E1 AND E2 USER'S GUIDE

Form 1563-220304—March 2022

Your Edge in Automation.™

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The information in this manual has been checked carefully and is believed to be accurate; however, Opto 22 assumes no responsibility for possible inaccuracies or omissions. Specifications are subject to change without notice.

Opto 22 warrants all of its products to be free from defects in material or workmanship for 30 months from the manufacturing date code. This warranty is limited to the original cost of the unit only and does not cover installation, labor, or any other contingent costs. Opto 22 I/O modules and solid-state relays with date codes of 1/96 or newer are guaranteed for life. This lifetime warranty excludes reed relay modules, *groov* and SNAP serial communication modules, SNAP PID modules, and modules that contain mechanical contacts or switches. Opto 22 does not warrant any product, components, or parts not manufactured by Opto 22; for these items, the warranty from the original manufacturer applies. Refer to Opto 22 form 1042 for complete warranty information.

Wired+Wireless controllers and brains are licensed under one or more of the following patents: U.S. Patent No(s). 5282222, RE37802, 6963617; Canadian Patent No. 2064975; European Patent No. 1142245; French Patent No. 1142245; British Patent No. 1142245; Japanese Patent No. 2002535925A; German Patent No. 60011224.

Opto 22
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Table of Contents

1: Introduction

E1 digital and E2 analog brain boards are intelligent I/O (input/output) processors that communicate with a host computer and also perform control functions at each point of I/O.

Designed as drop-in replacements for Opto 22's B1 and B2 brain boards, the E1 and E2 have the same Optomux and serial network capabilities, but they offer significant new features: Ethernet support, additional protocol support, and migration and expansion opportunities. For example, you can use PAC Project™ software applications with E1 or E2 I/O systems to control, monitor, and acquire data.

E1 and E2 brain boards can communicate using Optomux over serial and Ethernet, and using Opto 22's OptoMMP™ protocol over Ethernet. OLE for Process Control (OPC) and Modbus/TCP clients can readily obtain data from the system over Ethernet. For detailed information on protocols and system architecture, see Chapter 3: Architecture and Communication.

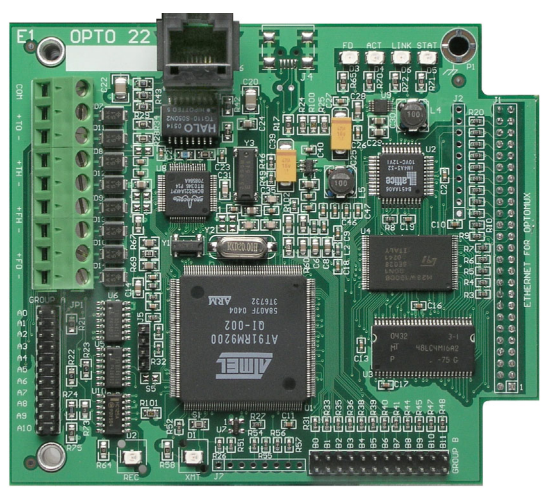
E1 Brain Board

The E1 brain board is a digital-only processor that can be used with a variety of input/output (I/O) modules and mounting racks. The E1 supports up to 16 I/O modules.

In addition to On/Off control, the E1 brain board provides the following digital functions:

- Read/write to point
- Input latches
- Counters
- Pulse duration measurement
- Pulse generation
- Time delays
- Watchdog timer

For detailed descriptions of E1 features, see "E1 and E2 Features and Specifications" on page 5.



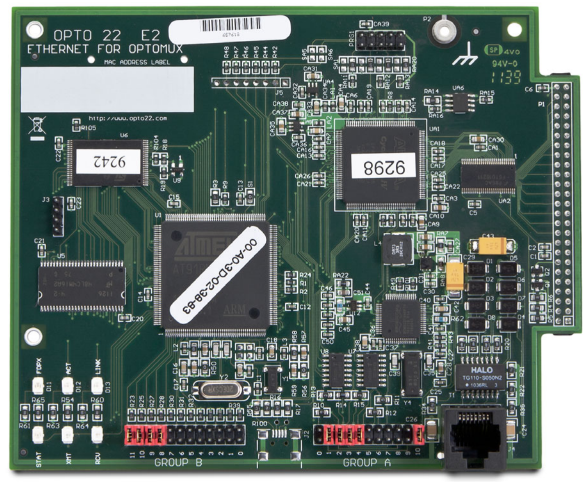
E1 Brain Board

E2 Brain Board

The E2 brain board is an analog-only processor used with G1 (Standard) analog modules and G1-series mounting racks.

In addition to simple input and output, the E2 brain board provides the following analog functions:

- Read/write to point in Engineering units
- Read/write to point in counts
- Input averaging
- Minimum/maximum values (peak/valley recording)
- High/low limit testing
- Offset and gain calculation
- Waveform generation
- Watchdog timer



E2 Brain Board

For detailed descriptions of E2 features, see E1 and E2 Features and Specifications on page 5.

ABOUT THIS GUIDE

This guide shows you how to install and use E1 and E2 brain boards. This guide assumes that you have some familiarity with TCP/IP, UDP/IP, and Ethernet networking. If you are not familiar with these subjects, we strongly suggest you consult commercially available resources to learn about them before attempting to install or use these products.

If you are using Modbus/TCP for communicating with E1 and E2 brain boards, this guide assumes that you are already familiar with Modbus/TCP.

The following chapters are included in this user's guide:

Chapter 1: Introduction—Provides a brief description of the E1 and E2 brain boards, the contents of this guide, a list of other important documents, and how to reach Opto 22 Product Support.

Chapter 2: Installation—Details what you need to install E1 and E2 brain boards, how to mount the brain board, and how to connect to a serial or Ethernet network.

Chapter 3: Architecture and Communication—Describes how E1 and E2 brain boards fit into your system architecture and how to communicate with them.

Chapter 4: Maintaining the E1 and E2—Describes assigning and changing IP addresses, resetting the brain board to factory defaults, and upgrading firmware.

Chapter 5: Using Modbus/TCP—Provides configuration information for those communicating with the E1 and E2 using Modbus/TCP.

Chapter 6: Troubleshooting—Provides tips for resolving difficulties you may encounter while working with E1 and E2 brain boards.

Appendix A: Serial-to-Ethernet Routing—Presents how to set up the E1 and E2 to route data between serial and Ethernet networks.

Appendix B: Using the OmuxSettings File—Describes how to set Optomux network settings using the OmuxSettings file.

Appendix C: Licensing Information—Presents licensing information for software components.

Other Documents You May Need

See the following additional guides for the information listed. All documents referenced in this document are available on our website, www.opto22.com..

For this information	See this guide	Form #
Writing custom applications using the Optomux protocol over Ethernet or serial. (Combines previous forms 92 and 203 into new form number.)	*Optomux Protocol Guide*	1572
Configuring E1s and E2s to use with PAC Project software, Modbus/TCP applications, and custom OptoMMP	For minimum E1/E2 firmware R1.2a, PAC firmware 9.5, and PAC Project 9.5: • *PAC Control User's Guide, Legacy Edition* • *PAC Manager User's Guide, Legacy Edition* For older firmware or software: *I/O Configuration for E1 and E2 Brain Boards*	1710 1714 1576
Writing custom applications using the OptoMMP protocol over Ethernet	*OptoMMP Protocol Guide*	1465
Providing reliable power to Opto 22 equipment	*Using Power Supplies with Opto 22 Systems*	1271
Programming Opto 22 SNAP PAC controllers	*PAC Control User's Guide, Legacy Edition* *PAC Control Command Reference. Legacy Edition*	1710 1711
B1/B2 system architecture, features, specifications, installation and wiring, and jumpers	*Optomux 16-Channel Digital and Analog Brain Board Data Sheet (B1/B2)*	463
E1/E2 protocol support, comparison of B1/B2 and E1/E2, detailed description	*E1 and E2 Brain Board Data Sheet*	1546

FOR HELP

If you have problems installing or using E1 and E2 brain boards and cannot find the help you need in this guide or on our website, contact Opto 22 Product Support.

Phone: 800-TEK-OPTO (800-835-6786 toll-free in the U.S. and Canada)
951-695-3080
Monday through Friday,
7 a.m. to 5 p.m. Pacific Time

NOTE: Email messages and phone calls to Opto 22 Product Support are grouped together and answered in the order received.

Email: support@opto22.com

Opto 22 website: www.opto22.com

When calling for technical support, you can help us help you *faster* if you provide the following information to the Product Support engineer:

- A screen capture of the Help > About dialog box showing software product and version (available by clicking Help > About in the application's menu bar).
- Opto 22 hardware part numbers or models that you're working with.
- Firmware version:
  - For SNAP controllers and brains: available in PAC Manager by clicking Tools > Inspect.
  - For *groov* EPIC processors and *groov* RIO modules: available in *groov* Manage by clicking Info and Help > About.
- Specific error messages you received.
- Version of your computer's operating system.
- For PAC Control, PAC Display, OptoOPCServer, or PAC Manager, you may be requested to provide additional information, such as log or dump files. You can find these files in a support files sub-folder:
  a. On your Windows Desktop, double-click the PAC Project 10.4 folder.
  b. Double-click Support Files.
  c. Double-click on the appropriate shortcut to open the sub-folder containing the requested files.

  Note: *PAC Control, PAC Display, OptoOPCServer, and PAC Manager create appropriate sub-folders when they create diagnostic log or dump files. If they have not created these files, the sub-folder may not exist; in this case, the shortcut will not work.*

E1 AND E2 FEATURES AND SPECIFICATIONS

E1 Brain Board Features

The following table shows features available on an E1 digital I/O unit depending on the protocol used.

Feature	Optomux	OptoMMP[1]	Modbus/TCP
Read/write to point	●	●	●
Input latches	●[2]	●[3]	●[3]
Counters[4]	●	●	●
Pulse duration measurement	●		
Pulse generation	●		
Time delays (10 ms resolution)	●		
Watchdog timer	●	●	●
Networks			
Serial (RS-422/485)	●		
Ethernet	●	●	●

1 This protocol is also used with all PAC Project applications.
2 One latch per point is available; it can be configured as on-to-off or off-to-on.
3 Two latches per point are always available; no configuration is needed.
4 Maximum counter frequency is 400 Hz. Counters roll over at 65,535.

About E1 and E2 brain boards: You can configure E1s and E2s like any other I/O unit if you have E1/E2 firmware R1.2a (and higher) and PAC Project 9.5000 (and higher). Also, if a SNAP PAC controller communicates with the E1 or E2, the controller must have PAC firmware R9.5a (or higher) to use this simplified configuration method. If you are not using these firmware and software versions (or if you prefer to use the previous method to reconfigure existing E1s or E2s), see I/O Configuration for E1 an E2 Brain Boards *(form 1576)*.

Each E1 feature is described below.

Read/Write to Point—The E1 can read the value of any input[3] or output point and turn digital output points on or off.

Input Latches—When the value of a digital input point changes from off to on, an on-latch can be set.

While the value of the point may return to off, the on-latch remains set until cleared, as a record of the change.

Similarly, an off-latch can be set when the value of a digital point changes from on to off, and it remains set until cleared. See note 2 in the table above.

Latching is different on an E1 depending on the protocol used with the brain board. When the E1 is used with the Optomux protocol, only one latch is available and you must configure it to be an off-to-on latch or on-to-off latch. When you use an E1 with OptoMMP or Modbus/TCP, however, both types of latches are automatically available for each point, and no configuration is required.

Counters—Digital input can be used as a counter, counting the number of times the input changes from off to on.

Pulse Duration Measurement (using the Optomux protocol)—Any or all of the input points can function as pulse duration timers. Either on or off pulses can be timed with a resolution of 10 milliseconds.

Pulse Generation (using the Optomux protocol)—The E1 can be instructed to output a specific number of pulses (with programmable period) at any output point. Continuous square waves can also be generated.

Time Delays (using the Optomux protocol)—Any or all output points can function in time delay mode. Outputs can be set to operate with four types of delays:

- Delay before turning off
- Delay before turning on
- Pulse on
- Pulse off

Time delays are programmable with a resolution of 10 milliseconds.

Watchdog Timer—You can set a watchdog timer to monitor communication with the PC or other host device. If the watchdog timer is set via the serial port, then any serial activity will trigger the watchdog (including communications to other devices). If it is set via the Ethernet port, then only Ethernet activity directed to the respective E1 or E2 will trigger the watchdog. If the watchdog isn't triggered for the length of time set, the brain board automatically sets designated I/O points to the values you have determined. This action makes sure the process is brought to a safe state if communication fails.

E2 Brain Board Features

The following table shows features available on an E2 I/O unit depending on the protocol used.

Feature	Optomux	OptoMMP[1]	Modbus/TCP
Read/write to point in Engineering units		●	●
Read/write to point in counts	●	●	
Input averaging	●		
Minimum/maximum values (peak/valley recording)[2]	●	●	●
High/low range testing	●		
Offset and gain calculation	●	●	●
Waveform generation	●		
Watchdog timer	●	●	
Networks			
Serial (RS-422/485)	●		
Ethernet	●	●	●
1 This protocol is also used with all PAC Project applications. 2 If an ICTD or thermocouple module is used, minimum and maximum values are returned as counts.			

About E1 and E2 brain boards: You can configure E1s and E2s like any other I/O unit if you have E1/E2 firmware R1.2a (and higher) and PAC Project 9.5000 (and higher). Also, if a SNAP PAC controller communicates with the E1 or E2, the controller must have PAC firmware R9.5a (or higher) to use this simplified configuration method. If you are not using these firmware and software versions (or if you prefer to use the previous method to reconfigure existing E1s or E2s), see I/O Configuration for E1 an E2 Brain Boards *(form 1576).*

Each E2 feature is described below.

Read/Write to Point in Engineering Units (using OptoMMP)—The E2 can read the value of an input point and send a value to an output point in engineering units, such as millivolts or milliamps.

Read/Write to Point in Counts—The E2 can read the value of an input point and send a value to an output point in 12-bit counts.

This is especially useful when integrating with existing Optomux systems. The Optomux protocol will return counts in a range of 0–4095.

The OptoMMP protocol returns counts based on how the E2 was configured:

- Modules configured directly as G1 modules (new method; requires E2 firmware R1.2a or higher and PAC Project 9.5 or higher) will report counts as G1 counts (0–4095 nominal range).
- Modules configured as similar SNAP modules (old method using form 1576) will report counts as 0–25000 or -25000 to +25000.

Input Averaging (using the Optomux protocol)—The E2 can be instructed to average the values of successive readings.

Minimum/Maximum Values (peak/valley recording)—The E2 automatically keeps track of minimum and maximum count values for each input. You can read these values at any time, and you can reset min/max values.

NOTE: The values returned for temperature modules will be counts, not linearized temperature values. See Read/Write to Point in Counts, above, for count values.

High/Low Range Testing—The E2 tests for the high and low limits (range) for the specified input points, and sets a flag if values exceed the specified range

Offset and Gain Calculations—The brain board can calculate offset and gain for analog input points. If a 0 VDC to +5 VDC input receives signals that are slightly off (not exactly 0 VDC at the lowest point, for example), the offset and gain can be calculated so that values will appear accurately.

NOTE: To calibrate analog points, use PAC Manager. See form #1714, the Legacy Edition PAC Manager User's Guide.

Waveform Generation (using Optomux)—Square waves, triangle waves, and ramps can be generated at any output point with programmable rates.

Watchdog Timer—You can set a watchdog timer to monitor communication with the PC or other host device. If the watchdog timer is set via the serial port, then any serial activity will trigger the watchdog (including communications to other devices). If it is set via the Ethernet port, then only Ethernet activity directed to the respective E1 or E2 will trigger the watchdog. If the watchdog isn't triggered for the length of time set, the brain board automatically sets designated I/O points to the values you have determined. This action makes sure the process is brought to a safe state if communication fails.

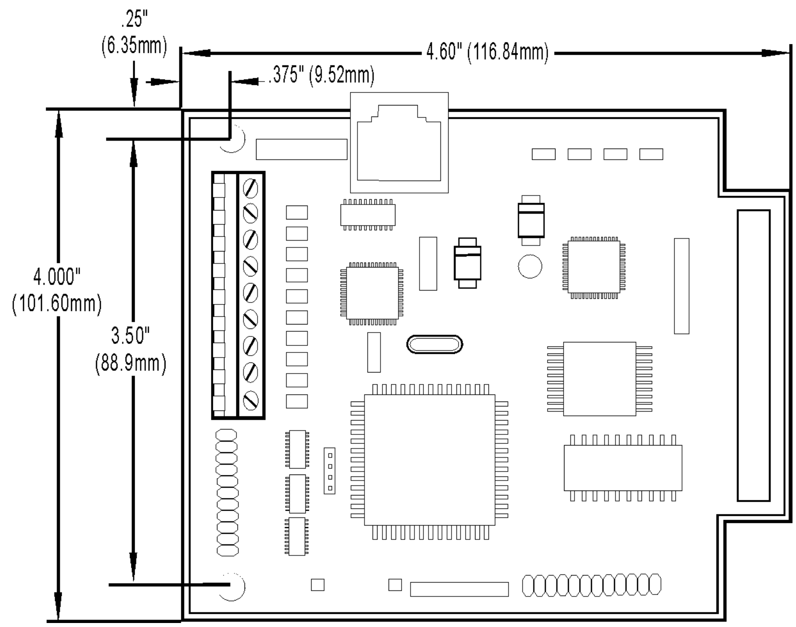
Specifications

Power Requirements	5.0–5.2 VDC @ 0.5 amps (excludes digital and analog module power requirements) *
Ethernet Network Interface: Type Connector Rate Supported Protocols Maximum Segment Length	 IEEE 802.3 network, 10Base-T/100Base-TX RJ-45: Supports Auto MDI-X (crossover cable not needed) 10/100 Mbps, half or full duplex Optomux over Ethernet, Modbus/TCP, OptoMMP (Opto 22's IEEE 1394-based memory-mapped protocol) 100 m (328 ft.) with Category 5 or superior UTP
Serial Network Interface: Type Connector Data Rates Supported Protocols Network Range	 RS-422/485 serial link **E1:** Terminal block; **E2:** Terminal block (on mounting rack) 300, 600, 1200, 2400, 4800, 9600, 19200, and 38400 baud Optomux Up to 32 Optomux stations configured for multidrop can be used on a serial network of up to 1524 m (5000 ft.) total length. Up to 256 Optomux stations and longer line lengths can be used by installing network repeaters. Up to 256 Optomux stations configured for repeat mode can exist on a network.
Optomux I/O Functions	**Digital I/O (E1):** Read Point, Write Point, Latch Point (On/Off), Count, Pulse Duration, Time Delay, Pulse Generation, Watchdog Timer **Analog I/O (E2):** Read Point, Write Point, Input Averaging, Min/Max Recording (peak and valley), High/Low Range Testing, Offset and Gain Calculation, Waveform Generation, Watchdog Timer
Modbus/TCP, OptoMMP, and OPC I/O Functions	With these protocols, the following brain-based features are not available: • No pulsing or time delay (E1) • No pulse measurement • No input averaging or waveform generation (E2)
LED Indicators	Status, Link, Activity, Full duplex, Transmit (serial), Receive (serial)
Jumper-selectable Serial Options	**Group A:** Multidrop or repeat mode, RS-485 termination and biasing **Group B:** Serial address (0 to 255), baud rate, 2- or 4-pass protocol
Operating Temperature	0 °C to 70 °C
Storage Temperature	–40 °C to 85 °C
Humidity	0–95% humidity, non-condensing
Agency Approvals	DFARS
Warranty	30 months

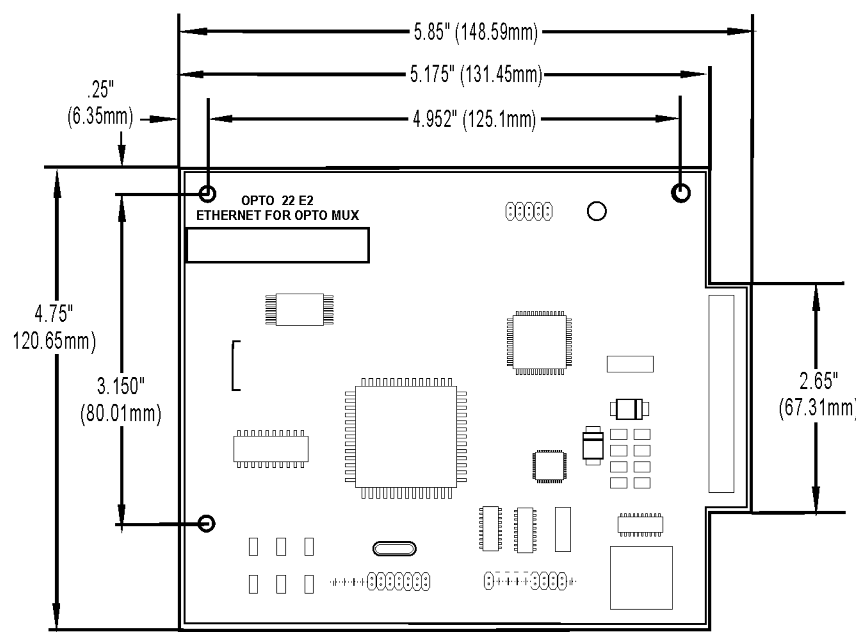
* ±15 VDC ±0.25 V is required for the analog modules. Current depends on the number and types of modules installed. A 24 VDC power supply is required for analog modules that need a current loop source.

