> blinks	2	LVDT secondary circuit open	Open circuit in LVDT secondary or its wiring	yes	no	yes	yes
<b>P</b> and <b>S</b> both blink	3	LVDT not connected	LVDT disconnected	yes	no	yes	yes
<b>P</b> alternates blinking with steady on, and <b>S</b> blinks	3	LVDT not connected to master module	LVDT not connected to master module	yes	no	yes	yes
<b>E</b> blinks (Note 1)	4	LVDT excitation signal drops low by overload or internal failure	Excitation level drops low because of overload by low primary impedance	no	no	yes	yes
<b>E</b> alternates blinking with steady on (Note 1)	8	No excitation signal to LVDT	No excitation signal detected; possible primary circuit short.	yes	no	yes	yes
<b>E</b> alternates blinking with steady on (Note 1)	16	Loss of LVDT excitation signal	No excitation signal detected; internal failure of excitation generator	yes	yes	yes	yes
<b>S</b> steady on	32	Frequency setting error in slave module	Slave DIP switch setting different from master's DIP switch setting	yes	no	n/a	n/a
<b>E</b> steady on	64	Sync bus for slave modules is shorted out	No sync pulse detected on sync bus pin of slave modules upon startup.	yes	no	n/a	n/a
<b>E</b> and <b>S</b> steady on	128	Sync pulse timeout error	Sync start pulse not detected on bus after specified elapsed time	yes	no	n/a	n/a
<b>E</b> blinks and <b>S</b> steady on	256	External frequency mismatch	External syncing frequency outside range of DIP switch settings	yes	no	n/a	yes
<b>POWER</b> LED blinks fast	512	Internal logic failure alarm	General failure; internal power failure in module	no	yes	yes	yes

**Note 1:** In a master/slave connection, master module will have **P** steady on in addition to specified LED display

**Note 2:** RS-485 error codes that develop due to multiple errors are additive, e.g.: an error code of 128 combined with an error code of 16 would result in an error code of 144 being reported on the RS-485 bus.