

DIN EN 61158-2:2011-09 (E)

Industrial communication networks - Fieldbus specifications - Part 2: Physical layer specification and service definition (IEC 61158-2:2010); English version EN 61158-2:2010, only on CD-ROM

Contents	Page
0 Introduction	16
1 Scope	20
2 Normative references	20
3 Terms and definitions	22
4 Symbols and abbreviations	45
5 DLL – PhL interface	55
6 Systems management – PhL interface	76
7 DCE independent sublayer (DIS)	90
8 DTE – DCE interface and MIS-specific functions	92
9 Medium dependent sublayer (MDS)	113
10 MDS – MAU interface	133
11 Types 1 and 7: Medium attachment unit: voltage mode, linear-bus-topology 150 Ω twisted-pair wire medium	141
12 Types 1 and 3: Medium attachment unit: 31,25 kbit/s, voltage-mode with low-power option, bus- and tree-topology, 100 Ω wire medium	156
13 Type 1: Medium attachment unit: current mode, twisted-pair wire medium	173
14 Type 1: Medium attachment unit: current mode (1 A), twisted-pair wire medium	183
15 Types 1 and 7: Medium attachment unit: dual-fiber optical media	191
16 Type 1: Medium attachment unit: 31,25 kbit/s, single-fiber optical medium	198
17 Type 1: Medium attachment unit: radio signaling	201
18 Type 2: Medium attachment unit: 5 Mbit/s, voltage-mode, coaxial wire medium	211
19 Type 2: Medium attachment unit: 5 Mbit/s, optical medium	222
20 Type 2: Medium attachment unit: network access port (NAP)	227
21 Type 3: Medium attachment unit: synchronous transmission, 31,25 kbit/s, voltage mode, wire medium	230
22 Type 3: Medium attachment unit: asynchronous transmission, wire medium	247
23 Type 3: Medium attachment unit: asynchronous transmission, optical medium	264
24 Type 4: Medium attachment unit: RS-485	273
25 Type 4: Medium attachment unit: RS-232	275
26 Type 6: <i>This clause has been removed</i>	276
27 Type 8: Medium attachment unit: twisted-pair wire medium	276
28 Type 8: Medium attachment unit: optical media	281
29 Type 12: Medium attachment unit: electrical medium	288
30 Type 16: Medium attachment unit: optical fiber medium at 2, 4, 8 and 16 Mbit/s	290
31 Type 18: Medium attachment unit: basic medium	302
32 Type 18: Medium attachment unit: powered medium	306
Annex A (normative) Type 1: Connector specification	315
Annex B (informative) Types 1 and 3: Cable specifications and trunk and spur lengths for the 31,25 kbit/s voltage-mode MAU	323
Annex C (informative) Types 1 and 7: Optical passive stars	325
Annex D (informative) Types 1 and 7: Star topology	326

Annex E (informative) Type 1: Alternate fibers	330
Annex F (normative) Type 2: Connector specification	331
Annex G (normative) Type 2: Repeater machine sublayers (RM, RRM) and redundant PhLs	334
Annex H (informative) Type 2: Reference design examples.....	345
Annex I (normative) Type 3: Connector specification.....	351
Annex J (normative) Type 3: Redundancy of PhL and medium.....	358
Annex K (normative) Type 3: Optical network topology	359
Annex L (informative) Type 3: Reference design examples for asynchronous transmission, wire medium, intrinsically safe	368
Annex M (normative) Type 8: Connector specification.....	370
Annex N (normative) Type 16: Connector specification	375
Annex O (normative) Type 16: Optical network topology	376
Annex P (informative) Type 16: Reference design example.....	381
Annex Q (normative) Type 18: Connector specification	385
Annex R (normative) Type 18: Media cable specifications.....	390
Bibliography.....	394
Annex ZA (normative) Normative references to international publications with their corresponding European publications	396
Figure 1 – General model of physical layer	17
Figure 2 – Mapping between data units across the DLL – PhL interface.....	56
Figure 3 – Data service for asynchronous transmission.....	61
Figure 4 – Interactions for a data sequence of a master: identification cycle	66
Figure 5 – Interactions for a data sequence of a master: data cycle	67
Figure 6 – Interactions for a data sequence of a slave: identification cycle.....	68
Figure 7 – Interactions for a data sequence of a slave: data cycle	69
Figure 8 – Interactions for a check sequence of a master	70
Figure 9 – Interactions for a check sequence of a slave	71
Figure 10 – Reset, Set-value, Get-value	79
Figure 11 – Event service	80
Figure 12 – Interface between PhL and PNM1 in the layer model.....	84
Figure 13 – Reset, Set-value, Get-value PhL services	86
Figure 14 – Event PhL service	86
Figure 15 – Allocation of the interface number	87
Figure 16 – Configuration of a master	91
Figure 17 – Configuration of a slave with an alternative type of transmission	92
Figure 18 – Configuration of a bus coupler with an alternative type of transmission	92
Figure 19 – DTE/DCE sequencing machines.....	97
Figure 20 – State transitions with the ID cycle request service.....	106
Figure 21 – MIS-MDS interface: identification cycle request service.....	106
Figure 22 – MIS-MDS interface: identification cycle request service.....	107
Figure 23 – State transitions with the data cycle request service	108
Figure 24 – MIS-MDS interface: data cycle request service	108

