



# TELEPHONY NETWORKING: INSTRUCTOR GUIDE TABLE OF CONTENTS

|  |                         |
|--|-------------------------|
| Course Description.....                                    | x                       |
| ProsoftTraining Courseware.....                            | xi                      |
| Course Objectives.....                                     | xii                     |
| Classroom Setup.....                                       | xiii                    |
| System Requirements.....                                   | xiii                    |
| Conventions and Graphics Used in This Book.....            | xv                      |
| <br>   |                         |
| Classroom Setup Guide.....                                 | Classroom Setup Guide-1 |
| <br>   |                         |
| <b>Lesson 1: Telephony Essentials</b> .....                | <b>1-1</b>              |
| Pre-Assessment Questions.....                              | 1-2                     |
| Telephony Basics.....                                      | 1-3                     |
| The Central Office.....                                    | 1-8                     |
| Cabling and Wiring.....                                    | 1-22                    |
| Call-Processing Steps.....                                 | 1-25                    |
| Lesson 1 Review.....                                       | 1-30                    |
| Lesson 1 Instructor Section.....                           | 1-31                    |
| Lesson 1 Quiz.....   | 1-37                    |
| <br>   |                         |
| <b>Lesson 2: Investigating the Local Loop</b> .....        | <b>2-1</b>              |
| Pre-Assessment Questions.....                              | 2-2                     |
| Inside the Demarcation Point.....                          | 2-3                     |
| Lesson 2 Review.....                                       | 2-18                    |
| Lesson 2 Instructor Section.....                           | 2-20                    |
| Lesson 2 Quiz.....   | 2-26                    |
| <br>   |                         |
| <b>Lesson 3: Infrastructure Issues and Standards</b> ..... | <b>3-1</b>              |
| Pre-Assessment Questions.....                              | 3-2                     |
| Common Telephony Issues.....                               | 3-3                     |
| The Network Equipment Building System.....                 | 3-6                     |
| British Approvals Board for Telecommunications (BABT)..... | 3-9                     |
| Office of Telecommunications (Ofcom).....                  | 3-10                    |
| Additional Telephony Regulators and Organizations.....     | 3-10                    |
| Proper Cabling Procedures.....                             | 3-13                    |
| Securing Equipment.....                                    | 3-19                    |
| Lesson 3 Review.....                                       | 3-21                    |
| Lesson 3 Instructor Section.....                           | 3-22                    |
| Lesson 3 Quiz.....   | 3-24                    |

|                                    |            |
|------------------------------------|------------|
| <b>Lesson 4: Troubleshooting</b>   | <b>4-1</b> |
| Pre-Assessment Questions.....      | 4-2        |
| Troubleshooting Terms.....         | 4-3        |
| Troubleshooting Tools.....         | 4-3        |
| Troubleshooting Analog Lines.....  | 4-13       |
| Troubleshooting Digital Lines..... | 4-13       |
| Lesson 4 Review.....               | 4-17       |
| Lesson 4 Instructor Section.....   | 4-18       |
| Lesson 4 Quiz.....                 | 4-22       |

|   |            |
|---|------------|
| <b>Lesson 5: Analog and Digital Signaling</b>   | <b>5-1</b> |
| Pre-Assessment Questions.....                   | 5-2        |
| Signaling Categories.....                       | 5-3        |
| In-Band and Out-of-Band Signaling.....          | 5-3        |
| Analog Signaling.....                           | 5-4        |
| Digital Signaling.....                          | 5-9        |
| Private Integrated Services Network (PISN)..... | 5-15       |
| Signaling System Seven (SS7).....               | 5-26       |
| Connecting to the PBX.....                      | 5-30       |
| Computer Telephony Integration.....             | 5-34       |
| CTI and Telephony Power Issues.....             | 5-36       |
| Lesson 5 Review.....                            | 5-39       |
| Lesson 5 Instructor Section.....                | 5-40       |
| Lesson 5 Quiz.....                              | 5-48       |

|                                     |                                       |
|-------------------------------------|---------------------------------------|
| <b>Course Assessment</b>            | <b>Course Assessment-1</b>            |
| <b>Appendixes</b>                   | <b>Appendixes-1</b>                   |
| <b>Glossary</b>                     | <b>Glossary-1</b>                     |
| <b>Index</b>                        | <b>Index-1</b>                        |
| <b>Supplemental CD-ROM Contents</b> | <b>Supplemental CD-ROM Contents-1</b> |
| <b>Handouts: Activities</b>         | <b>Handouts: Activities-1</b>         |
| <b>Handouts: Optional Labs</b>      | <b>Handouts: Optional Labs-1</b>      |
| <b>Handouts: Quizzes</b>            | <b>Handouts: Quizzes-1</b>            |
| <b>Handout: Course Assessment</b>   | <b>Handout: Course Assessment-1</b>   |

