KROHNE

CORIMASS

KROHNE SMART HART®

Instruction Manual

Instructions to use with

Krohne SMART or HART® Communications Protocol

and

MFC 081 / 085 Mass Flow Converters

WE'VE GOT HART FIELD COMMUNICATIONS PROTOCOL ABILITY

Hart is a registered trademark of the HART Communication Foundation

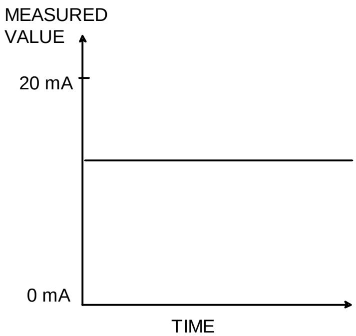
Contents

1. The Krohne SMART System

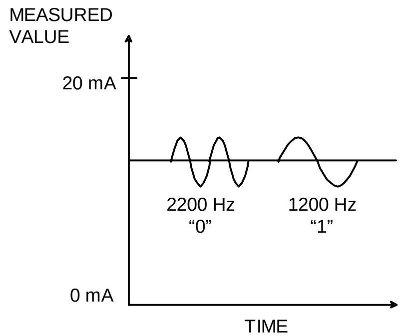
1.1 Description of operation

The interface for the Krohne Smart system is the current output. Bi-directional information can be transmitted via the current output cables. The current output signal (0/4 to 20 mA is not affected because the mean value of the signal containing the digital information is equal to zero.

The signals are superimposed by means of frequency shift keying (FSK), based on the Bell 202 communication standard. The digital transmission signal is formed from two frequencies: 2200 Hz = “0” and 1200 Hz = “1”.



CONVENTIONAL



SMART FSK MODE

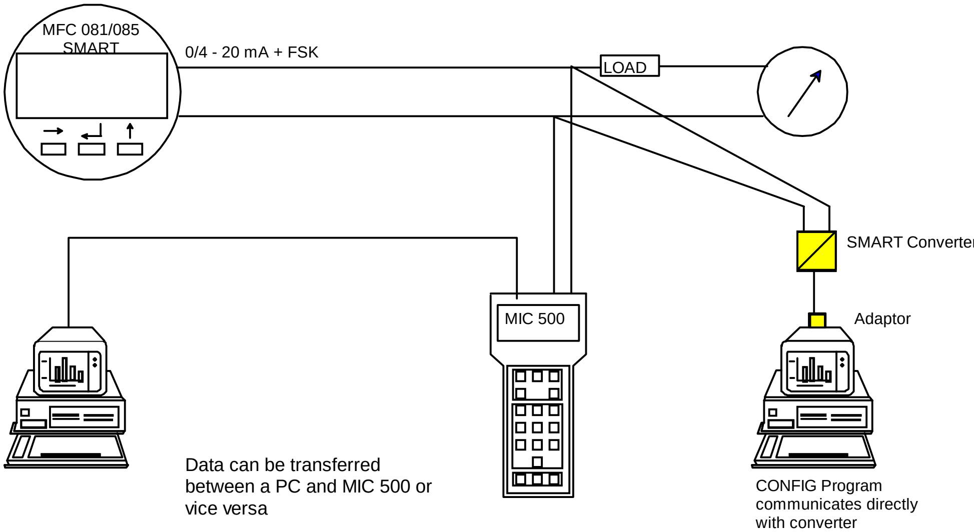
The Smart technology will enable you to utilize its advantages for initial start up, maintenance work and to change settings. All parameters for new measuring devices (in this case, the mass flow meter or meters) or those to be changed can be defined and entered into the PC in the workshop. The stored data can then be downloaded to the mass flow meter and started up from the control room (via the cable marshalling rack).

The same applies to operation and maintenance. The status of the mass flow meter can be displayed on-line, or in test mode, the current output can be set to a specific value or values in order to test the whole circuit. If a converter is replaced, the parameter set from the data base (PC) can be downloaded into the new converter. This eliminates time consuming data entry and programming. The possibility of errors being incurred during programming is also eliminated.

1.2 SMART overview

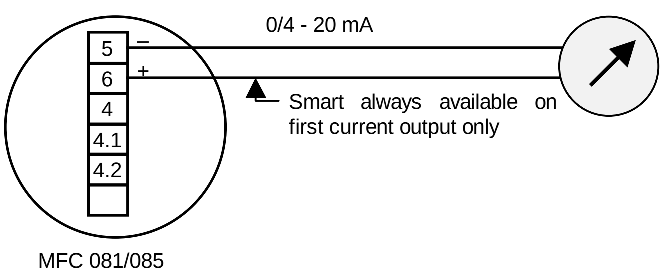
All Krohne Smart signal converters may be operated via PC. The transmission route may be up to 1600 m / 5250 ft long. The load between the coupling part of the PC and the converter output loop should be at least 100 ohms.

Note: This protocol is not compatible with HART ® even though it uses a similar method of communication.



1.3 Connecting the PC

The PC can only be connected to the first current output of the MFC 081/085, i.e. current output from terminals (5 (–) and 6 (+). The other current outputs that may be available (depending on options ordered) will not carry the FSK signal and the Smart system will not work. If another communication protocol option has been ordered, e.g. RS 485 or Profibus, then the Smart system will be inactive as the processor will only accommodate one communication protocol at a time.



Note:
This communication protocol is a Krohne designed protocol and for use with Krohne CONFIG Software package and not intended for use on non-Krohne equipment. The protocol description is thus also not available for distribution.

1.4 PC CONFIG Software package

The VDI/VDE-GMA 2187 Guideline issued in Germany is the first attempt to define a mode of operation for signal converters including those of different makes. The operating unit is the PC through which the all Krohne Smart converters can be controlled and programmed. The signal converters are linked via a RS 232 interface at the PC. All Krohne Smart transducers can be operated using the Krohne PC “CONFIG” operator package.

Minimum PC requirements

- PC, personal computer, with MSDos or compatible operating system
- Disk drive: 3½”
- Screen mode with 25 × 80 characters
- Serial interface RS 232
- No special requirements imposed on graphic adaptor (Hercules, EGA, VGA, etc.), the CONFIG program operates in the text mode so older PC’s can also be used.

Items supplied with Krohne PC operator package CONFIG

- 1 × 3½” diskette with complete CONFIG software
- Smart converter or RS 232 adaptor (or RS 232 - RS 485 converter on request)
- Smart cable, link between current output and Smart converter
- Adaptor for 25-pin RS 232 interface at PC

Screen layout, operator control and functions

- Operation via mouse or keyboard and hot keys
- Screen layout and operator control modelled on the Microsoft Windows user interface
- Connection set-up to Smart signal converters or the MIC 500 hand-held communicator
- Diagnostics, detailed presentation of signal converter messages, and call of simulation functions (tests)
- Change, compare, print and store instrument parameters
- Dynamic representation of measured values and signal converter status

1.5 Further Instruction Manuals

Krohne PC CONFIG Operating Manual Order No. 7.02196.71.00

These manuals should accompany the equipment when ordered.

