# ULTRA-LOW POWER INFRARED GAS SENSOR MIPEX-04-X-XX-3.1

# USER MANUAL

**ESAT.100100.00.07 UM**

# Document revisions

| Rev. | Date | Common changes |
|---|---|---|
| 07 | September 29, 2023 | Updated info on sensor marking and standard compliance. |
| 06 | March 25, 2020 | Updated info on sensor dimensions (see Fig. 6):<br>• Changed [16.4 ± 0.05] to [16.25 $^{+0.1}_{-0.15}$].<br>Fig. 9 has been removed. |
| 05 | April 12, 2019 | Updated info on sensor weight (see Table 2).<br>Updated info on maximum allowable pressure on sensor top surface (see section 5).<br>Updated info on sensor dimensions (see Fig. 6):<br>• Changed [0.88 ± 0.05] to [0.8 $^{+0.13}_{-0.05}$].<br>• Changed [16.4 ± 0.05] to [16.25 $^{+0.05}_{-0.25}$].<br>Updated response description for commands <@>, <@*X> and <DATAE2> (see Appendix C.2.1).<br>Document ID number has been changed from ESAT.100000.00.XX UM to ESAT.100100.00.XX UM. |
| 04 | April 8, 2019 | Updated info on sensor marking and standard compliance (see Table 4).<br>Updated Fig. 8. Intrinsic safety control drawing.<br>Updated description of <CCS>, <CFS> and <CKS> commands (see Appendix C.2.1). |
| 03 | March 21, 2019 | Updated info on sensor marking and standard compliance (see Table 4). |
| 02 | December 12, 2016 | Formatting.<br>Temperature zero adjustment manual mode has been excluded (see Appendix D.2).<br>Added information on displaying certain status word values in concentration field while “INDSIG” mode is active (see Table 12).<br>Added information on concentration values exceeding measurement range (see section 6.4).<br>Ordering codes for gas adapter and interface board have been added.<br>Direct UART output has been added on Fig. 9.<br>Recommended sampling frequency by sending command <F> is changed for troubleshooting from 0.1 Hz to 0.6 Hz (see Appendix |

| | | |
|---|---|---|
| | | F). |
| 01 | March 11, 2016 | Released version. |

# Table of contents

# 1. INTRODUCTION

This user manual (UM) is intended to describe design and operation of small-sized gas sensor MIPEX-04-X-XX-3.1 (hereinafter MIPEX-04 or sensor). UM contains basic technical data, recommendations and other information necessary for proper operation, maintenance and storage of sensor.

Sensor is intended for automatic continuous measurement of hydrocarbons concentration in atmosphere of hazardous areas. Sensor can be used as a part of gas-analyzing equipment groups I and II according to IEC 60079-0 in the explosion-hazardous zones classes 0, 1, 2 according to IEC 60079-10-1, and Class I, Division 1, Group A, B, C, D according to UL Std. 913, UL 60079-0, UL 60079-11, CAN/CSA –C22.2 NO. 60079-0, CAN/CSA –C22.2 NO. 60079-11.

Any command stated in this UM as <X>, where X stands for a command text consisted of any number of characters, must be read and/or sent without the symbols “<” and “>”.

**SIA MIPEX reserves the right to make changes to this manual, excluding intrinsically safe sensor parameters.**

## 1.1. List of abbreviations

- LEL stands for Lower Explosive Limit;
- LED stands for Light Emitting Diode;
- CGM stands for Control Gas Mixture;
- NDIR stands for Non-Dispersive Infra-Red;
- UART stands for Universal Asynchronous Receiver/Transmitter.
- CRC stands for Cyclic Redundancy Check.
- IP stands for Ingress Protection.
- PCB stands for Printed Circuit Board.

## 1.2. List of terms

- Target gas is a gas, which sensor is intended to detect and measure its concentration.
- Calibration gas refers to CGM containing that gas, used for sensor calibration.

Any command stated in this UM as <X>, where X stands for a command text consisted of any number of characters, must be read and/or sent without the symbols “<” and “>”.

# 2. DESCRIPTION

Sensor has several modifications for specific needs. They differ by photodiode and LED types, calibration gases, measuring ranges etc. (see Appendix A).

Sensor is a smart integrated system and includes mirror optical system, photodiode and LED, signal amplifiers, microcontroller, current driver of the infrared LED, UART interface signal generator and forming voltage supply unit. Sensor microcontroller performs storage of unique sensor calibration constants, processing of measurement results and concentration of measured gas, and information exchange.

Sensor operating principle is based on NDIR technology, i.e. on selective infrared radiation absorption by gas molecules.

Infrared radiation from LED permeates through a measuring diffusion-type gas cell and arrives on signal and reference photodetectors, one of which detects radiation only in the wavelength range of infrared radiation absorbed by gases, while the other one detects radiation only in the wavelength range of 3.5…3.7 μm. Gas flowing through the cell absorbs the radiation of the operating wavelength ($\lambda_s$) and does not affect the radiation of the reference wavelength ($\lambda_{ref}$). Amplitude $U_s$ of the photodetector operating signal varies with the concentration of the target gas in accordance with the following equation:

$$\frac{U_s}{U_{ref}} = \exp(-[K(\lambda_s) - K(\lambda_{ref})] \cdot C \cdot L)$$

where:

$K(\lambda)$ – absorption coefficient at the predetermined wavelength;

$L$ – optical length of the cell;

$C$ – measured concentration of gas;

$U_s$, $U_{ref}$ – signal amplitude at photodetector.

Differential dual wavelength method allows eliminating of water vapor, optical elements contamination and other non-selective hindrances influence.

Target gases available for MIPEX-04 are listed in Table 1.

**Table 1. Target gases for MIPEX-04 sensors**

| Target gas | Analytical tasks description | Optical elements code (see Appendix A) | Spectral characteristic maximum | Notes |
|---|---|---|---|---|
| $CH_4$ | Analyzing a gas mixture containing methane as the main component. | 1 | 3.31 μm | For the optical elements sensitivity to other hydrocarbons see Fig. 4. |
| $C_3H_8$ | Analyzing a gas mixture containing heavy hydrocarbons. The presence of methane is negligible. | 2 | 3.40 μm | For the optical elements sensitivity to other hydrocarbons see Fig. 5. |

# 3. TECHNICAL SPECIFICATIONS

**Table 2. General specifications (for available options see Appendix A)**

| | | |
|---|---|---|
| **Gas sampling method** | | Diffusion |
| **Operating principle** | | Non-Dispersive Infra-Red (NDIR) |
| **Target gas**[1] | | $CH_4$ |
| | | $C_3H_8$ |
| **Operating, storage and transportation conditions:** | **Relative humidity, %** | up to 98 |
| | **Atmospheric pressure, kPa** | 80…120 |
| | **Temperature**[2]**, °C** | -40...+60 |
| **Temperature range, °C** | | -10…+40 |
| | | -40…+60 |
| | | -20…+50 |
| **Overall dimensions, mm** | | 52×24×18 |
| **Warm-up time, sec** | | ≤ 120 |
| **Weight, g** | | 11.0…13.5 |
| **Housing material** | | Polycarbonate Lexan™ |
| **Lifetime expectancy**[3] **(not less than), years** | | 7 |
| **IP rating** | | 20 (without dust filter) |
| | | 54 (if a dust filter provided by SIA MIPEX is applied, see Appendix E) |

**Table 3. Measurement specifications**

| | |
|---|---|
| **Typical measurement range, % vol.** | 0…2.5 |
| | 0…5 |
| | 0…100 |
| **Basic variability (+20…+25 °C)**[4] | ± 0.1% vol. or ± 5% of readings (whichever is greater) for $CH_4$ |
| | ± 0.05% vol. or ± 5% of readings (whichever is greater) for $C_3H_8$ |
| **Response time t(90), sec** | < 30 ($CH_4$ sensors) |
| | ≤ 45 ($C_3H_8$ sensors) |

[1] See Appendix A for details.

[2] Term “operating temperature” refers to ambient temperature at which sensor operates and its intrinsic safety is ensured, but sensor accuracy stated in Table 3 is provided only in specified temperature range (see Table 5 and Table 6).

[3] To provide metrological properties during sensor lifetime, span calibration should be performed periodically (see Appendix D.1).

[4] For variability in whole operating temperature range for any sensor modification refer to Table 6.

**Table 4. Electrical specifications, marking and standards compliance**

| | |
|---|---|
| **Operating supply voltage, VDC** | +2.8…+5.0 |
| **Max supply voltage, VDC** | +5.5 |
| **Communication interface** | UART |
| **Average current, μA** | 35 |
| **Marking and standards compliance** | The details of certification are specified in Appendix B (see Fig. 8).<br>Sensor is suitable for use within end equipment with temperature classes T1-T6 at maximum ambient temperature of +60 °C.<br>**Ex ia I Ma / Ex ia IIC Ga**<br>According to standards:<br>IEC 60079-0:2017 7th Edition<br>IEC 60079-11:2011 6th Edition<br><br>**C I, Div 1, Gr A,B,C,D;**<br>**C I, Zone 0, AEx ia IIC Ga; Ex ia IIC Ga**<br>According to standards:<br>UL 913:2013 Ed.8<br>UL 60079-0:2019 Ed.7<br>UL 60079-11:2013 Ed.6<br>CSA C22.2 No. 60079-0:19 Ed.4<br>CSA C22.2 No. 60079-11:2014 Ed.2<br><br>**I M1/ II 1 G Ex ia I Ma/ Ex ia IIC Ga**<br>According to standards:<br>EN IEC 60079-0:2018<br>EN 60079-11:2012 |

# 4. INTRINSIC SAFETY

Sensor's intrinsic safety is provided by:

- limiting the parameters of its electrical circuits to intrinsically safe values in accordance with EN 60079-11;
- providing the required electrical clearances and creepage paths in accordance with EN 60079-11.

**Combined intrinsically safe sensor circuits parameters:**

- IECEx/ATEX: $U_i$ = 5.5 V, $I_i$ = 200 mA, $P_i$ = 0.13 W, $C_i$ = 26 μF, $L_i$ = 0.
- CAN/CSA: $V_{max}$ = 5.5 V, $I_{max}$ = 200 mA, $P_{max}$ = 0.13 W, $C_i$ = 26 μF, $L_i$ = 0.

