# GASERA ONE Service Manual

**Revision e**

**Revision history:**

| Date | Initials | Description |
|---|---|---|
| 2017-09-07 | TV | First draft; Added calibration |
| 2017-09-20 | TV | Updated calibration chapter |
| 2017-10-16 | TV | Added new chapters |
| 2017-11-02 | TV | Reorganized |
| 2017-12-05 | TV | Updated error code list, startup procedure and pneumatic diagram |
| 2017-12-08 | TV | Added GMU replacement; Minor updates elsewhere |
| 2017-12-12 | TV | Part B updated |
| 2017-12-18 | TV | Added replacement instruction for PAM, GMU, battery and covers |
| 2017-12-21 | TV | Updated Part A and appendices |
| 2017-12-22 | TV | Updated Part C; Minor updates elsewhere |
| 2017-12-27 | JaSa | Approval |
| 2018-02-20 | SS | Added remote connection and database export |
| 2018-08-30 | MJ | Additions and updates to Calibration and Performance test chapters, other minor modifications |
| 2018-08-31 | TV | Review and minor changes in calibration chapter |
| 2018-09-24 | MJ | Review and minor changes, added Test Sheet instructions and PI-diagram as attachments |
| 2018-10-30 | MJ | Additions to HCHO and HCl calibration instructions, added chapter “Evaluating the need for recalibration”, other minor changes. |

**Document Information**
Product name: GASERA ONE
Title: GASERA ONE Service Manual
Released: October 2018

**Publisher**
Gasera Ltd.
Web: http://www.gasera.fi
Email: support@gasera.fi

**Warranty Information**
Information presented in this document are not guarantee declarations.

Copyright © 2018 Gasera Ltd
All rights reserved. No part of this publication may be reproduced or distributed by any means without prior written authorization of Gasera Ltd.

# Table of contents in high level

# Complete table of contents

# Part A. Read first

## A.1 Preface

### A.1.1 Purpose of this manual

This manual provides maintenance guidance and service instructions for GASERA ONE gas analyzer products. Since these products cover various platforms and sub-modules, an individual GASERA ONE product may differ from that presented in this manual. In case this document does not match actual state of your device, please contact customer support to obtain the latest instructions for the product.

Service manual has two main parts:
Part B. Maintenance and calibration

> contains services performed regularly with aim of upkeeping device in good operational condition and maintain its performance. The chapter includes guidance for performance check and calibration. Actions in this chapter do not require opening the instrument covers. Some maintenance operations are guided in the User Manual.

Part C. Diagnostics and repair

> contains services performed in case of instrument failure with aim of instrument repairs. The chapter helps in diagnosing the fault and locating the faulty component. Instructions for repair actions with references to required documents are given. Repairing typically needs opening the instrument covers and thus the service personnel and infrastructure must fulfill requirements defined in chapters A.1.2 and A.2.

In this document, the term “User Manual” refers to “GASERA ONE User Manual”.

> *NOTE: Boxed notes like this contain warnings and notes that must be followed to ensure safe and proper operation.*

### A.1.2 Target group

This document is intended exclusively for trained users. Operations and tasks described in this manual must only be carried out by a skilled service person being appropriately qualified to perform maintenance and service for GASERA ONE products. Required skills include, for example, handling of electronics, optics, optical fibers, pneumatics, sampling of gases and performing measurements. Unauthorized intervention by a person without required skills voids the manufacturer's guarantee.

The reader must have advanced level knowledge of device usage and be familiar with the User Manual.

Service and maintenance staff is not permitted to perform any maintenance and repair actions not described in this manual without further consultation with customer support.

Service personnel must use only high-quality infrastructure and equipment to enable safe operation and successful service actions. Infrastructure must always meet local safety regulations. All service must be performed in a place having ESD protection and earthing capability because the GASERA ONE products have ESD sensitive parts inside. Successful service actions will also require proper gas handling equipment.

*This manual is intended exclusively for trained persons.*

*Improper working can damage health and equipment and affect the accuracy of measurements.*

## A.2 Safety

The GASERA ONE Single- and Multi-Gas Analyzer complies with IEC/EN 61010-1:2010; Safety requirements for electrical equipment for measurement, control, and laboratory use. To ensure safe operation, follow the instructions below.

- EXPLOSION HAZARD! To avoid the possibility of an explosion, monitoring of flammable gases in explosive concentrations must never be attempted.
- Do not operate the instrument in a potentially explosive environment.
- When monitoring gases that may have health effects, always follow local laws, rules and operating directives.
- The instrument contains a laser product. An open instrument should not be used under voltage.
- If the function or the operating safety of the instrument has been deteriorated, the instrument must be made inoperative and secured against unintended operation.
- If the instrument gives a failure notification that indicates that correct function of the instrument may be deteriorated, consult your local Gasera representative or Gasera customer support. Under no circumstance should repair be attempted by a person who is not qualified in the service of electronic instrumentation.
- Any adjustment, maintenance or repair of the instrument other than guided in this manual, must be carried out only by trained service personnel.
- Before using the instrument, verify that the available mains voltage meets the instrument technical specifications, and that the correct fuse is installed.
- The instrument should be positioned so that easy access to disconnecting the device is possible.
- Turn off all electrical equipment before connecting/disconnecting to the instrument. Failure to do so can damage the equipment.
- If the instrument has been transferred to a warmer and more humid environment, condensation may occur inside the instrument. To prevent shorts, let the instrument warm up about half an hour to avoid any failure due to the condensation.
- Never allow the incoming gas pressure to exceed 2.0 bar.

- If the instrument has been measuring wet gas, flush the gas line and the sample cell with dry gas before turning it off or continuing the actual measurements.
- If corrosive compounds are measured the measured concentration should not exceed 15 ppm for continuous measurements.
- Never connect GASERA ONE to unsafe networks or internet access without firewall. Before connecting instrument to network, please consult trained network administrator.
- Equipment shall only be used according to manufacturer's instructions. Equipment safety is impaired if not used according to manufacturer's instructions.

## A.3 Customer support

### A.3.1 Before contacting to customer support

Before contacting to the customer support, it is recommended to do following list to help support and speed up the finding the solution:

- Check if the error code list has a solution already, see chapter C.3.3 on page 45.
- Write down all error codes and all repair actions already tried.
- It is useful to Export service database to USB mass storage device since errors are logged only for the last three days. The export function is in Setup menu, refer chapter C.3.4 on page 62 and User Manual for detailed instructions.

### A.3.2 Customer support address

Gasera customer support e-mail address: support@gasera.fi

### A.3.3 Gasera on social media

Facebook: @GaseraLtd
Twitter: @gaserafinland
YouTube: @GaseraLtd
LinkedIn: Gasera Ltd.
SlideShare: Gasera Ltd

### A.3.4 Shipping GASERA ONE for service

Always contact Gasera customer support via e-mail for authorization and instructions prior to shipping any items for repair.

Pack the GASERA ONE unit carefully to avoid any damage during shipment. Send the package to the address provided by Gasera customer support.

# Part B. Maintenance and calibration

## B.1 Maintenance

This part contains maintenance and calibration instructions for GASERA ONE products. Purpose of these actions is to maintain the instrument functionality and performance. All actions are performed without opening any covers of the instrument. Actions include replacing consumable parts, updating software, testing the performance, and calibration.

User Manual has lots of guidance for basic maintenance listed in chapter B.4, so referring to User Manual is required.

All repairs requiring work inside the GASERA ONE unit are guided in Part C starting from page 33.

## B.2 Maintenance schedule

Maintenance schedule, in Table 1, must be followed to ensure proper functionality and specified performance. This schedule defines the minimum requirement so shorter intervals may be required is some applications.

**Table 1. Maintenance schedule for GASERA ONE products.**

| Maintenance action | Interval | Refer to |
|---|---|---|
| Performance check | < 6 months | Chapter **Error! Reference source not found.** |
| Calibration | < 12 months | Chapter B.5 |
| Consumables | According to Table 2 | Chapter B.3 |

## B.3 List of consumables

GASERA ONE products have some consumables and available spare parts. They are listed in Table 2. The recommendation for the replacement interval defines the minimum requirement, so shorter intervals may be required in some applications. Especially, replace particle and dust filters always when necessary.

**Table 2. Consumables of GASERA ONE products.**

| Part number | Part description | Pieces per unit | Recommended replacement interval | Replacement instructions in |
|---|---|---|---|---|
| Pall PALLAP-4225T Acrodisc® Syringe filter | Particle filter for sample gas | 2 | When necessary, or less than 12 months | User Manual |
| 33x2 mm FPM | O-ring 1 for particle filter | 2 | With the particle filter | User Manual |
| 6x1 mm FPM | O-ring 2 and 4 for particle filter | 4 | With the particle filter | User Manual |
| 29x2 mm FPM | O-ring 3 for particle filter | 2 | With the particle filter | User Manual |

| | | | | |
|---|---|---|---|---|
| Fanfilter 92x92x7 mm (for e.g. Farnell code 2536408 or TICOMP code MC32710) | Dust filter for cooling fan | 1 | When necessary, or less than 12 months | User Manual |
| CR2032 type 3.0 V button cell | The backup battery | 1 | Few years | C.4.2, p. 70 |
| Swagelok 55-6M0-1-0046 | Swagelok gas tube connector, complete set | 4 | When necessary | |
| SMC M-5G1, PVC Rigid | Gasket M5 for Swagelok connector | 4 | With Swagelok connector above | |
| Swagelok 55-6M2-1 | Swagelok gas tube connector, nut | 4 | When necessary | |
| Swagelok 55-6M0-SET | Swagelok gas tube connector, small bits | 4 | When necessary | |
| Fuse 5x20 mm 2A 250V Slow | Fuse | 1 | When necessary | User Manual |

## B.4 Basic maintenance instructions

User Manual has instructions for the basic maintenance, or the following:

- Updating software using software pack in USB mass storage device
- Removing old measurement results to get more free space for new measurements
- Replacing particle filters for sample inlets
- Replacing dust filters for cooling fans
- Replacing the fuse
- Cleaning outside surfaces of the instrument

## B.5 Calibration

### B.5.1 Calibration principles

Calibration is a process where the known sample and the instrument reading are coupled so that the instrument can produce values in the units of the gas concentration. Thus, the calibration is always required for the gas analyzers. The quality of the calibration affects directly to the instrument accuracy and performance. Only accurate calibration ensures accurate measurement results.

All GASERA ONE products are calibrated at the factory. Recommended calibration interval is defined in chapter B.2 on page 10.

GASERA ONE units have built-in calibration functionality. Thus, the user may calibrate the units. However, because the calibration affects critically to the performance, the recalibration should always be performed by a Gasera service representative or by the user trained by Gasera. If anything is unclear in calibration, the user should contact local distributor or Gasera before attempting to recalibrate.

All GASERA ONE products have short absorption length enabled by the photoacoustic technology, thus the sensor response is highly linear. The calculation model for the gas analysis is created at factory by extensive test measurements. As a result, the single point calibration is sufficient.

The instrument calibration is performed by measuring the signal levels obtained from all channels for each gas. In Chopper and Pulse models, the channels are equivalent to optical filters. These models can measure simultaneously ideally up to 10 gas components, which is the maximum number of optical filters.  DFB models have up to two lasers typically enabling measurement of two gases. The EC-QCL model can have thousands of channels and several gas components depending on the application. The QCL model can measure one gas component.

The calibration procedure is model dependent. NDIR models require background (zero-gas) calibration and water vapor calibration to compensate the span-calibration data. Laser instruments have much better resolution and the calibration procedure might be simpler although some applications demand some customization of the calibration procedure.

*Calibration affects to the accuracy of measurement results. The calibration should always be performed by a trained person or the manufacturer.*

*It is up to the user to decide whether the new calibration will be approved or not. Unexpected signal levels or large deviations of the filter signals may indicate leaks in the system, problems with the calibration gas, too strong vibrations or other issues. In such cases, it is always recommended to check the condition of the calibration gas cylinder, the gas line and the calibration environment before proceeding further.*

## B.5.2 Environmental requirements

GASERA ONE unit must be calibrated only in environmental requirements defined in the table below. This ensures adequate quality of calibration. Same requirements must be used also when making performance tests defined in chapter B.6.

**Table 3. Environmental requirements for calibration and testing.**

| Property | Requirement |
|---|---|
| Ambient temperature | 20 °C…25 °C |
| Ambient absolute pressure | 900 mbar…1100 mbar |
| Ambient humidity | < 90 %, non-condensing |
| Sample gas absolute pressure range | 930 mbar…1100 mbar |
| Vibration | Vibration isolation must be used |
| Sound pressure level, C weighted | < 50 dB |

## B.5.3 Gas samples for calibration

### B.5.3.1 Requirements for calibration gases

This chapter gives general rules for the calibration gas samples. Following chapters instruct how to ensure high-quality calibration in special cases.

It is critical to have as high-quality gas samples as possible for the calibration because the calibration affects very strongly on the accuracy of the measurement results. Use only certified gas cylinders. The calibration sample for the pure gas is typically a mixture of the compound and high purity nitrogen ($N_2$). Using synthetic air instead of nitrogen might bring up some relaxation effects in some cases so it should not be used in general. The recommended gas concentration is approximately 100–200 times the lowest detection limit with NDIR analyzers. To define calibration concentrations for laser based analyzers, see Test Sheet document or contact Gasera customer support.

Preferred accuracy in cylinder is ± 2%, but with some gases even ± 10% must be accepted.

For the background calibration, the recommended gas is pure nitrogen ($N_2$) with grade 6.0 or better.

To ensure that the calibration gas is valid, do not use gas after its expiration date.

In some rare cases, the compound for the calibration may not be available in the gas phase in a cylinder. Then, the calibration sample must be generated in a special way. Contact the local distributor or Gasera customer support for more information.

*Always take account local regulations and instructions for safety operation of pressurized gas and hazardous gases.*

### B.5.3.2 Gases requiring moisturized sample

When calibrating certain gas compounds, the calibration sample must be moisturized, or mixed with water vapor. Table 4 lists these gases. Moisturizing is required mainly by two reasons. Firstly, some compounds have complicated relaxation effects affecting how the photoacoustic signal is generated. Secondly, to improve mobility of certain gases as some compounds are reactive and thus tend to stick to surfaces in contact such as tubes, cell walls and valves. Both these phenomena are shortly described in B.5.3.3 and B.5.3.4. NDIR analyzers are usually calibrated with higher concentrations than laser based analyzers. Thus water is not required with calibration sample (HCHO, $C_2H_6O$ and $NH_3$) with NDIR based instruments.

**Table 4. Gases requiring moisturized sample for calibration.**

| Gas | Feature | Notes and recommendations |
|---|---|---|
| CO | Relaxation effects | Mix with water > 8000 ppm |
| $CO_2$ | Relaxation effects | Mix with water > 8000 ppm |
| NO | Relaxation effects | Mix with water > 8000 ppm |
| $N_2O$ | Relaxation effects | Mix with water > 8000 ppm |
| HCHO | Sticky | Mix with water > 8000 ppm |
| $H_2O$ | Sticky | Used to reduce effects of other sticky gases |
| $C_2H_6O$ | Sticky | May not need water |
| HCl | Very sticky | Mix with water |
| $NH_3$ | Very sticky | Mix with water |
| HF | Extremely sticky | Mix with water |

#### B.5.3.3 Relaxation effects in photoacoustic detectors

The relaxation phenomenon may affect to the measurement results, for example when the sample contains lots of nitrogen or is very dry. In the photoacoustic phenomenon, the energy that the gas molecule absorbs may be unintentionally transferred to another gas molecule before being released to thermal energy, thus delaying the photoacoustic signal and creating an error in the measurement result. The phenomenon is called relaxation. It affects the measurement of few gases when the gas is mixed with high concentration of nitrogen.

The relaxation usually occurs in a certain spectral range and therefore affects only certain optical filters or absorption lines used by the laser source. The range is typically from 2000 $cm^{-1}$ to 2400 $cm^{-1}$. This range cannot be avoided because it contains spectral fingerprints of many important compounds. Gases that must be measured mixed with water are listed in Table 4 on page 13.

Relaxation effects can be prevented by adding water to the sample gas. Water molecules speed up the energy release of the nitrogen molecules shortening the delay and cancel the error in the measurement result.

When monitoring ambient air, the sample usually contains an adequate amount of water, so the measurement results are not affected despite there is high concentration of nitrogen in ambient air. However, if the climate is extremely dry or the composition of the sample gas is otherwise favorable to the relaxation, adding water to sample is required.

#### B.5.3.4 Handling of sticky gases

Some molecules are very reactive and tend to stick to surfaces of materials in contact. How strong this tendency is, depends on physical and chemical properties of the gas molecule itself, compounds in the surrounding gas, gas concentrations, the surface material, the surface roughness, gas flow rate and environmental properties such as temperature and pressure. Thus, many Measurement task parameters will affect to the performance when measuring sticky gases.

One of the most common sticky gases is water. Common sticky gases are listed in Table 4 on page 13.

In Gasera products, materials in contact with the gas are selected to minimize the effects of stickiness. For example, the gas cell is gold coated and all tubes are PTFE or in some cases PVDF.

The sampling of sticky gases requires great care to make sure that the sample is correctly measured. Typically, stabile concentration of sticky gases is reached after a long time, even after several hours. Consequently, removing the traces of the sticky gas takes time. Stabilization time can be remarkably shortened by some handling tips. For example, water shortens the stabilization time because it sticks to surfaces preventing the actual sample gas reactions with the surface thus allowing the sample gas to flow more freely in the tubing.

$NH_3$, HCl and HF are very reactive, and sticky, gases. Stabilization in the gas tubing may take several hours, depending on the length of the tubing and the gas concentration. It is highly recommended to add moisture to make the gases saturate faster in tubing. Additionally, the saturation time can be shortened by flowing higher concentration first and then switching to possibly lower calibration concentration because higher concentration of HCl or HF saturates faster than low concentrations. HCl and HF traces remain long in the gas tubing, so it is recommended to flush the tubing and cell with a moisturized sample such as ambient air or the mixture of water and nitrogen or synthetic air.

## B.5.4 Setting up the calibration gas lines

### B.5.4.1 Gas lines for dry samples

Two gas line setups are required for calibration: one for dry pure gases and one for water and moisturized gases listed in chapter B.5.3.2 on page 13.

For dry pure gases, the recommended gas line is illustrated in Figure 1. Using the precision mass flow controller based setup is recommended for easier control and more steady gas flow. Alternative setup is sampling from the gas bottle with a regulator sketched in Figure 2.

Required equipment is a gas cylinder attached to a regulator, a mass flow controller for generating steady flow rate, a flow meter for ensuring the adequate flow rate, gas tubes and a “T”-shape connector for tubes. The tube material should be PTFE (polytetrafluoroethylene), or in some cases PVDF to minimize gas absorption from the surrounding air and to help gas flow of sticky gases. The stainless-steel tubes can be also used with most gases, but the compatibility of tube material and the sample must always be checked before calibration. Recommended gas tube lengths are

- As short as possible between the “T”-shape connector and GASERA ONE gas inlet: 5…10 cm is recommended
- Approximately one meter in other line parts

It is critical, that throughout the calibration process:

1. the gas pressure in the regulator output exceeds the ambient pressure
2. the gas flow through sampling line is 1000 ml/min or more

The rate is best measured using a flow meter in the output of the gas line. Check that the flow does not drop to zero during the gas exchange of the device to permit taking gas from the surrounding air to the gas line.

Calibrating a pure single gas from a gas cylinder can be performed using simpler setup than above although it is recommended to use mass flow controller based setup. Otherwise, the same setup instructions as above apply for this setup.

*Make sure that the gas cylinder is firmly placed and secured to prevent falling.*

*The waste gas from the gas line and the SAMPLE OUT should be vented to well-ventilated area such as fume-hood, especially when the gas may harm human health.*

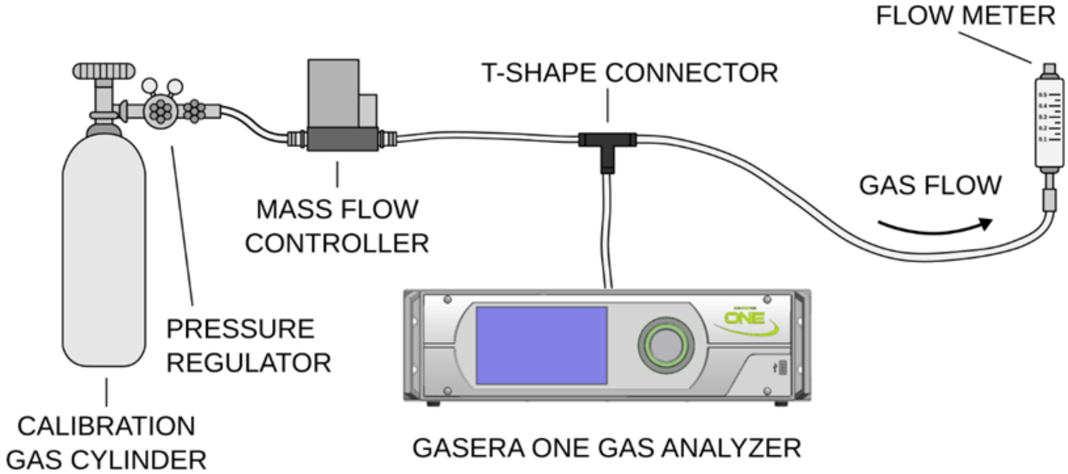



**Figure 1. Recommended calibration setup for a dry pure gas based on precision mass flow controller.**

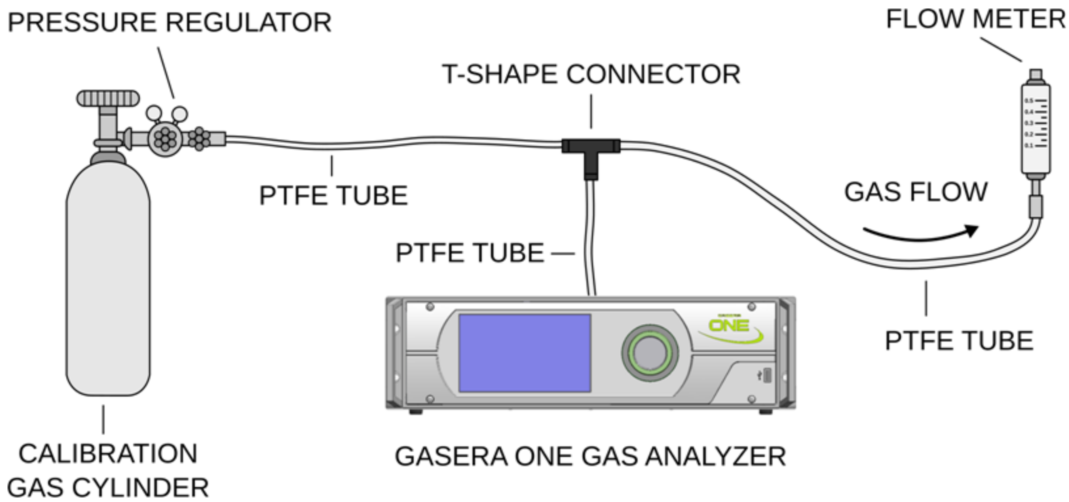



**Figure 2. Alternative calibration setup for a single pure gas from a gas cylinder.**

### B.5.4.2 Gas line for water and moisturized samples

Calibration of water sample itself and moisturized gas samples should be performed using the setup illustrated in Figure 3. The difference to the setup for dry pure gases is the added water line for generating the water vapor with known concentration. Setting up the water bath is instructed in chapter B.5.4.2.1**Error! Reference source not found.** on page 17. It is critical to first mix water and nitrogen and then mix the other gas component to the generate moisturized sample required by certain gases. Otherwise, the setup requirements are the same as with dry pure gas setup in chapter B.5.4.1 on page 15.

The typical mixing ratio of the water line and the sample gas line is 1:1. However, sometimes some other ratio is required, or even the third gas line having its own mass flow controller for generating the desired sample.

> *Do not use this setup for calibrating dry pure gases because possible leaking from water bath may contaminate the calibration sample or the water bath solutions.*

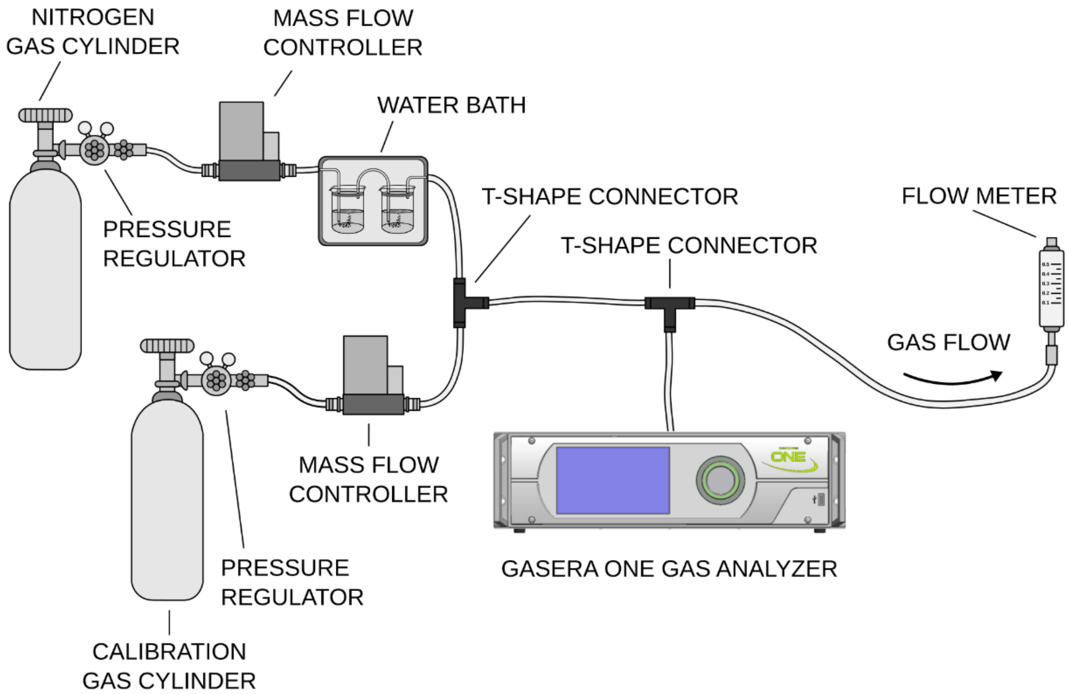



**Figure 3. Recommended calibration setup for water and moisturized samples. Setting up the water bath is instructed in chapter B.5.4.2.1 on page 17.**

#### B.5.4.2.1 Generating the water sample for calibration

Water is a critical compound to calibrate. In typical application, water is always present in the sample. Water concentration may influence on analysis of other gas concentrations. Additionally, the moisturized gas sample is required for calibrating certain gases listed in chapter B.5.3.2. Generating the water sample is a special case because water is not available in gas phase delivered in a cylinder as most of other gases. It is strongly recommended to contact Gasera before attempting to calibrate water.

Recommended method for generating the water sample for calibration is to use the water bath system shown in Figure 4. The system is based on two bottles filled with pure water mixed with 0.5 mol/l NaOH in a steady temperature. The bottle material must be compatible with NaOH. The gas line including all gas inlets and bottle lids must be leak free. When pure nitrogen flows through the bath, water evaporates to the nitrogen in a controlled manner. The water bath method requires great care to ensure accuracy of the water concentration in the gas sample.

The concentration of the water sample depends on the temperature of the water bath system and the atmospheric pressure of the surrounding air. Thus, the temperature of the water bath must be kept stable during the calibration and monitored using a precision temperature meter. It is recommended that an incubator or other temperature-controlled cabin is used for the stabilizing the water bath temperature. Using the temperature and the atmospheric pressure, it is possible to precisely calculate the water concentration in the gas phase.

