FAFNIR

TORRIX-HART

The magnetostrictive level sensor with HART Protocol

HART®
COMMUNICATION PROTOCOL

![FAFNIR logo]

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1 Introduction

This specification is designed to complement other TORRIX documents (e.g. TORRIX Technical Documentation). It provides a complete description of the TORRIX Field Device from a HART Communication point of view.

The FAFNIR GmbH magnetostrictive sensor TORRIX complies with the HART Protocol Revision 6. This document describes all the device specific features and documents HART Protocol implementation details. The functionality of the TORRIX is described in a way that allows its proper application in a process and its complete support in HART capable Host Devices.

This document assumes the reader is familiar with HART Protocol requirements and terminology.

The safety instructions in this manual are labelled as follows:

⚠️ *If you do not observe these safety instructions, there is a risk of accidents or the sensor could be damaged.*

☞ *Useful information which ensures proper functioning of the system and facilitates your work.*

2 Properties

The high-precision and robust TORRIX level sensor is designed to provide continuous gauging of liquid media levels in tanks. The measuring principle used by the sensor exploits the physical effect of magnetostriction and is largely unaffected by temperature. Magnetostriction is particularly ideal where level measurements are required to be extremely accurate, e.g. in the chemical industry.

The level sensor outputs measuring signals in the range 4 to 20 mA. Available in lengths of 200 to 6,000 mm, it is compatible with a variety of tank dimensions. It also comes in the following versions:

- Version for installation on a bypass with magnetic float
- Version with flange
- Version with screw-in unit for infinitely variable positioning of the level sensor

The Ex-approved version of the level sensor can be installed in potentially explosive atmospheres in which electrical equipment of category 1 (zone 0) or category 1/2 (zone 0/1) are required.

In the HART variant TORRIX can be ordered with 2 floats instead of 1 float. This allows to measure 4 different process values with only one sensor. In a tank with two liquids it is possible to read out the total level, the interface level, the interface layer thickness and the temperature via the HART protocol.

3 Device Identification

Fig. 1: TORRIX probe head

The name plate is located on the TORRIX probe head.

Manufacturer Name	FAFNIR GmbH
Manufacturer ID Code	198 (C6 Hex)
Model Name	TORRIX
Device Type Code	128 (80 Hex)
Device Revision	4
HART Protocol Revision	6
Number of Device Variables	1 to 4
Physical Layers Supported	FSK
Physical Device Category	2-wire transmitter

Table 1: Device Identification

4 HART Commands

4.1 Universal Commands

All HART Rev. 6 Universal Commands are supported.

CMD Id	Function
0	Read Unique Identifier
1	Read Primary Variable
2	Read Loop Current And Percent Of Range
3	Read Dynamic Variables And Loop Current
6	Write Polling Address
7	Read Loop Configuration
8	Read Dynamic Variable Classification
9	Read Device Variable With Status
11	Read Unique Identifier Associated With Tag
12	Read Message
13	Read Tag, Descriptor, Date
14	Read Primary Variable Transducer Information
15	Read Device Information
16	Read Final Assembly Number
17	Write Message
18	Write Tag, Descriptor, Date
19	Write Final Assembly Number
20	Read Long Tag
21	Read Unique Identifier Associated With Long Tag
22	Write Long Tag

Command #3 (Read Dynamic Variables And Loop Current)

The answer to Command #3 does always contain four Dynamic Variables (PV,SV,TV,QV).

Command #18 (Write Tag, Descriptor, Date)

Invalid date codes received within the Command #18 will result in not executing the command and returning Error Code #9 (Invalid Date Code Detected) instead.

Command #14 (Read Primary Variable Transducer Information)

The Transducer Serial Number returned within the answer to Command #14 is set to zero by default.

4.2 Common Practice Commands

The following Common Practice Commands are supported.