Figure 25 – State transitions with the data sequence classification service	109
Figure 26 – Protocol machine for the message transmission service	109
Figure 27 – Protocol machine for the data sequence identification service	111
Figure 28 – Protocol machine for the message receipt service	111
Figure 29 – Protocol data unit (PhPDU)	113
Figure 30 – PhSDU encoding and decoding	113
Figure 31 – Manchester encoding rules	114
Figure 32 – Preamble and delimiters	115
Figure 33 – Manchester coded symbols	117
Figure 34 – PhPDU format, half duplex	118
Figure 35 – PhPDU format, full duplex	120
Figure 36 – Data sequence PhPDU	123
Figure 37 – Structure of the header in a data sequence PhPDU	123
Figure 38 – Check sequence PhPDU	124
Figure 39 – Structure of a headers in a check sequence PhPDU	124
Figure 40 – Structure of the status PhPDU	125
Figure 41 – Structure of the header in a status PhPDU	125
Figure 42 – Structure of the medium activity status PhPDU	126
Figure 43 – Structure of the header in a medium activity status PhPDU	126
Figure 44 – Reset PhPDU	127
Figure 45 – Configuration of a master	128
Figure 46 – Configuration of a slave	129
Figure 47 – Configuration of a bus coupler	129
Figure 48 – Protocol data unit	129
Figure 49 – PhSDU encoding and decoding	130
Figure 50 – Manchester encoding rules	130
Figure 51 – Example of an NRZI-coded signal	132
Figure 52 – Fill signal	133
Figure 53 – Jitter tolerance	139
Figure 54 – Transmit circuit test configuration	145
Figure 55 – Output waveform	145
Figure 56 – Transmitted and received bit cell jitter (zero crossing point deviation)	146
Figure 57 – Signal polarity	148
Figure 58 – Receiver sensitivity and noise rejection	149
Figure 59 – Power supply ripple and noise	152
Figure 60 – Fieldbus coupler	154
Figure 61 – Transition from receiving to transmitting	161
Figure 62 – Power supply ripple and noise	165
Figure 63 – Test circuit for single-output power supplies	166
Figure 64 – Test circuit for power distribution through an IS barrier	167
Figure 65 – Test circuit for multiple output supplies with signal coupling	168
Figure 66 – Fieldbus coupler	170
Figure 67 – Protection resistors	170

