PLC Communication Enabler for Linux/UNIX

(PLCIO)

Communication & Application Series

Commercial Timesharing, Inc.

PLC Communication Enabler for Linux/UNIX (PLCIO) ver. 4.5.2 Manual Rev. 17_318

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1 INTRODUCTION

The PLC Communication Enabler (PLCIO), a communications library developed by CTI, is part of our Communication and Application Series (CAS) toolkit. With PLCIO, C programmers are able to quickly develop an effective interface with a programmable logic controller (PLC)—without expert knowledge of the communication specifics.

Overview

PLCIO is a light-weight UNIX communications library that enables C or C++ applications to communicate directly with a PLC. It operates in two modes: solicited and unsolicited (master and slave). In solicited mode, applications can read or write values directly to/from the PLC. In unsolicited mode, PLCs can send read or write requests to the PLCIO application.

PLCIO unifies communication between PLCs of different vendors through its concise API set. In short, PLCIO allows programmers to:

- utilize a variety of addressing formats for registers, coils, timers and other PLC constructs.
- give names to registers and addresses on PLCs that are normally only addressed by byte-offset.
- automatically byte-swap any type of data read from and written to the PLC, where the big- and little-endian byte-order differs between the source and destination CPU.
- construct a single application to talk to multiple PLCs simultaneously, using different addressing protocols such as Ethernet and Serial I/O.

PLCIO is also extensible, providing developers with the means of adding new communications protocols to future or proprietary PLCs.

Implementation

There are just a few basic steps for using PLCIO:

1. **Compile and install** the libraries and executables from the PLCIO source package. Follow the instructions outlined in the Installation Procedure section on page 3.
2. **Create the PLC configuration files** that define the scope of access to one or many PLCs. This optional step allows users to name physical PLCs on the network and use a single addressing format across multiple PLC types. See Configuration Files on page 12 for more information.
3. **Write the application** and link it against the PLCIO library. Refer to various programming examples provided throughout this manual. See Compiling Applications on page 11 for more information. The following example shows a compile command for Linux:

```
gcc –Wall –O3 myprog.c -o myprog -lplc
```

Equipment Supported

PLCIO version 4.5 has been tested to support the following PLC types:

- AEG Modicon Quantum PLC via Ethernet
- Allen-Bradley Logix 5000 family (ControlLogix, CompactLogix, FlexLogix, SoftLogix) via EtherNet/IP
- Allen-Bradley MicroLogix via EtherNet/IP
- Allen-Bradley SLC 500 series via DF1 serial, Ethernet, or EtherNet/IP

- Allen-Bradley PLC-5 via DF1 serial, Ethernet, or EtherNet/IP
- Modbus RTU modules via serial
- Modbus+ TCP/UDP modules via Ethernet
- Omron C/CS/CJ-series CPUs via Host Link over serial
- Omron CS/CJ-series CPUs via FINS over TCP, UDP, EtherNet/IP, or serial
- Siemens Step5 via AS511 serial
- Siemens Step5 via INAT Echolink over Ethernet
- Siemens S7-200/300/400/1200/1500-series CPUs via Ethernet
- Wago 750-842 PLC via Ethernet with optional unsolicited UDP support

PLCIO version 4.5 can communicate directly to the following I/O Bus Terminals:

- Beckhoff BK9105 via EtherNet/IP
- Phoenix Contact FL IL 24 BK ETH/IP-PAC via EtherNet/IP

PLCIO version 4.5 can identify as an I/O Bus Terminal to the following PLCs:

- Allen-Bradley Logix 5000 family via EtherNet/IP
- Schneider Electric PLC/PAC via EtherNet/IP

2 INSTALLATION

PLCIO installation requires a set of C development tools and libraries appropriate for your platform. See your system documentation for more information about these utilities.

Installation Procedure

The PLCIO library is distributed in source form, allowing you to configure the installation directory and optimize the library specifically for your system's architecture. The library can be compiled on either a UNIX or Windows system, using either the native *cc* compiler bundled with some UNIX installations, or the open-source *gcc* compiler from the GNU Compiler Collection suite (see http://gcc.gnu.org for installation instructions).

If installing under a Windows environment, first see the section titled Windows Installation on page 4.

Operating Systems Supported

PLCIO was designed to compile and operate on any 32- or 64-bit UNIX or Windows platform. PLCIO was specifically tested on the following systems (other systems might work but may require slight changes to the source code):

System	Requirements
GNU/Linux	GNU GLIBC 2.0 or later; Linux kernel 2.2 or later
HP-UX 11	HP aCC (cc) or gcc build environment
AIX 7	IBM XL C (xlc) or gcc build environment
Windows XP and later	Msys/MinGW build environment
FreeBSD 10	clang or gcc build environment

UNIX Installation

First, locate the compressed tar archive named "plcio-xx.tar.gz" that was shipped with the software package (substitute in the correct version for 'xx'). Extract the contents of this file into a temporary work directory using the *tar* command, as follows:

```
tar –xzvvf plcio-xx.tar.gz
```

or

```
gunzip plcio-xx.tar.gz
tar –xvvf plcio-xx.tar
```

This will create a new package directory called "plcio-xx".

