The Modbus RTU/TCP to HART gateway, the T310_H7

Reference Manual

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About this document

The Reference Manual gives an overview of the capabilities, and the use of the T310_H7 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

References

Ref. 1 Universal Command Specification, HCF_SPEC-127
Ref. 2 Common Practice Command Specification, HCF_SPEC-151

Summary

The T310_H7 allows Modbus RTU and Modbus TCP instruments to communicate with HART masters.

The T310_H7 capabilities can be summarized as follows:

- The T310_H7 is a DIN rail mounted module that provides HART transmitter functionality to Modbus RTU and Modbus TCP instruments.
- T310_H7 contains a serial input channel for Modbus communication.
- Modbus Baud rates supported are 9600 and 19200 kbit/s.
- T310_H7 supports four Dynamic Variables.
- T310_H7 supports eight Device Variables
- T310_H7 supports one status register
- T310_H7 supports range value configuration
- T310_H7 supports engineering unit selection
- T310_H7 supports DAC calibration and loop testing
- T310_H7 supports NAMUR NE43 loop current signaling
- T310_H7 Supports NAMUR NE 107status flags.
- T310_H7 is an active 4-20 mA source
- T310_H7 is supplied from 10-34Vdc power
- T310_H7 supports 3 wire loop wiring
- -40°C to 85°C operation range
- T310_H7 is a HART 7 device
- A DD that comes with the T310_H7 makes it possible for the user to configure the T310_H7 applying a standard third party's HART tool

The instrument interface:

Protocol:
- Modbus RTU
- Modbus TCP

Physical interface:
- RS 485
- Ethernet

1. INTRODUCTION

1..0. Functional Description

The T310_H7 is a HART 7 compliant DIN rail mountable gateway for connecting Modbus RTU and TCP instruments (Modbus slaves) to HART. A typical application is shown in **Figure 2**.

Figure 1. The T310_H7

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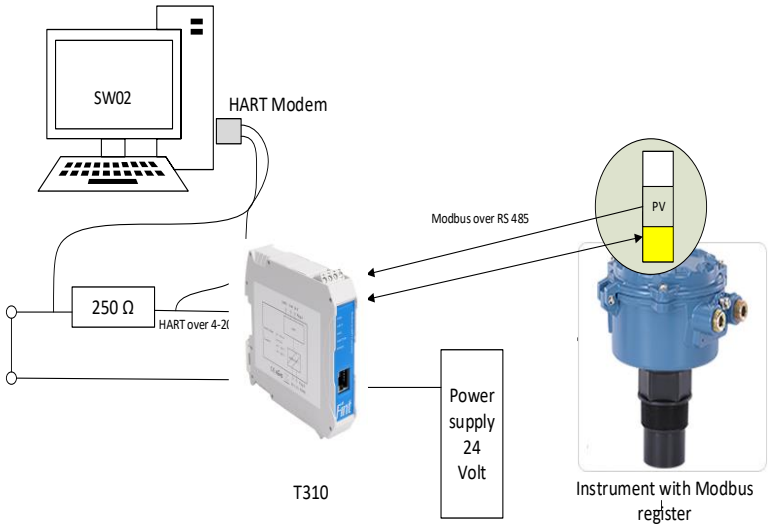

Figure 2. The T310 device in a typical application

The T310_H7 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.

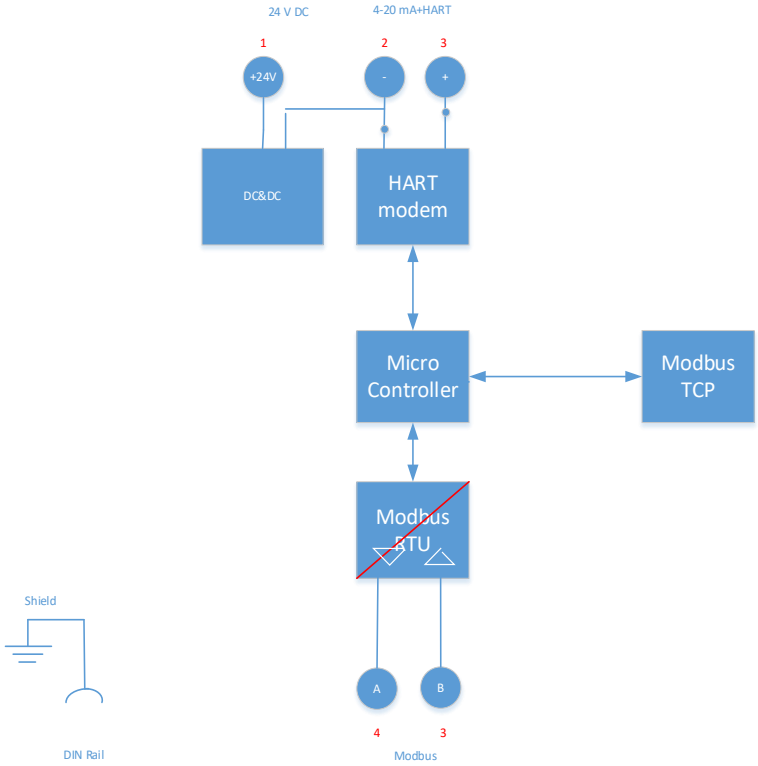

Figure 3. Functional Diagram

1..1. Connector coding

The coding of the plugs is shown in Figure 4.

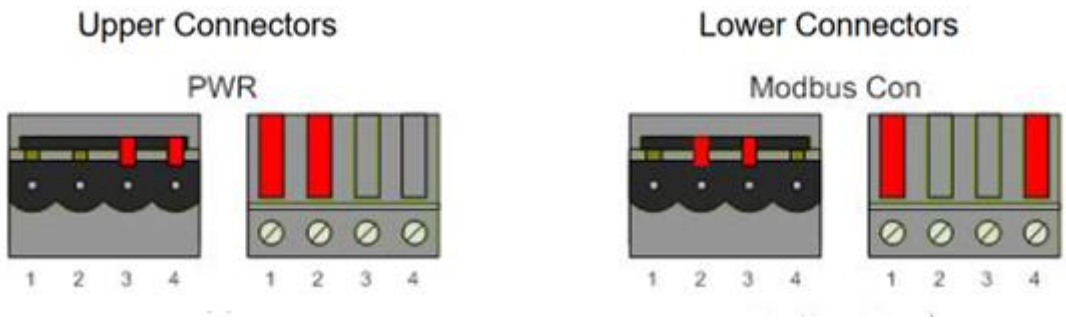

Figure 4. Plug coding of T310_H7

2. INSTALLATION

The T310_H7 is designed for being mounted in a cabinet on a DIN rail.

2..0. Electrical Connections

The T310_H7 contains 2 pluggable screw terminals.

The T310_H7 should use the connector pinout as shown in Table 1:

Connector	Pin	Comment
Upper	1	24 V DC (+)
	2	GND (-)
	3	4-20 mA & HART +
	4	No Connection
Lower	1	MODBUS – Signal B (+)
	2	MODBUS – Signal A (-)
	3	MODBUS – Signal B (+)
	4	MODBUS – Signal A (-)
RJ49		MODBUS TCP
DIN clip	-	PE connection for Modbus EMC (see Figure 3)

Table 1. Connector Arrangement Table

2..1. Wiring

Figure 5 is showing the three-wire configuration for HART and power supply and a Modbus instrument. It should be noted that the T310 is an active source for the 4-20 mA loop.

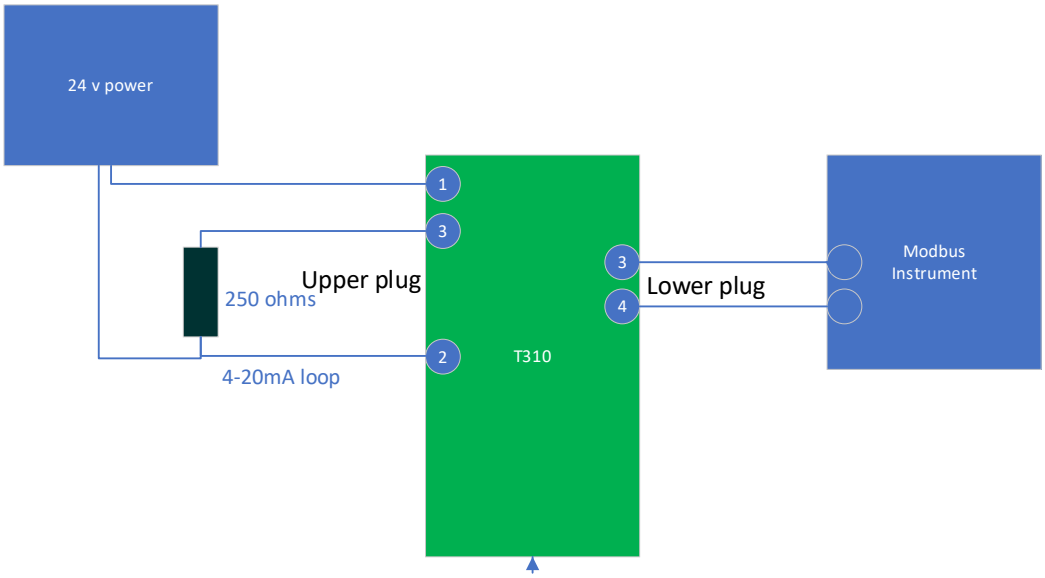

Figure 5. T310 wiring diagram - three wire HART connection

2..2. Diagnostic LEDs

There are five LEDs on the front. One for Power ON and one for Modbus communication. The green color Modbus LED is blinking on response to Modbus RTU 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. The Red LED will signal failure when there is no communication on Modbus. The Modbus LEDon the front panel will not light up if TCP is selected.

If TCP is selected, a blinking green LED on the Ethernet port indicates that there is traffic on the port.

3. OPERATION PRINCIPLE

3..0. Connecting Modbus devices to HART

The T310_H7 is a protocol converter that allows legacy Modbus devices to communicate on HART.

The T310_H7 shall be configured to read dynamic measurement values stored in Registers in the Modbus instrument. Up to eight distinctly separate variables are read and converted to HART variables. Both Holding and Read registers can hold the dynamic variables that T310_H7 reads.

T310_H7 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 T310_H7 reads.

The T310_H7 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.

3..1. Loop current

The loop current is proportional to the Modbus variable that is chosen to be Primary Variable (PV). The operating range is 4 – 20 mA. The Upper and Lower Range values represent 20 and 4 mA respectively. The range values can be configured by the user.

T310 supports the NAMUR NE43 standard. That defines the operation of the loop current outside the Upper and Lower Range values.

Under range readings are in the range 3.8 to 4.0 mA and overrange reading 20,0 to 20.5 mA, The loop current will correspond to the measured value also in the over and under range area.

Should the readings exceed these limits, the loop current saturates and remains at 3.8 or 20.5 mA. This will be flagged in the Device Status, bit 2, Analog Output Saturated.

Failures can be flagged by Failure currents, either 3.5 or 21.0mA. The user can select to use either of these two values using the PV alarm selection parameter. It is failure conditions in the Modbus device that defines the conditions for the Alarm current. The user has to define the mapping of the Modbus status flags to the Alarm current flag.