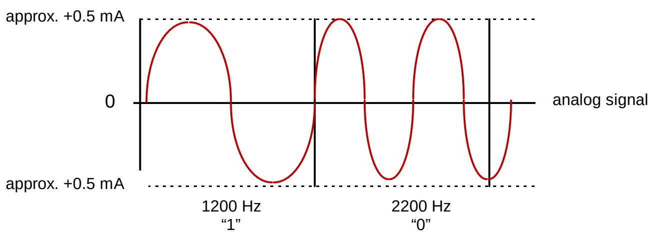
2. The HART® Protocol

2.1 Method of Operation

The HART® protocol operates using the frequency shift keying (FSK) principle, which is based on the Bell 202 [1] communication standard. The digital signal is made up from two frequencies - 1200 Hz and 2200 Hz, representing bits 1 and 0 respectively. Sine waves of these frequencies are superimposed on the DC analog signal cables to give simultaneous analog and digital communications. Because the average value of the FSK signal is always zero, the 4 - 20 mA signal is not affected.

This produces genuine, simultaneous communication with a response time of approximately 500 ms for each field device, without interrupting any analog signal transmission that might be taking place.

Up to two master devices may be connected to each HART® loop. The primary one is generally a management system or a PC while the secondary one can be a hand-held terminal or laptop computer. A standard hand-held terminal - called the HART® Communicator - is available to make field operations as uniform as possible. Further networking options are provided by gateways.



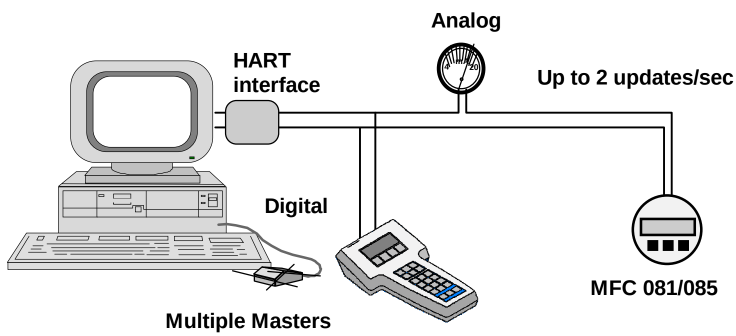
Simultaneous analog and digital signals

Because the mean harmonic signal value is zero, digital communication makes no difference to any existing analog signal as demonstrated in the figure above.

2.2 Point to point operation

The figure below shows some examples of point-to-point mode. The conventional 4 - 20 mA signal continues to be used for analog transmission while measurement, adjustment and equipment data is transferred digitally.

The analog signal remains unaffected and can be used for control in the normal way. HART® data gives access to maintenance, diagnostic and other operational data.



2.3 HART® Protocol Structure

HART® follows the basic Open Systems Interconnection (OSI) reference model, developed by the International Organisation for Standardisation (ISO) [3]. The OSI model provides the structure and elements of a communication system. The HART® protocol uses a reduced OSI model, implementing only layers 1,2 and 7.

OSI Reference Model
Open Systems Interconnection

	Layer	Function	HART®
7	Application	provides formatted data	HART instructions
6	Presentation	converts data	
5	Session	handles the dialogue	
4	Transport	secures the transport connection	
3	Network	establishes network connections	
2	Link	establishes the data link connection	HART protocol regulations
1	Physical	connects the equipment	Bell 202

The HART® *protocol implements layers 1,2 and 7 from the OSI model*

Layer 1, the Physical layer, operates on the FSK principle, based on the Bell 202 communication standard:

Data transfer rate: 1200 bit/s
Logic '0' frequency: 2200 Hz
Logic '1' frequency: 1200 Hz

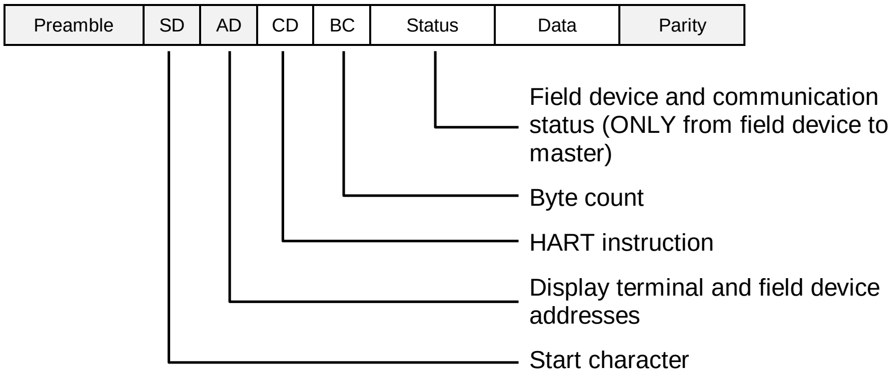
The vast majority of existing wiring is used for this type of digital communication. For short distances, unshielded, 0.2 mm^2 two-wire lines are suitable. For longer distances (up to 1500 m), single, shielded bundles of 0.2 mm^2 twisted pairs can be used. Beyond this, distances up to 3000 m can be covered using single, shielded, twisted 0.5 mm^2 pairs.

A minimum resistance of 230 ohms must be available in the communication circuit.

Layer 2, the Link layer, establishes the format for a HART® message. HART® is a master/slave protocol. All the communication activities originate from a master, e.g. a display terminal. This addresses a field device (slave), which interprets the command message and sends a response.

The structure of these messages can be seen in the figure below. In multi-drop mode this can accommodate the addresses for several field devices and terminals.

Structure of a HART® message



The HART message structure offers a high degree of data integrity

A specific size of operand is required to enable the field device to carry out the HART instruction. The byte count indicates the number of subsequent status and data bytes.

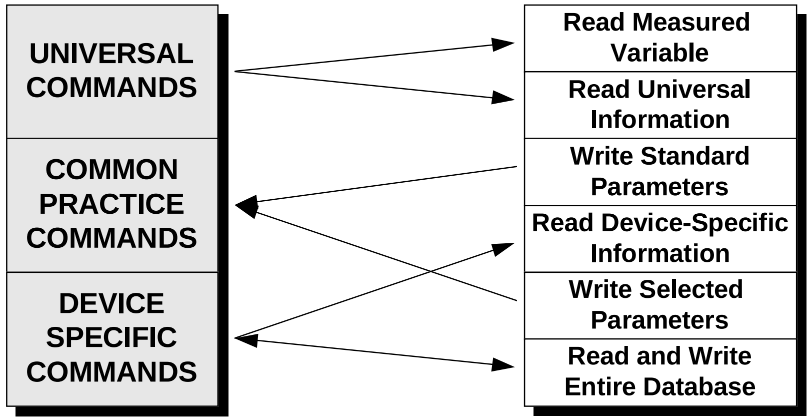
Layer 2 improves transmission reliability by adding the parity character derived from all the preceding characters; each character also receives a bit for odd parity.

The individual characters are:
1 start bit
8 data bits
1 bit for odd parity
1 stop bit

Layer 7, the Application layer, brings the HART instruction set into play. The master sends messages with requests for specified values, actual values and any other data or parameters available from the device. The field device interprets these instructions as defined in the HART protocol. The response message provides the master with status information and data from the slave.

To make interaction between HART compatible devices as efficient as possible, classes of conformity have been established for masters, and classes of commands for slaves. There are six classes of conformity for a master as seen in the figure below.

