



SmartQC Handbook

UNDERSTANDING EXO SMARTQC SCORES FOR GOOD DATA

HANDBOOK
E135-02



a xylem brand

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SmartQC Introduction

The EXO multiparameter water quality instruments have been used by scientists globally for reliable data collection for many years. The platform is relied upon for the accurate observation of water quality during floods, algal blooms, forest fires, and many other natural and artificial events which are deemed vital to monitor by government agencies, researchers, and the general public. Data collection is an intensive and tedious endeavor - any data can be collected but not all data is good. What exactly, then, is “good data”? There are many factors that go into defining this term and the following list encompasses just a few of the main questions:

Purpose: What is being monitored, and why?

Analysis: What are the accuracy and precision of the measured values?

Documentation: Are all data collection steps documented?

Quality Control: Is the data reliable and consistent?

EXO helps its users to collect not just any data, but good data. By the time that a unit has been purchased, the purpose and analysis questions have likely been answered through the selection of desired sensors and the stated specifications for those sensors. KorEXO Software documents important changes to the hardware settings such as deployment and calibration information for greater transparency, supplementing a user’s and organization’s record keeping.

This leaves just the quality control question unanswered from a user perspective, but EXO has an answer for it: **SmartQC™**.

SmartQC is a mechanism to normalize different sensors and to assess the current state of individual sensor performance relative to factory-defined performance parameters. Every EXO sensor has an embedded microprocessor which, along with calibration metadata, enables EXO to warn users of calibration errors or when a sensor is unable to be calibrated due to age, fouling, or damage, for example.

SmartQC labels the sonde and sensors with a red, yellow, or green color, which is indicative of its performance state.



A **green** SmartQC Score means the sensor is calibrated properly and all parameters used to assess its performance state are within factory-defined limits.



A **yellow** SmartQC Score means that the sensor will still perform within factory-defined limits, but that during calibration enough of an adjustment was required to suggest that the sensor is drifting from those limits or may soon require some adjustments, such as a new DO cap. A yellow QC Score might also result from variations in calibration standards and operators. One's comfort with a yellow score is sensor and customer-dependent. For example, a yellow score on a pH sensor might not be optimal prior to a 90-day deployment of that sensor, depending on the nature of the environment to be monitored and the customer's standard operating procedures. A yellow QC Score on a total algae sensor might be acceptable under the same conditions. In all cases, a yellow QC Score is not an indication that the sensor is performing outside of specifications.



A **red** SmartQC Score means that the sensor is not performing within factory-specified limits. Also, in some cases a red QC Score might mean that a component of the sensor is due to be replaced (such as a DO cap), or the user has defined some other limit, such as the term expired since the most recent calibration. These examples are captured under the term SoftQC because they are set by the user in Kor software, and such settings will override a green SmartQC Score when using the software.

The way in which EXO assesses the calibration metadata is dependent upon the sensor type, and examples of information used include signal to noise ratio, signal gain, raw millivolts, and cell constants. "Gain" is one of the most common principles applied in the SmartQC system, and one might think of gain as m in the linear relationship $y = mx + b$ where x is the real-time parameter result

computed from a particular factory setting and y is the same parameter but modified and computed from a setting as defined by the user's calibration.

For example, suppose that during a calibration the %ODO saturation is calculated from the factory settings to be 92%. This would be x . This same setting may be calculated to be 97% during the user's calibration, and this would be y . The gain, or m , would be calculated to be 1.054, and in this specific example that would be reported in the Calibration Report as the *ODO Gain*.

In an ideal world where gains are calculated, m would be 1 and b would be zero, meaning that there has been no change at all in the sensor's performance since it left the factory. For most sensors this simple relationship can be applied, and gain and offsets are the primary drivers of the QC Score (the ranges for them are proprietary, however). Other sensors have more complex sets of coefficients that are used, and factory-to-user calibration outputs are defined by more complex polynomial relationships.

Proprietary algorithms and equations are used in the calculations of the SmartQC Scores and some of this information is available to the user as metadata. These values were determined through extensive laboratory testing to ensure that the user will be able to accurately determine whether a sensor is functioning properly or if it needs an adjustment. Much of the metadata, such as the DO Gain or specific conductance calibration constant, will be of more use to the user than the SmartQC Score itself. It would be of benefit to the user to become familiar with these values as well so that SOPs and acceptance criteria can be developed.

SmartQC was developed to provide a user with reliable, consistent, replicable data. Through the use of manufacturer-recommended calibration practices and the use of SmartQC data, a user can be confident that they are collecting exactly what they intend to: "good data."

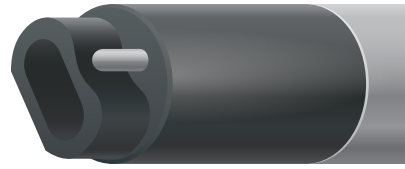
In the following section, the recommendations regarding the interpretation and steps to take based upon green, yellow, or red SmartQC Scores are further discussed.

Conductivity

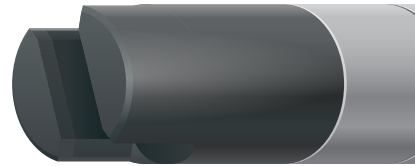
The SmartQC Score for conductance is based on a gain factor, which is then computed into a cell constant that appears on the Calibration Report. The gain may drift over time due to aging electrodes and wear, and this will ultimately affect the cell constant.