**List of Labs**

|   |      |
|---|------|
| Lab 1-1: Investigating a local telephone connection, North America (instructor-led).....  | 1-27 |
| Lab 1-2: Investigating a local telephone connection, United Kingdom (instructor-led)..... | 1-28 |
| Lab 2-1: Creating a telephone cable, North America (instructor-led).....                  | 2-11 |
| Lab 2-2: Creating a telephone cable, United Kingdom (instructor-led).....                 | 2-15 |
| Lab 4-1: Checking local loop voltage, North America.....                                  | 4-10 |
| Lab 4-2: Checking local loop voltage, United Kingdom.....                                 | 4-10 |

## List of Activities

|  |      |
|--|------|
| Activity 1-1: Converting carrier speeds.....   | 1-32 |
| Activity 1-2: Understanding SONET/SDH concepts.....  | 1-33 |
| Activity 1-3: Understanding timing concepts.....   | 1-34 |
| Activity 1-4: Understanding essential telephony terms and concepts.....                      | 1-35 |
| Activity 2-1: Making international phone calls, North America and the United Kingdom.....    | 2-21 |
| Activity 2-2: Understanding local loop terminology, North America.....                       | 2-22 |
| Activity 2-3: Understanding local loop terminology, United Kingdom.....                      | 2-23 |
| Activity 3-1: Understanding crossover cables.....  | 3-23 |
| Activity 3-2: Understanding safety procedures.....   | 3-23 |
| Activity 4-1: Choosing the correct testing tools.....  | 4-19 |
| Activity 5-1: Understanding E&M signaling.....   | 5-41 |
| Activity 5-2: Understanding analog loop- and ground-start (earth-start) trunk signaling..... | 5-42 |
| Activity 5-3: Understanding PISN network elements.....                                       | 5-43 |
| Activity 5-4: Understanding T1 and ISDN lines.....   | 5-44 |
| Activity 5-5: Reviewing digital signaling concepts.....                                      | 5-45 |
| Activity 5-6: Reviewing CTI terms and issues.....  | 5-46 |

## List of Optional Labs

|  |      |
|--|------|
| Optional Lab 1-1: Viewing telco equipment, North America and the United Kingdom.....                           | 1-36 |
| Optional Lab 2-1: Reviewing the Specified Numbering Scheme, United Kingdom.....                                | 2-23 |
| Optional Lab 2-2: Generating and viewing DTMF tones, North America<br>and the United Kingdom.....              | 2-24 |
| Optional Lab 2-3: Studying a phone jack, North America (instructor-led).....                                   | 2-25 |
| Optional Lab 2-4: Wiring a line jack unit, United Kingdom (instructor-led).....                                | 2-26 |
| Optional Lab 3-1: Wiring an RJ-45.....   | 3-24 |
| Optional Lab 4-1: Using a butt set on an analog line, North America.....                                       | 4-19 |
| Optional Lab 4-2: Using a butt set on an analog line, United Kingdom.....                                      | 4-20 |
| Optional Lab 4-3: Using a tone and probe kit, North America and the United Kingdom.....                        | 4-20 |
| Optional Lab 4-4: Using a line tester, North America.....  | 4-21 |
| Optional Lab 4-5: Using a line tester, United Kingdom.....   | 4-21 |
| Optional Lab 5-1: Investigating PBX connections, North America and the United Kingdom<br>(instructor-led)..... | 5-47 |

## List of Quizzes

|                    |      |
|--------------------|------|
| Lesson 1 Quiz..... | 1-37 |
| Lesson 2 Quiz..... | 2-26 |
| Lesson 3 Quiz..... | 3-24 |
| Lesson 4 Quiz..... | 4-22 |
| Lesson 5 Quiz..... | 5-48 |

## List of Figures

|  |      |
|--|------|
| Figure 1-1: Telephony converts sound to electrical energy.....     | 1-3  |
| Figure 1-2: Telephone connection diagram.....                      | 1-8  |
| Figure 1-3: Pulse Code Modulation.....                             | 1-9  |
| Figure 1-4: PBX connection.....                                    | 1-11 |
| Figure 1-5: Standard PBX installation.....                         | 1-12 |
| Figure 1-6: Typical SONET network section.....                     | 1-15 |
| Figure 1-7: A SONET STS-1 frame.....                               | 1-16 |
| Figure 1-8: The STM-1 frame.....                                   | 1-17 |
| Figure 1-9: SONET/SDH and multiplexing heterogeneous networks..... | 1-19 |
| Figure 1-10: Understanding timing strata.....                      | 1-21 |