CMD Id	Function
33	Read Device Variables
34	Write Primary Variable Damping Value
35	Write Primary Variable Range Value
36	Set Primary Variable Upper Range Value
37	Set Primary Variable Lower Range Value
38	Reset Configuration Changed Flag
40	Enter/Exit Fixed Current Mode
41	Perform Self Test
42	Perform Device Reset
44	Write Primary Variable Units
45	Trim Loop Current Zero
46	Trim Loop Current Gain
48	Read Additional Device Status
49	Write Primary Variable Transducer Serial Number
50	Read Dynamic Variable Assignments
51	Write Dynamic Variable Assignments
53	Write Device Variable Units
54	Read Device Variable Information
55	Write Device Variable Damping Value
59	Write Number Of Response Preambles
71	Lock Device
76	Read Lock Device State

Command #42 (Perform Device Reset)

After Command #42 is used to perform a device reset it takes about 2 seconds before the transmitter is ready to answer the next command.

Command #48 (Read Additional Device Status)

The answer to Command #48 does contain 8 response data bytes. See section 7.3 for information on the individual status bits.

4.2.1 Burst Mode

This field device does not support Burst Mode.

4.2.2 Reverse Mode

The device can be operated in Reverse Mode by setting the Upper Range Value lower than the Lower Range Value.
Reverse Mode can be set by using:

- Command #35 (Write Primary Variable Range Value)
- Command #36 (Set Primary Variable Upper Range Value)
- Command #37 (Set Primary Variable Lower Range Value)

4.3 Device Specific Commands

The following Device Specific Commands are implemented:

CMD Id	Function
200	Write Protection Mode
201	Read Protection Mode
202	Write Alarm Current
203	Read Alarm Current
204	Change Passcode
205	Write Device Variable Offset
206	Read Device Variable Offset
207	Read Diagnostics Data
208	Read Firmware Version
209	Write Device Variable Enable
210	Read Device Variable Enable
211	Restore Factory Defaults

A detailed description about all the Device Specific Commands can be obtained on request.

5 Device Variables

5.1 Device Variable 0, Level of Float 1

The Device Variable 0 contains the result of the level measurement done with float 1 (upper float). This level represents the total level.

Summary of Device Variable 0 properties:

Device Variable 0 – Level Of Float 1	
Number	0
Name	Level of float 1
Classification	Length
Engineering Units	mm, cm, m, inch, feet *
Device Family	None

* see section 12.1.1. Length Conversion for additional information.

5.2 Device Variable 1, Level of Float 2

The Device Variable 1 contains the result of the level measurement done with float 2 (lower float). This level represents the interface level.

Summary of Device Variable 1 properties:

Device Variable 1 – Level Of Float 2	
Number	1
Name	Level of float 2
Classification	Length
Engineering Units	mm, cm, m, inch, feet *
Device Family	None

* see section 12.1.1. Length Conversion for additional information.

☞ *The transmitter is not always equipped with a second float. If there is no second float the measurement data of Device Variable 1 is set to Not-A-Number.*

5.3 Device Variable 2, Temperature

The Device Variable 2 contains the result of the temperature measurement. The temperature sensor is located in the transmitters probe tube.

Summary of Device Variable 2 properties:

Device Variable 2 – Temperature	
Number	2
Name	Temperature
Classification	Temperature
Engineering Units	°C, °F *
Device Family	None

* see section 12.1.1. Length Conversion for additional information.

☞ *The transmitter is not always equipped with the possibility to measure the temperature. If there is no temperature measurement the measurement data of Device Variable 2 is set to Not-A-Number*

5.4 Device Variable 3, Interface Layer Thickness

The Device Variable 3 contains the result of the interface layer thickness measurement done with float 1 and float 2. The interface layer thickness is the result of the following calculation:

Interface layer thickness = Total level (upper float) – Interface level (lower float)

Summary of Device Variable 3 properties:

Device Variable 3 – Interface Layer Thickness	
Number	3
Name	Interface layer thickness
Classification	Length
Engineering Units	mm, cm, m, inch, feet *
Device Family	None

* see section 12.1.1 for additional information.

☞ *The transmitter is not always equipped with a second float. If there is no second float the measurement data of Device Variable 3 is set to Not-A-Number.*

6 Dynamic Variables

The device supports 4 Dynamic Variables (PV, SV, TV and QV) that can be mapped from the Device Variables.

