



Technology Training that Works

Practical Troubleshooting & Problem Solving of Industrial Data Communications

Contents

Preface		xiii
1	Introduction	1
1.1	Introduction	1
1.2	Modern instrumentation and control systems	2
1.3	Open systems interconnection (OSI) model	5
1.4	Protocols	6
1.5	Standards	7
2	Overall methodology	15
2.1	Introduction	15
2.2	Common problems and solutions	15
2.3	General comments on troubleshooting	16
2.4	A specific methodology	16
2.5	Grounding/shielding and noise	17
3	EIA-232 overview	29
3.1	RS-232 interface standard (CCITT V.24)	29
3.2	Half duplex operation of the RS-232 interface	35
3.3	Limitations	37
3.4	Troubleshooting	37
4	EIA-485 overview	47
4.1	The RS-485 interface standard	47
4.2	Troubleshooting	51
5	Current loop and EIA-485 converters overview	61
5.1	The 20 mA current loop	61
5.2	Serial interface converters	62
5.3	Troubleshooting	63



Technology Training that Works

6	Fiber optics overview	67
6.1	Introduction	67
6.2	Fiber-optic cable components	68
6.3	Fiber optic cable parameters	69
6.4	Types of optical fiber	70
6.5	Basic cable types	71
6.6	Connecting fibers	73
6.7	Splicing trays/organizers and termination cabinets	75
6.8	Troubleshooting	78
7	Modbus overview	85
7.1	General overview	85
7.2	Modbus protocol structure	87
7.3	Transmission modes	91
7.4	Detailed examples	93
7.5	Exception Responses	102
7.6	Troubleshooting	104
8	Modbus Plus overview	107
8.1	Introduction	107
8.2	Topology	108
8.3	Medium Access Control	110
8.4	Frame structure	110
8.5	Troubleshooting	111
9	Data Highway Plus/DH485 overview	115
9.1	Allen Bradley data highway (plus) protocol	115
9.2	Troubleshooting	122
10	HART overview	125
10.1	Introduction to HART and smart instrumentation	125
10.2	HART	126
10.3	Physical layer	127
10.4	Data link layer	129
10.5	Application layer	129
10.6	Troubleshooting	131



Technology Training that Works

11	AS-i overview	133
11.1	Introduction	133
11.2	Layer 1 – the physical layer	134
11.3	Layer 2 – the data link layer	136
11.4	Operating characteristics	138
11.5	Troubleshooting	138
12	DeviceNet overview	141
12.1	Introduction	141
12.2	Physical layer	142
12.3	Connectors	143
12.4	Cable budgets	145
12.5	Device taps	146
12.6	Cable description	148
12.7	Network power	150
12.8	System grounding	152
12.9	Signaling	153
12.10	Data link layer	153
12.11	Troubleshooting	156
13	Profibus overview	163
13.1	Introduction	163
13.2	Profibus protocol stack	164
13.3	System Operation	168
13.4	Troubleshooting	171
14	Foundation Fieldbus overview	175
14.1	Introduction	175
14.2	The physical layer and wiring rules	176
14.3	The data link layer	180
14.4	The application layer	180
14.5	The user layer	181
14.6	Error detection and diagnostics	182
14.7	High-speed Ethernet (HSE)	182
14.8	Good wiring and installation practice with Foundation FieldBus	183
14.9	Troubleshooting	184



Technology Training that Works

15	Industrial Ethernet overview	189
15.1	Introduction	189
15.2	10 Mbps Ethernet	190
15.3	100 Mbps Ethernet	197
15.4	Gigabit Ethernet	198
15.5	Industrial Ethernet	198
15.6	Troubleshooting	201
16	TCP/IP overview	213
16.1	Introduction	213
16.2	Internet layer protocols (packet transport)	215
16.3	Host-to-host layer: End to end reliability	224
16.4	Troubleshooting	226
17	Radio and wireless communications overview	231
17.1	Introduction	231
17.2	Components of a radio link	231
17.3	The radio spectrum and frequency allocation	233
17.4	Summary of radio characteristics of VHF/UHF	235
17.5	Radio modems	236
17.6	Intermodulation and how to prevent it	241
17.7	Implementing a radio link	242
17.8	Troubleshooting	249
Appendix A Glossary		251
Appendix B Basic Terminology		263
Appendix C Practical Exercises		283
Appendix D Local services, regulations and standards		323
Appendix E Telecommunications and Data Communications		
	Cable Pulling	333