Dimensional Drawings

E1 Dimensions



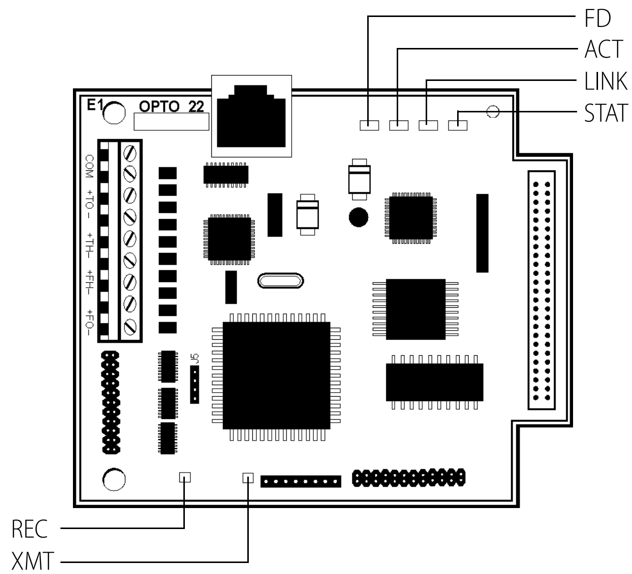
E2 Dimensions



LED DESCRIPTIONS

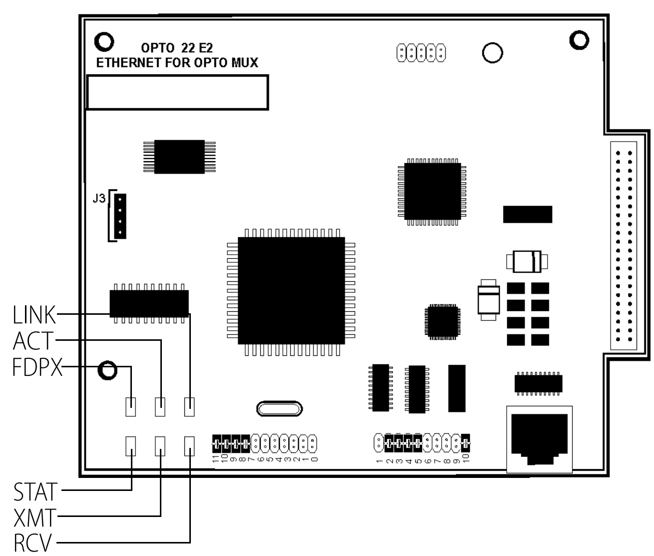
E1 LED Descriptions

LED	Description	Link Type
FD	Full Duplex Mode	Ethernet
ACT	Network Activity	Ethernet
LINK	Link	Ethernet
STAT	Status	n/a
REC	Data Receive	Serial
XMT	Data Transmit	Serial



E2 LED Descriptions

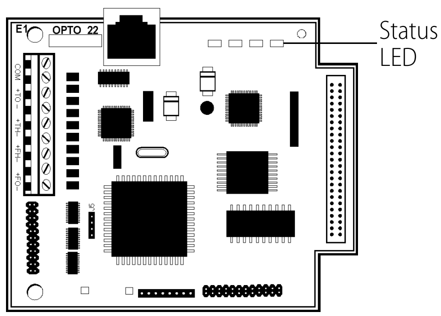
LED	Description	Link Type
LINK	Network Link	Ethernet
ACT	Network Activity	Ethernet
FDPX	Full Duplex Mode	Ethernet
STAT	Status	n/a
XMT	Data Transmit	Serial
RCV	Data Receive	Serial



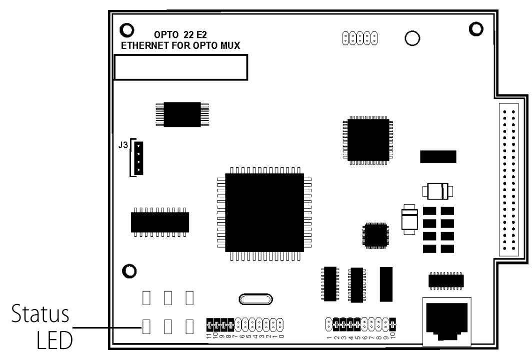
LED Blink Codes

The Status LED (STAT) on E1 and E2 brain boards provides both event and status information.

Code	Type	Meaning	Comments
3 short blinks	Event	The brain board is beginning to start up.	The LED starts to blink after the E1 or E2 is turned on or a reboot command is sent to the device.
6 short blinks	Event	The brain board is entering loader mode.	The LED starts to blink after the E1 or E2 is turned on or a reboot command is sent to the device with the Loader Mode Jumper installed.
LED on	Status	The brain board is running.	Once the brain board has started, the LED turns on and stays on. This should occur shortly after a series of 3 short blinks. Note that the color of the LED doesn't matter; as long as the LED is On and not blinking, the brain board is functioning normally.
LED flashing	Status	The brain board is restoring the factory defaults or updating the firmware.	**CAUTION:** DO NOT turn off power to the device while the LED is flashing, even if it takes a very long time. Turning off power might corrupt the firmware and the brain board will not be able to start up. For more information, see “Resetting the Brain Board to Factory Defaults” on page 35 and “Loading New Firmware” on page 36.



E1 Brain Board



E2 Brain Board

2: Installation

Use this chapter to install E1 and E2 brain boards. If you need more information on how to integrate E1s and E2s with your system, see Chapter 3: Architecture and Communication.

WHAT YOU WILL NEED

To install an E1 or E2, you need the following items:

- PC running Microsoft® Windows® 2000 or higher, with a 10/100 MB Ethernet adapter card, the TCP/IP protocol installed, and a valid IP address. The PC must be on the same subnet as the brain board.
- Serial cable for a serial network. For an Ethernet network, use Category 5 Ethernet cable. (For more information on cables, see page 22.)
- E1 or E2 brain board
- I/O modules and mounting racks (See compatible I/O modules and mounting racks on page 22.)
- Power supply (See page 23.)
- Voltmeter
- Screwdriver

INSTALLING SOFTWARE

The software for E1 and E2 brain boards is available on the Opto 22 website.

- The E1 product page lists all E1 software in the Downloads tab.
- The E2 product page lists all E2 software in the Downloads tab.

MOUNTING THE BRAIN BOARD

Racks vary in shape and design. The combination of rack, modules, and brain board (called the *I/O unit*) can be mounted in any attitude on any flat surface.

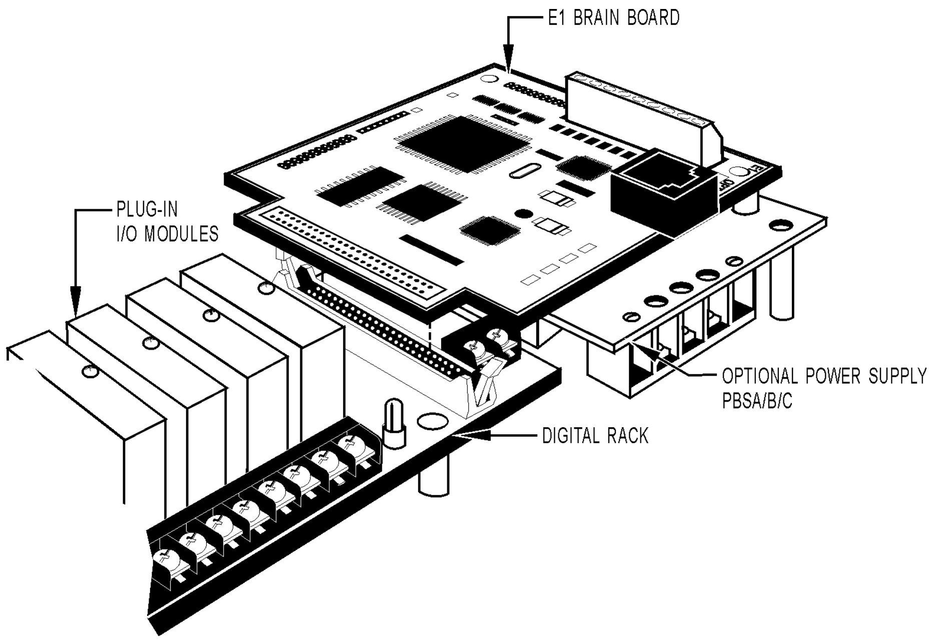
To ensure reliable and trouble-free communications, the following is recommended:

- Use twisted-pair wires for the serial communications wiring. See page 22.
- Keep communication and DC power wiring separate from any high-voltage field wiring.

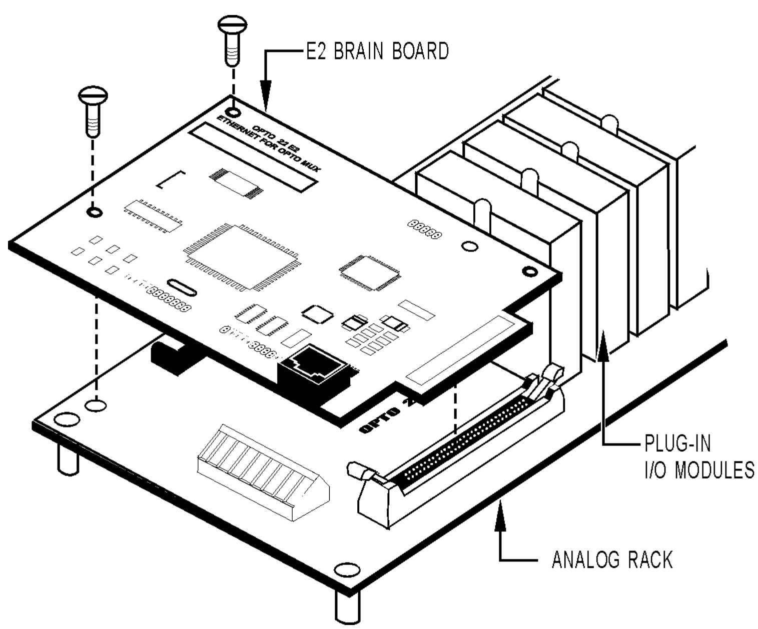
Steps for mounting:

1. If you are replacing an existing B1 or B2 brain board, turn off the power to the rack and carefully remove the B1 or B2 from the rack.
2. Carefully plug the E1 or E2 brain board into the mounting rack using the 50-pin connector.

E1 brain board/rack combination. As shown in the G1/Standard example below, the brain board extends out past the end of the rack when used with G4, G1, and Quad Pak I/O racks. For integral racks, which have permanent I/O circuitry built in, the brain board is inserted in the other direction, covering the rack.



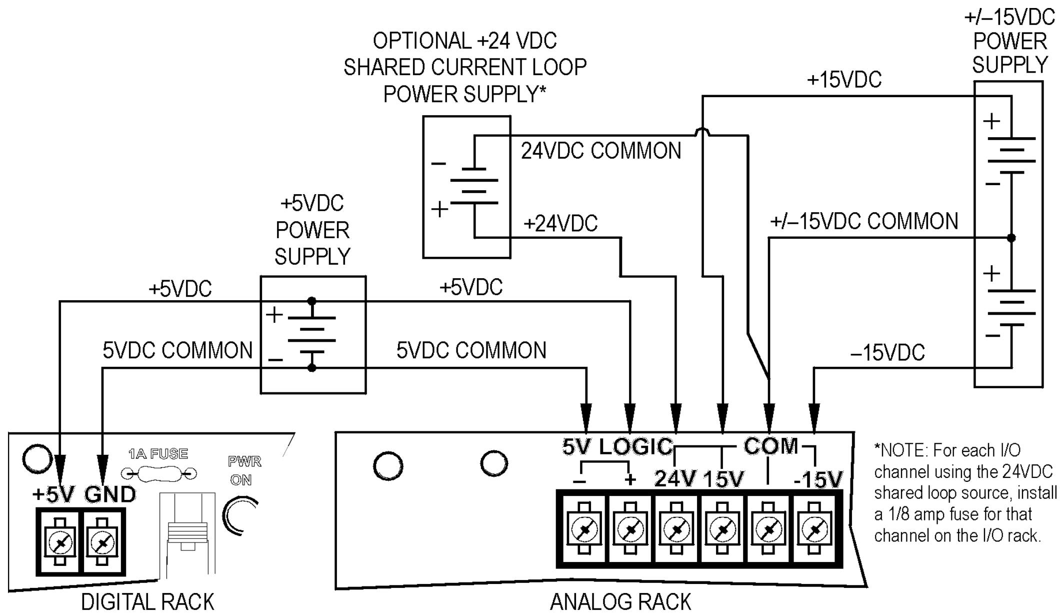
E2 brain board/rack combination



3. Place the I/O unit as close as possible to the controlled device to minimize wiring costs and noise for analog modules. When installing units next to each other, leave sufficient space between units for wiring.

4. For maximum physical strength, secure the brain board's permanently attached standoffs. Also secure standoffs on the rack, if available.

CONNECTING THE POWER SUPPLY



1. Using size 14 AWG or larger wire, connect 5-volt power to the + 5V and GND connectors on the mounting rack. If the + 5-volt supply is used by more than one unit or by other devices, make sure the voltage at each rack is 5.1–5.2 VDC. Use a consistent color code from the power supply to all brain boards to prevent wiring errors. See Opto 22 form #1271, *Using Power Supplies with Opto 22 Systems*, for more information on power wiring and voltage adjustments.

   EXCEPTION: If an Opto 22 PBSA/B/C power supply is used with digital racks, the + 5 VDC logic connection is made by the supply when it is screwed to the rack. In this case, the only connection required is the 120 VAC (220 VAC or 10–28 VDC depending on supply type) connection to the PBSA (or PBSB or PBSC) supply.

2. You can use either separate or combined 5.1–5.2 VDC and ± 15 VDC (± 0.25 VDC) supplies to provide power to analog racks. If you use a multiple-output supply, make sure that the 5 VDC RETURN line is separate from the 15-volt COMMON line to maintain module isolation.
3. Route the +5-volt and ±15-volt wires away from any high-voltage field wires. Make sure there is only one earth ground connection per network, typically at the host site.

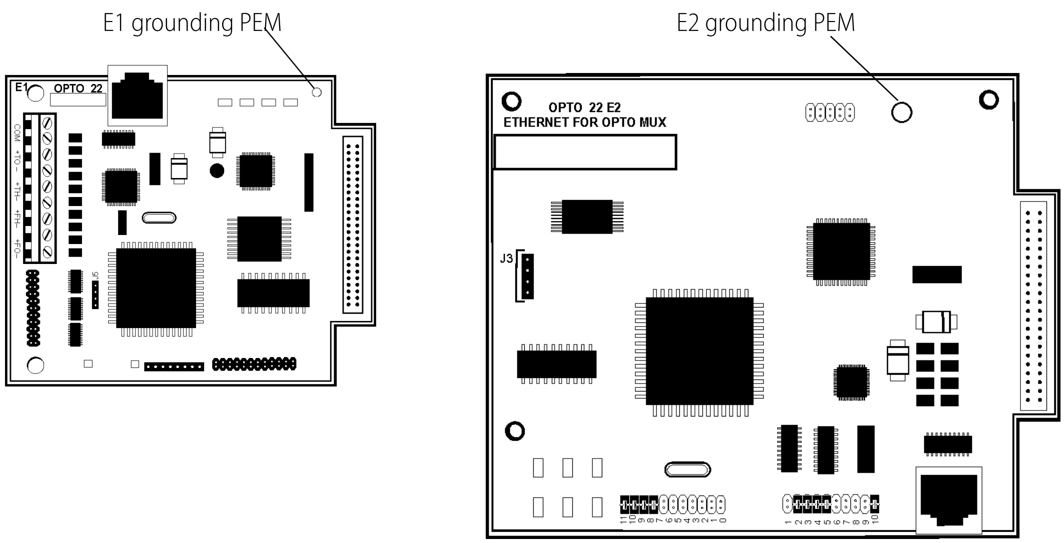
   If the ground connection is at the host site, make sure none of the power supplies is grounded. This method prevents ground loop problems due to offset voltages appearing between multiple ground points.
4. **IMPORTANT:** Check polarities of all power supply connections before applying power.

   Incorrect polarity can damage the brain board and I/O modules.