Figure 68 – Test configuration for current-mode MAU	176
Figure 69 – Transmitted and received bit cell jitter (zero crossing point deviation)	177
Figure 70 – Noise test circuit for current-mode MAU	179
Figure 71 – Transmitted and received bit cell jitter (zero crossing point deviation)	187
Figure 72 – Power supply harmonic distortion and noise	189
Figure 73 – Optical wave shape template.....	194
Figure 74 – Cellular radio topology and reuse of frequencies	205
Figure 75 – Radio segment between wired segments topology	206
Figure 76 – Mixed wired and radio medium fieldbus topology.....	207
Figure 77 – Components of 5 Mbit/s, voltage-mode, coaxial wire PhL variant.....	211
Figure 78 – Coaxial wire MAU block diagram	212
Figure 79 – Coaxial wire MAU transmitter	212
Figure 80 – Coaxial wire MAU receiver operation.....	213
Figure 81 – Coaxial wire MAU transmit mask.....	214
Figure 82 – Coaxial wire MAU receive mask	215
Figure 83 – Transformer symbol	216
Figure 84 – 5 Mbit/s, voltage-mode, coaxial wire topology example	218
Figure 85 – Coaxial wire medium topology limits.....	218
Figure 86 – Coaxial wire medium tap electrical characteristics.....	220
Figure 87 – MAU block diagram 5 Mbit/s, optical fiber medium	223
Figure 88 – NAP reference model	227
Figure 89 – Example of transient and permanent nodes.....	228
Figure 90 – NAP transceiver	229
Figure 91 – NAP cable	230
Figure 92 – Circuit diagram of the principle of measuring impedance	235
Figure 93 – Definition of CMRR	236
Figure 94 – Block circuit diagram of the principle of measuring CMRR.....	236
Figure 95 – Power supply ripple and noise.....	239
Figure 96 – Output characteristic curve of a power supply of the category EEx ib	246
Figure 97 – Output characteristic curve of a power supply of the category EEx ia	246
Figure 98 – Repeater in linear bus topology.....	249
Figure 99 – Repeater in tree topology	249
Figure 100 – Example for a connector with integrated inductance	251
Figure 101 – Interconnecting wiring	251
Figure 102 – Bus terminator.....	252
Figure 103 – Linear structure of an intrinsically safe segment.....	254
Figure 104 – Topology example extended by repeaters	255
Figure 105 – Bus terminator.....	257
Figure 106 – Waveform of the differential voltage	258
Figure 107 – Test set-up for the measurement of the idle level for devices with an integrated termination resistor	260
Figure 108 – Test set-up for the measurement of the idle level for devices with a connectable termination resistor	260

Figure 109 – Test set-up for measurement of the transmission levels	261
Figure 110 – Test set-up for the measurement of the receiving levels	261
Figure 111 – Fieldbus model for intrinsic safety	262
Figure 112 – Communication device model for intrinsic safety	262
Figure 113 – Connection to the optical network.....	265
Figure 114 – Principle structure of optical networking	266
Figure 115 – Definition of the standard optical link.....	266
Figure 116 – Signal template for the optical transmitter	271
Figure 117 – Recommended interface circuit	275
Figure 118 – MAU of an outgoing interface	277
Figure 119 – MAU of an incoming interface.....	277
Figure 120 – Remote bus link	278
Figure 121 – Interface to the transmission medium	278
Figure 122 – Wiring	281
Figure 123 – Terminal resistor network.....	281
Figure 124 – Fiber optic remote bus cable	282
Figure 125 – Optical fiber remote bus link.....	282
Figure 126 – Optical wave shape template optical MAU.....	284
Figure 127 – Optical transmission line	290
Figure 128 – Optical signal envelope	292
Figure 129 – Display of jitter (J_{noise}).....	293
Figure 130 – Input-output performance of a slave	295
Figure 131 – Functions of a master connection	298
Figure 132 – Valid transmitting signals during the transition from fill signal to telegram delimiters.....	300
Figure 133 – Valid transmitting signals during the transition from telegram delimiter to fill signal.....	300
Figure 134 – Functions of a slave connection	301
Figure 135 – Network with two slaves	302
Figure 136 – Minimum interconnecting wiring.....	303
Figure 137 – Dedicated cable topology	304
Figure 138 – T-branch topology	304
Figure 139 – Communication element isolation	306
Figure 140 – Communication element and I/O isolation.....	306
Figure 141 – Minimum interconnecting wiring.....	307
Figure 142 – Flat cable topology	308
Figure 143 – Dedicated cable topology	308
Figure 144 – T-branch topology	308
Figure 145 – Type 18-PhL-P power distribution.....	311
Figure 146 – Type 18-PhL-P power distribution.....	311
Figure 147 – Type 18-PhL-P power supply filtering and protection	313
Figure 148 – Communication element isolation	314
Figure 149 – Communication element and i/o isolation	314

