LEVIFLOW™ LFSC-iX MODBUS INTERFACE

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PURPOSE: MODBUS Interface description

SCOPE: LEVIFLOW™ Flowmeter LFSC-iX

Contents:

1 Communication

LEVIFLOW™ Clamp-On flowmeter supports MODBUS RTU over RS485.

Communication parameters:

Baudrate	57600
Data Bits	8 Bit
Parity	Even
Stop Bits	1 Bit

1.1 Supported MODBUS functions

Following MODBUS functions are supported by LEVIFLOW™

Function code	Description
03	Read Hold Registers
04	Read Input Registers
06	Write Single Hold Register

A detailed description of the MODBUS protocol and its functions in general can be found here:

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

1.2 MODBUS checksum calculation

Checksum generation function (c#)

```
int calculateChecksum(ref Byte[] byteStream, int start, int end)
{
   ushort CRC1 = 0xFFFF;
   for( int i= start; i < end; i++)
   {
      CRC1 = ((ushort)(CRC1 ^ byteStream[i]));
      for (int j = 0; j < 8; j++)
      {
         if ((CRC1 & 1) >0)
         {
            CRC1 = ((ushort)((CRC1 >> 1) ^ 0xA001));
         }
         else
         {
            CRC1 = ((ushort)((CRC1 >> 1)));
         }
       }
   }
   return (CRC1 & 0xFFFF);
}
```

Least significant byte (LSB) of checksum is second to last byte of MODBUS message. Most significant byte (MSB) of checksum is last byte of MODBUS message.

2 Input registers

Input registers are read-only. Modbus function 04 is used to read values of input registers.

2.1 Input register map

Register No.	Description	Type	Unit	Notes	Default value	Available since Version
0	Equipment status	ushort	-	**Bit 0** : Bubble detected **Bit 1** : Measurement error **Bit 2** : Reverse flow **Bit 3** : Volume counter pulse set error **Bit 4** : Zero adjustment active **Bit 5** : Zero adjustment error **Bit 6** : currently unused **Bit 7** : currently unused **Bit 8** : Flow Alarm high **Bit 9** : Flow Alarm low **Bit 10** : Volume Counter Alarm H **Bit 11** : Volume Counter Alarm HH **Bit 12** : Output test **Bit 13** : currently unused **Bit 14** : currently unused **Bit 15** : Firmware update active	-	
1	Current flow rate	short	%	Current flow rate in percentage of full scale -30000 ~ +30000 ≡ -300.00 ~ 300.00%	-	
2 3	Volume Pulse Counter	long	-	0 ~ 4 294 967 295	-	
4	reserved	short	-	0x0001	1	
5	reserved	short	-	0x0000	0	
6	Temperature	short	1/100 °C	Temperature For example: value 1234 is interpreted as 12.34 °C	-	04
7	Signal strength	short	digit	The signal strength in 0 to 133 % is calculated as: signal strength [%] = signal strength [digit] * 100 * 100 / 8191 / 75	-	04
8 9	Flow in µl/min	long	µl/min	flow value in µl/min (-2147483648 … 2147483647 µl/min)	-	04
10	reserved	short	-		-	04
11	reserved	short	-		-	04
12	reserved	short	-		-	04

2.1.1 Equipment status

Bit Nr.	Name	Description
Bit 0	Bubble detected	Active: Detected bubble in sensor. Stays active while 'bubble detect hold time'
Bit 1	Measurement error	Active: Sensor signal is abnormal. (Empty sensor, too many bubbles)
Bit 2	Reverse flow	Active: Reverse flow
Bit 3	Volume counter pulse set error	Active: Combination of Full scale and Volume Pulse setting is invalid.
Bit 4	Zero adjustment active	Active: Zero Adjustment is in progress
Bit 5	Zero adjustment error	Not active: Last Zero Adjustment was successful Active: Last Zero Adjustment was not successful because sensor was empty or there were too many bubbles in sensor.
Bit 6	Currently unused	
Bit 7	Currently unused	
Bit 8	Flow Alarm High	Active: Measured flow is higher than Alarm High level
Bit 9	Flow Alarm Low	Active: Measured flow is lower than Alarm Low level
Bit 10	Volume Counter Alarm H	Active: Volume Counter is greater than Volume Counter Alarm H limit (Volume Counter Alarm enabled)
Bit 11	Volume Counter Alarm HH	Active: Volume Counter is greater than Volume Counter Alarm HH limit (Volume Counter Alarm enabled)
Bit 12	Output test	Active: Analog or digital test output is active.
Bit 13	Currently unused	
Bit 14	Currently unused	
Bit 15	Firmware update active	Active: Device is in firmware download mode.

