

SC-100

**Low Voltage DIN Rail Mounted Signal
Conditioner for AC-LVDTs, RVDTs, and
Half-bridges**

Set-up and Operating Instructions



April, 2013

EC Declaration of Conformity

Alliance Sensors Group, a Div. of H. G. Schaevitz LLC,
102 Commerce Dr. Unit 8,
Moorestown, NJ 08057 USA,

Hereby declares that the product is in conformity with the provisions of the following category and types of the EC directive(s) listed below. Testing was done to requirements as stated in harmonized standards using the methods noted hereafter:

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

Model SC-100 LVDT Signal Conditioner, Measurement, Control Equipment, and Laboratory Use, EMC Directive 2004/108/EC. EN 61326-1: 2006 and CISPR 11, A-1: 2003 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.

Product Warranty

Alliance Sensors Group warrants the Model SC-100 LVDT Signal Conditioner to be free from defects in workmanship and materials for a period of one year 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 SC-100 LVDT Signal Conditioner, or for any damage to any electronic equipment connected to the input or outputs of the SC-100 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 to 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, a repaired or replaced unit will be promptly returned to the claimant freight prepaid.

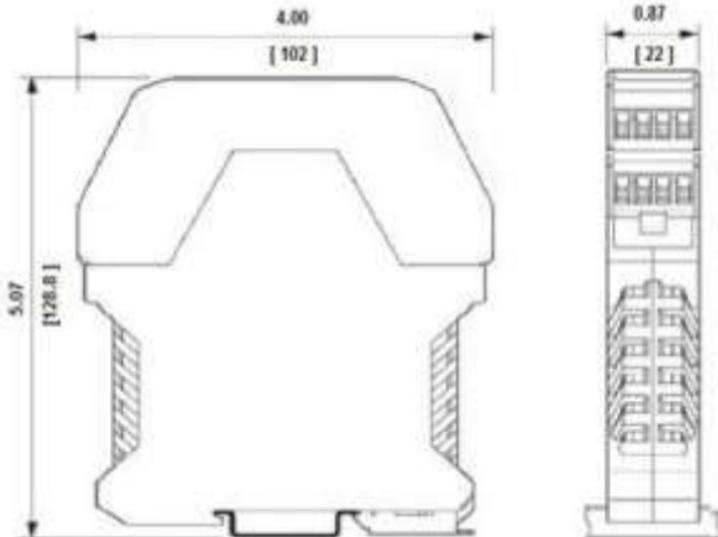
If inspection and evaluation of the device determines that it has been misused, abused, misapplied, or modified by the user; has been subjected to a fire, flood, or mishandling; or is damaged due to improper packing for the return shipment, no warranty claim will be allowed or accepted. Instead, the unit will be returned to the claimant freight collect, along with an invoice for the evaluation charge. Any questions about Alliance Sensors Group' 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.

PREFACE

In this manual, you will find a chart on page 3 for connecting your AC-LVDT, RVDT, LVRT, or inductive half-bridge sensor quickly to this SC-100 DIN-rail mounting, 24 Volt DC-operated signal conditioning module, and a **Quick Start Guide** on page 4 for calibrating it with two front-panel push buttons, eliminating any need for pot adjustments with a screwdriver. The specially developed software functioning within 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 1. Note that the term *LVDT* is used generically throughout the instructions for audio frequency AC-voltage-operated position sensors, i.e. LVDTs, RVDTs, LVRTs, and inductive half-bridges.

You will also find the SC-100 specifications and a more detailed description of the functions available for applications where you may wish to go beyond the basic features. Such possibilities include the master/slave synchronization of the LVDT excitation, the open-collector failure warning output, the null position indicator signal, and digital communications via an RS-485 addressable multi-drop port. The SC-100 LVDT Signal Conditioner is both RoHS and CE compliant. To assure a 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.

