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1 Introduction

This document describes the steps that need to be taken in order to interface to the OEM special variant of the ACG sensor block. It describes connection detail, communications settings and the Analox custom protocol required to communicate with each sensor.

2 Communications overview

Each of the sensors in the OEM sensor block are connected to a single RS485 serial bus as shown in Figure 1.

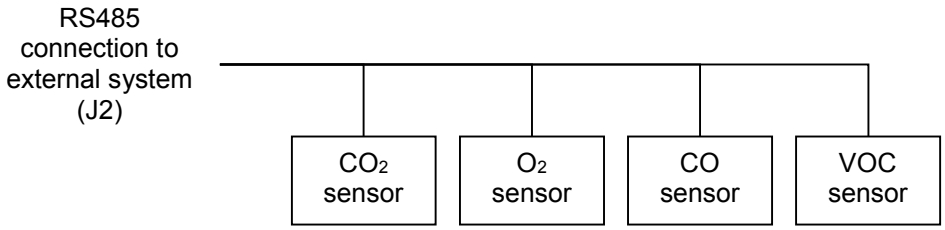


Figure 1 - Sensor communications bus

2.1 Making a serial connection

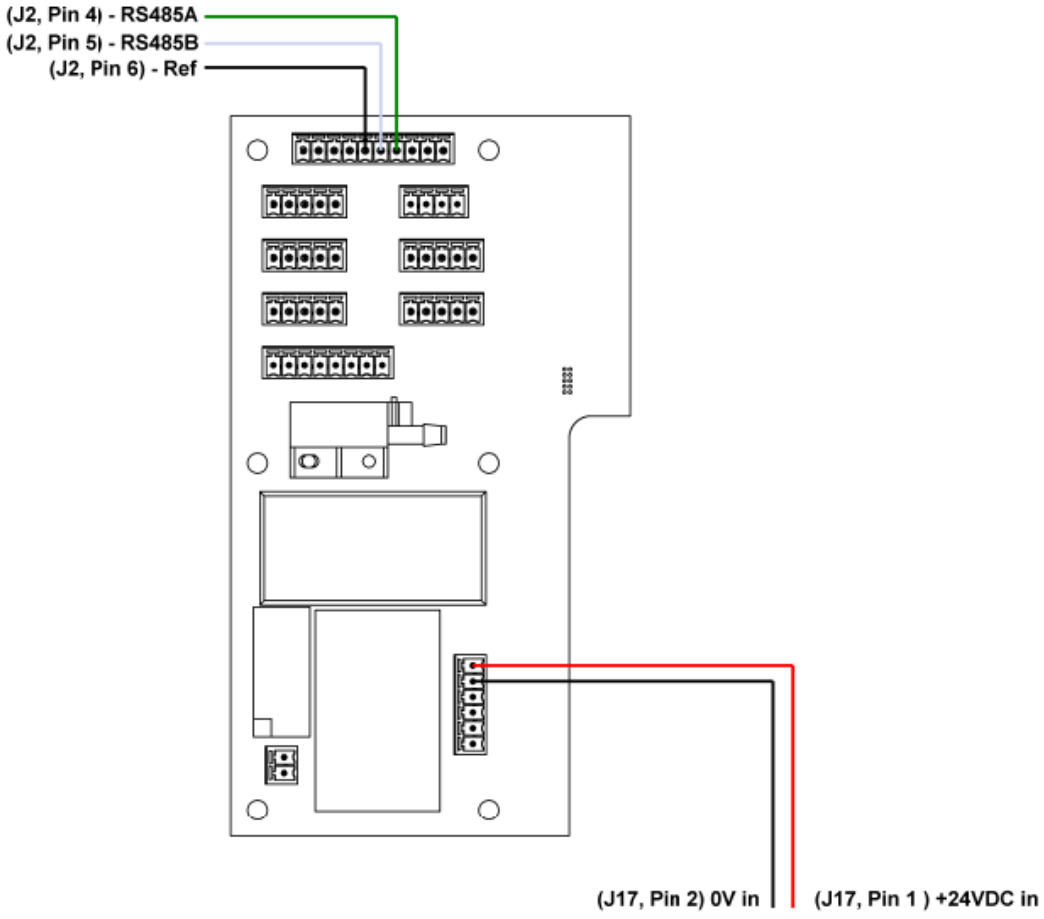


Figure 2 – Connection overview

An RS485 serial connection to the OEM sensor block can be made by connecting to connector J2 on the chassis PCB (Figure 2). Table 1 shows the pins that should be used for connecting to J2.

