The Modbus RTU to HART gateway, the T310H7

Reference Manual

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About this document

The Reference Manual gives an overview of the capabilities and the use of the T310H7 DIN rail mounted generic HART gateway. Furthermore, it explains how to configure the device.

The following abbreviations are used in this document:

HART	Communication protocol.
PV	Primary dynamic variable in the transmitter
SV	Secondary dynamic variable in the transmitter
TV	Third dynamic variable in the transmitter
FV	Fourth dynamic variable in the transmitter
DD	Device Description
CRC	Cyclic redundancy check. Check bits that ensure that bit errors are detected.
PLC	Control or monitoring system
DAC	Digital to Analog Converter. The DAC is controlling the 4-20 mA loop.
Dev Type Id	Device Type Id – An Id number in the device that is unique for a particular HART device

Summary

The T310H7 allows Modbus RTU instruments to communicate with HART masters

The T310H7 capabilities can be summarized as follows:

- The T310H7 is a DIN rail mounted module that provides HART transmitter functionality to Modbus RTU instruments.
- T310H7 contains a serial input channel for Modbus communication.
- Modbus Baud rates supported are 9600 and 19200 kbit/s.
- T310H7 supports four dynamic variables.
- T310H7 supports one status register
- T310H7 supports range value configuration
- T310H7 supports engineering unit selection
- T310H7 supports DAC calibration and loop testing
- T310H7 supports burst mode
- T310H7 supports generic read and write to Modbus registers.
- T310H7 is an active 4-20 mA source
- T310H7 is supplied from 10-34Vdc power
- -40°C to 85°C operation range
- T310H7 is a HART 7 device
- A DD that comes with the T310H7 makes it possible for the user to configure the T310H7 applying a standard third party HART tool

The instrument interface:

Protocol:
- Modbus RTU

Physical interface:
- RS 485

1. INTRODUCTION

1..1. Functional Description

The T310H7 is a HART 7 compliant DIN rail mountable gateway for connecting Modbus RTU instruments (Modbus slaves) to HART. A typical application is shown in Figure 2.

Figure 1. The T310H7

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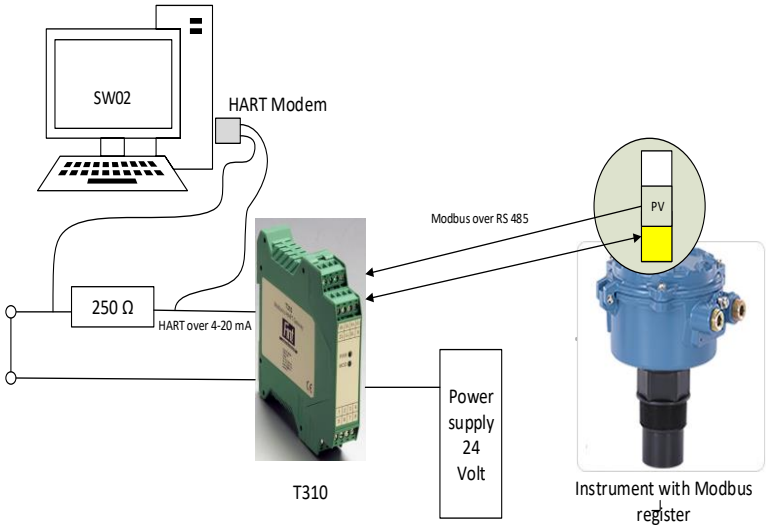

Figure 2. The T310 device in a typical application

The T310H7 is intended for installation on a DIN rail and within a cabinet. It is powered from a 10 – 34 VDC supply. Figure 3 shows the functional diagram.

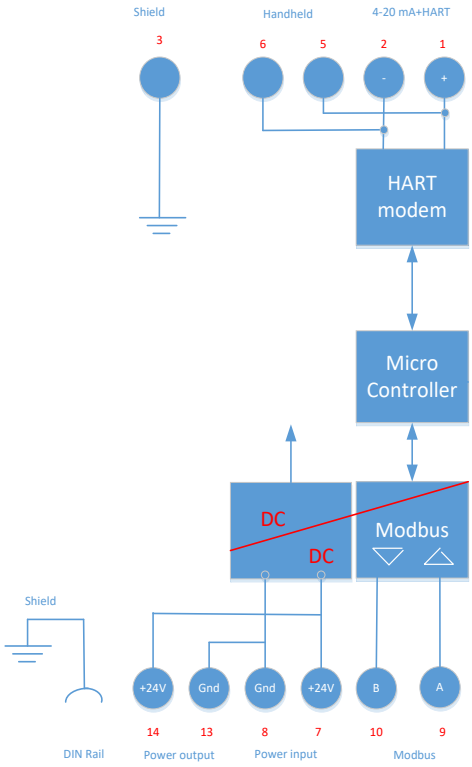

Figure 3. Functional Diagram

1..2. Mechanical Dimensions

The mechanical dimensions are shown in Figure 4.

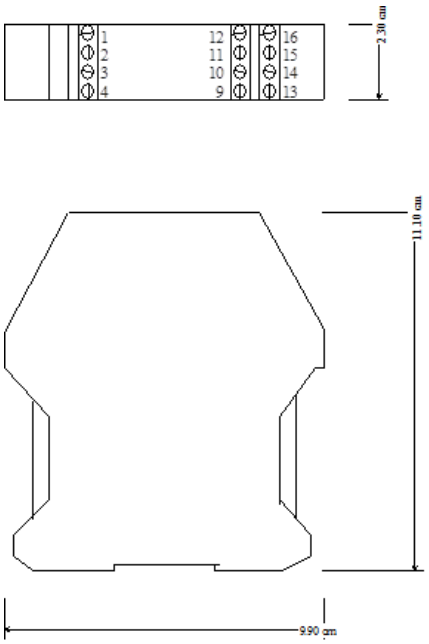

Figure 4. Dimensions of the T310H7

2. INSTALLATION

The T310H7 is designed for being mounted in a cabinet on a DIN rail.

2..1. Electrical Connections

The T310H7 contains 4 pluggable screw terminals.

The T310H7 shall use the connector pinout as shown in Table 1:

Connector	Pin	Comment
HART	1	4-20 mA & HART +
	2	Connection for HART hand held terminal
	3	EMC shield
	4	No Connection
	5	Connection for HART hand held terminal
	6	4-20 mA & HART -
Power	7	24 V DC (+)
	8	GND (-)
	13	GND (-)
	14	24 V DC (+)
Modbus	9	MODBUS – Signal A (-)
	10	MODBUS – Signal B (+)
	15	No Connection
	16	No Connection
DIN clip	-	PE connection for Modbus EMC (see Figure 3)

Table 1. Connector Arrangement Table

2..2. Diagnostic LEDs

There are two LEDs on the front. One for Power ON and one for the Modbus communication. The green color Modbus LED is blinking on response to Modbus telegrams. It will start blinking after the first response from Modbus is received. If there is no response from the Modbus instrument, there is no green light blinking. If the Modbus communication is lost, no response, the led will stay on after the first unanswered request. Red light when powered.

3. OPERATION PRINCIPLE

3..1. Connecting Modbus devices to HART

The T310H7 is a protocol converter, that allows legacy Modbus devices to communicate on HART.

The T310H7 shall be configured to read dynamic measurement values stored in Registers in the Modbus instrument. Up to four distinctly separate variables are read and converted to HART variables. Both Holding and Read registers can hold the dynamic variables that T310H7 reads.

T310H7 can be configured to read one status register from the Modbus instrument. The status is made available in the Additional Status command, Command 48. Both Holding and Read registers can hold the status register that T310H7 reads.

The T310H7 is supposed to be configured and set-up by an integrator or OEM User using the HART configuration tool from FINT, the SW02. When configured, the End-user can perform standard HART functions like setting damping value, re-ranging the 4-20 mA loop and DAC calibration. A DD for that purpose is available from Fint.

Transparent read and write to Modbus registers are supported. This allows read/write access to any Holding register in the Modbus device. However, in order to use this function in a plant, a tailored tool or Device Description (DD) must be developed. The device must be given a specific Dev Type Id. Contact FINT for assistance in providing that.

4. CONFIGURATION BY THE OEM USER

4..1. Device Variables and Dynamic Variables

The T310H7 supports up to four Dynamic Variables and four Device Variables. The Device Variables are read from four different channels in the Modbus device. The Device Variables are mapped to the Dynamic Variables. The Dynamic Variables are processed in the T310H7 and are made available to the user on the HART interface. See Figure 6.

Of these four variables, one is selected as the Primary Variable (PV). PV shall be the variable that represents the primary measurement and that controls the 4-20mA analog output.

The channel input variables constitute the Device Variables. There are up to four Device variables in T310H7. See Figure 5

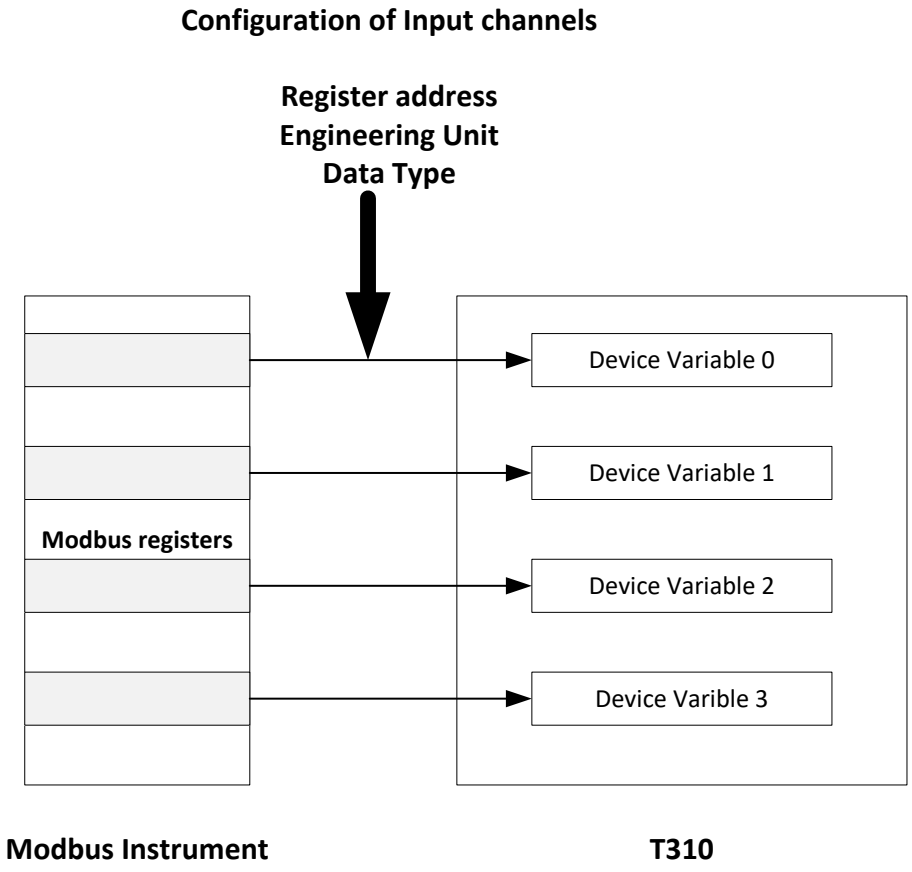

Figure 5. Input channels

The measured values can be stored in the Modbus register in either of the data-types Float, Short or Long. They may also be stored in Fixed format (with decimal point). To cope with these variations, the T310H7 needs to be configured accordingly by the OEM User. T310H7 needs to

know where to read the measurements, in what data type the data is represented, if scaling is required and the Engineering unit of the measurement.