Only use pure distilled water that is free from dissolved gases. The carrying gas must be high purity nitrogen defined in the chapter B.5.3.1 on page 12. The recommended steady temperature of the water is 17.6 °C corresponding to the water concentration of approximately 20 000 ppm when ambient pressure is close to 1000 mbar. When calibrating water, the accurate water concentration must be determined for example measuring ambient pressure and temperature in the water bottle and then using a humidity conversion tool.

The recommended water concentration is

- In water calibration: 1 %…2 % (the accurate concentration value must be determined)
- In moisturizing calibration sample: about 1 %

The recommended gas flow through the water bottles is 1…2 liters per minute. Do not choke the gas line with too narrow connectors etc. because it may change the sample gas pressure and thus the water concentration.

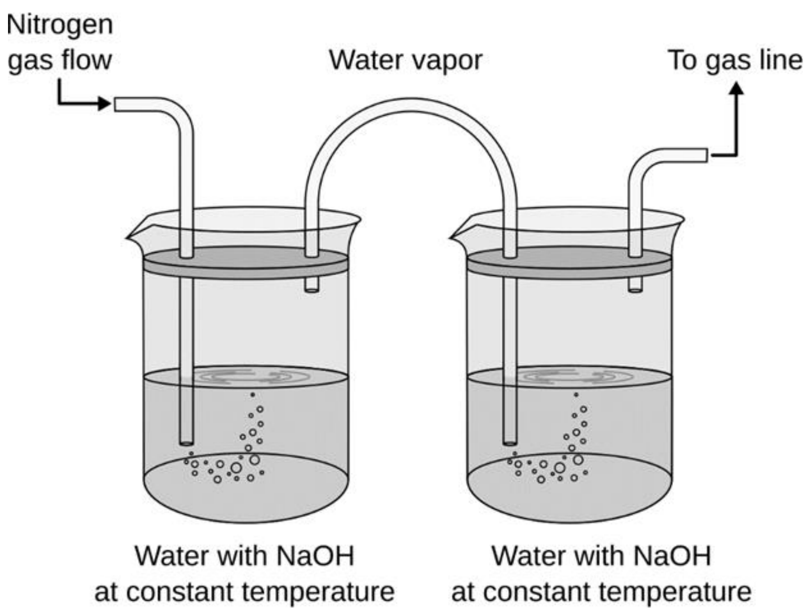



**Figure 4. The water bath system for generating a mixture of water and nitrogen.**

### B.5.5 Preparing the GASERA ONE for calibration

GASERA ONE preparations for calibration are

1. Replace the particle filters in the sample gas inlets.
2. Place the GASERA ONE on a steady table.
3. Ensure that environmental conditions are met, see Table 3 on page 12.
4. Prior to calibration let the GASERA ONE warm up for 30 minutes.
5. The self-test must have been passed.
6. Setup the gas lines and flow rates as instructed in chapter B.5.4 on page 15.
7. Flush the device as instructed in below.

If any reactive, or sticky, gases have been measured, the flushing should start with room air (or air having moisture). Water shortens time required to remove molecules stuck by adsorption to internal surfaces of gas lines. To completely remove traces of previous gases may take even hours of continuous flushing. See list of sticky gases in Table 4 on page 13.

After traces of sticky gases has been removed, the device should be flushed with dry nitrogen to remove any moisture from the cell to be ready for the calibration. The drying may take even couple hours depending initial water concentration.

For flushing, the normal calibration task may be used but for saving time, it is practical to create a measurement task having 999 flushes in each measurement cycle. An example is presented in Figure 5. This task will flush the gas cell for 999 times in each measurement iteration. Typically, one or two complete cycles is adequate.

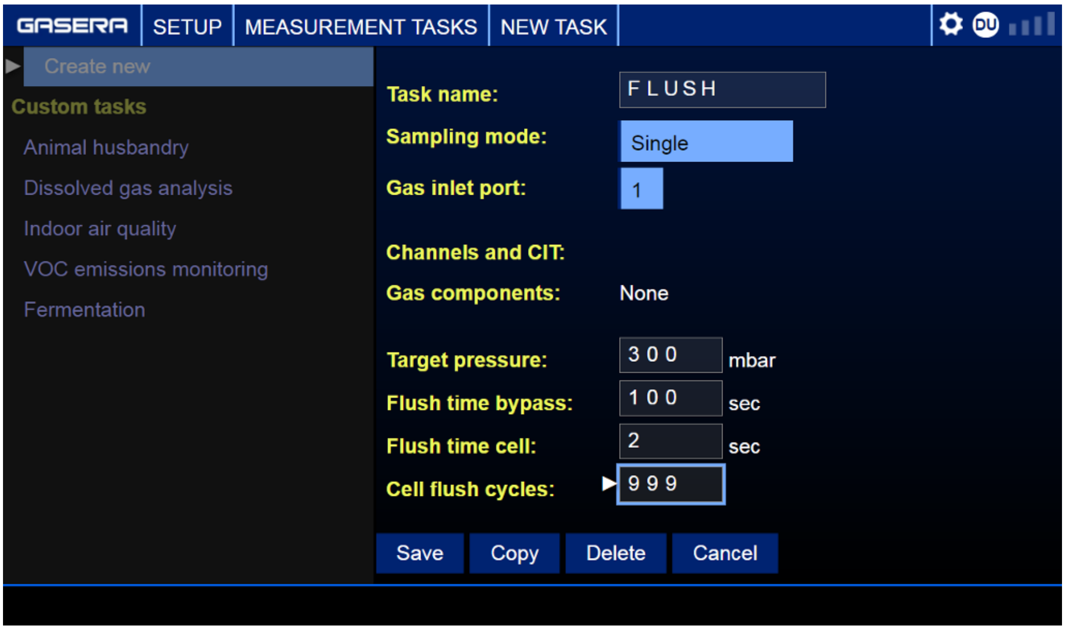



**Figure 5. Creating a task for flushing the cell before calibration.**

### B.5.6 Performing the calibration

#### B.5.6.1 Calibration recommendations

Gases can be calibrated in the order of convenience, but for practical reasons, the recommended calibration order is

1. Prepare the GASERA ONE and calibration setup as instructed in previous chapters.
2. Start with the background calibration. The background calibration can run over night to remove any traces from previous samples. Alternatively, the flushing may be used to shorten the time for flushing.
3. Calibrate all dry gases after background calibration because the background calibration has already dried the sample cell.
4. Finally, calibrate water, moisturized gases and any reactive, or sticky, gases.

Reason for the recommendation is the fact that the drying of the instrument takes usually several hours, and the above order saves working time and gases in most cases.

The calibration library is a combination of several individual gas calibration data files. Therefore, it is even possible to calibrate the device one gas at a time and update the calibration library occasionally. However, to secure the accuracy with all the gases it is strongly recommended to calibrate all the gases at once including the background.

#### B.5.6.2 Calibration settings

The **Calibration** menu is under the **Setup** menu as presented in Figure 6. When selected, the menu shows the available gas components. The gas components are application and infrared source dependent and permanently fixed at the factory.

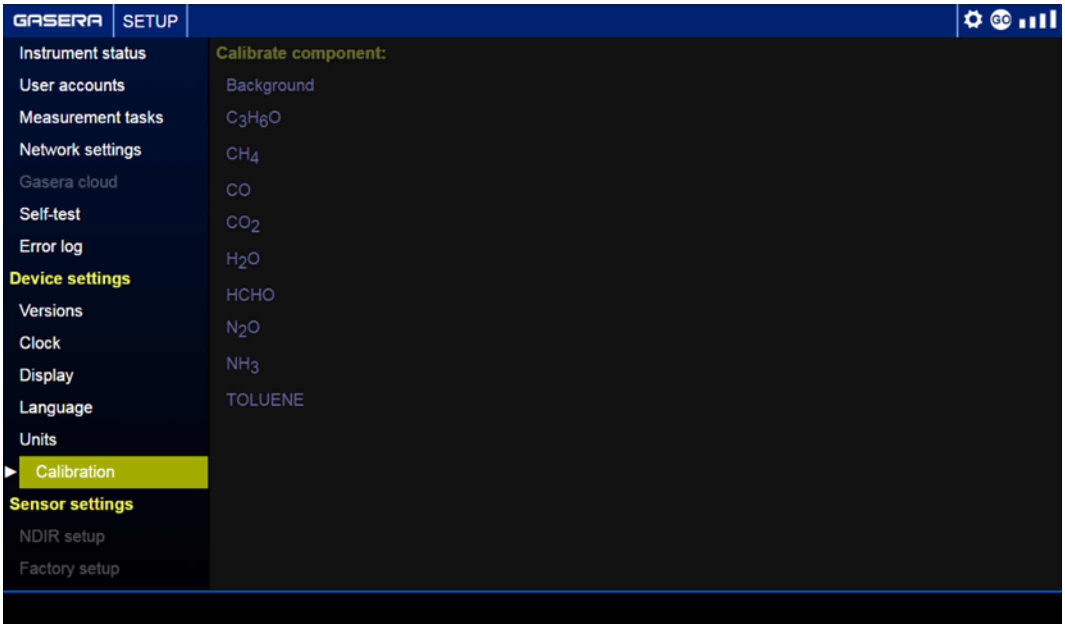



**Figure 6. The Calibration menu in the Setup menu. The available gas components depend on the GASERA ONE model.**

The **Calibration** menu shows the calibration parameters for the background or the gas component. Always prefer default calibration parameters. However, parameters can be edited before starting the calibration as presented in Figure 7. Normally, only **Sample concentration** must be changed to correspond the calibration sample. The last calibration date for each component is presented in the top of the parameter list. The calibration parameters are described in Table 5 on page 22.

> *Changing factory defaults for **Channels and CIT** or **Target pressure** may decrease the instrument performance. Changing these values requires deep understanding of their effects.*
> *Factory defaults are not stored in the device, so they cannot be automatically retrieved once changed.*

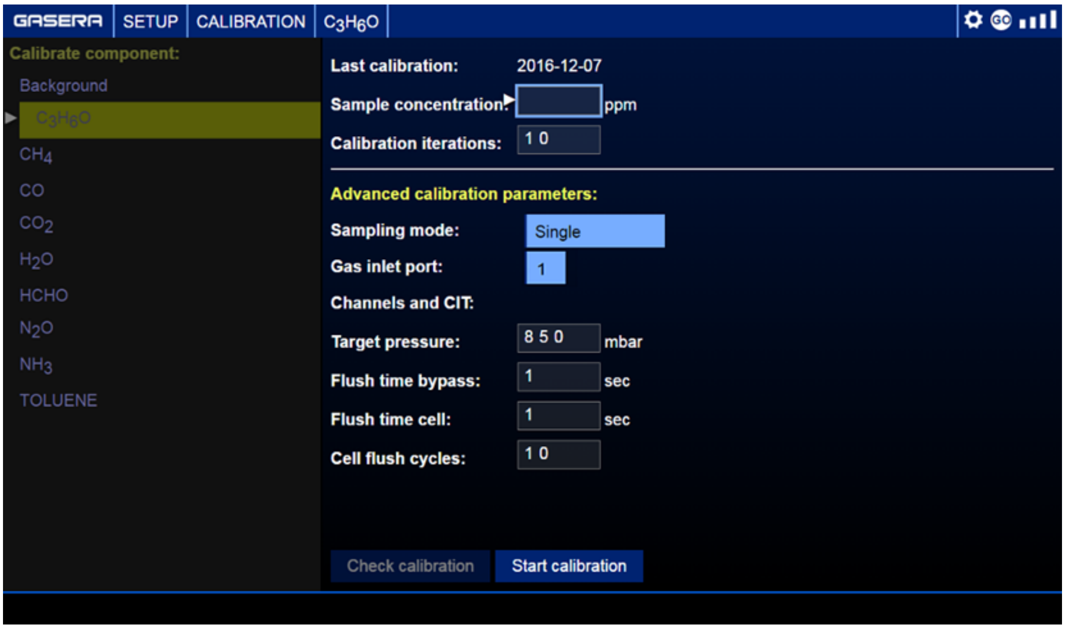



**Figure 7. Example of Calibration menu for defining parameters for $C_3H_6O$ calibration. Normally, only Sample concentration of the calibration gas is entered.**

**Table 5. The calibration parameters.**

| Parameter | Description |
|---|---|
| Last calibration | Shows the date of the last calibration in YYYY-MM-DD format. |
| Sample concentration | Enter the accurate concentration of the calibration gas. Not required for background calibration.<br><br>Normally, this is the only parameter required to modify in the calibration. Changing the factory settings for other parameters may compromise the performance. |
| Calibration iterations | This value defines the number of calibration points used for calculating the values for the new calibration. Recommended value is 10.<br><br>The calibration cannot be accepted before the number of iterations has been reached. |
| Sampling mode | For calibration, use only single mode. |
| Gas inlet port | Selects the gas inlet for calibration sample. The possible values are 1 or 2 indicating gas inlets SAMPLE 1 IN and SAMPLE 2 IN. |
| Channels and CIT | Defines which channels are being used and channel integration times (CIT) defining how long the signal will be integrated per channel.<br><br>WARNING: Never change these settings without deep understanding of their effects. Incorrect values will reduce instrument performance. |
| Target pressure | This value sets the calibration pressure. This pressure needs to be lower than the ambient pressure to ensure correct operation of the gas exchange procedure.<br><br>Because the pressure influences the signal levels, each used measurement pressure needs to be calibrated. The measurement results are valid only when measured with the equal pressure in the calibration.<br><br>Note: The gas concentration is proportional to the pressure. When the pressure decreases, the number of molecules decreases, which in turn decreases the signal. This means that as the pressure decreases, the performance decreases. The exception for this rule is DFB laser based instruments, in which the pressure influence is smaller than in Pulse, Chopper or EC-QCL and in some cases a very low pressure offers resolution advantages. |
| Flush time bypass | Defines how long bypass gas line is being flushed in the gas exchange procedure. The bypass line is the tubing parallel to the gas cell enabling to take as fresh gas sample as possible.<br><br>With some compounds such as with sticky gases, flushing parameters affect the performance. |
| Flush time cell | Defines how long the measurement cell is being flushed in the gas exchange procedure.<br><br>With some compounds such as with sticky gases, flushing parameters affect the performance. |
| Cell flush cycles | Defines the number of the cell flushes done in the gas exchange procedure.<br><br>With some compounds such as with sticky gases, flushing parameters affect the performance. |

### B.5.6.3 Starting the calibration

Before starting the calibration check that

1. The calibration gas meets the requirements given in the chapter B.5.3 on page 12 and water sample is generated as instructed in B.5.4.2.1 on page 17.
2. The gas line and the gas flow are as instructed in B.5.4 on page 15.
3. GASERA ONE is prepared for the calibration as instructed in chapter B.5.5 on page 19.
4. The correct **Sample concentration** is entered in the **Calibrate component** view, see chapter B.5.6.2 on page 20.

When everything is ready, start the calibration of the compound by selecting **Start calibration** in the **Calibration** menu presented in Figure 7. The running calibration task can be cancelled any time with the long press of the GASERA ONE button.

Acceptance criteria for the calibration are given in the following chapters.

### B.5.6.4 Running the calibration

During the calibration, signal statistics and a graph are presented as in **Error! Reference source not found.**. The table shows signal **Average**, **Slope**, standard deviation **St.Dev.** and **CIT(s)** or **CIT (Multip)**, all per channel. By default, 10 measurements are required to accept the calibration. These values can be used to evaluate calibration quality. Definitions of these properties are in Table 6**Error! Reference source not found.**.

**Table 6. Properties shown during the calibration.**

| Property | Definition |
|---|---|
| Channel name | Name of the channel. |
| Average | Mean value of last iterations used for the calibration. By default, 10 measurements are used. |
| Slope | Slope is the coefficient of the linear term of the line fitted to signal values of last iterations used for the calibration. Describes the signal trend. By default, 10 measurements are used. |
| St.Dev. | Standard deviation of last iterations used for the calibration. By default, 10 measurements are used. |
| CIT(s)<br>CIT(Multip.) | Channel integration time, given in seconds or as a multiplication factor of the shortest possible integration time. |
| Completed iterations | Number of completed iterations of measurements required to accept the calibration. By default, 10 measurements are used. |

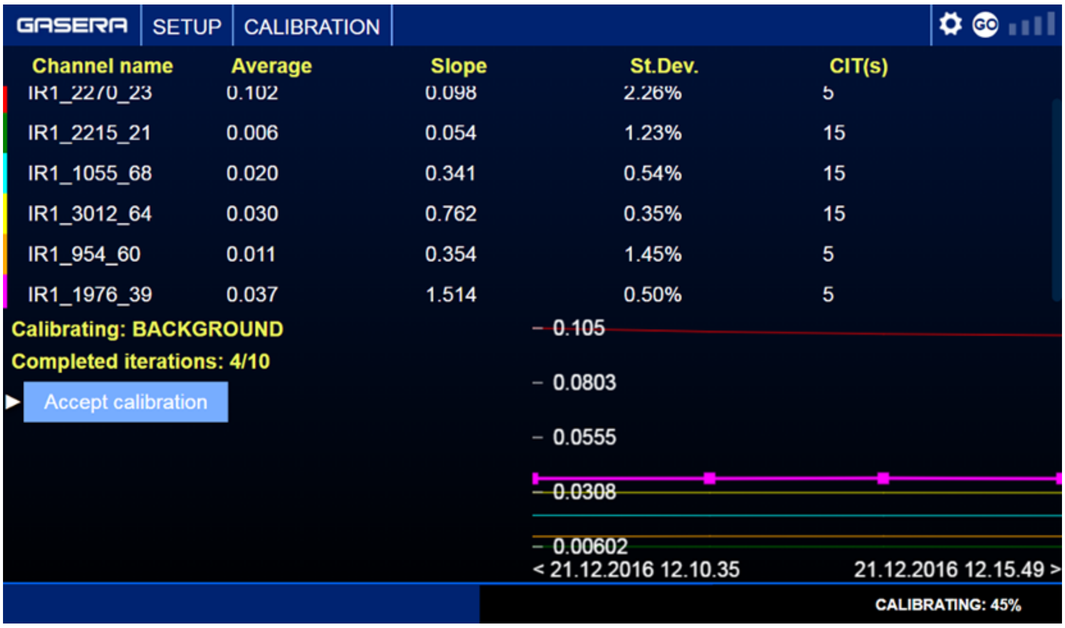



**Figure 8. Data presented during the calibration. The calibration is accepted based on this data by pressing Accept calibration.**

The signal values are plotted to the graph on the bottom right. The selected channel is emphasized in the graph. Points used for the calibration are also emphasized. The curve for a component can be shown or hided by pressing the corresponding **Channel name** in the table. Before accepting the calibration, the user should check the curves individually to find any possible trend or other unacceptable data.

When the signal is stable and statistics acceptable, the calibration can be accepted by selecting **Accept calibration**. The device will ask the user to confirm the use of the new calibration data. The calibration can be cancelled any time with a long press of the GASERA ONE button.

### B.5.6.5 Background calibration

The background calibration defines the signal level when there is no absorption of infrared light in the gas cell. The background calibration is sometimes known also as zero-point calibration. Therefore, the background calibration differs slightly from the calibration of the gas components. The sample must be as pure nitrogen as possible (see gas requirements in chapter B.5.3). Thus, no concentration value is required in calibration parameters. Otherwise, the parameters are similar as in the gas calibration.

It is likely that there is moisture and traces of the previously measured sample gases in the gas cell, which might produce signal. Especially, if the sample gas has cross interference with water it is critical to remove as much water as possible from the cell. Therefore, the background calibration process should be started by flushing the gas cell as instructed in chapter B.5.5 on page 19. Alternative way could be running the background calibration overnight.

Figure 9 illustrates the removal of water from the measurement system during the background calibration or cell flushing. As the calibration iterations increase, the water signal decreases and finally saturates to its background level. In the first phase, most of the water is flushed out from the cell, but there is still too much water left since there is a clear trend. During the second phase, the water continues to gradually flush out from the cell, and the trend continues to saturate. The background calibration must continue until the signal has no trend anymore as in the “Stabile phase”.

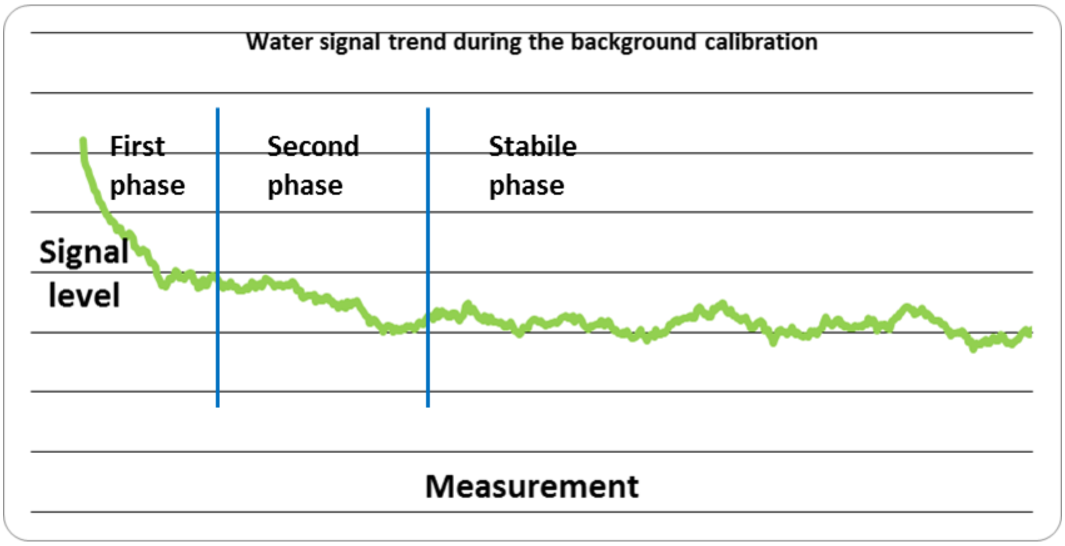



**Figure 9. Water signal trend during the background calibration. The background calibration can be accepted when no trend is left.**

**Acceptance criteria for the background calibration** are

1. Signal is saturated in all channels, or any trend cannot be observed in any channel.
2. Any of signals have no outliers or clear deviations, such as single data points far from the average level. All signals must be checked individually.

Typically, background signals are very low, so the relative standard deviation may be rather high. The most important is to accept only smooth looking data without trends. Gasera recommends consulting the customer support for getting the latest information on the acceptance criteria.

Note that some laser based instruments may not require background calibration as the signal level is zero with background gas. For more information, contact Gasera customer support.

### B.5.6.6 Sample calibration

If background calibration is performed first, the sample calibration is usually more straightforward. The sample calibration requires entering an accurate concentration of the sample gas to the calibration parameters described in chapter B.5.6.2 on page 20. Compounds requiring a moisturized sample in calibration are listed in Table 4 on page 13. Instructions for generating water sample are given chapter B.5.4.2.1**Error! Reference source not found.** on page 17**Error! Bookmark not defined.**.

After starting the calibration, the instrument present similar display as in Figure 8 on page 24**Error! Bookmark not defined.**.

**Acceptance criteria for the sample calibration** are

1. Signal is saturated in all channels, or any trend cannot be observed in any channel.
2. Any of signals have no outliers or clear deviations, such as single data points far from the average level. All signals must be checked individually.
3. For high signals, the relative standard deviation does not exceed 1 %. In channels having small signals, larger deviation can be accepted. However, as low as possible deviation values are desirable.

Gasera recommends consulting the customer support for getting the latest information on the acceptance criteria.

## B.6 Performance tests

### B.6.1 Environmental requirements

To obtain comparable test results about instrument performance, all tests must be performed in the environment fulfilling same requirements as used for the calibration. Requirements are defined in chapter B.5.2 on page 12.

### B.6.2 Measurements for test sheet

#### B.6.2.1 Test sheet content and purpose

Every GASERA ONE analyzer is delivered from the factory with the test sheet containing results from certain standard measurements performed for each individual unit. The test sheet describes the actual performance of the unit and proves that the unit fulfills its performance specifications. Performance specifications depend on the model and in some cases, may depend on the unit if agreed upon the order.

Test sheet measurements can be used for example to

- Check that the performance is as expected
- Monitor the instrument drift periodically
- Check if the instrument needs to be recalibrated
- Check that the performance after service or repair

Some results for the test sheet can be calculated using raw data from the calibration, others are measured separately after calibration. Making measurements for the test sheet is done very similarly than the calibration, so it is best to refer to Calibration chapter B.5 on page 11 for environmental requirements, gas handling, setting up gas lines and other necessary information for setting up the equipment and generating gas samples.

Templates of the test sheet are presented in chapter D.1 on page 82. The rest of this chapter, B.6.2, is organized as the sections of the test sheet.

### B.6.2.2 Measurement parameters

Always use same measurement parameters as used in factory calibration and tests. These parameters are listed in the test sheet created by the manufacturer. If this original test sheet is missing, contact Gasera customer support.

Figure 10 and Figure 11**Error! Reference source not found.** show the examples of parameters section in the test sheet. Parameter tables list channels, integration times and target pressure:

- Channels correspond to spectral band used for measurement. Band widths depend on technology: with lasers channels are very narrow but with NDIR they can be rather wide.
- Integration time is given as CIT defining the shortest integration time unit, kind of base unit. The total integration time is this base unit multiplied by CIT Multiplier.
- Target pressure is the absolute pressure of the sample gas closed to the sample cell. This is model dependent. Do not change the factory default.

**Parameters**

| Channel | CIT, Channel integration time [s] | CIT multiplier |
|---|---|---|
| HCHO | 0.5 | 20 |
| H2O | 0.5 | 20 |

| Target pressure | 200 mbar |
|---|---|

**Figure 10. Example of measurement parameters section of the test sheet for laser analyzer.**

**Parameters**

| Channel | Slot | CIT, Channel integration time [s] |
|---|---|---|
| IR1_943_75 | 0 | 15 |
| IR1_2273_22 | 1 | 10 |
| IR1_2891_33 | 2 | 5 |
| IR1_2139_73 | 3 | 10 |
| IR1_3012_64 | 4 | 20 |
| IR1_3066_61 | 5 | 5 |
| IR1_3268_64 | 6 | 20 |
| IR1_1976_39 | 8 | 10 |

| Target pressure | 850 mbar |
|---|---|

**Figure 11. Example of measurement parameters section of the test sheet for NDIR analyzer.**

### B.6.2.3 Detection limits and repeatability

Detection limits and repeatability section presents lower limits of detection and repeatability values for the gas components or compounds that the GASERA ONE unit is able to measure. See examples in Figure 12 and Figure 13**Error! Reference source not found.** below.

**Detection limits and repeatability**

| Gas | Channel | Detection limit* [ppb] | Repeatability |
|---|---|---|---|
| HCHO | 0 | 0.14 | 0.55 % |

*Method: 2 × standard deviation in 6 last measurement points in zero gas measurement

**Figure 12. Example of detection limits and repeatability section of the test sheet for laser analyzer.**

**Detection limits and repeatability**

| Gas | Channel | Detection limit* [ppm] | Repeatability |
|---|---|---|---|
| C2H4 | IR1_943_75 | 0.36 | 0.28 % |
| CO2 | IR1_2273_22 | 0.28 | 0.03 % |
| C2H6 | IR1_2891_33 | 0.62 | 0.51 % |
| CO | IR1_2139_73 | 0.17 | 0.18 % |
| CH4 | IR1_3012_64 | 0.20 | 0.03 % |
| C2H2 | IR1_3268_64 | 0.17 | 0.13 % |
| H2O | IR1_1976_39 | 46.70 | 0.15 % |

*Method: 2 × RMS noise × *c* / (*S* – bg); average of 6 consecutive measurements

**Figure 13. Example of detection limits and repeatability section of the test sheet for NDIR analyzer.**

**For laser analyzer**, values of the lower limit of detection, LoD, are determined from the measurement results of zero gas (e.g. gas sample that does not contain analyte gases). From the 6 last consecutive measurement points, standard deviation is calculated and multiplied by two, thus getting the lower limit of detection.

