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ess EARTH SCIENCES

EC1500/1550

4-20mA / SDI-12 ELECTRICAL CONDUCTIVITY SENSORS

PRODUCT USER MANUAL

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Quality Assurance Statement

ISO9001 accreditation

ESS Earth Sciences is currently an AS/NZS ISO9001:2008 certified organisation.

This certification is evidence that sound practices are used to get high quality instrumentation to your organization within a reasonable time interval. Standard practices are used for all areas of manufacture, beginning with the efficient procurement of incoming orders, right through to shipment.

Stringent quality assurance procedures are applied to all aspects of manufacturing, including the calibration of scientific instruments against NATA traceable references. Every sensor is accompanied by a test and calibration certificate that can be used as reference information as well as evidence of sensor accuracy.

Terms of Warranty

The warranty covers part or complete replacement, repair or substitution of new instrumentation that has failed in part or completely within the warranty period. While every effort has been made to supply robust and user friendly instrumentation, the warranty does not cover instruments incorrectly installed, misused or operated in conditions outside those specified. The warranty does not cover shipment costs for instrumentation, installation or removal and, under no circumstances whatsoever, indirect or consequential losses caused by the failed instrumentation.

ESS Earth Sciences believes the warranty conditions to be fair and just and in accordance with standard business practices worldwide. ESS Earth Sciences reserves the right to arbitrate any warranty issues and will ensure that warranty issues are treated with the highest standards of professional conduct.

At ESS Earth Sciences we believe your investment in our products and services is a good decision and we will therefore ensure all your requirements are met at all times, both now and in the future.

Introduction

The EC1500/1550 sensor is a fully submersible device used for measuring water conductivity. It is constructed from durable machined plastic components and epoxy resins. For reliability, there are no wetted metal components to corrode making this sensor suitable for high conductivity (high dissolved solids) application and even for water with high acidity. The EC1550 /1550 sensor is designed for very long term deployment at unattended monitoring stations.

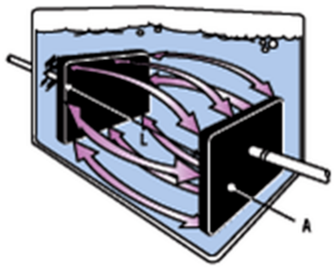
The sensor head is fully epoxy encapsulated and has a hole through the middle to allow the flow of water through it. It is here that the water provides magnetic coupling for the measurement to take place.

An 8mm diameter submersible rated cable is hardwired to the back of the sensor (length specified during ordering). Although care must be taken to secure the sensor at all times, the sensor may be suspended from the cable for short periods such as during installation.

Once installed and powered, the sensor will measure conductivity from 0 to full scale, as inscribed on the sensor body in microSiemens per centimetre (µS/cm).

There are no moving parts on the EC1500/1550 sensor, and no serviceable components. This sensor is a dual output 3 wire current loop device plus SDI-12 as detailed in the *Installation* section.

What is electrical conductivity?



Electrical conductivity is a measure of how easily electrons flow through a material. For all materials, conductivity is proportional to the cross sectional area of the current path, and inversely proportional to the distance the current has to flow.

Conductivity can be measured from first principles by using a conductivity cell. This is a box containing a liquid, with two plates, each of area A separated by a distance L.

The first step to determining conductivity is to measure the conductance of the material, which is simply the ratio of the current to the voltage across the cell. The basic unit of conductance is the Siemen (S). We then compensate for the size of the cell to derive the specific conductivity C in S/cm. This is simply the product of measured conductance (G) and the electrode cell constant $C = G \times (L/A)$

How is conductance measured in practice?

For field use, it is not practical to use two plates separated in a cell. A common method of field conductivity measurement uses a miniaturized version of the conductivity cell. Two electrodes are separated by a short distance (typically 1 cm) and a voltage is connected across them, and the current is measured (In practice, a sinusoidal voltage is used to reduce DC effects, and four electrodes rather than two are used.) The dimensions are compensated for, and the conductivity is derived a similar manner to the conductivity cell.