Next, change into the "plcio-xx" directory and configure the library using the following command:

```
./configure
```

This script will prompt you for the installation directories for the system files and the optional Web interface demo. For example, choosing the system directory "/usr/local" will install the binary executables to "/usr/local/bin", library files to "/usr/local/lib", and so on. For the Web interface demo, specify the top-level htdocs directory or choose 'none' to skip installing the demo files.

Next, type the following commands to clean, compile, install, and test the source package, respectively:

```
make clean
make
```

```
make install
make test
```

The ‘make install’ command installs the PLCIO package files into the following subdirectories off of the chosen system directory:

`bin/`	Contains the daemon programs *enipd* and *plciod*.
`include/`	Contains the header files for inclusion in user-level applications.
`lib/`	Contains the main libplc library file and the individual shared libraries for each PLC module.
`man/`	Contains the manual pages for each of the PLCIO library functions.
`plcio/`	Contains the data/ directory where the plcio.cfg and other shared system files are located. These files are not installed world-writable by default.

After running ‘make install’, you can run ‘make test’ to verify the PLCIO installation is working properly on your system.

Windows Installation

Compiling PLCIO under Windows requires first setting up the MinGW build environment. Since this is a complicated process, CTI provides a binary ZIP archive of PLCIO for easy installation.

Binary Installation

First, locate the compressed tar archive named “plcio-xx.tar.gz” that was shipped with the software package (substitute in the correct version for ‘xx’). Extract the contents of this file into a temporary work directory. The 7-Zip program from http://www.7-zip.org can be used to extract this file from within Windows.

Browse to the “windows” subfolder in the PLCIO software package. Choose either the “winplcio-32bit.zip” or “winplcio-64bit.zip” file according to your operating system type. Double-click on that file, and extract the contents to “C:\Program Files”. This will create a new folder called PLCIO that contains the bin, include, lib, man, and plcio folders like with the UNIX installation mentioned above.

To run PLCIO applications, the file “C:\Program Files\PLCIO\lib\libplc.dll” must be found by the application. To ensure this succeeds, you can perform one of three options:

1. Copy “C:\Program Files\PLCIO\lib\libplc.dll” to the same directory where your application is running from.
2. Copy “C:\Program Files\PLCIO\lib\libplc.dll” to the Windows system directory (“C:\Windows\System32”) or any directory specified in your PATH environment variable.
3. Add the directory “C:\Program Files\PLCIO\lib” to your PATH environment variable.

Once “libplc.dll” is made available to the application, it will automatically look for any other required module-specific .dll files in “C:\Program Files\PLCIO\lib”.

Source Installation

You will first need to install the Msys/MinGW build environment in order to compile PLCIO on a Windows operating system. For quickest installation, CTI recommends installing the Msys2 environment from http://msys2.github.io using the following steps:

1. Browse to http://msys2.github.io and run the one-click-installer for either “msys2-i686” or “msys2-x86_64” according to your operating system type.
2. Start Msys2. At the shell prompt, run:

```
pacman --needed -Sy bash pacman pacman-mirrors msys2-runtime
```

3. Exit the shell, the restart Msys2. Run the following commands to update the environment and install any extra required packages:

```
pacman –Su
pacman –S make tar vim zip
```

4. Next, install the mingw-w64 toolchain using one of the two commands below according to your operating system type (at the prompt, press Enter to install all listed packages):

```
pacman -S mingw-w64-i686-toolchain
```

or

```
pacman -S mingw-w64-x86_64-toolchain
```

After installation, follow the instructions given in the UNIX installation section to compile and install PLCIO from source. Note that when running the ./configure script, the default installation directory is "/c/Program Files/PLCIO". This corresponds to "C:\Program Files\PLCIO" in Windows and is the recommended installation directory for the Windows operating system.

Microsoft Visual Studio C++ Compatibility

To build C++ projects with PLCIO, you will need to create a .lib interface file for "libplc.dll". From the Visual Studio top menu, go to Tools -> Visual Studio Command Prompt. At the prompt, type one of the following commands according to your operating system type:

```
lib /def:"C:\Program Files\PLCIO\lib\libplc.def" /machine:x86
```

or

```
lib /def:"C:\Program Files\PLCIO\lib\libplc.def" /machine:x64
```

On Windows 7 or later, you may need to run these commands as an Administrator.

Note	For convenience, CTI provides the "libplc.lib" file as part of the binary ZIP archive.

3 USING PLCIO

This chapter provides a top-down explanation on how to use the PLCIO library. Details regarding setting up a configuration file and programming examples are also included.

Background

A *PLC* (Programmable Logic Controller) is a physical piece of hardware that is very much like a PC. It can run programs like a PC and keep data variables in its memory. In general, a PLC has communications ports (e.g. Ethernet port, Serial port, etc.) and a bank of terminals where wires can be attached. Programs running on the PLC can control output signals going to field devices on individual output wires, and similarly they can read input signals coming from field devices on input wires.

Each PLC has data variables in its memory. Programs on the PLC can write or update these variables in the same way they can control the output signals. It's the data in these variables that are of interest to the application.

