SGX SENSORTECH

The Integrated IR (INIR) Gas Sensor has been designed using the latest technology with an ARM7TDMI core microcontroller and via software design the necessary techniques have been implemented to increase the reliability of the device minimizing probability of faults. The INIR is a user friendly digital gas sensor, designed to decrease the implementation time, hence increasing productivity. The Integrated IR incorporates the necessary electronics and embedded firmware using infrared gas sensing technology with reduced power dissipation. The sensor will sample the raw signals to output a linear, temperature compensated signal proportional to the gas concentration applied. The output signal is available in digital and analogue forms. The INIR provides users with a simple method of incorporating an infrared gas sensor into their gas detection instrument significantly reducing development time and expertise required for implementation. The Integrated IR can also be factory calibrated to allow installation without the need for recalibration in various gases and target concentrations if required.

Introduction

This document gives an overview of the methods used to communicate with the Integrated IR Gas Sensor and specifically concentrates around the Universal Asynchronous Receive/Transmit (UART) communication protocol. In addition to the above this document incorporates examples of communication based on real life application assuming that the INIR Gas Sensor is connected to another Microcontroller via the UART (TX,RX pins).

The core technology used incorporates a very well-known and proven NDIR Gas Sensing technique together with a robust, highly reliable ARM7 MCU mounted on printed circuit board. The INIR has been designed as an improved digital version of the 7-pin single gas sensor like the IR12GM_1, which uses a supported filament lamp for additional shock protection. The necessary electronic circuit and embedded firmware calculates the linearized and temperature compensated concentration providing both digital and analogue (12-bits) outputs. The Configuration Unit EK4 can be used to set up, calibrate and evaluate the INIR with easy-to-use PC software.

Alternatively, control of the INIR via UART is available with an external microprocessor. The device contains full fault diagnostics – information is being sent via the Digital String along with the Temperature

output of the sensor and the linearized Concentration in parts per million (ppm).

Summary of Contents

The first chapter accommodates a complete guide on how to communicate with the INIR Gas Sensor. Highly detailed guidelines and summary tables are attached in order to explain the capabilities of the INIR Sensor and information how to implement the communication via UART with another microcontroller or a personal computer.

Chapter two contains a small tutorial on how to perform the Calibration Procedure via the Evaluation Software including examples to help to understand of the software's tools as well as the calibration procedure.

Chapter three covers condensation compensation algorithm.

The final chapter covers details on pressure compensation algorithms and suggestions on when it should be implemented.

Abbreviations & Glossary

Abbreviation	Meaning/Description
USB	Universal Serial Bus
ADC	Analog-to-Digital Converter
DAC	Digital-to-Analog Converter
INIR	Integrated IR Gas Sensor
UART	Universal Asynchronous Receiver and Transmitter
MCU	Microcontroller Unit
CPU	Central Processing Unit
PC	Personal Computer
DC	Direct Current
AC	Alternating Current
Config	Configuration
Init	Initialization
FLASH/EE	Flash memory, embedded to MCU

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Document Revision Record

Version	Issue Date DD/MM/YYYY	Main Changes
0.0 iss 0	10/06/2014	Original Draft version.
2.0 iss 1	12/12/2014	Amended DRAFT version to accommodate the new calibration and firmware communications. (Applies for SMIR firmware 4v0&above or INIR firmware 1v0&above).
2.0 iss 2	14/01/2014	Amended DRAFT version to accommodate the changes to the release of the INIR project. (Applies only to INIR 1v0&above).
Issue 3	11/11/2015	Officially issued Application Note.
Issue 4	21/03/2016	Added Guidelines for Dust, Mechanical Shock, Corrosion, Extreme Conditions.
Issue 5	26/02/2018	Added multi-sensor protocol, Backup calibration,
Issue 9	10/01/2019	Added separate error code for warm-up, warm-up concentration set to 0.0%v/v

Document Errata Record

Version	Issue Date DD/MM/YYYY	Errata Sheet Reference
		No Errata Sheet Exists yet.

1. Communicate with Integrated IR

There are two ways of communicating with the Integrated IR (INIR). The first way is by reading the Analogue Output of the INIR which should be connected to an Analogue to Digital Converter (ADC). The Analogue Output is providing a linearized value of the gas concentration detected, please see "Calculate Conc v.v% by Reading the Analogue Output" for more details. This method of communication is one-way and allows only to read the value coming from the INIR. For best resolution of the concentration the Analogue Output should be sampled with a minimum of 3 floating points precision.

The second way of communicating with the Integrated IR is by using the Universal Asynchronous Receive Transmit (UART) interface. The Digital Output String contains the information containing the calculated concentration, faults, active channel amplitude, reference channel amplitude as well as the internal temperature of the sensor. We can read the UART output either by plugging in the INIR in SGX's Configuration Unit and using the INIR Evaluation Software or by connecting the UART directly to another microcontroller/PC. This specific way of communication is bidirectional, meaning that it is possible to send commands to the INIR via UART as well.

With this method it is possible to send commands to the INIR and get answers back from the device accordingly, please see "Universal Asynchronous Receive Transmit (UART)" below.

The software for the device has been designed to increase response times making the whole module faster than most custom made equipment. The transmission protocol included CRC to warranty the correct data interpretation. Last but not least the Real Time Data Processing algorithms used in the module make the device suitable for Real Time Applications inside tight industrial standards.

1.1 Universal Asynchronous Receive Transmit

The Universal Asynchronous Receive Transmit (UART) is a protocol that many devices especially microcontrollers are using often to communicate with each other or with a computer. The INIR device has been designed to output a string with all the data required to implement the device into any gas sensing application. Please see paragraphs below for settings and more details on how to communicate with the INIR via the UART and the format used for the digital output string.

Whether it is required to communicate with another microprocessor or a computer via the serial communication protocol both devices must have the same settings otherwise the communication might be faulty or even impossible.

When calculating the gas response times of the INIR, it is advisable to take into consideration the delay resulting from the transmission and data processing. In case of the INIR Evaluation Software that delay is about 1 second, therefore the data in the Graph is effectively the data transmitted a second ago, overall 2 seconds delay from Real Time environment. If averaging of more than 2 values is chosen it is recommended to RE-calculate the response times.

1.1.1   UART Communication Settings

At the moment it is advisable to communicate with the UART of the Integrated IR module by using the recommended setting stated in the Table 1.0 - UART Settings seen below. Obviously the same settings will be valid when communicating with the INIR by using a PC or another microcontroller.

Please see below the settings for communicating with the UART.

Table 1 –UART Communication Default Settings

Baud Rate	38400
Data Bits	8
Parity	None
Stop Bits	2
Handshaking	None

IMPORTANT WARNING!

It is possible to change the Baud Rate using the equivalent variable stored into the Flash, but the 38400 is optimal setting for most applications. If the Baud Rate has been accidentally incorrectly changed (example "10") the INIR will not recognise the Baud Rate but it will use the 38400 by "default".

1.1.2   Digital Output String Via UART

IMPORTANT WARNING!

All the variables are HEX representation of the numbers but are transmitted via the UART as a Digital "String" - all the variables are send and read in ASCII format. See functions 1 to 4 for more details.

Every second the INIR uses the UART to send a string to the digital output. Therefore the TXD pin of the UART is transmitting all the information to the PC or another custom device. There are two different states in the transmission, depending on the "Mode" that the INIR is running. There are generally four modes that the MCU can run and all of them can be configured via the UART by sending an appropriate command. Please see the Table 3 - UART Commands for more information on the commands that are available to the Integrated IR. In the same way the INIR can send an answer back so it is possible to have a two-way communication with the Integrated IR device. See the Table 8 - Read Back the Settings from the

Integrated IR to understand how the data is being stored in the Microcontroller.

Table 10 contains answers from the Integrated IR UART when sending a command. The UART.

The probability of an error in communication protocol of the specific Baud Rate is around 0.015% given by the manufacturer assuming ambient temperature of 25°C, without strong electromagnetic field. CRC can be used to minimize or even eliminate communication errors. The basic difference between the NORMAL and ENGINEERING Mode is the digital output representation of the signal processing. In the ENGINEERING MODE INIR is sending two more variables that are representing the Active and Reference Peak-to-Peak amplitudes of both signals accordingly.

The Faults in both cases are extracted and can help to identify critical errors of the Gas Sensor itself. With the help of the CRC the Integrated IR can be used in a sensing network system able to interact with the environment via sophisticated PC software.

Please see the Table 2 below for more information about the digital output string depending on the different modes available.

Table 2 - Digital Output, UART String in Single-Sensor Protocol

Mode	String
"NORMAL" MODE	[// Start Character 0x000005B (HEX) 0xAAAAAAAA // Gas concentration in PPM (HEX) 0xAAAAAAAA // Faults (HEX) 0xAAAAAAAA // Sensor Temperature (HEX) 0xAAAAAAAA // CRC 0xAAAAAAAA // 1's Compliment of CRC] // End Character 0x000005Du (HEX)
"ENGINEERING" MODE	[// Start Character 0x000005Bu (HEX) 0xAAAAAAAA // Gas concentration in PPM (HEX) 0xAAAAAAAA // Faults (HEX) 0xAAAAAAAA // Sensor Temperature (HEX) 0xAAAAAAAA // Reference 1 sec Average value 0xAAAAAAAA // Active 1 sec Average value 0xAAAAAAAA // CRC 0xAAAAAAAA // 1's Compliment of CRC] // End Character 0x000005D (HEX)
"ON-DEMAND" MODE	[// Start Character 0x000005Bu (HEX) 0xAAAAAAAA // Gas concentration in PPM (HEX) 0xAAAAAAAA // Faults (HEX) 0xAAAAAAAA // Sensor Temperature (HEX) 0xAAAAAAAA // Reference 1 sec Average value 0xAAAAAAAA // Active 1 sec Average value 0xAAAAAAAA // CRC 0xAAAAAAAA // 1's Compliment of CRC] // End Character 0x000005D (HEX)
"CONFIGURATION" MODE	The UART (Digital Output) and the DAC (Analogue Output) are disabled but communication is fully functional.

NOTE: "0xAAAAAAAA" hex number is an example representing the 32-bit numbers that are being transmitted via the UART and is different in every case depending on the actual value that is representing, for example a concentration of 500 PPM will be 0x000001F4 in hex.

Table 3 - Digital Output, UART String in Multi-Sensor Protocol

Mode	String
"ON-DEMAND" MODE	[// Start Character 0x000005Bu (HEX) 0xAAAAAAAA // Serial number 0xAAAAAAAA // Gas concentration in PPM (HEX) 0xAAAAAAAA // Faults (HEX) 0xAAAAAAAA // Sensor Temperature (HEX) 0xAAAAAAAA // Reference 1 sec Average value 0xAAAAAAAA // Active 1 sec Average value 0xAAAAAAAA // CRC 0xAAAAAAAA // 1's Compliment of CRC] // End Character 0x000005D (HEX)
"CONFIGURATION" MODE	The UART (Digital Output) and the DAC (Analogue Output) are disabled but communication is fully functional.

1.1.3 Commands to the UART in Single-Sensor Protocol

The commands that can be sent to the UART are specified in the Table 4 below. All the commands must be initialized with the character "[" and terminated with the character "]", using capital letters all the time.

In this case structure of the command is : [(Letter of command)]. For example [C] where C is command.

The implementation of the commands from Table 4 can be used to communicate and perform tasks, in both high and low-end applications.

With integrated MCU the INIR is effectively a standalone device that can also be implemented in any network based system design. INIR is not a standalone gas sensing instrument - it still remains a digital gas sensor and should be handled as a component because it is classified as such.

Table 4 - INIR NEW UART Commands available in Single-Sensor Protocol

UART Command	HEX Code	Meaning of the Command	Detailed Description
[A]	[0x41]	Enter Normal Mode	Puts INIR into NORMAL MODE. In this Mode it is not possible to write or read the settings and the Active and Reference signals are not being transmitted via UART every one second. Available Commands: [B], [C], [E], [F], [G], [L], [M], [O], [P]
[B]	[0x42]	Enter Engineering Mode	Puts INIR into ENGINEERING MODE. In this mode the INIR is calculating everything. The Active and Reference signal values are also exported via UART every one second. Available Commands: [A],[B], [C], [E], [F], [G], [L], [M] , [O], [P]
[C]	[0x43]	Enter Configuration Mode	The INIR is not calculating anything; the UART and DAC are disabled. Available Commands: [A], [B], [C], [I], [J], [K], [L], [M], [N]
[D]	[0x44]	NOT USED	Reserved for future used, no effect.
[E]	[0x45]	Calibrate New Zero	Calibrates the new ZERO value. The value will be stored in the Flash/EE memory of the sensor automatically. Can be performed under NORMAL, ENGINEERING modes.
[F]	[0x46]	Calibrate New High Span	Calibrate new High SPAN value. The value will be stored in the Flash/EE memory of the sensor automatically. Can be performed in NORMAL or ENGINEERING modes
[G]	[0x47]	Calculate New Offset	Calculates an offset value that is being used to improve the precision and linearity in low concentrations. Can be performed in NORMAL, ENGINEERING modes.
[H]	[0x48]	On-demand Mode	Puts INIR into On-demand MODE (available starting 2v18 firmware version).