2.2 Example: Read Input register (MODBUS function 0x04)

LEVIFLOW™ Clamp-On flowmeter has device address ID = 3. In this example Input register 0, 1, 2, 3 are read.

→ Start Register 0 and Quantity of Registers = 4

MODBUS Request:

Device ID	Function Code	Start Register		Quantity of Registers		Checksum	
		MSB	LSB	MSB	LSB	LSB	MSB
0x03	**0x04**	**0x00**	**0x00**	**0x00**	**0x04**	**0xF0**	**0x2B**

MODBUS Response:

Device ID	Function Code	Byte Count (Nr. of value bytes)	Register #1 Value		Register #2 Value		Register #3 Value		Register #4 Value		Checksum	
			MSB	LSB	MSB	LSB	MSB	LSB	MSB	LSB	LSB	MSB
0x03	**0x04**	**0x08**	**0x00**	**0x00**	**0x05**	**0x6F**	**0x00**	**0x00**	**0x03**	**0xC2**	**0x7A**	**0x88**

→ Input register 0: Equipment Status 0x0000h

Input register 1: Current flow rate 0x056Fh = 1391 ≡ 13.91 %

Input register 2: Volume Pulse Counter (most significant short) 0x0000h

Input register 3: Volume Pulse Counter (least significant short) 0x03C2h

→ Volume Pulse Counter 0x000003C2h = 962 pulses

MODBUS Error Response:

Device ID	Function Code	Exception Code	Checksum	
			LSB	MSB
0x03	**0x84**			

Exception Code: 02 Invalid Start Register

03 Invalid combination (Start Register + Quantity of Registers)

3 Hold registers

Hold registers are writable. MODBUS function 03 is used to read values of hold registers. MODBUS function 06 writes to a single register.

3.1 Hold register map

Register No.	Parameter Name	Type	Unit	Description	Default value for LFSC-iX	Available since Version
0	Control	ushort	-	**Bit 0**: 0 = Normal. 1= Zero adjust mode (See 4.3 Zero adjustment) **Bit 2**: 0 = Normal. 1 = Reset (Use to reset converter) **Bit 5**: 0 = Normal. 1 = Factory setting (Use to set converter into default setting)	0000h	
1	Sensor Type	short	-	100 = LFSC-i06X 101 = LFSC-i10X 103 = LFSC-i14X 104 = LFSC-i16X 105 = LFSC-i19X 106 = LFSC-i25X 107 = LFSC-i35X	100	
2 3	Full Scale	long	L/min	0.010 ~ 500.000 = 10 ~ 500000	10.000	
4	Currently unused	short	-		0	
5	Currently unused	short			0	
6	K Factor	short	-	0.100 ~ 30.000 = 0 ~ 30000	1.000	
7	Damping Time	short	s	0 = No damping time 0.1 ~ 25.0s = 1 ~ 250	2.0	
8	Low Cutoff	short	%	0 = No low cut-off 0.1 ~ 25.0%FS = 1 ~ 250	2.0	
9	Measurement Error Ignore Time	short	s	0 = No hold 1 ~ 99s	10	
10	Flow Level on Measurement Error	short	-	0 = 0 % Output 1= -25% Output, 2 = 105% Output 3 = Hold	0	
11	Bubble Detect Hold Time	ushort	s	0 = No hold 1 ~ 99s	0	
12	Digital Output 1 signal logic	ushort	-	0 = N.O. 1 = N.C.	0000h	
13	Digital Output 2 signal logic	ushort	-	0 = N.O. 1 = N.C.	0000h	
14	AGC-control	ushort	-	Bit0 = 0 no agc control enabled Bit1 = 1 agc control enabled if implemented in sensor	0	04
15	Digital Input Setting	ushort	-	0 = Volume Counter reset 1 = Zero Adjust 2 = Inverse flow	1	
16	Analog Output Setting	short	-	Bit0: 0 = Analog Out1 4/20mA Bit0: 1= Analog Out1 0/20mA Bit8: 0 = Analog Out2 4/20mA Bit8: 1= Analog Out2 0/20mA	0	08
17	Digital Output 1 Setting	short	-	0 = Flow Alarm High 1 = Flow Alarm Low 2 = Vol. Counter Alarm H 3 = Vol. Counter Alarm HH 4 = Vol. Counter Pulse 5 = Measurement Error 6 = Flow as Frequency 7 = Bubble detect 8 = Custom Value	5	