Each variable is identified in the PLC by an *Address*, and addresses are specific to the type of PLC being used. For instance, some PLCs have addresses indexed by number, where "40001" has a different value and meaning than "40002". Other PLCs have named addresses called *tags*, like "Power_Level" or "Current_Clock," that represent different program variables. The extent and meaning of each variable is defined at the very moment a PLC programmer uploads a new program to the PLC. In other words, each variable is specific to the program being run on the PLC.

In addition to data variables, PLCs set aside special addresses that correspond to one or more of the connected inputs or outputs. For instance, reading from the address "I2" on a Siemens PLC will display the input signal coming in on wire #2. Similarly, writing a 0 or 1 to address "O5" will turn off or on the output signal sent to a device on wire #5.

PLCIO provides the means for UNIX applications to directly read and write data values on the PLC via its communications port, independent of the program being run on the PLC.

Transport Protocols

The *Transport Protocol* is the method by which PLCIO communicates with a specific PLC. Currently PLCIO only supports Ethernet or Serial I/O communications. Ethernet communication requires an IP Address and TCP/IP port, whereas serial communication requires selecting the device to use (such as COM1), the baud rate, and other port characteristics.

Just as two opposing movie file formats require different codecs in order to view them, different PLCs made by different manufacturers require different communications protocols. PLCIO implements only a tiny subset of each protocol: specifically, reading and writing to an address (or range of addresses) on a PLC.

PLCIO presents the available transport protocols to the application as *modules*. Each module implements the specific combination of the medium being used (Ethernet or Serial I/O) and the underlying communications protocol for a supported PLC. Applications can query as many modules as necessary in the same program to communicate with multiple PLCs.

Using the API

An application using PLCIO executes three main parts of the API:

- Open the communications link to the PLC using the plc_open( ) function call.
- Perform reads/writes in *solicited* mode or receives/replies in *unsolicited* mode.

- Close the link to the PLC using plc_close( ).

The plc_open( ) API function takes two space-separated arguments in string form: the name of the module being requested and the target device or address (other module-specific arguments can also be provided). The plc_open( ) function returns a pointer to a PLC object that contains information about the opened connection. This is similar to the UNIX fopen( ) in how it returns a pointer to a FILE object.

In the following example, this PLCIO application uses the "abeth" module to connect to a Allen-Bradley PLC-5 located on the network at IP Address "192.168.1.10":

```
#include <plc.h>

int main()
{
  PLC *plc_ptr;

  plc_ptr=plc_open("abeth 192.168.1.10");
}
```

If the plc_open( ) call returns a non-null pointer, then the connection to the PLC is successful. At this point, the application can read data from the PLC using plc_read( ), or write data to the PLC using plc_write( ). Both functions require the target PLC Address—the location in the PLC's memory where the data transfer is taking place.

When the application is finished with the PLC, it must call plc_close( ) with the *plc_ptr* variable as the argument. After a close, *plc_ptr* can no longer be used with any plc_*( ) function again until the next plc_open( ).

Here we've extended our original example to be a complete PLCIO application that uses both plc_read( ) and plc_write( ). In this example, we will read the 2-byte value at address "N7:0" into variable *i_data* in the C application, increment it by 1, and then write it back to the PLC. From the PLC's point of view, it is as if the value at N7:0 was suddenly incremented by 1.

```
#include <plc.h>

int main()
{
  PLC *plc_ptr;
  short i_data;

  /* Open a connection to the PLC */
  plc_ptr=plc_open("abeth 192.168.1.10");

  /* Read a value from N7:0 into i_data */
  plc_read(plc_ptr, PLC_RREG, "N7:0", &i_data, 2, 500, PLC_CVT_WORD);

  /* Increment the value */
  i_data++;

  /* Write the value back to the PLC */
  plc_write(plc_ptr, PLC_WREG, "N7:0", &i_data, 2, 500, PLC_CVT_WORD);

  /* Close the connection to the PLC */
  plc_close(plc_ptr);
}
```

The plc_read( ) and plc_write( ) functions are mirrors of each other in that they take the same arguments. These arguments are from left to right: PLC object pointer, operation mode, PLC address, data pointer, byte-length, timeout, and big-/little-endian conversion format.

Error Checking

In the real world, communications can drop, the PLC might go offline, or the PLC could be busy processing another request beyond the scope of your program. In any case, error checking is necessary to determine if the PLC received the request before continuing on with the next step in the application.

Each plc_*( ) function in the PLCIO API provides error reporting and a means for the application to detect if the function succeeded or failed. The plc_open( ) function call returns a NULL pointer on error. All other functions return -1 to indicate an error has occurred.

