CONTAMINATION MONITORING PRODUCTS

INSTALLATION, SERVICE AND MAINTENANCE MANUAL

ICS

INLINE CONTAMINATION SENSOR

EN

PASSION TO PERFORM

MPFILTRI®

PRODUCT OVERVIEW

ICS - Inline Contamination Sensor

The ICS automatically measures particulate contamination levels in various hydraulic fluids and is designed for industrial and mobile applications.

It is designed to be inline mounted directly to systems, where ongoing measurement or analysis is required, and where space and costs are limited.

Features & Benefits

- Inline mounting
- 3-channel contamination measurement
- Measures ISO 4406
- Space-efficient design
- Robust build quality
- Pressure max. 420 bar (6091PSI)
- Environmental Protection:
  Mobile version: IP69K
  Industrial version: IP67
- Impact Protection:
  Mobile version: IK04
  Industrial version: IK04
- 4-20mA analogue output (Industrial)
- RS485 Modbus RTU (industrial)
- CANbus (Mobile)

Industrial version

Mobile version

DECLARATION OF CONFORMITY

CE Declaration of Conformity

The products included in this Declaration are all variants of the following:

- Compatible with mineral oil/ synthetic fluids, offshore fluids.

For part codes see the Designation & Ordering Code (section 2.8)

Product Manufacturer:
MP Filtri UK Ltd
Keep House
Vale Park
Evesham
Worcestershire
WR11 1LB
01386 258500
sales-uk@mpfiltri.com

The products described are in conformity with the following directives:

2014/30/EU Electromagnetic Conformity

Certification Testing that has been carried out is in accordance with:

- DEF STAN 00-35 Part 3 issue 4 Environmental Test Methods
- BS EN 60068 range of standards covering environmental conditions
- BS EN 60529: 1992 + A2:2013 Degrees of Protection provided by enclosures (IP Code)
- BS EN 62262:2002 Degrees of Protection Provided for Electrical Equipment against External Mechanical Impacts (IK Code)
- BS EN 60721-3-4: 1995 Part 3: Classification of Groups of Environmental Parameters and their severities, Section 3.4

Date: September 2024

Signed:
Kris Perks (Engineering Director) on behalf of MP Filtri UK Ltd

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1. General warnings and information for the operator

1.1 General safety warnings

Do not operate, maintain or carry out any procedure before reading this manual. Any individual operating the unit shall wear the following Personal Protective Equipment:

- Protective eyewear
- Safety shoes
- Gloves
- Overalls (or other suitable protective clothing)

Before carrying out any machine installation procedures and/or before use, one should scrupulously follow the instructions listed in this manual. Moreover, it is necessary to comply with the current regulations related to occupational accident prevention and safety in the workplace.

Notices aimed at the prevention of health hazards for personnel operating the machine are highlighted in this document with signs having the following meaning:

It relates to important information concerning the product, its use or part of this documentation to which special attention must be paid

It means that failure to comply with the relevant safety regulations may result in mild injury or property damage.

It means that failure to comply with the relevant safety regulations may result in death, serious injury or serious property damage.

Failure to comply with the relevant safety regulations may result in death, serious injury or serious property damage.

GENERAL WARNINGS

To allow rapid identification of the employees who must read this manual, definitions have been used with the following meaning:

OPERATOR	This is any individual whose task is to use the machine for production purposes. The operator is aware of all the measures taken by the machine manufacturer in order to eliminate any source of injury risk in the workplace and takes into account the operational constraints.
PERSONNEL INVOLVED IN SLINGING AND HOISTING OPERATIONS	This is any individual whose task is to handle the machine or parts of it. Personnel involved in slinging and hoisting operations are aware of the issues regarding the safe transfer of machinery or parts of it and, therefore, uses appropriate lifting equipment, following the instructions provided by the product manufacturer.
MACHINE SETTER	This is any individual whose task is to set up the machine for its operation. The machine setter is aware of the measures taken to eliminate all sources of injury risks in the workplace and takes into account the operational constraints. The machine setter takes all the appropriate precautions in order to operate in utmost safety conditions.
MAINTENANCE TECHNICIAN	This is any individual whose task is to carry out maintenance activities on the machine. The maintenance technician is aware of the possible danger situations that may arise and takes the appropriate precautions in order to eliminate the risks of accidents in the workplace.
ELECTRICIAN	This is any individual whose task is to carry out maintenance activities on the electrical wiring of the machine. The electrician is aware of the possible danger situations that may arise and takes the appropriate precautions in order to eliminate the risks of accidents in the workplace.

The unit shall be taken out of service and/or dismantled in accordance with the current regulations in force in the country where the machinery is installed

CAUTION

1.2 Dangers and hazards that cannot be eliminated

- Risk of hydraulic injection injury
- Burn risk because of high temperatures
- Accidental oil leaks with consequent risk of slipping
- Hose breakage and resulting lubricant loss
- With oil temperatures exceeding 40/45 °C (100/115 °F), it is vital to be extremely careful when handling the unit. Avoid direct contact with hot oil.

AFTER USE - ALL EQUIPMENT SHOULD BE ALLOWED TO COOL PRIOR TO HANDLING

1.3 Personal protective equipment

When operating the unit, personnel must be wearing safety shoes, gloves and goggles/safety glasses. In general, the PPEs to be used according to the activities on the machinery are listed in the following table:

ACTIVITY	PPE
Ordinary operation	Shoes, gloves, goggles, overall
Planned maintenance	Shoes, gloves, goggles, overall

1.5 Precautions related to product handling of the Liquid Crystal Touchscreen display

- If the LCD panel breaks, be careful not to get the liquid crystal to touch your skin.
- If the liquid crystal touches your skin or clothes, please wash it off immediately by using soap and water
- Avoid any strong mechanical shock which can break the glass.

2. Transportation and Storage

2.1 Transportation and handling conditions

The unit is shipped in a cardboard box with appropriate protective packaging and these should be recycled accordingly where possible. The packed weight of the ISC and accessories is 0.9 kg (2 lbs)

2.2 Storage

The unit should be stored in a suitable location away from the production area when not in use. The unit should be stored with the caps provided on the ports. This location should not impede any other production or personnel.

WARRANTY

3. Warranty, Limitations and Disclaimers

MP Filtri warrants that the products that it manufactures and sells will be free from defects in material, workmanship & performance for a period of 12 months from the date of shipment.

Hardware/Firmware

Should the hardware prove defective during the warranty period, MP Filtri, at its discretion, will either repair the defective product or replace it with an equivalent product in exchange for the defective unit without charge for parts, labour, carriage and insurance.

Software

MP Filtri warrants that software will operate substantially in accordance with its functional specification for 12 months from date of shipment provided that the integrity of the operating environment has not been compromised through misuse, inappropriate handling, abnormal operating conditions, neglect or damage (unintentional or otherwise) or the introduction of third party product (software or hardware) that in any way conflicts with the MP Filtri product.