An ideal cell constant is dependent upon the type of conductivity sensor; there are two types of conductivity sensors (wiped and non-wiped) on the EXO platform:

- For non-wiped conductivity (599870), the ideal cell constant = $5.1/\text{cm} \pm 10\%$
- For wiped conductivity (599827), the ideal cell constant = $0.469/\text{cm} \pm 0.05$



Non-wiped C/T sensor.



Wiped C/T sensor.

Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain is within acceptable limits. Calibration was performed successfully and resulted in a gain within factory specified limits.



Yellow: The gain has drifted a minor amount from factory specified limits. The sensor is still reporting correctly but adjustments may need to be made. If a user calibration results in a yellow QC Score, perform the following actions:

1. Thoroughly clean the sensor and ensure that all debris is removed from the surfaces of the sensor. Refer to the [EXO User Manual](#) for additional information on how to properly clean the sensor in order to avoid damaging the sensor.
2. Next, perform a Factory Reset Calibration to reset the gain and cell constant to their factory default values.

3. Check specific conductivity readings in air, and verify they are less than 1 $\mu\text{s}/\text{cm}$. If reading higher in air, thoroughly clean the sensor, and allow it to dry completely before checking in air again.
4. Complete another calibration on the sensor using fresh standard solution.

If the QC Score remains yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations, including looking at the cell constant on the Calibration Reports.



Red: The gain has drifted significantly from the factory specified limits, and the sensor may not report correct values. If a user calibration results in a red QC Score, perform the following actions:

1. Verify that the standard value used during calibration was entered correctly. If the value was not entered correctly, the resulting QC Score would show a red value due to the gain changing significantly.
2. Thoroughly clean the sensor and ensure that all debris is removed from the surfaces of the sensor. Refer to the [EXO User Manual](#) for additional information on how to properly clean the sensor in order to avoid damaging the sensor.
3. Perform a Factory Reset Calibration.
4. Complete a calibration using fresh standard.

If the QC Score returns to red after these steps, please contact YSI Technical Support for further assistance.

Depth

The SmartQC Score for depth (non-vented) is based upon an expected offset that would be computed by the sensor at the time of calibration.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: The offset computed during the calibration is within factory specified limits.



Yellow: The offset computed during the calibration is near the threshold of factory specified limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. If the sensor is being deployed at high altitudes, the computed offset during calibration may be outside of the factory specified limits. The data collected by the depth sensor at higher elevations is not incorrect; simply the offset is outside of normal lower-elevation ranges. At higher elevations, all sensors may experience the yellow QC Score and a green QC Score may never be attainable.
2. Ensure that the sensor is free of debris. If there is debris clogging the inlet, use water to clear the inlet. Use care to avoid damaging the thin pressure membrane. Refer to the [EXO User Manual](#) for additional information on how to properly clean the instrument in order to avoid damaging the sensor.
3. Make sure that the sensor was completely dry before performing the calibration. If needed, use a can of compressed air to dry off the sensor to perform a better calibration. Do NOT stick any tools or utensils inside the pressure sensor vent hole. The sensor membrane is extremely thin and easily punctured.
4. Perform a Factory Reset Calibration to restore the offset to factory calibrated values and then perform another calibration.

If the QC Score is still yellow after performing another calibration, the sensor is still able to be used. The user should continue to monitor the sensor for additional drift away from the factory defaults.



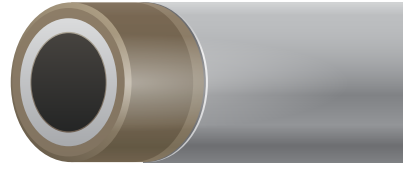
Red: The offset computed during the calibration is outside of factory specified limits. If a user calibration results in a red QC Score, perform the following actions:

1. Ensure that the sensor inlet is free of debris. If there is debris clogging the inlet, use water to clear the inlet. Use care to avoid damaging the thin pressure membrane. Refer to the [EXO User Manual](#) for additional information on how to properly clean the instrument in order to avoid damaging the sensor.
2. Perform a Factory Reset Calibration to restore the offset to factory calibrated values and then perform another calibration.

If the QC Score returns to red after the above procedures were performed, please contact YSI Technical Support for further assistance.

Dissolved Oxygen

Dissolved Oxygen (DO) calculations are derived from polynomial equations based on the K1-K7 coefficients that are provided with each new EXO Dissolved Oxygen sensor cap. Each sensor has been thoroughly tested during the production process to generate these unique calibration coefficients. Calibration of the probe essentially changes these coefficients. The DO SmartQC Score is based on a gain factor, which relates to the magnitude of coefficient change. The gain may drift as the sensor gets older and the optics begin to fade and may also be affected by the degradation of or damage to the unique material that is on the face of the sensor. If a zero-DO calibration is performed, SmartQC also calculates a zero-DO coefficient change.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain is within acceptable limits. Calibration was performed successfully and resulted in a gain within factory specified limit.



Yellow: The gain or zero-DO calibration coefficient has drifted a minor amount from the factory specified limits. The sensor is still reporting correctly but adjustments may need to be made. If a user calibration results in a yellow QC Score, perform the following actions:

1. Thoroughly clean the sensor and ensure that all debris is removed from the surfaces of the sensor. Refer to the [EXO User Manual](#) for additional information on how to properly clean the instrument in order to avoid damaging the sensor.
2. If the sensor has been left in dry air for longer than eight hours, it must be rehydrated. To rehydrate, soak the DO sensor cap in warm (room temperature) tap water for approximately 24 hours. Following this soak, calibrate the sensor and store it in a moist environment.