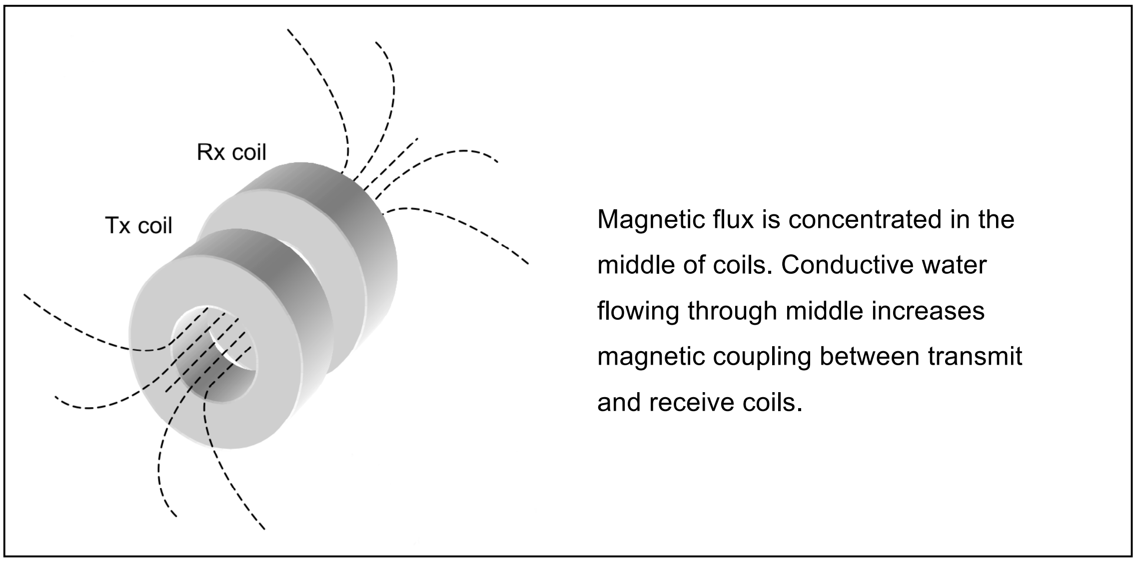
The above method is very common, it is simple to implement, and its operation is intuitively obvious. However it has a serious drawback: To work correctly, the electrodes must be in direct contact with the liquid. This leads to corrosion of the electrodes, resulting in unstable results, long term drift, and overall low reliability in the field.

How does a toroidal conductivity sensor work?

The EC1500/1550 sensor employs a different measuring technique. Instead of electrical contact probes, it uses an inductive (or magnetic) method to determine conductivity. By using this approach, there is no direct contact with the liquid. Although more difficult to implement, this toroidal method is inherently more reliable, and has very low drift compared with electrode type sensors, and will operate for many years, even in difficult environments.

Two coils are placed a known distance apart. One coil has an oscillating current applied that forms a magnetic field inside the coil centre. The other coil receives the magnetic flux produced inside the transmit coil. Because of the coil arrangement, the receiving coil will only receive signal when a conductive material is placed between the coils. If water is allowed to flow through the coil centre, impurities in the form of dissolved salts will provide the necessary magnetic coupling.

Note: Conductivity should not be confused with conductance, which is the inverse of the material's resistance.



The above diagram shows how the sensor works. Transmit (TX) coil forms a magnetic flux inside the coil pair. Conductive water increases the magnetic coupling which is seen as a transfer of oscillating current in receiver (Rx) coil. The degree of transfer is an indication of water conductivity.

What is temperature compensation?

Like resistance, conductivity changes with temperature. The lower the temperature, the less the conductivity and this is because electrons find it harder to flow through dissociated salt molecules at lower temperature. This makes measurement confusing when actually trying to determine the water conductivity over a temperature range. To overcome this effect, conductivity measurements at any temperature are output as if the temperature is 25°C and is called *temperature compensated output.*

The relationship between compensated and non compensated (raw) output is linear and simply put, a percentage is added or subtracted from the raw measurement to determine compensated output. For the EC1500/1550 sensor, the compensation is set at approximately 2% per °C. For temperatures below 25 °C the proportion is subtracted and is added for temperatures above 25°C. Of course the temperature needs to be measured for compensation and therefore the EC1500/1550 sensor has an internal temperature sensor. As an additional feature, the EC1500/1550 sensor also has a separate temperature output available to loggers and controllers as a 4-20mA signal. Temperature compensation operates between 0 and 50°C, the typical expected water temperature for most environmental conditions.

$$Corrected\ EC\ at\ 25C\ in\ \frac{uS}{cm} = (Raw\ EC\ in\ \frac{uS}{cm})/(1 + 0.02(sample\ temperature - 25C))$$

Installation

Site Selection

Before installing a EC1500/1550 sensor it is recommended a suitable site be selected first. The installation and maintenance complexity as well as the reliability of the instrument in critical applications depends on the site chosen and the length of cable required can then be determined.