Pin number	Description
1	Do not connect
2	Do not connect
3	Do not connect
4	RS485A
5	RS485B
6	0V
7	Do not connect
8	Do not connect
9	Do not connect
10	Do not connect

Table 1 - Connector J2 pin definitions

2.2 Communications settings

To establish communications over the sensor serial bus, the serial connection should be configured as follows:

Parameter	Value
BAUD rate	9600
Data bits	8
Parity	None
Stop bits	1
Flow control	None

Table 2 - Serial communications settings

2.3 Sensor node addressing

All sensors are connected to the same RS485 serial bus and so need to be individually addressed when communicating. For this reason, only one sensor can be communicated with at any one time. A node address value is included in each message (see section 3.1) to indicate which sensor is being addressed. Each sensor will receive the message, but only the sensor with the matching node address will reply. When replying, the sensor will reply with its node address in its reply message. For a list of sensor node addresses, see Table 3.

Sensor type	Node address (hexadecimal)	Output units
Carbon dioxide (CO_2)	00h	ppm
Oxygen (O_2)	40h	ppm
Carbon monoxide (CO)	50h	ppm
Volatile organic compounds (VOC)	60h	ppm

Table 3 - Sensor specific details

3 Communications protocol

This section gives details of the serial messages that can be used to communicate with each sensor.

3.1 Message format

The standard message format for all communications is as follows:

:<NN><M..M><B..B><CCCC><cr>

- All messages start with a colon. Each sensor will look for this character to indicate the start of a message sequence.
- <NN> - This is the node address of the target sensor expressed in hexadecimal format (see number formats below).
- <M..M> - This is the command section of the message defining the action to be undertaken by the sensor (see individual message explanations).
- <B..B> - This is the message body and will vary depending on the message type (see individual message descriptions).
- <CCCC> - This is the checksum value for the message expressed in hexadecimal format (see number formats below).
- <cr> - The carriage return character (0Dh). A carriage return indicates to the receiving device that message transmission is complete.

3.2 Message checksum

The checksum is the modulo 16 sum of all the characters between but excluding the colon and the start of the checksum.

Example

For the message:

:50GV0102<cr>

- The checksum value for the message is the unsigned 16bit value 0102h
- The checksum value is calculated by adding the ASCII characters '5', '0', 'G' and 'V'.

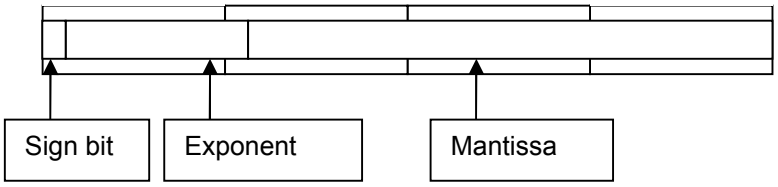
3.3 Number formats

All integer values are represented in hexadecimal format with each hexadecimal digit represented by an ASCII character (capital for all letters). Values are always represented by pairs of characters. All bytes are arranged with most significant byte first.

Value size	Decimal value	Hexadecimal value	ASCII representation in message
8 bit	90	5Ah	5A
16 bit	2268	8DCh	08DC
32 bit	1978621369	75EF5DB9h	75EF5DB9

Table 4 - Integer formatting

The floating point numbers are encoded in 32 bit IEEEE754 format:



The number is given by:

$$-1^{sign} \times 2^{\exp -127} \times 1.mantissa$$

Note that the sign bit is the most significant bit of the exponent byte, and the exponent is therefore shifted one bit to the right and crosses a byte boundary.

In a communications message they are transmitted as eight hex ASCII characters, most significant first. For example, 1.0f would be transmitted as `3F800000`.

