TCG Sensor with usb / wifi read-out — XEN-5320

Preliminary datasheet

Features

- Standard measurements
  - Helium 0-100%
  - Hydrogen 0-100%
  - General output
  - Vacuum reading (optional)
- Digital output: USB, WIFI (optional)
- Temperature and Humidity compensated
- Temperature range -20 ºC to +55 ºC
- Humidity range 0-95% non-condensing
- Start-up time: 1 second
- Data refresh time: 0.3 second
- T_{90} sensing and T_{10} recovery time: 0.6 s
- Power supply USB, Li-ion battery (optional)

Applications

- Hydrogen and helium gas experimentation
- Detection of gas dispersion rate in jets and plumes
- Fuel cell exhaust measurement
- Binary gas composition measurement
- Vacuum measurement (optional)

XEN-5320 sensor:
Above: USB PCB (57 × 40 × 15 mm^3);
Below: WIFI option including battery and housing (63 × 51 × 24 mm^3)

Not a Safety Device

The XEN-5320 sensor is not intended as a safety device: it is not to be used for the detection of hazardous concentrations of gases such as hydrogen in air.

The sensor is not conform the standards for hydrogen detection sensors.
The sensor is not designed to be a reliable safety device.
Any thermal conductivity sensor such as the XEN-5320 is not able to detect hazardous concentrations of carbon-monoxide (CO) in air, it can never be used reliably to detect CO.
The sensor is intended for test experiments only, under expert supervision, in safe experimental environments.

Contents

1 Description 3
2 Block Diagram 4
3 Preliminary Specifications 5
4 Functional Description 6
4.1 Transfer 6
4.2 Range and Poisoning 6
4.3 Selectivity 6
4.4 Response time and Transients 7
4.5 Accuracy and Noise 7
4.6 Calibration 8
4.7 Humidity influence 8
5 Instructions for use 10
5.1 Proper ventilation 10
5.2 Condensing and water dropping onto the sensors 10
5.3 Humidity sensor influence and care 10
5.4 Batteries and high operating temperatures 10
5.5 Flow and sudden changes in the ambient 11
6 I/O and Communication commands 12
6.1 Commands 12
6.2 WIFI examples 12
6.2.1 WIFI example 1 12
6.2.2 WIFI example 2 13
6.2.3 WIFI example 3 13
6.2.4 WIFI example 4 13
6.3 USB examples 14
6.3.1 USB example 1 14
6.3.2 USB example 2 14
6.3.3 USB example 3 14
6.3.4 USB example 4 14
7 Trouble shooting 15
8 Order Information and Accessories 16
9 Links 16

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1 Description

The XEN-5320 is an intelligent gas sensor for the measurement of gas composition, such as helium in air (hydrogen mimicking), oxygen (diving applications) or nitrogen; hydrogen in air or nitrogen (fuel cell applications). In addition, it can serve as a thermocouple-vacuum sensor, and it can give a general output signal, useable for other gas compositions.
The sensor is based on the measurement of the thermal conductivity of the ambient gas, using the proven thermal conductivity sensor XEN-TCG3880.
To compensate for the influence of temperature and humidity, these are measured separately and a correction is made for them in the micro-controller. Each device is factory calibrated (zeroed), the customer can re-zero.