6.1 Mapping of the Dynamic Variables

Use Command #50 (Read Dynamic Variable Assignments) to get the current mapping of the Dynamic Variables. To change the mapping use Command #51 (Write Dynamic Variable Assignments).

For the default mapping of the Dynamic Variables see section 13.2.2. Default Configuration Of Dynamic Variables.

7 Status Information

7.1 Field Device Status

<u>Non-Primary Variable Out Of Limits (bit 1)</u>

Non-Primary Variable Out Of Limits is set whenever the value of one of the Non-Primary Variables exceeds the upper or lower limit of the sensor that belongs to this variable.

<u>More Status Available (bit 4)</u>

More Status Available is set whenever Device Malfunction is set.

<u>Device Malfunction (bit 7)</u>

Device Malfunction is set whenever the Self-Test has detected a serious problem with the device. This problem will also set the corresponding Additional Device Status bit. See section 7.3 for more information about the Additional Device Status bits.

7.2 Extended Device Status

<u>Maintenance Required (0x01)</u>

Maintenance Required is not used.

<u>Device Variable Alert (0x02)</u>

Device Variable Alert is set whenever one of the following is true:

- Primary Variable Out Of Limits
- Non-Primary variable Out Of Limits
- Process Data Status *) of any Device Variable is different from status GOOD
- Limit Status *) of any Device Variable is different from status NOT LIMITED
  *) Process Data Status and the Limit Status are part of the Device Variable Status.

7.3 Additional Device Status

The device supports Command #48 (Additional Device Status). The answer to Command #48 contains 8 response data bytes (byte 0-7) including Device Specific Status, Extended Device Status and Device Operating Mode.

7.4 Device Specific Status Bits

Description of the Device Specific Status bits:

Byte	Bit	Function	Class
0	0	HART Parameter Error	Error
	1	Transmitter Parameter Error	Error
	2	Measurement Error	Error
	3	Error Counter Error	Error
	4	Low Voltage Error	Error
	5	Not used *	
	6	Not used *	
	7	Not used *	

* Device Specific Status bits that are not used are set to zero.

HART Parameter Error

It has been detected that the HART parameters have illegally been changed.

Transmitter Parameter Error

It has been detected that the transmitter parameters have illegally been changed.

Measurement Error

It has been detected that a measurement is not possible.

Error Counter Error

It has been detected that there are to many errors during the measurement.

Low Voltage Error

It has been detected that the supply voltage is to low. The analogue output has been set to 3.6 mA (independent from the alarm current that has been selected).

8 Analogue Output

The transmitter does only have one analogue output which is simultaneously used for the power supply. It is connected via the M12 connector on the transmitter head.

The analogue output corresponds to the Primary Variable. By default, the Primary Variable is mapped to the Device Variable 0 (level of float 1) and scaled according to the configured range. Further, it is possible to output the temperature and to output for sensors with two floats the interface level or the interface layer thickness via the analogue output.

HART Rev. 6 communication is supported. This device has a CN (Capacitance Number) of 4,4 which equates to a input capacity of 22 nF.

Analogue Output, Specification

	Direction	% Values of range	Values
Linear Over-Range	Down	-1.25 %	3.8 mA
	Up	103.125 %	20.5 mA
Device Malfunction Indication	Down	-2.5 %	3.6 mA
	Up	109.375 %	21.5 mA
Maximum Loop Current		109.375 %	21.5 mA
Multi-Drop Current Draw			4 mA
Lift-Off Voltage			8 V

Linear Over-Range

The linear output current range goes from 3.8 mA to 20.5 mA. Whenever the Primary Variable scaled according to the configured range is lower than 3.8 mA or higher than 20.5 mA the output saturates and does not follow the process anymore.

Device Malfunction Indication

The device malfunction indication on the analogue output is done according to NAMUR NE 43. The alarm current can be set to either under scale (3.6 mA) or over scale (21.5 mA). Over scale is set by default. Whenever the sensor detects an under voltage condition the analogue output is set to under scale (3.6 mA).