Eligibility

This warranty extends to the original purchaser only or to the end-user client of a MP Filtri authorised affiliate.

How to obtain service?

To obtain service under the terms of this warranty, the customer is required to notify MP Filtri before the expiration of the warranty period and to return the item in accordance with MP Filtri product return policy. Any product returned for warranty repair must be accompanied by a full fault report specifying the symptoms and the conditions under which the fault occurs. Should MP Filtri incur additional cost as a result of a failure to complete the appropriate paperwork, an administrative charge may be levied.

Exclusions

This warranty shall not apply to any defect, failure or damage caused by improper use or improper or inadequate care. MP Filtri shall not be obligated to provide service under this warranty if:

a) Damage has been caused by a failure to make a full and proper inspection of the product (as described by the documentation enclosed with the product at the time of shipment) on initial receipt of the product following shipment;

b) Damage has been caused by the attempts of individuals, other than MP Filtri staff to repair or service the product;

c) Damage has been caused by the improper use or a connection with incompatible equipment or product including software applications.

Charges

Under cover of this warranty, MP Filtri will pay the carriage and insurance charges for the shipment of defective product back to site of manufacture and for its return to the client's original site of despatch except when:
a) MP Filtri product return policy has not been followed.

b) Product failure is caused by any of the exclusions described above, when the customer will be liable for the full cost of the repair (parts and labour) plus all carriage and insurance costs to and from MP Filtri premises.

c) The product is damaged in transit and a contributory cause is inadequate packaging. It is the customer's responsibility to ensure that the packaging used to return equipment to MP Filtri is the same, or has equivalent protective qualities, to that used to ship the product to the customer in the first instance. Any damage resulting from the use of inadequate packaging will nullify MP Filtri

obligations under this warranty. Should the customer's product be damaged in transit following a repair at MP Filtri site, a full photographic record of the damage must be obtained (packaging and the product) to support any claim for recompense. Failure to present this evidence may limit MP Filtri obligations under this warranty.

THIS WARRANTY IS GIVEN BY MP FILTRI IN LIEU OF ANY OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, NON INFRINGEMENT OR FITNESS FOR A PARTICULAR PURPOSE. MP FILTRI LTD SHALL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OR LOSSES (INCLUDING LOSS OF DATA), WE SPECIFICALLY DISCLAIM ANY AND ALL WARRANTIES TO CUSTOMERS OF THE CUSTOMER. THE CUSTOMER'S SOLE REMEDY FOR ANY BREACH OF WARRANTY IS THE REPAIR OR REPLACEMENT, AT MP FILTRI DISCRETION, OF THE FAILED PRODUCT.

MP Filtri Ltd maintains a policy of product improvement and reserves the right to modify the specifications without prior notice.

3.1 Warranty on Recalibration

The CML3 is guaranteed for 12 months upon receipt of the product, subject to it being used for the purpose intended and operated in accordance with this User Guide.
MP Filtri will only verify the accuracy of the CML3 if the unit is recalibrated every 12 months.

Please ensure that the test results in the Log are downloaded to CMP View before the CML3 is despatched, in case action taken by MP Filtri during the service / recalibration causes the Log to be cleared.

NOTE

It is requested that only the CML3, not the support case or any other ancilliaries, be returned for recalibration.
MP Filtri will not be held responsible for any items returned as such.
Ensure that the CML3 is packed appropriately for transportation.

PRODUCT DOCUMENTATION

3.2 Download Area

Please scan the QR codes below to get updated electronic version of the related document.

CONTAMINATION MONITORING PRODUCTS General catalogue

Download PDF

CMP View Software
Quick Guide

Select your language and download PDF

CMP View Software
Software multilingual

Download Software

4. Technical Specification

4.1 Performance

Technology	LED Based Light Extinction Automatic Optical Contamination Sensor
Particle Sizing	>4, 6, 14 µm
Analysis range	ISO 4406
Calibration	Each unit individually calibrated with ISO Medium Test Dust (MTD) based on ISO 11171, on equipment certified by I.F.T.S. ISO 11943
Accuracy	±1 ISO code for 4, 6, 14 µm

4.2 Electrical interface

Supply Voltage	Industrial version: 24v DC +/- 20% Mobile version: 9-36v DC
Power Consumption	<1.5W
Test Time	Standard factory setting: 2 minutes
Communication Options	Industrial Version: 4-20mA Time Multiplexed; RS485 Modbus RTU Mobile Version: CANbus

Please note Comms protocols are covered in Section 4.

TECHNICAL SPECIFICATION

4.3 Physical attributes

Dimensions	Industrial: 58 mm (2.3 inches) (W) x 50 mm (2 inches) (D) x 68 mm (2.7 inches) (H) Mobile: 58 mm (2.3 inches) (W) x 50 mm (2 inches) (D) x 76 mm (3 inches) (H)
Hydraulic connection	Inline mounting
Weight	0.9 kg (2lbs)
IP Rating	Industrial version: IP67; Impact Protection IK04 Mobile version: IP69K; Impact Protection IK04

4.4 Fluid characteristics

Fluid compatibility	M version - mineral oils, synthetic fluids
Viscosity	≤ 1000 cSt
Fluid temperature	Industrial version: From -25°C (-13°F) to +80°C (+176°C) Mobile version: From -25 °C (-13°F) to +100°C (+212°C)
Operating flow rate	20 to 400 ml/minute
Minimum pressure	0.5 bar (6091PSI)
Maximum pressure	420 bar (6091PSI)