The PLC function “plc_print_error(plc_ptr, message)” behaves like the UNIX perror( ) function and can be used to quickly and easily display PLCIO errors to standard output. Here is our previous example, updated to include the proper error checking:

```
#include <plc.h>

int main()
{
  PLC *plc_ptr;
  short i_data;
  int j_ret;

  /* Open a connection to the PLC */
  plc_ptr=plc_open("abeth 192.168.1.10");
  if(plc_ptr == NULL) {
    print_plc_error(plc_ptr, "plc_open");
    exit(1);
  }

  /* Read a value from N7:0 into i_data */
  j_ret=plc_read(plc_ptr, PLC_RREG, "N7:0", &i_data, 2, 500, PLC_CVT_WORD);
  if(j_ret == -1) {
    print_plc_error(plc_ptr, "plc_read");
    plc_close(plc_ptr);
    exit(1);
  }

  /* Increment the value */
  i_data++;

  /* Write the value back to the PLC */
  j_ret=plc_write(plc_ptr, PLC_WREG, "N7:0", &i_data, 2, 500, PLC_CVT_WORD);
  if(j_ret == -1) {
    print_plc_error(plc_ptr, "plc_write");
    plc_close(plc_ptr);
    exit(1);
  }

  /* Close the connection to the PLC */
  j_ret=plc_close(plc_ptr);
  if(j_ret == -1)
    print_plc_error(plc_ptr, "plc_close");

  /* Exit with a "good" return status */
  exit(0);
}
```

Now, when you run the program and discover that the N7:0 address did not increment on the PLC, you can easily see what step of the program failed along with a short description of the problem. The program will now also return a status code to the calling application: 0 (success) or 1 (failure), depending on whether or not the program successfully sent the message to the PLC.

When a plc_*( ) function errors out, it stores an error code in the *plc_ptr->j_error* variable (or *plc_open_ptr->j_error* in the case that plc_open( ) failed to create a PLC object). Your application can check this error code to determine whether to retry the read/write operation or close the PLC. Error codes are listed along with their shorthand names in the back of this manual in Appendix A – Error Codes on page 103.

Timeouts

If the PLC is busy working on another request or if there is a connection failure, it might not respond to your request within the allotted time window. A timeout must be given in milliseconds as the sixth argument to each plc_read( ) or plc_write( ) call. In the case of a timeout, PLCIO will relinquish control back to the application with a PLCE_TIMEOUT error code.

Timeout errors are the only communication errors that an application can receive without having to reset the connection (by calling plc_close( ) followed by plc_open( )). If the application receives a PLCE_TIMEOUT, it can simply retry the read or write request again without any extra effort. PLCIO ignores any PLC responses to a previous request that was cancelled due to timeout.

The following code snippet uses timeouts to print “No response yet.” on the screen once per second. If the program receives any error other than a timeout, the program exits immediately.

```
while(1) {
  /* Read a value from N7:0 into i_data */
  j_ret=plc_read(plc_ptr, PLC_RREG, "N7:0", &i_data, 2, 1000, PLC_CVT_WORD);

  if(j_ret == -1) {
    /* Check if the error was caused by a timeout */
    if(plc_ptr->j_error == PLCE_TIMEOUT) {
      printf("No response yet.\n");
      continue;
    }

    /* Otherwise exit and say what happened */
    print_plc_error(plc_ptr, "Error in plc_read");
    plc_close(plc_ptr);
    exit(0);
  }

  else if(j_ret > 0) {
    printf("Value read from PLC is: %d\n", i_data);
    break;
  }
}
```

If the operating system determines that the connection to the PLC dropped due to a connection failure or other reset, then a PLCE_COMM_SEND or PLCE_COMM_RECV is returned to the application along with the UNIX errno indicating the cause. You can check the UNIX errno by looking at *plc_ptr->j_errno* after verifying that *plc_ptr->j_error* is either PLCE_COMM_SEND or PLCE_COMM_RECV. In this case, you must call plc_close( ) followed by plc_open( ) before doing any further read or write requests.

Threads

PLCIO is not reentrant or thread-safe. Programmers writing threaded applications must ensure that only one thread calls any PLCIO function at a given time. This can be done by making all PLCIO calls originate from a single main thread in the program, or by enforcing a mutual exclusion barrier around every plc_*( ) function in the program.

Compiling Applications on UNIX

PLCIO provides both static (libplc.a) and dynamic (libplc.so or libplc.sl) versions of its library for linking with applications.

To compile a PLCIO application in UNIX, use -lplc (lowercase -LPLC) on the compiler command line to link to libplc, as follows:

```
gcc myprog.c -o myprog –lplc
```

If PLCIO was installed in a non-standard location (i.e. not /usr or /usr/local), then you may need to additionally use the -I and -L options. The -I option specifies the directory to find the <plc.h> include file, and the -L option specifies where the library file is located. For instance, if PLCIO was installed in "/usr/local/cti", use the following command to compile your program:

```
gcc myprog.c -o myprog –I/usr/local/cti/include –L/usr/local/cti/lib –lplc
```

The PLCIO system dynamically loads additional modules at runtime depending on the type of PLC requested by the application. These modules are dynamically shared objects that are installed in the same directory as libplc. The path to these modules are hard-coded into the PLCIO library during installation time. They cannot be changed without rerunning the ./configure script and recompiling PLCIO.

When your PLCIO application is production-ready, compile it using the additional *gcc* compiler flags -O3 (capital oh) and -Wall. This enables the highest optimization for your architecture and also enables all compiler-generated warnings.