The Engineering unit must belong to a Device Variable Class. The T310H7 supports various units in each class and unit conversion within a class. Once a Variable Class is selected, the End-user can choose amongst the supported units in that class.

The measured value is transformed from the data type used in the Modbus device to a Device variable value (IEEE 785 float) in the Engineering unit selected by the End-user.

NOTE! *Once selected, the Engineering unit within the Modbus instrument should not be changed.*

The measured value can be read either from Modbus Holding Registers using Function Code 3 or Modbus Input Registers using Function Code 4.

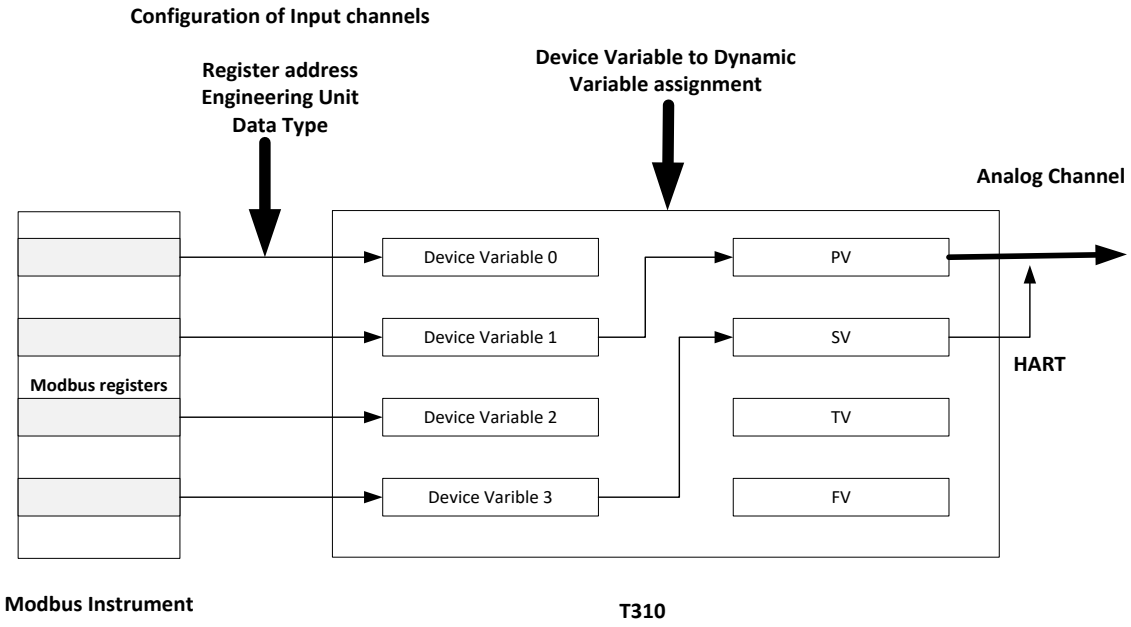

Figure 6. Device variables and Dynamic variables

Through assignment the Device Variables are mapped to the 4 Dynamic Variables: Primary (PV), Secondary (SV), Third (TV) and Fourth (FV).

The default mapping is that Device variable 0 goes to the PV.

4..2. Configuration and measurement mode

The T310H7 operates in two modes, Configuration Mode and Measurement Mode. The Configuration Mode is the mode where the OEM User is setting up the T310H7 for communication with the Modbus instrument. The communication between the T310H7 and the Modbus field device is halted in configuration mode.

The following tasks are performed in the Configuration Mode:

1. Modbus field device address (1-255) is specified,
2. Modbus baud rate is selected.
3. Device Variables Modbus Register addresses, data types and Function Codes are selected,
4. Device Variable units are specified,
5. Dynamic variable assignments are performed,
6. Sensor Limits are specified
7. Range is configured and possibly register addresses are selected,
8. Modbus device status register address with Function Code is selected,

In Measurement Mode, the T310H7 reads the measurement and status from the Modbus field device cyclically. The cycle periode depends on the number of field device variables to be read.

The configuration software, the SW02 is automatically swopping between Measurement and Configuration Mode when entering and leaving the T310H7 menus. The OEM User will not be notified when using SW02.

4..3. Setting up the Modbus

Parameter	Value	Comment
Modbus baud rate	9 600, 19 200, Kbits/s	
Modbus address		
# stop bits	1 or 2 (1 is default)	
Modbus Parity	0 = Odd parity 1= Even parity 2= No parity	
CRC byte order	0 = Normal byte order 1 = Reverse byte order	
Timeout	0 - 1000 ms	Modbus device response time (ms)

Table 2. The Modbus set-up parameters

Figure 7 shows how the Modbus set-up window appears in SW02.

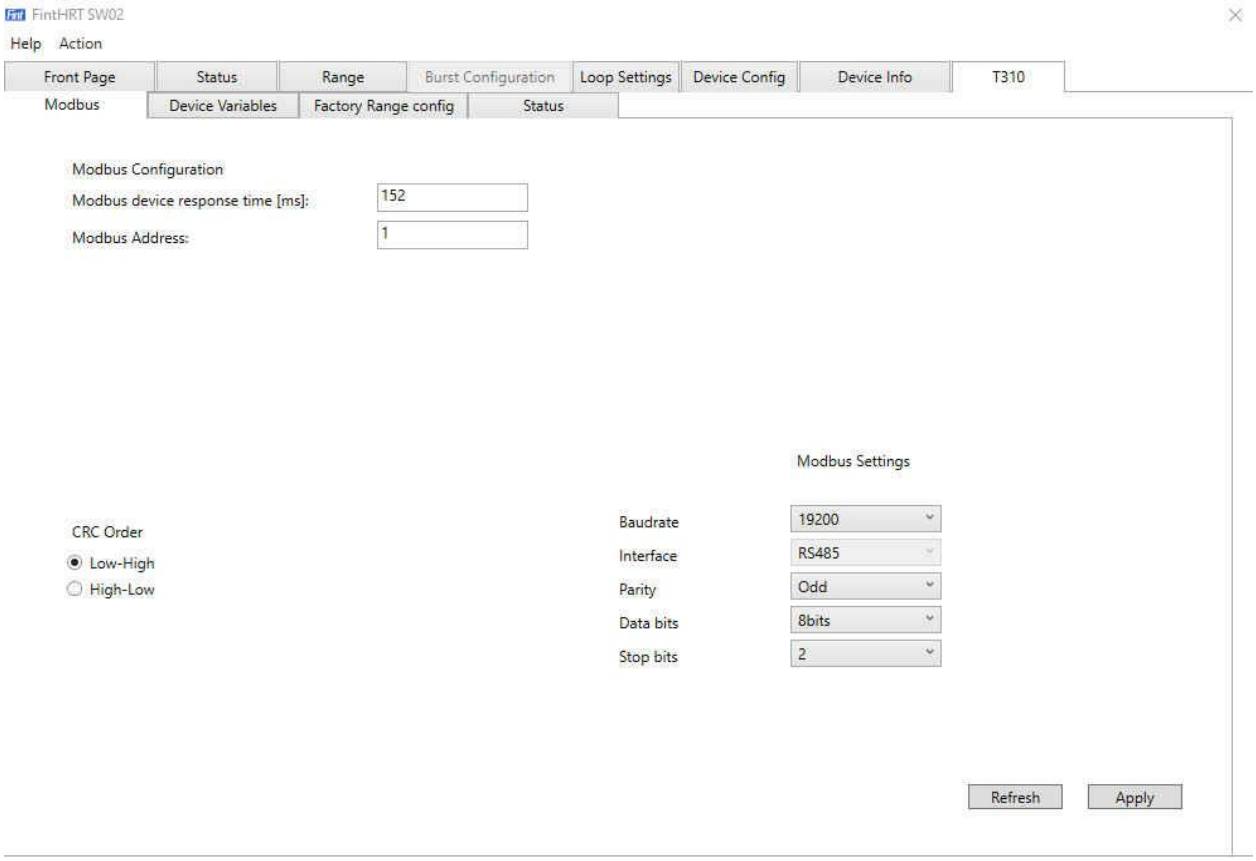

Figure 7. Set-up window for Modbus

4..4. Set-up of Device Variables and Dynamic variables

The T310H7 can support up to 4 Device Variables. Figure 8 shows the set-up in SW02

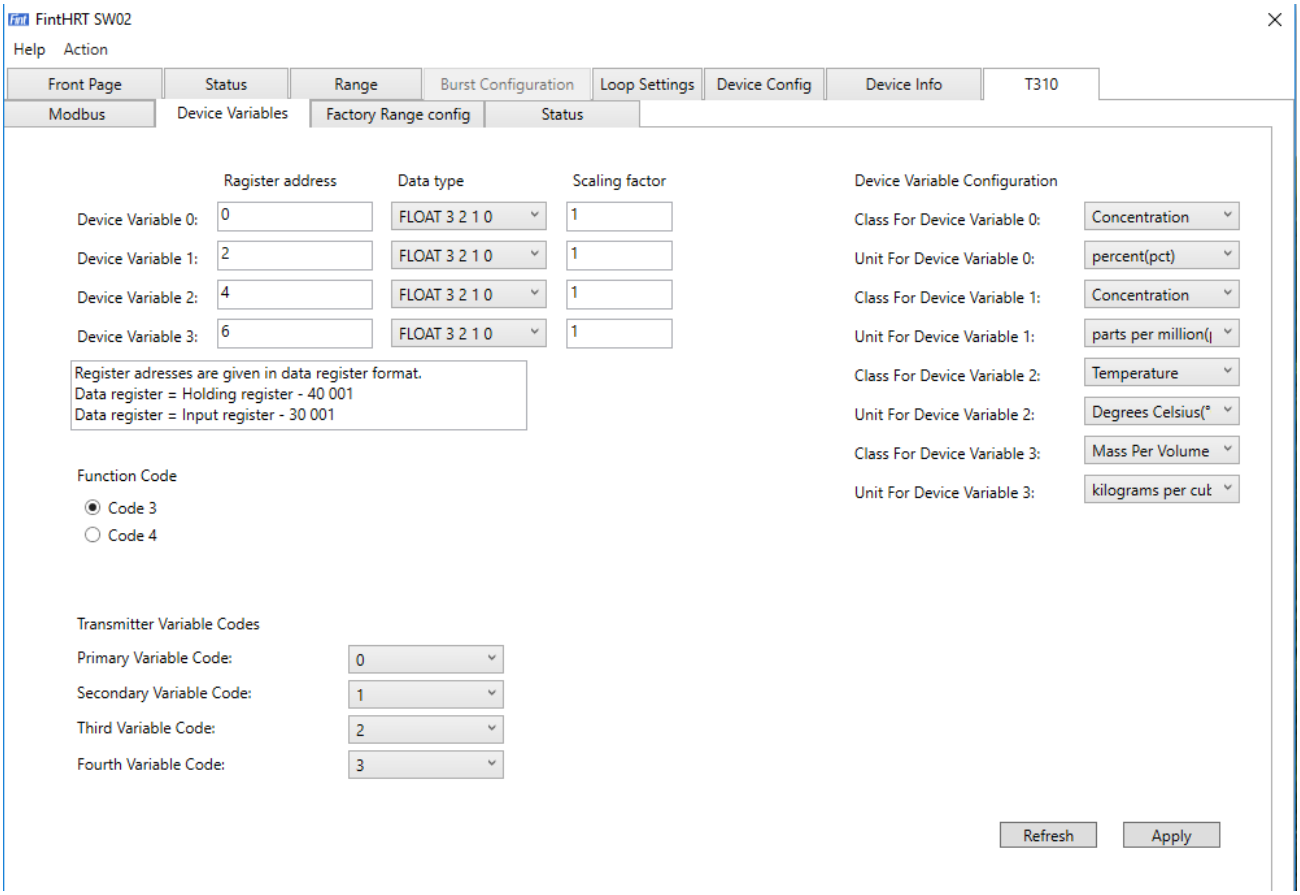

Figure 8. Device and Dynamic Variable set-up

The first step is to select the variables in the Modbus instrument. This is illustrated in Figure 9.