3.4 Messages

3.4.1 Poll sensor for gas value

Detail: Used to read the current gas value from the sensor

Send command:

`:<NN>GV<CCCC><cr>`

Reply:

`:<NN>gv<VVVVVVVV><FFFFFFFF><CCCC><cr>`

Data:

`<NN>`	– (8 bit unsigned integer) The node address of the sensor
`<VVVVVVVV>`	– (32 bit floating point) The current gas value
`<FFFFFFFF>`	– (32 bit unsigned integer) The sensor status flags (see Table 5)
`<CCCC>`	– (16 bit unsigned integer) The message checksum
`<cr>`	– The carriage return character

Notes:

The units of the value returned depend on the sensor type (see Table 3). The value will be returned as either mbar partial pressure or ppm. If ppm output, bit 4 of the status flags will always be set (see Table 5).

Bit	Mask	5S3/MIR Name	MEC Name	Description / Notes	Fault*	Reading valid	Action
31	$80000000	Warm-up		This bit is set when the sensor has just been switched on, and after any write to the configuration memory. Indicates that the sensor reading cannot be trusted yet. Clears automatically after a timeout (20-60 sec).	N	N	No action for at least 60 seconds. If flag is persistent, replace the 5S3, MIR or MEC unit.
30	$40000000	Failed		Software has hit a fatal error. We hope you will never see it. The sensor will not provide meaningful gas values while the fatal error flag is set.	N	N	Cycle the power to recover from a fatal error. If fault reoccurs, replace the 5S3, MIR or MEC unit.
29	$20000000	Fault		Sensor has identified a fault but is still operating. Always accompanied by another fault flag marked "Y" in the Fault column.	N	See faults	See faults*
28	$10000000	Config CRC error		The sensor has detected a corrupt configuration.	Y	N	Replace the 5S3, MIR or MEC unit as soon as possible. It is possible that the corruption has not affected the sensor performance. Its readings should not be relied upon unless consistent with other sensors in close proximity.
27	$08000000	Reference range	N/A	The 5S3/MIR reference channel signal is outside its permitted range.	Y	N	Replace the 5S3 or MIR unit.
26	$04000000	Lamp DAC saturated	N/A	5S3/MIR IR source at full scale output. It indicates some kind of fault with the source.	Y	N	Replace the 5S3 or MIR unit.
25	$02000000	Lamp fault	PID lamp fault	5S3/MIR IR source or MEC VOC PID lamp is outside its permitted range.	Y	N	Replace the 5S3 or MIR unit. Clean or replace the PID lamp in the MEC VOC. N/A for other MEC variants.
24	$01000000	Power supply fault		The sensor has detected that the power supply is outside its permitted range.	Y	N	Check the power supply to sensor.
23	$00800000	Temperature fault		The ambient temperature around the sensor is outside the calibrated range. The sensor reading has not been normalised at these temperatures so may read incorrectly.	Y	N	Reading cannot be trusted while the temperature is outside calibrated range. Sensor will recover to normal operation once temperature is inside range. Note that the MEC electrochemical sensor cells can be damaged if the temperature is extremely low (observe storage temperature specifications).
22	$00400000	Noisy	N/A	5S3/MIR Power supply rails have become noisy. This can be as the result of a noisy input supply or a fault in the internal circuit.	Y	N	Check the power supply to sensor or replace the 5S3 or MIR unit.