Limit of detection is calculated by

$$\mathrm{LoD} = 2RMS,$$

where

*RMS* = standard deviation of measurement results from 6 consecutive measurements in the zero gas measurement.

**For NDIR analyzer**, values of the lower limit of detection are determined from raw calibration data captured from the internal database. See chapter C.3.4.1 on page 62 for downloading the database from GASERA ONE. Detection limits are calculated per channel. If multiple channels are used for analyzing single component, the channel being most sensitive to the target compound is used for LoD calculation.

Limit of detection is calculated by

$$\mathrm{LoD} = \frac{2N_{\mathrm{RMS}}c}{S - S_0},$$

where

$N_{\mathrm{RMS}}$ = standard deviation of raw signal values of the channel from 6 consecutive measurements in the background calibration or measurement,
*c* = concentration of the gas sample in the sample calibration or measurement,

*S* = mean of raw signal values of the channel from 6 consecutive measurements in the sample calibration or measurement,
$S_0$ = mean of raw signal values of the channel from 6 consecutive measurements in the background calibration or measurement.

LoD values can be scaled to correspond 60 s measurement time if the duration of the measurement iteration is shorter than 60 s. Depending on the model and application, other time values can be used. The actual measurement time or response time may be different depending on GASERA ONE model and the gas compound. For example, sticky gases must be measured in time as short as possible because they will continuously adsorb to cell walls and thus the concentration of the gas phase will reduce over time leading to incorrect measurement results.

For example, if the response time is 20 s including the default gas exchange with 1 s bypass time and three 1 s flushes of the sample cell, the analyzer would perform 60 s/20 s = 3 measurement iterations in a minute. The LoD is first calculated using 6 consecutive 20 s measurements, and then scaled by dividing it by the factor

$$\sqrt{\frac{60}{20}} = \sqrt{3}.$$

Repeatability value is the relative standard deviation of 6 consecutive measurement points in calibration raw signals. This method is applied for both types of analyzers, laser and NDIR. It is the ratio of the standard deviation $\sigma(6)$ to the mean $\bar{S}(6)$ of raw signal values of the channel in the calibration

$$\mathrm{RSD} = \frac{\sigma(6)}{\bar{S}(6)}.$$

Acceptance criteria for LoD are defined in specifications of the GASERA ONE model or unit. Typical acceptance criteria for repeatability is < 2 %.

### B.6.2.4 Linearity

Linearity is demonstrated by measuring at least three different concentrations of one compound over its linear dynamic range. Example table is in Figure 14**Error! Reference source not found.** below.

**Linearity test**

| Gas | Sample concentration [ppm] | Measured concentration* [ppm] |
|---|---|---|
| HCl | 2.0 | 1.98 |
| HCl | 5.0 | 4.97 |
| HCl | 10.0 | 9.97 |

*Method: Average of 5 consecutive measurements

**Figure 14. Example of linearity section of the test sheet.**

The “Measured concentration” value is the mean of 5 consecutive measurement results. It is recommended to measure 3 to 5 concentration steps covering the dynamic range for the application. In each step, readings must be stabile before results can be used for the demonstration, or the concentration has no trend anymore.

Acceptance limit for linearity test is ± 5 %. With reactive or sticky gases, the acceptance limit is considered on case-by-case basis.

Measurement range is 0 ppm…100 ppm, or up to five orders of magnitude from the limit of detection.

> *Note: Never use higher concentrations than maximum allowed values defined in Safety A.2 on page 8. Some gas compounds in high concentrations may cause permanent damage of the instrument.*

### B.6.2.5 Measurement response time

Measurement response time is the duration of a measurement cycle. The measurement includes all phases or

- the default gas exchange depending on the analyzer type
- the pressure adjustment
- signal acquisition from all channels with their default CIT values defined in Measurement parameters section

The time took by the automated laser wavelength calibration is taken into account by reporting average measurement response time for laser analyzers. Wavelength calibration is done in every 5th measurement.

**Measurement response time**

XX seconds with 3 gas exchange cycles, channel integration times (CIT) according to “Parameters” table above.

**Figure 15. Example of measurement response time section of the test sheet.**

### B.6.2.6 Calibration gases

Calibration gases table lists gas samples used for the test measurement or calibration. See example in Figure 16**Error! Reference source not found.Error! Reference source not found.** below. Table lists compounds, their concentrations and accuracy of sample concentration. Samples are mixed with nitrogen, $N_2$, or with nitrogen and water if moisturized sample is required.

**Calibration gases and concentrations**

| Gas | Concentration [ppm] | Accuracy* |
|---|---|---|
| N2 | 100 % | Purity: grade 6.0 |
| HCl* ** | 3.0 | ± 3% |
| H2O** | 20 000 | ± 2% |

*Defined by the gas vendor
**Accuracy by Gasera sample generation system

**Figure 16. Example of calibration gases section of the test sheet.**

### B.6.3 Other test measurements

#### B.6.3.1 Ambient air measurement

Other measurements are used for testing GASERA ONE products in some cases. Results are not reported in the test sheet.

Ambient air measurement is an easy test to check that the analyzer gives reasonable readings from the ambient air. It can be used for example after calibration and test measurements to see if reproducibility and accuracy are reasonable and to flush out any traces of the calibration gases.

#### B.6.3.2 Cross-interference measurements

Cross-interference tests are used to demonstrate how the analyzer can discriminate components having overlapping absorption spectra. Cross-interferences are very typical in NDIR technology because the channel widths are rather wide, but some laser source based analyzers may also have cross-interferences. Amount of cross-interference depends on the model, the unit and compounds.

Effects of cross-interference is tested by measuring samples having both cross-interfering compounds present. At least two different mixing ratios are used to check the span. Usually, it is most useful to check interference between gases typically present in the application. For example, HCHO has a small interference with water so the testing mixtures could be

1. 500 ppb of HCHO in nitrogen
2. 500 ppb of HCHO and 10 000 ppm of water in nitrogen.

If the compensation of the cross-interference is working well, the HCHO concentration should change only a little even when high concentration of water is present.

#### B.6.3.3 Response time by zero-span test

Zero-span testing is usually used when determining the response time with sticky gases. This test requires also special equipment for generating the gas samples. Successful sampling of sticky gases requires special expertise to minimize sampling errors. Purpose of this test is to measure response of the analyzer, not the sampling system.

In the test, step response is measured by exchanging between span sample and zero sample. In the span step, a known concentration of sample gas is measured for a certain period. It is followed by the zero step, where the sample is a zero gas.

Test requires two separate sample lines

1. For span gas, such as certain concentration of the desired compound
2. For zero gas, such as nitrogen or wet nitrogen

Sample flows in both lines are kept constant to ensure the stable sample concentrations. The sample tube connected to the analyzer is exchanged in every step. Test procedure is defined in **Error! Reference source not found.Error! Reference source not found.** below.

**Table 7. Zero-span test procedure for response time of sticky gases.**

| Step | Sample | Measurement time |
|---|---|---|
| 1 | Zero | 10 min, or more if gas is very sticky |
| 2 | Span | 10 min, or more if gas is very sticky |
| 3 | Zero | 10 min, or more if gas is very sticky |
| 4 | Span | 10 min, or more if gas is very sticky |
| 5 | Zero | 10 min, or more if gas is very sticky |
| 6 | Span | 10 min, or more if gas is very sticky |
| 7 | Zero | 10 min, or more if gas is very sticky |

### B.6.4 Evaluating the need for recalibration

If bad accuracy or other need (for example long calibration interval) for recalibration is suspected, it is recommended to perform following tests before proceeding to recalibration:

1. Run ambient air test. If water or other component present in ambient air (for example $CO_2$) readings are not reasonable, recalibration may be needed.
2. Fix possible errors if there are error messages.
3. Run a calibration check with span gas. It is recommended to use span gas concentration close to calibration concentration. Calibration concentrations can be found in Test Sheet delivered with the analyzer. There is no need to perform a calibration check for all calibrated components. It is recommended to perform a calibration check with a gas that is relatively easy to sample (for example $CH_4$ with NDIR if possible). Use DEFAULT measurement task. For more information and analyzer-specific instructions, contact Gasera customer support.
4. Basic guideline for standard gas calibration check is that recalibration is required if analysis error is > ±5 % after signal is completely stabilized.
5. Recalibrate the analyzer following the instructions given in the Calibration section B.5 in this manual.

# Part C. Diagnostics and repair

## C.1 About diagnostics and repair

This part contains fault and error diagnostics and then repair actions typically requiring opening the instrument covers. This part starts by describing the instrument architecture or technical layout in general. Purpose is to help the service personnel to locate sub-modules inside the GASERA ONE products. Then, diagnostics guidance in high level is presented with complete listing of error codes. Finally, instruction for repair actions, such as replacing modules, are given.

*Before making any service to GASERA ONE products, refer to competence and safety requirements in Part A.*

## C.2 Instrument architecture

### C.2.1 Technical layout

Purpose of this chapter is to present GASERA ONE system architecture or technical layout in level that service is possible. Additionally, this chapter should help in locating the sub-modules. Following figures present examples of technical layouts of few GASERA ONE models. Other product models differ from these, but most sub-modules are similar and can usually be recognized using these example drawings.

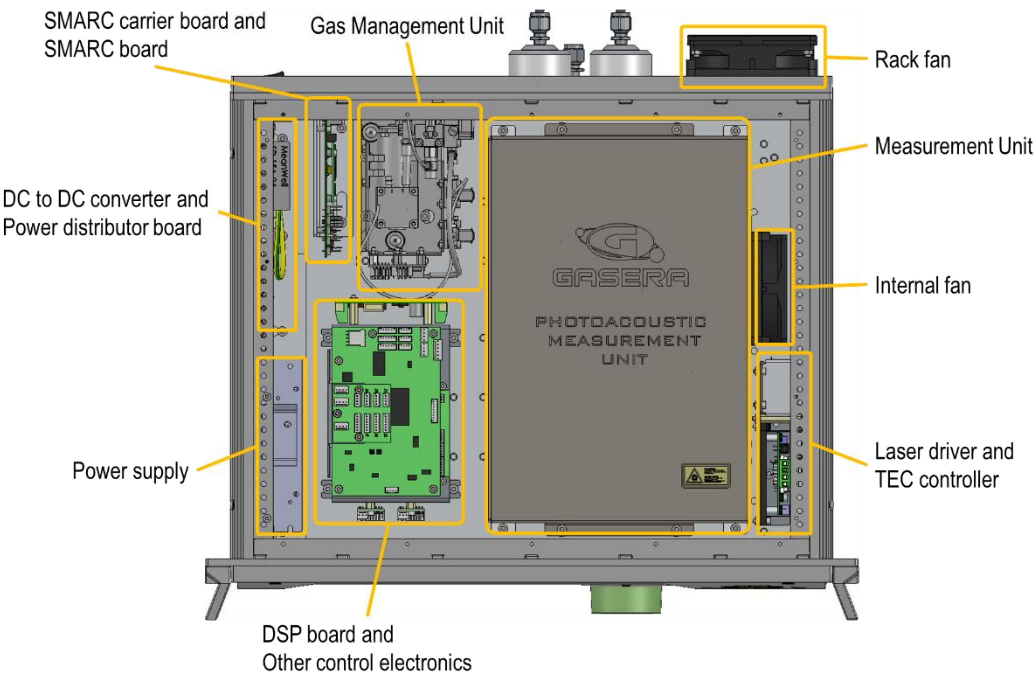



**Figure 17. Instrument architecture or technical layout of GASERA ONE FORMALDEHYDE.**

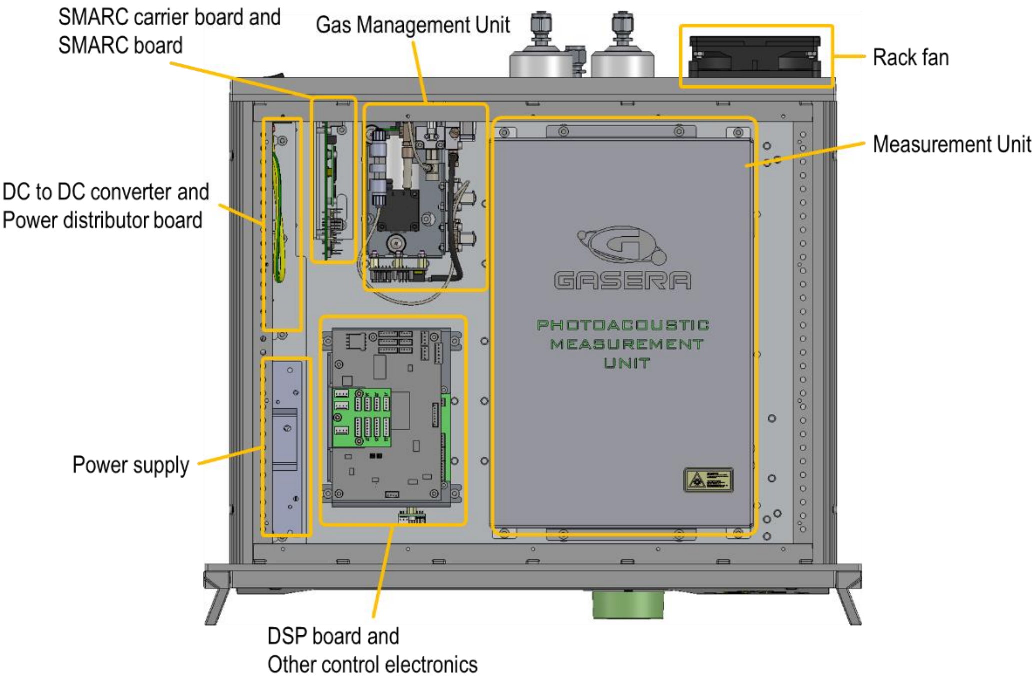



**Figure 18. Instrument architecture or technical layout of GASERA ONE product with DFB butterfly HHL packaged laser source.**

## C.2.2 Submodules

### C.2.2.1 Platform and power supplies

GASERA ONE platform is a submodule including the rack hull, instrument covers, the front panel with GASERA ONE button and the screen, power supplies and the instrument base plate where all other submodules will be mounted. The power supplies include the power supply, DC-to-DC converter and Power distributor board. The platform is similar in most GASERA ONE products, but some variation may have been done for some applications. See Figure 17 and Figure 18 for examples about the main parts of the GASERA ONE platform.

### C.2.2.2 Gas Management Unit

Gas Management Unit is a complete submodule that exchanges the sample gas and adjusts the sample pressure in the photoacoustic cell. The vacuum pump and pressure sensor are in this unit. Gas Management Unit also includes electronics for reading pressure sensor and for controlling valves and the pump. Gas Management Unit pictures are presented with its replacement instructions in chapter C.4.3 on page 73.

Complete pneumatic diagram of GASERA ONE including Gas Management Unit is presented in chapter C.2.3 on page 37.

*Never try to service or repair Gas Management Unit. It must be replaced by a factory tested spare part.*

### C.2.2.3 Measurement Unit

Measurement unit is thermally insulated module having protective covers inside GASERA ONE unit. Depending on the model, the Measurement Unit contains PA Module, infrared source, controls for infrared source, DSP board, thermal insulation and purge output. Example of Measurement Unit is presented in the following figure.

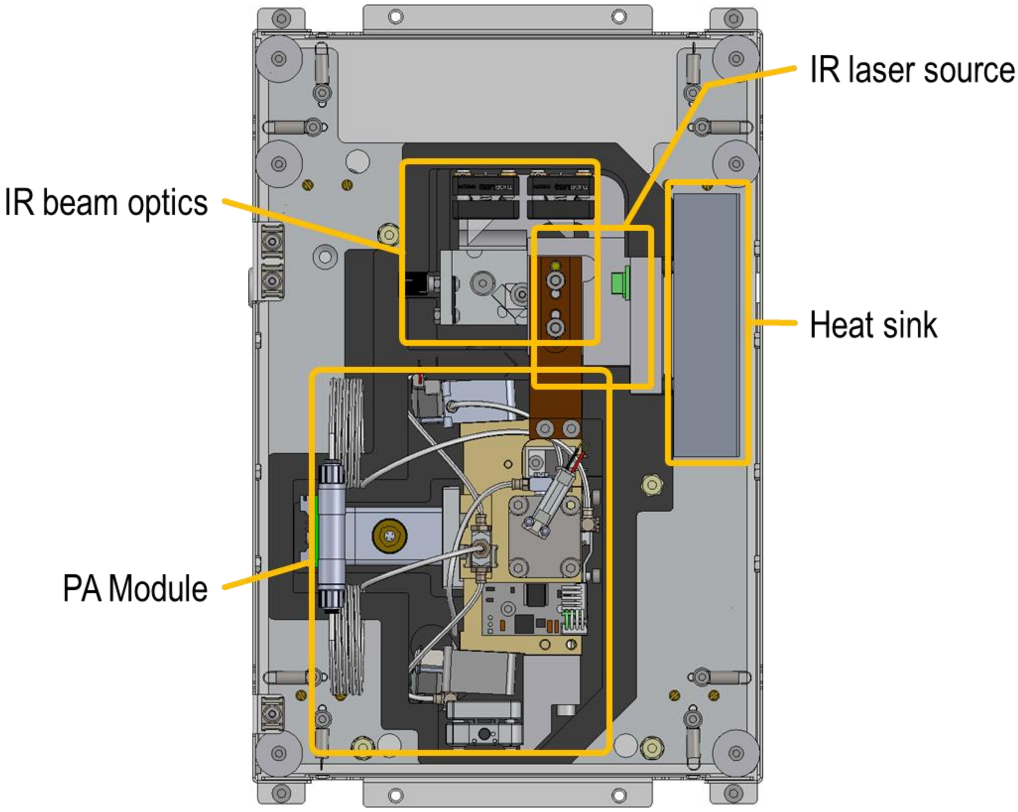



**Figure 19. Technical layout of the Measurement Unit of the GASERA ONE product in Figure 17.**

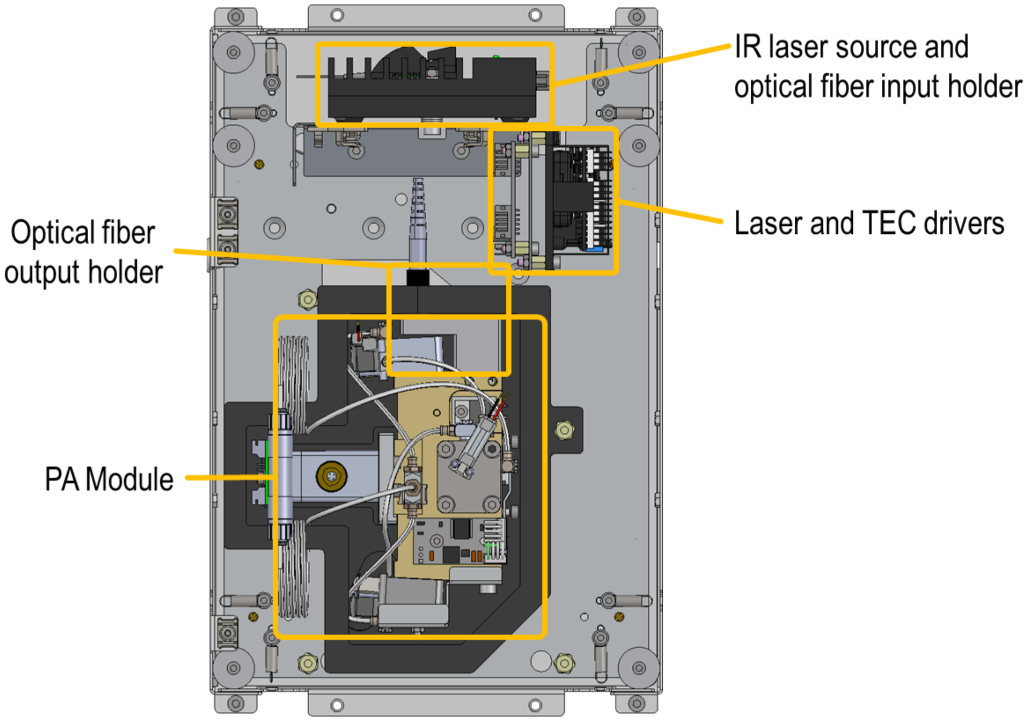



**Figure 20. Technical layout of the Measurement Unit of the GASERA ONE product in Figure 18.**

### C.2.2.4 PA Module

PA Module is the heart of the GASERA ONE analyzers. It contains the photoacoustic detector including the sample cell and readout interferometer. The cantilever pressure sensor is in the cell. The cell has all necessary gas valves for gas exchange and optical windows for passing modulated light into the cell for generating the photoacoustic signal. The readout interferometer reads the motion of the cantilever pressure sensor. GASERA ONE products have different PA Modules optimized for the light source they are coupled with. Figure 21 presents an example of the PA Module used for infrared laser sources.

Replacing PA Module is instructed in chapter C.4.4 on page 77.

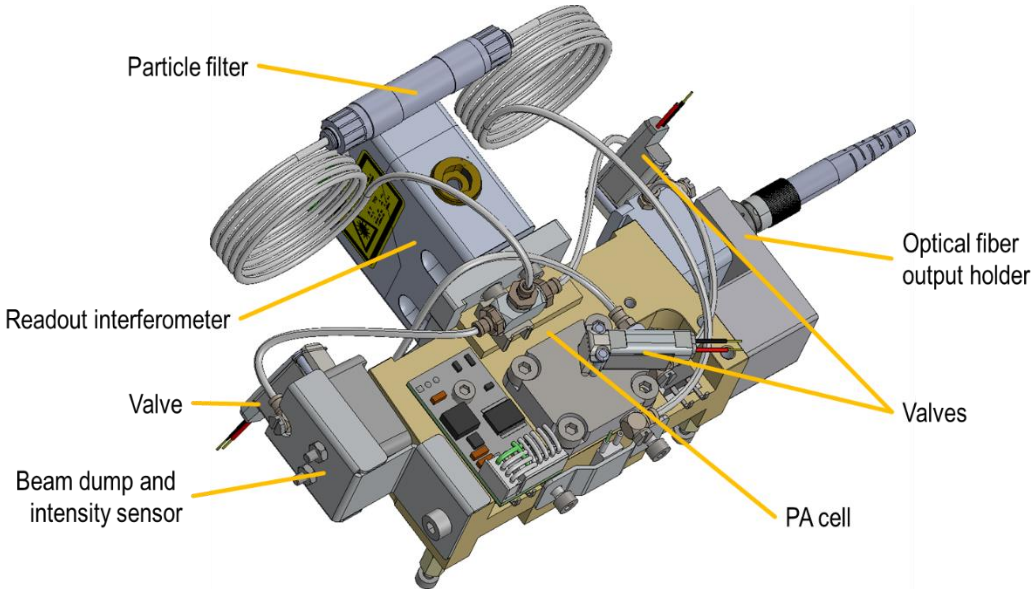



**Figure 21. Schematic drawing of the PA Module for infrared laser sources.**

> *Never try to service or repair PA Module. It must be replaced by a factory tested spare part.*

### C.2.3 Pneumatics diagram

Pneumatics diagrams of GASERA ONE products are illustrated in Figure 22 and Figure 23. The difference between those is the factory preassembled Nafion™ tube inside the unit for ensuring adequate moisture level in the sample required in certain models and applications.

Depending on the model, GASERA ONE pneumatics system has two completely separated gas lines:

1. Line for sample gas
2. In certain models: line for purging the Measurement Unit (MU)

The sample gas line has two modules:

1. PA Module
2. Gas Management Unit

These two modules are available as complete spare parts. Parts of these modules cannot be serviced. In addition to PA Module and Gas Management Unit, the sample gas line has other components and parts which are serviceable.

Gas Management Unit exchanges the sample gas and adjusts the sample pressure in the photoacoustic cell. The vacuum pump and pressure sensor are in this unit. Gas Management Unit also includes electronics for reading pressure sensor and for controlling valves and the pump. Additional particle filter is included to avoid cell contamination if a filter in an inlet is missing or broken.

PA Module contains the photoacoustic cell and a bypass line which can be used to ensure that the sample taken to the cell is as fresh as possible. The input valve for sample gas is attached directly to the cell to minimize the distance from the sampling point to the sample cell. The bypass line is a tube connecting input and output valves of PA Module. For setting the gas exchange parameters, see User Manual.

Purge line is available in certain models. Purge has tubing from rear panel to Measurement Unit. This line has no valves or other active components. See User Manual for guidance how to use the purge.

Internal gas tubes are polytetrafluoroethylene, PTFE, except the pressure sensor tube which is short polyurethane, PU, tube. The filters right after SAMPLE 1 IN and SAMPLE 2 IN locate inside particle filter cartridges in the rear panel.