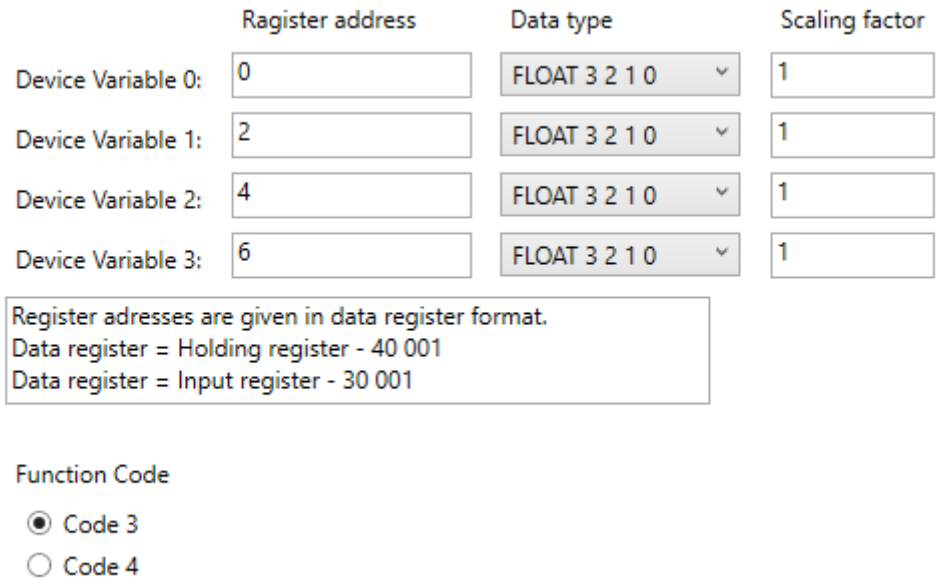

Figure 9. The Modbus instrument variables

The register address for one to four variables (Device Variable 0 -3) can be entered in the column, Register address. The address is specified in the Register format.

The measured value in the Modbus device is most likely stored in a format (data type) that needs to be converted to the IEEE 785 float format used by the HART standard. In order for T310H7 to perform the data type translation, the data type and byte order must be specified.

For T310H7 the byte ordering is defined in the data type. The byte is numbered so that the Most Significant byte has the higher number. This is illustrated in Table 3.

Data type in Modbus	Byte and nibble order	Data type code
Float	3 2 1 0	0
Float	1 0 3 2	1
Float	2 3 0 1	2
Float	0 1 2 3	3
Short Integer	1 0	4
Short Integer	0 1	5
Unsigned short	1 0	6
Unsigned short	0 1	7
Long Integer	3 2 1 0	8

Long Integer	1 0 3 2	9
Long Integer	2 3 0 1	10
Long Integer	0 1 2 3	11
Long unsigned	3 2 1 0	12
Long unsigned	1 0 3 2	13
Long unsigned	2 3 0 1	14
Long unsigned	0 1 2 3	15

Table 3. Data type and byte order for the measurements

If the variable is stored as a float or long in the Modbus device, T310H7 assumes that two consecutive registers are used, as illustrated in Figure 9. The Register address pointer in T310H7 will point to the lower address.

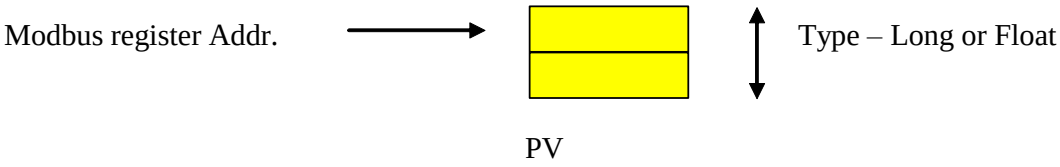

Figure 9. Storage when the measure value is a float or Long

The Scaling Factors is a multiplying factor to adjust the measured value before it is processed further to become a Device Variable. If i.e. a measured value is stored in an Integer fixed format with one decimal, the scaling factor must be specified to “0,1” to allow T310H7 to interpret the value correctly.

The Device Variable can be read both from Read registers and Holding Registers. Hence the correct Function Code needs to be selected. See Figure 10.

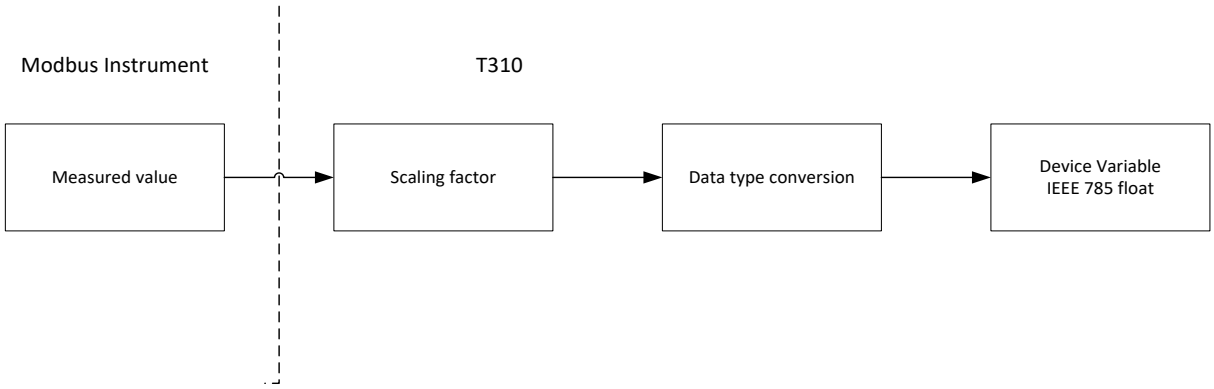

Figure 10. The calculation to obtain a Device Variable

The next step is to set up the Device Variable Configuration.

For each Device Variable the Device Variable Class and engineering unit of the measurement value fetched from the Modbus instrument shall be configured. The engineering unit is changeable through HART by the End-user. The unit conversion is handled in the T310H7, and it needs to know from which unit it shall convert. The Device Variable Class defines between which units the conversion can take place. This is illustrated in Figure 11.

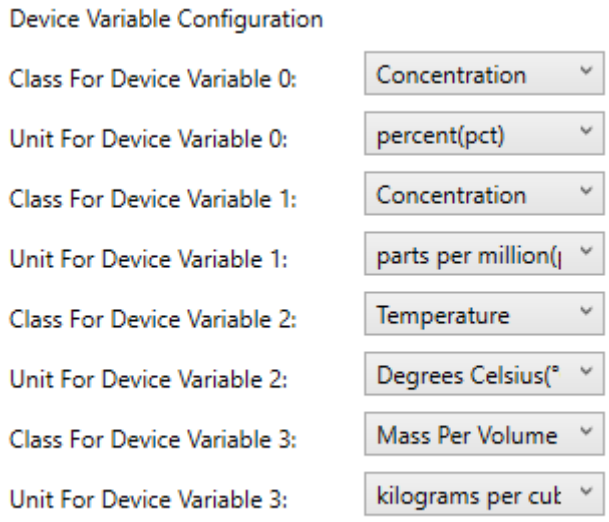

Figure 11. Configuration of Device Variable Class and Engineering Units of the measured value.

4..5. Device Variable Classification

The HART protocol classifies the Device Variables by the performed measurement function. The Device Variable Classification is determined by the process measurement type and will determine the Engineering Unit that is supported. The Table 4 shows the Device Variable Classes and the related Engineering Units supported by the T310H7.

Device Variable Class Temperature	Engineering Unit	
Device Variable Classification Code 64	Unit Code	Description
	32	Degrees Celsius
	33	Degrees Fahrenheit
	35	Kelvin

Device Variable Class Pressure	Engineering Unit	
	Unit Code	Description
	1	Inches of Water at 68 degrees F
	2	Inches of Mercury at 0 degrees C
	3	Feet of Water at 68 degrees F

Device Variable Classification Code 65	5	Millimeter of Mercury at 0 degrees C
	6	Pounds per square inch
	7	Bar
	8	milliBars
	9	Grams per square centimeter
	10	Kilograms per square centimeter
	11	Pascal
	12	Kilopascal
	13	Torr
	14	Atmospheres
	237	MegaPascal
	238	Inches of Water at 4 degrees C
	239	Millimeters of Water at 4 degrees C

Device Variable Class Volumetric Flow	Engineering Unit	
	Unit Code	Description
Device Variable Classification Code 66	15	Cubic feet per minute
	16	Gallons per minute
	17	Liters per minute
	18	Imperial gallons per minute
	19	Cubic meter per hour
	22	Gallons per second
	23	Million gallons per day
	24	Liters per second
	25	Million liters per day
	26	Cubic feet per second
	27	Cubic feet per day
	28	Cubic meters per second
	29	Cubic meters per day
	30	Imperial gallons per hour
	31	Imperial gallons per day
	130	Cubic feet per hour
	131	Cubic meters per minute
	132	Barrels per second
	133	Barrels per minute
	134	Barrels per hour
	135	Barrels per day
	136	Gallons per hour
	137	Imperial gallons per second
	138	Liters per hour
	235	Gallons per day

Device Variable Class Mass Flow	Engineering Unit	
Device Variable Classification Code 72	Code	Description
	73	kilograms per second
	74	kilograms per minute
	75	kilograms per hour
	76	kilograms per day
	77	metric tons per minute
	78	metric tons per hour
	79	metric tons per day
	80	pounds per second
	81	pounds per minute
	82	pounds per hour
	83	pounds per day
	84	short tons per minute
	85	short tons per hour
	86	short tons per day

Process Variable Density	Engineering Unit	
Device Variable Classification Code 73	Code	Description
	91	Gram per cubic centimeter
	92	Kilogram per cubic meter
	93	pounds per gallon (UK)
	94	Pounds per cubic foot
	95	Grams per milliliter
	96	Kilograms per liter
	97	Grams per liter
	98	Pounds per cubic inch

Process Variable Frequency	Engineering Unit	
Device Variable Classification Code 80	Code	Description
	38	Hertz

Process Variable Analytical	Engineering Unit	
Device Variable Classification Code 81 (No unit conversion supported)	Code	Description
	57	Percent
	59	pH
	161	Percent lower explosion level (%LEL)

Process Variable EMF (Potential)	Engineering Unit	
Device Variable Classification Code 83	Code	Description
	36	Millivolts
	58	Volts

Process Variable Concentration	Engineering Unit	
Device Variable Classification Code 90 (No unit conversion supported)	Code	Description
	139	Parts per Million (ppm)
	169	Parts per Billion (ppb)

Process Variable No classification	Engineering Unit	
Device Variable Classification Code 0	Code	Description
	250	Not Used
	251	None
	252	Unknown
	253	Special

Table 4. Device Variable Classes and the related Engineering Units

4..6. Dynamic Variable Assignment

The Device Variables are assigned to the Dynamic Variables. The assignment is configurable. The Dynamic Variables are known as PV, SV, TV and FV in HART. It is especially PV (Primary Variable) that is important as this is the Dynamic Variable that feeds the 4-20 mA loop. In the menu in Figure 12 you may change the order of the variables. The default setting is shown.