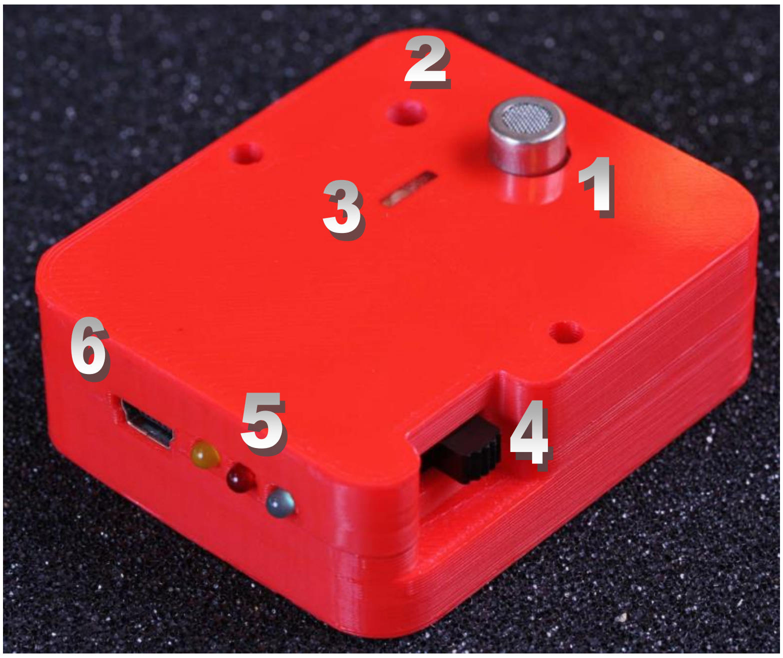
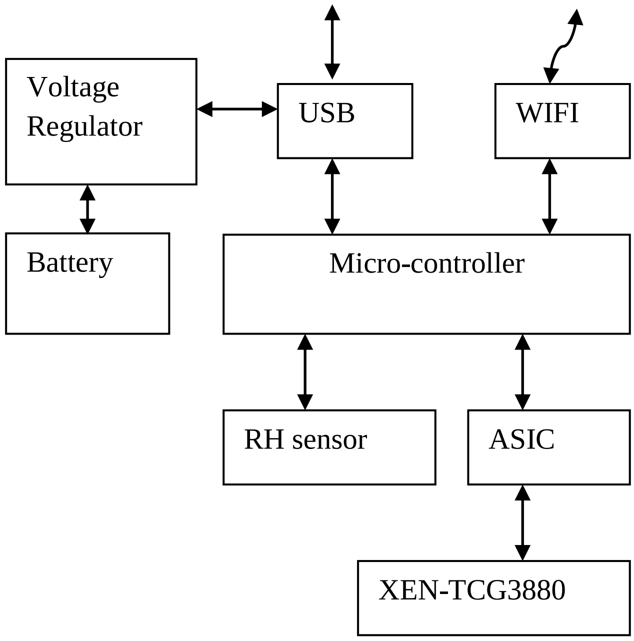


Figure 1: The XEN-5320 WIFI version.
1) The thermal conductivity sensor with built-in Pt100 temperature sensor.
2) Ventilation opening for the humidity sensor.
3) LEDs of the WIFI module: green (bottom) flashing when the WIFI module is operational; yellow (middle) transmitting; red (top) no connection. For details see the RN-171 data sheet.
4) On/off switch.
5) XEN-5320 LEDs: green (right) flashing when the XEN-5320 is operational; red (middle) Li-ion battery is charging; yellow (left) battery full.
6) USB mini-connector.

Standard the read-out and powering is done via USB.
Optionally, wireless read-out can be done by WIFI (module RN-171 from Roving Networks), with Li-ion battery power. The Li-ion battery is charged via the USB mini-connector.
LEDs are present to indicate the status of the WIFI module, the status of the battery, and the status of the micro-controller.

Biasing and measurements of the thermal conductivity sensor is via a custom-made ASIC.
The XEN-5320 performs 3 measurements per second.
Temperature measurement is done using a Pt100, and also using the temperature sensor of the humidity sensor (SHT21 of Sensirion).
Via digital communication the XEN-5320 can be instructed to calculate the output signal of the sensor assuming a helium-air mixture or a hydrogen-nitrogen mixture. Other options are to give the output signal uncalculated (i.e., only compensated for temperature and humidity), or with a calculation yielding the ambient vacuum pressure, assuming a reduced pressure of air.
On request, other output calculation algorithms can be implemented.
See the Par. on I/O for details about the programming of the XEN-5320 read-out.