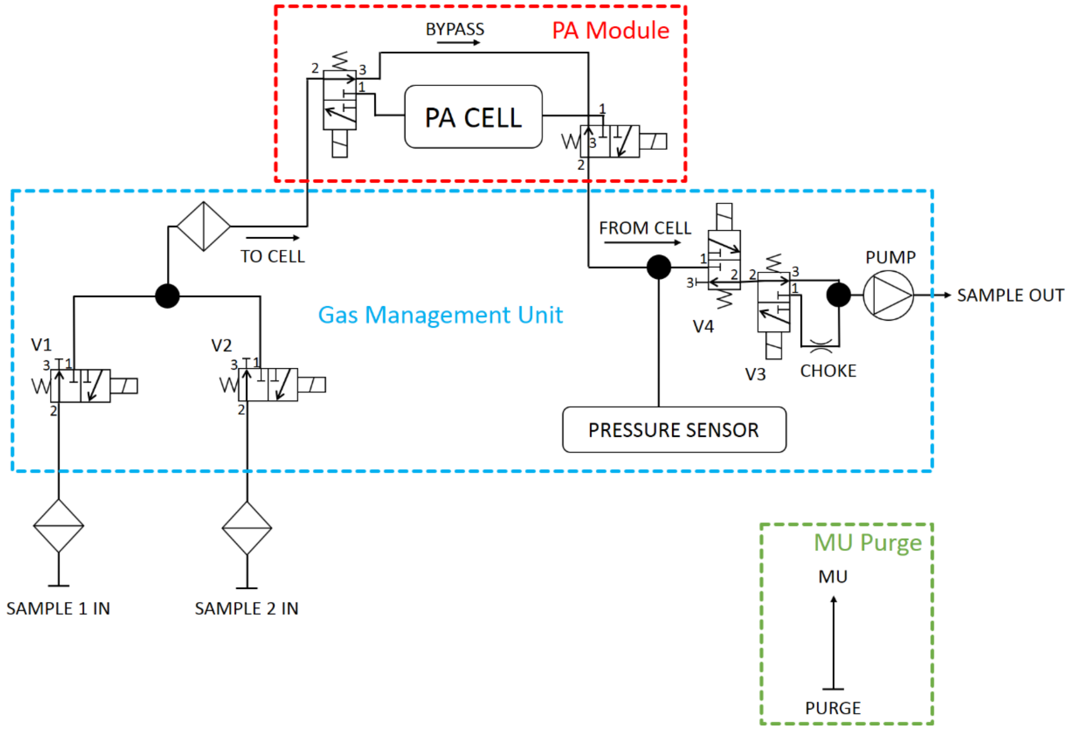



**Figure 22. Pneumatics diagram of GASERA ONE standard gas exchange system.**

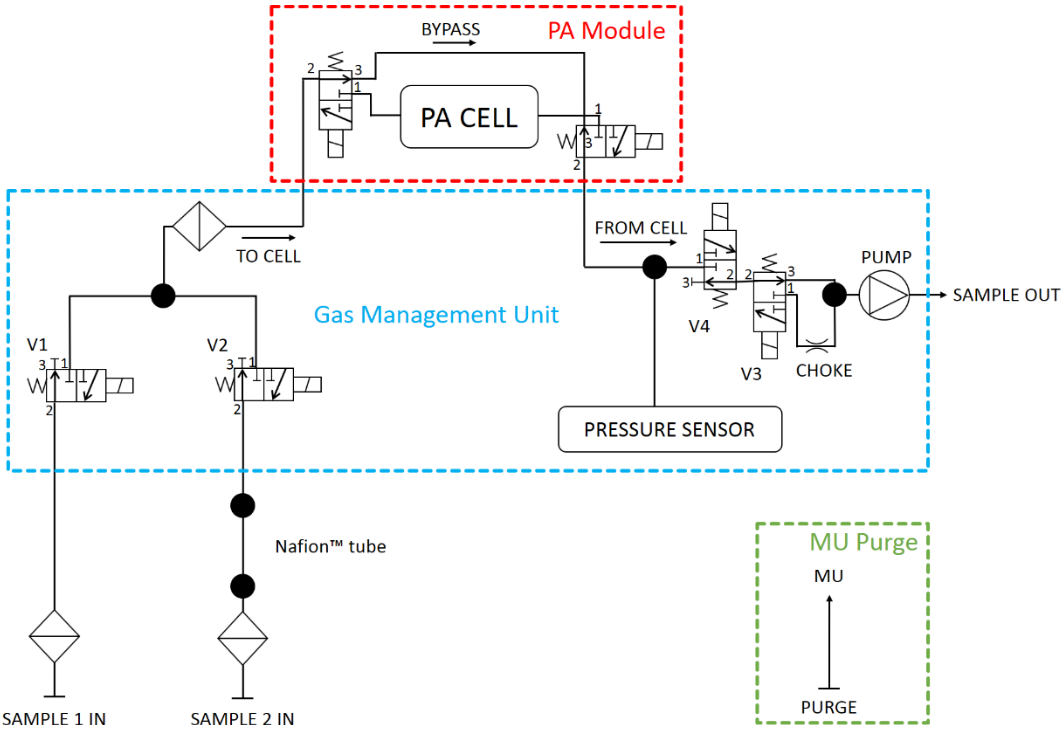



**Figure 23. Pneumatics diagram of GASERA ONE gas exchange system with an optional Nafion™ tube inside the unit.**

*Never startup the device without all particle filters properly installed. Small particles may break the PA Module.*

*Never try to service or repair Gas Management Unit. It must be replaced by a factory tested spare part.*

*Never try to service or repair PA Module. It must be replaced by a factory tested spare part.*

## C.2.4 Electronics HW diagram

The following electronics hardware diagram is an example of a GASERA ONE product illustrating the electronics in high level. The hardware diagram is very model dependent because different infrared sources require different driving and powering boards.

For more detailed electronics description of your product, refer to Cable specification of the product. If anything is unclear, contact to customer support for obtaining detailed unit specific information.

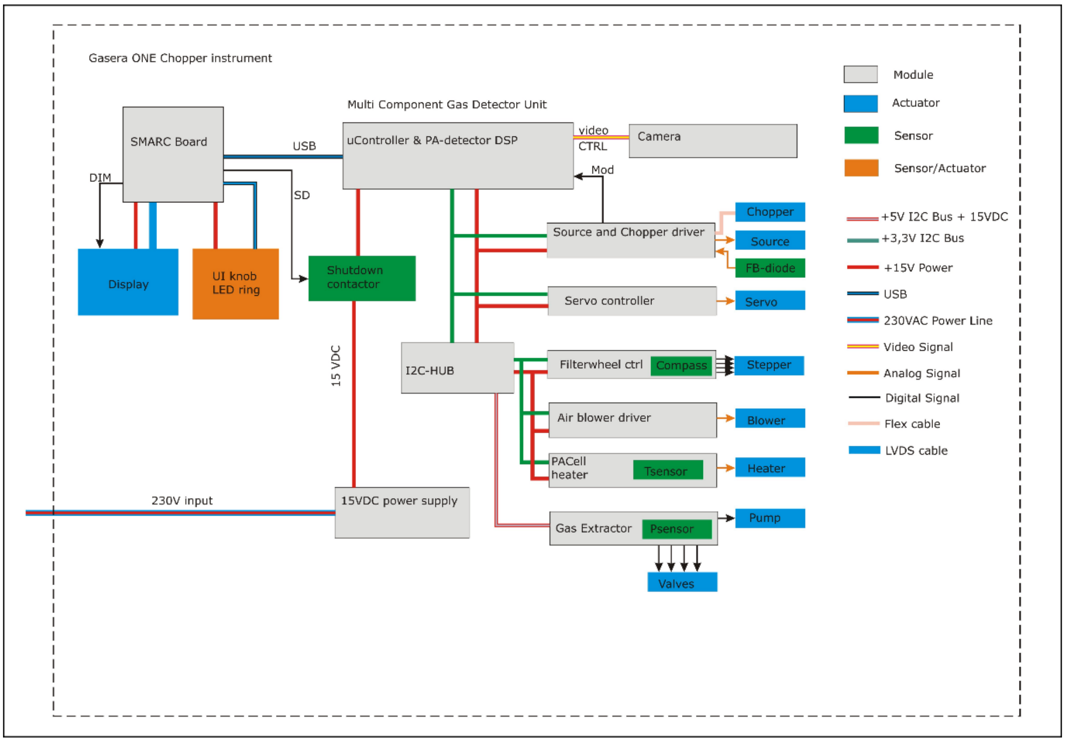



**Figure 24. Example of electronics hardware diagram of GASERA ONE products. Electronics is very model dependent, so this diagram may differ from unit to unit.**

## C.2.5 Software architecture

Major components of GASERA ONE software are

1. Firmware
2. Scribblets
3. Middleware, database and UI

The software is layered to different levels and is very modular. The three components listed above are updated separately. However, in most cases these modules have dependencies so usually all modules must be updated in the same time.

The firmware is the lowest level of software. It contains all software on integrated circuits handling the internal communication and basic functionality. Scribblets are device specific low-level software modules providing functionality such as measurement routine, self-test and gas exchange. Scribblets also communicate between the firmware and middleware. Middleware has the internal state machine, error management module, internal database management, gas analysis module and provides interface for user interface layer. The database is internal storage for calibration data, measurement results and parameters. User interface handles the display and GASERA ONE button, and delivers information between the human user and middleware.

# C.3 Diagnostics and troubleshooting

## C.3.1 Procedure for diagnostics

GASERA ONE products have internal error management system that will detect most of faults, which helps the troubleshooting. However, GASERA ONE analyzers are rather complicated systems, so sometimes finding a fault will require care and expertise. Error situations are categorized as

1. Starting up failures, for example: the instrument does not start at all or a failure during normal startup.
2. Error code: Instrument provides an error code that can be used for troubleshooting and repair. The error code could occur during the self-test or in operation.
3. Other unexpected behavior, for example: the unit can measure but the performance or accuracy is not as expected or something else seems to be wrong.

These are covered in the following subchapters.

Chapter C.3.4 guides how to work with the customer support by exporting internal databases and error logs from device and setting up the remote connection so that the customer support can access the device via internet to find out and fix the fault.

## C.3.2 Diagnostics during instrument startup

### C.3.2.1 Startup procedure and error diagnostics

The startup procedure of GASERA ONE contains all actions from powering on the unit to displaying the main menu or continuing the last measurement. It is best to first read the startup section in User Manual before proceeding to this chapter describing the startup in more details.

Flow chart in Figure 25 presents main stages of GASERA ONE startup. Purpose of the chart is to help error diagnostics, so minor details are excluded for clarity. Table 8 describes the stages in more detail and refers to more information and error diagnostics.

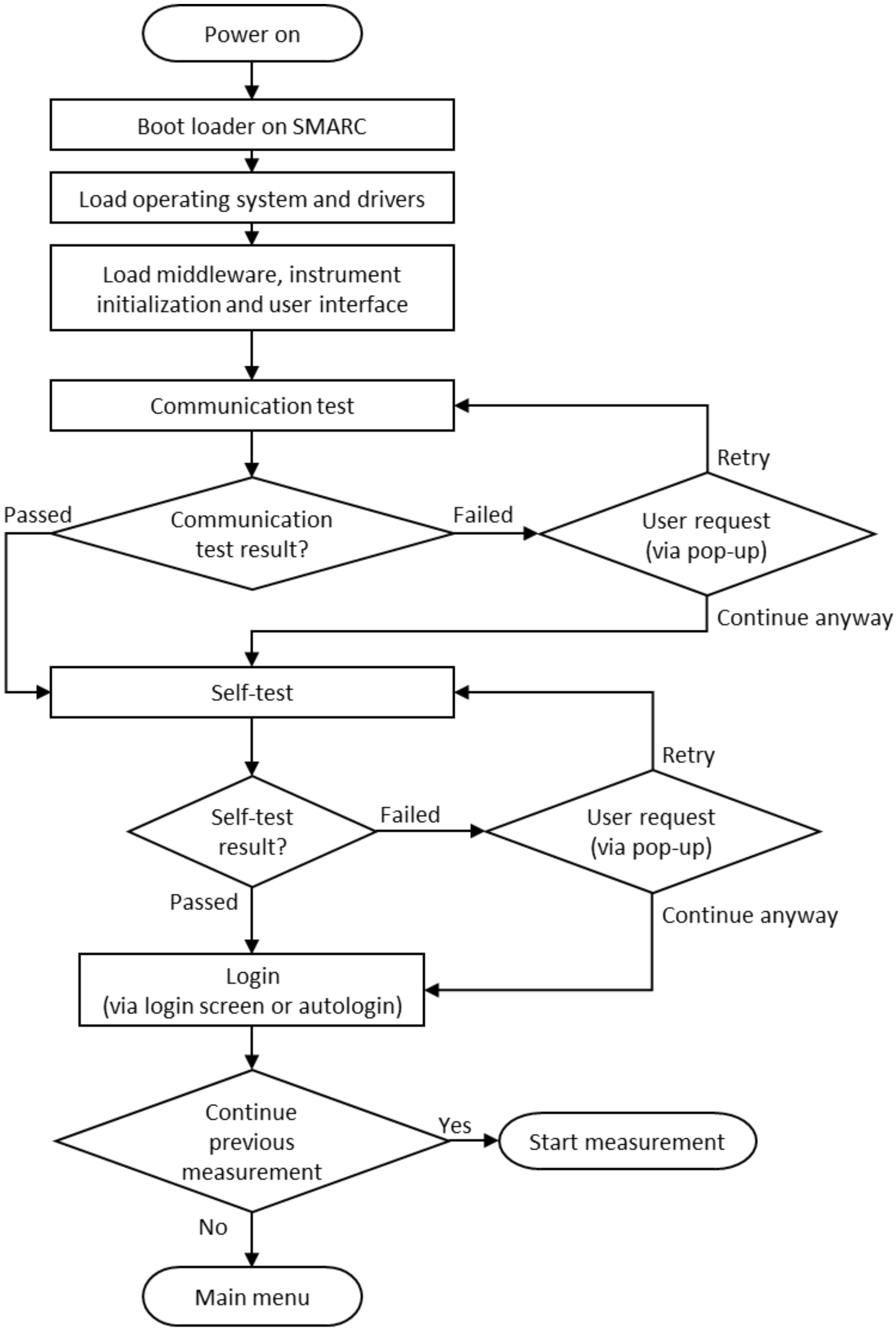



**Figure 25. Main stages of the GASERA ONE startup procedure. Minor details are excluded for clarity. Stages are described in Table 8.**

**Table 8. Descriptions of main stages of GASERA ONE startup procedure. See the startup flow chart in Figure 25.**

| Stage | Description |
|---|---|
| Power on | Instrument is powered. |
| Boot loader on SMARC | SMARC miniature pc starts boot loader of the embedded Linux operating system. |
| Load operating system and drivers | Operating system and required drivers are loaded. |
| Load middleware, instrument initialization and user interface | Operating system loads the middleware handling the high-level functionality of the unit such as the internal state-machine.<br><br>Middleware initializes the instrument by using model and unit specific parameters. See the following table for major differences between models.<br><br>Finally, the user interface processes are started. |
| Communication test | Middleware tests the internal communication bus by starting to ping the µDSP module for 10 s intervals. If no response is received before sending the next ping, an error is triggered.<br><br>If error is detected, the unit asks to retry test or continue. If “Continue anyway” is selected, the unit continues startup procedure and passes possible error codes forward. For error codes, see chapter C.3.3 on page 45. |
| Self-test | Middleware runs automated self-test routine which tests the most critical functions of the unit.<br><br>Automated self-test is described in detail in chapter C.3.2.3 on page 44.<br><br>If error is detected, the unit asks to retry test or continue. If “Continue anyway” is selected, the unit continues startup procedure and passes possible error codes forward. For error codes, see chapter C.3.3 on page 45. |
| Login | User interface request to add login credentials. If auto-login is enabled, the system automatically logs in with predefined credentials.<br><br>The unit will restart the last measurement and display the measurement screen if this feature is enabled from Setup menu. |
| Main menu | The main menu is displayed. |

**Table 9. Notes about GASERA ONE model specific instrument initialization, see also Table 8 and Figure 25.**

| Model | Instrument initialization notes |
|---|---|
| Chopper | Infrared source is powered on. |
| Pulse | Infrared source is ramped up by gradually increasing its voltage. Ramp up increases the source life-time. Error management starts to monitor the source after ramp-up. |
| EC-QCL | Infrared source is powered on. |
| DFB | Laser temperature stabilization is started. When stable conditions are reached, the laser current is ramped up. If critical error is detected, the laser will be ramped down to prevent permanent damage. |

| | |
|---|---|
| QCL | Similar initialization as with DFB models but the QCL is not ramped up in startup.<br><br>QCL will be ramped up when measurement is started and ramped down when the measurement is stopped, or severe error is detected. |

#### C.3.2.2 Instrument will not start, or no powers

If the instrument does not start at all when the power on switch is pressed to on position, check the following

1. Power cord is in condition and properly plugged
2. The fuse is not broken
3. Power cables from power switch to the Power module are connected and not broken
4. Power cables from Power module to SMARC are connected and not broken
5. Check if power switch is broken and replace the switch is necessary
6. If the previous parts are ok, replace Power module.

#### C.3.2.3 Automated self-test

During startup, GASERA ONE always runs a self-test to ensure proper functionality of critical components. The self-test may be started also manually from Setup menu, see User manual for details. For startup procedure illustration, see Figure 25 on page 42.

Self-test has three main stages as illustrated in Figure 26. The test runs always all stages. If an error occurs, the UI shows a popup dialog about Self-test failed and provides user possibility to continue anyway or repeat the test. Error codes detected by self-test are reported in the Active error list in Setup menu and stored to error logs.

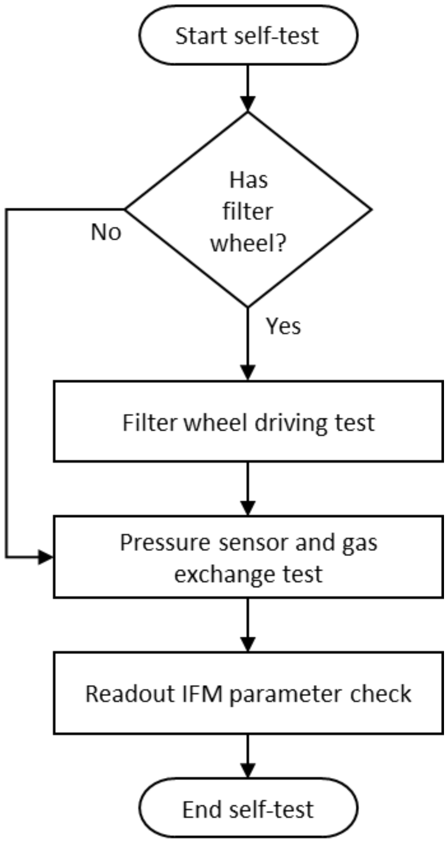



**Figure 26. Flow chart of automated self-test in high level. Individual tests and error state handling are not presented for clarity.**

Filter wheel driving test checks if the filter wheel can be rotated freely and to a correct position. The test is run only if the unit has filter wheel installed such as in Pulse and Chopper models.

Pressure sensor and gas exchange test includes testing of pressure sensor, pump functionality, a blockade in sample inputs, a leak in integral gas line or sample cell and a blockade in the internal gas lines.

Readout IFM parameter check checks the condition of the PA Module. The test can detect a failure in the readout interferometer itself or a broken cantilever.

If self-test is passed, the device continues its operation normally. In case of failure, self-test runs through all stages and finally returns an error code which is presented in Active errors list. Diagnostics is based on these error codes which are listed in chapter C.3.3 with repair actions.

## C.3.3 Error codes

### C.3.3.1 Severity levels

GASERA ONE has an internal error management system which indicates the user about error situations. If an error state is active, the indication bar on the top right corner of the display has an icon and the color of the LED ring around the GASERA ONE button is changed. Errors occurred in the past three days are logged to internal error logs which can exported using instructions in chapter C.3.4.

Errors are categorized to the four severity levels depending on their effects. The severity level defines how GASERA ONE system reacts to an error state and how the user can try to fix the error. GASERA ONE always acts according to the error of which severity level is the highest of all active errors. The severity levels are defined in Table 10. See also chapter about the error log in User manual.

Error codes and their severity levels are listed in Table 11 in the next chapter. The table includes also more detailed descriptions of each error and repair instructions.

**Table 10. Error severity levels.**

| Severity level | Effects | User action required |
|---|---|---|
| Warning | Operation of the device is fully allowed.<br><br>Some warnings give an early warning for service needed in near future.<br><br>Warnings have no effect or only a minor effect on the performance. | No immediate action required.<br><br>Warnings are typically temporary and GASERA ONE fixes most of these situations automatically.<br><br>For the best performance for e.g. in calibration, wait until the warning message disappears. |
| Retry | Device rejects the current measurement and will restart the iteration. For data integrity, the iteration counter is not increased and data from rejected measurement will not be stored.<br><br>This might occur for e.g. if the scanning of EC-QCL source fails. | No action required. |
| Blocker | A new measurement cannot be started until the blocking condition has ceased. An ongoing measurement can be continued.<br><br>Typical cause is that some sensor value is too much out of bounds.<br><br>There is a blocker right after startup before the gas cell has reached the target temperature. | Wait until a blocker message disappears.<br><br>Blockers are typically temporary and GASERA ONE fixes most of these situations automatically.<br><br>If the blocker persists more than 30 minutes, restart the device and wait again. If the blocker does not disappear, write down error code(s) and contact a local distributor or Gasera customer support. |
| Critical | A new measurement cannot be started until the critical error condition has ceased. An ongoing measurement will stop.<br><br>Typical cause is that some sensor value is critically out of bounds or there is a HW communication error.<br><br>The GASERA ONE button LED ring becomes red. | Restart the device.<br><br>If the problem reoccurs, write down the error code(s) and contact a local distributor or Gasera customer support. |
| Fatal | Major malfunction. Operation of the instrument is not possible. | Shutdown the device immediately. |

| Severity level | Effects | User action required |
|---|---|---|
| | The GASERA ONE button LED ring becomes red. | Write down the error code(s) and contact a local distributor or Gasera customer support. |

#### C.3.3.2 Error code listing and repairs

The following table lists error codes, corresponding severity levels, UI messages, error descriptions and repair instructions. Error codes are in hexadecimal format. Same codes are displayed in Error log, Error list and internal error logs. Table includes all error codes from every GASERA ONE model. Some codes are used only in certain models.

Column “Repairing” has repair instructions and tips. Perform repair actions in the order they are listed. Before trying the next action, try if the error has ceased. In most cases, it is useful to restart the unit for couple of times, to see if the error reoccurs.

The table has high level repair instructions. Thus, in most cases, more information is required. More detailed instructions can be found from this manual, User Manual or manufacturing documents.

Before making any repairs inside the GASERA ONE unit, especially when handling electronics or optics, ensure that you are familiar with warnings and required expertise and training defined in Part A.