SC-100 Module Outline Dimensions



SC-100 Specifications

Operating power:	+15 to +30 V DC (+24 V DC nominal), 60 mA max. at 24 V DC; +15 V DC and -15 V DC for -10 V to +10 V DC bipolar output
LVDT excitation voltage:	3.0 Vrms sine wave push-pull drive nominal (factory default) 4.5 Vrms sine wave push-pull drive via on-board J7 jumper shift 1.5 Vrms sine wave single ended to drive low impedance primary (100 - 200 Ω)
Excitation frequencies:	2.5 kHz, 5 kHz, 7.5 kHz, 10 kHz (nominal)
Master / Slave synchronization:	Master output couples up to fifteen slave inputs; if original master fails, new master is automatically generated for fail-safe excitation .
LVDT FS AC output signal 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 -10 V, -10 to +10 V, 0.5 - 9.5 V, 0 -20 mA sourcing, 4 -20 mA sourcing
Loop resistance:	850 Ω max. with 24 V DC supply
Output non-linearity:	$\leq 0.025\%$ of Full Span Output (FSO)
Frequency response:	-3 dB at 10% of excitation frequency (min. (standard: DS2-4 off) -3 dB at 0.1 to 10 Hz (default) (low noise setting: DS2-4 on)
Noise and ripple:	≤ 3 mVrms (voltage output), or ≤ 6 μ Arms (current loop output.)
Fault indication:	Loss of excitation, primary or secondary open, LVDT disconnected
Fault output:	LED indicators, open collector output, 50 mA, 26.5 V DC max.
Null detection:	Front panel LEDs, ± 30 mV threshold out of $\approx \pm 1.6$ V signal level
Null output:	LEDs, DC null voltage signal ($\approx \pm 3$ V DC = \pm FS)
Operating temperature:	-20 $^{\circ}$ C to +75 $^{\circ}$ C
Temperature Coefficient	0.002% of FSO/ $^{\circ}$ C (combined span and zero shift)
Zero set:	Front panel push button or RS-485 command
Full Scale set:	Front panel push button or RS-485 command
Digital interface:	RS-485 2-wire multi-drop network, 16 individual addresses

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Front Panel LEDs and Switch Functions

(Use with *Quick Start Guide* on page 4)

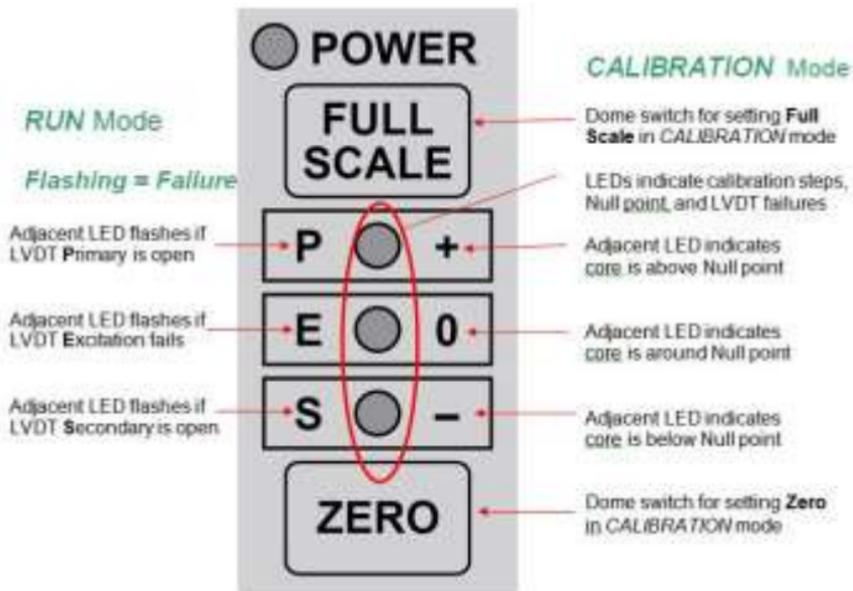


Figure 1.

PC board-mounted DIP switch functions & I/O connections

(Use with *Quick Start Guide* on page 4)

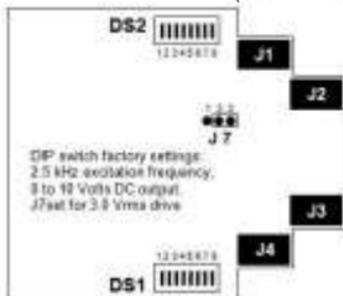


Figure 2. Internal DIP Switch Locations

D52-1 and D52-2 Switch positions	Excitation Frequency
D52-1 & D52-2 both OFF	7.5 kHz
D52-1 ON & D52-2 OFF	2.5 kHz
D52-1 OFF & D52-2 ON	5 kHz
D52-1 & D52-2 both ON	10 kHz

Table 1. Excitation Frequency Settings

D52 -	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

D51 Position	1	2	3	4	5	6	7	8
Output with D51-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