18	Digital Output 2 Setting	short	-	0 = Flow Alarm High 1 = Flow Alarm Low 2 = Vol. Counter Alarm H 3 = Vol. Counter Alarm HH 4 = Vol. Counter Pulse 5 = Measurement Error 6 = Flow as Frequency 7 = Bubble detect 8 = Custom Value	0	
19	Flow Alarm High Value	short	%	0.0 ~ 125.0% of FS = 0 ~ 1250	105.0	
20	Flow Alarm Low Value	short	%	-10.0 ~ 125.0% of FS = -100 ~ 1250	-5.0	
21	Alarm Hysteresis	short	%	0.0 ~ 20.0 = 0 ~ 200	0.0	
22	Currently unused	short	-		0	
23	Currently unused	short	-		0	
24	Volume Counter Enable	short	-	0 = No 1 = Yes	0	
25	Volume Counter Reset	short	-	0 = No 1 = Yes (After reset, it returns to "No" automatically)	0	
26	Volume Counter Base Unit	short	-	0 = mL 1 = L 2 = m3	0	
27	Volume Counter Multiplier Factor	short	-	0 = x0.1 1 = x1 2 = x10 3 = x100 4 = x1000 5 = x0.01	0	
28	Volume Counter Pulse Length	short	-	0 = 0.5ms(Max. 1000Hz) 1 = 50ms(Max. 10Hz) 2 = 100ms(Max. 5Hz)	0	
29	Volume Counter Alarm Enable	short	-	0 = No 1 = Yes	0	
30 31	Volume Counter Alarm H Value	long	-	0 ~ 4 294 967 295	0	
32 33	Volume Counter Alarm HH Value	long	-	0 ~ 4 294 967 295	0	
34 - 35	Currently unused	short	-		0	
36	RS485 Baud Rate	Short	-	0 = 57600bps, 1 = 38400bps, 2 = 19200bps, 3 = 9600bps, 4 = 115200bps	0	04
37	Number of User Linearizer	short	-	0 = No linearizer, 1 … 15 = Number of user linearizer points	0	04
38 39	Linearizer Output 1	long	µl /min	0 … 2147483647	0	04
40 41	Linearizer Input 1	long	µl /min	0 … 2147483647	0	04
42 43	Linearizer Output 2	long	µl /min	0 … 2147483647	0	04
44 45	Linearizer Input 2	long	µl /min	0 … 2147483647	0	04
46 47	Linearizer Output 3	long	µl /min	0 … 2147483647	0	04
48 49	Linearizer Input 3	long	µl /min	0 … 2147483647	0	04
50 51	Linearizer Output 4	long	µl /min	0 … 2147483647	0	04
52 53	Linearizer Input 4	long	µl /min	0 … 2147483647	0	04
54 55	Linearizer Output 5	long	µl /min	0 … 2147483647	0	04
56 57	Linearizer Input 5	long	µl /min	0 … 2147483647	0	04
58 59	Linearizer Output 6	long	µl /min	0 … 2147483647	0	04
60 61	Linearizer Input 6	long	µl /min	0 … 2147483647	0	04
62 63	Linearizer Output 7	long	µl /min	0 … 2147483647	0	04
64 65	Linearizer Input 7	long	µl /min	0 … 2147483647	0	04