2 Block Diagram



3 Preliminary Specifications

Preliminary Specifications (at 23 ºC, 101 kPa, 50 %RH)

Item	*Typical*	*Unit*	*Remarks*
General			
Sensitivity for traces of H_2	-2.0	%/%	Signal change for concentration in air
Sensitivity for traces of He	-1.1	%/%	Signal change for concentration in air
Sensitivity for traces of CO_2	+0.4	%/%	Signal change for concentration in air
Sensitivity for vacuum	-4.7	%/Pa	For low pressures
Noise	0.04	%	Of signal in air
Offset drift	0.2	%/yr	Of signal in air
Operating limits			
Temperature operating range	-20 to + 55	ºC	For full accuracy
Temperature changes	<1	ºC/min	Maximum rate of change
Humidity operating range	0-95	%RH	Non-condensing
Humidity changes	<1	%RH/min	Maximum rate of change
Pressure range	800-1200	mbar	Full accuracy
	200-800	mbar	Reduced accuracy
Operation speed			
System start up time	<1	Second	
T_{90} response time	<1	Second	For 0% to 2% hydrogen in air.
T_{10} recovery time	<1	Second	For 2% to 0% hydrogen in air.
Data update rate	3.3	Hz	Maximum
Electrical			
Current consumption	20	mA	USB
Average current consumption with WIFI	65	mA	
Battery life	15	hrs	950 mAh
Storage			
Temperature storage limits	10-40	ºC	
Humidity storage limits	20-70	%RH	
Dimensions			
USB version	57×40×15	mm^3	no housing, PCB version.
WIFI/battery version	63×51×24	mm^3	housing standard; including the extruding TCG sensor and LEDs.

4 Functional Description

The XEN-5320 determines the concentration of a specified gas in air. This is done by measuring the thermal conductivity of the ambient air using a thermal conductivity gauge (TCG), and comparing this to the factory calibration measurement. To eliminate the influence of temperature and humidity, these are measured separately, and a compensation is made by the micro-controller. The remaining difference between the measured and calibrated value of the thermal conductivity is then a measure of the gas concentration.

4.1 Transfer

In the Par. on output data the various data delivered by the XEN-5320 are described. In general, the thermal conductivity sensor measures the thermal conductivity of the ambient gases by heating a membrane with a certain amount of power, and measuring the temperature increase using a thermopile. Rather than using this thermopile voltage, it is preferred to use the transfer, i.e., the output voltage of the thermopile divided by the heating power. This is a signal that is less dependent on individual sensor characteristics

4.2 Range and Poisoning

Since the TCG is not poisoned by an overdose of gas, the operating range is 0-100% for non-corrosive and non-condensing gases. The digital output gives all concentrations, if calibration curves are available for the user-specified gas.
The capacitive humidity sensor can be sensitive to poisoning by silicone vapors, so these have to be avoided.

4.3 Selectivity

The TCG-based device is non-selective in that it will give an output in the presence of any gas having a thermal conductivity different than air.
The sensor is especially useful for the measurement of *helium* and *hydrogen*, which have thermal conductivities that are 6x resp. 7x as high as that of air at room temperature.
Most other gases have much lower thermal conductivities than helium, with *neon* at 2x the thermal conductivity of air as the highest of the others. So, other gases give much smaller signal changes. *Methane* has a thermal conductivity of about 40% higher than that of air, and CO_2 (*carbon-dioxide*) nearly 40% lower. These gases can still easily be measured using the XEN-5320.
However, CO (*carbon-monoxide*), for example, has about the same thermal conductivity as air, so this gas is very difficult to detect with a thermal conductivity measurement.

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4.4 Response time and Transients

The TCG has a response time (0% to 90%) of about 0.6 s, see Fig. 2, in which the time is measured in increments of 0.3 s. The recovery time is approximately the same. For other gases, different times may be valid, depending on the diffusivity of the gases.

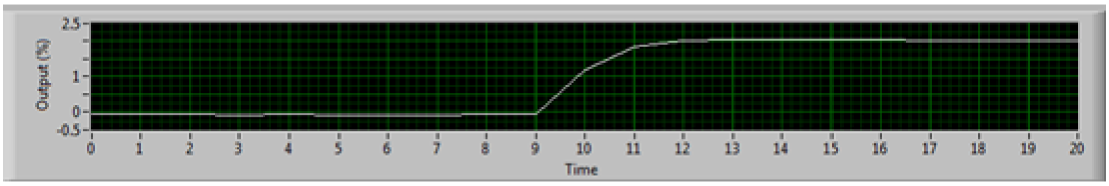


Figure 2: Response of the thermal conductivity sensor to a 2%-change in hydrogen concentration. Each increment of time is 0.3 s. The t90 response time (rise to 90% of final value) is of the order of 0.6 s

However, the measurement of humidity and temperature by the separate RH sensor is slower, and the consequence is that in transient conditions, where temperature and/or humidity are changing rapidly, the calculated output of the sensor can be off. This is caused by the fact that response time of the thermal conductivity gauge is much faster than that of the humidity sensor. And while temperature transients may be dampened by the fact that all solids take time to change their temperature, the humidity is a gas phase property, and this can change more rapidly.