3. Ensure that proper calibration procedures were followed. Typical errors include not allowing enough time for the calibration chamber to come to equilibrium with the atmosphere or the chamber was not of adequate humidity. Time to equilibrate to an air-saturated water chamber may also not have been adequate. It is recommended to allow between 10-15 minutes for equilibration.
4. Check the lens cap for scratches. If there are scratches, the resulting gain after calibration may change because the amount of membrane remaining on the lens cap has changed.
5. If a new lens cap was installed,
 - a. ensure that the new calibration coefficients were entered into the sensor using either the handheld or KorEXO software. The software will calibrate the sensor and also compute the QC Score based on the old lens cap coefficients if the values are not changed after installation of the new lens cap.
 - b. perform a Factory Reset Calibration before performing a calibration to revert the gain and zero-DO coefficient back to factory defaults.
6. If a zero-DO calibration resulted in a yellow QC Score, it is recommended to create a new zero-DO solution. Depending upon the method used (sparging with nitrogen or sodium sulfite), either ensure that the proper amount of sodium sulfite is fully mixed into the water, or ensure that the gas purge chamber has an adequate amount of time to purge all oxygen from the water.
7. Sometimes low-quality nitrogen tanks are contaminated with trace amounts of oxygen—check the certificate with your nitrogen source to assure its purity.

If the QC Score returns to yellow, the sensor is still able to be used but the user should monitor this sensor during calibrations for any further drift.

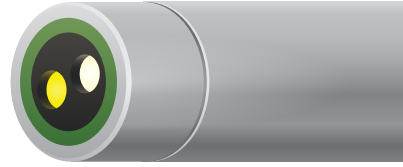


Red: The gain or zero-DO calibration coefficient has drifted significantly from the factory specified limits, and the sensor may not report correct values. If a user calibration results in a red QC Score, perform the following actions:

1. Thoroughly clean the sensor and ensure that all debris is removed from the surfaces of the sensor. Occasionally, thin films from sediment may affix to the lens cap surface and will affect readings and calibrations. Refer to the [EXO User Manual](#) for additional information on how to properly clean in order to avoid damaging the sensor cap.
2. If the sensor has been left in dry air for longer than eight hours, it must be rehydrated. To rehydrate, soak the DO sensor cap in warm (room temperature) tap water for approximately 24 hours. Following this soak, calibrate the sensor and store it in a moist environment.
3. Ensure that proper calibration procedures were followed. Gross errors can cause the gain to change significantly from factory default values. Errors in calibration include sealing the calibration cup to the sonde completely, allowing the calibration setup to equilibrate in the sun, or not properly saturating the air environment with water.
4. Inspect the lens caps for coating loss on the sensor window. If the sensor cap has excessive coating loss to the point that calibration is being affected, replace the sensor lens cap. Re-enter the calibration coefficients, execute a Factory Reset Calibration and perform a calibration on the newly installed sensor lens cap.
5. Verify that proper calibration coefficients were entered if the sensor lens cap was replaced.
6. If a zero-DO calibration was performed, perform a Factory Reset Calibration and redo the 2-point calibration procedure. Allow for ample time for the sensor to equilibrate to both zero and 100% saturation values.

If the QC Score returns to red after the above steps were attempted, please contact YSI Technical Support for further assistance.

The SmartQC Score for fDOM is based on a gain factor and an offset factor. Both of these values may change as the sensor and the optics age.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain and offset are within acceptable limits. Calibration was performed successfully and results are within factory specified limits.



Yellow: The sensor gain or offset is near the threshold of calibration limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration and complete a recalibration.
 - a. If performing a 1-point calibration, use fresh, clear water.
 - b. If performing a 2-point calibration, use fresh, clear water and freshly made quinine sulfate solution. (Refer to the [EXO User Manual](#) for instructions on creating quinine sulfate solution.)
2. Ensure that the standard value was entered correctly. Calibration of fDOM is temperature-dependent; make sure the appropriate value from the table below was entered during calibration for either RFU or QSU.
3. Ensure that the sensor is free of contamination. Refer to the [EXO User Manual](#) for additional information on how to properly clean the sensor in order to avoid damage.
4. Ensure that copper tape and the central wiper brush are removed from the sonde. Copper quenches the fluorescence of quinine sulfate, which will interfere with the calibration.

Temp (°C)	RFU	QSU	Temp (°C)	RFU	QSU
30	96.4	289.2	18	101.8	305.4
28	97.3	291.9	16	102.7	308.1
26	98.2	294.6	14	103.6	310.8
24	99.1	297.3	12	104.6	313.8
22	100	300	10	105.5	316.5
20	100.9	302.7	8	106.4	319.2

If the QC Score returns to yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations for any further drift.

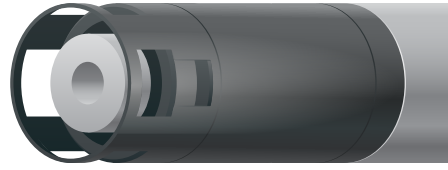


Red: The sensor gain or offset are outside of factory specified limits. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score.

If the QC Score remains red, please contact YSI Technical Support for further assistance.