UART Command	HEX Code	Meaning of the Command	Detailed Description
			In this mode the INIR is sending information in the same format like in Engineering Mode but only when user sends a read-out command. Available Commands: [E], [F], [G], [L], [M], [O], [P], [Q]
[I]	[0x49]	Read Back the Settings	Send this command to the INIR if you want to read the settings back. All the settings are in a hex form representing integer values only.*³, see Table 4.0. Can only be performed under CONFIGURATION mode.
[J]	[0x4A]	Load new settings to INIR	Write the new setting to the device, all the settings are in a hex form representing integer values only, see paragraph 1.2.10. Can only be performed under CONFIGURATION mode.
[K]	[0x4B]	RESET to Factory Default Values	Reset all the variables into the Factory Defaults and erase all the custom settings that customer have changed like the calibration or the coefficients. Can only be performed under CONFIGURATION mode.
[L]	[0x4C]	Turn Humidity Algorithm "ON"	By sending this command the Humidity Compensation Algorithm is turned "ON". Can be performed in all operation modes. Setting saved into the Flash Memory.
[M]	[0x4D]	Turn Humidity Algorithm "OFF"	By sending this command the Humidity Compensation Algorithm is turned "OFF". Can be performed in all operation modes. Setting saved into the Flash Memory.
[N]	[0x4E]	Download new coefficient	Customer can send/update only one coefficient into the MCU. If you want to update all coefficients at one time please use command [J] above. Eg:[N0000000300000006] -> [Nvariable_numbervariable_value]
[O]	[0x4F]	Save latest Calibration	Customer can save SPAN, ZERO and Temperature calibration to Backup memory
[P]	[0x50]	Read latest Calibration	Customer can read back from Backup latest SPAN, Zero and Temperature calibration to go back to last calibration
[Q]	[0x51]	Read Data in Answer On-demand Mode	(available from 2v18 firmware version) When INIR sensor is in On-demand MODE the data is sent from the sensor only by sending command [Q] as a request
[R]	[0x52]	Software Reset	By sending this command sensor will be reset. It can be performed in all operation modes.
[S]	[0x53]	Multi-Sensor Mode	By sending this command sensor will be working with multi-sensor protocol. It can be performed in Config mode only.
[T]	[0x54]	Single-Sensor Mode	By sending this command sensor will be working with single-sensor protocol. It can be performed in Config mode only.

NOTEs:
1. All commands must start with ("["= 0x0000005B) and finish with ("]"= 0x0000005D), for the UART to work.
2. The Error in the communication protocol UART and any device running at 38400 Baud rate is 0.015%.
3. see Table 8 – Read Back the Settings from the INIR

1.1.4   Commands to the UART in Multi-Sensor Protocol

The commands that can be sent to the UART are specified in the Table 5 below. All the commands must be initialized with the character "[", then letter of Command then serial number must be send and terminated with the character "]".In this case structure of the command is : [(Letter of command)(8 digits Serial Number)]. For example: [C82235901] where C is command and 82235901 is serial number of the sensor.

The implementation of the commands from Table 5 can be used to communicate and perform tasks, in both high and low-end applications.

With integrated MCU the INIR is effectively a standalone device that can also be implemented in any network based system design. INIR is not a standalone gas sensing instrument - it still remains a digital gas sensor and should be handled as a component because it is classified as such.

Table 5 - INIR NEW UART Commands available in Multi-Sensor Protocol

UART Command		Meaning of the Command	Detailed Description
[Caaaaaaaa]		Enter Configuration Mode	The INIR is not calculating anything; the UART and DAC are disabled. Available Commands: [A], [B], [C], [I], [J], [K], [L], [M], [N]
[Eaaaaaaaa]		Calibrate New Zero	Calibrates the new ZERO value. The value will be stored in the Flash/EE memory of the sensor automatically.
[Faaaaaaaa]		Calibrate New High Span	Calibrate new High SPAN value. The value will be stored in the Flash/EE memory of the sensor automatically.
[Gaaaaaaaa]		Calculate New Offset	Calculates an offset value that is being used to improve the precision and linearity in low concentrations.
[Haaaaaaaa]		On-demand Mode	Puts INIR into On-demand MODE (available starting 2v18 firmware version). In this mode the INIR is sending information in the same format like in Engineering Mode but only when user sends a read-out command. Available Commands: [E], [F], [G], [L], [M], [O], [P], [Q]
[Iaaaaaaaa]		Read Back the Settings	Send this command to the INIR if you want to read the settings back. All the settings are in a hex form representing integer values only.[*3], see Table 4.0. Can only be performed under CONFIGURATION mode.
[Jaaaaaaaa]		Load new settings to INIR	Write the new setting to the device, all the settings are in a hex form representing integer values only, see paragraph 1.2.10. Can only be performed under CONFIGURATION mode.
[Kaaaaaaaa]		RESET to Factory Default Values	Reset all the variables into the Factory Defaults and erase all the custom settings that customer have changed like the calibration or the coefficients. Can only be performed under CONFIGURATION mode.
[Laaaaaaaa]		Turn Humidity Algorithm "ON"	By sending this command the Humidity Compensation Algorithm is turned "ON". Can be performed in all operation modes. Setting saved into the Flash Memory.
[Maaaaaaaa]		Turn Humidity Algorithm "OFF"	By sending this command the Humidity Compensation Algorithm is turned "OFF". Can be performed in all operation modes. Setting saved into the Flash Memory.
[Naaaaaaaa]		Download new coefficient	Customer can send/update only one coefficient into the MCU. If you want to update all coefficients at one time please use command [J] above. Eg:[N0000000300000006] -> [Nvariable_numbervariable_value]
[Oaaaaaaaa]		Save latest Calibration	Customer can save SPAN, ZERO and Temperature calibration to Backup memory
[Paaaaaaaa]		Read latest Calibration	Customer can read back from Backup latest SPAN, Zero and Temperature calibration to go back to last calibration
[Qaaaaaaaa]		Read Data in Answer On-demand Mode	(available from 2v18 firmware version) When INIR sensor is in On-demand MODE the data is sent from the sensor only by sending command [Q]
[Raaaaaaaa]		Software Reset	By sending this command sensor will be reset. It can be performed in all operation modes.
[Saaaaaaaa]		Multi-Sensor Mode	By sending this command sensor will be working with multi-sensor protocol. It can be performed in Config mode only.
[Taaaaaaaa]		Single-Sensor Mode	By sending this command sensor will be working with single-sensor protocol. It can be performed in Config mode only.

NOTEs:
1. All commands must start with ("["= 0x0000005B) and finish with ("]"= 0x0000005D), for the UART to work.
2. All commands has to send with Serial Number (Serial Number aaaaaaaa is a value from the label)
3. The Error in the communication protocol UART and any device running at 38400 Baud rate is 0.015%.
4. see Table 8 – Read Back the Settings from the INIR

1.1.5   Initialization Procedure for INIR

In order to retain the compatibility with any past and future versions of the INIR firmware it is recommended to always following the procedure below. Please follow the same procedure every time the INIR is powered on or it was reset for any reason.

Initialization Procedure for INIR

1. After each power "ON" send COMMAND [C] to put the sensor into Configuration Mode.

2. Send COMMAND [I] to read back all the settings of the INIR. This step is recommended for a operation check. Perform CRC validation and confirm correct operation of the UART settings etc.

3. After the above steps, send COMMAND [B] to put the sensor into Engineering Mode.

4. Once the step 3 has been executed the sensor will automatically start sending the data around every second.

5. After the above steps it is recommended to leave the sensor to warm up for the required time specified inside the INIR Datasheet – usually 45 seconds.

6. From this step onwards the sensor can operate and perform any command given.

End of Initialization Procedure

In the past there were versions of the firmware and in the future this may also change as well, where the customer doesn't have to implement the initialization procedure for the INIR. Nevertheless from a safety point of view just in case something goes wrong it is strongly recommended to always implement the functionality check, hence initialization procedure as described in 1.1.4 paragraph.

Last but not least the CRC for eliminating any communication errors with the INIR - please read carefully the 1.7 Calculate the CRC for more information on this procedure. Using the Initialization Procedure and the CRC validation the overall errors from communication or loss of information will be down to zero.

1.1.6   Answers from the UART

Below the set of Readings coming as an answer from the INIR when we perform the command [I] -> Read Back Readings is shown, under CONFIGURATION mode (see 1.2.9). Every variable is being stored as an integer and user must keep them in the same format, otherwise the Integrated IR will not function properly. Please see the Table 6 – Read Back the Settings from the Integrated IR and Table 6 for examples on how to convert from the readings to the actual normal values of the data including required multipliers.

Table 6 - Integrated IR Variables & Multipliers[(a,b)]

Number	Variable Type	Variable Name	Example Value Stored as Integer	Multiplier	Detailed Description
1	uint32	sensor_type[c]	26	*1	Holding the Gas Sensor Type like eg. INIR-ME100%
2	uint32	gas_type[d]	0.0	*1	Holding the Gas Type eg. Methane, Propane etc…
3	uint32	conc_range	100.0	*10000	Full Scale Target for Analogue Output Calculations
4	float32	high_span_gas_conc	100.0	*10000	High Span gas Cylinder Conc. in %v.v (eg. 20%v.v)
5	float32	low_span_gas_conc	2.0	*10000	Low Span gas Cylinder Conc. in %v.v (eg 2%v.v)
6	float32	a_coeff_low_range[e]	0.2670	*1000000	"a" coefficient for low range of the target gas
7	float32	a_coeff_mid_range	0.0563	*1000000	"a" coefficient for middle range of the target gas
8	float32	a_coeff_high_range	0.0563	*1000000	"a" coefficient for high range of the target gas
9	float32	n_coeff_low_conc	0.7250	*1000000	"n" coefficient for low range of the target gas
10	float32	n_coeff_mid_conc	0.4970	*1000000	"n" coefficient for middle range of the target gas
11	float32	n_coeff_high_conc	0.4970	*1000000	"n" coefficient for high range of the target gas
12	float32	betaneg_coeff_low_range	-0.137	*1000000	"beta" negative coefficient for low range
13	float32	betaneg_coeff_mid_range	-0.137	*1000000	"beta" negative coefficient for middle range
14	float32	betaneg_coeff_high_range	-0.137	*1000000	"beta" negative coefficient for high range
15	float32	betapos_coeff_low_range	-0.106	*1000000	"beta" positive coefficient for low range
16	float32	betapos_coeff_mid_range	-0.106	*1000000	"beta" positive coefficient for middle range
17	float32	betapos_coeff_high_range	-0.106	*1000000	"beta" positive coefficient for high range
18	float32	alphaneg_coeff	0.000235	*1000000	"alpha" negative coefficient
19	float32	alphapos_coeff	0.000363	*1000000	"alpha" positive coefficient
20	uint32	averaging	12	*1	The number of averaging seconds in signal processing
21	uint32	baud_rate	38400	*1	The baud rate to run the UART communication
22	uint32	current_conc_range	0	*1	LOW_CONC = 0 , MID_CONC = 1 and HIGH_CONC = 2
23	uint32	customer_calibration_time	123032	*1	Set time in format: hhmmss, calibration time
24	uint32	customer_calibration_date	240615	*1	Set date in format: DDMMYY, calibration date
	uint32	serial_number	240614001	*1	Serial number of the device, eg. 060614001
	uint32	time_delay_ms	25	*1	Delay in ms of the signal before reaches the peak
	uint32	firmware_version	215	*1	Holding the firmware version and is fixed
	float32	Act_1s_Average_Calibrate	0.001200	*1000000	Calibrated Active 1s second average value
	float32	Ref_1s_Average_Calibrate	0.001200	*1000000	Calibrated Reference 1s second average value
	float32	zero	1.0	*1000000	Calibrated value of Zero, when calibration done
	float32	span	4.0	*1000000	Calibrated value of Span, when calibration done
	float32	offset	0.000	*10000	Offset Concentration in %v.v, precision in LOW Range
	uint32	calibration_temperature	293.1	*10	Calibration temperature stored in (Kelvin * 10)

a Marked with Green are the values that Customer CAN READ, WRITE, CHANGE.
  Marked with RED are the values that Customer CAN READ but NOT WRITE/CHANGE, overwriting those values will have no effect.
b All Readings are transmitted as integer numbers, in order to convert the integer into the normal value just divide by the multiplier.   eg.
high_span_gas_conc = 100 *10000 = 1000000
Convert high_span_gas_conc = 1000000 / 10000 = 100 32-bit floating number
The INIR Evaluation Software is doing all the calculations automatically.
c The sensor type is represented by a specific number: look at Table 5 – Number Equivalent for Sensor Type.
d The gas type is represented by specific number look at Table 6 – Number Equivalent for Gas Type.
e For the coefficient table please look at Appendix A – Table of Coefficients.

Please find attached below in the Table 7 the Equivalent Number for the Sensor Type in order to translate the information when it is required to read or write the coefficients.

Table 7 - Equivalent Number for Sensor Type

Sensor_type	Number Equivalent
INIR-CD	23
INIR-ME	26

Please find below in Table 8, the Equivalent Number used for the Gas Type in the variable position 2 in order to translate the equivalent number when you want to read or write the coefficients.