**Table 11. Error conditions and repairing**

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| 8001 | WARNING | Cell temperature is low | Photoacoustic cell temperature is slightly below the target.<br><br>Typically occurs after startup when the system has not yet reached a stable condition.<br><br>Temperature may also fluctuate during normal operation. | Wait until the temperature has been stabilized.<br><br>Ensure that the environment temperature is in operational temperature limits specified in User Manual. |
| 8002 | WARNING | Cell temperature is high | Photoacoustic cell temperature is slightly over the target.<br><br>See Error 8001. | See Error 8001 |
| 8003 | BLOCKER | Cell temperature is low | Photoacoustic cell temperature is too low for reliable measurements.<br><br>Typically occurs after startup when the system has not yet reached a stable condition. | Wait until the temperature has been stabilized. This may take even 30 minutes.<br><br>Ensure that the environment temperature is in operational temperature limits specified in User Manual.<br><br>If problem persists for at least over an hour, move the unit to a room having about 20°C–25°C temperature.<br><br>Check that all electrical connections to PA Module are in condition.<br><br>Replace PA Module. |
| 8004 | BLOCKER | Cell temperature is high | Photoacoustic cell temperature is too high for reliable measurements.<br><br>See Error 8003. | See Error 8003. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| 8005 | CRITICAL | Cell temperature is critically high | Photoacoustic cell temperature is equal to or higher than 55°C which is too high to operate. | Restart the unit to try if the error will disappear.<br><br>Ensure that the environment temperature is in operational temperature limits specified in User Manual.<br><br>Test if the error disappears when the environmental temperature is 20–25°C.<br><br>Replace PA Module. |
| 8006 | CRITICAL | Cell temperature is critically low | Photoacoustic cell temperature is equal to or lower than 10°C which is too low to operate. | See Error 8005. |
| 8013 | WARNING | Cell pressure is incorrect | Sample pressure in the cell deviates approximately 1% from the target value.<br><br>This level pressure deviation has only minor effect to measurement result. | If the error occurs frequently, run self-test for several times to detect any leaks in the internal sample line of the unit.<br><br>If the self-test does return any errors about leaks, there is no need to repair.<br><br>If self-test returns an error, proceed according to the error code. |
| 8011 | CRITICAL | Sampling line is blocked | There is a blockade in the sampling line last used. The blockade prevents a proper gas flow and thus taking a new sample.<br><br>This is detected during a measurement. | Remove any possible blockades from the incoming gas line. For e.g. if the gas cylinder valve has been closed in a closed incoming sample line, this error may happen.<br><br>Disconnect tubes from SAMPLE 1 IN and SAMPLE 2 IN, and run the self-test by restarting the unit or manually. If the self-test passes, the blockade is in the sample line outside the unit.<br><br>Otherwise, see error codes returned by the self-test. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| 8012 | CRITICAL | Measured overpressure in sampling line | The absolute pressure in the incoming gas is more than 1.2 bar. The pressure is checked in the start of every gas exchange.<br><br>The operation has been stopped to protect the pressure sensor in the photoacoustic cell. | Ensure that the pressure of the incoming gas is below safe limits given in User Manual. |
| 8015 | CRITICAL | Gas exchange module is offline | The Gas Management Unit does not respond, or the response is unreasonable. | Check that all electrical connections to Gas Management Unit are in condition.<br><br>Check that all gas tubes to Gas Management Unit are in condition and in place. Check that any tube has not been pressed between cover plates etc.<br><br>If any above repairs have been done, run the self-test by restarting the unit or manually.<br><br>Replace the Gas Management Unit. |
| 8021 | BLOCKER | Source intensity is too high | Source intensity is too high for reliable measurements.<br><br>Intensity may fluctuate during normal operation. | Wait if the intensity is within acceptable limits and the error disappears. The device adjusts the intensity automatically.<br><br>If the problem occurs frequently, contact to the customer support for more accurate diagnostics and further repair instructions. |
| 8022 | BLOCKER | Source intensity is too low | Source intensity is too low for reliable measurements.<br><br>Intensity may fluctuate during normal operation. | See Error 8021. |
| 8023 | WARNING | Source intensity is too high | Source intensity is slightly higher than the target value.<br><br>Intensity may fluctuate during normal operation. | See Error 8021. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| 8024 | WARNING | Source intensity is too low | Source intensity is slightly lower than the target value.<br><br>Intensity may fluctuate during normal operation. | See Error 8021. |
| 8025 | WARNING | Source voltage is too low | Source voltage is lower than the target value.<br><br>Source voltage may fluctuate during normal operation.<br><br>Used only in GASERA ONE Chopper products. | Wait until the voltage is within acceptable limits and the error disappears. The device adjusts the voltage automatically.<br><br>If the problem occurs frequently, the broadband infrared source is aged and must be replaced. Contact to the customer support for instructions. |
| 8026 | BLOCKER | Source is warming up | The infrared source is warming up to its target temperature.<br><br>Typically occurs after device startup.<br><br>Used only in GASERA ONE Pulse units during the source ramp-up. | Wait until the error code disappears after the source has warmed up. |
| 8031 | WARNING | Chopper period is short | Period of the rotating mechanical chopper is slightly shorter than the target value.<br><br>Chopper period may fluctuate during normal operation without remarkable effect on measurement results.<br><br>Used only in models equipped with a mechanical chopper. | If the error occurs frequently, the chopper motor or its controller electronics must be changed.<br><br>Contact to the customer support for further repair instructions. |
| 8032 | WARNING | Chopper period is long | See Error 8031. | See Error 8031. |
| 8041 | WARNING | Laser temperature is too low | The temperature of the infrared laser mount is slightly too low but still acceptable.<br><br>Typically occurs after startup when the system has not yet reached a stable condition. | The device adjusts the laser mount temperature automatically, so this error should disappear after a while. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | Laser temperature may fluctuate during normal operation. | |
| 8042 | WARNING | Laser temperature is too high | The temperature of the infrared laser mount is slightly too high but still acceptable.<br><br>Typically occurs after startup when the system has not yet reached a stable condition.<br><br>Laser temperature may fluctuate during normal operation. | See Error 8041. |
| 8043 | BLOCKER | Laser temperature is too low | The temperature of the infrared laser mount is too low for reliable measurements.<br><br>Typically occurs after startup when the system has not yet reached a stable condition.<br><br>Laser temperature may fluctuate during normal operation. | The device adjusts the laser temperature automatically, so this error should disappear after a while. This may take up to 30 minutes.<br><br>If the error occurs frequently, ensure that the environment temperature is in operational temperature limits specified in User Manual.<br><br>Contact to the customer support for further repair instructions. |
| 8044 | BLOCKER | Laser temperature is too high | The temperature of the infrared laser mount is too high for reliable measurements.<br><br>Typically occurs after startup when the system has not yet reached a stable condition.<br><br>Laser temperature may fluctuate during normal operation. | See Error 8043. |
| 8045 | WARNING | Source intensity is too low | Source intensity is slightly lower than the target value. | See Error 8021. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | Intensity may fluctuate during normal operation. | |
| 8046 | RETRY | Laser not available | Retries to startup the infrared laser module within the same iteration.<br><br>Used for e.g. in models having EC-QCL laser. | The device restarts the measurement iteration, which usually solves the issue and measurement process continues automatically.<br><br>If the laser fails to restart after multiple tryouts, the device ends up to the error state 8048. |
| 8047 | WARNING | Laser restart has occured | Gives a warning to the user that infrared laser module has been restarted.<br><br>See Error 8046. | See Table 10. |
| 8048 | CRITICAL | Laser restart reached maximum count without success | The device has tried to restart the infrared laser for maximum count without getting the laser running properly.<br><br>See Error 8046. | See Table 10.<br><br>Contact to the customer support for further repair instructions. |
| 8051 | CRITICAL | Filterwheel is not turning | System is unable to get the filter wheel position. Incorrect wheel position will lead to incorrect measurement results.<br><br>Used only in models equipped with a filter wheel. | Check that all electrical connections to filter wheel control board and the wheel motor are in place and in condition.<br><br>Check that filter wheel rotates freely and smoothly by carefully rotating it by hand.<br><br>Check that the wheel is not damaged.<br><br>Replace the filter wheel motor or filter wheel control board.<br><br>Note: Recalibration is required after any repair operation for the wheel or its motor. |
| 8061 | WARNING | Laser 1 temperature is too low | Internal temperature of the infrared laser 1 is slightly lower than the target value. | The device adjusts the laser driving parameters automatically, so this error should disappear after a while. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | Typically occurs after startup when the system has not yet reached the stable condition.<br><br>Stabilization may take even 30 minutes depending on the environment temperature and the target temperature for the laser.<br><br>Depending on the model, the unit runs the laser ramp-up on device start-up or after starting a measurement.<br><br>Temperature may also fluctuate during normal operation. | If the error will not disappear after 30 minutes or several restarts, ensure that the environment temperature is in operational temperature limits specified in User Manual.<br><br>Contact to the customer support for further repair instructions. |
| 8062 | WARNING | Laser 1 temperature is too high | Internal temperature of the infrared laser 1 is slightly higher than the target value.<br><br>See Error 8061. | See Error 8061. |
| 8063 | WARNING | Laser 1 locking parameter lower limit reached | Infrared laser 1 frequency locking parameter is slightly lower than the target value.<br><br>Typically occurs after startup when the system has not yet reached the stable condition.<br><br>Stabilization may take even 30 minutes depending on the environment temperature and the target temperature for the laser.<br><br>Depending on the model, the unit runs the laser ramp-up on device start-up or after starting a measurement.<br><br>May occur also occasionally during normal operation. | Ensure that the environment temperature is in operational temperature limits specified in User Manual.<br><br>Ensure that the sample has at least some water in it. Laser locking will not function properly with too dry sample.<br><br>If the error will not disappear after 30 minutes or several restarts, contact to the customer support for further repair instructions. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| 8064 | WARNING | Laser 1 locking parameter higher limit reached | Infrared laser 1 frequency locking parameter is slightly higher than the target value.<br><br>See Error 8063. | See Error 8063. |
| 8066 | BLOCKER | Laser 1 temperature is too low | Internal temperature of the infrared laser 1 is too low for reliable measurements.<br><br>See Error 8061. | See Error 8061. |
| 8067 | BLOCKER | Laser 1 temperature is too high | Internal temperature of the infrared laser 1 is too high for reliable measurements.<br><br>See Error 8061. | See Error 8061. |
| 8068 | BLOCKER | Laser 1 current is too low | Electrical current for infrared laser 1 is too low for reliable measurements. | Probably hardware failure or connection problem in the laser module, the laser sensor or the laser driver.<br><br>Contact to the customer support for further repair instructions. |
| 8069 | BLOCKER | Laser 1 current is too high | Electrical current for infrared laser 1 is too high for reliable measurements. | See Error 8068. |
| 806a | CRITICAL | Laser 1 temperature is critically low | Internal temperature of the infrared laser 1 is too low to operate.<br><br>System has automatically shut down the laser module to prevent permanent damage of the laser component. | If the error will not disappear after several restarts or occurs frequently, ensure that the environment temperature is in operational temperature limits specified in User Manual.<br><br>Contact to the customer support for further repair instructions. |
| 806b | CRITICAL | Laser 1 temperature is critically high | Internal temperature of the infrared laser 1 is too high to operate.<br><br>System has automatically shut down the laser module to prevent permanent damage of the laser component. | See Error 806a. |
| 806c | CRITICAL | Laser 1 current is critically low | Electrical current for infrared laser 1 is too low to operate. | See Error 8068. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | System has automatically shut down the laser module to prevent permanent damage of the laser component. | |
| 806d | CRITICAL | Laser 1 current is critically high | Electrical current for infrared laser 1 is too high to operate.<br><br>System has automatically shut down the laser module to prevent permanent damage of the laser component. | See Error 8068. |
| 806e | CRITICAL | Laser 1 current limit is active | Hardware limit circuit of infrared laser 1 has shut down the laser to prevent too high electrical current and possible permanent damage of the laser component. | If the error will not disappear after several restarts or occurs frequently, ensure that the environment temperature is in operational temperature limits specified in User Manual.<br><br>Contact to the customer support for further repair instructions. |
| 806f | CRITICAL | Laser 1 is disabled due to unstable conditions | The system has shut down the infrared laser 1 module. This follows the previous error message of codes 8061 to 806e. | See other error messages appeared at the same time. |
| 8071 | WARNING | Laser 2 temperature is too low | See Error 8061. | See Error 8061. |
| 8072 | WARNING | Laser 2 temperature is too high | See Error 8062. | See Error 8062. |
| 8073 | WARNING | Laser 2 locking parameter lower limit reached | See Error 8063. | See Error 8063. |
| 8074 | WARNING | Laser 2 locking parameter higher limit reached | See Error 8064. | See Error 8064. |
| 8076 | BLOCKER | Laser 2 temperature is too low | See Error 8066. | See Error 8066. |
| 8077 | BLOCKER | Laser 2 temperature is too high | See Error 8067. | See Error 8067. |
| 8078 | WARNING | Laser 2 current is too low | See Error 8068. | See Error 8068. |
| 8079 | WARNING | Laser 2 current is too high | See Error 8069. | See Error 8069. |
| 807a | CRITICAL | Laser 2 temperature is critically low | See Error 806a. | See Error 806a. |
| 807b | CRITICAL | Laser 2 temperature is critically high | See Error 806b. | See Error 806b. |
| 807c | CRITICAL | Laser 2 current is critically low | See Error 806c. | See Error 806c. |
| 807d | CRITICAL | Laser 2 current is critically high | See Error 806d. | See Error 806d. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| 807f | CRITICAL | Laser 2 is disabled due to unstable conditions | The system has shut down the infrared laser 1 module. This follows the previous error message of codes 8071 to 807e. | See other error messages appeared at the same time. |
| 8083 | CRITICAL | Rack unit internal fan speed is critical | Speed of the cooling fan in the rear panel is too low.<br><br>May lead to over-heating of the unit or instability of the infrared laser source. | Check that all electrical connections to fan controller board and to fan itself are in condition.<br><br>Ensure that the fan can rotate freely.<br><br>Replace the fan. Fan type is defined in manufacturing documents.<br><br>Replace the fan controller board. |
| 8084 | FATAL | Rack unit internal fan speed is fatal | The cooling fan in the rear panel has stopped.<br><br>May lead to over-heating of the unit or instability of the infrared laser source. | See Error 8083. |
| 8087 | CRITICAL | Rack unit internal fan speed is critical | Speed of the cooling fan in the Measurement Unit is too low.<br><br>May lead to over-heating and instability of the infrared laser source. | See Error 8083. |
| 8088 | FATAL | Rack unit internal fan speed is fatal | The cooling fan in the Measurement Unit has stopped.<br><br>May lead to over-heating and instability of the infrared laser source. | See Error 8083. |
| 8090 | CRITICAL | Selftest timeout | Pressure sensor will not return a proper value or any value at all. Sensor is offline or broken.<br><br>Typically detected during the self-test. | Check that all electrical connections to Gas Management Unit are in condition.<br><br>Check that all gas tubes to Gas Management Unit are in condition and in place. Check that any tube has not been pressed between cover plates etc. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | | If any above repairs have been done, run the self-test by restarting the unit or manually.<br><br>Replace the Gas Management Unit. |
| 8091 | CRITICAL | Pressure sensor is not responding | Pressure sensor values do not respond to pumping, or the pressure will not decrease while pump is on. Sensor or pump is offline or broken.<br><br>Typically detected during the self-test. | See Error 8090. |
| 8092 | CRITICAL | Sample input 1 is not responding | Under pressure is pumped to bypass line. Then, the inlet valve is opened and checked if pressure raises back.<br><br>Typically detected during the self-test. | Check that sampling line outside the unit is not blocked. For e.g. disconnect all gas lines from gas inlets when running the self-test. Replace the particle filter inside the cartridge of the inlet and retry the test.<br><br>Replace Gas Management Unit. |
| 8093 | CRITICAL | Sample input 2 is not responding | As error 8092, but for inlet 2. | As error 8092, but for inlet 2. |
| 8094 | WARNING | Internal sample line is leaking | See error 8095. | See error 8095. |
| 8095 | WARNING | Internal sample line is leaking | There is a leak in the internal sample line through the bypass line.<br><br>Usually, this does not have effect to measurement results since this leak does not relate to sample cell.<br><br>If the user desires to minimize leaks, repair could be considered.<br><br>Typically detected during the self-test. | Check that gas tube connections to Gas Management Unit are in condition.<br><br>Replace the Gas Management Unit. |
| 8096 | WARNING | Measurement cell is leaking | There is a small leak in the photoacoustic cell of the PA Module.<br><br>May affect to measurement results. However, if any other error related to sample | Check that gas tube connections to Gas Management Unit are in condition.<br><br>Replace PA Module. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | pressure or cell leakage will not occur, results are affected only slightly.<br><br>Typically detected during the self-test. | |
| 8097 | WARNING | Measurement cell is leaking | See error 8096. | See error 8096. |
| 8098 | WARNING | Sampling line has a blockade | Internal sampling line from SAMPLE 1 IN to SAMPLE OUT via the bypass line is opened and gas is pumped thorough the line. If pressure decreases too low, line has a blockade.<br><br>Typically detected during the self-test. | Check that sampling line outside the unit is not blocked. For e.g. disconnect all gas lines from gas inlets when running the self-test.<br><br>Replace the particle filter inside the cartridge of the inlet and retry the test.<br><br>Ensure that any gas tube is not bended or pressed anywhere inside the unit.<br><br>Replace the Gas Management unit. |
| 8099 | WARNING | Sampling line has a blockade | As error 8098 but for SAMPLE 2 IN. | See error 8098. |
| 8101 | WARNING | Sampling line has a blockade | Internal sampling line from SAMPLE 1 IN to SAMPLE OUT via the sample cell is opened and gas is pumped thorough the line. If pressure decreases too low, line has a blockade.<br><br>Typically detected during the self-test. | If this error occurs in self-test, the blockade is most probably in PA Module which must be replaced.<br><br>If the error occurs some other case, repair according to Error 8098 before replacing PA Module. |
| 8102 | WARNING | Sampling line has a blockade | As error 8101 but for SAMPLE 2 IN. | See error 8101. |
| 8103 | CRITICAL | MU IFM laser intensity is too low | The signal from the optical microphone too weak for reliable measurements. This might also indicate aging of laser of the optical microphone.<br><br>Typically detected during the self-test. | If this occurs without Error 8105, ensure that all electrical connections to PA Module are in condition.<br><br>If this will not help, there is probably a component fault in the optical microphone of PA Module.<br><br>Replace PA Module. |
| 8104 | WARNING | MU IFM laser intensity is low | The signal from the optical microphone is weak but measurements can be continued. | Monitor if this error message starts to gradually occur more frequently. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | This is an early warning about aging of the optical microphone.<br><br>Typically detected during the self-test. | Prepare to replace PA Module in near future.<br><br>See also Error 8103. |
| 8105 | CRITICAL | Measurement cell is offline | PA Module does not respond in timeout period.<br><br>May follow the error messages 8103 and 8104.<br><br>Typically detected during the self-test. | Ensure that all electrical connections to PA Module are in condition.<br><br>If occurs without errors 8103 or 8104, there is probably a permanent fault in PA Module.<br><br>Replace PA Module. |
| 8106 | CRITICAL | Measurement cell is offline | See error 8105. | See error 8105. |
| 8110 | WARNING | Multipoint Sampler under pressure | Too low absolute pressure in the sampling line of Multipoint Sampler unit.<br><br>Typically caused by a blocked particle filter in some of the inlets. | Replace particle filters in the inlet ends. |
| 8111 | CRITICAL | Multipoint Sampler over pressure | Too high absolute pressure in the sampling line of Multipoint Sampler unit.<br><br>Measurements will stop to prevent permanent damage of the PA Module. | Decrease the sampling pressure. |
| 8112 | CRITICAL | Multipoint Sampler not connected | GASERA ONE has not detected the Multipoint Sample unit or the connection is lost. | Contact to the customer support for more accurate diagnostics and further instructions. |
| 8113 | CRITICAL | Multipoint Sampler invalid input | Invalid internal input for the Multipoint Sampler unit. | Contact to the customer support for more accurate diagnostics and further instructions. |
| E001 | CRITICAL | UART communication not working | An internal communication bus has been disconnected.<br><br>May occur for e.g. if serial connection between SMARC board and µDSP is broken or if connection between UI and middleware software modules is broken. | If the error will not disappear after several restarts or occurs frequently, check that:<br>• internal power cables are connected<br>• DSP board has green light on<br>• USB cable connects the SMARC board to DSP board.<br>If cabling is ok, reload DSP firmware and middleware and UI. |

| Code | Severity level | Message in UI | Description | Repairing |
|---|---|---|---|---|
| | | | If this error occurs during device startup, the startup stops to “Communication error” before starting the self-test. See also chapter C.3.2.1 on page 41. | Contact to the customer support for further instructions. |
| E002 | WARNING | Device disk space low | There is less than 10% of free disc space left.<br><br>Note: Function “Compressing service database” will not complete if there is less disc space than database size because the systems tries to first make a backup copy of database before committing any changes. In that case, remove old measurement data and try again. | Backup measurement data from Results menu.<br><br>Free up disc space by removing old measurement data. |
| E003 | CRITICAL | Device disk space is critically low | There is less than 5% of free disc space left.<br><br>No new data can be stored to the disc, because the system needs some free space to work properly.<br><br>See also Error E002. | See Error E002. |

### C.3.4 Copying internal databases

#### C.3.4.1 Copying databases from internal memory

Middleware version 1.5.0 or newer, internal databases and error logs are copied to USB mass storage device using Export service database function is Setup menu.

Sharing the service database procedure:
1. In GASERA ONE: Stop all measurements
2. Connect USB memory to GASERA ONE
3. Go to Main Menu >Setup > Instrument status > Compress service database (this file includes the database and debug logs)
4. Select Export service database to transfer the database to the USB memory
5. When “OK” message appears, the USB memory can be removed from the GASERA ONE
6. Send the file via a suitable file transfer system e.g. WeTransfer:
    a. Go to https://wetransfer.com/
    b. Click "Add your files" and choose the compressed service database file.
    c. Click "..." and choose "link" ("link" is preferred because spam filters can reject the emails)
    d. Click "Transfer".
    e. Link appears. Copy the link and send it for us via email.

Files may be rather large, so it is recommended to archive files using for example ZIP/RAR/7zip and then use a file sharing service, for sending them to the customer support. Archiving tools usually include options for password protection and data encryption, if protection of confidential measurement data is required.

#### C.3.4.2 Copying databases manually

This applies only with Middleware version 1.4.9 or older. In later software versions, databases are copied to USB memory as guided above.

If copying internal databases and error logs, as instructed in the previous chapter, have been failed, they can be copied manually. Copying procedure depends on the software version installed to the unit.

Required tools are:
- Network cable for connecting the pc to GASERA ONE unit
- Sftp client software, such as FileZilla from https://filezilla-project.org
- Login credentials obtained by requesting them from customer support

Copying process:
1. In GASERA ONE: Stop all measurements
2. In GASERA ONE: Go to Network setting is Setup menu. Write down the device IP address from either DHCP or manually set IP.
3. In GASERA ONE: Go to main menu
4. Sftp client: Launch the sftp client program
5. Sftp client: Connect to the ONE unit using following login:

   a. Host: IP address of the unit
   b. Enter username and password obtained from the customer support
   c. Port: 22
6. Sftp client: Accept to connect without a server's host key
7. Sftp client: Copy following files or folders to pc
   a. Files (usually 3 files): /home/root/debug_log_*.txt
   b. Folder: /usr/lib/oneupdate/
   c. Folder: /usr/share/shared-mw/
8. Sftp client: Disconnect the client
9. Pc: Pack the copied files to a zip archive before sending them to support.

### C.3.5 Setting up the remote connection for support

In some cases, it is useful to setup a remote connection to the GASERA ONE unit for the customer support. The remote connection can be used for example to

- Support experts to check, how the device is working and diagnose a possible problem
- To update software manually
- To repair software, parameters, configurations etc.
- Other service procedures and diagnostics inaccessible from user interface

> *Establish only secured connection when using public networks. The manager of local network is responsible for the connection security. See also chapter A.2 on page 8.*

Remote access connection process:

1. PC with windows installed (either win7 or win10)

   a. Only LAN adapter enabled i.e. if PC is having WLAN and LAN, disable WLAN adapter. If WLAN and LAN are both enabled, some of our tools will not be able to connect into system, therefore only LAN is used

   b. User account that has admin rights is required (to install needed support tools to the PC by us)

2. TeamViewer Quick Support tool installed into the PC

   a. https://www.teamviewer.com/en/download/windows/ (use private option)

3. Check router settings
   a. DCHP enabled
   b. connected to internet
      i. port 50013 (outbound) enabled
      ii. port 50014 (inbound) enabled
   c. NOTE: No need to arrange separate router, if your intranet can be used. All devices just need to be connected to the same network and receiving IP addresses from the same DHCP server, and that the network should have internet connection

4. Connect GASERA ONE instrument to router (LAN connection)

5. Connect PC to router (LAN connection)

6. In GASERA ONE, enable DHCP from Setup > Network > enable DCHP check box

7. Make sure both the PC and GASERA ONE are in the same network (ping Gasera ONE instrument via PC)

8. When all above is done
    a. Start TeamViewer Quick Support tool
    b. Send "YourID" and "Password" provided by TeamViewer to us
    c. Provide us the GASERA ONE IP address

## C.4 Repairs/Repairing submodules

### C.4.1 Opening the instrument covers

#### C.4.1.1 Preparations

*Before repairing anything inside GASERA ONE, see safety instructions in chapter A.2 on page 8.*

Required equipment

- Set of hex wrenches in millimeter sizes

#### C.4.1.2 Opening the top cover

Opening the top cover:

- Unscrew the 4 pcs of M4x6 mm screws on the instrument sides and lift the cover up. See Figure 27 for locating screws.
- Unscrew 18 pcs of M3x5 screws of the ESD plate and lift the plate. See Figure 28 for locating screws.

Covering the instrument: Follow opening instructions in reverse order. Secure all screws to keep ESD shielding functional.

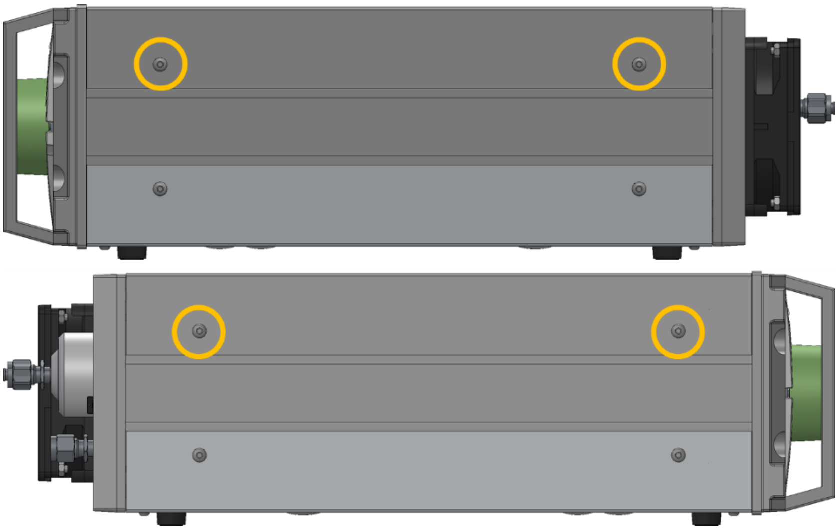


**Figure 27. Location of top cover screws.**

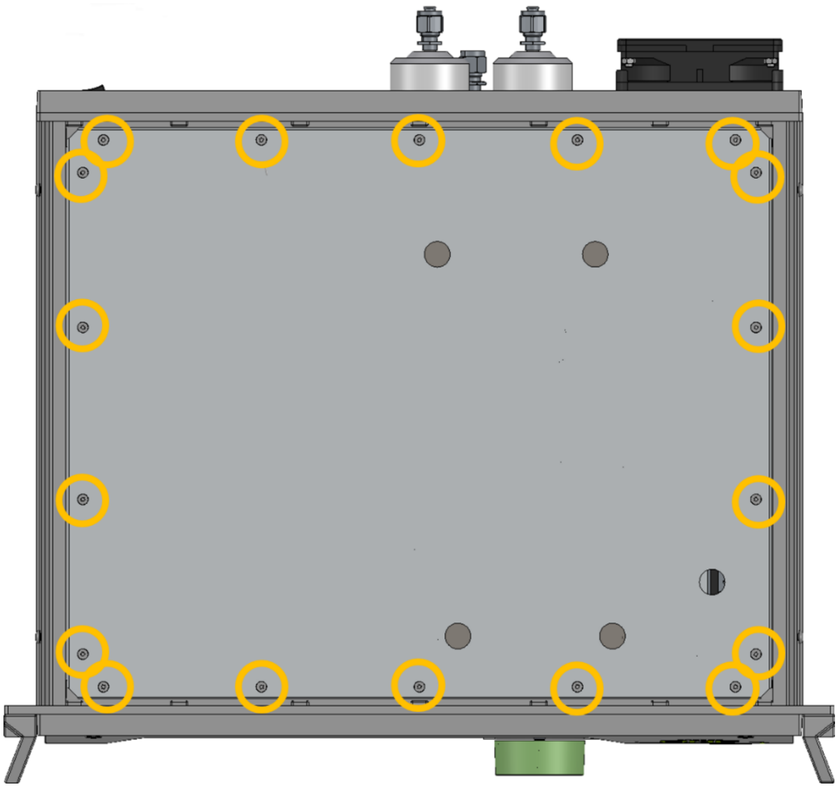


**Figure 28. Location of screws of ESD plate.**

#### C.4.1.3 Opening the bottom cover

Opening the bottom cover:

- Unscrew the 4 pcs of M4x6 mm screws on the instrument sides. See Figure 29 for locating screws.
- Unscrew 3 pcs of M3x8 mm screws on the bottom. See Figure 30 for locating screws.

- Lift the cover up.

Covering the instrument: Follow opening instructions in reverse order.

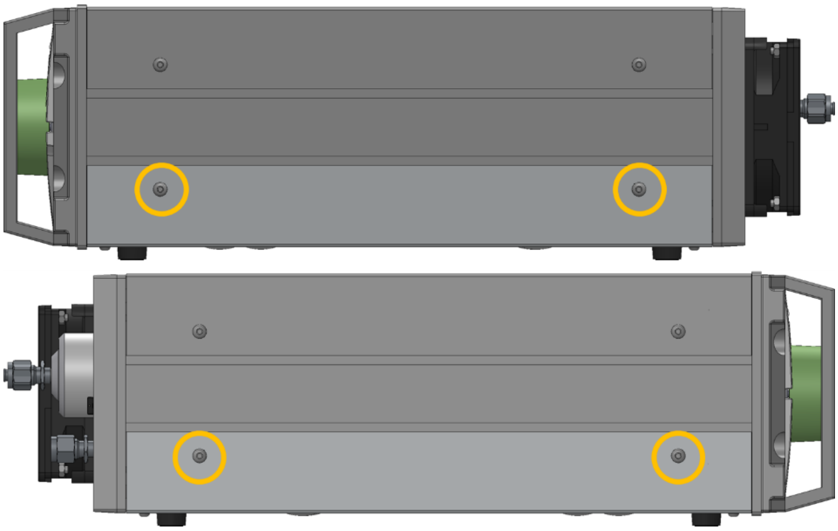


**Figure 29. Location of bottom cover screws on instrument sides.**

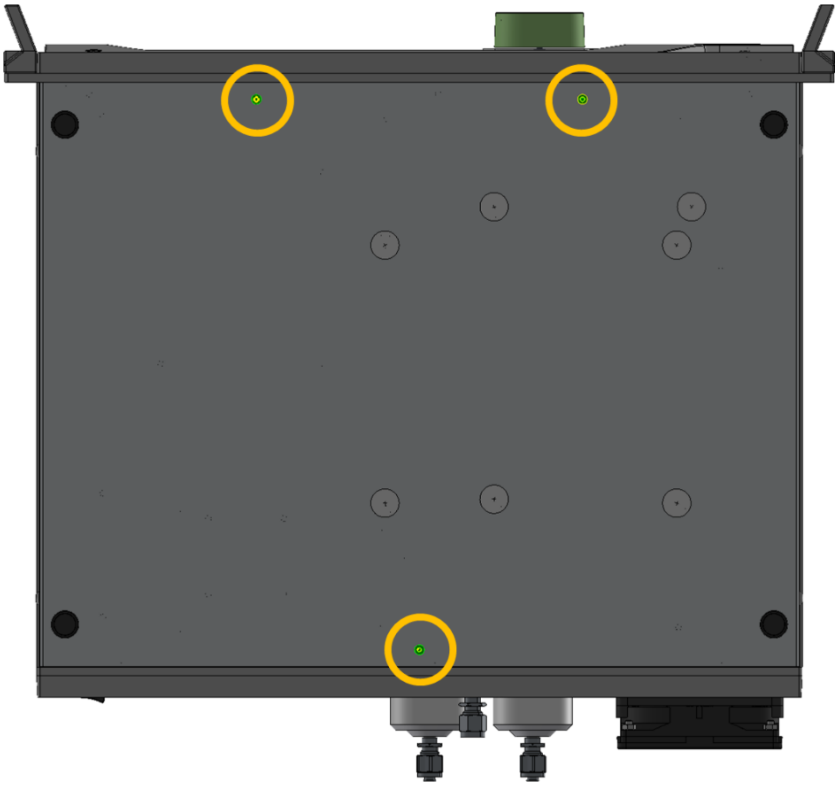


**Figure 30. Location of bottom cover screws on the instrument bottom.**

### C.4.1.4 Opening the MU cover and insulation

Opening Measurement Unit (MU) cover and removing thermal insulation is required for example in replacing PA Module. Mechanical structure of the MU depends on the

GASERA ONE model, so for example screws and insulators will differ. The following guide provides few examples.

> *Before repairing anything inside GASERA ONE, see safety instructions in chapter A.2 on page 8.*

> *Lasers are typically very ESD sensitive, so ESD protection must be used always when operating inside the Measurement Unit.*

Opening the MU cover and insulation:

1. Open the top covers as in chapter C.4.1.2 on page 64.
2. Usually, MU cover has a label "Measurement Unit" but this depends on the GASERA ONE model. If unclear, see drawings in chapter C.2 on page 33.
3. Open 4 pcs of M4x6 mm screws and carefully lift the cover up without stressing any electrical wires or gas tubes. See Figure 31 for example of the screw location.
4. Removing the thermal insulation:
    a. Open 4 pcs of M4x10 mm screws of insulation cover plate. See Figure 32 and Figure 33 for examples of screw locations.
    b. Lift the cover plate and top insulation layers. Figure 34 and Figure 35 present examples of two types of insulators.

