ECHELON®

2.0

Mini FX User's Guide

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Preface

The Mini FX Development Kit is a hardware and software platform for evaluating the LONWORKS® 2.0 platform and developing simple LONWORKS devices. The Mini kit lets you build Neuron® C applications and download them to LONWORKS devices, and test LONWORKS devices.

Purpose

This document describes how to use the Mini FX Evaluation Kit to develop and build simple Neuron C device applications, download the device applications to LONWORKS devices, and test the LONWORKS devices.

Audience

This guide is intended for device and system designers with an understanding of control networks.

Hardware Requirements

Requirements for computers running the Mini kit are listed below:

- Microsoft® Windows Vista® or Microsoft Windows® XP. Echelon recommends that you install the latest service pack available from Microsoft for your version of Windows.
- Intel® Pentium® III 600MHz processor or faster, and meeting the minimum Windows requirements for the selected version of Windows.
- 120 to 350 megabytes (MB) free hard-disk space, plus the minimum Windows requirements for the selected version of Windows.
  - The Mini kit requires 90 MB of free space.
  - Microsoft .NET Framework 3.5 SP1, which is required to run the Mini FX Application, requires 30 MB of free space.
  - The LonScanner™ Protocol Analyzer (Demo Edition), which is included with the Mini kit software, requires 26 MB of free space.
  - If you install Adobe® Reader 9.1 from the Mini FX Evaluation Kit CD, you need an additional 204 MB of free space. You need Adobe Reader or another PDF viewer to view the Mini kit documentation.
- 512 MB RAM minimum.
- **Note**: Windows Vista testing for the Mini FX Application has been performed on computers that have a minimum of 2 GB of RAM. For complete Windows Vista requirements, refer to *www.microsoft.com/windows/windows-vista/get/system-requirements.aspx*. You can use Microsoft's Vista Upgrade Advisor to determine upgrade requirements for a particular computer. To download this tool, go to the Microsoft Web site at *www.microsoft.com/windows/windows-vista/get/upgrade-advisor.aspx*.
- CD-ROM drive.
- 1024x768 or higher-resolution display with at least 256 colors.
- Mouse or compatible pointing device.
- LNS® network interface or IP-852 router. If an LNS network interface is used, it may be a local or remote interface.
  - Compatible local network interfaces include the U10/U20 USB network interface (included with the Mini FX/FT and Mini FX/PL Evaluation Kits); PCC-10,

PCLTA-20, or PCLTA-21 network interfaces; and the SLTA-10 Serial LonTalk Adapter.

- Compatible remote network interfaces include the *i*.LON® SmartServer, *i*.LON 100 *e*3 plus Internet Server, or *i*.LON 600 LONWORKS-IP Server.
- Compatible IP-852 routers include the *i*.LON SmartServer with IP-852 routing, *i*.LON 100 *e*3 plus Internet Server with IP-852 routing, or an *i*.LON 600 LONWORKS-IP Server. If you are using an IP-852 router, your computer must have an IP network interface such as an Ethernet card or modem with PPP software. In addition, the *i*.LON software must be installed on your computer, and the IP-852 channel must be configured using the LONWORKS-IP Configuration Server application software.

Content

This guide includes the following content:

- *Introduction:* Lists the new features in the Mini FX Evaluation Kit, and summarizes the components included with the Mini kit. Describes how to upgrade your device development environment with the NodeBuilder tool, LonMaker tool, and an activated LonScanner tool. It provides an overview of device development with the Mini kit and LONWORKS networks.
- *Installing the Mini FX Evaluation Kit*. Describes how to get started with your Mini FX, including how to install the Mini FX software and connect the Mini FX hardware.
- *Mini FX Quick-Start Exercise*. Demonstrates how to create a device with the Mini kit.
- *Using the Mini FX Application*. Describes how to use the Mini FX Application to build a Neuron C application image, download an application image into a device, and test a device.
- *Developing Device Applications*. Introduces the Neuron C Version 2.2 programming language, and provides a series of programming examples that demonstrate Neuron C concepts, including input/output, timers, network variables, configuration properties, functional blocks, and Interoperable Self-Installation (ISI).
- *Appendices*. Includes a glossary, an appendix describing how to create and edit custom hardware templates, and the Mini Kit Software License agreement.

Related Manuals

The documentation related to the Mini kit is provided as Adobe PDF files and online help files. The PDF files are installed in the **Echelon Mini** program folder when you install the Mini kit. You can download the latest Mini FX documentation, including the latest version of this guide, from Echelon's Web site at *www.echelon.com/docs*.

The following manuals provide supplemental information to the material in this guide. You can download these documents from Echelon's Web site at *www.echelon.com*.

FT 5000 EVB Examples Guide	Describes how to run the Neuron C example applications included with the Mini FX/FT Evaluation Kit on an FT 5000 EVB.

FT 5000 EVB Hardware Guide	Describes how to connect the FT 5000 EVBs, and describes the Neuron core, I/O devices, service pin and reset buttons and LEDs, and jumper settings on the FT 5000 EVB hardware. Two FT 5000 EVBs are included with the Mini FX/FT Evaluation Kit.
Introduction to the LONWORKS® Platform	Provides a high-level introduction to LONWORKS networks and the tools and components that are used for developing, installing, operating, and maintaining them.
I/O Model Reference for Smart Transceivers and Neuron Chips	Describes the many different I/O models that are available for use with the Neuron Chips and Smart Transceivers.
LonMaker® User's Guide	Describes how to use the LonMaker Integration Tool to design, commission, modify, and maintain LONWORKS networks.
LONMARK® SNVT and SCPT Guide	Documents the standard network variable types (SNVTs), standard configuration property types (SCPTs), and standard enumeration types that you can declare in your applications.
LonScanner™ Protocol Analyzer User's Guide	Describes how to use the LonScanner Protocol Analyzer to monitor, analyze, and diagnose ISO/IEC 14908-4, LONWORKS/IP, and native ISO/IEC 14908-1 channels, and how to interpret the data that the protocol analyzer collects.
LONWORKS® USB Network Interface User's Guide	Describes how to install and use the U10 and U20 USB Network Interfaces, which are included with the Mini FX/FT Evaluation Kit and Mini FX/PL Evaluation Kit, respectively.
Mini FX/PL Examples Guide	Describes how to run the Neuron C example applications included with the Mini FX/PL Evaluation Kit on PL 3150 and PL 3170 EVBs.
Mini FX/PL Hardware Guide	Describes how to connect the PL 3150 and PL 3170 EVBs, and describes the I/O devices, service pin and reset buttons and LEDs, and jumper settings on the PL 3150 and PL 3170 EVBs, and Mini Gizmo I/O Boards. The Mini FX/PL Evaluation Kit includes one PL 3150 EVB and one PL 3170 EVB.
Neuron® C Programmer's Guide	Describes how to write programs using the Neuron C Version 2.2 language.
Neuron® C Reference Guide	Provides reference information for writing programs using the Neuron C language.
Neuron® Tools Error Guide	Provides reference information for Neuron tool errors.

NodeBuilder® Resource Editor User's Guide	Describes how to use the NodeBuilder Resource Editor to create and edit resource file sets and resources such as functional profiles, network variable types, and configuration property types.
PL 3120® / PL 3150® / PL 3170™ Smart Transceiver Data Book	Provides detailed technical specifications on the electrical interfaces, mechanical interfaces, and operating environment characteristics for the PL 3120, PL 3150, and PL 3170 Power Line Smart Transceivers.

For More Information and Technical Support

The **Mini FX ReadMe** document provides descriptions of known problems, if any, and their workarounds. To view the **Mini FX ReadMe**, click **Start**, point to **Programs**, point to **Echelon Mini**, and then select **Mini FX ReadMe First**. You can also find additional information about the Mini kit at the Mini FX Web page at *www.echelon.com/mini*.

If you have technical questions that are not answered by this document, the Mini FX online help, or the Mini FX ReadMe file, you can contact technical support. Free e-mail support is available or you can purchase phone support from Echelon or an Echelon support partner. See *www.echelon.com/support* for more information on Echelon support and training services.

You can also view free online training or enroll in training classes at Echelon or an Echelon training center to learn more about developing devices. You can find additional information about device development training at *www.echelon.com/training*.

You can obtain technical support via phone, fax, or e-mail from your closest Echelon support center. The contact information is as follows (check *www.echelon.com/support* for updates to this information):

Region	Languages Supported	Contact Information
The Americas	English Japanese	Echelon Corporation Attn. Customer Support 550 Meridian Avenue San Jose, CA 95126 Phone (toll-free): 1.800-258-4LON (258-4566) Phone: +1.408-938-5200 Fax: +1.408-790-3801 *lonsupport@echelon.com*
Europe	English German French Italian	Echelon Europe Ltd. Suite 12 Building 6 Croxley Green Business Park Hatters Lane Watford Hertfordshire WD18 8YH United Kingdom Phone: +44 (0)1923 430200 Fax: +44 (0)1923 430300 *lonsupport@echelon.co.uk*

Region	Languages Supported	Contact Information
Japan	Japanese	Echelon Japan Holland Hills Mori Tower, 18F 5-11.2 Toranomon, Minato-ku Tokyo 105-0001 Japan Phone: +81.3-5733-3320 Fax: +81.3-5733-3321 *lonsupport@echelon.co.jp*
China	Chinese English	Echelon Greater China Rm. 1007-1008, IBM Tower Pacific Century Place 2A Gong Ti Bei Lu Chaoyang District Beijing 100027, China Phone: +86-10-6539-3750 Fax: +86-10-6539-3754 *lonsupport@echelon.com.cn*
Other Regions	English Japanese	Phone: +1.408-938-5200 Fax: +1.408-328-3801 *lonsupport@echelon.com*

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Introduction

This chapter introduces the Mini FX Evaluation Kit. It lists the new features in the Mini kit, and it summarizes the components included with the Mini kit. It describes how to upgrade your device development environment with the NodeBuilder tool, LonMaker tool, and an activated LonScanner tool. It provides an overview of device development with the Mini kit and LONWORKS networks.

Introduction to the Mini FX Evaluation Kit

The Mini FX Evaluation Kit is a hardware and software platform for evaluating the LONWORKS® 2.0 platform and developing LONWORKS devices based on the Series 5000 and 3100 Neuron Chips and Smart Transceivers. The Mini kit lets you build Neuron C applications and download them to LONWORKS devices, and test LONWORKS devices.

You can use the Mini kit to develop prototype or production devices, particularly in the rapidly growing, price-sensitive mass markets of smart light switches, thermostats, and other simple devices and sensors.

You can use the Mini kit to do the following:

- Compile, build, and download a Neuron C device application to a development platform or to your own devices.
- Test with prototype I/O hardware on either the FT 5000 EVBs included with the Mini FX/FT Evaluation Kit and available separately, or with the PL 3150 and PL 3170 EVBs included with the Mini FX/PL Evaluation Kit and available separately, or build and test your own I/O hardware with your own custom device.
- Create a self-installed LONWORKS network and test how your device interoperates with other LONWORKS devices—or use the Mini kit with a separately purchased LonMaker® Integration Tool to create a managed LONWORKS network.
- View standard resource file definitions for standard network variable types (SNVTs), standard configuration property (SCPTs), and standard functional profiles.
- Create your own resource files with user-defined network variable types (UNVTs), user-defined configuration property (UCPTs), and user-defined functional profiles.

New Features in the Mini FX Evaluation Kit

The Mini FX Evaluation Kit adds support for Echelon's new Series 5000 chips (the term used to collectively refer to the Neuron 5000 Processor and FT 5000 Smart Transceiver), support for Echelon's new FT 5000 EVB and new PL 3170 EVB, and the following key features:

- Neuron C Version 2.2 Enhancements
- Hardware Template Editor
- Microsoft Windows Vista support

Series 5000 Chip Support

The Mini FX Evaluation Kit supports Echelon's new Neuron 5000 Processor and FT 5000 Smart Transceiver, which are designed for the LONWORKS 2.0 platform. The Series 5000 chips are faster, smaller, and cheaper that previous-generation chips, as they include the following new features and functions.

- Improved memory architecture.
- Faster system clock.
- Improved performance for arithmetic operations.
- User-programmable interrupts.
- Additional I/O model support.
- Increased network variable support (NodeBuilder tool required).
- Smaller layout

- Backwards compatibility for device applications.

Improved Memory Architecture

The Series 5000 chips have a new memory architecture that speeds up the CPU operation and lowers development and device costs. The Series 5000 chips have internal on-chip memory that includes 16 KB of ROM to store the Neuron firmware image and 64 KB of RAM (44 KB is available for application code and data). The Series 5000 chips use external serial memory (EEPROM or flash) to store your application code, configuration data, and an upgradable Neuron firmware image (the Series 5000 chips have no user-accessible on-chip non-volatile memory). The external serial EEPROM and flash memory devices communicate with Neuron 5000 Core via a serial peripheral interface bus (SPI) or Inter-Integrated Circuit (I^2C) interface. EEPROM devices can use either the SPI or I^2C interfaces; flash devices must use the SPI interface.

When a device is reset, the application code and configuration data are copied from the external non-volatile memory into the internal on-chip RAM, and the device application is then executed. The Series 5000 chips require at least 2KB of off-chip EEPROM to store configuration data, and you can use a larger capacity EEPROM device or an additional flash device (up to 64 KB) to store your application code and an upgradable Neuron firmware image.

The Series 5000 chips also include a new interrupt processor that handles user-programmable interrupts, which improves chip performance.

Note: Many types of EEPROM devices are supported; however, Echelon currently supports and provides drivers for three external flash devices: **Atmel AT25F512AN**, **STM25P05**, and **SST25VF512A**. You can configure the external non-volatile memory used by a device in the Hardware Template Editor. For more information on using the Hardware Template Editor, see Chapter 3.

Figure 1.1 illustrates the architecture of the Series 5000 chips. For more information on the memory architecture of the Series 5000 chips, see the *Series 5000 Chip Data Book*.

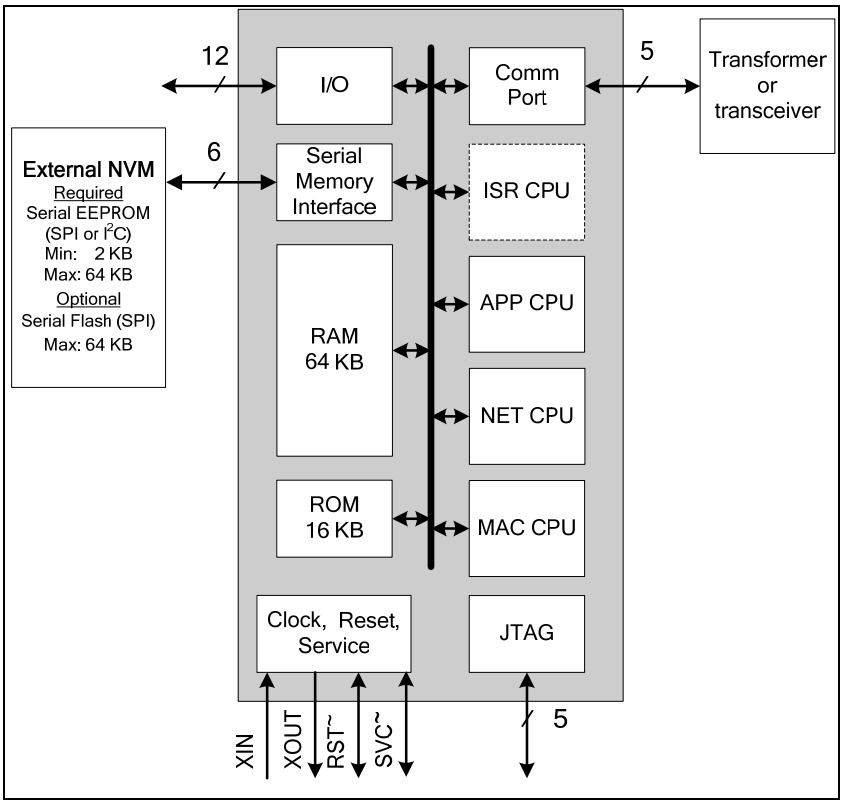


Figure 1.1 Series 5000 Chip Architecture

Faster System Clock

The Series 5000 chips support an internal system clock speed of up to 80 MHz (using an external 10 MHz crystal). This results in application processing power that equals a hypothetical FT 3150 Smart Transceiver operating at an external clock speed of 160MHz. You can adjust the internal system clock speed from 5 MHz to 80 MHz through the device's hardware template. For more information on configuring the system clock of the Series 5000 chips, see Appendix B, *Creating and Editing Hardware Templates*.

Improved Performance for Arithmetic Operations

The Series 5000 chips include 8-bit hardware multipliers and dividers, which are supported by new Neuron assembly language instructions for multiplication and division. These instructions use hardware multiply and divide functions to provide improved performance for 8-bit multiplication and division. The older software multiplication and division system functions are still supported, but many of these functions automatically benefit from these faster hardware multipliers and dividers.

User-Programmable Interrupts

The Series 5000 chips let you define user interrupts that can handle asynchronous I/O events, timer/counter events, and a dedicated, high-resolution system timer. A hardware semaphore is supplied to help you control access to data that is shared between the application (APP) and interrupt (ISR) processors on the Series 5000 chips.

At higher system clock rates (20 MHz or greater), these interrupts run in the dedicated interrupt processor (ISR) on the chip. This improves the performance of the interrupt

routines and your device application. At lower system clock rates, these interrupts run in the same application processor (APP) as the device application.

Additional I/O Model Support

The Series 5000 chips include hardware support for the Serial Peripheral Interface (SPI) and Serial Communication Interface (SCI) serial I/O models, which provide increased performance for devices that use these interfaces. The UART on the Series 5000 chips includes an increased FIFO (16 bytes), and supports software-configurable parity generation and validation (odd, even, none) for the SCI model.

Overall, the Series 5000 chips support 35 I/O models, including all of the I/O models that were previously only supported by the PL 3120, PL 3150, and PL 3170 Smart Transceivers. These I/O models include the new Infrared Pattern, Magcard Bitstream, SCI, and SPI models.

In addition, the Series 5000 chips support the Stretched Triac model, which is a new I/O model that improves performance for triac devices used with reactive loads.

Increased Network Variable Support

The Series 5000 chips can support up to 254 static network variables and 127 network variable aliases, subject to available system resources (for example, RAM and EEPROM) and application requirements. All current Series 3100 chips with Neuron firmware version 16 or better also support these increased network variable limits, subject to available memory resources.

You must build the application with the NodeBuilder FX tool to take advantage of these increased network variable limits. If you use the Mini FX Application, your device application is limited to 32 network variables.

Smaller Layout

The Series 5000 chips feature a more compact design using a 7 mm by 7 mm 48-pin quad flat no leads (QFN) packaging and 3.3V operation (I/O pins are 5V-tolerant)

Backwards Compatibility for Device Applications

The Series 5000 chips are compatible with device applications written for 3150 and 3120 Neuron Chips and Smart Transceivers. You can use the Mini kit to port your Series 3100 application to a Series 5000 chip. To do this, you open the Mini kit application and verify that the existing application can be built using Mini FX Application. If the build is successful, create a hardware template for your device based on the Series 5000 chip, and then re-build the device application using the new hardware template. See *Selecting the Hardware Template* in Chapter 4 and, Appendix B, *Creating and Editing Hardware Templates* See in Chapter 4 for more information on using the Hardware Template Editor.

Notes:

The Neuron firmware contains the implementation of the ISO/IEC 14908-1 protocol stack, the application scheduler, and many frequently used functions. The functions included in the Neuron firmware vary between firmware versions and chip models; therefore, when you rebuild an existing application for a FT 5000 Smart Transceiver, the application may have a smaller or larger memory footprint, subject to the application's use of library functions.

The Neuron C Version 2.2 language includes new keywords such as **interrupt**, **__lock**, **stretchedtriac**, **__slow**, **__fast**, and **__parity**. Some of these keywords use a double underscore prefix to avoid any likely naming collisions within existing device applications.

FT 5000 EVB Evaluation Board

The FT 5000 EVB is a complete Series 5000 LONWORKS device that you can use to evaluate the LONWORKS 2.0 platform and create LONWORKS devices. The FT 5000 EVB includes a FT 5000 Smart Transceiver with an external 10 MHz crystal (you can adjust the system's internal clock speed from 5MHz to 80MHz), an FT-X3 communication transformer, 64KB external serial EEPROM and flash memory devices, and a 3.3V power source. The FT 5000 EVB features a compact design that includes the following I/O devices that you can use to develop prototype and production devices and test the FT 5000 EVB example applications:

- 4 x 20 character LCD
- 4-way joystick with center push button
- 2 push-button inputs
- 2 LED outputs
- Light-level sensor
- Temperature sensor

The FT 5000 EVB Evaluation Board also includes EIA-232/TIA-232 (formerly RS-232) and USB interfaces that you can use to connect the board to your development computer and perform application-level debugging. You can also use the EIA-232 interface or other interfaces provided for development with the ShortStack® Developer's Kit. Note that only one interface can be used at a time.

Note: You must use the ShortStack FX Developer's Kit to develop ShortStack applications for the FT 5000 EVB. Earlier versions of the kit do not support the FT 5000 EVB.

The FT 5000 EVB supports the in-circuit programming of the external serial EEPROM and flash devices used by the FT 5000 Smart Transceiver on the FT 5000 EVB. This provides an alternative to loading application images into these external serial memory devices over the TP/FT-10 network.

The FT 5000 EVB also features a flash in-circuit emulator (ICE) header that you can use to connect an SPI flash ICE. This provides an alternative to using the external serial non-volatile memory flash device on the FT 5000 EVB.

For more information on the FT 5000 EVB hardware, including detailed descriptions of its Neuron core, I/O devices, service pin and reset buttons and LEDs, jumper settings, and in-circuit programming instructions, see the *FT 5000 EVB Hardware Guide*.

PL 3150 and 3170 EVB Evaluation Board

The PL 3170 EVB is a complete LONWORKS device that you can use to evaluate the LONWORKS 2.0 platform and create simple LONWORKS devices. The PL 3170 EVB includes a PL 3170 Smart Transceiver, which includes Interoperable Self Installation (ISI) functions built into the firmware that is stored in the on-chip ROM. This lets you create Neuron C device application that have a maximum of 4 KB code—even when using ISI functions in the application.

The PL 3150 EVB is a complete LONWORKS device that includes a PL 3150 Smart Transceiver operating at 10MHz external clock (5MHz system clock speed), 64KB of off-chip flash memory, and 2KB of on-chip RAM.

You can attach a Mini Gizmo I/O Board to the PL 3150/PL 3170 EVBs to test your device applications and test the example applications included with the Mini FX/PL Evaluation Kit.

Neuron C Version 2.2 Enhancements

The new features in the Neuron C Version 2.2 programming language include interrupt support, non-constant device-specific configuration properties, new and enhanced I/O models, and new and enhanced compiler directives. These new features are detailed in the *Neuron C Programmer's Guide* and *Neuron C Reference Guide*.

Interrupt Support

The Series 5000 chips support hardware user interrupts in addition to the support provided through I/O models. The Neuron C Version 2.2 language includes new keywords to manage hardware user interrupts and a semaphore for application programs. The Series 5000 chips support the following three types of interrupts: I/O interrupts, timer/counter driven interrupts, and periodic system interrupts.

When the Series 5000 chips are running at a system clock rate of 20 MHz or greater, these interrupts execute in the separate interrupt processor on the chips, which improves the performance of the interrupt and the device application.

Non-Constant Device-Specific Configuration Property Support

The Neuron C Version 2.2 language supports non-constant device-specific configuration properties. Non-constant device-specific configuration properties have values that can be modified by the device application, an LNS network tool such as the LonMaker® Integration Tool, or another tool not based on LNS. For example, a thermostat may include a user interface that allows the user to change the setpoint.

New and Enhanced I/O Models

The Neuron C Version 2.2 language now includes support for the stretched triac output model, and it includes some enhancements to the existing SCI and I2C I/O models.

The stretched triac output model provides improved control when driving inductive loads. The stretched triac model requires a Neuron 5000 Processor.

The SCI input/output model now supports a configurable parity bit (none, even, odd). The parity feature requires a Series 5000 chip even though the SCI model is available on some Series 3100 chips.

The I2C input/output model now supports slow and fast operation speeds for compliance with the I2C standard when operating at very high system clock speeds.

New and Enhanced Compiler Directives

The Neuron C Version 2.2 language includes new compiler directives and existing compiler directives that have been enhanced to help you develop location-independent and modular code.

You can enable and disable specific warnings using the new **#pragma enable_warning** and **#pragma disable_warning** compiler directives, and you can use the new **#error** and **#warning** compiler directives to manage conditional compilation, raising user-defined warning or error messages as necessary. You can use the new **#pragma library** directive to indicate any required library. You can use enhanced buffer control directives for statements of minimum or final requirements.

Compiler directives for control of the Neuron C Optimizer have been streamlined, and a new optimization phase for generating more compact code has been added.

Hardware Template Editor

The Mini kit now includes a Hardware Template Editor that you can use to create and configure new custom hardware templates and edit existing ones. The Hardware Template Editor can be launched from the Mini FX application, and it is available as a standalone tool.

A *hardware template* is a file with a **.NbHwt** extension that defines the hardware configuration for a target device. It specifies hardware attributes including platform, transceiver type, Neuron Chip or Smart Transceiver model, clock speed, system image, and memory configuration. Several standard hardware templates are included with the Mini kit. You can use these or create your own.

The Hardware Template Editor supports hardware templates based on any supported Neuron chip, including Series 5000 and Series 3100 chips. You use the Hardware Template Editor to map external non-volatile memory from 0x4000 to 0xE7FF in the Neuron address space (a maximum of 42 KB).

For more information on using the Hardware Template Editor, see *Selecting the Hardware Template* in Chapter 4 and, Appendix B, *Creating and Editing Hardware Templates*.

Microsoft Windows Vista Support

The Mini FX Application and online help files are compatible with Microsoft Windows Vista.

What's Included with the Mini FX Evaluation Kit

There are two Mini FX products: the *Mini FX/FT Evaluation Kit* and the *Mini FX/PL Evaluation Kit*. Table 1.1 lists the components included with the two Mini FX products:

Table 1.1 Mini FX Products

Component	Mini FX/FT Evaluation Kit	Mini FX/PL Evaluation Kit
Mini FX CD	☑	☑
Development Platforms		
FT 5000 EVB Evaluation Boards	☑	
PL 3150 EVB and PL 3170 EVB Evaluation Boards (1 each)		☑

LonScanner Protocol Analyzer CD (Demo Edition)	☑	☑
U10 or U20 USB Network Interface	☑	☑

The following sections describe each of the components.

Mini FX CD

The Mini FX CD contains the software required to build and download Neuron C applications for your LONWORKS devices, and it includes Neuron C example applications that you can run on your development platform and use to further learn how to develop your own device applications.

The Mini FX software includes the following programs:

- *Mini FX Application*. Manage Neuron C code, build Neuron C device applications, and download the device applications to your development boards. The Mini FX Application includes the following components:
  - *Hardware Template Editor*. Specify hardware attributes including platform, transceiver type, Neuron Chip or Smart Transceiver model, clock speed, system image, and memory configuration.
  - *Standard Program ID Calculator*. Specify the device's 16-hex digit program ID, which uniquely identifies the device application.
  - *Diagnostic Tool*. Reset the device application, wink a device, or get the current device status and statistics related to the device's performance.
- *NodeBuilder Resource Editor*. Provides a simple interface for viewing existing LONMARK® resources and defining your own resources. For more information on the NodeBuilder Resource Editor, see the *NodeBuilder Resource Editor User's Guide*.
- *ISI Developer's Kit*. Provides for easy development of devices that do not require installation tools. Consult the *ISI Programmer's Guide* for more information on ISI.
- *OpenLDV™ 3.4*. An API used by the Mini kit to send and receive ISO/IEC 14908-1 messages through Echelon's family of LONWORKS network interface products. The Mini FX Application and the Monitoring & Control C# example application that you can download from the Echelon Web site uses the OpenLDV API. For more information on OpenLDV, see the *OpenLDV Programmer's Guide*. You can download the *OpenLDV Programmer's Guide* and the OpenLDV Developer's Kit from the Echelon Web site at *www.echelon.com/openldv*.
- *Example Applications*. The Mini kit include three Neuron C example applications for the FT 5000 EVBs, and four Neuron C example applications for the PL 3150 EVB and PL 3170 EVB. You can use these examples to test the I/O devices on your EVBs, and create simple LONWORKS networks. You can view the Neuron C code used in the example applications, and then create a new device application by modifying the existing example applications or by developing the device application from scratch. For more information on using the FT 5000 EVB example applications, see the *FT 5000 EVB Examples Guide*. For more information on using the PL 3150 and PL 3170 example applications, see the *Mini FX/PL Examples Guide*.

  Note: Mini FX/PL users can download a Monitoring & Control C# example application from the Echelon Web site. This application monitors ISI messages and uses the OpenLDV API to monitor and control network variables on devices, including the PL 3150 and PL 3170 EVBs, running the MGDemo example.

Development Platforms

The Mini FX/FT Evaluation Kit includes two FT 5000 EVBs. The Mini FX/PL Evaluation Kit includes one PL 3150 EVB and one PL 3170 EVB. The following sections describe these development platforms.

FT 5000 EVB Evaluation Board

The FT 5000 EVB is a complete Series 5000 LONWORKS device that you can use to evaluate the LONWORKS 2.0 platform and create LONWORKS devices. The FT 5000 EVB includes an FT 5000 Smart Transceiver with an external 10 MHz crystal (you can adjust the system's internal clock speed from 5MHz to 80MHz), an FT-X3 communication transformer, 64KB external serial EEPROM and flash memory devices, and a 3.3V power source. The FT 5000 EVB features a compact design that includes the following I/O devices that you can use to develop prototype and production devices and test the FT 5000 EVB example applications:

- 4 x 20 character LCD
- 4-way joystick with center push button
- 2 push-button inputs
- 2 LED outputs
- Light-level sensor
- Temperature sensor

Figure 1.2 FT 5000 EVB

PL 3150 and PL 3170 EVB Evaluation Boards

The Mini FX/PL Evaluation Kit includes one PL 3150 EVB and one PL 3170 EVB. The PL 3150 and 3170 EVBs utilize Echelon's Power Line Smart Transceivers to signal over any AC or DC power circuit, eliminating any need for additional wiring. The power

supplies included with the PL 3150 and 3170 EVBs pass the network signals directly into the AC power lines over the same two wires that power the evaluation boards. With the PL 3150 and 3170 EVBs, you can begin building a power line control network by simply plugging the evaluation boards into an electrical outlet. You can also attach the included Mini Gizmo I/O Boards to the PL 3150/PL 3170 EVBs to test your device applications and run the example applications included with the Mini FX/PL Evaluation Kit.

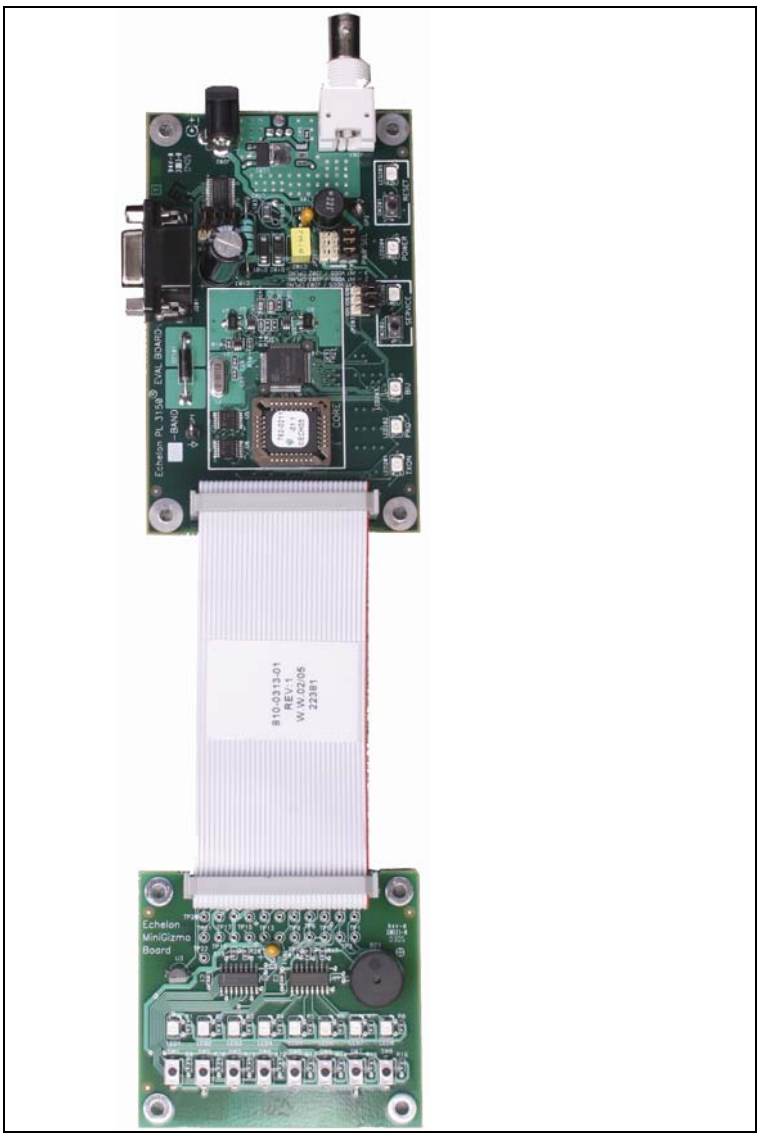


Figure 1.3 PL 3150/PL 3170 EVB (top) and Mini Gizmo I/O Board (bottom)

LonScanner Protocol Analyzer CD (Demo Edition)

The LonScanner Protocol Analyzer is a software package that provides network diagnostic tools to observe, analyze, and diagnose the behavior of installed LONWORKS networks, including network with devices that you have built with the Mini kit. A demo version of the LonScanner Protocol Analyzer is included with your Mini kit. It is not required to use the Mini kit, but the protocol analyzer will make your development and integration efforts more productive. You can use the LonScanner tool with the U10 or U20 USB network interface included with the Mini FX/FT and Mini FX/PL kits, and you

also use it with other network interfaces including an IP-852 (ISO/IEC 14908-4) interface as described in the *LonScanner Protocol Analyzer User's Guide*.