Classes of instruction and classes of conformity



For slave devices, logical, uniform communication is provided by the following command sets:

Universal commands
understood by all field devices

Common practice commands
provide functions which can be carried out by many, though not all, field devices. Together, these commands comprise a library of the most common field device functions.

Device-specific commands
provide functions which are restricted to an individual device, permitting special features to be incorporated that are accessible by all users.

Examples of all three command sets can usually be found in a field device, including all universal commands, some common-practice commands and any necessary device-specific commands.

2.4 Hand-held Communicator

A standard HART® hand-held communicator may be used on Krohne equipment. The operating instructions for this communicator is not supplied by Krohne and should accompany the hand-held communicator when purchased.

A HART® Communicator is available from Krohne and may be purchased with all customer requested DDL's already downloaded to the instrument.

The Krohne CONFIG software package can also be supplied for HART® compatible instruments. The functions are similar to that described in Sect. 1.4 (available end 1996).

Further information on HART® may be found in the HART® Field Communication Protocol book available on request.

The Corimass MFC 081/085 HART® protocol is available from Krohne on request. Should you require any further information, please contact your nearest Krohne office or Product Management in Duisburg, Germany.

Krohne RS 485
Bus-Protocol

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Contents

1. General

The Mass flow Converter, MFC 081/085 with RS 485 interface fitted, is able to communicate with an external device (PC or other suitable computer system). This option allows data exchange between PC or computer and single or multiple devices.

The Bus configuration consists of one external device as a master and one or more converters (MFC 081 or MFC 085) as slaves. For Bus operation the device address and baud rate must be programmedin the menu 3.11.0 of the MFC 081/085. Devices connected to the Bus must have different or unique addresses and the same baud rate.

The transmission uses 8 (eight) data bits, even parity and 2 (two) stop bits at a selectable baud rate of 1200 to 19 200.

2. Technical Specifications

Interface	RS 485, potential isolated
Baud rate	1200, 2400, 4800,9600,19200 baud
Maximum participants on Bus	32 per line,master included (may be extended by repeaters)
Coding	NRZ bit coding
Address range	0 - 239
Transmission procedure	half duplex, asynchronous
Bus access	master/slave
Protocol	Krohne RS 485 Communication Bus Protocol (Available as a separate instruction document on request)
Cable	screened twisted pair cable
Distances	maximum 1.2 km without repeater. (Dependant on baud rate and cable specifications)

Technical data of the RS 485 interface (according to EIA standards)

Kind of signal transmission:	differential
Maximum number of transmitter/receivers:	32
Maximum voltage on driver output:	–7 V to +12 V
Minimum voltage on driver output, max.load:	U diff > 1,5 V
Maximum input current (off state)	–20 to +20 • A
Receiver input voltage	–7 V to +12 V
Sensitivity of the receiver	–200 mV to +200 mV
Receiver input resistance	> 12 k ohm
Short circuit current of transmission	< 250 mA

3. Connection of instruments on the Bus system

The following terminals are used in the MFC 081/085 converters for the signal receive (Rx), transmission (Tx) and ground.

3.1 Single Master/Slave configuration (Non Ex applications only)

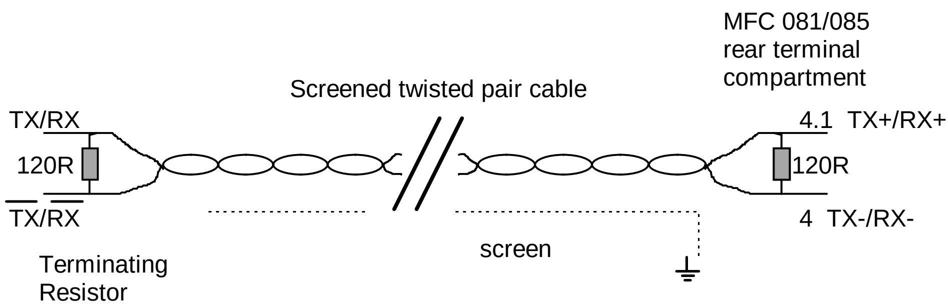


Fig. 1

Notes:

1. Terminating resistors to be used at both ends.
2. Terminating resistors to be mounted externally between terminals 4 and 4.1 if not internally connected.
3. For Ex instruments the terminating resistors **must** be internally connected. (See section below).

3.2 Single Master/Slave configuration (Ex applications)

For Ex instruments the termination resistor has to be inside the pressure tight section of the housing. A terminating resistor is already supplied on the RS 485 module and only needs to be enabled by soldering the two solder pads together (Fig. 2) or enabling the jumper which is supplied on modules of a later design. (Fig. 3)

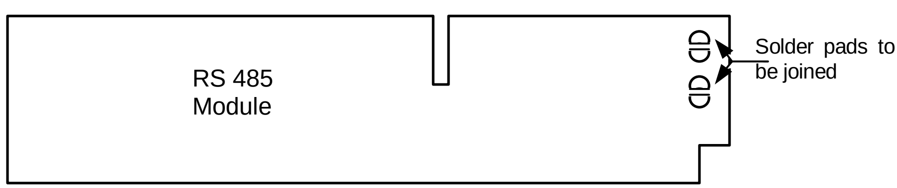


Fig. 2

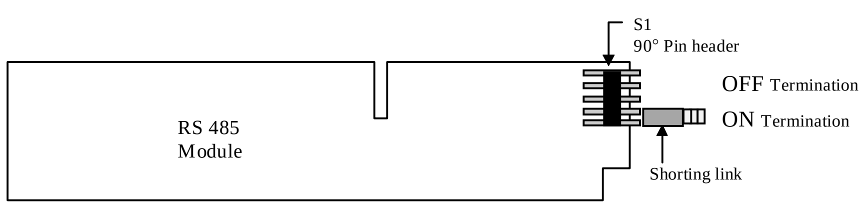


Fig. 3

3.3 Multi-drop applications

RS 485 allows multiple instruments to be connected in half duplex on a single twisted wire pair for “party line” type of communications. A method must be used to stop more than one instrument being online at any time, ensuring that all other instruments are in a high impedance state. No damage is done when more than one instrument is online simultaneously, but data will be lost.

In a multiple RS 485 transmitter installation, the application program controls the bi-directional data communication and selects the instrument to be addressed.

The program control used should be a “master/slave” method. The “master/slave” method designates one device on the network as master, and this device supervises all transmissions by communicating with each of the slaves in turn and offering it a transmission slot.

3.4 Bus termination

For proper operation of the RS 485 Bus in half duplex mode in single or multi-drop communication, it is recommended that a termination resistor (typically 120 ohm) is applied to both ends of the data line. The simplest form of termination is line to line resistor across the differential input.

In a multi-drop system, the terminator resistors are only required at the ends of the bus, usually the master and the last device on the line. The devices in-between do not require termination.

The Bus configurations are shown in Fig. 4 and Fig. 5.

