HART Protocol Specification

HART Field Communications

HART COMMUNICATION FOUNDATION

pH Device Family Specification

HCF_SPEC-160.8, Revision 1.0

Release Date: 31 October, 2001

PRELIMINARY

Date of Publication: 31 October, 2001

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Preface

The pH 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 pH devices to hosts accessing them using the pH 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 pH Device Family Specification was developed to take advantage of the advanced features currently available in HART pH devices. These features allow the user to more closely configure a pH device to the needs of the pH application, and provide information on the health of the pH sensor and the validity of the pH measurement. They represent the advances made in pH measurement technology, through the application of microprocessors and digital circuitry, over traditional analog pH devices, which only transmit the pH measurement.

The pH Device Family Specification exposes variables representing the physical measurements provided by a pH device, the calibration information resident in the device, and temperature compensation configuration. In addition to a pH measurement, the typical HART pH device can also provide a temperature measurement, and glass and reference electrode impedance measurements, both of which are useful indications of the health of pH sensor and indicators of sensor failure. Calibration information includes the values of the standards used for calibration, and the results of a calibration, i.e., the slope and zero, which are measures of the sensitivity of the pH electrode and the stability of the reference electrode. Temperature compensation variables, made available, indicate whether temperature compensation is being used or not, and include the isopotential point, which relates to the temperature behavior of the pH sensor, and the temperature coefficient, which can be used to compensate for changes in the actual process pH with temperature.

A host, having access to the information provided by the pH Device Family Commands, can make simple decisions as to the validity of the pH measurement and the continued functioning the of pH sensor. The host’s decision making capability can be enhanced with detailed information on the device’s temperature measurement, if a pH device makes use of Temperature Device Family Commands. In pH 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 pH and Temperature Device Families.

1. SCOPE

This Device Family defines the properties of a pH measurement Device Variable. This Device Family is applicable to pH measure and includes a temperature measurement, and the measurement of pH glass electrode and reference electrode impedance measurements. PID control can also be supported in a pH device. Temperature sensor type can be accessed using the Temperature Device Family commands. PID control information can be accessed 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 pH Device Family supports the measurement of pH and the determination of pH Status using the device variables measured by a typical pH sensor. Addition properties are defined that specify the temperature compensation used to calculate pH from the device variables, and the methods and standards used in calibrating a pH device, and the calibration constants resulting from calibration. A typical pH sensor is shown in Figure 1.

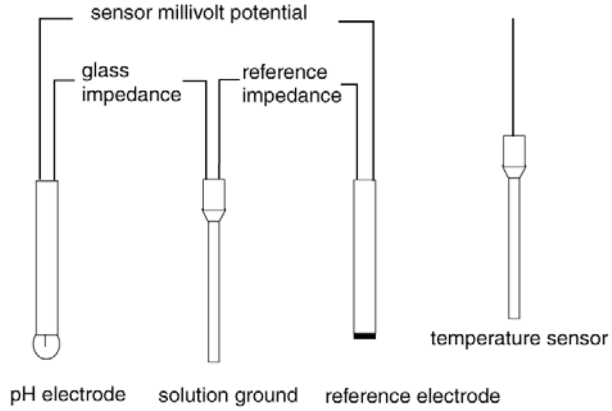

Figure 1. pH Sensor Diagram

A. Device Variables

The device variables for the pH Device Family include the basic measurements made using a pH sensor, which are:

1. The sensor millivolt potential is the difference between the millivolt potential of the pH electrode and the millivolt potential of the reference electrode.

2. The process temperature is measured by a temperature element in the pH sensor, or by a separate temperature sensor connected to the analyzer.

3. The glass impedance is the glass pH electrode impedance measured against the solution ground. In some cases, the glass impedance is measured against the reference electrode, which typically has negligible impedance in comparison to the glass impedance. The units of impedance are megOhm.

4. The reference impedance is the impedance of the reference electrode measured against the solution ground. The units are kOhm.