Figure 150 – PhL-P power supply circuit	314
Figure A.1 – Internal fieldbus connector	315
Figure A.2 – Contact designations for the external connector for harsh industrial environments	317
Figure A.3 – External fieldbus connector keyways, keys, and bayonet pins and grooves	317
Figure A.4 – External fieldbus connector intermateability dimensions	318
Figure A.5 – External fieldbus connector contact arrangement	319
Figure A.6 – Contact designations for the external connector for typical industrial environments	320
Figure A.7 – External fixed (device) side connector for typical industrial environments: dimensions	320
Figure A.8 – External free (cable) side connector for typical industrial environments: dimensions	321
Figure A.9 – Optical connector for typical industrial environments (FC connector)	321
Figure A.10 – Optical connector for typical industrial environments (ST connector)	322
Figure C.1 – Example of an optical passive reflective star	325
Figure C.2 – Example of an optical passive transmissive star	325
Figure D.1 – Example of star topology with 31,25 kbit/s, single fiber mode, optical MAU	326
Figure D.2 – Multi-star topology with an optical MAU	326
Figure D.3 – Example of mixture between wire and optical media for a 31,25 kbit/s bit rate	328
Figure D.4 – Example of mixture between wire and optical media	329
Figure F.1 – Pin connector for short range optical medium	332
Figure F.2 – Crimp ring for short range optical medium	332
Figure G.1 – PhL repeater device reference model	334
Figure G.2 – Reference model for redundancy	336
Figure G.3 – Block diagram showing redundant coaxial medium and NAP	337
Figure G.4 – Block diagram showing ring repeaters	338
Figure G.5 – Segmentation query	339
Figure G.6 – Segmentation response	339
Figure G.7 – Main switch state machine	342
Figure G.8 – Port 1 sees network activity first	343
Figure G.9 – Port 2 sees network activity first	344
Figure H.1 – Coaxial wire MAU RXDATA detector	346
Figure H.2 – Coaxial wire MAU RXCARRIER detection	347
Figure H.3 – Redundant coaxial wire MAU transceiver	347
Figure H.4 – Single channel coaxial wire MAU transceiver	348
Figure H.5 – Coaxial wire medium tap	349
Figure H.6 – Non-isolated NAP transceiver	350
Figure H.7 – Isolated NAP transceiver	350
Figure I.1 – Schematic of the station coupler	351
Figure I.2 – Pin assignment of the male and female connectors IEC 60947-5-2 (A coding)	352
Figure I.3 – Connector pinout, front view of male and back view of female respectively	353
Figure I.4 – Connector pinout, front view of female M12 connector	355

Figure I.5 – Connector pinout, front view of male M12 connector	355
Figure I.6 – M12 Tee	356
Figure I.7 – M12 Bus termination	357
Figure J.1 – Redundancy of PhL MAU and Medium	358
Figure K.1 – Optical MAU in a network with echo	359
Figure K.2 – Optical MAU in a network without echo	360
Figure K.3 – Optical MAU with echo via internal electrical feedback of the receive signal ...	360
Figure K.4 – Optical MAU without echo function.....	360
Figure K.5 – Optical network with star topology	361
Figure K.6 – Optical network with ring topology	362
Figure K.7 – Optical network with bus topology.....	362
Figure K.8 – Tree structure built from a combination of star structures.....	363
Figure K.9 – Application example for an ANSI TIA/EIA-485-A / fiber optic converter	363
Figure L.1 – Bus termination integrated in the communication device	368
Figure L.2 – Bus termination in the connector	369
Figure L.3 – External bus termination.....	369
Figure M.1 – Outgoing interface 9-position female subminiature D connector at the device.	370
Figure M.2 – Incoming interface 9-position male subminiature D connector at the device....	370
Figure M.3 – Terminal connector at the device.....	370
Figure M.4 – Ferrule of an optical F-SMA connector for polymer optical fiber (980/1 000 μm)	371
Figure M.5 – Type 8 fiber optic hybrid connector housing	372
Figure M.6 – Type 8 fiber optic hybrid connector assignment.....	373
Figure O.1 – Topology	376
Figure O.2 – Structure of a single-core cable (example).....	379
Figure O.3 – Optical power levels	380
Figure P.1 – Example of an implemented DPLL	382
Figure P.2 – DPLL status diagram	383
Figure P.3 – DPLL timing.....	383
Figure Q.1 – PhL-P device connector r-a	385
Figure Q.2 – PhL-P device connector straight.....	386
Figure Q.3 – PhL-P flat cable connector and terminal cover – body and connector	386
Figure Q.4 – PhL-P flat cable connector and terminal cover – terminal cover	387
Figure Q.5 – Type 18-PhL-P round cable connector body	387
Figure Q.6 – Type 18-PhL-P round cable connector terminal cover.....	388
Figure Q.7 – Type 18-PhL-P round cable alternate connector and body.....	388
Figure Q.8 – Type 18-PhL-P round cable alternate connector terminal cover	389
Figure R.1 – PhL-B cable cross section twisted drain.....	390
Figure R.2 – PhL-B cable cross section non-twisted drain.....	391
Figure R.3 – PhL-P flat cable cross section - with key.....	392
Figure R.4 – PhL-P flat cable cross section - without key.....	392
Figure R.5 – PhL-P flat cable polarity marking	392
Figure R.6 – Round cable – preferred; cross section.....	393
Figure R.7 – Round cable – alternate; cross-section	393