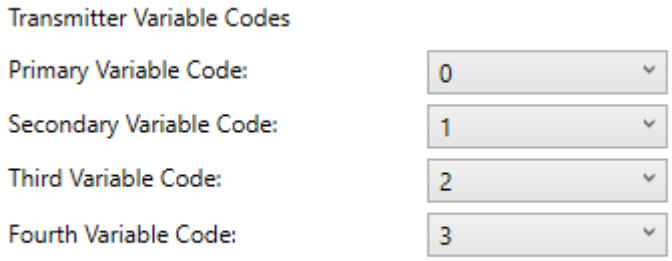

Figure 12. Default settings for Device variables

4..7. Range values and Sensor Limits for Primary Variable (PV)

The Range values define the 4-20 mA range.

T310H7 Range values (Upper & Lower) may reside either in the Modbus instrument or in T310H7 module itself. The Range Source parameter tells T310H7 where to find the Range values. It is either Local (it is configured and stored in T310H7) or is Remote (In the Modbus instrument).

If it is local, the Range values, Upper Range corresponding to 20 mA and Lower Range corresponding to 4 mA must be written to T310H7 by the OEM User. This will be an initial value that later can be changed by the End-user.

If the Source is Remote, the PV Register Options become active. This option allows the OEM User to select whether the Range values are Read-only or if it is possible to change the Range. If so, the End-user is allowed to change the Range through HART commands (Read/Write). When the Remote option is selected the Modbus registers for upper and lower ranges have the same format as the Modbus register for the selected device variable register assigned to PV.

Example: PV is assigned to device variable 0. Modbus register for device variable 0 is a float with byte ordering 3210. The Modbus registers for upper- and lower range get the same type of Modbus register.

Note: If the dynamic assignment is changed the Range configuration must be run again. See Fig.13

For both the Remote cases the register address for the Upper and Lower Range value must be set.

In all these cases the T310H7 uses these Range values to calculate the loop current and % of Range.

- Percent of range = $\left(\frac{PV - Lower\_Range}{Upper\_Range - Lower\_Range}\right) \times 100\%$
- Current = $(Percent\_of\_Range \times 0.16) + 4.00$ => Range (4.00 to 20.0 mA)

The configuration window is shown in Figure 13.

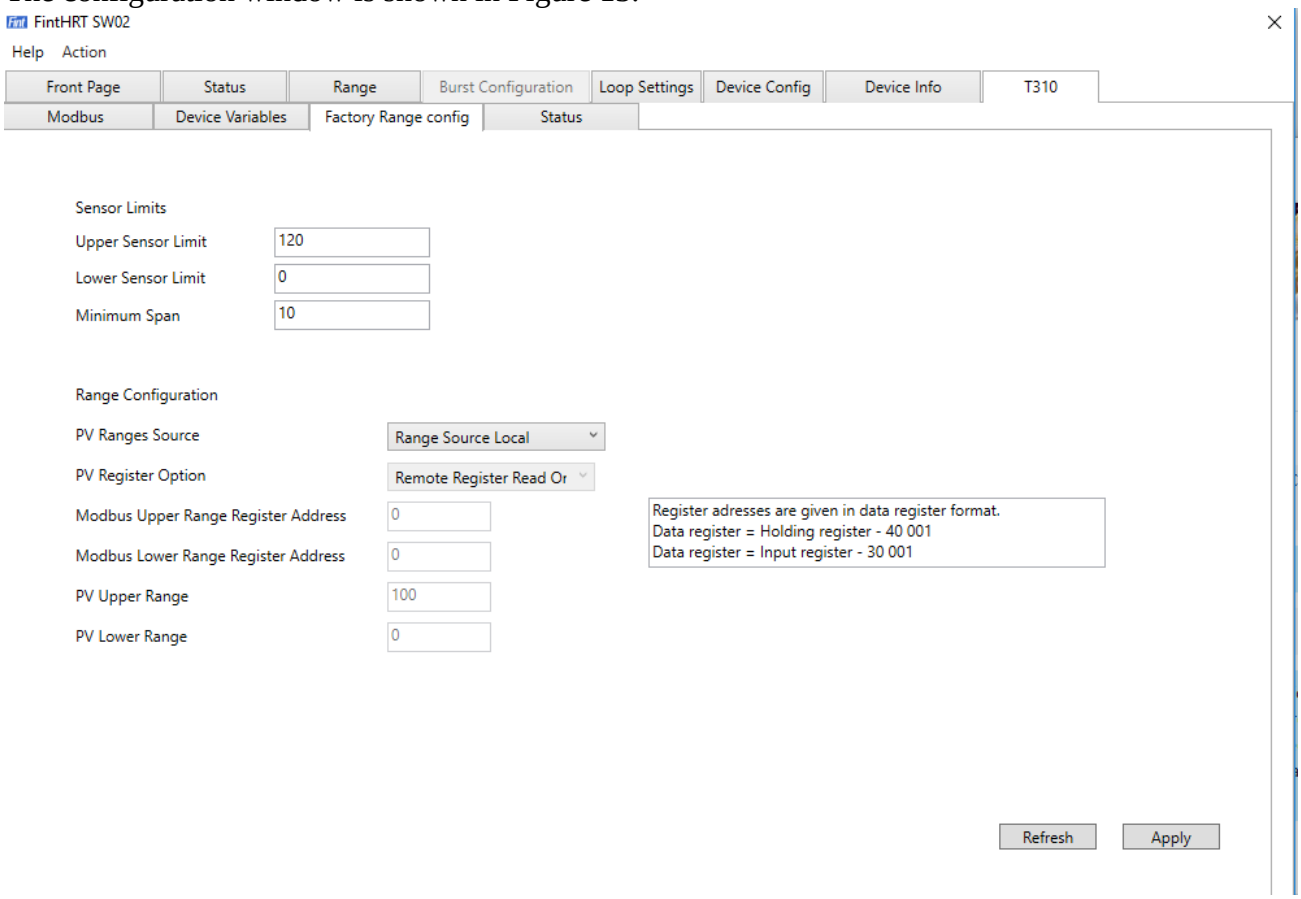

Figure 13. Configuration of Range in SW02

The End-user may have the option to re-range the 4-20 mA loop. He might want to do that in order to focusing the control on a narrower part of the measuring range. In order to avoid that this is in conflict with the accuracy and performance of the sensor, Sensor Limits and Minimum Span shall be configured. The End-user can never set the Upper and Lower Range outside the Sensor Limits and the Range can never be set smaller than the Minimum Span. An example is shown in Figure 14.

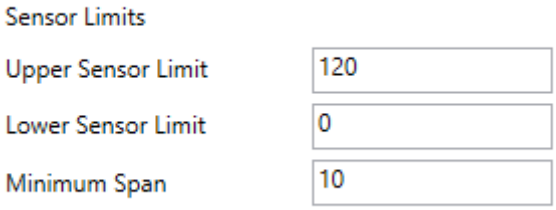

Figure 14. Configuration of Sensor limits

If the range shall be fixed as is often the case, the Upper and Lower Limits and Upper and Lower Range shall be configured to be equal. Minimum Span shall be set equal to Range.

The Upper-, Lower sensor and Span Limits define the absolute limits for the re-ranging of the device. The sensor limits are the limits in which the manufacturer can guarantee the accuracy of the measurement, and the minimum span is the minimum range that can be configured for the loop current within the accuracy specified for the Modbus instrument. The sensor limits are local to the T310H7 module. The Sensor Limits units must belong to the Device Variable Class of the PV.

4..8. Modbus instrument device status

The device status can be read cyclically from the Modbus instrument. Hence, any change of state in the Modbus device status can be detected by the HART Master when it happens. The content of the device status is device specific, and the device status is transmitted transparently through the T310H7. The device status is read using Command 48 (Read Additional Status).

The Status can reside in a Holding register or a Read register. The Register address must be specified. Only one register is supported. And it is copied to the first two bytes in the Command 48 response.

The data format can either be of the type Bit Enumerated or as an Enumeration.

The least significant byte of the Modbus instrument status register is placed in the first byte of the Command 48 response. The most significant byte is the second byte.

Status setting is exemplified in Figure 15.

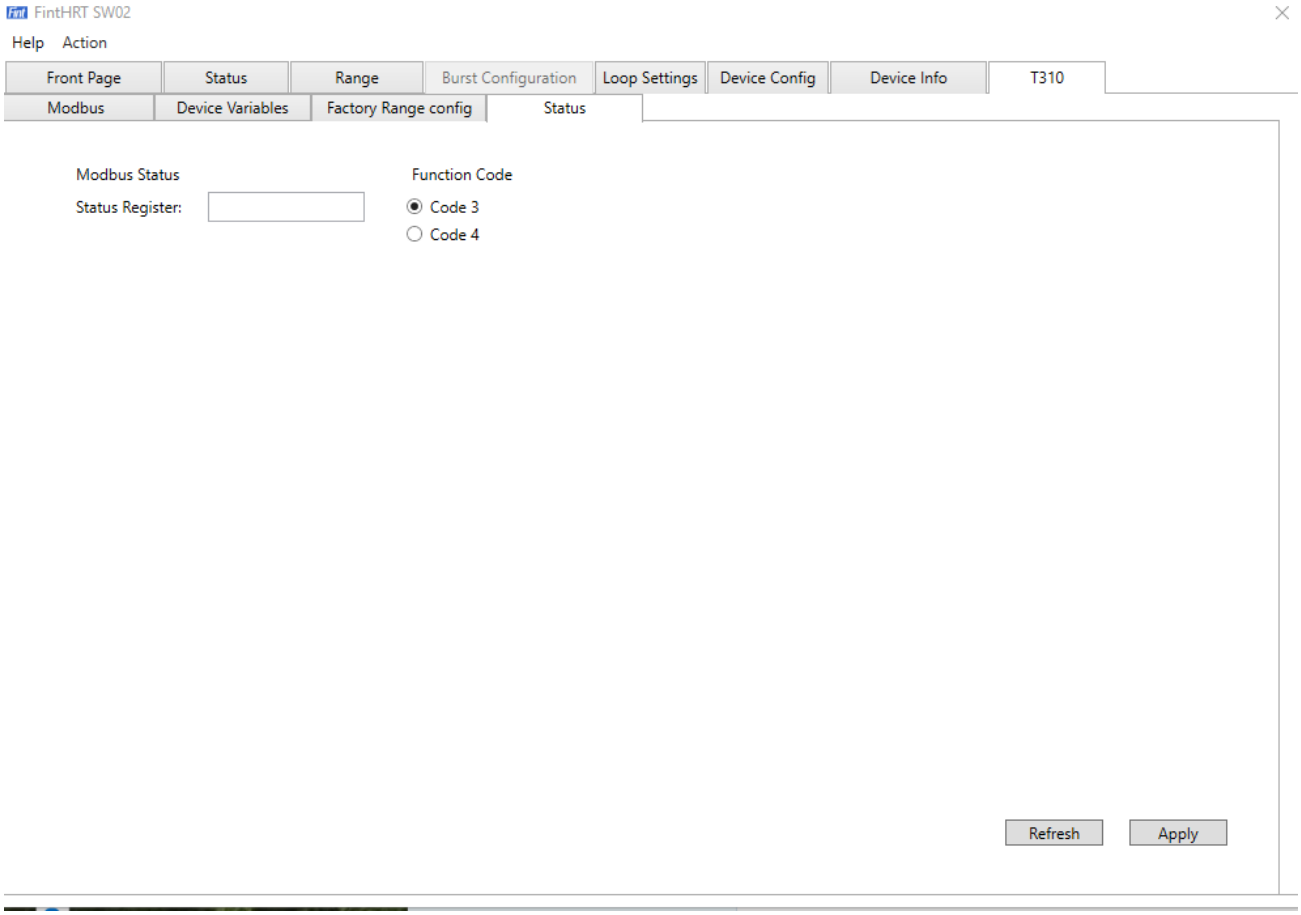

Figure 15. Setting Modbus instrument device status

5. T310H7 FUNCTIONALITY APPLICABLE FOR THE END-USER

This chapter describes features of the T310H7 that are intended to be used by the End-user. A DD is provided with the T310H7 that will allow the End-user to configure the T310H7. SW02 is used to describe this functionality.