66 67	Linearizer Output 8	long	µl /min	0 … 2147483647	0	04
68 69	Linearizer Input 8	long	µl /min	0 … 2147483647	0	04
70 71	Linearizer Output 9	long	µl /min	0 … 2147483647	0	04
72 73	Linearizer Input 9	long	µl /min	0 … 2147483647	0	04
74 75	Linearizer Output 10	long	µl /min	0 … 2147483647	0	04
76 77	Linearizer Input 10	long	µl /min	0 … 2147483647	0	04
78 79	Linearizer Output 11	long	µl /min	0 … 2147483647	0	04
80 81	Linearizer Input 11	long	µl /min	0 … 2147483647	0	04
82 83	Linearizer Output 12	long	µl /min	0 … 2147483647	0	04
84 85	Linearizer Input 12	long	µl /min	0 … 2147483647	0	04
86 87	Linearizer Output 13	long	µl /min	0 … 2147483647	0	04
88 89	Linearizer Input 13	long	µl /min	0 … 2147483647	0	04
90 91	Linearizer Output 14	long	µl /min	0 … 2147483647	0	04
92 93	Linearizer Input 14	long	µl /min	0 … 2147483647	0	04
94 95	Linearizer Output 15	long	µl /min	0 … 2147483647	0	04
96 97	Linearizer Input 15	long	µl /min	0 … 2147483647	0	04
98	Dig. Out 1 Custom Value	ushort	-	Every bit from equipment status can be linked to digital output 1 (bitwise activation). “Custom value” has to be set in hold register 17 to activate this register.	0000h	
99	Dig. Out 2 Custom Value	ushort	-	Every bit from equipment status can be linked to digital output 2 (bitwise activation). “Custom value” has to be set in hold register 18 to activate this register.	0000h	
100	Flow control	ushort	-	Bit 0: 0 normal operation Bit 0: 1 flow inverted	0	08
101	Currently unused	short	-		0	
102	Output Test	ushort	-	**Bit 0** : Analog output test, 0 = Off, 1 = On **Bit 1** : Digital output 1 test, 0 = Off, 1 = On (Flashing) **Bit 2** : Digital output 2 test, 0 = Off, 1 = On (Flashing) **Bit 3** : Digital output 1 test, 0 = Off, 1 = On (Steady) **Bit 4** : Digital output 2 test, 0 = Off, 1 = On (Steady)	0	
103	Analog Output Test Value	short	-	-310.0 ~ 310.0% FS = -3100 ~ 3100	0.0	
104	Analog Out1 0mA adjust	short	mA	+/- 1.00 mA = +/- 100	0	08
105	Analog Out1 4mA adjust	short	mA	+/- 1.00 mA = +/- 100	0	08
106	Analog Out1 20mA adjust	short	mA	+/- 1.00 mA = +/- 100	0	08
107	Analog Out2 0mA adjust	short	mA	+/- 1.00 mA = +/- 100	0	08
108	Analog Out2 4mA adjust	short	mA	+/- 1.00 mA = +/- 100	0	08
109	Analog Out2 20mA adjust	short	mA	+/- 1.00 mA = +/- 100	0	08
110 …118	Currently unused				0	
119 120 121 122 123 124 125 126	Converter serialnumber	ushort	-	16 characters ASCII code, two characters stored in each register (high byte, low byte). First char. stored in hold register 119 High byte Last char. stored in hold register 126 Low byte	0000h	
127	LFSC-iX Modbus Device Address	ushort	-	1~99 (0 is not allowed)	3	
128 - 187	Currently unused	short	-		0	
188	Reserved	short	-		0	
189	Reserved	short	-		0	

190	Reserved	short	-		0	
191	Reserved	short	-		0	
192	Reserved	short	-		0	
193	Reserved	short	-		0	
194 - 203	Currently unused	short	-		0	
204	Calibration set selection	short	-	0 = Calibration Set 1 (Silicone, 20°C) 1 = Calibration Set 2 (Silicone, 37°C) 2 = Calibration Set 3 (CFlex, 20°C) 3 = Calibration Set 4 (CFlex, 37°C) 4 = Calibration Set 5 5 = Calibration Set 6 6 = Calibration Set 7 (AdvantaFlex, 20°C) 7 = Calibration Set 8 (AdvantaFlex, 37°C) After changing “calibration set” the new calibration set data gets read from sensor and new calibration set selection is stored to sensor.	0	
205 - 255	Currently unused	short	-		0	

Each hold register addresses a 16-bit (short) value. All parameters are non-volatile and stored in FRAM.

All not described Hold-Registers are currently unused or used for internal purposes. Please do not access undescribed Hold-Registers.

3.2 Example: Read Hold register (MODBUS function 0x03)

LEVIFLOW™ Clamp-On flowmeter has device address ID = 3. In this example Hold register 7 is read.

→ Start Register 7 and Quantity of Registers = 1

MODBUS Request:

Device ID	Function Code	Start Register		Quantity of Registers		Checksum	
		MSB	LSB	MSB	LSB	LSB	MSB
0x03	**0x03**	**0x00**	**0x07**	**0x00**	**0x01**	**0x34**	**0x29**

MODBUS Response:

Device ID	Function Code	Byte Count (Nr. Of value bytes)	Register #1 Value		Checksum	
			MSB	LSB	LSB	MSB
0x03	**0x03**	**0x02**	**0x00**	**0x02**	**0x40**	**0x45**

→ Hold register 7: Damping time 0x0002h = 2 ≡ 0.2 sec

MODBUS Error Response:

Device ID	Function Code	Exception Code	Checksum	
			LSB	MSB
0x03	**0x83**			

Exception Code: 02 Invalid Start Register

03 Invalid combination (Start Register + Quantity of Registers)

3.3 Example: Write Single Hold register (MODBUS function 0x06)

LEVIFLOW™ Clamp-On flowmeter has device address ID = 3. In this example Hold register 7 is written.