It is allowed to connect sensor only to intrinsically safe circuits with the rated direct current output voltage ($U_0$) within the range of +2.8…+5.5 V and with the output power ($P_0$) range of 0.02…0.13 W in accordance with IEC 60079-0, IEC 60079-11 and whose parameters conform MIPEX-04 intrinsic safety values pointed above. Current provided by power supply unit must be 20 mA ≤ $I_0$ ≤ 200 mA.

# 5. HANDLING PRECAUTIONS

- Do not use damaged sensor. It must be repaired only by personnel authorized by manufacturer.
- Keep sensor out of contact with aggressive substances e.g. acidic environments, which can react with metals, as well as solvents, which may affect polymeric materials.
- Diffusion holes of sensor should be protected against ingress of dust and sprayed materials.
- Sensor is not intended to measure hydrocarbons contained in fluids.
- It is not allowed to use brazing furnace, infrared or convection ovens for soldering sensor contacts to end-user equipment. Soldering conditions stated in 6.2 must not be violated. Spot soldering only.
- Maximum pressure on sensor top surface must not exceed 0.27 $N/mm^2$.
- It is not allowed to apply pressure on sensor side surface.
- Sensor updates information about concentration every 1.32 ± 0.04 seconds. Sending any command more often than one time per 2 second (0.5 Hz) may reduce sensor accuracy and increase its current consumption.
- Correct measurement is provided when ambient temperature changes not faster than 0.6 °C/min.
- Sensor may accumulate an electrostatic charge on its housing. Thus, there is risk of electrostatic discharge. Clean only using a damp cloth. Note this during installation and use of sensor in the end-user equipment.
- Covering diffusion holes of sensor increases its response time t(90).
- When operating sensor, observe conditions stated in Table 2 and Table 4.
- Inspection and maintenance should be carried out by suitably trained personnel in accordance with the applicable code of practice (e.g. EN 60079-17).
- Persons, who have studied this UM, must be briefed on safety precautions when operating electrical equipment intended for use in explosive areas in due course.
- When dealing with cylinder containing gas mixture under pressure, it is necessary to follow the safety regulations. Dumping of CGM into the work area is not allowed.
- There is no risk of pollution and negative impact on human health. Sensor does not contain any harmful substances that may be released during its normal operation.
- It is strictly prohibited to remove label from sensor or to damage marking information in any way.

# 6. INSTALLATION AND SERVICE

- MIPEX-04 may accumulate an electrostatic charge on its housing. Thus, there is risk of electrostatic discharge. Clean only using a damp cloth. Note this during installation and use of sensor in the end-user equipment.
- Sensor must be mounted with its contacts soldered to mating PCB pads. Using of brazing furnace for this purpose is not allowed. Soldering conditions stated in 6.2 must not be violated. Spot soldering only.
- Maximum pressure load on sensor top surface must not exceed 0.27 N/mm$^2$.
- It is not allowed to apply pressure on sensor side surface.
- Span calibration is necessary during initial installation to gas analyzers and during preparation for the yearly tests. Manual zeroing must be performed after prolonged storage without power supply, after transportation as well as after dust filter is applied (see Appendix D.1).
- It is required to perform span calibration at least once in 2.5 years.

## 6.1. Preparation

- If sensor has been kept in transport containers at temperatures below zero centigrade, leave it at 10…35 °C for at least an hour.
- Remove the packaging. Make sure there are no mechanical injuries on sensor surfaces.

## 6.2. Mounting

Sensor should be mounted with its contacts soldered to mating PCB pads. Spot soldering only. Maximum soldering temperature is 350 °C; maximum soldering time is 3 s.

Recommended mating board configuration and sensor pinout are shown in Appendix A.

End-user equipment design has to provide that sensor is free of excessive pressure on its housing, ingress of dust, dirt and condensed moisture, as these factors may affect the accuracy of measurement. It is recommended to use dust filter (available as an option; see Appendix E). Filter has to be checked regularly and replaced when fouling is significant.

## 6.3. Electrical conditions

- During first 0.01 seconds after power up, sensor consumes up to 18 mA (see Fig. 1).
- During operation MIPEX-04 has pulsed power consumption. Pulse repetition period is about 320 ms, maximum surge current is 4 mA. Average power consumption is 35 μA (see Fig. 2 and Fig. 3).
- Sending any command more often than one time per 2 second (0.5 Hz) may reduce sensor accuracy and increase its current consumption.

Use intrinsically safe circuit connections represented in Appendix B.

Sensor power supply has to follow requirements of IEC 60079-0 and IEC 60079-11, with rated output range of intrinsically safe DC voltage $U_0$ of +2.8…+5.0 V, with rated power range $P_0$ of 0.02…0.13 W. Current provided by power supply unit must be 20 mA ≤ $I_0$ ≤ 200 mA.

Sensor transmits information about measured concentration via UART interface. Sensor supports embedded self-testing while operating and is designed for continuous 24/7 operation.

End-user equipment UART transceiver should meet the requirements of standards IEC 60079-0, IEC 60079-11.

Sensor UART transceiver communication properties are:

- High logic level for transmitting line TxD is +2.1 V;
- High logic level for receiving line RxD is in range of +2.1…+2.3 V;
- Low logic level is in range of +0.1…+0.6 V;
- Maximum output current of UART is not more than 2.1 mA.

