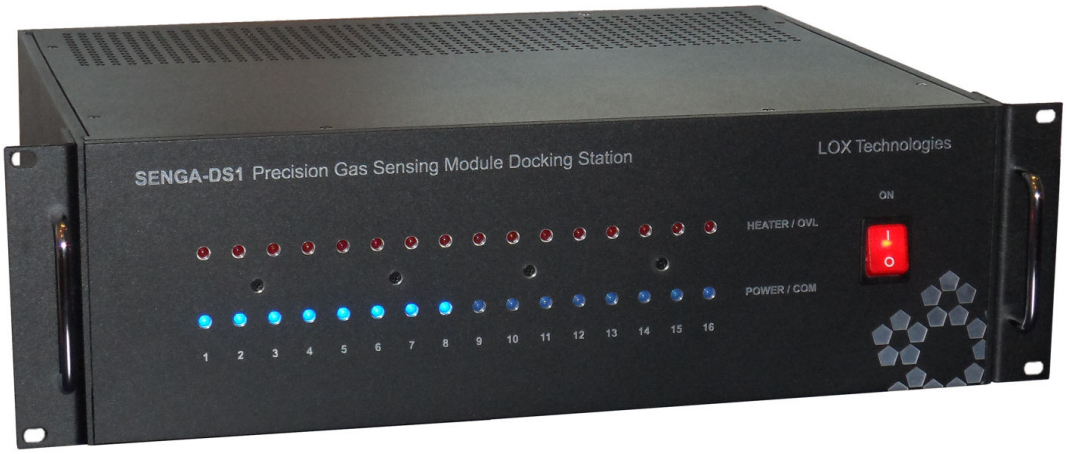
SENGA

Precision Gas Sensing Module and Docking Station



User Guide

About

This document describes operation of SENGA intelligent sensoric system and related PC application.

SENGA is multi-channel gas sensing system comprising set of independent intelligent modules and a docking station for up-to 16-channel configuration, with its prior mission in precision gas sensor characterization and long-term sensor data acquisition. Intelligent SENGA modules come with state-of-the-art power-efficient boosting circuitry, enabling utilization of a wide range of gas sensors with up-to 25V, 10W power requirements at one side, or novel micro-heating elements with power requirements down to 10mW, on the other. Two independent resistance measurement inputs found at each module, which span more than 6 orders of magnitude, can be utilized for single or differential gas concentration measurements, as well as an independent feedback for heater or ambient temperature data. By default, the module is equipped with on-the-fly temperature measurement in the platinum heater circuitry utilizing DC current-voltage method. SENGA modules are equipped with RS485 industrial serial bus that enables connection of up-to 64 modules with the same host. To provide housing and docking for multiple modules, SENGA docking station in industrial 19" case, involving 16 module slots, integrated power supply and a USB/RS485 bus converter, is readied.

Though communication with SENGA modules is maintained by serial interface with easy text-oriented protocol, dedicated measurement software is provided to enable intuitive, user-friendly operation of swarm of SENGA modules distributed in space or bound in the docking station.

Contents

Basic Features

- **instant measurement data from all sensors with 1 sec temporal resolution**
- **uniform data interface to individually addressable sensors**
- **5V..12V module power supply range**
- **max heating performance 1.5A, 25V, 10W per sensor**
- **0.5W 400Ω Pt heater to 500°C with 5V supply**
- **3W 100Ω Pt heater to 300°C with 5V supply**
- **10W 10Ω Pt heater to 500°C with 12V supply**
- **on-the-fly Pt heater resistance measurement with Kelvin (4-wire) sensing**
- **two independent resistance measurement inputs with 100Ω..100MΩ range**
- **alternative Pt100/1000 sensor temperature measurement**
- **temperature control to 1°C**
- **industry standard RS485 bus**
- **stand-alone module in 5" x 3" case**
- **19" docking station with power supply and USB connectivity**