5..1. Measurements

The front page of SW02 shows the readings from the instrument and the main identification of the T310H7, the TAG name.

The Primary Variable (PV) can be shown in a window as a function of time. See Figure 16. The readings are either fetched by the T310H7 using Command 3, or Read Requests from the T310H7 (Continuous Update). This will lead to two updates a second. An alternative is to use the Burst Update button. This will force the T310H7 to send updates three times a second.

The Analog output is supposed to show the actual loop current from the T310H7. This value is defaulted to 10 mA, so if no communication is established on Modbus, the value will stay at 10 mA.

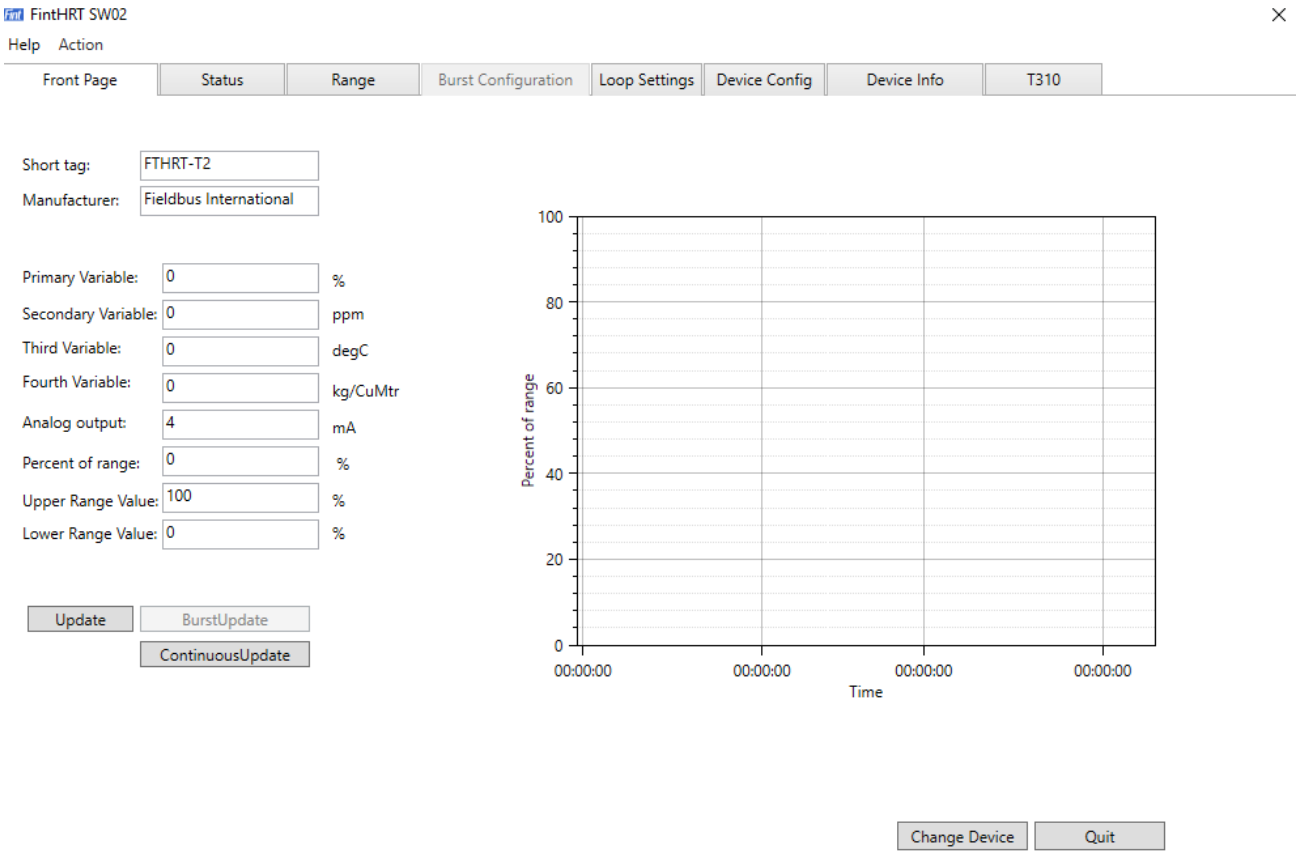

Figure 16. The appearance of the Front page in SW02

5..2. Loop settings

T310H7 supports Loop testing and DAC calibration.

The 4-20 mA loop may become inaccurate due to drift, but applying the DAC Trim routine it can be trimmed. See Figure 17.

The Test Loop function can be used for commissioning and for verification of the loop wiring.

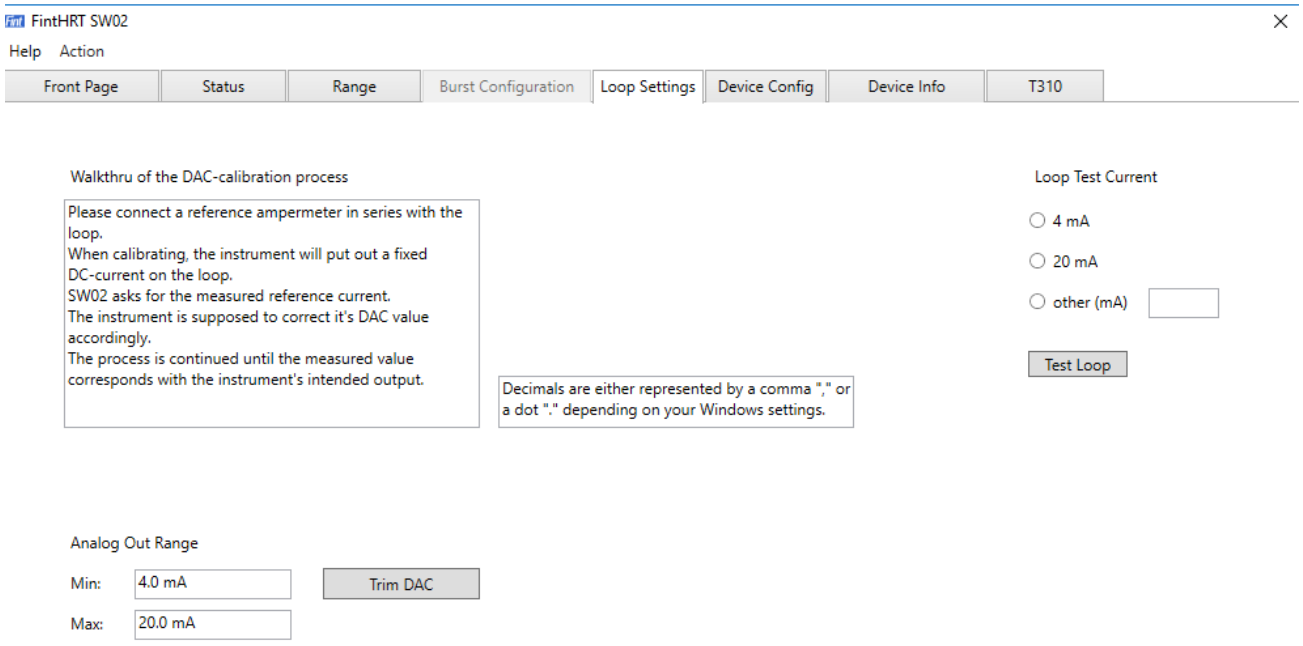

Figure 17. Loop testing and DAC calibration

5..3. Device Configuration

T310H7 supports the basic HART functions.

It is possible to write and store the following parameters:

- TAG name
- Date, i.e..installation date
- Description, the End-user can describe the properties of the measurement

- Message, the End-user can store a message or a help text
- Final Assembly number is a number that the End-user can specify.

The T310H7 low pass filter is characterized by the Damping factor. Given a step on the input the output will have risen to 67 % of the step after the Damping value time. See Figure 18.

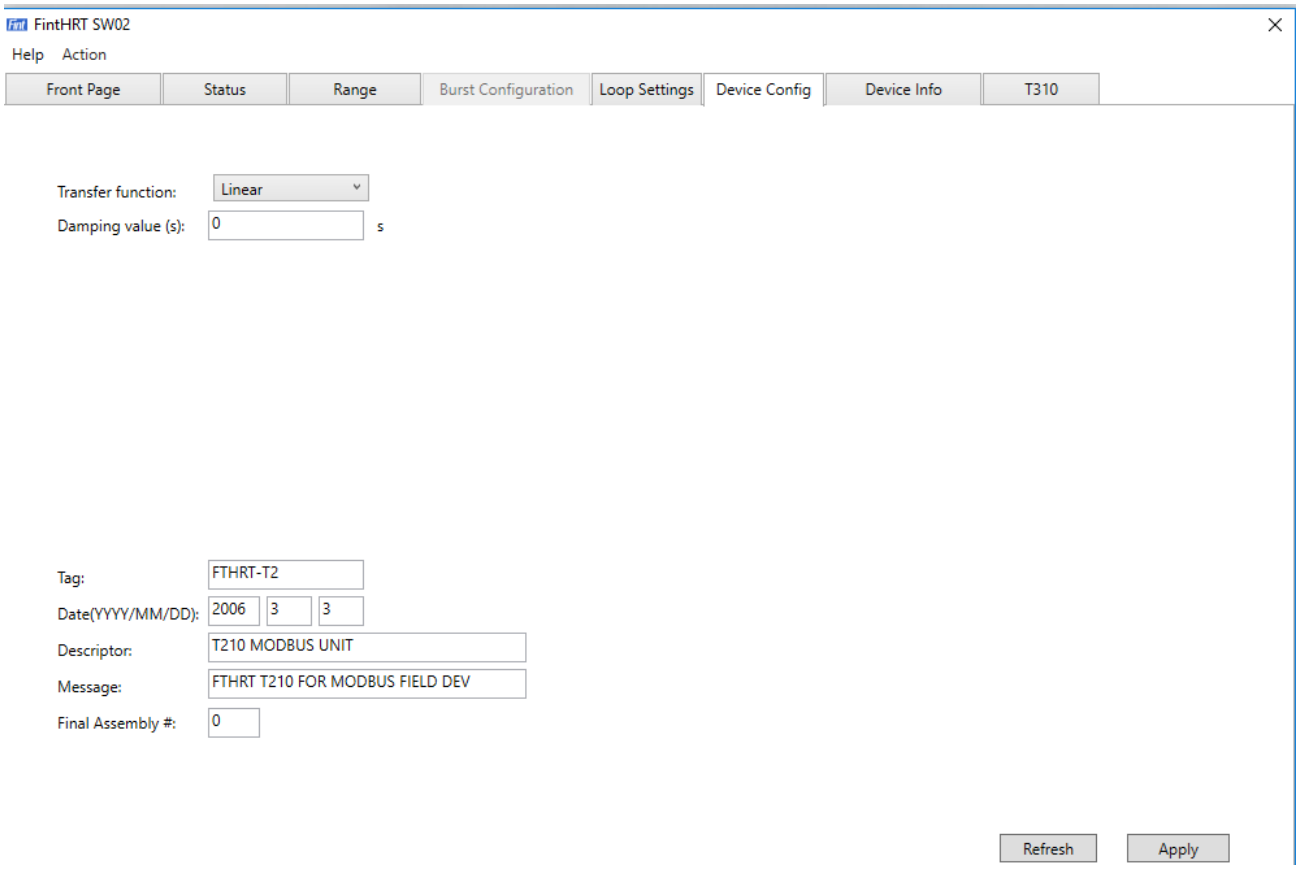

Figure 18. Device configuration

5..4. Device Info

The Device Info menu contains data characterizing the T310H7.