Ion Selective Electrodes (ISE)

ISE sensor algorithms are derived from three independent coefficients (called J, S, and A) as well as mV, temperature and salinity. J, S, and A are the calibrated coefficients and S specifically is concentration of the analyte being detected by the sensor. S is the coefficient whose gain factor is the basis of SmartQC for these sensors.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain and offset are within acceptable limits. Calibration was performed successfully and results are within factory specified limits.



Yellow: The S gain is near the threshold of calibration limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration and re-do the calibration.
2. If the sensor had not been properly stored it may be necessary to rehydrate the reference junction, as described in the [EXO User Manual](#).
3. Pre-calibration soaking is advisable for ISEs, especially if a non-green SmartQC Score occurs. Pre-soak the ISE tip in its higher concentration calibration solution for at least 12 hours prior to trying another calibration.
4. During calibration, ensure that the standard solutions were thermally equilibrated, meaning that the temperature was stable and not changing during calibration. Sometimes putting the solutions in a water bath can help ensure this.
5. Ensure that the standard value was entered correctly.
6. It is imperative that the sensors, calibration cup, and sonde guard are all very clean when calibrating.

7. Since these modules have a relatively short lifespan, a prior user may have entered an expiration date into the software for when the sensor should be replaced. Check to see if that date is near.
8. Ensure that the sensor is free of debris. Refer to the [EXO User Manual](#) for additional information on how to properly clean the sensor in order to avoid damage.

If the QC Score remains yellow, the sensor is still able to be used, but ISE's are the one case where a yellow-scored sensor should not be used for a continuous deployment, because the period of time before it would become red is probably short. It can be used for spot sampling, and should be recalibrated before each day's use.



Red: The S gain is outside of factory specified limits. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score. If the QC Score remains red, it is likely time to replace the sensor module.

If replacement of the module does not return the sensor to a Green QC Score, please contact YSI Technical Support for further assistance.

NitraLED

The SmartQC Score NitraLED is based on a gain factor and an offset factor. Both of these values may change as the sensor and the optics age.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain and offset are within acceptable limits. Calibration was performed successfully and results are within factory specified limits.



Yellow: The sensor gain or offset is near the threshold of calibration limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration and complete a recalibration.
 - a. For calibration point 1, the 0 mg/L NO₃-N standard, use Type 1 water or commercially purchased distilled water with NO minerals added. DO NOT USE commercially purchased Reverse Osmosis, Deionized, or Distilled Water with Minerals added.
 - b. For calibration point 2, use YSI NitraLED calibration standards 5 mg/L NO₃-N [Item# 608072] or 10 mg/L NO₃-N [Item# 608073] for best results. These standards are free of the interfering species that would result in a less than optimal calibration.
2. Ensure that the standard value was entered correctly.
3. Ensure that the sensor is free of contamination. Refer to the [EXO User Manual](#) for additional information on how to properly clean the sensor in order to avoid damage.
4. Remove the central wiper brush and thoroughly clean the brush guard. Contaminants can reside within the bristles of the wiper brush and the small gaps of the plastic brush guard.

If the QC Score returns to yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations for any further drift.

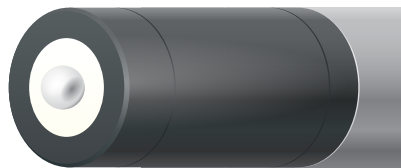


Red: The sensor gain or offset are outside of factory specified limits. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score.

If the QC Score remains red, please contact YSI Technical Support for further assistance.

pH

The SmartQC Score for pH is based on both a gain and an offset. The offset calculation is based on the millivolts recorded during sensor calibration.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain and offset are within acceptable limits. Calibration was performed successfully and results are within factory specified limits.



Yellow: Either the gain or the offset is near the threshold of factory specified limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Ensure that all debris is removed from the surfaces of the sensor. Refer to the [EXO User Manual](#) for information on proper sensor cleaning in order to avoid damaging the sensor.
2. Verify that there are no cracks or visual damage to the glass bulb.
3. A yellow score can result from a contaminated standard; ensure that all buffers are clear (not cloudy) and free of debris, and that the calibration cup was clean.
4. A Factory Reset Calibration should be performed.
5. The electrolyte solution inside the sensor may be partially depleted which causes the millivolt values to drift over the range of calibration. This is not a user-addressable problem, but to prevent it make sure that sensor modules are stored in the same bottle of solution that was shipped with the new modules. Avoid storage of sensor modules in distilled or deionized water.
6. If the sensor is new, make sure that there are no air bubbles in the pH bulb. Sensors actually do have air in the reference solution, but if the sensor is in the upright position, as it should be during calibration, an air bubble should not be in the bulb. If air bubbles are found, shake the sensor gently to encourage electrolyte

solution to flow into the bulb and the air to rise to the top (where it will not be visible).

7. Check the delta slope and mV per decade. Generally, the delta slope should be ≥ 165 mV, and the mV per decade should not deviate by more than 5 units from an ideal of 59.16 (assumes the calibration was performed at or near 25°C).

If the QC Score returns to yellow, the sensor (or module) is still able to be used but one should be cautious if a long-term deployment is planned. With a yellow QC Score it is more acceptable to use the sensor for discrete sampling because the mV value can be easily monitored under those conditions. In either case, the user should monitor this sensor during calibrations and perform periodic calibration checks for any further drift. Finally, the sensor could be reconditioned by soaking it in a bleach solution and then an HCl solution (see the [EXO User Manual](#) for detailed instructions). Persistent yellow QC Scores are typically a sign that the time to replace the sensor module may be approaching.