Specification

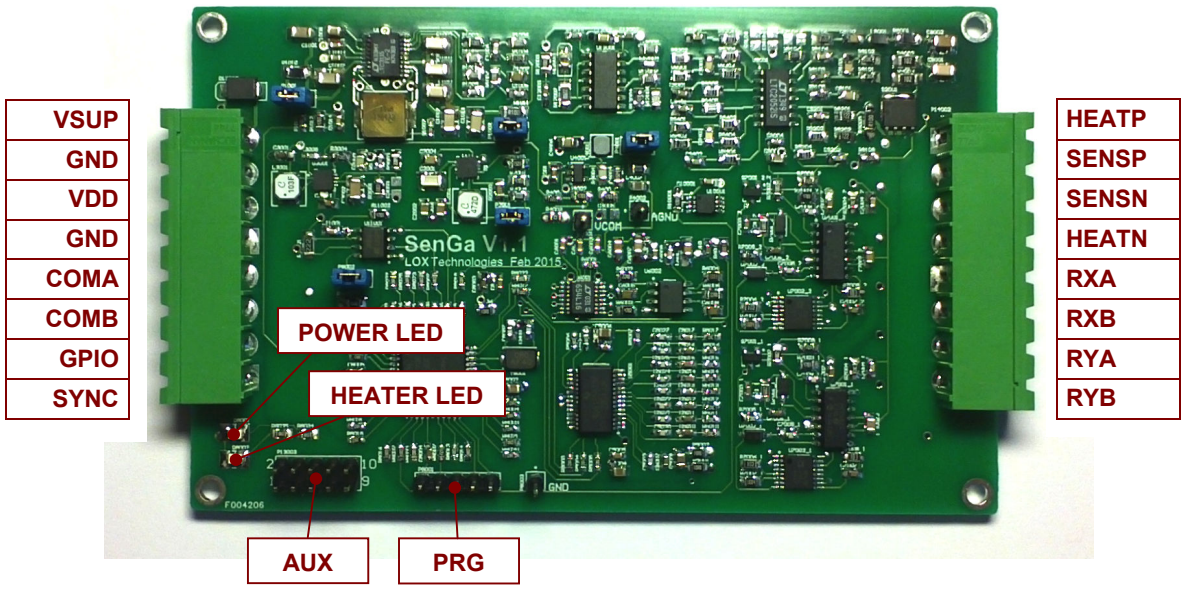
SENGA Module

Maximum Ratings			
Characteristic	**Symbol**	**Value**	**Unit**
Supply Voltage	V_{SUP}	14	V
Heater Voltage	V_{HEATP}, V_{HEATN}	30	V
Sensor Voltage	$V_{RX(Y)A}$, $V_{RX(Y)B}$	5	V
I/O Voltage	V_{IO}	5	V

Electrical Characteristics					
Characteristic	**Symbol**	**Min**	**Typ**	**Max**	**Unit**
Supply Voltage	V_{SUP}	5		12	V
Idle Supply Current	I_{SUP} at V_{SUP}=12V I_{SUP} at V_{SUP}=5V	40	60	80 200	mA
Idle Consumption	P_{IDLE}		0.6		W
Efficiency			70		%
Heater Voltage		0		25	V
Heater Current		0		1.5	A
Heater Power		0		10	W
Heater Resistance		0		10	kΩ
Heater Resistance Error			0.5	2	%
Resistance X		100		10^8	Ω
Resistance X Error	$R_X \leq 10M\Omega$ $R_X > 10M\Omega$		0.05 5	1 10	%
Resistance Y		100		10^7	Ω
Resistance Y Error	$R_X \leq 1M\Omega$ $R_X > 1M\Omega$		0.1 5	1 20	%
Digital I/O Voltage	Hi Lo		3.3 0		V

Connectors and Indication

SENGA Module Connectors and Indication



Digital Interface Connector

Signal	**Description**
VSUP	Module supply input with +5V..+12V voltage range
GND	Common ground
VDD	+3.3V output
GND	Common ground
COMA	RS485 line A to be connected with COMA of another SENGA modules
COMB	RS485 line B to be connected with COMB of another SENGA modules
GPIO	General purpose digital I/O
SYNC	Synchronization I/O to be connected with SYNC of another SENGAs

Sensor Connector

Signal	**Description**
HEATP	Heater positive supply
SENSP	Heater positive sense
SENSN	Heater negative sense
HEATN	Heater negative supply
RXA	Sensor A resistance measurement source
RXB	Sensor A resistance measurement sink
RYA	Sensor B resistance measurement source
RYB	Sensor B resistance measurement sink

AUX Connector

Pin	**Signal**	**Pin**	**Signal**
1	GPIO	2	GND
3	SYNC	4	GND
5	POWER	6	GND
7	HEATER	8	GND
9	VDD	10	GND