The device's ID is the serial number for the T310H7. There is no support for the Sensor Serial Number in T310H7. The menu is shown in Figure 19.

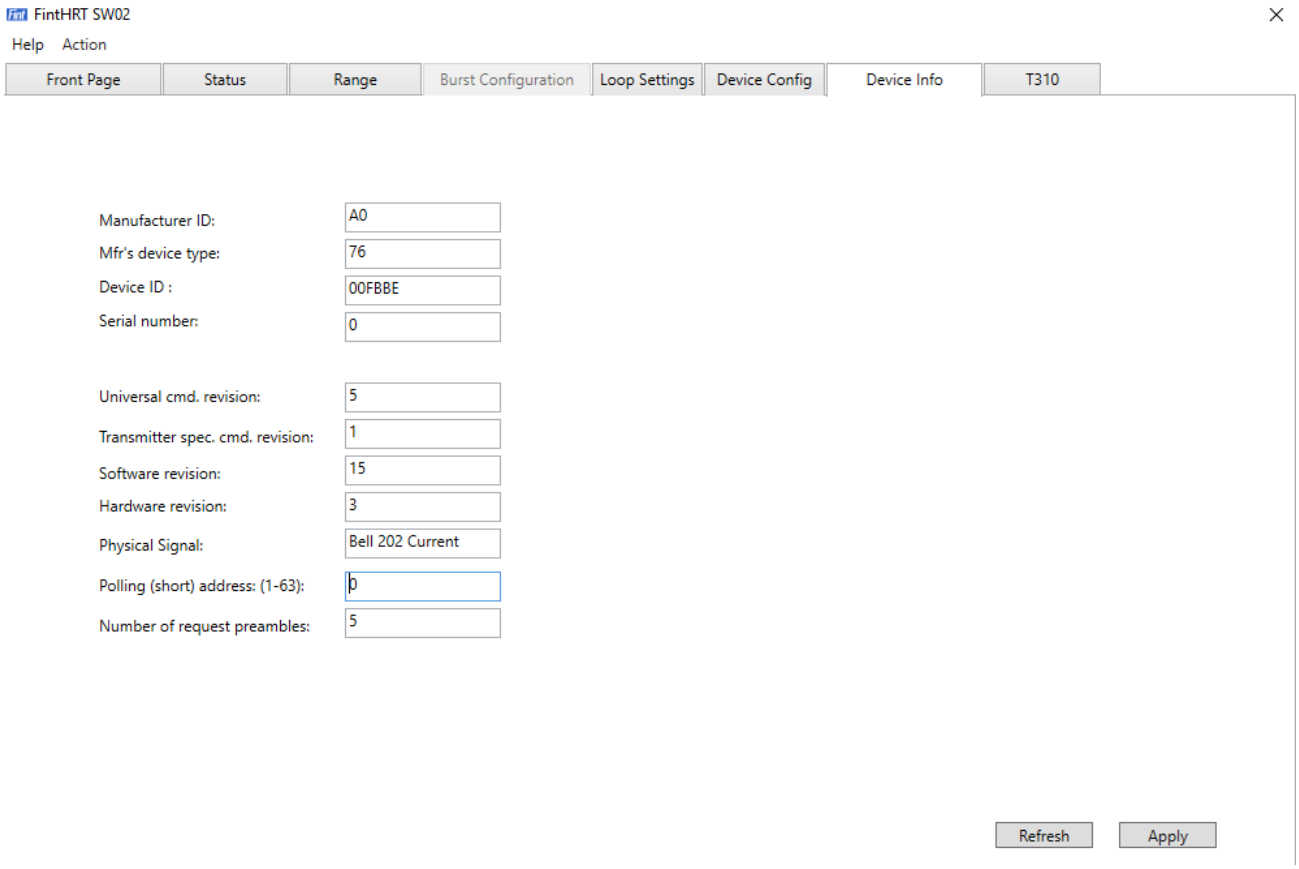

Figure 19. The Device Information menu

5..5. Field Device Status flags supported by T310H7

The eight-bit Field Device Status is included in all HART responses. The following flags are supported in T310H7:

Cold-start flag:
This is a temporary flag used to notify the user that the T310H7 has been power-cycled or of the occurrence of a reset (either due to Master reset or Watch-dog reset). This flag is automatically reset on the first HART request either from the primary or the secondary Master.

More Status Available Flag:
This is a flag set on an Additional Device Status event. An event is any change of state of the bit flags in the Additional Device Status. The Additional Status information is read through the HART Command 48. The T310H7, being a general purpose converter, does not have a predefined encoding of the Additional Status bytes. T310H7 copies the status of the Modbus device read through Modbus directly into the Additional Status. Hence it is up to the field device manufacturer to define and interpret the events of the Additional Status.

5..7. Command 48, Additional Device Status

When the More Status Available flag is set, a change in the device status has occurred. This change can be read using Command 48. The T310H7 returns 3 bytes of Additional Device Status information. The two first bytes are copied from the status read from the Modbus instrument. The last byte is the communication status between the T310H7 and the Modbus instrument.

Status 0 and Status 1 are copied from the Modbus device.

Status 2 is flagging the Modbus communication status.
If Status 2 = 0 the communication with the Modbus instrument is working

One example is shown in Figure 20.

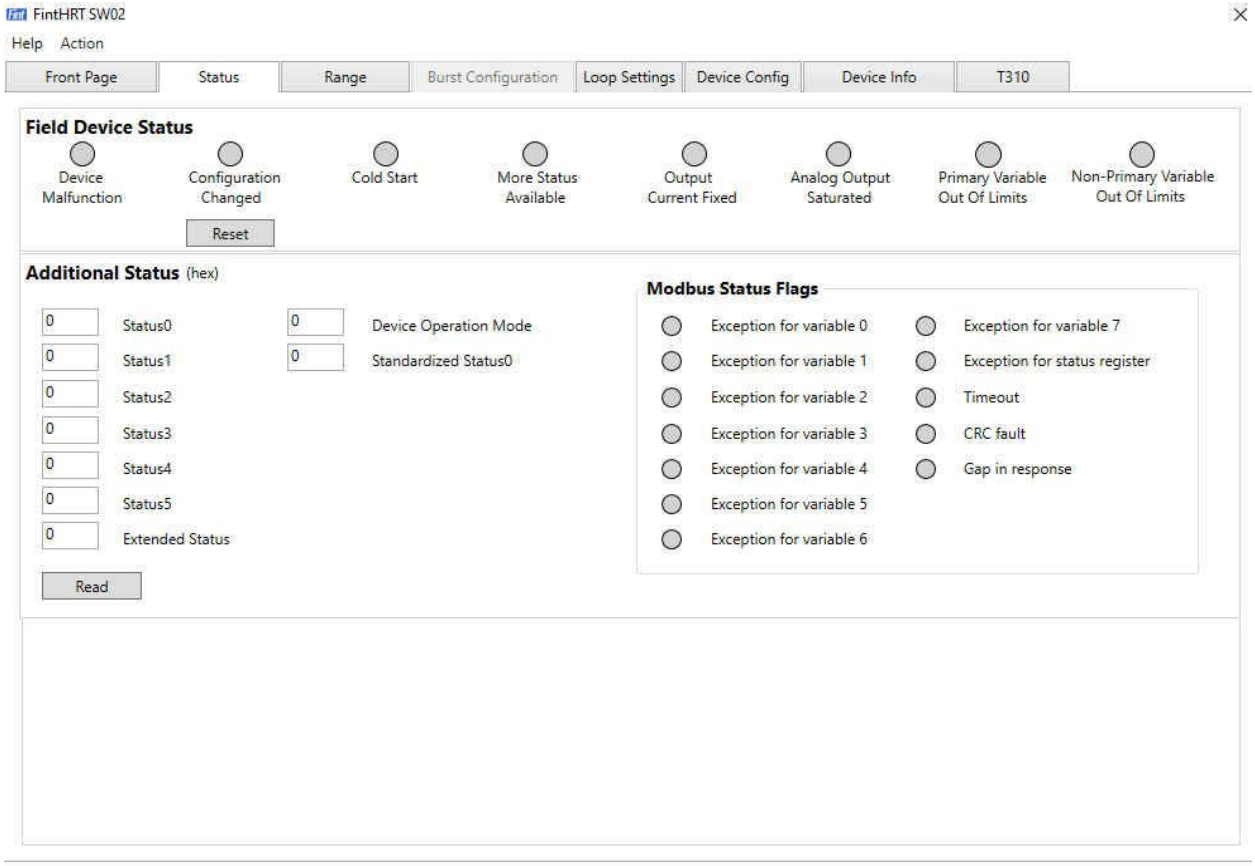

Figure 20. Example of the Command 48

Status 2 has the following encoding

bit 0: Modbus Timeout
bit 1: Modbus CRC fault
bit 2: not used
bit 3: Modbus Gap in response
bit 4: Modbus Exception received for device variable 0 register
bit 5: Modbus Exception received for device variable 1 register
bit 6: Modbus Exception received for device variable 2 register
bit 7: Modbus Exception received for device variable 3 register

Status 3 has the following encoding

bit 0: Modbus Exception received for External Upper Range register
bit 1: Modbus Exception received for External Lower Range register
bit 2: not used
bit 3: not used
bit 4: Modbus Exception received for Status register

5..8. Re-ranging

The 4-20 mA range can be reconfigured by the End-user. This is a standard functionality in HART. The window shown in Figure 21 is used to enter the new range values in the relevant Unit code. Sensor Limits are included as a guidance.

