

CONTENTS

CHAPTER 1. INDUSTRIAL COMMUNICATIONS	1
1.1. Introduction.....	1
1.2. “Smart” field devices.....	1
1.3. Digital communication.....	1
<i>Figure 1.1 A smart transmitter</i>	2
<i>Figure 1.2 A smart system</i>	2
1.4. Multidrop communication.....	2
<i>Figure 1.3 Multidrop connection</i>	3
1.5. The HART Protocol.....	3
1.6. Other digital field protocols.....	3
CHAPTER 2. HART – AN OVERVIEW	5
2.1. Introduction.....	5
2.2. History.....	5
2.3. The HART Communication Foundation.....	5
2.4. The HART Protocol and the OSI model.....	5
<i>Figure 2.1 The OSI 7-layer protocol model</i>	5
<i>Figure 2.2 HART and the OSI model</i>	6
<i>Figure 2.3 Universal commands</i>	8
<i>Figure 2.4 Some common-practice commands</i>	8
<i>Figure 2.5 Examples of device-specific commands</i>	8
<i>Figure 2.6 Standard data</i>	9
2.5. Applications.....	9
2.6. Devices.....	9
2.6.1. Field devices.....	9
2.6.2. Host devices.....	10
<i>Figure 2.7 Host conformance classes</i>	10
2.6.3. Multiplexers.....	10
<i>Figure 2.8 Multiplexer as the only I/O to a SCADA system</i>	11
<i>Figure 2.9 Multiplexer in parallel with analog I/O to a control system</i>	11
2.6.4. Other devices.....	12
2.7. Revisions.....	12
<i>Figure 2.10 Major HART revisions</i>	12
2.8. Device Descriptions.....	12
CHAPTER 3. THE HART PHYSICAL SIGNAL	14
3.1. Introduction.....	14
3.2. Frequency shift keying.....	14
<i>Figure 3.1 The HART FSK signal</i>	14
<i>Figure 3.2 Analog and HART signal frequencies</i>	15
3.3. Signal levels.....	15
<i>Figure 3.3 HART signal levels</i>	15
3.4. The connection loop.....	16
3.4.1. Measurement (input) devices.....	16
<i>Figure 3.4 Current loops for measurement devices</i>	16
3.4.2. Actuator (output) devices.....	16
<i>Figure 3.5 Current loops for output devices</i>	17
3.5. Multidrop connection.....	17
<i>Figure 3.6 Current loops for multidrop connections</i>	18
3.6. Device characteristics.....	18
<i>Figure 3.7 Impedance specifications</i>	19
<i>Figure 3.8 Device types in a typical system</i>	20
3.7. Signal path characteristics.....	20
3.8. The 65 microsecond rule.....	20
<i>Figure 3.9 Permissible capacitance</i>	21
3.9. Other physical layers.....	21
3.9.1. Introduction.....	21
3.9.2. Voltage mode HART.....	21
3.9.3. RS-485 HART.....	21