5. The pH, which is the pH calculated by the pH device using the device variables and properties.

B. **Temperature Compensation Variables**

The temperature compensation variables are used by the pH device to calculate a pH value, temperature compensated to 25C. 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 pH sensor to correct the pH reading for changes in the sensor millivolt potential with temperature. In some cases, it also corrects the pH reading for changes in the actual solution pH with temperature, correcting it to a 25 C value. In the manual mode, the pH is calculated using a manually entered temperature value.

2. Manual Temperature is a temperature value used by the analyzer to calculate pH in the manual mode.

3. Isopotential pH is the pH value, at which the sensor millivolt potential is independent of temperature. This value is used by the temperature compensation routine in the device, and the usual value is 7.0 pH.

4. Temperature Coefficient (Figure 2) is the change of the solution pH with temperature in units of pH/degree C. The pH of a solution can change with temperature to varying degrees depending upon composition of the solution. Solution temperature dependence is most often observed in solutions with pH values greater than 7 pH. Using the Temperature Coefficient in the temperature compensation routine of a pH device makes it possible for the device to correct the pH reading to a 25 C value. A Temperature Coefficient with a value of 0 pH/degree C means that no solution temperature compensation is being used.

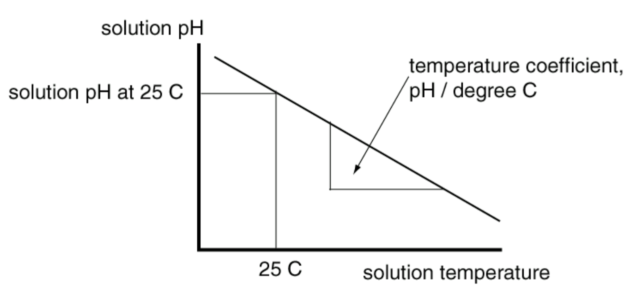

Figure 2. Solution Temperature Coefficient

C. **Calibration Variables**

The calibration variables include the calibration constants, which result from a calibration, as well as variables used to define the nature of the pH calibration. They include:

1. Slope is a measure of the sensitivity of the pH electrode, which is determined using a two point buffer calibration. The slope can be expressed in terms of mV/pH at 25 C, or in terms of percent efficiency, which is the slope of the electrode as a percentage of the theoretical slope of 59.16 mV/pH. Depending on the particular device, the slope can therefore be expressed in units of mV/pH or %.

2. Zero (Figure 3) is a point on the calibration line of a pH sensor, which relate sensor millivolt potential to pH. Depending upon the expression of the pH calculating equation in the device, the zero point can alternately be defined as the sensor millivolt potential at the isopotential pH, or the pH corresponding to a sensor millivolt potential of 0 millivolt at 25 C. As a result, zero variables can have units of mV or pH.

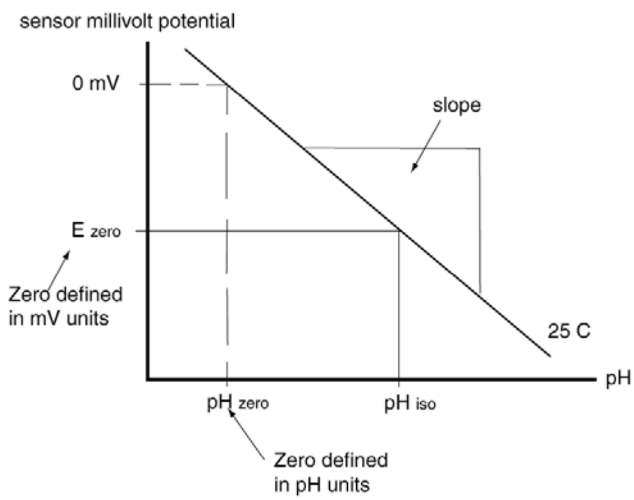

Figure 3. Alternate Definitions of pH Sensor Zero

3. Buffer Calibration toggles the device between automatic buffer calibration and manual buffer calibration. Automatic buffer calibration provides temperature correction for a known buffer used for calibration, by using stored data on the pH behavior of the buffer with temperature. Automatic buffer calibration can also include stabilization criteria for accepting a buffer value, and other features promoting accurate buffer calibrations. Manual buffer calibration involves manual entry of pH values during calibration.