4.5 Accuracy and Noise

The accuracy of the XEN-5320 is determined by several effects. The zero of the sensor can be recalibrated, but also be determined from the measurement results in case a measurement is being performed that should give back zero output.
The gain of the measurement, how an output signal is calculated, depends on the temperature and humidity measurement and correction, and also on the calibration curve for a specific gas combination.
In general the calibration curve for a gas combination is determined at room temperature (≈ 20-25 ºC). At other temperatures, it is expected that this curve will be different. This introduces an error. For di-atomic gases such as nitrogen, hydrogen and CO the ratio of the thermal conductivity at 300 K and at 400 K is roughly the same. For the mon-atomic gas helium, this ratio is slightly lower, while for the tri-atomic gas CO_2 it is much higher. Especially for CO_2 one will expect an error when using the room-temperature sensitivity curve at other temperatures.
Also the correction for temperature and humidity will introduce errors, firstly because of the inaccuracy of the temperature and humidity measurement, and secondly because of the inaccuracy of the correction factors used. They may be slightly different for individual sensors.

At a typical 250 ppm/ ºC temperature coefficient (TC) of the sensor's basic signal (the transfer = output voltage of the TCG sensor divided by the input heating power), the correction for a 40 ºC temperature deviation is 10 000 ppm. If the TC is off by 10%, this means that an error of 1000 ppm is be introduced by the temperature correction alone.

For the humidity it holds that the correction factor, at low humidities, is of the order of -2500 ppm/kPa. and 1 kPa is equivalent to about 33% RH at room temperature. Also here noticeable errors can be introduced if the correction factor is inaccurate. At high temperatures the problems can get out of hand, for instance, at 80 ºC 100% RH is equivalent to about 47 kPa. Now, an error in % RH measurement of 5% RH is equivalent to 2 kPa, or an error of about 5000 ppm in the output signal. See below for some details on the humidity measurement and errors.

Finally there is noise in all measurements that are made, and this introduces noise in the output signal as well. The total noise level of the sensor is of the order of 250-500 ppm of the transfer, see Fig. 3 for a typical read-out, with 0.3 s data refresh time.

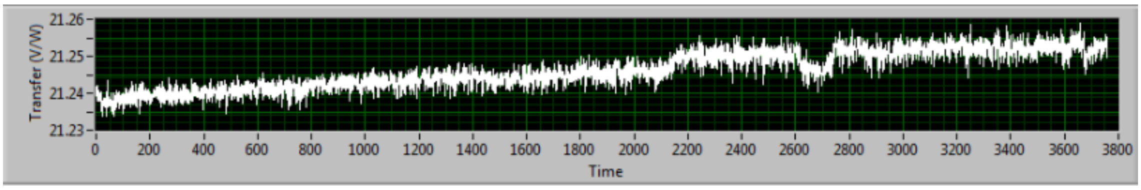


Figure 3: Transfer of XEN-5320 at 0.3 s data refresh time. The peak-to-peak noise of this measurement is typically 0.005 on 21.24, or 250-500 ppm. RMS noise is then of the order of 50-100 ppm.

If the parameter being measured allows it, averaging of the signal is an option, thereby greatly reducing the noise.

4.6 Calibration

In order to minimize the inaccuracies described above, it helps to zero the sensor as close as possible to the eventual operating conditions. This will at least eliminate any errors occurring due to the difference between room temperature zeroing and operating conditions.
When using the LabView program for reading and storing the measurement data, the user has the option to further analyze the stored data and determine correction curves around the user's point of operation.