Linux Shared Library Troubleshooting

Linux caches all available shared libraries in the /etc/ld.so.cache binary file. If PLCIO is installed in a non-standard location, then this cache will need to be updated before you can run any PLCIO programs. To update the cache, first add the full path of the lib/ directory (where libplc.so was installed) to the /etc/ld.so.conf file, then run 'ldconfig' as root user.

Alternatively, if you have no access to /etc/ld.so.conf, you can set the environment variable LD_LIBRARY_PATH to the directory containing libplc.so. For example, if you installed PLCIO in "/usr/local/cti", then type the following before running any PLCIO programs:

```
export LD_LIBRARY_PATH=/usr/local/cti/lib
```

The *ldd* command on Linux can be used to diagnose shared-library issues. After compiling your application program, run 'ldd progname' to display the libraries linked by the program and whether they are being correctly resolved.

QNX Shared Library Troubleshooting

QNX only searches for shared libraries in the /lib, /usr/lib, and /usr/local/lib directories. If you install PLCIO in a non-standard location, then the LD_LIBRARY_PATH environment variable must be set to the directory containing libplc.so. For example, if you installed PLCIO in "/usr/local/cti", then type the following before running any PLCIO programs:

```
export LD_LIBRARY_PATH=/usr/local/cti/lib
```

Compiling Applications on Windows

Although the MinGW environment is required to compile the PLCIO library on Windows, it is not needed in order to compile PLCIO applications. The libplc.dll and libplc.lib files installed with the Windows version of PLCIO enable you to use any C/C++ compiler available for Windows. The following sections describe how to configure a few common Windows compilers for linking with the PLCIO library.

Note	Compiled PLCIO applications will not run unless the operating system can find the associated libplc.dll library file. Make sure that this file exists either in the same folder as the PLCIO application, or somewhere in the library search path (such as "C:\Windows\System32").

MinGW

The MinGW environment allows you to compile PLCIO applications using *gcc* and a Makefile just as on UNIX. Instructions are equivalent to the section "Compiling Applications on UNIX" above, however the paths to the library and include files are different. If you installed PLCIO into the directory "C:\Program Files\PLCIO", then use the following command to compile your program:

```
gcc myprog.c -o myprog "–I/c/Program Files/PLCIO/include"
"-L/c/Program Files/PLCIO/lib" –lplc
```

The above example will compile a program using the Windows text interface. That is, running the application will open a 80×25 text console on the screen. To compile an application directly for the Windows API without opening a text console, add the -mwindows flag to the *gcc* command line.

Microsoft Visual C++ 6.0

Here are the necessary steps to compile a PLCIO application using Microsoft Visual C++ 6.0:

1. Open the Tools->Options menu option and click on the Directories tab.
   a. For "Include Files", add "C:\Program Files\PLCIO\include".
   b. For "Library Files", add "C:\Program Files\PLCIO\lib".
   c. Click OK.
2. Next, open the Project->Settings menu option and click on the Link tab.
   a. Add "libplc.lib" to the end of the "Object/library modules" field.
   b. Click OK.
3. Add #include <plc.h> to the top of your .cpp file.
4. Compile and link your program as usual.

Note	When linking with Microsoft Visual C++ 6.0, be sure to use the libplc.lib file in the 'winplcio.zip' binary archive (see Binary Installation on page 4). The libplc.lib file, when created by GNU *libtool* during 'make', has a linker compatibility problem.

Configuration Files

PLCIO applications can operate without any configuration files. However, they are a powerful tool in making application programming easier in three basic ways:

- First, configuration files provide a means of assigning names to PLCs and addresses to make programs more legible.
- Second, they place restrictions on how addresses are used so that a program cannot mistakenly use the address in a way it was not intended (such as accidental writing to a variable that should be read-only).
- Third, they allow managers to change the location of the PLC (i.e. its IP Address), the type of PLC (i.e. Allen-Bradley vs. Siemens), or the PLC's data addresses without needing to recompile the PLCIO application or track down where those addresses were used in the program.

Note	This manual uses the following convention in regard to configuration files: Opening a PLC via plc_open( ) using a hard coded module name/IP Address is referred to as opening a Physical PLC. Opening a PLC using its name or alias as defined in the PLCIO configuration file is referred to as opening a Soft PLC. The same is true for Physical Addresses and Soft Addresses (data points).

PLCIO Configuration File

The PLCIO configuration file (defaults to "/usr/local/cti/plcio/data/plcio.cfg" on UNIX systems or "C:\Program Files\PLCIO\plcio\data\plcio.cfg" on Windows systems) contains a list of soft PLC names, each corresponding to a single Physical PLC. A soft PLC can be used in place of a physical PLC in the plc_open( ) call by using the syntax: plc_open("PLC xxx"), where xxx is the name of the soft PLC.

The file format is as follows:

- Each soft PLC is listed in plcio.cfg one per line.
- Blank lines and all text after the comment character # on each line are ignored.
- A line beginning with the character $ denotes a special configuration option (see $TRACE Keyword below).
- Lines are limited to 250 characters in length.

