HART Protocol Specification

Field Communications

HART®
COMMUNICATION FOUNDATION

Temperature Device Family Specification

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1. SCOPE

This Device Family defines the properties of a temperature measurement Device Variable. This Device Family is applicable to any temperature measurement that includes a user selectable sensing element. This includes classical temperature transmitters, flow meters, pH meters, and hydrostatic tank gauges, to name a few.

The Temperature Device Family supports milli-volt and resistance measurements in addition to temperature sensors like RTDs and thermocouples.

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:

Field Device Specification Guide. HCF_LIT-18

2.3 Related Documents

The following documents provide background information relevant to temperature measurement and this device family:

International Practical Temperature Scale of 1968 (IPTS-68) U.S. Dept. of Commerce, National Bureau of Standards, 1968.

"International Temperature Scale of 1990 (ITS-90)" *Metrologia*. Springer-Verlag. 1990

"OMEGA ENGINEERING – Technical Reference Section."
http://www.omega.com/techref

"Honeywell Hvac - Temperature Tutorial".
http://content.honeywell.com/building/components/Hycal_Html/temp.asp

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

Figure 1shows a diagram of a typical temperature device and some of properties associated to be characterized and configured with this Device Family

**Cold Junction
Compensation Setting**

Number of Wires

**Single or Differential
Probe Connection**

Type of Probe
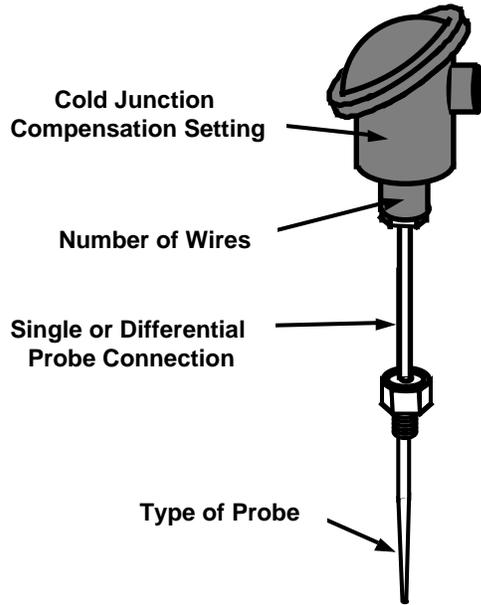
Figure 1. Temperature Family Properties

In addition to the properties shown in Figure 1 this Device Family allows for connecting calibrated RTDs using their Callendar-Van Dusen coefficients; and specifying the temperature scale standard (e.g., IPTS-68 or ITS-90).

5. COMMANDS

5.1 Command 1024 Read Temperature Status (Mandatory)

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	Temperature Family Device Variable Status (See Section 6.1)
2	Bits	Temperature 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
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

5.2 Command 1025 Read Temperature Configuration (Mandatory)

This command reads the temperature configuration including: the type of probe (thermocouple, RTD, milli-volt, resistance); the number of wires used by the probe; and the temperature standard used for this measurement.

There are two widely used temperature standards: ITS-90 and IPTS-68. There is a difference of 0.01 to 0.1 Kelvin between the two standards over the range from 10K to 700K. Please see relevant standards for details.

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	Probe Type (see Section 6.3)
2	Unsigned-8	Number Of Wires
3	Enum	Temperature Standard (see Section 6.6)

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
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

5.3 Command 1026 Read Thermocouple Configuration (Mandatory if thermocouples are supported)

This command reads the additional installation and configuration information necessary when the connected temperature probe is a thermocouple. Most of the properties read by this command relate to Cold Junction Compensation. Cold-Junction Compensation is used to eliminate parasitic thermocouple effects. This is accomplished by using the reference-junction temperature to estimate the parasitic thermocouple thermoelectric voltage contributions.

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	Probe Connection (see Section 6.4)
2	Enum	Cold Junction Compensation Type (see Section 6.5)
3	Enum	Manual Cold Junction Compensation Temperature Units (refer to *Common Tables Specification*)
4-7	Float	Manual Cold Junction Compensation 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 - 15		Undefined
16	Error	Access Restricted
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

5.4 Command 1027 Read Callendar-Van Dusen Coefficients (Mandatory if Calibrated RTDs are supported)

Callendar-Van Dusen Coefficients allow an RTDs temperature response to be precisely described. If calibrated RTDs are supported, then this command must be supported. The Callendar-Van Dusen equation is:

$$R_T = R_0 (1 + AT + BT^2 - 100CT^3 + CT^4)$$

Where R_0 is the resistance at 0^OC; T is the temperature (in degrees C); and R_T is the resistance at temperature T.