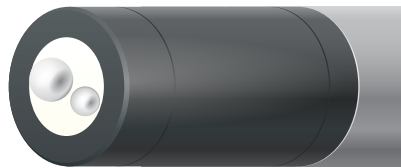
Red: The gain or offset is outside of factory specified limits. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score. If the score remains red then replace the sensor module with a new module, perform a Factory Reset Calibration, and calibrate the new module with fresh buffers.


If the QC Score remains red after the Factory Reset Calibration and recalibration, or after replacement of the module and performing a calibration, please contact YSI Technical Support for further assistance. Further, if a upon replacement with a new module the QC Score is yellow, contact YSI Technical Support.


ORP

The SmartQC Score for ORP is based on an offset from 0 mV.

Guidance on interpretation of the SmartQC Score for this sensor is as follows:



 **Green:** Offset is within acceptable limits. Calibration was performed successfully and results are within factory specified limits.

 **Yellow:** The sensor offset is near the threshold of factory specified limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration. Complete a recalibration using freshly-prepared Zobell solution. Incorrect mixing of the Zobell solution can cause errors in calibration.
2. The electrolyte solution in the sensor may be partially depleted causing shifts to the millivolt readings. This is not a user-addressable problem, but to prevent it make sure that sensor modules are stored in the same bottle of solution that was shipped with the new modules. Avoid storage of sensor modules in distilled or deionized water.
3. ORP calibration is temperature-dependent so make sure that the correct standard value was entered, using the instructions that came with the Zobell solution.
4. Ensure that the sensor is free of debris. Refer to the [EXO User Manual](#) for information on proper sensor cleaning in order to avoid damaging the sensor.

If the QC Score returns to yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations for any further drift. Consideration should be made to eventually replacing the pH/ORP sensor module.

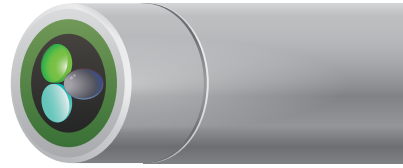


Red: The sensor offset is outside of factory specified limits. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score.

If the QC Score remains red after the Factory Reset Calibration and recalibration, or after replacement of the module and performing a calibration, please contact YSI Technical Support for further assistance.

Rhodamine

The SmartQC Score for Rhodamine is based on gain factor and an offset factor. Both of these values may change as the sensor and optics age..



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain and offset are within acceptable limits. Calibration was performed successfully and results are within factory specified limits.



Yellow: The sensor gain or offset is slightly outside of calibration limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration and complete a recalibration.
2. Ensure that the standard value was entered correctly. Calibration points #2 and #3 must be set at 25 µg/L. Calibration point #4 must be set at a minimum of 125 µg/L, but no greater than 1,000 µg/L.
3. Ensure that the sensor is free of contamination. Refer to the [EXO User Manual](#) for additional information on how to properly clean the sensor in order to avoid damaging the sensor.

If the QC Score returns to yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations for any further drift.



Red: The sensor gain or offset are significantly outside of factory specified limits. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score.

If the QC Score remains red, please contact YSI Technical Support for further assistance.

Total Algae

The SmartQC Score for any TAL sensor is based on an offset from 0 RFU, and a gain factor. Each individual channel (Chlorophyll, Phycocyanin, Phycoerythrin) has a unique offset and gain factor. It is possible to have a green SmartQC Score for calibration of one channel, but a yellow or red SmartQC Score for the second channel. In this case the TAL sensor SoftQC that is shown in Kor Software will appear as the worst QC Score (yellow or red), and one must look at the individual channels to investigate where the issue is. Thus the steps outlined here are for each channel, and for each unit calibrated within that channel.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: Gain and offset are within acceptable limits. Calibration was performed successfully and results are within factory specified limits.



Yellow: The sensor gain or offset is near the threshold of calibration limits. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration and complete a recalibration.
 - a. If performing a 1-point calibration, use fresh, clear water.
 - b. If performing a 2-point calibration, use fresh, clear water and freshly made Rhodamine WT solution (refer to the [EXO User Manual](#) for instructions on mixing Rhodamine WT calibration solution).
2. Ensure that the standard value was entered correctly. Calibration of TAL channels is temperature-dependent; make sure the appropriate value from the table below was entered during calibration for either RFU or $\mu\text{g/L}$.

Solution Temp (°C)	Chlorophyll 0.625 mg/L Rhodamine		Phycocyanin 0.625 mg/L Rhodamine		Phycoerythrin 0.025 mg/L Rhodamine	
	Chl RFU	µg/L chl	PC RFU	µg/L PC	PE RFU	µg/L PE
30	14.0	56.5	11.4	11.4	37.3	104.0
28	14.6	58.7	13.1	13.1	39.1	109.0
26	15.2	61.3	14.1	14.1	41.0	115.0
24	15.8	63.5	15.0	15.0	43.0	120.0
22	16.4	66	16.0	16.0	45.0	126.0
20	17.0	68.4	17.1	17.1	47.0	132.0
18	17.6	70.8	17.5	17.5	49.2	138.0
16	18.3	73.5	19.1	19.1	51.4	144.0
14	18.9	76	20.1	20.1	53.6	150.0
12	19.5	78.6	21.2	21.2	55.9	157.0
10	20.2	81.2	22.2	22.2	58.2	163.0
8	20.8	83.8	22.6	22.6	60.6	170.0

3. Ensure that the sensor is free of debris. Refer to the [EXO User Manual](#) for additional information on how to properly clean the sensor in order to avoid damage.