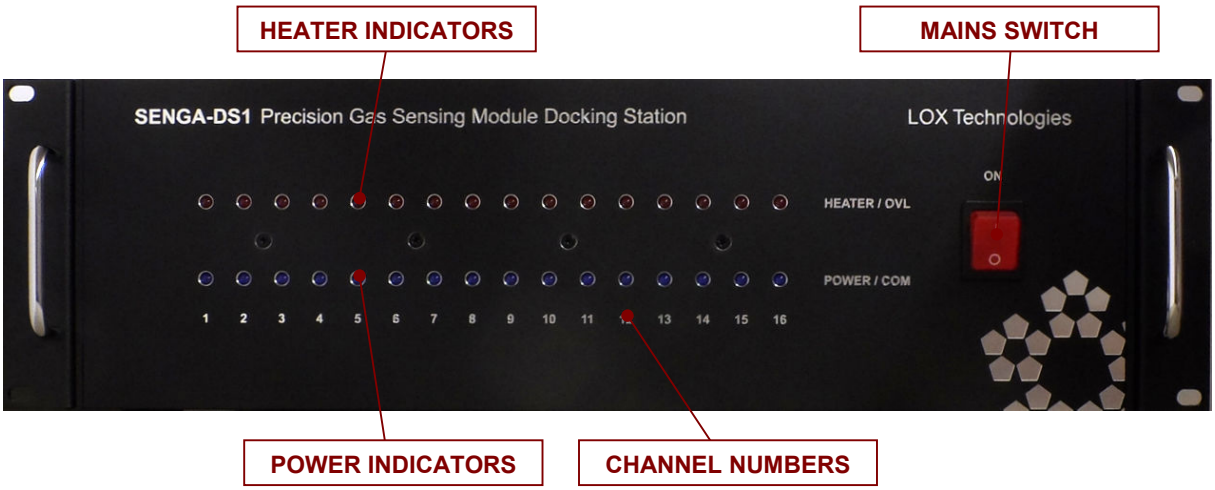
PRG Connector

Pin	**Signal**
1	MCLR
2	VDD
3	GND
4	PGD
5	PGC

SENGA Docking Station Connectors and Indication

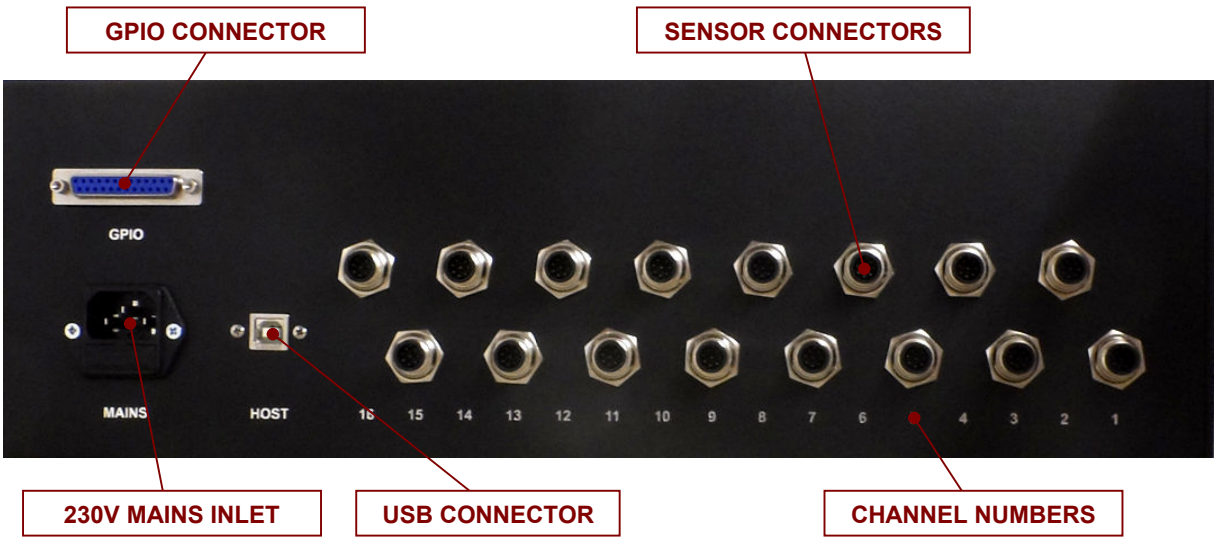
Front Panel

Front panel of the 19" 3U case of the SENGA Docking Station involves mains switch with active light and operation mode indication LEDs for all SENGA modules found in the docking station. SENGA modules are represented as numbered vertical slots with lower LED representing operation and communication status and upper red LED indication of active heating at the corresponding sensor.



Rear Panel

Rear panel involves 230V AC mains inlet, USB type B connector for PC connectivity, 16 sensor connectors, and a 25-pin D-type GPIO connector fox auxiliary digital connectivity. The 8-way male-type sensor connectors are organized in two rows and numbered from right to left according to channel numbers of corresponding SENGA modules.



Sensor Connector

Numbering and cable colors of the 8-way male-type sensor connector, found at SENGA Docking Station rear panel, is depicted below as viewed from outside (connection side). The same picture can be utilized as reference for connection of female-type sensor cable connector as viewed from solder tips, when preparing sensor cables. Docking station male connectors are of type AMPHENOL LTW12-08PMMS-SF8001 and corresponding female cable part is LTW12-08BFFA-SL8001.

Assignment of sensor connector pins to signals is in the table below.

Connector pin	**Cable color**	**Signal**
1	White	RYB
2	Brown	RYA
3	Green	SENSN
4	Yellow	SENSP
5	Gray	RXB
6	Pink	RXA
7	Blue	HEATN
8	Red	HEATP

Installation and Operation

Heater Connection

2-wire

For basic heater operation, connect one heater pole with HEATN plug and the second pole with HEATP plug. The sensor inputs are internally connected with heating outputs through 1kΩ resistances, so no additional connections are necessary. This renders resistance measurement slightly less precise (adding approx. 1% error).