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	CVD A
5-8	Float	CVD B
9-12	Float	CVD C
13-16	Float	CVD R0

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
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

5.5 Command 1152 Write Temperature Probe Type (Mandatory)

Writes the temperature probe type and number of wires connecting the probe to the field device.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code (see Device Variable Codes Table in appropriate device-specific document)
1	Enum	Probe Type (see Section 6.3)
2	Unsigned-8	Number Of Wires

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Probe Type (see Section 6.3)
2	Unsigned-8	Number Of Wires

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		Undefined
9	Error	Unsupported Probe Type
10	Error	Invalid Number of Wires
11-15		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.
20-31		Undefined
32	Error	Busy (A DR Could Not Be Started)
33	Error	DR Initiated
34	Error	DR Running
35	Error	DR Dead
36	Error	DR Conflict
37 - 127		Undefined

5.6 Command 1153 Write Temperature Standard (Optional)

Allows the temperature standard to be selected. There are two widely used temperature standards:
ITS-90 and IPTS-68. These two standards differ by about 0.01 to 0.1Kelvin between 10K to 700K.
Please see relevant standards for details.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code (see Device Variable Codes Table in appropriate device-specific document)
1	Enum	Temperature Standard (see Section 6.6)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Temperature Standard (see Section 6.6)

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		Undefined
9	Error	Invalid Temperature Standard Code
10-15		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.
20-31		Undefined
32	Error	Busy (A DR Could Not Be Started)
33	Error	DR Initiated
34	Error	DR Running
35	Error	DR Dead
36	Error	DR Conflict
37 - 127		Undefined

5.7 Command 1154 Write Thermocouple Probe Connection (Optional)

Allows the thermocouple probe connection style to be entered (e.g. single or differential).

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code (see Device Variable Codes Table in appropriate device-specific document)
1	Enum	Probe Connection (see Section 6.4)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Probe Connection (see Section 6.4)

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		Undefined
9	Error	Invalid Probe Connection Code
10-15		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.
20-31		Undefined
32	Error	Busy (A DR Could Not Be Started)
33	Error	DR Initiated
34	Error	DR Running
35	Error	DR Dead
36	Error	DR Conflict
37 - 127		Undefined

5.8 Command 1155 Select Cold Junction Compensation Type (Optional)

Allows the method of Cold Junction Compensation to be selected.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code (see Device Variable Codes Table in appropriate device-specific document)
1	Enum	Cold Junction Compensation Type (see Section 6.5)

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Cold Junction Compensation Type (see Section 6.5)

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		Undefined
9	Error	Invalid Cold Junction Compensation Code
10-15		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.
20-31		Undefined
32	Error	Busy (A DR Could Not Be Started)
33	Error	DR Initiated
34	Error	DR Running
35	Error	DR Dead
36	Error	DR Conflict
37 - 127		Undefined

5.9 Command 1556 Write Manual Cold Junction Temperature (Optional)

Allows a manual CJC temperature to be written to the device.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code (see Device Variable Codes Table in appropriate device-specific document)
1	Enum	Manual Cold Junction Compensation Temperature Units (refer to *Common Tables Specification*)
2-5	Float	Manual Cold Junction Compensation Temperature

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1	Enum	Manual Cold Junction Compensation Temperature Units (refer to *Common Tables Specification*)
2-5	Float	Manual Cold Junction Compensation 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	In Write Protect Mode
8		Undefined
9	Error	CJC Temperature too High
10	Error	CJC Temperature too Low
11-15		Undefined
16	Error	Access Restricted
17	Error	Invalid Device Variable Index. The Device Variable does not exist in this field device.
18		Invalid Units Code
19	Error	Device Variable index not allowed for this command.
20-31		Undefined
32	Error	Busy (A DR Could Not Be Started)
33	Error	DR Initiated
34	Error	DR Running
35	Error	DR Dead
36	Error	DR Conflict
37 - 127		Undefined

5.10 Command 1157 Write Temperature Callendar-Van Dusen Coefficients (Mandatory if Calibrated RTDs are supported)

This command allows the Callendar-Van Dusen Coefficients for a calibrated RTD to be written to the field device. This command must be supported if the device supports Callendar-Van Dusen Coefficients. (See Section 5.4 for more information).

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code (see Device Variable Codes Table in appropriate device-specific document)
1-4	Float	CVD A
5-8	Float	CVD B
9-12	Float	CVD C
13-16	Float	CVD R0

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Variable Code
1-4	Float	CVD A
5-8	Float	CVD B
9-12	Float	CVD C
13-16	Float	CVD R0

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		Undefined
9	Error	Coefficient A Invalid
10	Error	Coefficient B Invalid
11	Error	Coefficient C Invalid
12	Error	Coefficient R0 Invalid
13-15		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.
20-31		Undefined
32	Error	Busy (A DR Could Not Be Started)
33	Error	DR Initiated
34	Error	DR Running
35	Error	DR Dead
36	Error	DR Conflict
37 - 127		Undefined

6. TEMPERATURE DEVICE FAMILY TABLES

6.1 Table 1. Temperature Family Device Variable Status

Code	Measurement
0xF0	Data Quality/Limit Status
0x08	More Device Family Status Available
0x01	Probe Break Detected

6.2 Table 2. Temperature Family Status 0

Code	Measurement
	Reserved

6.3 Table 3. Temperature Probe Types

Note: Unless otherwise indicated, thermocouple references are: IEC 584, NIST MN 175, DIN 43710, BS 4937, ANSI MC96.1, JIS C1602 and NF C42-321.