The LonScanner tool included with the Mini kit will run in demo mode until you purchase a key and activate it. When operating in demo mode, the protocol analyzer does not display every captured packet and displays only the first 20 packets of a saved or imported log file. In addition, the LonScanner License Activation dialog will appear every time you open the protocol analyzer, and give you the option to activate your LonScanner software. For more information on the LonScanner tool, including how to purchase a key activate the software, see the *LonScanner Protocol Analyzer User's Guide*.

U10/U20 USB Network Interface

The Mini FX/FT Evaluation Kit and Mini FX/PL Evaluation Kit include U10 and U20 USB network interfaces, respectively. The U10 and U20 USB Network Interfaces are low-cost, high-performance LONWORKS interfaces for USB-enabled computers and controllers.

The U10 USB Network Interface connects directly to a TP/FT-10 Free Topology Twisted Pair (ISO/IEC 14908-2) LONWORKS channel through a high-quality removable connector.

The U20 USB Network Interface connects to a PL-20 C-Band Power Line (ISO/IEC 14908-3) LONWORKS channel through an included power supply with integrated coupler. The U20 USB Network Interface can also be connected directly to 10.8-18VDC power systems (such as those in automobiles, trucks and buses) without a coupling circuit, or to virtually any powered line through a customer-supplied coupler/power supply.

The USB Network Interfaces can be used with virtually any computer-based LONWORKS application, including all LNS and OpenLDV based applications such as the Mini kit, NodeBuilder tool, LonMaker tool, and LonScanner tool. Drivers for the U10 and U20 USB Network Interfaces are automatically installed when you install the Mini FX software.

For more information on installing and using the U10 and U20 USB network interfaces, see the *LONWORKS USB Network Interface User's Guide*.

Upgrading the Development Environment

You can upgrade your device development environment with the NodeBuilder FX Development Tool or the LonMaker tool, or by activating the LonScanner tool included with your Mini kit. The following sections describe the features provided by each tool, and how they can improve your device development projects.

Upgrading to the NodeBuilder FX Tool

You can upgrade your Mini kit to the NodeBuilder FX Development Tool to build larger device applications and build them faster in an integrated development environment with a source-level debugger. The NodeBuilder FX Development Tool also provides free activation of the included LonMaker and LonScanner tools. The NodeBuilder tool includes the following components to help speed up your device development projects:

- *Code Wizard*. Use a drag-and-drop interface to create your device's interface and then automatically generate Neuron C source code that implements the device interface and creates the framework for your device application.
- *Code Editor*. Edit the Neuron C source code generated by the Code Wizard to create your device's application.

- *Debugger*. Debug your application with a source-level view of your application code as it executes. The debugger lets you control and observe the behavior of your device application over a LONWORKS channel. The debugger lets you set breakpoints, monitor network variables, halt the application, step through the application, view the call stack, and peek and poke memory. You can make changes to the code as you debug a single device or debug multiple devices simultaneously.
- *Project Manager*. Build and download your application image to your development platform or to your own device hardware.
- *LonMaker® Integration Tool*. Install, connect, configure, test, and update the devices in your project using an LNS based application that combines a powerful, client-server architecture with an easy-to-use Visio user interface. For more information, see the *LonMaker User's Guide*.

  Activation of the LonMaker tool included with the NodeBuilder FX Development Tool is free.
- *LonScanner Protocol Analyzer (LNS Turbo Edition)*. Observe, analyze, and diagnose the behavior of installed LONWORKS networks, including network with devices that you have built with the Mini kit or NodeBuilder tool. For more information, see the *LonScanner Protocol Analyzer User's Guide*

  Activation of the LonScanner tool included with the NodeBuilder FX Development Tool is free.
- *LNS Plug-in Framework Developer's Kit*. Write LNS device plug-ins in .NET programming languages such as C# and Visual Basic .NET and re-distribute them. For more information, see the *LNS®Plug-in Programmer's Guide*.

Table 1.2 compares the Mini kit to the NodeBuilder FX tool.

Table 1.2 Comparison of the Mini Kit to the NodeBuilder Tool

Feature	**Mini FX Evaluation Kit**	**NodeBuilder FX Tool**
Neuron C Compiler	☑	☑
Network Variables per Device (maximum number)	32	254[a]
Network Variables Aliases per Device (maximum number)	32	127[a]
Application Code and Constant Data per Device (maximum size in KB)	32	44
Integrated Development Environment	☐	☑
Code Wizard	☐	☑
Code Editor	☐	☑
Debugger	☐	☑
Project Manager	☐	☑
LonMaker Tool	☐	☑

Feature	Mini FX Evaluation Kit	NodeBuilder FX Tool
LonScanner Protocol Analyzer (Demo Edition)	☑	☐
LonScanner Protocol Analyzer (LNS Turbo Edition)	☐	☑
LNS Plug-in Framework Kit	☐	☑

[a] The NodeBuilder FX tool supports up to 254 static network variables and 127 network variable aliases for Neuron-hosted devices that use version 16 firmware or greater (for example, the Series 5000 chips, which use version 18 firmware). This limit is subject to available system resources (for example, RAM and EEPROM) and application requirements.

When you upgrade to the NodeBuilder tool, you can use your existing development hardware, and you can incorporate the Neuron C source files, library files, and hardware templates you developed with the Mini kit into your NodeBuilder projects.

Note: The Mini kit build process requires the automatic creation of NodeBuilder device template files. The Mini kit uses the name of the Neuron C source file as the name of the device template file. For example, compiling the **myDeviceApplication.nc** source file with the Mini FX Application leads to the creation of a hidden **myDeviceApplication.nbdt** device template file.

To use the same device template file for both the Mini and NodeBuilder build processes, specify different names for the source file and the device template when you build the source file with NodeBuilder tool. Possible conflicts resulting from the sharing of the same NodeBuilder device template file can be resolved by viewing and editing the device template preferences in the NodeBuilder tool.

For more information on the NodeBuilder tool, see the NodeBuilder Web page at *www.echelon.com/nodebuilder*. For more information on ordering the NodeBuilder tool, contact your Echelon sales representative.

Upgrading to the LonMaker Tool

You can use the Mini kit to create self-installed devices, which do not require a network management tool such as the LonMaker tool. The Mini kit supports standalone applications (which may not require any network management), and self-installed applications using the ISI protocol.

For more complex networks and applications that do require a network management tool, you can use the LonMaker tool to install your development devices in a network, and then configure, monitor, and test those devices. The LonMaker tool includes the following features that you can use to test the Neuron C device applications you have developed with the Mini kit: the LonMaker Browser, Data Point shapes, the LonMaker Device Manager, and connection monitoring.

The LonMaker Browser is a standalone application that monitors all the network outputs from your device and allows you to control all the network inputs to your device. You can open the LonMaker Browser on any device or functional block in the network. The LonMaker Browser displays all the network variables and configuration properties for the selected network variables and configuration properties. You can change the value of any of the input network variables or writeable configuration properties.

The Data Point shape provides similar functionally as the LonMaker Browser, but directly in your LonMaker drawing. The Data Point shape is a LonMaker Basic Shape that you can add to your LonMaker drawing to monitor and control individual network variables and configuration properties in your device. You can use a Data Point shape to monitor the value of any input or output network variable, configuration property, or functional block state (enabled or in override). You can also use a Data Point shape to control the value of an input network variable or a configuration property. You can also use Data Point shapes to create simple human-machine interface (HMI) applications for your development devices within your LonMaker drawing.

The LonMaker Device Manager allows you to control the state of your device and its functional blocks. You can use the device manager to reset your device, put your device online or offline, and test network communication with your device. You can also use the Device Manager to enable or disable individual functional blocks on your device, and to invoke the self-test function of any of your functional blocks that support self-test.

The LonMaker tool allows you to connect the network variables in your devices, and then monitor those connections on the same page that you created the connections. You can use monitored connections to view the values of network variables on your LonMaker drawing. This feature is useful for monitoring and debugging your device because monitored connections provide an easy way to visualize the flow of data through your functional blocks.

Note: You cannot simultaneously use the same network interface with both the LonMaker tool and the Mini FX Application. The Mini FX Application is an OpenLDV application; therefore, it cannot share a network interface with other LONWORKS applications. This means that when the Mini FX Application is attached to a network interface, network tools such as the LonMaker tool cannot use that network interface at the same time, and vice versa. To avoid network interface conflicts, you can use the LonMaker tool to download and test device applications that you have compiled with the Mini FX Application, or you can use separate network interfaces for the LonMaker tool and the Mini FX Application.

Activating the LonScanner Tool

You can purchase a key to activate the LonScanner tool that is included with your Mini kit. Once you activate your LonScanner tool, you can view every captured packet transmitted and received by you development device and view all entries in saved or imported log files.

Introduction to Mini FX Device Development and LONWORKS Networks

A LONWORKS network consists of intelligent *devices* (such as sensors, actuators, and controllers) that communicate with each other using a common *protocol* over one or more *communications channels*. Network devices are sometimes called *nodes*.

Devices may be *Neuron hosted* or *host-based*. Neuron hosted devices run a compiled Neuron C application on a Neuron Chip or Smart Transceiver. You can use the Mini kit to develop, test, and debug Neuron C applications for Neuron hosted devices.

Host-based devices run applications on a processor other than a Neuron Chip or Smart Transceiver. Host-based devices may run applications written in any language available to the processor. A host-based device may use a Neuron Chip or Smart Transceiver as a

communications processor, or it may handle both application processing and communications processing on the host processor. The Mini kit supports some of the common tasks occurring in the creation of host-based devices; however, an additional host-based device development tool, such as the ShortStack® FX or the FTXL™ Developer's Kit combined with a host development tool, is required.

Each device includes one or more processors that implement the ISO/IEC 14908-1 Control Network Protocol (CNP). Each device also includes a *transceiver* to provide its interface to the communications channel.

A device publishes and consumes information as instructed by the application that it is running. The applications on different devices are not synchronized, and it is possible that multiple devices may all try to talk at the same time. Meaningful transfer of information between devices on a network, therefore, requires organization in the form of a set of rules and procedures. These rules and procedures are the *communication protocol*, which may be referred to simply as the *protocol*. The protocol defines the format of the messages being transmitted between devices and defines the actions expected when one device sends a message to another. The protocol normally takes the form of embedded software or firmware code in each device on the network. The CNP is an open protocol defined by the ISO/IEC 14908-1 standard (defined nationally in the United States, Europe, and China by the ANSI/EIA 709.1, EN 14908, and GB/Z 20177 standards, respectively).

Channels

A *channel* is the physical media between devices upon which the devices communicate. The CNP is media independent; therefore, numerous types of media can be used for channels: twisted pair, power line, fiber optics, IP, and radio frequency (RF) to name a few. Channels are categorized into *channel types,* and the channel types are characterized by the device transceiver. Common channel types include TP/FT-10 (ISO/IEC 14908-2 twisted pair free topology channel), TP/XF-1250 (high-speed twisted pair channel), PL-20 (ISO/IEC 14908-3 power line channel), FO-20 (ANSI/CEA-709.4 fiber optics channel), and IP-852 (ISO/IEC 14908-4 IP-communication).

Different transceivers may be able to interoperate on the same channel; therefore, each transceiver type specifies the channel type or types that it supports. The choice of channel type affects transmission speed and distance as well as the network topology.

The Mini kit, LonMaker tool, and LonScanner tool, and Neuron chips support all standard channel types, but not all Neuron chips support all transceiver and channel types. Smart Transceivers combine the transceiver and Neuron chip core in the same chip, and therefore support the channel types supported by the integrated transceiver.

Routers

Multiple channels can be connected using *routers*. Routers are used to manage network message traffic, extend the physical size of a channel (both length and number of devices attached), and connect channels that use different media (channel types) together. Unlike other devices, routers are always attached to at least two channels.

The Mini kit does not install routers, but it can be used on networks with routers installed by the LonMaker tool or other network management tool.

Applications

Every LONWORKS device contains an *application* that defines the device's behavior. The application defines the inputs and outputs of the device. The inputs to a device can include information sent on LONWORKS channels from other devices, as well as information from the device hardware (for example, the temperature from a temperature sensing device). The outputs from a device can include information sent on LONWORKS channels to other devices, as well as commands sent to the device hardware (for example, a fan, light, heater, or actuator). You can use the Mini kit to write a device's Neuron C application.

Program IDs

Every LONWORKS application has a unique, 16 digit, hexadecimal standard program ID with the format **FM:MM:MM:CC:CC:UU:TT:NN**. Table 1.3 provides a break down of the fields within the program ID.

Table 1.3 Program ID Fields

Field	Description
Format (F)	A 1 hex-digit value defining the structure of the program ID. The upper bit of the format defines the program ID as a *standard program ID (SPID)* or a *text program ID*. The upper bit is set for standard program IDs, so formats 8–15 (0x8–0xF) are reserved for standard program IDs. • Program ID format 8 is reserved for LONMARK certified devices. • Program ID format 9 is used for devices that will not be LONMARK certified, or for devices that will be certified but are still in development or have not yet completed the certification process. • Program ID formats 10–15 (0xA–0xF) are reserved for future use. Text program ID formats are used by network interfaces and legacy devices and, with the exception of network interfaces, should not be used for new devices. The Mini kit can be used to create applications with program ID format 8 or 9.
Manufacturer ID (M)	A 5 hex-digit ID that is unique to each LONWORKS device manufacturer. The upper bit identifies the manufacturer ID as a *standard manufacturer ID* (upper bit clear) or a *temporary manufacturer ID* (upper bit set). • Standard manufacturer IDs are assigned to manufacturers when they join LONMARK International, and are also published by LONMARK International so that the device manufacturer of a LONMARK certified device is easily identified. Standard manufacturer IDs are never reused or reassigned. If your company is a LONMARK member, but you do not know your

Field	Description
	manufacturer ID, you can find your ID in the list of manufacturer IDs at *www.lonmark.org/spid*. The most current list at the time of release of the Mini kit is also included with the Mini kit software. • Temporary manufacturer IDs are available at no charge to anyone on request by filling out a simple form at *www.lonmark.org/mid*.
Device Class (C)	A 4 hex-digit value identifying the primary function of the device. This value is drawn from a registry of pre-defined device class definitions. If an appropriate device class designation is not available, LONMARK International Secretary will assign one, upon request.
Usage (U)	A 2 hex-digit value identifying the intended usage of the device. The upper bit specifies whether the device has a changeable interface. The next bit specifies whether the remainder of the usage field specifies a standard usage or a functional-profile specific usage. The standard usage values are drawn from a registry of pre-defined usage definitions. If an appropriate usage designation is not available one will be assigned upon request. If the second bit is set, a custom set of usage values is specified by the primary functional profile for the device.
Channel Type (T)	A 2 hex-digit value identifying the channel type supported by the device's LONWORKS transceiver. The standard channel-type values are drawn from a registry of pre-defined channel-type definitions. A custom channel-type is available for channel types not listed in the standard registry.
Model Number (N)	A 2 hex-digit value identifying the specific product model. Model numbers are assigned by the product manufacturer and must be unique within the device class, usage, and channel type for the manufacturer. The same hardware may be used for multiple model numbers depending on the program that is loaded into the hardware. The model number within the program ID does not have to conform to your published model number. See the *LonMark Application Layer Interoperability Guidelines* for more information about program IDs.

Network Variables

Applications exchange information with other LONWORKS devices using *network variables*. Every network variable has a *direction* and a *type*. The network variable direction can be either input or output, depending on whether the network variable is used to receive or send data. The network variable type determines the format of the data.

Network variables of identical type but opposite directions can be connected to allow the devices to share information. For example, an application on a lighting device could have

an input network variable that was of the switch type, while an application on a dimmer-switch device could have an output network variable of the same type. A network management tool such as the LonMaker Integration Tool could be used to connect these two devices, allowing the switch to control the lighting device, as shown in Figure 1.4:

Figure 1.4 Network Variable Connection

A single network variable may be connected to multiple network variables of the same type but opposite direction. Figure 1.5 shows the same switch being used to control three lights:

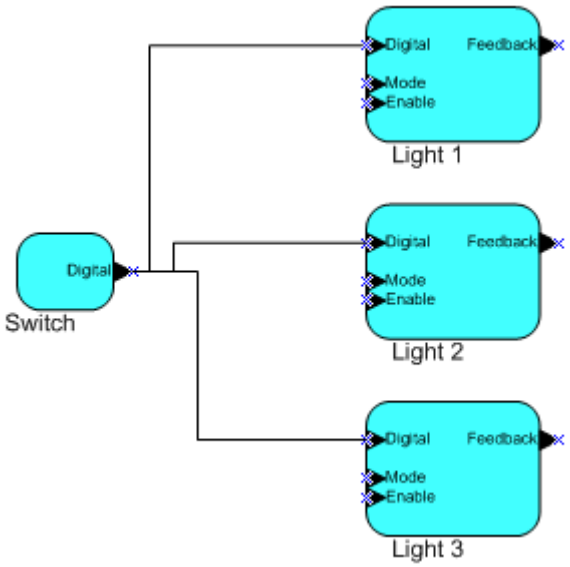


Figure 1.5 Network Variable Fan-Out Connection

The application program in a device does not need to know where input network variable values come from or where output network variable values go. When the application program has a changed value for an output network variable, it simply assigns the new value to the output network variable.

Through a process called *binding* that takes place during network design and installation, the device is configured to know the logical address of the other device or group of devices in the network expecting that network variable's values. The device's embedded firmware assembles and sends the appropriate packet(s) to these destinations. Similarly, when the device receives an updated value for an input network variable required by its application program, its firmware passes the data to the application program. The binding process thus creates logical *connections* between an output network variable in one device and an input network variable in another device or group of devices.

Connections may be thought of as virtual wires. For example, the dimmer-switch device in the dimmer-switch-light example could be replaced with an occupancy sensor, without making any changes to the lighting device.

You can declare a maximum of 32 network variables in a Neuron C application to be compiled with the Mini kit. The NodeBuilder FX Development Tool supports up to 254 network variables.

If you are creating a device to be used in a managed network, you typically don't need implement any code in the device application to handle the binding process, or the source or destination devices for network variable values. If you are creating a device to be used in a self-installed network, you need to implement code to support the enrollment process, which is how you create network variable connections in such a network. Neuron C provides an easy-to-use programming model familiar to any C language programmer that encapsulates the complexity of distributed applications.

Configuration Properties

LONWORKS applications may also contain *configuration properties*. Configuration properties allow the device's behavior to be customized using a network management tool such as the LonMaker tool or a customized plug-in created for the device (see the *LNS Plug-in Programmer's Guide* for more information on creating LNS device plug-ins).

For example, an application may allow an arithmetic function (add, subtract, multiply, or divide) to be performed on two values received from two network variables. The function to be performed could be determined by a configuration property. Another example of a configuration property is a heartbeat interval setting that determines how often a device transmits network variable updates over the network.

Like network variables, configuration properties have types that determine the type and format of the data they contain.

You will need to declare the required configuration properties for your device's Neuron C application. The Mini kit supports configuration properties with an easy-to-use programming model in Neuron C.

Functional Blocks

Applications in devices are divided into one or more *functional blocks*. A functional block is a collection of network variables and configuration properties, which are used together to perform one task. These network variables and configuration properties are called the *functional block members*. For example, a digital input device could have four digital input functional blocks that contain the configuration properties and output network variable members for each of the four hardware digital inputs on the device. You will need to declare the required functional blocks for your device's Neuron C application. A functional block is an implementation of a functional profile.

Functional Profiles

A *functional profile* defines mandatory and optional network variable and configuration property members for a type of functional block. For example, the standard functional profile for a light actuator has mandatory **SNVT_switch** input and output network variables, optional **SNVT_elapsed_tm** and **SNVT_elec_kwh** output network variables, and a number of optional configuration properties. Figure 1.6 illustrates the components of the standard light actuator functional profile:

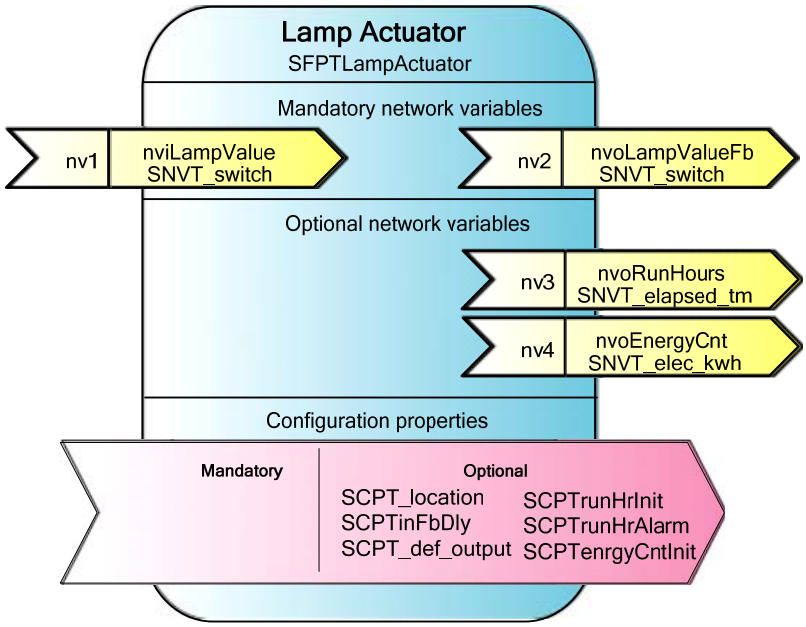


Figure 1.6 Functional Profile

When a functional block is created from a functional profile, the application designer can determine which of the optional configuration properties and network variables to implement. With some functional profiles, you can control certain aspects of the implementation such as the network variable type, or the size of a configuration property array.

Hardware Templates

A *hardware template* is a file with a **.NbHwt** extension that defines the hardware configuration for a device. It specifies hardware attributes that include the transceiver type, Neuron Chip or Smart Transceiver model, clock speed, system image, and memory configuration. Several hardware templates are included with the Mini kit. You can use these or create your own. Third-party development platform suppliers may also include hardware templates for their platforms.

Neuron C

Neuron C is a programming language, based on ANSI C, used to develop applications for devices that use a Neuron Chip or Smart Transceiver as the application processor. Neuron C includes extensions for network communication, device configuration, hardware I/O, interrupt handling, and event-driven scheduling.

Device Templates

A *device template* defines a device type. The Mini kit generates a NodeBuilder device template (**.NbDt** extension) that specifies the information required for the NodeBuilder tool to build the application for a device. It contains a list of the application Neuron C source files, device-related preferences, and the hardware template name. The NodeBuilder device template is automatically generated, managed, and removed by the Mini FX application, unless a matching NodeBuilder device template already exists (for example, an existing NodeBuilder project includes the device template). In this case,

Mini kit will upgrade this device template as necessary, but it will not delete or manage it.

If you build the application with the NodeBuilder tool, the NodeBuilder tool automatically produces an *LNS device template* and passes it to the LonMaker tool and other network tools. The LNS device template defines the external device interface, and it is used by the LonMaker tool and other network tools to configure and bind the device. The Mini kit does not generate LNS device templates, but it generates device interface files (with **.XIF** and **.XFB** extensions). These interface files can be used with the LonMaker tool to generate LNS device templates.

Device Interface Files

A *device interface file* (also known as an *XIF file* or an *external interface file*) is a file that specifies the interface of a device. It includes a list of all the functional blocks, network variables, configuration properties, and configuration property default values defined by the device's application. LNS tools such as the LonMaker tool use device interface files to create an *LNS device template*. This enables the network tool to be used to create network designs without being connected to the physical devices, and it speeds up some configuration steps when the network tool is connected to the physical device. A text device interface file with a **.XIF** extension is required by the *LonMark Application Layer Interoperability Guidelines*.

The Mini kit automatically creates a **.XIF** file when you build a device application. The Mini kit also automatically creates a binary (**.XFB** extension) version of the device interface file that speed the import process for LNS tools such as the LonMaker tool.

Resource Files

Resource files define network variable types, configuration property types, and functional profiles. Resource files for standard types and profiles are distributed by LONMARK International. The standard resource files define standard network variable types (SNVTs), standard configuration property types (SCPTs), and standard functional profiles. For example, **SCPTlocation** is a standard configuration property type for configuration properties containing location information as a text string, and **SNVT_temp_f** is a network variable type for network variables containing temperature as a floating-point number. The standard network variable and configuration property types are defined at *types.lonmark.org*.

As new SNVTs and SCPTs are defined, updated resource files and documentation are posted to the LONMARK Web site. Standard functional profiles are included with the Mini kit, and their documentation is also available on the LONMARK Web site. To view and download the latest resource files and documentation, go to the LONMARK Web site at *www.lonmark.org*.

Device manufacturers may also create user resource files that contain manufacturer-defined types and profiles called user network variable types (UNVTs), user configuration property types (UCPTs), and user functional profiles (UFPTs).

You can create applications that only use the standard types and profiles. In this case, you do not need to create user-defined resource files. If you need to define any new user types or profiles, you will use the *NodeBuilder Resource Editor* included with the Mini kit to create them.

2

Installing the Mini FX Evaluation Kit

This chapter describes how to get started with your Mini kit, including how to install the Mini FX software and connect the Mini FX hardware.

Installing the Mini FX Evaluation Kit

To install your Mini FX Evaluation Kit, follow these steps:

1. Verify that you have a manufacturer ID. A manufacturer ID is required for many Mini kit functions.

   Standard manufacturer IDs are assigned to manufacturers when they join LONMARK International, and are also published by LONMARK International so that the device manufacturer of a LONMARK certified device is easily identified. If your company is a LONMARK member, but you do not know your manufacturer ID, you can go to *www.lonmark.org/spid* and find your ID in the list of manufacturer IDs. The most current list at the time of release of the Mini kit is also included with the Mini kit software.

   If you do not have a manufacturer ID, you can instantly get a temporary manufacturer ID by filling out a simple form at *http://www.lonmark.org/mid*.

2. Register your Mini kit. This entitles you to a free replacement CD or serial number if you lose either one in the future. To register your Mini kit, go to *www.echelon.com/register*, select the Mini FX Evaluation Kit product, enter the serial number from the back of your Mini FX CD case, enter the other information requested by the form, and then click **Register Now**.

3. A demo version of the LonScanner Protocol Analyzer is included with your Mini kit. It is not required to use the Mini kit, but the protocol analyzer will make your development and integration efforts more productive. To try the demo version, insert the **LonScanner Protocol Analyzer CD** into your computer, install the LonScanner software, and then optionally purchase an activation key and activate the LonScanner software as described in the *LonScanner Protocol Analyzer User's Guide*.

   Note: If you plan on installing the LonScanner software, you must install it before installing the Mini FX software. If you install the LonScanner software after installing the Mini FX software, re-install the Mini FX software and chose the Repair option when prompted.

4. Insert the **Mini FX CD** into your computer and install the Mini FX software as described in the next section, *Installing the Mini FX Software*. You must install Microsoft .NET Framework 3.5 SP1 before installing the Mini FX Evaluation Kit. Optionally, you can install Adobe Reader 9.1, the provided FTDI USB driver if you plan on using the USB port on the Mini FX/FT hardware (FT 5000 EVB) for debugging, and the SLTA-10 driver if you are using an SLTA-10 Serial LonTalk Adapter as the network interface.

   Note: The Mini FX software automatically installs the following programs on your computer: NodeBuilder Resource Editor 4.0, LONMARK Resource Files 13.00, OpenLDV 3.40, and ISI Developer's Kit 3.02.

5. Connect the Mini FX hardware as described in *Connecting the Mini FX Hardware* later in this chapter.

Installing the Mini FX Software

To install the Mini FX software, follow these steps:

1. Insert the **Mini FX Evaluation Kit CD** into your CD-ROM drive.

2. If the Mini FX setup application does not launch immediately, click **Start** on the Windows taskbar and then and click **Run**. Browse to the Setup application on the Mini FX CD and click **Open**. The **Echelon Mini FX Evaluation Kit** main menu opens.

Figure 2.1 Mini FX Evaluation Kit Main Menu

3. Click **Install Products**. The **Install Products** dialog opens.

Figure 2.2 Mini FX Evaluation Kit Install Products Dialog

4. Click **Microsoft .NET Framework 3.5 SP1** to install Microsoft .NET Framework 3.5 SP1 and then follow the on-screen instructions. Microsoft .NET Framework 3.5 SP1 is required to run the Mini FX Application.

5. After Microsoft .NET Framework 3.5 SP1is installed, click the Echelon Mini FX Evaluation Kit button in the taskbar to return to the Mini FX installer, and then click **Mini FX Evaluation Kit** in the **Install Products** dialog. The Welcome window of the Mini FX software installer opens.

Figure 2.3 Mini FX Evaluation Kit Installer—Welcome Dialog

6. Click **Next**. The Mini FX Evaluation Kit License Agreement window opens.

Figure 2.4 Mini FX Evaluation Kit Installer—License Agreement

7. Read the license agreement (see Appendix C, *Mini FX Software License Agreement*, for a printed version of this license agreement). If you agree with the terms, click **Accept the Terms** and then click **Next**. The Customer Information window appears.

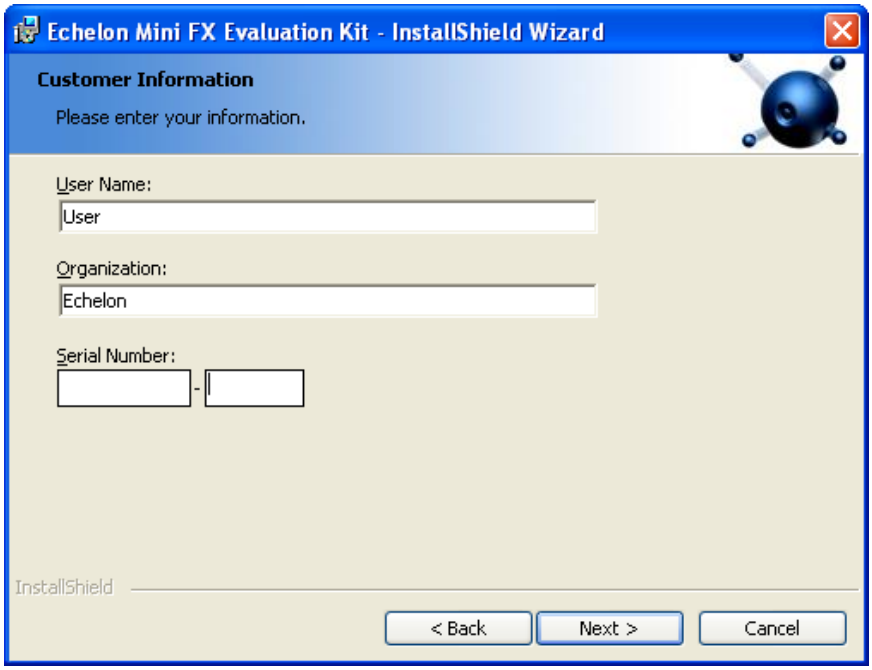


Figure 2.5 Mini FX Evaluation Kit Installer—Customer Information

8. Enter the Mini FX serial number on the back of Mini FX Evaluation Kit CD in the **Serial Number** box. Optionally, you can enter the following registration information.

User Name	Your name. The name may be entered automatically based on the user currently logged on and whether other Echelon products are installed on your computer.
Organization	The name of your company. The name may be entered automatically based on the user currently logged on and whether other Echelon products are installed on your computer.

9. Click **Next**. If your computer does not have a LONWORKS directory, the Destination Location window appears. Choose a LONWORKS folder in which you want the Mini FX software installed. By default, the Mini FX software is installed in your existing LONWORKS folder, which is typically **C:\LONWORKS**, or **C:\Program Files\LONWORKS** if you have not previously installed any Echelon or LONMARK products. Click **Next**.
10. The Setup Type window opens.

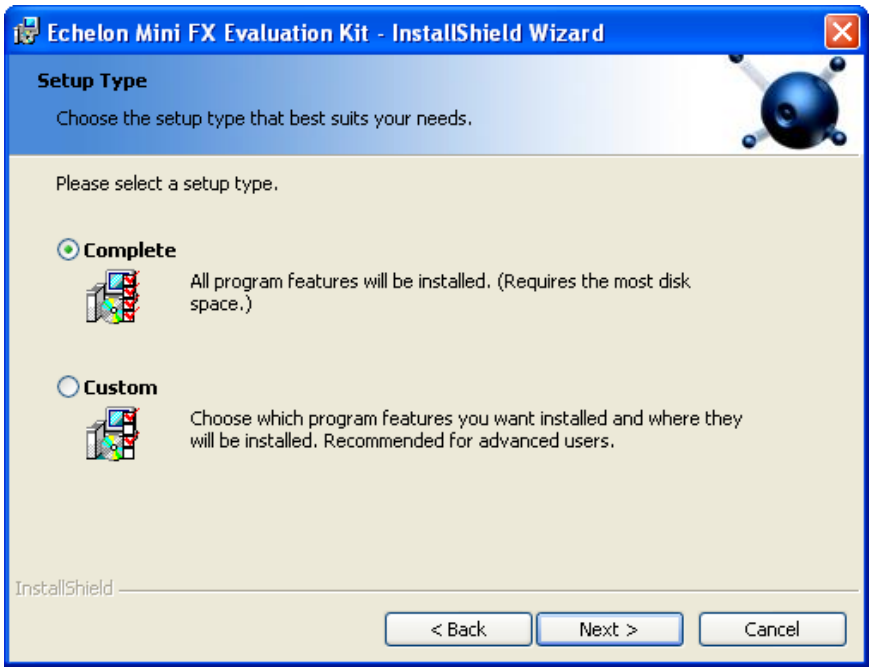


Figure 2.6 Mini FX Evaluation Kit Installer—Setup Type

11. Select the type of installation to be performed. Select **Complete** to install all the Mini kit features or select **Custom** to choose whether to install the FT 5000 EVB examples, Mini EVB examples, both sets of examples, or neither on your computer. Click **Next**. The Ready to Install window appears.