Take care not to connect heater alone to SENSN and SENSP plugs, as this forces current flow through the internal resistances and may lead to excess device heating and damage.

Kelvin (4-wire)

For precision heater resistance measurements utilizing Kelvin method, connect one heater pole with separate wires to HEATN and SENSN plugs, and the second pole with HEATP and SENSP plugs. The connection of power and sense signals should be provided as close to the heater as possible, i.e. if using 8-way cable, connect the HEATN with SENSN and HEATP with SENSP signals at the other end of the cable, close to the heater of the gas sensor. For better results in laboratory tests, use Kelvin clips with 2 plugs each for connecting heater poles.

Sensing Resistance Connection

Sensor connector RXA and RXB inlets are recommended to connect sensing resistance of the gas sensor. When sensors with independent temperature measurement are utilized, connect the independent platinum temperature sensor best with RYA and RYB inlets. Then, select the proper temperatures sensor input in the PC control application by TempSource selector found in the Temp tab.

USB port

SENGA DS-1 involves USB/UART converter circuitry based on an FTDI device. Thus, FTDI driver must be installed to enable operation with SENGA control application (or direct terminal console based control) . The virtual COM port driver can be downloaded from:

http://www.ftdichip.com/Drivers/VCP.htm

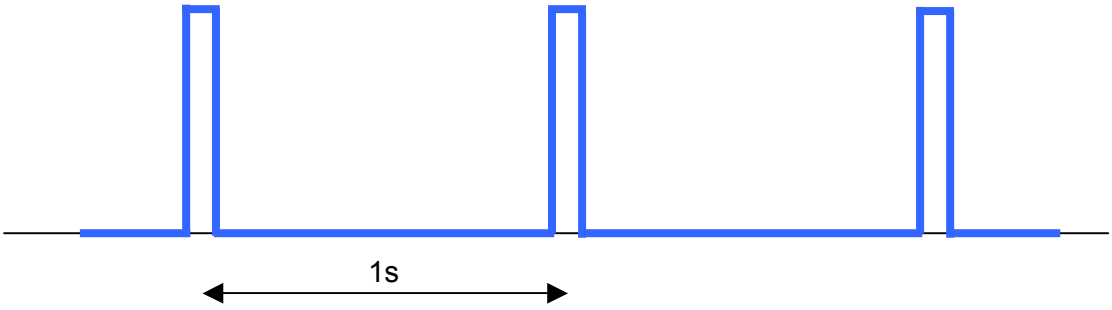
After installing the driver, connect SENGA Docking Station to the PC USB port. Then, open Device Manager, expand Ports (COM and LPT) directory and look for USB Serial Port item. If properly connected, the virtual port designation is indicated in parentheses behind the item (for example, COM5).

For connecting stand-alone SENGA module, you can use FTDI cable with integrated USB/RS485 converter or other standard serial-to-RS485 module.

Operation Mode Indication

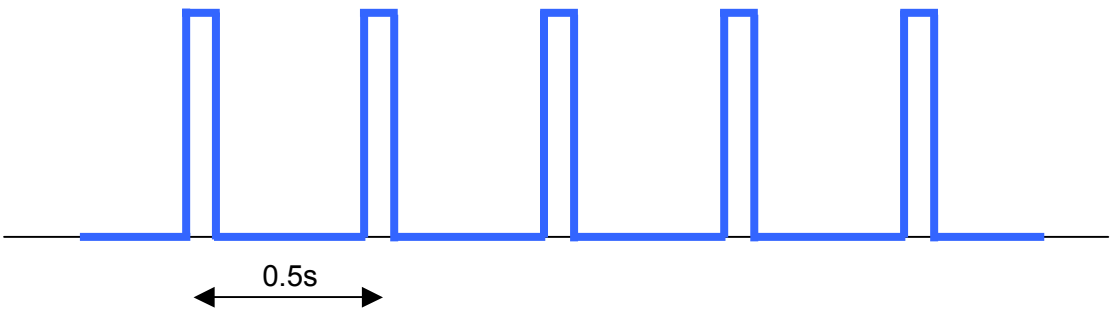
Power On

In standard operation mode, the blue Power LED on front panel (yellow on the module PCB) is lit with reduced intensity all the time and provides short flashes of higher intensity each 1 second.