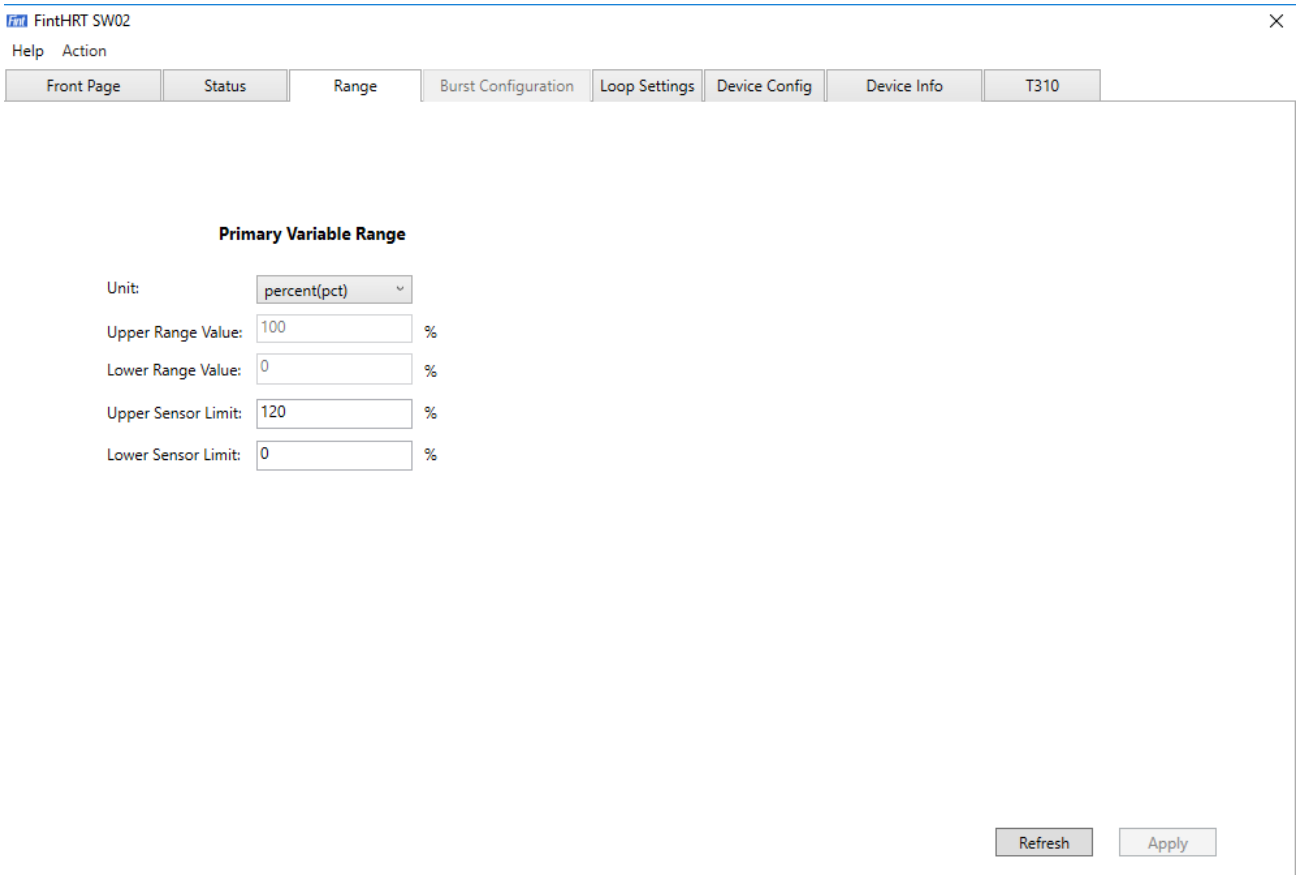

Figure 21. Re-ranging window

6. APPENDIX A. TECHNICAL SPECIFICATIONS

Mechanical:

Size	114,5 * 99 mm
Mounting	DIN rail
Module width	23,2 mm
Weight	160 gram
Housing	Plastic, IP-20 protection

Electrical:

Supply voltage	10....34 VDC
Supply current	25 mA MAX

Environmental:

Operating temperature range	-40 °C to + 85 °C
Shock	IEC 600068-2-27
Vibration resistance	IEC 600068-2-6

Protocols and Ports:

Number of HART ports	1
Number of Modbus ports	1
HART protocol	HART 5
Modbus protocol	Modbus RTU, Master
Modbus serial standard	RS-485

7. APPENDIX B. MODBUS COMMUNICATION

The communication between the T310H7 and the Modbus field device is carried out in a master-slave approach. The T310H7 acts as a master and the Modbus field device as a slave.

7..1. Modbus byte encoding

The T310H7 supports the standard Modbus RTU framing transmission mode. In this mode, the entire message frame is transmitted as a continuos stream.

The byte format is:

- Coding system : 8-bit binary, Hexadecimal 0-9, A-F
- Bits per Byte : 1 start bit
  8 data bits, least significant bit sent first
  1 stop bits
  No parity
- Baud Rate : 9600, 19200
- Error Check field: CRC

The Character framing is specified in Table 5

BIT SEQUENCE										
	LSB							MSB		
START	1	2	3	4	5	6	7	8	STOP	STOP

Table 5. Character framing

7..2. The T310H7 MODBUS FUNCTIONS

The T310H7 supports the following Modbus functions:

- Function Code 3 (Read Holding Registers)
- Function Code 4 (Read Input Registers)
- Function Code 16 (Preset Multiple Registers)

7..3. Field device Register types

Two types of data registers are supported: Input Register and Holding Register.

INPUT REGISTER: A Register used for the analog inputs from the field (process under observation), or the configuration/information of the field device. The input register is a read only 16-bit long register. The valid addresses are device dependent. Single float variables or multiple float variables can be handled when consecutive addresses are used.

HOLDING REGISTER: A Register used for the value of the analog inputs from the field, or to set configuration of the field device. The Holding register is a read/write 16-bit long register. The valid addresses are device dependent. Single float variables or multiple float variables can be handled when consecutive addresses are used.

7..4. Reading of Field device parameters

Read/Write Holding Registers: TheT310H7 conducts a cyclic scanning of the dynamic variables and the status-flag register. Other device measurements and configuration parameters may be read and written using generic HART commands.

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7..5. Query-Response Cycle Modbus

The Query-Cycle starts once the T310H7 operation mode is set to Measurement mode. The T310H7 issues a query to the field device to read the Device Variable and Modbus Device Status holding registers. The field device reply shall consist of the Field device Address, Function Code, the number of data bytes and the data itself. The Figure 22 shows the Query-Response message contents. The T310H7 query cycle consists of a cyclic request for the field device's measured value. The cyclic request for the Status is at a lower rate. The User query requests for reading and writing set-up parameters are handled when the cyclic reading of device variables and status is idle.

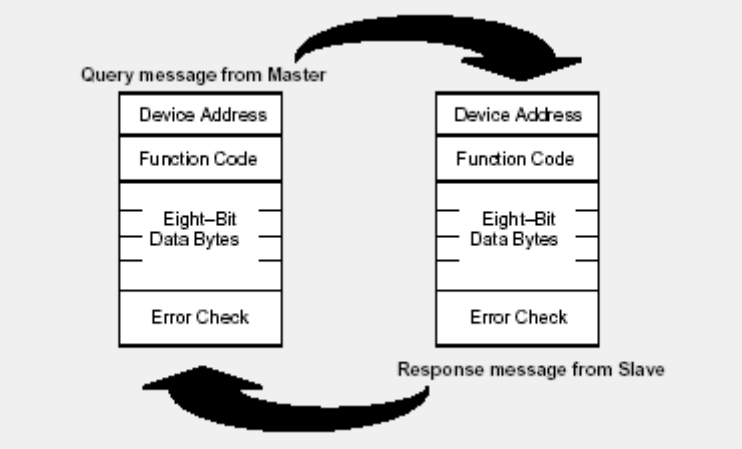

Figure 22. The Query-Response message contents

In RTU serial transmission mode, the Modbus message frame consists of a silent interval of at least 3.5 character times, a message frame followed by a similar interval of at least 3.5 character times. The 3.5 character times are the beginning and at the end marks of the frame. See Table 6.

START	Address	Function	Data	CRC	END
3.5 character Times	8 Bits	8 bits	n x 8 bits	16 bits	3.5 character Times

Table 6. RTU Mode Message Frame

The CRC field, Table 6, is appended to the message as the last field in the message. The low-order byte of the CRC is appended first, followed by the high-order byte. The CRC high-order byte is the last byte to be sent in the message. See Table 7.

CRC (16-bit Data)	
Append first the Low-order byte (LSB of CRC)	Append Last the High-order byte (MSB of CRC)

Table 7. Appending of the CRC to the Message Frame

T310H7 allows the usage of an inverted byte ordering for the CRC field. This can be configured in the configuration mode.

7..6. T310H7 Modbus Function code example

The function code 0x03 (Read Holding Registers) is used to read the contents of one or two consecutive registers in a field device. The following request data units specify the start register address and the number of registers to read. The register content is returned in the response message, two bytes per register, the first byte consisting of the high-order byte bits and the second byte consisting of low-order byte bits. An example is shown in Table 8.

REQUEST		RESPONSE	
FIELD NAME	**HEX**	**FIELD NAME**	**HEX**
DEVICE ADDRESS	0x02	DEVICE ADDRESS	0x02
FUNCTION	0x03	FUNCTION	0x03
STARTING ADDRESS HI	0x00	NUMBER OF BYTES	0x04
STARTING ADDRESS LO	0x00	REGISTER VALUE HI	0x43
NO. OF REGISTERS HI	0x00	REGISTER VALUE LO	0x0A
NO. OF REGISTERS LO	0x02	REGISTER VALUE HI	0x00
CRC LOW-BYTE	0x38	REGISTER VALUE LO	0x00
CRC HIGH-BYTE	0xC4	CRC LOW-BYTE	0xB5
		CRC HIGH-BYTE	0xFC

Table 8. Example: Query cycle to read start register 40001, number of registers, 2

If the returned values were of the type float it would read 0x 43 0A 00 00 which corresponds to 138.0

7..7. HART Response code to Modbus errors and exception codes

Table 9 shows an overview of Modbus mapping on HART. for Commands 130-133

MODBUS ERROE CODE		HART CMD RESPONSE CODE & STATUS BYTE	
CODE	NAME	CODE	NAME
1	ILLEGAL FUNCTION	64	COMMAND NOT IMPLEMENTED (CMD RESPONSE)
2	ILLEGAL ADDRESS	2	INVALID SELECTION (CMD RESPONSE)
3	ILLEGAL DATA VALUE	2	NON-PRIMARY VARIABLE OUT OF LIMITS (STATUS)
		1	PRIMARY VARIABLE OUT OF LIMITS (STATUS)
4	DEVICE FAILURE	6	TRANSMITTTER SPECIFIC ERROR (CMD RESPONSE)
		0	NO-COMMAND ERROR (CMD RESPONSE)

Table 9. Mapping of Modbus errors and Exception codes to HART response codes

8. APPENIX C . HART COMMANDS

8..1. Universal Commands

Command Number and Function	Data in Command	Data in reply	Response code	Comment
0 Read unique identifier	none	Byte 0 "254" (expansion) Byte 1 -2 Mfr. Device. Type Byte 2 Byte 3 Number of preamble Byte 4 Universal command revision Byte 5 transm. Specific cmd rev Byte 6 software revision Byte 7 hardware revision Byte 8 device function flag Byte 9-11 Device ID numbe Byte 12 Min Num of preambles from slave Byte 13 Max number of device variables Byte 14-15 Config change counter Byte 16 Extended Device status r	0 No command error	T310 =0xA078 Used for long address Universal cmd rev 7 Dev Specific 1 Dev Application software rev xx HART module rev. xx Multisensor device = No , EEPROM control = No -> 0 Serial number configured by Fint before shipment
1 Read PV	none	Byte 0 PV unit code Byte 1-4 Primary variable F	0 No command error	Modbus Register PV Unit %
2 Read Current & % of range	None	Byte 0-3 current (mA) F Byte 4-7 % of range F	0 No command error	Calculated in the T310H7 module based on the measured value Calculated in the HART module
3 Read Current & four variables	None	Byte 0-3 Current F Byte 4 PV unit code Byte 5-8 PV F Byte 9 SV unit Code Byte 10-13 SV F Byte 14 TV unit Code Byte 15-18 TV F Byte 19 FV unit Code Byte 20-23 FV F	0 No command error	Calculated in the T310H7 module % Number of Dynamic Variables depends on the number of variables supported by the field device.