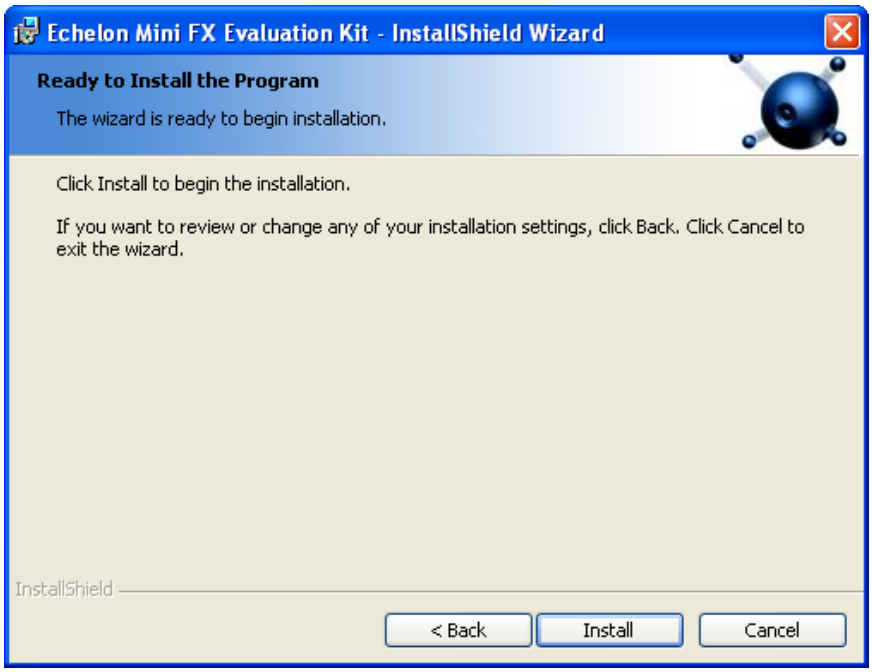


Figure 2.7 Mini FX Evaluation Kit Installer—Ready to Install

12. Click **Install** to begin the Mini FX software installation. Before the Mini FX Evaluation Kit is installed, the following programs are automatically installed or upgraded on your computer (if they are not already installed on your computer, or if

they are installed, but have a lower version): ISI Developer's Kit 3.02, OpenLDV 3.40, NodeBuilder Resource Editor 4.0, and LONMARK Resource Files 13.00.

13. After the Mini kit software has been installed, a window appears stating that the installation has been completed successfully.

Figure 2.8 Mini FX Evaluation Kit Installer—Completed

14. Click **Finish**. If a window appears prompting you to reboot your computer now or later, click **Yes** to reboot your computer now.
15. Once the installation has completed, you will be given the option to view the **ReadMe** file. See the ReadMe file for updates to the Mini kit documentation.
16. Optionally, install Adobe Reader 9.1. Adobe Reader (or another PDF viewer) is required to open the user documentation PDF files included with the Mini FX software. To do this, click the Echelon Mini FX Evaluation Kit button in the taskbar to return to the Mini FX installer, click **Adobe Reader 9.1** in the **Install Products** dialog, and then follow the on-screen instructions.
17. Optionally, install the FTDI USB driver if you plan on using the USB port on the FT 5000 EVB for application-level debugging. To do this, click the Echelon Mini FX Evaluation Kit button in the taskbar to return to the Mini FX installer, and then click **FTDI USB Driver 2.04.06** in the **Install Products** dialog.
18. Optionally, install the SLTA-10 driver if you plan on using an SLTA-10 Serial LonTalk Adapter as the network interface. To do this, click the Echelon Mini FX Evaluation Kit button in the taskbar to return to the Mini FX installer, and then click **SLTA-10 Driver** in the **Install Products** dialog.

Connecting the Mini FX Hardware

The following sections describe how to connect the Mini FX/FT hardware (FT 5000 EVBs) and the Mini FX/PL hardware (PL 3150 and PL 3170 EVBs).

Connecting the Mini FX/FT Hardware

To connect the Mini FX/FT hardware, follow these steps:

1. Unpack the equipment from the shipping carton.

   Note: The FT 5000 EVBs are shipped in protective anti-static packaging. When assembling the FT 5000 EVBs, the boards must not be subjected to high electrostatic potentials. Avoid touching the component pins, or any other metallic equipment on the evaluation boards.

2. Verify that all of the following hardware and software items listed in Table 2.1 are present.

Table 2.1 Mini FX/FT Evaluation Kit Hardware and Software Items

Item	Qty
FT 5000 EVB	2
Power supplies (90–240VAC 50/60Hz) with power cords (US/Japan and Continental European)	2
Network cable and terminator	1
U10 USB Network Interface	1
USB Extension Cable	1
Mini FX CD	1
LonScanner CD (Demo Edition)	1

3. Connect the barrel connectors of the included power supplies into the barrel jacks on the FT 5000 EVBs, connect the power supplies to the included power cords that are appropriate for you region (US/Japan or Continental European), and then plug the power cords into a power outlet. The power LEDs on the boards will activate when they are powered on.

Figure 2.9 FT 5000 EVB Power Supply Connection

4. Connect the orange network connector on each FT 5000 EVB to the included network cable.

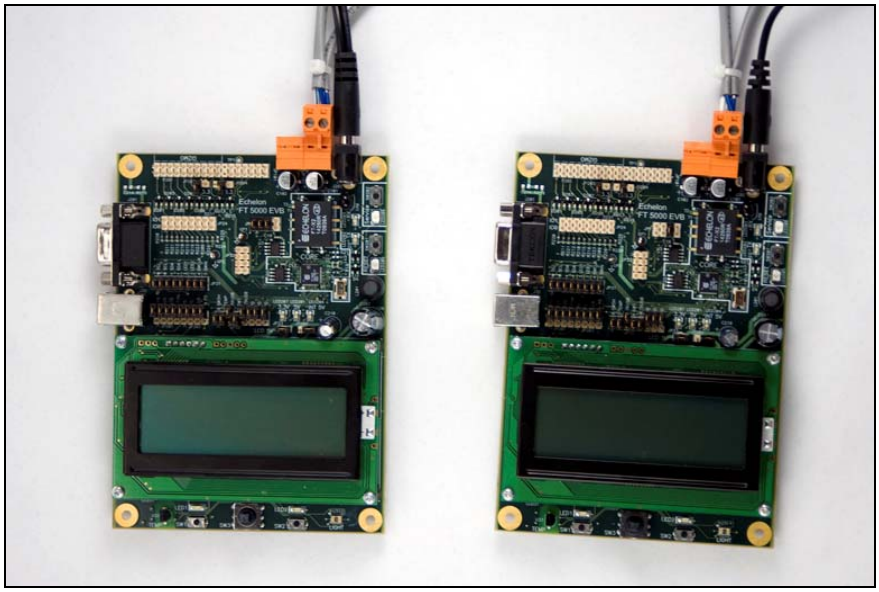


Figure 2.10 FT 5000 EVB Network Connection

5. Use the included U10 USB Network Interface to attach the computer running the Mini FX Application to the TP/FT-10 channel. To do this, connect the black network connector on the network cable to the U10 USB Network Interface, and then plug the U10 USB Network Interface into an available USB port on your computer. You can use the included USB extension cable to help connect the USB 10 Network Interface to your development computer.

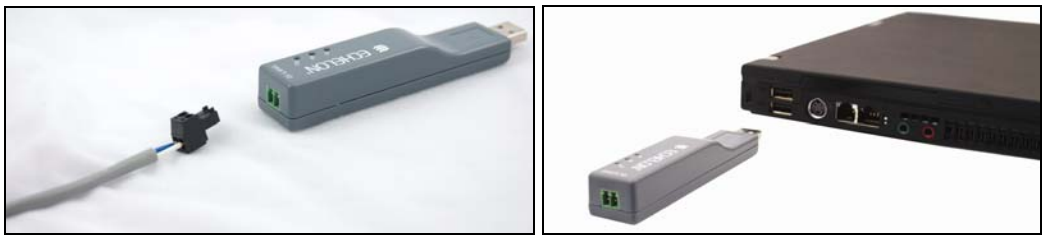


Figure 2.11 USB 10 Network Interface Connection

If this is the only LONWORKS interface installed on your computer, it will automatically use the default name **LON1**, and you can proceed directly to your software application and begin using the interface as **LON1**.

If you have another network interface installed on your computer, you can check the name used by the U10 USB Network Interface in the LONWORKS Interfaces application. You can also use this application to configure the buffer sizes and counts used by the U10 USB Network Interface. To open the LONWORKS Interfaces application, and check the name of the U10 USB Network Interface and configure it, click **Start** on the taskbar, click **Control Panel**, double-click **LONWORKS Interfaces**, and then click the **USB** tab.

For more information on installing and using the U10 USB Network Interface, see the *LONWORKS USB Network Interface User's Guide*.

Note: You can use a different network interface such as a PCC-10, PCLTA-20, or PCLTA-21; SLTA-10; remote network interface (*i*.LON SmartServer, *i*.LON 100 *e*3 plus Internet Server, *i*.LON 600 LONWORKS-IP Server); or an IP-852 interface (*i*.LON SmartServer with IP-852 routing, *i*.LON 100 *e*3 plus Internet Server with IP-852 routing, or *i*.LON 600 LONWORKS-IP Server).

To use a PCC-10, a PCLTA-20, or a PCLTA-21 as the network interface, you first need to configure it as a layer-5 network interface using the LONWORKS Plug 'n Play application. To do this, click **Start** on the taskbar, click **Control Panel**, and then double-click **LONWORKS Plug 'n Play**. In the **Device Selected** box, select your network interface. In the **NI application** box, select **PCC10NSI** if you are using a PCC-10, or select **NSIPCLTA** if you are using a PCLTA-20 or a PCLTA-21. Click **OK** to save your changes and close the LONWORKS Plug 'n Play application.

6. Complete the quick-start exercise in Chapter 3, *Mini FX Quick-Start Exercise*. In the quick-start exercise, you will develop a device with one sensor and one actuator. The sensor is a simple sensor that monitors a push button on the FT 5000 EVB. The actuator drives the state of an LED on the FT 5000 EVB based on the state of the button.

   This quick-start guides you through all the steps of creating a device with the Mini kit, including writing the Neuron C code that implements your device functionality, building the device application, downloading the device application, and testing the device.

7. Run the Neuron C example applications included with the Mini kit on your FT 5000 EVBs. The Mini kit includes three Neuron C example applications (*NcSimpleExample*, *NcSimpleIsiExample*, and *NcMultiSensorExample*) that you can use to test the I/O devices on the FT 5000 EVBs, and create simple self-installed and managed LONWORKS networks. Note that you need the LonMaker tool or other network tool to create a managed network with the FT 5000 EVB example applications.

The *NcMultiSensorExample* application is pre-loaded on the FT 5000 EVBs and runs in Interoperable Self-Installation (ISI) mode by default. You install and connect this example application and the other examples using the LonMaker tool, or using the ISI protocol. See the *FT 5000 EVB Examples Guide* for more information on using these example applications.

For more information on the FT 5000 EVB, including how to use the I/O components, service buttons, interfaces, and jumpers on the FT 5000 EVB hardware, see the *FT 5000 EVB Hardware Guide*.

Connecting the Mini FX/PL Hardware

To connect the Mini FX/PL hardware, follow these steps:

1. Unpack the equipment from the shipping carton. Avoid touching areas of integrated circuitry, as static discharge could damage circuits.
2. Verify that all of the following hardware and software items listed in Table 2.2 are present.

Table 2.2 Mini FX/PL Evaluation Kit Hardware and Software Items

Item	Qty
PL 3150 EVB	1
PL 3170 EVB	1
Power supplies (90–240VAC 50/60Hz) with power cords (US/Japan and Continental European) and integrated couplers	2
MiniGizmo	2
MiniGizmo Cables	2
U20 USB Network Interface	1
USB Extension Cable	1
Mini FX CD	1
LonScanner CD (Demo Edition)	1

3. Connect the PL 3150 and PL 3170 EVBs to the MiniGizmo I/O Boards using the included MiniGizmo ribbon cables.
4. Connect the barrel connectors of two of the included power supplies into the barrel jacks on the PL 3150 and PL 3170 EVBs, connect the power supplies to the included power cords that are appropriate for you region (US/Japan or Continental European), and then plug the power cords into a power outlet.

   This connects the PL EVBs to the power line channel. The Mini FX/PL power supplies include internal coupling to enable the evaluation boards to communicate through the power supply. You cannot substitute another power supply for the Mini kit power supplies, unless your alternative power supply provides equivalent coupling.

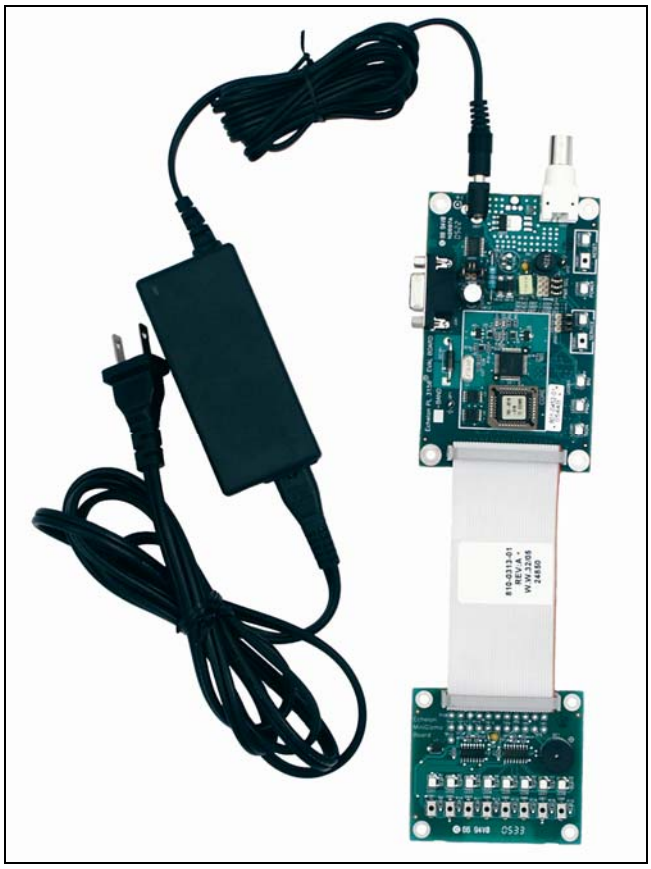


Figure 2.12 PL 3150/PL 3170 EVB Connections

5. After you plug in the power supplies, **LED1** will begin flashing, indicating that the PL Evaluation Board has entered CENELEC configuration mode. If **LED8** is on, then the CENELEC access protocol is enabled. If **LED8** is off, CENELEC is disabled. By default, CENELEC is enabled.

   You must enable the CENELEC access protocol when operating within one of the CENELEC member states. When operating outside the CENELEC member states, disable the CENELEC access protocol for optimum performance and reliable communications.

   To change the current setting, you can press the **SW8** button on the MiniGizmo I/O Board to toggle CENELEC support. When you have made a selection, press the **SW1** button to confirm your selection and exit CENELEC configuration mode. Make sure that **LED8** is on before pressing **SW1** if you want CENELEC enabled, or off if you want CENELEC disabled. You will not be able to perform any network operations with the PL EVB until you have made a selection and exited CENELEC configuration mode.

   The CENELEC setting affects the hardware template and program ID (channel type) selections you will make when using the Mini FX Application with the PL EVBs. See Chapter 4 for more information on these settings.

   The CENELEC EN 50065-1 standard specifies an access protocol for C-band channels to allow multiple power line signaling devices from different manufacturers to operate on a common AC-mains circuit. See Chapter 8 of the *PL 3120 / PL 3150 / PL 3170 Smart Transceiver Data Book* for more information on the CENELEC

protocol. To view this book, click **Start**, point to **Programs**, point to **Echelon Mini**, point to **Smart Transceiver Data Books**, and then click it.

6. Insert the barrel connector of the included power supply into the barrel jack of the included U20 USB network interface, connect the power supply to the included power cord that is appropriate for you region (US/Japan or Continental European), plug the power cord into a power outlet, and then plug the U20 USB network interface into an available USB port on your computer. For more information on installing and using the U20 USB Network Interface, see the *LONWORKS USB Network Interface User's Guide*.

Figure 2.13 USB 10 Network Interface Connection

Note: You can use a different network interface such as remote network interface (*i*.LON SmartServer or *i*.LON 100 e3 plus Internet Server), or an IP-852 interface (*i*.LON SmartServer with IP-852 routing or *i*.LON 100 e3 plus Internet Server with IP-852 routing, or *i*.LON 600 LONWORKS-IP Server).

7. Complete the quick-start exercise in Chapter 3, *Mini FX Quick-Start Exercise*. In the quick-start exercise, you will develop a device with one sensor and one actuator. The sensor is a simple sensor that monitors a push button on a PL 3150/PL 3170 EVB. The actuator drives the state of an LED on the PL 3150/PL 3170 EVB based on the state of the button.

   This quick-start guides you through all the steps of creating a device with the Mini kit, including writing the Neuron C code that implements your device functionality, building the device application, downloading the device application, and testing the device.

8. Run the *MGDemo*, *MGSwitch*, *MGLight*, and *MGKeyboard* Neuron C example applications included with the Mini kit on your PL 3150 and PL 3170 EVBs. You can use the example applications to test the I/O devices on the Mini Gizmo I/O Boards that you can attach to the PL 3150/PL 3170 EVBs, and create simple self-installed and managed LONWORKS networks. You need to purchase a LonMaker tool or other network tool to create a managed network with the Mini FX/PL example applications.

   The PL 3150 EVB comes pre-loaded with the *MGDemo* example application; the PL 3170 EVB comes pre-loaded with the *MGSwitch* example application. With these pre-loaded example applications, you can create a simple self-installed LONWORKS network where the push buttons on the PL 3170 EVB are connected to the LEDs on the PL 3150 EVB.

   For more information on using the Mini FX/PL example applications, see the *Mini FX/PL Examples Guide*.

Note: Echelon power line technology combined with ISI self-installation provides virtual plug and play communication in a single-family home environment. Mini kit users are encouraged to explore the communication capabilities of these evaluation units in a variety of home environments.

Reliable power line communication in a commercial environment—where nearby outlets may be serviced from different distribution transformers with very long branch circuits—is possible with the addition of routers, as described in the *Centralized Commercial Building Applications with the PLT-21 Power Line Transceiver Engineering Bulletin* (005-0056-01). Communication in a commercial environment without the additional routers described in this engineering bulletin may not be reliable.

For best results, do not attempt to communicate through mains power bars or power strips that contain EMC filters. This can be accomplished by plugging the Mini kit supply into a plug on the input side of a filtered power bar.

3

Mini FX Quick-Start Exercise

This chapter demonstrates how to create a LONWORKS device using the Mini kit.

Mini FX Quick-Start Exercise

The following quick-start exercise demonstrates how to create a LONWORKS device with the Mini kit. It introduces Mini kit features; familiarizes you with the Mini FX Application user interface; and guides you through all the steps of developing a device with the Mini kit, including creating, writing, compiling and building, and downloading the Neuron C device application.

For this quick-start exercise, you will develop a standalone device application with one sensor and one actuator. The sensor is a simple sensor that monitors a push button on the EVB. The actuator drives the state of an LED on the EVB based on the state of the push button. You can use either the FT 5000 EVB, or PL 3150/PL 3170 EVB as the hardware platform for this exercise.

Note: For simplicity, this device application does not include functional blocks and network variables, which are used by interoperable LONWORKS devices. In addition, this device application does not include any ISI code, which is required to connect your device to other LONWORKS devices in a self-installed network. After you complete this exercise, you can add functional block and network variable declarations to the Neuron C device application so that your device has an interoperable interface, and then you can add ISI code so that you can connect your device to other devices that have compatible ISI assemblies, or connect your devices using the LonMaker tool or other network tool. For more information on declaring functional blocks and network variables and using ISI in your device application, see *Creating Example Device Applications* in Chapter 5.

After you complete this exercise, you can also load and run the Neuron C example applications that are included with the Mini kit. The Mini FX software includes three Neuron C example applications that you can load into your FT 5000 EVBs (included with the Mini FX/FT Evaluation Kit, and available separately), and four Neuron C example applications that you can load into PL 3150 and PL 3170 EVBs (included with the Mini FX/PL Evaluation Kit, and available separately). You can use these examples to test the I/O devices on your EVBs, and you can browse the Neuron C code used by these examples to further learn how to develop your own device applications. For more information on using the FT example applications, see the *FT 5000 EVB Examples Guide*. For more information on using the PL example applications, see the *Mini FX/PL Examples Guide*.

To develop a LONWORKS device with the Mini kit, you perform the following steps:

1. Create a new device application.
2. Write Neuron C source code for your device application.
3. Build your device application.
4. Download your device application
5. Test your device application.

Step 1: Creating the Device Application

You can use the Mini FX Application to create a new device application. To do this, follow these steps:

1. Start the Mini FX Application. To do this, click **Start** on the taskbar, point to **Programs**, point to the **Echelon Mini** program folder, and then click **Mini FX Application**. The **Mini FX Application** opens with the **Application** tab selected.
2. Click **New** to create a new device application, browse to the desired location on your hard drive or create a new folder, then enter **main** as the file name, and then click

Save. This creates a new empty Neuron C source file named **main.nc** in your chosen location, and it opens the file using your computer's default text editor.

3. Proceed to the next section to write your Neuron C device application in the **main.nc** file.

Step 2: Writing the Device Application

When developing the device application, you will typically concentrate on writing the algorithms that implement your device's functionality. To do this, you will program any required interaction between the device application and the I/O devices on your device hardware. In this step, you will create Neuron C I/O declarations and implement your desired I/O functionality in the **main.nc** Neuron C source file that you created in the previous section. If you are using the Mini FX/FT Evaluation Kit, you will additionally add code that writes to the LCD on the FT 5000 EVB.

Note: The I/O device declarations used for the Mini FX/FT hardware (FT 5000 EVBs) and the Mini FX/PL hardware (PL 3150/PL 3170 EVBs) are different. Therefore, follow the section corresponding with the development platform or platforms you are using for the appropriate code to use.

FT 5000 Evaluation Boards

1. Enter the following directives:

```
#include <string.h>
#include <io_types.h>
#include <control.h>

//required to compile Neuron C source code
#pragma num_alias_table_entries 0

//run application even if device is uncommissioned
#pragma run_unconfigured
```

2. Add the following code that declares the I/O hardware for the SW1 button and LED1 on the FT 5000 EVB (both LED1 and SW1 are connected directly to the I/O 2 and I/O 9 I/O pins, respectively):

```
IO_2 output bit ioLed1 = 1;
IO_9 input  bit ioSwitch1;
```

3. Add the following code that adds functionality to the Switch and LED I/O:

```
//Create global variable to store the previous LED state
boolean switchState;
// Function for setting LED1
void SetLed(boolean led1)
{
    io_out(ioLed1, !led1);
}
// Read the SW1 button when pressed and then set LED1
void DisplayStatus(boolean led, boolean sw);
when(io_changes(ioSwitch1) to 0)
{
    switchState ^= TRUE;
    SetLed(switchState);
    DisplayStatus(switchState, switchState);
}
```

4. Add the following code that initializes the I/O devices and writes to the LCD when the FT 5000 EVB is reset:

```
void InitializeIO()
{
    io_change_init(ioSwitch1);
}

void LcdDisplayString(unsigned row, unsigned column, const char* data);

when(reset) {
    InitializeIO();

    LcdDisplayString(0,0, "Mini FX QuickStart  ");
    LcdDisplayString(1,0, "====================");
    LcdDisplayString(2,0, "Press SW1 to toggle ");
    LcdDisplayString(3,0, "LED1                ");
}
```

5. Add the following code that writes to the LCD on the FT 5000 EVB:

```
IO_0 i2c __slow ioIIC;
#   define LCD_COMMAND_PREFIX       0xFEu
#   define LCD_COMMAND_ON           0x41u
#   define LCD_COMMAND_SETCURSOR    0x45u
#   define LCD_COMMAND_CLEARSCREEN  0x51u
#   define LCD_COMMAND_BRIGHTNESS   0x53u
    // The datasheet states the address as 0x50, but the
    // 7-bit right-justified address is really 0x28 (0x50 >> 1):
#   define I2C_ADDRESS_LCD          (0x50u >> 1)

// The SendLcdCommand() function is used within this driver kit.
// The function sends a one- or two-byte command to the display.

void SendLcdCommand(unsigned command, unsigned parameter, unsigned size)
{
    unsigned data[3];

    data[0] = LCD_COMMAND_PREFIX;
    data[1] = command;
    data[2] = parameter;

    (void)io_out(ioIIC, data, I2C_ADDRESS_LCD, 1+size);
}


void LcdDisplayString(unsigned row, unsigned column, const char* data)
{
    // Set the cursor position:
    static const unsigned lcdRowAddress[4] = {0x00, 0x40, 0x14, 0x54};
    SendLcdCommand(LCD_COMMAND_SETCURSOR, lcdRowAddress[row]+column, 2);
    // Send the data:
    (void)io_out(ioIIC, data, I2C_ADDRESS_LCD, (unsigned)strlen(data));
}

// The InitializeLCD function enables and clears the display.  Call this
// function from InitializeIO() (which in turn is called from when(reset).

// InitializeIO() is called from the when(reset) task and initalizes
// the I/O system and related driver functions.

// display SW1 and LED1 state when on

void DisplayStatus(boolean led, boolean sw)
{
    LcdDisplayString(2, 0, “SW1  =             ”);
```

```
    LcdDisplayString(3, 0, “LED1 =              “);
    LcdDisplayString(2, 7, led ? “ON” : “OFF”);
    LcdDisplayString(3, 7, sw  ? “ON” : “OFF”);
}
```

6. Save your **main.nc** Neuron C source file.
7. Proceed to *Step 3: Building the Device Application* to compile and build your Neuron C device application.

For more information on writing Neuron C code to implement your device's functionality, see Chapter 5, *Developing Device Applications*.

PL 3150 and PL 3170 Evaluation Boards

1. Enter the following directives:

```
//Required to compile Neuron C source code
#pragma num_alias_table_entries 0

//Run application even if device is uncommissioned
#pragma run_unconfigured
```

2. Add the following code that declares the I/O hardware for the SW1–SW8 buttons and LED1–LED8 on the PL 3150/PL 3170 EVB (all the switches and LEDs on the Mini Gizmo I/O board are connected through serial-in parallel-out and parallel-in serial-out shift registers:

```
// Configure the I/O pins for SW1–SW8 buttons
IO_4 input bitshift numbits(8) clockedge(-) ioButtons;
IO_6 output bit ioButtonLoad = 1;

// Configure the I/O pins for LED1–LED8
IO_2 output bitshift numbits(8) ioLeds;
IO_1 output bit ioLedLoad = 1;
```

3. Add the following code that adds functionality to the Switch and LED I/O:

```
// Read state of MiniGizmo SW1 button
boolean GetButton(void)
{
    unsigned debounce;
    unsigned data;
    data = 0xFF;

    for (debounce = 0; debounce < 3; ++debounce) {
        // Strobe:
        io_out(ioButtonLoad, 0);
        io_out(ioButtonLoad, 1);
        // Sample data and debounce:
        data &= (unsigned)io_in(ioButtons);
    }
    return ~data & 0x01;
}

// Set MiniGizmo LED1
void SetLeds(boolean led1)
{
    unsigned data;

    // Compute the data byte for the shift register:
    data = led1 ? 0x01 : 0x00;

    // Push inverted data into shift register:
    io_out(ioLeds, ~data);
```

```
    // strobe:
    io_out(ioLedLoad, 0);
    io_out(ioLedLoad, 1);
}

//Create global variable to store the previous SW1 button state.

boolean switchState;

// Create function that sets LED1 when SW1 button is pushed.

void OnButtonPressed()
{
    switchState ^= TRUE;
    SetLeds(switchState, ~switchState);
}

// Timer that checks SW1 button every 25ms

mtimer repeating buttonTimer = 25;

when(timer_expires(buttonTimer))
{
    static boolean previousButton;

    boolean currentButton;
    currentButton = GetButton();

    if (currentButton && !previousButton){
        OnButtonPressed();
    }
    previousButton = currentButton;
}
```

4. Save your **main.nc** Neuron C source file.
5. Proceed to the next section to compile and build your Neuron C device application.

For more information on writing Neuron C code to implement your device's functionality, see Chapter 5, *Developing Device Applications*.

Step 3: Building the Device Application

You can use the Mini kit to compile your Neuron C application and build an application image that can be loaded into your device.

When you build your application, the Mini kit will create *downloadable application image files* and *device interface files*. The downloadable application image file is used by the Mini kit and other network tools to download the compiled application image to a device. The device interface file describes the external interface for your device. It is used by network tools such as the LonMaker tool to determine how to bind and configure your device. The device interface file is also used by the NodeBuilder tool to automatically create the LNS device template. The device interface file is not used in this exercise because it does require the device to be configured.

The Mini kit also generates other application image files that are appropriate for to your hardware. For example, if your hardware contains off-chip memory parts such as the flash memory device commonly used with a PL 3150 Smart Transceiver, the Mini kit generates a programmable application image file (**.NEI** extension) that can be used to program the flash memory part using a device programmer. For more information on the

application image files used for various memory parts, see Chapter 8 of the *NodeBuilder FX User's Guide*.

To compile and build, your device application, follow these steps:

1. In the **Target Hardware** box on the **Application** tab, select the standard hardware template for your EVB.

   - If you are using the Mini FX/FT Evaluation Kit, select **FT 5000 Evaluation Board**.
   - If you are using the Mini FX/PL Evaluation Kit, select **PL 3150 Evaluation Board (CENELEC off)**, **PL 3150 Evaluation Board (CENELEC on)**, **PL 3170 Evaluation Board (CENELEC off)**, or **PL 3170 Evaluation Board (CENELEC on)**.

     The CENELEC EN 50065-1 standard is a European-standard protocol for controlling access to a power line used for communication. It is required for power line communication in most CENELEC member states, which include most of Europe and some neighboring countries. For operation outside states governed by the CENELEC committee, you must disable the CENELEC access protocol for optimum performance and reliable communication. See Chapter 8 of the *PL 3120 / PL 3150 / PL 3170 Smart Transceiver Data Book* for more information on the CENELEC protocol. To view this book, click **Start**, point to **Programs**, point to **Echelon Mini**, point to **Smart Transceiver Data Books**, and then click it.

2. In the **Standard Program Identifier** box, click **Calculate**. The **Standard Program ID Calculator** dialog opens.

3. Specify the program ID for your device application. The program ID uniquely identifies an application, and must be different for every type of device on a network. The program ID includes fields that define the manufacturer, device class, device subclass, transceiver type, and model number for a device type.

   Enter the following values for the program ID fields:

   - In the **Manufacturer ID (M:MM:MM)** property, enter your standard manufacturer ID or temporary manufacturer ID in decimal format, or select the **Examples** manufacturer ID.
   - If your company is a LONMARK member, but you do not know your manufacturer ID, you can find your ID in the list of manufacturer IDs at *www.lonmark.org/spid*.
   - If you do not have a standard manufacturer ID, you can request a temporary manufacturer ID by filling out a simple form at *www.lonmark.org/mid*.
   - In the **Category** property, select the **I/O** option.
   - In the **Device Class (CC:CC)** property, select the **Multi-I/O module (5.01)** option.
   - In the **Usage (UU)** property, select the **General** option.
   - In the **Channel Type (TT)** property, select the **TP/FT-10** option if your development platform is a FT 5000 EVB, or select the **PL-20** option if your development platform is a PL 3150/PL 3170 EVB.
   - In the **Model Number (NN)** property, enter **01**.

Note: The current list of manufacturer IDs, device classes, usage values, and channel types are defined in an XML file (**spidData.xml**) that is available at *www.lonmark.org/spid*. This file is updated as LONMARK International adds new manufacturer IDs, device classes, usage values, and channel types.

4. Click **OK** to return to the Mini FX Application. The program ID you specified in the **Standard Program ID Calculator** dialog appears in the **Standard Program Identifier** box.
5. Click **Build** to compile the application and create the application image files.
6. The status box at the bottom of the **Application** tab informs you when the application has successfully been compiled, and it displays build errors (if any).

   Figure 3-1 demonstrates that the device application in this quick-start exercise has successfully been built. In addition, it displays the properties set in the **Application** tab to build it.