Bit	Mask	5S3/MIR Name	MEC Name	Description / Notes	Fault*	Reading valid	Action
21	$00200000	N/A		N/A	Y	Y	N/A
20	$00100000	Initialisation fault		A power-on check during startup has failed. This is usually an internal fault, however the external power supply can be the root cause.	Y	N	Cycle the power, Check the power supply to sensor. If fault persists, replace the 5S3, MIR or MEC unit.
19	$00080000	Local pressure Fault		Only applicable for sensors fitted with pressure sensors. The local pressure value is out of range. Though it is possible for the atmospheric pressure to be outside the sensor's range, it is more likely to be an incorrect pressure calibration attempt or a pressure sensor fault.	Y	N	N/A if no pressure sensor is fitted. Check pressure value in calibration command if attempting to calibrate the pressure sensor. Otherwise replace the 5S3, MIR or MEC unit.
18	$00040000	Remote pressure Fault	N/A	Only applicable for sensors configured for use with a remote pressure source. 5S3/MIR has detected the remote pressure value supplied is out of range. This is a check on the variable passed to the sensor when a remote pressure source is used.	Y	N	N/A if no remote pressure sensor is used. Check external pressure value in command.
17	$00020000	Program CRC error		The sensor has detected a corruption in program memory.	Y	N	Replace the 5S3, MIR or MEC unit as soon as possible. It is possible that the corruption has not affected the sensor performance. Its readings should not be relied upon unless consistent with other sensors in close proximity.
16	$00010000	Table CRC error	N/A	The 5S3/MIR has detected a corruption in its data tables.	Y	N	Replace the 5S3 or MIR unit as soon as possible.
15	$00008000	N/A		N/A	N	Y	N/A
14	$00004000	N/A		N/A	N	Y	N/A
13	$00002000	N/A		N/A	N	Y	N/A
12	$00001000	N/A		N/A	N	Y	N/A
11	$00000800	N/A	User cal points too close	The MEC calibration points are too close together, which results in amplifying any error in the calibration. This flag is unlikely to be seen, as the limits on accepted calibration gases tend to make this state impossible.	N	Y	Recalibrate the sensor with recommended calibration gases. Provided the reading is between the calibration gases used the reading will be reliable. Accuracy will be degraded the further the reading is from the calibration gases used.

Bit	Mask	5S3/MIR Name	MEC Name	Description / Notes	Fault*	Reading valid	Action
10	$00000400	Detector range or ADC over range	N/A	N/A	N	Y	N/A
9	$00000200	ADC under range	N/A	N/A	N	Y	N/A
8	$00000100	Over range	ADC Over range	The 5S3/MIR reading is out of range, either the gas is outside the range or an error has been made the calibration process. Local or remote pressure readings are above the permitted range. Though it is possible for the atmospheric pressure to be outside the range, it is more likely to be an incorrect pressure value or a pressure sensor fault. The MEC ADC reading is outside its usable range.	Y	N	For 5S3/MIR: Check the gas is correct or the calibration has been performed correctly. If local pressure sensor, check pressure value in calibration command if attempting to calibrate the pressure sensor. If external pressure sensor, check external pressure value in command. Otherwise replace the 5S3 or MIR unit. For MEC: Replace the MEC unit
7	$00000080	Under range	N/A	The 5S3/MIR local or remote pressure reading is below the permitted range. Though it is possible for the atmospheric pressure to be outside the sensors range, it is more likely to be an incorrect pressure value or a pressure sensor fault.	Y	N	N/A if no pressure sensor is used. If local sensor, check pressure value in calibration command if attempting to calibrate the pressure sensor. If external sensor, check pressure value in command. Otherwise replace the 5S3 or MIR unit.
6	$00000040	N/A	PID power fault	MEC VOC PID sensor has detected a power failure.	Y	N	Check the power supply to sensor. Cycle the power, if fault persists, replace the MEC VOC unit. N/A for other MEC variants.
5	$00000020	N/A	PID oscillator fault	MEC VOC PID sensor has detected an Oscillator fault.	Y	N	Cycle the power, if fault persists, replace the MEC VOC sensor pellet or whole PID sensor. N/A for other MEC variants.
4	$00000010	ppm / mbar		This bit is set if the value returned form the senor is in ppm units. If cleared, the value is returned in mbar partial pressure units.	N	Y	No action.
3	$00000008	N/A	N/A	N/A	Y	N	N/A
2	$00000004	N/A	N/A	N/A	N	Y	N/A
1	$00000002	N/A	N/A	N/A	N	Y	N/A
0	$00000001	N/A	N/A	N/A	N	Y	N/A

*This column denotes that if any of the bits marked 'Y' are set by the sensor, they will be accompanied by a set bit 29 which is the global 'sensor in fault' flag.