If the QC Score returns to yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations for any further drift.



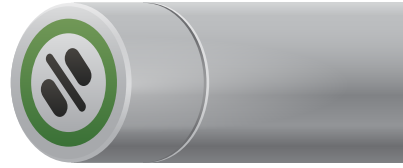
Red: The sensor gain or offset are outside of factory specified limits.

If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score.

If the QC Score remains red, please contact YSI Technical Support for further assistance.

Turbidity

The turbidity response is nonlinear across the sensor's range, and a proprietary algorithm that employs up to five terms is used during calibration and for generation of the SmartQC Score. Three of those terms are the actual calibration points, and those calibration points must read within an absolute range set within the sensor (this is slightly different than the concept of an offset that is used for SmartQC on most sensors). Two of the terms are calculated from the ratios of the calibration points, and likewise must be within an absolute range set within the sensor. The result is that the SmartQC calculation for turbidity is slightly different depending upon whether one does a 1, 2, or 3 point calibration. Since each individual term used by the algorithm must fall within an absolute range SmartQC is most reliable when the YSI standards, upon which these algorithms were built, are used.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: A green SmartQC Score means that the point for a single-point calibration is within the specified range. For a two-point calibration a green SmartQC Score means that both calibration points, as well as the slope between them, is within the specified range for each term. For a three-point calibration a Green SmartQC Score means that all three calibration points, as well as the slope between the first two points and the slope between the second two points, are within the specified ranges for each term.



Yellow: A yellow SmartQC Score can result if any one of the five terms of interest is outside of the factory-specified range. If a user calibration results in a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration and re-do the calibration.
2. If a two-point calibration was performed, make sure that the second point is between 5-200 FNU.

3. If a three point calibration was performed with formazin, make sure that each calibration point was within the specified ranges of 0-1 FNU, 5-200 FNU, and 400-4200 FNU.
4. If a three point calibration was performed with YSI's polymer standards, make sure the correct values from the bottles were entered during calibration. For example, make sure the EXO values, and not the 6-Series values, were entered from the label.
5. Make sure you are using YSI's polymer standards. Difficulties in calibration may occur if AMCO-AEPA standards that were not produced for YSI instruments are used. These will not have a YSI label on them.
6. It is imperative that the sensors, calibration cup, and sonde guard are all very clean when calibrating turbidity.
7. Customers who use the 12.4 NTU standard to calibrate will often see a yellow QC Score, even with a perfect calibration.
8. Always use an EXO calibration cup and EXO probe guard with bottom plate during the turbidity calibration.

If the QC Score returns to yellow, the sensor is still able to be used, but the user should monitor this sensor during calibrations for any further drift.

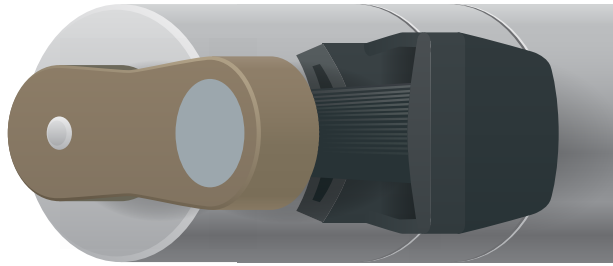


Red: Any of the five terms of interest may be outside of the factory-set specifications. If a user calibration results in a red QC Score, follow the same steps described above for a yellow QC Score.

If the QC Score remains red, please contact YSI Technical Support for further assistance.

Central Wiper

The central wiper has a QC Score based on the expected voltage of the sensor when seated in the central wiper housing.



Guidance on interpretation of the SmartQC Score for this sensor is as follows:



Green: The voltage when the wiper is seated in its housing is within the factory specified limits.



Yellow: The voltage when the wiper is seated in its housing is slightly outside of the factory specified range. If the wiper has a yellow QC Score, perform the following actions:

1. Perform a Factory Reset Calibration.
2. Calibrate the central wiper so that it seats itself in the correct location.
3. Perform a series of wipes on the sonde to ensure that the wiper continues to reseat itself in the correct location after each wipe. Do not manually adjust the central wiper. The wiper calibration will associate a voltage to a location. Manually moving the wiper will negate the calibration. To perform a sensor wipe:
 - a. In KorEXO: On Live Data screen, click the "Start Wiping" button
 - b. On the Handheld: Click the "Calibration" button, select "Wipe Sensors".

If the central wiper continues to show a yellow QC Score after recalibration, it is still able to be used and will wipe all of the sensors properly. However, the wiper may be nearing its time to be serviced in the factory.



Red: The voltage when the wiper is seated in its housing is outside of the factory specified limits. If the wiper has a red QC Score, perform the same three steps described above for a Yellow QC Score.

If the QC Score returns to red after the above procedures when performed, please contact YSI Technical Support for further assistance. It will possibly be recommended that the wiper should be returned to the factory for maintenance.

Closing Statement

We hope that the SmartQC Handbook has been useful for those seeking a deeper understanding of the SmartQC system, and how one might interpret and respond to SmartQC Scores, particularly yellow or red scores. The SmartQC Handbook was prepared in response to the main questions we have received about SmartQC from our customers since the launch of the EXO platform. In order to keep the SmartQC Handbook brief, as a handbook should be, some details may not be found here, but rather may be found in the [EXO User Manual](#). If users want more information than they find in the Manual, we strongly encourage inquiries and suggestions using the contact information provided on the back cover.