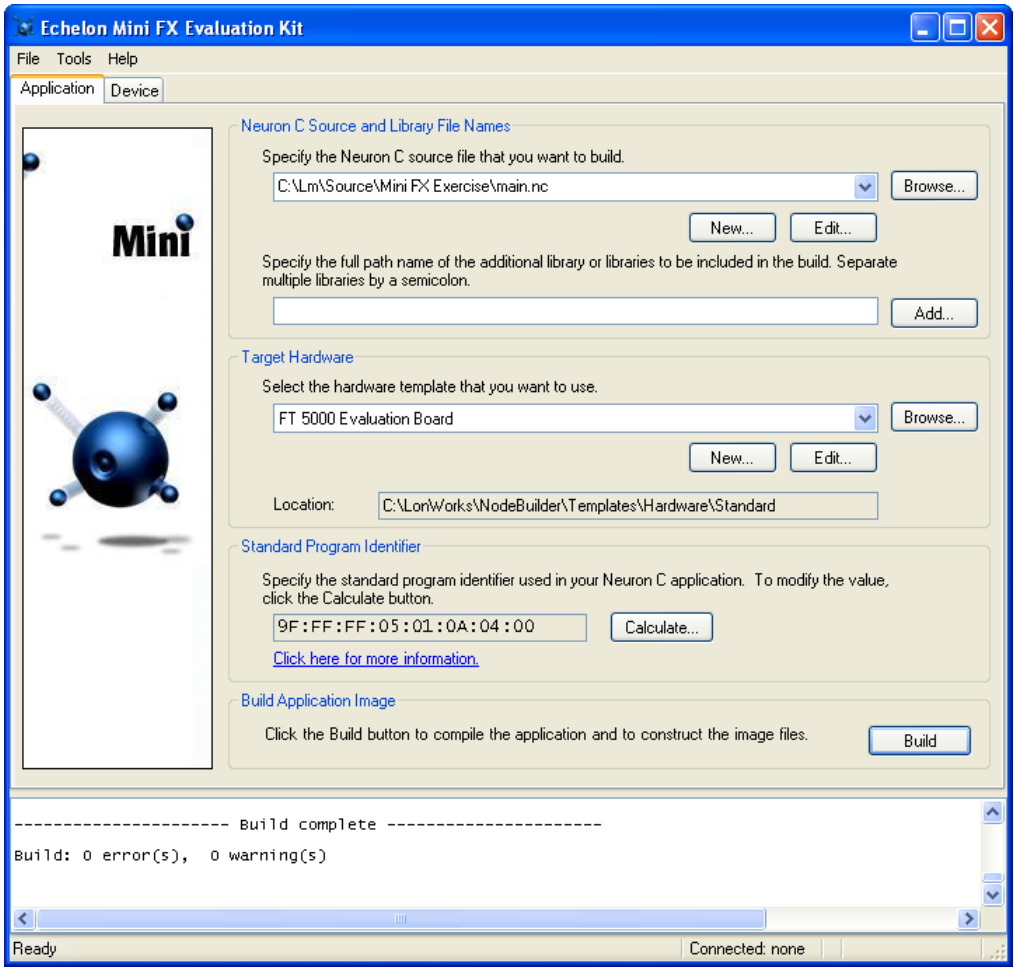


Figure 3.1 Building the Device Application

7. If you receive any build errors, double-check that the code you entered matches that listed in *Step 2: Writing the Device Application* (you may receive some warnings, which can be ignored in the context of this quick-start exercise).

Step 4: Downloading the Device Application

You can use the Mini FX Application to download an application image over a LONWORKS network into your development platform. In this step, you will download the application image file that was automatically created when you built the device in the previous section. To download the application image file into your EVB, follow these steps.

1. Click the **Device** tab.
2. In the **Network Interface** box, select the network interface attached to your development computer that is to be used for communication between the Mini FX Application and your EVB, and then click **Connect**. If you are using the U10 or U20 USB Network Interface included with the Mini kit and you have not installed any other network interfaces on your computer, select **LON1**. The Status box at the bottom indicates whether the Mini FX Application is connected to a network interface.

   You can alternatively use a different layer 5 network interface such as a PCC-10, PCLTA-20, PCLTA-21, *i*.LON 10 Ethernet Adaptor, *i*.LON server. To use a PCC-10, PCLTA-20, PCLTA-21 as the network interface for communication with an FT 5000 EVB, you must first configure it as a layer 5 interface. To do this, click **Start** on the taskbar, click **Control Panel**, and then double-click **LonWorks Plug 'n Play**. In the **Device Selected** box, select your network interface. In the **NI application** box, select **PCC10NSI** if you are using a PCC-10, or select **NSIPCLTA** if you are using a PCLTA-20 or a PCLTA-21. Click **OK** to save your changes and close the LonWorks Plug 'n Play application.
3. Press the service pin on the FT 5000 EVB or PL 3150/PL 3170 EVB. The service pin is a black button that is located along the right side of the board and is labeled "**Service**".
4. The **Service Pin Message** dialog opens. The Neuron ID of the FT 5000 EVB appears in the **Neuron ID** box and its program ID in the **Program ID** box.

   The **Neuron ID** is a unique 48-bit (12-hex digit) identifier contained in every LONWORKS device. The Mini kit uses the Neuron ID to communicate with your selected device. For more information on Neuron IDs, see the *Introduction to the LONWORKS Platform* document in the **Echelon Mini FX** program folder.
5. Click **Yes** to register the device with the Mini FX Application.
6. The EVB device is added to the **Device** list, which includes devices that you have added. The device will remain in the **Device** list until you close the Mini FX Application, or connect to a new network interface. You will need to add the device again when you restart the Mini FX Application, or when you connect to a different network interface.
7. In the **Application Image** box, the application image file that was automatically created when you built the device (**main.NDL**) is displayed. The application image file that was built last appears in this box by default. If the **main.NDL** file is not displayed, you can select it from the list of those application images recently built or added, or click **Add** to browse to and select it.
8. Click **Load** to load the **main.NDL** application image file into your EVB. The **Status** box informs you when the application image has been successfully loaded into the device, and it also informs you of any load errors.

Figure 3-2 demonstrates that the device application in this quick-start exercise has successfully been downloaded to the EVB. In addition, it displays the properties set in the **Device** tab to download the device application.

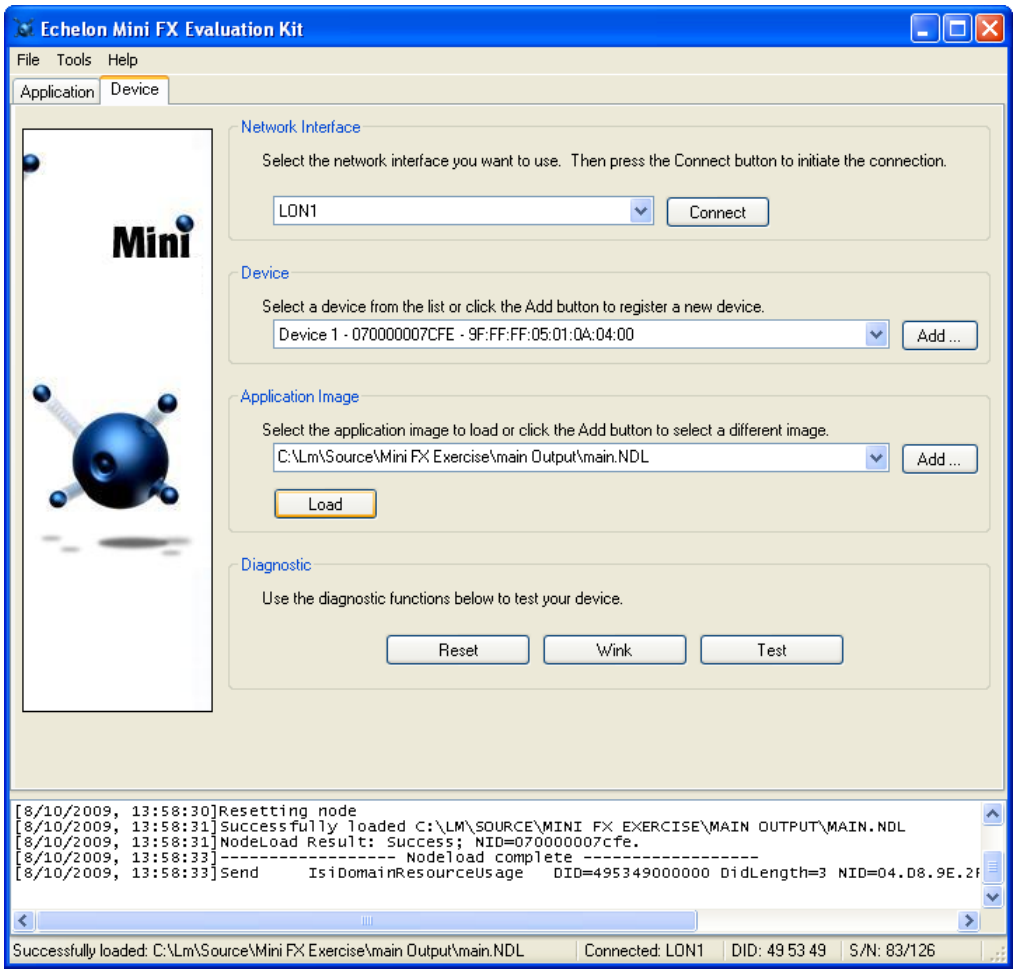


Figure 3.2 Downloading the Device Application

Step 5: Testing the Device Application

You can use the switch and LED I/O devices on your EVB to test your device application, and verify that it is functioning as designed. To test your device application, follow these steps:

1. Press the **SW1** button located on the bottom left side of the FT 5000 EVB or Mini Gizmo I/O board.
2. Observe that **LED1** is illuminated (**LED1** is located directly above the **SW1** button).
3. Press the **SW1** button to extinguish **LED1**.

4

Using the Mini FX Application

This chapter describes how to use the Mini FX Application to build a Neuron C device application and download it into a device. This chapter also describes how to use the Mini FX Application to reset, wink or test a device.

Introduction to the Mini FX Application

The Mini FX Application is an easy-to-use program consisting of two tabs: the **Application** tab and the **Device** tab. You use the **Application** tab to create/edit, compile, and build Neuron C device applications, and you use the **Device** tab to download your device applications.

You can use the **Application** tab to create new Neuron C device applications or edit existing ones. Neuron C (Version 2.2) is a programming language that includes network communication, I/O, interrupt-handling, and event-handling extensions to ANSI C, which make it a powerful tool for the development of LONWORKS device applications. After you develop your Neuron C device application, you can use the **Application** tab to compile it. The Mini FX Application can compile device applications that have a maximum of approximately 32 KB of code and 32 network variables. When you successfully compile your Neuron C device application, the Mini FX Application generates a downloadable application image file (**.NDL** extension) that you download into a device based on a Neuron chip or Smart Transceiver, including your FT 5000 EVBs or PL 3150/PL 3170 EVBs.

You use the **Device** tab to download the application image file into your EVBs or into other LONWORKS devices based on Neuron chips or Smart Transceivers. You can also use the **Device** tab to reset, wink, and test the devices that you have registered with the Mini FX Application.

The following sections describe how to perform the following tasks with the Mini FX Application:

1. Compile and build a device application.
2. Download a device application.
3. Reset, wink, and test a device.

Building a Device Application

You can use the **Application** tab in the Mini FX Application to create a new Neuron C device application or modify an existing one, compile the device application, and build a downloadable application image file.

1. Create a new Neuron C source file (**.nc** extension) or open an existing one. Optionally, you can specify any libraries required by your Neuron C source code (for example, the ISI libraries if you are creating an ISI device.

   You can also specify required libraries from within your source code by using the #pragma library compiler directive. Using this directive usually simplifies application management because the application's dependency on a particular function library is expressed within the application code itself. For more information on using the library pragma, see Chapter 2 of the *Neuron C Reference Guide*.

2. Select a hardware template. The hardware template defines the hardware configuration for the development platform or device into which your device application is to be downloaded.

3. Specify the program ID of your device application. The program ID is a unique, 16-hex digit ID that uniquely identifies the device application.

4. Build the application image and device interface files.

Creating and Opening Neuron C Source Files

You can use the **Application** tab in the Mini FX Application to create a new Neuron C source file or open an existing one. To create/open a Neuron C source file and include library files, follow these steps:

1. Start the Mini FX Application. To do this, click **Start** on the taskbar, point to **Programs**, point to the **Echelon Mini** program folder, and then click **Mini FX Application**. The **Mini FX Application** opens with the **Application** tab selected.

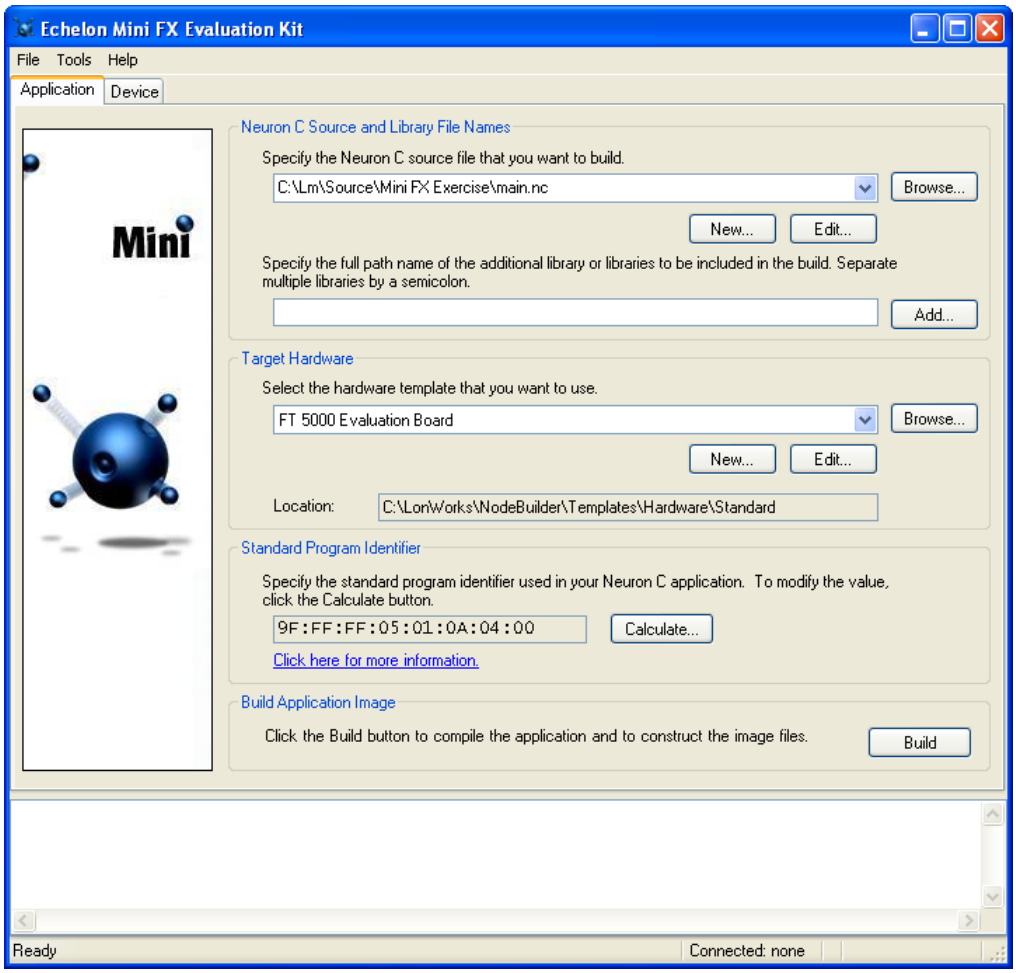


Figure 4.1 Application Tab

2. To create a new Neuron C source file, click **New** in the **Neuron C Source Files and Library Box**. This creates a new empty source file (**.nc** extension), and opens the file using your computer's default editor for Neuron C source files (or Notepad if you have not registered any specialized Neuron C editor on your computer). To open an existing Neuron C source file, select a file from the list of those that have been compiled most recently or click **Browse** and select a file, and then click **Edit**.

   The Mini FX Evaluation Kit includes several pre-built example applications that you can view or edit. To select one of the example applications, click **Browse**, navigate to the **C:\LONWORKS\NeuronC\Examples** folder, open the folder corresponding to your development platform (**FT 5000 EVB** or **Mini EVB** [for PL 3150/PL 3170 EVBs]), and then select the **.nc** file to be opened. For more information on the FT

5000 EVB example applications, see the *FT 5000 EVB Examples Guide*. For more information on the PL 3150/PL 3170 EVB example applications, see the *Mini FX/PL Examples Guide*.

Note: Windows Notepad is typically your default Neuron C source editor. To use a different editor, open the **Folder Options** in the Windows Control Panel, click the **File Types** tab, select the **NC** extension, and then click **Change** to change the program to be used to open **.NC** files, and then click **Close**. The Mini FX Application will then use the selected editor as the default.

Tip: Choose an editor that includes line numbers as your default editor. This helps you navigate your device application if it fails to compile because the Status box at the bottom of the **Application** tab in the Mini FX Application lists any errors in your code, and it includes the line numbers of the errors. You can download a free editor that includes line numbers such as TextPad® (for evaluation), UltraEdit (for evaluation), or Crimson Editor.

3. Write the Neuron C code for your device application. See Chapter 5, *Developing Device Applications*, for more information on the Neuron C programming language and examples to help you get started with programming in Neuron C.

4. If your Neuron C source code references any functions contained in a standard ISI library or any other standard or custom library, you may need to instruct the Mini kit to use these libraries. Failing to do so will lead to link errors because functions and variables provided with those libraries cannot be found.

   You can reference a library several ways: (1) you can include a reference to the required library with your source code, or (2) you can explicitly advise on required libraries through the tool. The Mini kit supports both methods; however, it is recommended that you include the library references in your source code. This is because the source code makes references to certain functions and libraries provided with certain required libraries; therefore, it is logical that the same source code states this library requirement. In addition, including the library reference in your source does not require any additional steps; therefore, it makes the build process easier to manage. For more information on using the pragma library compiler directive, see Chapter 2 of the *Neuron C Reference Guide*.

   - To reference a library within your source code, add a pragma library compiler directive to your application source code that specifies the required library in its argument.
   - To reference a library outside your source code, click **Add** in the **Neuron C Source and Library File Names** box, and then browse to and select the library to be included in the **Add Library/Libraries** window. This window defaults to the **C:\LonWorks\NeuronC\ Libraries** directory, which contains the standard Neuron C libraries, and the ISI libraries described in the *ISI Programmer's Guide*.

     Alternatively, you can type the full path of the library to be added in the box. You can enter multiple libraries by clicking **Add** multiple times, or by entering them in the box and separating them with semicolons.

   Note: The Mini FX Application automatically links your Neuron C device application with all required standard libraries (see Chapter 5 of the *NodeBuilder FX User's Guide* for descriptions of these standard library files). However, some Neuron C applications have specific library requirements. For example, the example applications included with the Mini FX/PL Evaluation Kit all require the ISI libraries and the CENELEC Configuration Library (CCL). Seven different ISI

libraries are supplied, varying in features provided and application memory required. For more information on the libraries required by the various Mini FX/PL example applications, see the *Mini FX/PL Examples Guide*.

Selecting the Hardware Template

You can use the **Application** tab in the Mini FX Application to select the hardware template for your device application. A hardware template specifies the attributes for the hardware into which your device application is to be downloaded including platform, transceiver type, Neuron Chip or Smart Transceiver model, clock speed, system image, and memory configuration.

In the **Target Hardware** box, select the hardware template corresponding to your development platform from the list of standard hardware templates stored in the **C:\LONWORKS\NodeBuilder\Templates\Hardware\Standard** folder. The list includes hardware templates for the FT 5000 EVBs, and PL 3150/PL 3170 EVBs.

- If you are using the Mini FX/FT Evaluation Kit, select **FT 5000 Evaluation Board**.
- If you are using the Mini FX/PL Evaluation Kit, select **PL 3150 Evaluation Board (CENELEC off)**, **PL 3150 Evaluation Board (CENELEC on)**, **PL 3170 Evaluation Board (CENELEC off)**, or **PL 3170 Evaluation Board (CENELEC on)**.

  The CENELEC EN 50065-1 standard is a European-standard protocol for controlling access to a power line used for communication. It is required for power line communication in most CENELEC member states, which include most of Europe and some neighboring countries. For operation outside states governed by the CENELEC committee, you must disable the CENELEC access protocol for optimum performance and reliable communication. See Chapter 8 of the *PL 3120 / PL 3150 / PL 3170 Smart Transceiver Data Book* for more information on the CENELEC protocol. To view this book, click **Start**, point to **Programs**, point to **Echelon Mini**, point to **Smart Transceiver Data Books**, and then click it.
- To use a custom hardware template you have created, click **Browse**, and then browse to and select the hardware template. By default, custom hardware templates are stored in the **C:\LONWORKS\NodeBuilder\Templates\Hardware** folder on your computer.
- To create a custom hardware template, click **New** and then configure the hardware, memory, and description properties of your new custom hardware template as described in the *Configuring Hardware Templates* section in Appendix B.
- To view or edit the hardware, memory, and description properties of the selected hardware template, click **Edit**. If you save changes to a hardware template, you will be prompted to confirm that you want to clear the read-only attribute of the hardware template and save the file. Click **Yes** to overwrite the hardware template.

  Note: Do not overwrite Standard hardware templates. Instead, create a custom hardware template from a copy of a Standard hardware template and then configure your custom hardware template. For more information on creating and configuring custom hardware templates, see Appendix B, *Creating and Configuring Hardware Templates*.

Specifying the Program ID

You can use the **Application** tab in the Mini FX Application to specify the program ID for your device application. The program ID is a 16-hex-digit number that uniquely

identifies the device application. The program ID may be formatted as a standard or non-standard program ID. When formatted as a standard program ID, the 16 hex digits are organized as six fields that identify the manufacturer, classification, usage, channel type, and model number of the device.

To specify the program ID for your device application, follow these steps:

1. Click **Calculate** in the **Standard Program Identifier** box. The **Standard Program ID Calculator** dialog opens.

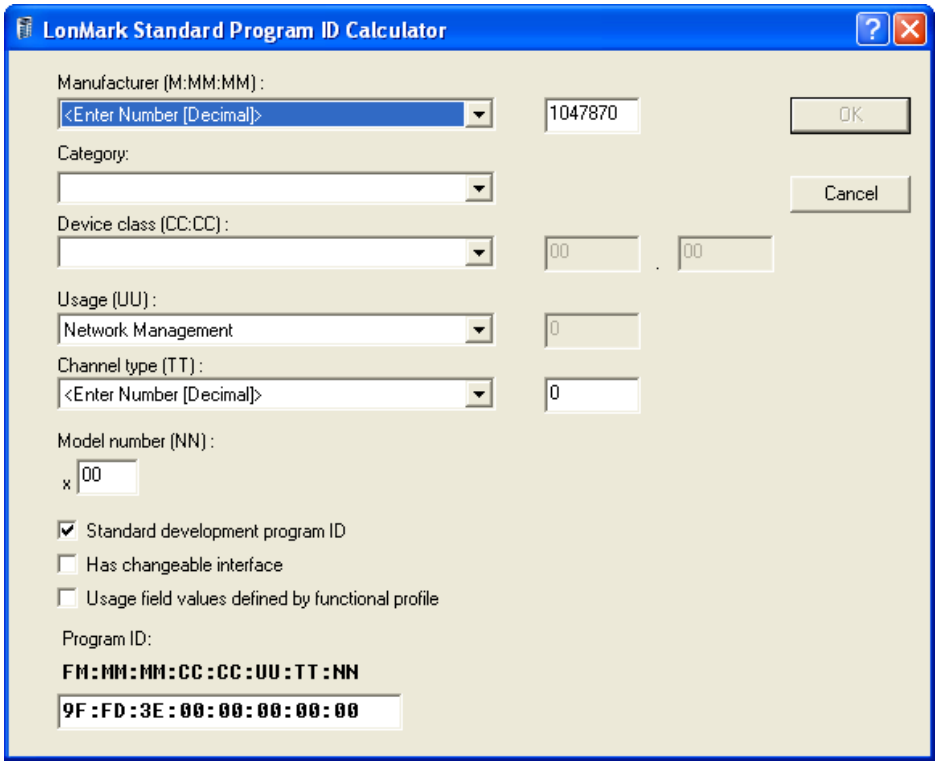


Figure 4.2 Standard Program ID Calculator

The **Standard Program ID Calculator** helps you select the appropriate values for the program ID fields. It lets you select the values from lists contained in a program ID definition file distributed by LONMARK International. The current file (**spidData.xml**) is available at *http://www.lonmark.org/spid*. This file is updated as LONMARK International adds new manufacturer IDs, device classes, usage values, and channel types.

The **Program ID** box at the bottom of this dialog is automatically updated as you enter the program ID fields. You can manually enter some or all of the program ID fields directly into this box. If you enter values directly in this box, the calculator updates the properties above in the dialog with those values.

2. In the **Manufacturer ID (M:MM:MM)** property, either select your company from the list, enter your 5 hex-digit standard manufacturer ID or temporary manufacturer ID in the box to the right in decimal format (the calculator will convert it to hex format), or select the **Examples** manufacturer ID.

   - If your company is a LONMARK member, but you do not know your manufacturer ID, you can find your ID in the list of manufacturer IDs at *www.lonmark.org/spid*.

- If you do not have a standard manufacturer ID, you can request a temporary manufacturer ID by filling out a simple form at *www.lonmark.org/mid*.

3. In the **Category** property, select the general purpose or industry of the device. The **Category** determines the device classes that will be available in **Device Class** property. Alternatively, you can select one of the following options to determine and organize the device classes shown in the **Device Class** property:

   - **ALL**. Show all the existing device classes.
   - **Profiles By Name**. Show an alphabetical list of all device classes with a profile.
   - **Profiles By Number**. Show a numeric list (sorted by device class number) of all device classes with a profile.

4. In the **Device Class (CC:CC)** property, select the primary function of the device. To enter a device class value that has not yet been added to the standard list, select **<Enter Number[Decimal]>**, and then enter decimal values from 0 to 255 in the boxes to the right (the calculator will convert the values to hex format).

5. In the **Usage (UU)** property, select the intended use of the device. The most significant two bits are determined by the **Has Changeable Interface** and **Use Field Valued Defined By Functional Profile** check boxes below the **Usage** property.

   If you are using a standard usage value, select the **Use Field Defined By Functional Profile** check box below the **Usage** property, and select a standard usage value from the list.

   If the primary functional profile implemented by your device specifies custom usage values, clear the **Use Field Defined By Functional Profile** check box below the **Usage** property, select **<Enter Number[Decimal]>** from the list, and then enter a decimal value from 0-255 in the box to the right (the calculator will convert the value to hex format).

6. In the **Channel Type (TT)** property, select the channel type supported by the device's transceiver.

   - If you are using an FT 5000 EVB or you are developing a device based on an FT Smart Transceiver, select **TP/FT-10**.
   - If you are using a PL 3150/PL 3170EVB or you are developing a device based on a PL Smart Transceiver or PLT-22 transceiver, select **PL-20C** or **PL-20N**. The PL-20C transceiver has the CENELEC EN 50065-1 standard protocol enabled, the PL-20N transceiver does not.
   - If you are using a transceiver that is not compatible with any of channel types in the list, select **Custom**. To enter a channel type value that has not yet been added to the standard list, select **<Enter Number[Decimal]>** and enter a decimal value from 0 to 255 in the box to the right (the calculator will convert the value to hex format).

     Note: Applications linking with the ISI libraries must select the program ID so that it reports the channel type correctly. Non-interoperable device applications should still use a standard program ID and advertise the channel type field correctly.

7. In the **Model Number (NN)** property, enter the specific product model within the range specified by the **Min Model #** and **Max Model #** properties in the **Program ID** dialog. You can assign a unique model number for the specified manufacturer,

device class, usage, and channel type. The same hardware may be used for multiple model numbers depending on the program that is loaded into the hardware. The model number within the program ID does not have to conform to your published model number.

8. In the **Standard Development Program ID** property, identify your device as a standard development/prototype device or as a LONMARK certified device. If your device is a development or prototype device that is not yet LONMARK certified, select the **Standard Development Program ID** check box (the calculator sets the **F** field of the program ID to **9**). Clear this checkbox if your prototype is LONMARK certified (the calculator sets the **F** field of the program ID to **8**). This check box is selected by default.

9. If your device has a changeable interface (it has *changeable-type network variables*, or the device supports *dynamic network variables*), select the **Has Changeable Interface** check box. This check box is cleared by default.

   Integrators can use a network tool to change the types of *changeable-type network variables* when installing a network. You can implement changeable-type network variables on any type of device.

   Dynamic network variables are network variables that are created or removed during installation time by a network tool. Network variables with changeable types may be implemented by any device; dynamic network variables may only be implemented by some host-based devices. For more information on changeable-type network variables, see Chapter 3 of the *Neuron C Programmer's Guide*. For more information on changeable-type network variables and dynamic network variables, see the *Application Layer Interoperability Guidelines*.

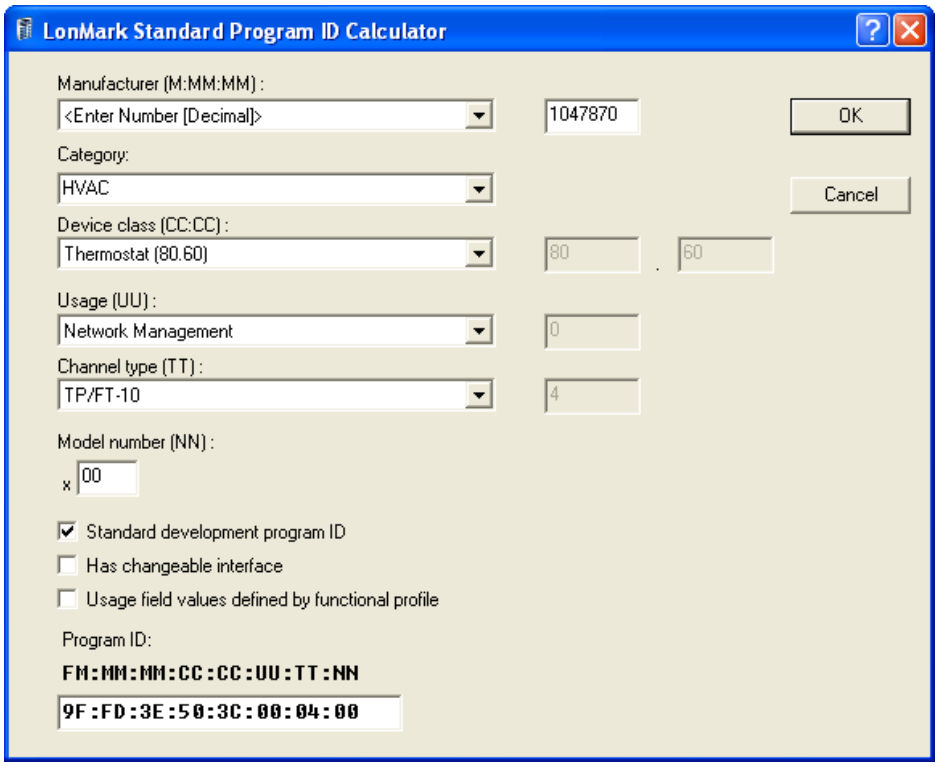


Figure 4.3 Standard Program ID Calculator Completed

10. Click **OK** to return to the **Application** tab in the **Mini FX Application**. The program ID you calculated appears in the **Standard Program Identifier** box.

Building the Application Image File

You can use the **Application** tab in the Mini FX Application to compile your device application and generate a downloadable application image file for it. To do this, follow these steps:

1. Click **Build** in the **Build Application Image** box.
2. The status box at the bottom of the **Application** tab informs you when the application has successfully been compiled, and it displays build errors (if any).
3. If you receive any build errors, double-check that your code and fix the errors. For more information on Neuron errors, including tips on how to resolve them, see Chapter 7 of the *Neuron Tools Errors Guide*.

   Note: The FT 5000 EVB example applications contain multiple Neuron C source and header files, which are all referenced by the **main.nc** file. If you modify any of these files and you want to build the modified device application with the Mini FX Application, re-build the **main.nc** file in the example's LONWORKS\NeuronC\Examples\FT50000 EVB\<*Example*>\Source folder.