6 Write short address	Byte 0 = short address	Byte 0 same as command	0 No command error	Address 0 when used in 4-20 mA mode A different address sets the device into multi-drop mode

Command Number and Function	**Data in Command**	**Data in reply**	**Response code**	**Comment**
8 Read dynamic variable families	none			
9 Read Device variables with status	Device variables	Device variables with status		
11 Read Uniq id associated with tag	Byte 0-5 TAG (8 characters)	Same as Command 0	0 No command error	
12 Read message	None	Byte 0-23 message	0 No command error	
13 Read tag descriptor, date	None	Byte 0-5 Tag A Byte 6-17 descriptor A Byte 18-20 date D	0 No command error	
14 Read PV sensor info.	None	Byte 0-2 Sensor serial number Byte 3 Unit code for sensor limits Byte 4-7 Upper sensor limit F Byte 8-11 Lower sensor limit F Byte 12-15 Minimum span F	0 No command error	
15 Read PV output information	None	Byte 0 Alarm select code Byte 1 Transfer code Byte 2 Range values unit code Byte 3-6 Upper range value F Byte 7-10 Lower range value F Byte 11-14 Damping value (sec) F Byte 15 Write protect code Byte 16 Private-label distributor code	0 No command error	**250 = Not Used** 0=Always linear PV unit code Upper range Lower range 250 Not Used Code = Damping value 0 No write protect mode supported. 0xA0= Fint
16 Read final Assembly number	None	Byte 0-2 final assembly number	0 No command error	
17 Write message	Byte 0-23 message A	As in command	0 No command error	
18 Write tag, descriptor and date	Byte 0-5 Tag A Byte 6-17 Descriptor. A Byte 18-20 Date D	As in command	0 No command error	

19 Write final assembly number	Byte 0-2 Final assembly number	As in command	5 Too few data bytes 16 Access restricted	
20 Read Long TAG	None	0-31 Long TAG		
21 Read Unique Id associated with LongTAG	0-31 Long TAG	As in command 0		
22 Write LongTAG	0-31 Long TAG	0-31 Long TAG		

A = ASCII string (packed 4 characters per 3 bytes) – valid ASCII codes 32-96 ***D*** Date(day,month,year –1990) ***F*** Floating point (4 bytes IEEE 754)

8..2. Common Practice Commands

Command Number and Function	Data in Command	Data in reply	Response code	Comments
35 Write PV Variable Range Values	Byte 0 Range Value unit Byte 1-4 Upper Range Value Byte 5-8 Lower Range Value	as in command	2 Invalid Selection 5 Too few data-bytes received 9 Lower Range Value too high 10 Lower Range Value too low 11 Upper Range Value too high 12 Upper Range Value too low 14 Span too small	
38 Reset Configuration changed flag	None	None		
42 Master Reset	None	None		
44 Write PV Units	Byte 0 PV units Code	as in command	2 Invalid selection 5 Too few data-bytes received	
48 Read additional transmitter status	None	Byte 0 -1 = status Byte 2 = com status		Instrument status Register content: Com status 0 = ok 1 = Fail
50 Read Dynamic Variable Assignments	None	Byte 0 Device Variable Code for PV Byte 1 Device Variable Code for SV Byte 2 Device Variable Code for TV		Unsupported Dynamic Variables return ”250” Default is “250” to all Dynamic variables

		Byte 3 Device Variable Code for FV		
51 Write Dynamic Variable Assignments	Byte 0 Device Var. Code for PV Byte 1 Device Var. Code for SV Byte 2 Device Var. Code for TV Byte 3 Device Var. Code for FV	As in Command	2 Invalid selection 5 Too few data-bytes received 6 Device Specific Error	Unsupported Dynamic Variables return ”250” Invalid selection = Variable not supported by the device. This should be issued after the field device variables are specified (cmd 139)
53 Write Device Variable Units	Byte 0 Device Var. Code Byte 1 Device Var. unit	As in Command	5 Too few data-bytes received 6 Device Specific Error 11 Invalid Device Variable code 12 Invalid Units	This should be issued after the field device variables are specified (cmd 139).
59 Write number of preambles	Byte 0 # of response preamble bytes	as in command	3 Passed parameter too large 4 Passed parameter too small 5 Too few data-bytes received	EEPROM Default 5
108 Write burst mode command number	Byte 0 Burst mode command number	As in command	2 Invalid selection 5 Too few data-bytes received	Command 1,2 and 3 possible choices
109 Burst mode control	Byte 0 Control: 0 = exit , 1 = enter	As in command	2 Invalid selection 5 Too few data-bytes received	

8..3. Device Specific Commands

Command Number and Function	Data in Command	Data in reply	Response code	Comments
130 Read Float type data from Register	Byte 0-1 Register Address	Byte 0 - 3 Modbus data	2 Invalid Selection (Exception code) 5 Too few data-bytes received 6 Device Specific Cmd error	Modbus Register = Register Address as in the fields Device. The Register Address value is transparent to T004. Device specific Error = No field device or com. failed
131 Write Float type data to Register	Byte 0-1 Register Address Byte 2- 5 Register data F	As in command	2 Invalid Selection (Exception code 5 Too few data-bytes received 6 Device Specific Cmd error	Device specific Error = No field device or com. failed
132 Read Short type data from Register	Byte 0-1 Register Address	Byte 0- 1 Modbus data I	2 Invalid Selection 5 Too few data-bytes received 6 Device Specific Cmd error	Modbus Register = Register Address as in the fields Device. The Register Address value is transparent to T210. Device specific Error = No field device or com. failed
133 Write Short type data to Modbus Register	Byte 0-1 Register Address Byte 2- 3 Register data I	As in command	2 Invalid Selection (Exception code 5 Too few data-bytes received 6 Device Specific Cmd error	Device specific Error = No field device or com. failed
134 Enter Device Variable Register Address	Byte 0-1 Register Address Byte 2 Byte order Byte 3 Scaling factor Byte 7 Device Variable Index Byte 8 Offset	As in command	2 Invalid selection (0-3) 5 Too few data-bytes received	Invalid selection = device is not in configuration mode or Index is invalid. Valid Indices are 0-3
135 Enter Status Reg. Address	Byte 0-1 Status Register Address	As in command	2 Invalid selection 5 Too few data-bytes received	Invalid selection = device is not in configuration mode
136 Enter RANGES SOURCE	Byte 0 Range Data source (0/1) Byte 1 Register Option (R/W)	As in command	2 Invalid selection (0/1) 5 Too few data-bytes received 6 Device Specific Cmd error	0 = Range source Local 1 = Range source Remote 0 = Remote Register Read/Write 1 = Remote Register Read Only Default Source = Local
137 Enter Variable Ranges Modbus Reg. Address	Byte 0 – 1 Upper Range Reg. Byte 2-3 Lower Range Reg. Byte 4 Device Variable Index	As in command	2 Invalid selection (0-3) 5 Too few data-bytes received 6 Device Specific Cmd error	Invalid Selection = Index error Device Specific Cmd error = source Local
138 Enter Sensor Limits	Byte 0 Sensor Limit Unit Byte 1-4 Upper Sens. Lim. F Byte 5-8 Lower Sens. Lim. F Byte 9-12 Min Span F Byte 13 Device Variable Index	As in command	2 Invalid selection (Unit) 5 Too few data-bytes received	Invalid selection = Unit or Dev. Var. class code not valid. This must be issued after command 139.
139 Enter Device Variable Class and Unit	Byte 0 Dev Var. Class. Code Byte 1 Unit code Byte 2 Device Variable Index	As in command	2 Invalid selection (Unit/Index) 5 Too few data-bytes received	Valid Classification codes :- 64, 65, 66, 72, 73, 80, 81, 83 , 90 & 250. Valid Variable Index :- 0-3 Unit code = Units in Modbus device.

140 Read Device Variable Class and Unit		Byte 0 Dev Var. Class. Code (PV) Byte 1 Device Variable Unit code Byte 2 Dev Var. Class. Code (SV) Byte 3 Device Variable Unit code Byte 4 Dev Var. Class. Code (TV) Byte 5 Device Variable Unit code Byte 6 Dev Var. Class. Code (FV) Byte 7 Device Variable Unit code Byte 8 Number of Variable used		
141 Enter T310H7 Operation mode	Byte 0 Operation mode (0 to 1)	As in command	2 Invalid selection (0 to 1) 5 Too few data-bytes received	0 = Configuration Mode 1 = Normal Operation Mode
142 Read T310H7 Module Data	None	Byte 0 Index (0 to 1) Byte 1 PV Range Source		Byte 0 = Operation mode Byte 1 = PV range source
143 Read Device Variable Modbus Register Address	Byte 0 Device Variable index	Byte 0-1 Modbus Reg.Address Byte 2 Device Variable index	2 Invalid selection (0-3)	Get the Modbus Address of the selected variable
144 Read Modbus Status Reg. Address	None	Byte 0-1 Status Reg. Address		
145 Read Range Register Addresses	Byte 0 Device Variable Index	Byte 0 - 1 Upper Range Reg. Byte 2 - 3 Lower Range Reg. Byte 4 Device Variable Index	2 Invalid selection (0-3) 6 Device Specific Cmd error (Local)	If Range Source is Remote = Range register addresses are returned
146 Read PV-Range Source & R/W Option	None	Byte 0 Range Data Source Byte 1 Source Reg. option (R/W)		0 = Source Local , 1 = Source Remote 0 = Read/Write , 1 = Read Only
147 Write Device Variable Upper Range	Byte 0 Range Data Unit Byte 1-4 Upper Range data F Byte 5 Device Variable index	As in command	2 Invalid selection (Unit code) 5 Too few data-bytes received 6 Device Specific Cmd error	Unit = Unit code as in command 140 . Device Specific Cmd error follows cmd 136
148 Read Device Variable Upper Range	Byte 0 Device Variable index	Byte 0 Range Data Unit Byte 1-4 Lower Range data F Byte 5 Device Variable index	2 Invalid selection (If local) 6 Device Specific Cmd error	
149 Write Read Device Variable Lower Range	Byte 0 Range Data Unit Byte 1-4 Lower Range data F Byte 2 Device Variable index	As in command	2 Invalid selection (Unit code) 5 Too few data-bytes received 6 Device Specific Cmd error	Unit = Unit code as in command 140. Device Specific Cmd error follows cmd 136
150 Read Device Variable Lower Range	Byte 0 Device Variable index	Byte 0 Range Data Unit Byte 1-4 Lower Range data F Byte 5 Device Variable index	2 Invalid selection (if Local) 6 Device Specific Cmd error	
151 Enter Device Status Bit-Patter	Byte 0-1 Pattern Hex data	As In command	5 Too few data-bytes received 7 Write Protected	1 means Bit is selected / Status flag
152 Read Device Status Bit-Patter	None	Byte 0-1 Pattern Hex data		
154 Set/Reset Write Protection	Byte 0 Protection code	As in command	2 Invalid selection (0/1) 5 Too few data-bytes received	0:Write Not Protected 1: Write Protected
200 Read Modbus Address	None	Byte 0 Modbus Address		
201 Write Modbus Address	Byte 0 Modbus Address	As in Command	2 Invalid selection (1 - 255)	**Valid Address range 1 – 255**

			5 Too few data-bytes received 7 Write Protected	**(0 address not used)**
202 Read Modbus Baudrate	None	Byte 0-1 Modbus Baudrate		
203 Write Modbus Baudrate	Byte 0-1 Baud rate Byte 2 Parity Byte 3 Number of data bits Byte 4 Number of stop bits Byte 5 Physical interface I	As in Command	2 Invalid selection (Baudrate) 5 Too few data-bytes received 7 Write Protected	**Baud rate 9600 or 19200** **Physical interface is fixed to RS485**
204 Read Modbus Message CRC Order	None	Byte 0 CRC-Byte order		0 : Low – High order (Standard Opt.) 1: High - Low order
210 Set Modbus response delay				
211 Read Modbus response delay	None			
212 Set Function code for Dynamic Variables				
213 Set Function code for Status register				
214 Read Function code for Dynamic Variables				
215 Read Function code for Status register				
212 Set Function code for Dynamic Variables				
205 Write Modbus Message CRC Order	Byte 0 CRC Byte Order	As in Command	2 Invalid selection (0/1) 5 Too few data-bytes received 7 Write Protected	0 : Low – High order (Default) 1: High - Low order
253 Read T310H7-Module Name & Number	Byte 0 Index (0 to 1)	Byte 0 index Byte 1-12 Module data	2 Invalid selection (0 to 1) 5 Too few data-bytes received	0 = Module Name 1 = Module Number