Table 8 - Equivalent Number for Gas Type

Gas_type	Number Equivalent	Gas_type	Number Equivalent	Gas_type	Number Equivalent
METHANE	0	Reserved	4	Reserved	8
Reserved	1	Reserved	5	Reserved	9
Reserved	2	Reserved	6	Reserved	10
CARBON DIOXIDE	3	Reserved	7	Reserved	11

Below in the Tables 9 & 10 – Answers from the INIR UART you can find attached the possible answers from the INIR via the UART communication port after we have performed a command.

Table 9 - Answers from the INIR UART in Single-Sensor Protocol

UART Answer	HEX Code	Meaning of the Answer	Detailed Description
[AK]	0x5B414B5D	ACKNOWLEDGEMENT	Everything went OK, if we have sent a command that the command has been executed correctly.
[NA]	0x5B4E415D	NO ACKNOWLEDGEMENT	Something went wrong; if we have sent a command or the command has not been executed correctly.

NOTE: All the commands should begin with ("["= 0x5B00000) and finish with ("]"= 0x000005D). I.e. [AK] => 0x5B414B5D in HEX.

Table 10 - Answers from the INIR UART in Multi-Sensor Protocol

UART Answer	HEX Code	Meaning of the Answer	Detailed Description
[AK]	0x5B414B5D	ACKNOWLEDGEMENT	Everything went OK, if we have sent a command that the command has been executed correctly.

NOTE: All the commands should begin with ("["= 0x5B00000) and finish with ("]"= 0x000005D). I.e. [AK] => 0x5B414B5D in HEX.

Single-Sensor Protocol description

1.2 Communication between INIR & Custom Device in Single-Sensor Mode

The following example for communicating with the INIR Gas Sensor have been created to help customers to use the device assuming that it is connected with another device via UART, see Figure 1 below.

It is advised to send the commands by each 32-bit hex number individually. Sending one string will make the process of debugging more complicated and the technical support will require extra time to translate the string of data from one system to another.

It is advised to use a function to send messages via UART for unsigned/signed 32-bit HEX numbers based on the commands stated in table. The received message from INIR can be identified based on tables 2 & 7.
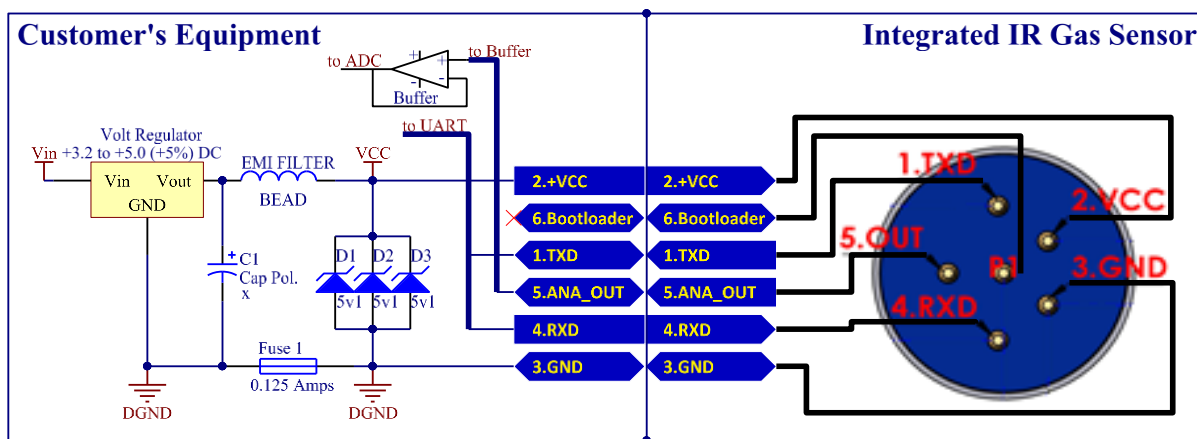

Figure 1 -Schematic Diagram for Communicating with the INIR

1.2.1 COMMAND [A], NORMAL Mode

See below how to enter the NORMAL Mode:

COMMAND	HEX	ASCII
Send Com.	0x005B415D	[A]
Answer	0x5B414B5D	[AK] , everything OK
Answer	0x5B4E415D	[NA], error

When in this mode only the following commands can be performed:
[A], [B], [C], [E], [F], [G], [L], [M], [O], [P] and [R].

1.2.2 COMMAND [B], Enter ENGINERING Mode

See example below how to enter the ENGINEERING Mode:

COMMAND	HEX	ASCII
Send Com.	0x005B425D	[B]
Answer	0x5B414B5D	[AK], everything OK
Answer	0x5B4E415D	[NA], error

When in this mode only the following commands can be performed:
[A], [B], [C], [E], [F], [G], [L], [M], [O], [P] and [R].

1.2.3 COMMAND [C], Enter CONFIGURATION Mode

Only in Configuration Mode we can change the settings. In this Mode no data are transmitted from the INIR, DAC is disabled. See example below how to enter the CONFIGURATION Mode:

COMMAND	HEX	ASCII
Send Com.	0x005B435D	[C]
Answer	0x5B414B5D	[AK], everything OK
Answer	0x5B4E415D	[NA], error

When in this mode only the following commands can be performed:
[A], [B], [C], [I], [J], [K], [L], [M] and [N].

1.2.4   COMMAND [D], Reserved

This command has been reserved for future use; no effect on the Integrated IR (INIR), no function performed when sending this command to the INIR.

COMMAND	HEX	ASCII
Send Com.	0x005B445D	[D]
Answer	0x5B4E415D	[NA], not executed

1.2.5   COMMAND [E], ZERO Calibration (for NORMAL, ENGINEERING or ON-DEMAND Modes)

In order to perform ZERO Calibration the INIR should be set in NORMAL, ENGINEERING or ON-DEMAND Mode. Please read Chapter 2 – New Calibration Routine for more information on how to perform the ZERO calibration.

COMMAND	HEX	ASCII
Send Com.	0x005B455D	[E]
Answer	0x5B414B5D	[AK], everything OK
Answer	0x5B4E415D	[NA], error

1.2.6   COMMAND [F], SPAN Calibration (for NORMAL, ENGINERRING or ON-DEMAND Modes)

SPAN calibration can only be performed in the NORMAL, ENGINEERING or ON-DEMAND Mode. No need to perform calibration in ranges as the INIR is a single range operating Module with automatic switchover between ranges depending on Gas Concentration. Please also read Chapter 2 – New Calibration Routine explaining how to perform SPAN calibration.

COMMAND	HEX	ASCII
Send Com.	0x005B465D	[F]
Answer	0x5B414B5D	[AK], everything OK
Answer	0x5B4E415D	[NA], error

SPAN Calibration with define High SPAN Gas Calibration in one command.

COMMAND	HEX	ASCII
Send Com.	0x005B475D	[FAAAAAAAA][1]
Answer	0x5B414B5D	[AK], everything OK
Answer	0x5B4E415D	[NA], error

[1]AAAAAAAA is hexadecimal value of High SPAN Gas Concentration in ppm

1.2.7   COMMAND [G], OFFSET Calculation (NORMAL, ENGINERRING or ON-DEMAND Modes)

In order to calculate OFFSET the NORMAL ,ENGINEERING or ON-DEMAND Mode has to be set. No need to perform calibration in ranges as the INIR is a single range operating Module with automatic switchover between internally calibrated sub-ranges depending on Gas Concentration. Please read Chapter 2 – New Calibration Routine explaining how to perform the OFFSET calibration.

COMMAND	HEX	ASCII
Send Com.	0x005B485D	[G]
Answer	0x5B414B5D	[AK], everything OK
Answer	0x5B4E415D	[NA], went wrong

1.2.8   COMMAND [H], Enter On-Demand Mode

See below how to enter the On-Demand Mode:

COMMAND	HEX	ASCII
Send Com.	0x005B495D	[H]
Answer	0x5B414B5D	[AK] , everything OK
Answer	0x5B4E415D	[NA], error

When in this mode only the following commands can be performed: **[E], [F], [G],[Q], [L], [M], [O], [P].**

1.2.9   COMMAND [I], Read Back Settings (only in CONFIGURATION Mode)

See example below how to perform commands under the CONFIGURATION Mode:

COMMAND	HEX	ASCII
Send Command	0x005B4a5D	[I]

ANSWER -> **Table 10 – Answers from the Integrated IR via UART**

> **Note:** In this example the values could be different from the ones shown in the table if the customer has already changed the values or SGX has performed calibration on the INIR. Those values are just an example of how the data is transmitted via the UART.

Table 11 - Reading Back Settings in Configuration Mode

Number	HEX Number	Variable Name	Decimal format	Divider	Detailed Description
	0x0000005B		[		Start String Character
1	0x00003236	sensor_type[c]	=26	/1	Holding the Gas Sensor Type like eg. INIR-M100%
2	0x00000000	gas_type[d]	=0	/1	Holding the Gas Type eg. Methane, Propane etc…
3	0x000F4240	conc_range	=1000000	/1	Full Scale Target for Analogue Output Calculations
4	0x000F4240	high_span_gas_conc	=1000000	/10000	High Span gas Cylinder Conc. in ppm (eg. 20000 ppm)
5	0x00004E20	low_span_gas_conc	=20000	/10000	Low Span gas Cylinder Conc. In ppm (eg 2000 ppm)
6	0x000412F8	a_coeff_low_range[e]	=267000	/1000000	"a" coefficient for low range of the target gas
7	0x0000DBEC	a_coeff_mid_range	=56300	/1000000	"a" coefficient for middle range of the target gas
8	0x0000DBEC	a_coeff_high_range	=56300	/1000000	"a" coefficient for high range of the target gas
9	0x000B1008	n_coeff_low_conc	=725000	/1000000	"n" coefficient for low range of the target gas
10	0x00079568	n_coeff_mid_conc	=497000	/1000000	"n" coefficient for middle range of the target gas
11	0x00079568	n_coeff_high_conc	=497000	/1000000	"n" coefficient for high range of the target gas
12	0xFFFDE8D8	betaneg_coeff_low_range	=-137000	/1000000	"beta" negative coefficient for low range
13	0xFFFDE8D8	betaneg_coeff_mid_range	=-137000	/1000000	"beta" negative coefficient for middle range
14	0xFFFDE8D8	betaneg_coeff_high_range	=-137000	/1000000	"beta" negative coefficient for high range
15	0xFFFE61F0	betapos_coeff_low_range	=-106000	/1000000	"beta" positive coefficient for low range
16	0xFFFE61F0	betapos_coeff_mid_range	=-106000	/1000000	"beta" positive coefficient for middle range
17	0xFFFE61F0	betapos_coeff_high_range	=-106000	/1000000	"beta" positive coefficient for high range
18	0x000000EB	alphaneg_coeff	=235	/1000000	"alpha" negative coefficient
19	0x0000016B	alphapos_coeff	=363	/1000000	"alpha" positive coefficient
20	0x0000000A	averaging	=10	/1	Used for the Active and Reference signal processing
21	0x00009600	baud_rate	=38400	/1	The baud rate to run the UART communication
22	0x00000000	current_conc_range	=0	/1	LOW_CONC = 0 , MID_CONC = 1 and HIGH_CONC = 2
23	0x00019465	customer_calibration_time	=103525	/1	Set time in format: hhmmss, calibration time
24	0x00030FA6	customer_calibration_date	=200614	/1	Set date in format: DDMMYY, calibration date
	0x00000001	serial_number	=1	/1	Serial number of the device, eg. 060614001
	0x00000019	time_delay_ms	=25	/1	Delay in ms of the signal before reaches the peak
	0x00000190	firmware_version	=400	/1	Holding the firmware version and is fixed
	0x000034BC	Act_1s_Average_Calibrate	=13500	/1000000	Calibrated Active 1s second average value
	0x00003458	Ref_1s_Average_Calibrate	=13400	/1000000	Calibrated Reference 1s second average value
	0x0010C8E0	zero	=1100000	/1000000	Calibrated value of Zero, when calibration done
	0x0006DDD0	span	=450000	/1000000	Calibrated value of Span, when calibration done
	0x00000000	offset	=0.000	/10000	Calculated Offset Concentration in ppm, precision in LOW
	0x00000B73	calibration_temperature	=2931	/10	Calibration temperature stored in Kelvin * 10 as an integer
		val_crc	=	/1	CRC
		Inv_crc	=	/1	1's Compliment of CRC
	0x0000005D		]		End String Character

a Marked with Green are the values that Customer CAN READ, WRITE, CHANGE.
Marked with RED are the values that Customer CAN READ but NOT WRITE/CHANGE, overwriting those values will have no effect.
b All Readings are transmitted as integer numbers, in order to convert the integer into the normal value just divide by the multiplier.   eg.
high_span_gas_conc = 100 *10000 = 1000000
Convert high_span_gas_conc = 1000000 / 10000 = 100 32-bit floating number
The INIR Evaluation Software is doing all the calculations automatically.
c The sensor type is represented by specific number look at Table 5.0 – Number Equivalent for Sensor Type.
d The gas type is represented by specific number look at Table 6.0 – Number Equivalent for Gas Type.
e For the coefficient table please look at Appendix A – Table of Coefficients.