Configuration with single slave:

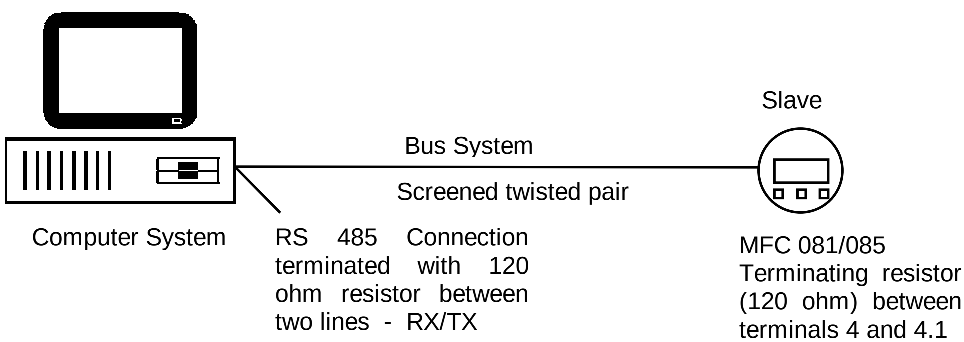


Fig. 4

Configuration with multiple slaves:

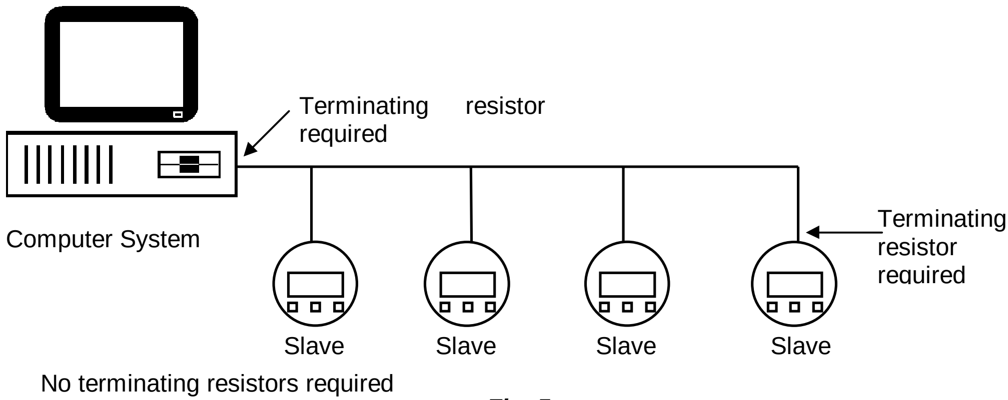


Fig. 5

Please note: If other instruments are to operate on the same Bus, all the devices must use the same communication protocol.

To avoid interfering signal reflections from the ends of the Bus line, both ends (at computer system as well as at the last instrument) should be terminated with the typical line resistance value of 120 ohm.

3.5 Network Biasing Resistors

In RS 485 multi-drop operation, noise may be detected at the master. In a multi-drop configuration there can be brief periods when no instrument is enabled or addressed, and the network is therefore allowed to float. Some devices on the network may then be susceptible to noise and may be liable to float to a potential that is detected as an input.

If this problem is encountered, two extra resistors can be added externally to one end of the Bus, so that the network is biased to a value of approximately 1 Volt when all devices are disabled. For non-Ex systems, resistors could be added to the last MFC 081/085 device as shown in Fig. 6 or to the Master (PC).

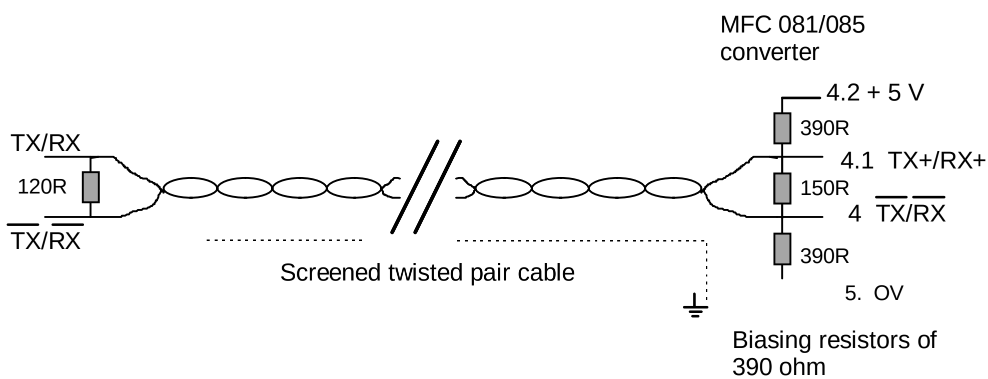


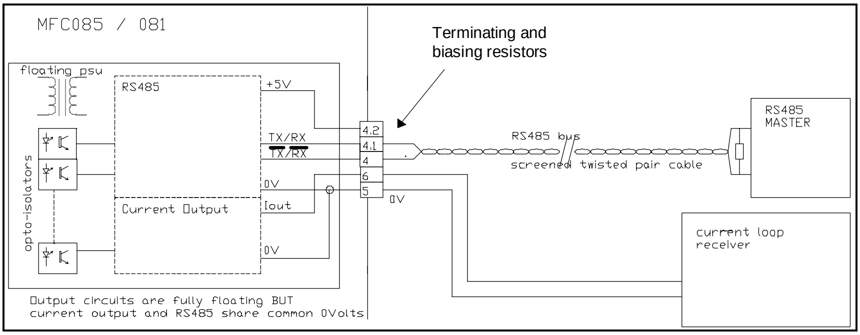
Fig. 6

However, for Ex systems, adding resistors within the terminal compartment is not allowed as this would contravene the Ex requirements. In this case the biasing resistors should be added at the Master's end of the bus, provided it is located in a safe area.

4. Using the Current Output with the RS 485 Bus

The MFC 081/085 Converter is fitted with one current output in addition to the RS 485 connection. This current loop is connected between terminals 6, Iout, and 5, 0 volts (refer to the normal Installation and Operating manual). However extra care must be taken when connecting this output.

The MFC 081/085 output circuitry is fully floating. It is galvanically isolated from protective earth, PE and from the converter's power supply. (See below).



If just the RS 485 bus is connected then the converter's output circuitry will float to the potential of the bus. However the current output shares a common 0 volt reference with the RS 485 output and hence also with the bus**. The current loop receiver must therefore have a fully floating input.** If not it will try to drag the RS 485 bus to some potential of its own. This could in turn result in interference with stable operation of either, or both of the current loop and the RS 485 bus.

5. Converter Configuration

Setting up the RS 485 System:

Use the 3.11.0 Serial I/O menu to set up the RS 485 communications:

Fct. 3.11.0	Serial I/O
Fct. 3.11.1	Protocol Select OFF to disable communications or "KROHNE" to use the Krohne Bus Protocol.
Fct. 3.11.2	Address Enter an address number between 0 and 239. The converter will only respond to Bus messages which have a matching address.
Fct. 3.11.3	Baudrate Select the required communications baudrate from the following list: 1200, 2400, 4800, 9600, 19200

If the instrument is connected correctly, it should now communicate with an external master.

6. Transmission format

The data string has the following format:

syn	...	syn	STX	< Data-Field >	CS	ETX

The transmission is initiated through an arbitrary number (at least 3) of Synchronisation bytes. (Syn hex 16). This initialises the receiver to receive a data string. The string itself begins with a start byte (STX, Hex 16) followed by the data field. The transmission is concluded with a verification sum (Check sum, CS) and the end byte (ETX Hex 3).