→ Write value 10 into Hold register 7

MODBUS Request:

Device ID	Function Code	Register		Register Value		Checksum	
		MSB	LSB	MSB	LSB	LSB	MSB
0x03	**0x06**	**0x00**	**0x07**	**0x00**	**0x0A**	**0xB9**	**0xEE**

MODBUS Response:

Device ID	Function Code	Register		Register Value		Checksum	
		MSB	LSB	MSB	LSB	LSB	MSB
0x03	**0x06**	**0x00**	**0x07**	**0x00**	**0x0A**	**0xB9**	**0xEE**

→ Wrote value 10 to Hold register 7: Damping time 0x000Ah = 10 ≡ 1.0 sec

MODBUS Error Response:

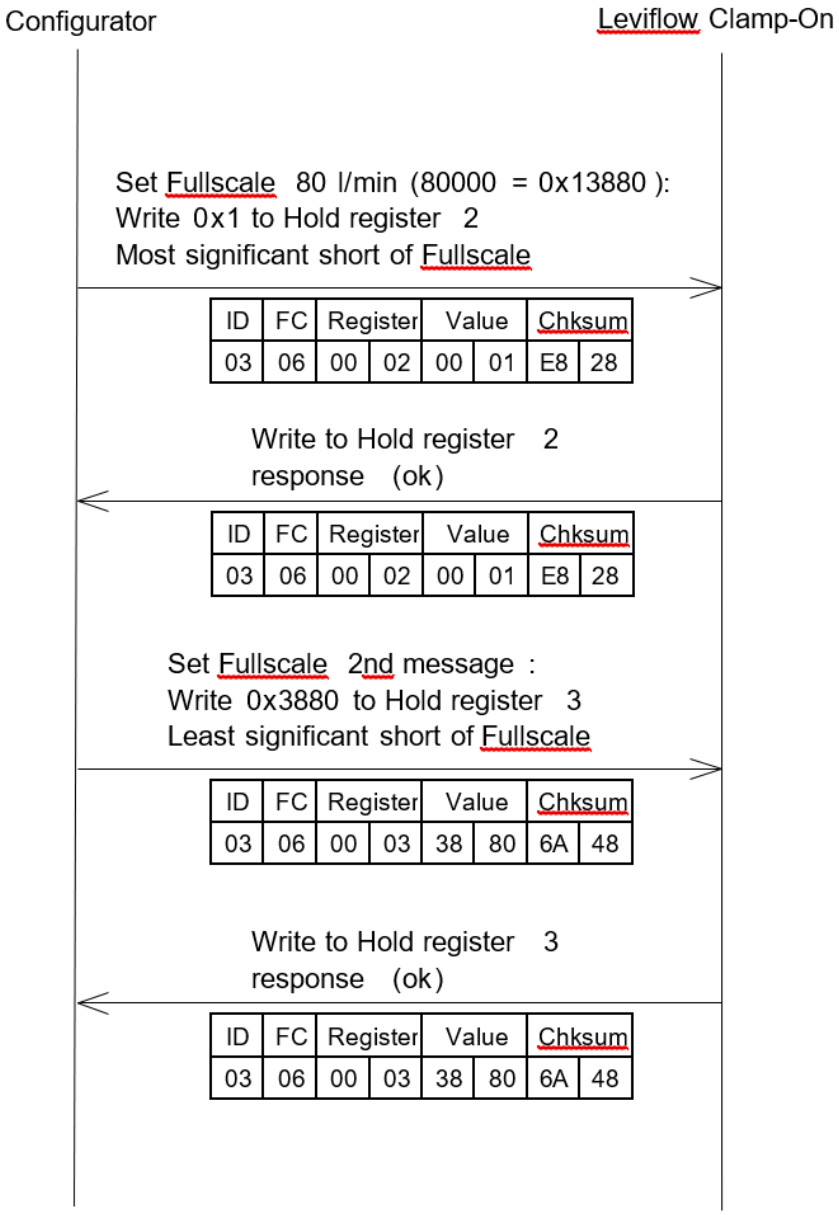
Device ID	Function Code	Exception Code	Checksum	
			LSB	MSB
0x03	**0x86**			

Exception Code:
02 Invalid Start Register
03 Invalid combination (Start Register + Quantity of Registers)
05 Impossible to execute.