NOTE: In this example the values could be different from the ones displayed in the table if the customer has already changed the values or SGX has performed calibration on the INIR. Those values are just an example of how the data transmitted via the UART.

1.2.10 COMMAND [J], Load NEW Settings (only in CONFIGURATION Mode)

In order to be able to Load NEW Settings to the INIR the module must operate in the CONFIGURATION MODE.

For that process please complete the following:
1. Perform COMMAND [**C**], Enter CONFIG. Mode
2. Perform COMMAND [**I**], Read Back Settings.

It is advised to always download the existing settings before attempting to change them. After the above steps perform COMMAND [**J**], Load NEW Settings.

COMMAND	HEX	ASCII
Send Command	See below	See below

SEND SETTINGS -> see Table 11 – Loading New Settings/Coefficients to INIR.

The above commands can be send as a single cascaded string. **The order of the variables should be correct and should be exactly the same as if commands were sent one by one.**

Example:
"**[J**0x000000060x000000000x000F42400x000F4240 ………………………………… 0x00030FA6**]**"

Table 12 - Loading New Settings/Coefficients to INIR

HEX Number SEND	Variable Name	Decimal format	Divider	Detailed Description
0x0000005B		[		**Start String Character**
0x0000004A		J		Letter J, representing Command J load new data
0x00000024	sensor_type[c]	=6	/1	Holding the Gas Sensor Type like eg.IR12GM_1
0x00000000	gas_type[d]	=0	/1	Holding the Gas Type eg. Methane, Propane etc…
0x000F4240	conc_range	=100	/10000	Full Scale Target for Analogue Output Calculations
0x000F4240	high_span_gas_conc	=1000000	/10000	High Span gas Cylinder Conc. in ppm (eg. 20000 ppm)
0x00004E20	low_span_gas_conc	=20000	/1000000	Low Span gas Cylinder Conc. In ppm (eg 2000 ppm)
0x000412F8	a_coeff_low_range[e]	=267000	/1000000	"a" coefficient for low range of the target gas
0x0000DBEC	a_coeff_mid_range	=56300	/1000000	"a" coefficient for middle range of the target gas
0x0000DBEC	a_coeff_high_range	=56300	/1000000	"a" coefficient for high range of the target gas
0x000B1008	n_coeff_low_conc	=725000	/1000000	"n" coefficient for low range of the target gas
0x00079568	n_coeff_mid_conc	=497000	/1000000	"n" coefficient for middle range of the target gas
0x00079568	n_coeff_high_conc	=497000	/1000000	"n" coefficient for high range of the target gas
0xFFFDE8D8	betaneg_coeff_low_range	=-137000	/1000000	"beta" negative coefficient for low range
0xFFFDE8D8	betaneg_coeff_mid_range	=-137000	/1000000	"beta" negative coefficient for middle range
0xFFFDE8D8	betaneg_coeff_high_range	=-137000	/1000000	"beta" negative coefficient for high range
0xFFFE61F0	betapos_coeff_low_range	=-106000	/1000000	"beta" positive coefficient for low range
0xFFFE61F0	betapos_coeff_mid_range	=-106000	/1000000	"beta" positive coefficient for middle range
0xFFFE61F0	betapos_coeff_high_range	=-106000	/1000000	"beta" positive coefficient for high range
0x000000EB	alphaneg_coeff	=235	/1000000	"alpha" negative coefficient
0x0000016B	alphapos_coeff	=363	/1000000	"alpha" positive coefficient
0x0000000A	averaging	=10	/1	Used for the Active and Reference signal processing
0x00009600	baud_rate	=38400	/1	The baud rate to run the UART communication
0x00000000	current_conc_range	=0	/1	LOW_CONC = 0 , MID_CONC = 1 and HIGH_CONC = 2
0x00019465	customer_calibration_time	=103525	/1	Set time in format: hhmmss, calibration time
0x00030FA6	customer_calibration_date	=200614	/1	Set date in format: DDMMYY, calibration date
0x0000005D		]		**End String Character**

a Marked with Green are the values that Customer CAN READ, WRITE, CHANGE.
b All Readings are transmitted as integer numbers, in order to convert the integer into the normal value just divide by the multiplier.   eg. high_span_gas_conc = 100 *10000 = 1000000
Convert high_span_gas_conc = 1000000 / 10000 = 100 32-bit floating number
The INIR Evaluation Software is doing all the calculations automatically.
c The sensor type is represented by specific number look at Table 5.0 – Number Equivalent for Sensor Type.
d The gas type is represented by specific number look at Table 6.0 – Number Equivalent for Gas Type.
e For the coefficient table please look at Appendix A – Table of Coefficients.
NOTE: In this example the values could be different from the ones displayed in the table if the customer has already changed the values or SGX has performed calibration on the INIR. Those values are just an example of how the data transmitted via the UART.

1.2.11 COMMAND [K], RESET to FACTORY Defaults (only in CONFIGURATION Mode)

In order to RESET to Factory Default values CONFIGURATION Mode should be set. The Integrated IR has and internal Repository that is holding the Factory Default values that were calculated during Factory Production/Calibration and cannot be erased unless a "mass erase" command is send to the microprocessor (not used by customers).

Performing this command will also erase the values that were potentially changed later and also the other calibrations done after initial production.

COMMAND	HEX	ASCII
Send Com.	0x005B4B5D	[K]
Answer	0x5B414B5D	[AK],everything OK
Answer	0x5B4E415D	[NA], error

WARNING!
Performing this command will erase the custom values changed and also any calibrations we have done after factory production. Proceed with this command carefully. It is recommended always perform a valid re-calibration after that command has been executed.

1.2.12 COMMAND [L], TURN "ON" Humidity Algorithm (all Modes)

This command can be performed in all operation modes. When executed this command will switch "ON" the Humidity Compensation Algorithm that will minimize the response of the sensor due to condensation or humidity problems. This algorithm reduces the recovery time from condensation effects as well.

COMMAND	HEX	ASCII
Send Com.	0x005B4C5D	[L]
Answer	0x5B414B5D	[AK], everything OK
Answer	0x5B4E415D	[NA], error

1.2.13 COMMAND [M], TURN "OFF" Humidity Algorithm (all Modes)

This command can be performed in every mode, when executed it will switch "OFF" the Humidity Compensation Algorithm. Disabling the algorithm will result in a much higher Concentration response due to condensation or humidity.

COMMAND	HEX	ASCII
Send Com.	0x005B4D5D	[M]
Answer	0x5B414B5D	[AK],everything OK
Answer	0x5B4E415D	[NA], error

1.2.14 COMMAND [N], Download new coefficient

This command can be performed in CONFIG MODE only. When executed it will send only one coefficient to the MCU.

COMMAND	HEX	ASCII
Send Com.	0x005B4E5D	[**N**numbervalue]
Answer	0x5B414B5D	[AK],everything OK
Answer	0x5B4E415D	[NA], error

As **number** please use the coefficient number: see table 4 or 8. As **value** please use an appropriate value to upload.

1.2.15 COMMAND [O], Set Last Calibration Backup

This command can be performed in every mode, when executed it will copy latest SPAN, ZERO and Temperature of Calibration to the Flash Memory.

COMMAND	HEX	ASCII
Send Com.	0x005B4F5D	[O]
Answer	0x5B414B5D	[AK],everything OK
Answer	0x5B4E415D	[NA], error

1.2.16 COMMAND [P], Read Last Calibration Backup

This command can be performed in every mode, when executed it will copy SPAN, ZERO and Temperature of Calibration from Backup memory.

COMMAND	HEX	ASCII
Send Com.	0x005B505D	[P]
Answer	0x5B414B5D	[AK],everything OK
Answer	0x5B4E415D	[NA], error

1.2.17 COMMAND [R], Software Reset

By this Command customer can restart sensor.

COMMAND	HEX	ASCII
Send Com.	0x005B525D	[R]

1.2.18 COMMAND [S], Check Sensor No. or switch to the Multi-Sensor Protocol

This command can be preformed in CONFIG mode only. By sending [S00999900] (00999900 is unique sensor number) customer can read Sensor No. from the FLASH. It is the same Number like on the Label.

COMMAND	HEX	ASCII
Send Com.	0x005B53 009999005D	[S00999900][1]
Answer	0x5B414B AAAAAAAA5D	[AK(Serial No], everything OK
Answer	0x5B4E415D	[NA], error

By sending [S(Serial No.)] customer can change protocol from Single-Sensor to Multi-Sensor.

1.2.19 COMMAND [Q], Answer by the data readings in ON-DEMAND Mode

This command can be performed in ON-DEMAND MODE only. When executed it will send reading data as a request. For more details please see table 4.

COMMAND	HEX	ASCII
Send Com.	0x005B515D	[Q]
Answer	0x5B414B5D	[AK(Serial No], everything OK
Answer	0x5B4E415D	[NA], error

Multi-Sensor Protocol description

1.3 Communication between INIR & Custom Device in Single-Sensor Mode

The following example for communicating with the INIR Gas Sensor have been created to help customers to use the device assuming that it is connected with another device via UART, see Figure 1 below.

It is advised to send the commands by each 32-bit hex number individually. Sending one string will make the process of debugging more complicated and the

technical support will require extra time to translate the string of data from one system to another.

It is advised to use a function to send messages via UART for unsigned/signed 32-bit HEX numbers based on the commands stated in table. The received message from INIR can be identified based on tables 2 & 7

1.3.1 COMMAND [Caaaaaaaa], Enter CONFIGURATION Mode

Only in Configuration Mode we can change the settings. In this Mode no data are transmitted from the INIR, DAC is disabled. See example below how to enter the CONFIGURATION Mode:

COMMAND	HEX	ASCII
Send Com.	0x005B43AAAAAAAA5D	[CAAAAAAAA]
Answer	0x5B414BAAAAAAAA5D	[AKAAAAAAAA], everything OK

When in this mode only the following commands can be performed:

[H], [I], [J], [K], [L], [M], [N], [O], [P], [R]

1.3.2 COMMAND [Eaaaaaaaa], ZERO Calibration (for NORMAL/ENGINEERING Modes)

In order to perform ZERO Calibration the INIR should be set in NORMAL or ENGINEERING Mode. Please read Chapter 2 – New Calibration Routine for more information on how to perform the ZERO calibration.

COMMAND	HEX	ASCII
Send Com.	0x005B45AAAAAAAA5D	[EAAAAAAAA]
Answer	0x5B414B5D	[AKAAAAAAAA], everything OK

1.3.3 COMMAND [Faaaaaaaa], SPAN Calibration (for NORMAL/ENGINERRING Modes)

SPAN calibration can only be performed in the NORMAL or ENGINEERING Mode. No need to perform calibration in ranges as the INIR is a single range operating Module with automatic switchover between ranges depending on Gas Concentration. Please also read Chapter 2 – New Calibration Routine explaining how to perform SPAN calibration.

COMMAND	HEX	ASCII
Send Com.	0x005B46AAAAAAAA5D	[FAAAAAAAA]
Answer	0x5B414BAAAAAAAA5D	[AKAAAAAAAA], everything OK

1.3.4 COMMAND [Gaaaaaaaa], OFFSET Calculation (NORMAL or ENGINERRING Modes)

In order to calculate OFFSET the NORMAL or ENGINEERING Mode has to be set. No need to perform calibration in ranges as the INIR is a single range operating Module with automatic switchover between internally calibrated sub-ranges depending on Gas Concentration. Please read Chapter 2 – New Calibration Routine explaining how to perform the OFFSET calibration.

COMMAND	HEX	ASCII
Send Com.	0x005B47AAAAAAAA5D	[GAAAAAAAA]
Answer	0x5B414BAAAAAAAA5D	[AKAAAAAAAA], everything OK

1.3.5 COMMAND [Haaaaaaaa], Enter On-Demand Mode

See below how to enter the On-Demand Mode:

COMMAND	HEX	ASCII
Send Com.	0x005B48AAAAAAAA5D	[HAAAAAAAA]
Answer	0x5B414BAAAAAAAAA5D	[AKAAAAAAAA], everything OK

When in this mode only the following commands can be performed: **[Q].**

1.3.6 COMMAND [Iaaaaaaaa], Read Back Settings (only in CONFIGURATION Mode)

See example below how to perform commands under the CONFIGURATION Mode:

COMMAND	HEX	ASCII
Send Command	0x005B49AAAAAAAA5D	[IAAAAAAAA]

ANSWER -> **Table 8 – Answers from the Integrated IR via UART**

> **Note:** In this example the values could be different from the ones shown in the table if the customer has already changed the values or SGX has performed calibration on the INIR. Those values are just an example of how the data is transmitted via the UART.

