

X2Change™ Sensors: User Manual

For more information visit AMLoceanographic.com or call +1 250-656-0771

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1 Introduction

AML Oceanographic's X2Change™ Sensors enable users to equip X2Series™ AML-1, AML-3, and AML-6 instruments with sensing parameters as required. Each sensor head contains its own embedded calibration and can be moved from instrument to instrument without impacting performance.

This manual covers all X2Change™ sensors and is intended for use as a supplement to the main instrumentation manuals.

1.1 List of Sensors

The following X2Change™ sensors are covered by this manual:

- SV (sound velocity)
- SVT (sound velocity and temperature)
- P (pressure)
- CT (conductivity and temperature)
- T (temperature)
- Turbidity (including Non-Wiper and Wiper Equipped Turbidity X2Change™)
- DO (dissolved oxygen)
- Fluorometers powered by the Turner Designs Cyclops-7F and C-FLUOR series

Sensors installed as RSE (remote sensor integration, aka piggyback sensors) are not covered by this manual. Please refer to the relevant manual from the manufacturer.

1.2 Related Manuals and Documentation

See https://amloceanographic.com/ for an up to date collection of data sheets, drawings, application notes, and manuals. Navigate to the item of interest in the webstore for the related documents.

2 Using the Sensor

X2Change™ sensors are typically installed on AML-1, AML-3, and AML-6 instruments, but they can also be integrated into 3rd party equipment via OEM connectors and electronics.

2.1 Pressure Ratings

Each X2Change™ sensor has its own pressure rating which is indicated by a label or engraving on the sensor itself. Sensors that meet or exceed 6000 m pressure ratings are not labeled with an explicit pressure rating. The sensor's pressure rating can be different from the pressure rating of the AML instrument or OEM device that it is connected to, and deployments must not exceed the lowest pressure rating in the system.

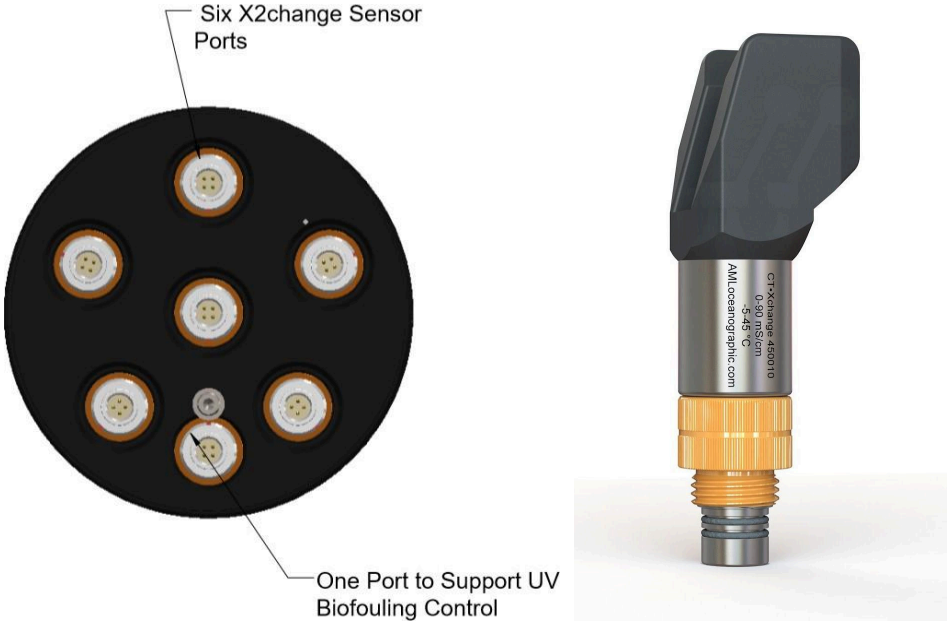
For example, an AML-3 LGR rated at 500 dBar pressure with SVT X2Change™ rated at above 6000 dBar and P X2Change™ rated at 100 dBar installed has a combined pressure rating of 100 dBar. Exceeding the lowest pressure rating will result in damage to the sensor and/or instrument.

Refer to the X2Change™ Brochure for sensor pressure ratings and specifications.

2.2 Installing and Removing X2Change™ Sensors

X2Change™ sensors are installed on the AML Instrument end caps. The instrument's name indicates the number of sensor ports available. AML-1 RT for example has 1 sensor port, whereas AML-6 LGR has 6 sensor ports. UV Antifouling is not installed in a sensor port, and on UV enabled instruments the UV Antifouling device is installed in its own dedicated port. Sensors are installed or removed by hand with no special tools required. Most combinations of X2Change™ sensors are permitted. Contact AML for guidance if you are having trouble installing the desired sensor payload.

The AML-6 LGR / RTS end cap is shown in the drawing below for reference:



To install:

1. Before installing X2Change™ sensors, ensure that the instrument socket is clean and dry.
2. Check the X2Change™ sensor's o-rings for cleanliness and replace if damaged. Apply o-ring grease to the new o-ring before replacing it.
3. Align the sensor with the sensor port so that the key and keyway of the Lemo connectors are aligned.
4. Place the sensor into the port.
5. Push the sensor until it drops down into the port enough to allow the orange locking sleeve threads to engage the port threads.
6. Screw down the orange locking sleeve until it stops. The bottom of the sleeve should be within 1 mm of the instrument end cap.