Downloading an Application Image File

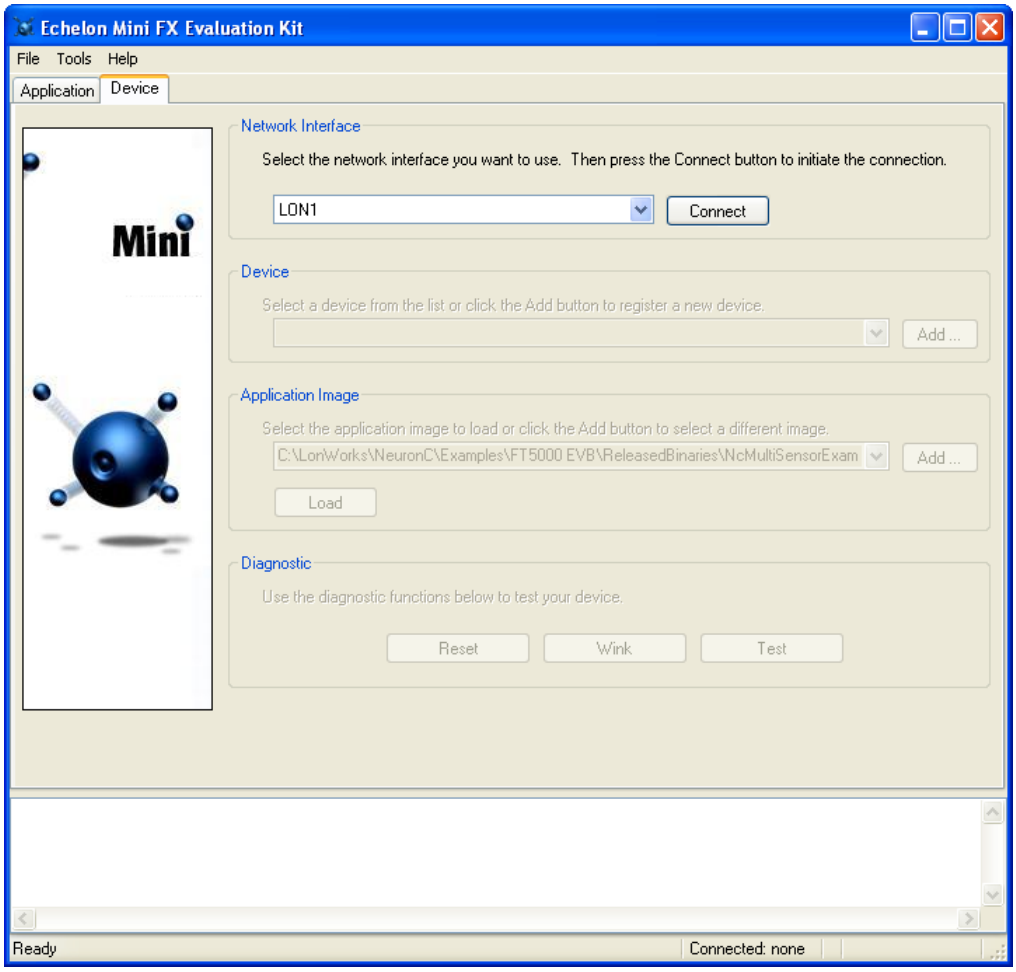
You can use the **Device** tab in the Mini FX Application to download an application image file over a LONWORKS network into your development platforms or any other LONWORKS device based on a Neuron Chip or Smart Transceiver. To do this, you select a network interface, select a device, select the application image file to be downloaded into the specified device, and then download the application image file.

Note: Your EVBs ship with example applications pre-loaded on them. This means that out-of-the-box you can install and bind them using the ISI protocol—without any additional steps (no network tool is required). You can also install and bind your EVBs using the LonMaker tool (available separately), or other network tool. Binding refers to the process in which devices are logically connected via the network variables in their device applications.

- The FT 5000 EVBs come with the *NcMultiSensorExample* application pre-loaded on them. See the *FT 5000 EVB Examples Guide* for more information on downloading and using this example application.
- The PL 3150 EVB comes with the *MgDemo* application pre-loaded on it, and the PL 3170 EVB comes with the *MgSwitch* application pre-loaded on it. See the *Mini FX/PL Examples Guide* for more information on downloading and using these example applications.

To download an application image file into a device, follow these steps.

1. Click the **Device** tab.

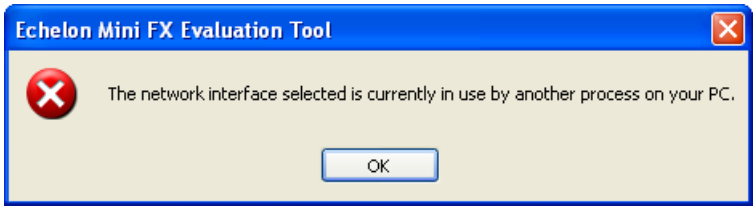


2. In the **Network Interface** box, select the network interface attached to your development computer that is to be used for communication between the Mini FX Application and your EVB, and then click **Connect**. If you are using the U10 or U20 USB Network Interface included with the Mini kit and you have not installed any other network interfaces on your computer, select **LON1**. The Status box at the bottom indicates whether the Mini FX Application is connected to a network interface.

   You can alternatively use a different layer 5 network interface such as a PCC-10, PCLTA-20, PCLTA-21, *i*.LON 10 Ethernet Adaptor, *i*.LON server. To use a PCC-10, PCLTA-20, PCLTA-21 as the network interface for communication with an FT 5000 EVB, you must first configure it as a layer 5 interface. To do this, click **Start** on the taskbar, click **Control Panel**, and then double-click **LonWorks Plug 'n Play**. In the **Device Selected** box, select your network interface. In the **NI application** box, select **PCC10NSI** if you are using a PCC-10, or select **NSIPCLTA** if you are using a PCLTA-20 or a PCLTA-21. Click **OK** to save your changes and close the LonWorks Plug 'n Play application.

Note: The Mini FX Application is an OpenLDV application; therefore, it cannot share a network interface with other LONWORKS applications. This means that when the Mini FX Application is attached to a network interface, network tools such as the LonMaker tool cannot use that network interface at the same time. To make the network interface available to other applications, you must close the Mini FX Application.

Conversely, the Mini FX Application cannot use a network interface that is currently attached to another LONWORKS application. If you try to attach the Mini FX Application to a network interface that is already connected, the following dialog opens.



To make a connected network interface available to Mini FX Application, you must close any LONWORKS applications using that network interface. If you are using the LonMaker tool, you can also alternatively detach the application from the network interface by clicking **LonMaker**, clicking **Network Properties**, clicking the **Network Interface** tab, and clearing the **Network Attached** box, and then clicking **OK**.

To use the Mini FX Application with network tools while avoiding network interface conflicts, follow these guidelines:

- Use the network tool to download device applications that you have compiled with the Mini FX Application into the target device, and to test that target device.
- Use a separate network interfaces for the network tool and the Mini FX Application. For example, you can install two U10 USB Network Interfaces in your computer, and use one for the network tool, and use the other for the Mini FX Application.

3. Select the device into which the application image is to be downloaded. You can do this in three ways: sending a service pin message from the device, manually adding a device, or selecting a previously registered device or a device automatically discovered through the ISI protocol.

    - To send a service pin message to register the device and select it, follow these steps:

        a. Press the Service button on the device. For the FT 5000 EVB or PL 3150/PL 3170 EVB, the Service button is a black button that is located along the right side of the board and is labeled "**Service**".

        b. The **Service Pin Message** dialog opens. The Neuron ID of the device appears in the **Neuron ID** box and its program ID in the **Program ID** box.

Figure 4.4 Service Pin Message Dialog

The **Neuron ID** is a unique 48-bit (12-hex digit) identifier contained in every LONWORKS device. The Mini FX Application uses the Neuron ID to communicate with your selected device. For more information on Neuron IDs, see the *Introduction to the LONWORKS Platform* document in the **Echelon Mini FX** program folder.

The program ID is a 16-hex-digit number that uniquely identifies the device application. The program ID is displayed as eight pairs of hexadecimal encoded digits, separated by colons. The 16 hex digits are organized as 6 fields (FM:MM:MM:CC:CC:UU:TT:NN) that identify the manufacturer, classification, usage, channel type, and model number of the device. For more information on program IDs, see the *Program IDs* section in Chapter 1.

c. Click **Yes** to register the device with the Mini FX Application.

d. The device is added to the **Device** list, which includes devices that you have added. The device will remain in the **Device** list until you close the Mini FX Application, or connect to a new network interface. You will need to add the device again when you restart the Mini FX Application, or when you connect to a different network interface.

- To manually register the device and select it, follow these steps:

  a. Click **Add**. The **Add Device** dialog opens.

  b. Either press the Service button on the device, or manually enter the 12-digit Neuron ID in hexadecimal format.

  c. Click **OK**.

  d. The device is added to the **Device** list.

- To select a device that was registered during the current Mini FX Application session with the currently selected network interface, select the device from the **Device** list. You can also select a device that has automatically been discovered

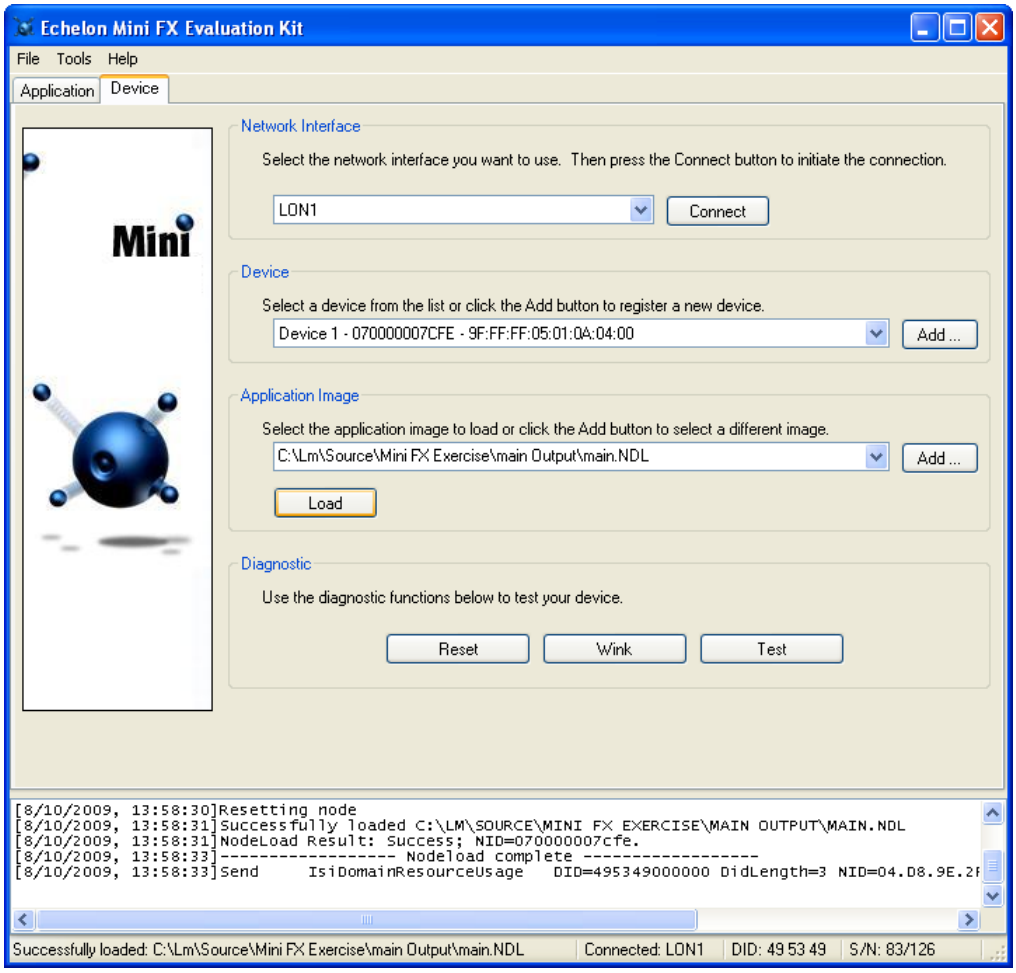
through the ISI protocol (all self-installed devices in the network are silently registered and added to the **Device** list).

4. From the list in the **Application Image** box, select the application image file to be downloaded into the device you selected in step 3. The list includes all the application images you have recently built or added with the Mini FX Application. The last application image file that was built with the Mini FX Application appears in this box by default.

   To select an application image file that is not listed, click **Add**, and then browse to and select the application image file (**.NDL** extension) to be downloaded. You can select an application image file that you built using the **Application** tab, or you can select any other existing application image file. The Mini FX Application builds multiple types of application image files to support various network tools; however, you must select an **.NDL** file when loading a device with the Mini FX Application.

   Note: You cannot load the *MgDemo* Mini FX/PL example application on a PL 3170 EVB.

5. Click **Load** to load the selected Neuron application image into the selected device. The Status box at the bottom of the **Device** tab informs you when the application image has been successfully loaded into the device, and it also informs you of any load errors. For more information on Neuron linker (NLD) errors, including tips on how to resolve them, see Chapter 7 of the *Neuron Tools Errors Guide*.



Note: After you load one of the MgDemo, MgSwitch, MgKeyboard or MgLight application image files into a PL 3150/PL 3170EVB, **LED1** will begin flashing, indicating that the PL EVB has entered CENELEC configuration mode. If **LED8** is on, then the CENELEC EN-50065-1 protocol is currently enabled. If **LED8** is off, this CENELEC protocol is currently disabled.

The initial setting depends on the hardware template you selected when you loaded the application image into a PL EVB. For example, if you selected the **PL 3150 Evaluation Board (CENELEC on)** hardware template, CENELEC will be enabled by default, and **LED8** will be on. If you selected the **PL 3150 Evaluation Board (CENELEC off)** hardware template, CENELEC will be disabled by default, and **LED8** will be off.

You can press the **SW8** button to enable or disable CENELEC. When you have made a selection, press the **SW1** button to confirm your selection and exit CENELEC configuration mode. You will not be able to load another application into the PL 3150/PL 3170EVB, or perform any other network operations, until you have made a selection and exited CENELEC configuration mode.

The PL EVB will enter CENELEC configuration mode every time you load a Mini FX/PL example application image file into it (as well as the first time you power up the EVB). To disable this behavior for any of the Mini FX/PL example applications, comment out the following line in the Neuron C source file:

```
#define SUPPORT_CCL
```

For more information on CENELEC configuration mode, see the **CENELEC Configuration Library ReadMe** file that is automatically installed with the Mini FX software. To view this document, click **Start**, point to **Programs**, point to **Echelon Mini**, point to **Mini FX Documentation**, and then select **CENELEC Configuration Library ReadMe**. Alternatively, you can browse to the **C:\LONWORKS\NodeBuilder** folder on your computer and then open the **CCL_ReadMe.htm** file.

Resetting, Winking, and Testing Devices

You can use the **Device** tab to reset, wink, or test a device that you have registered with the Mini FX Application. To do this, open the Mini FX Application, follow steps 1–3 in the previous section to select a network interface and register the device to be tested, and then click one of the following options:

- **Reset**. You can reset a device to test its reset behavior, or to restart the device application if the device becomes unresponsive. Resetting a device clears the device statistics that are reported when you click **Test**.
- **Wink**. You can wink a device to identify it on the network and verify that it is communicating properly. A device that supports the Wink command generates an application-dependent audio or visual feedback such as a beep or a flashing service LED when winked. Wink commands are typically used when installing or diagnosing multiple devices in a system, where a network tool may be needed to confirm the identity of a given device. You can program your device application to so that it provides some clear audio or visual feedback in response to a Wink command.
    - When you wink an FT 5000 EVB running any of the provided Neuron C example applications, the TX (transaction send) and RX (transaction receive) LEDs quickly flash on and off.

- When you wink a PL EVB when it is running an example application LED1–LED3 on the Mini Gizmo I/O Board turn on and LED4–LED8 blink rapidly for a few seconds, and the TX and RX LEDs on the EVB quickly flash.

- **Test**. You can test a device to check its current status. After the test has been completed, the Status box displays the current state of the device, as well as statistics such as the number of packets received by the device, the number of packets addressed to the device, and the number of missed or lost messages. Each statistic displayed by the test will remain static when it reaches the maximum value of 65,535. You can reset the device statistics after a test by clicking **Reset**.

5

Developing Device Applications

This chapter provides an overview of the Neuron C Version 2.2 programming language. It provides a series of programming examples that demonstrate Neuron C concepts, including input/output, timers, network variables, configuration properties, functional blocks, and Interoperable Self-Installation (ISI).

Introduction to Neuron C

Neuron C Version 2.2 is a programming language based on ANSI C that you can use to develop applications for Neuron Chips and Smart Transceivers. It includes network communication, I/O, interrupt-handling, and event-handling extensions to ANSI C, which make it a powerful tool for the development of LONWORKS device applications. Following are a few of the extensions to the ANSI Standard C language:

- A network communication model based on *functional blocks* and *network variables* that simplifies and promotes data sharing between like or disparate devices.
- A network configuration model based on functional blocks and *configuration properties* that facilitates interoperable network configuration tools.
- A type model based on standard and user *resource files* expands the market for interoperable devices by simplifying integration of devices from multiple manufacturers.
- An extensive built-in set of *I/O objects* that supports the powerful I/O capabilities of Neuron Chips and Smart Transceivers. Powerful *event-driven programming* extensions based on *when*-tasks that provide easy handling of network, I/O, and timer events.
- Language extensions that define application interrupt handlers and use synchronization tools, where available.

Neuron C provides a rich set of language extensions to ANSI C tailored to the unique requirements of distributed control applications. Experienced C programmers will find Neuron C a natural extension to the familiar ANSI C paradigm. Neuron C offers built-in type checking and allows the programmer to generate highly efficient code for distributed LONWORKS applications.

Neuron C omits ANSI C features not required by the standard for free-standing implementations. For example, certain standard C libraries are not part of Neuron C. Other differences between Neuron C and ANSI C are detailed in the *Neuron C Programmer's Guide*.

This chapter provides an introduction to Neuron C. For more details on Neuron C, see the *Neuron C Programmer's Guide*.

Unique Aspects of Neuron C

Neuron C implements all the basic ANSI C types, and type conversions as necessary. In addition to the ANSI C data constructs, Neuron C provides some unique data elements.

Network variables are fundamental to Neuron C and LONWORKS applications. Network variables are data constructs that have language and Neuron firmware support to provide the look and feel of a regular global C variable, but with additional properties of communicating across a LONWORKS network, to or from one or more other devices on that network. The network variables make up part of the device interface for a LONWORKS device.

Configuration properties are Neuron C data constructs that are another part of the device interface. Configuration properties allow the device's behavior to be customized using a network tool such as the LonMaker tool or a customized plug-in created for the device. Configuration properties provide the look and feel of a normal variable to the C program, with the addition of controlled access by network configuration tools.

Neuron C also provides a way to organize the network variables and configuration properties in the device into functional blocks. Functional blocks provide a collection of network variables and configuration properties that are used together to perform one task. These network variables and configuration properties are called the functional block members.

Each network variable, configuration property, and functional block is defined by a type definition contained in a resource file. Network variables and configuration properties are defined by network variable types (NVTs) and configuration property types (CPTs). Functional blocks are defined by functional profile templates (FPTs).

Network variables, configuration properties, and functional blocks in Neuron C can use standardized, interoperable types. The use of standardized data types promotes the interconnection of disparate devices on a LONWORKS network. For network variables, the standard types are called standard network variable types (SNVTs). For configuration properties, the standard types are called standard configuration property types (SCPTs). For functional blocks, the standard types are called standard functional profiles (SFPTs). If you cannot find standard types or profiles that meet your requirements, Neuron C also provides full support for user-defined network variable types (UNVTs), user-defined configuration property types (UCPTs), and user-defined functional profile templates (UFPTs).

A Neuron C application executes in the environment provided by the Neuron firmware. This firmware provides an event-driven scheduling system as part of the Neuron C language's run-time environment. Therefore, a Neuron C application does not use a single entry point, as is the case with ANSI C's **main()** function. Instead, a Neuron C application uses *when*-tasks and *interrupt*-tasks to specify application code to be executed in response to various system events or interrupt requests, much in the way of a .NET event handler.

The Neuron firmware contains a scheduler, which executes these *when*-tasks in an orderly and deterministic fashion as and if needed. Neuron C *when*-tasks can be triggered by system events (such as reset), network events (such as a network variable update or network error), I/O events (such as a new reading from an I/O input), timer events, or any arbitrary application-defined event.

Interrupt-tasks are activated as the interrupt request occurs, subject to interrupt prioritization rules. Neuron C interrupt-tasks can be triggered by edge or level conditions on any of the dedicated I/O pins, by events occurring in the embedded timer and counter units, or by a dedicated high-resolution system timer. *Interrupt*-tasks are only supported by Series 5000 chips. Other interrupt sources, such as those related to sending or transmitting serial data over the embedded UART, are handled transparently by the Neuron firmware.

Neuron C also provides a lower-level application messaging service integrated into the language in addition to the network variable model. While the network variable model has the advantage of being a standardized method of information interchange that promotes interoperability between multiple devices from multiple vendors, application messaging is available for proprietary and standard special-purpose solutions. Application messages are used with the LONWORKS file transfer protocol, a standard mechanism for transfer of large amounts of data, and the ISI protocol, a standard mechanism to manage networks without intervention of a dedicated tool or specialist.

Another Neuron C data object is the application timer object. Timer objects can be declared and manipulated like variables. When a timer expires, the Neuron firmware automatically manages the timer events and notifies the program of those events.

Timers may be automatically reloading (repeating), or one-shot timers, with a duration ranging from 0.001–65,535 seconds.

Neuron C supports programmable hardware timer units through a variety of I/O library functions. These functions provide a resolution up to 1 MHz (1 µs) or better, subject to the selected I/O model, Neuron type, clock speed, and other factors (see the *I/O Model Reference* for more information). The Series 5000 chips also support a configurable high-resolution system timer, which can be used to generate periodic interrupt requests.

Neuron C supports up to 35 different I/O models, ranging from simple bit Direct I/O models for typical input or output hardware to complex Timer/Counter models for triacs. Neuron C also includes serial and parallel I/O models for serial and parallel communication busses. These I/O models are standardized I/O "device drivers" for the Neuron Chip or Smart Transceiver I/O hardware. Each I/O model fits into the event-driven programming model. A function-call interface is provided to interact with each I/O object. The function-call interfaces are optimized for their respective I/O models, yet they are similar to each other so that they are easy to use.

Neuron C Variables

The following sections briefly discuss various aspects of Neuron C-specific variable declarations. Data types affect what sort of data a variable represents. Storage classes affect where the variable is stored, whether it can be modified (and if so, how often), and whether there are any device interface aspects to modifying the data.

Neuron C Variable Types

Neuron C supports the following C variable types. The keywords shown in square brackets below are optional. If omitted, they will be assumed by the Neuron C language, per the rules of the ANSI C standard:

- **[signed] long [int]** 16-bit quantity
- **unsigned long [int]** 16-bit quantity
- **signed char** 8-bit quantity
- **[unsigned] char** 8-bit quantity
- **[signed] [short][int]** 8-bit quantity
- **unsigned [short][int]** 8-bit quantity
- **enum** 8-bit quantity (**int** type)

Neuron C provides some predefined enum types. One example is shown below:

typedef enum {FALSE, TRUE} boolean;

You should use the **unsigned int** type whenever possible because it is the type best supported by the Neuron Chip and Smart Transceiver's hardware architecture. The **unsigned int** type is preferred over **signed int** type.

Neuron C also provides predefined objects that, in many ways, provide the look and feel of an ANSI C language variable. These objects include Neuron C timer and I/O objects. See Chapter 2 of the *Neuron C Programmer's Guide* for more details on I/O objects, and see Chapter 4 in the *Neuron C Reference Guide* for more details on timer objects.

The extended arithmetic library also defines **float_type** and **s32_type** for IEEE 754 and signed 32.bit integer data respectively. These types are detailed further in Chapter 3 of the *Neuron C Reference Guide*.

Neuron C Storage Classes

If no class is specified for a declaration at file scope, the data or function is global. *File scope* is that part of a Neuron C program that is not contained within a function, a *when*-task, or an *interrupt*-task. Global data (including all data declared with the **static** keyword) is present throughout the entire execution of the program, starting from the point where the symbol was declared. Declarations using **extern** references can be used to provide forward references to variables, and function prototypes must be declared to provide forward references to functions. In addition, **extern** references can be used to publish a symbol and allow for linking with other object files.

Upon power-up or reset of a Neuron Chip or Smart Transceiver, the global data in RAM is initialized to its initial-value expression, if present; otherwise, it is set to **0**.

Neuron C supports the following ANSI C storage classes and type qualifiers:

- **auto** declares a variable of local scope. Typically, this would be within a function body. This is the default storage class within a local scope and the keyword is normally not specified. Variables of auto scope that are not also static are not initialized upon entry to the local scope. The value of the variable is not preserved once program execution leaves the scope.
- **const** declares a value that cannot be modified by the application program. Affects self-documentation (SD) data generated by the Neuron C compiler when used in conjunction with the declaration of CP families or configuration network variables. The Neuron C language does not permit the use of **const** with **auto**.
- **extern** declares a data item or function that is defined in another module, in a library, or in the system image.
- **static** declares a data item or function which is *not* to be made available to other modules at link time. Furthermore, if the data item is local to a function or to a **when()**task, the data value is to be preserved between invocations, and is not made available to other functions at compile time.

In addition to the ANSI C storage classes, Neuron C provides the following classes and class modifiers:

- **network** begins a network variable declaration. See Chapter 3, *How Devices Communicate Using Network Variables*, of the *Neuron C Programmer's Guide* for more details.
- **uninit** when combined with the **eeprom** keyword (see below), specifies that the EEPROM variable is not initialized or altered on program load or reload over the network.

The following Neuron C keywords allow you to direct portions of application code and data to specific memory sections.

- **eeprom**
- **far**
- **offchip** (only on Neuron Chips and Smart Transceivers with external memory)
- **onchip**

These keywords are particularly useful on the Neuron 3150 Chip and 3150 Smart Transceivers, since a majority of the address space for these parts is mapped off chip. See *Using Neuron Chip Memory* in Chapter 8 of the *Neuron C Programmer's Guide* for a more detailed description of memory usage and the use of these keywords.

Variable Initialization

Initialization of variables occurs at different times for different classes. The **const** variables, except for network variables, *must* be initialized. Initialization of **const** variables occurs when the application image is first loaded into the Neuron Chip or Smart Transceiver. The **const ram** variables are placed in off-chip RAM that must be non-volatile. The **eeprom** and **config** variables are also initialized at load time, except when the **uninit** class modifier is included in these variable definitions.

Automatic variables cannot be declared **const** because Neuron C does not implement initializers in declarations of automatic variables.

Global RAM variables are initialized at reset (specifically when the device is reset or powered up). By default, all global RAM variables (including **static** variables) are initialized to zero at this time.

Initialization of I/O objects, input network variables (except for **eeprom**, **config**, **config_prop**, or **const** network variables), and timers also occurs at reset. Zero is the default initial value for network variables and timers.

Local variables (except **static** ones) are not automatically initialized, nor are their values preserved when the program execution leaves the local scope.

Neuron C Declarations

The Neuron C Version 2.2 programming language and ANSI C both support the following declarations listed in Table 5.1:

Table 5.1 ANSI C and Neuron C Declarations

Declaration	Example
Simple data items	`int a, b, c;`
Data types	`typedef unsigned long ULONG;`
Enumerations	`enum hue {RED, GREEN, BLUE};`
Pointers	`char *p;`
Functions	`int f(int a, int b);`
Arrays	`int a[4];`

Structures and unions	`struct s {`
	`  int field1;`
	`  unsigned field2 : 3;`
	`  unsigned field3 : 4;`
	`};`

The Neuron C Version 2.2 programming language also supports the following declarations listed in Table 5.2:

Table 5.2 Neuron C Declarations

Declaration	Example
I/O objects	`IO_0 output oneshot relay_trigger;`
Timers	`mtimer led_on_timer;`
Network variable	`network input SNVT_temp nviTemperature;`

Declaration	Example
Configuration Properties	`SCPTdefOutput cp_family cpDefaultOut;`
Functional Blocks	`fblock SFPTnodeObject { … } myNode;`

Getting Started with Neuron C

This section provides a series of Neuron C examples that demonstrate how to use Neuron C to perform I/O functions. These programming examples are designed to work with both the FT 5000 EVB and the PL 3150/PL 3170 EVB, with minor functional differences based on the hardware and system resources on the boards. The examples use the I/O devices on the FT 5000 EVB, and the Mini Gizmo I/O board that you can attach to a PL 3150/PL 3170 EVB. The I/O devices used in these examples include the push buttons, LEDs, temperature sensors, serial ports, and displays on the boards. By following these examples, you will create a set of I/O utility functions that is summarized in *I/O Examples Toolkit* later in this chapter. These utility functions are used in the subsequent example device applications.

This section then provides a series of increasingly complex device applications based on the I/O examples. These device applications introduce Neuron C and device development concepts such as I/O objects and timers, network variables, configuration properties, functional profiles, and Interoperable Self-Installation (ISI). The device applications are as follows:

- A digital sensor that senses a push button, and a digital actuator that drives an LED.
- A thermostat that samples ambient temperature readings, displays current and setpoint temperature values, executes a controller algorithm to drive a heating and cooling system, and provides status information.

You can copy the programming examples or the complete device applications to a text editor, save them to a file with an **.nc** extension, and then build and download them into your EVB with the Mini FX Application.

Note: You must use the **.nc** file extension for Neuron C source code. You cannot use the **.c** file extension, which is common to ANSI C programmers. If you compile code packaged in a file with a **.c** file extension, the Neuron C Compiler classifies the source as "pure C" and disables most of the Neuron C extensions. As a result, you will not be able to download the resulting application image file into a Neuron Chip or Smart Transceiver. You cannot use the Mini kit to create user-defined function libraries with the pure C feature, but you can use the NodeBuilder tool to create them with pure C.

If you have changed the jumper configurations on your EVB, you must return them to their default settings to run the examples provided in this chapter. Table 5-3 lists the minimum jumper configurations required for the FT 5000 EVB, PL 3150 EVB, and PL 3170 EVB to run the examples. The table lists separately the jumper pins that must be connected and disconnected.

See the *FT 5000 EVB Hardware Guide* for more information on the jumper locations and settings of the FT 5000 EVB. See the *Mini FX/PL Examples Guide* for more information on the jumper locations and settings of the PL 3150/PL 3170 EVB.

Table 5.3 **Required EVB Jumper Configurations**

Board	**Required Connections**		**Required Disconnections**	
	Jumper	**Pin**	**Jumper**	**Pin**
FT 5000 EVB	JP31	all	JP21	all
	JP32	1-2 (SWSH) 3-4 (TEMP) 7-8 (SW1)	JP32	11-12 (3PD) 13-14 (1PD) 15-16 (9PD)
	JP33	LCD 5V	JP201	all
	P201	7-8 (10 T1IN)	JP203	1-2 (SPD) 3-4 (6PD) 5-6 (T2IN) 7-8 (FON PD)
PL 3150 EVB	Mini Gizmo I/O Board (P201)		—	—
PL 3170 EVB	Mini Gizmo I/O Board (P201)		JP201	all
			JP203	IO5
			JP204	IO6

Note: You can use other Series 3100 EVBs to run the examples applications. To do this, connect the Mini Gizmo I/O Board to the P201 connector on the EVB, connect the IO10 jumper, and remove the IO5, IO6, IO0, IO8, IO4, and IO1 jumpers.

Performing Neuron C Input/Output

A Neuron Chip or Smart Transceiver may be connected to one or more physical I/O devices via up to 12 versatile I/O pins. Examples of simple I/O devices include temperature, light, and position sensors; valves; switches; LEDs; and LCDs. Neuron Chips and Smart Transceivers can also be connected to other microprocessors. The Neuron firmware implements numerous I/O objects that manage the interface to these devices for a Neuron C application. For more details on I/O objects, see the *Neuron C Programmer's Guide* and the *Neuron C Reference Guide*.

To set up I/O devices in your Neuron C code, you declare the I/O objects that monitor and control the Neuron Chip or Smart Transceiver I/O pins, named IO_0 – IO_10 or IO_11 (depending on the Neuron Chip or Smart Transceiver model). To perform I/O, you use the built in I/O events and functions in the Neuron C programming language.

You can then use the built in I/O events and functions to debug your device application. For example, you can use the LED outputs on your EVBs to signal events from within your application.

You can also perform application level debugging using the serial ports on your EVBs, or exchange other data to any other computer using a serial connection. To do this, you insert code in your device application that sends output to the serial ports, enable serial communication on your EVB, and connect your EVB to your development computer via a serial interface. You can then monitor the serial output with Windows HyperTerminal, PuTTy, or another terminal emulation program on your computer.

- You can connect an FT 5000 EVB to your development computer via a USB or EIA 232 interface For more information on connecting the serial interface on an FT 5000 EVB, see Chapter 2 of the *FT 5000 EVB Hardware Guide*. The examples in this

chapter, and the jumper configuration discusses earlier in this chapter, use an EIA-232 connection.

- You can connect your PL 3150 EVB to your development computer via an EIA 232 interface. For more information on connecting the serial interface on a PL 3150 EVB, see the *Mini FX/PL Examples Guide*.

If you are using the Mini FX/FT Evaluation Kit, you can also use the LCDs on the FT 5000 EVBs to display debug output, application data, and usage information. The programming samples in this chapter demonstrate how to do this.

For more information on the built in Neuron C I/O functions and events, see the *Neuron C Reference Guide*. For more information on performing I/O with a Smart Transceiver or Neuron Chip, see the *I/O Model Reference for Smart Transceivers and Neuron Chips* and the Engineering Bulletins listed in Table 5.4, which are available at *www.echelon.com/docs*.