4.5 Environment

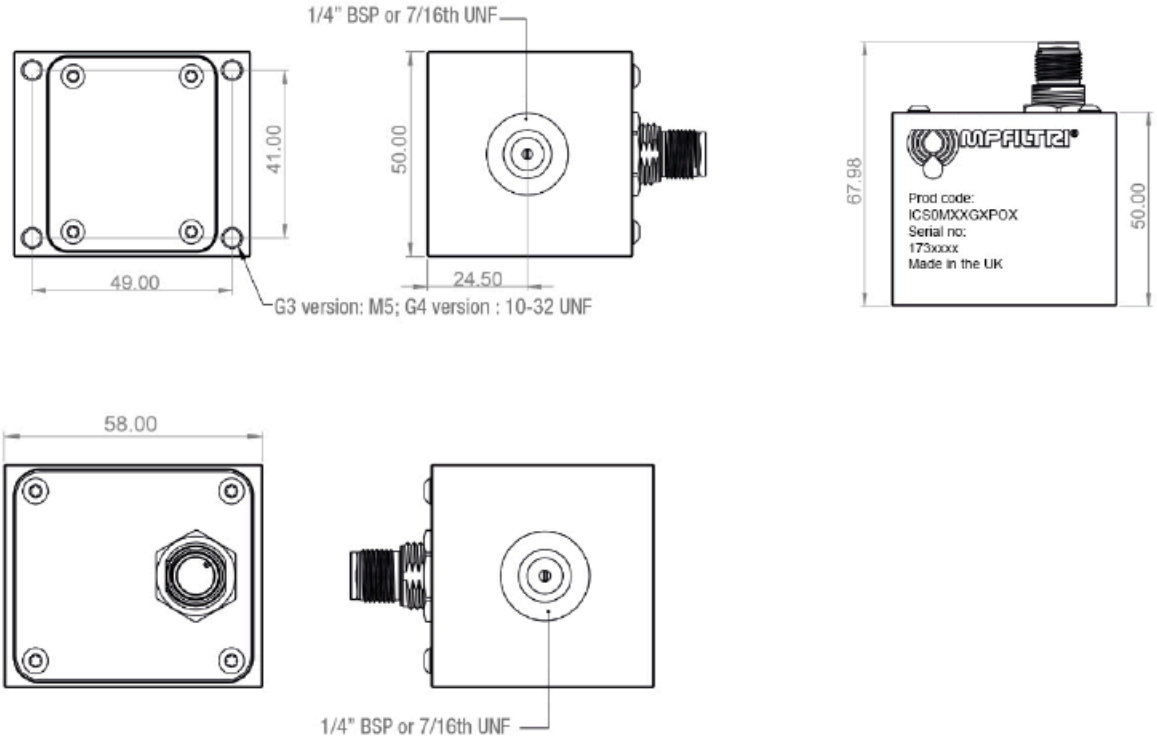
Ambient working temperature	Industrial version: From -10°C (+14°F) to +55°C (+131°F) Mobile version: From 0°C (+32°F) to +50°C (122°F)
Electrical load (Mobile version only)	In accordance with ISO 16750-2
Mechanical load (Mobile version only)	In accordance with ISO 16750-3

4.6 Wetted Parts

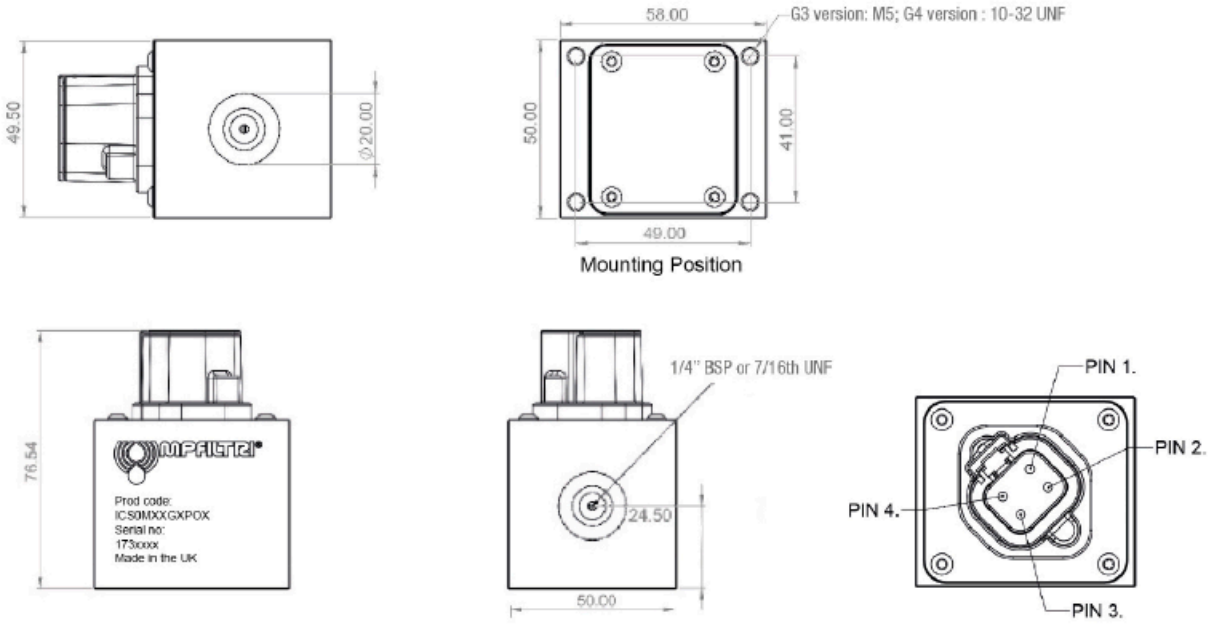
M - 316 stainless steel, FPM, PTFE, sapphire.

4.7 Dimensions

INDUSTRIAL VERSION



MOBILE VERSION



TECHNICAL SPECIFICATION

4.8 Designation & Ordering code

ICS AUTOMATIC CONTAMINATION MONITORING SENSOR

Configuration example: ICS | 0 | M | 0 | 0 | G3 | P01

Contamination Monitoring Product

ICS	Inline Contamination Monitoring Sensor

Sensor options

0	Standard

Fluid compatibility

M	Mineral oil and synthetic fluids

Communication protocol

0	420mA
1	RS485 Modbus RTU
2*	CANBUS

Electric connection

0	M12 4pin
1*	DTP10-4P

Port Options

G3	1/4" BSPP Female
G4	7/16th UNF Female

Design Ref

P01	Standard

* *Mobile version only*

5. Product Installation and General Operation

5.1 Installation

Each ICS supplied consists of the following:

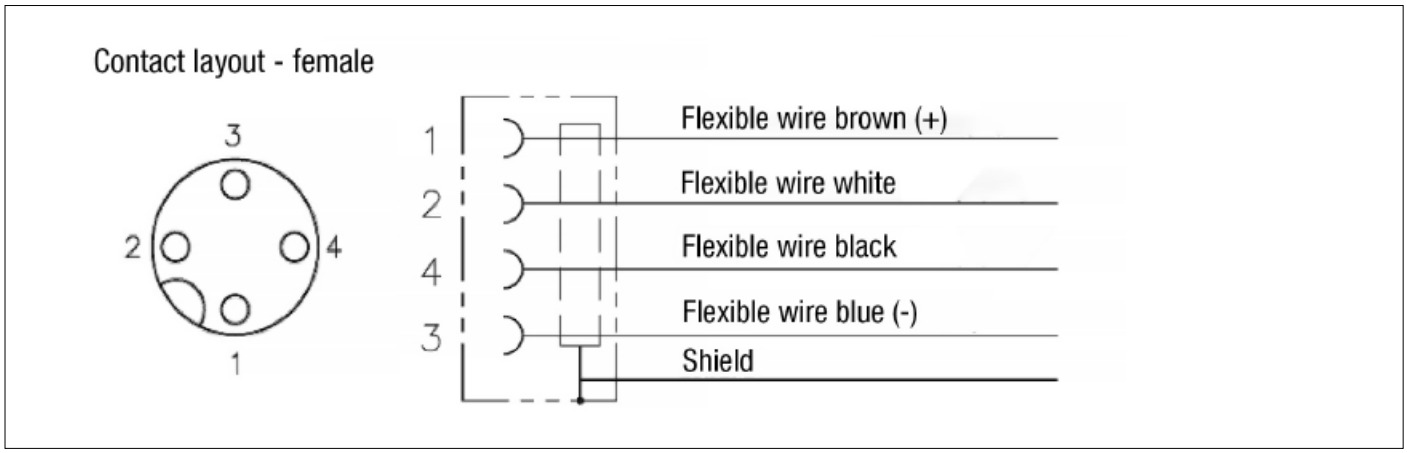
- 1 x ICS as specified

1 x Installation kit, containing:

- 1 x ICS* Version as specified
- 2 x Hard copy of calibration certificate
- 1 x Datastick with installation guide and user manual
- 1 x Hard-copy quick start guide

5.2 Industrial Version: 4-20mA installation

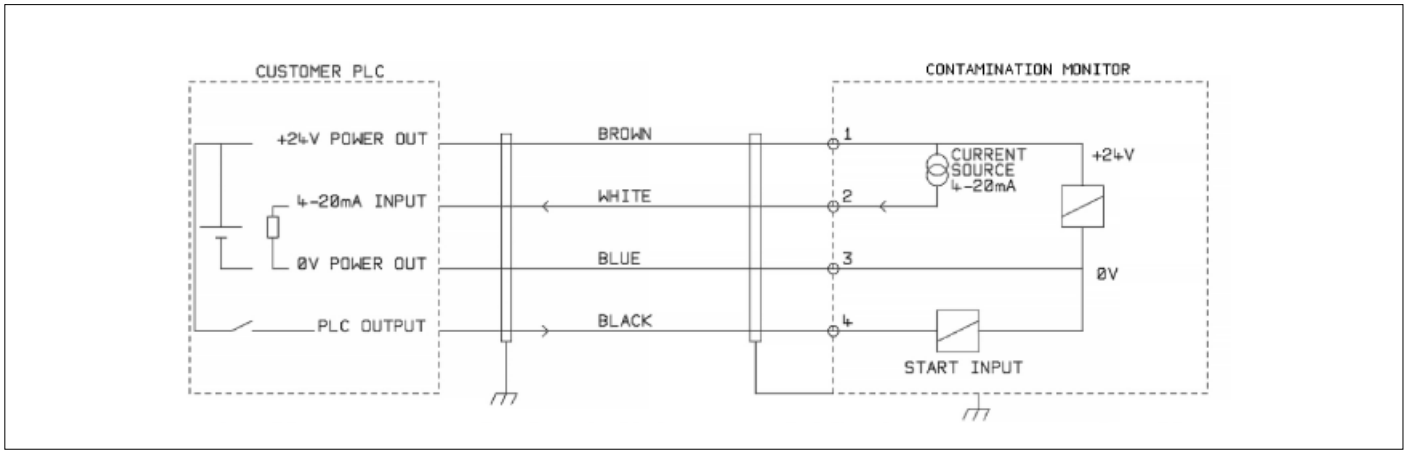
Connectors are 4pin M12, “A-Coded”. The connector on the device has the male pins. The diagram below is a view from end of the cable plug not the ICS socket.



The 0V is connected internally to the case as well as the shield.

Signal	Pin	Colour	Comment
+24V	1	Brown	DC POWER
4-20mA	2	White	CURRENT SOURCE
0V	3	Blue	0V is internally connected to the metal block by design
START+	4	Black	Connect to +24 during test time

PRODUCT INSTALLATION



The cable + connector needs to be a shielded 4way, A-coded, female pin type. An example could be TE 2273099-1. Alternatively a re-wireable type can be used.

5.3 Customer PLC Program Example

The customer PLC communicates with the unit by energizing a switched START signal and reading the results result from a 4-20 mA current signal

- The START signal duration controls the test period
- The 4-20 mA signal is time-multiplexed. That is, the parameters are output in a timed sequence.

We report the 4, 6 and 14um ISO codes. We also include a function to report the status of the unit (OK, ERROR, TESTING etc) but decoding this is optional An example test sequence is shown below, the highlighted sections may not be required for the application.

5.3.1 Sequence

If pump not running

- Turn on pump
- Wait until flow is stable and piping flushed, perhaps 60 seconds

If ICS not powered

- Turn on ICS power
- Wait >3 seconds
- Option: read status signal

- Turn on START signal
- Wait 300 seconds for testing (example)
- Option: check status

- Turn off START signal
- Wait 1 second
- Read 4-20 mA signal. ISO4 = (mA x 2) - 8
- Wait 2 seconds
- Read 4-20 mA signal. ISO6 = (mA x 2) - 8
- Wait 2 seconds
- Read 4-20 mA signal. ISO14 = (mA x 2) - 8
- Option: check status
- Wait 2 seconds
- Read status

Optional

- The customer program can also read and decode the STATUS signal
- The flow can be continuous
- The power can be continuous

5.3.2 Detailed Sequence

Duration (seconds)	Device Action	START Signal	4-20 mA	PLC Responsibility
	Power off	OFF		Start pumps, flow etc.
	Power on	OFF		Apply power
<3	(ICS starts up, self tests)	OFF		
	Output status value	OFF	STATUS	Optional: Check status
>10 s if required perhaps 60 seconds		OFF	STATUS	If flow is not continuous, ensure machine operation is stable, and there has been time for old fluid to be flushed from the system
	Start testing	ON	TESTING	Turn on START signal Start test timer
Customer defined, perhaps 300 seconds	Count particles	ON	TESTING	Test timer running
<0.1s	Calculate result codes	OFF		Test timer finished Turn off START signal Start 1.0 second timer
2.0 s	Output 4 µm result	OFF	ISO(4um)	Timer finished: Read 4 µm result Start 2.0 second timer
2.0 s	Output 6 µm result	OFF	ISO(6um)	Timer finished: Read 6 µm result Start 2.0 second timer
2.0 s	Output 14 µm result	OFF	ISO(14um)	Timer finished: Read 14 µm result Start 2.0 second timer
	Output status	OFF	STATUS	
				Start another test or wait or power off etc

5.3.3 ISO Coding

ISO CODE = 2 x (mA-4) = (2 x mA) - 8 (reverse: mA = 4.0 + ISO/2)

CODE	Nominal Current (mA) +/- 0.2 mA
0	4.0
1	4.5
2	5.0
3	5.5
4	6.0
5	6.5
6	7.0
7	7.5
8	8.0

CODE	Nominal Current (mA) +/- 0.2 mA
9	8.5
10	9,0
11	9.5
12	10.0
13	10.5
14	11.0
15	11.5
16	12.0
17	12.5

CODE	Nominal Current (mA) +/- 0.2 mA
18	13.0
19	13.5
20	14.0
Saturation	17.0
No value	18.0
Reserved	19.0
Reserved	20.0

Note: any value above 14.0 up to but not including the 17.0

5.3.4 Status Values

- It is optional to read these
- These functions may be changed or removed before final project release

STATUS	Nominal Current (mA) +/- 0.2mA	When Output
OK – Ready	4	After power-up or after test
Testing	5	During test
Fault: LED fail or blocked	6	After power up or during test or after test
Not ready	20	During power-up and self- test
	11-19	Reserved for future use

5.3.5 Mobile version: CANbus installation electrical connections

ICS-M Connection

DTP10-4 Pin		
Signal	**Pin**	**Comment**
0V = CHASSIS	1	0V is internally connected to the metal block by design
+12 / +24	2	Product is designed for +12V and +24V automotive / mobile equipment supplies
CANL	3	CANbus termination must be done externally at each end of the CANbus, or using a through terminator if the ICS at one end
CANH	4	

The ICS requires a DC power supply and the two CAN-bus signals CANL and CANH, as shown in Figure 1. The numbers shown are the pin numbers of the circular connector that plugs into the ICS.