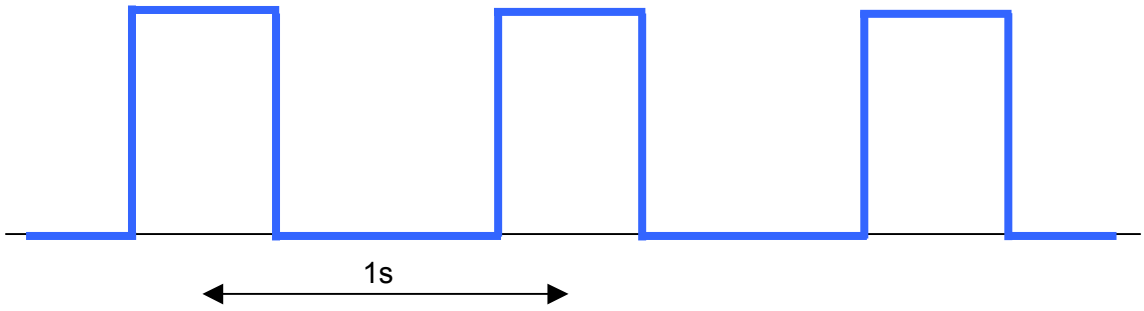
Calibration

In calibration mode, which spans for about a minute, Power LED flashes with the same intensity but twice the frequency as in the Power On status.



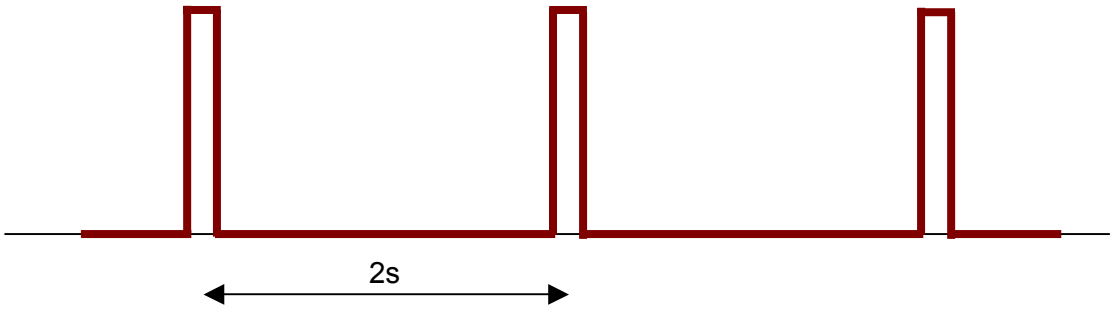
Communication

When ongoing communication is provided with one of the SENGA modules, e.g. through the PC control application, the module indicates that with more intensive and longer flashes of its Power LED.



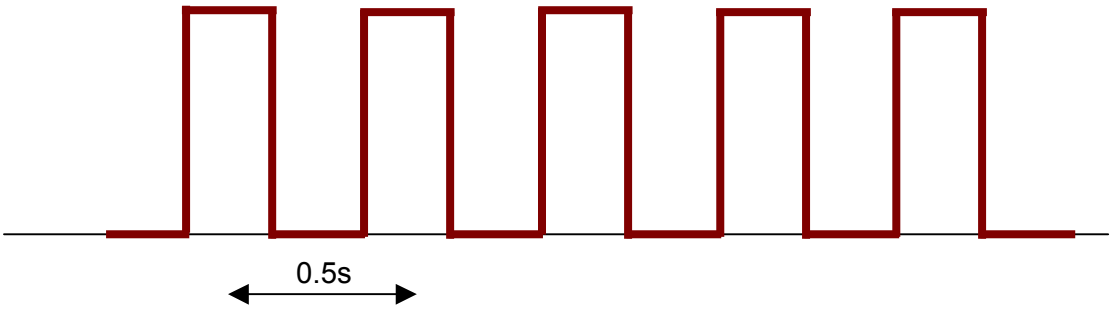
Oscillator Error

If PLL of the microcontroller oscillator fails to start, the module indicates it with short flashes of its red Heater LED with 2 second period. This state can occur at power-on and can last for several seconds, then, nominal operation is resumed.



Overload

If overload conditions in the heater circuitry occur, the module indicates that with flashing Heater LED twice per second.



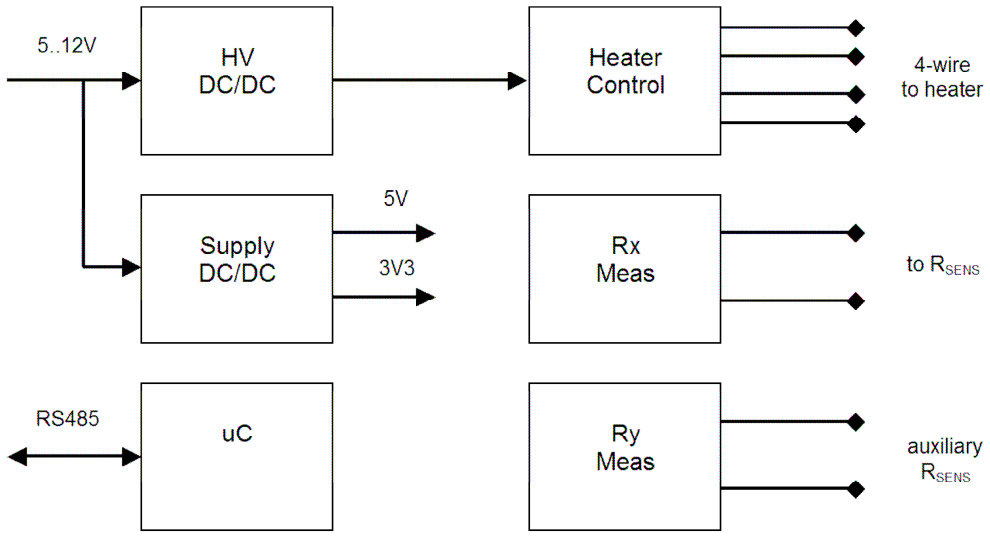
Heater On

If sensed heater current is greater than minimal current set in the ISetMin value, module indicates that with Heater LED constantly lit for all the time.