Installing the insulators and the MU cover:

1. Repeat above removal instructions is reverse order.

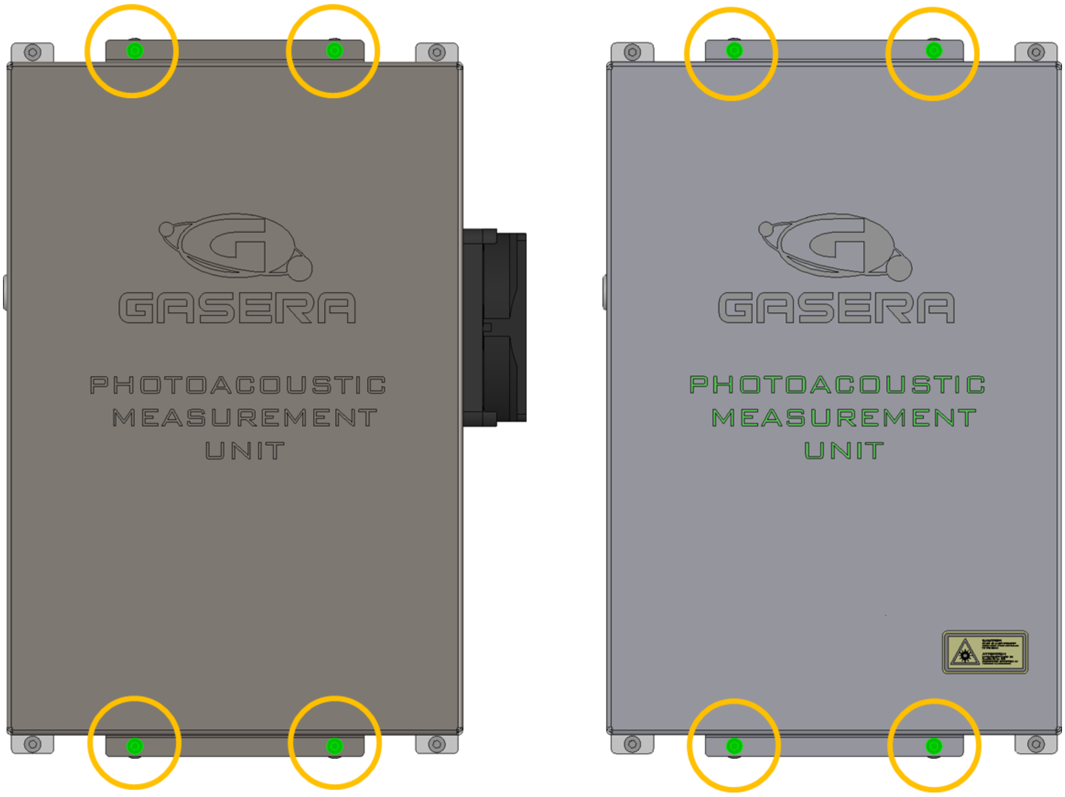



**Figure 31. Examples for the location of cover screws of the MU.**

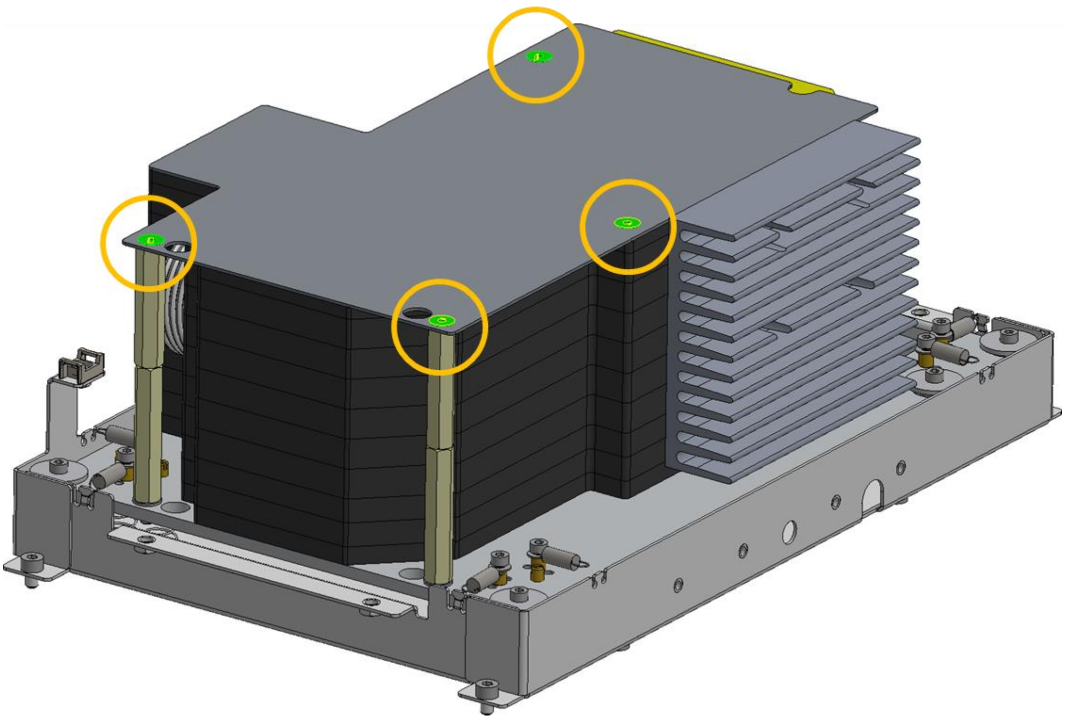


**Figure 32. Example for location of insulation cover plate screws of the MU.**

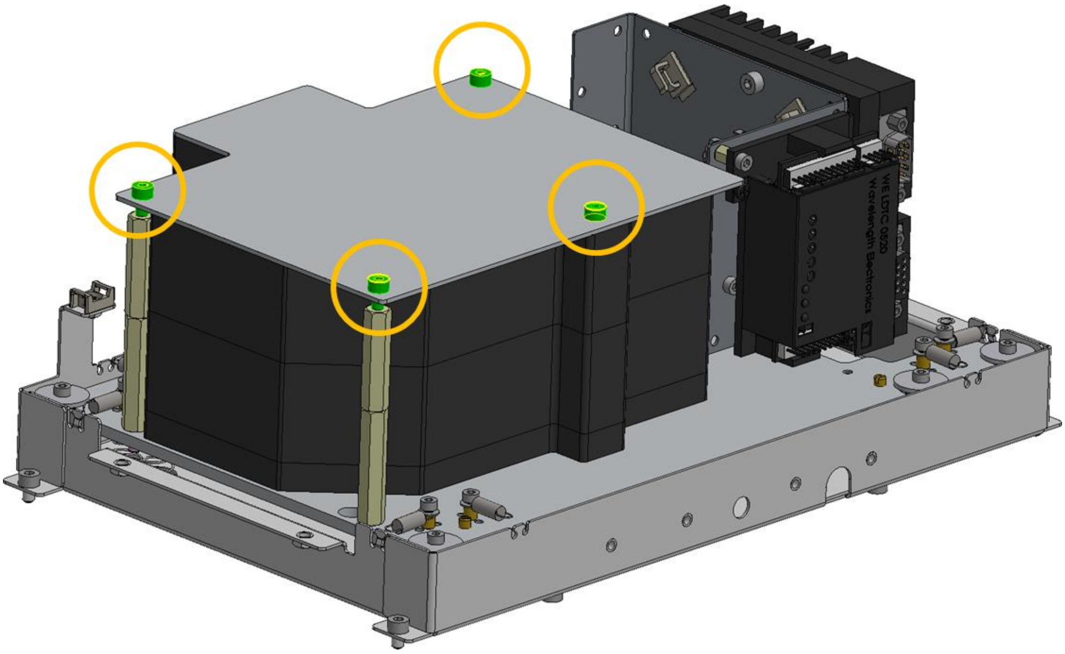


**Figure 33. Example for location of insulation cover plate screws of the MU.**

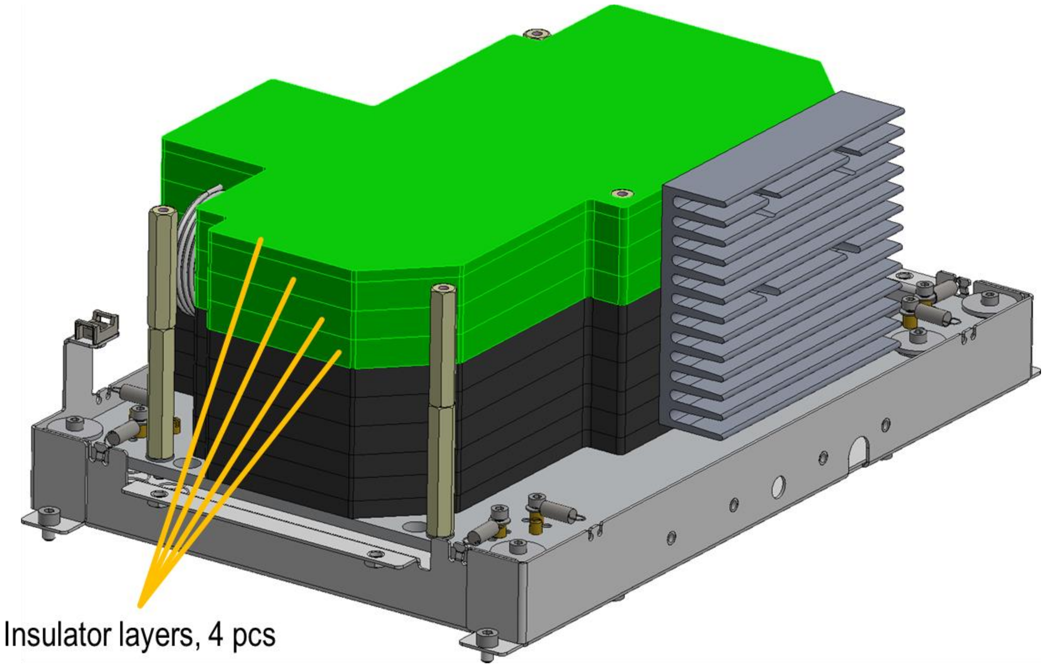



**Figure 34. Example of insulator layers to be removed before repair actions inside MU. Same MU as is Figure 32.**

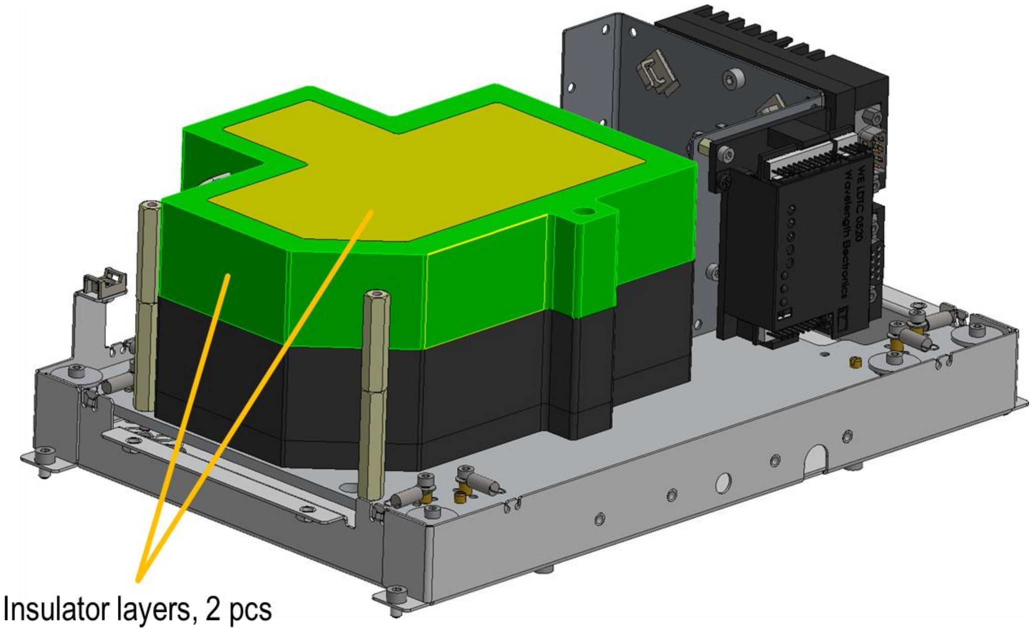



**Figure 35. Example of insulator layers to be removed before repair actions inside MU. Same MU as is Figure 33.**

## C.4.2 Replacing the backup battery

### C.4.2.1 Preparations

> *Before repairing anything inside GASERA ONE, see safety instructions in chapter A.2 on page 8.*

The backup battery on the SMARC carrier board is replaced every few years. Battery specification is in the list of consumables in chapter B.3 on page 10.

Required tools:
- Set of hex wrenches in millimeter sizes
- A tool having a small tip may be useful

Opening the instrument top cover is guided in chapter C.4.1 on page 64.

### C.4.2.2 Locating the battery

The backup battery is on the SMARC carrier board typically located as in Figure 36. The battery location on the board is presented in Figure 37.

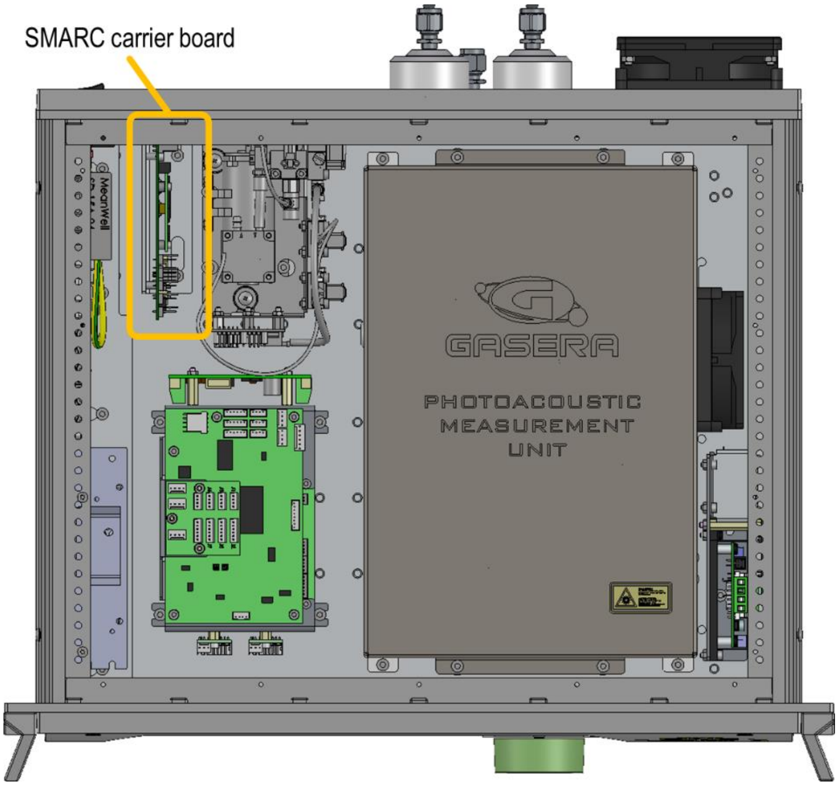



**Figure 36. Typical location of SMARC carrier board in GASERA ONE. Exact location depends on the model.**

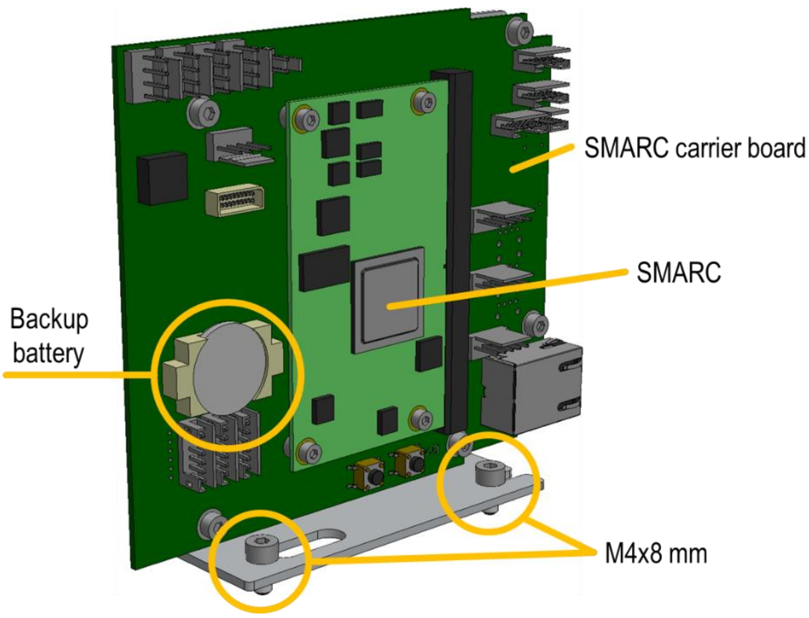



**Figure 37. The backup battery on the SMARC carrier board and screws for the board mount.**

### C.4.2.3 Replacement

<u>Replacing the backup battery</u>

1. Depending on the model, loosen 2 pcs of M4x8 mm screws of board holder plate to have better access to the battery
2. Remove the old battery
3. Carefully install new battery (see specification: chapter B.3 on page 10).
4. Check that pins are in the correct position:
    a. Correctly installed battery looks like in Figure 38
    b. Examples on typical mistakes with battery installation are in Figure 39
5. Place the board with its holder back to its correct location and secure mounting screws.

*Note: If the backup battery is incorrectly installed, the backup battery may not work at all or the battery lifetime may be shortened.*

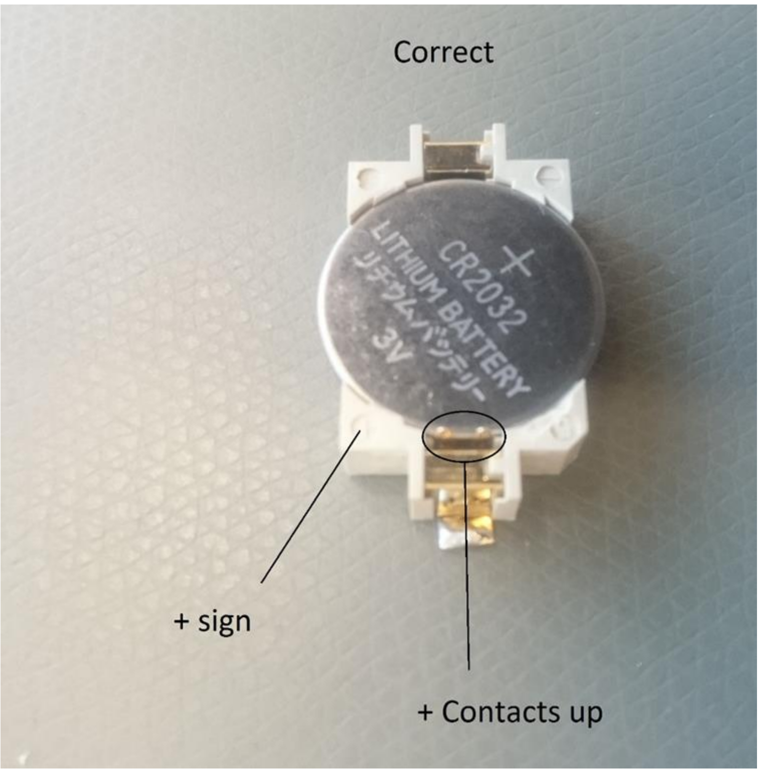
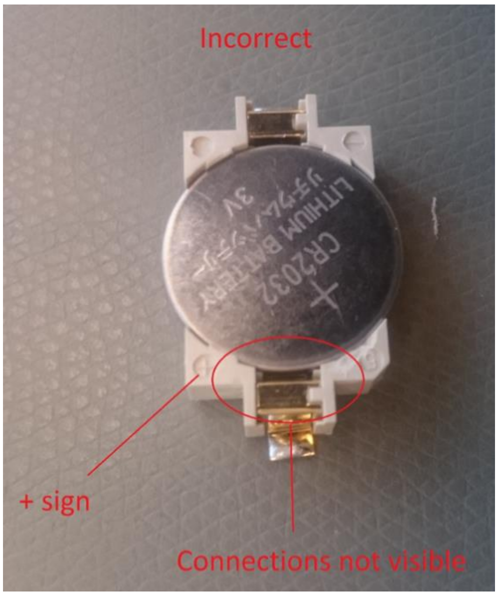



**Figure 38. Correctly installed backup battery.**



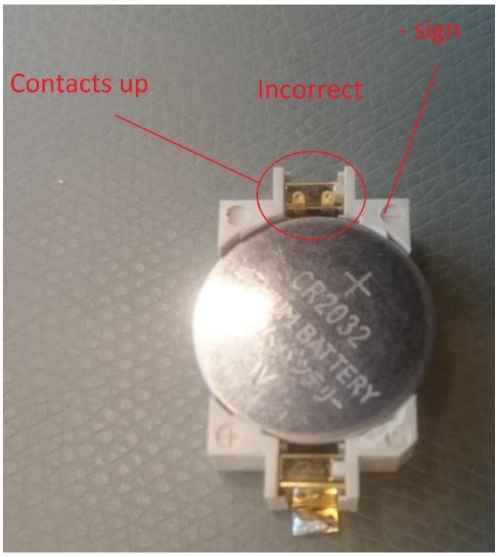




**Figure 39. Examples of incorrectly installed backup battery. Left: positive voltage pins should point up from battery. Right: negative voltage pins should be under the battery**

### C.4.3 Replacing Gas Management Unit

#### C.4.3.1 Preparations

*Before repairing anything inside GASERA ONE, see safety instructions in chapter A.2 on page 8.*

Replacing the Gas Management Unit is instructed in this chapter. The Gas Management Unit has no replaceable parts so the whole unit must be replaced.

Required equipment:

- Set of hex wrenches in millimeter sizes
- Gas tube cutter
- Gas connector tool
- Cable ties
- Cable tie cutter
- Factory tested Gas Management Unit

Required documents:

- Pneumatic diagram in chapter C.2.2.1 on page 34.
- Cable specification for electrical connections
- Tubing specification for gas tube connections

Opening the instrument top cover is guided in chapter C.4.1 on page 64.

### C.4.3.2 Locating Gas Management Unit

Gas Management Unit is typically located as in Figure 40.

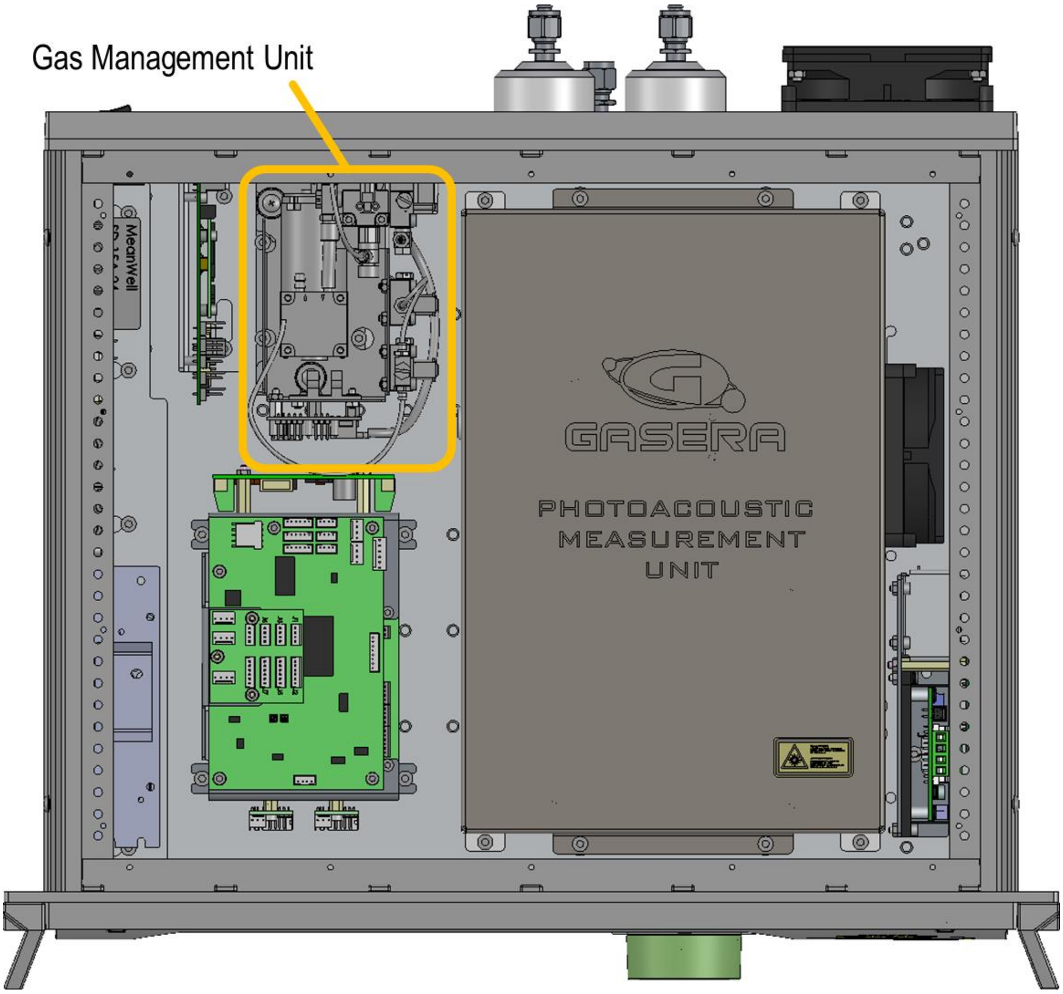



**Figure 40. Typical location of the Gas Management Unit in GASERA ONE. Location may differ somewhat depending on the model.**

### C.4.3.3 Replacement

Removing the Gas Management Unit (GMU):

1. Disconnect electrical cables, see Figure 41
    a. +12V Power cable from PD board
    b. I2C bus cable from DSP board
    c. Valve control cable from the connector in the cable going to MU
    d. Refer to “Cable specification” of the unit for more details.
2. Unmount GMU from the base plate (screws: 4 pcs of 4xM4 mm), see Figure 42.
3. Lift GMU up from the rack as much as possible by tube lengths.
4. Disconnect gas tubes, see Figure 43:
    a. “Pump” tube (6 mm tube)

b. Unmount the “Particle filter of PA Module” from GMU. Disconnect the “In” tube coming from GMU. See Figure 44.
   Ensure that the filter stays all the time attached on the tube end going to PA Module input to prevent any particles entering to the sample cell. Filter has an arrow that must always point to PA Module.
c. “Out” tube from valve V4 (T-connector).
d. Tubes from “V1” and “V2” coming from the rear panel.
e. Refer to “Tubing specification” for more details.