NOTE: If the brain board is connected to an Ethernet network, before powering up see the section about assigning an IP address in form #1714, Legacy Edition PAC Manager User's Guide.

CONNECTING THE E1 AND E2 TO EARTH GROUND

In installations where electrical noise is a concern, the E1 and E2 each provide a grounding point to improve noise immunity. Using 18 AWG, connect the insulated wire from the grounding PEM to the point where the earth ground is connected. Each brain should have a separate wire to connect to ground. Each grounding point should be tied to a single point earth ground.



INSTALLING I/O MODULES

1. Turn off all power to the unit and to the field devices.

   IMPORTANT: All power must be turned off before installing or removing I/O modules.

2. Install input and output modules in any rack position. Compatible modules are shown in the table on page 22. For specifications and wiring information on modules, see the module's data sheet.

3. Depending on the networks you are using, continue with the following:
   - "Connecting to a Serial Network," below
   - "Connecting to an Ethernet Network" on page 21

   NOTE: You can use both serial and Ethernet networks simultaneously. E1 and E2 brain boards are set by default to communicate on both networks.

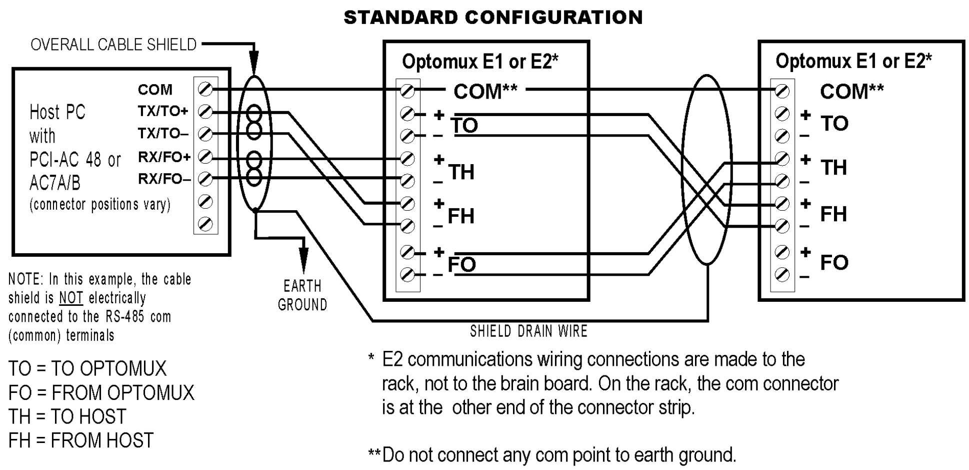
CONNECTING TO A SERIAL NETWORK

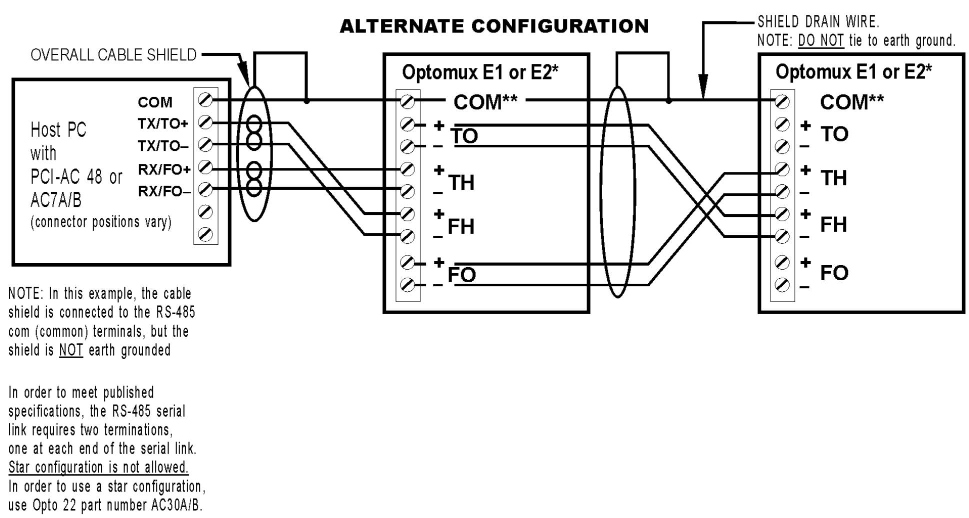
Wiring Serial Communications and Power

A complete connection at each brain board consists of 10 wires as well as an overall cable shield: two twisted pairs and a common coming from the computer or previous brain board, and two twisted pairs and a common going to the next brain board. To ensure reliable communications, we recommend the following:

- Use shielded twisted-pair wires for the communications wiring. (See recommended cables on page 22.)
- Route the communication and DC power wiring separately from any high-voltage field wiring or AC power wiring.
- Make sure the communications COM terminals on each rack are connected.

The following graphic shows standard and alternate wiring diagrams. When wiring a series of brain boards, always think of the previous brain board as the host.





Setting Jumpers (Serial Only)

Jumpers in groups A and B are set during initial configuration:

- Group A jumpers set repeat or multidrop mode, and termination.
- Group B jumpers set baud rate, 2-pass or 4-pass message, and address.

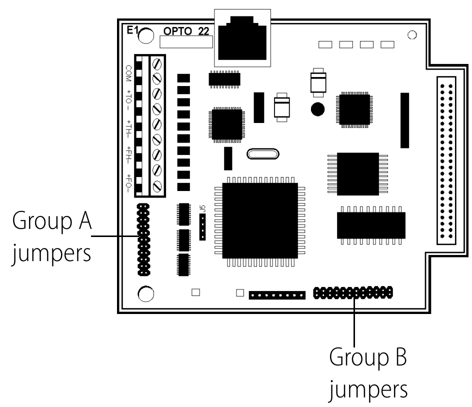
For an easy way to see which jumpers to set, go to our website and use the E1/B1 Brain Jumper Configurator or the E2/B2 Brain Jumper Configurator.

> *Note: If you have an existing brain and need to know how it is currently configured (for example, if you are replacing a B1 with an E1 and need to configure them the same), use these interactive demos: Read E1/B1 Jumper Settings or Read E2/B2 Jumper Settings.*

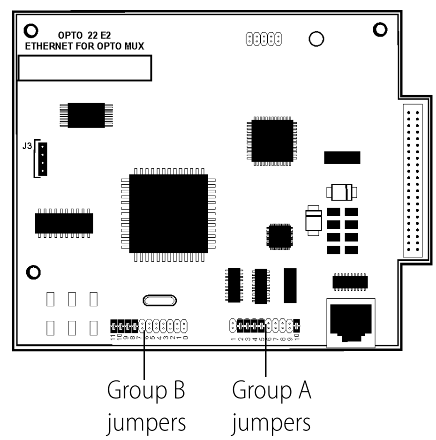
For information on using jumpers to reset the brain board, see "Resetting the Brain Board to Factory Defaults" on page 35.

Also see "Jumper Tips" on page 54.

NOTE: When the E1 or E2 is powered up, it periodically reads the jumpers. You can change the jumpers at any time and the firmware will detect the change and reconfigure accordingly.

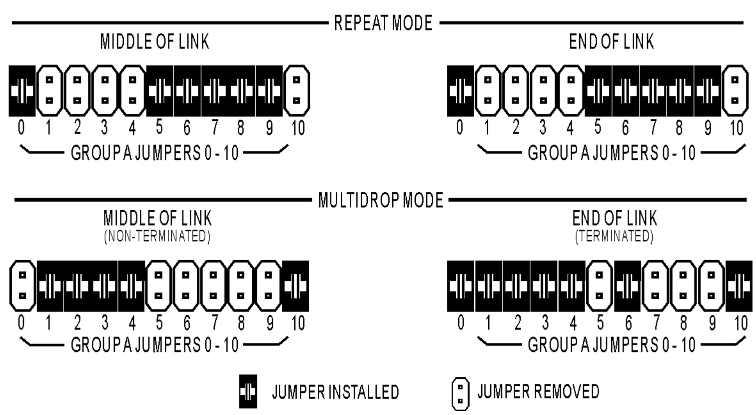


E1 Brain Board



E2 Brain Board

1. Set the jumpers in Group A for repeat or multidrop mode, and proper termination and biasing.

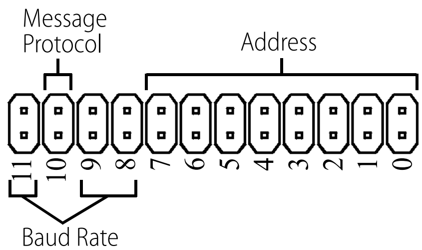


Multidrop—When wiring a multidrop communications cable, keep in mind that the cable is a high-speed data-transmission line. To reduce reflections, make sure the line is terminated properly at both ends and that all stubs are less than three inches long.

Repeat—In this configuration, each brain board acts as a repeater, allowing up to 5,000 feet between units. Since a power failure at any unit breaks the communications link, battery backup is recommended.

NOTE: You cannot mix units operating in repeat mode and units operating in multidrop mode on the same network.

2. Set the Group B jumpers, including baud rate, message protocol, and address.



Group B Jumpers

a. Select the **baud rate** using jumpers 8, 9, and 11 in Group B. Make sure to set all brain boards on the same network at the same baud rate.

Baud Rate	Jumper 11	10	9	8
38.4 kBaud	■	□	■	■
19.2 kBaud	□	□	■	■
9600 Baud	□	□	■	□
4800 Baud	■	□	■	□
2400 Baud	■	□	□	■
1200 Baud	□	□	□	■
600 Baud	■	□	□	□
300 Baud	□	□	□	□

■ = JUMPER INSTALLED □ = NO JUMPER

b. Set the **message protocol** using jumper 10 in Group B for 2-pass or 4-pass. Make sure all brain boards on the same network use the same message protocol.

Protocol	Jumper 10	
2-PASS	■	(Recommended)
4-PASS	□	

■ = JUMPER INSTALLED □ = NO JUMPER

Use 2-pass for normal operation. It provides more efficient and faster communications. For a detailed description of 2-pass and 4-pass modes, see form # 1572, the *Optomux Protocol Guide*.

c. Set the **address** using jumpers 0–7 on Group B, according to the following chart. Each brain board on the same network must have a unique address. Addresses do not need to be sequential.

Address	7 6 5 4 3 2 1 0
0	■■■■■■■■
1	■■■■■■■□
2	■■■■■■□■
3	■■■■■■□□
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■ = JUMPER INSTALLED   □ = NO JUMPER

CONNECTING TO AN ETHERNET NETWORK

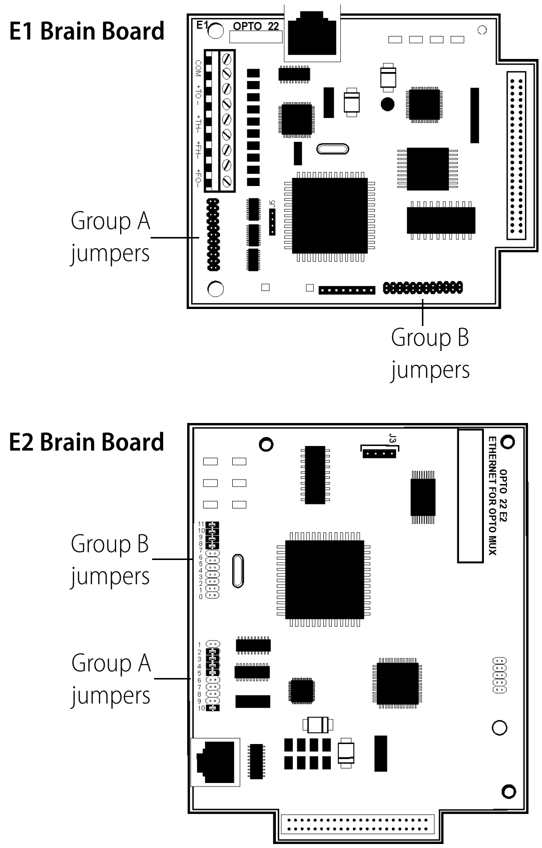
To connect to an Ethernet network, see form #1714, the *PAC Manager User's Guide, Legacy Edition*.

IMPORTANT: *If you are communicating only on an Ethernet network (no serial connections), make sure that Group A jumpers on E1 and E2 brains are set for multidrop mode/middle of link (see diagram below).*

If jumpers are not set in this way, the RS-485 communication lines may cause interference.

Group A Jumpers Set for Multidrop Mode/ Middle of Link

0	Out
1	In
2	In
3	In
4	In
5	Out
6	Out
7	Out
8	Out
9	Out
10	In



Security

When designing your Ethernet network, be sure to consider security as required for your application. You can use PAC Manager to limit access to Ethernet-based I/O units, either by allowing access only from specific computers or other devices on the network (IP filtering), or by limiting access to specific protocols that are used with the I/O unit (port access).

See form #1714, the Legacy Edition PAC Manager User's Guide, for more information on security.

SYSTEM COMPONENTS

This section gives additional information on some items listed in "What You Will Need" on page 13.

I/O Modules and Mounting Racks

The brain board plus the mounting rack and modules are often referred to as the *I/O unit*. Choose compatible I/O modules and mounting racks from the following tables.

E1 (Digital)	
I/O modules	**Digital mounting racks**
G4 Digital I/O	G4PB8H G4PB16H G4PB16HC
Quad Pak	PB16HQ
Standard (G1) I/O	PB4H PB8H PB16H PB16HC
Combination I/O and rack (Integral racks)	
G4PB16J/K/L PB16J/K/L	

E2 (Analog)	
I/O modules	**Analog mounting racks**
Standard (G1)	PB4AH PB8AH PB16AH

Cable

For serial (RS-422/485) communications, the following cables are recommended. Cables listed are 24-gauge, 7x32 stranded, with 100-ohm nominal impedance and a capacitance of 12.5 pF/ft. If you use other cables, they should have a nominal impedance of 100–120 Ohms and a capacitance of less than 15 pF/ft.

We also recommend that you choose a cable with one more pair than your application requires, so you can use one of the extra wires, rather than the shield, for the signal common.

Four-pair	Three-pair
• Belden P/N 8104 (with overall shield) • Belden P/N 9728 (individually shielded) • Belden P/N 8164 (individually shielded with overall shield) • Manhattan P/N M3477 (individually shielded with overall shield) • Manhattan P/N M39251 (individually shielded with overall shield)	• Belden P/N 8103 (with overall shield) • Belden P/N 9730 (individually shielded) • Belden P/N 8163 (individually shielded with overall shield) • Manhattan P/N M3476 (individually shielded with overall shield) • Manhattan P/N M39250 (individually shielded with overall shield)

For Ethernet communications, use a Category 5 Ethernet connection to a standard 10BASE-T or 100BASE-TX Ethernet network. If you need a direct connection to a PC, use an Ethernet crossover cable.

Power Supply

Choose the power supply appropriate for the rack. E1 and E2 brain boards require 5.0–5.2 VDC at 0.5 amps (see note). Although it is possible to distribute DC from a common power supply to several locations, better noise immunity is obtained by having separate power supplies for each I/O unit. For more information, see Opto 22 form #1271, *Using Power Supplies with Opto 22 Systems Technical Note*.

NOTE: For all Opto 22 products that require 5 VDC, we recommend adjusting the power supply so that the Opto 22 products are receiving 5.10 –5.20 VDC. This recommendation is based on years of experience and will eliminate many startup and maintenance issues.

Analog racks also require +15 VDC and -15 VDC (± 0.25 VDC) to power the analog I/O modules. The amount of power required depends on the type and number of analog I/O modules that are plugged into the rack. Power requirements for each of the analog modules are included in the module specifications.

Analog racks also provide terminals for a separate +24 volt supply that can be used for powering 4–20 mA current loops using 4–20 mA analog I/O modules. For this type of application, the +24 volt supply is required in addition to the supplies mentioned above. Refer to the module data sheets for information on wiring 4–20 mA modules with a loop supply.

The current requirements given for the output modules are only for the modules. To determine what size power supply is needed, add the load requirements for each module to determine total power supply requirements.

NOTE: Use only isolated supplies. Isolated supplies reduce the risk of ground loops in the communication wiring. Do not connect the power supply's DC common to earth ground. Linear power supplies are recommended. See Opto 22 form #1271, for more information.

3: Architecture and Communication

This chapter describes the options you have for communicating with E1 and E2 brain boards, illustrates system architecture for the E1 and E2, and discusses options to change from serial B1 or B2 systems to E1 or E2 Ethernet systems.

It includes the following topics:

COMMUNICATION OPTIONS

Each E1 and E2 can communicate with a host through its serial port, its Ethernet port, or both, using a variety of protocols. The Optomux protocol can be used on both serial and Ethernet networks; other protocols are also available on Ethernet. You can use all of the Ethernet and serial protocols shown in the table below simultaneously.

The protocols and networks have specific advantages and disadvantages, summarized below.

Protocol & Network	Advantages	Disadvantages	See
Optomux over Ethernet	All possible brain board features are available. Ethernet network allows multiple hosts and more than 256 I/O units.		page 27
OPC over Ethernet	OPC clients communicate to E1 and E2 via OptoOPCServer. Can be used simultaneously with Optomux control software running over Ethernet or serial.	Brain board features are somewhat limited.*	page 28
Modbus/TCP over Ethernet	E1 and E2 become part of a Modbus/TCP system. Can be used simultaneously with Optomux control software running over Ethernet or serial.	Brain board features are somewhat limited.*	page 29
OptoMMP over Ethernet	E1 and E2 can be part of an PAC Project control system. Custom applications can be built for E1, E2, and other Opto 22 memory-mapped devices, such as SNAP PAC brains. Ethernet network allows multiple hosts and more than 256 I/O units.	Brain board features are somewhat limited.*	PAC Project: page 29 OptoMMP: page 31
Optomux over serial	All Optomux protocol features are available.	Limited to one host and 256 I/O units. Host must be on the serial network.	page 32

* No pulsing or time delay on E1; no input averaging or waveform generation on E2.

Accessing E1 and E2 Brain Boards Over the internet

Since E1 and E2 brain boards operate like any other device on an Ethernet network, you can access them over the internet in exactly the same way you would access a computer. Remote monitoring, data acquisition, and control applications can communicate with the brain boards over the internet. The details of doing so depend on your network and internet connection.

Consult your system or network administrator or your Internet Service Provider (ISP) for more information.

SYSTEM ARCHITECTURE

E1 and E2 brain boards provide processing power for Opto 22 input/output (I/O) modules. E1 brain boards support digital I/O modules, and E2 brain boards support analog modules.

Digital—The E1 can be used with single-point G4 or G1 modules, four-point Quad Pak modules, or integral racks (digital I/O built into the rack).

Analog—The E2 can be used with single-point G1 modules.

The combination of brain board, I/O modules, and mounting rack is often referred to as an *I/O unit*.