4. Buffer Type is a listing of standard buffer types used for buffer temperature correction during an automatic buffer calibration.

5. Buffer 1 is one of the buffer values used during a buffer calibration.

6. Buffer 2 is one of the buffer values used during a buffer calibration.

7. Buffer 3 is a buffer value, which may be used during a buffer calibration to provide a three point curve fit for buffer calibration, or as a calibration point at a different temperature to provide a correction to the isopotential pH.

8. Zero Value is the pH value used during a one-point calibration (standardization), which is typically used to match the on-line reading of the device to a referee pH measurement.

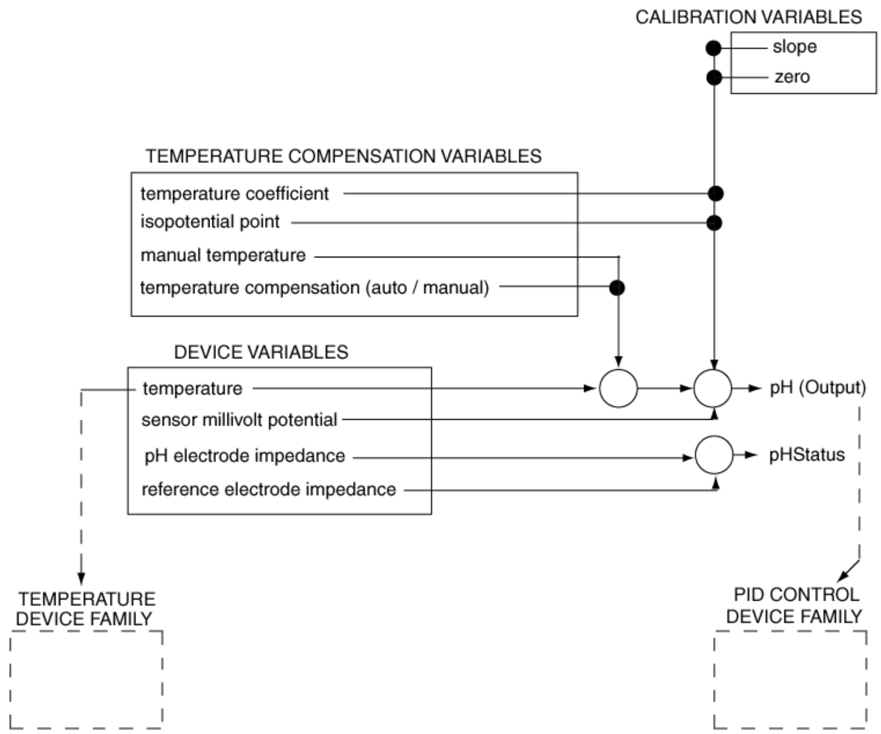

Figure 4. pH Device Family Block Diagram

The way in which a pH device calculates pH can be outlined as follows:

1. The pH sensor provides the Device Variables used in the calculation of pH and pH Status.

2. The variable Temperature Compensation determines whether the temperature reading from the temperature element in the pH sensor, or a manually entered value is used for temperature

compensation. If Temperature Compensation is set to automatic, the temperature value from the pH sensor is used by the analyzer to calculate pH. If it is set to manual, the temperature value supplied by the variable, Manual Temperature, is used by the device to calculate pH. More information on the temperature measurement provided by the pH sensor can be obtained by using the Temperature Device Family.

3. The Sensor Millivolt Potential is used in combination with a live or manual temperature value to calculate pH. The variable, Isopotential pH, provides the framework for the pH calibration curve, which is set to the characteristics of the pH sensor by the variables Slope and Zero. Additional solution temperature compensation may be provided by the variable, Temperature Coefficient.

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

5. The Device Variables, Glass Impedance and Reference Impedance are used to determine pH Status. Glass Impedance is a measure of the integrity of a glass pH electrode and is usually in the range of tens to hundreds of megOhm. A cracked or broken glass electrode is no longer functional, although the sensor millivolt potential of a broken electrode can result in a believable pH value. When a glass electrode cracks the impedance drops drastically and so comparing the Glass impedance to a low setpoint allows a breakage to be alarmed and the pH Status Set to "bad".