5. GMU is completely disconnected and can be removed.

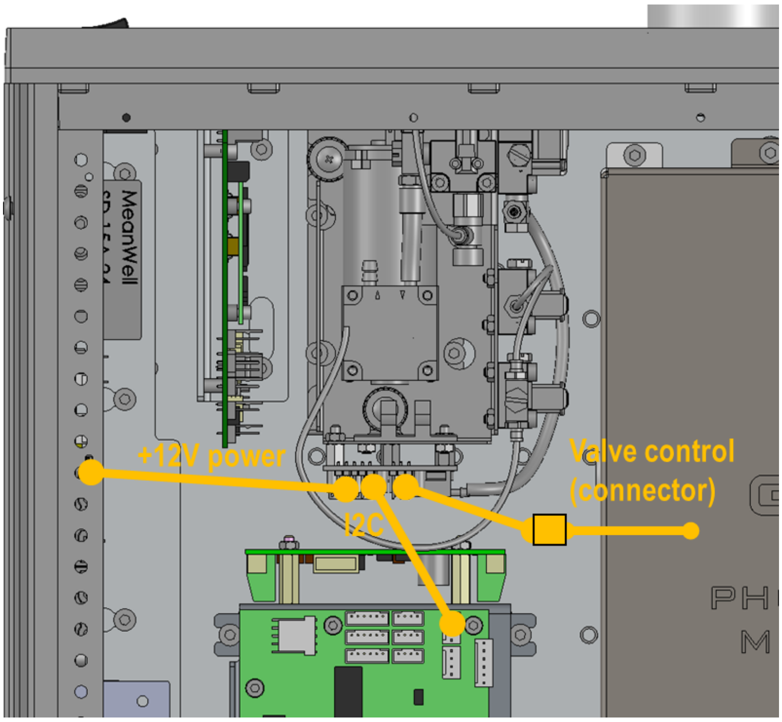



**Figure 41. Electrical connections of the Gas Management Unit.**

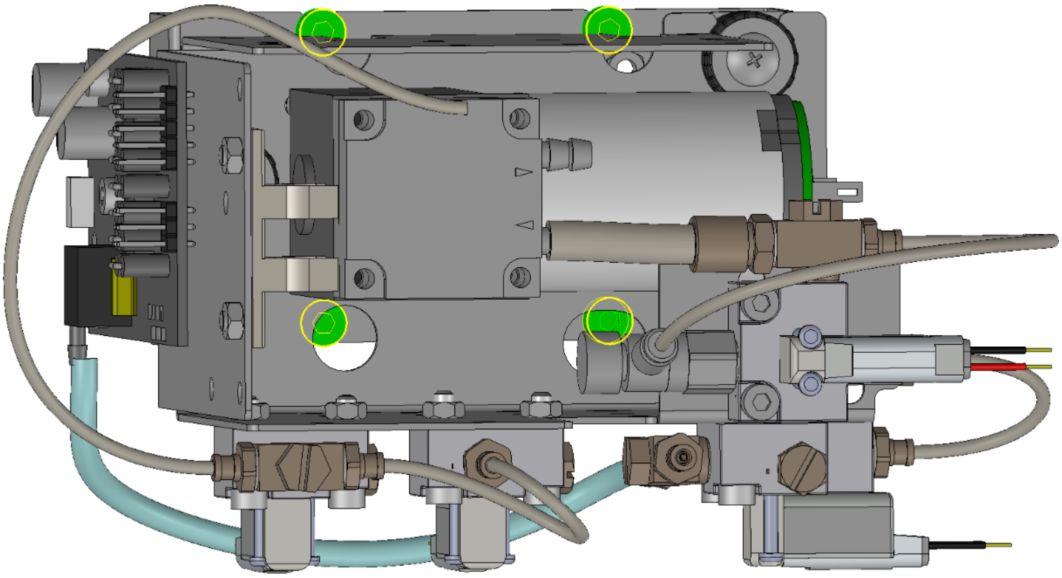


**Figure 42. Mounting screws of the Gas Management Unit.**

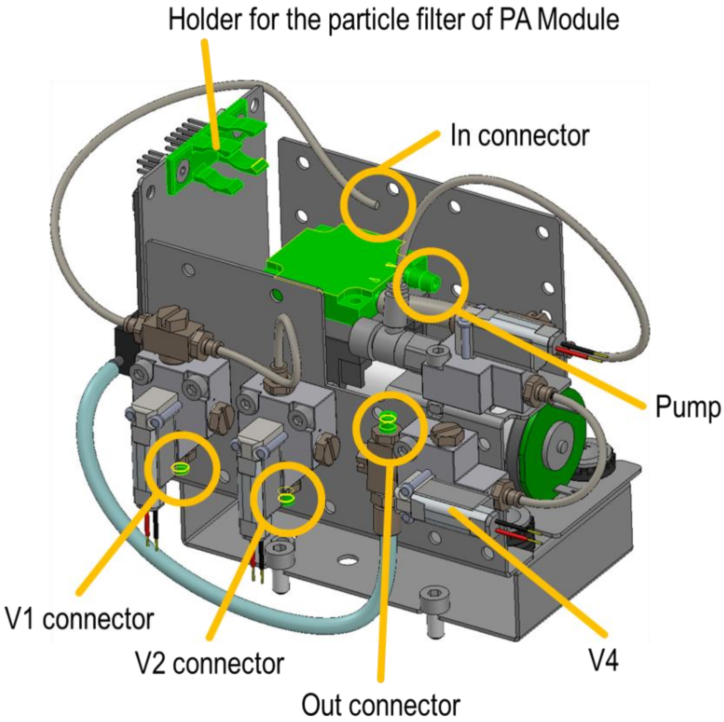



**Figure 43. Gas tube connections for the Gas Management Unit.**

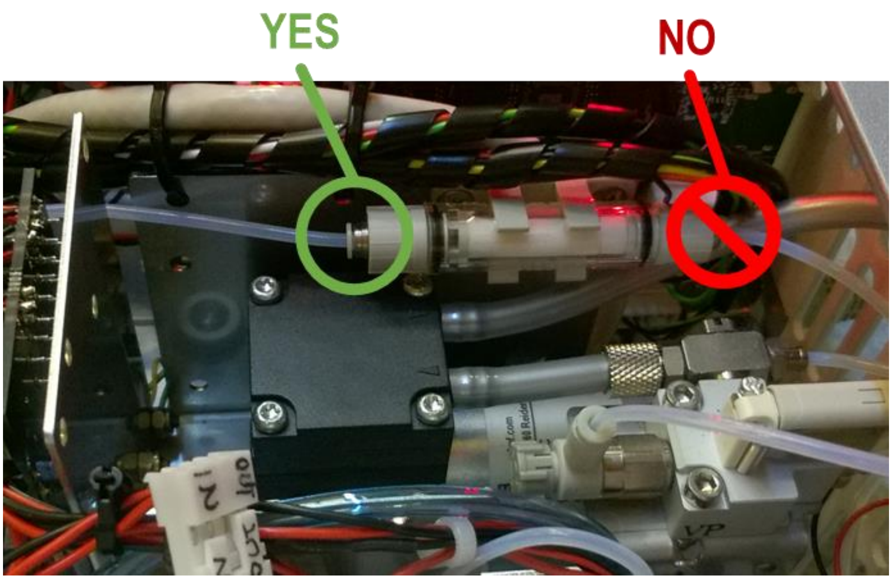



**Figure 44. Correct connection point in the particle filter.**

Installing a new Gas Management Unit:

1. Follow the above instructions in reverse order to install a new GMU
   a. Note: you probably must cut approx. 5 mm from PTFE tube ends for valves V1, V2 and Out. Usually, tube ends are stretched or damaged so that they are not air tight anymore after insertion to the gas connector.

2. When GMU is installed, power on the analyzer and wait for the self-test. If self-test returns an error, refer to chapter C.3.3 on page 45 for further instructions.
3. Adjust the choke by running a measurement and see if the unit can achieve the correct sample pressure. Tighten the choke until the unit will frequently end up to incorrect sample pressure error, then slightly release the choke, until the pressure adjustment runs only once.
4. Install instrument top cover.

*Never startup the device without all particle filters properly installed. Particles may break the PA Module.*

*Never try to service or repair Gas Management Unit. It must be replaced as a complete module provided and tested by the factory.*

## C.4.4 Replacing PA Module

### C.4.4.1 Preparations

*Before repairing anything inside GASERA ONE, see safety instructions in chapter A.2 on page 8.*

*PA Module is ESD sensitive so proper ESD protection must be used.*

Replacing the PA Module is instructed in this chapter. The PA Module has no service replaceable parts, so the whole unit must be replaced once determined defected. Depending on the GASERA ONE model, the possible light source and filter wheel attached to the PA Module need to undergo model dependent re-alignment procedure. Contact customer support for model specific instructions, see chapter A.2 on page 8 for contact details.

Required equipment:

- Set of hex wrenches in millimeter sizes
- Gas tube cutter
- Gas connector tool
- Cable ties
- Cable tie cutter
- Factory tested PA Module
- GONE-tester software

Required documents:

- Model specific light source replacement and alignment instructions
- Pneumatic diagram in chapter C.2.2.1 on page 34.
- Cable specification for electrical connections
- Tubing specification for gas tube connections

Preparations:

1. Power off the unit.
2. Open the following as guided in chapter C.4.1 on page 64:
    a. the instrument *top* cover
    b. the instrument *bottom* cover
    c. the Measurement Unit cover and remove the thermal insulation

*After replacing the PA Module, GASERA ONE will need a full recalibration.*

### C.4.4.2 Locating PA Module

PA Module is typically located inside the Measurement Unit as in Figure 45.

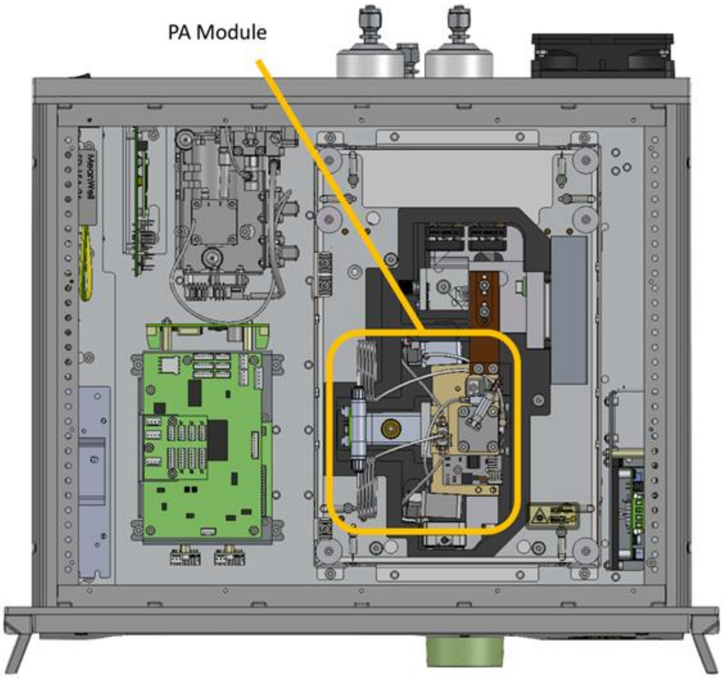



**Figure 45. Typical location of PA Module in Measurement Unit. Location may differ somewhat depending on the model.**

### C.4.4.3 Replacement

*Never try to service or repair PA Module. It must be replaced by a factory tested spare part.*

*NOTE: Gas valves are alignment sensitive and thus the PA Module must be handled carefully to avoid any occurring leakages from dispositioned valves.*

*Request model specific light source replacement and alignment instructions from the customer support before starting the repair.*

Removing the PA Module:

1. Disconnect electrical cables, see Figure 46 and Cable specification
   a. GMU valve control cables for V6 and V7
   b. PAM CMOS cable
   c. PAM heater power and $I^2C$ cables
2. Disconnect the PA Module gas tubes from the Gas Management Unit side (GMU) as in Figure 47, see also
   a. “In” tube (make sure the particle filter is always connected into the input line of the PA Module to prevent the PA Module from contamination!).
   b. “Out” tube by pulling out the tightening sleeve with gas connector tool and disconnecting the tube.
3. Unmount the PA Module from the base plate using screws 4 pcs of M3x10 mm and 4 pcs of M4x10 mm from the bottom of the GASERA ONE. See Figure 48.
4. Lift the PA Module up from the rack, as much as possible while being careful that any cables or optical fibers do not stress on any of the components. Exact cabling depends on the model.
   a. Different models of GASERA ONE are equipped with different modules attached to the PA Module. To remove these additional modules, refer to the model dependent light source assembly and realignment instructions.
5. PA Module is now completely disconnected from the Measurement Unit and can be removed.

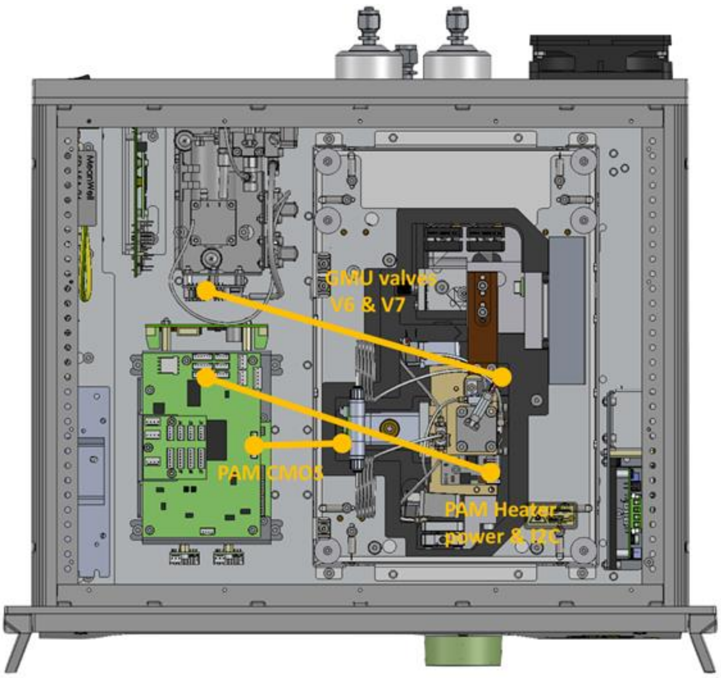



**Figure 46. Electrical connections of the PA Module in GASERA ONE.**

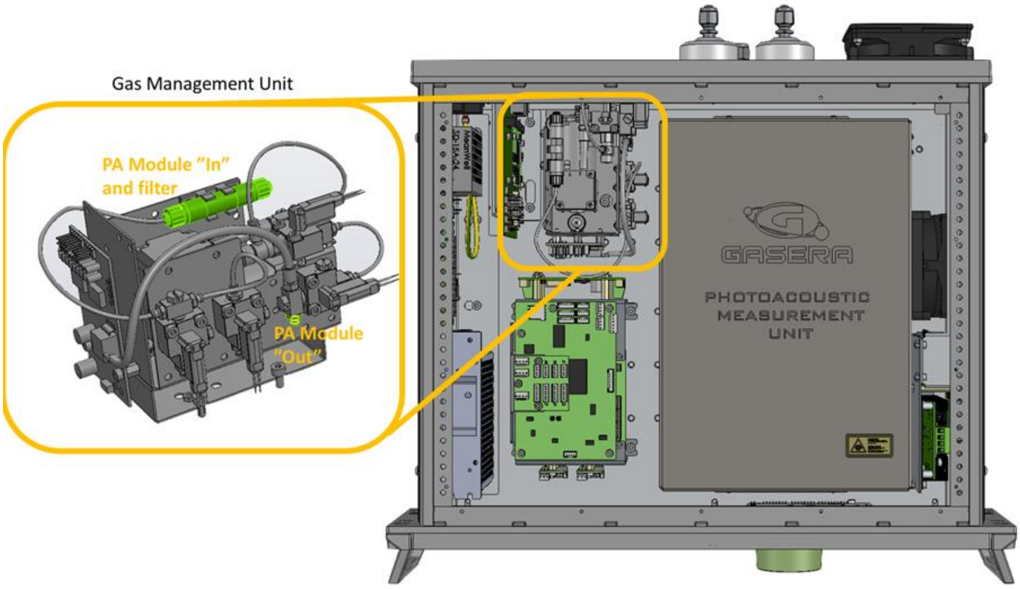



**Figure 47. PA Module gas tube connections to Gas Management Unit.**

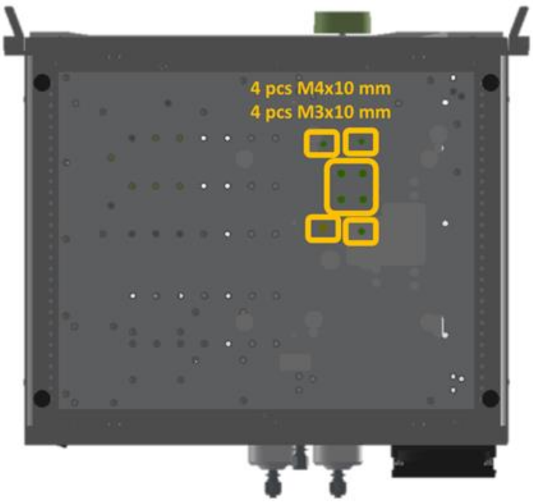



**Figure 48. Screws to unmount PA Module from Measurement Unit. Screws are 4 pcs of M4x10 mm and 4 pcs of M3x10 mm.**

<u>Installing a new PA Module:</u>

1. Follow the instructions above in reverse order to install new PA Module
   a. Note: When connecting "Out" tube to Gas Management Unit (GMU), you probably need to cut approx. 5 mm from PTFE tube end before connecting to the valve "Out" in the GMU. Typically, tube ends are stretched or damaged after removal so that they are not air tight anymore after insertion to the gas connector.
2. When the PA Module is installed, power on the analyzer and wait for the self-test to complete. If self-test returns an error, refer to chapter C.3.3 on page 45 for further instructions.
3. Further tests to be conducted with "GONE Tester.exe". For detailed guide to test procedures and using the software refer to GONE tester manual or request to customer support. Tested items are:

   a. Leakage test
   b. Fringe number
   c. Noise test
   d. Automated transportation lock, if installed to the unit
4. Install Measurement Unit cover, and bottom and top covers of the analyzer as instructed in chapter C.4.1 on page 64.
5. After PA Module replacement, recalibration for the GASERA ONE is required. Please refer to chapter B.5 on page 11 for instructions on performing the calibration.

# Part D. Appendices

## D.1 Terminology

The following table lists terms used in this manual and their descriptions.

| Term | Description |
|---|---|
| Measurement task | Template for the measurement. Task contains set of predefined parameters for running a measurement. |
| Measurement | Running continuous measurements using parameters predefined in a template called Measurement Task. |
| Channel | General term for spectral band used for the measurement and chemometry. In laser source based units, the bandwidth is very narrow, and the band is selected to measure only single absorption line. In NDIR units, the bands are so wide that they cover large set of absorption lines. With widely scanning lasers such as with EC-QCL, the channel is a group of scan steps. |
| Optical bandpass filter | An optical component that transmits light only in certain pass band. Used in NDIR technology. |
| Cell, PA cell | The sample cell of the photoacoustic module. In Gasera products, the cell is typically a cylinder shaped small volume. |
| PA Module | Photoacoustic module containing the sample cell and optical readout microphone for reading the cantilever motion and DSP algorithm for signal processing. PA Module is temperature stabilized. |
| Laser source | Source of modulated infrared laser radiation used to generate photoacoustic signal. Various laser types, such as DFB, QCL and EC-QCL, are used in GASERA ONE products according to application. |
| NDIR | Nondispersive infrared sensor technology used in certain GASERA ONE products. Based on a broad band infrared source which is modulated mechanically or electronically. The spectral band, or channel, is selected by optical band pass filters. |
| Channel integration time | Total channel integration time is the duration used for averaging signal values. Total channel integration time is Channel Integration Time base unit, which is the smallest possible time duration for signal reading, multiplied by the CIT Multiplication factor. |
| Readout interferometer | Submodule of PA Module used for reading the cantilever position. Readout interferometer is based on a small optical interferometer. |
| Readout interferometer laser | Diode laser used as a light source in the readout interferometer. This is not the infrared source. |
| Gas Management Unit | GASERA ONE submodule used to exchange the sample gas in the sample cell and set the sample pressure. |
| Cell flush | Flushing the sample cell by a fresh sample or by an inert gas such as nitrogen. Flushing is used to ensure that the sample conditions has been stabilized in the cell, or the concentration is not trending anymore. |
| By-pass line (cell) | GASERA ONE internal line by-passing the sample cell. It can be used to flush the internal gas line to ensure that as fresh sample as possible is taken into the cell. |
| Measurement Unit | Submodule of GASERA ONE product containing typically the temperature stabilized PA Module, vibration isolation, and infrared light source. |
| Chemometry | Analysis methods for discriminating gas components in the spectrum and calculating their concentrations. GASERA ONE products use chemometry methods optimized for photoacoustic spectroscopy and Gasera products. |
| User Manual | GASERA ONE User Manual |

# D.2 Test sheet templates

## D.2.1 Test sheet template for laser based units

Page 1 of 1
Test sheet

**TEST SHEET**

Product: GASERA ONE
Serial number: xxxxxx

Date: 2018-10-13
Initials: AA

**Parameters**

| Channel | CIT, Channel integration time [s] | CIT multiplier |
|---|---|---|
| HCl | 0.5 | 20 |

| Target pressure | 300 mbar |
|---|---|

**Detection limits and repeatability**

| Gas | Detection limit* ** [ppb] | Repeatability |
|---|---|---|
| HCl | 0.9 | 0.55 % |
| | | % |

*Method: 2 × standard deviation in 6 last measurement points in zero gas measurement
** scaled to X min response time

**Linearity test**

| Gas | Sample concentration [ppm] | Measured concentration* [ppm] |
|---|---|---|
| HCl | | |
| HCl | | |
| HCl | | |

*Method: Average of 5 consecutive measurements

**Measurement response time**

Average XX seconds with X gas exchange cycles, channel integration times (CIT) according to "Parameters" table above.

**Calibration gases and concentrations**

| Gas | Concentration [ppm] | Accuracy* |
|---|---|---|
| N2 | 100 % | Purity: grade 6.0 |
| HCl* ** | 3.0 | ± 3% |
| H2O** | 69 | ± 2% |

*Defined by the gas vendor
**Accuracy by Gasera sample generation system

Gasera Ltd. | Lemminkäisenkatu 59, 20520 Turku, FINLAND | www.gasera.fi | contact@gasera.fi | Business ID : 1930453-0

**Figure 49. Test sheet template for the GASERA ONE unit having laser infrared source.**

## D.2.2 Test sheet template for NDIR based units

Page 1 of 2
Test sheet

# TEST SHEET

Product: GASERA ONE
Serial number: xxxxxx

Date: 2018-10-13
Initials: AA

**Parameters**

| Slot | Channel | CIT, Channel integration time [s] |
|---|---|---|
| 0 | IR1_2801_31 | 10 |
| 1 | IR1_2703_80 | 5 |
| | | |
| | | |
| | | |
| 5 | IR1_1167_29 | 20 |
| 6 | IR1_1235_35 | 5 |
| 8 | IR1_1976_39 | 5 |

| Target pressure | 850 mbar |
|---|---|

**Detection limits and repeatability**

| Gas | Channel | Detection limit* [ppm] | Repeatability |
|---|---|---|---|
| CH4 | IR1_3012_16 | 47 | 0.15 % |
| | | | % |
| | | | % |
| | | | % |
| | | | % |
| | | | % |
| | | | % |
| | | | % |
| | | | % |

*Method: 2 × RMS noise × *c* / (*S* – bg); average of 6 consecutive measurements

**Linearity test**

| Gas | Sample concentration [ppm] | Measured concentration* [ppm] |
|---|---|---|
| CH4 | 10 | 10.1 |
| CH4 | 50 | 4.5 |
| CH4 | 1000 | 16 |

*Method: Average of 5 consecutive measurements

**Measurement response time**

XX min XX s with default gas exchange cycles and channel integration times (CIT) as in the "Parameters" table above.

Gasera Ltd. | Lemminkäisenkatu 59, 20520 Turku, FINLAND | www.gasera.fi | contact@gasera.fi | Business ID : 1930453-0

**Figure 50. First page of the test sheet template for the GASERA ONE unit having broad band infrared source and topical filters, or NDIR technology based.**

GASERA

Page 2 of 2
Test sheet

Calibration gases and concentrations

| Gas | Concentration [ppm] | Accuracy* |
|---|---|---|
| N2 | 100 % | Purity: grade 6.0 |
| CO2* ** | 3.0 | ± 2% |
| H2O** | 69 | ± 2% |
| | | |
| | | |
| | | |
| | | |
| NH3 | | ± 2% |
| EtOH | | ± 2% |
| CH4 | | ± 2% |

*Defined by the gas vendor
**Accuracy by Gasera sample generation system

Gasera Ltd. | Lemminkäisenkatu 59, 20520 Turku, FINLAND | www.gasera.fi | contact@gasera.fi | Business ID : 1930453-0

**Figure 51. Second page of the test sheet template for the GASERA ONE unit having broad band infrared source and topical filters, or NDIR technology based. Cylinder gases can be diluted and mixed with water by using gas dilution system.**

## D.3 PI-diagram for gas sampling system in Performance tests

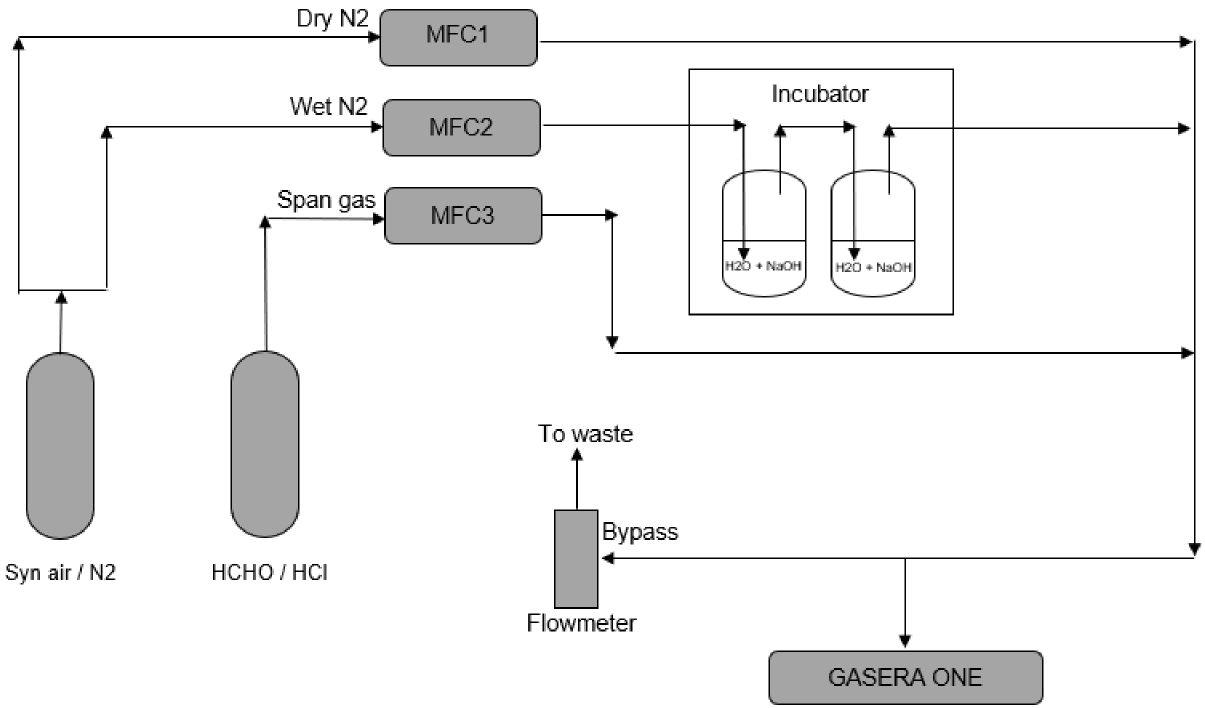



**Figure 52. PI-diagram for gas sampling system in Performance tests. Note that in dry gases measurements MFC2 line is removed.**

**Table 12. Parts used in Gasera's gas dilutors, examples for HCHO and HCl sampling system.**

| Part | Manufacturer and code | Material | Other info |
|---|---|---|---|
| Mass flow controllers | Brooks 5850 | - | 150 ml/min for HCHO (example)<br>350 ml/min for HCl (example)<br>1500 ml/min for dry N2 (example)<br>15 ml/min for wet N2 (example) |
| Tube | - | PTFE | Ø 6/4 mm |
| T-connector | - | Stainless steel | For 6 mm tube |
| Plug in connector | - | Stainless steel | For 6 mm tube |
| Flowmeter | KYTÖLÄ LH-4B R-R | - | 0,2 - 1,8 Nl-min |
| Incubator | Medline/Jeiotech ILP-12 | - | - |
| Water bottles | VWR VITL159497<br>VWR 215-0906 | PFA<br>Polypropene | Cap parts: VWR 554-3000, 554-3004, 554-3008, 201-1965 |

Notes about sampling system:

- Tubes are as short as possible – especially with sticky gases!
- No throttling parts after waterbath.
- Connect gas cylinder to mass flow controller. Adjust pressure 3 - 3.5 bar from gas cylinder regulator.
- Connect GASERA ONE in bypass flow. Make sure there is enough tube after gas input!
- Sticky gases require long time to stablilize.
- MFC error is <1 % in 20 - 100 % FS, so flowrate 20 - 100 % FS is preferred to use in dilutions.