Because E1 and E2 brain boards communicate over both serial and Ethernet networks, you can use them for remote monitoring, data acquisition, and industrial control using Optomux, OptoOPCServer, Modbus/TCP, and software applications built with Opto 22's PAC Project software suite (requires an Opto 22 SNAP PAC industrial controller). OPC and PAC Project applications use Opto 22's memory-mapped protocol, OptoMMP.

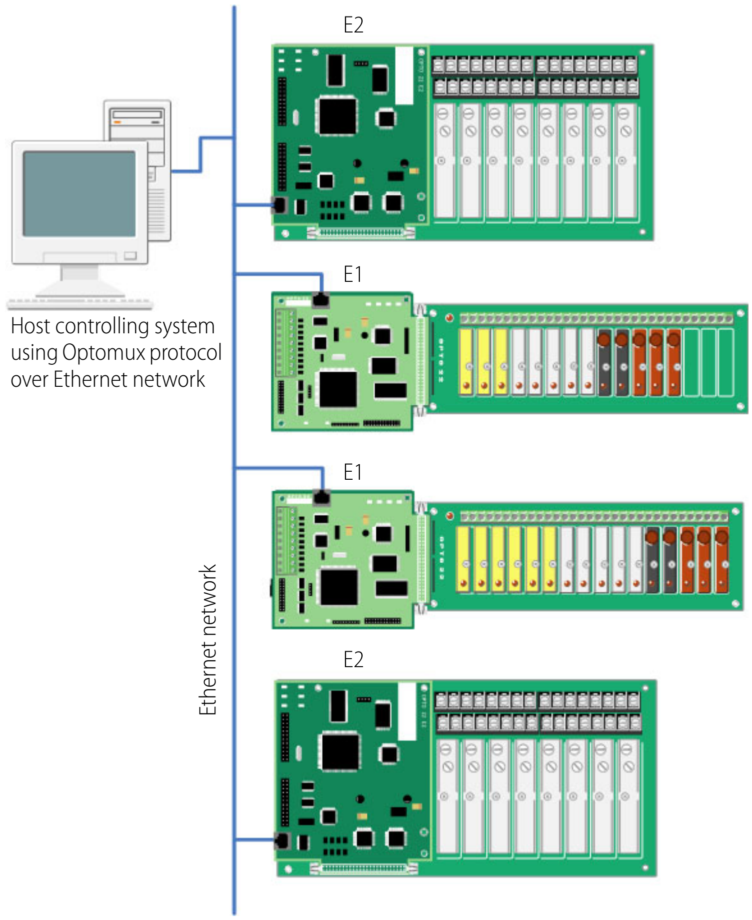
The following sections include information and architectural diagrams illustrating these uses.

Typical Control System Using Optomux

Optomux Over Ethernet

A control system using the Optomux protocol and running over an Ethernet network is a typical use for E1 and E2 brain boards. E1s and E2s use UDP for Ethernet communication.

Here is an example of such a system:



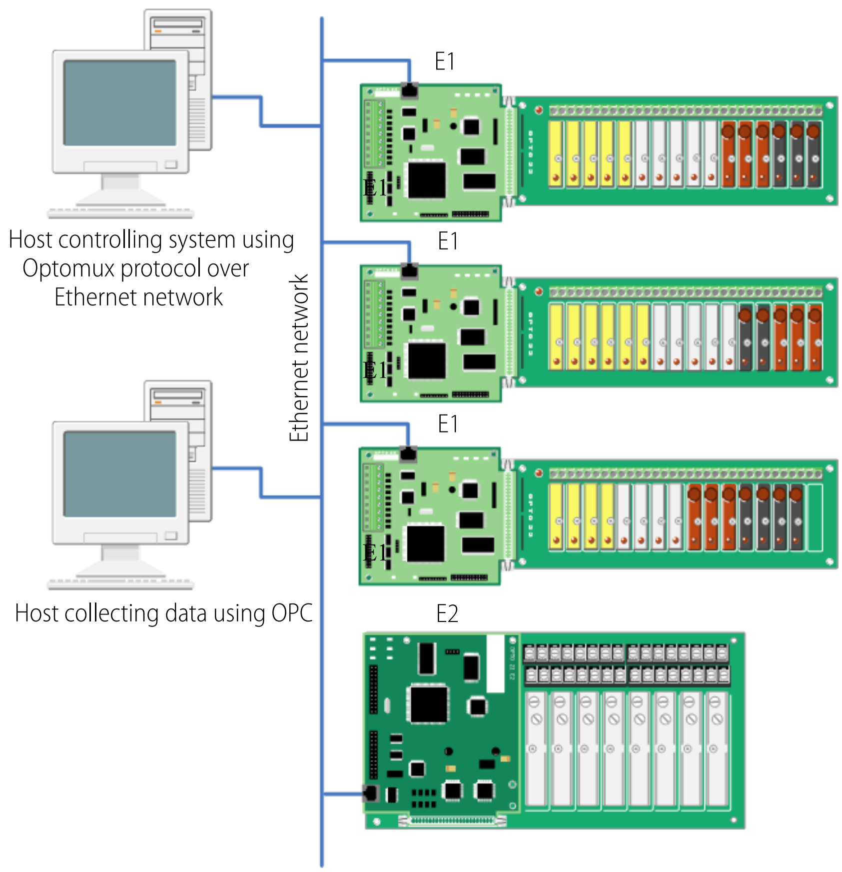
Optomux Over Serial

Since E1 and E2 brain boards also support RS-422/485 serial networks, they can communicate using the Optomux protocol over serial. Programming information for this use is in Opto 22 form #1572, the *Optomux Protocol Guide*.

Control System Plus Data Acquisition via OPC

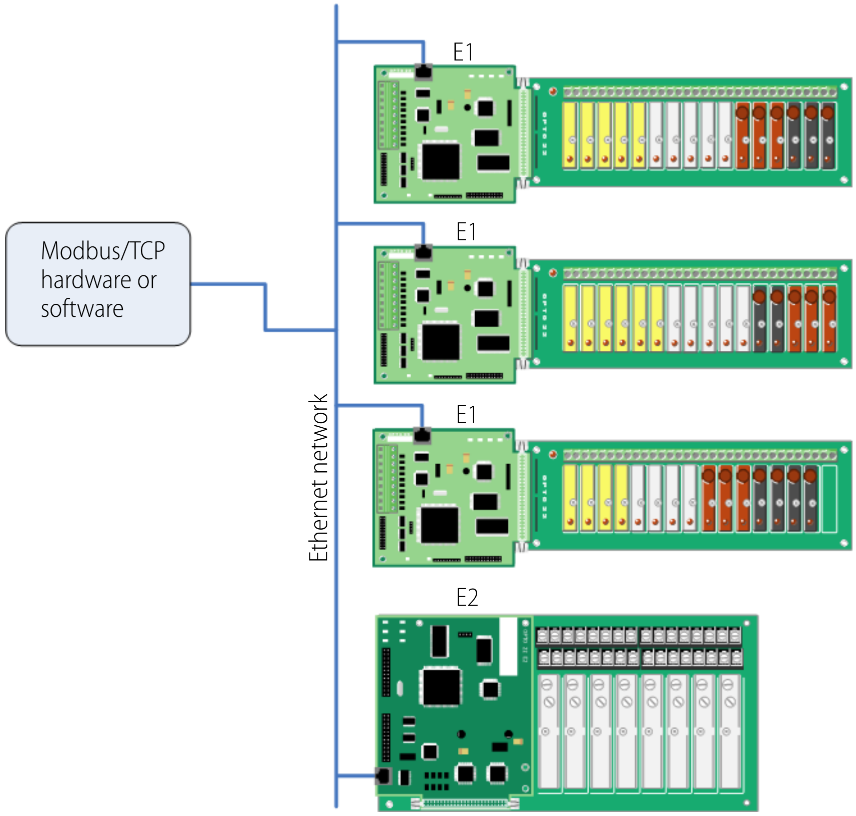
Use OptoOPCServer to provide communication between E1 and E2 brain boards and OPC clients. OptoOPCServer is a fast, efficient OLE for Process Control (OPC) 2.0-compliant server available for purchase through Opto 22's distributors or on Opto 22's website, www.opto22.com. Documentation for the server is included.

A control system that's also serving data to OPC clients might look like this:



Communicating with Modbus/TCP Clients

Complete information to communicate with Modbus/TCP clients is in Chapter 5: Using Modbus/TCP. Here is an example of system architecture:



PAC Project Control System

E1 and E2 brain boards can be used as part of a complete SNAP PAC System, with an Opto 22 SNAP PAC programmable automation controller, SNAP I/O units, and control and HMI applications you have built using the PAC Project Software Suite. The suite comes in two forms: PAC Project Basic™ and PAC Project Professional™.

PAC Project Basic is free from our website, www.opto22.com, and includes:

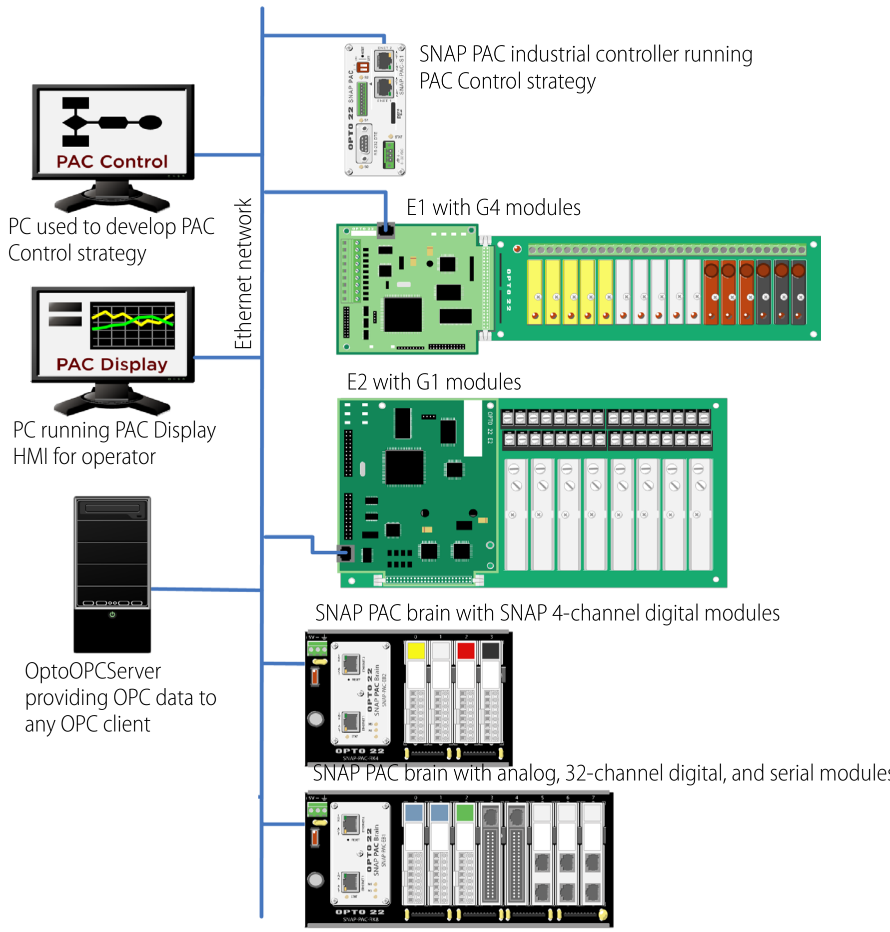
- **PAC Control™,** a flowchart-based programming tool for machine control and process applications. You build the control strategy, download it to a SNAP PAC industrial controller, and it runs independently on the controller.
- **PAC Display™,** an HMI package for building operator interfaces for your Microsoft® Windows®-based clients. PAC Display includes alarming, trending, security, and a built-in library of industrial graphics.
- **PAC Manager™,** a utility application used to assign IP addresses, configure I/O points and I/O unit features, and inspect, read from, or write to I/O units.

PAC Project Professional is available for purchase from our distributors or on Opto 22's website. The Pro version adds:

- **OptoOPCServer™,** a fast, efficient OPC 2.0-compliant server.
- **OptoDataLink™**, for exchanging data with common databases such as Microsoft SQL Server® and MySQL®.
- Support for legacy mistic I/O units, redundant controllers, and complex networks.

Complete documentation is included with the software suite. For E1s and E2s, use the Legacy Editions of all guides; for example, *PAC Control User's Guide, Legacy Edition* (form #1710); *PAC Control Command Reference, Legacy Edition* (form #1711); and *PAC Manager User's Guide, Legacy Edition* (form #1714).

An example of a SNAP PAC System incorporating E1s and E2s is shown below.



Building Custom Applications with the OptoMMP Protocol

If you do not want to use Optomux and are not using an Opto 22 controller, you can communicate with the E1 and E2 over Ethernet using custom applications you have written with OptoMMP, Opto 22's memory-mapped protocol. This protocol is open and documented, one for C++ and one for .NET. Both are available on our website:

- C++ OptoMMP Software Development Kit for *groov* EPIC and SNAP PAC
- .NET OptoMMP Software Development Kit for *groov* EPIC and SNAP PAC

NOTE: Some E1 and E2 features are available only using Optomux. For details, see *"E1 and E2 Features and Specifications" on page 5*.

OptoMMP is the same protocol used with all current Opto 22 Ethernet-based hardware and software. Therefore, custom applications you build using OptoMMP can consolidate E1s and E2s with SNAP Ethernet-based systems, and applications you may have already built for SNAP Ethernet-based systems can be easily expanded to include E1s and E2s.

Documentation for each SDK is included in the kit. Opto 22 form #1465, the *OptoMMP Protocol Guide*, provides complete documentation of the memory map.

MIGRATION OPTIONS

E1 and E2 brain boards provide processing power for I/O just like their predecessors, the B1 and B2 brain boards. Designed as drop-in replacement boards for the B1 and B2, the E1 and E2 have the same Optomux and serial network capabilities, but also add significant features: Ethernet support, additional protocol support, and migration and expansion opportunities.

Since the E1 and E2 were designed to be interchangeable with existing B1s and B2s, you can simply remove an older brain board from the rack and replace it with an E1 or E2. Your Optomux application will run on the E1 or E2 without any software changes.

With its additional capabilities, however, the E1 or E2 is ideal for migrating to newer networks, hardware, and software applications, as it has the flexibility to work with both older and newer networks and protocols.

If you are using E1 or E2 brain boards to migrate from an existing Optomux system using B1 or B2 brain boards, the protocol and network you choose are determined by your goals for the system. The following table shows how to accomplish specific migration goals with the E1 and E2 and refers you to sources for more information.

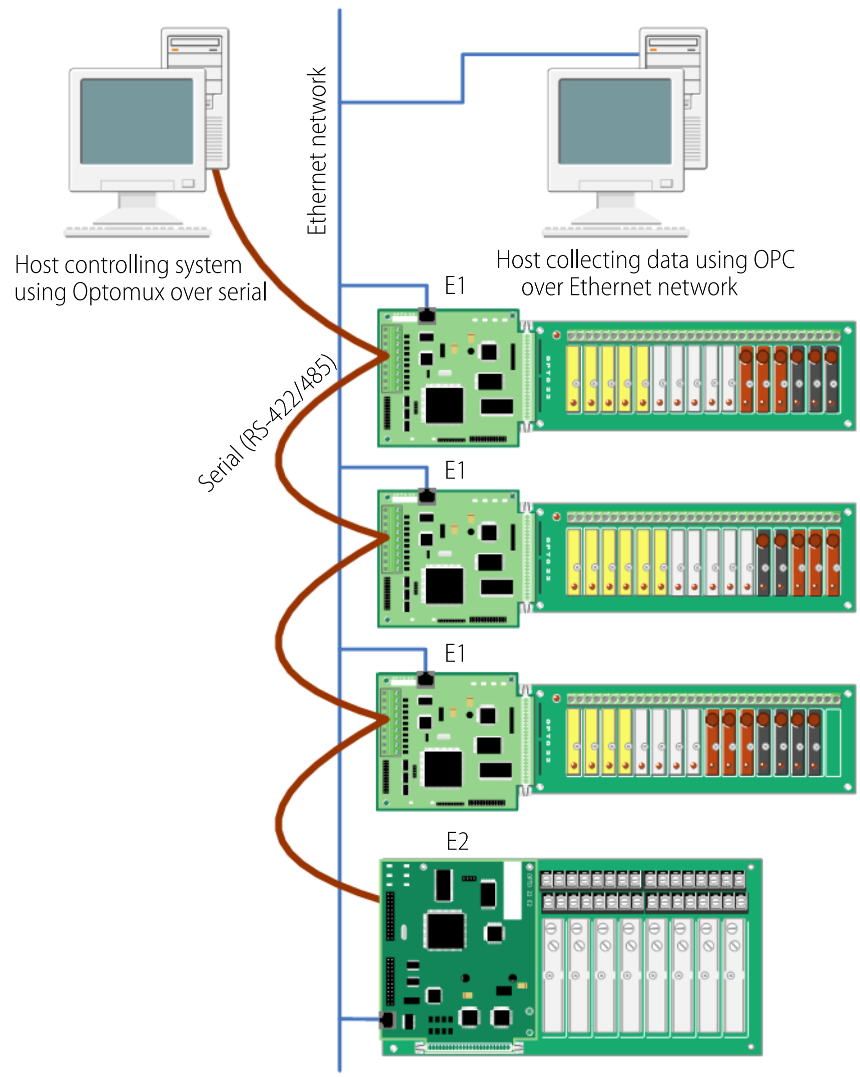
Your goal	Hardware and network changes	Software changes	See
Keep existing software running over serial. Add Ethernet capability so you can acquire data from the system using OPC.	Replace B1s and B2s with E1s and E2s, keeping same racks and I/O. Keep serial network; add Ethernet network and OPC host computer.	Existing software continues to run over serial. Use OptoOPCServer to acquire system data from E1s or E2s over Ethernet.	Architecture: page 33 Programming: *OptoOPCServer User's Guide* (form #1439)
Keep existing software running over serial. Add Ethernet capability so that Modbus/TCP clients can communicate with the system.	Replace B1s and B2s with E1s and E2s, keeping same racks and I/O. Keep serial network; add Ethernet network.	Existing software continues to run over serial. Use Modbus/TCP to communicate with E1s or E2s over Ethernet.	Architecture: page 33 Programming: Chapter 5: Using Modbus/TCP in this guide
Keep existing software running over serial. Add Ethernet capability so you can extend the system beyond serial network physical limitations.	Replace B1s and B2s with E1s and E2s, keeping same racks and I/O. Retire serial network except for first link; add Ethernet network.	Existing software continues to run over serial. Configure first E1 or E2 as a serial-to-Ethernet router.	Architecture and Programming: See "A: Serial-to-Ethernet Routing" on page 61.
Replace serial network with Ethernet network, but continue using Optomux protocol.	Replace B1s and B2s with E1s and E2s, keeping same racks and I/O. Replace network.	Modify or replace current software using the Optomux Protocol Driver.	Architecture: page 27 Programming: *Optomux Protocol Guide*, form #1572
Replace serial network with Ethernet network. Use PAC Project with an Opto 22 industrial controller to control the system.	Replace B1s and B2s with E1s and E2s, keeping same racks and I/O. Replace network. Add SNAP PAC controller. (Optional) Expand system to include SNAP hardware.	Replace current control software with software built using PAC Control™. (Optional) Add an HMI or OPC support using other PAC Project software applications.	Architecture: page 29 Programming: *PAC Control User's Guide* (form #1710) and *Command Reference* (#1711)

Acquiring Data Using OPC

You can use OPC to acquire data from E1 and E2 brain boards without disturbing your existing software. OptoOPCServer can serve data from E1s and E2s over Ethernet separately from the software running over the serial network.