Table 5.4 Neuron C I/O Engineering Bulletins

Document Title	Description	Part Number
Analog-To-Digital Conversion With the Neuron Chip	Describes some of the more popular analog to digital (A/D) conversion schemes available for use with a Smart Transceiver or Neuron Chip. Provides schematics, parts lists and code examples.	*005-0019-01*
Driving a Seven Segment Display with the Neuron Chip	Describes how a Smart Transceiver or Neuron Chip can be used to drive a seven-segment display controller chip, the Motorola MC14489, using the Neurowire device. Includes Neuron C software drivers to display decimal numbers from binary data.	*005-0014-01*
EIA-232C Serial Interfacing with the Neuron Chip	Describes a simple level conversion circuit to allow a Smart Transceiver or Neuron Chip to communicate with RS-232C devices. Also includes Neuron C software to drive an RS-232C CRT terminal.	*005-0008-01*
Neuron Chip Quadrature Input Function Interface	Describes the use of the quadrature device in a Smart Transceiver or Neuron Chip to interface to external devices such as shaft encoders.	*005-0003-01*
Parallel I/O Interface to the Neuron Chip	Describes hardware and software to interface a Smart Transceiver or Neuron Chip to a microprocessor using the parallel I/O port.	*005-0021.01*

Document Title	Description	Part Number
Scanning a Keypad with the Neuron Chip	Describes how a Smart Transceiver or Neuron Chip can be used to scan a simple 16-key switch matrix to provide a numeric or special-function keyboard without the use of a keyboard encoder.	*005-0004-01*
Using the Hardware Serial Peripheral Interface (SPI) and Neurowire I/O Object Models to Interface with Peripherals and Microcontrollers	Describes communications between Smart Transceivers or Neuron Chips and other microcontrollers for designs that intend to make use of the SPI interface for simpler applications and also for understanding how the SPI interfaces are implemented in the Smart Transceivers and Neuron Chips. Neuron C code examples of an SPI interface are explained in this engineering bulletin, and the source code is available for download.	*005-0165*

The programming samples in this section are designed to work with both the FT 5000 EVB and the PL 3150/PL 3170 EVB. Conditional compilation is used where necessary because some of the I/O devices on the EVBs are different. For the examples in this chapter, define the USE_5000EVB symbol to use the FT 5000 EVB, and define the USE_MINIGIZMO symbol to use a PL 3150/PL 3170 EVB (other Series 3100 EVB) with a Mini Gizmo I/O board attached.

This following section demonstrates how to write Neuron C code to perform I/O on switches, LEDs, temperature sensors, serial ports, and displays. To view the collection of I/O definitions and functions created by these examples, see *I/O Examples Toolkit* at the end of this section. The subsequent example device applications in this chapter are based on the I/O definitions and functions.

Note: This section includes code fragments rather than complete application code. To view complete example Neuron C device applications, see *Creating Example Device Applications* later in this chapter.

Switches

The following sections describe how to write Neuron C code that interoperates with the push buttons on the FT 5000 EVB and the Mini Gizmo I/O Board that you can attach to a PL EVB. The code that samples the **SW1** button on both EVB types can be combined using conditional compilation. The complete code for the I/O drivers is provided in *I/O Examples Toolkit* at the end of this section.

FT 5000 EVB

The FT 5000 EVB includes two push buttons: **SW1** and **SW2**. The **SW1** button is wired straight to the I/O 9 pin and can be sampled using a simple input bit model. The **SW2** push button is connected to a parallel-in/serial-out shift register. For simplicity, this example uses the **SW1** button only.

The state of a bit input signal can be read at any time through the **io_in()** Neuron C library function:

```
IO_9 input  bit ioSwitch1;

void example()
{
    if ((boolean)io_in(ioSwitch1)) {
        …
    }
}
```

The Neuron C language implements a largely event-driven programming model. This means that instead of constantly polling all I/O for new data, your device application only needs to respond to changes. The following example initializes this system during reset processing, and calls an **OnButtonPressed()** event handler whenever an activated button is detected. The **OnButtonPressed()** event handler does nothing in this example, but it will be modified later to respond to button events:

```
IO_9 input  bit ioSwitch1;

extern void OnButtonPressed(void);       // button event handler

//
// InitializeIO() is called from the when(reset) task and initializes
// the I/O system and related driver functions.
//
void InitializeIO()
{
    io_change_init(ioSwitch1);
}
//
// when(reset) executes whenever the device resets.  It performs housekeeping
// and initialization tasks as required by the application.
//
when(reset)
{
    InitializeIO();
    //
    // TODO: add other initialization code, if necessary
    //
    …
}

//
// when(io_changes…) executes whenever the switch
//
when(io_changes(ioSwitch1) to 0)
{
    OnButtonPressed();
}

//
// OnButtonPressed() is called whenever the button becomes active.  This
// initial implementation here does nothing.
//
void OnButtonPressed()
{
}
```

Note: The FT 5000 EVB examples included with the Mini kit contain a **EvalBoardGetSwitch()** function that demonstrates how to efficiently handle both push buttons on the FT 5000 EVB. This function is contained in the **ft5000evalboard.h** file, which is located in the LONWORKS**NeuronC\Examples\FT5000 EVB\Common** folder on your computer.

Mini Gizmo I/O Board

The Mini Gizmo I/O board includes eight buttons that are connected to a parallel-in serial-out shift register. These buttons are sampled using a bitshift input model for data,

and a bit output model for the latch pulse. To read any of these buttons, all eight buttons must be read from the shift register.

The following **GetButton()** function takes three subsequent readings to suppress a bouncing signal, and returns the logical state of the **SW1** button:

```
IO_4 input bitshift numbits(8) clockedge(-) ioButtons;
IO_6 output bit ioButtonLoad = 1;

boolean GetButton(void)
{
    unsigned debounce;
    unsigned data;
    data = 0xFF;

    for (debounce = 0; debounce < 3; ++debounce) {
        // strobe:
        io_out(ioButtonLoad, 0);
        io_out(ioButtonLoad, 1);
        // sample data and debounce:
        data &= (unsigned)io_in(ioButtons);
    }
    return ~buttons & 0x01;
}
```

Because the eight Mini Gizmo buttons are connected through a shift register, state changes cannot be detected through the **io_changes()** event used with the **SW1** button on the FT 5000 EVB. The following example uses a repeating application timer, which expires every 25 ms, to take the button reading. When an activated **SW1** button is detected, the timer event handler calls the same **OnButtonPressed()** event handler introduced earlier:

```
extern void OnButtonPressed(void);       // button event handler
//
// buttonTimer expires every 25ms, and triggers the timer_expires event
// with each expiry
//
mtimer repeating buttonTimer = 25;

//
// The Neuron C scheduler activates the following when-task whenever the
// button timer expires.  The task samples the button state, detects a
// newly activated SW1 button, and fires the OnButtonPressed() event when
// necessary.
//
when(timer_expires(buttonTimer) {
    static boolean previousButton = TRUE;
    boolean currentButton;

    currentButton = GetButton();
    if (currentButton && !previousButton) {
        OnButtonPressed();
    }
    previousButton = currentButton;
}

//
// OnButtonPressed() is called whenever the button becomes active.  This
// initial implementation here does nothing.
//
void OnButtonPressed()
{
}
```

Conditional Compilation Example

The following is the combined code for the switch driver, capable of driving the **SW1** button on FT 5000 EVB and the Mini Gizmo I/O board:

```
#ifdef  USE_5000EVB

IO_9 input  bit ioSwitch1;

//
// when(io_changes…) executes whenever the button is pressed
//
when(io_changes(ioSwitch1) to 0)
{
    OnButtonPressed();
}

#ifdef USE_MINIGIZMO

IO_4 input bitshift numbits(8) clockedge(-) ioButtons;
IO_6 output bit ioButtonLoad = 1;
boolean GetButton(void)
{
    unsigned debounce;
    unsigned data;
    data = 0xFF;
    for (debounce = 0; debounce < 3; ++debounce) {
        // Strobe:
        io_out(ioButtonLoad, 0);
        io_out(ioButtonLoad, 1);
        // Sample data and debounce:
        data &= (unsigned)io_in(ioButtons);
    }
    return ~data & 0x01;
}

//
// buttonTimer expires every 25ms, and triggers the timer_expires event
// with each expiry
//
mtimer repeating buttonTimer = 25;
//
// The Neuron C scheduler activates the following when-task whenever the
// button timer expires.  The task samples the button state, detects a
// newly activated SW1 button, and fires the OnButtonPressed() event when
// necessary.
//
when(timer_expires(buttonTimer)) {
    static boolean previousButton = TRUE;
    boolean currentButton;

    currentButton = GetButton();
    if (currentButton && !previousButton) {
        OnButtonPressed();
    }
    previousButton = currentButton;
}

#else

#endif  // 5000 evb
#endif  // mini gizmo
```

LEDs

LEDs are normally connected to Vcc through a suitable resistor, and driven active low: a '0' output signal normally switches the LED on, and a '1' switches it off. The following sections describe how to program the LEDs on the FT 5000 EVB and the Mini Gizmo I/O Board that you can attach to a PL EVB. The code that drives the LEDs on both EVB types can be combined using conditional compilation. The complete code for the I/O drivers is provided in *I/O Examples Toolkit* at the end of this section

FT 5000 EVB

The FT 5000 EVB includes two LEDs: **LED1** and **LED2**. **LED1** and **LED2** are connected to pins I/O 2 and I/O 3, respectively. You can drive the state of these LEDs by simply declaring a one bit output model for each LED, and assigning the desired output value with the **io_out()** Neuron C library function:

```
IO_2 output bit ioLed1 = 1;
IO_3 output bit ioLed2 = 1;
```

For use with the examples provided in this chapter, a **SetLeds()** function takes two arguments, the logical on/off state for each LED. The function provides hardware abstraction, translates the logical on/off state into the physical signal, and drives the I/O lines accordingly:

```
void SetLeds(boolean led1, boolean led2)
{
    io_out(ioLed1, !led1);
    io_out(ioLed2, !led2);
}
```

Mini Gizmo I/O Board

The Mini Gizmo I/O board includes eight LEDs that are connected to the Smart Transceiver using a serial-in/parallel-out shift register. To control any of these LEDs, the desired state of all eight LEDs must be shifted into this register. Similar to the **SetLeds()** function for the FT 5000 EVB, the **SetLeds()** function for the Mini Gizmo I/O board in this example only supports two LEDs, **LED1** and **LED2**. The remaining six LEDs are always off.

The following is an implementation of the **SetLeds()** function for use with the Mini Gizmo I/O board. The function uses a bitshift output model for the serialized data, and a bit output object to drive the shift register's low-active Load signal.

```
IO_2 output bitshift numbits(8) ioLeds;
IO_1 output bit ioLedLoad = 1;

void SetLeds(boolean led1, boolean led2)
{
    unsigned data;

    // Compute the data byte for the shift register:
    data = led1 ? 0x80 : 0x00;
    data |= led2 ? 0x40 : 0x00;

    // Push inverted data into shift register:
    io_out(ioLeds, ~data);

    // Strobe:
    io_out(ioLedLoad, 0);
    io_out(ioLedLoad, 1);
}
```

Conditional Compilation Example

The following is the combined code for the LED driver, capable of driving two LEDs on FT 5000 EVB and the Mini Gizmo I/O board:

```
#ifdef USE_5000EVB

IO_2 output bit ioLed1 = 1;
IO_3 output bit ioLed2 = 1;

#else
#ifdef USE_MINIGIZMO

IO_2 output bitshift numbits(8) ioLeds;
IO_1 output bit ioLedLoad = 1;

#endif // mini gizmo
#endif // 5000 evb

void SetLeds(boolean led1, boolean led2)
{
#ifdef USE_5000EVB
    io_out(ioLed1, !led1);
    io_out(ioLed2, !led2);
#else
#ifdef USE_MINIGIZMO
    unsigned data;

    // Compute the data byte for the shift register:
    data = led1 ? 0x01 : 0x00;
    data |= led2 ? 0x02 : 0x00;

    // Push inverted data into shift register:
    io_out(ioLeds, ~data);

    // Strobe:
    io_out(ioLedLoad, 0);
    io_out(ioLedLoad, 1);
#endif // mini gizmo
#endif // 5000 evb
} // SetLeds
```

Temperature Sensor

Both the FT 5000 EVB and the Mini Gizmo I/O board include a Dallas DS18S20 temperature sensor. This temperature sensor is connected to the Smart Transceiver through a one-wire touch I/O interface to pin I/O 7.

The following example illustrates the use of the touch I/O model. The **GetTemperature()** function drives the 1-wire protocol to obtain two data bytes from the sensor, maps those to a local variable in big endian notation, and transforms the data received to meet the definition of a **SNVT_temp_p** standard network variable type, which holds temperature information in Celsius, with a resolution of 0.01°.

```
IO_7 touch ioTemperatureSensor;

#define DS18S20_SKIP_ROM    0xCCu
#define DS18S20_CONVERT     0x44u
#define DS18S20_READ        0xBEu

SNVT_temp_p GetTemperature(void)
{
    union {
        SNVT_temp_p value;
        unsigned    raw[2];
    } current;

    current.value = 32767l;

    if (touch_reset(ioTemperatureSensor)) {
        (void)touch_byte(ioTemperatureSensor, DS18S20_SKIP_ROM);
        (void)touch_byte(ioTemperatureSensor, DS18S20_READ);
        // Read data into big-endian variable:
        current.raw[1] = (unsigned)touch_byte(ioTemperatureSensor, 0xFFu);
```

```
            current.raw[0] = (unsigned)touch_byte(ioTemperatureSensor, 0xFFu);

            if (touch_reset(ioTemperatureSensor)) {
                //  The value currently held in 'current' is the raw DS18S20
                //  data, in Celsius, at a resolution of 0.5 degrees.
                //  SNVT_temp_p, however, provides a resolution of 0.01 in
                //  a fixed-point implementation.
                //  Correct the raw reading by factor 50 thus:
                current.value *= 50ul;

                // Start the next conversion cycle:
                (void) touch_byte(ioTemperatureSensor, DS18S20_SKIP_ROM);
                (void) touch_byte(ioTemperatureSensor, DS18S20_CONVERT);
            } else {
                current.value = 32767l;
            }
        }
        return current.value;
    }
```

Serial I/O

Serial I/O is often used to exchange application data with other processors or computers. A simple serial text output is also often useful for simple application-level debugging and diagnosing, or for reporting calibration data during manufacture.

Both the FT 5000 EVB and the PL 3150/PL 3170 EVB support a EIA-232 line driver and a 9-pin standard serial port (J201). To use this serial port, you must configure your EVB as described in Table 5-3 in the *Getting Started with Neuron C* section earlier in this chapter. This enables your application to drive the asynchronous serial output from the Smart Transceiver's I/O 10 pin through the EIA-232 line driver and to the J201 connector.

To monitor the serial output generated by the examples in this chapter, you can connect your EVB to your computer using a DB9 Male-Female Serial Extension Cable or a USB Type A to Type B Cable (FT 5000 EVB only), and then run Windows HyperTerminal, PuTTY, or another terminal emulation program on your computer. Configure the terminal emulation program for direct connection to your serial port (typically COM1 or COM2), 9600 bps, 8 data bits, no parity, one stop bit, and no flow control.

The following example implements the **SerialOutput()** function, which uses the SCI serial I/O model through pins I/O 8 (RxD, which is not used in this example) and I/O 10 (TxD, which is used to send data). The **SerialOutput()** function sends a zero-terminated string (without the termination byte) to the serial output, using the SCI input/output model. The function automatically appends a "\r\n" line termination.

The SCI I/O model uses the on-chip hardware UART. If the SCI I/O model is not available on your hardware platform, you can use the serial output model instead.

```
IO_8 sci baud(SCI_9600) ioSerial;
void SerialOutput(const char *data)
{
    // Send data:
    io_out_request(ioSerial, data, strlen(data));
    while(!io_out_ready(ioSerial)) ;

    // Send line termination:
    io_out_request(ioSerial, "\r\n", 2);
}
```

LCD Display

The LCD display included with the FT 5000 EVB may be used to display status or other application data in an easy-to-read fashion. In addition, it can be used to debug and diagnose applications.

The display is connected to the Smart Transceiver through an I2C interface to the I/O 0 and I/O 1 pins. The functions shown in the following example use the i2c input/output model. For applications built in debug mode, the **LcdDisplayString()** function automatically forwards the data to the serial output. The Debug mode is supported in the NodeBuilder tool, but it is not available with Mini kit.

The Mini Gizmo I/O board does not include an LCD display. When used with the Mini Gizmo I/O board, the **LcdDisplayString()** function always uses a remote display and forwards the data to the serial output.

```
#ifndef USE_MINIGIZMO

    IO_0 i2c __slow ioIIC;

#   define LCD_COMMAND_PREFIX       0xFEu
#   define LCD_COMMAND_ON           0x41u
#   define LCD_COMMAND_SETCURSOR    0x45u
#   define LCD_COMMAND_CLEARSCREEN  0x51u
#   define LCD_COMMAND_BRIGHTNESS   0x53u
    // The datasheet advertizes the address as 0x50, but in reality,
    // the 7-bit right-justified address is 0x28 (0x50 >> 1):
#   define I2C_ADDRESS_LCD          (0x50u >> 1)

//
// The SendLcdCommand() function is used within this driver kit.
// The function sends a one- or two-byte command to the display.
//
void SendLcdCommand(unsigned command, unsigned parameter, unsigned size)
{
    unsigned data[3];

    data[0] = LCD_COMMAND_PREFIX;
    data[1] = command;
    data[2] = parameter;

    (void)io_out(ioIIC, data, I2C_ADDRESS_LCD, 1+size);
}

#endif  // !mini gizmo
//
// The InitializeLCD function enables and clears the display.  Call this
// function from InitializeIO() (which in turn is called from when(reset).
//
static void InitializeLCD(void)
{
#ifndef USE_MINIGIZMO

    SendLcdCommand(LCD_COMMAND_ON, 0, 1);
    SendLcdCommand(LCD_COMMAND_BRIGHTNESS, 1, 2);
    SendLcdCommand(LCD_COMMAND_CLEARSCREEN, 0, 1);

#else   // use mini gizmo:

    SerialOutput("\r\n---Reset");

#endif  // mini gizmo
}

void LcdDisplayString(unsigned row, unsigned column, const char* data)
{
#ifndef USE_MINIGIZMO
```

```
    // Set the cursor position
    static const unsigned lcdRowAddress[4] = {0x00, 0x40, 0x14, 0x54};

    SendLcdCommand(LCD_COMMAND_SETCURSOR, lcdRowAddress[row]+column, 2);

    // Send the data
    (void)io_out(ioIIC, data, I2C_ADDRESS_LCD, (unsigned)strlen(data));

#   ifdef _DEBUG
    // in a debug build, forward the same data to the serial port:
    watchdog_update();
    SerialOutput(data);
#   endif  // _debug
#else  //  Use mini gizmo:
    // Always send data to serial port (in lieu of a local display)
    SerialOutput(data);
#endif  // mini gizmo
}

//
// InitializeIO() is called from the when(reset) task and initalizes
// the I/O system and related driver functions.
//
void InitializeIO()
{
#ifdef USE_MINIGIZMO

#else
    InitializeLCD();
#ifdef USE_5000EVB
    io_change_init(ioSwitch1);
#endif  // USE_5000EVB
#endif // USE_MINIGIZMO
}  // InitializeIO
```

I/O Examples Toolkit

The following code is the combined I/O driver toolkit from the I/O examples in this section. You can copy and paste this code into a file (the suggested filename is "**io.nc**"), and use it with the example device applications in the following *Creating Example Device Applications* section. Alternatively, you can paste the I/O toolkit code straight into your application's main Neuron C source file. Note that you must define either **USE_MINIGIZMO** or **USE_5000EVB** based on your EVB.

```
//
//  io.nc is the I/O toolkit that drives both FT 5000 EVB and PL 3150 EVB
//  (actually, almost anything with a Mini Gizmo I/O board)
//
#ifndef __IO_NC__
#define __IO_NC__

#include <string.h>
#include <io_types.h>
#include <control.h>

//
//  Make sure one of USE_5000EVB and USE_MINIGIZMO is defined.  If both are
//  defined, USE_MINIGIZMO has priority (allowing to use the Mini Gizmo I/O
//  board with the FT 5000 EVB).
//
#ifndef USE_5000EVB
#ifndef USE_MINIGIZMO
#   error "You must define either USE_5000EVK or USE_MINIGIZMO"
#endif // mini gizmo
#endif // 5000 evb

//
//  Driver to support two leds.  Use SetLeds(a, b) to drive the LEDs with
logical
```

```
//  levels, i.e.  TRUE for "on".
//  The driver function translates the logical levels as necessary.
//
#ifdef USE_MINIGIZMO
    IO_2 output bitshift numbits(8) ioLeds;
    IO_1 output bit ioLedLoad = 1;
#else
#ifdef USE_5000EVB
    IO_2 output bit ioLed1 = 1;
    IO_3 output bit ioLed2 = 1;
#endif // 5000 evb
#endif // mini gizmo

void SetLeds(boolean led1, boolean led2)
{
#ifdef USE_MINIGIZMO
    unsigned data;

    // compute the data byte for the shift register:
    data = led1 ? 0x01 : 0x00;
    data |= led2 ? 0x02 : 0x00;

    // push inverted data into shift register:
    io_out(ioLeds, ~data);

    // strobe:
    io_out(ioLedLoad, 0);
    io_out(ioLedLoad, 1);
#else
#ifdef USE_5000EVB
    io_out(ioLed1, !led1);
    io_out(ioLed2, !led2);
#endif // 5000 evb
#endif // mini gizmo
}   // SetLeds

//
//  Driver to support one button.  The driver calls the OnButtonPressed()
//  function, which is a callback function implemented by the application.
//
extern void OnButtonPressed(void);

#ifdef USE_MINIGIZMO

IO_4 input bitshift numbits(8) clockedge(-) ioButtons;
IO_6 output bit ioButtonLoad = 1;
boolean GetButton(void)
{
    unsigned debounce;
    unsigned data;
    data = 0xFF;
    for (debounce = 0; debounce < 3; ++debounce) {
        // Strobe:
        io_out(ioButtonLoad, 0);
        io_out(ioButtonLoad, 1);
        // Sample data and debounce:
        data &= (unsigned)io_in(ioButtons);
    }
    return ~data & 0x01;
}

//
// buttonTimer expires every 25ms, and triggers the timer_expires event
// with each expiry
//
mtimer repeating buttonTimer = 25;
//
// The Neuron C scheduler activates the following when-task whenever the
// button timer expires.  The task samples the button state, detects a
// newly activated SW1 button, and fires the OnButtonPressed() event when
// necessary.
```

```
//
when(timer_expires(buttonTimer)) {
    static boolean previousButton = TRUE;
    boolean currentButton;

    currentButton = GetButton();
    if (currentButton && !previousButton) {
        OnButtonPressed();
    }
    previousButton = currentButton;
}

#else
#ifdef  USE_5000EVB

IO_9 input  bit ioSwitch1;

//
// when(io_changes…) executes whenever the switch
//
when(io_changes(ioSwitch1) to 0)
{
    OnButtonPressed();
}

#endif  // 5000 evb
#endif  // mini gizmo

//
//  Driver to support a 1-Wire Dallas DS18S20 digital thermometer device.
//  This implementation uses a simplified protocol, skipping the
//  search ROM step, because the boards provide only one 1-Wire device.
//  The same code works for both FT 5000 EVB and Mini Gizmo I/O boards.
//
// 1-Wire is a registered trademark of Dallas Semiconductor.
// You can find out more about this device on www.maxim-ic.com
//
IO_7 touch ioTemperatureSensor;

#define DS18S20_SKIP_ROM    0xCCu
#define DS18S20_CONVERT     0x44u
#define DS18S20_READ        0xBEu

SNVT_temp_p GetTemperature(void)
{
    union {
        SNVT_temp_p value;
        unsigned    raw[2];
    } current;

    current.value = 32767l;

    if (touch_reset(ioTemperatureSensor)) {

        (void)touch_byte(ioTemperatureSensor, DS18S20_SKIP_ROM);
        (void)touch_byte(ioTemperatureSensor, DS18S20_READ);

        // read data into big-endian variable
        current.raw[1] = (unsigned)touch_byte(ioTemperatureSensor, 0xFFu);
        current.raw[0] = (unsigned)touch_byte(ioTemperatureSensor, 0xFFu);

        if (touch_reset(ioTemperatureSensor)) {
            //  The value currently held in 'current' is the raw DS18S20
            //  data, in Celsius, at a resolution of 0.5 degrees.
            //  SNVT_temp_p, however, provides a resolution of 0.01 in
            //  a fixed-point implementation.
            //  Correct the raw reading by factor 50 thus:
            current.value *= 50ul;
            // Start the next conversion cycle:
            (void) touch_byte(ioTemperatureSensor, DS18S20_SKIP_ROM);
            (void) touch_byte(ioTemperatureSensor, DS18S20_CONVERT);
```

```
        } else {
            current.value = 32767l;
        }
    }
    return current.value;
}

//
//  Driver to support simple serial output.  The SerialOutput() function
//  sends a zero-terminated string (without the termination byte) to the
//  serial output, using the SCI input/output model.  The function auto-
//  matically appends a "\r\n" line termination.
//  The SCI model is not available on all target chips, as it requires
//  and uses the on-chip UART.  Consider using the serial output model on
//  IO 10 as a replacement in this case.
//
IO_8 sci baud(SCI_9600) ioSerial;

void SerialOutput(const char *data)
{
    io_out_request(ioSerial, data, (unsigned)strlen(data));
    while(!io_out_ready(ioSerial)) ;
    // Send line termination:
    io_out_request(ioSerial, "\r\n", 2);
}

//
//  Driver to support the LCD display provided with the FT 5000 EVB.  In a
//  debug build, the driver automatically forwards the output to the serial
//  port, using the SerialOutput() function.
//  On a device using a Mini Gizmo I/O board, which does not include
//  a LCD display, display data is always sent to the serial output.
//
//  The main API is LcdDisplayString()
//
#ifndef USE_MINIGIZMO
    IO_0 i2c __slow ioIIC;

#   define LCD_COMMAND_PREFIX       0xFEu

#   define LCD_COMMAND_ON           0x41u
#   define LCD_COMMAND_SETCURSOR    0x45u
#   define LCD_COMMAND_CLEARSCREEN  0x51u
#   define LCD_COMMAND_BRIGHTNESS   0x53u

    // The datasheet advertizes the address as 0x50, but in reality, the 7-bit
    // right-justified address is 0x28 (0x50 >> 1)
#   define I2C_ADDRESS_LCD          (0x50u >> 1)

//
// The SendLcdCommand() function is used within this driver kit.  The function
// sends a one- or two-byte command to the display.
//

void SendLcdCommand(unsigned command, unsigned parameter, unsigned size)
{
    unsigned data[3];

    data[0] = LCD_COMMAND_PREFIX;
    data[1] = command;
    data[2] = parameter;

    (void)io_out(ioIIC, data, I2C_ADDRESS_LCD, 1+size);
}
#endif  // !mini gizmo

//
// The InitializeLCD function enables and clears the display.  Call this
// function from InitializeIO() (which in turn is called from when(reset).
//
void InitializeLCD(void)
```

```
{
#ifndef USE_MINIGIZMO
    SendLcdCommand(LCD_COMMAND_ON, 0, 1);
    SendLcdCommand(LCD_COMMAND_BRIGHTNESS, 1, 2);
    SendLcdCommand(LCD_COMMAND_CLEARSCREEN, 0, 1);
#else   // use mini gizmo:
    SerialOutput("\r\n---Reset");
#endif  // mini gizmo
}

void LcdDisplayString(unsigned row, unsigned column, const char* data)
{
#ifndef USE_MINIGIZMO
    // Set the cursor position:
    static const unsigned lcdRowAddress[4] = {0x00, 0x40, 0x14, 0x54};
    SendLcdCommand(LCD_COMMAND_SETCURSOR, lcdRowAddress[row]+column, 2);
    // Send the data
    (void)io_out(ioIIC, data, I2C_ADDRESS_LCD, (unsigned)strlen(data));

#   ifdef _DEBUG
    // In a debug build, forward the same data to the serial port:
    SerialOutput(data);
#   endif   //  _debug
#else   //  Use mini gizmo
    // always send data to serial port (in lieu of a local display)
    SerialOutput(data);
#endif  //  mini gizmo
}

//
//  initialization entry point.  The application calls this from when(reset):
//
//
// InitializeIO() is called from the when(reset) task and initalizes
// the I/O system and related driver functions.
//
void InitializeIO()
{
#ifdef USE_MINIGIZMO

#else
    InitializeLCD();
#ifdef USE_5000EVB
    io_change_init(ioSwitch1);
#endif  // USE_5000EVB
#endif  // USE_MINIGIZMO
}   // InitializeIO

#endif  // __IO_NC_
```

Creating Example Device Applications

This section provides a series of device applications based on the I/O examples created in the previous section. These device applications introduce Neuron C and device development concepts such as I/O objects and timers, network variables, configuration properties, functional profiles, and ISI. There are three types of device applications demonstrated in this section: digital sensor and digital actuator examples, a thermostat example, and an ISI example.

Notes:

- The digital sensor and digital actuator examples require the LonMaker tool for commissioning and for connecting their network variable to compatible devices. Alternatively, you can add code to make these example applications self-installed (see the *ISI Example* later in this section for how to do this). The thermostat example can be run as a standalone application and does not require network integration. You can use the LonMaker tool or ISI to integrate the thermostat example into a network.

- The example device applications presented in this section are not considered interoperable mainly because they do not include a Node Object functional block. For examples of interoperable device applications that are more complex, see the FT 5000 EVB examples or Mini FX/PL examples included with the Mini kit.
    - To view the source code for the FT 5000 EVB examples click **Start**, point to **Programs**, pointing to **Echelon Mini**, point to **Examples,** point to **FT 5000 EVB**, click the desired **Example Source Code** folder, and then click the **Source** folder. For more information on the FT 5000 EVB examples, see the *FT 5000 EVB Examples Guide*.
    - To view the source code for the Mini FX/PL examples click **Start**, point to **Programs**, pointing to **Echelon Mini**, point to **Examples,** point to **Mini EVB**, and then click the desired **Example Source Code** folder. For more information on the FT 5000 EVB examples, see the *Mini FX/PL Examples Guide*.

Digital Sensor and Actuator Examples

The digital sensor and actuator examples creates a simple device which can sense a switch, and drive an output network variable to reflect the switch's on/off position. The physical implementation uses the **SW1** pushbutton to toggle the switch state with every activation.

The digital actuator implements an input network variable of the same type, and reflects every new value received in this input network variable by driving a lamp accordingly. The physical implementation on the FT 5000 EVB or Mini Gizmo I/O board uses **LED1** to represent that lamp.

The network variable is defined as a **SNVT_switch** type, which is defined similar to the following pseudo-definition. The true definition of **SNVT_switch** is embedded in the standard resources, and includes additional data such as scaling factors, comments or supported value ranges:

```
typedef struct {
   unsigned value;
   unsigned state;
} SNVT_switch;
```

SNVT_switch reports the on/off state with its *state* member, where 0 indicates Off and 1 indicates On. The *value* field supports raw data in the 0–200 range, representing 0–100% dimming level, in increments of 0.5%.

Simple Digital Sensor

The simple digital sensor example demonstrates the event-driven Neuron C programming model, and showcases the integration of network variables into Neuron C. The application code defines a network variable, **nvoSwitch**, similar to a global 'C' variable, and uses it just like any other global variable. The system firmware automatically sends any newly assigned network variable value over the network. Typically, the application code does not need to know where output network variable values go.

Based on the I/O toolkit created by the examples in *Performing Neuron C Input/Output*, the following code defines the simple digital sensor example.

```
#include "io.nc"

#pragma num_alias_table_entries 2

//
// Output network variable declaration.  Will always be cleared to
```

```
// zero after reset.
network output SNVT_switch nvoSwitch;

//
// OnButtonPressed() is called whenever the button becomes active.
//
void OnButtonPressed()
{
    // toggle the reported switch status:
    nvoSwitch.state ^= 1;
    nvoSwitch.value = nvoSwitch.state ? 200u : 0;
}

when(reset) {
    InitializeIO();

    LcdDisplayString(0,0, "Simple Digital");
    LcdDisplayString(1,0, "Sensor Example");
    LcdDisplayString(2,0, "-+-+-+-+-+-+-+-+-+-+");
    LcdDisplayString(3,0, "SW1 drives nvoSwitch");
}
```

Simple Digital Actuator

Similar to the **OnButtonPressed()** function, which was called by the I/O toolkit, the **when(nv_update_occurs)** task executes when the specified network variable received an update from the network. Most Neuron C applications focus on the application algorithm, while delegating most or all of the processing related to the network to the system firmware. The corresponding simple digital actuator is defined by the following application.

```
#include "io.nc"

#pragma num_alias_table_entries 2 // required by compiler

//
// Input network variable declaration.  Will always be cleared to
// zero after reset.
network input SNVT_switch nviSwitch;

//
// when(nv_update_occurs) executes when the referenced input network
// variable receives a new value:
//
when(nv_update_occurs(nviSwitch))
{
    SetLeds(nviSwitch.state, FALSE);
}

when(reset) {
    InitializeIO();

    LcdDisplayString(0,0, "Simple Digital");
    LcdDisplayString(1,0, "Actuator Example");
    LcdDisplayString(2,0, "-+-+-+-+-+-+-+-+-+-+");
    LcdDisplayString(3,0, "nviSwitch drives LED");
}
```

Advanced Digital Actuator

This example demonstrates a slightly more complex version of the digital actuator. This example implements two digital actuators (driving **LED1** and **LED2** through one input network variable each. This application also implements two **SCPTlocation** configuration properties, which can be used to describe the lamps (for example, through their location). Each lamp is represented by one functional block of type

SFPTopenLoopActuator, where each functional block encapsulates the network variable and configuration property for each lamp.

Following the declaration of the input network variables and configuration properties, the *fblock* construct defines the functional block, and it describes how locally implemented network variables and configuration properties map to the definitions in the **SFPTopenLoopActuator** functional profile instantiated by the functional block.