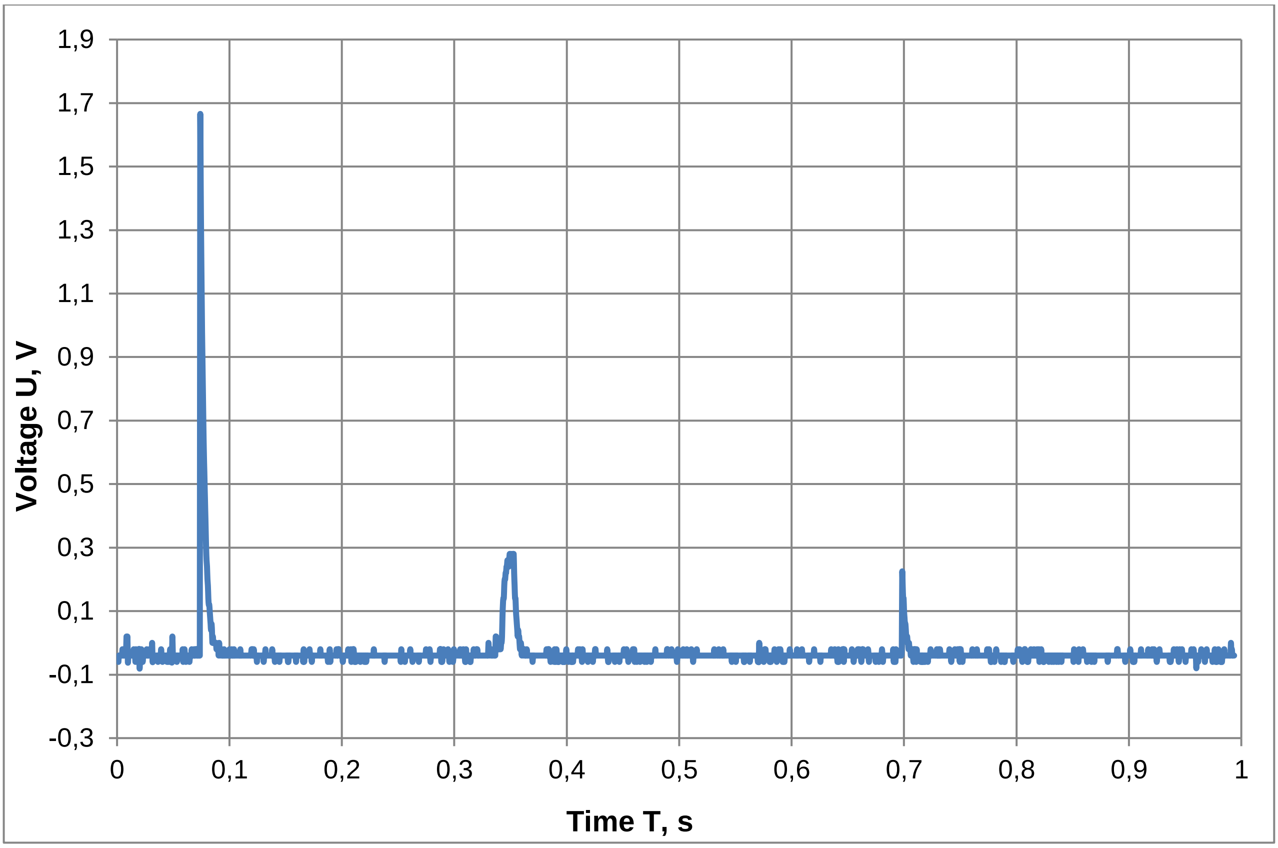


**Fig. 1. Typical sensor voltage drop after power up (load resistance R = 100 Ohm)**

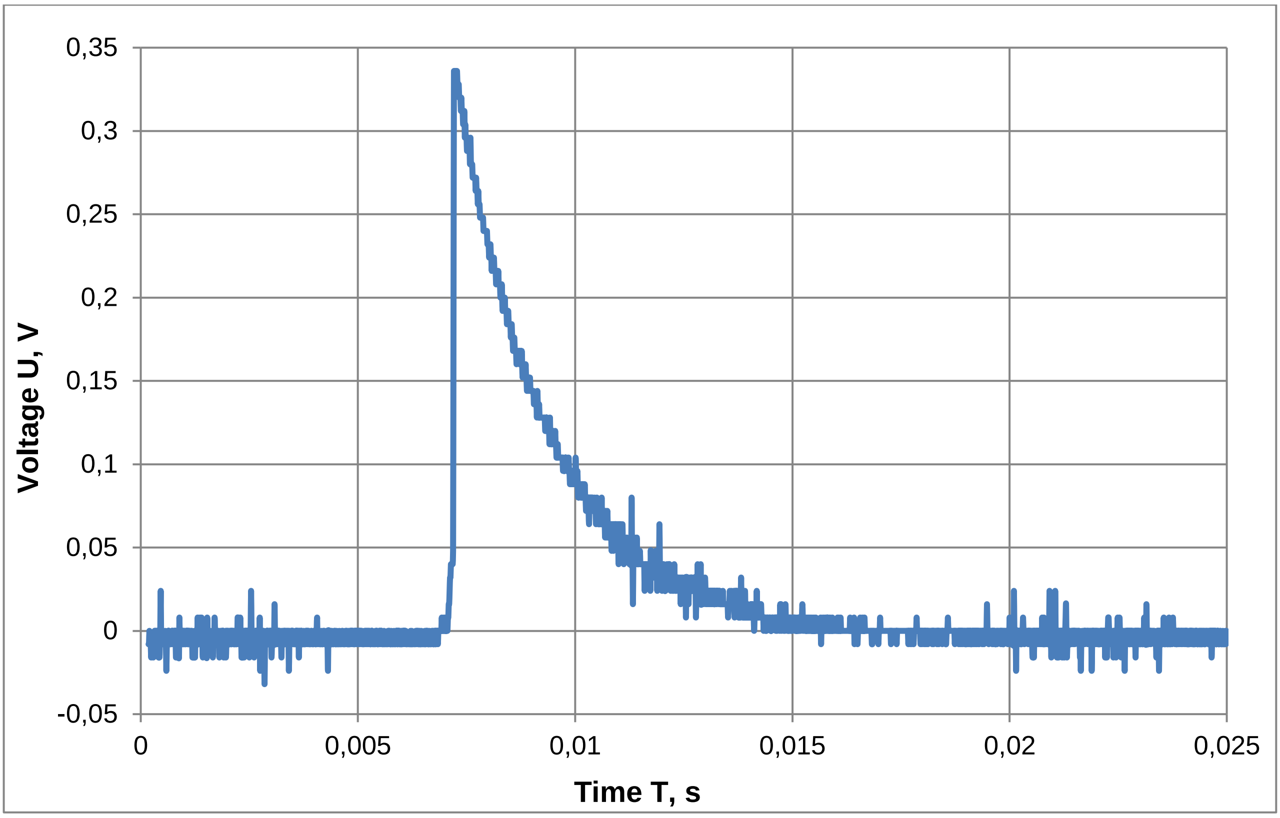


**Fig. 2. Typical voltage drop within a single operating period (3.3 V Input; R = 100 Ohm)**

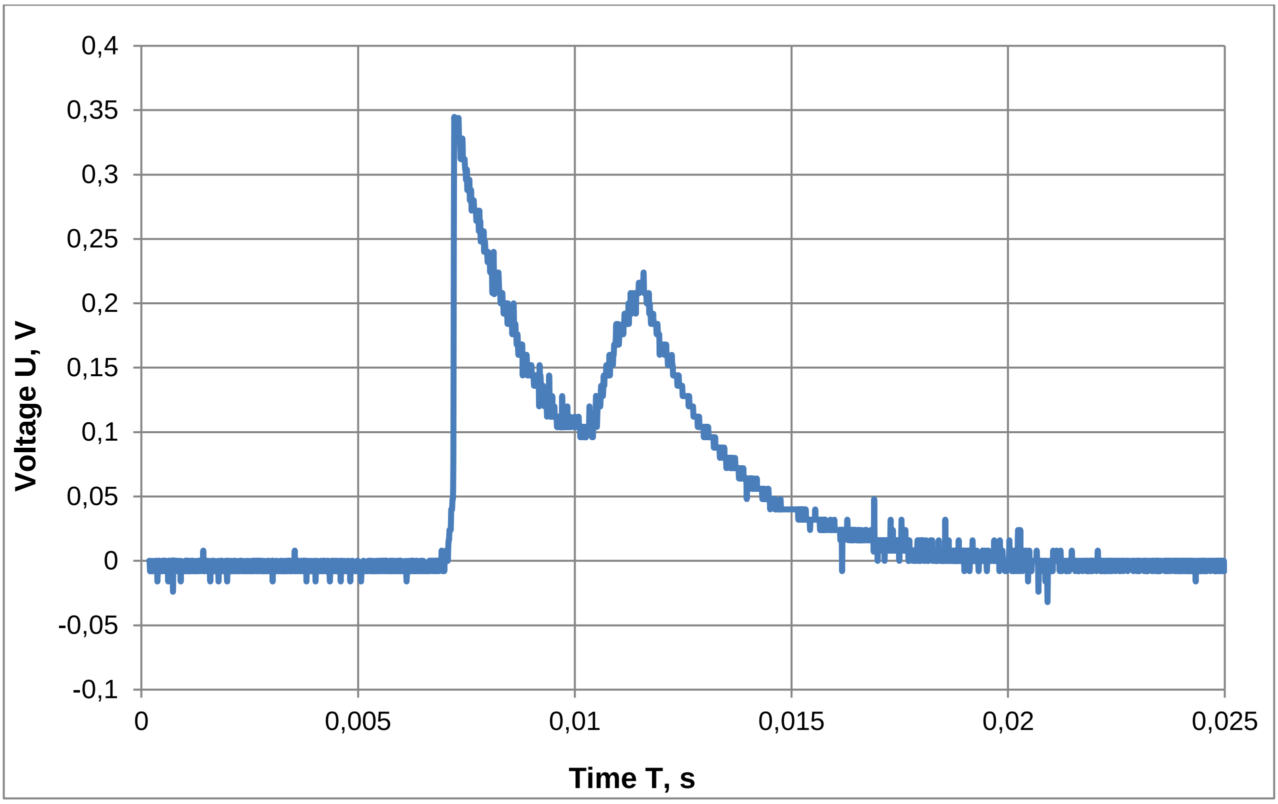


**Fig. 3. Typical voltage drop within a single operating period and while data transferring (3.3 V input; R = 100 Ohm)**

## 6.4. Getting started

- If “INDSIG” mode is active, during first 40 seconds after the power is up sensor does not return the measured concentration value (the value is displayed as “-1”, hex: “8001”, see Table 12).
- When the measurement range is exceeded, concentration value is displayed as “32767” (hex: “7FFF”).
- Sensor updates information about concentration every 1.32 ± 0.04 seconds (depends on ambient temperature and whether UART is active or not).
- Correct measurement is provided when ambient temperature changes not faster than 0.6 °C/min.

Switching on/off sensor is performed automatically upon feeding/disconnecting power supply.

After sensor is installed into end-user equipment check its status by sending command <DATAE2> via UART interface:

- for <DATAE2> command description see Appendix C.2.1;
- for response description and recommendations see Table 10.

Sensor span calibration and zeroing should be performed next. Methods of sensor span calibration and zeroing are given in Appendix D.1.

# 7. STORAGE AND TRANSPORATION

Transportation can be done by all means of transportation in covered vehicles as well as in a heated pressurized plane compartments in accordance with the rules of cargoes transportation actual for the respective type of transportation.

Sensor in manufacturer's package should be kept in supplier's and customer's storages under storage conditions specified in Table 2. Ambient atmosphere should be free of any harmful impurities, which can cause corrosion.

# 8. WARRANTY

Manufacturer guarantees sensor compliance with specifications and requirements stated in this UM if customer follows operating, transportation and storage terms.

During warranty period, manufacturer replaces or repairs for free all products, which do not work because of production fault.

Warranty period is 24 months since product is shipped to customer. Shipment date is registered in the ESAT.100000.00.XX PS manufacturer's certificate.

Manufacturer is not responsible for sensor fault and discontinues warranty in following cases:

- if the rules and conditions of operation, transportation and storage stated in this UM and in Data Sheet for sensor were violated;
- if sensor has marks of unauthorized repair attempts;
- if any mechanical damage occurs and/or if any damage is caused by exposure to extremely high or low temperatures, corrosion, oxidation, ingression of any foreign objects, materials, liquids, insects;
- if sensor was damaged by using connection circuit, which not complies with requirements stated in this UM;
- if damage is caused by force majeure, accident, intentional or careless actions of the customer or third parties;
- if damage (or fault) is caused by installing, editing or damaging sensor firmware and/or by making changes to the firmware settings using service codes;
- if damage (or fault) is caused by the fact of power and signal cables does not meet the standard or technical regulations and/or by electromagnetic interferences exceeding permissible according to EN 60079-29-1.

Replacement or repairs of faulty sensor does not extend initial warranty period.

Manufacturer is not responsible for any possible damage directly or indirectly caused by sensor to people and property in case it is a result of improper usage, storage and transportation or due to intentional or careless actions of the customer and/or third parties.

Risks and costs of transportation and packaging as well as other contingencies concerning product return to manufacturer are carried out by the customer.

# 9. CONTACTS

**MIPEX TECHNOLOGY**

# APPENDIX A. SENSOR TYPES AND CHARACTERISTICS

**MIPEX-04-B-RX-3.1**

**Interface options:**
**1.** UART

**Housing type:**
**3.** “Plastic”

**Application:**
**R** – calibration gas and range*
**X** – temperature class and accuracy**

**Target gas**:**
**1.** $CH_4$ (methane)
**2.** $C_3H_8$ (propane, $C_mH_n$ – hydrocarbons)

**MIPEX model number**

***** See Table 5 for details.

****** See Table 6 for details.

**Table 5. Metrological properties of sensor (RX-code)**

| Part number | Target gas[5] | Calibration gas | Measurement range, % vol. | Temperature range, °C | RX-code |
|---|---|---|---|---|---|
| MIPEX-04-1-00-3.1 | $CH_4$ | $CH_4$ | 0…2.5 | -10…+40 | 00 |
| MIPEX-04-1-10-3.1 | | | 0…5 | | 10 |
| MIPEX-04-1-20-3.1 | | | 0…100 | | 20 |
| MIPEX-04-1-01-3.1 | | | 0…2.5 | -40…+60 | 01 |
| MIPEX-04-1-11-3.1 | | | 0…5 | | 11 |
| MIPEX-04-1-21-3.1 | | | 0…100 | | 21 |
| MIPEX-04-1-02-3.1 | | | 0…2.5 | -20…+50 | 02 |
| MIPEX-04-1-12-3.1 | | | 0…5 | | 12 |
| MIPEX-04-1-22-3.1 | | | 0…100 | | 22 |
| MIPEX-04-1-61-3.1 | | $C_3H_8$ | 0…1.5 | -40…+60 | 61 |
| MIPEX-04-1-71-3.1 | | | 0…2.5 | | 71 |
| MIPEX-04-1-62-3.1 | | | 0…1.5 | -20…+50 | 62 |
| MIPEX-04-1-72-3.1 | | | 0…2.5 | | 72 |
| MIPEX-04-2-61-3.1 | $C_3H_8$ | $C_3H_8$ | 0…1.5 | -40…+60 | 61 |
| MIPEX-04-2-71-3.1 | | | 0…2.5 | | 71 |
| MIPEX-04-2-62-3.1 | | | 0…1.5 | -20…+50 | 62 |
| MIPEX-04-2-72-3.1 | | | 0…2.5 | | 72 |

[5] Typical sensor sensitivity to other hydrocarbons is shown on Fig. 4 and Fig. 5.

