HART Protocol Specification

HART Field Communications

HART® COMMUNICATION FOUNDATION

Conductivity Device Family Specification

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Preface

The Conductivity Device Family Specification was a joint effort of Alfred Peer of Mettler-Toledo and James Gray of Rosemount Analytical. The intent of this specification is to expose the most useful features of HART conductivity devices to hosts accessing them using the Conductivity Device Family, in a manner allowing broad application by all manufacturers of HART pH devices and HART users. Wally Pratt of the HART Foundation deserves special thanks for his insights and assistance in the preparation of this specification.

Introduction

The Conductivity Device Family Specification was developed to take into account the variety of measurement technologies used to measure conductivity, which are driven by the needs of the conductivity application. Although the conductivity measurement technologies vary significantly in the actual physical implementation of the measurement, all ultimately derive a raw conductivity measurement, which is the conductivity at process temperature. A temperature compensation routine is usually then applied to the raw conductivity value to correct the reading to a standard temperature, in order to separate the effects of temperature from the effects of solution composition on the transmitted conductivity value. This conductivity value may be further processed to derive the concentration of an electrolyte(s). The variables in a typical HART conductivity are used to configure the device for the appropriate conductivity measurement technology and temperature compensation, and to provide access to the physical measurements made by the device. The Conductivity Family Specification provides a set of commands to give a HART host access to these variables.

The Conductivity Device Family Commands expose variables representing the physical measurements provided by a conductivity device, the conductivity measurement technology used, the calibration information resident in the device, and temperature compensation configuration. In addition to a conductivity measurement, the typical HART conductivity device can also provide a temperature measurement, and often, raw conductivity and concentration measurements, as well as a diagnostic indication of sensor health. A variable is provided to identify the conductivity measurement technology, which is especially useful for HART conductivity devices that can use more than one measurement technology. Conductivity devices typically use the cell constant as a calibration constant, which can be the result of a calibration or input by the user to match a pre-calibrated sensor. Temperature compensation variables, made available, indicate whether temperature compensation is being used or not, and include the type of compensation used, which is chosen to meet the needs of the process.

A host, having access to the information provided by the Conductivity Device Family Commands, can access various measurements and can make simple decisions as to the validity of the Conductivity measurement, based on a sensor diagnostic variable. The host's decision making capability can be enhanced with detailed information on the device's temperature measurement, if a conductivity device makes use of Temperature Device Family Commands. In Conductivity devices having PID control, the PID Control Family can provide information relevant to the control application, and supervision of the control application can be further enhanced with information provided by the Conductivity and Temperature Device Families.

1. SCOPE

This Device Family defines the mandatory and optional properties required to configure and operate a conductivity measurement. It is applicable to conductivity measurements, using 2-electrode, 4-electrode, and inductive conductivity sensors, and conductivity devices that can output concentration in addition to conductivity. Due to the fact that multiple sensor technologies are covered by this definition, Device Variables do not include any conductivity-related variables more intrinsic to the device than Raw Conductivity. In addition to Raw Conductivity, Device Variables include Conductivity, Concentration, and Temperature. Additional temperature sensor information can be accessed using the Temperature Device Family commands. PID control can also be supported in a conductivity device and addition PID information can be obtained using the PID Control Family commands.

2. REFERENCES

2.1 HART Field Communications Protocol Specifications

These documents published by the HART Communication Foundation are referenced throughout this specification:

HART Field Communications Protocol Specification. HCF_SPEC-12

Command Summary Specification. HCF_SPEC-99

Device Families Command Specification. HCF_SPEC-160

Common Tables Specification. HCF_SPEC-183

Command Response Code Specification. HCF_SPEC-307

2.2 Related HART Documents

The HART Protocol Specifications frequently reference the manufacturers' device-specific document. Device-specific documents are developed and controlled by the respective manufacturer and should follow the requirements of the following HART Communication Foundation document:

Requirements for Device Specific Documentation. HCF_LIT-18

2.3 HART Device Family Documents

The applicable HART Device Family Documents for Temperature Devices and PID control are:

Temperature Device Family Specification. HCF_SPEC-160.4, Revision 1.0

PID Control Device Family Specification. HCF_SPEC-160.7, Revision 1.0

3. DEFINITIONS, SYMBOLS AND ACRONYMS

Terms used in this document and defined in *HART Field Communications Protocol Specification* include: Delayed Response, Delayed Response Mechanism, Device Variable, Busy, DR_CONFLICT, DR_DEAD, DR_INITIATE, DR_RUNNING, Floating Point, Request Data Bytes, Response Data Bytes, Response Message, Units Code

Device Family, or Device Family Specification:

The definition of the properties, diagnostics and commands required to manage a Device Variable. The Device Family specification includes all the mandatory and optional properties necessary to configure the corresponding class of process connections.