The checksum byte is the sum [module 256 of all the bytes in the bus telegram (including STX)] plus the number of bytes.

If one of the control characters (Syn, STX, ETX) appears in the data field or in the check sum, then the symbol DLE (Hex 10) is placed in front of it. This is true for the symbol DLE itself. These intentional prefix symbols are not entered in the check sum.

Examples (all values in hex code):

```
 16 –  16 –  16 –  02 – AO – 01 – 6F – 07 – 1E – 03
Syn   Syn   Syn   STX  DEV  ADR  VER  FKT  CS   ETX

 16 –  16 –  16 –  02 – AO – 10 – 03 – 6F – 07 – 20 – 03
Syn m Syn m Syn m STX  DEV  DLE  ADR  VER  FKT  CS   ETX
```

Address 03 represented as DL03
DLE is not included in checksum calculation

7. Format of the data field

The data field format for Bus transmission is as follows:

DEV	ADR	VER	FKT	< Parameter - Field >

The device code byte (DEV) recognises the unique code assigned to the particular type of KROHNE device connected to the Bus. For MFC 085 this code is OAO hex, and OA1 for the MFC 081.

The address byte (ADR) contains the bus address of the requested device. Values from 0 to 239 (0 hex to 0EF hex) are permissible. Addresses 240 to 255 are reserved for special functions.

The version byte (VER) is relevant only for acknowledgement purposes. In a acknowledgement request it may be set to an arbitrary value. This field is a composite one: bits 5 - 7 define the version number of the device software, bits 0 - 4 subversion number, e.g. a device with version 3.15 Software will acknowledge in VER field as 6F hex.

The function byte (FKT), like the VER byte, is also split into two fields: bits 5 - 7 define a generalised function which will later on be referred to as **Function**, while bits 0 - 5 define additional identification information being either a logical address of a device data block or descriptor of a special request to device (like calibration, quit errors, etc.). These latter 5 bits will later be referred to as **Subfunction**. For complete list of FKT-driven functionality refer to the **Function Byte Codes** table in the protocol manual.

Device response time depends on requested operation:

- Read measurement block ≈ 20 msec
- Read single static block ≈ 5 msec
- Write single block ≈ 200 msec
- Write two blocks ≈ 400 msec

In a case where a special operation is requested that deals with complete device reset, bus-connection will be lost until the instrument bypass re-initialisation.

8. Format of the Data Blocks

8.1 Measurement Block, Function Code (FKT) = OO Hex

Offset	Variable/Format	Length	Meaning
0	drive_level (int, LSB first)	2	Installation factor
2	mass_flow_rate_LPF (float, inversed IEEE 754)	4	Mass flow in g/sec
6	master_total (double, LSB first)	8	Mass totalizer in g
14/0E hex	volume_total (float, inversed IEEE 754)	4	Volume totalizer in cm^3
18/12 hex	tube_temperature (int, LSB first)	2	Temperature in °C × 10
20/14 hex	strain (int, LSB first)	2	Strain gauge in Ω × 20
22/16 hex	frequency (float, inversed IEEE 754)	4	Resonant frequency in Hz
26/1A	density_LPF (float, inversed IEEE 754)	4	Fluid density in g/cm^3
30/1E hex	zeroadj_flow_LPF (float, inversed IEEE 754)	4	Mass flow in g/sec. Valid during zero calibrations
34/22 hex	phase (float, inversed IEEE 754)	4	Raw sensor phase in radians. Used for debug purposes.
38/26 hex	percentage_by_vol float, inversed IEEE 754)	4	Valid only for General Concentration option. Units: 0.01% (thus a value of 1.0 corresponds to 100%)
42/2A hex	percentage_by_mass (float, inversed IEEE 754)	4	Valid if any concentration option is active. Units: 0.01 of concentration unit related to option. i.e. a value of 1.0 corresponds to: 100% for General Concentration 100°Brix for Brix Concentration 100°Baumé for Baumé Concentration
46/2E hex	solid_flow_rate (float, inversed IEEE 754)	4	Valid if any Concentration option is active in g/sec.
50/32 hex	sum_angle (float, inversed IEEE 754)	4	Used for debug purposes
54/36 hex	converter_status (byte)	4	Refer to *actual_errors* field of Error list (section 7.2)
58/3A hex	system_state (byte)	1	Instrument state 1 - Stop 2 - Startup 3 - Measurement 5 - Standby 6 - Calibration
59/3B hex	r1 (float, inversed IEEE 754)	4	Used for maintenance service
63/3F hex	r2 (float, inversed IEEE 754	4	Used by maintenance service
67/43 hex	reserved	8	

8.2 Error list, Function Code (FKT) = OA Hex

Offset	Variable/Format	Length	Meaning
0	actual_errors (long, LSB first)	4	Actual error messages: Bit 0 : Mass Flow (Measured flow > 2 nominal flows of primary head Bit 1 : Zero Error (Excessive flow measured during zero calibration Bit 2 : Totalizer Overflow (Fixed precision totalizer has rolled over) Bit 3 : Frequency Bit 4 : Temperature (measured temperature > 180°C or < –25°C Bit 5 : Sensor A OOR (Sensor A signal too small) Bit 6 : Sensor B OOR (Sensor B signal too small) Bit 7 : Ratio A/B (One sensor signal much bigger than the other Bit 8 : DC A (Sensor A has a large DC offset) Bit 9 : DC B (Sensor B has a large DC offset) Bit 10 : Temperature AC Bit 11 : Sampling (No synchronisation with primary head oscillations) Bit 12 : Not used Bit 13 : ROM Default (EEPROM checksum error detected on power up) Bit 14 : Not used Bit 15 : EEPROM (Unable to save data into EEPROM chip) Bit 16 : NVRAM (Checksum error detected in NVRAM on power up) Bit 17 : NVRAM Cycles (NVRAM chip has had > 10000 save cycles) Bit 18 : Power Failure -Main supply has been switched off Bit 19 : Watchdog (System has been rebooted by WATCHDOG chip) Bit 20 : System (Software has got into an illegal state) Bit 21 : Temp.Custody (Temp. drifted ±30°C from zero calibration temp.) Bit 22 : Strain OOR (Measured strain out of range) Bit 23 : Current 1 (Measured quantity outside range limits for the output) Bit 24 : U36 (Measured quantity outside range limits for the output) Bit 25 : Process Alarm (Measured quantity exceeded user defined limits) Bits 26 - 31 : Not used
4	stored_errors (long, LSB first)	4	Stored error messages For bits layout refer to *actual_errors*

Any actual_error becomes a *stored_error* when the reasons that caused it disappear. Only *stored_errors* may be cleared via special request.

9. Reference documentation

If any problems are encountered, please contact your nearest Krohne office or representative or contact Product management at Krohne Duisburg - Germany.

Further documentation available as follows:

a) Krohne Massflow Installation and Operating manual:

MFM 2081 K / MFM 3081 K	P- and E-Series with MFC 081 Converter
MFM 4085 K	G-Series with MFC 085 Converter

b) Krohne application Engineering Release
Krohne Communication Protocol - Communication with Krohne Bus Protocol.

These documents are available from Product management on request.