Well-chosen sites:

- slow flowing water (no stratification)
- minimal or no accumulation of debris around sensor
- easy and safe access, away from waterway traffic
- sensor head is always submerged in at least 200mm of water
- sensor head is at least 100mm from bottom and at least 50mm from any metal
- sensor cannot be dislodged during high flows

Avoid sites with:

- very low or stagnant water flows
- where debris can accumulate inside sensor head
- excessive air bubbles in water
- difficult or unsafe access
- high siltation rates
- where sensor will be exposed in air during low flows

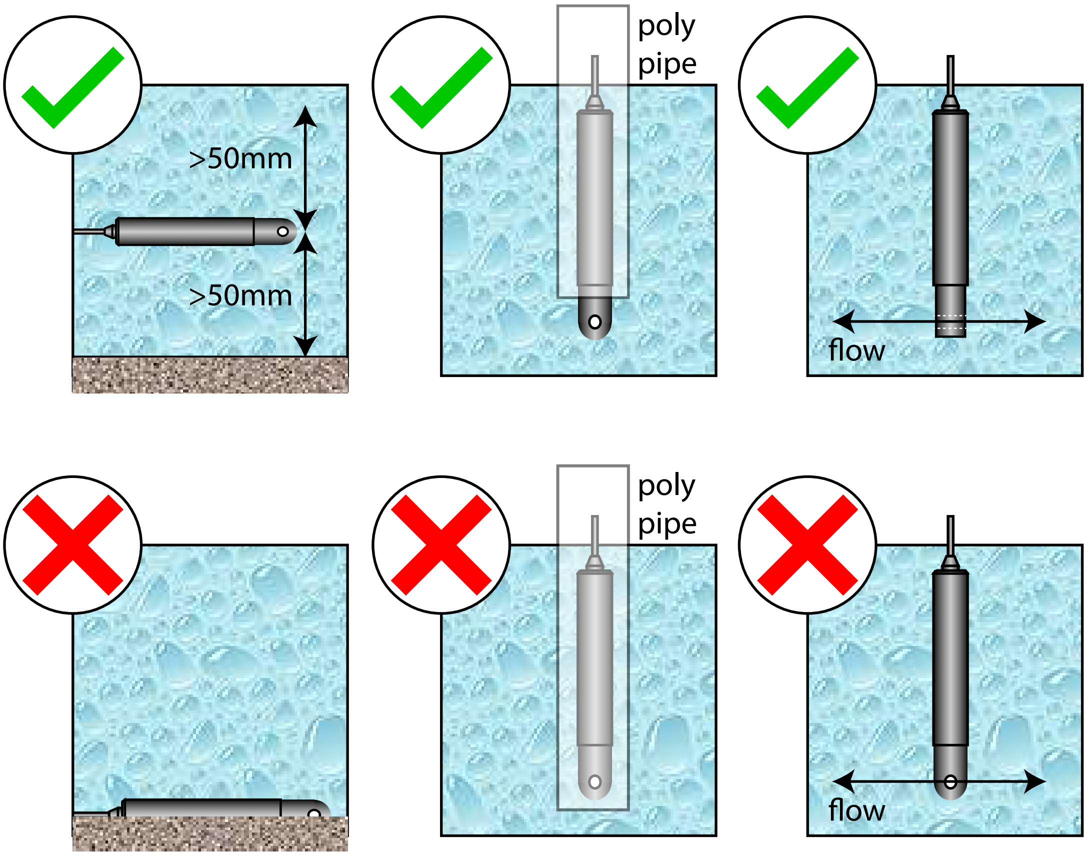
The following is also recommended for EC sensor installation

- Install the sensor out of direct sunlight, especially when in shallow water. Sunlight will heat the sensor head to produce a false temperature and compensated EC reading.
- Algae will tend to grow within the sensor hole. This can be minimized by covering the sensor with a shield to make the head as dark as possible. No sunlight means no algae
- Silt can accumulate in the sensor hole. Install the sensor so water can flow through the hole.

Typically, most sites that are already equipped with hydrographic instrumentation can be used for installation of the EC1500/1550 sensor.

Installation Orientation

For correct installation, the following recommendations apply:



With the exception of the sensor head (the part with the hole through it), the rest of the sensor can be completely covered by an installation tube. If 50mm ID poly tube is used for installation, a suitable compression gland is available from irrigation hardware suppliers. The sensor outside diameter is smaller than the compression gland internal diameter and can be clamped easily and securely using this method. When this system is used, the sensor head must protrude from the gland by at least 60mm.