Table 1 – Data encoding rules	58
Table 2 – Ph-STATUS indication truth table	59
Table 3 – Jabber indications	60
Table 4 – Parameter names and values for Ph-SET-VALUE request	77
Table 5 – Parameter names for Ph-EVENT indication	78
Table 6 – Summary of Ph-management services and primitives	79
Table 7 – Reset primitives and parameters	80
Table 8 – Values of PhM-Status for the Reset service.....	80
Table 9 – Set value primitives and parameters.....	81
Table 10 – Mandatory PhE-variables	81
Table 11 – Permissible values of PhE-variables.....	81
Table 12 – Values of PhM-Status for the set-value service.....	82
Table 13 – Get value primitives and parameters	82
Table 14 – Current values of PhE-variables	82
Table 15 – Values of PhM-Status for the get value service.....	83
Table 16 – Event primitive and parameters	83
Table 17 – New values of PhE-variables	83
Table 18 – Parameter names and values for management	84
Table 19 – PH-RESET	86
Table 20 – Ph-SET-VALUE	86
Table 21 – PhL variables	87
Table 22 – Ph-GET-VALUE	88
Table 23 – Ph-EVENT	88
Table 24 – PhL events	89
Table 25 – Parameter names and values for Ph-SET-VALUE request.....	90
Table 26 – Signals at DTE – DCE interface.....	94
Table 27 – Signal levels for an exposed DTE – DCE interface	95
Table 28 – MDS bus reset	104
Table 29 – Signals at the MIS-MDS interface.....	105
Table 30 – Manchester encoding rules.....	114
Table 31 – MDS timing characteristics	116
Table 32 – MDS data encoding rules	117
Table 33 – SL bit and TxSL signal assignment.....	124
Table 34 – SL bit and RxSL signal assignment	124
Table 35 – SL bit and TxSL signal assignment.....	125
Table 36 – SL bit and RxSL signal assignment	125
Table 37 – SL bit and TxSL signal assignment.....	126
Table 38 – SL bit and RxSL signal assignment	126
Table 39 – Coding and decoding rules	127
Table 40 – Decoding rules for the idle states	127
Table 41 – Coding rules for the reset PhPDU.....	128
Table 42 – Decoding rules of the reset PhPDU	128