Functional Description

SENGA Module Parts

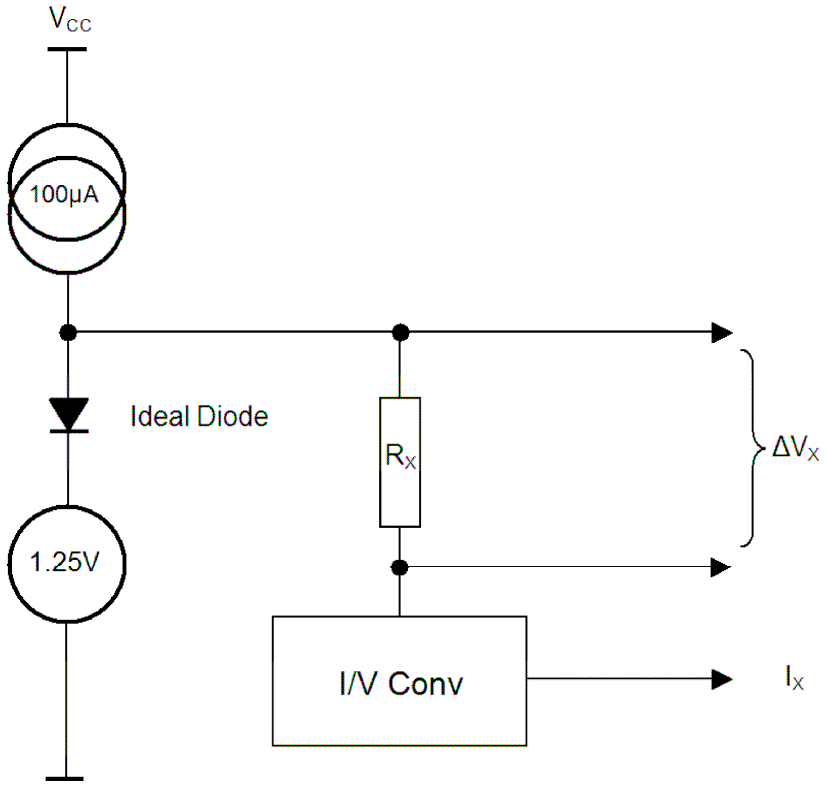
The module, schematically depicted in next figure, comprises controlled DC-DC converter and linear current controller as heater power source, two independent resistance measurement circuits, analog-digital frontend, 16-bit digital signal controller and diverse power management and communication circuits. The power unit that can supply up to 10W into heater located on the MOX gas sensor is equipped with 4-wire (Kelvin) heater resistance measurement, enabling heater temperature control with 1 degree Celsius precision. Analog acquisition is provided by fast-sampling, low noise 24-bit Delta-Sigma converter (ADS1256), while control voltages are generated in a 16-bit DAC with integrated low-drift voltage reference (LTC2654). Great attention is paid for proper grounding and decoupling of power supplies and digital part from sensitive analog circuitry.



Digital signal controller from dsPIC family is responsible for data acquisition and filtration of ADC signals in digital filters down to 4Hz bandwidth, subsequent data processing, measurement process control and communication of the results. In the first 4-pole filter banks, which are operated at ADC acquisition speed of 400Hz per channel, signals are low-pass filtered to 16Hz corner frequency. The first stage filter is conceptualized as an effective 5-pole low-pass Butterworth with one 16Hz pole in analog RC filter circuitry found at each of the eight ADC inputs. After the first-stage filtration, signals are re-sampled with 100Hz sampling clock and again filtered in the second stage 5-pole low-pass Butterworths (with coefficients equal to the first stage filter) down to 4Hz. The process ensures that the rest of noise over the Nyquist point is negligible in comparison to nominal circuit noise expected in the 4Hz range. Biquad architecture, i.e. a sequence of 1- and 2-pole units, has been utilized to implement the 4- and 5-pole filter banks. Signals in filters are treated as _Q32_16 (32 bit fractional format with LSB weight of 2-16) integer numbers, then converted to represent actual physical values into 32-bit float format.