3.9.4. C8PSK HART	22
CHAPTER 4. SYSTEM COMPONENTS	23
4.1. Introduction	23
4.2. Cable	23
<i>Figure 4.1 Cable parameters</i>	23
<i>Figure 4.2 Some typical cables</i>	24
<i>Figure 4.3 Maximum length for typical 1 mm² cables</i>	24
4.3. Grounding	24
4.4. Power supply	24
<i>Figure 4.4 Power supply specifications</i>	25
4.5. Analog signal bandwidth	25
4.6. Intrinsic safety	25
<i>Figure 4.5 A shunt diode IS barrier</i>	25
<i>Figure 4.6 An IS isolator</i>	26
4.7. Compatibility with non-HART equipment	26
CHAPTER 5. MESSAGE STRUCTURE	28
5.1. Introduction	28
5.2. Character coding	28
<i>Figure 5.1 Bit structure of each character</i>	28
5.3. Message format	28
5.3.1. Introduction	28
<i>Figure 5.2 Message structure</i>	29
5.3.2. Preamble	29
5.3.3. Start delimiter	29
<i>Figure 5.3 Start delimiter structure</i>	30
<i>Figure 5.4 Start delimiters (revision 5 and earlier)</i>	30
5.3.4. Address	30
<i>Figure 5.5 Long and short address frames</i>	31
5.3.5. Unique Identifier	31
<i>Figure 5.6 The Unique Identifier</i>	32
5.3.6. Expansion	32
5.3.7. Command	32
5.3.8. Byte count	32
5.3.9. Status	32
5.3.10. Data	32
5.3.11. Checksum	33
5.4. Example messages	33
5.5. Receiving a message	33
<i>Figure 5.7 Short frame transaction example (command #1, HART revision 4)</i>	34
<i>Figure 5.8 Long frame transaction example (command #1, HART revision 5+)</i>	35
CHAPTER 6. MESSAGE TRANSACTIONS	36
6.1. Introduction	36
6.2. Master-slave operation	36
6.3. Multimaster operation	36
6.4. Transaction procedure	36
6.5. Burst mode	36
<i>Figure 6.1 Summary of timing rules</i>	37
6.6. Token passing	37
<i>Figure 6.2 Token passing</i>	37
<i>Figure 6.3 Example message sequences</i>	38
6.7. Delayed response	38
6.8. Error recovery	39
CHAPTER 7. COMMANDS	40
7.1. Introduction	40
7.2. Command types	40
7.3. Universal commands	40
<i>Figure 7.1 Universal commands (summary)</i>	40
7.4. Common-practice commands	40

<i>Figure 7.2 Common-practice commands (summary)</i>	41
7.5. Non-public commands	41
7.6. Device-specific commands	41
7.7. Device family commands	41
CHAPTER 8. DATA	42
8.1. Introduction	42
8.2. HART variables	42
8.2.1. Device variables	42
8.2.2. Dynamic variables	42
<i>Figure 8.1 Dynamic variable mapping</i>	43
8.2.3. Multiple analog outputs	43
8.2.4. Configuration parameters	43
8.2.5. Device information	43
8.2.6. Engineering units	43
8.2.7. Device status	44
8.3. Data types	44
8.3.1. Introduction	44
8.3.2. Integer	44
8.3.3. Floating point	44
8.3.4. Alphanumeric	44
8.3.5. Enumerated	44
<i>Figure 8.2 Examples of enumerated variables</i>	45
8.3.6. Bit	45
8.3.7. Date	45
CHAPTER 9. STATUS INDICATIONS	46
9.1. Introduction	46
<i>Figure 9.1 The two status bytes</i>	46
9.2. Communication status	46
<i>Figure 9.2 Communication errors</i>	47
9.3. Command response	47
<i>Figure 9.3 Single-meaning command response codes</i>	47
9.4. Field device status	48
<i>Figure 9.4 Field device status</i>	48
9.5. Device-specific status by command #48	48
9.6. Extended field device status	48
9.7. Device variable status	48
9.8. Device family status	48
<i>Figure 9.5 Device variable status byte</i>	49
9.9. Analog signal status indication	49
<i>Figure 9.6 Status indicators and HART variable ranges</i>	50
CHAPTER 10. HOST CONNECTION PROCEDURE	51
10.1 Introduction	51
10.2. Identifying field devices	51
10.2.1. Short frame Command #0 (“Read unique identifier”)	51
<i>Figure 10.1 Short frame command #0 and response (HART 6)</i>	52
10.2.2. Broadcast Command #11 (“Read unique identifier associated with tag”)	52
10.2.3. Broadcast Command #21 (“Read unique identifier associated with long tag”)	52
10.2.4. Command #73 (“Find device”)	52
10.2.5. Commands #74 (“Read I/O system capabilities”) and #75 (“Poll sub-device”)	52
10.2.6. Device information returned	53
<i>Figure 10.2 Device information</i>	53
10.2.7. Manual entry of device identification information	53
10.3. Continuing communication	53
CHAPTER 11. DEVICE DESCRIPTIONS	54
11.1. Introduction	54
11.2. Benefits of DDL	54
11.3. DDL	54
11.4. The Standard Dictionary	55