As shown below, simply replace the existing B1s and B2s with E1s and E2s, keeping the same racks and I/O, and link the E1s and E2s to the Ethernet network. Because the new brain boards have a serial port, they work exactly like the old ones over serial, and your existing Optomux software application needs no changes.

Use OptoOPCServer (sold separately) to acquire system data from E1 and E2s over the Ethernet link, and to read and write data to E1 and E2s. See the *OptoOPCServer User's Guide* (form #1439) for more information.

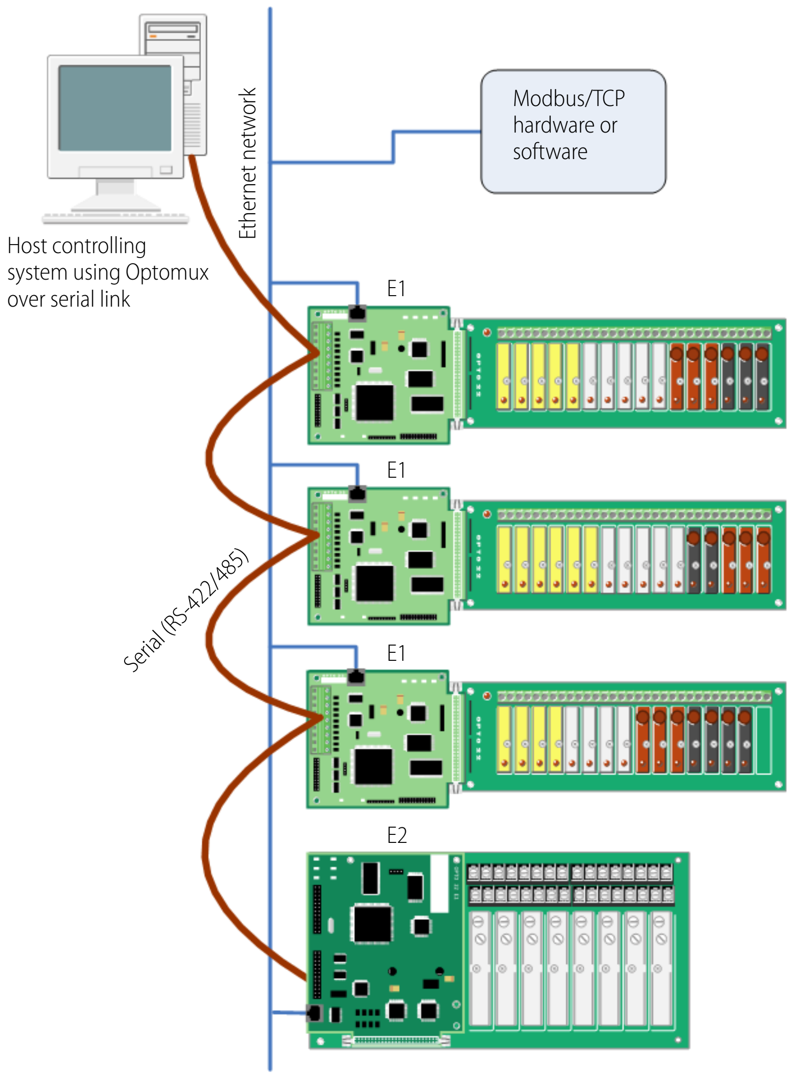


Adding Modbus/TCP Communication

You can communicate with the E1 and E2 using Modbus/TCP over Ethernet without disturbing the existing software running over serial.

Replace the existing B1s and B2s with E1s and E2s as shown below, keeping the same racks and I/O, and attach the new brain boards to the Ethernet network. Because the E1s and E2s have a serial port with the same capabilities as the B1 and B2, your existing Optomux software application does not need to be changed.

Modbus/TCP clients can read and write to E1 and E2s over the Ethernet network. For more information, see Chapter 5: Using Modbus/TCP.



4: Maintaining the E1 and E2

This chapter describes how to maintain E1 and E2 brain boards. It includes the following topics:

ASSIGNING OR VIEWING THE IP ADDRESS

Any E1 or E2 used with PAC Project software (PAC Control, PAC Display, or OptoOPCServer) or applications built with the OptoMMP Communication Toolkit or the Optomux Driver Toolkit must be assigned a static IP address, because you will use the IP address to communicate with the device. For more information about IP addresses and instructions to assign them, see the *Legacy Edition PAC Manager User's Guide,* form #1714.

RESETTING THE BRAIN BOARD TO FACTORY DEFAULTS

If you need to reset an E1 or E2 brain board to factory default settings, you can do so using a jumper. *When you reset the brain board, any files and configuration settings are erased.* If you only need to reset points to their defaults, see the instructions in the PAC *Manager User's Guide*.

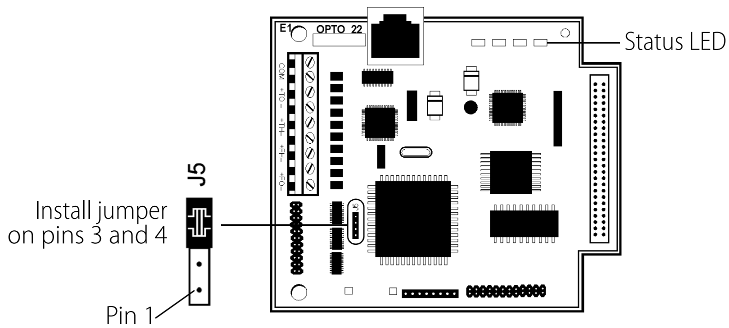
NOTE: Other jumpers on the E1 and E2 (groups A and B) are used to configure the brain board. For information on setting the Group A and Group B jumpers, see "Setting Jumpers (Serial Only)" on page 17. Also see "Jumper Tips" on page 54.

To reset the brain board to factory defaults:

1. Turn off power to the brain board and remove the Ethernet connector.

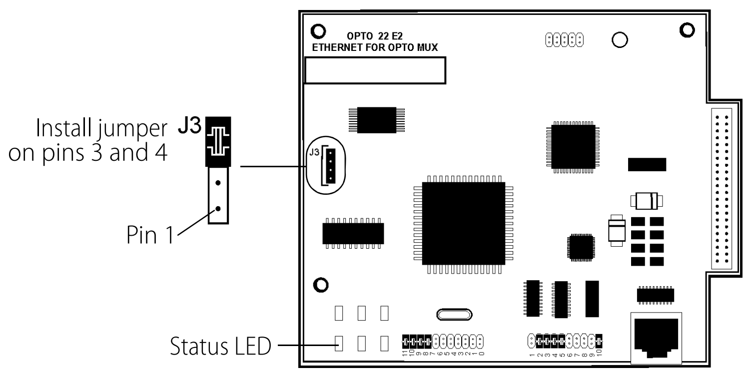
2. Using needle-nosed pliers, install a jumper as follows:

– For the E1 brain board, use pins 3 and 4 on jumper block J5.



E1 Brain Board

– For the E2 brain board, use pins 3 and 4 on jumper block J3.



E2 Brain Board

3. Turn on power to the brain board.

   The Status LED starts blinking. The Status LED is labeled STAT on the board and is shown in the graphic above.

   CAUTION: *Do not turn off power to the brain board while the STAT LED is flashing! Doing so may corrupt the brain board firmware. In most cases, you will need to wait about 5 minutes or less. However, if your brain board has version R1.1e firmware, you may need to wait a very long time, even overnight. Be patient and wait till the STAT LED stops flashing.*

4. Wait until the light stops blinking and is solidly on (in approximately 30 seconds), and then turn off power to the brain board.

   For more information on LEDs and blink codes, see "LED Descriptions" on page 10.

5. Remove the Reset to Factory Defaults jumper, and reconnect the Ethernet cable.

6. Before turning on power to the brain board, follow the steps in form #1714, the *Legacy Edition PAC Manager User's Guide,* to assign a new IP address.

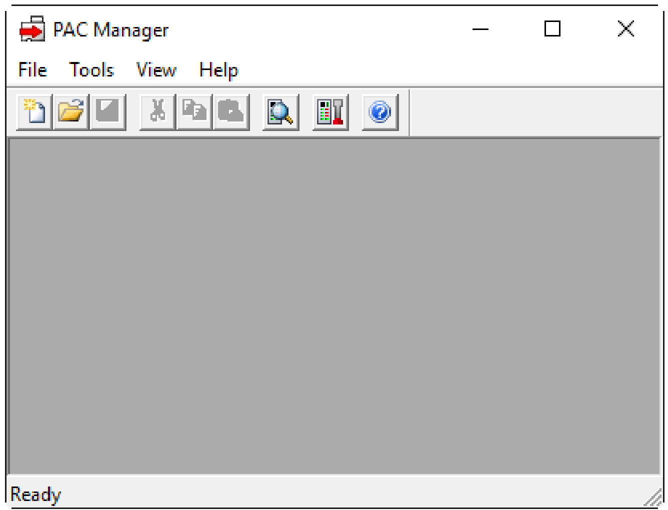
LOADING NEW FIRMWARE

Each E1 and E2 brain board contains firmware (sometimes referred to as the *kernel*), which is similar to an operating system. If the firmware should become damaged, or if a new version of the firmware is released, you can load new firmware to the E1 or E2 device using PAC Manager.

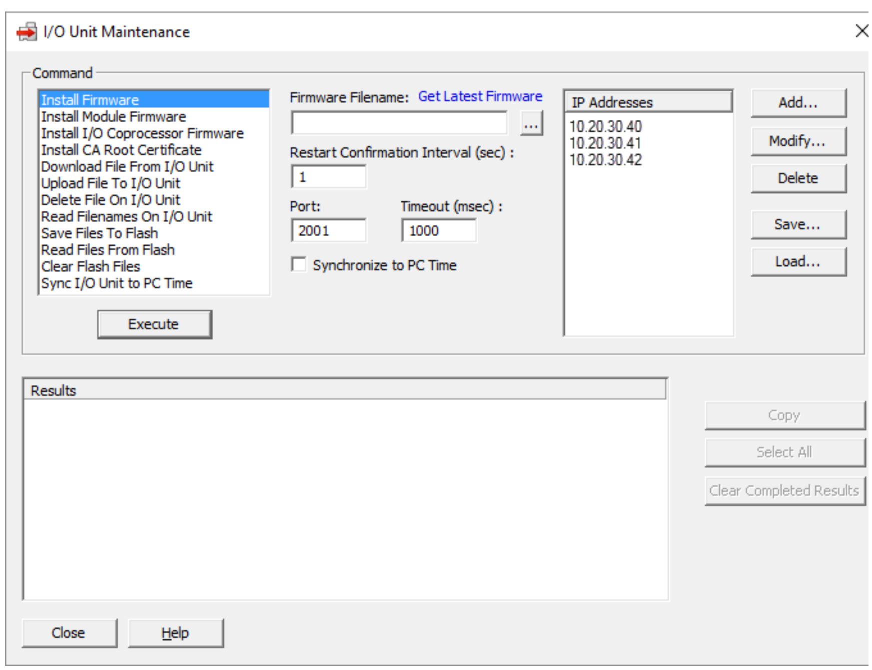
IMPORTANT: *Before you begin, review the E1/E2 Firmware Readme for any changes that may affect which version of firmware to use or which version of PAC Manager software is required to update the firmware.*

1. Before beginning, make sure you have the IP address(es) of the E1s and E2s that will receive the new firmware.
2. Choose Start > Programs > Opto 22 > PAC Project Software > PAC Manager.

   The PAC Manager main window opens:



3. Click the Maintenance icon .



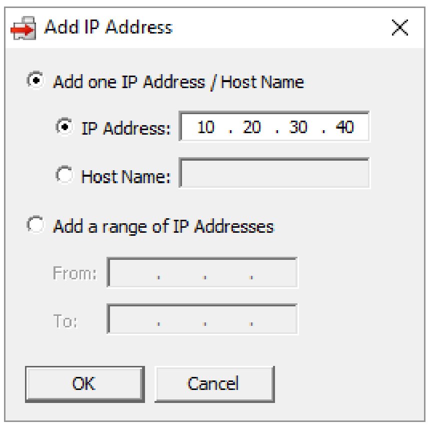
4. If you have files on the E1 or E2 that you want to preserve, download them now.

   For example, if you are using the Optomux routing capabilities and have uploaded the OmuxSettings and OmuxRoutes files to the brain, you may want to copy these files to your computer. For a description of how to do this, see step 3 on page 65.

5. Make sure Install Firmware is highlighted in the Command list.
6. If you do not have the new firmware file, click Get Latest Firmware to go to the Opto 22 website. In the Search Downloads field, type `E1` for E1 firmware or `E2` for E2 firmware. Click the links to download the firmware file and save it to your computer.

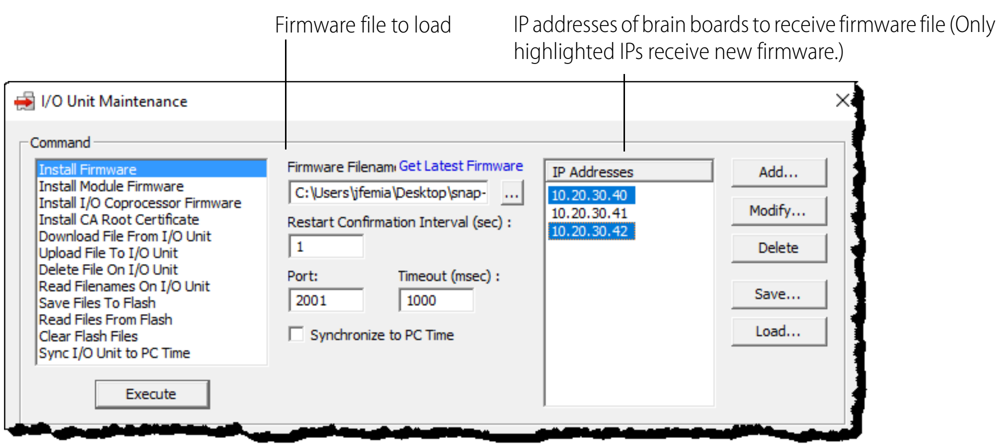
   If you have any difficulty obtaining new firmware, contact Opto 22 Product Support.
7. Click the Browse button **...** . From the drop-down list for Files of Type, select E1/E2 Firmware (*.bin). Locate the firmware file you downloaded from our website, and then double-click the filename.

   The Filename appears in the Filename field.
8. If the IP address(es) of the target E1 and E2 devices appear in the IP Addresses list, skip to step 10. (Or, if you have previously saved a list of IP addresses, click Load to load the saved list.) If the address(es) you need don't appear in the list, click Add.



9. Enter the address or a range of consecutive addresses, and then click OK.

   The address(es) you entered appear in the I/O Unit Maintenance dialog box.
10. In the I/O Unit Maintenance dialog box, highlight the IP addresses to send firmware to.



CAUTION: *If you mistakenly enter the address of some other E1 or E2, you will erase the current firmware in that device, and there is no undo. Make certain you have the correct IP addresses and that you want to download new firmware.*

11. Click the Execute button.

    The file is loaded to the brain boards, and progress is shown in the Results area. When the file is loaded and the brain boards are automatically rebooted, a "Success" message appears.

    CAUTION: *Do not turn off power to the brain board while the STAT LED is flashing! Doing so may corrupt the brain board firmware. In most cases, you will need to wait about 5 minutes or less. However, if your brain board has version R1.1e firmware before the update, you may need to wait a very long time, even overnight. Be patient and wait till the STAT LED stops flashing.*

12. After installing new firmware, reconfigure all of the I/O and reset the calibration settings (offset and gain).

    Also, if you are using the routing capabilities, you need to replace the OmuxSettings and OmuxRoutes files. For a description of how to do this, see Appendix A: Serial-to-Ethernet Routing.

5: Using Modbus/TCP

INTRODUCTION

This chapter includes instructions for using Modbus/TCP to communicate with E1 and E2 brain boards. It includes information on Modbus communication and working with I/O points, and it includes the Modbus memory map for the brain boards.

The following topics are included in this chapter:

This chapter assumes that you already have an understanding of Modbus/TCP programming and communications. Use this chapter in conjunction with the *Open Modbus/TCP Specification* and the *Modicon Modbus Protocol Reference Guide*, both available from Modicon, Inc., Industrial Automation Systems.

OVERVIEW OF MODBUS/TCP COMMUNICATION

Communicating with E1 and E2 brain boards using Modbus/TCP requires four basic steps: connect, configure, read/write, and disconnect. When opening a TCP/IP connection to an E1 or E2 system, you normally use port 502.

Up to eight Modbus masters or clients can be simultaneously handled by E1 and E2 brain boards. When communicating with a master, use a slave address (Unit ID) of 1 or 0 for the brain board.

Understanding Opto 22 and Modbus/TCP Differences

Notice that Opto 22 module position numbers start numbering at 0 (zero), while Modbus coil, input, and register numbers start at 1; so Modbus coil 1, input 1, or register 1 refers to the module in position 0 on the rack. To reduce confusion, use the I/O reference diagrams starting on page 44 when working with Modbus.

Also notice the differences in Opto 22 and Modbus terms:

Modbus Term	Opto 22 Term
Coils	Digital outputs
Inputs	Digital inputs

Modbus Term	Opto 22 Term
Register inputs	Analog inputs
Holding registers	Analog outputs and miscellaneous

Function Codes Supported

E1 and E2 brain boards use the Modbus register number and function code to access the appropriate memory map location on the brain board.

The following table shows supported Modbus function codes:

Modbus Command (Hex)	Definition	Opto 22 Equivalent
01	Read coil status	Read digital output
02	Read input status	Read digital input
03	Read holding registers	Read analog output and miscellaneous
04	Read input registers	Read analog input
05	Force single coil	Turn on/off one digital output
06	Preset single register	Write one analog output or miscellaneous
0F	Force multiple coils	Turn on/off multiple digital outputs
10	Preset multiple registers	Write multiple analog outputs or miscellaneous
11	Report slave ID	Report hardware and firmware revision levels

NOTE: Command 0x11, Report slave ID, returns data bytes as shown in the following table. Bytes 1 and 2 are always in the formats shown. The 0x22 in byte 1 indicates an Opto 22 brain board; 0xFF appears in byte 2 because, since the brain board is a slave, it is always running.