4.7 Humidity influence

The influence of humidity on the TCG can best be described using the absolute humidity (AH) or partial vapor pressure in kPa, this is for measurements at sea level (100 kPa total pressure). Then, this influence is mostly temperature independent. Fig. 4 below shows that the saturation partial pressure of water vapor vs temperature rises quickly with temperature, and at temperatures around 80 ºC the influence is very large. A fortunate property of the TCG is that at around 19-20 kPa, the transfer has a minimum (see Fig. 5), after which it rises again. So, at a humidity level of about 20 kPa, the sensor is not sensitive to small humidity changes.

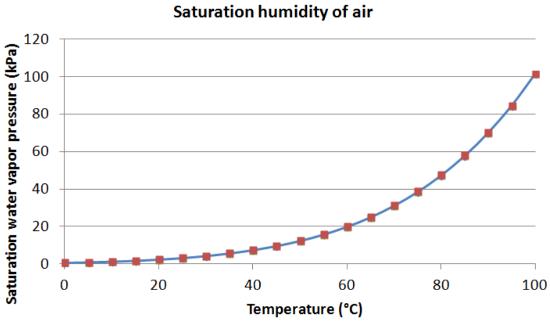


Figure 4: Saturation partial pressure of water vapor vs temperature.

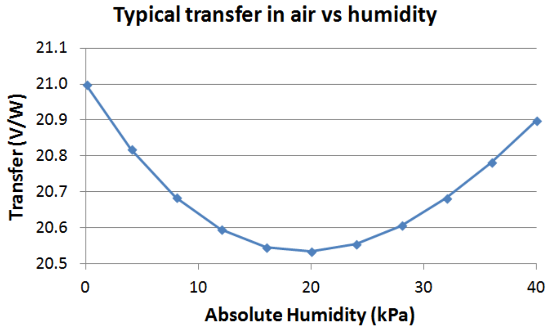


Figure 5: Typical XEN-5320 transfer as a function of partial pressure of water vapor (measured at 80 ºC)

This is nicely illustrated in Fig. 6, where a measurement of the transfer of the XEN-5320 (at 500 ms time increment) is shown. Between measurement 2000 and 3000, the humidity is close to 20 kPa, and the transients in the humidity are not seen in the transfer (amplitude) of the sensor, while in later data points, at ever higher humidity, the transients in the humidity give ever larger transients in the transfer.

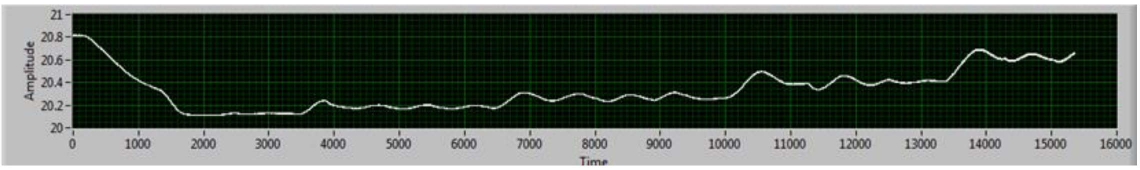


Figure 6: Transients in humidity do not show in the transfer of the XEN-53210 around 20 kPa partial water vapor pressure (measurement 2000-3000), but lead to increasingly larger transients in the transfer at ever higher partial water vapor pressure levels (further measurements).

If we combine the inaccuracy of the RH sensor with the sensitivity of the TCG for humidity, we still end up with large inaccuracies due to humidity at elevated temperatures.
The RH sensor has a basic inaccuracy of about 3%, rising up to 5-8% at high and low humidities and temperatures. As calculated above, the graph shows that the difference in transfer at 0 kPa and 3 kPa, which is 6% RH at 80 ºC (the typical error of the RH sensor), is easily 0.75% or 7500 ppm.
At 55 ºC the absolute humidity is a third of that at 80 ºC, while also the RH sensor performs better at this lower temperature. Consequently, the errors due to humidity at 55 ºC are an order of magnitude smaller and will generally stay below 0.1%.

5 Instructions for use

5.1 Proper ventilation

Above all other measures, the user must take care that the sensing element is properly ventilated so that the gas to be measured can access the sensing element through diffusion into the cap via the hole in the cap. Blocking this hole or proper ventilation of the instrument in general will make the device non-functional, while still it will indicate values that appear to be proper.