## D.4 Example of Performance tests for GASERA ONE FORMALDEHYDE

# TEST SHEET

| | | | |
|---|---|---|---|
| Product: | GASERA ONE | Date: | 2018-08-29 |
| Serial number: | 040009 | Initials: | MJ |

### Parameters

| Channel | CIT, Channel integration time [s] | CIT multiplier |
|---|---|---|
| HCHO | 0.5 | 50 |

| Target pressure | 280 mbar |
|---|---|

*Parameters are adjusted before starting calibration task.*

### Detection limits and repeatability

| Gas | Detection limit* ** [ppb] | Repeatability |
|---|---|---|
| HCHO | 4.34 ppb | 0.61 % |

*Method: 2 × standard deviation in 6 last measurement points in zero gas measurement
** 1 min response time

*Detection limit is calculated from zero gas measurement.*

| | | | | |
|---|---|---|---|---|
| **Measurement parameters:** | STEPS_2018-06-05_15-20-59_40009.meas | | | |
| TargetPressure | 280 | mbar | | |
| FlushTimeBypass | 1 | sec | | |
| FlushTimeCell | 1 | sec | | |
| NFlushCell | 3 | | | |
| GasInput | 1 | | | |
| SamplingMode | 0 | | | |
| **Timestamp** | **H2O (ppm)** | **CH2O (ppm)** | | |
| ***[hidden results, 5 last meas points from each step below]*** | | | | |
| 5.6.2018 16:10 | 6493,5 | 0,00459 | | |
| 5.6.2018 16:11 | 6493,5 | 0,00235 | | |
| 5.6.2018 16:11 | 6493,5 | 0,0047 | | |
| 5.6.2018 16:13 | 6493,5 | 0,00361 | | |
| 5.6.2018 16:14 | 6434,45 | 0,00223 | | |
| 5.6.2018 16:14 | 6434,45 | 0,00451 | | |
| 5.6.2018 16:15 | 6434,45 | 0,00643 | | |
| 5.6.2018 16:16 | 6434,45 | 0,00413 | | |
| 5.6.2018 16:18 | 6434,45 | 0,00858 | | |
| 5.6.2018 16:18 | 6359,63 | 0,00479 | | |
| | | | | |
| stdev(6) | | 0,002167971 | | |
| 2 x stdev(6) | | 0,004335941 | **4,34** | **ppb** |
| Scaled to 1 min | LoD/√(60/55) | | **4,15** | **ppb** |

*ion. This data is currently not accessible by normal user.*

*Following data is from 0.6 ppm HCHO calibration:*

| meas_group_id | id | 0 | 2 |
|---|---|---|---|
| ***[hidden data, 10 last meas points below]*** | | | |
| 72 | 4273 | 0,006315756 | 0,155402 |
| 72 | 4274 | 0,006344041 | 0,155402 |
| 72 | 4275 | 0,006339399 | 0,155402 |
| 72 | 4276 | 0,006352611 | 0,155402 |
| 72 | 4277 | 0,006304173 | 0,155138 |
| 72 | 4278 | 0,006341536 | 0,155138 |
| 72 | 4279 | 0,006340647 | 0,155138 |
| 72 | 4280 | 0,006410733 | 0,155138 |
| 72 | 4281 | 0,006341473 | 0,155138 |
| 72 | 4282 | 0,006305229 | 0,154688 |
| 72 | 4283 | | |
| | | | |
| | stdev(6) | 3,873E-05 | |
| | average(6) | 6,341E-03 | |
| | RSD% | 0,61 % | |

## Linearity test

| Gas | Sample concentration [ppm] | Measured concentration* [ppm] |
|---|---|---|
| HCHO | 0.3 | 0.29 |
| HCHO | 0.6 | 0.58 |
| HCHO | 1.0 | 0.96 |
| HCHO | 2.0 | 1.90 |

*Method: Average of 5 consecutive measurements

*The results are from HCHO steps.*

*Examples of sample dilutions:*
*Gasera's HCHO cylinder is 16.4 ppm*

*0.3 ppm HCHO*

- *490 ml/min syn air through water bath – approx. 10 000 ppm H2O in the sample (490 ml/min set flow corresponds 500 ml/min outcoming flow from water bath.*
- *18.2 ml/min HCHO flow*
- *463.6 ml/min dry gas flow*

*0.6 ppm HCHO*

- *490 ml/min syn air through water bath*
- *36.4 ml/min HCHO flow*
- *481.8 ml/min dry gas flow*

*1.0 ppm HCHO*

- *490 ml/min syn air through water bath*
- *61 ml/min HCHO flow*
- *439 ml/min dry gas flow*

*2.0 ppm HCHO*

- *490 ml/min syn air through water bath*
- *122 ml/min HCHO flow*
- *378 ml/min dry gas flow*

| | | | |
|---|---|---|---|
| **Measurement parameters:** | STEPS_2018-06-05_15-20-59_40009.meas | | |
| TargetPressure | 280 | mbar | |
| FlushTimeBypass | 1 | sec | |
| FlushTimeCell | 1 | sec | |
| NFlushCell | 3 | | |
| GasInput | 1 | | |
| SamplingMode | 0 | | |
| **Timestamp** | **H2O (ppm)** | **CH2O (ppm)** | |
| ***[hidden results, 5 last meas points from each step below]*** | | | |
| 5.6.2018 19:16 | 6898,08 | 0,29852 | |
| 5.6.2018 19:16 | 6871,7 | 0,286 | |
| 5.6.2018 19:17 | 6871,7 | 0,29418 | |
| 5.6.2018 19:18 | 6871,7 | 0,29262 | |
| 5.6.2018 19:18 | 6871,7 | 0,29234 | |
| | **Average(5)** | **0,293** | |
| | | | |
| 5.6.2018 22:14 | 6980,89 | 0,5739 | |
| 5.6.2018 22:15 | 6980,89 | 0,57852 | |
| 5.6.2018 22:16 | 6980,89 | 0,58239 | |
| 5.6.2018 22:16 | 6980,89 | 0,58251 | |
| 5.6.2018 22:18 | 6980,89 | 0,58517 | |
| | **Average(5)** | **0,580** | |
| | | | |
| 6.6.2018 1:14 | 7043,04 | 0,96866 | |
| 6.6.2018 1:16 | 7043,04 | 0,96564 | |
| 6.6.2018 1:17 | 7058,65 | 0,95009 | |
| 6.6.2018 1:17 | 7058,65 | 0,96186 | |
| 6.6.2018 1:18 | 7058,65 | 0,9694 | |
| | **Average(5)** | **0,963** | |
| | | | |
| 6.6.2018 4:15 | 7060,29 | 1,86704 | |
| 6.6.2018 4:15 | 7060,29 | 1,88689 | |
| 6.6.2018 4:16 | 7060,29 | 1,90049 | |
| 6.6.2018 4:17 | 7060,29 | 1,9113 | |
| 6.6.2018 4:18 | 7060,29 | 1,91017 | |
| | **Average(5)** | **1,895** | |

## Measurement response time

In average 55 seconds with 3 gas exchange cycles (1 s), channel integration times (CIT) according to “Parameters” table above.

*Time consumed for 5 measurement cycles is measured and divided by 5, thus getting average duration of one measurement cycle. Automatic laser wavelength tuning is done every 5th iteration, so every 5th measurement takes longer time.*

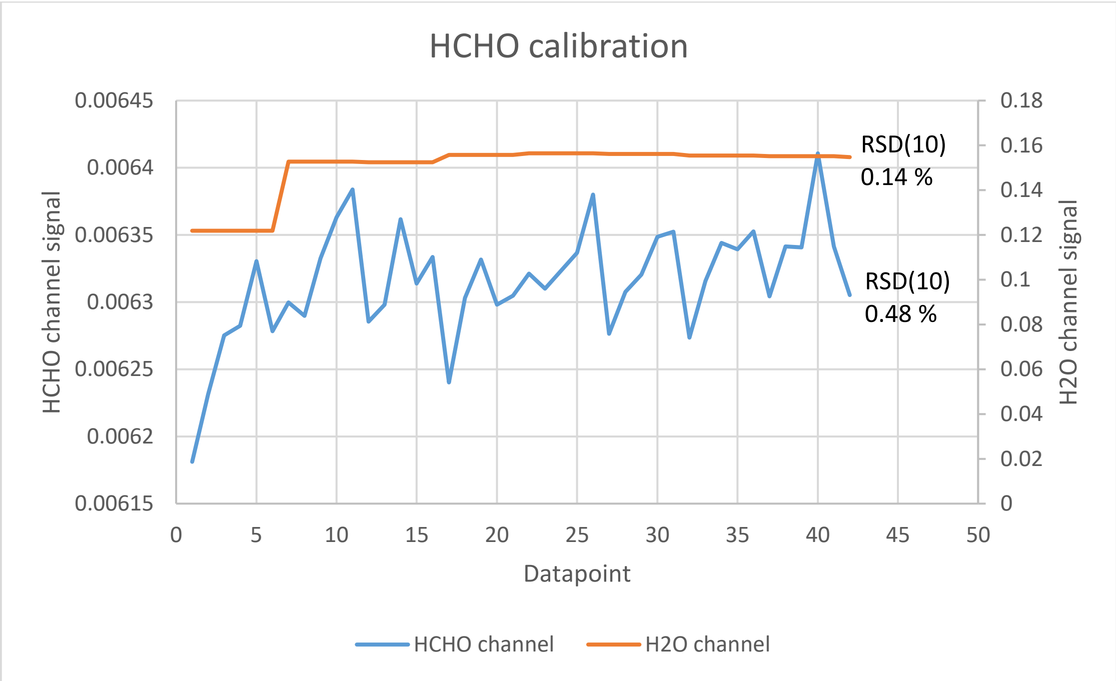
### Calibration gases and concentrations

| Gas | Concentration [ppm] | Accuracy* |
|---|---|---|
| HCHO* ** | 0.6 | ± 3% |
| H2O** | 20 000 | ± 2% |

*Defined by the gas vendor
**Accuracy by Gasera sample generation system

*Calibration gases are listed in table above. For FORMALDEHYDE analyzer, using Synthetic air instead of N2 in dilutions is recommended. Required purity grade for Syn. air is 5.6 or better. HCHO calibration accuracy is partly from gas inaccuracy (±2 %) and partly from dilution (±1 %).*

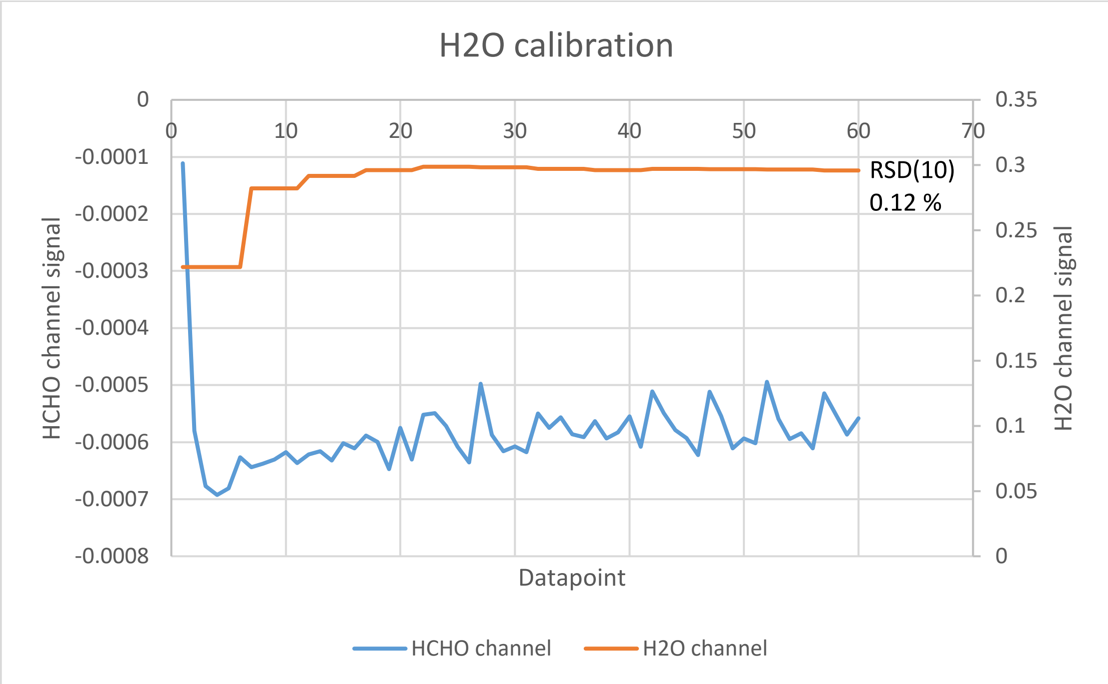
*A good concentration for HCHO calibration would be around 0.7 ppm (0.4 - 1 ppm) depending on what cylinder concentration is available. Water concentration in HCHO calibration should be about 10 000 ppm.*




*HCHO calibration can be accepted when signal levels in both channels are stable and there is no trend. Relative standard deviation (RSD) should be <1 % in both channels.*

*See HCHO dilution example in Linearity section.*

*H2O is synthetic air from cylinder, approx. 1 L/min flow through water bath. With 17.6 C temperature and ambient air pressure, the concentration is about 20 000 ppm.*




*H2O calibration can be accepted when signal levels in both channels are stable and H2O channel RSD is <1 %. Since HCHO channel signal is basically zero, RSD does not determine calibration acceptance and it can be very high.*

## D.5 Example of Performance tests for GASERA ONE DFB (HCl)

# TEST SHEET

| | | | |
|---|---|---|---|
| Product: | GASERA ONE | Date: | 2018-08-29 |
| Serial number: | 060007 | Initials: | MJ |

### Parameters

| Channel | CIT, Channel integration time [s] | CIT multiplier |
|---|---|---|
| HCl | 0.5 | 20 |

| | |
|---|---|
| **Target pressure** | 300 mbar |

*Parameters are adjusted before starting calibration task.*

### Detection limits and repeatability

| Gas | Detection limit* **[ppb] | Repeatability |
|---|---|---|
| HCl | 66.02 ppb | 0.34 % |

*Method: 2 × standard deviation in 6 last measurement points in zero gas measurement
** 1 min response time

*Detection limit is calculated from zero gas measurement.*

| | | | | |
|---|---|---|---|---|
| Measurement parameters: | | | | |
| TargetPressure | 300 | mbar | | |
| FlushTimeBypass | 1 | sec | | |
| FlushTimeCell | 1 | sec | | |
| NFlushCell | 15 | | | |
| GasInput | 1 | | | |
| SamplingMode | 0 | | | |
| **Timestamp** | **H2O (ppm)** | **HCl (ppm)** | | |
| ***[hidden results, 5 last meas points from each step below]*** | | | | |
| 5.6.2018 16:10 | 8804,07 | 0,170632 | | |
| 5.6.2018 16:11 | 8804,07 | 0,097534 | | |
| 5.6.2018 16:11 | 8804,07 | 0,072209 | | |
| 5.6.2018 16:13 | 8963,61 | 0,065747 | | |
| 5.6.2018 16:14 | 8963,61 | -0,068601 | | |
| 5.6.2018 16:14 | 8963,61 | 0,010905 | | |
| 5.6.2018 16:15 | 8963,61 | 0,040814 | | |
| 5.6.2018 16:16 | 8963,61 | -0,008625 | | |
| 5.6.2018 16:18 | 8897,15 | -0,005530 | | |
| 5.6.2018 16:18 | 8897,15 | 0,022862 | | |
| | | | | |
| stdev(6) | | 0,037702325 | | |
| 2 x stdev(6) | | 0,075404651 | **75,40** | **ppb** |
| Scaled to 1 min | LoD/√(60/46) | | **66,02** | **ppb** |

*Repeatability is calculated from raw signals in span calibration. This data is currently not accessible by normal user.*

*Following data is from 7.98 ppm HCl calibration:*

| meas_group_id | id | 0 | 2 |
|---|---|---|---|
| [hidden data, 10 last meas points below] | | | |
| 144 | 50358 | 0,001625 | 0,003235 |
| 144 | 50359 | 0,001594 | 0,003238 |
| 144 | 50360 | 0,001624 | 0,003238 |
| 144 | 50361 | 0,00162 | 0,003238 |
| 144 | 50362 | 0,001631 | 0,003238 |
| 144 | 50363 | 0,001616 | 0,003238 |
| 144 | 50364 | 0,001621 | 0,00326 |
| 144 | 50365 | 0,001617 | 0,00326 |
| 144 | 50366 | 0,001626 | 0,00326 |
| 144 | 50367 | 0,00162 | 0,00326 |
| 144 | 50368 | | |
| | | | |
| | stdev(6) | 5,594E-06 | |
| | average(6) | 1,622E-03 | |
| | RSD% | 0,34 % | |

**Linearity test**

| Gas | Sample concentration [ppm] | Measured concentration* [ppm] |
|---|---|---|
| HCl | 2.00 | 2.19 |
| HCl | 4.99 | 4.96 |
| HCl | 9.98 | 10.20 |

*Method: Average of 5 consecutive measurements

*Results are from HCl steps.*

*Examples of sample dilutions:*
*Gasera's HCl cylinder is 39.9 ppm*

*2.00 ppm HCl*

- *490 ml/min syn air through water bath – approx. 10 000 ppm H2O in the sample (490 ml/min set flow corresponds 500 ml/min outcoming flow from water bath.*
- *50 ml/min HCl flow*
- *450 ml/min dry gas flow*

*4.99 ppm HCl*

- *490 ml/min syn air through water bath*
- *125 ml/min HCHO flow*
- *375 ml/min dry gas flow*

*9.98 ppm HCl*

- *490 ml/min syn air through water bath*
- *250 ml/min HCl flow*
- *250 ml/min dry gas flow*

| | | | |
|---|---|---|---|
| Measurement parameters: | | | |
| TargetPressure | 300 | mbar | |
| FlushTimeBypass | 1 | sec | |
| FlushTimeCell | 1 | sec | |
| NFlushCell | 15 | | |
| GasInput | 1 | | |
| SamplingMode | 0 | | |
| Timestamp | H2O (ppm) | HCl (ppm) | inlet |
| ***[hidden results, 5 last meas points from each step below]*** | | | |
| 25.5.2018 10:05 | 7015,44 | 10,0947 | |
| 25.5.2018 10:06 | 7015,44 | 10,1245 | |
| 25.5.2018 10:07 | 7015,44 | 10,2268 | |
| 25.5.2018 10:07 | 7015,44 | 10,308 | |
| 25.5.2018 10:08 | 7015,44 | 10,2642 | |
| | **Average(5)** | **10,204** | |
| | | | |
| 25.5.2018 11:11 | 6183,42 | 4,97686 | |
| 25.5.2018 11:11 | 6183,42 | 4,95294 | |
| 25.5.2018 11:12 | 6183,42 | 4,9444 | |
| 25.5.2018 11:13 | 6183,42 | 4,98187 | |
| 25.5.2018 11:14 | 6197,62 | 4,96429 | |
| | **Average(5)** | **4,964** | |
| | | | |
| 25.5.2018 12:27 | 6037,25 | 2,17025 | |
| 25.5.2018 12:28 | 6037,25 | 2,12008 | |
| 25.5.2018 12:28 | 6037,25 | 2,26065 | |
| 25.5.2018 12:29 | 6037,25 | 2,13977 | |
| 25.5.2018 12:30 | 6076,49 | 2,25974 | -1 |
| | **Average(5)** | **2,190** | |

## Measurement response time

46 seconds with 15 gas exchange cycles, channel integration times (CIT) according to “Parameters” table above.

*Time consumed for 5 measurement cycles is measured and divided by 5, thus getting average duration of one measurement cycle. Automatic laser wavelength tuning is done every 5$^{th}$ iteration, so every 5$^{th}$ measurement takes longer time.*

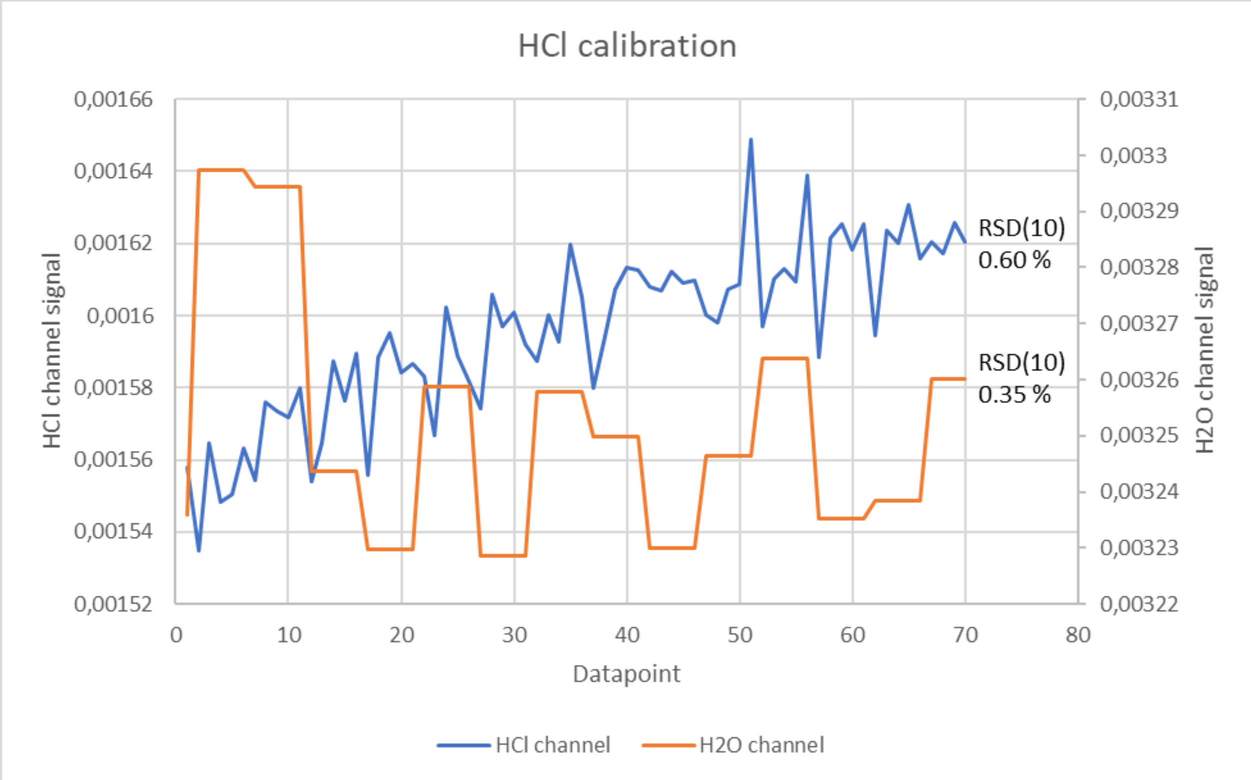
## Calibration gases and concentrations

| Gas | Concentration [ppm] | Accuracy* |
|---|---|---|
| HCl* ** | 7.98 | ± 3% |
| H2O** | 20 000 | ± 2% |

*Defined by the gas vendor
**Accuracy by Gasera sample generation system

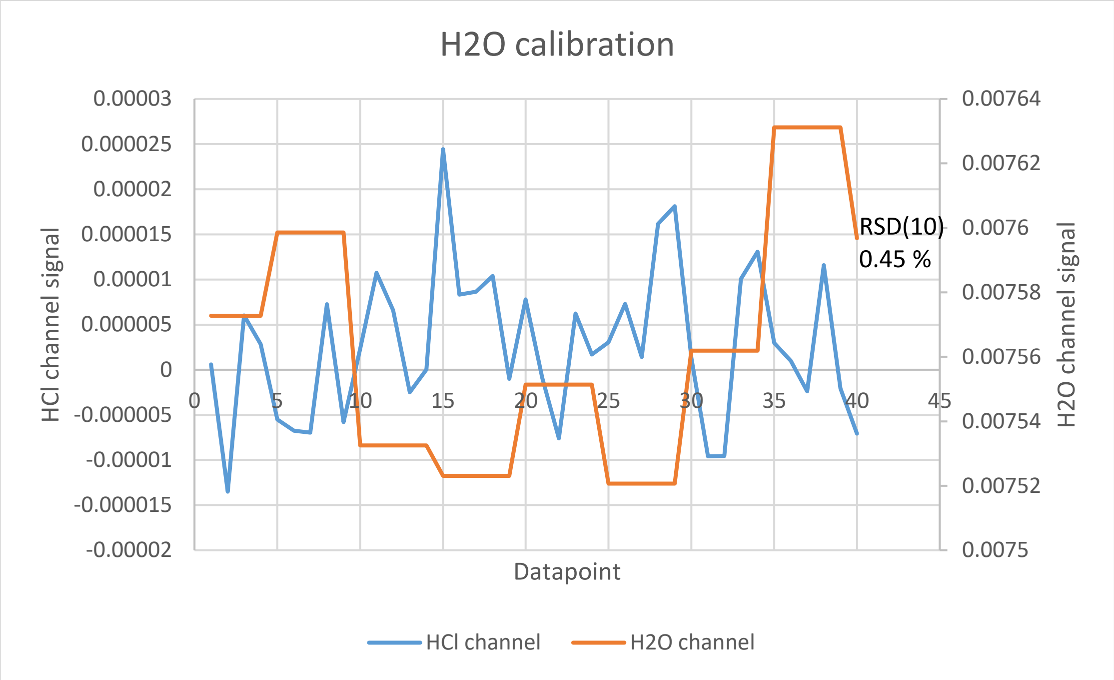
*Calibration gases are listed in table above. Required purity grade for N2 used for gas dilution is 6.0 or better. HCl calibration accuracy is partly from gas inaccuracy (±2 %) and partly from dilution (±1 %). HCl sample is generated mixing 490 ml/min H2O, 200 ml/min HCl (39.9 ppm cylinder c) and 300 ml/min N2.*

*A good concentration for HCl calibration would be around 10 ppm (5 - 15 ppm) depending on what cylinder concentration is available. Water concentration in HCl calibration should be about 10 000 ppm.*




*HCl calibration can be accepted when signal levels in both channels are stable and there is no trend. Relative standard deviation (RSD) should be <1 % in both channels.*

*H2O is N2 from cylinder, approx. 1 L/min flow through water bath. With 17.6 C temperature and ambient air pressure, the concentration is about 20 000 ppm.*




*H2O calibration can be accepted when signal levels in both channels are stable and H2O channel RSD is <1 %. Since HCl channel signal is basically zero, RSD does not determine calibration acceptance and it can be very high.*