Maximum Loop Current

The maximum loop current of 21.5 mA does flow when there is an alarm condition and over scale signalling is selected.

Multi-Drop Current Draw

If loop current signalling is disabled, the current is fixed to 4 mA. If loop current signalling is enabled the current will follow the value of the Primary Variable scaled according to the configured range.

Lift-Off Voltage

TORRIX needs at least 8 V to operate.

9 Performance

9.1 Power-Up

At power-up the transmitter reads back configuration data from flash memory into RAM. All configuration data is then checked and if there are no errors detected the measurement is started. During this period of time the analogue output is set to 4 mA.

When the transmitter is able to do measurements the values of the Device Variables and the percent of range are calculated. The analogue output is set to the value of the Primary Variable scaled by the current range values.

If a measurement is not possible due to a device malfunction the values of the Device Variables and the percent of range are set to Not-A-Number. In this case the analogue output is set to the configured alarm current (21.5 mA by default).

A HART communication is possible about 2 seconds after the device is powered on.

The following functions / modes will be cancelled if power is cycled:
- Fixed Current Mode
- Temporary Lock

9.2 Device Reset

When Command #42 (Perform Device Reset) has been received the field device controller will do a software reset. The resulting re-start is identical to the normal power up sequence (see section 9.1).

9.3 Self Test

The transmitter is doing self tests at power-up, after receiving Command #41 (Perform Self Test) and as continuous self tests during normal operation. The following tests are done:

- Transmitter configuration parameter check
- HART configuration parameter check
- Level of float 1 measurement ok check
- Level of float 2 measurement ok check
- Temperature measurement check
- Interface layer thickness measurement ok check
- Measurement error counter check
- Supply voltage check

☞ *After Command #41 (Perform Self Test) has been used the transmitter will be able to continue the HART communication without any interruption.*

9.4 Sampling Rate

The following table shows typical sampling and update rates.

Level of float 1, sampling rate	50 per second
Level of float 2, sampling rate	50 per second
Interface Layer Thickness, sampling rate	50 per second
Device Variable 1, update rate	50 per second
Device Variable 3, update rate	50 per second
Temperature measurement	50 per second
Analog output, update rate	50 per second

9.5 Command Response Delay

The following table shows the Command Response Delay Times.

Minimum	10 msec
Typical	20 msec
Maximum	150 msec

9.6   Non-Volatile Memory

All configuration data is stored in flash memory. New configuration data is written to the flash memory about 10 seconds after the last write command has been processed. De-energising the sensor before the data is written to the flash memory will result in a loss of the configuration changes. While writing data to the flash memory the current consumption will be temporary fixed to 12 mA.

⚠️   *Death or serious injury could result from doing configuration changes when the transmitter is used for process control at that time. So be sure that the transmitters analogue output is not used for process control when doing configuration changes.*

9.7   Write Protection

Write Protection can be enabled or disabled using Device Specific Command #200 (Write Protection Mode). The current state of the Write Protection can be checked using Device Specific Command #201 (Read Protection Mode). By default Write Protection is disabled.

☞   *In Write Protection Mode Commands #40 (Enter/Exit Fixed Current Mode), #41 (Perform Self-Test) and #42 (Perform Device Reset) can still be used.*

9.8   Damping

Damping can be set for Device Variable 0 (level of float 1) and Device Variable 1 (level of float 2) using Command #34 (Write Primary Variable Damping Value) or Command #55 (Write Device Variable Damping Value). See section 12.2 for more information about possible Damping Values.

10 HART recommendations

10.1 Wiring and installation

For HART installations an individually shielded twisted pair cable is recommended. The cable can be either single-pair or multi-pair. Theoretically the maximum cable length of a HART installation is 3000 m. However, the electrical characteristics of the used cable and the input impedance of the connected devices can reduce the maximum cable length. Minimum conductor size:

< 1500 m   AWG24 (0.2 mm^2)

> 1500 m   AWG20 (0.5 mm^2)

In general, the cable should have a low resistance and a low capacitance.