Sensor Clearance

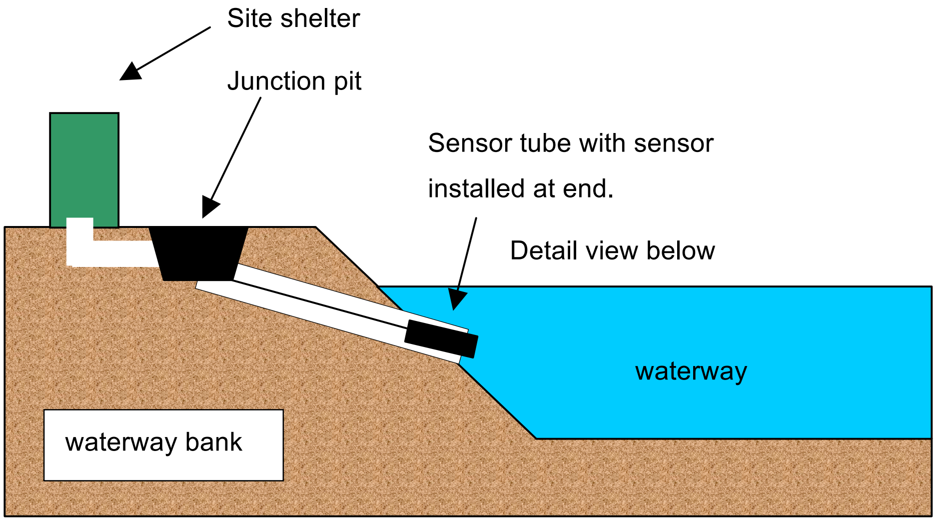
Correct orientation of the sensor will help to reduce the buildup of silt and debris within the hole in the center of the EC head. Where algal blooms are likely it is recommended the sensor is covered with a sun shield, keeping the sensor in the shade, thereby reducing algae buildup. When installing a shield, ensure the shield clears the sensor head by at least 50mm. The shield should ideally be installed 100mm from the sensor, and cover the sensor sufficiently from direct sunlight. A shield will also prevent excessive temperature variations.

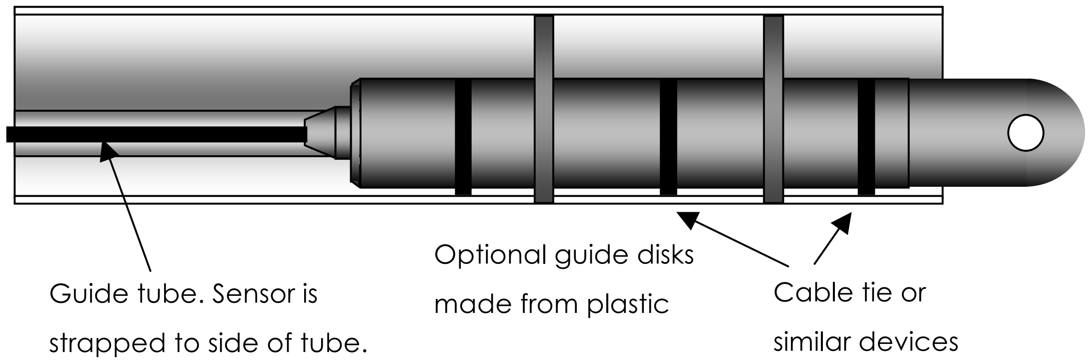
Site preparation

Before the sensor can be installed, the site must be prepared to ensure the sensor will be secured, protected and serviceable.

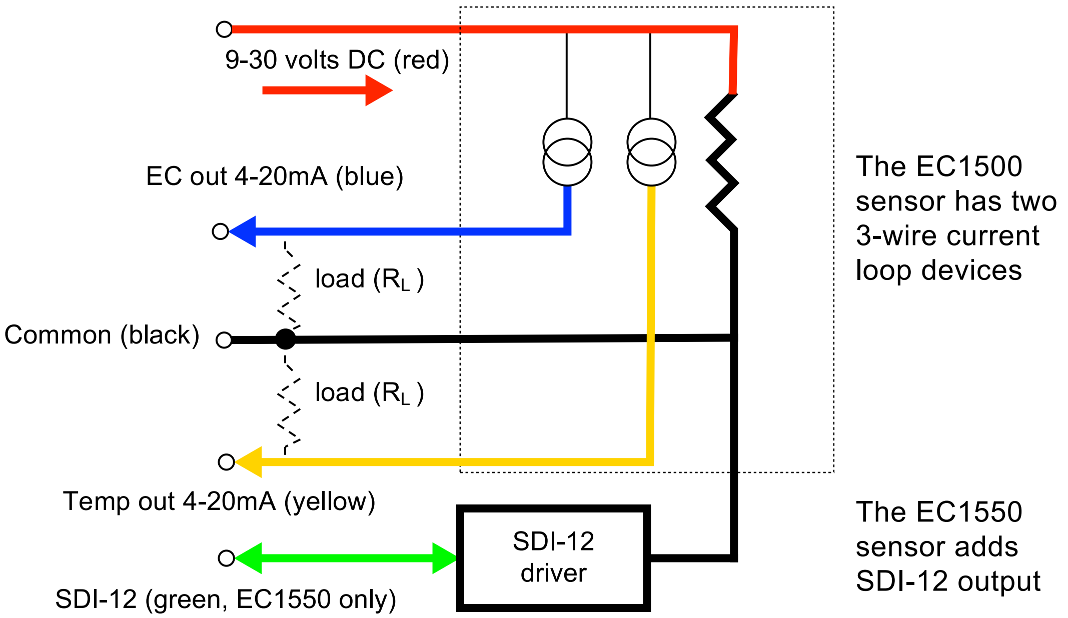
The following recommendation is based on typical installation methods practiced by today's hydrographers. Several variations of this method are used to suit particular applications.