**Table 6. Basic sensor readings variability[6]**

| Calibration gas | Readings variability within a temperature range | Additional variability due to pressure | Additional variability due to humidity |
|---|---|---|---|
| $CH_4$ | ±0.1% vol. or ±5% of indication (whichever is greater) within the range of +20…+25 °C | ±0.2% vol. or ±30% of indication (whichever is greater) at 100 kPa (tested at: 80 kPa, 100 kPa, 120 kPa) | ±0.2% vol. or ±15% of indication at 40 °C and 0% RH (tested at: 20% RH, 50% RH, 90% RH) |
| | ±0.2% vol. or ±10% of indication (whichever is greater) within the range of -10…+20 °C and +25…+40 °C | | |
| | ±0.4% vol. or ±20% of indication (whichever is greater) within the range of -40…-10 °C and +40…+60 °C | | |
| $C_3H_8$ | ±0.05% vol. or ±5% of indication (whichever is greater) within the range of +20…+25 °C | ±0.1% vol. or ±30% of indication (whichever is greater) at 100 kPa (tested at: 80 kPa, 100 kPa, 120 kPa) | ±0.1% vol. or ±15% of indication (whichever is greater) at 40 °C and 0% RH (tested at: 20% RH, 50% RH, 90% RH) |
| | ±0.1% vol. or ±10% of indication (whichever is greater) within the range of -10…+20 °C and +25…+40 °C | | |
| | ±0.2% vol. or ±20% of indication (whichever is greater) within the range of -40…-10 °C and +40…+60 °C | | |

[6] Table shows basic variability of MIPEX-04 readings. For each sensor modification, readings variability stated in Table 6 is provided within a temperature range determined by a sensor RX code (see Table 5).

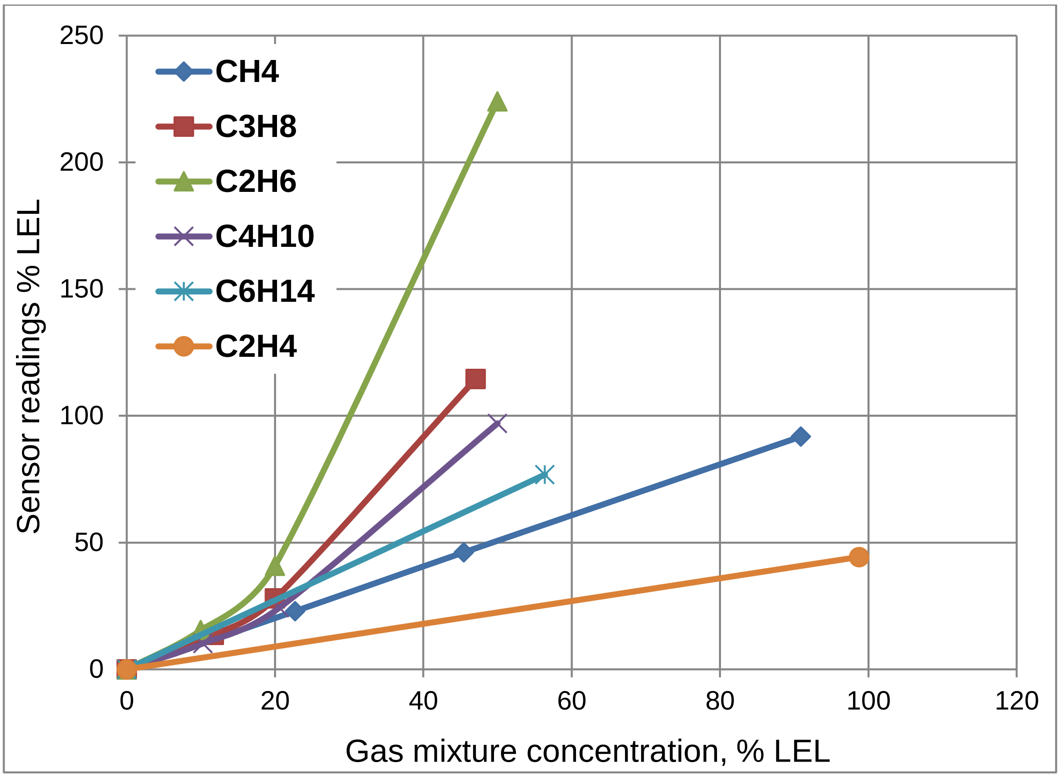


**Fig. 4. Typical sensitivity of MIPEX-04-1-XX-3.1 (target and calibration gas is $CH_4$) to other hydrocarbons**

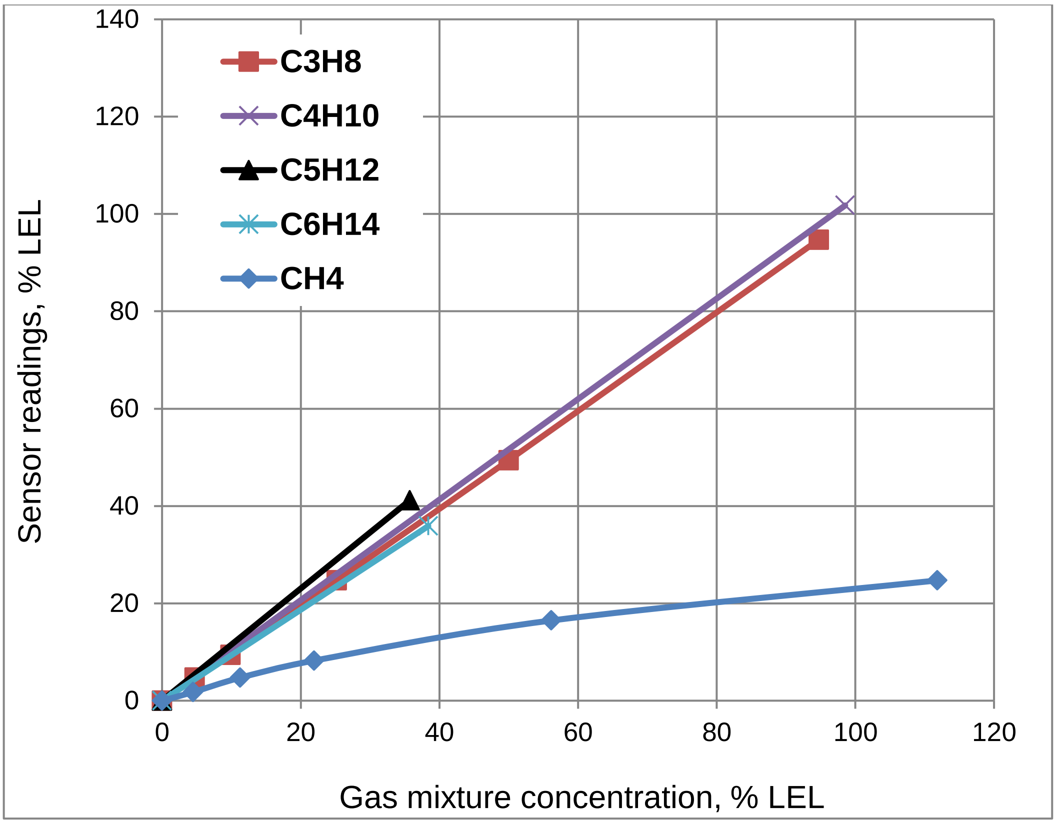


**Fig. 5. Typical sensitivity of MIPEX-04-2-XX-3.1 (target and calibration gas is $C_3H_8$) to other hydrocarbons**

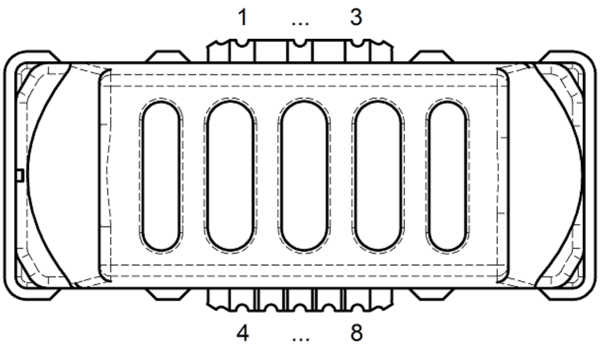


**Table 7. Sensor pinout**

| Pin | Purpose |
|---|---|
| 8 | +2.8…+5.0 VDC |
| 1-3, 7 | GND |
| 6 | Empty |
| 5 | UART Rx in |
| 4 | UART Tx out |