Notes:

- X2Change™ sensors are identified by their orange locking sleeve matching the orange sensor port.
- Only the orange plastic collar of the sensor is to rotate while removing or installing any of the X2Change™ sensors. The remaining portion of the sensor body is to remain stationary while the collar rotates.

- Older AML XChange™ sensors with blue locking sleeves are not compatible with the AML-1/AML-3 and AML-6 line of instruments.
- On all instruments CT•X2Change™ should be installed in port 1 due to the mechanical fit between the sensor and the cage. All other X2Change™ sensors can be installed in any of the sensor ports.
- A sensor port riser may be required when installing a CT•X2Change™ if other tall X2Change™ sensors are installed nearby. A short riser is available to accommodate the CT, SV, and P configuration whereas a longer riser is available for multiparameter configurations that include sensors such as DO, fluorometers, etc.

2.3 Commands

The following sections include tables of commonly used sensor settings. These tables are not exhaustive but cover most user configurable settings. Contact AML Oceanographic for more detail.

Commands are issued directly to the sensor. When using an AML-1 or similar single sensor connection, there is no special procedure required to communicate with the sensor. Simply power the AML-1 and communicate via a terminal program. When using AML-3 or AML-6 instruments it is required to RAWTALK to the sensor port where the sensor is installed. The procedure is:

1. Power the AML-3 / AML-6 instrument and establish communications via terminal program (if serial RS-232 / RS-485 is available) or using the Sailfish command window when connecting via USB or WiFi.
2. You can access the command window in Sailfish at the bottom of the instrument settings page or by using the shortcut key **ctrl+alt+x** if using Sailfish version 1.4.6.0 or newer.
3. Issue the command **DISPLAY SENSORS**. The instrument will respond with a list of sensors installed by port number.
4. Issue the command **RAWTALK x** where x is the port number of the sensor.
5. Issue the desired commands to the sensor.
6. When finished, power cycle the AML-3 / AML-6 to restore normal operations. Alternatively, exit RAWTALK mode by waiting one second, entering **+++**, wait one second, enter a carriage return. This will exit from RAWTALK mode and re-enable communications with the AML-3 / AML-6 instrument.

2.3.1 SV / SVT

The table below provides a summary of typical commands which are common to both SV and SVT•X2Change sensors.

Table 1: Common Settings for both SV and SVT•X2Change™ sensors

Setting	Applicable Command	Description	Default	Alternate Options
Identify firmware version	DISPLAY VERSION	Will provide sensor name and installed firmware version	-	-
Monitor on Startup	SET STARTUPMONITOR [YES|NO]	If YES, the instrument will start streaming data when power is applied. If NO, the instrument will await a command after header information.	Yes	No
Output Rate	SET OUTPUTRATE xxx	Time between provided measurements in ms (1/output frequency)	40ms (25 Hz)	40ms-1000ms
Automonitor	SET AUTOMONITOR xxx	Instrument will start to stream data automatically after user interrupt, time specified in milliseconds of inactivity	0s, will not start streaming	5000ms - 100000ms (User configurable from 5 - 100s)
Leading Space	SET LEADINGSPACE [YES|NO]	Adds a leading space to the output stream. Used to emulate output from legacy Micro•X instruments.	no	yes
Format of SV output	SET SVFORMAT XY	X is the number of digits before decimal. Y is the number of digits after decimal.	43 (xxxx.yyy)	User configurable
Baud rate (non persistent)	SET BAUD x	Non-persistently set the baud rate. X is the desired baud rate. Effective immediately (without power cycle). Baud will revert to 9600 after a power cycle.	9600	9600, 19200, 38400, 57600 115200
Baud rate (persistent)	SEC 652 SET OUTBAUD x	Persistently set the baud rate of header and sensor data. X is the desired baud rate. Baud will persist after a power cycle. Note: the ident string will output at 9600 baud regardless of the OUTBAUD setting. This is a secure command, and must be preceded with SEC 652.	9600	9600, 19200, 38400, 57600 115200
Configure ident string duration	SET IDENTMS x	Configures the duration of the ident string duration. X is the duration in milliseconds, and can be between 1 and 10000. Setting IDENTMS to 0 disables the ident string. Warning: Disabling the ident string makes X2Change™ sensors incompatible with AML-3 and AML-6 instruments.	2000	0 (disables ident), 1-10000
Startup Header	SET STARTUPHEADER [YES|NO]	Enables or disables the header on startup. If enabled, the sensor outputs the version header on startup after the ident string, before monitor.	YES	NO

SV sample averaging	SET SVAVG x	Rolling ‘boxcar’ average. Continuously averages last ‘x’ samples. Note: increasing averages will smooth output data but reduce response time.	8	1-100
SV units	SET SVUNITS [m/s|ft/s]	Sets the sound speed output units in metres per second or feet per second.	m/s	ft/s

SVT•X2Change sensors have some additional functionality pertaining to temperature measurements. These commands are summarized below.