Sensor Resistance Measurement

SENGA large-span resistance measurement involves utilization of both constant current and constant voltage methods in a composite circuitry (next figure). For resistances lower as certain value, constant current source generates voltage difference across the unknown resistance, which is linearly proportional to its value. With increased resistance, at some point, voltage reaches clamping point of the constant voltage generator, which begins to sink current through the ideal diode. Thus, device switches into constant-voltage mode and useful information is obtained in measuring the resistance current, which is then inverse-proportional to the unknown resistance. In this way, span of measured resistance decades can be almost doubled.



At any time, voltage and current are independently measured, thus the unknown resistance can be derived by dividing the voltage and current values without prior knowledge of actual current or voltage limits, as is the case for simple constant current or constant voltage methods. This enables utilization of low-cost limiting circuits, without much effort needed for ensuring precision or temperature stability of the limits. On the other hand, voltage and current readout amplifiers should excel in precision, low offsets and low temperature drifts.

Considering a two-channel ADC with at least 20-bit resolution is provided, the resistances measured in either method can span for 4 decades, given that at least 2 valid digits have to be always provided. Thus, the composite resistance readout may span for up to 8 orders of magnitude, in theory. Because of some overlapping in current and voltage channels, the actual span will be lower.

Control Cascade

Control cascade in SENGA devices maintains electrical and thermal parameters of the sourced sensor heater within nominal values for all the sensor activation time. The control cascade can be viewed as encapsulated sub-processes with heater voltage and current control as internal, low level processes, and temperature control as the top level control system. The cascade can be however broken at each point to allow user-specific measurements - this but with great carefulness.

Current Control

Heater current is controlled by the hardware of the SENGA current source, involving a power MOSFET and an analog PI controller loop, which cannot be switched inactive. Lower and upper limits to the current set-point are implemented in the software; the lower limit is necessary for reliable measurement of heater resistance by DC current/voltage method, while the upper limit avoids over-excitation of the heater circuitry, which can result in sensor damage.

Voltage Control

This is a parallel control loop maintaining set-point of a DC/DC voltage source just above the necessary voltage needed for the sensor heater. The software controller ensures that voltage across MOSFET of the current controller is always 250mV, thus, power losses at the current source will not exceed 375mW. Voltage control can be set inactive by resetting HVConEna variable of the SENGA module (found in Current panel of the control application).

Power Control

Heater power control is superior to current and voltage control loops. It involves non-linear algorithm and a PI-type controller which maintains desired power dissipation in the heater. Power controller is enabled by PowConEna variable (Power panel). An upper limit to power set-point is available.

Temperature Control

This is the top-level control sub-system for sensor heater circuitry. PI-type controller implemented in software which maintains desired gas sensor temperature is enabled by TempConEna variable (panel Temp). Again, upper limit to temperature set-point prevents possible damages to gas sensor.

Control Application

Availability and Requirements

SENGA Control is a PC application aimed for control of SENGA devices and generation of sensor measurement data. The application comes as self-extracting archive that runs on both 32-bit and 64-bit Windows operating systems. The software together with documentation is available for download at LOX Technologies web pages at:

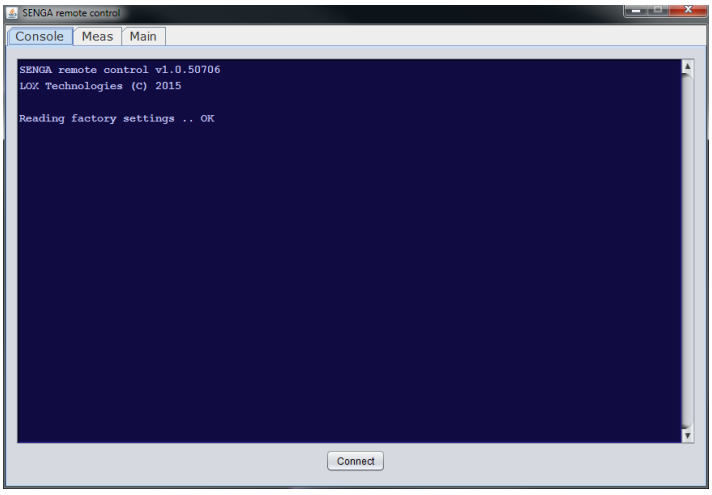
www.loxtechnologies.com/senga

The application will create c:\LOX\ directory with subdirectories for data and executables. At the same time, a link to SENGA Control application at desktop will be created.

Control Panels

SENGA Control graphic user interface consists of several tab-selectable panels, enabling connecting or disconnecting to SENGA devices, loading and saving settings, selecting SENGA device of focus, user control to device power output, temperature set-point and readout of sensing resistance, and logging of measurement data.