- The DC voltage is typically 24V, but can be 9-36V.
- Twisted pair cable should be used for the CAN-bus signals, for cable lengths over a few meters.
- CAN-bus requires the network to be terminated at each end. This must be done externally to the ICS.
- The CAN-bus signals CANL and CANH are referred to the system 0V supply.

These should stay within the common mode range allowed by the ISO-11898-4 CAN-bus standard relative to the ICS 0V connection. This range is -2V to +7V.

This can be normally be ensured by connecting together the ICS 0V and the 0V of the CAN-bus controller. The ``CAN 0V" wire shown indicates this link.

Not needed if both CAN-bus controller and ICS are connected to a vehicle chassis or otherwise ``Earthed".

6. CANBUS Configuration

6.1 Recommended Configuration

All Mobile versions are preset to CANbus communications protocol

6.2 CAN 2.0B and J1939

The default 29 bit format is designed to be compatible with the J1939 standard. It should also be possible to use the ICS with any system that permits arbitrary raw CAN-bus 2.0B identifiers to be received.

The dialogue shows the default CAN-bus settings. The ICS transmits all data using a range of message identifiers starting at that selected. If the ``Use Defaults" button is pressed, the program constructs an identifier suitable for J1939*.

At the end of each test, the ICS will generate a ``test result codes" message using the selected CAN-bus identifier.

On a J1939 network the test result will appear as PGN 0x00ff00. Users not using J1939 can simply listen for messages with the identifier shown in the dialogue, e.g. 0x18FFB53F.

* This will use PGNs within the region allocated to proprietary applications, starting at 0x00FFB53F

6.3 CAN 2.0A and CanOpen

The 11 bit format is designed to be compatible with the CanOpen standard. It can also be used with any system that allows raw CAN-bus 2.0A identifiers to be received.

In order to use 11 bit identifiers (CAN 2.0A) set a value below 0x7ff for the ``Base Address".

For a CanOpen network, use a base address of 0x182 for example. This will result in message IDs corresponding to the CanOpen ``pre-defined connection set".

6.4 CANbus settings

CANbus physical layer	ISO 11898
Protocol type	CAN 2.0B (29 bit identifiers) / CAN 2.0A (11 bit idetifiers)
Baud	User set 1M/800k/500k/250k/125k/100k/50k/20k/10k
Identifier range	User set

6.5 Operation

Typically the installer will have configured the ICS to automatically start continuous testing. At the end of each set test interval (e.g. 2 minutes) the ICS will emit a CAN ``Result Codes" message using the set CAN identifier (e.g. 0x18FFB53F using hexadecimal notation). So a typical CAN message might be:

	Byte							
	1	2	3	4	5	6	7	8
0x18FFB53F	12	8	2					

7. Walkthrough Example

Real applications will generally have an existing CAN network, but in this chapter we show how the ICS can be connected to a PC using a USB:CAN adaptor.

The adaptor used in this example is the ``PCAN-USB", available from Peak System Technik GmbH or a distributor.
We also need to make up a special cable to connect this to the ICS.

PCAN-USB CAN-bus to USB Adaptor

7.1 Equipment required

- ICS with CAN-bus capability
- PCAN-USB USB:CAN Adaptor
- USBi interface for initial ICS setup
- PC with USB ports running Windows
- Special made-up CAN-bus cable detailed below
- 12 or 24 Volt DC power supply

7.2 General settings

Press the Settings button to open the Settings dialogue. The important settings for this walk-through are:

- Test Duration; 10 seconds
- Test Continuously: On, interval 0.
- Start Testing Automatically: On
- Stop Testing When Clean: Off
- Simulate Test: On

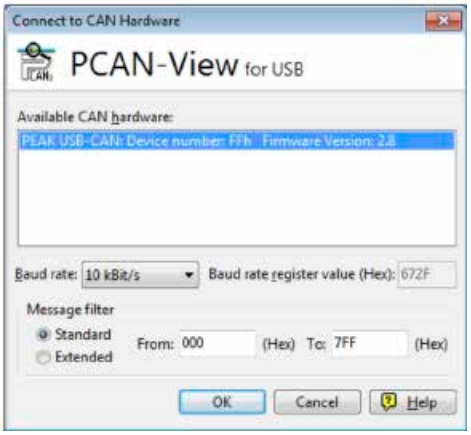
7.3 PCAN-USB Software

The PCAN-USB adaptor comes with a software USB datastick. This includes a simple CAN-bus diagnostic utility called ``PCAN-View USB". This should be installed from the datastick

Connect the ICS to the computer using the special made-up cable and the PCAN-USB.

Power-up the ICS by turning on the power supply.

Upon connecting the PCAN-USB and starting PCAN-View, the Connect dialogue is presented.



Select a baud rate to match that being used on the ICS, for example 250k. Select the ``Extended" message filter (so that 29 bit identifiers are used). Press OK to go to the main PCAN-View screen.

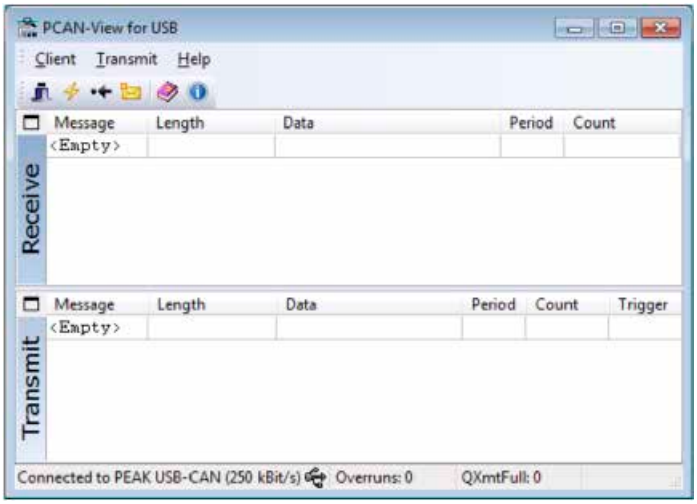
7.4 Simulated Tests

Plug the ICS into its circular connector. It should power up and start performing a test.