The first element of the **nviSwitch** network variable array implements the profile's **nviValue** member (and subsequent members of this network variable array are distributed among the other elements of the fblock array). Similarly, the first element of the **lamp[0]** fblock array uses the first element of the **nciLocation** configuration property array.

```
#include "io.nc"

#pragma num_alias_table_entries 2 // required by compiler

//
// Input network variable declaration.  For multiple lamps
// of the same characteristic, it is best to declare the
// related network variables as an array:
//
network input SNVT_switch nviSwitch[2];

//
// Configuration network variables are used just like any
// other network variable, but are updated very infrequently,
// and their values reside in non-volatile memory (e.g.  EEPROM
// or flash memory)
//
network input cp SCPTlocation nciLocation[2];

//
// Functional blocks group network variables, configuration
// properties and other aspects of a logical unit within a
// device's application together.  Similar to other data items,
// functional blocks can also be implemented as arrays:
//
fblock SFPTopenLoopActuator {
    nviSwitch[0] implements nviValue;
} lamp[2] fb_properties {
    nciLocation[0]
};

//
// when(nv_update_occurs) executes when the referenced input network
// variable receives a new value:
//
when(nv_update_occurs(nviSwitch))
{
    SetLeds(nviSwitch[0].state, nviSwitch[1].state);
}

void OnButtonPressed(void)
{
    // Do nothing in this application
}

when(reset) {
    InitializeIO();

    LcdDisplayString(0,0, "Second Digital");
    LcdDisplayString(1,0, "Actuator Example");
    LcdDisplayString(2,0, "-+-+-+-+-+-+-+-+-+-+");
    LcdDisplayString(3,0, "nviSwitch drives LED");
}
```

Advanced Digital Sensor Example

The advanced digital sensor example expands the previous simple digital sensor and advanced digital actuator examples by adding an implementation of the **SFPTopenLoopSensor** functional profile to the first digital sensor example, and by adding configuration property processing to the application algorithm.

While the advanced digital actuator example added **SCPTlocation** configuration properties, this advanced digital sensor example adds a **SCPTclOffDelay** configuration property, which controls the duration after which the switch automatically returns to the Off position. Network integrators can set this configuration property to 0.1–6553.5s, or to 0 to disable the auto-off feature. The **SCPTclOffDelay** configuration property is set to **300s** by default and by definition of the SCPT type.

The implementation supports the entire value range of **SCPTclOffDelay**, but it implements a resolution of 1s.

The **SCPTclOffDelay** configuration property is applied to the output network variable, which in turn implements the **nvoValue** member of the **SFPTopenLoopSensor** profile. This differs from the advanced digital actuator example, which applied **SCPTlocation** to the entire functional block,

Repeated activation of the **SW1** pushbutton toggles the switch state (as before), if the auto-off feature is disabled. If the auto-off feature is enabled (the default), repeated activation of the pushbutton re-triggers the timer, thus implementing a stairwell light switch.

```
#include "io.nc"

#pragma num_alias_table_entries 2 // required by compiler

//
// Output network variable and configuration property declaration
//
network input cp SCPTclOffDelay nciOffDelay;

network output SNVT_switch nvoSwitch nv_properties {
    nciOffDelay
};

//
// Functional block
//
fblock SFPTopenLoopSensor {
    nvoSwitch implements nvoValue;
} mySwitch;

//
//  The auto off timer
stimer autoOffTimer;

void OnButtonPressed(void)
{
    if (nciOffDelay) {
        //
        // We are in stairwell mode.  Set switch to "On" and
        // retrigger the autoOffTimer.  The timer implements a
        // 1s resolution, but any non-zero CP values should
        // activate the auto-off feature, so we correct the
        // value towards the next full second:
        //
        nvoSwitch.state = 1;
        autoOffTimer = (nciOffDelay + 9ul) / 10ul;
    } else {
       //
       // We are in normal 'toggle mode.' Toggle the switch
```

```
        // and make sure the timer is stopped:
        //
        nvoSwitch.state ^= 1;
        autoOffTimer = 0;
    }

    // Finally, set the switch value according to its state:
    nvoSwitch.value = nvoSwitch.state ? 200u : 0;
}

//
// when(timer_expires(....)) executes when the timer specified in
// the event condition has expired.  In this example, this happens
// when the auto-off timer expires
//
when(timer_expires(autoOffTimer)) {
    // Shut down the light
    nvoSwitch.state = nvoSwitch.value = 0;
}

when(reset) {
    InitializeIO();

    LcdDisplayString(0,0, "Second Digital");
    LcdDisplayString(1,0, "Sensor Example");
    LcdDisplayString(2,0, "-+-+-+-+-+-+-+-+-+-+");
    LcdDisplayString(3,0, "SW1 drives nvoSwitch");
}
```

Thermostat Example

The Thermostat example expands the previous digital sensor and actuator examples by implementing more aspects of Neuron C programming. The Thermostat example works not only once it is integrated with other devices in the network like the digital sensor and actuator examples, but it automatically switches to standalone mode, if necessary, and runs as a single, independent device.

The application implements the **SFPTthermostat** standard functional profile. The application samples the local ambient temperature through the temperature sensor supplied with both the FT 5000 EVB and the Mini Gizmo I/O board. Current ambient temperature and setpoint values are shown on the display (where available). The application drives the **nvoCool** and **nvoHeat** network variables using a simple proportional controller algorithm, which is parameterized through **SCPTgain** configuration properties, implements a hysteresis through the **nciMinDelta** configuration property, and indicates whether the application is currently heating or cooling through **LED1** and **LED2**, respectively.

For brevity, the example implementation of **SCPTthermostat** ignores the **SCPTsetPnts** (**nciSetPnts**) configuration property. This configuration property holds a number of temperature setpoints, subject to the occupancy state of the controlled environment. This example ignores this setpoint vector, and draws the temperature setpoint from the **nviSetpoint** input network variable. To support standalone mode, this application defaults the **nviSetpoint** variable to 21°C (69.8F).

The application first defines the device interface by declaring functional blocks, network variables, and configuration properties. The declaration of the **nvoCool** and **nvoHeat** output network variables use the **bind_info*()*** modifier to request that this network variable shall use the unacknowledged service when connected with other network variables, as required by the **SFPTthermostat** functional profile. Each of these network variables has a proportional control coefficient with individually assigned default values applied.

```
#include <stdlib.h>
```

```
#include <string.h>
#include <snvt_hv.h>

#include "io.nc"

#pragma enable_sd_nv_names          // Show useful names to integrator
#pragma run_unconfigured            // Allow running standalone
#pragma num_alias_table_entries 10  // required by compiler

//
// Configuration properties:
//
network input cp SCPTsetPnts nciSetPnts;        // See text!
network input cp SCPTmaxSendTime nciHeartbeat;
network input cp SCPTminDeltaTemp nciHysteresis;

network input cp SCPTgain nciCoolFactor;    // Cooler coeff.
network input cp SCPTgain nciHeatFactor;    // Heater coeff.

//
// Network variables
//
network input  SNVT_temp_p nviSetpoint = 2100ul;

network output bind_info(unackd) SNVT_lev_percent nvoCool nv_properties {
    nciCoolFactor = {3, 1}
};

network output bind_info(unackd) SNVT_lev_percent nvoHeat nv_properties {
    nciHeatFactor = {5, 2}
};

network output bind_info(unackd) SNVT_temp_p nvoCurrent;
network output bind_info(unackd) SNVT_hvac_status nvoUnitStatus;

fblock SFPTthermostat {
    nviSetpoint implements nviSetPoint;
    nvoCool implements nvoCoolOutput;
    nvoHeat implements nvoHeatOutput;
    nvoCurrent implements nvoSpaceTemp;
    nvoUnitStatus implements nvoUnitStatus;
} MyThermostat fb_properties {
    nciSetPnts,
    nciHeartbeat,
    nciHysteresis = { 100 } // 1 degree
};
```

The application drives the control algorithm, which is implemented in the Thermostat() function, when necessary:

```
//
//  The application's main algorithm is run from the 'Thermostat'
//  function.  This function is being called under three conditions:
//  (a) during reset processing, (b) when the setpoint input network
//  variable changes, or (c) once every second for periodic sampling
//  of the current ambient temperature.  Periodic sampling is governed
//  by the sampleTimer application timer, whose interval is governed
//  by SCPTmaxSendTime (nciHeartbeat).  If this heartbeat CP is zero,
//  the application samples at SAMPLETIMER_DEFAULT_INTERVAL (1s).
//

void Thermostat(void);

stimer sampleTimer;
#define SAMPLETIMER_DEFAULT_INTERVAL    1   // 1s

when(reset) {
    InitializeIO();

    LcdDisplayString(0,0, "Thermostat Example");
    LcdDisplayString(1,0, "-+-+-+-+-+-+-+-+-+-+");
```

```
    Thermostat();
}

when(timer_expires(sampleTimer)) {
    Thermostat();
}

when(nv_update_occurs(nviSetpoint)) {
    Thermostat();
}

void OnButtonPressed(void)
{
    // do nothing in this application

}
```

The Thermostat() function then implements the behavior of the functional block:

```
//
//  The Thermostat function samples the current temperature,
//  computes the control values for heater and cooler, and
//  updates the status network variable as it goes along.
//  Current and setpoint values are being displayed, and the
//  next sample is scheduled.
//
//  Thermostat() uses the Display() utility function.
//
void Display(unsigned row, unsigned column,
    const char* format, SNVT_temp_p value);

void Thermostat(void)
{
    SNVT_temp_p reading;

    // Get the true current temperature
    reading = GetTemperature();

    // Discard current reading and use previous value, if new
    // reading is still within hysteresis band:
    if (nciHysteresis == 0
    || reading < nvoCurrent-nciHysteresis
    || reading > nvoCurrent+nciHysteresis) {
        nvoCurrent = reading;
    } else {
        // refresh output network variable for re-propagation
        // (heartbeat)
        nvoCurrent = nvoCurrent;
    }

    // compute cooler and heater control values
    if (nvoCurrent < nviSetpoint) {
        nvoCool = 0;
        nvoHeat = nvoUnitStatus.heat_output_primary =
                    muldiv(nviSetpoint-nvoCurrent,
                           nciHeatFactor.multiplier,
                           nciHeatFactor.divisor);
        nvoUnitStatus.mode = HVAC_HEAT;
    }
    if (nvoCurrent > nviSetpoint) {
        nvoHeat = 0;
        nvoCool = nvoUnitStatus.cool_output =
                    muldiv(nvoCurrent-nviSetpoint,
                           nciCoolFactor.multiplier,
                           nciCoolFactor.divisor);
        nvoUnitStatus.mode = HVAC_COOL;
    }
    // Indicate heat/cool status and drive value display
    SetLeds((boolean)nvoCool, (boolean)nvoHeat);

    Display(2,0, "Current:        0.00", nvoCurrent);
```

```
    Display(3,0, "Setpoint:       0.00", nviSetpoint);

    // Schedule next sample:
    if (nciHeartbeat) {
        // Round to the next full second
        sampleTimer = (nciHeartbeat + 9u) / 10ul;
    } else {
        sampleTimer = SAMPLETIMER_DEFAULT_INTERVAL;
    }
}
```

Finally, the application provides two utility functions, **ToAscii()** and **Display()**, to help display the current ambient temperature and setpoint values:

```
//
// The ToAscii() utility function converts an unsigned
// long number into its decimal representation, stored
// in the requested buffer backwards.
//
void ToAscii(char* buffer, unsigned long value)
{
    while(value) {
        *buffer-- = (char)(value % 10) + '0';
        value /= 10;
    }
}

void Display(unsigned row, unsigned column,
    const char* format, SNVT_temp_p value)
{
    char buffer[21];

    (void)strcpy(buffer, format);
    ToAscii(buffer+19, value % 100);
    ToAscii(buffer+16, value / 100);

    LcdDisplayString(row, column, buffer);
}
```

ISI Example

The following example demonstrates an application that uses the Interoperable Self-Installation (ISI) engine and API. Most commercial networked devices are integrated into a network using the LonMaker tool or other network tool. The integration process can be semi-automated, but it typically involves manual steps and decisions taken by an experienced network integrator.

Home network and other small networks cannot afford the complexity and cost of a manual integration step. In addition, their limited size and complexity makes them more conducive for automatic integration. User interaction (if any) can be limited to simple tasks such as pushing a button in response to a flashing LED.

Applications that use the ISI engine can be divided into three major tasks: defining the application algorithm and interface, starting and running the ISI engine, and providing application-specific information to the ISI engine when requested.

The application algorithm and interface of an ISI-enabled application is almost identical to that of a non ISI-enabled application. The ISI-aware application simply adds a **SCPTnwrkCnfg** configuration property, which allows the network tool to disable the self-installation procedures. As a result, the self-installed device can be integrated into a managed network.

The ISI engine is started through a simple function call, usually from the **when(reset)** task. The application adds logic to decide whether to start the engine, considering the current value of the **SCPTnwrkCnfg** configuration property. The application must

decide whether to start the ISI engine at reset time, but it does not have to make the same decision repeatedly. The remainder of the application can make calls into the ISI API regardless of the ISI engine's running state. If the ISI engine is not currently running, the calls into the ISI API are ignored (or yield a benign response).

The ISI engine itself has no knowledge of the application it serves. Some generic services are provided fully automatically, such as allocation and maintenance of unique device addresses. However, other services need feedback from the application. For example, when establishing network variable connections, a process described in the ISI protocol as *enrollment,* the application must inform the ISI engine about the set of network variables applicable to the pending enrollment. Similarly, when the application opens an ISI enrollment, it must inform the ISI engine how to describe the enrollment.

ISI enrollments can describe a large variety of network variable sets that are available for connections. In the following example, which builds on the simple digital actuator example, the enrollment information simply is "any **SNVT_switch** network variable".

Following is the application algorithm and interface for this example application:

```
#include <snvt_cfg.h>
#include "io.nc"

#pragma num_alias_table_entries 4

boolean isiLed;

//
// Network variables
//
network input  SNVT_switch nviSwitch;

//
// Configuration properties
//
// The SCPTnwrkCnfg configuration property must be
// implemented as a configuration network variable to ease
// transitions between self-installed and managed networks.
// This property defaults to CFG_EXTERNAL.  This is
// the default value required by the LonMark Interoperability
// Guidelines, and is the best choice when using the device in a
// managed network.  See the when(reset) task, below, for more
// details about application start-up.
//
network input SCPTnwrkCnfg cp cp_info(reset_required) nciNetConfig
    = CFG_EXTERNAL;

//
// when(nv_update_occurs) executes when the referenced input network
// variable receives a new value.  The current switch position is shown
// through LED2, while LED1 (and SW1) are used to implement the ISI
// user interface.
//
when(nv_update_occurs(nviSwitch))
{
    SetLeds(isiLed, nviSwitch.state);
}
```

Observe that **LED1** now provides ISI status information, and is driven through the **isiLed** global variable.

The first part of starting and running the ISI engine is shown in the following code snippet, including the reset logic, periodic calls into the **IsiTickS()** API, and processing of any incoming messages destined for ISI:

```
//
// Include the ISI definitions and link with the ISI library.  Use
// IsiFull.lib where possible.  Use IsiPl3170.lib for a  device that
```

```
// uses the PL 3170 Smart Transceiver, and use IsiCompactS.lib for
// devices using an FT 3120 or PL 3120 Smart Transceiver.
//
#include <isi.h>
#pragma library "$STD$\IsiFull.lib"

//
// Reset Processing
//
// The when(reset) task executes when the device resets.  To control
// the ISI engine start-up, or to prevent the ISI engine from starting,
// reset processing contains the following logic:
// a) If this is the first reset with a new application image, the reset
//    code sets nciNetConfig to CFG_LOCAL.  This allows the ISI engine to
//    start on a brand new device.
//    The initial value of CFG_NUL of the local, persistent, OldNwrkCnfg
//    variable is used to detect the first start.
// b) If nciNetConfig is set to CFG_LOCAL but the previous value is
//    CFG_EXTERNAL (determined by the tracking variable OldNetConfig),
//    the device returns itself to factory defaults.
// c) If nciNetConfig is set to CFG_LOCAL, the ISI engine starts
eeprom SCPTnwrkCnfg oldNetConfig = CFG_NUL;

when(reset) {
    SCPTnwrkCnfg networkConfig;

    // Prepare the ISI engine.  This call is required before starting the
    // ISI engine, and should be made under all circumstances.
    IsiPreStart();

    networkConfig = oldNetConfig;

    if (networkConfig == CFG_NUL) {
        // For the first application start, set nciNetConfig to CFG_LOCAL,
        // allowing the ISI engine to run by default:
        nciNetConfig = CFG_LOCAL;
    }
    oldNetConfig = nciNetConfig;

    if (nciNetConfig == CFG_LOCAL) {
        if (networkConfig == CFG_EXTERNAL) {
            // The application has just returned into the self-installed
            // environment.  Make sure to re-initialize the ISI engine:
            IsiReturnToFactoryDefaults();   // This call resets the device
        }
        //  We are in a self-installed network, so let's start:
        IsiStartS(isiFlagNone);
    }

    InitializeIO();

    LcdDisplayString(0,0, "Simple ISI Example");
    LcdDisplayString(1,0, "-+-+-+-+-+-+-+-+-+-+");
}

mtimer repeating isiTick = 1000ul / ISI_TICKS_PER_SECOND;

void SignalIsiState(void);

when(timer_expires(isiTick)) {
    IsiTickS();
    SignalIsiState();
}

when(msg_arrives) {
    if (IsiApproveMsg()) {
        if (IsiProcessMsgS()) {
            //  TODO: process unprocessed ISI messages here (if any)
            ;
        }
    } else {
```

```
            // TODO: process other application messages here (if any)
            ;
        }
    }
```

The second part of this segment provides visual feedback about the ISI enrollment status to the user (through **LED1** in this example). The ISI API provides an **IsiUpdateUserInterface()** callback for this purpose:

```
IsiEvent    isiState;

void IsiUpdateUserInterface(IsiEvent Event, unsigned Parameter)
{
    isiState = Event;
    SignalIsiState();
#pragma ignore_notused  Parameter
}

void SignalIsiState(void)
{
    if(isiState == isiPending
    || isiState == isiPendingHost) {
        // Flash LED in any 'pending' state
        isiLed ^= TRUE;
    } else if(isiState == isiApproved
    || isiState == isiApprovedHost) {
        // LED is solid on in any 'approved' state
        isiLed = TRUE;
    } else {
        // LED is off otherwise:
        isiState = isiLed = 0;
    }
    SetLeds(isiLed, nviSwitch.state);
}
```

The third part of this segment forwards user input to the ISI API:

```
//
// Handler to act when the user presses the ISI connect button
// (SW1 in this example).  When the ISI engine is idle, this opens
// an ISI enrollment.  When an enrollment is pending, this completes
// the enrollment.  A pending enrollment is automatically cancelled
// after some time, but a more sophisticated user interface could,
// for example, detect a prolonged activation of SW1 and explicitly
// cancel the pending enrollment, or delete an existing connection.
//
void OnButtonPressed(void)
{
    if(isiState == isiPending || isiState == isiApprovedHost) {
        IsiCreateEnrollment(0);
    } else if(isiState == isiNormal) {
        IsiOpenEnrollment(0);
    }
}
```

Finally, in the third segment, the application provides application-specific information to ISI through a set of dedicated callback functions:

```
//
// When this application opens enrollment, ISI requests a CSMO data
// package from the application.  This data informs all other devices
// on the type of enrollment on offer; its number, type and direction
// of network variables, etc.
//
// The following myCsmo constant describes this enrollment as "any
// network variable of type SNVT_switch":
//
static const IsiCsmoData myCsmo =  {
```

```
    ISI_DEFAULT_GROUP, isiDirectionVarious, 1, 0xFF, 95u, 0,
    {
        0, 0, isiScopeStandard, {0x00, 0x00, 0x00, 0x00, 0x00, 0x00}, 1
    }
};

void IsiCreateCsmo(unsigned Assembly, IsiCsmoData* pCsmoData)
{
    memcpy(pCsmoData, &myCsmo, sizeof(IsiCsmoData));
#pragma ignore_notused  Assembly
}

//
// When ISI receives an open enrollment, it inquires with the
// application whether this is an eligible enrollment.  The
// application returns an application-specific assembly number
// if this is the case, or returns ISI_NO_ASSEMBLY.
// This simple example accepts all enrollments that consist of
// the same enrollment description than its own, but more advanced
// applications can accept a larger variety of enrollments, or be
// more specific which enrollment to accept.
//
unsigned IsiGetAssembly(const IsiCsmoData* pCsmo, boolean automatic)
{
    return memcmp(pCsmo, &myCsmo, sizeof(IsiCsmoData)) == 0 ?
        0 : ISI_NO_INDEX;
#pragma ignore_notused automatic
}

//
// The ISI application groups network variables that apply to the
// same enrollment in logical assemblies, using application-defined
// assembly numbers 0..254.  Then ISI processes an assembly, the engine
// inquires with the application about the mapping of locally
// implemented network variables to the members of that assembly.
//
// This simple example supports only one assembly, which consists of
// only one network variable:
//
unsigned IsiGetNvIndex(unsigned assembly, unsigned offset)
{
   return nviSwitch::global_index;
#pragma ignore_notused assembly
#pragma ignore_notused offset
}
```

Appendix A

Glossary

This appendix provides definitions for many terms commonly used with Mini FX device development.

Application Device

A LONWORKS device that runs an ISO/IEC 14908-1 application (OSI Layer 7). The application may run on a Neuron Chip or Smart Transceiver, in which case the device is called a "Neuron hosted" device.

Application Image

Device firmware that consists of the object code generated by the Neuron C compiler from the user's application program and other application-specific parameters, including the following:

- Network variable fixed and self-identification data
- Network variable device interface data
- Program ID string
- Optional self-identification and self-documentation data
- Number of address table entries
- Number of domain table entries
- Number and size of network buffers
- Number and size of application buffers
- Number of receive transaction records
- Input clock speed of target Neuron Chip or Smart Transceiver
- Transceiver type and bit rate

Application Program

The software code in a LONWORKS device that defines how it functions. The application program, also referred to as the *application*, may be in the device when you purchase it, or you may load it into the device from application image files (**.APB**, **.NDL**, and **.NXE** extensions) using the LonMaker tool or other network management tool. The application program interfaces with the ISO/IEC 14908-1 firmware to communicate over the network. It may reside completely in the Neuron Chip or Smart Transceiver, or it may reside on an attached host processor (in a host-based device).

Binding

Process of connecting network variables. Binding creates logical connections (virtual wires) between LONWORKS devices. Connections define the data that devices share with one another. Tables containing binding information are stored in the device's non-volatile memory, and may be updated by the LonMaker tool or the ISI protocol.

Changeable-Type Network Variable

A network variable that has a type and length that can be changed to that of another network variable type of equal or smaller size. You can use changeable-type network variables to implement generic functional blocks that work with different types of inputs and outputs.

Channel

The physical media between devices upon which the devices communicate. The ISO/IEC 14908-1 protocol is media independent; therefore, numerous types of media can be used for channels: twisted pair, power line, fiber optics, IP, and RF, and other types.

Clock Multiplier

For Series 5000 chips, you can select the frequency at which the Neuron Chip or Smart Transceiver runs to modify the internal system clock speed. You can select multipliers of ½, 1, 2, 4, and 8 to adjust the internal system clock speed from 5 MHz to 80 MHz (based on a crystal running at 10 MHz). For Series 3100 chips, the clock multiplier is fixed at ½.

Commissioning

The process in which the LonMaker tool or other network management tool downloads network and application configuration data into a physical device. For devices whose application programs are not contained in ROM, the network management tool also downloads the application program into non-volatile RAM in the device. Devices are usually either commissioned and tested one at a time, or commissioned and then brought online and tested incrementally.

Configuration Properties (CPs)

Configuration properties are data values that define the behavior of an application device by determining the manner in which device application data is manipulated and when device application data is transmitted. Configuration properties can be applied to the device, functional block, or network variable level. Configuration properties can determine the functions to be performed on the values stored in network variables. For example, a configuration property may specify a minimum change that must occur on a physical input to a device before the corresponding output network variable is updated.

Configured

A device state where the device has both an application image and a configured network image. This indicates that the device is ready for network operation.

Control Network Protocol (CNP)

The ISO/IEC 14908-1 Control Network Protocol. The CNP is a complete seven-layer communications protocol, with each layer optimized to the needs of control applications. The seven layers follow the reference model for open systems interconnection (OSI) developed by the International Standard Organization (ISO).

Device

A device that communicates on a LONWORKS network using CNP. A device may be an application device, network service device, or a router. Devices are sometimes referred to as nodes in LONWORKS documentation.

Device Interface

The logical interface to a device, abbreviated as *XIF*. A device's interface specifies the number and types of functional blocks; number, types, directions, and connection attributes of network variables; and the number of message tags. The program ID for a device is used as the key to identify each device interface. Each program ID uniquely defines the static portion of the interface. However, two devices with identical static portions may differ if dynamic network variables are added or removed, or if the types of changeable network variables are changed. Thus it is possible to have devices with the same program ID but different device interfaces.

Device Interface (XIF) File

A file that documents a device's interface with a network. The file can be a text file (**.XIF** extension), or it can be a binary file (**.XFB** extension).

Device Template

A device template defines a device type. The Mini kit generates a NodeBuilder device template (**.NbDt** extension) that specifies the information required for the NodeBuilder tool to build the application for a device. It contains a list of the application Neuron C source files, device-related preferences, and the hardware template name.

Download

An installation process in which data, such as the application program, network configuration, and/or application configuration, is transferred over the network into a device.

Free Topology

A connection scheme for a communication channel that eases traditional transmission line restrictions of trunks and drops of specified lengths and at specified distances, and terminations at both ends. Free topology allows wire to be strung from any point to any other, in bus, daisy chained, star, ring, or loop topologies, or combinations thereof. It only requires one termination anywhere in the network. This can reduce the cost of wiring significantly.

FT 5000 EVB

A LONWORKS evaluation board that uses Echelon's FT 5000 Smart Transceiver. It features a compact design that includes the following I/O devices that you can use to develop prototype devices and run the FT 5000 EVB examples: 4 x 20 character LCD display, 4-way joystick with center push button, 2 push-button inputs, 2 LED outputs, light-level sensor, and temperature sensor.

FT 5000 Smart Transceiver

A chip that integrates a high-performance Neuron 5000 processor core and a TP/FT-10 transceiver. The FT 5000 Smart Transceiver, combined with an FT-X3 Communications Transformer and inexpensive serial memories, provides a lower-cost, higher-performance alternative to the previous generation LONWORKS TP/FT-10 solution. See *Neuron 5000 Processor* for more information about the key features of the Neuron 5000 processor.

PL 3150 EVB

A LONWORKS evaluation board that uses Echelon's PL 3150 Smart Transceiver. It can be connected to a MiniGizmo I/O board for testing device applications running on the EVB.

PL 3170 EVB

A LONWORKS evaluation board that uses Echelon's PL 3170 Smart Transceiver, which includes Interoperable Self Installation (ISI) functions built into the firmware. It can be connected to a MiniGizmo I/O board for testing device applications running on the EVB.

Functional Block (FB)

A collection of network variables, configuration properties, and associated behavior that defines a specific system functionality. Functional blocks define standard formats and semantics for how information is exchanged between devices on a network. Each functional block implements a functional profile.

Functional Profile

A template for a functional block that enables equipment specifiers to select the functionality they need for a system. Each functional profile defines mandatory and optional network variable and configuration property members along with their intended usage. A number of generic standard functional profiles are available for generic devices such as simple sensor and actuators. Many industry-specific standard functional profiles are available for industry-specific applications. Industry-specific standard profiles are developed through a review and approval process, including a cross-functional review to ensure the profile will interoperate within an individual subsystem and also provide interoperability with other subsystems in the network.

User-defined functional profiles can be created if no appropriate standard profiles are available.

Hardware Template

A file with a **.NbHwt** extension that defines the hardware configuration for a target device. It specifies hardware attributes including platform, transceiver type, Neuron Chip or Smart Transceiver model, clock speed, system image, and memory configuration. Several hardware templates are included with the Mini kit. You can use these or create your own. Third-party development platform suppliers may include NodeBuilder hardware templates for their platforms

***i*.LON IP-852 Router**

An *i*.LON IP-852 router forwards ISO/IEC 14908-1 packets enveloped in ISO/IEC 14908-4 packets over an IP-852 channel. *i*.LON IP-852 routers include the *i*.LON SmartServer with IP-852 routing, *i*.LON 100 *e*3 plus Internet Server with IP-852 routing, and the *i*.LON 600 LONWORKS-IP Server.

I/O Object

An instantiation of an I/O model. An I/O objects consists of a specific I/O model, and its pin assignment, modifiers, and name.

IP-852 Channel

Also known as an ISO/IEC 14908-4 channel or an ANSI/CEA-852 LONWORKS/IP channel, an IP-852 channel carries ISO/IEC 14908-1 packets enveloped in ISO/IEC 14908-4 packets. An IP-852 channel is a LONWORKS channel that uses a shared IP network to connect IP-852 devices and is defined by a group of IP addresses. These IP addresses form virtual wires that connect IP-852 devices so they can communicate with each other. IP-852 devices include the LNS Server computers, LNS client computers, LonMaker computers, and *i*.LON IP-852 routers. An IP-852 channel enables a client computer to connect directly to a LONWORKS network and perform monitoring and control tasks.

IP-852 Network Interface

An IP-852 network interface enables IP-852 devices such as LNS Server computers, LNS client computers, LonMaker computers, and *i*.LON IP-852 routers to be attached to IP-852 channels. An IP-852 network interface requires that the LONWORKS-IP Configuration Server be configured before trying to communicate with remote devices or remote computers.

Interoperable Self-Installation (ISI) Protocol

The standard protocol for performing self-installation in LONWORKS networks. ISI is an application-layer protocol that lets you install and connect devices without using a separate network management tool. It is typically used in home networks, and may be used in any network with less than 200 devices with simple connection and configuration requirements.

ISI Mode

An installation scenario in which the ISI protocol is used (instead of the LonMaker tool or other network tool) to install devices and create network variables connections.

LNS

A network operating system that provides services for interoperable LONWORKS installation, maintenance, monitoring, and control tools such as the LonMaker tool. Using the services provided by the LNS client/server architecture, tools from multiple

vendors can work together to install, maintain, monitor, and control LONWORKS networks. The LNS architecture consists of the following elements:

1. LNS client applications, which can be used to develop, monitor and control LONWORKS networks.
2. The LNS Object Server ActiveX Control, which is a language-independent programming interface for LNS client applications to access the LONWORKS network.
3. The LNS Server, which manages the network and maintains a database containing the network configuration.

LNS Device Template

An LNS device template defines the external interface to a device, and it is used by the LonMaker tool and other LNS network tools to configure and bind the device.

LNS Network Database

Each LONWORKS network has its own LNS network database (also referred to as the network database) that is managed and maintained by an LNS Server. The network database includes the network and device configuration data for that network. The network database also contains extension records, which are user-defined records for storing application data.

LNS Server Computer

A computer running the LNS Server software. The LNS Server computer contains the LNS global database, which includes the group of LONWORKS networks being managed by the LNS Server, plus a network database for each network managed by the server.

Local Client

An LNS application running on the same computer as the LNS Server.

LonMaker Integration Tool

An LNS network tool that is used to design, commission, maintain, and document distributed control networks. The LonMaker tool features a simple graphical interface based on Microsoft Visio.

LONMARK Logo

A distinctive logo applied to LONWORKS devices that have been certified to the interoperability standards of LONMARK International.

LonTalk Protocol

Echelon's implementation of the ISO/IEC 14908-1 Control Network Protocol (CNP). CNP provides a standard method for devices on a LONWORKS network to exchange data. CNP defines the format of the messages being transmitted between devices, and it defines the actions expected when one device sends a message to another. The protocol normally takes the form of embedded software or firmware code in each device on the network. The LonTalk protocol is implemented in the Neuron firmware for Neuron Chips and Smart Transceivers.

LONWORKS 2.0 Platform

The next generation of LONWORKS products designed to both increase the power and capability of LONWORKS devices, and to decrease the costs of device development and devices.

LONWORKS Network

A network of intelligent devices (such as sensors, actuators, and controllers) that communicate with each other using a common protocol over one or more communications channels.

LONWORKS Technology

The technology that allows for the creation of open, interoperable control networks that communicate with the ISO/IEC 14908-1 Control Network Protocol. LONWORKS technology consists of the tools and components required to build intelligent device and to install them in control networks.

Mandatory Network Variable/Configuration Property

A network variable/configuration property that must be implemented by the functional block, as specified by the functional profile that the functional block is instantiating.

Mini FX Evaluation Kit

A tool for evaluating the development of control network applications with the ISO/IEC 14908-1 standard. You can use the Mini FX to develop a prototype or production control system that requires networking, particularly in the rapidly growing, price-sensitive mass markets of smart light switches, thermostats, and other simple devices and sensors. You can also use the Mini FX to evaluate the development of applications for such control networks using the LONWORKS platform.

Mini Gizmo I/O Board

A board that can be connected to a PL 3150 or 3170 EVB. The Mini Gizmo I/O board contains the following I/O devices for testing device application running on a PL EVB: eight push buttons, eight LEDs, a temperature sensor, and a piezo buzzer.

Monitored Connection

A network variable connection in which the current values are being monitored, typically by an HMI. The connector shape and reference connection in a LonMaker drawing demonstrate monitored connections.

Network Interface

A LONWORKS device that provides a layer 2 or 5 ISO/IEC 14908-1 interface to an external host computer such as a computer or a handheld maintenance tool. Network interfaces include IP-852 interfaces (*i*.LON SmartServer with IP-852 routing, *i*.LON 100 *e*3 plus Internet Server with IP-852 routing, and the *i*.LON 600 LONWORKS-IP Server); U10 and U20 USB network interfaces; and PCC-10 and PCLTA-10, 20, and 21 PCI network interfaces

Network Variable (NV)

Network variables allow a device to send and receive data over the network to and from other devices. Network variables are data items (such as temperature, the state of a switch, or actuator position setting) that a particular device application program expects to receive from other devices on the network (an *input network variable*) or expects to make available to other devices on the network (an *output network variable*).