Each entry consists of six fields separated by the ! character. Here is an example of a PLCIO configuration file:

```
# file: /usr/local/cti/plcio/data/plcio.cfg
#
#       This file defines all PLCs known by this computer.
#
# PLC Name ! Mode   ! Node ! Timeout ! PtCfg  ! Physical PLC
Mach1      ! master ! NULL ! 5       ! ab001  ! abeth plc5 10.0.10.3
Mach2      ! master ! NULL ! 5       ! mod002 ! modeth a40c0102
```

The fields are described as follows:

Soft_PLC_Name ! Mode ! Node ! Timeout ! Point_Cfg ! Physical_PLC

Soft_PLC_Name A case-insensitive string that identifies the soft PLC entry.

Mode This field is one of the following keywords, which indicates the mode of interaction for this PLC entry:

- **Master.** Master PLC communication allows the PC application to be the initiator of read/write requests to the PLC. The PLC performs the actions requested by the program and responds with information.
- **Slave.** Allows the PC application to receive unsolicited data from the PLC. In slave mode, the PLC sends a read/write request to the PC, and the application program must respond with the information. PLCIO limits slave communication to register Read and Write operations.
- **Stream.** Allows the PC application to communicate with a Streaming I/O Bus Terminal. These devices will send a buffer containing their current state of inputs a number of times per second. Similarly, the application must refresh the device with new output states a number of times per second.

Node This feature is obsolete and should be set to **NULL**.

Timeout	This field sets the timeout for opening the PLC via plc_open( ), in seconds. Specify -1 to disable the timeout, or 0 to use the default timeout specific to the module being used. This timeout can be overridden by the application by setting the global variable *j_plcio_open_timeout* prior to calling plc_open( ) (see page 37 for details).
Point_Cfg	This field specifies the point-configuration file for the PLC (see page 13). All reads and writes in master mode must be to addresses (or points) listed in this file. The filename is treated as an absolute path if the first character is "/". Otherwise, this file must reside in the /usr/local/cti/plcio/data directory. A .cfg suffix is automatically appended to the filename if no suffix is specified. Set this field to **NULL** if a point-configuration file is not used. This file is ignored if the PLC is opened in **Slave** or **Stream** mode.
Physical_PLC	All remaining characters on the line (up to the # comment character) form the PLC-specific open string as normally passed to the plc_open( ) function call. Redirection to another soft PLC is not allowed (that is, specifying a value in this field similar to "PLC xxx" results in a syntax error at runtime).

The following code example opens the soft PLC "Mach1", substituting in the module and arguments from the Physical_PLC field:

```
#include <plc.h>

int main()
{
  PLC *plc_ptr;

  plc_ptr=plc_open("PLC Mach1");
}
```

Note Make sure that the PLCIO configuration file and any applicable point-configuration files are readable by all programs that use the PLCIO library.

$TRACE Keyword

The TRACE feature is helpful when debugging problems with PLC communications. There are four levels of diagnostics available with an increasing order of verbosity (the actual debugging output depends on the module being used). Usually the basic level shows simple one-line messages, and the most verbose level will display all raw data being sent or received over the transport protocol. Often times you can determine if the PLCIO application or the PLC is at fault simply by viewing these diagnostics.

The $TRACE keyword must be specified in plcio.cfg above the list of PLCs for it to be read by PLCIO. $TRACE only takes one argument: the output logfile name for writing the debug information. Only the first occurrence of $TRACE in the config file is acknowledged by PLCIO.

Each soft PLC in the PLCIO configuration file can have a different debugging level assigned. This is enabled on a per-PLC basis by inserting a special character before the PLC name. The characters associated with each of the four levels are:

!	Level 1	Basic tracing
@	Level 2	
$	Level 3	
*	Level 4	Most verbose, creating very large debug files

To diagnose communications for Mach2, the plcio.cfg file might look like this:

```
# file: /users/local/cti/plcio/data/plcio.cfg
#
$TRACE /tmp/plcio.log
#
#       This file defines all PLCs known by this computer.
#
# PLC Name ! Mode   ! Node ! Timeout ! PtCfg  ! Physical PLC
Mach1      ! master ! NULL ! 5       ! ab001  ! abeth plc5 10.0.10.3
*Mach2     ! master ! NULL ! 5       ! mod002 ! modeth a40c0102
```

After restarting the PLCIO application, all communication to and from Mach2 will be logged to the file /tmp/plcio.log in the most verbose mode possible.

The point configuration file is only read in whenever the application opens a soft PLC. Because of this, an alternative method is used when debugging physical PLCs. You can define the trace logfile at any time during program execution by calling plc_log_init( ) (see page 36).

Note	Each program can only have one logfile open at any given time, regardless of how many PLCs are opened at once.

$LOGSIZE Keyword

This keyword is used to set the maximum size of the $TRACE logfile. When the logfile approaches the specified size, PLCIO will automatically rename it with a .1 suffix and open a new logfile with the original name to replace it. Size identifiers K, M, or G can be used after the number to specify that the value is in kilobytes, megabytes, or gigabytes, respectively.