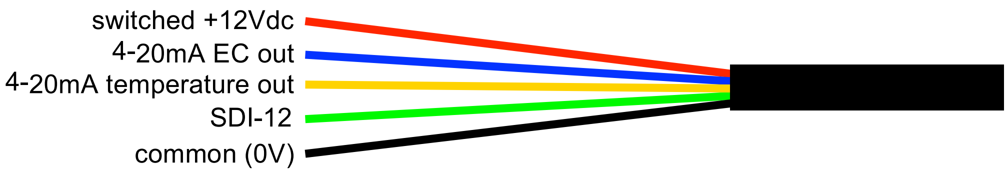
Please study the diagram below. Site preparation involves the installation of a larger plastic tube along the waterway bank as shown. The tube should ideally be continuous but may also be made from sections. One end of the tube must be installed into the water ensuring the sensor optical path will not be obstructed according to the previous section *Sensor Clearance*. The other end can be terminated in a junction pit that is large enough so that the sensor can be inserted from the pit. Typically, an underground electrical pit is used as this also allows a sensor carrier assembly to be inserted easily. The pit must be installed on a stable part of the bank that cannot erode.





EC1500 Electrical Connection





Conductor Colour	Conductor Designation	Requirement	Connector 3-pin	Connector 5-pin
red	switched +12vdc input	80mA min	A	A
blue	4-20mA output, EC	Source current	B	B
black	Common	0V dc	C	C
yellow	4-20mA output, Temp	Source current	B (plug 2)	D
green	SDI-12 (EC1550 only)	Digital I/O		E

Apply power to your sensor, then follow the guides below to take a reading.

EC1500 –4-20mA output

A current output signal will be available for measurement after 1 second. For power conserving applications, the sensor can be switched off immediately after the reading is attained. The sensor can also be left on continuously if required. The 4-20mA current output will be available for reading 1 second after switched power is applied.

EC1550 –SDI-12 and 4-20mA output

The above 4-20mA is available, but the EC1550 also provides the SDI-12 I/O. The following table lists the SDI-12 commands:

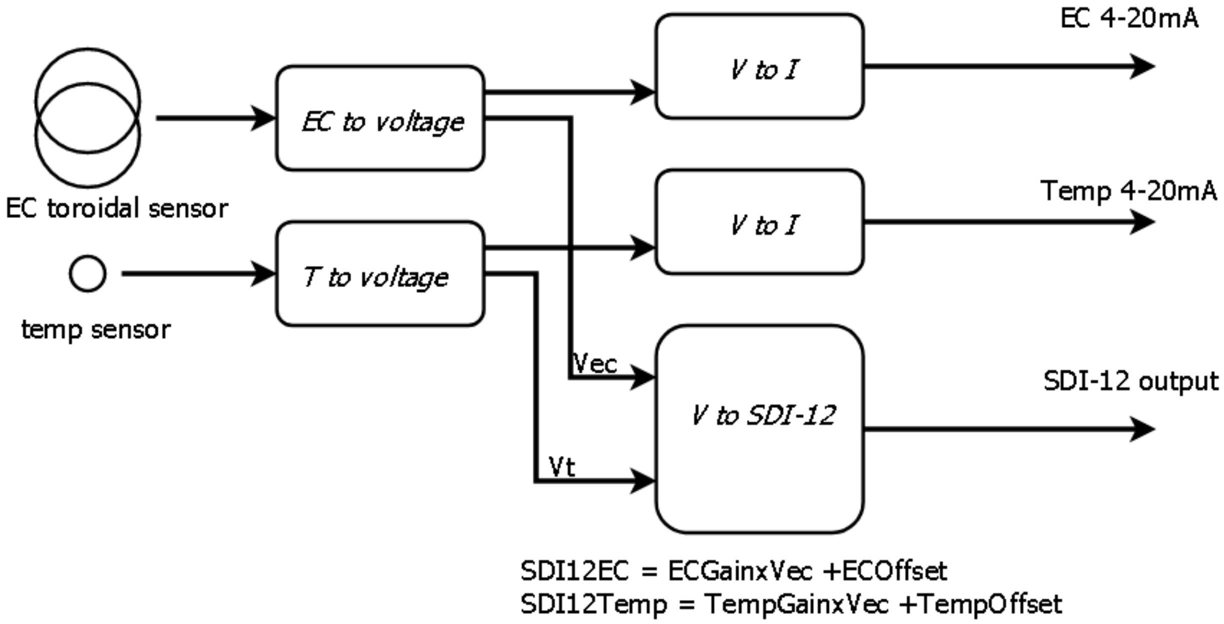
SDI-12 Commands (EC1550 only)