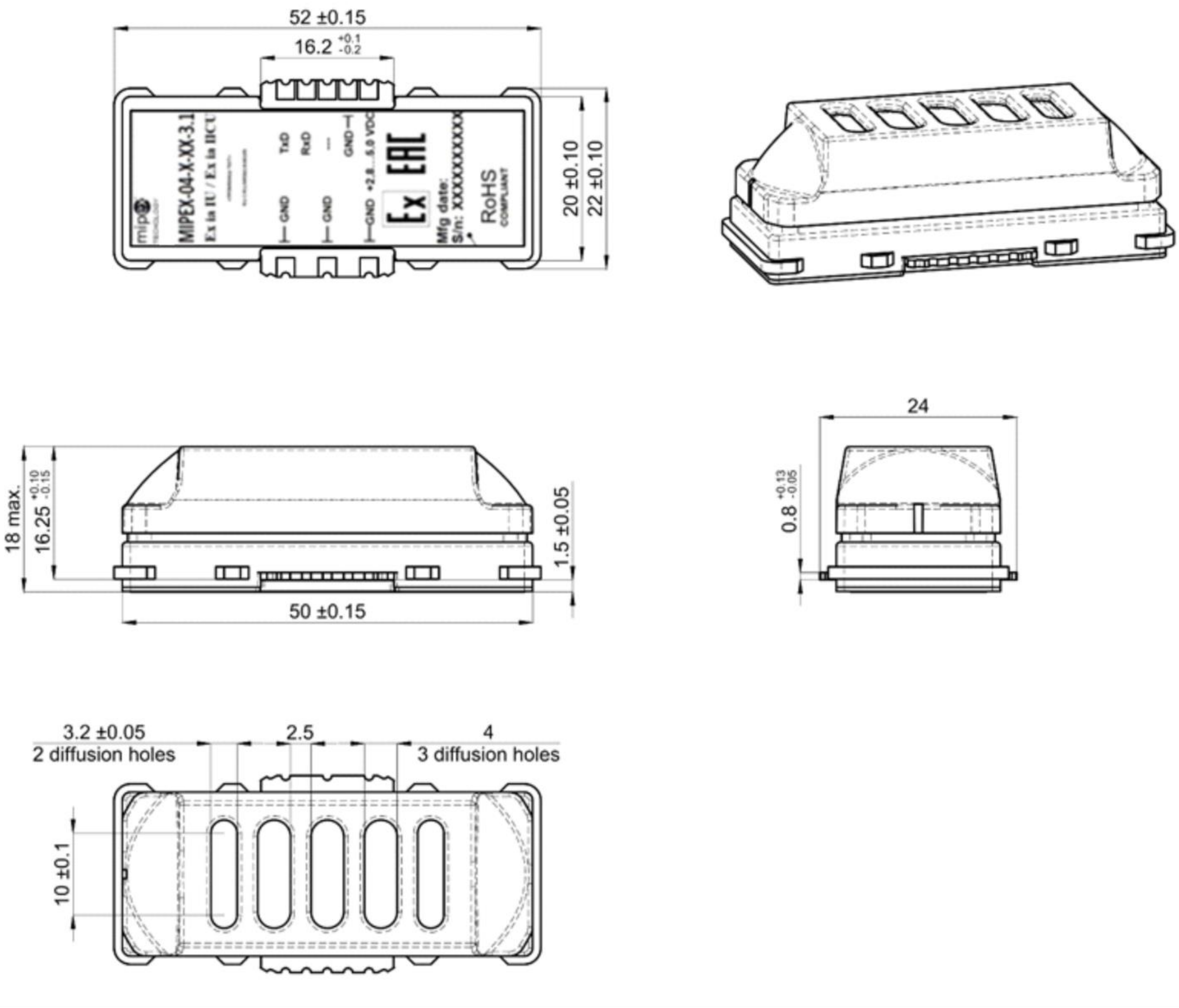


**Fig. 6. Sensor outline (all dimensions are in millimeters)**

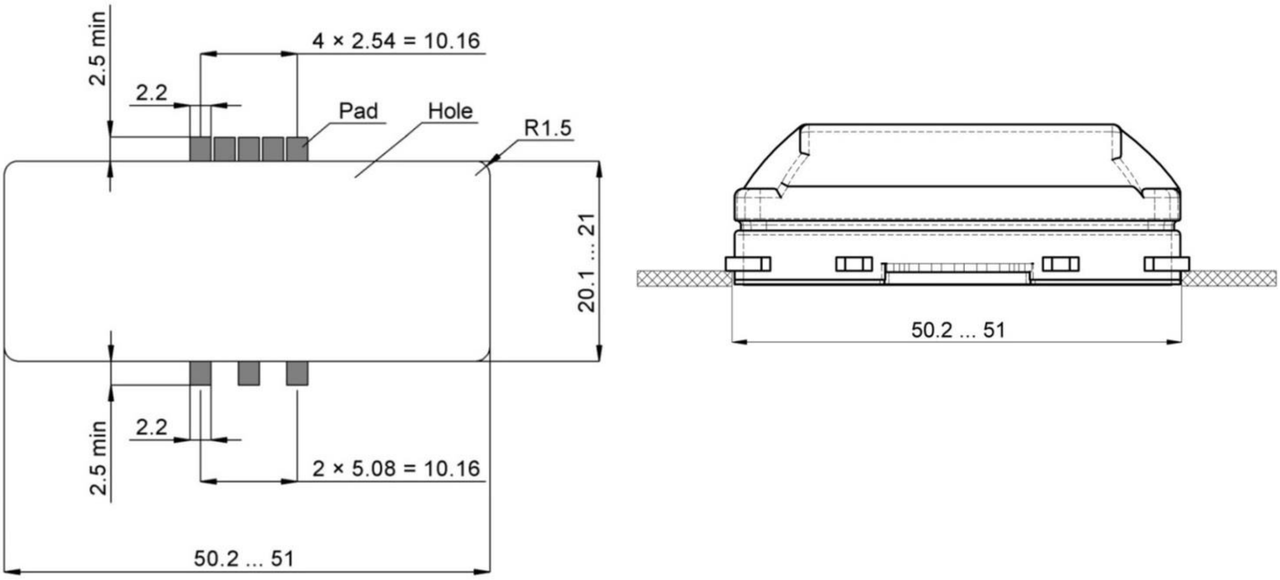


**Fig. 7. Recommended mating board configuration (all dimensions are in millimeters)**

# APPENDIX B. CONNECTION DIAGRAMS

*HAZARDOUS (CLASSIFIED) LOCATION*

Group I, II, Zone 0, 1, 2

or

Class I, Division 1, Group A, B, C, D, T6

Note: T6 temperature code based on +60 °C ambient

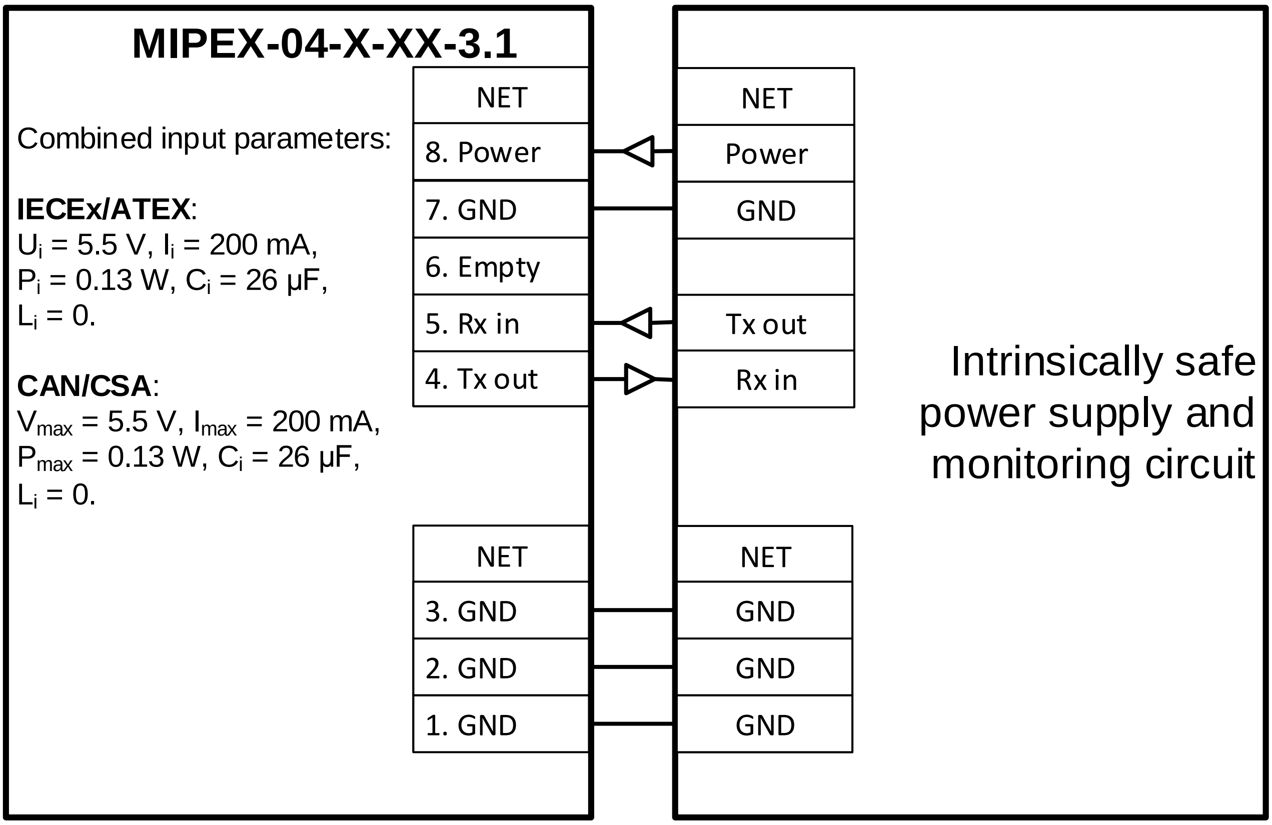


**Fig. 8. Intrinsic safety control drawing**

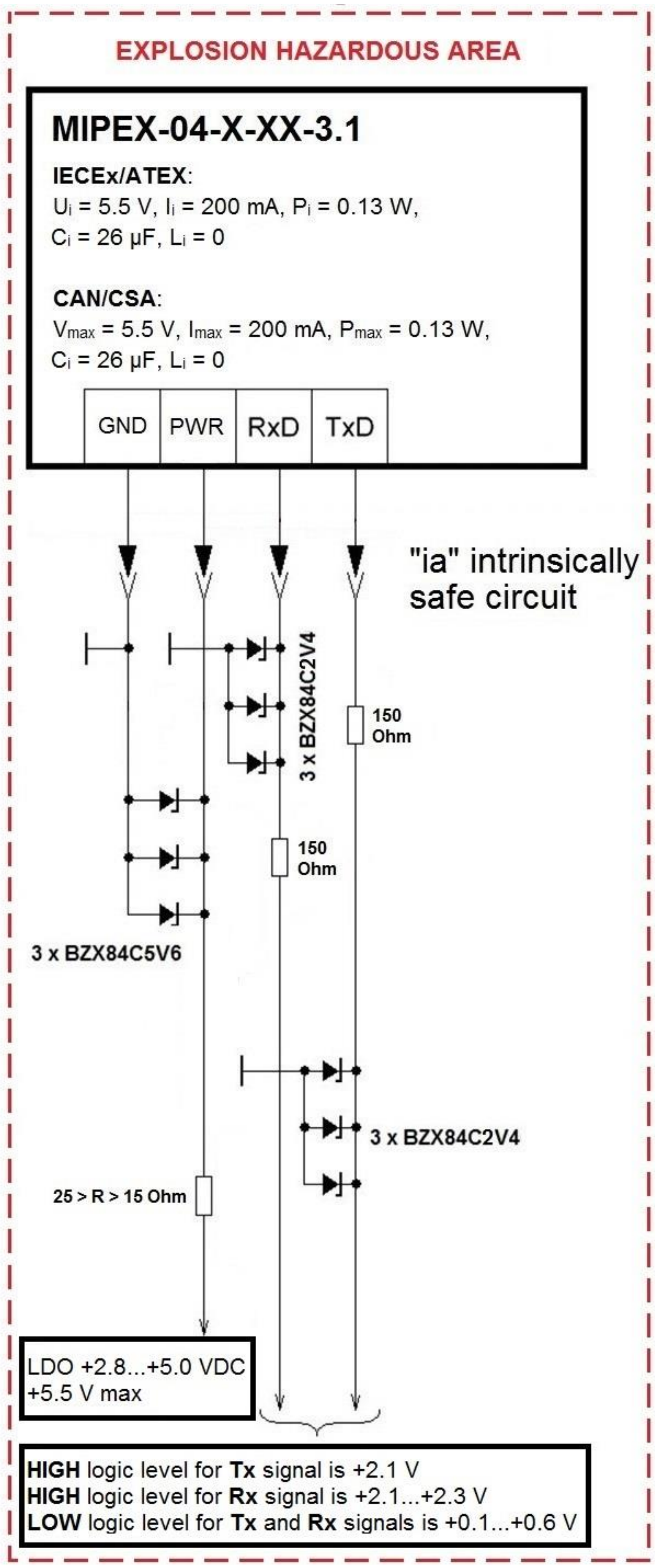


**Fig. 10. Example of connecting sensor to “ia” intrinsically safe circuit**

# APPENDIX C. SENSOR COMMUNICATION PROTOCOL

Current manual describes firmware release 11.9. Sensor communication protocol is based on UART interface.

