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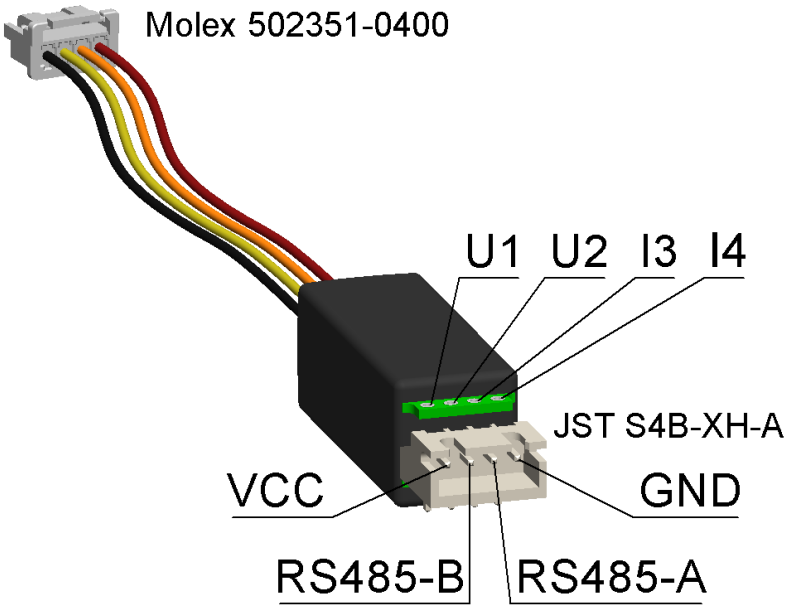
FDO2-EXT

Modbus-AnalogOut-Module for the Oxygen Sensor FDO2

DATA SHEET



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Modbus-AnalogOut-Module for the Oxygen Sensor FDO2

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valid for

FDO2-EXT firmware version >= 1.00

FDO2 firmware version >= 3.41

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TABLE OF CONTENT

1 INTRODUCTION

The module **FDO2-EXT** is an extension module for the optical oxygen sensor **FDO2** from PyroScience, providing 4 analog outputs and a Modbus interface. The module has two interfaces, a RS485 interface and a UART interface. The UART interface can be directly connected to the FDO2. The RS485 interface can be connected to a Modbus bus. Further, the **FDO2-EXT** provides 2 current outputs and 2 voltage outputs, which can be used even if the module is not operated via the Modbus interface.

1.1 Principle of Operation

Several features of the FDO2-EXT (e.g. slave address, sample interval, analog output features) can be configured by the user. The actual configuration is NOT saved within the FDO2-EXT module, but it is automatically saved within the flash memory of the FDO2. After a power cycle, the FDO2-EXT automatically reads out the last configuration from the connected FDO2.

IMPORTANT: The communication protocol of the optical gas sensor FDO2 offers so called "user memory registers", which can be used for storing 64 numbers (32bit signed integer) in the flash memory of the FDO2. The FDO2-EXT uses the last 8 user memory registers in the FDO2 for storing the Modbus configuration. So if the FDO2 is used in combination with the FDO2-EXT, then only the first 56 user memory registers can be used for other purposes.

If you have never heard about "user memory registers", then you probably do not have to bother about this at all!

1.2 Plug & Play with Default Configuration

If an optical oxygen sensor FDO2 is connected the very first time to a FDO2-EXT, then the configuration is automatically adjusted to the default values (refer to chapter 4.1)

- Modbus Slave Address = 1
- Sample Interval = 2s
- Default Analog Output Configuration (refer to chapter 2.3)
- CRC checksum in the FDO2 is enabled

This default configuration ensures plug & play. Simply connect a new FDO2 with a new FDO2-EXT, apply the power supply, and periodic oxygen measurements will start immediately with 2s sample interval. The oxygen partial pressure and the oxygen