|   |      |
|---|------|
| Figure 1-11: Punchdown block .....  | 1-22 |
| Figure 1-12: Series of punchdown blocks for a PBX installation .....            | 1-23 |
| Figure 1-13: Patch panel .....  | 1-23 |
| Figure A1-1: SONET/SDH network diagram .....                                    | 1-33 |
| Figure A1-2: Telephony equipment .....  | 1-36 |
| Figure 2-1: Customer's local loop.....  | 2-3  |
| Figure 2-2: Demarcation point.....  | 2-3  |
| Figure 2-3: NANP convention.....  | 2-4  |
| Figure 2-4: RJ-11 modular connector .....                                       | 2-9  |
| Figure 2-5: RJ-11 wiring diagram .....  | 2-9  |
| Figure 2-6: RJ-12 wiring diagram .....  | 2-11 |
| Figure 2-7: Standard analog phone jack .....                                    | 2-12 |
| Figure 2-8: RJ-11 wall connector wiring diagram .....                           | 2-12 |
| Figure 2-9: BT-style connectors .....   | 2-13 |
| Figure 2-10: BT-431A connectors .....   | 2-14 |
| Figure 2-11: Wiring for BT-631A connectors .....                                | 2-14 |
| Figure 2-12: Master and secondary line jack units (screw type).....             | 2-16 |
| Figure 2-13: Wall jack wiring diagram.....                                      | 2-17 |
| Figure A2-1: U.S. number connection.....  | 2-22 |
| Figure OL2-1: UK Telephone Code Locator.....                                    | 2-24 |
| Figure OL2-2: Viewing results of DTMF parsing tool.....                         | 2-25 |
| Figure 3-1: Sample BABT certification marker .....                              | 3-9  |
| Figure 3-2: AWG gauge sizes.....  | 3-14 |
| Figure 3-3: Wiring for standard RJ-45 connector (EIA/TIA 568A standard) .....   | 3-16 |
| Figure 3-4: Amphenol connector .....  | 3-18 |
| Figure 4-1: Lineman test handset (butt set) .....                               | 4-4  |
| Figure 4-2: Bed of nails connector .....  | 4-5  |
| Figure 4-3: Tone and probe kit.....   | 4-7  |
| Figure 4-4: Tracing signal in cable pair.....                                   | 4-8  |
| Figure 4-5: Digital multimeter.....   | 4-9  |
| Figure 4-6: Line tester .....   | 4-11 |
| Figure 4-7: AppDancer .....   | 4-12 |
| Figure 4-8: Clocking configuration.....   | 4-14 |
| Figure OL4-1: Connection diagram .....  | 4-21 |
| Figure 5-1: Analog E&M signaling.....   | 5-5  |
| Figure 5-2: Wink start process.....   | 5-7  |
| Figure 5-3: Loop-start connection.....  | 5-7  |
| Figure 5-4: Ground-start signaling for idle and outgoing calls.....             | 5-8  |
| Figure 5-5: Incoming call for analog ground start line .....                    | 5-9  |
| Figure 5-6: Typical I.430 connection.....                                       | 5-13 |
| Figure 5-7: Q.931/932 information field.....                                    | 5-13 |
| Figure 5-8: Traditional PBX-to-PBX network.....                                 | 5-15 |
| Figure 5-9: PISN network, showing connections via two different PINX types..... | 5-16 |
| Figure 5-10: Collection of PINX networks .....                                  | 5-16 |
| Figure 5-11: End to End services in a PISN.....                                 | 5-17 |
| Figure 5-12: QSIG BC signaling sequence.....                                    | 5-21 |
| Figure 5-13: Q and C reference points .....                                     | 5-22 |
| Figure 5-14: Digital E&M signaling .....  | 5-23 |
| Figure 5-15: PBX ground-start call initiation .....                             | 5-24 |
| Figure 5-16: FXS receiving call .....   | 5-25 |
| Figure 5-17: Loop-start incoming call .....                                     | 5-25 |
| Figure 5-18: HDLC frame.....  | 5-26 |
| Figure 5-19: UI frame used to establish TEI information .....                   | 5-27 |
| Figure 5-20: Standard PBX connections .....                                     | 5-31 |
| Figure 5-21: PBX connections with LAN.....                                      | 5-34 |
| Figure 5-22: UnPBX attached to LAN and PSTN .....                               | 5-35 |
| Figure A5-1: Problem E&M signal trunk wiring.....                               | 5-41 |

|   |      |
|---|------|
| Figure A5-2: Analog loop-start line condition .....                 | 5-42 |
| Figure A5-3: Analog earth-start (ground-start) line condition ..... | 5-42 |
| Figure A5-4: Analog ground-start condition .....                    | 5-42 |
| Figure A5-5: Analog loop-start condition .....                      | 5-43 |
| Figure A5-6: Reference points .....                                 | 5-43 |
| Figure A5-7: ISDN signaling .....                                   | 5-44 |
| Figure A5-8: E&M signaling condition .....                          | 5-45 |