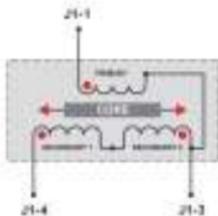
Table 2. SC-100 Analog Output Settings



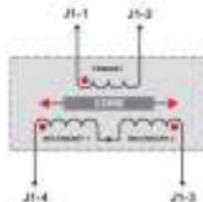
J1-1	LVDI Primary High or Half-bridge High
J1-2	LVDI Primary Low or Half-bridge Low
J1-3	LVDI Secondary Low (Common Ground)
J1-4	LVDI Secondary High or Half-bridge Mid-tap
J2-1	LVDI "Center Tap" Junction Point (No internal connection)
J2-2	Failure Flag (Open Collector, +24 V DC, 50 mA max.)
J2-3	-15 V DC input for ±10 V DC output
J2-4	Sync Input / Output (Master / Slave Bus)
J3-1	RS-485 (2-Wire Digital Data Line B) (+)
J3-2	RS-485 (2-Wire Digital Data Line A) (-)
J3-3	Analog Output (-) (Common Ground)
J3-4	Analog Output (+) (Voltage or Current, as selected by D51)
J4-1	Null Indicator Differential DC Output (floating)
J4-2	Null Indicator Differential DC Output (floating)
J4-3	Power Return (-) (Common Ground)
J4-4	Power Input (+) (+15 to 30 V DC) +24 V DC nominal

Table 3. SC-100 I/O Connections

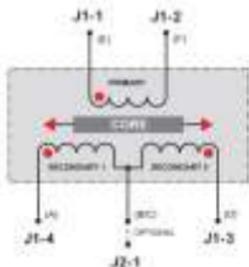
Note: J1-3, J3-3, and J4-3 share the same Common Ground so use only one ground connection to prevent possible ground loops



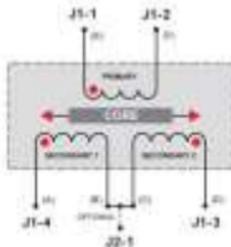
a) 3-Wire LVDTs/RVDTs (see note 4)



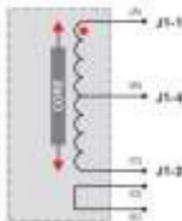
b) 4-Wire LVDTs/RVDTs



c) 5-Wire LVDTs/RVDTs



d) 6-Wire LVDTs/RVDTs (see note 5)



e) Half-Bridges and LVRTs

Notes:

1. J1-1 through J1-4 and J2-1 are connections to signal conditioner's screw terminal plugs.
2. LVDT/RVDT secondary windings are shown connected in series-opposition, where • indicates the windings' magnetic polarization.
3. Letters in parentheses are connector pinouts for typical 5- and 6-wire LVDTs or RVDTs and for half-bridge-style LVRTs.
4. A 3-wire LVDT/RVDT connection applies only $\frac{1}{2}$ of the nominal excitation voltage to the primary. Move J7 to the high excitation output position for best results.
5. 6-wire LVDTs or RVDTs require the secondaries be connected externally in series-opposition, preferably as close to the sensor as practical.

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 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 set LVDT excitation frequency is 2.5 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 the DIP switch changes, if any, are finished, slide the circuit board back into the case on its tracks and snap the two sections of the module's case back together.

3. Mount the module: Install the SC-100 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 catch at the back of the module, lift the catch, and disengage the module from the rail.

4. Make the IO connections: Following Table 3 and the schematics on page 3, use the screw terminals to connect the LVDT primary and secondaries (and the "center tap pair" junction point if needed), DC power, and the analog output as set in Step 2 to the system or indicator.

5. Calibrate the LVDT's core positions: When the appropriate DC power is applied, the red POWER LED should glow steadily and the green LEDs should be off. If any of the 3 green LEDs are flashing, check the LVDT connections: **P** indicates open primary; **S** indicates open secondary; **E** indicates loss of excitation. When only the red POWER LED is on, the calibration procedure can be started. (**P** is solid on for the master module in a master/slave configuration; see page 5.) **NOTE: The LVDT's core must not protrude from the LVDT 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 operating in its *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.

▶ Set 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. Move the workpiece (now coupled to the LVDT's core) to the Full Scale (maximum or end of travel) position. Depress the FULL SCALE button until the green LEDs flash once.

▶ Next, move the workpiece (now coupled to the LVDT's core) to the Zero (start of travel) position at the other end of its range of motion. Now depress the ZERO button until the green LEDs flash 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 SC-100 LVDT Signal Conditioner

The SC-100 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 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 ± 10 Volt DC output, +15 V DC is connected to J4-4 and -15 V DC is connected to J2-3.