	Loop current (mA)	Device Status	PV alarm selection
Transmitter failure	3.5	Field device malfunction	Lo
Saturated	3.8	Analog output saturated	
Normal under range	3.8 -4.0		
Normal	4.0 – 20.0		
Normal over range	20.0 – 20.5		
Saturated	20.5	Analog output saturated	
Transmitter failure	21.0	Field device malfunction	Hi

Table 2. Operation of the loop current

3..2. NAMUR NE107 status flags

T310 supports the NAMUR NE107 status flags

Failed	Out of Specification	Maintenance Required	Check Function
			
High severity: signal invalid due to malfunction in the device, sensor, or actuator	Medium severity: permissible ambient or process conditions exceeded or the measuring uncertainty of sensors or deviations from the set value in actuators is probably greater than expected	Low severity (advisory): although the signal is valid, the remaining life is nearly exhausted or a function will soon be restricted due to operational conditions e.g. aging of a pH-electrode.	Signal temporarily invalid (e.g. frozen) due to on-going work on the device.

The conditions for these flags are defined in the Modbus instrument. The user can map status flags from the instrument into either of these flags as appropriate. For each of the four flags there is a mask that needs to be defined in order to map a condition in the Modbus instrument to the correct NAMUR flag.

The NAMUR flags are found in the Extended status byte of command 48.

See also Chapter 4..8

4. CONFIGURATION BY THE OEM USER

4..0. Device Variables and Dynamic Variables

The T310_H7 supports up to four Dynamic Variables and eight 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 T310_H7 and are made available to the user on the HART interface. See Figure 7

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 eight Device Variables in T310_H7. In Figure 6 four of these are activated and mapped.

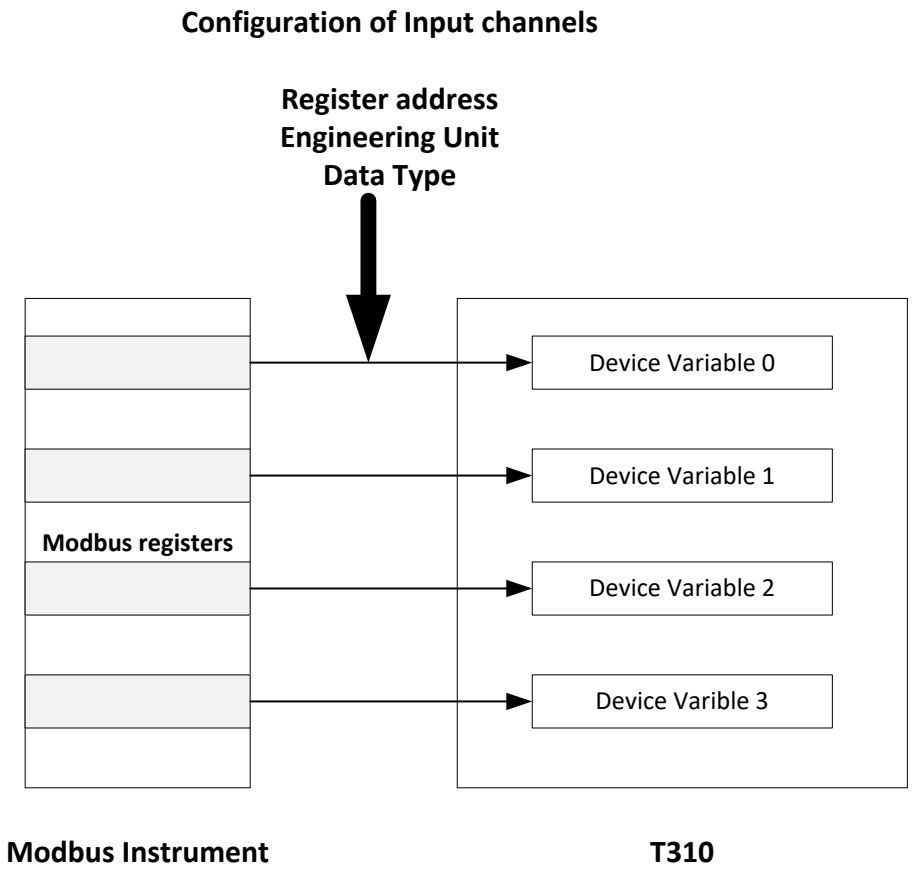

Figure 6. Input channels

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 T310_H7 needs to be configured accordingly by the OEM User. T310_H7 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 T310_H7 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.

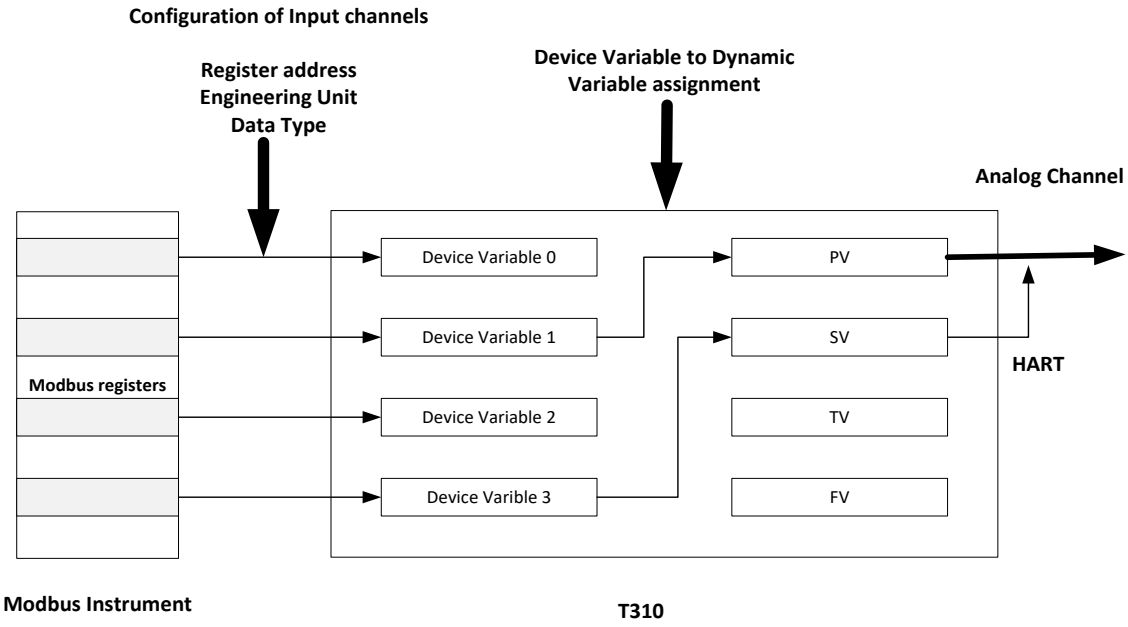

Figure 7. Device variables and Dynamic variables

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..1. Configuration and measurement mode

The T310_H7 operates in two modes, Configuration Mode and Measurement Mode. The Configuration Mode is the mode where the OEM User is setting up the T310_H7 for communication with the Modbus instrument. The communication between the T310_H7 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 T310_H7 reads the measurement and status from the Modbus field device cyclically. The cycle period depends on the number of field device variables to be read.

The configuration software, the SW02 is automatically swapping between Measurement and Configuration Mode when entering and leaving the T310_H7 menus. The OEM User will not be notified when using SW02.

4..2. Setting up the Modbus RTU

Parameter	Value	Comment
Modbus baud rate	4800, 9 600, 19 200, 38400, 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 - 2000 ms	Timeout time on Modbus (ms)
Delay between requests	5 – 2000 ms	Waiting time between Modbus transaction measured from end of previous message reception.
Write delay		Applicable for Remote range setting
Modbus Interface type	RTU, TCP	When selecting TCP a separate configuration window is opened

Table 3. The Modbus set-up parameters

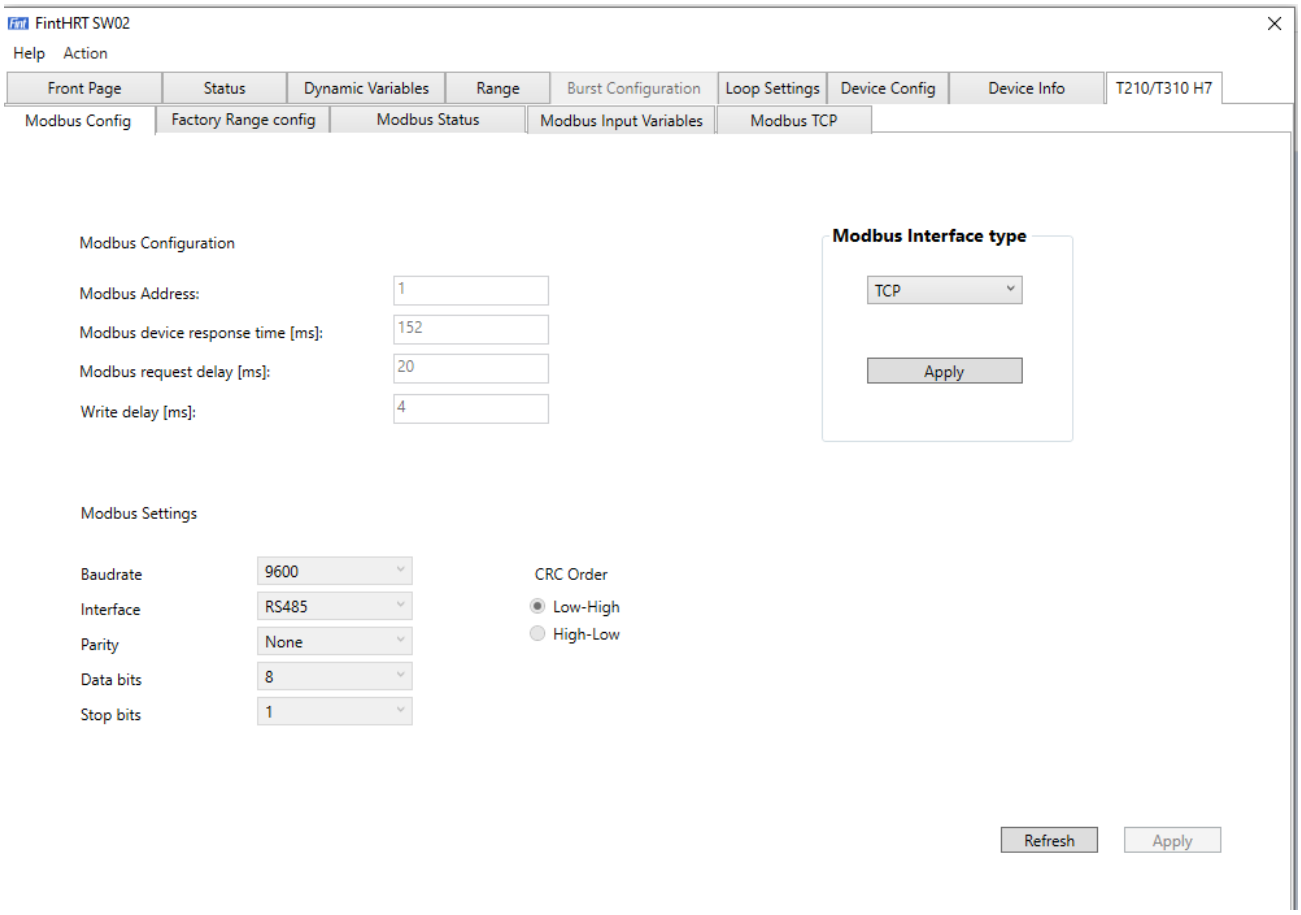

Figure 8. Modbus setup page

“Modbus device response time” gives the time in milliseconds If no response is received from the Modbus device in that time, the T310 will move on requesting data from the next register in is read queue. The event is flagged in the status as “Timeout” ‘

“Modbus request delay” is used to get some time space between requests to reduce the traffic load on the Modbus slave.