## List of Tables

|  |                         |
|--|-------------------------|
| Table CS-1: Preparing for labs (North America) .....                   | Classroom Setup Guide-8 |
| Table CS-2: Preparing for labs (United Kingdom) .....                  | Classroom Setup Guide-8 |
| Table 1-1: Understanding ITU-T documents .....                         | 1-7                     |
| Table 1-2: Switch types .....  | 1-9                     |
| Table 1-3: U.S. digital signal hierarchy .....                         | 1-13                    |
| Table 1-4: E-carrier line speeds .....                                 | 1-14                    |
| Table 1-5: SONET/SDH terms .....                                       | 1-14                    |
| Table 1-6: PTE, STE and LTE responsibilities .....                     | 1-15                    |
| Table 1-7: SONET standards documents .....                             | 1-16                    |
| Table 1-8: SONET rates .....   | 1-18                    |
| Table 1-9: OC rates .....  | 1-18                    |
| Table 1-10: SDH rates .....  | 1-19                    |
| Table 1-11: Japanese J-carrier standard speeds .....                   | 1-20                    |
| Table 1-12: Analog transmission issues .....                           | 1-25                    |
| Table 2-1: Telephone code changes .....                                | 2-6                     |
| Table 2-2: Country codes .....   | 2-6                     |
| Table 2-3: Rotary/pulse signals .....                                  | 2-7                     |
| Table 2-4: DTMF values .....   | 2-8                     |
| Table 2-5: Tip and ring rules, analog loop line .....                  | 2-10                    |
| Table 2-6: On-hook voltage (North America) .....                       | 2-10                    |
| Table 2-7: Off-hook voltage (North America) .....                      | 2-10                    |
| Table 2-8: On-hook voltage (United Kingdom) .....                      | 2-13                    |
| Table 2-9: Off-hook voltage (United Kingdom) .....                     | 2-13                    |
| Table 3-1: Electromagnetic issues .....                                | 3-3                     |
| Table 3-2: NEBS levels .....   | 3-6                     |
| Table 3-3: GR-63-CORE document and NEBS levels .....                   | 3-7                     |
| Table 3-4: Issues addressed by GR-1089 .....                           | 3-8                     |
| Table 3-5: Additional telephony authorities .....                      | 3-10                    |
| Table 3-6: ITL rooms and equipment .....                               | 3-11                    |
| Table 3-7: Standard types .....  | 3-12                    |
| Table 3-8: EIA/TIA 568-A twisted pair categories .....                 | 3-14                    |
| Table 3-9: IBM cabling standards .....                                 | 3-15                    |
| Table 3-10: RJ-45 wiring (EIA/TIA 568 standard, tab facing down) ..... | 3-15                    |
| Table 3-11: RJ-45 to BT wiring .....                                   | 3-16                    |
| Table 3-12: Crossover cable wiring (T568B) .....                       | 3-17                    |
| Table A3-1: Crossover cable diagram .....                              | 3-23                    |
| Table 4-1: Telephony troubleshooting terms .....                       | 4-3                     |
| Table 4-2: Common loopback tests .....                                 | 4-6                     |
| Table 4-3: Tools for troubleshooting digital lines .....               | 4-15                    |
| Table A4-1: Troubleshooting tools .....                                | 4-19                    |
| Table 5-1: Signaling categories .....                                  | 5-3                     |
| Table 5-2: Common alert tones .....                                    | 5-3                     |
| Table 5-3: E&M signaling types .....                                   | 5-5                     |
| Table 5-4: H channels .....  | 5-11                    |
| Table 5-5: ISDN end points .....                                       | 5-12                    |
| Table 5-6: Q.931 message types .....                                   | 5-14                    |
| Table 5-7: Basic call services .....                                   | 5-20                    |

|                                       |      |
|---------------------------------------|------|
| Table 5-8: SS7/C7 elements .....      | 5-29 |
| Table 5-9: RJ-48 pinouts .....        | 5-31 |
| Table A5-1: Choosing trunk lines..... | 5-46 |

**Appendixes**

- Appendix A: Objectives and Locations\*
- Appendix B: Wiring Cross-Reference \*

*\* Appendix found on Supplemental CD-ROM*