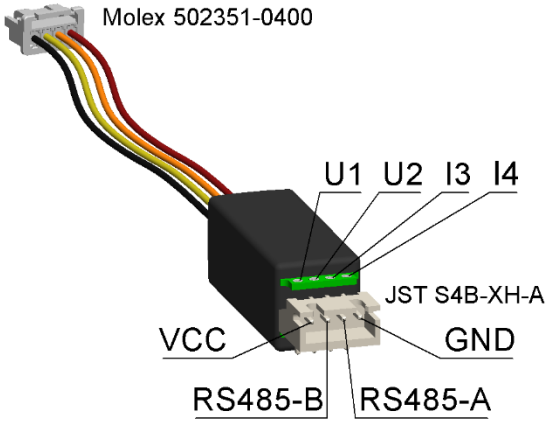
volume percent are given at the analog outputs (both voltage and current outputs). And the Modbus result registers contain always the results of the last data point.

For advanced users: The 57th user memory register (index 56) of the FDO2 is used for storing the Modbus slave address. If a value outside the range of 1-247 is detected at startup of the FDO2-EXT, then the FDO2-EXT automatically falls back to the default configuration.

2 INTERFACES

2.1 RS485 Interface

The RS485 interface provides the connection to the Modbus bus. It is based on the standard half-duplex configuration using two wires for the communication. The pin configuration is:



	Symbol	Description	Range
1	VCC	Supply Voltage	10 – 15 VDC (typ. 12V) *
2	RS485-B	Transceiver B	0 – 3.3V (5V tolerant)
3	RS485-A	Transceiver A	0 – 3.3V (5V tolerant)
4	GND	Ground	

*The minimum supply voltage of 10V is required to assure the full output range of the current outputs. If only the voltage outputs are used, then the supply voltage can be as low as 6V. If none of the analog outputs is used, then the supply voltage can be as low as 5V.

The RS485 configuration is: **19200 Baud, 8 data bits, 1 stop bit, even parity**.

2.2 Modbus Implementation

The module complies with the “BASIC Implementation Class” of Modbus using the RTU mode. Details can be found in the official documentation “Modbus over serial line specification and implementation guide V1.02” provided by the Modbus - Organization, Inc. (homepage: Modbus.org).

The enumeration of Modbus registers is always based on 16bit registers. **The FDO2-EXT uses by default always 32bit registers (signed integer), so two Modbus registers are coupled to a 32bit register.** Within this document a 32bit register is therefore indicated

for example like “45001/45002”, which refers to a signed 32bit integer located in the two 16bit Modbus registers 45001 and 45002. The used byte order is “CDAB”, so in this example the register 45001 contains the least significant 16bit of the 32bit integer, and the register 45002 contains the most significant ones.

The **Modbus slave address** can be adjusted in the **configuration registers** (refer to chapter 4.1).

2.3 Analog Outputs

The Module offers 2 voltage outputs and 2 current outputs with 14bit resolution. They provide the oxygen partial pressure (Modbus register s 30001/30002) and oxygen volume percent (Modbus registers 30013/30014) of the last measurement. Note, the two Modbus registers designated as AOR and AOF (refer to chapter 4.1) have influence on the analog output configuration.

Pin	Parameter	Range	Output Range	A = Offset	B = Slope
U1	Oxygen Partial Pressure	0 – AOR hPa	AOF – 5000 mV	AOF mV	AOR / (5000-AOF) hPa/mV
U2	Oxygen Volume Percent *	0 – AOR/10 %O2	AOF – 5000 mV	AOF mV	AOR/10 / (5000-AOF) %O2/mV
I3	Oxygen Partial Pressure	0 – AOR hPa	4 – 20 mA	4 mA	AOR / 16 hPa/mA
I4	Oxygen Volume Percent *	0 – AOR/10 %O2	4 – 20 mA	4 mA	AOR / 160 %O2/mA

If X corresponds to the output voltage or the output current, then the following formula is used for converting it to the result Y: $Y = B * (X - A)$

If a measurement is faulty, then the output will be set to 0 V or 0 mA respectively. A faulty oxygen measurement is given, if any of the bits 1-5 are set in the Status register (refer to chapter 3.1). Further, a faulty ambient pressure measurement (Status bit 9) would make the oxygen volume percent measurement faulty. In order to detect such errors at the voltage outputs, AOF must be adjusted >0. For example AOF = 200 mV would give 200 mV for zero oxygen levels, and 0 mV for a faulty measurement.