4..3. Setting up the Modbus TCP

The T310_H7 is configured with a static IPv4 address, with customizable network settings. The following default values are applied from the factory:

- IP address: 192.168.7.100
- Subnet Mask of 255.255.255.0
- Default Gateway of 192.168.7.1.

These values can be modified by the user via the configuration interface.

To ensure proper communication, any connected sensor or Modbus device must be configured on the same IP subnet.

Parameter	Value	Comment
Port	Default: 502	Modbus TCP port
Timeout	0 – 20,000 ms	Modbus device response time
Polling interval (Delay between requests)	1 – 20,000 ms	Modbus device response time

Table 4. Modbus TCP set-up parameters

Recommended Configuration Sequence

- Switch to RTU mode
- Apply or modify TCP/IP settings
- Switch back to TCP mode

Important note: The Polling interval is the delay between successive register reads

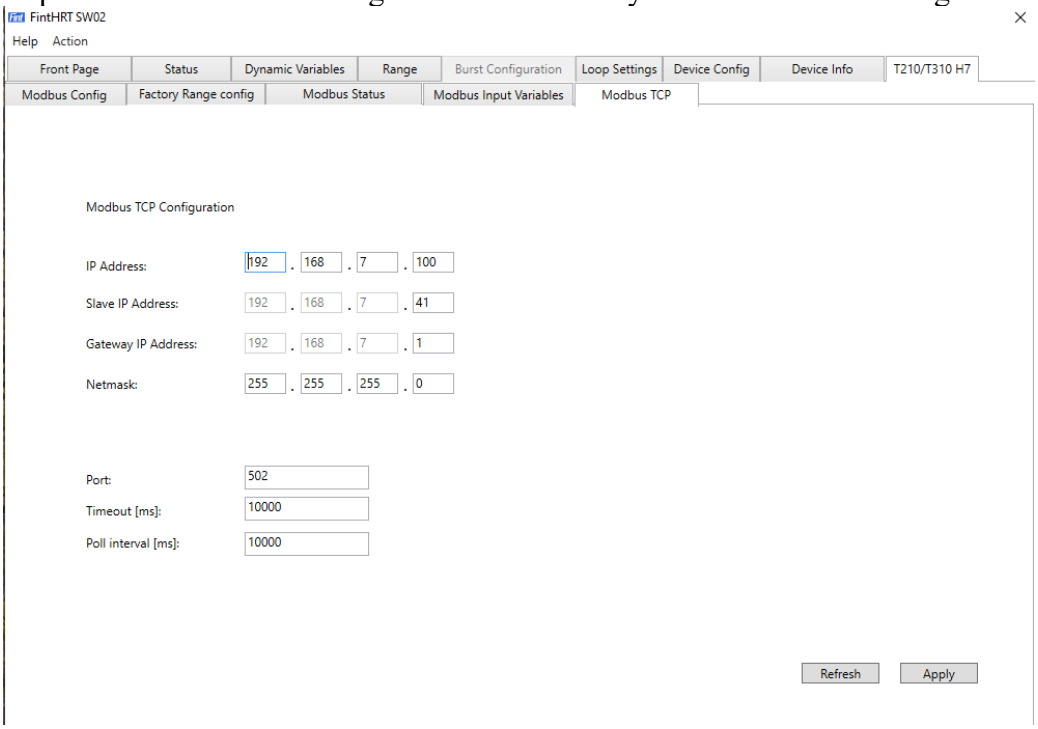

Figure 9. The Modbus TCP set-up window in SW02.

4..4. Set-up of Device Variables

The T310_H7 can support up to 8 Device Variables. Figure 10 shows the set-up in SW02

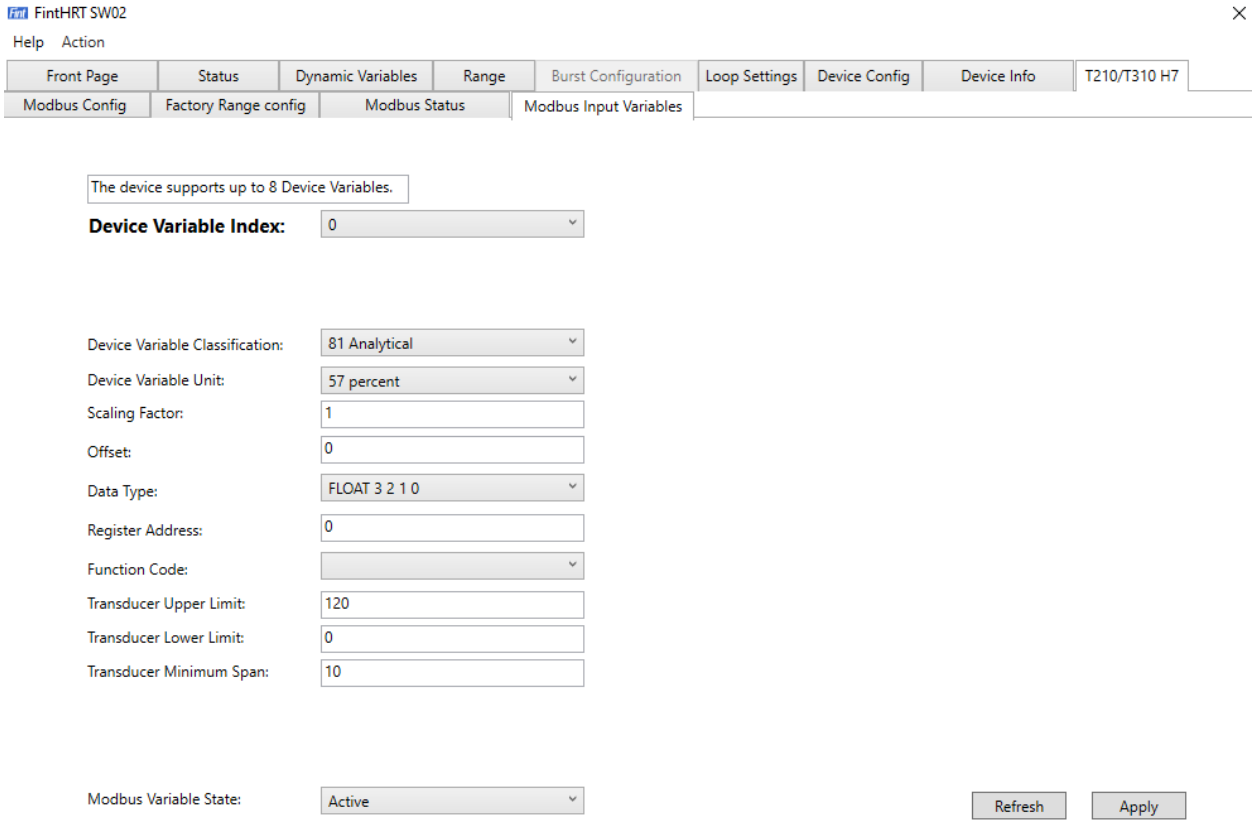

Figure 10. Device Variable set-up

The Device Variables are addressed by their index, Device Variable Index. The Device Variables should be configured one by one starting from index 0 and increasing upwards. Only the number of Device Variables supported by the Modbus device should be configured. The Device Variables in use shall be activated by swapping the parameter Modbus Variable State to "Active".

The configuration window is used to define the input on Modbus, so it shall describe the variable.

The register address for one to up to eight variables (Device Variable 0 -7) can be entered.

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 T310_H7 to perform the data type translation, the data type and byte order must be specified.

For T310_H7 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 5.

The Unit Class and the specific engineering unit for storing the measurement as stored in the Modbus register, must be specified. The register storing the variable and Function code for reading it out, needs to be specified. And also the data type used for storing variables. The T310 shall convert the variable to a float value, so it needs to know what to convert from. The scaling factor can be used to move the decimal point if data is stored as an integer with one or more decimals.

For each Device Variable configured, press “Apply” to send the configuration to T310.

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
Signed Short	1 0	4
Signed Short	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 5. Data type and byte order for the measurements

If the variable is stored as a float or long in the Modbus device, T310_H7 assumes that two consecutive registers are used, as illustrated in Figure 11. The Register address pointer in T310_H7 will point to the lower address.

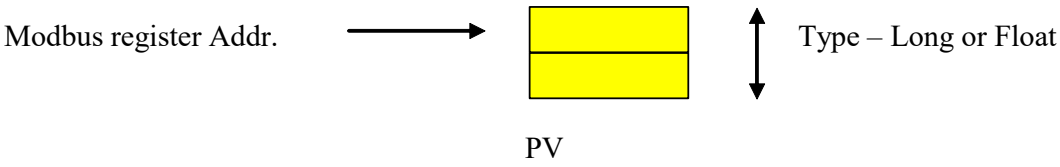

Figure 11. Storage when the measure value is a float or Long

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 T310_H7 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.

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 T310_H7, 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 12.

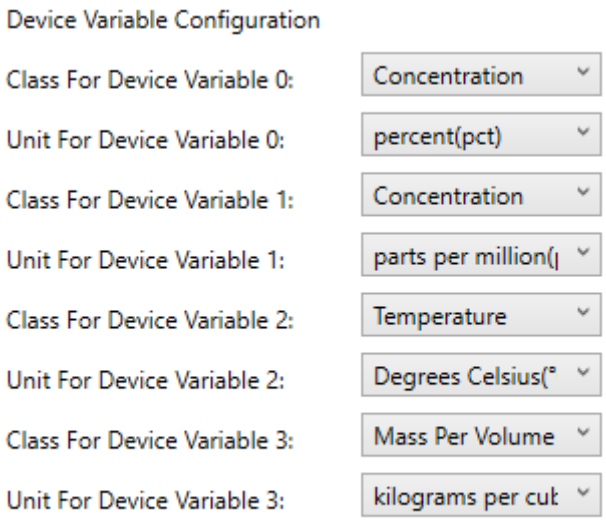

Figure 12. Device Variable Class and Engineering Units of the measured value.

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. Table 6 shows the Device Variable Classes and the related Engineering Units supported by the T310_H7.