Table 43 – Manchester encoding rules.....	130
Table 44 – Minimum services at MDS – MAU interface	134
Table 45 – Signal levels for an exposed MDS – MAU interface	135
Table 46 – MDS-MAU interface definitions: 5 Mbit/s, voltage-mode, coaxial wire	136
Table 47 – MDS-MAU interface 5 Mbit/s, optical fiber medium	137
Table 48 – Services of the MDS-MAU interface.....	138
Table 49 – Minimum services at MAU interface.....	140
Table 50 – Signal levels for an exposed MAU interface.....	140
Table 51 – Bit-rate-dependent quantities of voltage-mode networks.....	141
Table 52 – MAU transmit level specification summary.....	144
Table 53 – MAU transmit timing specification summary for 31,25 kbit/s operation	144
Table 54 – MAU transmit timing specification summary for ≥ 1 Mbit/s operation.....	144
Table 55 – MAU receive circuit specification summary.....	148
Table 56 – Network powered device characteristics	151
Table 57 – Network power supply requirements	151
Table 58 – Test cable attenuation limits	153
Table 59 – Recommended color coding of cables in North America	155
Table 60 – MAU transmit level specification summary.....	159
Table 61 – MAU transmit timing specification summary.....	159
Table 62 – MAU receive circuit specification summary.....	162
Table 63 – Network powered device characteristics	164
Table 64 – Network power supply requirements	164
Table 65 – Type 3 cable color specification.....	172
Table 66 – MAU transmit level specification summary.....	176
Table 67 – MAU transmit timing specification summary.....	176
Table 68 – Receive circuit specification summary	178
Table 69 – Network power supply requirements	180
Table 70 – Transmit level specification summary for current-mode MAU	186
Table 71 – Transmit timing specification summary for current-mode MAU	186
Table 72 – Receive circuit specification summary for current-mode MAU	188
Table 73 – Network power supply requirements	189
Table 74 – Bit-rate-dependent quantities of high-speed (≥ 1 Mbit/s) dual-fiber networks	192
Table 75 – Transmit level and spectral specification summary	193
Table 76 – Transmit timing specification summary	194
Table 77 – Receive circuit specification summary	194
Table 78 – Transmit and receive level and spectral specifications for an optical active star	197
Table 79 – Timing characteristics of an optical active star.....	198
Table 80 – Transmit level and spectral specification summary	199
Table 81 – Transmit and receive level and spectral specifications for an optical active star	201
Table 82 – Interfering frequencies for testing receiver performance	210
Table 83 – Transmit control line definitions 5 Mbit/s, voltage-mode, coaxial wire	212
Table 84 – Receiver data output definitions: 5 Mbit/s, voltage-mode, coaxial wire.....	213
Table 85 – Receiver carrier output definitions: 5 Mbit/s, voltage-mode, coaxial wire.....	213

Table 86 – Coaxial wire medium interface – transmit specifications	214
Table 87 – Coaxial wire medium interface – receive.....	215
Table 88 – Coaxial wire medium interface – general	216
Table 89 – 5 Mbit/s, voltage-mode, coaxial wire transformer electrical specifications	217
Table 90 – Coaxial spur cable specifications.....	221
Table 91 – Coaxial trunk cable specifications.....	221
Table 92 – Transmit control line definitions 5 Mbit/s, optical fiber medium	223
Table 93 – Fiber medium interface 5,0 Mbit/s, optical	223
Table 94 – Fiber signal specification 5 Mbit/s, optical medium, short range.....	224
Table 95 – Fiber signal specification 5 Mbit/s, optical medium, medium range	225
Table 96 – Fiber signal specification 5 Mbit/s, optical medium, long range.....	226
Table 97 – NAP requirements	228
Table 98 – Mixing devices from different categories.....	231
Table 99 – Input Impedances of bus interfaces and power supplies	234
Table 100 – Required CMRR	236
Table 101 – Network powered device characteristics for the 31,25 kbit/s voltage-mode MAU237	
Table 102 – Network power supply requirements for the 31,25 kbit/s voltage-mode MAU... 238	
Table 103 – Electrical characteristics of fieldbus interfaces	243
Table 104 – Electrical characteristics of power supplies.....	244
Table 105 – Characteristics for non intrinsic safety	248
Table 106 – Characteristics using repeaters	248
Table 107 – Cable specifications	250
Table 108 – Maximum cable length for the different transmission speeds	250
Table 109 – Characteristics for intrinsic safety.....	253
Table 110 – Cable specification (function- and safety-related)	256
Table 111 – Maximum cable length for the different transmission speeds	256
Table 112 – Electrical characteristics of the intrinsically safe interface	259
Table 113 – Maximum safety values	263
Table 114 – Characteristic features	264
Table 115 – Characteristics of optical transmitters for multi-mode glass fiber.....	267
Table 116 – Characteristics of optical transmitters for single-mode glass fiber.....	268
Table 117 – Characteristics of optical transmitters for plastic fiber.....	268
Table 118 – Characteristics of optical transmitters for 200/230 μm glass fiber	268
Table 119 – Characteristics of optical receivers for multi-mode glass fiber.....	269
Table 120 – Characteristics of optical receivers for single-mode glass fiber.....	269
Table 121 – Characteristics of optical receivers for plastic fiber	269
Table 122 – Characteristics of optical receivers for 200/230 μm glass fiber.....	270
Table 123 – Permissible signal distortion at the electrical input of the optical transmitter	270
Table 124 – Permissible signal distortion due to the optical transmitter.....	271
Table 125 – Permissible signal distortion due to the optical receiver.....	272
Table 126 – Permissible signal influence due to internal electronic circuits of a coupling component.....	272
Table 127 – Maximum chaining of standard optical links without retiming	273