YSI has always prioritized instrument and data quality above all other principles that often guide product development. The SmartQC system was developed at YSI in the hope that it would afford even greater confidence in data collected on the EXO platform. We aimed to transparently provide users with insights into how sensors are operating at any point in time, and how sensor performance is subject to factors that include environment, handling by different users, and aging.

Users who also prioritize data quality are reminded that it has never been recommended or intended that the SmartQC system be the entirety of a quality assurance program or quality control checks on instruments. Rather, SmartQC is intended to be one of many tools that users should incorporate into QA/QC, and quality systems should always be defined by a program's objectives and unique standards.

Input from our customers is always the guidance we use when preparing tools like the SmartQC Handbook, and we thank our customers for their ongoing engagement with our team.



Dr. Stephanie A. Smith
Outdoor Water Quality Segment Manager, YSI

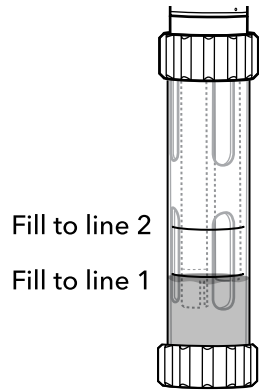
Appendix A: Calibration Overview

EXO sensors (except temperature) require periodic calibration to assure high performance. Calibration procedures follow the same basic steps with slight variations for particular parameters. Calibration procedures described in this section will mainly focus on using KorEXO Software. Users should refer to the [EXO Handheld Mini-Manual](#) for calibration procedures utilizing the handheld.

NOTE: All EXO sensors should be user-calibrated before initial use.

Calibration set-up

For accurate results, thoroughly rinse the EXO calibration cup with water, and then rinse with a small amount of the calibration standard for the sensor you are going to calibrate. Two to three rinses are recommended. Discard the rinse standard, then refill the calibration cup with fresh calibration standard. Fill the cup to approximately the first line with a full sensor payload or the second line with small sensor payload. Recommended volumes will vary, just make certain that the sensor is submerged. Be careful to avoid cross-contamination with other standards.



Begin with clean, dry probes installed on the EXO sonde. Install the clean calibration guard over the probe(s), and then immerse the probe(s) in the standard. We recommend using one dedicated sonde guard for calibration procedures only, and another sonde guard for field deployments. This ensures a greater degree of cleanliness and accuracy for the calibration procedure.

Basic calibration in KorEXO software

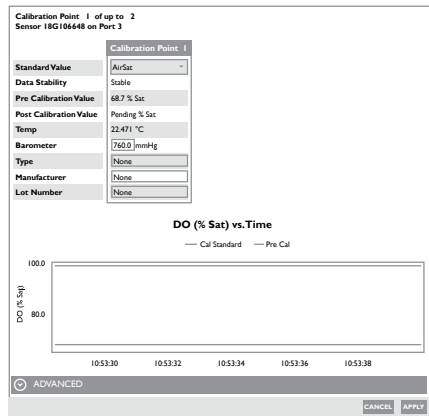
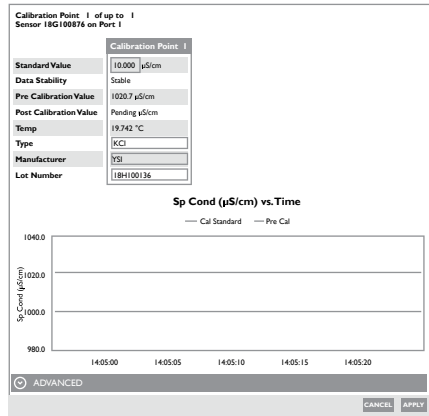
Go to the Calibrate menu in KorEXO Software. This menu's appearance will vary depending on the sensors installed in the sonde. Select the sensor you are going to calibrate from the list. Next select the parameter for the sensor you are going to calibrate. Some sensors have only one parameter option, while other sensors have multiple options.

Selecting the parameter will initiate the probe's calibration in the standard; initially the data reported will be unstable and then will move to stable readings. Enter the Standard Value if necessary. The Standard Value should match that of the standard you are using. You may also enter optional information for type of standard, manufacturer of standard, and lot number by accessing the Advanced menu.

Users should confirm that the value is within their acceptable margin of error. Once readings are stable, click Apply to accept this calibration point. Repeat the process for each calibration point.

Click Complete when all points have been calibrated.

A calibration summary appears with a QC Score. View, export, and/or print the Calibration Report. If a calibration error appears, repeat the calibration procedure.