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	
Device Variable Classification Code 65	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
	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
	145	Inches of water at 60degrees C
	170	Centimeter of water at 4 degree C
	171	Meter of water at 4 degree C
	172	Centimeters of mercury at 0 degree C
	173	Pounds per square foot
	174	Hectopascals
	175	Pounds per square inch absolute
	176	Kilograms per square meter
	177	Feet water at 4 degree C
	178	Feet water at 60-degree F
	179	Meter of mercury at 0 degree C
	180	Mega pounds per square inch
	181	Ounces per square inch

	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	
Device Variable Classification Code 66	Unit Code	Description
	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
	121	Normal cubic meter per hour
	122	Normal liter per hour
	123	Standard cubic feet per minute
	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
	170	Beer barrels per second
	171	Beer barrels per minute
	172	Beer barrels per hour
	173	Beer barrels per day
	174	Normal liter per day
	175	Normal liter per minute
	176	Normal liter per second
	177	Standard liter per day
	178	Standard liter per hour
	179	Standard liter per minute
	180	Standard liter per second
	181	Normal cubic meter per day
	182	Normal cubic meter per minute
	183	Normal cubic meter per second
	184	Standard cubic feet per day
	185	Standard cubic feet per hour

	186	Standard cubic feet per second
	187	Standard cubic meter per day
	188	Standard cubic meter per hour
	189	Standard cubic meter per minute
	190	Standard cubic meter per second
	235	Gallons per day

Device Variable Class Volume	Engineering Unit	
Device Variable Classification Code 68	Unit Code	Description
	40	Gallon
	41	Litre
	42	Imperial Gallon
	43	m^3
	46	bbl
	110	bu
	111	yd^3
	112	ft^3
	113	in^3
	124	bbl liq
	166	Norm m^3
	167	Norm l
	168	Std ft^3
	236	hl

Device Variable Class Mass	Engineering Unit	
	Code	Description
Device Variable Classification Code 71	60	grams
	61	kilograms
	62	metric tons
	63	pounds
	64	short ton
	65	ton (UK)
	125	ounce

Device Variable Class Mass Flow	Engineering Unit	
	Code	Description
Device Variable Classification Code 72	70	grams per second
	71	grams per minute
	72	grams per hour
	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
	87	ton (UK)/h (1016,047 kg/hr
	88	ton (UK)/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
	99	ton/yd^3
	146	microgram/l
	147	Microgram/m^3
	170	mg/l
	171	mg/m^3
	172	t/m^3

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
	150	Percent steam quality
	160	Percent plato
	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 Conductance Unit ccodes	Engineering Unit	
Device Variable Classification Code 87 (No unit conversion)	Code	Description
	56	microSiemens
	66	mS/cm
	67	microS/cm

Process Variable Turbidity	Engineering Unit	
Device Variable Classification Code 97 (No unit conversion supported)	Code	Description
	170	Fermazin Nephelometric Units
	171	Fermazin Turbidity Unit
	172	Nephelometric Turbidity Unit

Process Variable Miscellaneous	Engineering Unit	
Device Variable Classification Code 111 (No unit conversion supported)	Code	Description
	57	%
	156	dB
	170	g/mol

Process Variable Concentration	Engineering Unit	
Device Variable Classification Code 90 (No unit conversion supported)	Code	Description
	57	percent
	101	degree brix
	105	percent solid per weigh
	106	percent solid per volume
	108	proof per volume
	109	proof per mass
	139	parts per Million (ppm)
	169	parts per Billion (ppb)
	170	parts per thousands (ppth)

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

Table 6. Device Variable Classes and the related Engineering Units

4..6. Dynamic Variable Assignment

The Device Variables are assigned to 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 13 you may change the order of the variables. The default setting is shown.

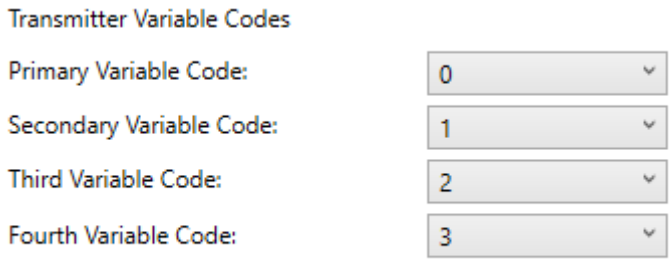

Figure 13. Default settings for Device variables

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

The Range values define the 4-20 mA range.

T310_H7 Range values (Upper & Lower) may reside either in the Modbus instrument or in T310_H7 module itself. The Range Source parameter tells T310_H7 where to find the Range values. It is either Local (it is configured and stored in T310_H7) 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 T310_H7 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 Figure 14.

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

In all these cases the T310_H7 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 14

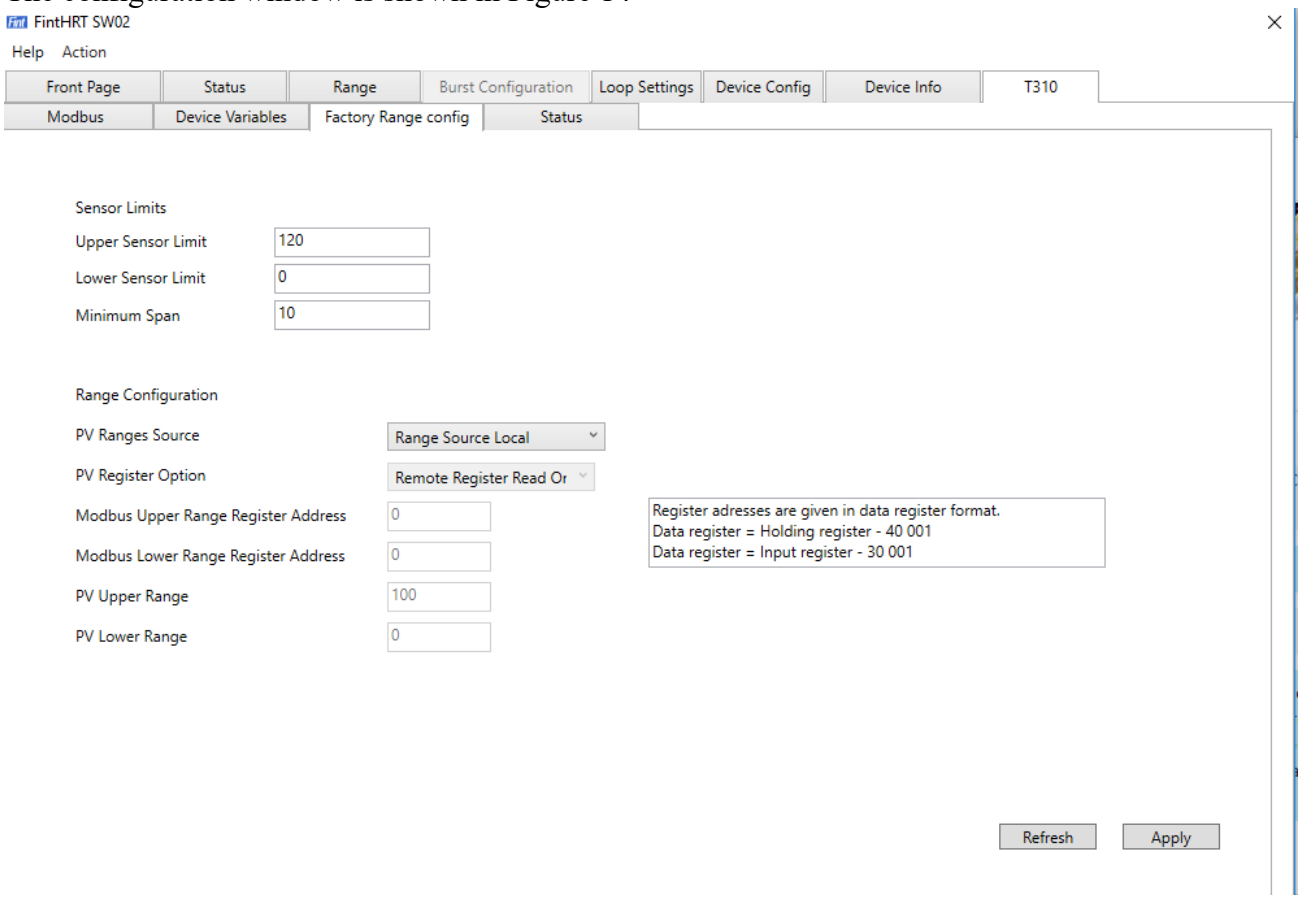

Figure 14. Configuration of Range in SW02

The End-user may have the option to re-range the 4-20 mA loop. He might want to do that in order to focus 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 15.

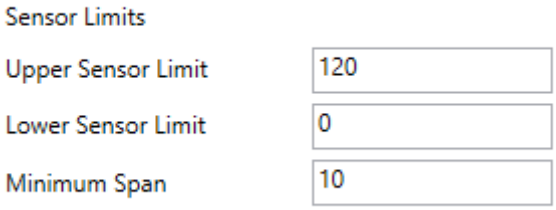

Figure 15. Configuration of Sensor limits

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 T310_H7 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 T310_H7. 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. When coded Bit Enumerated, the status bits from the Modbus instrument can be mapped to NAMUR NE107 status flags using the four masks Failure, Maintenance, Out of Spec and Function Check. The status bits marked will be controlling the related NAMUR flag.

In the same way the NAMUR NE43 mask will select which bits shall control the NE43 alarm current. When the corresponding flag is set, the loop current will be forced to the alarm current 3.5 mA (Lo) or 21 mA (Hi), depending on the Alarm Level setting in the Status menu.

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 16.

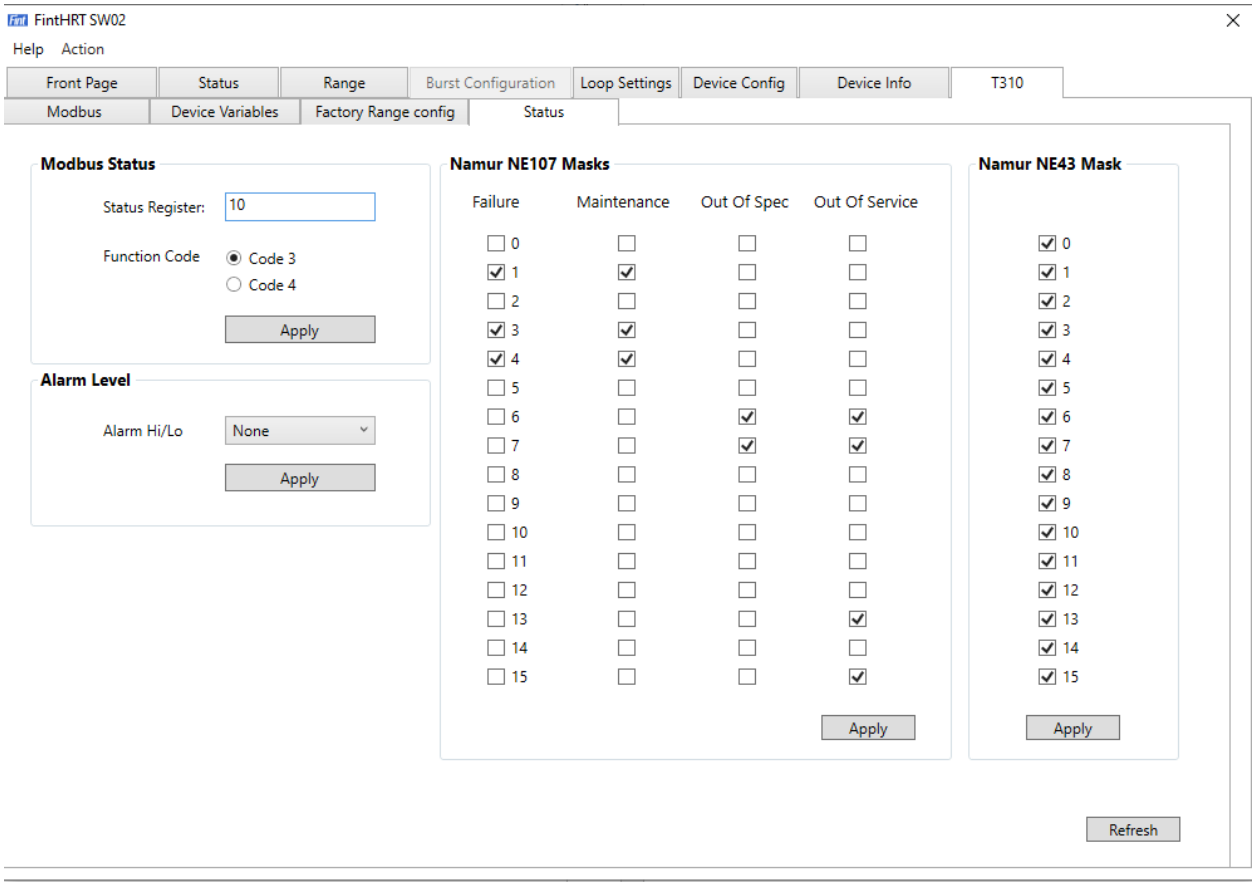

Figure 16. Setting Modbus instrument device status

5. T310_H7 FUNCTIONALITY APPLICABLE FOR THE END-USER

This chapter describes features of the T310_H7 that are intended to be used by the End-user. A DD is provided with the T310_H7 that will allow the End-user to configure the T310_H7. SW02 is used to describe this functionality.