The following is also available for further software development:

a) A simple PC test program to excercise the RS 485 Bus.
b) ”C” Source code for the RS 485 protocol to help customers with software development.

Modbus Protocol

Version: 1.0
Applies to Software Versions P 2.22 (MFC081) & G 3.00 (MFC085) and above

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Contents

1. General

The Mass flow Converter, MFC 081/085 with Modbus/RS 485 interface fitted, is able to communicate with an external device (PC or other suitable computer system) using the Modbus protocol. This option allows data exchange between PC or computer and single or multiple devices.

The Bus configuration consists of one external device as a master and one or more converters (MFC 081 or MFC 085) as slaves. For Bus operation the device address and baud rate must be programmed in the menu 3.11.0 of the MFC 081/085. Devices connected to the Bus must have different unique addresses and the same baud rate and settings.

The transmission uses 8 (eight) data bits, even or odd parity and 1(one) or 2 (two) stop bits at a selectable baud rate of 1200 to 19200.

2. Technical Specifications

Interface	RS 485, galvanically isolated
Baud rate	1200, 2400, 4800, 9600, 19200 baud
Protocol	Modbus RTU (Available as a separate document on request)
Maximum participants on Bus	32 per line, master included (may be extended by repeaters)
Coding	NRZ bit coding
Address range	Modbus: 1 – 247
Transmission procedure	half duplex, asynchronous
Bus access	master/slave
Cable	screened twisted pair cable
Distances	maximum 1.2 km without repeater. (Dependant on baud rate and cable specifications)

Technical data of the Modbus interface (according to EIA standards)

Kind of signal transmission:	Differential
Maximum number of transmitter/receivers:	32
Maximum voltage on driver output:	–7 V to +12 V
Minimum voltage on driver output, max.load:	U diff > 1,5 V
Maximum input current (off state)	–20 µA to +20 µA
Receiver input voltage	–7 V to +12 V
Sensitivity of the receiver	–200 mV to +200 mV
Receiver input resistance	> 12 k ohm
Short circuit current of transmission	< 250 mA

3. Connection of instruments on the Bus system

The Bus configurations are shown in Fig. 1 and Fig. 2.

Configuration with single slave:

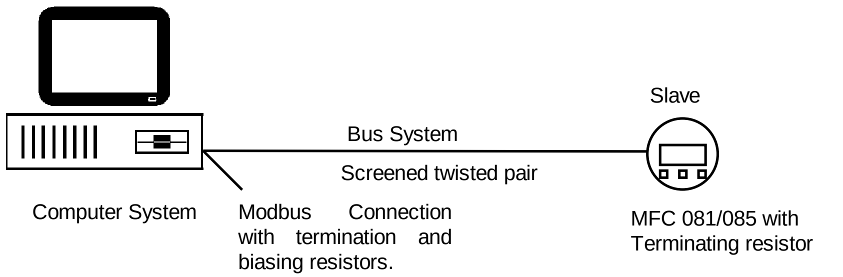


Fig. 1

Configuration with multiple slaves:

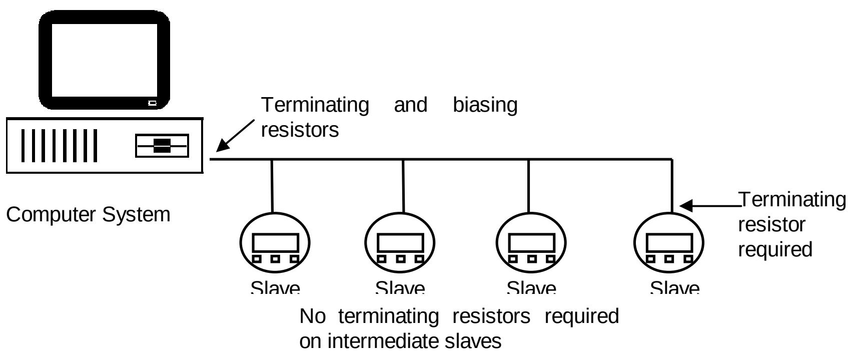


Fig. 2

Please note: If other instruments are to operate on the same Bus, all the devices must use the same communication protocol.

3.1 Bus termination and Biasing Resisters

For proper operation of Modbus in half duplex mode in single or multi-drop communication, it is recommended that a termination resistor (typically 120 ohm) is applied to both ends of the data line. The simplest form of termination is line to line resistor across the differential input.

In RTU mode the Modus protocol requires quite periods on the communications bus for synchronisation. It is therefore important that the Modbus is not allowed to 'float', i.e. unreferenced to 0V, as this could lead to spurious signals due to noise pick-up. It is therefore necessary to employ biasing resistors at one point on the bus network as shown in figure 3.

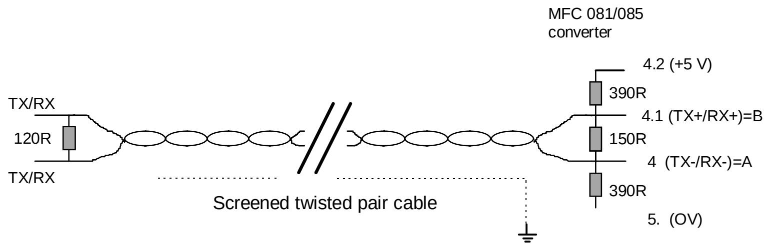


Fig. 3

For Ex instruments the termination resistor has to be inside the pressure tight section of the housing or other suitable enclosure. For convenience terminating and biasing resistors are already supplied on the RS 485/Modbus module. These can be enabled by soldering the two solder pads together
(Fig. 3) or enabling the jumper which is supplied on modules of a later design. (Fig. 4).

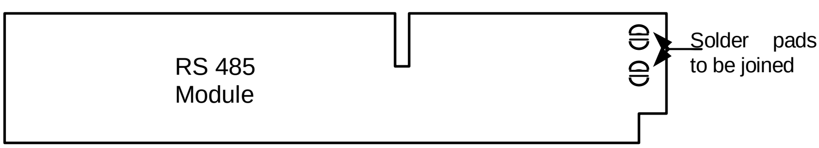


Fig. 4

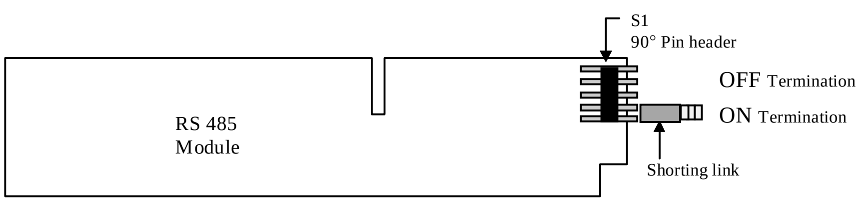
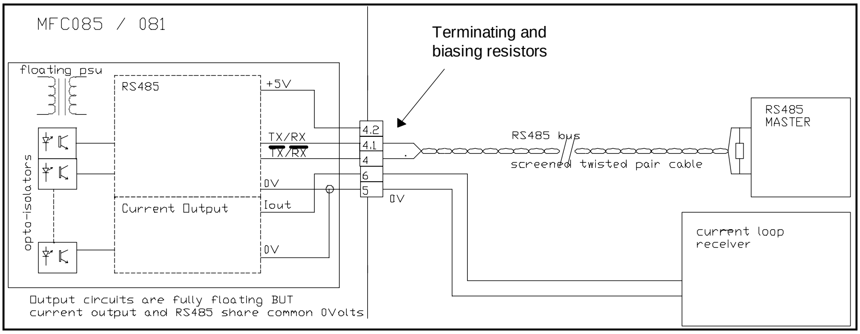


Fig. 5

4. Using the Current Output with the Modbus

The MFC 081/085 Converter is fitted with one current output in addition to the Modbus connection. This current loop is connected between terminals 6, Iout, and 5, 0 volts (refer to the normal Installation and Operating manual). However extra care must be taken when connecting this output.