5.2 Condensing and water dropping onto the sensors

Precaution must be taken against condensing of water vapour in the sensor or water drops falling onto the sensors, as this may lead to (irreversible) malfunctioning. Preferably the sensor is installed in such a way that the *opening of the thermal conductivity gauge is downwards*, to avoid contamination by water drops, dust or other matter falling onto the gauge and the humidity sensor. However, the sensor will function properly in any orientation.

5.3 Humidity sensor influence and care

More specific caution should be taken when subjecting the humidity sensor to extreme values of temperature and humidity. When subjected to temperatures below zero or humidities around zero, the humidity sensor may take some time to recover. It is therefore not advised to use the XEN-5320 at these extremes and then suddenly expose the XEN-5320 to high temperatures (above room temperature) and humidities, this can temporarily lead to falsely indicated concentrations.
Another problem may be that condensation of water vapour can occur, with the risk of short circuits.
Exposure to very high humidities over the 90% RH may lead to some drift of the sensor, and thus to drift of the XEN-5320 at the high end of the temperature range. For more details, go to the Sensirion website for the SHT21 RH sensor.

5.4 Batteries and high operating temperatures

For customers requiring higher operating temperatures than 55 ºC, it is advised to use the sensor without battery, because the battery is not designed to function at high temperatures. The XEN-5320 in the USB version (no battery, no WIFI) has been successfully tested for short periods (hours) at temperatures of 80 ºC and humidities of 90% RH (around 40 kPa water vapour partial pressure, at sea level pressures around 100 kPa).

5.5 Flow and sudden changes in the ambient

Sudden temperature shocks and humidity shocks may lead to spurious signals in the sensor output. Also sudden movement of the sensor and strong air flow directly onto the sensor may lead to spurious signals.

Although the sensor has a double shielding against flow effects, exposing the sensor to gas flows may influence the calibration curves and correction curves for temperature and humidity, and lead to residual offset (output signals) even when exposed to the calibration gas only.

6 I/O and Communication commands

Extended instructions for using the LabView program with the XEN-5320 are given in the separate manual. Below, the commands to the XEN-5320 via USB and WIFI are explained.

6.1 Commands

For those who want to organize their own communication between XEN-5320 and control device (computer, lap top, smart phone?), the following commands are available.
For USB send command
For WIFI send command + CR (carriage return)

a send 1× data (USB)
b keep sending data until char “s” is received (WIFI)
d send device info (WIFI+USB)
e send device name and firmware (WIFI)
p go into WIFI module programming mode (USB)
+ Exit WIFI module programming mode (USB)
x automatic calibration (WIFI+USB)

6.2 WIFI examples

In Red: Sent by Computer
In Blue: Received from sensor
WIFI will echo back the command + CR that the WIFI module has received. The ‘x’ is a special case.

6.2.1 WIFI example 1

b+CR
b+CR
a-65.287162784b21.095815656c31.775995264d32.472824096e39.639038080 f1.930234880g1.000118255h0.020606604i0.001256073j0.777675776 k0.000976817l3.282298080m3.947505216n a-65.287162784 b21.095815656c31.775995264d32.472824096e39.639038080f1.930234880g1.000118255h0.020606604i0.001256073j0.777675776k0.000976817l3.282298080m3.947505216n

Computer sends command *b+CR*
Computer receives char *b* followed by a *CR* and the data string: a(output in ppm)b(transfer)c(temp PT100)d(temp senserion)e(rel humidity)f(abs humidity)g(corrected transfer)h(thermocouple)i(heater current)j(heater voltage)k(heater power)l(v supply)m(battery voltage)n

'n' is the stop sign for the data of the measurement. Then come new measurement data starting with 'a'.
The data transfer will be stopped by sending any char to the sensor.

6.2.2 WIFI example 2

d+CR
d
START08AC60NAME1.4.1SOFTH2MODE-1.929999936CAL250.000000000CAL-0.002450000CAL0.000075000CAL-0.000000416CAL0.996363456CAL21.125057224CAL29.008617401CAL

Computer sends command *d+CR*
Computer receives char *d* followed by a *CR* and START(device name)NAME(firmware version)SOFT(measurement mode)MODE(sensitivity)CAL(TC transfer)CAL(AH1)CAL(AH2)CAL(AH3)CAL(Y_AH_CAL)CAL(TF_CAL)CAL(temp cal)CAL

6.2.3 WIFI example 3

e+CR
e
o08AC60NAME1.4.1SOFT

Computer sends command *e+CR*
Computer receives char *e* followed by a *CR* and o(device name)NAME(firmware version)SOFT

6.2.4 WIFI example 4

x+CR
x
Computer sends command *x+CR*
Computer receives char *x* followed by a *CR*. When the auto calibration has been finished another *CR* is received. During auto calibration no char should be send or the calibration routine will be stopped.