Console



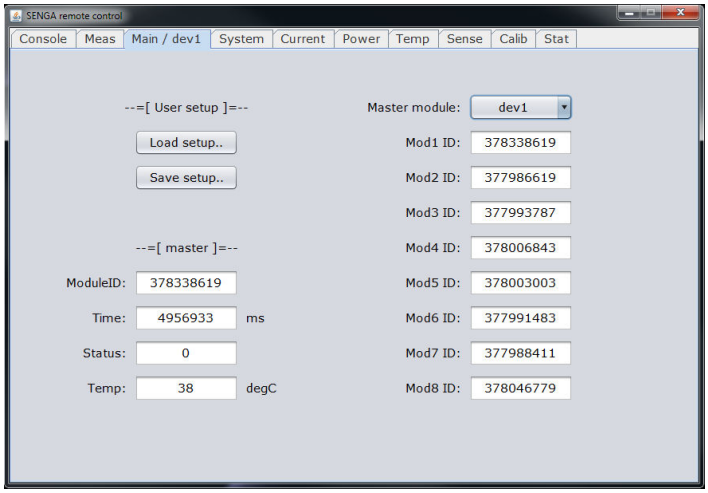
Console panel shows information about serial connection synchronization with SENGA devices. CONNECT/DISCONNECT button at bottom of the panel allows to start or stop connection session with all SENGA devices found at one of the existing serial ports.

Meas

Meas panel shows measurements taken from first 8 SENGA devices. It enables user selection of data source (first or second resistance measurement input, or current or voltage measurement) and provides a button for start/stop of measurement logging into *.csv data. The measurement data will be appended into a file within the \data subdirectory, named with current date, with optional suffix of user choice.

If data logging is active, other panels in the application are not available. Therefore, to set another temperature or parameters in the SENGA device, stop data logging, set the new parameter and start logging again. The data will be appended into the same logger file.

Main



Main panel enables to load or store settings for all connected SENGA devices, and selection of SENGA module of user focus.

When user selects particular SENGA device into focus by Master module selector, several new panels will appear, allowing detailed control of parameters of the selected SENGA module.

System

System panel shows basic system variables of the focused SENGA module. No user-editable parameters in this panel are available.

Current

Besides setting of wished heater current, this panel involves basic electrical properties in the heater circuitry. It is recommended to keep ISetMax at safe value for the particular gas sensor. The panel can be utilized for direct heater current control, which can be done only if power controller is disabled (PowConEna in Power panel unchecked).

Power

Power panel involves readout and selection of desired heater power dissipation. Power controller is enabled, if PowConEna is checked, which then means that power controller overrides heater current set-point. Upper limit to heater power can be set in the PowSetMax variable. The panel also enables to set power PI-type controller constants.

Temp

Temp panel enables selection of temperature readout sensor by TempSource selector, between on-the-fly sensing of the platinum heater resistance (ResLoad), resistance of the X channel (RMeasX) or Y channel (RMeasY). Proper temperature sensor parameters, involving reference temperature (Temp0), reference resistance (Res0) and resistivity coefficient of the sensor (Alpha) have to be set prior enabling temperature control. The controller is then enabled by TempConEna box checked, then, wished temperature set by TempSet variable is maintained, when all lower-level controller loops are also active. Upper temperature limit is set in the TempSetMax variable. Coefficients of the PI-type temperature controller are also available in this panel.

Sense

Sense panel enables readout of the X and Y resistance measurement channels, which besides resistance measurement in kΩ units, involves readout of the actual sensing voltage and current. For calibration and verification purposes, user can select one of the nominal resistances (Open, Short, 1k, 1M), or the actual module sensing input resistance (Sample).

Calib

Calib panel provides informative calibration values for both resistance measurement channels and enables to start calibration process for focused SENGA module by clicking at Calibrate button. The calibration then takes about a minute to complete. Besides calibration values visible in the Calib panel, current offsets (ISenseOff, ISetOff) in the current panel are also affected.

Stat

Stat panel enables to provide approximate statistics of resistance measurement for heater resistance and resistances of X and Y channels. The statistics starts with selection of RMeasSource and is updated each 10 seconds, as 1000 measurement values are averaged. After 20 seconds, standard deviation (RMeasSigma) value can be read, besides the average resistance value (RMeasAv).

Standard measurement procedure

1. Power-up SENGA module or Docking Station
2. Wait a minute for auto-calibration completion
3. Start SENGA Control application
4. At *Console* panel, click at *Connect*
5. If *Starting communication..* message appears at *Console*, go to *Main* tab
6. Click *Load setup* and in the child window, open a proper *.set file (e.g. senga.set)
7. Wait as application synchronizes with available SENGA devices shown at *Console*, and click OK
8. In *Main* tab, select one of the available SENGA devices (e.g. dev1)
9. Go to *Temp* tab and check if readout of sensor temperature (*TempHeater*) corresponds with ambient temperature
10. Set desired heater temperature in *TempSet* value (e.g. 300 degrees)
11. Repeat steps 6-8 for all available devices
12. In *Meas* tab, enter arbitrary suffix to log file and click at *Measure* button
13. After measurement is done, click at *Stop msr*
14. A folder with measurement logs will open by clicking at *Open data*