The shield of the cable must only be connected on one side. It is recommended to connect the cable shield to the central earthing point.

If a non twisted and/or non shielded cable (e.g. from an existing 4 … 20 mA installation) should be used it has to be checked that an error free HART communication is possible under all conditions.

10.2 Devices on a HART network

It is recommended that all devices on a HART network are designed conforming to HART. All devices (not only devices doing HART communication) on a HART network can have negative effects on the HART communication. When using devices that have been designed only for the analogue 4 … 20 mA signalisation it can happen, that these devices short-circuit the digital HART signal because of its higher frequency.

11 Configurations using the HART protocol

There are a lot of configuration tools available that can be used for HART devices. These tools do either consist of a PC software and a HART modem or are build as Universal Handheld Communicator (with integrated Modem).

At the moment TORRIX does not have a HART Device Description (DD). When selecting a configuration tool for TORRIX this tool must be able to work with devices not having their own DD. In general, the configuration tools do have a universal DD that can be used for HART devices not having an own DD. These universal DD's do only use Universal Commands and Common Practice Commands when communicating to a HART device.

The following configuration tools have been tested with TORRIX and can be used. These tools offer enough functionality to do most of the configurations that are possible with TORRIX.
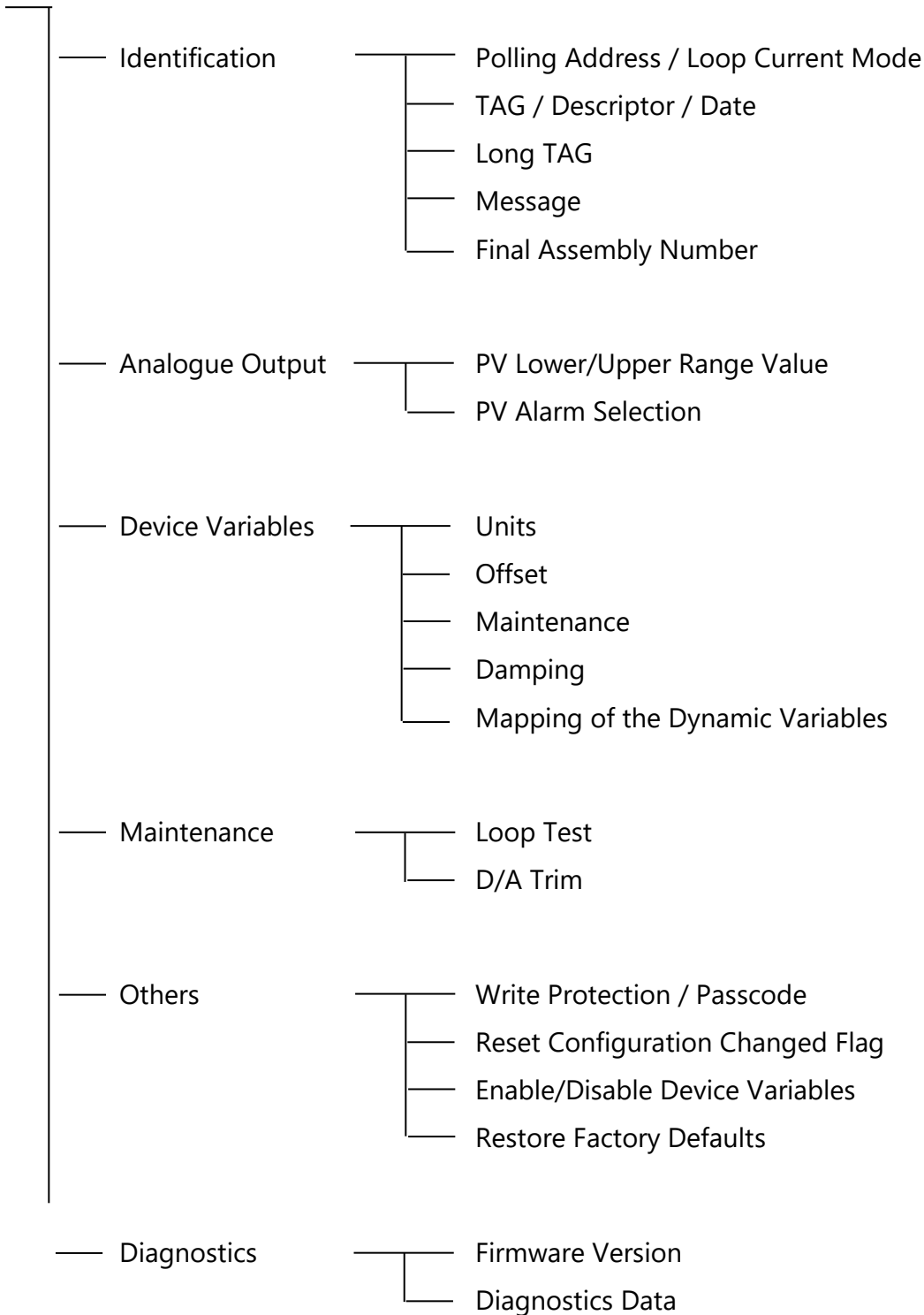
11.1 FAFNIR HART-Setup