a=channel number

Command name	**SDI-12 command**	**Notes**
Acknowledge Active	a!	Check if sensor active
Send Identification	aI!	Get information
Change Address	aAb!	Changed channel number
Address Query	?!	Checks presence of a sensor if the sensor address is unknown. Note: Avoid using this command with multiple sensors connected. If multiple sensors are connected, all sensors will respond with their address making received address values invalid.
Start Measurement and Request CRC	aMC!	Start measurement (with CRC)
Start Measurement	aM!	Start measurement
Send Data	aD0!	Get data
Measure and return data	aXM1	Start measurement and get data
Start Concurrent Measurement	aC!	Start Concurrent Measurement The sensor responds with a numeric string indicating its address, the time it will take before measurements are ready, and the number of values it will return. The recorder is then free to instruct other sensors to begin taking measurements before returning to retrieve data from the sensor after the elapsed time.

Power off	aXPF	Turn off power (sensor will power on after M command). Response to a subsequent "M" command would be that measurements are available in 2 seconds time. (Power ON delay).
Power on	aXPO	Turn on power. Response to a subsequent "M" command would be that measurements are available immediately. (No Power ON delay).
Save power status	aXPL	Save power status (use after XPF or XPO command. This will set the default power state for the initial application of power (reset). If power status was saved as ON, the unit powers up ON, if power status was OFF, the unit powers up OFF. Note: Factory default is set to ON for EC1500 compatibility mode.
EC Gain	XG0 XG0!	Set EC Gain Return EC Gain setting
EC Offset	XO0 XO0!	Set EC Offset Return EC Offset setting
Temperature Gain	XG1 XG1!	Set Temperature Gain Return Temperature Gain setting
Temperature Offset	XO1 XO1!	Set Temperature Offset Return Temperature Offset setting

EC and Temperature calibration



A block diagram of the EC1550 is shown above.

The XG and XO commands allow the gain and offset of the SDI-12 conversion to be calibrated. This is normally done in factory, however the user can modify the calibration to cover a different range.

The XGO command sets EC Gain (ECGain), XO0 sets EC offset (ECOffset)

XG1 sets temperature gain (TempGain), XO1 sets temperature offset (TempOffset)

The procedure for calibrating EC Gain and Offset is as follows. (Note, these are described for EC, since the Temperature is calibrated in factory.)

1. Set ECGain = 1 and ECOffset = 0 using the XGO and XO0 commands

This will produce the raw ADC values in the SDI12 string.

2. For a set of known EC solutions (typically 5-6 values), generate the raw ADC values for each EC value. This will create a table of raw ADC vs EC values.

3. Since there is a linear relationship between the raw ADC values and the actual EC value (in uS/cm), a first order transformation of raw values to EC is possible using a gain and offset.

From the table of known values of EC versus raw ADC values, calculate (e.g. using Excel) the gain and offset values to transform the raw values to EC.

4. Enter these values as EC Gain and EC Offset using the XGO and XO0 commands.

Setting the Gain and Offset

Gain range: 0.0000 to 9.9999 (Xg000000 to Xg099999)

Offset range: -9999.9 to +9999.9 (Xo0-99999 to Xo0+99999)

Both gain and offset allow five decimal places. The gain has an implicit decimal point after the first digit, and the offset has an implicit decimal point before the last digit.

An example:
Some sample values are shown in the table below.

The "EC ref" column is measured using a reference instrument, e.g. Inolab.