The MFC 081/085 output circuitry is fully floating. It is galvanically isolated from protective earth, PE and from the converter's power supply. (See below).



If just the Modbus is connected then the converter's output circuitry will float to the potential of the bus. However the current output shares a common 0 volt reference with the Modbus output and hence also with the bus**. The current loop receiver must therefore have a fully floating input.** If not it will try to drag the Modbus to some potential of its own. This could in turn result in interference with stable operation of either, or both of the current loop and the Modbus.

5. Converter Configuration

Setting up the Modbus System:

Use the 3.11.0 Serial I/O menu to set up the Modbus communications:

Fct. 3.11.0	Serial I/O
Fct. 3.11.1	Protocol Select "MODBUS"
Fct. 3.11.2	Address Enter an address number between 1 and 247. The converter will only respond to Bus messages which have a matching address.
Fct. 3.11.3	Baudrate Select the required communications baudrate from the following list: 1200, 2400, 4800, 9600, 19200 and the data format from E81,E82,O81,O82,N81,N82. N=no parity: E=even parity: O=odd parity 1 or 2 stop bits

If the instrument is connected correctly, it should now communicate with an external master.
Please note, that all devices on the bus (including the master) must be set to the same communications protocol, baudrate and format, but with a different address.

6. Modbus Protocol

Using **RTU** (Remote Terminal Unit) format, data is transmitted as 8 bit binary characters. There are no special characters to determine the start and end of a message frame, synchronization is achieved by a minimum silent period of at least 3.5 character times before the start of each frame transmission and a maximum silent period of 1.5 character times between characters in the same frame.

6.1 RTU Frame Format

The format of the Query and Response frames vary slightly depending upon the command function. The basic form is outlined below.

Silent Period	Slave Address	Function Code	Register Start Address or Byte Count when required	No.of.Points or Data bytes when required	CRC
3.5 T	8 bits	8 bits	8 bit byte count 16 bit address	n x 8 bits	16 bits

Silent period.
All transmissions must be preceded by a minimum silent period of 3.5 x T, where T is the transmission time of a single character. This can be calculated from the baud rate e.g. at 19.2 Kb no parity with 1 stop bit (10 bits), T= 520 us.

Slave Address.
This is a single byte slave address which is transmitted first and must be in the range of 1-247. Address 0 is reserved for a broadcast address which all slaves should recognize, and therefore requires no response.

Function Code.
This is an eight bit code in the range of 1-255 although only 126 functions exist as the codes 129-255 represent an error condition. An error condition occurs when the addressed slave does not accept the command, in which case it responds with the function code + 128, i.e. with its MSB set to 1.

Byte Count.
In general this is only present in frames that are transferring data, and has a value equal to the number of bytes contained in the data field.
The data field is limited to a maximum of 250 bytes

Register Start Address
For a Query command that requires data to be returned, this field will contain the 16 bit start address of the register (or data) to be returned.

Number of Points.
For a Query command that requires data to be returned, this field will contain the number of registers to be returned regardless of their bit size.

CRC
This field contains a 16 bit CRC which is calculated on all the data bits of the message bytes.

6.2 Function Codes

Table 1 shows the function codes and data types supported by the MFC081/085. All data types occupy one holding register location. This is achieved by storing the address index of the data in the holding registers. However, this is invisible to the user who should access register data in the normal way.

Table 1. Supported ModBus codes.

Register Address (hex)	Function Codes	Data Type	Access	Description
00000-0000F	01 05	bit	R W	Read On/Off status of status/control bit. (8 bits blocks per read) Force Single control bit.
20010-2004F	03 16	float	R W	Read multiple registers. Read 2 registers for each float. Write multiple registers. Write 2 16bit registers for each float.
40050-4006F	03 06 16	int	R W W	Read multiple registers. Reads 1 register per integer. Write single register / integer. Write multiple registers/integers
A0070-A008F	03 06 16	byte	R W W	Read multiple registers. Read 1 byte per register. Write single byte. Write multiple bytes
B0090-B009F	03 16	double	R W	Read multiple registers. Read 4 registers for each double. Write multiple registers. Write 4 registers for each double .

R=read, W=write.

6.3 Data Formats

Table 2. Integers

Bits	
15-8	High byte
7-0	Low byte

Table 3. Single Precision Floating Point.

Bits	Bit order MSB - LSB	Mnemonic
Bits 32-24	SEEEEEEE	S/E
Bits 23-16	EMMMMMMM	E/M1
Bits 15-8	MMMMMMMM	M2
Bits 7-0	MMMMMMMM	M3

Table 4. Double precision floating Point.

Bits	Bit order MSB - LSB	Mnemonic
Bits 63-56	SEEEEEEE	S/E
Bits 55-48	EEEEMMMM	E/M1
Bits 47-40	MMMMMMMM	M2
Bits 39-32	MMMMMMMM	M3
Bits 32-24	MMMMMMMM	M4
Bits 23-16	MMMMMMMM	M5
Bits 15-8	MMMMMMMM	M6
Bits 7-0	MMMMMMMM	M7

S = sign bit E = exponent M = mantissa

Table 5. Transmission Order

Transmission order/type	1st byte							Last byte
Bits	see 4.2.1							
Bytes	0	Low						
Integers	High	Low						
Float	M2	M1	S/E	E/M1				
Double	M6	M7	M4	M5	M2	M3	S/E	E/M1

6.4 Addresses Allocation

The following table shows the supported data types and their address block allocation

Address Range	Type
0xxxx	Bit (Descrete Outputs)
1xxxx	
2xxxx	Float (Word swapped)
3xxxx	Integer (Input Registers)
4xxxx	

5xxxx	
6xxxx	
7xxxx	
8xxxx	
9xxxx	
Axxxx	Byte
Bxxxx	Double (Word swapped)