4. OVERVIEW

The Conductivity Device Family supports the measurement of conductivity and the determination of Conductivity Status using the device variables measured by 2-electrode, 4-electrode, and inductive conductivity sensors. Addition properties are defined that specify the temperature compensation used in conductivity measurements, and the types of conductivity sensors used.

A. Device Variables

The device variables for the Conductivity Device Family include:

1. Temperature: The process temperature is measured by a temperature element in the conductivity sensor, or by a separate temperature sensor connected to the device.

2. Conductivity: The temperature compensated conductivity or resistivity derived by the device. The units of Conductivity can include μS/cm, mS/cm, and S/cm. Resistivity units can include megOhm-cm, kOhm-cm, and Ohm-cm.

3. Raw Conductivity: the conductivity of the solution before the application of temperature compensation. Access to Raw Conductivity makes it available for certain applications that require this measurement, and makes it possible for a host to apply temperature compensation or a concentration derivation not available in the conductivity device. . The units of Raw Conductivity can include μS/cm, mS/cm, and S/cm

4. Concentration: Concentration of an electrolyte can be derived from the conductivity reading in many applications of conductivity. The ability to derive concentration is resident in a large number of conductivity devices. The units of concentration can include percent, parts per million (ppm), or any other unit applicable to solids dissolved in liquids.

5. Conductivity Sensor Diagnostic: Conductivity devices can include a diagnostic that detects a problem with the conductivity sensor. Sensor diagnostics are available for 2-electrode, 4-electrode, and inductive sensors and can indicate a failure of the sensor, or in the case of 2-electrode or 4-electrode sensors, can detect coating or corrosion or the surface of the electrodes.

B. Temperature Compensation Variables

The temperature compensation variables are used by the conductivity device to correct a the conductivity or concentration reading to 25C, or another reference temperature. They include:

1. Temperature Compensation toggles the device between automatic and manual temperature compensation. In automatic temperature compensation, the device uses the temperature measurement of the temperature element in the conductivity sensor to correct the conductivity reading for changes in the solution conductivity with temperature. In the manual mode, the conductivity is corrected using a manually entered temperature value.

2. Manual Temperature is a temperature value used by the device to temperature compensation in the manual mode.

3. Temperature Compensation Type determines the nature of the temperature compensation used to correct the conductivity reading. These types include linear temperature compensation for typical conductivity applications, as well as non-linear temperature compensation for applications involving high purity water and concentration measurements.

4. Temperature Slope is the change of the solution conductivity with temperature in units of % /degree C. It is used with linear temperature compensation.

5. Reference Temperature: Conductivity measurements are corrected to a reference temperature, which is usually 25 C, but can be any temperature.

C. Conductivity Sensor Type

1. The variable, Sensor Type, identifies the type of conductivity sensor used by the device, as a 2-electrode, 4-electrode, or inductive conductivity sensor.

2. Cell Constant: In a conductivity devices using a 2-electrode or 4-electrode conductivity sensor, the cell constant relates the raw conductivity to the conductance directly measured by the device. Cell Constant can also be applied to devices using inductive sensors in a similar fashion. Cell Constant functions as a calibration constant for the conductivity measurement. The cell constant has units of cm^{-1}.