Code	Probe Type/Measurement
1	Ohms
2	KiloOhms
3	Calibrated RTD (The Write Calendar-Van Dusen Coefficients Device Family Command must be supported to use this enumeration.)
11	RTD Pt 50 a=0.003850 (IEC751)
12	RTD Pt 100 a=0.003850
13	RTD Pt 200 a=0.003850
14	RTD Pt 500 a=0.003850
15	RTD Pt 1000 a=0.003850
21	RTD Pt 50 a=0.003916 (JIS C1604-81)
22	RTD Pt 100 a=0.003916
31	RTD Pt 50 a=0.003920 (MIL-T-24388)
32	RTD Pt 100 a=0.003920
33	RTD Pt 200 a=0.003920
34	RTD Pt 500 a=0.003920
35	RTD Pt 1000 a=0.003920
41	RTD Pt 10 a=0.003923 (SAMA RC21-4-1966)
42	RTD Pt 100 a=0.003923
43	RTD Pt 200 a=0.003923
51	RTD Pt 100 a=0.003926 (IPTS-68)
61	RTD Ni 50 a=0.006720 (Edison curve #7)
62	RTD Ni 100 a=0.006720

Code	Probe Type/Measurement
63	RTD Ni 120 a=0.006720
64	RTD Ni 1000 a=0.006720
71	RTD Ni 50 a=0.006180 (DIN 43760)
72	RTD Ni 100 a=0.006180
73	RTD Ni 120 a=0.006180
74	RTD Ni 1000 a=0.006180
81	RTD Cu 10 a=0.004270
82	RTD Cu 100 a=0.004270
91	RTD Cu 10 a=0.004260 (SAMA RC21-4-1966)
92	RTD Cu 100 a=0.004260
101	RTD Cu 10 a=0.004250 (JEM 1252-1991)
102	RTD Cu 100 a=0.004250
128	Micro-Volts
129	Milli-Volts
130	Volts
131	TC Type B (Pt30Rh-Pt6Rh) (IEC 584 etc.)
132	TC Type W5, Omega type C (W5-W26Rh)(ASTM E 988)
133	TC Type W3, Omega type D (W3-W25Rh)(ASTM E 988)
134	TC Type E (Ni10Cr-Cu45Ni) (IEC 584 etc.)
135	TC Type W, Omega type G (W-W26Rh)(ASTM E 988)
136	TC Type J (Fe-Cu45Ni) (IEC 584 etc.)
137	TC Type K (Ni10Cr-Ni5) (IEC 584 etc.)
138	TC Type N (Ni14CrSi-NiSi) (IEC 584 etc.)
139	TC Type R (Pt13Rh-Pt) (IEC 584 etc.)
140	TC Type S (Pt10Rh-Pt) (IEC 584 etc.)
141	TC Type T (Cu-Cu45Ni) (IEC 584 etc.)
142	TC Type L (Fe-CuNi) (DIN 43710)
143	TC Type U (Cu-CuNi) (DIN 43710)

Code	Probe Type/Measurement
144	TC Pt20Rh-Pt40Rh (ASTM E 1751)
145	TC Ir-Ir40Rh (ASTM E 1751)
146	TC Platinel II
147	TC Ni-NiMo
221	Bi-metallic strip
222	Vapor pressure bulb
223	Liquid expansion
224	Mercury bulb
240 - 249	For Manufacturer Specific Temperature Probes Types
251	None
252	Unknown
253	Special

6.4 Table 4. Thermocouple Probe Connections

Code	Probe Connection Type
1	Single. One probe is used to measure temperature.
2	Differential. Two probes are connected in series to read differential temperature.
240 - 249	For Manufacturer Specific Probe Connections
250	Not Used
251	None
252	Unknown
253	Special

6.5 Table 5. Thermocouple Cold Junction Compensation

Code	CJC Temperature Source
1	Internal CJC Temperature Measurement
2	External CJC Temperature Measurement
3	A Fixed CJC temperature value is supplied
240 - 249	For Manufacturer Specific CJC Types
250	Not Used
251	None
252	Unknown
253	Special

6.6 Table 6. Temperature Standards

Code	Temperature Standard
1	International Practical Temperature Scale of 1968 (IPTS-68)
2	International Temperature Scale of 1990 (ITS-90)
240 - 249	For Manufacturer Specific Temperature Standards
250	Not Used
251	None
252	Unknown
253	Special

ANNEX A.   REVISION HISTORY

A1.   Revision 1.0
Initial Revision.