Table 2: Common Settings for SVT•X2Change™ sensors

Setting	Applicable Command	Description	Default	Alternate Options
Temperature format	SET TEMPFORMAT xy	X is the number of digits before decimal. Y is the number of digits after decimal.	‘23’ (‘XY’ = xx.yyy)	User configurable
Temperature output on/off	SEC 652 TEMPDISPLAY [YES|NO]	Controls whether or not a second column is streamed displaying temperature. This is a secure command, and must be preceded with SEC 652.	YES	NO
Temperature averaging	SET TEMPAVG x	Rolling ‘boxcar’ average. Continuously averages last ‘x’ samples. Note: increasing averages will smooth output data but reduce response time.	4	1-100
Smart-X SVT legacy format	SEC 652 SET SMARTSVT [YES|NO]	Output will match the legacy Smart-X with SV and T Xchange installed. This is a secure command, and must be preceded with SEC 652.	NO	YES

Configuring SV and SVT X2Change™ sensors installed on AML-1 RT for use with multibeam echosounder (MBES) systems often requires specific settings. For example, a MBES top side unit expecting a legacy format at 9600 baud, so the settings required are:

SEC 652 (enable secure mode)
SET LEADINGSPACE YES (enable legacy format / leading space before SV value)
TEMPDISPLAY NO (disable temperature channel if present)
SET OUTBAUD 9600 (configure 9600 baud rate)
SET STARTUPHEADER NO (no header on startup)
SET IDENTMS 0 (no ident string on startup)
SET STARTUPMONITOR YES (data output on powerup)
SET OUTPUTRATE 40 (data output 40 ms between scans; 25 Hz data rate)
SET AUTOMONITOR 10000 (restart data output after 10000 ms if interrupted)

For more information on the specific settings required for a MBES top side unit, please contact us (see Section 5 Contact AML).

2.3.2 CT

The table below summarizes typically used commands for CT•X2Change Sensors.

Table 3: Common Settings for CT•X2Change™ Sensors

Setting	Applicable Command	Description	Default	Alternate Options
Identify firmware version	DISPLAY VERSION	Will provide sensor name and installed firmware version	-	-
Baud rate	SEC 652 SET OUTBAUD x	Persistently set the baud rate of header and sensor data. X is the desired baud rate. Baud will persist after a power cycle. Note: the ident string will output at 9600 baud regardless of the OUTBAUD setting. This is a secure command, and must be preceded with SEC 652.	9600	9600, 19200, 38400, 57600 115200
Output Rate	SET OUTPUTRATE xxx	Time between provided measurements in ms (1/output frequency)	40ms (25 Hz)	40ms-1000ms
Automonitor	SET AUTOMONITOR xxx	Instrument will start to stream data automatically after user interrupt, time specified in milliseconds of inactivity	0s, will not start streaming	5000ms - 100000ms (User configurable from 5 - 100s)
Conductivity Data format	SET CONDFORMAT xy	X is the number of digits before decimal. Y is the number of digits after decimal.	24, for example 00.0000	User configurable
Temperature Data Format	SET TEMPFORMAT	X is the number of digits before decimal. Y is the number of digits after decimal.	23, for example 20.000	User configurable
Temperature Units	SET TEMPUNIT	Sets the temperature output unit between Celsius and Fahrenheit	C	‘C’, ‘F’

2.3.3 Pressure

The table below summarizes typically used commands for P•X2Change sensors. These commands apply to both standard accuracy P•X2Change™ and high accuracy P•X2Change™.

Table 4: Common Settings for P•X2Change™ sensors

Setting	Applicable Command	Description	Default	Alternate Options
Identify firmware version	DISPLAY VERSION	Will provide sensor name and installed firmware version	-	-
Header	SEC 652 SET STARTUPHEADER [ON|OFF]	Specify whether the sensor will show a header on startup. If enabled, the header will display immediately after the ident string.	ON	OFF
Startup Monitor	SEC 652 SET STARTUPMONITOR [ON|OFF]	Specify whether the sensor starts monitoring on powerup. If enabled, the output will commence immediately after the ident string and header.	ON	OFF
Baud rate	SEC 652 SET BAUD x [PERSISTENT]	X is the desired baud rate. Effective immediately (without power cycle). Does not alter ident header baud rate. Optionally, the argument PERSISTENT can be added to make the baud rate change persistent after cycling power to the sensor. This is a secure command, and must be preceded with SEC 652.	9600	9600, 19200, 38400, 57600 115200
Sample Rate	SEC 652 SET SAMPLETRATE xxx	Time between provided measurements in ms (1/output frequency)	40ms (25 Hz)	40ms-1000ms
Automonitor	SET AUTOMONITOR xxx	Instrument will start to stream data automatically after user interrupt, time specified in milliseconds of inactivity	0s, will not start streaming	5000ms - 100000ms (User configurable from 5 - 100s)