5..0. Measurements

The front page of SW02 shows the readings from the instrument and the main identification of the T310_H7, the TAG name.

The Primary Variable (PV) can be shown in a window as a function of time. See Figure 17. The readings are either fetched by the T310_H7 using Command 3 or Read Requests from the T310_H7 (Continuous Update). This will lead to two updates a second. An alternative is to use the Burst Update button. This will force the T310_H7 to send updates three times a second.

The Analog output is supposed to show the actual loop current from the T310_H7. This value is defaulted to 10 mA, so if no communication is established on Modbus, the value will stay at 10 mA.

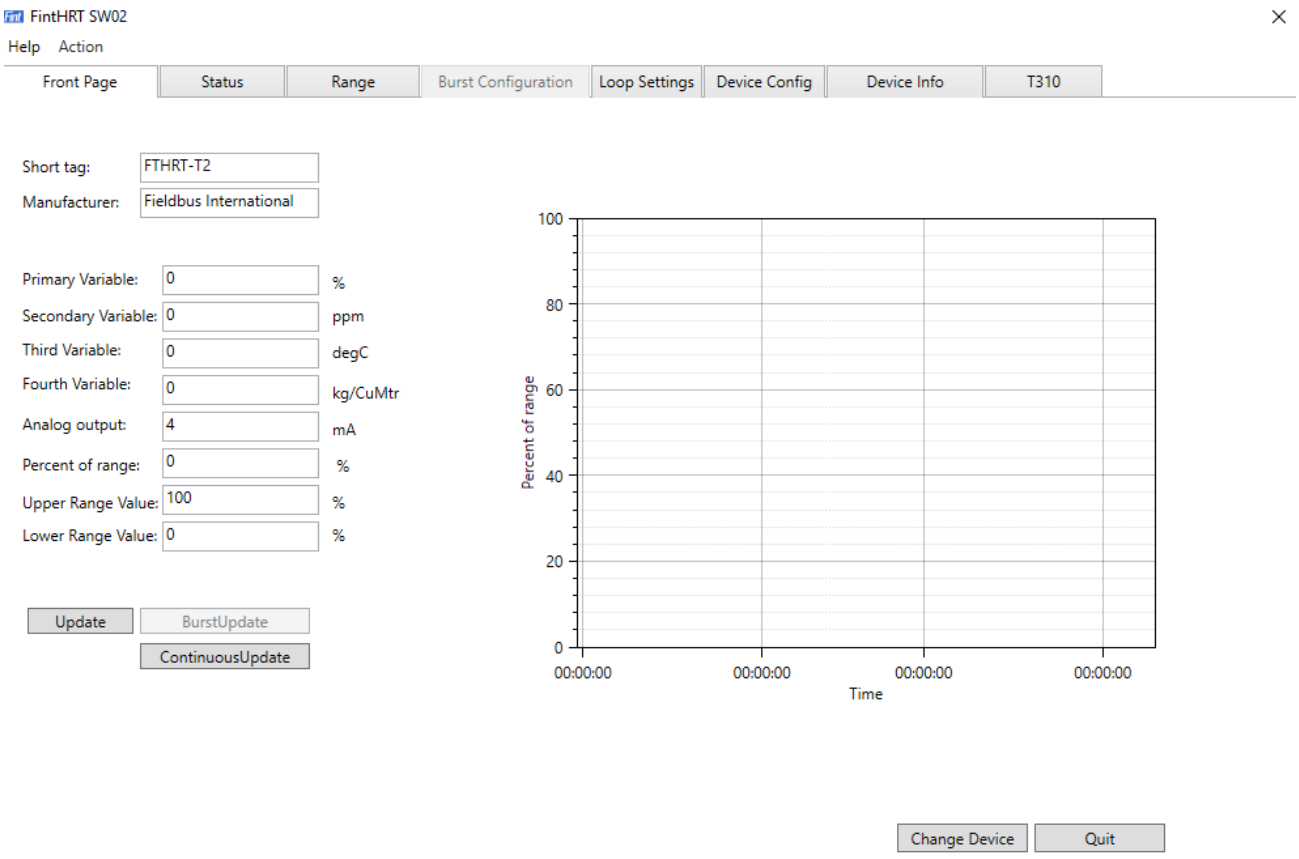

Figure 17. The appearance of the Front page in SW02

5..1. Loop settings

T310_H7 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 18.

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

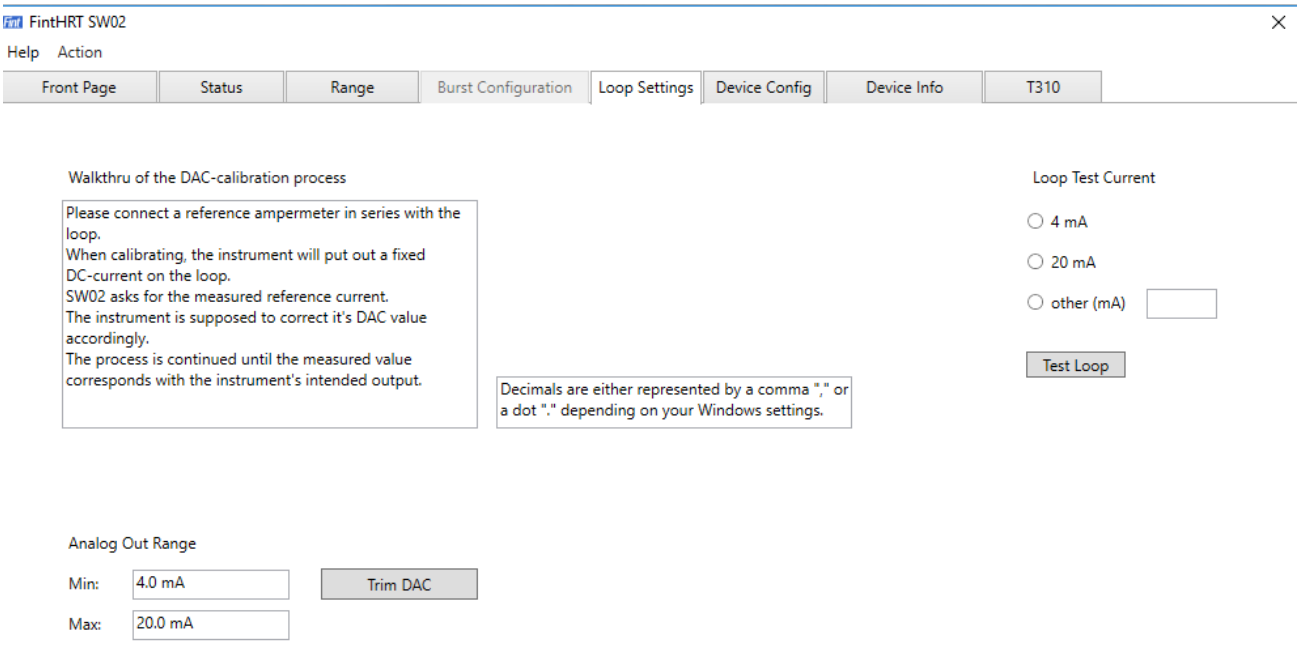

Figure 18. Loop testing and DAC calibration

5..2. Device Configuration

T310_H7 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 T310_H7 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 19.

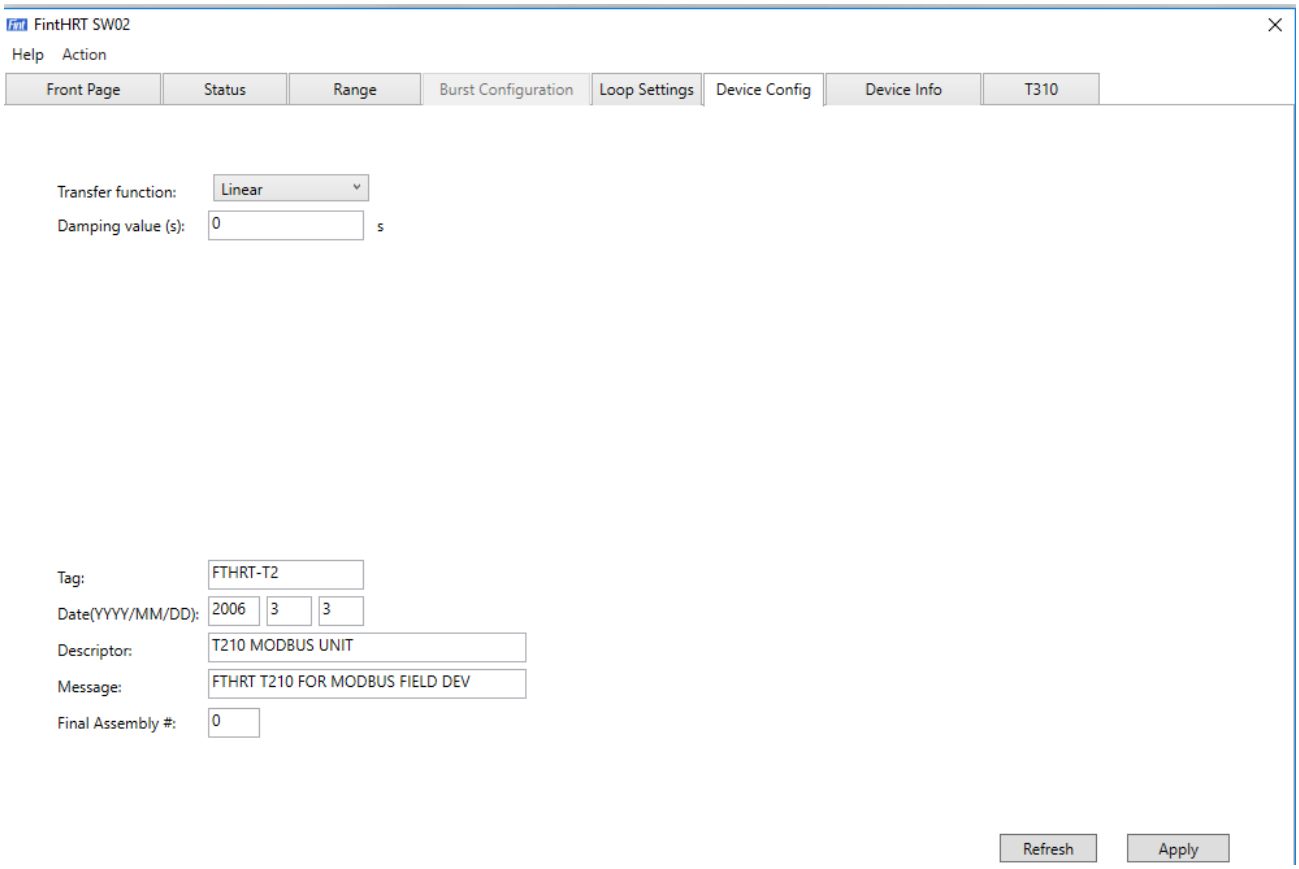

Figure 19. Device configuration

5..3. Device Info

The Device Info menu contains data characterizing the T310_H7.