Network Variable/Configuration Property Types

A network variable or configuration property type defines the structure and contents of a data object. A network variable type can be either a standard network variable type (SNVT) or a user-defined network variable type (UNVT). A configuration property type

can be a standard configuration property type (SCPT) or a user-defined configuration property type (UCPT)

Neuron 5000 Processor

Echelon's next-generation Neuron chip designed for the LONWORKS 2.0 platform. The Neuron 5000 processor is faster, smaller, and cheaper that previous-generation Neuron chips. The Neuron 5000 processor includes a fourth processor for interrupt service routine (ISR) processing.

The Neuron 5000 processor supports an internal system clock speed of 5 MHz to 80 MHz (using a 10 MHz external crystal). The Neuron 5000 processor includes 16KB of on-chip ROM to store the Neuron firmware image and 64 KB on-chip RAM (44 KB is user-accessible). The Neuron 5000 processor requires at least 2KB of off-chip EEPROM to store configuration data, and you can use a larger capacity EEPROM device or an additional flash device (up to 64KB) to store your application code, configuration data, and an upgradable Neuron firmware image. The Neuron 5000 processor supports the mapping of external non-volatile memory from 0x4000 to 0xE7FF in the Neuron address space (a maximum of 42KB).

Neuron Assembler (NAS)

A component of the Neuron C development tools that is used to translate Neuron Assembly source, such as the code generated from your Neuron C application by the Neuron C Compiler, into Neuron object code.

Neuron C

A programming language based on ANSI C that you can use to develop applications for Neuron Chips and Smart Transceivers. It includes network communication, I/O, interrupt-handling, and event-handling extensions to ANSI C, which make it a powerful tool for the development of LONWORKS device applications.

Neuron Chip

A semiconductor component specifically designed for providing intelligence and networking capabilities to low-cost control devices. The Neuron Chip includes a communication port for connections to various network types.

Neuron Core

The Neuron core includes up to four processors that provide both communication and application processing capabilities. Two processors execute the layer 2 through 6 implementation of the ISO/IEC 14908-1 Control Network Protocol and the third executes layer 7 and the application code. Series 5000 chips include a fourth processor for interrupt service routine (ISR) processing.

Neuron C Compiler (NCC)

A Neuron C tool that is used to produce Neuron assembly code from Neuron C source code.

Neuron Exporter (NEX)

A component of the Neuron C development tools that takes input from the Neuron C compiler and the linker and produces the following types of files: downloadable application image files (**.APB**, **.NDL**, and .**NXE** extensions), programmable application image files (**.NRI**, **.NFI**, **.NEI**, **.NME**, and **.NMF**, extensions), and device interface files (**.XIF** and **.XFB** extensions).

Neuron Firmware

A complete operating system including an implementation of the ISO/IEC 14908-1 protocol used by a Neuron Chip or Smart Transceiver. The Neuron firmware is a program that is inserted into memory of a Neuron Chip or Smart Transceiver.

Neuron ID

A 48-bit number assigned to each Neuron core at manufacture time. Each Neuron core has a unique Neuron ID, making it like a serial number.

Neuron Librarian (NLIB)

A component of the Neuron C development tools that is used to create and manage libraries, or to add and remove individual object files to and from an existing library. The Neuron Librarian is included with the NodeBuilder tool, but it is not included with the Mini kit.

Neuron Linker (NLD)

A component of the Neuron C development tools that is used to produce Neuron executable files. It links the application image, user-libraries, system libraries, and the Neuron firmware.

Neuron Object File

A Neuron object file (**.NO** extension) is an intermediate file that contains the data and executable code in the Neuron object code format, and contains information about exported and imported symbols. Neuron object files are the link between the Neuron Assembler and the Neuron Linker, but other data also contributes to the linking

Node Object

A functional block that monitors the status of all functional blocks in a device and makes the status information available for monitoring by the LonMaker tool. A LONMARK-compliant device that has more than one functional block must have a node object. Each Node Object functional block implements the SFPTnodeObject standard functional profile, or a user-defined profile that inherits from SFPTnodeObject.

NodeBuilder Tool

A hardware and software platform that is used to develop applications for Neuron Chips and Smart Transceivers. The NodeBuilder tool provides complete support for creating, debugging, testing, and maintaining LONWORKS devices. You can use the NodeBuilder tool to create many types of devices, including VAV controllers, thermostats, washing machines, card-access readers, refrigerators, lighting ballasts, blinds, and pumps. You can use these devices in a variety of systems including building controls, factory automation, and transportation.

Non-const Device-specific Configuration Property

A configuration property that can be changed by the device application, an LNS network tool such as the LonMaker tool, or another tool not based on LNS. For example, a thermostat may include a user interface that allows the user to change the setpoint. Device-specific configuration properties have values that can be modified independent of the LNS network database.

Optional Network Variable/Configuration Property

A network variable or configuration property listed as an optional component in a functional profile. Functional blocks can elect not to implement optional network

variables or configuration properties specified by the functional profile that the functional block is instantiating.

PCC-10

A type II PC (formerly PCMCIA) card network interface that includes an integral TP/FT-10 transceiver. Other transceiver types can be connected to the PCC-10 via external transceiver "pods".

PCLTA-20/21

A ½ size ISA card network interface.

Peer-To-Peer

A control strategy in which independent intelligent devices share information directly with each other and make their own control decisions without the need or delay of using an intermediate, central, or master controller. Peer-to-peer control provides enhanced system reliability by eliminating the master (a single point of failure) and reduces installation and configuration cost.

PL-20

A communication channel type that enables devices to communicate over the power mains, eliminating the need for any new wiring for communication. The PL 3150 and PL 3170 Smart Transceivers include an on-chip PL-20 transceiver core.

Program ID

A unique, 16-hex digit ID that uniquely identifies a device application.

Remote Client

An LNS application that communicates with an LNS Server (running on a separate computer) over a LONWORKS channel (an IP-852 or TP/XF-1250 channel) or over an LNS/IP interface.

Remote Network Interface (RNI)

A network interface that enables you to connect an LNS or OpenLDV-based application to a LONWORKS network via a TCP/IP connection. RNIs include the *i*.LON SmartServer, *i*.LON 100 *e*3 plus Internet Server, and *i*.LON 600 LONWORKS-IP Server.

Resource File

A file included with a LONWORKS device that defines the components of the device interface to be used by integration and development tools. Defined components include network variable types, configuration property types, and functional profiles implemented by the device application. Resource files hold definitions of standard and user-defined resources, including network variable and configuration property types, functional profiles, enumerations, and formatting rules to display network variable and configuration properties in a readable form. Resource files are used during device development, installation and management. Standard resource files are distributed by LONMARK International. User-defined resource files are created and managed during device development.

SLTA-10

A serial network interface with built-in twisted pair transceiver that connects to any host with an EIA-232 (formerly RS232) port. It can also connect to the host remotely using a modem.

The SLTA-10 network interface is supported, but not recommended unless dial-up operation through a modem and a serial connection is required. You should use a PCC-10 or U10/20 USB network interface instead. For accessing remote networks, you can use an RNI such as the *i*.LON SmartServer, *i*.LON 100 *e*3 plus Internet Server, or *i*.LON 600 LONWORKS-IP Server.

Self-Installed Network

A network that has network addresses and connections created without the use of a network management tool. In a self-installed network, each device contains code (the Neuron C ISI library, which implements the ISI protocol) that replaces parts of the network management server's functionality, resulting in a network that no longer requires a special tool or server to establish network communication or to change the configuration of the network.

Series 3100 Chip

The term used to collectively refer to all previous-generation Neuron Chips and Smart Transceivers, including the 3150 and 3120 Neuron chips; the 3150 and 3120 FT Smart Transceivers; and the 3170, 3150, and 3120 PL Smart Transceivers.

Series 5000 Chip

The term used to collectively refer to the Neuron 5000 Processor and FT 5000 Smart Transceiver.

Service Button

A push button or other actuator on a LonWorks devices that is used during installation to acquire the device's Neuron ID. For a Neuron hosted device, the button is connected to the service pin of the Neuron Chip or Smart Transceiver. When this pin is activated, the Neuron core sends a broadcast message containing its Neuron ID and program ID, which is called service pin message or packet. The method used to implement the Service button varies from device to device. Examples of mechanical methods include grounding via a push button or using a magnetic reed switch. By attaching one of the device's I/O pins to the service pin, the service pin can also be put under software control as long as the application code is being executed. For example, the device can ground the pin when the device is moved or when a predefined series of I/O occurs. The service pin can also be used to drive an LED that indicates the device's state. The service LED is solid on when the device is applicationless, blinks slowly when the device has an application and is unconfigured, is off when the device has an application and is configured. Some applications also implement additional service pin blink patterns.

Smart Transceiver

A chip that integrates a Neuron core and a transceiver.

Standard Configuration Property Type (SCPT)

A standard configuration property type defined by LONMARK International to facilitate interoperability. SCPTs are defined for a wide range of configuration properties used in many kinds of functional profiles, such as hysteresis bands, default values, minimum and maximum limits, gain settings, and delay times. SCPTs should be used for configuration in a LONWORKS network wherever applicable. In situations where there is not an appropriate SCPT available, manufacturers may define UCPTs for configuring their devices.

In addition to standard or user-defined network variable types, which define the data type, formatting rules, limits and units, SCPT also define semantics. For example, the **SNVT_time_sec** standard network variable type defines a data type for exchanging

durations of time, in seconds. The **SCPTmaxSentTime** standard configuration property type references **SNVT_time_sec**, but adds semantics by clarifying that this configuration property defines the maximum period of time between consecutive transmissions of the current value. See *types.lonmark.org* for a current list and documentation.

Standard Functional Profile

A standard set of functional profiles defined by LONMARK International. See *types.lonmark.org* for a current list and documentation. See *Functional Profile* for more information about functional profiles.

Standard Network Variable Type (SNVT)

A standard set of network variable types defined by LONMARK International to facilitate interoperability by providing a well-defined interface for communication between devices made by different manufacturers. See *types.lonmark.org* for a current list and documentation.

TP/FT-10

The free topology twisted pair LONWORKS channel type, which has 78Kbps bit rate.

U10/20 USB Network Interface.

A low-cost, high-performance LONWORKS network interface with a built-in TP/FT-10 or PL-20 transceiver that can be used with USB-enabled computers and controllers.

User-defined Configuration Property Type (UCPT)

A non-standard data structure used for configuration of the application program in a LONMARK device. UCPTs should be used only when there is no appropriate standard configuration property type (SCPT) defined. LONMARK-certified devices must have UCPTs documented in resource files according to a standard format, in order to allow the devices to be configured without the need for proprietary configuration tools. See *Standard Configuration Property Type (SCPT)* for more information on configuration property types.

User-defined Functional Profile

A non-standard functional profile defined by a device manufacturer. A user-defined functional profile should be used only when there is no appropriate standard functional profile defined. See *Functional Profile* for more information about functional profile templates.

User-defined Network Variable Type (UNVT)

A non-standard network variable type defined by the manufacturer of a device. UNVTs should be used only when there is no appropriate standard network variable type (SNVT) defined. LONMARK-certified devices must have UNVTs documented in resource files according to a standard format, in order to allow the devices to be interoperable.

Appendix B

Creating and Editing Hardware Templates

This appendix explains how to edit standard hardware templates with the Mini FX Application.

Using Hardware Templates

You can create new custom hardware templates and then configure them with the Hardware Template Editor in the Mini FX Application. A *hardware template* is a file with a **.NbHwt** extension that defines the hardware configuration for a target device. It specifies hardware attributes including platform, transceiver type, Neuron Chip or Smart Transceiver model, clock speed, system image, and memory configuration. Several Standard hardware templates are included with the Mini FX Evaluation Kit.

To view the standard hardware templates included with the Mini kit, open the Mini FX Application, and then click the arrow in the **Target Hardware** box. A list of the standard hardware templates stored in the LONWORKS **NodeBuilder\Templates\Hardware\Standard** folder on your computer is displayed, as demonstrated by Figure B-1.

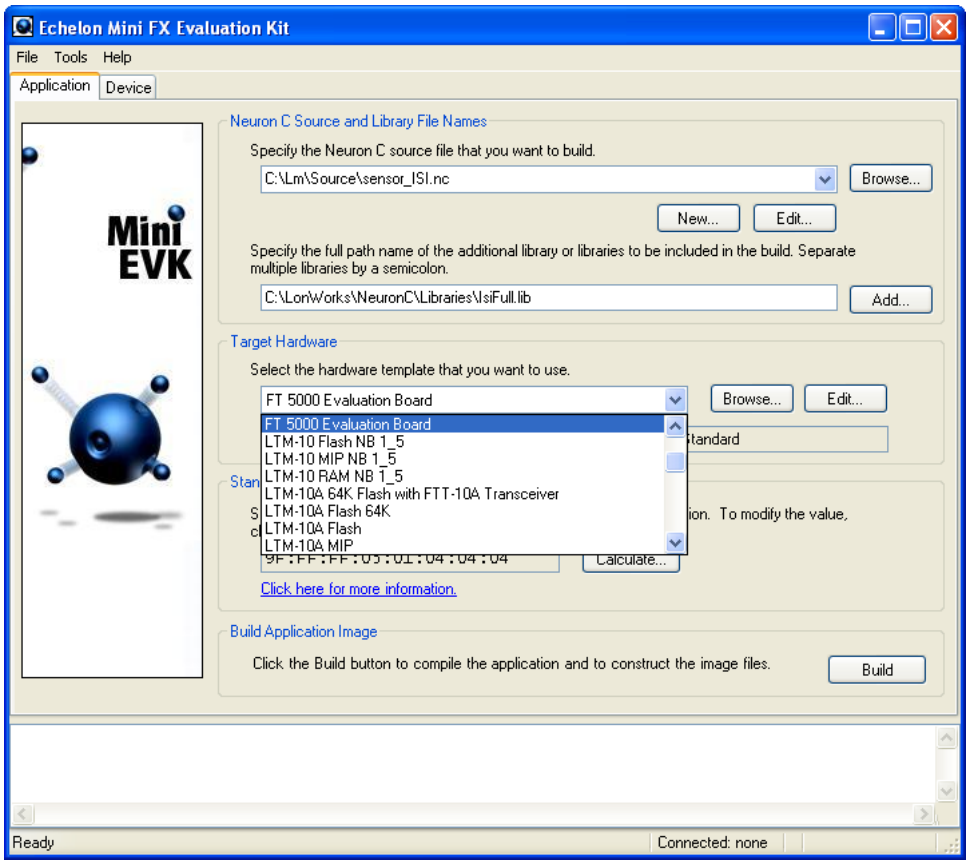


Figure B-1 Standard Hardware Template List

The standard hardware templates are read-only; however, you can create custom hardware templates from a copy of a Standard hardware template and then configure your custom hardware template, or you can create and configure a custom hardware template from scratch. The following sections describe how to do this.

Note: Do not edit or overwrite Standard hardware templates using the Hardware Template Editor in the Mini FX Application. Instead, create custom hardware templates from a copy of a Standard hardware template and then configure your custom hardware template, as described in the next section.

Creating Custom Hardware Templates

You can create a new custom hardware template from a copy of a Standard hardware template, or you can create and configure a custom hardware template from scratch using the Hardware Template Editor.

To create a new custom hardware template from a copy of a Standard hardware template, follow these steps:

1. Browse to the LONWORKS**NodeBuilder\Templates\Hardware\Standard** folder.
2. Copy the Standard hardware template to be used as the source. Select the Standard hardware template that has the same transceiver used by the target device (whether an EVB or a custom device), if available.

   For example, if the target device uses a FT 5000 Smart Transceiver, select the **FT 5000 Evaluation Board** hardware template as the source. Similarly, if the target device uses a PL 3150 Smart Transceiver, select the PL 3150 Evaluation Board (CENELEC on) or **PL 3150 Evaluation Board (CENELEC off)** hardware template as the source.
3. Browse to the LONWORKS**NodeBuilder\Templates\Hardware** folder (or other desired location for custom hardware templates on your computer), and then paste the Standard hardware template you copied in step 2.
4. Rename your new custom hardware template.
5. Configure the hardware, memory, and description properties of your new custom hardware template as described in the next section, *Configuring Hardware Templates*.

To create a new custom hardware template from scratch using the Hardware Template Editor in the Mini FX Application, follow these steps:

1. Start the Mini FX Application.
2. In the **Target Hardware** box in the **Application** tab, click **New**.
3. Enter the name of your custom hardware template and save it. By default, new custom hardware templates are stored in the LONWORKS**NodeBuilder\Templates\Hardware** folder on your computer.
4. Configure the hardware, memory, and description properties of your new custom hardware template as described in the next section, *Configuring Hardware Templates*.

Configuring Hardware Templates

You can configure the hardware, memory, and description properties of a hardware template with the Hardware Template Editor in the Mini FX Application. The following sections describe how to set these properties.

Setting Hardware Properties

You can set hardware properties for a hardware template on the **Hardware** tab of the **Hardware Template Properties** dialog. This tab displays the properties of the selected hardware template. For example, Figure B-2 displays the default properties for the **FT 5000 Evaluation Board** hardware template.

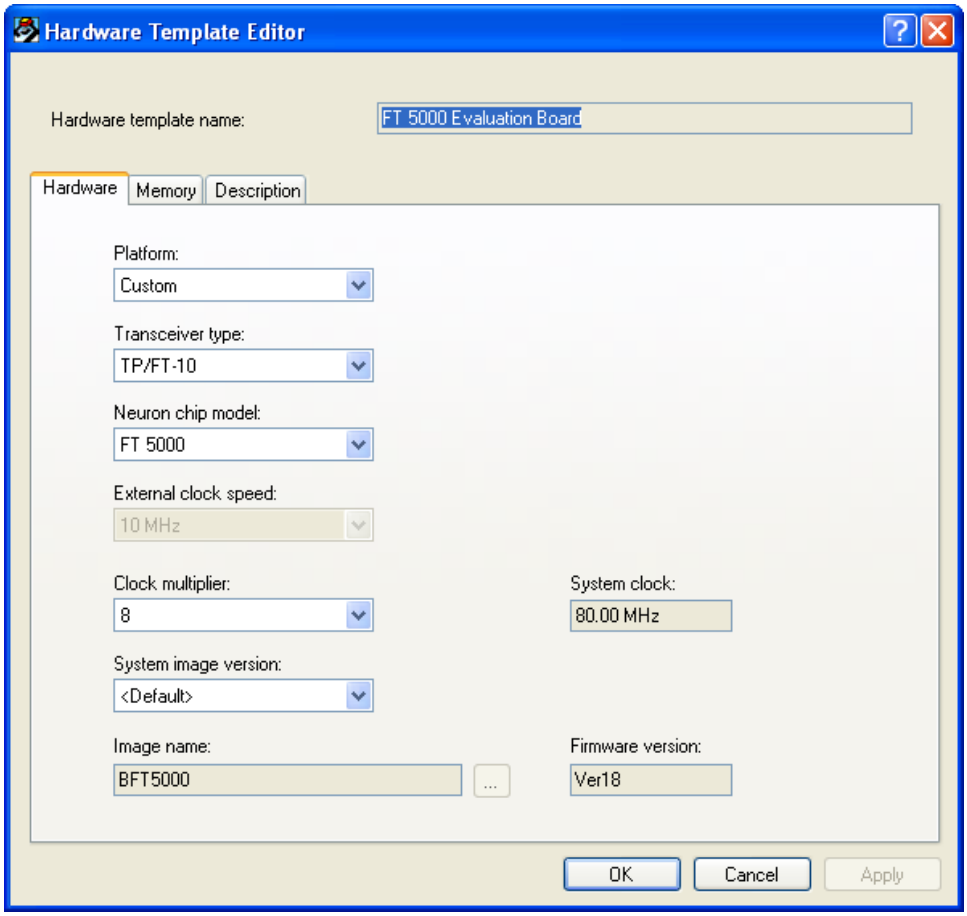


Figure B-2 Default Hardware Properties

You can set the following properties on the **Hardware** tab:

Hardware Template Name — Enter the name of the hardware template. By default, new hardware templates are named Custom 1, Custom 2, and so on. The hardware template name may be any valid Windows file name. The name can contain up to 210 characters, including spaces. The name cannot contain the following characters: \ / : * ? " < > |.

Platform

A platform is a category of hardware implementations. Most hardware templates, including standard and user-defined hardware templates, are implemented using the **Custom** platform. The **Custom** platform is suitable for all user-defined hardware.

If you are building a device application to be downloaded into a device that has an SMX transceiver, select **LTM-10** or **LTM-10A** platform and then specify the transceiver type supported by your device in the **Transceiver Type** property.

Select one of the following hardware platforms:

- **Custom**. Select this if you are not using an LTM-10, LTM-10A, or LonBuilder® Emulator. This is the default.
- **LTM-10**.
- **LTM-10A**.
- **LonBuilder Emulator 3150**.

Transceiver Type

Select the transceiver type supported by the Neuron Chip or Smart Transceiver model selected in the **Neuron Chip Model** property. Each transceiver type identifies a unique set of transceiver parameters that are included in the application image. The default transceiver type is **TP/FT-10**.

Neuron Chip Model

Select the Neuron Chip or Smart Transceiver model supported by the hardware platform selected in the **Platform** property. The default Neuron Chip model is **FT 5000**.

External Clock Speed

Displays the frequency of the external crystal used for the Neuron Chip or Smart Transceiver model selected in the **Neuron Chip Model** property.

For Series 5000 chips, the external crystal has a frequency of **10MHz**; however, you can change the system's internal clock speed from 5MHz to 80MHz. To do this, you change the frequency at which the Neuron Chip or Smart Transceiver runs in the **Clock Multiplier** property.

For Series 3100 chips, you can select a different clock speed from the list of those available for the selected Neuron Chip and transceiver type, or for the selected Smart Transceiver. This property is unavailable for those Neuron Chip or Smart Transceiver models that support only one external clock speed. See your Neuron Chip or Smart Transceiver data book for more information.

Clock Multiplier

For Series 5000 chips, you can select the frequency at which the Neuron Chip runs to modify the system clock speed. You can select multipliers of ½, 1, 2, 4, and 8. The default multiplier is **8**.

This property is fixed at ½ for the Series 3100 chips.

System Clock

The effective clock speed of the application processor. This is the product of the **External Clock Speed** and the **Clock Multiplier**.

For Series 5000 chips, the default internal system clock speed is **80.00 MHz** (the crystal's speed external clock speed of 10MHz multiplied by the default clock multiplier of 8), and it may be as low as 5 MHz (10MHz * ½).

Note: The **5.00 MHz** system clock setting is intended only to facilitate backward compatibility with older designs that cannot scale to higher clock rates. There is no power consumption advantage to using **5.00 MHz** over **10.00 MHz**.

For Series 3100 chips, this is the same value as the **External Clock Speed** multiplied by ½.

System Image Version

Select the Neuron firmware version for the selected Neuron Chip or Smart Transceiver model. See your Neuron Chip or Smart Transceiver data book for more information.

Select **<Default>** to use the default system image for the chosen chip. The default system image is the most current system image version included with this version of the Mini kit and any applied service packs. If you are prototyping devices, you typically select **<Default>**.

Select **<Custom>** to specify your own custom system image in the Image Name property. See the *Neuron C Programmer's Guide* for information on creating custom system images.

Select **VerXX**, where *XX* is the desired version number, to use a specific system firmware version. After you have completed the initial prototyping phase of your device's development and you are beginning the testing or production phases, you should select a specific system firmware version. This ensures that further development and maintenance of your device is subject to controlled conditions even when newer versions of the system firmware become available.

Image Name

Displays the file name of the system image containing the Neuron Firmware. If **<Custom>** is selected in the **System Image Version** property, you can enter a system image file name or click the button to the right and browse to a system image symbol file (**.sym** extension).

For Series 5000 chips, the name of the default system image is **BFT5000**.

Firmware Version

Displays the Neuron Firmware version used by the selected system image if the **System Image Version** property is set to **<Default>**; otherwise **N/A** is displayed. This field is read-only.

Setting Memory Properties

You can view and set the on-chip and off-chip memory properties for a hardware template on the **Memory** tab of the **Hardware Template Editor** dialog. **Figure B-3** displays the default memory properties for the **FT 5000 Evaluation Board** standard hardware template

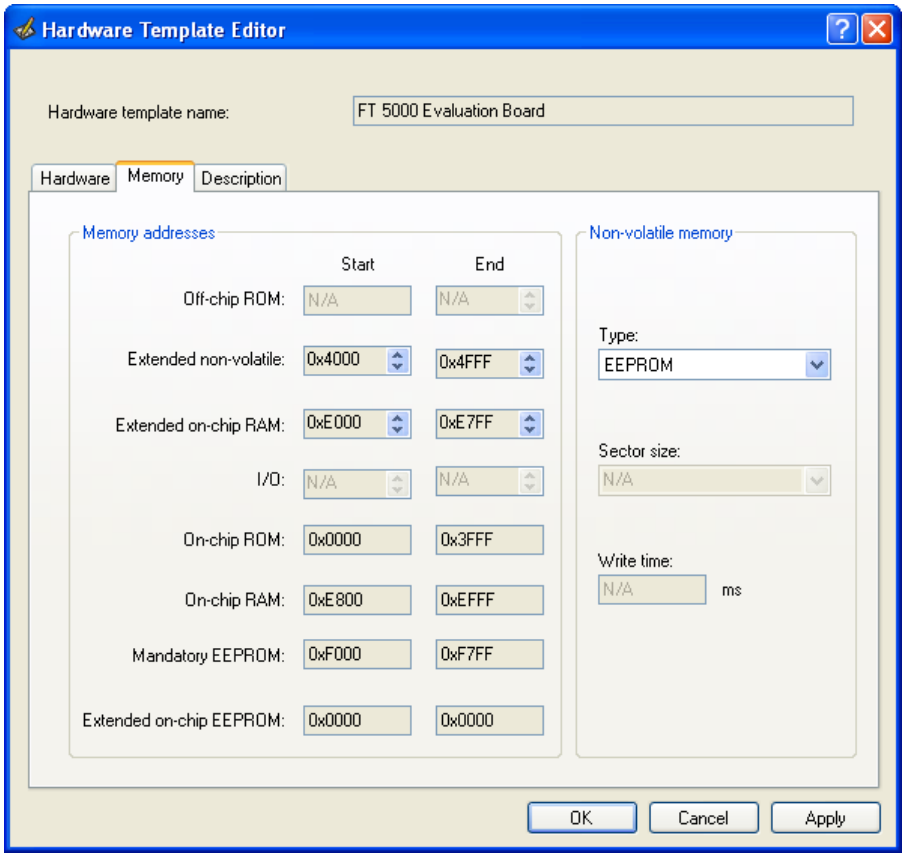


Figure B-3 Default Memory Properties for FT 5000 Evaluation Board Hardware Template

The **Memory Addresses** box details how on chip and off-chip memory is organized on the selected Neuron Chip or Smart Transceiver model. These values are dependent on the chip type and may be modified depending on the Neuron model and available memory. You can modify the **Start** and **End** locations for available memory by clicking the arrows. A value of **0x0000** is displayed for any memory location that has not been set; **N/A** is displayed for any memory location that is not available.

The **Non-Volatile Memory** box specifies the type of external non-volatile memory (EEPROM, FLASH, and NVRAM) used, if any. If **EEPROM** is selected, the **Write Time** field specifies the EEPROM write time. If **Flash** is selected, the **Sector Size** field specifies the flash memory sector size.

The following sections describe the memory properties of the Series 5000 chips, 3150 Neuron core, and 3120 and 3170 Neuron core.

Series 5000 Chips

The address ranges and consumption for the on-chip and off-chip memory of the Series 5000 chips are as follows:

Off-Chip ROM — The Series 5000 chips do not support off-chip memory; therefore, this property is set to **N/A**.

Extended Non-Volatile	The Series 5000 chips use a serial memory interface for external non-volatile memory devices (EEPROM or flash). The application code and configuration data are stored in the external non-volatile memory device and then copied into the internal RAM when the device is reset. The device application is then executed from the internal RAM. The Extended Non-Volatile memory always starts at **0x4000** and can extend to a configurable address of less than **0xE7FF** (a maximum of 42KB). Echelon currently supports and provides drivers for the following flash devices, which you can select from the **Type** property in the **Non-Volatile Memory** box: **Atmel AT25F512AN**, **STM25P05**, and **SST25VF512A**. See the Neuron Chip or Smart Transceiver data book for more information. **Note**: The drivers for different flash devices consume varying amounts of EEPROM code space because of the different programming algorithms required for the different flash devices. For example, the SST driver takes 40 bytes more of EEPROM than the other two supported flash devices.
Extended On-chip RAM	The Extended On-chip RAM can start at a configurable address at or above **0x4000** or at the end of any extended non-volatile memory and must end at **0xE7FF**.
On-chip ROM	The On-chip ROM is set from **0x0000** to **0x3FFF**.
On-chip RAM	The On-chip RAM is set from **0xE800** to **0xEFFF**.
Mandatory EEPROM	The On-chip EEPROM is set from **0xF000** to **0xF7FF**. This reflects the fact that a minimum of 2K of external serial EEPROM is required for the Series 5000 chips.
Extended On-chip EEPROM	The Series 5000 chips do not use Extended On-chip EEPROM; therefore, this property is set from **0x0000** to **0x0000**.

3150 Neuron Core

For the 3150 PL Smart Transceivers, the on-chip memory values are dependent on the chip type and may not be modified with the exception of the **Extended On-chip RAM**. The **Type** property in the **Non-Volatile Memory** box specifies the type of non-volatile memory (EEPROM, FLASH, and NVRAM) used, if any. For devices where the system image is kept in non-volatile memory, select either **flash** or **NVRAM**. EEPROM is not supported for this configuration.

3170 Neuron Core

For the 3170 PL Smart Transceivers, the on-chip memory values are dependent on the chip type and may not be modified with the exception of the **Extended On-chip RAM**. These chips do not support off-chip memory, therefore, the **Off-Chip ROM**, **Off-Chip RAM**, **Off-Chip Non-Volatile** and **I/O** properties are set to **N/A**.

Setting the Hardware Template Description

You can enter an optional description for a hardware template in the **Description** tab of the NodeBuilder Hardware Template Properties dialog. This description will be saved in the hardware template file and will be available if this hardware template is used in other NodeBuilder projects. **Figure B-4** displays the description of the **FT 5000 Evaluation Board** standard hardware template

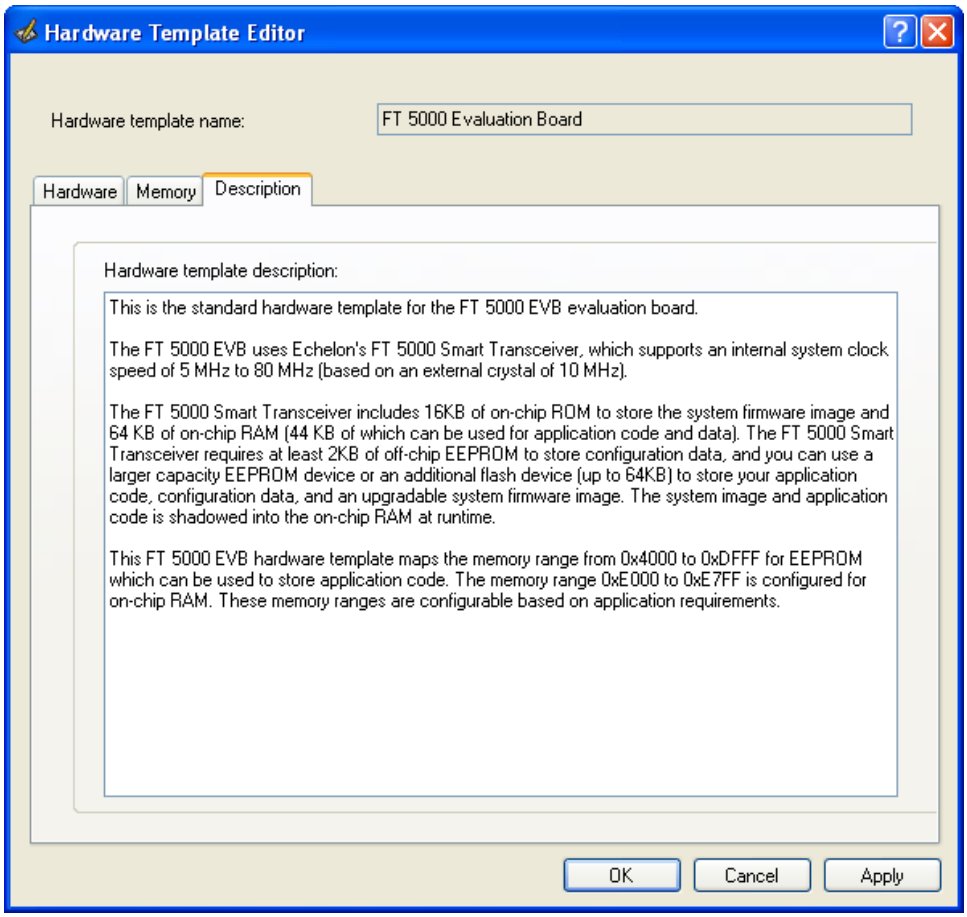


Figure B-3 FT 5000 Evaluation Board Hardware Template Description

Appendix C

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When installing the Mini FX software, you must agree to the terms of the software license agreement detailed in this appendix.

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