Setting	Applicable Command	Description	Default	Alternate Options
Taring the sensor	ZERO and ZERO [ON|OFF]	ZERO ON / OFF enables or disables the tare. When the tare is enabled, the sensor will output its current value minus the tare value. When the tare is disabled, the sensor will output its current value without adding or subtracting the tare value. Issuing ZERO by itself (without ON or OFF) updates the sensor's tare value with the current output value. Normally this is done when the sensor is in air so that the sensor reads zero before deploying the sensor in water. Issuing ZERO will automatically enable the tare (equivalent to the command ZERO ON) if it is not currently enabled.	-	-
Manual Tare	SET ZERO x	To set the tare to a specific value, issue the command SET ZERO x, where x is the tare value in dBar. Note: the tare is always set in dBar regardless of the current output display units such as Bar, PSI, etc.	-	-
Data format	SET DATAFORMAT xy	X is the number of digits before decimal. Y is the number of digits after decimal.	2	4
Display format	SET DISPLAYFORMAT [RAW|REAL|MUX|VERBOSE]	Persistently set the output display format. - RAW sensor raw counts - REAL units per the SET DISPLAYUNITS command - MUX both raw and real values including description of units (eg. [data=Pressure,0.254469,dBar][rawi=ADC,856992,2sComp]) - VERBOSE both raw and real values in comma separated format	REAL	RAW, MUX, VERBOSE
Pressure averaging	SET SAMPLESTOAVERAGE x	Rolling 'boxcar' average. Continuously averages last 'x' samples. Note: increasing averages will smooth output data but reduce response time.	1	1-4096
Emulate Paroscientific output format	SET PARO [ON|OFF]	Changes output format from default to Paroscientific. "*0001" is added before the output value. E.g. *000112.4692 instead of 12.4692	OFF	ON
Suppress negative values	SET NEGSUPPRESS [ON|OFF]	With NEGSUPPRESS ON, the sensor will output 00.000 instead of any negative values	ON	OFF

Setting	Applicable Command	Description	Default	Alternate Options
Units	SET DISPLAYUNITS [dBar|Bar|PSI|feet|metres]	Changes output units to dBar, Bar, PSI, feet, or metres. Depth units of feet & metres are calculated using the TEOS-10 Gibbs-SeaWater (GSW) Oceanographic Toolbox version 3.05, available at http://www.teos-10.org/software.htm	dBar	Bar, PSI, feet, metres
Latitude	SET LATITUDE x	Set the latitude in decimal degrees. This is used in the equation to convert pressure to depth in feet or metres. For example 48° 24' 26.3736" N would be entered as SET LATITUDE 48.407326, and 22° 54' 29.9988" S would be entered as SET LATITUDE -22.908333	0	Between -180 and 180 degrees.

Taring the pressure sensor is routinely done for a few reasons, including:

- Zeroing the sensor before deploying in water to account for atmospheric pressure
    - Process: Send the ZERO command to the pressure sensor before deployment.
- Setting the sensor to read absolute pressure (the sensor is calibrated to read zero in one atmosphere of pressure, or 10.1325 dBar)
    - Process: Send the command SET ZERO -10.1325
- Calibrate the sensor at the zero point
    - Process: Send the command ZERO OFF and observe the sensor values while the sensor is in air. Compare the sensor's output to a known barometric pressure value. A well calibrated sensor should read the ambient pressure minus 10.1325 dBar, but if an offset is detected use the SET ZERO command to compensate. If the sensor does not produce reasonable values in air or water after this process, it may require factory calibration.

2.3.4 Other sensors

The tables below summarize general commands for other sensors offered by AML Oceanographic. This table covers all Cyclops and C-FLUOR variants (chlorophyll, turbidity and more), and wipered turbidity.

Table 5: Common Settings for other X2Change™ sensors

Setting	Applicable Command	Description	Default	Alternate Options
Identify firmware version	DISPLAY VERSION	Will provide sensor name and installed firmware version	-	-

Setting	Applicable Command	Description	Default	Alternate Options
Baud rate	SEC 652 SET BAUD x	X is the desired baud rate. Effective immediately (without power cycle). Does not alter ident. header baud rate.	9600	9600, 19200, 38400, 57600 115200
Sample Rate	SEC 652 SET SAMPLETRATE xxx	Time between provided measurements in ms (1/output frequency)	40ms (25 Hz)	40ms-1000ms
Automonitor	SET AUTOMONITOR xxx	Instrument will start to stream data automatically after user interrupt, time specified in milliseconds of inactivity	0s, will not start streaming	5000ms - 100000ms (User configurable from 5 - 100s)
Data format	SET DATAFORMAT xy	X is the number of digits before decimal. Y is the number of digits after decimal.	2	4
Output averaging	SET SAMPLESTOAVERAGE x	Rolling 'boxcar' average. Continuously averages last 'x' samples. Note: increasing averages will smooth output data but reduce response time.	1	1-4096
Sensor Gain (Cyclops Only)	SET SENSORGAIN x	Changes the output range of the sensor by modifying the analog gain setting	1	1,10,100
Suppress negative values	SET NEGSUPPRESS [ON|OFF]	With NEGSUPPRESS ON, the sensor will output 00.000 instead of any negative values	ON	OFF