For the default configuration with AOF = 0 and AOR = 1200 this means:

Pin	Parameter	Range	Output Range	A = Offset	B = Slope
U1	Oxygen Partial Pressure	0 - 1200 hPa	0 – 5000 mV	0 mV	0.24 hPa / mV

U2	Oxygen Volume Percent *	0 - 120 %O2	0 – 5000 mV	0 mV	0.024 %O2 / mV
I3	Oxygen Partial Pressure	0 - 1200 hPa	4 – 20 mA	4 mA	75 hPa / mA
I4	Oxygen Volume Percent *	0 - 120 %O2	4 – 20 mA	4 mA	7.5 %O2 / mA

* IMPORTANT: The oxygen volume percent is within the FDO2-EXT calculated by the following formula:

Oxygen Volume Percent = 100%O2 * pO2 / P

with pO2 = Oxygen Partial Pressure (hPa)
P = Ambient Pressure (hPa)

This calculation is only valid, if the ambient pressure at the oxygen sensing membrane of the FDO2 is identical to the ambient pressure at the venting capillary on the backside of the FDO2 housing. The internal pressure sensor of the FDO2 measures the ambient pressure P through this venting capillary.

Example calculations based on the default configuration:

U1 = 513 mV gives 0.24 hPa / mV * (500 mV – 0 mV) = 123.12 hPa partial pressure oxygen.
U2 = 4110 mV gives 0.024 %O2 / mV * (4100 mV – 0 mV) = 98.64 %O2.
I3 = 12 mA gives 75 hPa / mA * (12 mA – 4 mA) = 600 hPa partial pressure oxygen.
I4 = 17 mA gives 7.5 %O2 / mA * (17 mA – 4 mA) = 97.5 %O2.

2.4 UART Interface

The UART interface (connector Molex 502351-0400) provides the connection to the optical gas sensor FDO2. All communication between the FDO2-EXT and the FDO2 is handled automatically, so no configuration is required.

Pin	Symbol	Description	Range
1	U_{supply}	Supply Voltage	3.3 VDC
2	TX	UART Transmit	0 – 3.3V
3	RX	UART Receive	0 – 3.3V
4	GND	Ground	

UART default configuration: 19200 Baud, 8 data bits, 1 stop bit, no parity.

3 READ-ONLY MODBUS REGISTERS

Read-only Modbus registers (called “input registers”) are used for information which can be only read from the Modbus master. They use the address space 3xxxx starting with address 30001.

3.1 Result Registers

The results registers contain the results of the last measurement performed by the attached optical gas sensor FDO2.

Modbus Address	Description
30001/30002	**Oxygen Partial Pressure**, signed 32 bit integer in units of 10-3 hPa (O = 203456 corresponds to 203.456 hPa, typ. range 0-210 hPa)
30003/30004	**Temperature**, signed 32 bit integer in units of m°C (T = 17892 corresponds to 17.892°C T = -1965 corresponds to -1.965°C, typ. range 0 – 50°C)
30005/30006	**Status Register** with warning and error bits (details see below)
30007/30008	**Phase Shift** „dphi“, signed 32 bit integer in units of m° (millidegrees) (e.g. D = 24385 corresponds to 24.385°, typ. range 5°- 60°)
30009/30010	**Signal Intensity** of the oxygen sensor, signed 32 bit integer in units of µV (e.g. I = 124072 corresponds to 123.072 mV, typ. range 100-500mV)
30011/30012	**Ambient Light** entering the sensor, signed 32 bit integer in units of µV (e.g. A = 12792 corresponds to 12.792 mV, typ. range 0 - ca. 100mV)
30013/30014	**Ambient Pressure** at the BACKSIDE of the module, signed 32 bit integer in units of µbar (e.g. P = 999734 corresponds to 999.734 mbar, typ. range 900-1100mbar)
30015/30016	**Relative Humidity** inside the housing in units of m%RH (e.g. H = 40365 corresponds to 40.365 %RH, typ. range 10-90%RH)
30017/30018	**Data Point Counter** (32 bit unsigned integer) starts at 1 after each power cycle, incremented by 1 after each measurements.