Reference Impedance is the impedance of the reference electrode, which is typically in the kOhm range. The most resistive element in a reference electrode is usually the liquid junction, and so blockage of the liquid junction by coating or precipitation increases the impedance of the reference electrode. Comparing Reference Impedance to a high setpoint can be used to allow blockage of the liquid junction to be alarmed, and the pH Status set to "bad".

5. COMMANDS

5.1 Command 2048 Read pH 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	pH Family Device Variable Status (See Section 6.1)
2	Bits	pH 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
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 2049 Read pH Device Variables (Required)

This command provides access to the typical device variables available with a pH device. In devices, which do not support glass and reference impedance readings the response NAN (not a number) should be returned for these 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
1-4	Float	pH
5-8	Float	Temperature
9-12	Float	Glass Impedance
13-16	Float	Reference Impedance
17-20	Float	Sensor Millivolt Potential

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
7-15		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 2050 Read pH Calibration Variables (Required)

This command provides access to the calibration variables available with a typical pH device. For calibration variables not supported by the pH device, 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
1-4	Float	Slope
5-8	Float	Zero
9	Enum	Buffer calibration (0 - automatic, 1 -manual)
10	Enum	Buffer Type (see Table 6.3)
11-14	Float	Buffer 1
15-18	Float	Buffer 2
19-22	Float	Buffer 3
23-26	Float	Zero Value

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
7-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.

Code	Class	Description
18		Undefined
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

5.4 Command 2051 Read Temperature Compensation Variables (Required)

This command provides access to the temperature compensation variables available with a typical pH device. For temperature compensation variables not supported by the pH device, 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	Temperature Compensation (0 – automatic, 1 – manual)
2-5	Float	Manual Temperature
6-9	Float	Isopotential pH
10-13	Float	Temperature Coefficient

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
7-15		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 2176 Write Buffer Calibration Type (Required)

This command provides access to the calibration variables available with a typical pH device. In cases where automatic buffer calibration is not supported, the value 1 should be returned for Buffer calibration. Devices not supporting Buffer Type should return a value of 250 (not supported).

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Buffer calibration (0 - automatic, 1 -manual)
2	Enum	Buffer Type (see Table 6.3)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Buffer calibration (0 - automatic, 1 -manual)
2	Enum	Buffer Type (see Table 6.3)

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	In Write Protect Mode
8	Error	Invalid Buffer Table Value
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

5.6 Command 2177 Write Calibration Variables (Optional)

This command provides access to the calibration variables available with for a pH device, which allows these variables to be written to.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1-4	Float	Slope
5-8	Float	Zero

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1-4	Float	Slope
5-8	Float	Zero

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	In Write Protect Mode
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

5.7 Command 2178 Write Temperature Compensation Variables (Optional)

This command provides access to the temperature compensation variables available with a typical pH device. For temperature compensation variables not supported by the pH device, 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
6-9	Float	Isopotential pH
10-13	Float	Temperature Coefficient

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
6-9	Float	Isopotential Point
10-13	Float	Temperature Coefficient

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
7-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Undefined

Code	Class	Description
19	Error	Device Variable index not allowed for this command.
20-127		Undefined

6. PH DEVICE FAMILY TABLES

6.1 Table 1. pH Family Device Variable Status

Code	Measurement
0xC0	Data Quality
0x40	More Device Family Status Available
0x01	Low Glass Impedance
0x02	High Reference Impedance

6.2 Table 2. pH Family Status 0

Code	Measurement
	Reserved

6.3 Table 3. pH Buffer Table

Code	Description
0	NIST
1	DIN 19266
2	JIS 8804
3	BSI
4	Merck
5	Ingold
6	DIN 19267
7	Hach
8	Ciba
9	Knick/Mettler-Toledo

Code	Description
249	Other
250	Not Supported

ANNEX A. REVISION HISTORY