LVDT Primary Excitation

The AC-LVDT's primary is excited by a digitally synthesized low distortion ($\leq 1\%$ THD) sine wave signal. The nominal excitation frequency selections are 2.5, 5, 7.5, or 10 kHz. The sine wave synthesizer operates from a crystal oscillator, so the resulting frequencies will be very stable. 2.5 kHz is chosen as the factory default setting, since most commercial LVDTs specify 2500 to 3000 Hz excitation and will operate very satisfactorily at this frequency. To select another of the excitation frequencies, it is necessary to open the SC-100 module's case and change the setting of DIP switches DS2-1 and DS2-2 according to Table 1. The DIP switch settings are also printed on the module's 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 moving jumper J7 to pins 1 and 2, or decreased by 50% by exciting the primary single ended to ground (J1-1 to J1-3). A fault detector in the LVDT's excitation circuitry detects if the LVDT's primary is electrically open-circuited or disconnected. If so, the green **P** LED on the front panel flashes and the failure warning output at J2-2 is triggered.

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 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. 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 could occur if there are slight differences in the modules' excitation frequencies. If a beat frequency develops, it will be seen 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. One module is chosen as master and the other modules are slaves connected synchronously to the master, using the built-in auto-master synchronizing system.

The modules' syncing is 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 digital 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 2, or by using the chart on the left side label. No duplicate addresses are allowed. The factory default address, 00, is usually applied to the master module. Finally, 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's oscillator fails, a new master will be automatically developed to produce the excitation oscillator frequency, thereby 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 becomes 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 flashes the green **S** LED on the module's front panel and triggers the failure warning output at J2-2.

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 to 10 V, -10 to +10 V, 0.5 to 9.5 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.

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 same DIP switch setting information is also printed on the module's left side label. 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. Its analog output is first sent to a single-pole low pass R/C filter having a -3 dB cutoff frequency of approximately 10% of the excitation frequency set by DS2-1 and DS2-2, and then to the output terminals. For applications requiring very low noise and ripple, the analog output can be subjected to further filtering by turning DIP switch DS2-4 *on*, which engages a single-pole low pass filter with a default -3 dB cutoff frequency of about 10 Hz, but which can be programmed via the RS-485 port to any frequency between 0.1 Hz to 10 Hz. The factory default setting for DS2-4 is *off*.

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 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, including faults on the master/slave bus. Any of these faults will trigger the failure warning output, which is an

open-collector-type output that pulls the failure warning output terminal (J2-2) to common ground for any case where the DSP detects a fault or failure. The failure warning terminal includes protections against overcurrent, overvoltage, and ESD. Page 10 and Table 6 offer more detailed explanations about the LED indications and the failure warning output.

RS-485 Communications

The SC-100 incorporates a two-wire half-duplex RS-485 communications multi-drop interface for up to 16 devices. The RS-485 communications permits a module to be set up and calibrated remotely and various data to be read or stored at a PC or terminal. A PC utilizing an RS-485 serial port or USB port converter can be connected as a data terminal to module terminals J3-1 and J3-2 to implement specific commands listed later in this manual on page 13. Any command sent to the module must start with the letter "U" followed by that module's decimal digital address identification number, which can be set from 00 through 15 by DIP switches DS2-5, DS2-6, DS2-7, and DS2-8 in accord with Table 1a. The DIP switch positions for setting the any of the 16 digital addresses are also printed on the left side label on the module's case. The side label also has a box for annotating the module's address. The factory default address setting is 00.

Graphic User Interface

A Graphic User Interface (GUI) program that operates over the RS-485 multi-drop communications link with an SC-100 is available for download from the following website: www.alliancesensors.com. The GUI facilitates setting up, calibrating, and monitoring any SC-100 on the 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 module during a possible hot swap action in the future.

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 2. Besides switches for excitation frequency and analog output, there are choices for additional low pass filtering to improve signal-to-noise ratio, inversion of the output slope, and selection of up to 16 separate 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 system output. First, 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; there is no definable *full scale* or *zero* position for most LVDTs. The workpiece is set for the middle of its expected range of motion and then the LVDT's core is mechanically connected to it. The LVDT core and connected workpiece are moved to their Full Scale or final position so the module's *Full Scale Output* can be set accordingly. Finally, the LVDT core and connected workpiece are moved to their Zero or starting position, where the module's *Zero Output* can be set, completing a typical end-point calibration procedure for the LVDT-based position measuring system.