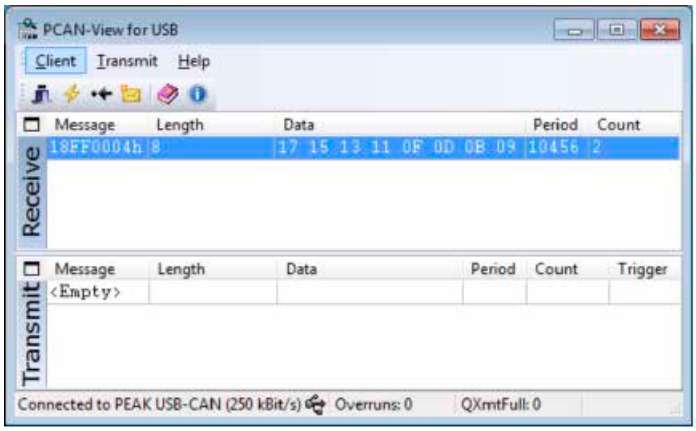
If everything is working, after about 20 seconds you should see CAN messages similar to that shown below.

This shows the 2nd result received. The first 3 bytes 0x17, 0x15, 0x13 show the 3 ISO codes*

**The display is in hexadecimal (base 16) so the actual code are 23/21/19*



PCAN-View Main Screen



Reception of a Test Result Codes Message

7.5 Messages

CAN2.0B and J1939

The ICS CANbus implementation is designed to be interoperable with J1939 networks. This is done by restricting CAN-bus message IDs to those within the proprietary ranges allocated by J1939. Advanced J1939 features have been avoided, so that customers not using J1939 will also be able to communicate using ``generic" CAN-bus frames.

For non-J1939 users the only requirement is that their network should support CAN2.0 (29 bit identifiers).

Broadcast messages use the J1939 PDU2 format. These are transmitted periodically to communicate the ICS status and the latest test results.

Peer-to-peer messages use the J1939 PDU1 format. These are used to control the ICS. These are generally optional; customers may opt to leave the ICS automatically testing and broadcasting results.

J1939 Parameters

Node address (PDU1)	0x3F (J1939 'Oil sensor')
Command and configuration message PGN	0xEF3F
Broadcast Messages PGNS	0xFFB5 - 0xFFB9
Default Broadcast Interval	1s
Data page	0
Priority	6
PDU format / PDU specific	Derived from PGN
Byte Endianness	All data is little-endian byte order

CAN-bus Parameters for J1939 Interoperation

Non-J1939 CAN2.0B Users

- Taken together these imply a generic CAN "base address" of 0x18FFB53F
- Command and control messages can then be sent to CAN address 0x18EF3F00

CAN2.0A and CanOpen

On CanOpen networks the results need to be transmitted as ``process data objects" (PDOs) from the ``predefined connection set". In order to do this, ensure that the set base address is equal to (0x180 + node number). For example, 0x182 to make the ICS node address 2.

CAN-bus Message List

The message ID numbers shown are examples only and are dependent on the set base address.

For CAN2.0A/CanOpen we have an example base address of 0x182. So you see ``2" as the last digit of all the message IDs. Can-Open interprets this as the device node number.

For CAN2.0B/J1939 we have an example base address of 0x18FFB53F. The equivalent node number is ``3F" so you see this appear in all the message IDs.

For other node numbers change the set base address value as required. CanOpen has node numbers from 0x01 to 0x7f. J1939 has node numbers from 0x01 to 0xff.

Parameter Name	CAN2.0A ID	CanOpen PDO	CAN2.0B ID	J1939 PGN
Results Codes	0x182	Transmit PDO 1	0x18FFB53F	0xFFB5
Status	0x282	Transmit PDO 2	0x18FFB63F	0xFFB6
Commands	0x202	Transmit PDO 1	0x18EF3F00	PDU1

CAN-bus Messages

7.6 Message: Result Codes

This message is transmitted after each test.

The test result is expressed as a set of codes in the selected Test Format (ISO4406).
The test result message is always 8 bytes long, with the result codes packed as follows:

FORMAT	ISO 4406
Byte	Code
1	4µm(c)
2	6µm(c)
3	14µm(c)

7.7 Message: Status

The message is transmitted every 1 second so that it can be used as a ``heartbeat".

However if no test has been performed yet, the ICS will wait until it sees other CAN-bus activity before sending anything.

Byte	Bit	Length	Type	Item
1-4	1	32	unsigned	Test Number
5	1	8	unsigned	Status code
6	1	8	unsigned	Completion

Test Number - The current Test Number is an auto-incremented integer or can also be set as part of the Test Start command. This is used to distinguish tests / circuits.

Status Code - This is a number used to indicate the current state of the ICS, or a fault code in the case of a problem being detected. The codes are listed in the STATUS CODE parameter Table below. This allows a system to remotely monitor the ICS operation, if desired, allowing more specific diagnostics.

Completion - A number between 0 and 100 indicating the progress of the test. This will increase from 0 to 100 during the set test time. It can be used to drive a progress indicator.

Status Flags - This is a group of flags indicating test status.

Value	Function	Comment
0	Not ready	Unit is powering-up, or there is some problem
1	Ready	Ready to start a test[1]
2	Testing	Test in progress
3	Waiting	Waiting between tests[2]
128	Fault - Optical	LED failure / sensor blocked / filled with air
129	Fault - Flow Low	Flow too low for reliable test[3]
130	Fault - Flow High	
131	Fault Logging	Fault with data logging

The STATUS CODE Parameter

[1] User has not set tests to occur automatically
[2] User has set a non-zero test interval
[3] Or fluid is totally clean (no particle counts). Flow alarm can be turned off by user if this is a problem, for example cleaning rigs.

7.8 Status Flags Bitmask

This represents the states of various items in a bitmask format.

Bit	Function	Comment
0	RESULT_VALID	Current result is valid
1	RESULT_NEW	A new result is available
2	RESULT_LOG	Current result should be logged
3	TESTING	Test in progress
4	COMPLETE	Test is complete
11	REMOTE_CONTROL	Unit is under remote control
15	UNUSED	Not currently used

Status Flags

Bits 0-2 are so that external equipment (for example external software a PLC/MMI) can display, update and log results intelligently.

Bits 3 and 4 can be used to monitor the test progress.

Bit 11 is used internally to detect that the ICS is being controlled by modbus (from a PLC or by external software).

7.9 Message: Commands

Various commands can be sent to the ICS via CAN-bus.
For J1939 networks Peer-to-Peer (PDU1) Messages are used.
For CanOpen networks Receive Process Data Objects are used.

Command

Byte	Bit	Length	Type	Item
1	1	8	unsigned	Command Byte (0x00)
2	1	8	enum	Command (0,1,2...)
3-6	1	32	unsigned	Parameter

Commands

enum	Function	Parameter
1	Start	Test None
9	Stop Test	—
13(0xd)	Start Test	Fixed Test Number
14	Format	ISO4406 Set ISO4406 result format

8. MODBUS Configuration

8.1 Overview

- Connect the ICM to RS485 port on your Modbus controller (PC or PLC)
- Connect 24V DC power supply
- Configure your controller as a Modbus RTU master, addressing slave address 204

Modbus is a simple, popular, open and freely available protocol for industrial communication.