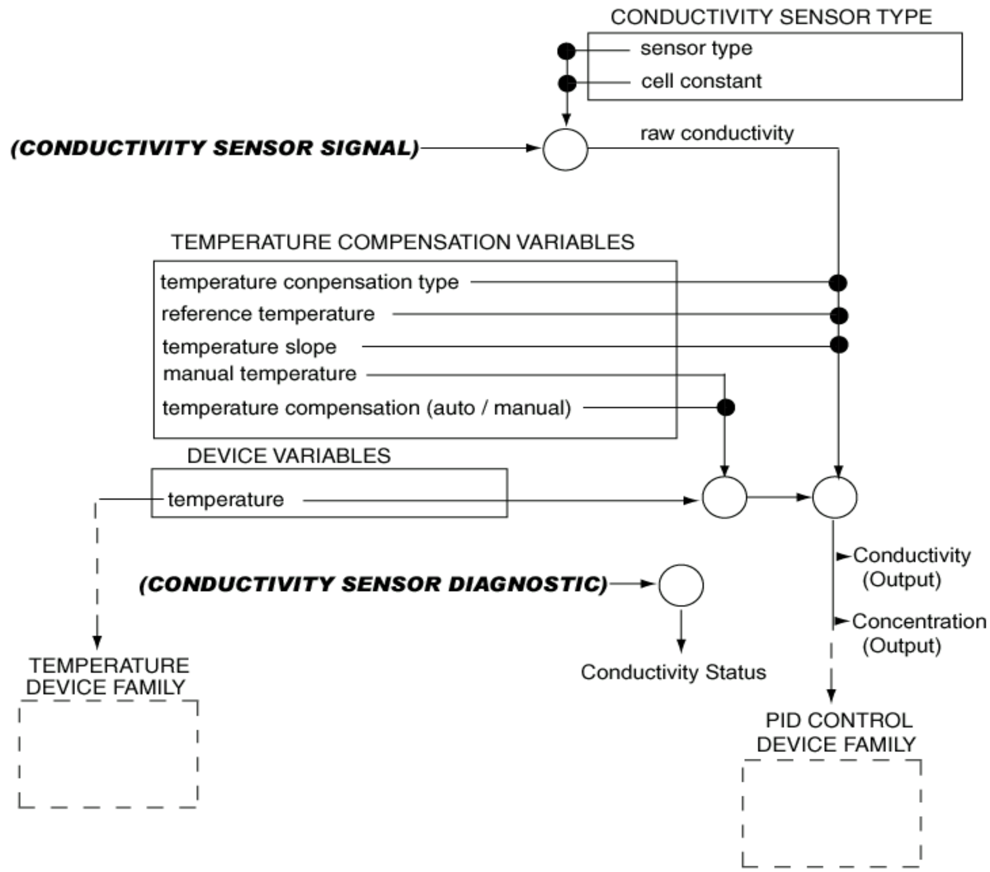

Figure 1. Conductivity Device Family Block Diagram

The way in which a conductivity device derives conductivity can be outlined as follows (Figure 1):

1. The conductivity sensor, which can be 2-electrode, 4-electrode, or inductive sensor, provides a raw conductivity signal. In the classical model, using a 2-electrode sensor, this signal is conductance, which, when multiplied by the Cell Constant yields Raw Conductivity. Raw Conductivity is the conductivity of the solution at the process temperature.

2. The variable Temperature Compensation determines whether the temperature reading from the temperature element in the conductivity sensor is used for temperature compensation. If Temperature Compensation is set to automatic, the temperature value from the conductivity sensor is used by the device to temperature compensate the conductivity reading. If it is set to manual, the temperature value supplied by the variable, Manual Temperature is used by the device for temperature compensation. More information on the temperature measurement provided by the conductivity sensor can be obtained by using the Temperature Device Family.

3. The variable Temperature Compensation Type determines which type of temperature compensation is applied to the conductivity measurement. If the Temperature Compensation Type is linear, the variable Temperature Slope is the slope of the linear temperature compensation in units

of %/degree C. The conductivity is usually corrected to the value at 25 C, but it can be corrected to any temperature; the variable, Reference Temperature, gives this temperature.

4. After the application of temperature compensation, the conductivity device may either output temperature compensated conductivity or apply an additional routine to derive concentration.

5. In some cases, a conductivity device can include PID control using the conductivity or concentration value as the measurement value. In these instances, more information about the PID block can be obtained using the PID Control Family.

6. If the conductivity device includes conductivity sensor diagnostics, detection of a failure will set the Conductivity Status to "bad".