## Appendix C.1. General information

Data exchange with MIPEX-04 sensors is performed via UART interface:

- Sensor has symbol rate of 57600 bauds.
- Data format: 8-bit message, 1 stop bit, no parity checking.
- Electrical parameters of UART-transceiver are pointed in section 6.3.

**General command format:**

- any command stated in this UM as <X>, where X stands for a command text consisted of any number of characters, must be read and/or sent without the symbols “<” and “>”;
- ASCII code for commands and responses;
- command ends with carriage return symbol (hexadecimal: “0x0D”);
- words and/or values in a response on most commands are separated by space symbol (hexadecimal: “0x20”) or in some cases by tabulation (hex: “0x09”);
- all symbols in command must be sent as one word without delays;
- sensor does not respond to incorrectly sent commands;
- sensor has two operating modes (access levels): “OEM” and “USER”; “OEM” has extended command set for developers, while “USER” mode is used for field operations.

# Appendix C.2. Communication protocol commands

There are several types of commands used for communication with sensor:

1. commands for requesting measured data (see Appendix C.2.1);
2. commands for controlling operating mode (see Appendix C.2.2);
3. commands for requesting factory settings and properties (see Appendix C.2.3);
4. commands for sensor configuring and span calibration (see Appendix C.2.4).

> Always check command syntax before sending. Commands that are not listed in this user manual are prohibited. Otherwise, it may result in malfunction of sensor.

## Appendix C.2.1. Commands for requesting measured data and diagnosing

There are four commands available for user to request concentration value. Primary command to request measured data is <@*X> as it requires minimum power to process it.

Sending rate of these commands should not be more than 0.5 Hz.

| Request syntax | USER mode | OEM mode | Response description | Command description |
|---|---|---|---|---|
| @ | yes | yes | 2 bytes in unsigned integer format (see Table 8). | Returns sensor readings of scaled concentration $C_1$ (not periodically, single time only). |
| **@*X** | yes | yes | "@" symbol and 2 bytes in unsigned integer format (see Table 8). | Returns sensor readings of scaled concentration $C_1$ periodically (every [1.32 ± 0.04] × **X** seconds), where **X** is a value within the range 0…9 in ASCII format). |
| **CCS** | yes | yes | 5 bytes in ASCII format, space symbol or minus symbol, 5 bytes in ASCII, tabulation, 5 bytes in ASCII and "0D" symbol. | Returns sensor readings of scaled concentration $C_1$, current ambient temperature in Celsius degrees and status word. |
| **CFS** | yes | yes | *Same as response description for <CCS> command.* | Returns sensor readings of scaled concentration $C_1$, current ambient temperature in Fahrenheit degrees and status word. |
| **CKS** | yes | yes | *Same as response description for <CCS> command.* | Returns sensor readings of scaled concentration $C_1$, current ambient temperature in Kelvins and status word. |
| **DATA** | yes | yes | 5 bytes in ASCII format and "0D" symbol (see Table 9). | Returns sensor readings of scaled concentration $C_1$. |
| **DATAE2** | yes | yes | 5 bytes in binary format and "0D" symbol (see Table 10). | Returns sensor readings of scaled concentration $C_1$ as unsigned integer, two **status bytes** and CRC value. |

**Table 8. Structure of response to <@> and <@*X> commands**

| | Command <@> (hex: “40 0D”) | | Command <@*X> (hex: “40 2A X 0D”) | | |
|---|---|---|---|---|---|
| Byte number | 1 | 2 | 1 | 2 | 3 |
| Byte data | $C_1H$[7] | $C_1L$ | @ (hex: “0x40”) | $C_1H$ | $C_1L$ |

**Table 9. Structure of response to <DATA> command**

| | Command <DATA> (hex: “44 41 54 41 0D”) | |
|---|---|---|
| Byte number | 1-5 | 6 |
| Byte data | $C_1$ | hex: “0x0D” |

**Table 10. Structure of response to <DATAE2> command**

| | Command <DATAE2> (hex: “44 41 54 41 45 32 0D”) | | | | |
|---|---|---|---|---|---|
| Byte number | 1 | 2 | 3 | 4 | 5 |
| Byte data | $C_1H$ | $C_1L$ | StatusByteH[8] | StatusByteL | hex: “0x0D” |

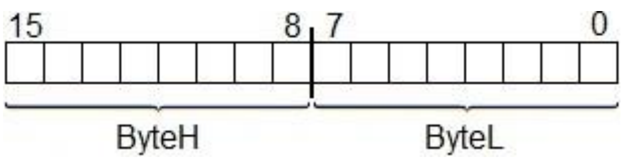


**Fig. 9. High and low bytes’ structure**

[7] High and low bytes’ structure is represented on Fig. 9.

[8] If bits of status bytes are true, check their meanings in Table 11 and perform recommended operations. High and low bytes structure is represented on Fig. 9.

**Table 11. Bits of status bytes' description**

| Bit number | Status word compliance[9] | Description | Recommendations |
|---|---|---|---|
| – | 00 | Normal mode, static temperature | – |
| 0 | 10 | Sensor is warming up. | Do not perform span calibration. |
| 1 | 50 | An abrupt signal change (due to feeding a gas mixture to sensor atmosphere) or increased noise on sensor optical elements. | Do not perform span calibration or zeroing. If this status longer than for 20 minutes at stable conditions, replace sensor. |
| 2 | 30 | One of the signal values is lower than it is allowed. | Possible exposure to moisture. Dry sensor. After drying, if this status lasts longer than for 20 minutes at stable conditions, replace sensor. |
| 3 | – | reserved | Does not contain any significant information. |
| 4 | 21 | Dynamic temperature mode (temperature changes faster than by 0.6 °C/min). | Do not perform span calibration or zeroing. |
| 5 | 22 | Dynamic temperature mode (temperature changes faster than by 2 °C/min). | Do not perform span calibration or zeroing. |
| 6 | 40 | Exceeding temperature limits. | Check the ambient temperature. |
| 7 | 90 | Firmware failure (flash memory issues). | Contact support for details. |
| 8 | 11 | Data request rate is more than 1 Hz. | Do not perform span calibration or zeroing. Decrease request rate. |
| 9 | 31 | Ratio $S_{tz0}$ (see Table 15) exceeds allowable upper limit. | Possible exposure to moisture. After drying, if this status lasts longer than for 20 minutes at stable conditions, perform zeroing (see Appendix D.1 for procedure description). |
| 10 | – | reserved | Does not contain any significant information. |
| 11 | 51 | Complex status. Technological failure. | Contact support for details. |
| 12 | – | reserved | Does not contain any significant information. |
| 13 | – | reserved | Does not contain any significant information. |
| 14 | – | reserved | Does not contain any significant information. |
| 15 | – | reserved | Does not contain any significant information. |
| (4 ∨ 5) & 9 | 24 | Dynamic temperature mode; zero shifts to negative value. | Do not perform span calibration or zeroing. |

[9] Status word is contained in response to command <F> (see Table 15).

### Appendix C.2.2. Commands for controlling operating mode

| Request syntax | USER mode | OEM mode | Response description | Command description |
|---|---|---|---|---|
| **OEM XXXX** | yes | no | Response contains of word "OEM" or, if the password is incorrect, word "USER" in ASCII format and "0D" symbol. | Switches commands level from "USER" to "OEM"; **XXXX** stands for current password. Default password is 0000. |
| **PASS?** | no | yes | Response contains of 4 bytes in ASCII format and "0D" symbol. | Returns current password for switching commands level from "USER" to "OEM". |
| **PASS XXXX YYYY** | no | yes | PASS XXXX YYYY OK<br>or<br>PASS XXXX YYYY FAULT | Intended for changing current password for switching commands level from "USER" to "OEM". **XXXX** stands for old password and **YYYY** stands for new one. New password should contain only digits 0…9 in ASCII format. |
| **UART?** | yes | yes | USER<br>or<br>OEM | Returns active access level. |
| **USER** | no | yes | Response contains of word "USER" in ASCII format and "0D" symbol. | Switches commands level from "OEM" to "USER". |

### Appendix C.2.3. Commands for requesting factory settings and properties

| Request syntax | USER mode | OEM mode | Response description | Command description |
|---|---|---|---|---|
| **ID?** | yes | yes | Contains the summary info in ASCII format about sensor type, its serial number, characteristics and firmware version. | Returns sensor ID. |
| **RT?** | yes | yes | 5 bytes in ASCII format and "0D" symbol (the codes list is available upon query). | Returns sensor type. |
| **RX?** | yes | yes | 2 bytes in ASCII format and "0D" symbol. See Table 5 for details. | Returns sensor characteristics (temperature class, calibration range and accuracy). |
| **SRAL?** | yes | yes | 8 bytes in ASCII format and "0D" symbol. | Returns sensor serial number (SN). |
| **SREV?** | yes | yes | Sensor firmware version. | Returns the firmware version. |