The data in the following table is in hex.

Byte 1	Byte 2	Bytes 3–6				Bytes 7–10				Bytes 11–14			
Slave ID	Run Indicator	Hardware Version				Firmware Version				Loader Version			
		Month	Day	Year		Month	Day	Year		Month	Day	Year	
22	FF	01	01	01	01	01	01	01	01	01	01	01	01

Communication Packet

As the Modbus/TCP specification requires, E1 and E2 brain boards use a Modbus RTU packet inside TCP/IP. The Modbus checksum is not used; instead, the Ethernet TCP/IP link layer checksum guarantees data. The size of the packet is limited to 256 bytes. The packet follows the standard Modbus format and contains the following:

Byte 0	Identifier, copied by responder (usually 0)
Byte 1	Identifier, copied by responder (usually 0)
Byte 2	Protocol identifier = 0
Byte 3	Protocol identifier = 0
Byte 4	Length field (upper byte) = 0, since all messages are smaller than 256
Byte 5	Length field (lower byte) = number of bytes following
Byte 6	Unit identifier (slave address, normally 1)
Byte 7	Modbus function code (See table on page 42.)
Byte 8 and following	Data as needed

NOTE: You can read a maximum of 125 input or holding registers in one command 03 or 04.

Exception Errors

If an error occurs, standard Modbus exception codes are returned in the Modbus packet. See the Modicon documentation for more information.

The following table, reprinted from the *Modicon Modbus Protocol Reference Guide*, shows the Modbus exception codes:

Code	Name	Meaning
01	ILLEGAL FUNCTION	The function code received in the query is not an allowable action for the slave.
02	ILLEGAL DATA ADDRESS	The data address received in the query is not an allowable address for the slave.
03	ILLEGAL DATA VALUE	A value contained in the query data field is not an allowable value for the slave.
04	SLAVE DEVICE FAILURE	An unrecoverable error occurred while the slave was attempting to perform the requested action.
05	ACKNOWLEDGE	The slave has accepted the request and is processing it, but a long duration of time will be required to do so. This response is returned to prevent a timeout error from occurring in the master. The master can next issue a Poll Program Complete message to determine if processing is completed.
06	SLAVE DEVICE BUSY	The slave is engaged in processing a long-duration program command. The master should retransmit the message later when the slave is free.
07	NEGATIVE ACKNOWLEDGE	The slave cannot perform the program function received in the query. This code is returned for an unsuccessful programming request using function code 13 or 14 decimal. The master should request diagnostic or error information from the slave.
08	MEMORY PARITY ERROR	The slave attempted to read extended memory, but detected a parity error in the memory. The master can retry the request, but service may be required on the slave device.

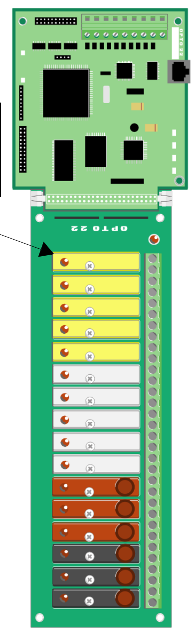
REFERENCING I/O POINTS FOR E1 AND E2 BRAIN BOARDS

E1 brain boards can be used with a variety of digital module families; E2s are used with G1 analog modules only. However, the maximum number of points for either an E1 or an E2 brain board is 16 on the largest rack. When you use Modbus/TCP, point numbers are shown in the following examples. The largest rack is shown in each case.

E1 shown with G4 modules

Points on G1s and integral racks are numbered the same.

Module position on rack	Point numbers
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8
8	9
9	10
10	11
11	12
12	13



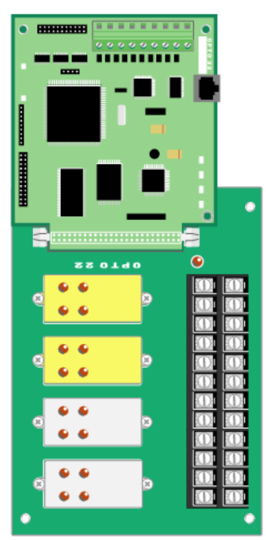
E2 with G1 modules

Module position on rack	Point numbers
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8
8	9
9	10
10	11
11	12
12	13

E1 with Quad Pak modules

Quad Pak modules have four input or four output points.

Module position on rack	Point numbers			
0	1	2	3	4
1	5	6	7	8
2	9	10	11	12
3	13	14	15	16



CONFIGURING I/O POINTS

Before you can read or write to I/O points, you must configure point types and point features.

See instructions in form #1576, *I/O Configuration for E1 and E2 Brain Boards*.

Using Digital Point Features

For explanations of digital point features, see "E1 Brain Board Features" on page 5.

Latches

Latches are a digital point feature available on E1 brain boards. They do not require configuration. Read and clear latches as shown in the following table and the Modbus memory maps beginning on page 46:

To do this	Use these addresses
Read the on-latch state	Read inputs 65–80
Read the off-latch state	Read inputs 129–144
Clear on-latches	Write to coils 129–144
Clear off-latches	Write to coils 193–208

Counters

Using counters involves three steps: configure the counter (holding registers 769-800), activate the counter (coils 65-80), and read data (input registers 385-416). See "Modbus/TCP Memory Map for E1 and E2 Brain Boards" on page 46 to find the addresses mentioned.

<table>
<tr><th>To do this</th><th>Use these addresses</th></tr>
<tr><td>Configure a counter</td><td>Write to holding registers 769–800. Remember that you use two consecutive registers for each point, since the data is in the form of a 32-bit integer but the registers are 16 bits each. For example, to configure point #1 as a counter, you would write 01 to registers 769-770.<table><tr><td>To these registers:</td><td>769</td><td>770</td></tr><tr><td>Write this:</td><td>0</td><td>1</td></tr></table></td></tr>
<tr><td>Activate a counter</td><td>Write to coils 65-80. For example, to activate the counter for point #1, you would write to coil number 65.</td></tr>
<tr><td>Read counter data</td><td>Read input registers 385–416. Read two consecutive registers per point.</td></tr>
<tr><td>Clear a counter</td><td>Write to coils 257–272. For example, to clear the counter on point #1, you would write a 1 to coil 257.</td></tr>
</table>

Using Analog Point Features

For explanations of analog point features, see "E2 Brain Board Features" on page 6.

Analog point features generally require that you read or write two consecutive registers for each point, since the data is in the form of a 32-bit IEEE float. Data is in Big Endian format. You can change the word order if you wish, using Holding Register 1029, which is described in the table on page 48. If you change word order, be sure to store configuration information to flash (Holding Register 1026) so it will be saved when power to the brain board is cycled.

Scaling

You must scale analog points when you configure I/O. For instructions, see form #1576, *I/O Configuration for E1 and E2 Brain Boards*.

Maximum and Minimum Values (Peaks and Valleys)

Minimum and maximum values are analog point features. The brain board automatically keeps track of minimum and maximum values. For example, you can read the values at any time to record minimum and maximum pressures. You can also clear them.

NOTE: The E2 does not maintain minimum and maximum values for temperature.

- To read min/max values, read input registers 129–160 (min) and 257–288 (max). Read two consecutive addresses per point.
- To clear min/max values, write 1 bit to coils 321–336 (min) and 385–400 (max).

Offset and Gain

You can monitor current values for offset and gain using holding registers 129–160 and 257–288. To perform calibration on analog points, use PAC Manager. See form #1714, *Legacy Edition PAC Manager User's Guide*.

MODBUS/TCP MEMORY MAP FOR E1 AND E2 BRAIN BOARDS

Coils

For digital I/O counter activation and clearing of latches, and analog minimum/maximum values: Each address contains the data for one point. Data is either 0 or 1.

Coil Numbers	E1	E2	Action	Notes
1–16 (available) 17–64 (unavailable)	●		Read or Write Digital Outputs	1 = On, 0 = Off
65–80 (available) 81–128 (unavailable)	●		Activate Counters (digital modules)	1 = On, 0 = Off. Configure as a point feature first. See "Counters" on page 45.
129–144 (available) 144–192 (unavailable)	●		Clear On-latch (digital modules)	1 = clear latches; 0 = do nothing
193–208 (available) 208–256 (unavailable)	●		Clear Off-latch (digital modules)	1 = clear latches; 0 = do nothing
257–272 (available) 272–320 (unavailable)	●		Clear Counters (digital modules)	1 = clear counters; 0 = do nothing
321–336 (available) 336–384 (unavailable)		●	Clear Analog Minimum Values	1 = clear minimum values; 0 = do nothing
385–400 (available) 400–448 (unavailable)		●	Clear Analog Maximum Values	1 = clear maximum values; 0 = do nothing

Inputs

Digital inputs, latch states, and counter states: Each address contains the data for one point. Data is either 0 or 1. Digital inputs are available only on an E1.

Input Numbers	E1	E2	Action	Notes
1–16 (available) 17–64 (unavailable)	●		Read Digital Inputs	1 = On, 0 = Off
65–80 (available) 81–128 (unavailable)	●		Read State of On-latches (digital modules)	1 = On, 0 = Off
129–144 (available) 145–192 (unavailable)	●		Read State of Off-latches (digital modules)	1 = On, 0 = Off
193–208 (available) 209–256 (unavailable)	●		Read Counter Active State (digital modules)	1 = Active, 0 = Inactive

Input Registers

Analog input values and digital counter values. Register data is in the form of 32-bit floats or 32-bit integers. Because Modbus registers contain only 16 bits, you must use two consecutive registers to read the data for one point, starting with an odd-numbered register. See the example on page 48.

Register Numbers	E1	E2	Action	Notes
1–32 (available) 33–128 (unavailable)		●	Read Analog Values	IEEE 32-bit float
129–160 (available) 161–256 (unavailable)		●	Read Analog Minimum Values (Inputs only)	IEEE 32-bit float
257–288 (available) 289–384 (unavailable)		●	Read Analog Maximum Values (Inputs only)	IEEE 32-bit float
385–416 (available) 417–512 (unavailable)	●		Read Digital Counter Data (digital modules)	32-bit integer

You can read a maximum of 125 registers in one command.

Holding Registers

Analog output values, point and feature configuration, and miscellaneous. Most of this data is also in the form of 32-bit integers or 32-bit floats. For these formats, you must use two consecutive registers to read or write the data for one point, starting with an odd-numbered register. See the example on page 48.

Holding Register Numbers	E1	E2	Action	Notes
1–32 (available) 33–128 (unavailable)		●	Read or Write Analog Outputs (Engineering Units)	IEEE 32-bit float
129–160 (available) 161–256 (unavailable)		●	Analog Offset	IEEE 32-bit float
257–288 (available) 289–384 (unavailable)		●	Analog Gain	IEEE 32-bit float
385–416 (available) 417–512 (unavailable)		●	Set Point Low Scale Value	IEEE 32-bit float
513–544 (available) 545–640 (unavailable)		●	Set Point High Scale Value	IEEE 32-bit float
641–672 (available) 673–768 (unavailable)	●	●	Configure Points	32-bit integer (For information on configuring points, see form #1576, *I/O Configuration for E1 and E2 Brain Boards*.)

Holding Register Numbers	E1	E2	Action	Notes
769–800 (available) 801–896 (unavailable)	●		Configure counters on digital input modules	32-bit integer (See page 45 for information on using counters.)
897–1024			Reserved	Reserved
1025		●	Set Degrees in F or C	16-bit integer. 1 sets degrees in F; 0 sets degrees in C.
1026	●	●	Store Configuration to Flash	16-bit integer. Any non-zero value stores configuration to flash, so it is restored when the brain board is turned on. 0 = no action. Stores the contents of Status Write, Point Config, and IP Security Config. Also stores IP information, including IP address, subnet mask, gateway address, and DNS address.
1027	●	●	Reset Points to Default	16-bit integer. Any non-zero value resets the brain board to defaults as follows: • Clears offsets and gains, counters, latches, and min/max data. • Turns off digital outputs. • Sets analog outputs to zero scale (0 counts). • (1027 is equivalent to 1028 followed by 1030. See 1030 below.)
1028	●	●	Erase Configuration in Flash	16-bit integer. Any non-zero value clears flash.
1029	●	●	Set 32-bit Float Format	16-bit integer. 0 = Big Endian; 1 = Word-swapped Big Endian.
1030	●	●	Hardware Reset	Using Modbus Command 06 (Preset Single Register), write any non-zero value to reset hardware, which is just like cycling power to the brain board. If point configuration information has not been stored to flash or flash has been cleared (1028), points are reset to defaults. Reading always returns 0.

You can read a maximum of 125 registers in one command.

Using Input and Holding Registers

An example may help clarify how to use input and holding registers. Holding registers 1–31 are used to read or write analog values for 16 possible points. The first point is located in the first two registers, 1 (the low register) and 2 (the high register).

To figure out the Modbus register numbers for a specific analog point, use the following formula:

Modbus low register number = (analog point number * 2) –1

Remember that modules on the rack start with position 0, but that I/O points for Modbus start with point 1. For example, to read point #1 (position 0) and point #9 (position 8):

For point #1:

(1 x 2) –1	=	1 for low register
	=	2 for high register

For point #9:

(9 x 2) –1	=	17 for low register
	=	18 for high register

Since the first register is odd-numbered, a read should always begin with an odd-numbered register. You can read a maximum of 125 registers in one command.

6: Troubleshooting

If you are having difficulty using an E1 or E2 brain board, here are some suggestions that might help. If you cannot find the answers you need in this book, contact Opto 22 Product Support. Contact information is on page 4.

This chapter includes the following topics:

TROUBLESHOOTING ETHERNET COMMUNICATIONS

If you attempt to connect to the brain board using its IP address and you cannot, first check the following:

- Make sure the brain board has been turned on and the Status LED is on. (See "LED Descriptions" on page 10.)
- Make sure the brain board is firmly attached to the rack.
- Verify that you typed in the correct address for the brain board. Check the small white area next to the Ethernet port on the brain board, where the IP address should be written.
- Make sure the brain board has been assigned a valid IP address and subnet mask. E1 and E2 brain boards come from the factory with a default IP address of 0.0.0.0, which is invalid. The default subnet mask is 255.255.255.0. To assign the IP address and subnet mask, see form #1714, the *Legacy Edition PAC Manager User's Guide*.
- If you are communicating only on an Ethernet network (no serial connections), make sure that only jumpers A1-A4 and A10 are installed on the brain. If any other jumper configuration is used, the RS-485 communication lines may cause interference. See page 21 for more information.
- Make sure you have up-to-date drivers installed on your computer's Network Interface Card (NIC). Contact your system administrator or the manufacturer of the card for help.
- Make sure you have Administrator privileges on your computer and that any firewall in the computer (such as the built-in firewall in Windows XP) is temporarily disabled before you try to assign or change IP addresses, load firmware using PAC Manager's Maintenance window, or FTP files to the brain board. DHCP and FTP cannot function through a firewall in the PC. Firewalls in a router are less likely to be a problem unless certain ports (such as FTP client) have been blocked, either by default or on purpose.

Pinging the Brain Board

If you still cannot communicate with the brain board after you have checked these items, try to reach it using the PING protocol.

1. Open an MS-DOS command prompt window.
2. At the prompt, type: `ping [brain board's IP address]`

   For example, type: `ping 10.192.54.40`

If the brain board responds, go to "Accessing the Brain Board with PAC Manager" on page 52.

If the PING command cannot be found, choose Start > Control Panel > Network. Make sure TCP/IP is configured as a protocol and that an IP address and subnet mask are assigned.

If you see the message "Destination host route not defined," the brain board probably has an inappropriate IP address and subnet mask. Make sure the IP address and subnet mask on the brain board are compatible with those on the computer. Follow the directions beginning on page 35 to check the IP address and subnet mask on the brain board, and change them if necessary.

If you see the message "No response from host," check the following:

- Are the computer and brain board correctly connected? Is the brain board turned on?
- Are the IP address and subnet mask on the brain board compatible with those on the computer?
- Is the brain board in reset mode? (Check for a blinking STAT LED. STAT LED blink codes are shown on page 10.)

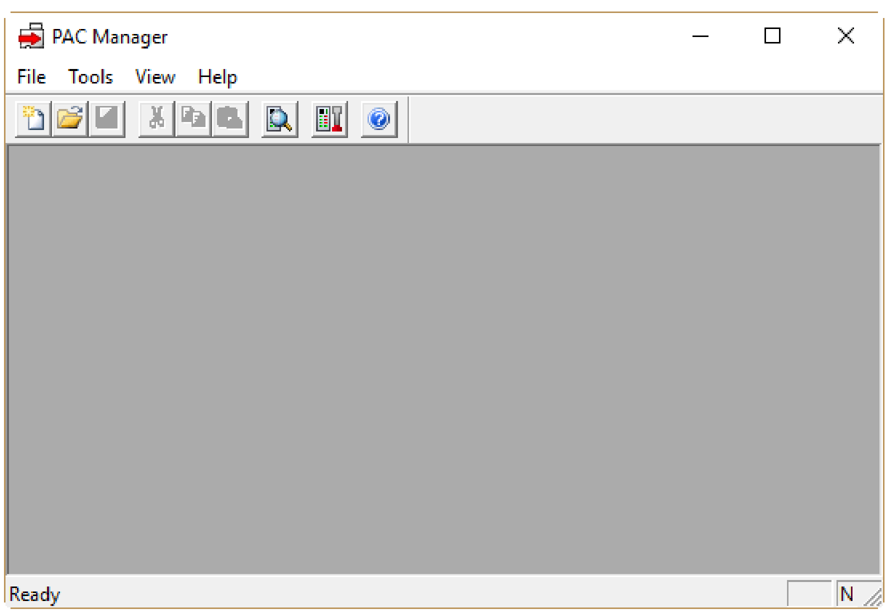
If you still cannot ping the brain board, contact Opto 22 Product Support. (See page 4.)

Accessing the Brain Board with PAC Manager

Once you know you can ping the brain board, try to access it using PAC Manager. You will need to know the brain board's IP address.