Table 13 - Reading Back Settings in Configuration Mode

Number	HEX Number	Variable Name	Decimal format	Divider	Detailed Description
	0x0000005B		[		Start String Character
1	0x00003236	sensor_type[c]	=26	/1	Holding the Gas Sensor Type like eg. INIR-M100%
2	0x00000000	gas_type[d]	=0	/1	Holding the Gas Type eg. Methane, Propane etc…
3	0x000F4240	conc_range	=1000000	/1	Full Scale Target for Analogue Output Calculations
4	0x000F4240	high_span_gas_conc	=1000000	/10000	High Span gas Cylinder Conc. in ppm (eg. 20000 ppm)
5	0x00004E20	low_span_gas_conc	=20000	/10000	Low Span gas Cylinder Conc. In ppm (eg 2000 ppm)
6	0x000412F8	a_coeff_low_range[e]	=267000	/1000000	"a" coefficient for low range of the target gas
7	0x0000DBEC	a_coeff_mid_range	=56300	/1000000	"a" coefficient for middle range of the target gas
8	0x0000DBEC	a_coeff_high_range	=56300	/1000000	"a" coefficient for high range of the target gas
9	0x000B1008	n_coeff_low_conc	=725000	/1000000	"n" coefficient for low range of the target gas
10	0x00079568	n_coeff_mid_conc	=497000	/1000000	"n" coefficient for middle range of the target gas
11	0x00079568	n_coeff_high_conc	=497000	/1000000	"n" coefficient for high range of the target gas
12	0xFFFDE8D8	betaneg_coeff_low_range	=-137000	/1000000	"beta" negative coefficient for low range
13	0xFFFDE8D8	betaneg_coeff_mid_range	=-137000	/1000000	"beta" negative coefficient for middle range
14	0xFFFDE8D8	betaneg_coeff_high_range	=-137000	/1000000	"beta" negative coefficient for high range
15	0xFFFE61F0	betapos_coeff_low_range	=-106000	/1000000	"beta" positive coefficient for low range
16	0xFFFE61F0	betapos_coeff_mid_range	=-106000	/1000000	"beta" positive coefficient for middle range
17	0xFFFE61F0	betapos_coeff_high_range	=-106000	/1000000	"beta" positive coefficient for high range
18	0x000000EB	alphaneg_coeff	=235	/1000000	"alpha" negative coefficient
19	0x0000016B	alphapos_coeff	=363	/1000000	"alpha" positive coefficient
20	0x0000000A	averaging	=10	/1	Used for the Active and Reference signal processing
21	0x00009600	baud_rate	=38400	/1	The baud rate to run the UART communication
22	0x00000000	current_conc_range	=0	/1	LOW_CONC = 0 , MID_CONC = 1 and HIGH_CONC = 2
23	0x00019465	customer_calibration_time	=103525	/1	Set time in format: hhmmss, calibration time
24	0x00030FA6	customer_calibration_date	=200614	/1	Set date in format: DDMMYY, calibration date
	0x00000001	serial_number	=1	/1	Serial number of the device, eg. 060614001
	0x00000019	time_delay_ms	=25	/1	Delay in ms of the signal before reaches the peak
	0x00000190	firmware_version	=400	/1	Holding the firmware version and is fixed
	0x000034BC	Act_1s_Average_Calibrate	=13500	/1000000	Calibrated Active 1s second average value
	0x00003458	Ref_1s_Average_Calibrate	=13400	/1000000	Calibrated Reference 1s second average value
	0x0010C8E0	zero	=1100000	/1000000	Calibrated value of Zero, when calibration done
	0x0006DDD0	span	=450000	/1000000	Calibrated value of Span, when calibration done
	0x00000000	offset	=0.000	/10000	Calculated Offset Concentration in ppm, precision in LOW
	0x00000B73	calibration_temperature	=2931	/10	Calibration temperature stored in Kelvin * 10 as an integer
		val_crc	=	/1	CRC
		Inv_crc	=	/1	1's Compliment of CRC
	0x0000005D		]		End String Character

a Marked with Green are the values that Customer CAN READ, WRITE, CHANGE.
Marked with RED are the values that Customer CAN READ but NOT WRITE/CHANGE, overwriting those values will have no effect.
b All Readings are transmitted as integer numbers, in order to convert the integer into the normal value just divide by the multiplier.   eg.
high_span_gas_conc = 100 *10000 = 1000000
Convert high_span_gas_conc = 1000000 / 10000 = 100 32-bit floating number
The INIR Evaluation Software is doing all the calculations automatically.
c The sensor type is represented by specific number look at Table 5.0 – Number Equivalent for Sensor Type.
d The gas type is represented by specific number look at Table 6.0 – Number Equivalent for Gas Type.
e For the coefficient table please look at Appendix A – Table of Coefficients.

NOTE: In this example the values could be different from the ones displayed in the table if the customer has already changed the values or SGX has performed calibration on the INIR. Those values are just an example of how the data transmitted via the UART.

1.3.7 COMMAND [Jaaaaaaaa], Load NEW Settings (only in CONFIGURATION Mode)

In order to be able to Load NEW Settings to the INIR the module must operate in the CONFIGURATION MODE.

For that process please complete the following:

    3. Perform COMMAND [C], Enter CONFIG. Mode

    4. Perform COMMAND [I], Read Back Settings.

It is advised to always download the existing settings before attempting to change them. After the above steps perform COMMAND [J], Load NEW Settings.

COMMAND	HEX	ASCII
Send Command	See below	See below

SEND SETTINGS -> see Table 9 – Loading New Settings/Coefficients to INIR.

The above commands can be send as a single cascaded string. **The order of the variables should be correct and should be exactly the same as if commands were sent one by one.**

Example:

"**[J**0x000000060x000000000x000F42400x000F4240 …………………………………. 0x00030FA6**]**"

Table 14 - Loading New Settings/Coefficients to INIR

HEX Number SEND	Variable Name	Example of Answer	Divider	Detailed Description
0x0000005B		[		**Start String Character**
0x0000004A		J		Letter J, representing Command J load new data
0x00000024	sensor_type[c]	=6	/1	Holding the Gas Sensor Type like eg.IR12GM_1
0x00000000	gas_type[d]	=0	/1	Holding the Gas Type eg. Methane, Propane etc…
0x000F4240	conc_range	=100	/10000	Full Scale Target for Analogue Output Calculations
0x000F4240	high_span_gas_conc	=1000000	/10000	High Span gas Cylinder Conc. in ppm (eg. 20000 ppm)
0x00004E20	low_span_gas_conc	=20000	/1000000	Low Span gas Cylinder Conc. In ppm (eg 2000 ppm)
0x000412F8	a_coeff_low_range[e]	=267000	/1000000	"a" coefficient for low range of the target gas
0x0000DBEC	a_coeff_mid_range	=56300	/1000000	"a" coefficient for middle range of the target gas
0x0000DBEC	a_coeff_high_range	=56300	/1000000	"a" coefficient for high range of the target gas
0x000B1008	n_coeff_low_conc	=725000	/1000000	"n" coefficient for low range of the target gas
0x00079568	n_coeff_mid_conc	=497000	/1000000	"n" coefficient for middle range of the target gas
0x00079568	n_coeff_high_conc	=497000	/1000000	"n" coefficient for high range of the target gas
0xFFFDE8D8	betaneg_coeff_low_range	=-137000	/1000000	"beta" negative coefficient for low range
0xFFFDE8D8	betaneg_coeff_mid_range	=-137000	/1000000	"beta" negative coefficient for middle range
0xFFFDE8D8	betaneg_coeff_high_range	=-137000	/1000000	"beta" negative coefficient for high range
0xFFFE61F0	betapos_coeff_low_range	=-106000	/1000000	"beta" positive coefficient for low range
0xFFFE61F0	betapos_coeff_mid_range	=-106000	/1000000	"beta" positive coefficient for middle range
0xFFFE61F0	betapos_coeff_high_range	=-106000	/1000000	"beta" positive coefficient for high range
0x000000EB	alphaneg_coeff	=235	/1000000	"alpha" negative coefficient
0x0000016B	alphapos_coeff	=363	/1000000	"alpha" positive coefficient
0x0000000A	averaging	=10	/1	Used for the Active and Reference signal processing
0x00009600	baud_rate	=38400	/1	The baud rate to run the UART communication
0x00000000	current_conc_range	=0	/1	LOW_CONC = 0 , MID_CONC = 1 and HIGH_CONC = 2
0x00019465	customer_calibration_time	=103525	/1	Set time in format: hhmmss, calibration time
0x00030FA6	customer_calibration_date	=200614	/1	Set date in format: DDMMYY, calibration date
0x0000005D		]		**End String Character**

a Marked with Green are the values that Customer CAN READ, WRITE, CHANGE.

b All Readings are transmitted as integer numbers, in order to convert the integer into the normal value just divide by the multiplier.   eg. high_span_gas_conc = 100 *10000 = 1000000

Convert high_span_gas_conc = 1000000 / 10000 = 100 32-bit floating number

The INIR Evaluation Software is doing all the calculations automatically.

c The sensor type is represented by specific number look at Table 5.0 – Number Equivalent for Sensor Type.

d The gas type is represented by specific number look at Table 6.0 – Number Equivalent for Gas Type.

e For the coefficient table please look at Appendix A – Table of Coefficients.

NOTE: In this example the values could be different from the ones displayed in the table if the customer has already changed the values or SGX has performed calibration on the INIR. Those values are just an example of how the data transmitted via the UART.

1.3.8 COMMAND [Kaaaaaaaa], RESET to FACTORY Defaults (only in CONFIGURATION Mode)

In order to RESET to Factory Default values CONFIGURATION Mode should be set. The Integrated IR has and internal Repository that is holding the Factory Default values that were calculated during Factory Production/Calibration and cannot be erased unless a "mass erase" command is send to the microprocessor (not used by customers).

Performing this command will also erase the values that were potentially changed later and also the other calibrations done after initial production.

COMMAND	HEX	ASCII
Send Com.	0x005B4BAA AAAAAA5D	[KAAAAAAAA]
Answer	0x5B414BAA AAAAAA5D	[AKAAAAAAAA],everything OK

WARNING!

Performing this command will erase the custom values changed and also any calibrations we have done after factory production. Proceed with this command carefully. It is recommended always perform a valid re-calibration after that command has been executed.

1.3.9 COMMAND [Laaaaaaaa], TURN "ON" Humidity Algorithm (all Modes)

This command can be performed in all operation modes. When executed this command will switch "ON" the Humidity Compensation Algorithm that will minimize the response of the sensor due to condensation or humidity problems. This algorithm reduces the recovery time from condensation effects as well.

COMMAND	HEX	ASCII
Send Com.	0x005B4C AAAAAAAA5D	[LAAAAAAAA]
Answer	0x5B414B AAAAAAAA5D	[AKAAAAAAAA], everything OK

1.3.10 COMMAND [Maaaaaaaa], TURN "OFF" Humidity Algorithm (all Modes)

This command can be performed in every mode, when executed it will switch "OFF" the Humidity Compensation Algorithm. Disabling the algorithm will result in a much higher Concentration response due to condensation or humidity.

COMMAND	HEX	ASCII
Send Com.	0x005B4DAA AAAAAA5D	[MAAAAAAAA]
Answer	0x5B414BAA AAAAAA5D	[AKAAAAAAAA],everything OK

1.3.11 COMMAND [Naaaaaaaa], Download new coefficient

This command can be performed in CONFIG MODE only. When executed it will send only one coefficient to the MCU.

COMMAND	HEX	ASCII
Send Com.	0x005B4EAA AAAAAA**num bervalue**5D	[N**AAAAAAAAnum bervalue**]
Answer	0x5B414BAA AAAAAA5D	[AKAAAAAAAA],everything OK

As **number** please use the coefficient number: see table 4 or 8. As **value** please use an appropriate value to upload.

1.3.12 COMMAND [Oaaaaaaaa],

This command can be performed in every mode, when executed it will copy latest SPAN, ZERO and Temperature of Calibration to the Flash Memory.

COMMAND	HEX	ASCII
Send Com.	0x005B4FAA AAAAAA5D	[OAAAAAAAA]
Answer	0x5B414BAA AAAAAA5D	[AKAAAAAAAA],everything OK

1.3.13   COMMAND [Paaaaaaaa],

This command can be performed in every mode, when executed it will copy SPAN, ZERO and Temperature of Calibration from Backup memory.

COMMAND	HEX	ASCII
Send Com.	0x005B50AA AAAAAA5D	[PAAAAAAAA]
Answer	0x5B414BAA AAAAAA5D	[AKAAAAAAAA],everything OK

1.3.14   COMMAND [Qaaaaaaaa],

This command can be performed in ON-DEMAND MODE only. When executed it will send reading data as a request. For more details please see table 4.

COMMAND	HEX	ASCII
Send Com.	0x005B515D	[Q]
Answer	0x5B414B5D	[AK(Serial No), everything OK
Answer	0x5B4E415D	[NA], error

1.3.15   COMMAND [Raaaaaaaa],

By this Command customer can restart sensor.

COMMAND	HEX	ASCII
Send Com.	0x005B52AA AAAAAA5D	[RAAAAAAAA]
Answer	0x5B414BAA AAAAAA5D	[AKAAAAAAAA],everything OK

1.3.16   COMMAND [Saaaaaaaa],

This command has been reserved for future use; no effect on the Integrated IR, no function performed if you do sent this command to the MCU.

COMMAND	HEX	ASCII
Send Com.	0x005B53AA AAAAAA5D	[SAAAAAAAA]
Answer	0x5B414B5D	[AKAAAAAAAA],everything OK

1.3.17   COMMAND [Taaaaaaaa],

By sending [T(Serial No.)] customer can change protocol from Multi-Sensor to Single-Sensor.