To set the maximum logfile size during runtime, the application can set the global variable *j_plcio_logsize* to a new size in bytes. However, if the $LOGSIZE keyword exists in plcio.cfg, *j_plcio_logsize* will be overwritten each time the application opens (or reopens) a soft PLC. Setting *j_plcio_logsize* to zero or a negative value disables log rotation altogether. The maximum possible size is 2 gigabytes.

Like $TRACE, this keyword must be specified in plcio.cfg above the list of PLCs for it to be read by PLCIO. The following example plcio.cfg file sets a maximum log size of 4 megabytes, using at most 8 megabytes between the two files /tmp/plcio.log and /tmp/plcio.log.1:

```
# file: /users/cti/plcio/data/plcio.cfg
#
$TRACE /tmp/plcio.log
$LOGSIZE 4M
#
#       This file defines all PLCs known by this computer.
#
# PLC Name ! Mode   ! Node ! Timeout ! PtCfg  ! Physical PLC
Mach1      ! master ! NULL ! 5       ! ab001  ! abeth plc5 10.0.10.3
*Mach2     ! master ! NULL ! 5       ! mod002 ! modeth a40c0102
```

Point Configuration Files

A point configuration file contains a list of soft address names, each corresponding to a physical address (point) or memory location on the PLC. There can be at most one point-config file for each soft PLC listed in plcio.cfg.

When a PLCIO application opens a soft PLC, its address space is limited to only those entries named in the point-config file. Each entry can place further restrictions on how the address is used, in terms of read/write capability and the size of data that the address can touch. This methodology defines a fine-grained access window into the PLC, protecting private data members from being overwritten accidentally by PLCIO.

The file format is as follows:

- Each soft address is listed one per line.
- Blank lines and all text after the comment character # on each line are ignored.
- Lines are limited to 250 characters in length.

Each entry consists of four fields separated by the ! character. Here are some examples:

```
# Here is a typical table for an Allen-Bradley PLC
# file: /usr/local/cti/plcio/data/ab001
# Name      ! Bytes ! Access ! PLC-Specific Address Info
Pstatus     ! 2     ! R      ! N7:102 # 1 Read Only Reg
Pdata       ! 100   ! RW     ! N7:50  # 50 Registers
Active_bit  ! 2     ! RW     ! O:0/2  # 1 Coil
Coil_bank1  ! 16    ! R      ! O:7/0  # 8 Coils
I_Switches  ! 16    ! R      ! I1:11  # 8 Inputs


# Here is a typical table for a Modicon PLC
# file: /usr/local/cti/plcio/data/mod002
# Name      ! Bytes ! Access ! PLC-Specific Address Info
Pstatus     ! 2     ! R      ! 40366  # 1 Read Only Reg
Pdata       ! 100   ! RW     ! 40200  # 50 Registers
Active_bit  ! 2     ! RW     ! 00031  # 1 Coil
Coil_bank1  ! 16    ! R      ! 00030  # 8 Coils
I_Switches  ! 16    ! R      ! 30021  # 8 Inputs


# Here is a typical table for an Allen-Bradley Control Logix 5000
# file: /usr/local/cti/plcio/data/Ctrlgx
# Name      ! Bytes ! Access ! PLC-Specific Address Info
Pstatus     ! 2     ! R      ! MainProgram:pstatus # 1 Read Only Reg
Pdata       ! 100   ! RW     ! MainProgram:pdata   # 50 Registers
Active_bit  ! 2     ! RW     ! Active_array.3      # 1 Coil in global context
```

By setting up multiple point-config files with similarly named entries, your PLCIO application can easily switch between different types of PLCs by simply editing plcio.cfg to indicate the correct point-config file and physical PLC to use.

The fields are described as follows:

Pt_Name ! Bytes ! Access ! PLC_Addr

Pt_Name	A case-insensitive string that specifies the soft address (point) name. Calls to plc_read( ), plc_write( ), or plc_valid_addr( ) must use one of these addresses when talking to the PLC.
Bytes	Specifies the maximum number of bytes PLCIO will allow the application to access for this address. This value can be greater than the actual data element size on the PLC and is meant only as an upper-limit restriction.
Access	Limits the read/write access to this particular PLC address. Use the letter **R** to indicate this point is readable by the PLCIO application, and **W** to indicate the point is writable by PLCIO. For example, specify **RW** for coils and **R** for switch inputs. This feature can be used to prohibit applications from writing/reading a specific PLC address during development.
PLC_Addr	Specifies the physical PLC address for this point. Comments can follow after this field starting with the # character.

Soft Point Override

There often comes a time during development when a programmer needs to access other PLC addresses that are not listed in the point-config file. The soft point address space can be bypassed by inserting a ! as the first character of the physical address during reads and writes, as in the following example:

```
  /* Read 100 registers from address 40200, bypassing the restriction */
  plc_read(plc_ptr, PLC_RREG, "!40200", ai_data, 200, 5000, PLC_CVT_WORD);
```

This override will work for a plc_open( ) call related to either a physical or soft PLC. However, we recommend that you use the soft point override only as a temporary measure during development and never in production software.