Details of the **status register**: The single bits of the status register gives information about warnings or fatal errors, which occurred during the latest measurement. Under normal operation the status should be always S=0 or S=1. In all other cases the oxygen and the temperature readings are or can be faulty. It is on the users authority to check the status for each single measurement, in order to detect a faulty sensor operation. Especially the error bits marked with „FATAL ERROR“ will lead to incorrect oxygen readings. The single bits of the status register have the following meaning:

Status Bit	Description
0	WARNING, the detector amplification was automatically reduced in order to avoid saturation of the detector. The oxygen reading is still valid. This might happen at low temperatures together with low oxygen values causing high luminescent intensities of the oxygen indicator. Or the sensor might be exposed to excessive ambient light (e.g. sun light).
1	FATAL ERROR, oxygen sensor signal intensity too low (<20mV)
2	FATAL ERROR, oxygen sensor signal or ambient light too high
3	FATAL ERROR, oxygen reference signal intensity too low (<20mV)
4	FATAL ERROR, oxygen reference signal or ambient light too high (>2400mV)
5	FATAL ERROR, failure of the temperature sensor
6	reserved
7	WARNING, the humidity within the sensor housing is >90%RH. This might lead to fatal electronic problems and therefore to a failure of the oxygen measurement.
8	reserved
9	ERROR, failure of the pressure sensor within the sensor housing, this has no direct influence on the measured oxygen partial pressure.
10	ERROR, failure of the humidity sensor within the sensor housing, this has no direct influence on the measured oxygen partial pressure.

3.2 Device Info Registers

The registers starting at 36001 contain information about the firmware and unique device IDs.

Modbus Address	Description
36001/36002	Firmware version of the connected FDO2 module. For example, 341 corresponds to firmware version 3.41.
36003/36004	MSW of Unique ID number (most significant 32bit of 64bit UID) of the connected FDO2 module (unsigned 32bit integer).
36005/36006	LSW of Unique ID number (least significant 32bit of 64bit UID) of the connected FDO2 module (unsigned 32bit integer).
36007/36008	Firmware version of the firmware in the FDO2-EXT module. For example, 114 corresponds to firmware version 1.14.

4 READ-WRITE MODBUS REGISTERS

Read-write Modbus registers are called “holding registers” are used for data which can be read or written. They use the address space 4xxxx starting with address 40001.

4.1 Configuration Registers

The following registers contain the configuration of the FDO2-EXT.

Modbus Address	Description (Units)	Range	Default
45001/45002	Sample Interval (ms)	0 or 100-10000	2000

Modbus Address	Description (Units)	Range	Default
47001/47002	Modbus Slave Address	1 - 247	1
47003/47004	AOR, Analog Output Range in units of (hPa) or (%O2 / 10)	1 - 2000	1200
47005/47006	AOF, Analog Output Offset of Voltage Outputs (mV)	0 - 4000	0
47007/47008	reserved		
47009/47010	reserved		
47011/47012	reserved		
47013/47014	reserved		
47015/47016	reserved		