The ICS incorporates a serial data connection using the Modbus protocol for comprehensive remote control and monitoring. The Windows based CMPView software package is provided as a ready-made, dedicated solution.

However an alternative is to directly implement Modbus in the customers' own application. The Modbus controller can be a PLC or PC, allowing the ICS to be fully integrated into the machine control system.

The responsibilities of a customer implementation can be as simple as continuously reading the current contamination class from a Modbus `register'.

8.2 Use PC software for configuration

The free CMPView software package can act as is a ready-made Modbus controller for the ICS - even if a customer intends to implement their own Modbus system,

We suggest that CMPView is used initially to check the ICS configuration and to verify correct operation.

Where possible, the easiest approach is to use CMPView to configure the test parameters and result format. Then the customer application only has to read the results, and optionally perhaps signal the test start.

8.3 Electrical Connection

This user guide assumes a Modbus network consisting of a Controller (PC or PLC) connected to a single ICS. It is also possible to share the network with other ICS units or other devices, providing these are allocated separate node addresses.

More details can be provided on request.

The ICS requires a DC power supply and the two Modbus RS485 signals.

- The DC voltage is typically 24V
- Twisted pair cable should be used for the RS485 signals, for cable lengths over a few meters
- Cable lengths over a few meters should have termination resistors at each end
- These consist of, typically, 100Ω resistors connected across the two Modbus signals (DATA+ and DATA-)

9. MODBUS Operation

9.1 MODBUS settings

Protocol type	RTU (not ASCII)
Data bits	8
Stop bits	1
Parity	Required, Even
Baud	Auto-sensing 1200-115200
Signalling	RS485
Node Address	4 (or user set)

9.2 Communications check

You should be able to read the product ID code from register 0 (from Modbus node address 204). The product ID code is the value 54237 (decimal) or 0xD3DD (hexadecimal)

9.3 Result format

The ICS presents results in ISO 4406 format.

9.4 Result codes

The most recent measurements are presented as numeric codes (i.e. numbers) according to the the selected TEST FORMAT. These codes can be read from registers 56-58, as per the table below:

Register	ISO4406 code
56	≥4 µ
57	≥6 µ
58	≥14 µ

9.4.1 Null values

For all formats, the special value -32768 (0x8000 hex) is used to represent a `null' or `no result' condition. This enables `No Result' to be distinguished from a 0/0/0 ISO code, for example. `No Result' could be due to an error condition, or to a measurement not having been commanded yet.

This convention is also used for other parameters such as temperature and water content measurements, where applicable. *User written programs should take note, to avoid displays like -32768/-32768/-32768 appearing on their front panels.*

9.4.2 ISO 4406

ISO 4406 defines a set of code values to represent ranges of counts of particles greater than the nominated sizes of ≥4,≥6 and ≥14µm(c). The ICS can display codes from 0 to 24. The three-part code is available in the first 3 RESULT CODES.

9.4.3 Test Status

A test status code is available in register 30. This contains a number indicating the current state of the ICS. This allows a system to remotely monitor the ICS operation, if desired, allowing more specific diagnostics.

Value	Function	Comment
0	Not ready	Unit is powering-up, or there is some problem
1	Ready	Ready to start a test (User has not set tests to occur automatically)
2	Testing	Test in progress
3	Waiting	Waiting between tests (User has set a non-zero test interval.)
128	Fault optical	LED failure / sensor blocked / filled with air
129	Fault flow low	Flow too low for reliable test. (Or fluid is totally clean (no particle counts). Flow alarm can be turned off by user if this is a problem,for example cleaning rigs.)
130	Fault flow high	

9.4.4 Test Completion

The TEST COMPLETION is indicated by register 36. This contains a number between 0 and 1000 indicating the test progress. CMPView uses this to drive the test progress bar graph.

10. Reference

10.1 Modbus Node Addressing

Modbus requests are sent to the configured ICS node address. If there is only one ICS on network segment, then the ``Permanent Address" of 204 can be used. If there is more than one, then unique node addresses must be configured for each.

This is not part of the Modbus specification (and in fact violates it). The ICS will always respond on node address 204, in addition to the other set value. This has been done so that CMPView can connect directly without configuration or scanning of the network.

10.2 MODBUS settings

Protocol type	RTU (not ASCII)
Parity	Even
Baud	Auto-sensing 1200-115200
Signalling	RS485
Node Address	Factory set to 4. User settable 1-254
Permanent address	204

10.3 General Description

The ICS is a Modbus Slave. That is, it responds only to commands sent to it by the Modbus controller (the Modbus Master). The controller can be a program running on a PC, or a PLC.

The Master periodically sends a Modbus command ``frame" to the ICS node address.

The ICS acknowledges each request with a response frame.

10.4 Modbus registers

The Modbus protocol defines many types of information interchange commands (`function codes'). However in order to simplify implementation the ICS only uses one type - the Modbus `Register'. Conceptually the ICS appears as a collection of Modbus Registers. Each register is numbered.

10.5 Modbus Register Numbering

Addresses shown here are those appearing ``on the wire". Unfortunately some Modbus controllers may translate these addresses to different ones. For example for some controllers the user will need to use ``addresses" starting at 40000 instead of 0.

The ICS uses the registers from 0-124. This allows all registers to fit in a single Modbus frame Registers can be divided into classes as follows:

Status Registers

These are ``read-only" registers that indicate test results and ICS status. They can be read freely at any time (although test results are only valid after a successful test).

Setting Registers

These are read-write registers used to hold the ICS settings. Take care not to inadvertently write to any of these registers since the ICS settings will be altered!

Some `Setting' registers also change by themselves, for example the test number register can be set, but will also automatically increment after each test.

Calibration Registers

Some registers, not documented here, are protected settings that can only be altered during factory calibration.

10.6 Modbus Register Table

Number	Function	Units	Representation
0	Product ID		Unsigned integer
1	Protocol ID		Unsigned integer
2	Firmware Version	x100	Unsigned integer
3	Hardware Options		Bitmap
4-5	Machine Serial Number		32 bit unsigned integer
6	Modbus Address		Integer
10-17	Test Reference		Array of 16 packed characters
18	Test Duration	S	Unsigned integer
19	Test Format		Integer
30	Status		Unsigned integer
31	Status Flags		Bitmap Unsigned integer
32	LED Levels		Unsigned integer
35	Peak Pulse		Unsigned integer
36	Test Completion		Unsigned integer
37	Flow Indication		Unsigned integer
56-63	Result Codes		Array of 8 signed integers
117-118	Calibration Due		
119-120	Calibration Last		

Modus Registers

All quantities are represented using Modbus registers. Modbus registers are 16 bit (0-65535 decimal or 0-0xFFFF in hexadecimal notation).

Unsigned Integers

These are simply single modbus registers. Each can take values from 0 to 65535.