COMMAND	HEX	ASCII
Send Com.	0x005B54 AAAAAAAA5D	[TAAAAAAAA][2]
Answer	0x5B414B5D	[AK(Serial No), everything OK
Answer	0x5B4E415D	[NA], error

1.4   Changing Between Low/Mid/High Concentration Ranges

From Firmware version 2v0 the INIR is using automatic range switchover and the customer doesn't need to send external commands.

1.5   Convert Temperature in KELVIN to CELCIUS

The internal temperature that is sent in the digital string from the Integrated IR is in the following format : (Kelvin*10)

- To convert that temperature into Kelvin divide that number by 10, which is the scaling factor.

$$\text{Temp(}^{o}\text{K)}= \frac{\text{Temp.Reading from INIR}}{10}$$

- To convert the temperature into Celsius use the following equation:

$$^{\circ}\text{C} = \left[\left(\frac{Value\ in\ Kelvin}{10} \right) - 273.15 \right] in\ ^{\circ}\text{C}$$

1.6   Calculate Conc v.v% from Analogue Output

The DAC output voltage can vary from 0 to 2.5 Volts. In order to calculate the concentration from the Volts the following equation should be used:

$$\%vol = \left(\frac{DACvolts}{1.25} - 1 \right) * Range$$

where $Range = 5\ or\ 100$ or whatever is the range in concentration of the sensor (see Appendix A – Table of Coefficients).

The maximum current that the DAC can source is 0.5 mA, based on a 5K resistive Load at 2.5Volts. There are some limitations in the concentration:

1. If DACvolts = 0 then the DAC is stopped or not functioning.
2. If DACvolts = 0.5 then the INIR sensor has a fault.

Anything between the 1.25 and 2.5 can represent the 100% Full Scale with 1.25 being the zero of the scale.

The scale representing the DAC output can be found in Figure below.

NOTE: If there is a fault the Analogue Output will be fixed at around 0.5 Volts DC. It is not possible to identify the source of the problem. If the DAC is exactly 0 Volts DC please make sure the connections are correct. If above mentioned operation don't show the problem check if the INIR is not in the configuration mode.

IMPORTANT!

The precision in the Analogue Output is not as high as the Digital output, therefore is recommended to use at least a 12-bit ADC to read it.

Example 1: If Range = 5: 4 Floating points precision => 0.0024%vol/mV of DACvolts

Example 2: If Range = 100: 3 Floating points precision => 0.08%vol/mV of DACvolts

If Range = 100 : 4 Floating points precision => 0.048%vol/mV of DACvolts
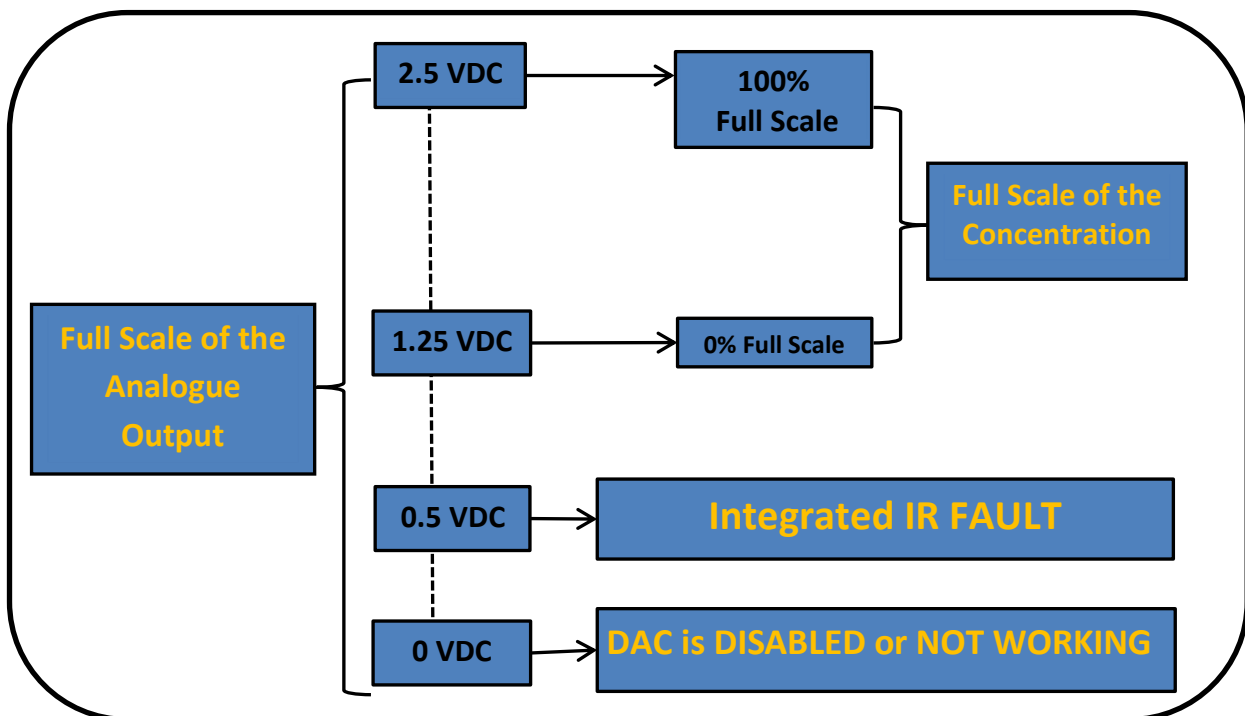
Figure 2 - Full Scale Representing the DAC Output

1.7   TRANSLATING THE "FAULTS" CODE

The Fault is a 32-bit unsigned integer number that is representing all the errors codes. The Fault is transmitted via UART like the Concentration. Fault variable consists of 4-bits which represent different levels of errors; up to 8 different sources of errors can be monitored simultaneously. The association between the Fault variable and the different errors can be found below in the Table 9.0 – Integrated IR Faults/Errors Interpretation.

The value of the digit for each source shows identifies the error according to the table below.

Table 15 - Integrated IR Faults/Errors Interpretation

Variable	Associated Part	Assigned DIGIT	Error Meaning	Value UART
Fault	ALL Parts	**7 to 0**	NO ERROR IN ALL PARTS (EVERYTHING OK)[*1]	0xAAAAAAAA
ENABLED	Gas Sensor	**0**	NO ERROR	0x0000000A
			01-Sensor not Present	0x00000001
			02-Temperature sensor not working **OR** Device Temperature Out of the Operating Range	0x00000002
			03-Active or Reference are weak	0x00000003
			04-First Time Configuration Mode, no settings present	0x00000004
ENABLED	Power Related	**1**	NO ERROR	0x000000A0
			01-Last Reset was because of a Power on Reset	0x00000010
			02-Last Reset was because of a Watchdog Timer	0x00000020
			03-Last Reset was because of a Software Reset	0x00000030
			04-Last Reset was because of an External Pin Interrupt	0x00000040
			05-Not assigned yet	0x00000050
ENABLED	ADC Related	2	NO ERROR	0x00000A00
			01-Gas concentration is not stable yet.	0x00000100
ENABLED	DAC Related	**3**	NO ERROR	0x0000A000
			01-DAC is switched off	0x00001000
			02-DAC output disable in Configuration mode	0x00002000
ENABLED	UART Related[*2]	**4**	NO ERROR	0x000A0000
			01-Break Indicator P1.0 set LOW for more than the maximum word length	0x00010000
			02-Framing Error, stop bit was invalid	0x00020000
			03-Parity Error, stop bit was invalid	0x00030000
			04-Overrun Error, data overwrite before being read	0x00040000
DISABLED	TIMERS Related	**5**	NO ERROR	0x00A00000
			01-Timer1 Error	0x00100000
			02-Timer2/Watchdog Error	0x00200000
			03-Not assigned yet	0x00300000
ENABLED	General Error	**6**	NO ERROR	0x0A000000
			01-Over Range of Conc.%v.v Operation > Full Scale	0x01000000
			02-Under Range of Conc.%v.v	0x02000000
			03-Warm-Up Time, data not valid	0x03000000
ENABLED	MEMORY Related[*3]	**7**	NO ERROR	0xA0000000
			01-Unable to store Data, to the INIR	0x10000000
			02-Unable to read Data from the INIR	0x20000000
			03-Not assigned yet	0x30000000

*1: It normal to get a Fault = 0xAAAAAA1A because the "1" in the second digit representing the Power on Reset process of the MCU which is a normal operation when we turn on the Integrated IR.

*2: This is the function that will check the UART Status (COMSTA0) register, to produce a fault depending on the previous experience. Obviously if the error is serious we will not be able to receive the message via UART, but we can check it later to find out what caused it.

*3: The Memory will work correctly as long as the MCU is working but it will not be able to store the data in the flash upon reset, if the Error 01 is present. If we cannot read the Memory then check if the INIR is in CONFIGURATION MODE.

1.8   Calculating the Cyclic Redundancy Check (CRC), Validate Data

The Cyclic Redundancy Check (CRC) is a simple way to validate data transmitted via any protocol from one side of the communication channel to the other side. Every time we are transmitting data via the Universal Asynchronous Receive Transmit (UART) protocol there is a chance from the physical properties of the channel for an error (around 0.0017%). In addition to that percentage error there are other parameters that could cause a loss in information or even synchronization between the INIR and a custom made instrument or with a PC. Strong Electromagnetic Fields or a quick reset because of a power failure or a lighting strike could also create a temporary loss of information or communication. For the above reasons and to minimize or completely eradicate the communication errors or loss of information SGX has implement a custom CRC, which is basically

a simple value carrying a checksum from all the data transmitted via UART within the 1 second period of time. In functions 1, 2 an exemplary C code on how SGX is calculating the CRC is provided. By using the same Algorithm for those transmitted values the same CRC value should be calculated, otherwise data is not correct - most likely have been corrupted during transmission. Equation SGX is using to calculate the CRC and the 1s Compliment of the CRC as well are shown.

Equation for CRC Calculation

$$\sum_{i=0}^{n} (byte)[\,X_k \gg (8*i)\,]$$

$where \;\; n = 1, 2, 3, 4$

$\quad X_k : Each\; number\; we\; are\; sending\; out.$

>> : is the right shift bit operator from the C programming language.

Example 1

"ENGINEERING" MODE	[	// Start Character 0x000005Bu (HEX) 4 bytes hex value
	0xAAAAAAAA	// Gas concentration in PPM (HEX) 4 bytes hex value
	0xAAAAAAAA	// Faults (HEX) 4 bytes hex value
	0xAAAAAAAA	// Sensor Temperature (HEX) 4 bytes hex value
	0xAAAAAAAA	// Reference 1 sec Average value 4 bytes hex value
	0xAAAAAAAA	// Active 1 sec Average value 4 bytes hex value
	0xAAAAAAAA	// CRC 4 bytes hex value
	0xAAAAAAAA	// 1's Compliment of CRC 4 bytes hex value
	]	// End Character 0x000005D (HEX) 4 bytes hex value

The val_crc variable is holding the final summation of the CRC transmitted value and the inv_crc is the Bitwise Compliment of CRC.

val_crc $= \sum_{i=0}^{n}[\,X_k \gg (8*i)\,]$, $where \;\; n = 1,2,3,4$ and $X_k : Each\; number\; sent$.

In case of the Engineering mode, Function 3 the data below is sent:

For k=1: $\sum X1 = \sum_{i=0}^{n}[\,0x0000005Bu \gg (8*i)\,]$ // START Character "[", counts in CRC.

For k=2: $\sum X2 = \sum_{i=0}^{n}[\,(Gas\_Conc\_PPM) \gg (8*i)\,]$
// Gas Concentration in PPM.

For k=3: $\sum X3 = \sum_{i=0}^{n}[\,(uint32\_t)(Fault) \gg (8*i)\,]$ // Output the Final Fault code for all the parts, counts in CRC

For k=4: $\sum X4 = \sum_{i=0}^{n}[\,(uint32\_t)(Temp.) \gg (8*i)\,]$
// Send the Sensor Temperature, counts in CRC.

For k=5: $\sum X5 = \sum_{i=0}^{n}[\,(uint32\_t)(Ref) \gg (8*i)\,]$ // Send the reference average value of the 1 second, counts in CRC.

For k=6: $\sum X6 = \sum_{i=0}^{n}[\,(uint32\_t)(Act) \gg (8*i)\,]$
// Send the active average value of the 1 second, counts in CRC.

val_crc $= \sum X1 + \sum X2 + \sum X3 + \sum X4 + \sum X5 + \sum X6;$
inv_crc = ~val_crc

2. Calibration Procedure

The following procedure is implemented in the Calibration of the INIR Sensors during production. The coefficients that are used for calibration are depending on the Sensor and the targeted Gas. Please find the correct coefficients from the Table of Coefficients at the Appendix A – Table of Coefficients or contact SGX Ltd for more details.

The INIR Gas Sensor has custom coefficients. It is not advised to change them when sensor is calibrated.

IMPORTANT WARNING!

It is not advisable to do any kind of Re-Calibrate on a factory calibrated pair other than Re-Zero, as this will void the certificate. Please be aware that different rules apply for every country. SGX's recommendations are here to be used as guidelines and not to supersede or overwrite any standard, law, rule or regulation that applies in any case. The equipment used for performing the calibration should be suitable to ensure the reliability and the repeatability of the linearity.