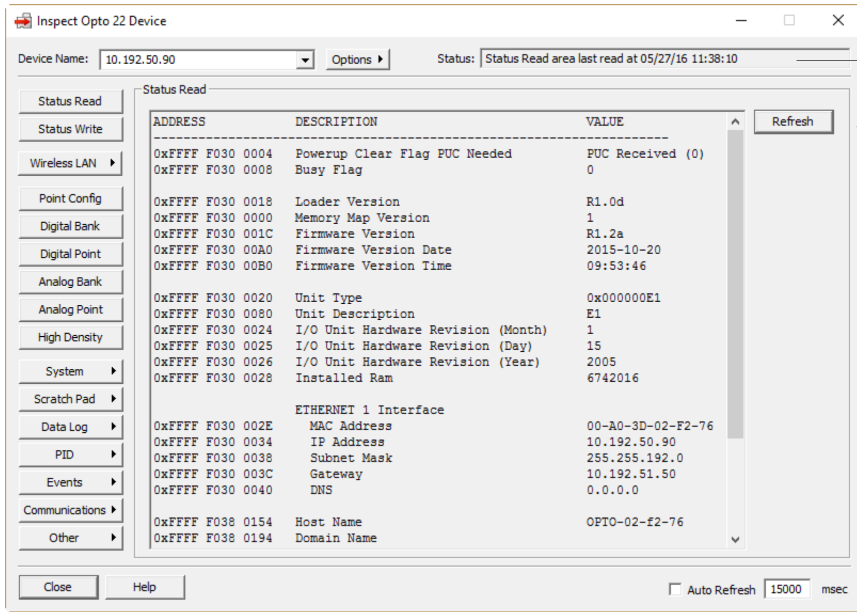
1. If PAC Manager is not already open, choose Start > Programs > Opto 22 > PAC Manager.

   The PAC Manager main window opens:



2. In the PAC Manager main window, click the Inspect button .

3. In the IP Address field, type the IP address of the brain board (or choose it from the drop-down list).
4. Click Status Read.
   Information from the brain board is displayed in the window:



Date and time data was last read

Click to update data

If information does not appear and an error is indicated in the Status field, contact Product Support. (See page 4.)

Solving Network Problems

If problems in communicating with the E1 and E2 recur, check your network. The wires, switches, and so on in your Ethernet network are not part of the Opto 22 hardware, but any problems in your network may affect communication with Opto 22 products.

Create a Network Diagram

First, create a network diagram and verify the following:

- Cable connectors are firmly inserted.
- The switch has power. Switch LEDs indicate that the connection is up.
- Neither the PC nor the I/O unit uses the switch's uplink port.
- The brain board's Link LED is lit.

Analyze Communication Packets

If it appears that you have network problems, you can use a network sniffer utility, such as Wireshark (http://www.wireshark.org/) to log and analyze network communication packets.

Have Your Network Certified

If you suspect network problems, you may need to have your network professionally certified. Opto 22 does not offer network validation or certification services, but many network hardware manufacturers do. Contact the manufacturer of your Ethernet network hardware to have them diagnose, fix, and certify your network.

If you continue to have problems communicating with the E1 and E2after your network is certified, contact Opto 22 Product Support. (See page 4.)

TROUBLESHOOTING SERIAL COMMUNICATIONS

Solving Common Communications Errors

Use this section to diagnose the most common causes of communication problems:

- 5 VDC power adjusted too low at brain boards
- Incorrect jumper settings
- Wiring problems

For error codes that might appear when using Optomux, see page 56.

Power Tips

1. Ensure that the 5 VDC power supply wiring *connections* are secure.
2. Ensure that the *voltage* is 5.1-5.2 VDC as measured on the brain board. Check voltage at all the Optomux brain boards by measuring across a capacitor on the brain board itself, not across the power supply terminals. For more information, see form #1271, *Using Power Supplies*.
3. Ensure that the power supply has no ripple. If possible, inspect the power supply voltage with an oscilloscope, instead of using only a multimeter. Multimeters sometimes do not catch fast AC signals and transients.
4. Make certain that the power supplies are *floating*; that is, do *not* connect the power supply common (5 VDC return) to chassis/earth ground.
5. Make sure that the 5 VDC power supply common is *not* connected to the +/- 15 VDC common terminal on analog mounting racks; this can cause unstable analog readings.

Jumper Tips

For an easy way to see which jumpers to set, go to our website and use the E1/B1 Brain Jumper Configurator or the E2/B2 Brain Jumper Configurator.

If you need to know how a brain board is currently configured, use these interactive demos: Read E1/B1 Jumper Settings or Read E2/B2 Jumper Settings.

1. Make sure the jumpers are intact. The red jumpers provided with Optomux brain boards consist of a metal jumper on the inside covered by red plastic. Sometimes the metal portion of the jumper separates from the red plastic piece, causing incorrect jumper settings even though the jumpers seem to look correct.

   For example, if a jumper is removed but the internal metal pieces stay attached to the brain board, the jumper will look like it is removed, but the brain will detect that it is installed.

   On the other hand, the jumper can appear to be installed when it is not. This happens when the red plastic part is installed but is missing the metal internal piece. In this case, the brain board will detect that the jumper is removed.
2. Make certain that the addresses are set correctly. No two brain boards on the same network can have the same address. If two or more brains on the same network have the same address, they will respond at the same time, causing a garbled response received at the host.
3. Make certain that the baud rates are set correctly. The host device and all brain boards must be operating at the same baud rate. A brain board set for the wrong baud rate will not respond.
4. Make certain the last Optomux brain board on the communications link has the correct termination jumpers installed (jumpers A0 and A6 for brains set up in multi-drop mode).

5. Make sure the host RS-422/485 device is configured to provide the correct termination and biasing.
   - The host receive pair (FO) must provide both termination and biasing, because this part of the link is RS-485.
   - The host transmit pair (TO) must provide for termination and possibly biasing, depending on the interface device. Check the following to make sure it is set up correctly:
     - The RS-422 transmit pair must provide end-of-line termination resistor.
     - If the transmitter is actually an RS-485 transmitter, then biasing resistors are also necessary.

   NOTE: An RS-485 transmitter will be disabled (tri-stated) when not transmitting, so the transmit pair will "float" and might allow fluctuations to be interpreted as data or errors. However, an RS-422 transmitter will remain enabled in either high or low state when not actively transmitting data, so it is not possible for fluctuations, and thus, biasing is not needed.

   NOTE: Some non-Opto 22 RS-422/485 interface products do not provide an option for termination and/or biasing. If the interface product does not provide the necessary options, then it will have to be replaced with one that does. Termination resistors can be applied externally, but biasing resistors typically cannot.

Communication Wiring Tips

1. Make sure to use a shielded, twisted-pair RS-422/485 communication cable with at least three twisted pairs as detailed below. If you use a cable with four twisted pairs, you will have one extra pair.
   - Two pairs for data (a transmit pair and a receive pair), and
   - One pair to use for the signal common
     - The signal common requires only one insulated conductor, but it is hard to find a cable with two pairs plus an extra insulated wire that is separate from the shield drain wire.
     - For the signal common, you can use both wires from the pair tied together or just one of the wires.
2. Ensure that the signal common is connected from one brain board to the next and also to the host RS-422/485 device. This must be done with an insulated wire, which is typically one wire in the overall communication cable.
3. Make sure that the COM terminal (signal common) on the brain boards is *not* connected to chassis/earth ground.
4. Ensure that the overall cable shield drain wire is connected to chassis/earth ground at one location only. Do *not* connect the shield drain wire to the COM (signal common) terminal on any brain board.
5. Make sure the communications cable is daisy-chained from brain to brain; no "Ts" are allowed under the RS-422/485 specification.
6. Make sure the communications pairs are not crossed. In some types of cable, one wire from each pair is the same color. This makes it very easy to get those wires mixed up. If you strip back the jacket and shield far enough, it will become clear which wire belongs to which pair.
7. Check the polarity of the + and – communication wires throughout each twisted pair. If you have one or more receive LEDs stuck on, this may be the cause. Incorrect biasing might also cause this.
8. Power down each brain board in the link, and check the resistance of each twisted pair. One basic check of the communication wiring in a multidrop system is to measure the resistance across the + and – lines of each twisted pair. There should be a 220 ohm resistor across the + and – wires of each data pair (transmit and receive) at each end of the cable. If both ends are terminated properly, you should see about 110 ohms, because there should be termination (220 ohms) at both ends. Make certain that in a multidrop system, only the last physical brain board on the communication link has jumpers A0 and A6 installed.
9. If using an RS-232 to RS-422/485 converter at the host end of the system, make sure that CTS handshaking is disabled on the host. Otherwise, jumper RTS to CTS at the host end. If RTS/CTS handshaking is enabled (and not jumpered), the host will not transmit; no data will be allowed to go out the computer's RS-232 com port.

Other Tips:

1. **Diagnostic/Test Utilities**: Test the system using one of the Optomux utilities, such as OptoScan, which can trap errors. Often, the errors received can help determine the nature of the problem. If OptoScan works properly and there are no errors, the cause of the problem might be the host software.
2. **Baud Rate**: Try running the system at a lower baud rate. Lower baud rates are more forgiving in a noisy environment.
3. **LED Indicators**: If you see receive LEDs blinking on the brain boards, but not transmit LEDs, the cause of the problem could be incorrect address or baud rate settings on one or more brain boards. It can also be caused by wiring problems, low voltage, or noisy power.
4. **Computer Issues**: If you are using an ISA bus RS-422/485 card in the host computer, make sure that there are no I/O port or IRQ conflicts.
5. **Loopback test**: If the host device is a PC, it is possible to verify the operation of the RS-422/485 port by jumping TX+ to RX+, and TX- to RX- (these are TO and FO on Opto 22 brain boards) at the computer. A communication program such as Windows Terminal or Hyperterminal can be used to test the communications with the port.

   Make sure the terminal test utility is set up with flow control set to None and that the local echo is turned off. Once started, anything typed on the keyboard should be displayed on the screen. If this does *not* happen, there may be a hardware or configuration problem with the communication port. Also remember that Opto 22 ISA bus serial adapter cards do not use standard Windows COM port settings (I/O port base address and IRQ) for COM3 and COM4. Make sure that the host software is using the correct I/O port base address and IRQ.
6. Call Opto 22 Product Support. Contact information is on page 4.

Error Codes When Using Opto 22 Optomux Driver

This is a list of the most common driver error codes relating to problems with the RS-422/485 network or brain boards. For a complete list, see form #1572, the *Optomux Protocol Guide*.

Errors Returned by the Brain Board

The following error conditions are caught by (generated by) the brain board.

–1 Power Up Clear Expected.

Command Ignored. A command other than "A" (Power-Up Clear) was attempted after power-up or power failure. Once the error is received, it is not necessary to execute a Power-Up Clear command. The next command will be executed normally. **IMPORTANT:** If this error message is received, it means that the Optomux unit has gone through its power-up sequence and has reset all characteristics to defaults. The unit needs to be reinitialized.

The brain contains a voltage watchdog circuit. If the 5 VDC logic supply voltage falls below the reset voltage, the brain will automatically reset. Use a high-quality DVM (Digital Volt Memory) or a high-precision oscilloscope to examine the brain's supply voltage. Power supply selection or design, poor power distribution techniques, or loose power wiring may cause spurious power-up-clear alerts. For more information, see form #1271, *Using Power Supplies*.

–3 Checksum Error.

This error indicates that the checksum received by the brain board did not match the checksum calculated by the brain board. The command message was corrupted while being transferred over the wire. Data corruption can occur due to improper wiring, termination, and/or radio frequency or electromagnetic noise.

–5 The brain received a non-printable ASCII character.
Only characters from 21 Hex to 7F Hex are permitted within Optomux messages. This error is most likely caused by some kind of data corruption. The command is ignored. Data corruptions may occur due to improper wiring, termination, and/or spurious radio frequency or electromagnetic noise.

Driver Errors

These are error conditions caught by (generated by) the driver.

–29 Turnaround Time Out.
The brain board did not respond within the specified time interval or did not respond at all. Timeouts occur if the timeout interval is too short or the brain board is not available. Possible causes of a brain board not being available include power/voltage problems, the brain board's jumper settings being incorrect (address, baud rate, 2/4 pass mode, termination, etc.), or there is a problem with the communication wiring.

–31 Checksum Error.
The checksum of the message received by the Optomux driver does not match the checksum calculated by the driver. Data corruption can occur due to improper wiring, termination, and/or radio frequency or electromagnetic noise.

–33 Send Error.
This error indicates that the Optomux driver cannot send the message. The most likely cause is a problem with the serial port being in use by another application.

–34 Incorrect Command Echo In Four-Pass.
The command echo does not match the command sent. The addressed brain board is probably in the two-pass mode. This error can occur only when the driver is configured for 4-pass mode. 4-pass mode was originally intended for diagnostic purposes, but it is generally not used even for that purpose. It is best to always use 2-pass mode.

Other Error Codes

These are error codes returned from brain when not using Opto 22 driver:

00 Powerup Clear Expected - Command Ignored . See "–1 Power Up Clear Expected" on page 56.

02 Checksum Error. See "–3 Checksum Error" on page 56.

GENERAL TROUBLESHOOTING

I send a command to activate several outputs. The brain board responds with no error, but none of my outputs comes on.

If an output point does *not* turn on, check the following:

- Make sure you configured the output points correctly. On power-up, the unit defaults to all points configured as inputs.
- If power went out and came back on, the unit will have lost its configuration.
- Make sure you are using output modules with a 5 VDC logic voltage (OAC5, ODC5, etc.). Sometimes modules with a 15 VDC or 24 VDC logic voltage (ODC15, OAC24, etc.) are used by mistake. The LED may turn on or be dim with the 15 VDC and 24 VDC modules, but there will be no output on the field side.
- If the output LED is on, but the load does not turn on, check the field voltage, wiring, and fuse. This could result in a field device *not* turning on.

I send a command to turn on output point 5 of a digital brain board and output point 4 goes on.

Points are numbered from 0 to 15; therefore the fifth bit in the bitmask is for point 4. Following are the bitmask values for each point, in hex:

Point	Bitmask (Hex)	Point	Bitmask (Hex)
0	0001	8	0100
1	0002	9	0200
2	0004	10	0400
3	0008	11	0800
4	0010	12	1000
5	0020	13	2000
6	0040	14	4000
7	0080	15	8000

I'm using OptoMMP, and the counts returned are very different from what I expect.

Check the configuration on your E2. The OptoMMP protocol returns counts differently, based on how the E2 was configured. (See "E2 Brain Board Features" on page 6.)

- Modules configured directly as G1 modules (new method; requires E2 firmware R1.2a or higher and PAC Project 9.5 or higher) will report counts as G1 counts (0–4095 nominal range).
- Modules configured as similar SNAP modules (old method using form 1576) will report counts as 0–25000 or -25000 to +25000.

When I read point 3 on an E2 Optomux unit via the Optomux protocol, I receive 0000 hex, which converts to a decimal -4096 value when I subtract the 1000 hex offset.

A -4096 decimal reading may indicate one of the following:

- You are reading a point where no input module is installed.
- You are reading a point on a thermocouple module that has no thermocouple installed, or the thermocouple probe is open.
- An ICTD module has the ICTD wired in reverse.
- A 4–20 mA module is wired with reverse polarity.
- The field connections are made to the wrong terminals. Field connections vary with each module. Refer to the module data sheet for information on wiring each module. In general, field connections made to the terminals on the rack are made to the terminals labeled UPPER (closest to module), and if the module has terminals on the top of the module, connections would be made there. Analog racks have the module positions labeled from 1 to 16. These points correspond to module positions 0 to 15, respectively.
- If all inputs on that brain board have the same -4096 reading, then check to make sure the unit has +15 and -15 VDC at the corresponding terminals (with reference to the terminal that is marked COMMON).

Does Opto 22 have any troubleshooting software for the Optomux system?

Yes. Opto 22 has the OptoScan (oswin32.exe) and OmuxUser (omuxuser.exe) utilities that can be used to troubleshoot an Optomux system attached to a PC. These are Visual Basic 6 applications and are included with the Optomux Protocol Drivers and Utilities download. Source code is included as an example of Opto 22's Optomux driver DLLs. These applications include the ability to manually configure and poll a digital or analog brain board. The toolkit is available on Opto 22's website, www.opto22.com. For MS-DOS and Windows for Workgroup (WFWG) versions of OptoScan, contact Opto 22 Product Support.

Serial Communications Questions and Answers

I send a command message to a brain board, and I get no response. However, the unit's LED flashes.

The receive LEDs on all the brain boards wired in a multidrop mode should blink whenever a command is sent from the host. Only the unit at the address that matches the command message address should respond. When a brain board responds, the XMT (transmit) LED blinks. At high baud rates, and for messages with only a short response, the blink will be so brief that it may be missed visually.

If the host receives no response, and no blink of the XMT light is visible (even at slower baud rates), then check the following:

- Make sure the address in the command message matches the unit's address. Check the jumpers. A common mistake is a reversal of jumpers. All address jumpers (B0 through B7) installed corresponds to address 0, and all address jumpers (B0 through B7) removed corresponds to address 255. See "Setting Jumpers (Serial Only)" on page 17.
- Make sure the baud rate is correct between the host and the unit. All brain boards on the same link should be configured to the same baud rate.
- Make sure you have a solid 5.1–5.2 VDC (as measured on the brain) powering the brain board. If the voltage is too low, the RCV light may flash, but the unit will not be able to respond. Measure the voltage across one of the yellow capacitors on the brain board. See form #1271, *Using Power Supplies*.
- Check to make sure the communications link is wired with the correct polarity and that jumper group A is configured correctly.

I receive a large number of checksum errors when I send commands to Optomux brains.

Make sure that you are using twisted pair cable. See the cables recommended on page 22. The RS-422/485 network is reliable only when the communications cable is twisted pair (+ and – lines of EACH pair twisted together). If there are two or more wires in the cable with the same color (such as a red/black pair, a white/black pair), sometimes the same-colored wires may be associated with the wrong mates. To make sure the wiring is correct, strip the jacket back far enough to properly identify the individual pairs.

Also check the Group A jumpers to make sure the termination jumpers are configured correctly.