They may be simple numeric quantities such as ``test time in seconds". They can also be enumerations such as `result format' where `0' means ISO4406

Signed Integers

These are used for quantities that may become negative, such as °C.
Signed integers are represented in single modbus registers using the `twos complement' standard, as usual in computing. If a user-written program incorrectly interprets a signed integer as unsigned, then positive numbers will still be interpreted correctly. However small negative numbers will appear as large positive ones. In particular, -1 appears as 65535 and -2 as 65534.

32 Bit Unsigned Integers

Some quantities are (or may become) too large to fit into a single 16-bit register. For example the Test Number could eventually increment to more than 65535. These items are represented using two consecutive registers; the combination makes up a 32-bit integer.
For example, the value of such a 32 bit unsigned integer stored in registers 8-9 may be calculated using the formula:
value = (65536 × (register 8)) + (register 9)

Bitmaps

Bitmaps are again single 16-bit Modbus registers, but they have a special interpretation.

Each ``bit" in the register has a separate function. The most important example is the `status flags' register (31). Each register bit encodes a separate function, for example `result valid', 'new result', `over temperature alarm' etc. In this document bits are numbered starting with bit 0 = least significant bit.
A user programming environment such as a PLC programming system or a high level computer language will normally have functions that allow easy access of individual bit values in a register.

Arrays

An Array is simply a sequence of objects packed in consecutive registers. For example the ``result codes" are in an array of 8 registers. Code[0] is in register 56, code[1] is in register 57 etc.

In the case of an array of 32-bit integers, each element itself takes up 2 registers, so there are are twice as many registers used as elements in the array. In the case of the particle counts array, there are 8 particle sizes counted so these are stored in 8 × 2 = 16 registers.

Packed Characters

These are used to encode the user-settable ``test reference" string, used to label each test. Characters are packed two per Modbus register. This will probably not be used in a user-written Modbus program, but in principle the test reference could be set to a different value for each test. The test reference string consists of of 16 characters packed into an array of 8 consecutive registers.

10.7 Register Functions

Test Mode

Factory set value: 0

This is the test mode, each bit represents an option corresponding to a tickbox on the ICS settings screen (see our CMPView software).

Each bit of the register encodes one tickbox.

The factory set mode is 0 for all bits, so all the tickboxes are turned off. You may want to turn on bit 8 (disable low flow alarm when clean) if you have a very clean system.

Here are the bit definitions:

Bit	Function	Comment
0	Cycle_Continuous	Continuous Testing
7	Simulate	Produces simulated test results
8	Low-Flow_Clean_Disabled	Prevents spurious low flow alarms on clean systems

10.8 Status Register

This is read-only register 30. It contains a number (an enumeration) indicating the status of the ICS.

Value	Function	Comment
0	Not Ready	Unit is powering-up, or there is some problem
1	Ready	Ready to start a test (User has not set tests to occur automatically)
2	Testing	Test in progress
3	Waiting	Waiting between tests (User has set a non-zero test interval)
128	Fault Optical	LED failure / sensor blocked / filled with air
129	Fault Flow Low	Flow too low for reliable test (Or fluid is totally clean (no particle counts). Flow alarm can be turned off by user if this is a problem, for example cleaning rigs)
130	Fault Flow High	

Status Flags Bitmap

This is read-only register 31. It represents the states of various items in a bitmap format.

Bits 0-2 are so that external equipment (for example LPA-View or a PLC/MMI) can display, update and log results intelligently.

Bits 3 and 4 can be used to monitor the test progress.

Bits 5-10 are used to generate alarms. Depending on the selected alarm mode, they operate the alarm relay output(s). But they can also be monitored directly by a PLC/MMI program and used to drive indicators, for example.

Bit 11 is used internally to detect that the ICM is being controlled by modbus (froma PLC or by LPA-View).

Finally bits 12-14 reflect the state of the ICS `start signal' input and alarm output relays.

Bit	Function	Comment
0	Result_Valid	Current result is valid
1	Result_New	New result available
2	Result_Log	Current result should be logged
3	Testing	Test in progress
4	Complete	Test complete

Fault Flags Bitmap

This is read-only register 28XIV. It represents detected device or installation faults in a bitmap format. The faults are also available as result codes in the status register, however those are transient and may only appear briefly before a new test is started.

The fault bits here remain until the end of the next test (where they may be cleared if the fault has gone).

Bit	Function	Comment
0	Optical Fault	Current result is valid
1	Low-Flow	New result available
2	High_Flow	Current result should be logged

See table in 10.7 for information

Result Codes

The test result ``codes" use up to 8 registers 56-58.

The interpretation of these result code registers depends on the selected result format.

The various interpretations are listed in the following table.

Register	ISO4406 code
56	≥ 4 µm
57	≥6 µm
58	≥14 µm

11. Implementing MODBUS

This section is for advanced users who wish to do their own programming to implement the modbus controller. It is not needed if the users control system already has direct support for being a modbus master. The following describes a minimal system capable of periodically reading data from the ICS, it is not intended as a general purpose modbus implementation.

For a background to this section the implementor can review the modbus source documents:

http://www.modbus.org/docs/Modbus_over_serial_line_V1.pdf

http://www.modbus.org/docs/Modbus_Application_Protocol_V1_1b.pdf

In order to collect data from the ICS, the users control system needs to be able to send a modbus command frame and receive a response frame via the RS485 signals.

A frame consists of a sequence of bytes, transmitted back-to-back over the RS485 interface.

A command frame can be generated corresponding to a modbus `read registers'

command. Using hexadecimal notation, the sequence required to return all registers would be a sequence of 8 bytes:

<0xCC> <0x04> <0x00> <0x00> <0x00> <0x7D> <0x20> <0x36>

This sequence is decoded by the ICS as:

<0xCC> = <slave address>

<0x04> = <function code:read registers>

<0x00> <0x00> = <start register high> <start register low> (2 bytes)

<0x00> <0x7D> = <number of registers high> <number of registers low> (2 bytes)

<0x20> <0x36> = <checksum high> <checksum low> (2 bytes)

The ICS will then return a 255 byte long response frame containing the requested register contents.

This 255 byte response frame looks like:

<0xCC> <0x04> <0xfa> <250 bytes of data> <2 bytes of checksum>

The <250 bytes of data> contains the contents of the 125 registers requested. Each 16 bit register is encoded in two sequential bytes, in high-low (`big-endian') order.

The simplest method is then to read the required registers directly out of the data area of this response frame. For example, the ICS product ID code appears in modbus register 0. This would therefore appear in the first two bytes of the data area above, or at the 4th and 5th bytes counting from the start of the frame. In a programming language like ``C" the product ID could be extracted from an array containing the frame using a statement like:

unsigned product_id = 256*buf[3+0] + buf[3+1];

Users of PLCs or other programming languages will hopefully be able to translate using the information provided here.

The ICS product ID is 0xD3DD (hexadecimal) or 54237 (decimal). This fact can be used as a check when attempting the above implementation.

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