Table 128 – Services of the MDS-MAU interface, RS-485, Type 4	274
Table 129 – Services of the MDS-MAU interface, RS-232, Type 4	276
Table 130 – Bit rate dependent quantities twisted pair wire medium MAU	277
Table 131 – Incoming interface signals	279
Table 132 – Outgoing interface signals	279
Table 133 – Remote bus cable characteristics	280
Table 134 – Bit rate dependent quantities optical MAU	282
Table 135 – Remote bus fiber optic cable length	283
Table 136 – Encoding rules	283
Table 137 – Transmit level and spectral specification summary for an optical MAU	283
Table 138 – Optical MAU receive circuit specification summary	285
Table 139 – Specification of the fiber optic waveguide	285
Table 140 – Specification of the single fiber	286
Table 141 – Specification of the cable sheath and mechanical properties of the cable	286
Table 142 – Recommended further material properties of the cable	286
Table 143 – Specification of the fiber optic waveguide	287
Table 144 – Specification of the single fiber	287
Table 145 – Specification of the cable sheath and mechanical properties of the cable	287
Table 146 – Specification of the standard test fiber for an optical MAU	288
Table 147 – Transmission rate support	293
Table 148 – Transmission data parameters	294
Table 149 – Possible slave input signals	296
Table 150 – Possible slave output signals	296
Table 151 – Valid slave output signals	296
Table 152 – Specifications of the clock adjustment times	297
Table 153 – Optical signal delay in a slave	297
Table 154 – Basic functions of the connection	297
Table 155 – Pass-through topology limits	304
Table 156 – T-branch topology limits	305
Table 157 – Terminating resistor requirements	305
Table 158 – Pass-through topology limits	309
Table 159 – T-branch topology limits	309
Table 160 – Terminating resistor requirements – flat cable	310
Table 161 – Terminating resistor requirements – round cable	310
Table 162 – 24 V Power supply specifications	311
Table 163 – 24V Power consumption specifications	312
Table A.1 – Internal connector dimensions	315
Table A.2 – Contact assignments for the external connector for harsh industrial environments	316
Table A.3 – Contact assignments for the external connector for typical industrial environments	320
Table A.4 – Fixed (device) side connector dimensions	320
Table A.5 – Free (cable) side connector dimensions	321

Table A.6 – Connector dimensions.....	322
Table B.1 – Typical cable specifications.....	323
Table B.2 – Recommended maximum spur lengths versus number of communication elements.....	324
Table C.1 – Optical passive star specification summary: example.....	325
Table D.1 – Passive star topology.....	327
Table D.2 – Active star topology.....	328
Table E.1 – Alternate fibers for dual-fiber mode.....	330
Table E.2 – Alternate fibers for single-fiber mode.....	330
Table F.1 – Connector requirements.....	331
Table F.2 – NAP connector pin definition.....	333
Table H.1 – 5 Mbit/s, voltage-mode, coaxial wire receiver output definitions.....	346
Table H.2 – Coaxial wire medium toroid specification.....	349
Table I.1 – Contact assignments for the external connector for harsh industrial environments.....	351
Table I.2 – Contact designations.....	353
Table I.3 – Contact designations.....	354
Table I.4 – Contact designations.....	354
Table K.1 – Example of a link budget calculation for 62,5/125 μm multi-mode glass fiber....	365
Table K.2 – Example of a link budget calculation for 9/125 μm single mode glass fiber.....	366
Table K.3 – Example of a link budget calculation for 980/1 000 μm multi-mode plastic fiber.....	366
Table K.4 – Example of a level budget calculation for 200/230 μm multi-mode glass fiber...	367
Table M.1 – Pin assignment of the 9-position subminiature D connector.....	370
Table M.2 – Pin assignment of the terminal connector.....	371
Table M.3 – Type 8 fiber optic hybrid connector dimensions.....	374
Table O.1 – Transmitter specifications.....	378
Table O.2 – Receiver specifications.....	379
Table O.3 – Cable specifications (example).....	379
Table O.4 – System data of the optical transmission line at 650 nm.....	380
Table R.1 – PhL-B cable specifications.....	390
Table R.2 – PhL-P flat cable specifications.....	391
Table R.3 – PhL-P round cable specifications – preferred.....	392
Table R.4 – PhL-P round cable specifications – alternate.....	393