Table 5 - The sensor status flags

3.4.2 Calibrate the sensor

Detail: Used to read the current local pressure value from the sensor

Send command:

`:<NN>JG<XX><AAAAAAAA><CCCC><cr>`

Reply:

`:<NN>jg<XX><FFFF><CCCC><cr>`

Data:

`<NN>`	- (8 bit unsigned integer) The node address of the sensor
`<XX>`	- (8 bit unsigned integer) The calibration control byte (see Table 6)
`<AAAAAAAA>`	- (32 bit floating point) The gas value to use for calibration
`<FFFF>`	- (16 bit unsigned integer) The calibration status (see Table 7)
`<CCCC>`	- (16 bit unsigned integer) The message checksum
`<cr>`	- The carriage return character

Notes:
When a calibration message is received, the sensor will determine whether or not a requested calibration adjustment is valid. If the value supplied is determined to be outside of acceptable limits, or would be too large a deviation from the current calibration then the calibration will be rejected and will not be stored in the sensor's memory. The calibration status flags indicate the result of the calibration (see Table 7)

After each successfully received calibration command, the sensor will enter a warm-up state whilst the calibration is processed.

The calibration value must be passed as either mbar partial pressure or ppm, setting or clearing the appropriate flag bit in the calibration controls byte to indicate which units type is being provided.

Each sensor's calibration is defined by two calibration points. To fully calibrate a sensor a high calibration and a low calibration must be performed. The high calibration should generally be performed using a gas concentration towards the high end of the sensor's range, whilst the low calibration should be performed close to the low end of the sensor range. In most cases, this will be zero concentration gas. The high or low calibration is performed by setting or clearing the appropriate bit in the calibration control byte (see Table 6).

For CO_2 sensors, the concentration of the zero gas should always contain 0% CO_2. Any other value passed to the sensor for a low calibration will be rejected.

For the CO sensor to calibrate successfully all calibration gases must contain at least a small concentration of O_2 in order for the chemical reaction to take place within the cell. The balance gas composition should reflect the atmosphere to be monitored (e.g. use cal. gas with air balance when monitoring CO in air).

Bit	Name	Description, meaning when set
7	N/A	N/A
6	N/A	N/A
5	N/A	N/A
4	ppm/mbar	Set if calibration value supplied is in ppm units, clear for calibration value in partial pressure units (mbar)
3	N/A	N/A
2	N/A	N/A
1	N/A	N/A
0	Cal point	Set for high calibration, clear for low calibration

Table 6 - The calibration control byte flags

Bit	5S3/MIR Name	MEC Name	Description	Action
15	N/A		N/A	N/A
14	N/A		N/A	N/A
13	N/A		N/A	N/A
12	N/A		N/A	N/A
11	N/A		N/A	N/A
10	N/A		N/A	N/A
9	N/A		N/A	N/A
8	Cannot Cal	N/A	5S3/MIR sensor is unable to perform calibration due to the presence of another fault.	Refer to corrective actions for faults indicated by command gas value poll (GV command).
7	Cal Value High		Calibration value supplied by user is too great. The concentration of gas that is being used to attempt the calibration is too high and not within the range of calibration gases that the sensor will permit.	Check that the calibration command is correctly formed and that the gas value is within the range allowed by the sensor.
6	Cal Value Low		Calibration value supplied by user is too small. The concentration of gas that is being used to attempt the calibration is too low and not within the range of calibration gases that the sensor will permit.	Check that the calibration command is correctly formed and that the gas value is within the range allowed by the sensor.
5	Cal Correction Too Big		The upper limit of calibration correction has been exceeded. The sensors reading is lower than would be expected for a calibration with the gas value supplied. This could also indicate that an MEC sensor cell needs to be replaced as it is worn out.	Check that the calibration command is correctly formed and that the gas value corresponds to the gas being applied to the sensor. Replace the MEC sensor cell.
4	Cal Correction Too		The lower limit of calibration correction has been exceeded. The sensors	Check that the calibration command is correctly formed

	Small		reading is higher than would be expected for a calibration with the gas value supplied.	and that the gas value corresponds to the gas being applied to the sensor.
3	N/A		N/A	N/A
2	Units Invalid	N/A	5S3/MIR calibration value units are not valid for the type of sensor. The units specified in the calibration command control byte are incorrect.	Check that the calibration command is correctly formed and that the units specified in the control byte are correct.
1	Invalid Point	N/A	This 5S3/MIR fault should never be triggered by sensor calibration command (JG command).	Check that the calibration command is correctly formed.
0	Other Error	N/A	This 5S3/MIR fault should never be triggered by sensor calibration command (JG command).	Check that the calibration command is correctly formed.

Note: If no bits are set then the calibration adjustment is considered to have been successfully applied.

Table 7 - The calibration status flags

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