The device's ID is the serial number for the T310_H7. There is no support for the Sensor Serial Number in T310_H7. The menu is shown in Figure 20.

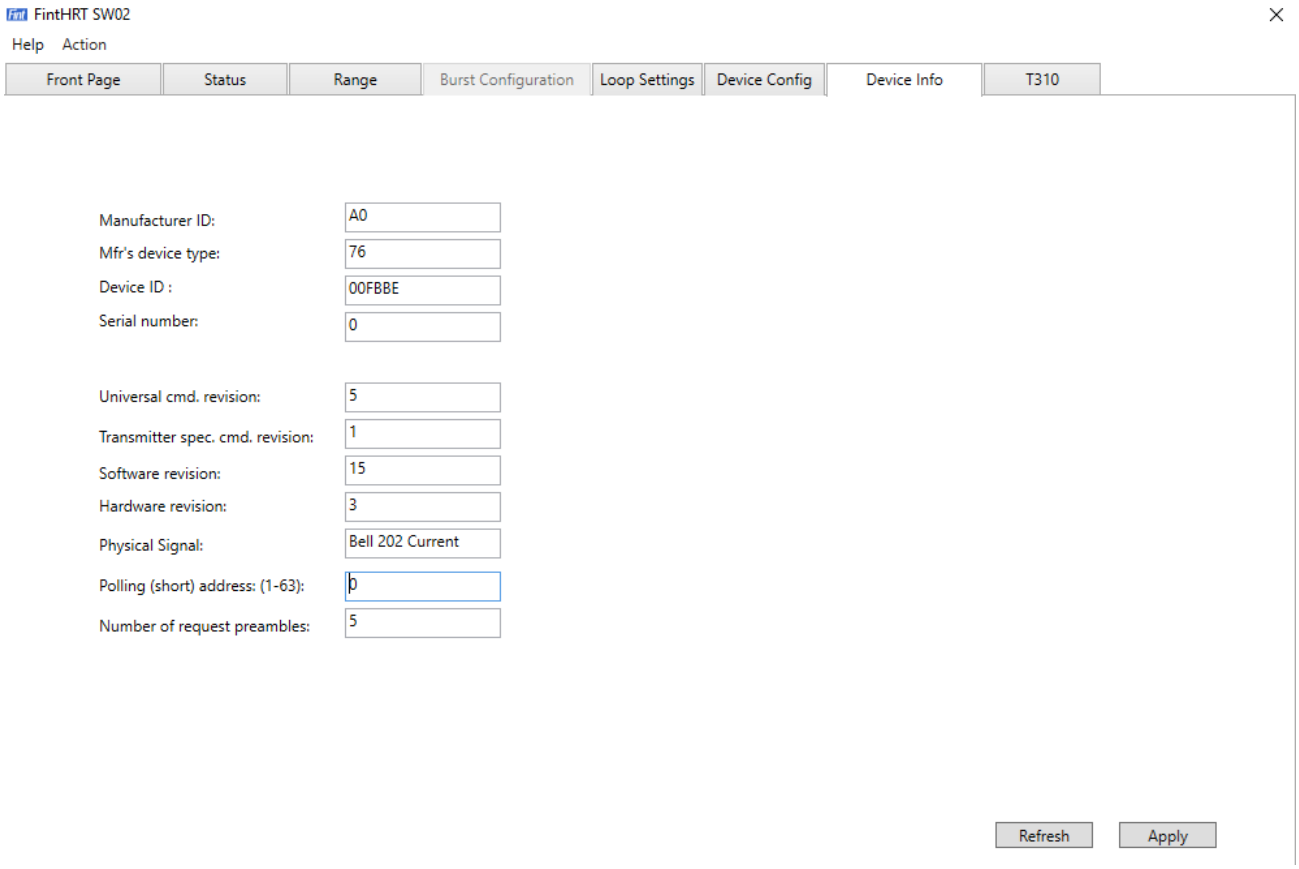

Figure 20. The Device Information menu

5..4. Field Device Status flags supported by T310_H7

The eight-bit Field Device Status is included in all HART responses. The following flags are supported in T310_H7:

Cold-start flag:
This is a temporary flag used to notify the user that the T310_H7 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 T310_H7, being a general-purpose converter, does not have a predefined encoding of the Additional Status bytes. T310_H7 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..6. 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 T310_H7 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 T310_H7 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 21.

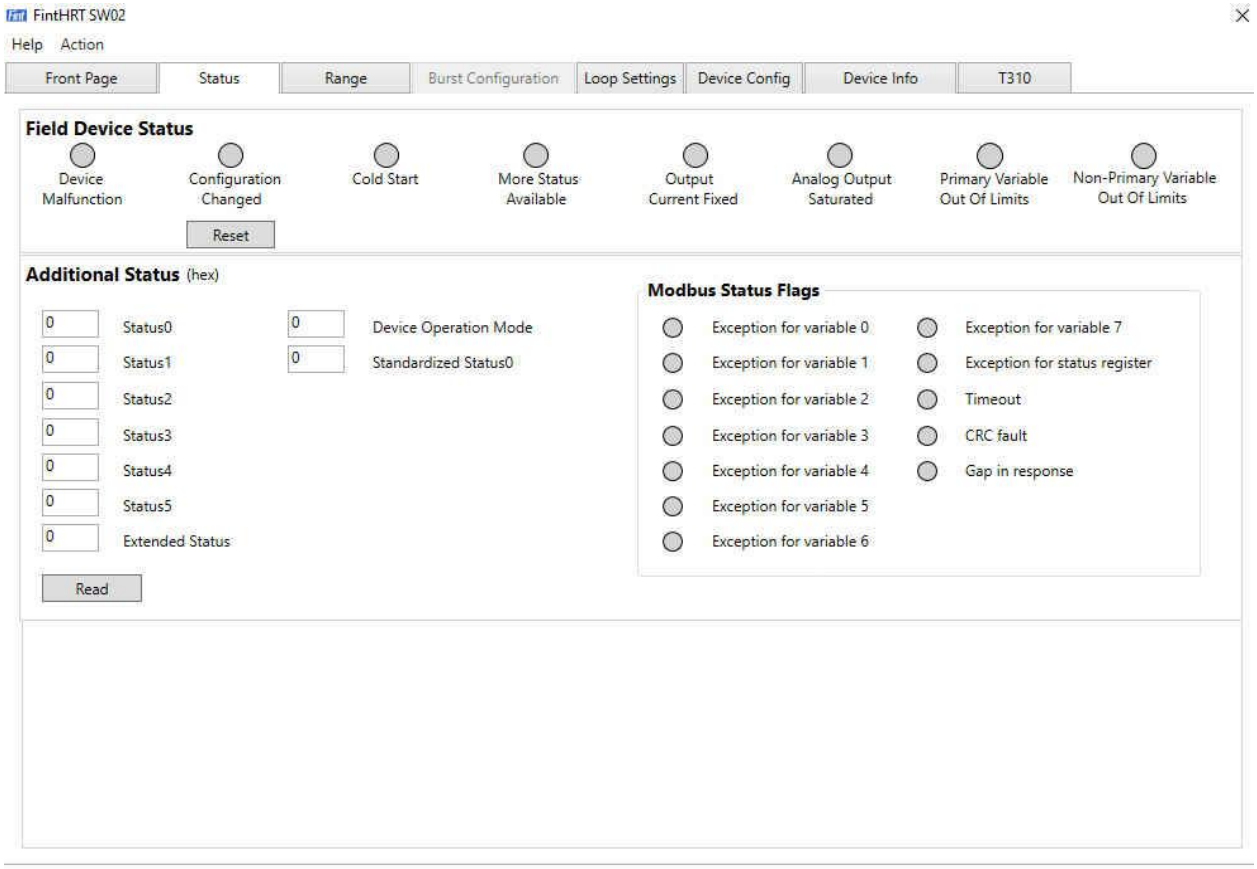

Figure 21. Example of the Command 48

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 device variable 4 register
bit 1: Modbus Exception received for device variable 5 register
bit 2: Modbus Exception received for device variable 6 register
bit 3: Modbus Exception received for device variable 7 register
bit 4: Modbus Exception received for Status register
bit 5: Modbus Exception received for External Upper Range register
bit 6: Modbus Exception received for External Lower Range register
bit 7: Range setting error.

5..7. 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 22 is used to enter the new range values in the relevant Unit code. Sensor Limits are included as a guide.

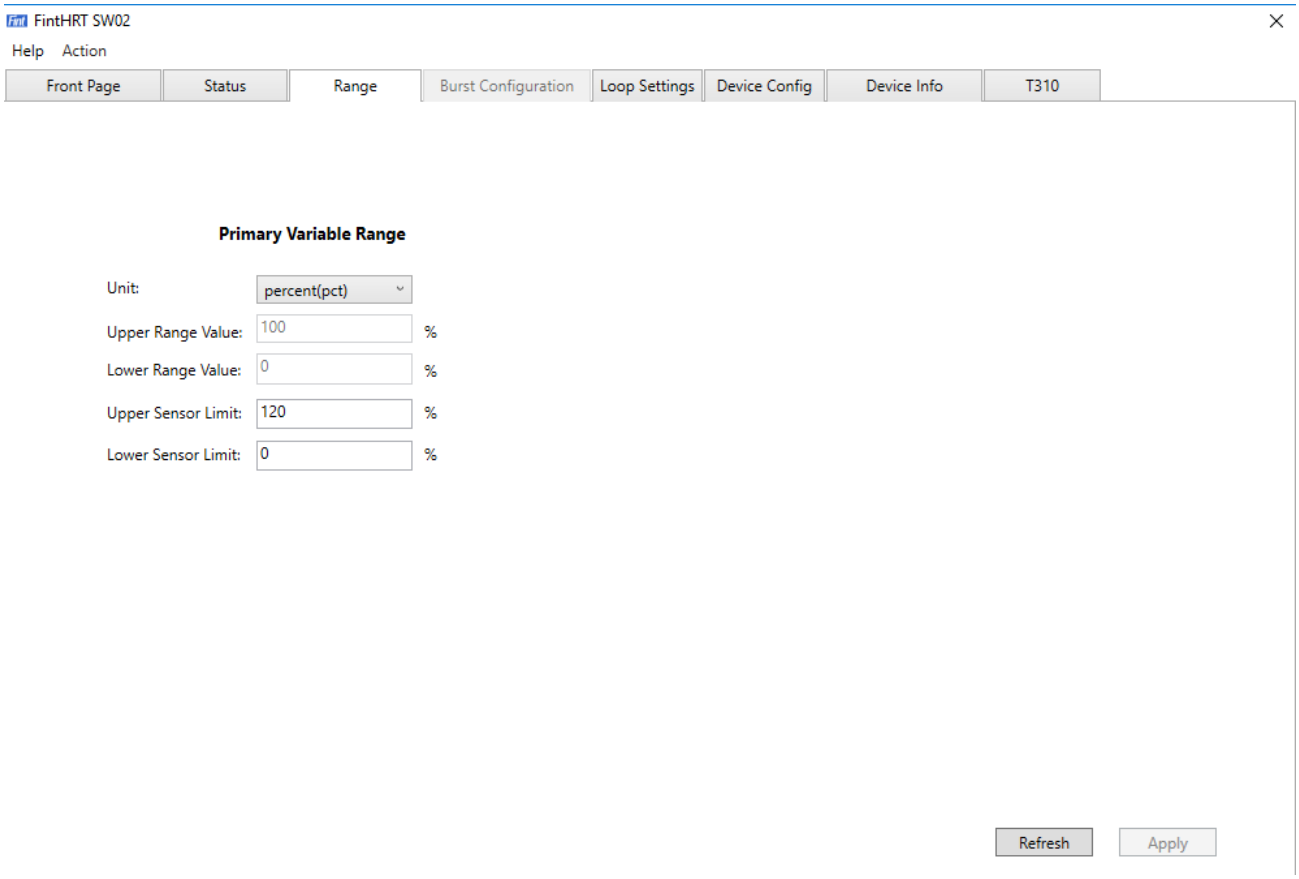

Figure 22. Re-ranging window

6. APPENDIX A. TECHNICAL SPECIFICATIONS

Mechanical:

Size	114,5 * 107,3 mm
Mounting	DIN rail
Module width	23,2 mm
Weight	112 gram
Housing	Plastic, IP-20 protection

Electrical:

Supply voltage	10....34 VDC
Supply current	27 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 7
Modbus protocol	Modbus RTU/TCP, Master
Modbus serial standard	RS-485

7. APPENDIX B. MODBUS COMMUNICATION

The communication between the T310_H7 and the Modbus field device is carried out in a master-slave approach. The T310_H7 acts as a master and the Modbus field device as a slave.

7..0. Modbus byte encoding

The T310_H7 supports the standard Modbus RTU framing transmission mode. In this mode, the entire message frame is transmitted as a continuous 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 7.

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

Table 7. Character framing

7..1. The T310_H7 MODBUS FUNCTIONS

The T310_H7 supports the following Modbus functions:

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

7..2. 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..3. Reading of Field device parameters

Read/Write Holding Registers: TheT310_H7 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.

.

7..4. Query-Response Cycle Modbus

The Query-Cycle starts once the T310_H7 operation mode is set to Measurement mode. The T310_H7 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. Figure 23 shows the Query-Response message contents. The T310_H7 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.

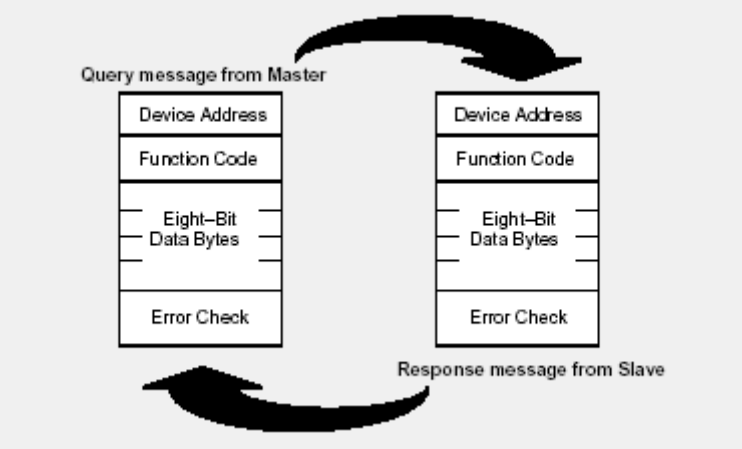

Figure 23. The Query-Response message contents

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 8.

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 8. RTU Mode Message Frame

The CRC field 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 9.

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

Table 9. Appending of the CRC to the Message Frame

T310_H7 allows the usage of an inverted byte ordering for the CRC field. This can be configured in the configuration mode.

7..5. T310_H7 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 10.

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 10. 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..6. HART Response code to Modbus errors and exception codes

Table 11 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 11. Mapping of Modbus errors and Exception codes to HART response codes

8. APPENIX C . HART COMMANDS

8..0. Universal Commands

Command Number	Command Function	Data in Command			Data in reply			Response code	Comment
		Byte no.	Description	Data type	Byte no.	Description	Data type		
0	Read unique identifier		none		0 1-2 3 4 5 6 7 8 9-11 12 13 14-15 16 17-18 19-20 21	"254" (expansion) Extended Device. Type Number of preamble. Master to Slave Universal command revision Specific cmd rev Software revision Hardware revision Device function flag Device ID number Number of preambles. Slave to Master Last Device Variable code Configuration Change Counter value Extended Field Device Status Manufacturer Identification Code Private Label Descriptor Code Device Profile	u8 u16 u8 u8 u8 u8 u8 u8 u24 u8 u8 u16 u8 u16 u16 u8	See Universal Command description. Ref. 1	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		0 1-4	PV unit code Primary Variable	u8 F	See Universal Command description. Ref. 1	Modbus Register PV Unit %
2	Read Current & % of range		none		0-3 4-7	Current (mA) Percent of range	F F	See Universal Command description. Ref. 1	Calculated in the T310_H7 module based on the measured value Calculated in the HART module
3	Read Current & four variables		none		0-3 4 5-8 9 10-13 14 15-18	Loop Current PV Unit code PV value SV Unit Code SV value TV Unit code TV value	F u8 F u8 F u8 F	See Universal Command description. Ref. 1	Calculated in the T310_H7 module % Number of Dynamic Variables depends on the number of variables supported by the field device.

					19 20-23	QV Unit code QV value	u8 F		
6	Write short address	0 1	Short address Loop Current Mode	u8 u8		same as command		See Universal Command description. Ref. 1	Address 0 when used in 4-20 mA mode A different address sets the device into multi-drop mode
8	Read dynamic variable classifications		none			PV Classification SV Classification TV Classification QV Classification	u8 u8 u8 u8	See Universal Command description. Ref. 1	
9	Read Device variables with status	0-7	Device variables	u8	0 1 3 3 4-7 8 9 10 11 12-15 16 17 18 19 20-23 24 25 26 27 28-31 32 33 34 35 36-39 40 41 42 43 44-47 48 49 50 51 52-55	Extended Field Device Status Device Variable Code Device Variable Class Unit Code Device Variable Value Device Variable Status Device Variable Code Device Variable Class Unit Code Device Variable Value Device Variable Status Device Variable Code Device Variable Class Unit Code Device Variable Value Device Variable Status Device Variable Code Device Variable Class Unit Code Device Variable Value Device Variable Status Device Variable Code Device Variable Class Unit Code Device Variable Value Device Variable Status Device Variable Code Device Variable Class Unit Code Device Variable Value Device Variable Status Device Variable Code Device Variable Class Unit Code Device Variable Value	u8 u8 u8 u8 F u8 u8 u8 u8 F u8 u8 u8 u8 F u8 u8 u8 u8 F u8 u8 u8 u8 F u8 u8 u8 u8 F u8 u8 u8 u8 F	See Universal Command description. Ref. 1	

					56 57 58 59 60-63 64 65-68	Device Variable Status Device Variable Code Device Variable Class Unit Code Device Variable Value Device Variable Status Time	u8 u8 u8 u8 F u8 Time		
11	Read Unique id associated with tag	0-5	TAG (8 characters)	A		Same as Command 0		See Universal Command description. Ref. 1	
12	Read message		none		0-23	Message	A	See Universal Command description. Ref. 1	
13	Read tag descriptor, date		None		0-5 6-17 18-20	Tag Descriptor Date	A A D	See Universal Command description. Ref. 1	
14	Read PV sensor info.		none		0-2 3 4-7 8-11 12-15	Transducer serial number Unit code for sensor limits Upper sensor limit Lower sensor limit Minimum span	u24 u8 F F F	See Universal Command description. Ref. 1	
15	Read PV output information		none		0 1 2 3-6 7-10 11-14 15 16 17	PV Alarm selection code PV Transfer Function code Upper and Lower range value units code PV Upper Range value PV Lower Range value PV Damping value (units of second) Write Protect code Reserved. PV Analog Channel Flags	u8 u8 u8 F F F u8 u8 u8	See Universal Command description. Ref. 1	**250 = Not Used** 0=Always linear PV unit code 250: Not Used Code = Damping value 251: No write protect mode supported. 250_Not used
16	Read final Assembly number		none		0-2	Final assembly number	u24	See Universal Command description. Ref. 1	
17	Write message	0-23	Message string	A		As in command		See Universal Command description. Ref. 1	
18	Write tag, descriptor and date	0-5 6-17 18-20	Tag Descriptor Date	A A D		As in command		See Universal Command description. Ref. 1	

19	Write final assembly number	0-2	Final assembly number	u24		As in command		See Universal Command description. Ref. 1	
20	Read Long TAG		none		0-31	Long Tag	ASCII	See Universal Command description. Ref. 1	
21	Read Unique Identifier with Long Tag	0-31	Long Tag	ASCII		As in command 0		See Universal Command description. Ref. 1	
22	Write Long TAG	0-31	Long Tag	ASCII		As in command		See Universal Command description. Ref. 1	
38	Reset Configuration Change Flag	0-1	Configuration Change Counter value	u16		As in command		See Universal Command description. Ref. 1	
48	Read additional device status	0-5 6 7 8 9 10 11 12 13 14-24	Device specific status Extended Field device status Device Operating Mode Standardized status 0 Standardized Status 1 Analog Channel Saturated Standardized Status 2 Standardized Status 3 Analog Channel Fixed Device specific status	u8 u8 u8 u8 u8 u8 u8 u8 u8 u8		As in command		See Universal Command description. Ref. 1	

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..1. Common Practice Commands

Command Number	Command function	Data in Command			Data in reply			Response code	Comments
		Byte no.	Description	Data type	Byte no.	Description	Data type		
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		See Common Practice Command description. Ref. 2	
40	Enter/Exit Fixed Current Mode	0-3	PV Fixed Current Level	F	0-3	Actual PV Current Level	F	See Common Practice Command description. Ref. 2	
42	Master Reset		None			None		See Common Practice Command description. Ref. 2	
44	Write PV Units	0	PV units Code	u8		As in command		See Common Practice Command description. Ref. 2	
45	Trim Loop Current Zero	0-3	Externally Measured PV Loop current	F		As in command		See Common Practice Command description. Ref. 2	
46	Trim Loop Current Gain	0-3	Externally Measured PV Loop current	F		As in command		See Common Practice Command description. Ref. 2	
50	Read Dynamic Variable Assignments		None		0 1 2 3	Device Variable assigned to PV Device Variable assigned to SV Device Variable assigned to TV Device Variable assigned to QV	u8 u8 u8 u8	See Common Practice Command description. Ref. 2	Unsupported Dynamic Variables return ”250” Default is “250” to all Dynamic variables
51	Write Dynamic Variable Assignments	0 1 2 3	Device Variable assigned to PV Device Variable assigned to SV Device Variable assigned to TV Device Variable assigned to QV	u8 u8 u8 u8		As in Command		See Common Practice Command description. Ref. 2	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	0 1	Device Variable Code Device Variable Unit	u8 u8		As in Command		See Common Practice Command description. Ref. 2	This should be issued after the field device variables are specified (cmd 139).
54	Read Device Variable Information	0	Device Variable Code	u8	0 1-3 4 5-8 9-12 13-16 17-20 21 22 23-26 27	Device Variable Code Device Variable Transducer number Device Variable Limits unit code Device Variable Upper Transducer Limit Device Variable Lower Transducer Limit Device Variable Damping Value Device Variable Min Span Device Variable Classification Device Variable Family Acquisition Period Device Variable Properties	u8 u24 u8 F F F F u8 u8 time u8	See Common Practice Command description. Ref. 2	
59	Write number of preambles	0	Number of preambles to be sent with the response message from the Slave to the Master	u8		As in command		See Common Practice Command description. Ref. 2	Default is 5