1 x Certified Gas Cylinder of Dry 100% Nitrogen (Gas Cylinder for doing the Zero Calibration)
1 x Certified Gas Cylinder of Dry 5.0% v/v / Balance Nitrogen (Gas Cylinder of the target Gas)
1 x INIR Digital Gas Sensor
2 x Plastic Tubing
2 x Flow Regulators
1 x Gas Cap
1 x EK4/PC or customer's instrument

Recommended Environmental Conditions

Pressure	100.5 kpa -101.5 kpa
Temperature	20°C – 25°C
Relative Humidity	10% or completely Dry
Gas Flow	Maximum 1000 ml/min
Averaging	20 /sec
Warm Up Time Before Calibration	45 to 60 mins

Note: If more accurate Evaluation is required please use an Environmental Chamber to keep temperature, humidity, vibration and pressure stable to desired values.

Equipment Used
Basic Set Up
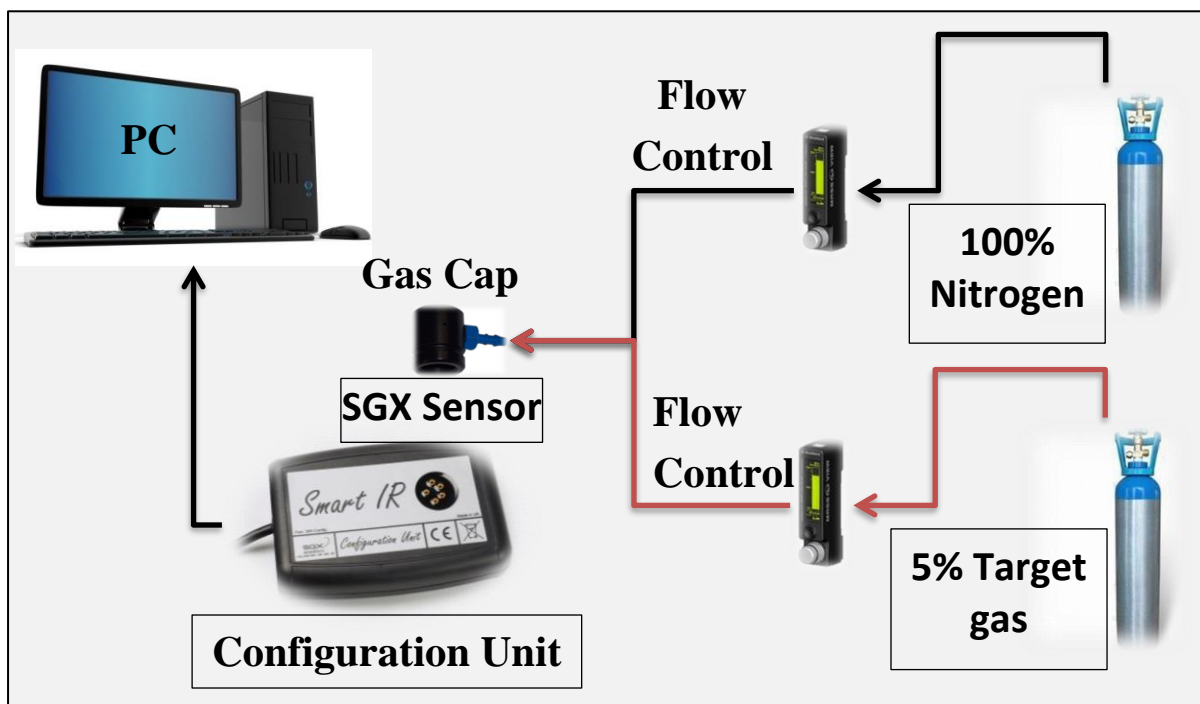
Figure 3 - Basic Calibration Set Up

2.1. Calibration Routine using the Evaluation Software

Step 1 (Communicate):

a. Plug the Gas Sensor into the EK4 and Connect the Configuration Unit to the PC.

c. Plug the Cap onto the Gas Sensor.

d. Run/Open the Integrated IR Evaluation Software version 3.0.0 and above.

e. Go to "**Communications" Tab** -> "**Search for Devices"**, by pressing the Orange Button
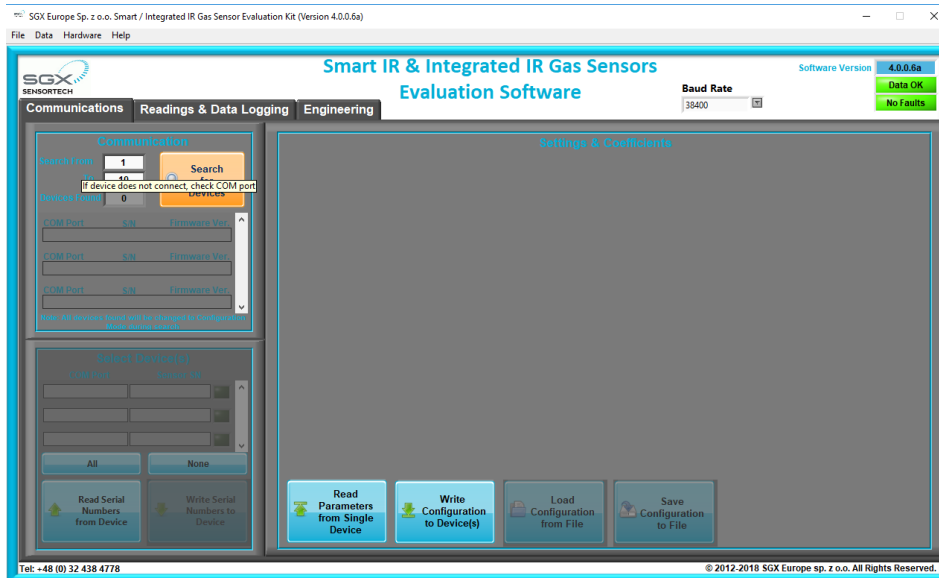
Step 2 (Configure):

a. Once connection established -> Go to "**Communications" Tab**

c. Set up the **Sensor Type, Target Gas Type etc..**

d. Fill in the correct coefficients for the target Gas as in an example below:
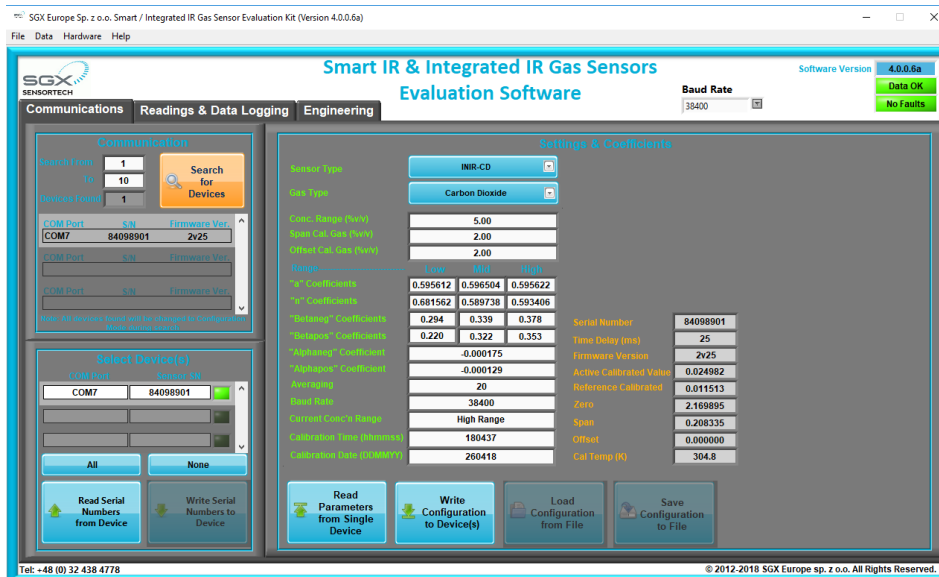
e. Press **Write Configuration to Device(s)** to write the settings to the INIR.
   (HINT: It is not possible to rewrite the Orange Variables, only the Green ones).

f. Select **Engineering Mode**

g. Go to "**Readings & Data Logging" Tab**.

Step 3 (Warm Up):

  a. Connect the 100% Nitrogen, open the Gas Regulator. Use the flow controller to regulate the gas flow ideally around 500ml/min.

  b. **Press Start** for the Software to start reading from Integrated IR.

  c. Wait for 45 mins for the Sensor to warm up and reach the Ambient Temperature (ideally 20°C).
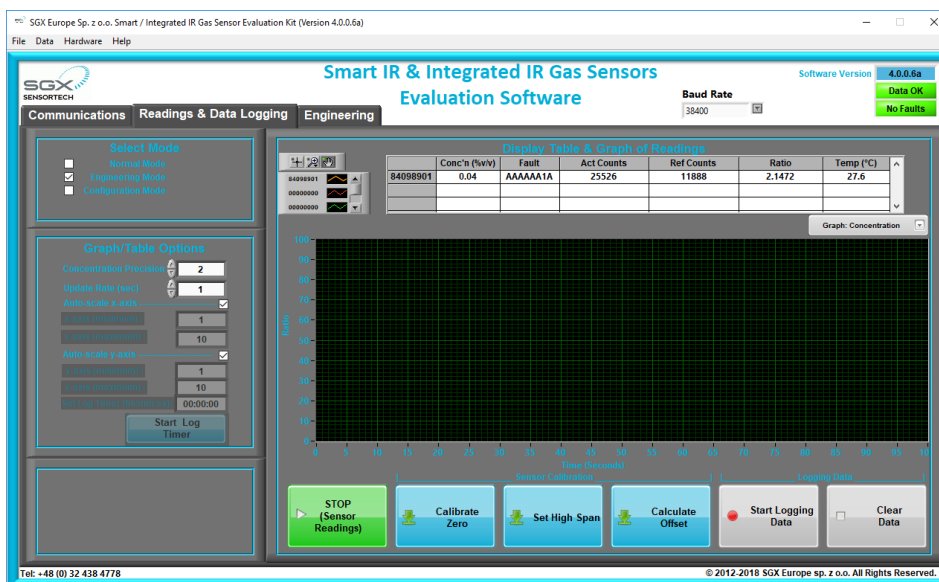
IMPORTANT WARNING!

  Try to keep the ambient temperature stable during the Calibration Process. Zero, High Span Calibration and Offset Calculations should be performed ideally in the same Temperature (+/-1.0°C). Temperature variations will cause additional inaccuracy in the temperature compensation algorithm.

Step 4 (Calibrate Zero):

  a. When sensor is stable press the **Set Zero Button - it should be made after additional 30 minutes.**
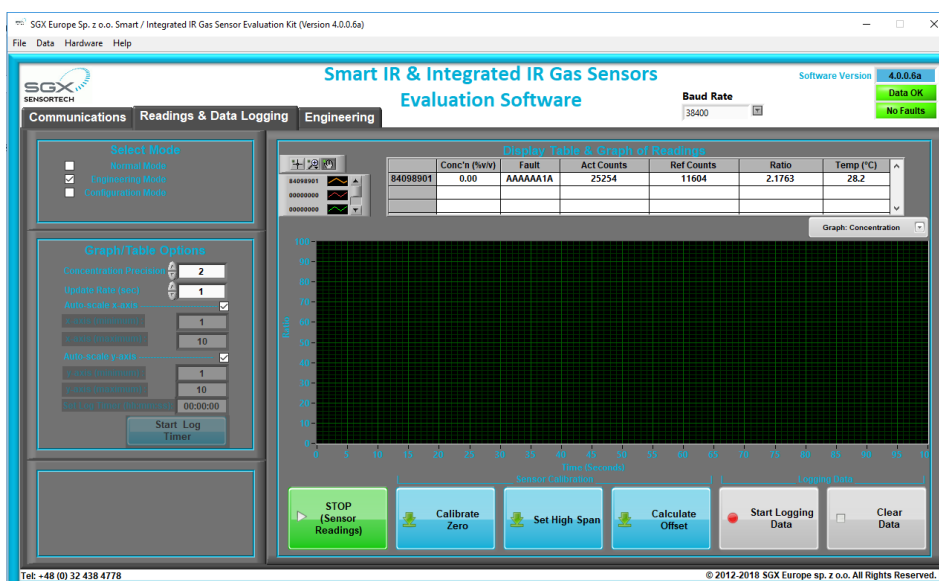
  b. Wait for valid gas concentration in fault code (section ADC Related).

Step 5 (Calibrate Span):

a. Disconnect the Gas Cap of the 100% Nitrogen

b. Connect the Gas Cap of the 5.00% Target gas/ Balanced Nitrogen

c. Wait for 5 mins.

d. After Signals are stable, press **Set High Span Button**

e. Wait for valid gas concentration in fault code (section ADC Related).

f. Disconnect the 5.00% Target Gas Cap.

g. Connect the Gas Cap of the 100% Nitrogen

h. Wait for 5 mins.

HINT: Since version 2.20 is not necessary. In older versions of firmware use perform Offset Calculation only if proven your sensor is reading outside +/-6% limits.

Step 6 (Calculate Offset):

a. Connect the Gas Cap of the 2.00% Methane/ Balance Nitrogen

b. Wait for 5 mins.

c. After Signals are stable, press **Calculate Offset**

d. Wait for valid gas concentration in fault code (section ADC Related).