## Appendix C.2.4. Commands for sensor configuring and span calibrating

| Request syntax | USER mode | OEM mode | Response description | Command description |
|---|---|---|---|---|
| **AZERO?** | no | yes | AZERO ON<br>or<br>AZERO OFF | Intended for checking current auto-zeroing algorithm status. |
| **AZERO OFF** | no | yes | AZERO OFF | Turns off the auto-zeroing algorithm. |
| **AZERO ON** | no | yes | AZERO ON | Turns on the auto-zeroing algorithm. |
| **CALB AAAA** | no | yes | CALB AAAA OK<br>or<br>CALB AAAA FAULT | This command is used for gas span calibration, where **AAAA** is a CGM concentration value in % vol. × 100. For example, **AAAA** = 0198 corresponds to 1.98 % vol. See Appendix D.1 for detailed procedure description. |
| **CALB1 XXXXX** | no | yes | CALB1 XXXXX OK<br>or<br>CALB1 XXXXX FAULT | Writes scale coefficient for sensor calibration range of 0…5 % vol. **XXXXX** is the coefficient value incremented to 10000 (for example: to write the scale coefficient of 0.009 send <CALB2 00090>). This command can be used to recalibrate sensor if scale coefficient is known. The scale coefficients for different gases are individual for each sensor. To achieve cross-coefficients contact support. |
| **CALB2 YYYYY** | no | yes | CALB2 YYYYY OK<br>or<br>CALB2 YYYYY FAULT | Writes scale coefficient for sensor calibration range of 5…100 % vol. **YYYYY** is the coefficient value incremented to 10000 (for example: to store the scale coefficient of 0.01 send <CALB2 00100>). This command can be used to recalibrate sensor if scale coefficient is known. The scale coefficients for different gases are individual for each sensor. To achieve cross-coefficients contact support. |
| **CALB3 ZZZZZ** | no | yes | CALB3 ZZZZZ OK<br>or<br>CALB3 ZZZZZ FAULT | Writes scale coefficient Conc3 for the whole sensor calibration range (0…100% vol.). **ZZZZZ** is the coefficient value incremented to 10000 (for example: to store the scale coefficient of 0.7 send <CALB3 07000>). This command can be used to recalibrate sensor if scale coefficient is known. The scale coefficients for different gases are individual for each sensor. To achieve cross-coefficients contact support. |

| Request syntax | USER mode | OEM mode | Response description | Command description |
|---|---|---|---|---|
| **DATEZC?** | yes | yes | DD.MM.YY | Returns date of the last span calibration operation. |
| **DATEZC DD.MM.YY** | no | yes | DATEZC DD.MM.YY OK<br>or<br>DATEZC DD.MM.YY FAULT | Writes the last date of span calibration to sensor memory (**DD** – 00…31; **MM** – 0…12; **YY** – 00…99). |
| **INDSIG OFF** | no | yes | OFF | Turns off status word displaying in concentration field. |
| **INDSIG ON** | no | yes | ON | Turns on status word displaying in concentration field. |
| **INIT** | no | yes | INIT OK<br>or<br>INIT FAULT | Resets sensor to the factory calibration settings. |
| **SETC XXXXX** | yes | yes | SETC XXXXX OK<br>or<br>SETC XXXXX FAULT | Intended for determining the current ambient temperature in Celsius degrees (**XXXXX** stands for degrees; i.e. 00023 = 23 °C). Sensor writes current temperature ADC value to its memory. |
| **UPLOAD** | no | yes | U_OK | By this command, sensor is set to firmware updating mode. This mode switches off auto-matically upon the firmware is updated. To switch it off manu-ally reset sensor power supply. |
| **ZERO** | no | yes | ZERO OK<br>or<br>ZERO FAULT | Writes current temperature ADC value and ratio $S_t$ value to sensor controller memory by this command. |
| **ZERO0** | no | yes | ZERO0 OK<br>or<br>ZERO0 FAULT | Erases temperature coeffi-cients previously defined by user. |
| **ZERO2** | no | yes | ZERO2 OK<br>or<br>ZERO2 FAULT | Intended for zeroing sensor. It initiates calculation and storing of the unifying zero coefficient within sensor memory. C and $C_1$ values are zeroed and ratio $S_{tz}$ becomes equal 1 by this command. |

| Request syntax | USER mode | OEM mode | Response description | Command description |
|---|---|---|---|---|
| **USERDATA?** | yes | yes | Contains 59 bytes of information and “0D” symbol. | Returns all the ten numbers contained in user section of sensor memory separated from each other with “0D” symbol. |
| **USERDATAXX?** | yes | yes | Contains 5 bytes of information and “0D” symbol | Returns a number contained in cell **XX** (00…09) of sensor memory user section. |
| **USERDATAXX YYYYY** | no | yes | USERDATAXX YYYYY OK | Writes a number **YYYYY** (00000…99999) to cell **XX** (00...09) of sensor memory user section. |

**Table 12. Status word displaying in concentration field while "INDSIG" mode is active**

| Concentration value in ASCII format | Concentration value in hex format | Status word compliance (see Table 16) | Description | Recommendations |
|---|---|---|---|---|
| -0001 | 8001 | 10 | Sensor is warming up. After power up, measured concentration value is displayed after 40 s, but sensor metrological properties are provided only after 120 s. | Do not perform span calibration. |
| -0002 | 8002 | 31 | Zero shifts to negative value. | Possibility of condensed moisture on optical elements. Dry the sensor. After drying, if this status lasts longer than for 20 minutes at stable conditions, perform zeroing (see Appendix D.1 for procedure description). |
| -0003 | 8003 | 24 | Dynamic temperature mode; zero shifts to negative value. | Do not perform span calibration or zeroing. |

# APPENDIX D. SENSOR CONFIGURATION

## Appendix D.1. Zeroing and span calibration

Sensor zeroing and span calibration must be carried out during its initial installation as well as annually during the period of preparation for the test. It is also recommended to perform zeroing when sensor status word “**31**” shows up (see Appendix F, Table 15 and Table 16). In any case zeroing operation should be done before span calibration. For the list of CGMs recommended for span calibration, see Table 13 and Table 14.

1. Covering gas-sampling holes of sensor increases response time t(90).
2. Before span calibration operation, it is recommended to send command <INIT> for calibration and zeroing coefficients initialization. To perform this step, fill the sensor atmosphere with nitrogen before sending the command.
3. While span calibration is being carried out, avoid:
   - excessive pressure on sensor housing,
   - > 98% humidity,
   - pressure of flowing gas less than 99 kPa and more than 103 kPa;
   - temperature changes faster than by 0.6 °C/min,
   - dust ingress (if dust filter is not used),
   - data request rate more than 1 Hz.
4. Recommended gas feeding rate when using gas adapters ESAT.300355.00:
   - 100-150 mL/min for one sensor;
   - 500-600 mL/min for 50 sensors consecutively connected into gas flow.

Zeroing and span calibration should be carried out by qualified personnel outside of an explosive area under normal conditions in the following sequence:

1. Communicate sensor via UART interface (example based on MIPEX-04 interface board ESAT.200100.00 is shown on Fig. 10; gas adapter ESAT.200105.00 is available as an option).
2. Auto-zeroing procedure of sensor concentration readings is started automatically during sensor self-diagnostics after power is switched on. Sensor self-diagnostics runs constantly while power is on. Use the following commands to control the algorithm: <AZERO ON>, <AZERO OFF> and <AZERO?>. However, if zero shifts anyway, it is recommended to perform zeroing manually:
   - 2.1. within 5 minutes after power was supplied start feeding CGM #1 (high purity nitrogen) into sensor atmosphere;
   - 2.2. one minute after CGM #1 was supplied, send command <ZERO2>; thus, sensor readings on the concentration will be set to zero;
   - 2.3. stop feeding CGM #1 into sensor atmosphere.
3. Start feeding CGM #2 into sensor atmosphere.

4. One minute after CGM #2 was supplied, send <CALB AAAA> command, where AAAA is a value of CGM concentration (e.g. value 0198 corresponds to 1.98% vol.). Thereafter scaled concentration value $C_1$ becomes equal to the sent value AAAA. Scale coefficient is stored in sensor microcontroller memory until the next span calibration. Before sending command <CALB AAAA>, ensure the following conditions:
   4.1. entered concentration value must not deviate from the current readings of more than 20 times and also must not be less than 11:

$$(C \cdot 20 > C_1 > C \cdot 0.05) \; \&\& \; C > 10$$

   4.2. CGM must contain more than 0.2% vol. of target gas;
   4.3. if these conditions are not met, sensor responds “CALB AAAA FAULT”.
5. Stop feeding CGM #2 into sensor atmosphere.
6. Feed CGM #3 into sensor atmosphere and check sensor readings.
7. For methane sensors calibrated up to 100% vol. repeat the procedure steps 3, 4 and 5 with CGM #4.

If requirements to sensor readings variation are not met in accordance with Table 6, zeroing and span calibration procedure should be repeated. In case of the repeated mismatch between sensor readings and target gas concentration value in CGM #3, sensor should be sent to the manufacturer for repair or replacement.

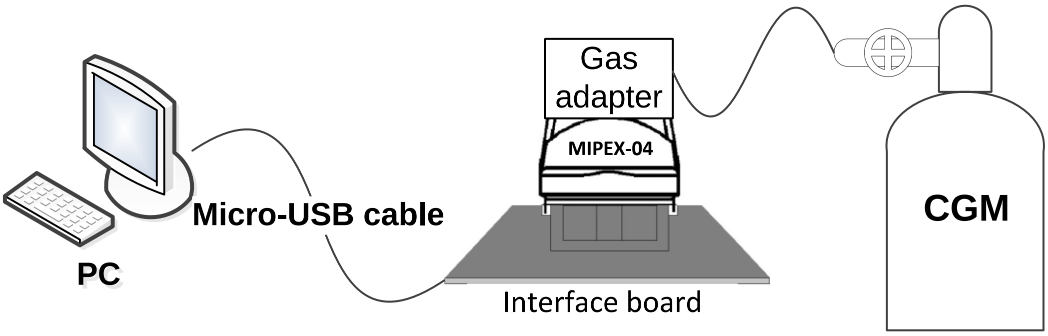


**Fig. 10. Typical scheme of MIPEX-04 span calibration**

Converting of <u>% vol.</u> to <u>% LEL</u> is performed according to the following formula:

$$\mathrm{LFSCL} = \frac{100 \times C}{C(h)}$$

where:

$\mathrm{LFSCL}$ – component concentration, % LEL;

$C$ – component concentration, % vol.;

$C(h)$ – the lower explosive limit of component, % vol. (constant).

For methane $C(h) = 4.4\%$ vol.; for propane $C(h) = 1.7\%$ vol.