<i>Figure 11.1 Example Device Description fragments</i>	56
<i>Figure 11.2 Standard dictionary – example entries</i>	57
<i>Figure 11.3 Principal DDL data types</i>	57
11.5.DDL objects	58
11.5.1. Variables	58
11.5.2. Commands	58
11.5.3. Menus	58
<i>Image 1 Traditional menus</i>	58
11.5.4. Edit Displays	58
<i>Image 2 Edit Display Window</i>	59
11.5.5. Methods	59
<i>Image 3 Method Window</i>	59
11.5.6. Enhanced Data displays	59
<i>Image 4 Enhanced Data Visualization</i>	59
11.6.Creating a Device Description.....	60
<i>Figure 11.10 Generation and use of a Device Description</i>	60
11.7.Using a Device Description	61
11.8.Distribution of Device Descriptions.....	61
11.9.Summary	61
CHAPTER 12. DEVICE FAMILIES	62
12.1.Introduction	62
12.2.Device family commands	62
<i>Figure 12.1 Device family command structure</i>	62
12.3Device (family) variable status	62
12.4.Device families	62
12.4.1. Temperature	63
<i>Figure 12.2 Temperature Device Family commands</i>	63
12.4.2. Pressure	63
12.4.3. Actuators.....	63
12.4.4. PID control	63
<i>Figure 12.3 PID Control Device Family commands</i>	64
C8PSK HART	65
12.5.Introduction	65
12.6Signal	65
<i>Figure 13.1 C8PSK signal waveform</i>	65
<i>Figure 13.2 Symbol phases</i>	66
12.7.Message frame	66
<i>Figure 13.3 C8PSK message structure</i>	66
12.8.Scrambler	66
12.9.Conclusion	66
APPENDIX 1. HART COMMANDS	67
Table A1.1 Universal commands	68
Table A1.3 Universal commands in HART revisions 2, 3 and 4 (differences from revision 5)	77
APPENDIX 2. HART TABLES	79
Table A2.1 HART tables	79
Table A2.2 Standard units codes	80
APPENDIX 3. STATUS INDICATIONS	82
Table A3.1 Communication errors	82
Table A3.2 Command response codes with a single meaning.....	82
Table A3.3 Command response codes with multiple meanings	83
Table A3.4. Field device status.....	84
APPENDIX 4. DEVICE FAMILY COMMANDS AND TABLES	85
Table A4.1 Temperature device family commands	85
Table A4.2 Temperature device family tables	85
Table A4.3 PID control device family commands	86
Table A4.4 PID control device family tables.....	87

APPENDIX 5. BLOCK TRANSFER SERVICE	88
Table A5.1 Port allocations	88
APPENDIX 6. TIMERS	89
Table A6.1 Data link timers	89
APPENDIX 7. COMPATIBILITY	90
12.10 Introduction	90
12.11 Compatibility testing	90
12.12 Controller input: load impedance	90
12.13 Controller output: source impedance	90
12.14 Controller input: tolerance to HART signals	91
<i>Figure A7.1 Filter for fast controller inputs</i>	91
12.15 Controller output: tolerance to HART signals	91
12.16 Loop integrity checking: tolerance to HART signals	91
12.17 Controller output: rapid changes in the analog signal	92
12.18 Noise generated by the controller	92
12.19 Controller tolerance to noise	92
REFERENCE: THE HART COMMUNICATION FOUNDATION	93
12.20 Contacts	93
12.21 HCF Membership	93
12.21.1. HART Regular Membership	93
12.21.2. The HART Users Group	94
12.22 Specifications	94
12.23 HCF software	95
12.24 HCF educational programs	95
12.24.1. <i>HART Device & Control System Integration Requirements</i> webcast on CD-ROM	95
12.24.2. <i>The POWER of HART</i> audio training program	95
12.24.3. <i>The Complete HART Guide</i> CD-ROM	95
12.25 HCF training courses	95
12.25.1. HART Fundamentals Workshop	95
12.25.2. Writing Enhanced Device Descriptions Workshop	96
12.25.3. HART Applications onsite seminar	96
ACRONYMS	97
GLOSSARY	98