Table 6: Wipered Turbidity• X2Change™ specific

Setting	Applicable Command	Description	Default	Alternate Options
Wipe	WIPE	Will wipe the sensor face once immediately	-	-
Wiper Period	SET WIPEPERIOD X	X is the period in minutes with which the wiper will clean the sensor face	60	'Bootonly', 'off'
Wiper channel output	SET WIPEHIDE [ON|OFF]	SET WIPEHIDE ON will disable the wiper channel and only display a single column. SET WIPEHIDE OFF will return the wiper channel	ON	OFF
Automonitor	SET AUTOMONITOR xxx	Instrument will start to stream data automatically after user interrupt, time specified in milliseconds of inactivity	0s, will not start streaming	5000ms - 100000ms (User configurable from 5 - 100s)
Suppress negative values	SET NEGSUPPRESS [ON|OFF]	With NEGSUPPRESS ON, the sensor will output 00.000 instead of any negative values	ON	OFF

3 Maintenance

3.1 Recommended Calibration Interval

The recommended calibration interval for most sensors is as needed or every one or two years, depending on the sensor type. The table below summarizes AML's X2Change™ sensors by parameter and includes notes relevant to the recommended calibration interval.

X2Change™ Parameter	Calibration interval	Notes
Temperature Relevant for: • T•X2Change™ • CT•X2Change™	As needed, or every year.	AML utilizes precision aged thermistor beads in all of its temperature sensors. The aging ensures the sensors delivered are stable. Nevertheless, the inherent nature of the materials in the thermistor will cause continued changes over time or when exposed to various environmental conditions.
Pressure Relevant for: • P•X2Change™	As needed, or every year.	AML utilizes a piezo-resistive sensor element within its pressure sensors. There are various factors which can cause changes in accuracy but in general, the greater the number of pressure cycles, the more likely that a pressure offset will begin to occur. The likelihood of such an offset increases with the prolonged exposure to the upper pressure range of a sensor's calibrated range, for example in long term in-situ applications. If physical damage causes deformation in the diaphragm of the sensor, the calibration of that sensor will also likely be impacted. A pressure sensor should always be returned for recalibration if there is physical impact or damage to the diaphragm. Irrespective of physical damage, the inherent nature of ceramic materials and the environment the sensor is exposed to can also impact the accuracy over time.

X2Change™ Parameter	Calibration interval	Notes
Conductivity Relevant for: • CT•X2Change™	Under typical oceanographic use where the sensor is maintained for cleanliness, an annual calibration period is recommended.	AML Oceanographic conductivity sensors utilize multiple conductive electrodes in its cell design. The cell constant is reliant on the resistivity of the electrodes and a constant volume of the cell. The electrodes are of platinum material therefore non corroding. The largest impact on calibration frequency is cleanliness of the cell as foreign particles or growth can alter the cell constant.
Sound Velocity Relevant for: • SV•X2Change™	AML recommends SV sensor recalibration on an annual basis. NOAA guidelines also recommend calibration of sound velocity sensors and profilers as needed. (see: section 5.2.3.3 Speed of Sound Corrections https://nauticalcharts.noaa.gov/publications/docs/standards-and-requirements/specs/HSSD_2021.pdf)	AML Oceanographic sound velocity sensors are factory calibrated at the time of manufacture. SV•X2Change™ is recommended for calibration if bathymetric data shows signs there may be an issue with beamforming (as recommended by NOAA), or annually.
Sound Velocity Relevant for: • SVT•X2Change™	AML recommends SV sensor recalibration every 2 years. NOAA guidelines also recommend calibration of sound velocity sensors and profilers as needed. (see: section 5.2.3.3 Speed of Sound Corrections https://nauticalcharts.noaa.gov/publications/docs/standards-and-requirements/specs/HSSD_2021.pdf)	SVT•X2Change™ is recommended for calibration if bathymetric data shows signs there may be an issue with beamforming (as recommended by NOAA), or every 2 years. Compared to the composite rod sensor, the all-titanium monolithic construction of SVT•X2Change™ is more durable providing better stability in extreme conditions such as prolonged surface deployments and deep water usage. This is due to the reduction in exposed polymers and fewer assembled joints. The onboard temperature

X2Change™ Parameter	Calibration interval	Notes
		sensor provides supplemental data and can be used as a quality check given changes in SV are strongly correlated with changes in temperature. See application note AN-G-0020 Application Note - SVT Sensor Verification with AML-3 LGR_RTS_XC for more information on verification techniques.
Turbidity (with and without wiper) Relevant for: • Turbidity•X2Change™	AML recommends annual recalibrations of its turbidity sensors.	AML Oceanographic makes use of Turner Designs Turbidity Plus based transducer, manufactured with a high quality infrared LED. A gradual loss of intensity due to aging is, however, unavoidable, and will cause the sensor to slowly drift over time.
Fluorometers Relevant for: • Chlorophyll•X2Change™ • CDOM/FDOM•X2Change™ • Fluorescein•X2Change™ • Rhodamine•X2Change™ • Phycocyanin•X2Change™ • Crude Oil•X2Change™ • Refined Fuels•X2Change™ • Tryptophan•X2Change™ • Optical Brighteners•X2Change™ • Phycoerythrin•X2Change™	AML recommends annual recalibration of all fluorometer sensors.	AML Oceanographic makes use of Turner Designs Cyclops-7F and C-FLUOR based transducers, manufactured with high quality LEDs. A gradual loss of intensity due to aging is, however, unavoidable, and will cause the sensor to slowly drift over time.
Dissolved Oxygen Relevant for: • DO•X2Change™	AML recommends annual recalibration for Dissolved Oxygen sensors.	AML Oceanographic makes use of JFE Advantec's RINKO FT transducer. The RINKO series is based on the optical (phosphorescence) principle that is both fast response and stable. Despite the high performance of the sensor, gradual drift due to components aging is inevitable.