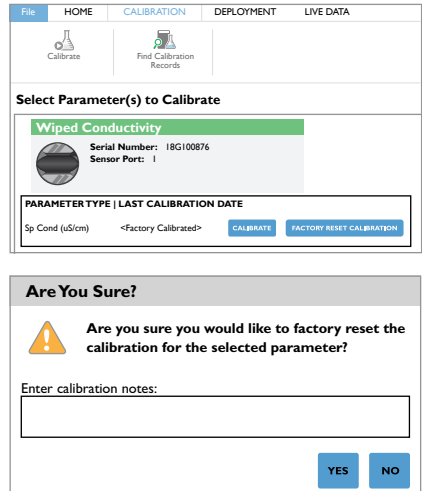


Factory Reset Calibration

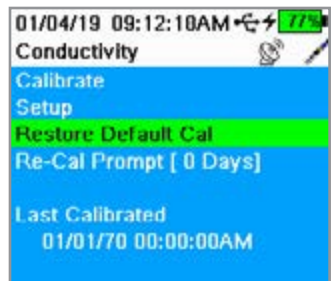
A Factory Reset Calibration can be performed to return the sensor gain and offset to factory settings. More will be said about how gain and offset are defined in the sections to follow, but it is important for users to understand when and how to use a Factory Reset Calibration. Performing a Factory Reset Calibration will allow the user to start a calibration with default sensor metadata values. A new calibration of the sensor will then help with additional troubleshooting, if needed.

Performing a Factory Reset Calibration in KorEXO:

1. Click on the Calibration tab or button.
2. Click the turn-out arrow next to the parameter desired.
3. Click the Factory Reset Calibration button.
4. Type any desired notes into the pop-up window and then click the Yes button to confirm the action.



A Factory Reset Calibration can also be performed using an EXO Handheld; note that this action is referred to as "Restore Default Cal" under the sensor calibration menu in the handheld.



Appendix B: Calibration Report

The Calibration Report is a record of the calibration for an EXO sensor. The report contains quality assurance information including date and time of calibration, date of previous calibration, sensor firmware version, type of calibration performed, standard used, and QC Score.

Calibration Reports are saved in the KorEXO Software database on the computer or the EXO Handheld that was used during calibration. A highly valuable feature is that the calibration itself is stored on each EXO sensor, enabling one to move sensors from sonde to sonde without having to redo the calibration. However, the Calibration Reports themselves are *not* stored on the sensors. All reports can be accessed and viewed through the Calibration Records menu in KorEXO Software.

1-point calibration of specific conductance on EXO conductivity/temperature probe

1-point calibration of percent saturation on EXO optical dissolved oxygen probe

Calibration Record:
 Sensor Type: Wiped Conductivity And Temperature
 Last Calibration Time: <Unknown>
 Calibration Start Time: 1/14/2019 2:04:21 PM
 Calibration End Time: 1/14/2019 2:07:40 PM

General

Parameter Sp Cond (µS/cm)
 Instrument Serial Number 18H109272
 Instrument Firmware Version 1.0.68
 Instrument Type EXO2
 Instrument Name Sonde 18H109272
 Sensor Serial Number 18G100876
 Sensor Firmware Version 3.0.5
 Calibrated By <Unknown>
 Calibration Status Completed
 QC Score Good

Calibration Point #1

Pre Calibration Value 1019.2 µS/cm
 Post Calibration Value 1000.0 µS/cm
 Temperature 19.890 °C
 Standard Value 1000.0 µS/cm
 Type KCl
 Manufacturer YSI
 Lot Number 18H100136
 Is Stable True

Sensor Specific

Cell Constant 0.46

Notes

ADD NOTE

Calibration Record:
 Sensor Type: DO
 Last Calibration Time: 11/21/2018 8:09:59 AM
 Calibration Start Time: 11/30/2018 2:00:58 PM
 Calibration End Time: 11/30/2018 2:07:36 PM

General

Parameter Dissolved Oxygen
 Instrument Serial Number 18H109272
 Instrument Firmware Version 1.0.68
 Instrument Type EXO2
 Instrument Name Sonde 18H109272
 Sensor Serial Number 18G106648
 Sensor Firmware Version 3.0.0
 Calibrated By <Unknown>
 Calibration Status Completed
 QC Score Good

Calibration Point #1

Pre Calibration Value 109.6 % Sat
 Post Calibration Value 100.0 % Sat
 Temperature 18.425 °C
 Standard Value 100.0% Sat
 Type
 Manufacturer
 Lot Number
 Is Stable True
 Barometer 760.0 mmHg

Sensor Specific

DO Cap Serial Number 18G101787
 DO Cap Replacement Date 8/13/2018
 DO Gain 1.04
 DO (mg/L) 9.26 mg/L

Notes

ADD NOTE

Sample Reports:

Additional Post-Calibration Info

ODO Gain: The ODO gain is a diagnostic value recorded on the Calibration Report and used for advanced diagnostic purposes. The nominal value is 1, and accurate calibrations of the DO sensor will only slightly deviate from this number.

Cell Constant: The cell constant is a function of the factory original cell constant and the most recent user calibration. The cell constant will drift over time based on the sensor's electrodes, and the cell constant can be used to track drift.

Slope: The slope for the pH sensor is the mV per decade (pH unit) where 59 is the typical value. Slope allows the user to track drift away from 59 to determine the life/aging of the sensor module.

Change mV: The change millivolts is the mV change between either 4 and 7 or 7 and 10 calibration values for the pH sensor. It is the mV deviation away from the middle calibration point number.

Xylem |'zīləm|

- 1) The tissue in plants that brings water upward from the roots;
- 2) a leading global water technology company.

We're a global team unified in a common purpose: creating advanced technology solutions to the world's water challenges. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. Our products and services move, treat, analyze, monitor and return water to the environment, in public utility, industrial, residential and commercial building services settings. Xylem also provides a leading portfolio of smart metering, network technologies and advanced analytics solutions for water, electric and gas utilities. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise with a strong focus on developing comprehensive, sustainable solutions.

For more information on how Xylem can help you, go to www.xylem.com



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