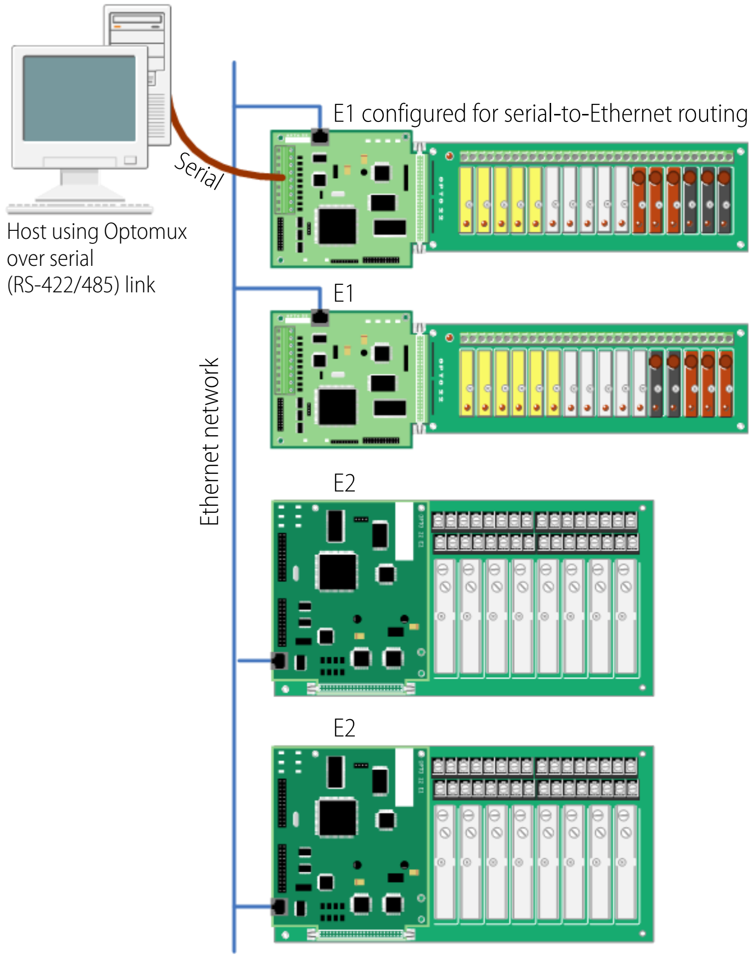
A: Serial-to-Ethernet Routing

If you need to keep existing serial-based host Optomux software, you can extend your system beyond the physical limitations of an RS-422/485 link by using an E1 or E2 to route control coming through a serial network to remote locations over Ethernet.

To do so, replace existing B1s and B2s with E1s and E2s, keeping the same racks and I/O. Keep the serial link from the host to the first E1's or E2's serial port, and put all the E1s and E2s on an Ethernet network. With an Ethernet network, the I/O units can be literally anywhere in the world.

This scenario is shown in the diagram on the following page.

Your existing Optomux application continues to run over serial without needing any changes; the first E1 or E2 translates communications between the host and all other I/O units. You can acquire data over Ethernet via OPC or Modbus/TCP at the same time.



This figure shows an E1 used as a serial-to-Ethernet router.

The host communicates to the first E1 or E2 over serial, using Optomux. The first brain routes communication to other E1 and E2 I/O units on the Ethernet network.

In this scenario, existing software running on the host does not have to be changed.

Serial-to-Ethernet Routing uses a routing table that resides on the first E1 or E2, in which each entry associates an Optomux address with an Ethernet host name or IP address, a protocol (currently UDP only), and a port. When an Optomux packet is received from the serial port, the brain board compares the Optomux address in the packet to the Optomux addresses in the routing table. If there's a match, the packet is forwarded to the appropriate device (including itself) via UDP/IP.

When the response is received via UDP, it is forwarded to the serial network. The maximum number of Optomux devices that can be accessed through serial-to-Ethernet routing is 256, because an Optomux host can communicate with no more than 256 devices. The E1 or E2 doing serial-to-Ethernet routing also behaves as an Optomux device on the RS-422/485 link.

To use serial-to-Ethernet routing, you need to follow the steps below to create the OmuxRoutes routing table and then enable serial-to-Ethernet routing in the OmuxSettings file.

CREATING A ROUTING TABLE

The routing table is a text file that you can create or edit in Notepad and then transfer to the E1 or E2 using PAC Manager. The OmuxRoutes table should reside only on the first E1 or E2.

NOTE: PAC Manager uses FTP to transfer files. FTP cannot be used through a firewall in the PC. Make sure any firewall in the computer (such as the built-in firewall in Windows XP) is disabled before you try to transfer the file to the brain board. (Firewalls in a router should not be a problem.)

1. Open Notepad or any simple text tool and create a new file.
2. In the file, type one line for each Optomux address, in the following format:

   ```
   [Optomux_address]  [type]:[host name or IP address]:[port]
   ```

   The space between [Optomux address] and [type] can be one or more spaces. The value for [type] is currently `udp`. The default value for [port] is `5000`. (Change it only if port 5000 on the Ethernet network is already being used for another purpose.) Each entry must end with a carriage return.

   For example:

   ```
   42 udp:valve_control:5000
   112 udp:10.192.55.61:5000
   ```

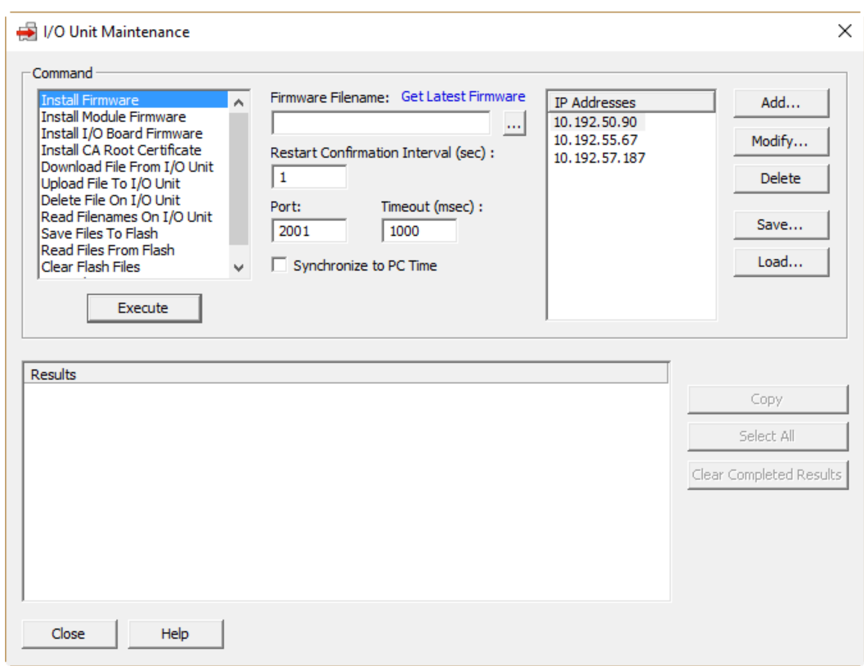
   Alternatively, you can use commas as follows:

   ```
   42,udp,valve_control,5000
   112,udp,10.192.55.61,5000
   ```

   A sample routing table is shown on page 64.
3. Save the file with the filename `OmuxRoutes`

   NOTE: An example of an OmuxRoutes file is provided in the software available on the Opto 22 website.

4. If PAC Manager is not already open, choose Start > Programs > Opto 22 > PAC Manager.
5. In the PAC Manager main window, click the Maintenance button.



6. In the I/O Unit Maintenance window, do the following to copy the OmuxRoutes file to the first E1 or E2:
   a. In the Command list, choose Upload File To I/O Unit.
   b. In the Filename field, click the browse button ... .
   c. In the Open dialog, browse to the OmuxRoutes file, and double-click it to open it.
      The path and filename appear in the Filename field.
   d. In the Destination field, type the name `OmuxRoutes`.
   e. If the IP Address for the E1 or E2 is listed under IP Addresses, go to the next step. If the IP address is not in the list, click the Add button and add it.
   f. Highlight the IP address, and click Execute.
      The updated OmuxRoutes file is copied to the E1 or E2, and the new settings take effect right away.
7. Continue with "Enabling Serial-to-Ethernet Routing," below, to change the OmuxSettings file.

Sample Routing Table

Following is a sample OmuxRoutes file. (Text after a `#` on any line is a comment.)

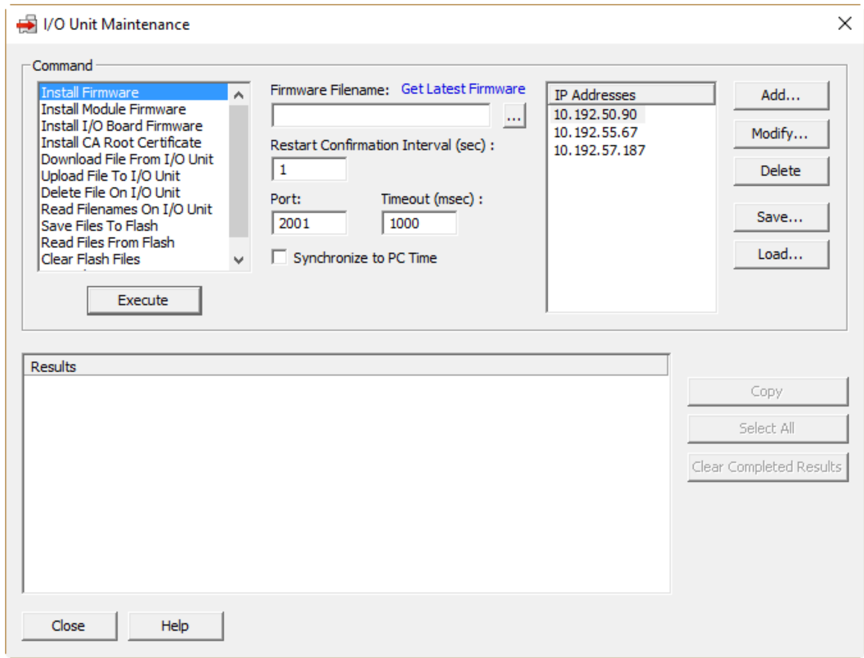
```
# Routing Entries for the system.
# Note that port 5000 is the default
# E1 UDP port.

4       udp:10.0.0.8:5000    # comment
5       udp:10.0.0.9:5000
6       udp:10.0.0.10:5000

# The following entry uses hostname instead of IP
# address.

55      udp:my_e1_hostname:5000
```

ENABLING SERIAL-TO-ETHERNET ROUTING

NOTE: PAC Manager uses FTP to transfer files. FTP cannot be used through a firewall in the PC. Make sure any firewall in the computer (such as the built-in firewall in Windows XP) is disabled before you try to transfer the file to the brain board. (Firewalls in a router should not be a problem.)

1. If PAC Manager is not already open, choose Start > Programs > Opto 22 > PAC Manager.

2. In the PAC Manager main window, click the Maintenance button .



3. In the I/O Unit Maintenance window, do the following to copy the OmuxSettings file to your computer:
   a. In the Command list, choose Download File From I/O Unit.
   b. In the Filename field, type `OmuxSettings`.
   c. In the Destination field, click the browse button ... .
      The Save As window opens.
   d. Browse to a convenient directory on the computer. Type `OmuxSettings` and click Save.
      The path and filename appear in the Destination field.
   e. Click the Add button.
      The Add IP Address window opens.
   f. Enter the IP address of the E1 or E2 and click Save.
      The IP address appears in the IP Addresses list.
   g. Select the appropriate IP address, then click the Execute button.
      The OmuxSettings file is copied to your computer.
4. Open the OmuxSettings file in Notepad or another simple text tool.

   NOTE: An example of an OmuxSettings file is included in the software available on the Opto 22 website.

5. Add the text `SerialToEthernetRouting`
6. Save the file as `OmuxSettings`
7. In PAC Manager's I/O Unit Maintenance window, do the following to copy the OmuxSettings file to the E1 or E2:
   a. In the Command list,
      choose Upload File To I/O Unit.
   b. In the Filename field, click the browse button ... .
      The Open File dialog opens.

- **c.** Browse to the OmuxSettings file, then click Open.

  The path and filename appear in the Filename field.
- **d.** In the Destination field, type the name `OmuxSettings`
- **e.** If the IP Address for the E1 or E2 is listed under IP Addresses, go to the next step. If the IP address is not in the list, click the Add button and add it.
- **f.** Highlight the IP address, and click Execute.

  The updated OmuxRoutes file is copied to the E1 or E2, and the new settings take effect right away.

DISABLING SERIAL-TO-ETHERNET ROUTING

To stop serial-to-Ethernet routing:

1. Open the OmuxSettings file.
2. Remove the text: `SerialToEthernetRouting`
3. Save the file.
4. Send the OmuxSettings file to the E1 or E2. See "Enabling Serial-to-Ethernet Routing" on page 64.

B: Using the OmuxSettings File

ABOUT THE OMUXSETTINGS FILE

In addition to jumper settings, E1 and E2 brain boards are configured in the OmuxSettings file, a text file located on the E1 and E2. This file determines whether the E1 and E2 listen on the serial link or the Ethernet link (or both), whether Serial-to-Ethernet routing is enabled, and what happens to troubleshooting log files. The brain board will function using the default settings unless you change them as described below.

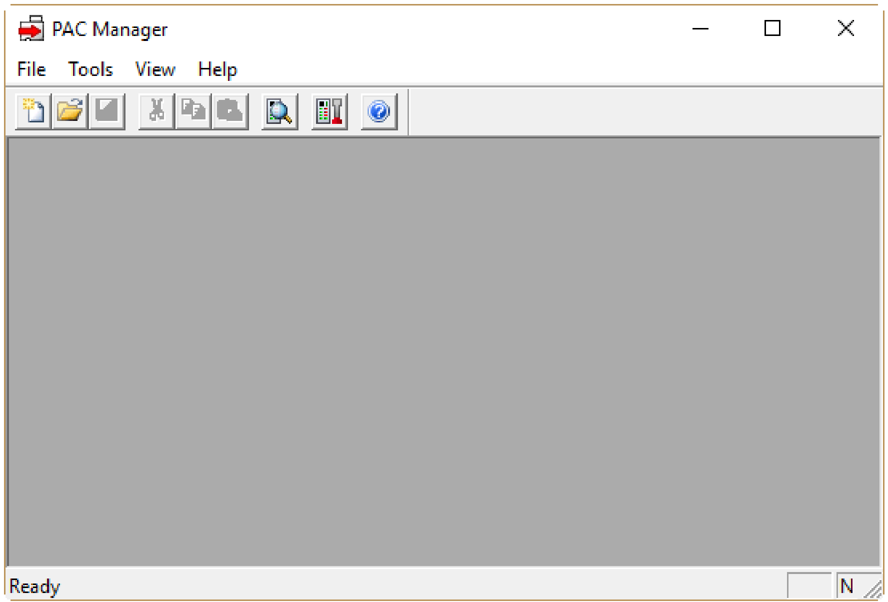
The default settings for the OmuxSettings file are as follows:

Setting	Default	Description
EthernetPort	5000	The UDP port number the E1 or E2 responds to for communications.
EthernetServer	enabled	Listens for Optomux commands (UDP) on the UDP port specified by EthernetPort.
SerialServer	enabled	Listens for Optomux commands on the Serial port.
SerialToEthernetRouting	disabled	When enabled, E1 or E2 can serve as a serial-to-Ethernet router. See Appendix A: Serial-to-Ethernet Routing.

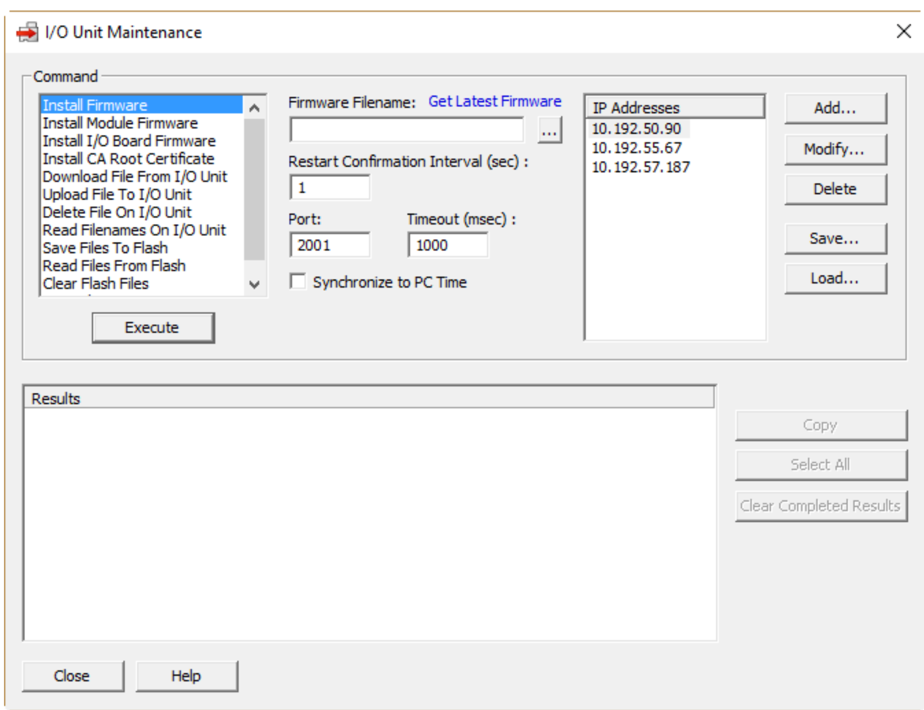
CHANGING THE OMUXSETTINGS FILE

NOTE: PAC Manager uses FTP to transfer files. FTP cannot be used through a firewall in the PC. Make sure any firewall in the computer (such as the built-in firewall in Windows) is disabled before you try to transfer the changed OmuxSettings file to the brain board. (Firewalls in a router should not be a problem.)

1. If PAC Manager is not already open, choose Start > Programs > Opto 22 > PAC Manager.
   The PAC Manager main window opens:



2. In the PAC Manager main window, click the Maintenance button .
   The I/O Unit Maintenance window opens:



3. In the I/O Unit Maintenance window, do the following to copy the OmuxSettings file to your computer:
   a. In the Command list, choose Download File From I/O Unit.
   b. In the Filename field, type `OmuxSettings`
   c. In the Destination field, click the browse button ... .
   The Save As window opens.

d. Browse to a directory on the computer, type `OmuxSettings` and click Save.
   The path and filename appear in the Destination field.
e. Click the Add button.
   The Add IP Address window opens.
f. Enter the IP address of the E1 or E2, and click Save.
   The IP address appears in the IP Addresses list.
g. Select the appropriate IP address, then click the Execute button.
   The OmuxSettings file is copied to your computer.

NOTE: An example of an OmuxSettings file is included in the software available on the Opto 22 website.

4. Open the OmuxSettings file in Notepad or another simple text tool.
5. Add, change, or delete the following communication items, depending on your needs:

To do this	Add/change/delete this text
Change the Ethernet port number	Add: `EthernetPort=[port number]`
Listen on the Ethernet link	Add: `EthernetServer`
Stop listening on the serial link	Delete: `SerialServer`
Enable Serial To Ethernet Routing	Add: `SerialToEthernetRouting`

6. Save the file as `OmuxSettings`
7. In PAC Manager I/O Unit Maintenance window, do the following to copy the OmuxSettings file to the E1 or E2:
   a. In the Command list, choose Upload File To I/O Unit.
   b. In the Filename field, click the browse button.
   c. In the Open dialog, browse to the OmuxSettings file, then click Open.
      The path and filename appear in the Filename field.
   d. In the Destination field, type the filename `OmuxSettings`.
   e. If the IP Address for the E1 or E2 is listed under IP Addresses, go to the next step. If the IP address is not in the list, click the Add button and add it.
   f. Highlight the IP address, and click Execute.
      The updated OmuxSettings file is copied to the E1 or E2, and the new settings take effect.

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Version 2.1, February 1999

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Index

N

O

P

Q

R

S

T

U

W