Calibration Procedure

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 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 operation, the **P** LED will glow steadily on the master module. 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 LED flashes, indicating the signal conditioner is in *CALIBRATION* mode. The module can also be put into *CALIBRATION* mode by sending the appropriate command via the RS-485 port. (See page 13 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 a false null indication 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 with respect to common ground, so the voltmeter will read zero volts between the terminals. As the LVDT's core is moved, one terminal's voltage increases toward +3 V as the other terminal's voltage decreases toward 0 V (and vice versa for the other core direction), for a maximum voltmeter reading of about ± 3 Volts DC. **NOTE: LVDT's core must not protrude from the LVDT during null point measurements or false 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 range. This step also assumes the Full Scale output was 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 still be flashing, indicating *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 (FULL SCALE) LED flashes once, or send a "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 (ZERO) LED 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 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 function LEDs (except for the master module in a master/slave configuration) will not be glowing.

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 3.6 mA. These output limit values can vary a little from module to module, depending on circuit and component tolerances.

Using the Voltage and Current Outputs

When in any of the voltage output modes, 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 a *current loop output*, either 0 to 20 mA or 4 to 20 mA, the maximum loop load resistance permitted depends on the power supply voltage, as shown in Figure 5 below. When the module is powered from the recommended 24 Volt DC supply, the maximum loop load resistance is 850 Ohms. Typical loop loads are 250 or 500 Ohms, so this gives adequate capacity for long connecting lines.



Figure 5.
Maximum Loop Load Resistance vs. Supply Voltage

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 ± 3 Volts to terminals J4-1 and J4-2, the Null Indicator output for a continuous indication, recalling that each terminal is floating with respect to ground. (Refer to **Null Indicator Output** on page 8)

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 so that the output of the voltmeter at each end of the range of motion is approximately the same, thereby establishing that the LVDT is operating in a symmetrical manner within its nominal range of measurement. Now proceed to calibrate the system's Zero and Full Scale as noted on page 8.

NOTE: The LVDT's core must not protrude from the LVDT during any of the measurements or erroneous calibration will result.

Failure Diagnostics

The SC-100 incorporates diagnostics to identify internal failures, mistakes made during the setup, and operational failures due to external causes, providing failure indication both visually and electrically.

When the SC-100 is in *RUN* mode, the front panel LEDs indicates 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 SC-100 is in *CALIBRATION* mode.)

<i>RUN</i> <i>MODE</i>	Normal Operation	Master Operation	Primary Open	Secondary Open	LVDT not Connected
POWER	●	●	●	●	●
P	○	●	⚙	○	⚙
E	○	○	○	○	○
S	○	○	○	⚙	⚙

<i>RUN</i> <i>MODE</i>	Excitation Error	Shorted Sync Line	Frequency Set Error	General Failure
POWER	●	●	●	⚙
P	○	○	○	○
E	⚙	●	○	○
S	○	○	●	○

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 LEDs as illustrated by Table 6, the SC-100 also provides electrical outputs that allow the failure warning to be transmitted to a remote indicator, system controller, or other device. These electrical outputs include an open collector failure warning output and various error codes accessible via the RS-485 digital bus. A matrix identifying the meaning of these digital error codes is listed in *Appendix A* on page 14.

Failures identified by the diagnostics incorporated in the SC-100 can be classified either as errors in setting up the SC-100 module during installation that should be corrected before the module is brought online, or operational failures that occur sometime after the SC-100 module has been properly installed and put into service. The SC-100 module may produce different error outputs for each of these different classes of failures, as illustrated in the matrix table in *Appendix A* on page 14. If an error code or failure is presented, it usually requires a "soft" reset to clear it, but occasionally might require a "hard" reset to clear it, which is accomplished by powering the module down for 10 seconds and then powering it back up. A soft reset on an SC-100 module can be initiated either by depressing the FULL SCALE button three times in a row for at least half a second each time, or by entering the "Reset" command on the RS-485 bus for that module's digital address.

Failure Warning Output

When any of the operational failures shown in Table 6 occur, the DSP activates the continuous failure warning output that comes from an open collector transistor that can operate a relay, an alarm, or use a pull-up resistor to generate a TTL output signal. This failure warning output is subject to a short delay before activation to eliminate trips due to momentary effects such as power line noise spikes, nearby lightning strikes, and similar transients. This delay time is programmable from 0 to 900 ms in 100 ms increments using a command sent over the RS-485 communication port. The factory default delay is 200 ms. 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 SC-100 module can function properly, including its ability to output the continuous failure warning signal.