The "Raw ADC" column shows values read from the SDI-12 output after setting Gain=1 and Offset=0 (XG0+10000 and XO0+00000)

Gain and Offset are derived using Excel or a scientific calculator, to transform the "Raw ADC" values into the "Converted" values.

In this example, the derived values are: Gain = 0.2009 and Offset = 22.697.

The commands used to set these values are:

Gain Command = XG002009

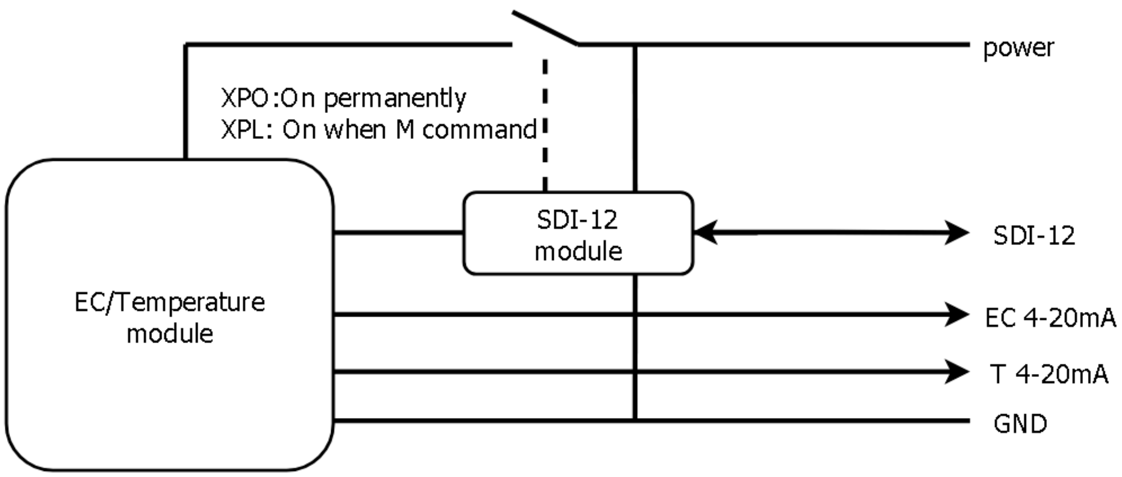
Offset Command = XO0+00227

The EC1550 will now generate the "Converted" column values (which appear in the SDI-12 output) by applying the Gain and Offset to the Raw ADC values.

(i.e. Converted value (in uS/cm) = 0.2009 x Raw ADC + 22.697)

EC ref	Raw ADC	Converted
1937.5	9531	1936.8
1625.0	7973	1623.9
1125.0	5486	1124.6
750.0	3623	750.6
375.0	1753	375.1
62.5	197	62.6

Operation of the XPO and XPL commands



Operation of the XPO and XPL SDI-12 commands is illustrated above.

The SDI-12 module is always powered continuously. The EC/Temperature module is powered by a switch activated by the SDI-12 module.

Setting XPO means that the power switch is always activated. This allows an EC1550 to exactly substitute for a EC1500 module. That is, there is no need for an SDI-12 logger, and only the 4-20mA outputs are used.

Setting XPL causes the power switch to turn off, de-powering the EC/Temperature module, and therefore greatly reducing standby power. The power switch is activated by an SDI-12 “M” command (take measurement). The power switch will power the EC/Temperature module long enough to do a measurement (2 seconds), then the power switch will open and the EC/Temperature module will be powered down. The data measurements will be retained in the SDI-12 module, waiting for a “D” command. Operating in this mode greatly reduces overall power consumption.

If another SDI “M” command is received in before a “D” command, a new measurement is taken, stored in the SDI module, and the previous value(s) are discarded.

With proper care and routine maintenance, the sensor can be left operating unattended for several months. Of course, as each application will be different, it is recommended that the total time between services is determined experimentally.

Maintenance

The 1500 sensor will require little periodic maintenance to ensure that measurements remain accurate. While all wetted components are no metallic and cannot corrode in high salt or acidity liquids. Debris, silt and algae lodged in the hole can cause inaccurate readings. It is recommended the sensor is checked during every visit, or at least every 3-6 months. You may find the sensor will not require any maintenance for even longer periods however, warmer climates or high silt laded rivers and streams can accelerate these effects.

General

- Ensure the sensor is not affected by debris, silt or algae (or marine growth). The sensor should be removed from its installed location for a thorough inspection. Using the recommended installation method outlined in the section Installation, removal should be easy and maintenance staff do not need to enter the waterway
- Ensure the installation is sound and the sensor is still secure from moving and there are no obvious signs of erosion or damage.