8..2. Device Specific Commands

Command Number	Command Function	Data in Command				Data in reply		Response code	Comments
		Byte no.	Description	Data type	Byte no.		Data type		
130	Read Float type data from Register	0-1	Register Address	u16	0-3	Modbus data		0 No command errors 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	0-1 2-5	Register Address Register data	u16 F		As in command		0 No command errors 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	0-1	Register Address	u16	0-1	Modbus data	u16	0 No command errors 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	0-1 2-3	Register Address Register data	u16 u16		As in command		0 No command errors 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	0-1 2 3-6 7 8-11 12	Register Address Data type/Byte order Scaling factor Device Variable code Offset State (Active/Inactive)	u16 u8 F u8 F u8		As in command		0 No command errors 2 Invalid selection 5 Too few data-bytes received	Valid Device Variable codes: 0-7
135	Enter Status Reg. Address	0-1 2	Status Register Address State (Active/Inactive)	u16 u8		As in command		0 No command errors 2 Invalid selection 5 Too few data-bytes received	Valid States: 0 = Inactive 1 = Active
136	Write Range Data Source	0 1	Range Data source (Local/Remote) Register Option (R/W)	u8 u8		As in command		0 No command errors 2 Invalid selection	Range source: 0 = Local 1 = Remote

								5 Too few data-bytes received	Default Local Option: 0 = Remote Register Read/Write 1 = Remote Register Read Only
137	Write Variable Ranges Modbus Reg. Address	0-1 2-3 4 5	Upper Range Reg. Lower Range Reg. Device variable code State(Active/Inactive)	u16 u16 u8 u8		As in command		0 No command errors 2 Invalid selection 5 Too few data-bytes received 6 Device Specific Cmd error	Valid States: 0, 1 Device Specific Cmd error = source Local
138	Write Sensor Limits	0 1-4 5-8 9-12 13	Sensor Limit Unit Code Upper Sensor Limit Lower Sensor Limit Min Span Device Variable Code	u8 F F F u8		As in command		0 No command errors 2 Invalid selection (Unit) 5 Too few data-bytes received	Invalid selection = Unit or class code not valid. This must be issued after command 139.
139	Write Device Variable Class and Unit	0 1 2	Device Variable Class Code Device Variable Unit code Device Variable Code	u8 u8 u8		As in command		0 No command errors 2 Invalid selection 5 Too few data-bytes received	Invalid selection = Unit or class code not valid Valid Classification codes: see device documentation. Valid Variable Code: 0-7 Unit code = Units in Modbus device.
140	Read Device Variable Class and Unit				0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	Device Variable 0 Class Code Device Variable 0 Unit code Device Variable 1 Class Code Device Variable 1 Unit code Device Variable 2 Class Code Device Variable 2 Unit code Device Variable 3 Class Code Device Variable 3 Unit code Device Variable 4 Class Code Device Variable 4 Unit code Device Variable 5 Class Code Device Variable 5 Unit code Device Variable 6 Class Code Device Variable 6 Unit code Device Variable 7 Class Code Device Variable 7 Unit code Number of Variable active	u8 u8 u8 u8 u8 u8 u8 u8 u8 u8 u8 u8 u8 u8 u8 u8 u8	0 No command error	
141	Write T310 Operation mode	0	Operation mode (Normal/Configuration)	u8		As in command		0 No command errors 2 Invalid selection 5 Too few data-bytes received	0 = Configuration Mode 1 = Normal Operation Mode

142	Read T310 Operation Mode		None			Operation Mode	u8		0 = Configuration Mode 1 = Normal Operation Mode
143	Read Device Variable Modbus Register Address	0	Device Variable Code	u8	0-1 2 3-6 7 8 9	Modbus Register Address Data type Scaling Device Variable Code Offset State (Active/Inactive)	u16 u8 F u8 F u8	0 No command error 2 Invalid selection	Valid Device Variable codes: 0-7
144	Read Modbus Status Register Address		None		0-1 2	Status Register Address State (Active/Inactive)	u16 u8	0 No command error	
145	Read Range Register Addresses		None		0-1 2-3 4 5	Upper Range Reg. Lower Range Reg. Device variable code State (Active/Inactive)	u16 u16 u8 u8	0 No command error	If Range Source is Remote: Range register addresses are returned
146	Read PV-Range Source & R/W Option		None		0 1	Range Data Source Source Reg. option (R/W)	u8 u8	0 No command error	0 = Source Local 1 = Source Remote 0 = Read/Write 1 = Read Only
147	Write Device Variable Upper Range	0 1-4 5	Range Data Unit Upper Range data Device Variable code	u8 F u8		As in command		0 No command error 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	0	Device Variable code	u8	0 1-4 5	Range Data Unit Upper Range data Device Variable code	u8 F u8	0 No command error 2 Invalid selection. If local 6 Device Specific Cmd error	
149	Write Device Variable Lower Range	0 1-4 5	Range Data Unit Lower Range data Device Variable index	u8 F u8		As in command		0 No command error 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	0	Device Variable code	u8	0 1-4 5	Range Data Unit Lower Range data Device Variable code	u8 F u8	0 No command error 2 Invalid selection. If local 6 Device Specific Cmd error	
151	Enter Device Status Bit-Pattern (Mask)	0 1	Pattern byte 0 Pattern byte 1	u8 u8		As In command		0 No command error 5 Too few data-bytes received	1 means Bit is selected / Status flag
152	Read Device Status Bit-Patter (Mask)		None		0 1	Pattern byte 0 Pattern byte 1	u8 u8	0 No command error	1 means Bit is selected / Status flag

154	Set/Reset Write Protection	0	Protection code	u8		As in command		0 No command error 2 Invalid selection 5 Too few data-bytes received	0: Write Not Protected 1: Write Protected 251: None
199	Write Modbus termination	0	Termination on/off	u8		As in command		0 No command error 2 Invalid selection 5 Too few data-bytes received	0 Termination off 1 Termination on
200	Read Modbus Address		None		0	Modbus Address	u8	0 No command error	
201	Write Modbus Address	0	Modbus Address	u8		As in Command		0 No command error 5 Too few data-bytes received	Valid Address range 1 – 255 (0 address not used)
202	Read Modbus settings		None		0-1 2 3 4 5	Baudrate Parity [N, E, O] Number of data bits (8, 9) Number of stop bits (1, 2) Physical interface (0, 1, 2)	u16 u8 u8 u8 u8	0 No command error	Physical interface: 1 = RS485
203	Write Modbus settings	0-1 2 3 4 5	Baudrate Parity [N, E , O] Number of data bits (8, 9) Number of stop bits (1, 2) Physical interface (0, 1, 2)	u16 u8 u8 u8 u8		As in Command		0 No command error 2 Invalid selection 5 Too few data-bytes received	Baud rate 9600 or 19200 Physical interface is fixed to RS485
204	Read Modbus Message CRC Order		None		0	CRC-Byte order	u8	0 No command error	0 = Low – High order (Standard Opt.) 1 = High – Low order
205	Write Modbus Message CRC Order	0	CRC-Byte order	u8		As in Command		0 No command error 2 Invalid selection 5 Too few data-bytes received	0 = Low High 1 = High Low
210	Write Modbus response and request timing	0-1 2-3 4-5	Response timeout (ms) Request delay (ms) Write delay (ms)	u16 u16 u16		As in Command		0 No command error 3 Parameter too large 4 Parameter too small 5 Too few data-bytes received	Response timeout: 50ms - 2s Request delay: 2ms – 2s Write delay: 2ms – Response timeout
211	Read Modbus response delay and request timing		None		0-1 2-3 4-5	Response timeout (ms) Request delay (ms) Write delay (ms)	u16 u16 u16	0 No command error	
212	Write Function code for reading Modbus Dynamic Variables	0 1	Function code (3, 4) Dev var no.	u8 u8	0 1	Function code Dev var no.		0 No command error 2 Invalid selection 5 Too few data-bytes received	3 = Read Holding Registers 4 = Read Input Registers
213	Write Function code for reading Modbus Status register	0	Function code (3, 4)	u8		As in Command		0 No command error 2 Invalid selection	3 = Read Holding Registers 4 = Read Input Registers

								5 Too few data-bytes received	
214	Read Function code for Dynamic Variables	0	Dev var no	u8	0 1	Dev var no Function code	u8 u8	0 No command error 2 Invalid selection	3 = Read Holding Registers 4 = Read Input Registers
215	Read Function code for Status register		None		0	Function code	u8	0 No command error	3 = Read Holding Registers 4 = Read Input Registers
220	Write Alarm Current	0	Alarm Current High/Low	u8		As in Command		0 No command error 2 Invalid selection 5 Too few data-bytes received	Alarm Codes: 0 = High 1 = Low 251 = None
221	Write NAMUR bit mask	0 1-2	Mask number [0-3] Mask bits	u8 u16		As in Command		0 No command error 2 Invalid selection 5 Too few data-bytes received	NAMUR bits in Extended Field Device Status byte (cmd 48) Mask number: 0: Maintenance required 1: Failure 2: Out of Specification 3: Function check
222	Read NAMUR bit mask	0	Mask number [0-3]	u8	0 1-2	Mask number Mask bits		0 No command error 2 Invalid selection 5 Too few data-bytes received	
223	Write Fault current bit mask	0-1	Mask bits	u16		As in Command		0 No command error 5 Too few data-bytes received	Select bits from Modbus Status register that will set alarm current
224	Read Fault current bit mask		None		0-1	Mask bits	u16	0 No command error	
225	Read Modbus configuration		None		0	Configuration bits	u8	0 No command error	
227	Read Modbus interface type		None		0	Interface type	u8	0 No command error	0: RTU 1: TCP 2: RTU_ONLY (T210)
228	Write Modbus interface type	0	Interface type	u8		As in Command		0 No command error 2 Invalid selection 5 Too few data-bytes received	0: RTU 1: TCP
229	Read Modbus TCP configuration		None		0-3 4 5 6-9 10 11 12	T310 IP address Slave IP Gateway IP Netmask Port no. Timeout (ms) Polling interval (ms)	u8 u8 u8 u8 u16 u16 u16	0 No command error	

230	Write Modbus TCP configuration	0-3 4 5 6-9 10 11 12	T310 IP address Slave IP Gateway IP Netmask Port no. Timeout (ms) Polling interval (ms)	u8 u8 u8 u8 u16 u16 u16		As in Command		0 No command error 2 Invalid selection 5 Too few data-bytes received	See section 4.4 for defaults Port no.: default 502 Timeout: default 10 s Polling interval default: 10 s
253	Test command	0	Test function	u8	0	Test function Byte 1…. Test data	u8	0 No command error	For compliance testing only