6.5 Register Addresses

Address	Description	Units/Value	Access	Menu Ref.
Hex(Decimal)	Bit registers			
0000/0000	Update configuration data	Save changes in EEPROM	R/W	
0001/0001	Begin zero flow calibration	-	R/W	3.1.1
0002/0002	Reset totals	-	R/W	
0003/0003	Switch to standby mode	-	R/W	3.1.4
0004/0004	Switch to measure mode	-	R/W	3.1.4
	Float registers			
0010/0016	Mass flow rate	g/s	R	
0011/0017	Volume flow rate	cm^3/s	R	
0012/0018	Volume total	cm^3	R	
0013/0019	% volume flow rate	%	R	
0014/0020	% mass flow rate	%	R	
0015/0021	Solid flow rate	g/s	R	
0016/0022	Density	g/cm^3	R	
0017/0023	Referred density	g/cm^3	R	
0018/0024	Solute density	g/cm^3	R	3.10.1
0019/0025	Solute k1 constant	$g/cm^3/\ °C$	RW	3.10.2
001A/0026	Solute k2 constant	$g/cm^3/\ °C^2$	RW	3.10.3
001B/0027	Liquid density	g/cm^3	RW	3.10.4
001C/0028	Liquid k1 constant	$g/cm^3/\ °C$	RW	3.10.5
001D/0029	Liquid k2 constant	$g/cm^3/\ °C^2$	RW	3.10.6
001E/0030	Reference temperature	x10 °C	RW	
001F/0031	Reference density slope	-	RW	
0020/0032	Fixed density	g/cm^3	RW	
0021/0033	Head constant	-	R	3.1.6
0022/0034	(G) Density coefficient CF1 (P&E) Water calibration reference frequency	- 50-200 Hz	R R	3.9.1 3.9.1
0023/0035	(G) Density coefficient CF2 (P&E) Air calibration reference frequency	- 50-200 Hz	R R	3.9.2 3.10.3.
0024/0036	(G) Reference strain CF3 (P&E) Temperature constant	-	R R	3.9.3
0025/0037	(G) Reference Temp. CF4 (P&E) Frequency constant	-	R R	3.9.4
0026/0038	Zero flow cutoff	% of nominal	R	3.1.2
0027/0039	Low flow threshold	% of full scale x 10	RW	3.1.1
0028/0040	Frequency	Hz	R	2.7.3
0029/0041	Maximum trigger value	as base unit	RW	3.7.4
002A/0042	Minimum trigger value	as base unit	RW	3.7.3
	Integer registers			
003C/0060	Measurement time-constant	x10 s	R/W	3.1.3
003D/0061	Drive level	-	R	
003E/0062	Strain	ohms x 20	R	

003F/0063	Tube temperature (x10)	x10 °C	R	
0040/0064	Sensor A average level	-	R	
0041/0065	Sensor B average level	-	R	
	Byte registers			
005A/0090	Mass flow display units	note[3]	RW	3.2.3
005B/0091	Mass flow display format	note[3]	RW	3.2.3
005C/0092	Mass total display units	note[3]	RW	3.3.4
005D/0093	Mass total display format	note[3]	RW	3.3.4
005E/0094	Volume flow display units	note[3]	RW	3.2.7
005F/0095	Volume flow display format	note[3]	RW	3.2.7
0060/0096	Volume total display units	note[3]	RW	3.2.8
0061/0097	Volume total display format	note[3]	RW	3.2.8
0062/0098	Density display units	note[3]	RW	3.2.5
0063/0099	Density display format	note[3]	RW	3.2.5
0064/0100	Solid flow display units [1]	note[3]	RW	3.2.9
0065/0101	Solid flow display format [1]	note[3]	RW	3.2.9
0066/0102	Temperature units	note[3]	RW	3.2.6
0067/0103	Concentration by mass display format [1]	%	RW	3.2.10
0068/0104	Concentration by volume display format [1]	%	RW	3.2.11
0069/0105	Density mode [2]	1= actual 2=fixed 3=referred	RW	3.2.5
006A/0106	Concentration function	1=none 2=brix 3=general 4=baume 1443 5=baume 1450 6=NaOH 7=Referred Density	RW	5.5.4
006B/0107	Transducer Model	1 = 10G 2 = 100G 3 = 300G 4 = 800G 5 = 1500G 6 = 3000G	R	3.1.5
006C/0108	Transducer Material/type	0=Titanium G-Classic 1=Titanium G+ 2=Zirconium G-Classic 3=Zirconium G+	R	3.1.5
006D/0108	Software version	-	R	5.1.5
006E/0109	Software sub-version	-	R	5.1.5
006F/0110	System state	1 = Initialisation 2 = startup 3 = measure 5 = standby 6 = zero adjust	R	3.1.4
0070/0111	Flow direction	1=forward 2=backwards	R	3.1.7
0071/0112	Flow mode	1=positive 2=negative	R	3.1.8
0072/0113	Control function	1=off 2=force flow to zero 3=zero flow and totalisers 4=disable o/p	R	3.7.1
0073/0114	Control condition		R	
0074/0115	Language	1 = Deutsch	R	3.8.0

		2 = English 3 = French		
0075/0116	Liquid type	1=water 2=non-water	RW	
	Double registers			
0083/0131	Mass Total	g	R	

[1]. Only available when concentration measurement installed.
[2]. Only available when concentration set to referred density
[3]. For display format this indicates number of digits after the decimal point and is in the range 0-7. Bit 4 is set if the measurement is enabled.

For display units the byte is divided into a high and low nibble. Each nibble indicates the units type depending on the measurement as shown in the following table.

1	grams	°C		seconds	cm^3
2	kilograms	°F		minutes	dm^3
3	tonnes			hours	Litres
4	ounces			days	m^3
5	pounds				in^3
6	Specific Gravity				ft^3
7					US gallons
8					Gallons

6.6 Error return codes

In the event of a command not being completed, the following error codes may be returned.

1	Function code not allowed
2	Illegal data address
3	Illegal data value
4	Slave device failure
5	Acknowledge - extended time required
6	Slave device busy
7	Failed to carry out request
8	Request to change value refused
9	Custody locked

6.7 Diagnostic codes

These are related to the Modbus command 08.

Sub command	Description
0	Echo Query command
1	Restart communcations[1]
2	Return 16bit status register [2]
3	Not supported
4	Turn off communications[1]
5	Not supported
6	Not supported
7	Not supported
8	Not supported
9	Not supported
10	Clear event log
11	Return bus message count
12	Return CRC error count
13	Return Exception count
14	Return Slave message count
15	Return No response count
16	Return NAK count
17	Return SlaveBusy count
18	Return Communications Overrun count

[1]. These commands do not return a response.
[2]. Status Register

Bit No	Meaning
00	Zero Error - Excessive flow measured during zero calibration.
01	Temperature measured > 180 C or < -25 C.
02	Sensor A out of range.
03	Sensor B out of range.
04	Ratio of sensors A/B exception. One sensor reading is >> than other.
05	Sensor A has a large DC offset.
06	Sensor B has a large DC offset.
07	No synchronization with primary head oscillations.
08	ROM checksum error detected on power-up.
09	EEPROM save error.
10	Non Volatile RAM checksum error detected on power-up
11	Power Failure recorded.
12	Watchdog System Reboot has been activated.
13	Software exception registered.
14	Temperature drifted +/- 30 C from zero calibration temperature.
15	Current Loop measurement Out of Range.

7. Reference documentation

If any problems are encountered, please contact your nearest Krohne office or representative or contact Product management at Krohne Duisburg - Germany.

Further documentation available as follows:

a) Krohne Massflow Installation and Operating manual:

MFM 2081 K / MFM 3081 K P- and E-Series with MFC 081 Converter

MFM 4085 K G-Series with MFC 085 Converter

b) Krohne application Engineering Release: Modbus Protocol.

These documents are available from Product management on request.
The following is also available for further software development:

a) A simple PC test program to exercise the RS 485 Modbus.
b) ”C” Source code for the Modbus protocol to help customers with software development.