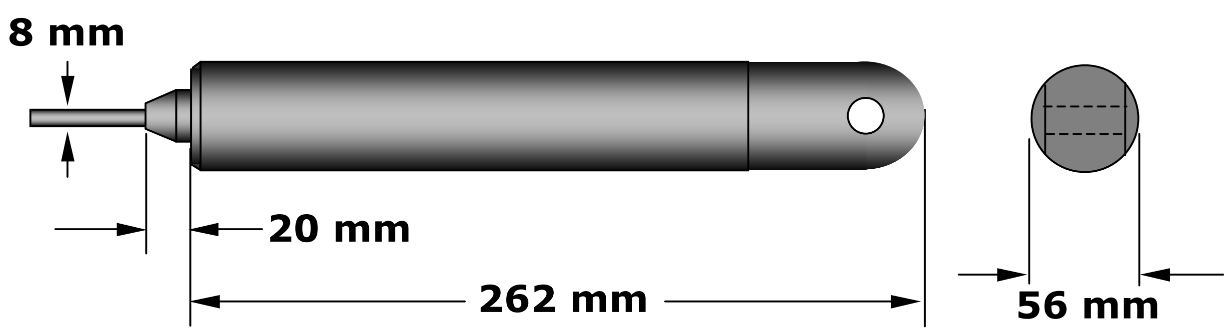
Calibration check

The sensor output can be checked against a reference instrument if it is available. Ideally, the measurement should be taken in the same solution as the sensor while the sensor is installed. If there is a large difference, an installation problem may be highlighted. All sensor measurements should be within the specified accuracy.

- Compare the sensor measurement to that of the reference instrument.
- Ensure the reference instrument calibration error is also known.

Specifications

Range	Standard ranges of 500, 1000, 2000, 5000, 10000, 20000, 50000, 70000 µS/cm. Other ranges available on request.	
Accuracy	EC linearity	< 2% of full scale range, 0 to 30°C
	Temperature	< 0.2°C over the range, 0 to 30°C.
Temperature	Storage:	-10 to 60°C storage (in dry environment),
	Operating:	0 to 50°C
	Output range:	0 to 50°C
	Compensation:	0 to 30°C
Response Time	2 seconds to full accuracy	
Type	Magnetic inductive coupling, toroid	
Outputs	4-20mA	scaled to maximum EC and Temperature range:
	Reading = Cm/16*(R-4) *where Cm = Max range, R=reading*	
	e.g. for Cm=20000µS/cm: Conductivity = 1250*(R-4) µS/cm	
	e.g. for Cm=50°C: Temperature = 3.125*(R-4) °C	
	SDI-12	EC and Temperature digital output
Power Supply	9-30VDC	
	1500/1550 4-20mA mode	< 50mA
	1550 in SDI-12 mode:	< 50mA measurement, 2mA standby
Surge	Secondary surge protection. Can absorb 0.6J of energy	
Dimensions	262 long, 56 dia (mm)	



Product Return Form

As part of our Quality Assurance initiative, and to improve response time, we request that the forms below are completed in as much detail as possible for product returns.

OPERATOR INFORMATION	
Name and contact details	
Company	
Date/Time	
Logger Site	
Location of product	
PRODUCT INFORMATION	
Model	
Serial number	
S/W version number(s)	
H/W version number(s)	
SOFTWARE USED	
Download program	
Remote or Local download	
Other software used	
CONFIGURATION	
Logger	
Length of tube	
Last logged values	
Measurement interval	
SITE - Describe site. Is unit in protective hut or enclosure? List any other sensors which are used at the site. Estimate cable length to sensors	
POWER SUPPLY	
Battery	
Voltage / Capacity	
Internal/External	
Solar/Mains charger	
Measured battery volts	
Solar Panel	
Voltage/Capacity	
Regulator make / model	
Switching/Linear regulator	
Mains supply	
EARTHING -Describe any special earthing arrangements in place.	

DESCRIPTION OF PROBLEM How did the problem manifest itself?	
Weather conditions while fault occurred (especially temperature)	
What commands were being used (SDI12 or serial)? *If possible, list the exact commands used, and the sequence. List the commands sent through the logger*	
What action was taken to get the unit going again?	
Have you noticed anything in common with the last time there was a fault?	
Was the unit permanently disabled, or is the fault intermittent?	
Is this the first time the fault occurred?	
Is there anything unusual about this site compared to other sites?	
Is there any other equipment or facilities (e.g. local power lines) which could cause interference?	
Please list any other issues relating to the site or the fault.	