4 Communication procedures

This chapter describes the most important communication procedures. The LEVIFLOW™ Clamp-On flowmeter has MODBUS device address ID = 0x03.

4.1 Write parameters



ID	FC	Register		Value		Chksum	
03	06	00	02	00	01	E8	28

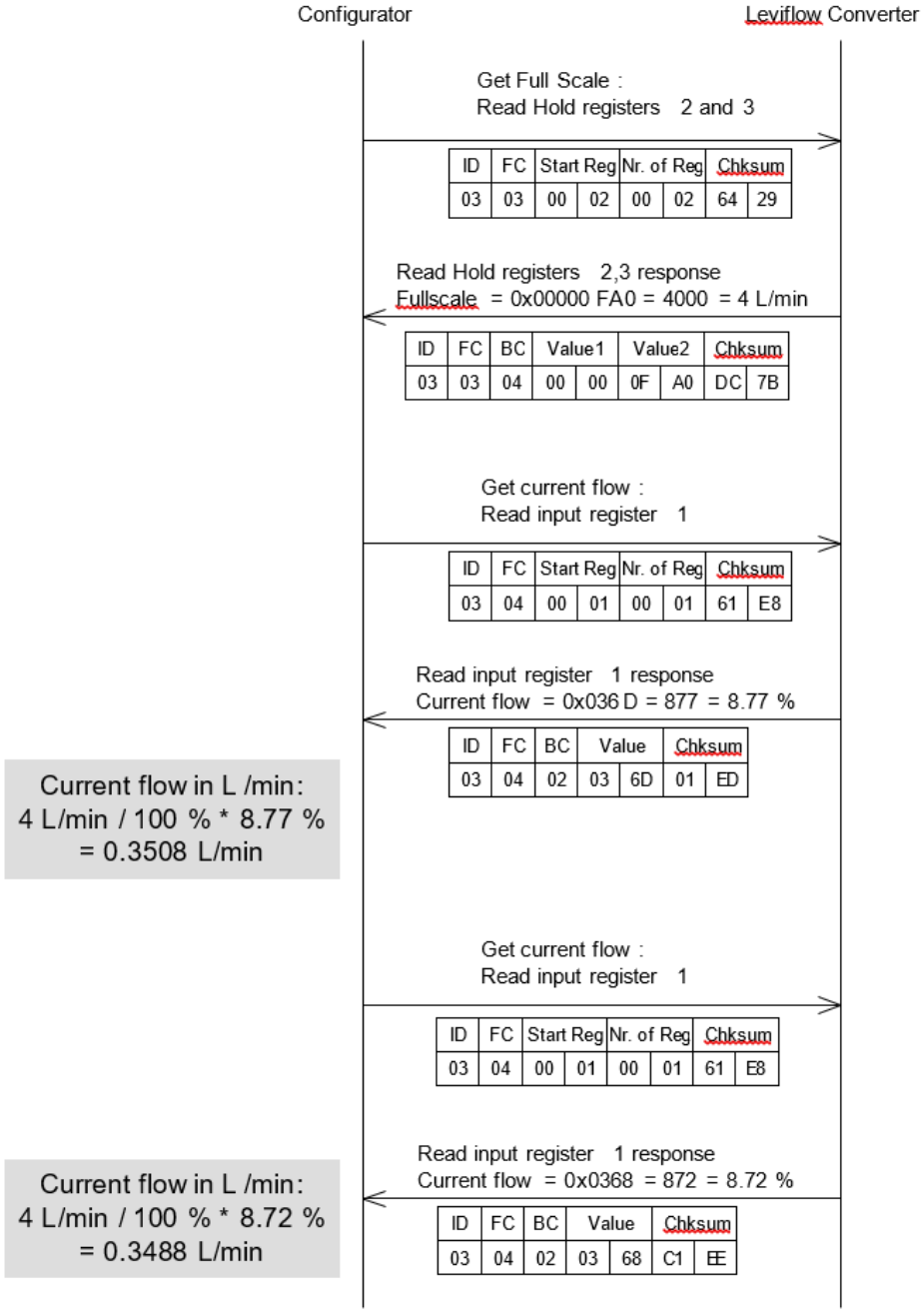
ID	FC	Register		Value		Chksum	
03	06	00	02	00	01	E8	28

ID	FC	Register		Value		Chksum	
03	06	00	03	38	80	6A	48

ID	FC	Register		Value		Chksum	
03	06	00	03	38	80	6A	48

4.2 Read current flow

Input register 1 contains the current measured flow in percentage of the full scale.