Troubleshooting LVDT Connections

Table 6 on the previous page shows the SC-100 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 pin outs against the specifications for that LVDT in order to make sure that all of the wires are correctly identified and properly connected. When running cables between LVDTs and signal conditioners, the most common wiring errors are a disconnected LVDT primary lead, a disconnected secondary lead, or a failure to properly connect the two secondaries together. This latter issue occurs quite often and should be checked first and foremost. For operation with the SC-100, the secondaries of the LVDT are connected together in a series-opposing configuration. It is strongly recommended that the interconnection of the secondaries be done at the LVDT itself, before any cabling or wiring is attached. Normally, the junction of the two secondaries is not connected to the LVDT signal conditioner at all. However, when an SC-100 is hooked up in close proximity to the LVDT, the secondary junction connection may be hooked up to J2-1, which is merely a convenient tie point not connected to anything within the signal conditioner. With a long cable run between the LVDT and the module, the secondary interconnection absolutely should be made at the LVDT, not run back to the module. Note that the SC-100 signal conditioner does not utilize each secondary's signal, but only operates on the net differential AC output that results from the series-opposing winding connection.

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, only one place in the circuit must be the common ground point, which is usually at the signal conditioner module. Note that terminals J1-3, J3-3, and J4-3 all share the same common ground, so only a single ground wire should run from just one of those terminals to the system common ground point. When an AC ground current flows in a shielded wire, the shield current could induce unwanted voltages into the signal wires contained inside, so do not connect the shield to the sensor's housing or to any separate ground point. Connect it as a Faraday shield only to the system ground point.

Commands for the RS-485 port

Commands for transmission via the RS-485 communications link can be sent to an SC-100 from a PC using a program such as Hyper Terminal, and a 2-wire RS-485 serial or USB port adapter. Verify that the adapter is connected with the correct data polarity: Data B (*D+*) to J3-1 and Data A (*D-*) to J3-2. Always follow the data polarity (*D*) indicated, regardless of which letters are used for the data lines. Communication parameters are: 9600 bps, no parity, 8 data bits, 1 stop bit (9600, NP, 8, 1), echo on. 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 that is the decimal digital address of the specific module as set using Table 1a, or using the settings information on the left side label.

RS-485 Commands

Analog Returns nominal analog output value scaled in units that depend on the setting of DS1.

Cal Enters *CALIBRATION* mode; same as pressing FULL SCALE and ZERO pushbuttons together.

Config Lists a module's setup data with DIP switch settings and present EEPROM values: address (00-15), analog output DIP setting (1-8), excitation frequency DIP setting (1-4), invert output switch (off or on), low freq. filter (off or on and -3dB frequency), excitation drive jumper (J7) position, and EEPROM values for: ADC Hi, ADC Lo, input pot, gain pot, and failure flag delay (FD) time. (Log all "Config" names and values for future SC-100 reconfiguration during possible "hot swap" actions).

Exit Required to exit any setting command, and to write any reconfiguration value to EEPROM in *RUN* mode.

FS In "CAL" mode sets full scale position of the core; same as pushing the FULL SCALE pushbutton.

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

LEDs Outputs the present LED status. In "CAL" mode, "LEDs" may be sent several times for the DSP to send the present status of the 3 green LEDs; e.g. xx0 means top and middle LEDs are on.

Reset Produces a "soft" reset of the module's processor so the module restarts as if it is powering on; same as pressing FULL SCALE pushbutton three times in a row for one-half second each time.

Set ADC Hi In *RUN* mode, sets high value of A / D converter input during hot swap reconfiguration.

Set ADC Lo In *RUN* mode, sets low value of A / D converter input during hot swap reconfiguration.

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

Set Gain In *RUN* mode, sets value of *gain pot* logged from "config" command for reconfiguration.

Set In Pot In *RUN* mode, sets value of *input pot* logged from "config" command for reconfiguration.

Set LF In *RUN* mode, sets the -3 dB frequency of low pass filter between 0.10 Hz and 10 Hz when DS2-4 is *ON*

Z In "CAL" mode, sets the zero position of the LVDT's core; same as pushing the ZERO pushbutton.

Appendix A

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

Note 1: Master module may have **P** steady on in addition to specified LED display The RS-485 numerical codes that correspond to multiple errors are additive, e.g.: an error code 128 combined with an error code 16 would result in an error code reported as 144.

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