FAFNIR HART-Setup is a PC program specially designed by FAFNIR to display and change configuration data of FAFNIR HART devices. FAFNIR HART-Setup can be downloaded free of charge from the FAFNIR internet site www.fafnir.com.

☞ *A HART modem is needed.*

11.1.1 Configuration with FAFNIR HART-Setup

The following functions for commissioning and maintenance are available:

- **Identification**
  - Polling Address / Loop Current Mode
  - TAG / Descriptor / Date
  - Long TAG
  - Message
  - Final Assembly Number

- **Analogue Output**
  - PV Lower/Upper Range Value
  - PV Alarm Selection

- **Device Variables**
  - Units
  - Offset
  - Maintenance
  - Damping
  - Mapping of the Dynamic Variables

- **Maintenance**
  - Loop Test
  - D/A Trim

- **Others**
  - Write Protection / Passcode
  - Reset Configuration Changed Flag
  - Enable/Disable Device Variables
  - Restore Factory Defaults

- **Diagnostics**
  - Firmware Version
  - Diagnostics Data

Configurations using the HART protocol

11.2 Emerson 375 Field Communicator

The Emerson 375 Field Communicator is a Handheld Terminal. It has especially been designed for the use in the field. A HART modem is integrated. For the configuration of devices installed in explosive atmospheres there is an option that meets the intrinsic safety requirements.

☞ *The Emerson 375 Field Communicator must have the generic DD for HART Rev. 6 installed to be able to configure TORRIX. It is not possible to change the mapping of the Dynamic Variables using this tool.*

11.2.1 Configuration using the Emerson 375 Field Communicator

After switching on the Emerson 375 Field Communicators the Main Menu is displayed. To establish a HART communication the HART Application has to be started. As there is currently no DD available for the level sensor TORRIX the display of the Emerson 375 Field Communicators will show the following text:

> HART Application
> Device Description not installed…The
> Device Description for manufacturer 0xC6
> model 0x80 dev rev 3 is not installed on the
> System Card … See Programming Utility for
> details on Device Description updates … Do
> you wish to proceed in forward
> compatibility mode?

After **YES** has been entered (this starts loading of the HART Rev. 6 generic DD) the online menu is started. This menu offers the functions that are needed to do configuration changes on TORRIX.

11.3 Smar CONF401

Smar CONF401 is a powerful and user friendly PC software. In conjunction with TORRIX it offers very good functionality. TORRIX is automatically recognised.

11.4 Siemens PDM

Siemens PDM is a PC software that can be used for commissioning and maintenance of HART devices. PDM offers a standard HART Device Description file (DDL) for HART devices that has to be used for TORRIX. This DDL file can be found in the PDM-Device Catalogue as HART\Universal\Standard.

11.5 FDT/DTM based configuration tools

When using FDT/DTM based configuration tools (e.g. PACTware or Smart Vision) a generic HART DTM has to be used as there is no special DTM available for TORRIX.