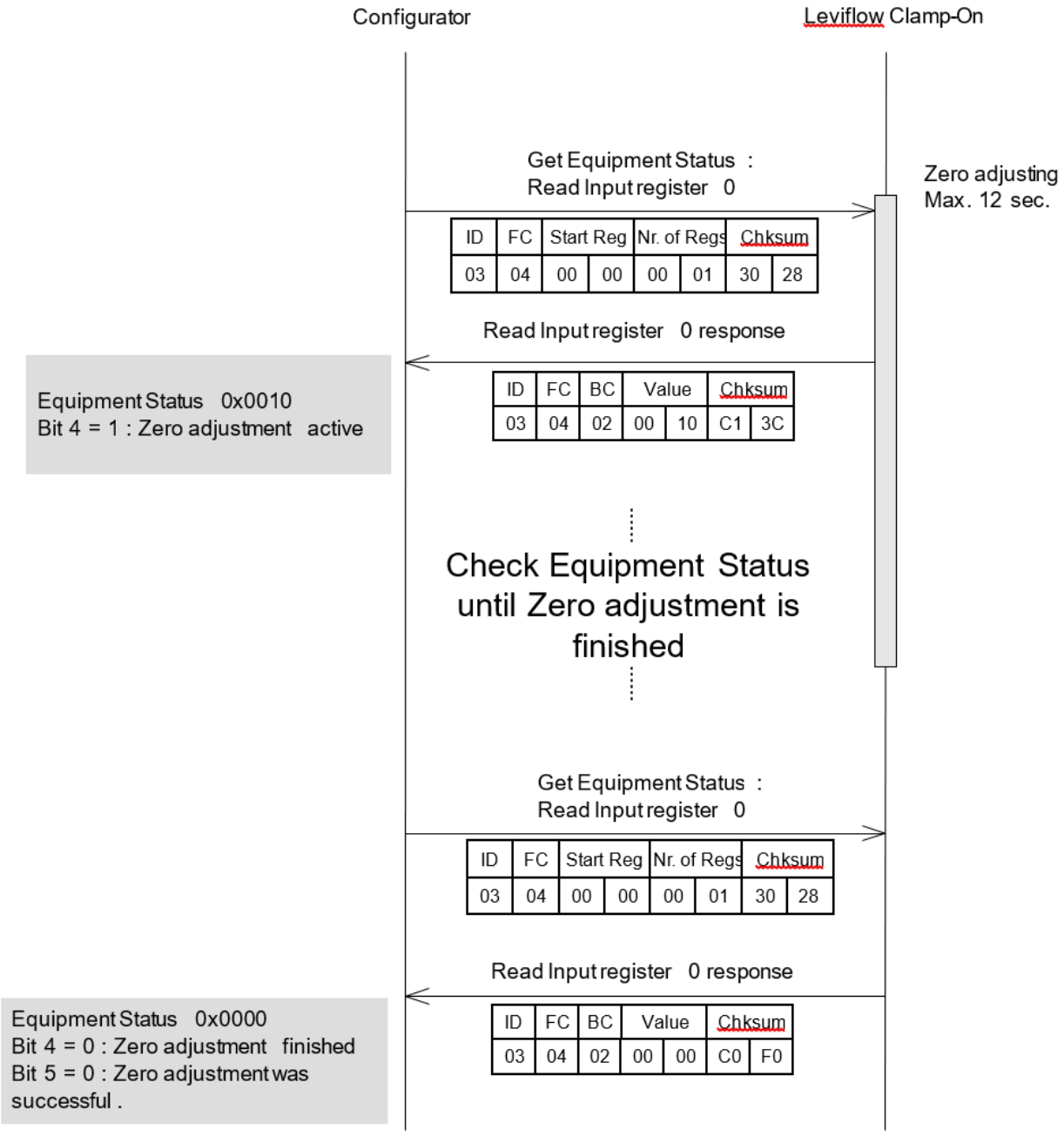
4.3 Zero adjustment

For a successful Zero flow adjustment, make sure that sensor is completely filled with liquid.

Trigger zero adjustment by setting ‘zero adjustment bit’ of control register.