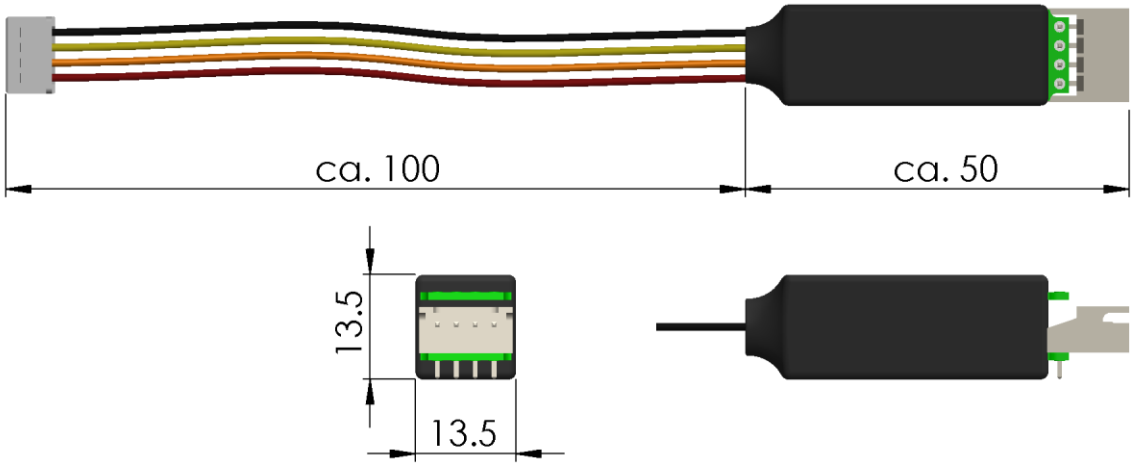
4.2 Command Registers

The command registers are used for executing special commands. Some commands affect the FDO2-EXT module directly; some other commands are forwarded to the attached FDO2 module.

<table>
<tr><td>Modbus Address</td><td colspan="2">Description</td></tr>
<tr><td>49001/49002</td><td colspan="2">Command Register
If any of the following numbers are written to this register, the module will first send the Modbus response confirming the writing of this module. Then one of the following actions is executed.</td></tr>
<tr><td></td><td>Register Content</td><td>Performed Action</td></tr>
<tr><td></td><td>0</td><td>Sensor module is ready, the command register block can be written and a new command can be triggered by writing a number to this register here.</td></tr>
<tr><td></td><td>1</td><td>Sensor module is busy. The command registers cannot be written. A write access to any register within 49001-49200 will give the Modbus error “Slave Busy”.</td></tr>
<tr><td></td><td>10</td><td>Flash status LED of the FDO2.
(sends the #LOGO command to the FDO2)</td></tr>
<tr><td></td><td>11</td><td>Trigger a single oxygen measurement.
(sends the #MRAW command to the FDO2)</td></tr>
<tr><td></td><td>12</td><td>Calibrate zero oxygen level.
(sends the #CALO command to the FDO2)</td></tr>
<tr><td></td><td>13</td><td>Calibrate high oxygen level. The Parameter Register 49003/49004 must contain the partial pressure oxygen of the calibration sample in units of 10^{-3} hPa. For example, a register contant of 213020 corresponds to 213.02 hPa.
(sends the #CAHI command to the FDO2)</td></tr>
<tr><td></td><td>14</td><td>Revert to factory calibration of the FDO2.
(sends the #CAFC command to the FDO2, requires FDO2 with firmware version >=3.42)</td></tr>
<tr><td></td><td>707</td><td>Revert to default configuration of the FDO2-EXT followed by a firmware reset equivalent to a power cycle. CRC checksum in the FDO2 is enabled.</td></tr>
<tr><td></td><td>777</td><td>Triggers a firmware reset of the FDO2-EXT equivalent to a power cycle.</td></tr>
<tr><td></td><td>789</td><td>Test Analog Outputs. The Parameter Register 49003/49004 defines the percentage of output level, e.g. 100 will give highest level (5V, 20mA) and 0 will give lowest level (0V, 0 mA). The next measurement result will overwrite this again.</td></tr>
<tr><td>49003/49004</td><td colspan="2">Parameter Register
Optional parameter required by the some commands.</td></tr>
</table>

5 APPENDIX

5.1 Dimensions



5.2 Warnings

Do not use these products in safety critical devices or in any other application where failure of the product could result in loss of life, personal injury, or damaged property.

This device and the sensors are not intended for aerospace, medical, breath control, diving, military or other safety-relevant applications.

Avoid all sources of ignition especially if the sensors are used in pure oxygen or oxygen enriched atmospheres.

The information and specifications in this document are subject to change without prior notice.

The data contained in this document is for guidance only. Customers should test under their own conditions, to ensure that the sensors are suitable for their own requirements.

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