12 Tables

12.1 Unit Conversion

As the transmitter supports more than one Engineering Unit for each of the different Device Variables unit conversion is needed. See the next section about how this is done.

12.1.1 Length Conversion

Accepted length unit codes are: mm, cm, m, inch and feet.
The transducer is using mm for all internal length operations.
Conversions between the accepted length unit codes are done as follows:

1 mm = 0.1 cm	1 cm = 10 mm
1 mm = 0.001 m	1 m = 1000 mm
1 mm = 0.0393700787 inch	1 inch = 25.4 mm
1 mm = 0.0032808399 feet	1 feet = 304.8 mm

12.1.2 Temperature Conversion

Accepted temperature unit codes are: °C and °F.
The transducer is using °C for all internal temperature operations.
Conversions between the accepted temperature unit codes are done as follows:

°F = (°C * 1.8) + 32.0	°C = (°F - 32.0) / 1.8

12.2 Damping Values

A Damping Value received is rounded and truncated to the nearest possible value if it does not equate one of the transmitters fixed Damping Values. See the next sections about which Damping Values are possible with the different Device Variables.

12.2.1 Damping Values for Device Variables 0 and 1 (level of float 1 and 2)

The following Damping Values can be set for Device Variables 0 and 1:
0 sec – 0.5 sec – 1 sec – 2 sec – 4 sec – 8 sec – 16 sec – 32 sec – 64 sec

12.2.2 Damping Values for Device Variable 3 (interface layer thickness)

The Damping Value for Device Variable 3 can not be changed directly. As the interface layer thickness is calculated out of the levels measured with float 1 and float 2 the Damping Values defined for the two floats are effective also for the interface layer thickness.

13 Annexes

13.1 Annex A. Capability Checklist

This is a brief overall checklist of the capabilities of TORRIX-HART:

Device type	Transmitter
HART revision	6
Device Description available	no
Number and type of sensors	up to 4 (internal)
Number and type of host side signals	2, 4 – 20 mA (analogue) and HART FSK (digital)
Number of Device Variables	4
Number of Dynamic Variables	4
Mappable Dynamic Variables	yes
Number of Common Practice Commands	22
Number of Device Specific Commands	12
Bits of additional device status	5
Alternative operating modes	none
Burst Mode	no
Write protection	yes

13.2 Annex B. Default Configuration

When TORRIX is leaving the factory it is pre-loaded with a default device configuration. This default configuration includes parameter values and variable mappings.

13.2.1 Default Configuration Of Variables

Variables are set to the following values by default.

Parameter	Default Value
Polling Address	0
Number Of Request Preambles	5
Number Of Response Preambles	5
Configuration Change Counter	0
PV Upper Range Value	depends on the sensor length
PV Lower Range Value	50 mm
PV Damping	0
PV Engineering Units	mm
Final Assembly Number	0
Sensor Serial Number	0
Tag	"FAFNIR__"
Long Tag	"FAFNIR_TORRIX_____"
Descriptor	"FAFNIR_TORRIX___"
Date	set to the manufacturing date
Message	32 x ?
Primary Master Device Lock	0 (no lock active)
Secondary Master Device Lock	0 (no lock active)
Write Protection	0 (not write protected)
Password	0 (0X0000)

13.2.2 Default Configuration Of Dynamic Variables

The Dynamic Variables are mapped to the following Device Variables by default.

Variable	Default Value
Primary Variable (PV)	Device Variable 0 (Level of float 1)
Secondary Variable (SV)	Device Variable 1 (Level of float 2) *
Tertiary Variable (TV)	Device Variable 2 (Temperature) **
Quaternary Variable (QV)	Device Variable 3 (Interface Layer Thickness)***

*   if Device Variable 1 is not available (sensor has only 1 float) or Device Variable 1 is not enabled, SV is not mapped to Device Variable 1

**   if Device Variable 2 is not available (without temperature sensor) or Device Variable 2 is not enabled, TV is not mapped to Device Variable 2

***   if Device Variable 3 is not available (sensor has only 1 float) or Device Variable 3 is not enabled, QV is not mapped to Device Variable 3