Then check equipment status until Bit 4 of Equipment status register is 0, which means the adjustment procedure has finished.

Bit 5 of Equipment status contains the result of the zero adjustment.



4.4 Error handling

4.4.1 Equipment status 0x0001: Bubble detected

LEVIFLOW™ Clamp-On flowmeter detected a bubble in sensor. Actually, this isn't an error. Once a bubble was detected, bit stays active during 'Bubble detect hold time'. LEVIFLOW™ Clamp-On flowmeter tolerates bubbles up to a certain amount and size. If flow measurement is impossible 'Measurement Error' gets active.

4.4.2 Equipment status 0x0002: Measurement Error

Sensor signal is abnormal. This error can have multiple reasons:

1. Sensor is empty.
2. There are too many bubbles or particles in sensor.

4.4.3 Equipment status 0x0004: Reverse flow

LEVIFLOW™ Clamp-On flowmeter measures reverse flow (Out → In). This isn't an actual error, but it can be a sign of misconfiguration if there's no physical reverse flow.

Misconfiguration could be:

1. Zero adjustment was done while there was still a flow. Reverse flow is detected, if flow rate is below the flow rate measured during zero adjustment. → No flow during Zero adjustment
2. Sensor is mounted the opposite way around.

4.4.4 Equipment status 0x0008: Setting error Fullscale vs. Pulse width

Volume Counter is enabled and its pulse length, multiplier factor and base unit (Hold registers 26, 27 and 28) combination doesn't fit to the current Fullscale.

For example, Volume Counter pulse width is set to 50ms which allows maximum 10 pulses per sec and at the same time a Volume pulse represents 0.1 ml (multiplier factor 0.1, base unit ml) and Fullscale is 4 L/min. With this setting combination the current flow can't be represented in pulses, because the Fullscale is too big. Up to 667 pulses per second are needed.

Pulse length [ms]	Pulse rate [pps]	Volume base unit	Maximum Full Scale[L/min]					
			Multiplier factor					
			0.01	0.1	1	10	100	1000
0.5	1000	mL	0.6	6.000	60.000	600.000	6‘000.000	60‘000.000
0.5	1000	L	600.000	6‘000.000	60‘000.000	600‘000.000	6‘000‘000.000	60‘000‘000.000
0.5	1000	m3	600‘000.000	6‘000‘000.000	60‘000‘000.000	600‘000‘000.000	6‘000‘000‘000.000	60‘000‘000‘000.000
50	10	mL	0.006	0.060	0.600	6.000	60.000	600.000
50	10	L	6.000	60.000	600.000	6‘000.000	60‘000.000	600‘000.000
50	10	m3	6‘000.000	60‘000.000	600‘000.000	6‘000‘000.000	60‘000‘000.000	600‘000‘000.000
100	5	mL	0.003	0.030	0.300	3.000	30.000	300.000
100	5	L	3.000	30.000	300.000	3‘000.000	30‘000.000	300‘000.000
100	5	m3	3‘000.000	30‘000.000	300‘000.000	3‘000‘000.000	30‘000‘000.000	300‘000‘000.000

4.4.5 Equipment status 0x0020: Zero adjustment error

Last Zero Adjustment failed because:

1. There was no liquid or too many bubbles in sensor during last Zero adjustment.
   → The sensor needs to be filled with liquid and the Zero adjustment restarted.

4.5 Get version information

The version information of the LFSC-iX sensor is stored in the hold register 4097. Reading the hold register 4097 transmits the version register (type ushort) to the host system.

The most significant byte of the version register shows the FPGA version.

The least significant byte of the version register shows the hardware version of the LFSC-iX sensor.

For example:

Reading hold register 4097 (hexadecimal 0x1001) transmits the value 1026 to the host system. The Version number 1026 is interpreted as hexadecimal 0x0402. This means the version of the FPGA configuration is 0x04 and the version of the LFSC-iX hardware is 0x02.

5 REVISION HISTORY

Rev.	DCO No.	DCO Author	Effectivity Date	Summary Description of Changes
00	19-189	E. Hoffmann	11-Oct-2019	First Release
01	20-218	K. Wilhelm	20-Oct-2020	Firmware 04 features added
02	20-256	K. Wilhelm	10-Nov-2020	Zero Adjustment link added; 4.5 Get version information added
03	22-082	K. Wilhelm	18-Mai-2022	Flow unit changed to µl/min Hold register 14 AGC control defined Hold register 15 and 16 enhanced Hold register 100 flow control defined Hold register 104 to 109 defined