3.2 Sensor Verification

While the best method for ensuring that sensors are reading properly is factory calibration, it is not always possible to return sensors from the field. The methods below suggest techniques for verifying sensor performance using materials and processes that are readily available outside of a laboratory. **Verification of laboratory calibrated sensors is challenging, and users should take care when collecting data and interpreting results.**

Some of the verification methods can be done with individual sensors, but others rely on comparing values between sensors with the same parameter installed on a multi sensor instrument such as AML-3 or AML-6. When comparing sensors against each other, if the data are approximately the same given the test environment, it is assumed that the sensors are well calibrated.

Contact AML for more detailed information as needed.

X2Change™ Parameter	**Verification Method**	**Method Details**
Temperature Relevant for: • T•X2Change™ • CT•X2Change™ • SVT•X2Change™	Compare multiple sensors installed on AML-3 or AML-6 in a stable water bath. Sensors should agree to within 4 x the accuracy specification provided that the water bath is sufficiently homogeneous.	A stable water bath is critical for this verification method. The water bath should be kept in an air conditioned environment for at least 24 hours prior to verification testing. The bath should be vigorously stirred such as with a fish tank stirrer. Temperature values should be observed in real time using a fast sampling rate such as 20 Hz.

X2Change™ Parameter	Verification Method	Method Details
Pressure Relevant for: • P•X2Change™	Compare multiple sensors installed on AML-3 LGR or AML-6 LGR. Collect a water column profile to the desired depth (do not exceed the depth rating of the sensor or instrument). Sensors should agree to within 4 x the accuracy specification.	It is important that all of the P•X2Change™ are zeroed using the ZERO command at the same time, immediately before this verification test. Note: Sailfish does not automatically tare or ZERO multiple P•X2Change™ installed on the same instrument, but this can be done in sequence. If connecting without Sailfish, it is necessary to RAWTALK to each sensor individually to issue the ZERO command before this field verification test. The LGR instrument should be configured to sample at the fastest sampling rate (20 Hz). Slowly lower the profiler to the desired depth and hold at the deepest point for approximately 1 minute. After recovering the instrument, compare the pressure sensor data collected during the profile and also at the deepest point.
Conductivity Relevant for: • CT•X2Change™	It is extremely difficult to verify the performance of a conductivity sensor at its calibrated accuracy without laboratory equipment. Nevertheless it is possible to detect gross errors in the field. Use a commercially available conductivity standard to verify the sensor. The sensor should agree with the conductivity standard with an accuracy of +/- 1 mS/cm provided that the test was done at	Conductivity standards can be purchased from chemical supply companies. Choose a conductivity in the same range as the AML sensor (0 to 90 mS/cm). Take care to read the instructions on the conductivity standard as they will only read accurately at the appropriate temperature. Make sure to use fresh, uncontaminated fluid for each test, and discard the fluid after use.

X2Change™ Parameter	Verification Method	Method Details
	the correct temperature	
Sound Velocity Relevant for: • SV•X2Change™	Compare multiple sensors installed on AML-3 or AML-6 in a stable water bath. Sensors should agree to within 4 x the accuracy specification provided that the water bath is sufficiently homogeneous.	SV sensors are highly sensitive to contamination such as debris or bubbles on the transducer and reflector surfaces. The transducer and reflector must be cleaned with a Q tip or similar before sensor verification. A stable water bath is also critical for this verification method. The water bath should be stored in an air conditioned environment for at least 1 hour prior to verification testing. The bath should be vigorously stirred such as with a fish tank stirrer. SV values should be observed in real time using a fast sampling rate such as 20 Hz
Sound Velocity Relevant for: • SVT•X2Change™	Compare measured SV values against calculated SV in distilled water. The measured and calculated values should agree within 4 x the accuracy specification provided that the water bath is sufficiently homogeneous and pure water is used.	This verification technique is documented in AN-G-0020 Application Note - SVT Sensor Verification with AML-3 LGR_RTS_XC. SV sensors are highly sensitive to contamination such as debris or bubbles on the transducer and reflector surfaces. The transducer and reflector must be cleaned with a Q tip or similar before sensor verification. A stable pure water bath is also critical for this verification method. The water bath should be stored in an air conditioned environment for at least 1 hour prior to verification testing. The bath should be vigorously stirred such as with a fish tank stirrer. SV values should be observed in real time using a fast sampling rate such as 20 Hz
Turbidity (with and without wiper)	Use commercially available turbidity	It is important to use a non-reflective opaque bottle or container for this