6.3 USB examples

Chars should not be followed by a CR. USB does not echo back the commands as WIFI does.

6.3.1 USB example 1

a

a716299.000000b-8.004925c29.794994d29.373268e50.541443f2.063262g-0.382457h-0.007101i0.001250j0.709453k0.000887l3.309419m4.194404na703089.750000b-7.469872c29.766468d30.370705e48.977417f2.157631g-0.356963h-0.006627i0.001250j0.709502k0.000887l3.308895m4.191533n

Computer sends command *a*
Computer receives the data string: a(output in ppm)b(transfer)c(temp PT100)d(temp senserion)e(rel humidity)f(abs humidity)g(corrected transfer)h(thermocouple)i(heater current)j(heater voltage)k(heater power)l(v supply)m(battery voltage)n

This is the same data string as sent by WIFI, but only once per sent command *a* in the case of USB.

6.3.2 USB example 2

d

START08AC26NAME1.4.1SOFTH2MODE-1.930000CAL250.000000CAL-0.002450CAL0.000075CAL-0.000000CAL0.995915CAL20.965000CAL25.789000CAL

Computer sends command *d*
Computer receives START(device name)NAME(firmware version)SOFT(measurement mode)MODE(sensitivity)CAL(TC transfer)CAL(AH1)CAL(AH2)CAL(AH3)CAL(Y_AH_CAL)CAL(TF_CAL)CAL(temp cal)CAL

6.3.3 USB example 3

p

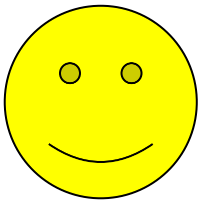
Computer sends command p. Now all chars are echoed to the WIFI module, and all chars received from the WIFI module are echoed back the computer. This process ends until char + is send by the computer.

6.3.4 USB example 4

x

[00:21:53]
Computer sends command *x*.

When the auto calibration has been finished 2x *CR* + system time from the sensor board is received. During auto calibration no char should be send or the calibration routine will be stopped.



7 Trouble shooting

The measurement data show a lot of zero’s instead of real data.	It can be that your computer shows only zeros after the decimal separator, if this separator is a comma. This separator should be changed into a point (.), and then, correct trailing digits will appear. This can be done in the Country & Language part of the configuration screen of your PC.
The time data are wrong when importing the measurement file into EXCEL.	Be sure to define the time data column as ‘time’ in the cell properties.
When importing the measurement data into EXCEL they are of an incorrect magnitude.	This is a point/comma settings result. When importing the data in EXCEL, use the advanced settings to exchange the designation of a point and a comma.
Communication of the LabView program with the WIFI router is not working.	Be sure to have the settings of the computer and the router exactly as explained in the WIFI chapter.
The communication with the WIFI devices is not working.	Be sure to have the settings of the devices corresponding to the settings of the router.
Measurement mode change or zeroing does not work.	Stop the measurement before performing these actions.

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8 Order Information and Accessories

Standard version: the order code for the XEN-5320 sensor, with standard options indicated: XEN-5320.

Order codes for the XEN-5320 sensor

Option	*Order code*	*Content*	*Remarks*
USB	XEN-5320-U	USB PCB	Bare PCB
USB with housing	XEN-5320-UH	USB PCB + housing	(a)
WIFI/battery	XEN-5320-W	USB PCB + housing + WIFI + battery	(a)
Housing for USB PCB	XEN-85040	Housing	(a)
Other gas curve	-	Calibration curve for other gas	On request

(a) Housing color depending on availability

9 Links

For the WIFI module: www.microchip.com search for WiFly RN171XV
For the humidity sensor: www.sensirion.com search for SHT21

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