5. COMMANDS

5.1 Command 1024 Read Conductivity Status (Recommended)

All Device Families allow additional status information to be provided to host applications. This Device Family Status is in addition to the Device Variable Status information provided with all Device Variables and Dynamic Variables.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code(see Device Variable Codes Table in appropriate device-specific document)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Bits	Conductivity Family Device Variable Status (See Section 6.1)
2	Bits	Conductivity Family Status 0 (See Section 6.2)

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
1		Undefined
2	Error	Invalid Selection
3-4		Undefined
5	Error	Too Few Data Bytes Received

Code	Class	Description
6	Error	Device-Specific Command Error
7-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Undefined
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

5.2 Command 1025 Read Conductivity Device Variables (Required)

This command provides access to the device variables available with a typical conductivity device. If the device does not support Raw Conductivity, the response NAN (not a number) should be returned. If the device does not report Conductivity and Concentration simultaneously, the response NAN (not a number) should be returned for the variable not reported.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code(see Device Variable Codes Table in appropriate device-specific document)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1-4	Float	Conductivity
5-8	Float	Temperature
9-12	Float	Concentration
13-16	Float	Raw Conductivity

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
1		Undefined
2	Error	Invalid Selection

Code	Class	Description
3-4		Undefined
5	Error	Too Few Data Bytes Received
6	Error	Device-Specific Command Error
7-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Undefined
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

5.3 Command 1026 Read Conductivity Sensor Type (Required)

This command provides access to the conductivity sensor type used with the conductivity device. If the device, using an inductive conductivity sensor, does not support Cell Constant, the response NAN (not a number) should be returned.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code(see Device Variable Codes Table in appropriate device-specific document)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Sensor Type (0 - contacting, 1 –inductive, 2 – 4-electrode)
2-5	Float	Cell Constant (units cm-1)

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
1		Undefined
2	Error	Invalid Selection
3-4		Undefined

Code	Class	Description
5	Error	Too Few Data Bytes Received
6	Error	Device-Specific Command Error
7-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Undefined
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

5.4 Command 1027 Read Temperature Compensation Variables (Required)

This command provides access to the temperature compensation variables available with a typical conductivity device. If the device does not support Temperature Slope or Reference Temperature, the response NAN (not a number) should be returned. If the device does not support Temperature Compensation Type, a value of 250 should be returned.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code(see Device Variable Codes Table in appropriate device-specific document)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Temperature Compensation (0 – automatic, 1 – manual)
2-5	Float	Manual Temperature
6	Enum	Temperature Compensation Type (0 – linear, 1 – ultra-pure water, 2 – cation, 3 – concentration, 4 – none)
7-10	Float	Temperature Slope
11-14	Float	Reference Temperature

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
1		Undefined
2	Error	Invalid Selection
3-4		Undefined
5	Error	Too Few Bytes Received
6	Error	Device-Specific Command Error
7-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Undefined
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

5.5 Command 1152 Write Conductivity Sensor Type (Required)

This command provides access to the conductivity sensor type.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Sensor Type (0 - contacting, 1 –inductive, 2 – 4-electrode)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Sensor Type (0 - contacting, 1 –inductive, 2 – 4-electrode)
2-5	Float	Cell Constant (units cm-1)

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
1		Undefined
2	Error	Invalid Selection
3-4		Undefined
5	Error	Too Few Data Bytes Received
6	Error	Device-Specific Command Error
7	Error	Invalid Sensor Type
8-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Undefined
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

5.6 Command 1153 Write Temperature Compensation Variables (Optional)

This command provides access to the temperature compensation variables available with a typical conductivity device. For conductivity devices that do not support Temperature Slope and Reference Temperature, the response NAN (not a number) should be returned.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Temperature Compensation (0 – automatic, 1 – manual)
2-5	Float	Manual Temperature
6	Enum	Temperature Compensation Type (0 – linear, 1 – ultra-pure water, 2 – cation, 3 – concentration, 4 - none)
7-10	Float	Temperature Slope
11-14	Float	Reference Temperature

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Temperature Compensation (0 – automatic, 1 – manual)
2-5	Float	Manual Temperature
6	Enum	Temperature Compensation Type (0 – linear, 1 – ultra-pure water, 2 – cation, 3 - concentration)
7-10	Float	Temperature Slope
11-14	Float	Reference Temperature

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
1		Undefined
2	Error	Invalid Selection
3-4		Undefined
5	Error	Too Few Data Bytes Received
6	Error	Device-Specific Command Error
7	Error	Invalid Temperature Compensation
8	Error	Invalid Temperature Compensation Type
9-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Undefined
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

6. CONDUCTIVITY DEVICE FAMILY TABLES

6.1 Table 1. Conductivity Family Device Variable Status

Code	Measurement
0xC0	Data Quality
0x40	More Device Family Status Available
0x01	Sensor Diagnostic Failure

6.2 Table 2. Conductivity Family Status 0

Code	Measurement
	Reserved

ANNEX A. REVISION HISTORY