X2Change™ Parameter	Verification Method	Method Details
Relevant for: • Turbidity•X2Change™	standards to verify the sensor. The sensor should read within 2 x the accuracy specification.	verification process. The sensor's transducer face should be placed at least 2.5 cm below the surface, and there should be at least 5 cm between the optical face of the sensor and the sides and bottom of the container. Distilled water can be used to check the sensor's output at the zero point. AML recommends specific turbidity standards that can be purchased from GFS Chemicals to check other ranges: 3000 NTU - GFS Part Number 87575 (8621) AMCO CLEAR TURBIDITY STANDARD 1L 100 NTU - GFS Part Number 87258 (8507) AMCO CLEAR TURBIDITY STANDARD 1L 10 NTU - GFS Part Number 87256 (8506) AMCO CLEAR TURBIDITY STANDARD 1 L 1000 NTU - GFS Part Number 87273 (8620) AMCO CLEAR TURBIDITY STANDARD 1L
Fluorometers Relevant for: • Chlorophyll•X2Change™ • CDOM/FDOM•X2Change™ • Fluorescein•X2Change™ • Rhodamine•X2Change™ • Phycocyanin•X2Change™ • Crude Oil•X2Change™ • Refined Fuels•X2Change™ • Tryptophan•X2Change™ • Optical Brighteners•X2Change™ • Phycoerythrin•X2Change™	Use commercially available standards and follow Turner Designs recommended process	See: http://docs.turnerdesigns.com/t2/doc/tech-notes/S-0243.pdf Turner Designs Technical Note: Cyclops-7 or 7F Calibration Using Liquid Dye Standards See application note AN-G-0019 for C-FLUOR calibration information.
Dissolved Oxygen Relevant for:	Check the sensor in oxygen saturated water and water with no dissolved oxygen	It is important to soak the sensor in water overnight to ensure proper readings.

X2Change™ Parameter	Verification Method	Method Details
• DO•X2Change™		Saturate a container of water using a fish tank bubbler stone and take a measurement. The reading should be within 10% of full saturation (~120% saturation) depending on local air pressure and temperature. Remove oxygen from a container of water by adding sodium sulphite and take a measurement. The reading should be close to zero.

After performing field verifications, if any sensor does not meet the criteria described above, contact AML for an RMA to obtain a factory calibration or replacement sensor as needed.

3.3 Sensor Recalibration

It is recommended that sensors be returned to AML for calibration on the rhythm described in Section 3.1. It is possible to calibrate certain sensors in the field or remote laboratory, those sensors have been outlined in the following section 3.3.1 and 3.3.2. To field calibrate sensors not listed in these sections please contact AML Oceanographic.

3.3.1 Fluorometer Field Calibration

AML integrated fluorometers powered by Turner Designs Cyclops-7F are capable of multiple gain settings to adjust the measurement range of the sensor. By default these sensors are calibrated on the 10x gain setting with readings on the 1x and 100x gains derived from minimum detection limits and hardware correlations. This process is described by Turner Designs in the document “Turner Designs Technical Note:Cyclops-7 or 7F Calibration Using Liquid Dye Standards” which is linked in the table above. Users can calibrate individual ranges according to application note AN-G-0009 (Fluorometer Single Gain Calibration) and the accompanying spreadsheet to calculate the calibration coefficients.

AML integrated fluorometers powered by Turner Designs C-FLUOR have a single linear gain channel so no gain adjustment is required during calibration. Liquid Dye Standards from Turner Designs in the correct concentration ranges are appropriate for calibration. The application note AN-G-0019 (Fluorometer (Powered by Turner Designs C-FLUOR) Calibration Guide) and accompanying spreadsheet can be referenced to perform calibration and calculate calibration coefficients.

3.4 O-rings

It is crucial to keep the sensor's O-rings clean and greased. Any fibers or dirt on the O-rings will allow water into the connector and damage both the sensor and the sensor mount. To gain access to the O-rings, perform the following steps:

- Remove the sensor from the instrument.
- The O-rings should be slick with grease. If they are dry, apply silicone grease.
- Inspect the O-rings for dirt. Clean and reapply grease, if necessary.
- Inspect the O-rings for nicks and cracks. If any are found, the O-rings must be replaced. Use part number 2-015-N70D Buna Nitrile O-rings. Apply silicone grease to the new O-rings before using them.

Caution: Do not use a sharp instrument to remove the O-rings. If the O-ring grooves are scratched, the O-rings will not provide a waterproof seal. The O-rings can be removed easily with bare hands.

3.5 Cleaning

Cleaning will prolong the life of the sensor, but care must be taken to avoid accidental sensor damage during cleaning. The following steps are recommended:

X2Change™ Sensor	**Cleaning products**	**Cleaning notes / cautions**
T•X2Change™	• CLR or similar calcium, lime, rust remover • 5% acetic acid solution • Dish soap	Caution: do not apply force to the thermistor tip when cleaning. Bending the thermistor tip may require recalibration or sensor replacement.
P•X2Change™	• CLR or similar calcium, lime, rust remover • 5% acetic acid solution • Dish soap	Caution: do not touch the transducer diaphragm when cleaning. The diaphragm is very sensitive and the sensor may require recalibration or sensor replacement if the diaphragm is scratched or dented.
CT•X2Change™	• CLR or similar calcium, lime, rust remover • 5% acetic acid solution • Dish soap	Caution: the glass parts of the sensor are fragile. Avoid cleaning with a hard brush or tool.