**Table 13. CGMs used for $CH_4$ span calibration**

| CGM number according to text | Components composition | Content of methane, % vol. (% LEL) | Permissible deviation limits, % vol. | Limits of permissible error of qualification, % vol. | Number as listed in the State Register or in the Standard designation |
|---|---|---|---|---|---|
| 1 | $N_2$ | 0 | – | – | ISO 2435-73 |
| 2 | $CH_4$, $N_2$ | 2.2 (50) | ±0.25 | ±0.04 | |
| 3 | $CH_4$, $N_2$ | 4.15 (94) | ±0.25 | ±0.04 | |
| 4 | $CH_4$, $N_2$ | 40 | ±2.5 | ±0.4 | |

**Table 14. CGMs used for $C_3H_8$ span calibration**

| CGM number according to text | Components composition | Content of propane, % vol. (% LEL) | Permissible deviation limits, % vol. | Limits of permissible error of qualification, % vol. | Number as listed in the State Register or in the Standard designation |
|---|---|---|---|---|---|
| 1 | $N_2$ | 0 | – | – | ISO 2435-73 |
| 2 | $C_3H_8$, $N_2$ | 0.85 (50) | ±0.05 | ±0.015 | |
| 3 | $C_3H_8$, $N_2$ | 1.6 (94) | ±0.1 | ±0.05 | |

## Appendix D.2. Temperature dependence of zero adjustment

It is allowed for user to adjust the temperature dependence of zero. Adjustment may be performed for up to 10 values within operating temperature range. Any temperature range is split into equal intervals about 12.5 °C each (300 ADC counts). Each interval is used for corresponding operating temperature.

An example of procedure for temperature range of -40…+60 °C:

1. Fill sensor atmosphere with nitrogen.
2. Power on sensor.
3. 1 minute after, send <ZERO0> command. This command erases previously defined temperature coefficients.
4. Change sensor ambient temperature in range of -40…+60 °C with a pitch of 12.5 °C. For each of 9 points of temperature range, lock the temperature for at least 20 minutes.
5. When temperature is stable, for each of 9 points of temperature range send <ZERO> command by which current temperature ADC value and ratio $S_t$ value (see Table 15) are written to sensor memory (see Fig. 11).

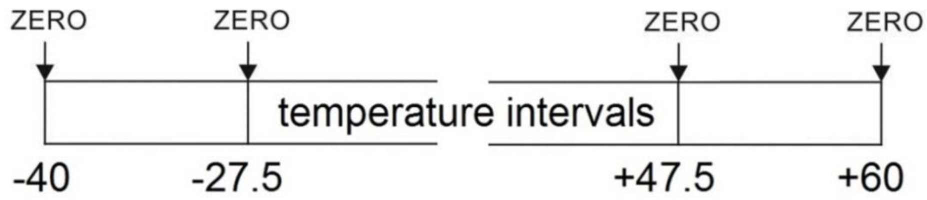


**Fig. 11. Scheme of the temperature coefficients adjustment**

# APPENDIX E. DUST FILTER ATTACHING

To improve sensor operation reliability dust filter should be attached to sensor top side. Filters are optional and available separately. Filter material is fluoroplastic membrane “Vladipor MFFC TC 6-55-221-1413-2004”. On the filter back side there is an adhesive layer “3M Double Linered Laminating Adhesive 7952” in hatched areas in Fig. 12.

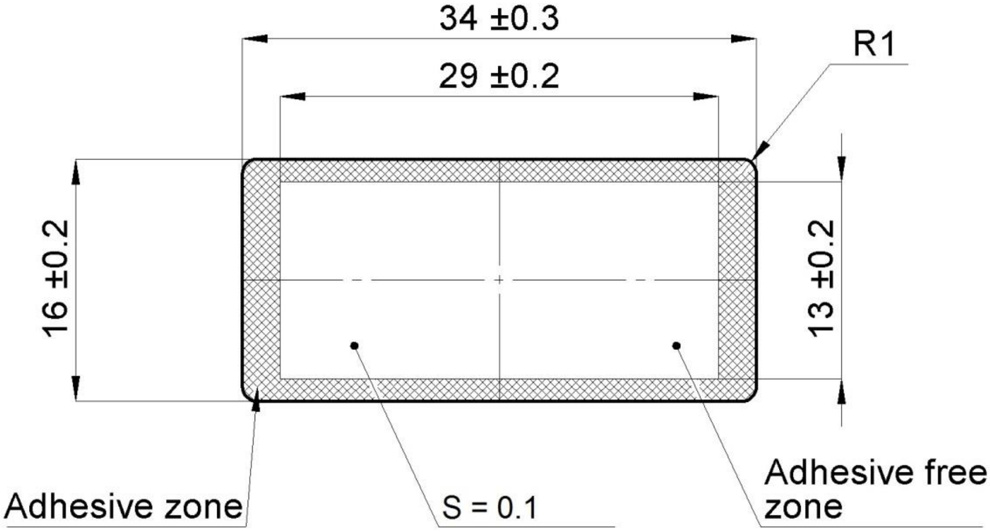


**Fig. 12. Dust filter outline (all dimensions are in millimeters)**

Perform the following steps to attach dust filter:

- Perform this work in a well illuminated and well-ventilated area.
- Once a dust filter is attached to sensor surface, perform zeroing procedure (see Appendix D.1 for details).

1. Degrease sensor top surface.
2. Extract filter from the pack and remove its substrate with tweezers.
3. Align the filter exactly to the center of the upper side of sensor with tweezers and then press on it.

# APPENDIX F. TROUBLESHOOTING

If there is suspicion that sensor returns wrong data and / or operates improperly, it is necessary to check its status by sending command <DATAE2> (see Appendix C.2.1). It returns concentration value and two status bytes. If any bits of status bytes are true, check their meaning in Table 11 and follow to specified recommendations. If suspicion of error or status corresponding to error persists, please contact support.

Contacting support, send log file with periodic responses to command <F>, which is intended exclusively for detailed diagnostics. It returns comprehensive information on sensor readings and its status. Sensor power consumption stated in Table 4 is not guaranteed while using this command. Command <F> returns 72 bytes in ASCII format and “0D” symbol. Unlike <DATAE2>, it returns status word whose value corresponds to certain combination of true status byte bits (see Table 11). Detailed description of command <F> is contained in Table 15.

Sending rate of <F> command should not be more than 0.6 Hz.

In case if status word value is stable, log file with few (approx. 10) responses is enough. In case if status word varies eventually or periodically, log file must contain sufficient number of responses obtained before status word occurs and in time of its occurrence.

It is recommended to provide in end-user equipment possibility to form a log file using command <F>.

**Table 15. Structure of response to <F> command**

| Command <F> (hex: "46 0D") response | | |
|---|---|---|
| Byte number | Byte data | Data description |
| 1 | Hex: "0x0E" | Special character |
| 2-6 | T | Sensor temperature expressed in ADC counts |
| 7 | Hex: "0x09" | Tabulation symbol |
| 8-12 | $S_t$ | The ratio $\frac{U_s}{U_{ref}}$ considering temperature correction |
| 13 | Hex: "0x09" | Tabulation symbol |
| 14-18 | $U_s$ | Operating signal in ADC counts |
| 19 | Hex: "0x09" | Tabulation symbol |
| 20-24 | $U_{ref}$ | Reference signal in ADC counts |
| 25 | Hex: "0x09" | Tabulation symbol |
| 26-30 | $S_{tz0}$ | The ratio $S_t$ considering ZERO and ZERO2 coefficients |
| 31 | Hex: "0x09" | Tabulation symbol |
| 32-36 | $S_{tz}$ | The ratio $S_{tz0}$ considering the drift compensation algorithm |
| 37 | Hex: "0x09" | Tabulation symbol |
| 38-42 | $S_{tzkt}$ | The ratio $S_{tz}$ considering the coefficient of temperature sensitivity |
| 43 | Hex: "0x09" | Tabulation symbol |
| 44-48 | C | Concentration based on factory settings |
| 49 | Hex: "0x09" | Tabulation symbol |
| 50-54 | $C_1$ | Concentration based on user settings |
| 55 | Hex: "0x09" | Tabulation symbol |
| 56-60 | **Status word** | Status word (see Table 16 for details) |
| 61 | Hex: "0x09" | Tabulation symbol |
| 62-69 | S/N | Sensor serial number |
| 70 | Hex: "0x09" | Tabulation symbol |
| 71 | CRC | CRC calculated using "exclusive OR" method |
| 72 | Hex: "0x09" | Tabulation symbol |
| 73 | Hex: "0x0D" | Carriage return |

**Table 16. Status word values description**

| Status word | Priority level[10] | Description | Recommendations |
|---|---|---|---|
| 00 | 12 (lowest) | Normal operating mode, temperature is static. | |
| 10 | 2 | Sensor is warming up. | Do not perform span calibration. |
| 11 | 3 | Data request rate is more than 1 Hz. | Do not perform span calibration or zeroing. Decrease request frequency. |
| 21 | 10 | Dynamic temperature mode (temperature changes faster than by 0.6 °C/min). | Do not perform span calibration or zeroing. |
| 22 | 9 | Dynamic temperature mode (temperature changes faster than by 2 °C/min). | Do not perform span calibration or zeroing. |
| 24 | 7 | Dynamic temperature mode; zero shifts to negative value. | Do not perform span calibration or zeroing. |
| 30 | 4 | One of the signal values ($U_s$ or $U_{ref}$) is lower than it is allowed | A possibility of exposure to moisture. Dry sensor. After drying, if this status lasts longer than for 20 minutes at stable conditions, replace sensor. |
| 31 | 8 | The ratio $S_{tz0}$ exceeds allowable upper limit. | A possibility of exposure to moisture. Dry sensor. After drying, if this status lasts longer than for 20 minutes at stable conditions, perform zeroing (see Appendix D.1 for procedure description). |
| 40 | 6 | Exceeding temperature limits. | Check the ambient temperature. |
| 50 | 11 | An abrupt signal change (due to feeding a gas mixture to sensor atmosphere) or increased noise on sensor optical elements. | Do not perform span calibration or zeroing.<br>If this status lasts longer than for 20 minutes at stable conditions, replace sensor. |
| 51 | 5 | Complex status. Technological failure. | Contact support for details |
| 90 | 1 (highest) | Firmware failure (flash memory issues). | Contact support for details |

NOTE: If any status word value except “00” and “21” appears, metrological properties of sensor are not provided.

[10] Sensor condition is characterized by set of status word parameters. <F> command returns only one status word value in accordance with priority. To view all parameter values, use command <DATAE2>.