Step 7 (Finish):

a. Start doing the Experiments you want, the Integrated IR Gas Sensor is now fully calibrated.

IMPORTANT WARNING!

Every time the sensor is changed for maintenance or repair the Calibration procedure should be done again - it is against the law and regulations to use an un-calibrated device in the field. Make sure that the equipment used is calibrated as well. If you are not experienced in the calibration process or you do not have the equipment to do it, SGX Europe sp. z o.o. can provide you with a pre-calibrated pair, but still you should calibrate the instrument at regular intervals as required by regional regulations.

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3. Condensation Compensation Algorithm

What is Humidity?

Humidity is the amount of water vapor in the air. Water vapor is the gaseous state of water and is invisible. Humidity indicates the likelihood of precipitation, dew, or fog. Higher humidity reduces the effectiveness of sweating in cooling the body by reducing the rate of evaporation of moisture from the skin. This effect is calculated in a heat index table or humidex.

There are three main measurements of humidity: absolute, relative and specific. Absolute humidity is the water content of air at a given temperature expressed in gram per cubic metre. Relative humidity, expressed as a percent, measures the current absolute humidity relative to the maximum (highest point) for that temperature. Specific humidity is a ratio of the water vapor content of the mixture to the total air content on a mass.

The relative humidity (ϕ) of an air-water mixture is defined as the ratio of the partial pressure of water vapor (H_2O) (e_w) in the mixture to the saturated vapor pressure of water $(e^*{}_w)$ at a given temperature. Thus the relative humidity of air is a function of both water content and temperature.

Relative humidity is normally expressed as a percentage and is calculated by using the following equation:

$$\phi = \frac{e_w}{e^*{}_w} \times 100\%$$

Relative humidity is an important metric used in weather forecasts and reports, as it is an indicator of the likelihood of precipitation, dew, or fog. In hot summer weather, a rise in relative humidity increases the apparent temperature to humans (and other animals) by hindering the evaporation of perspiration from the skin. For example, according to the Heat Index, a relative humidity of 75% at 80.0 °F (26.7 °C) would feel like 83.6 °F ±1.3 °F (28.7 °C ±0.7 °C) at ~44% relative humidity.

What is Condensation?

Condensation is the formation of liquid drops of water from water vapor. It is the process which creates clouds, and is necessary for rain and snow formation as well. Condensation in the atmosphere usually occurs as a parcel of rising air expands and cools to the point where some of the water vapor molecules clump together faster than they are torn apart from their thermal energy.

A very important part of this process is the release of the latent heat of condensation. This is the heat that was absorbed when the water was originally evaporated from the surface of the Earth, a process which keeps the Earth's surface climate much cooler that it would otherwise be if there were no water. The heat removed from the surface through evaporation is thereby released again higher up in the atmosphere when clouds form.

Another way in which condensation occurs is on hard surfaces, such as during the formation of dew. Water condensing on a glass of ice water, or on the inside of windows during winter, is the result of those glass surfaces' temperature cooling below the dewpoint of the air which is in contact with them.

How INIR performs under Condensation?

The Integrated IR (INIR) Gas Sensor has the relevant Algorithm to minimize the effect that condensing or humidity has on the sensor. The Condensation in mining industry usually comes from two sources: the first one being sprayed water to minimize the dust clouds and the second being due to hard surfaces effect described above.

Irrelevant where the condensation comes from or how it forms IR Gas Sensors will react to that effect the same way they are reacting to the presence of Methane. For that reason sometimes false alarms occur down the mine and that is why SGX Ltd has implemented the Condensation Algorithm to keep the effect minimal under the first alarm point usually got underground. Eventually the Condensation will evaporate as the sensor warms up and the re-bounce of that effect is within a small period of time.

The above algorithm is recommended to be "ON" in INIR-MEGG% as the effect of Humidity and Condensation only appears to Methane, Propane or Butane detectors, the Carbon Dioxide Gas Sensors due to different IR spectra operation do not appear to correspond to that effect and are not affected the way the Methane Gas Sensors do.

Please read page 24 containing results from test performed to prove the theory and validate the use of the algorithm under controlled environmental conditions of pressure and temperature. The only variable measurable condition was the condensation that was produced using a commercial humidifier. The algorithm and firmware or software information or design about related products is proprietary information of SGX Ltd and is protected under United Kingdom, EU or global Copyright Law.
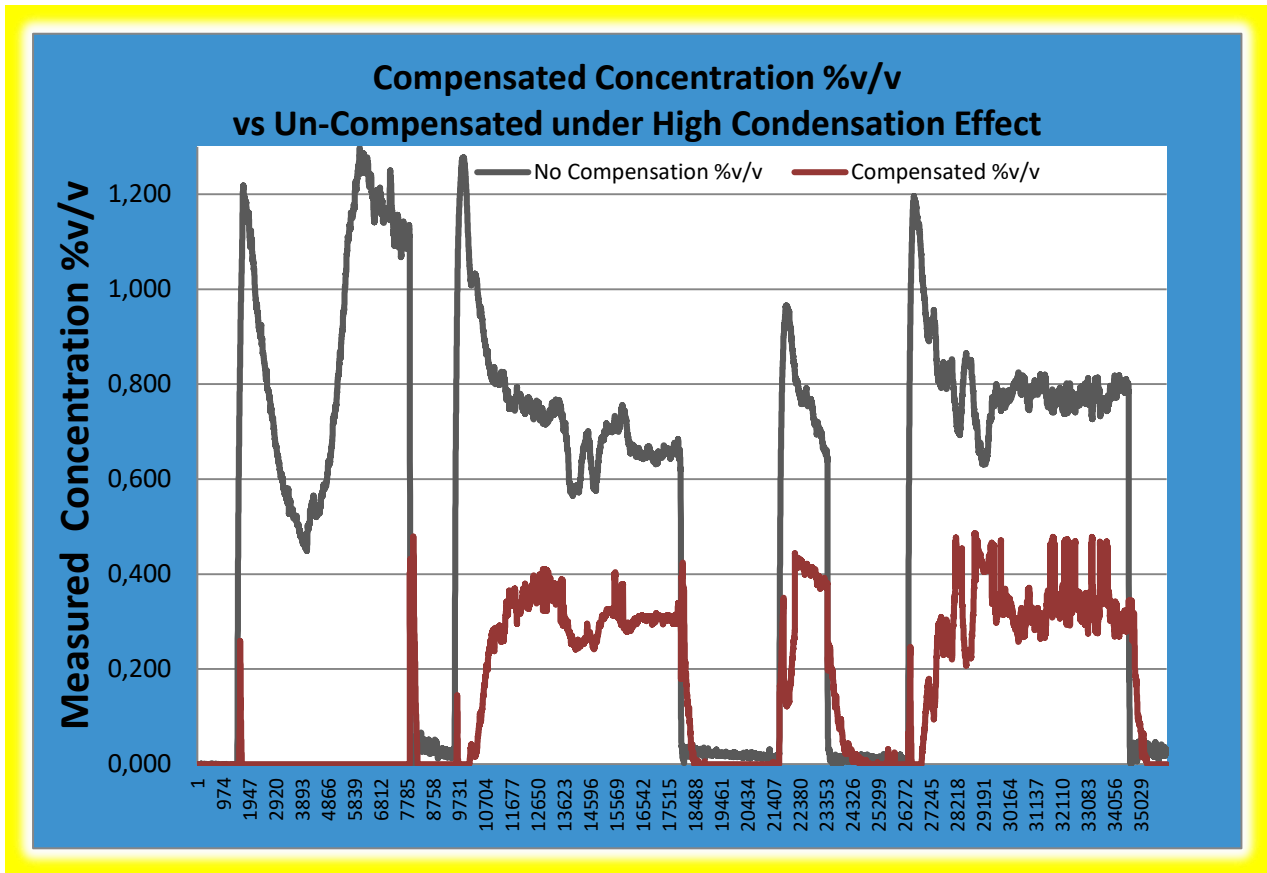
Figure 3 - Representative Condensation Compensation Test results

IMPORTANT WARNING!

The Compensation Condensation Algorithm is a tool that customers may choose to use or switch off. It is strongly recommended to customers to test extensively the algorithm and the INIR after they have implemented the INIR Gas Sensor into their own instrument and then based on real-life in the field experiments to decide whether to enable the Algorithm or not.

SGX Ltd has no liability if the specific tool is not used as intended "to minimize the response effect due to condensation forming inside the INIR Gas Sensor".

The specific algorithm is not designed to "cure" the problem and it will not work with the same performance in the presence of Gas because of the physical properties of the Detector and the way that the IR Gas Sensors are designed.

SGX Ltd suggests to "Turn ON" the algorithm and Turn it "OFF" after a short period of time or Turn it "ON" only during the exposure to water particles is certain for a short period of time.

To Turn "ON or "OFF" the algorithm, please see 1.2.12.

4. Extreme Conditions of Operation

4.1 Corrosive Environment

In an ideal situation the INIR is corrosive resistant because internally it is using a Gold Plated Reflector and the electronics are protected with conformal coating and epoxy potting. Nevertheless when customer intents to use the INIR in an extremely high corrosive environment extra protection will be needed as INIR is not designed to operate in such conditions without any loss of performance.

The performance of the INIR would be highly degraded if corrosion starts building inside the reflective gas sensing cavity.

Damaged caused by operating the sensor with corrosive gases or inside in highly corrosive environment will not be covered with the warranty, see Datasheet for more details on what the warranty is covering.

4.2 Dust or Coal Dust

The INIR shall be protected in service from dust by fitting external semi-permeable membrane. The gas sensor is dust-proof (IP5X) but offers no protection against the ingress of water. Please read the Datasheet and the Certificate of the sensor for more details on protection from dust. It is highly recommended to always use a dust filter which will also prevent water droplets going inside the sensor. The dust filter will always reduce the response times of the INIR - tests have proven that even with a dust filter the INIR stays within the limits for all the EU and Chinese standards for T90 and T10 response times. For more details on performance and timings please read the INIR Datasheet.

4.3 Mechanical Shock

The INIR components other than the Lamp are highly resistant to vibrations.

On the other hand the sensor is not design to withstand continuous levels of vibration and extreme Mechanical Shock like a hammer hit or crushing or smashing. The INIR Gas Sensor head shall be protected from impact in service. The Sensing Head shall be mounted in a protective enclosure such that an impact of 7 J in accordance with IEC 60079-0:2007 clause 26.4.2 from any direction shall not cause the impact head to make contact with the Sensing Head.

4.4 Extreme Environmental Conditions

The INIR will not function as expected in most extreme environmental conditions especially if more than one condition is present at the time.

An extreme environment contains conditions that are hard to survive for most known life forms. These conditions may be extremely high or low temperature or pressure; high levels of radiation, acidity, or alkalinity; absence of water; water containing a high concentration of salt or sugar; presence of sulphur, petroleum, and other toxic substances.

Exemplary extreme environments include:
- Alkaline: broadly conceived as natural habitats above pH 9 whether persistently, or with regular frequency or for protracted periods of time.
- Acidic: broadly conceived as natural habitats below pH 5 whether persistently, or with regular frequency or for protracted periods of time.
- Extremely cold: broadly conceived habitats periodically or consistently below -20°C either persistently, or with regular frequency or for protracted periods of time.
- Extremely hot: broadly conceived habitats periodically or consistently in excess of 60°C either persistently, or with regular frequency or for protracted periods of time.
- Hypersaline: (high salt) environments with salt concentrations greater than that of seawater, that is, >3.5%.
- Under pressure: broadly conceived as habitats under extreme hydrostatic pressure — i.e. aquatic habitats deeper than 2000 meters and enclosed habitats under pressure.
- Radiation: broadly conceived as habitats exposed to abnormally high radiation or of radiation outside the normal range of light. Includes habitats exposed to high UV and IR radiation.

Appendix A - Table of Coefficients

Sensor Type	Gas Type	Range (%v.v)	a Low	a Mid	a High	n Low	n Mid	N High	alphapos	alphaneg	Betapos Low	Betapos Mid	Betapos High	Betaneg Low	Betaneg Mid	Betaneg High
INIR	CH_4 (ME)	0-100%	0.000318	0.000326	0.000399	0.77777	0.616451	0.480544	0.001001	0.000969	-119.166	-71.772	-72.386	-101.352	-81.328	-39.756
INIR	C_3H_8 (PR)	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX
	C_4H_{10} (BU)	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX	Contact SGX
INIR	CO_2 (CD)	0-5%	0.652279	0.649793	0.649875	0.673821	0.647638	0.647597	0.000157	0.000082	0.178	0.251	0.303	0.208	0.259	0.293

NOTE:

1. These coefficients are based upon results measured at SGX Europe sp. z o.o. using standard test equipment. These coefficients may vary slightly when using different circuits. It may be required to recalculate some of these coefficients if small inaccuracies are observed during testing (refer to Infrared Sensor Application Note 5 for determination of coefficients).

2. The above coefficients are representing the average typical coefficients that the customers can use for evaluation. SGX Europe sp. z o.o.is making sure for all the internal calibrations to recalculate and check the coefficients for best fitting the individual characteristics of each sensor.

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