X2Change™ Sensor	Cleaning products	Cleaning notes / cautions
SV•X2Change™	• CLR or similar calcium, lime, rust remover • 5% acetic acid solution • Dish soap	
SVT•X2Change™	• CLR or similar calcium, lime, rust remover • 5% acetic acid solution • Dish soap	
Wiper equipped Turbidity Turbidity•X2Change™	• Dish soap	Note: the wiper can be removed for cleaning. Wiper blades and wiper holders can be replaced as needed. Caution: avoid scratching the transducer surface as this may result in sensor drift requiring recalibration or sensor replacement.
Fluorometers based on Turner Designs Cyclops-7F: • Chlorophyll•X2Change™ • CDOM/FDOM•X2Change™ • Fluorescein•X2Change™ • Rhodamine•X2Change™ • Phycocyanin•X2Change™ • Crude Oil•X2Change™ • Refined Fuels•X2Change™ • Tryptophan•X2Change™ • Optical Brighteners•X2Change™ • Phycoerythrin•X2Change™	• Dish soap	Caution: avoid scratching the transducer surface as this may result in sensor drift requiring recalibration or sensor replacement.
Fluorometers based on Turner Designs C-FLUOR: • Chlorophyll•X2Change™ • CDOM/FDOM•X2Change™ • Fluorescein•X2Change™ • Rhodamine•X2Change™ • Phycocyanin•X2Change™ • Crude Oil•X2Change™ • Refined Fuels•X2Change™ • Optical	• CLR or similar calcium, lime, rust remover • 5% acetic acid solution • Dish soap	Note: C-FLUOR based fluorometer sensors have a transducer face made of sapphire. This material is robust and easy to clean, but care should be taken to avoid scratching the surface.

X2Change™ Sensor	Cleaning products	Cleaning notes / cautions
Brighteners•X2Change™ ● Phycoerythrin•X2Change™		
DO•X2Change™	● Distilled water	Caution: avoid wiping or cleaning the optical face as this can damage the oxygen detection film

General cleaning practices:

- Rinse all sensors in freshwater after recovering from deployment
- If the sensor is dirty or oily, allow it to soak in warm, soapy water before cleaning with a rag or soft brush. When finished, rinse with fresh water to remove any residual soap or dirt.
- Before each use:
    - Before installing on an instrument, check the O-rings under the orange locking sleeve of the sensor for silicon grease.
    - Ensure that the sensor is clean and undamaged.
    - Ensure that the sensor is properly installed on the instrument.
    - Install connector and sensor blanking plugs in the instrument where needed.

3.6 Storage

Proper storage can extend the working life of a sensor and preserve its accuracy. The following steps are recommended:

- After each deployment:
    - Clean and rinse the sensor using fresh water.
    - Dry the sensor completely, and store it in a cool, dry place.
- Yearly
    - Send the sensor to a service center for diagnostics and re-calibration (see section 3.1)
- Long term storage preparation
    - Ensure the instrument has been thoroughly cleaned and dried.
    - Remove all X2Change™ sensors from the instrument and dry the connectors.
    - Lubricate the instrument and X2Change™ sensor connector contacts with a silicone spray or connector grease.
    - Lubricate the retainer rings and O-rings with silicone grease.
    - Install connector and sensor blanking plugs in the instrument.

4 Drawings

Refer to supplemental documents.

4.1 X2Change™ Weights

X2Change™ Sensor	Weight in air (grams)
SV	103
SVT	115
P	60
P (High Accuracy)	165
CT (STD model)	166
CT (XF model)	171
Fluorometer (Turbidity, CDOM, etc)	91 (Cyclops), 97 (C-FLUOR)
Turbidity with Wiper	153
T	68
DO	190

5 Contact AML

Service

To request an RMA or technical support

Email: service@AMLoceanographic.com

Phone: 1-250-656-0771

Phone: 1-800-663-8721 (NA)

http://www.AMLoceanographic.com

Sales

For all general sales inquiries

Email: sales@AMLoceanographic.com

Phone: 1-250-656-0771

Phone : 1-800-663-8721 (NA)

http://www.AMLoceanographic.com

6 Warranty Statement

AML Warranty Policy: New Product (Instrumentation)

AML warrants the instrument and sensor for a period of TWO YEARS (24 months) from the date of delivery. AML will repair or replace, at its option and at no charge, components which prove to be defective. The warranty applies only to the original purchaser of the instruments and only to instruments and sensors manufactured by AML Oceanographic. The warranty of third party sensors will apply as per the specific vendor's warranty policy. The warranty does not apply if the instrument has been damaged, by accident or misuse, and is void if repairs or modifications are made by other than authorized personnel.

This warranty is the only warranty for new products given by AML. No warranties implied by law, including but not limited to the implied warranties of merchantability and fitness for a particular purpose shall apply. In no event will AML be liable for any direct, indirect, consequential or incidental damages resulting from any defects or failure of performance of any instrument supplied by AML.