Programming Example

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

int main(int argc, char **argv)
{
  PLC *ptr;
  unsigned short ai_data[50];
  int i, j_bytes;

  /* Open access to PLC */
  ptr=plc_open("PLC Mach2");
  if(ptr == NULL) {
    plc_print_error(ptr, "plc_open");
    return 1;
  }

  /* Read 50 16-bit registers (100 bytes total) from the address "Pdata" */
  j_bytes=plc_read(ptr, PLC_RREG, "Pdata", ai_data, 100, 5000, PLC_CVT_WORD);
  if(j_bytes == -1) {
    plc_print_error(ptr, "plc_read");
    return 1;
  }

  /* Display the bytes read in hexadecimal */
  printf("Read %d bytes:", j_bytes);
  for(i=0;i < j_bytes/2;i++)
    printf(" %04x", ai_data[i]);
  printf("\n");

  /* Close communications link to PLC */
  if(plc_close(ptr) == -1)
    plc_print_error(ptr, "plc_close");

  return 0;
}
```

<plc.h> contains PLCIO constants and structures and is required to interface your C program with the PLCIO Library.

This soft PLC open will look in plcio.cfg for an entry called “Mach2”.

Reports the error returned from plc_open( ) to standard output. This is a special case when “ptr” is NULL.

Frees up resources so other applications can open a connection to this PLC. This need not be specified at program exit.

4 API REFERENCE

This section documents all API functions available to a PLCIO application.

Library at a Glance

plc_open( )

PLC *plc_open(const char *pc_destination)

The plc_open( ) function operates like the fopen( ) function in UNIX. It takes a single argument, *pc_destination*, which refers to either a physical PLC or a soft PLC.

A physical PLC destination specifically instructs PLCIO what module to use and how to connect to the PLC. The *pc_destination* takes the form “<module> <destination> [module-specific parameters]”, where <module> is a module name (see PLC Modules on page 39 for a list), <destination> is an Ethernet IP Address/Hostname or serial device name, and [module-specific parameters] is a space-separated list of extra parameters specific to the module selected. An example of a valid *pc_destination* string is “cipab5 192.168.1.90”.

A soft PLC references one of the entries listed in the PLCIO Configuration File and is a direct substitute for a physical PLC. By specifying a soft PLC name rather than hard coding a physical PLC destination, it is possible to change the target of the plc_open( ) call without recompiling the application. To open a PLC by soft name, the *pc_destination* address takes the form “PLC <name>”, where <name> is one of the entries in the configuration file. An example of a valid *pc_destination* string is “PLC plc1”. See PLCIO Configuration File on page 13 for more details.

In master mode (solicited communication), plc_open( ) will immediately attempt to make a connection to the remote PLC. Since different PLCs use different protocols, the default timeout for this operation is defined by the module being used. The application can override this initial timeout only in soft PLC mode by specifying a value in the Timeout field in the PLCIO Configuration File.

Serial Port Parameters

When opening a connection to a serial device, <destination> takes on the following syntax: “<device>[:baud:bits:parity:stopbits:flowctrl]”. <device> is a serial device name, such as “/dev/ttyS0” on UNIX or “COM1” on Windows. The remaining five colon-separated parameters are optional and normally do not need to be specified. If left blank, the PLCIO module fills these in with the defaults most commonly used for that type of PLC.

Each of the parameters are explained in detail below:

Baud	Selects the baud rate, which can be one of the following: 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, 230400, or 460800.
Bits	Sets the number of bits per byte, which can be 5, 6, 7, or 8. Binary data access requires 8 bits per byte.
Parity	Selects the parity to use: N, E, O (capital oh), M, or S. This corresponds to No Parity, Even, Odd, Mark, or Space.
Stop Bits	Sets the number of stop bits, which can be either 1 or 2.
Flow Control	Selects the type of flow control to use when one side of the serial connection is sending data faster than the other side can handle. This can be either left blank (no flow control), or set to “S” for software (using XON/XOFF) or “H” for hardware (monitors the Request To Send – RTS and Clear To Send – CTS signals).

An application can call plc_open( ) for the same serial device more than once, provided all calls are made within a single process and all port parameters are identical. This allows the application to communicate with more than one PLC on the same serial bus while targeting different destination node numbers.

Ethernet Parameters

When opening a network connection, <destination> takes on the following syntax: “<hostname>[:port]”. <hostname> refers to either an Ethernet IP Address (such as “192.168.1.90”) or named network host.

[:port] is an optional TCP/IP port number to use, if different from the default specified by the PLCIO module. An example of a network-based <destination> is: "controlplc.host.com:2222".

Return Value

This function returns a pointer to a newly allocated PLC object, or NULL if the open fails. Since plc_open( ) returns NULL on error, you must use the global variable *plc_open_ptr* instead of the returned pointer to test any associated error codes.

General Errors

PLCE_INVAL_MODULE	Function called with a NULL or empty destination string, or PLCIO could not locate the requested shared library module (.so or .sl) in the filesystem.
PLCE_MOD_VERSION	The versions of the PLCIO shared library and the requested module do not match. Verify that the PLCIO package is completely installed and the LD_LIBRARY_PATH environment variable is pointing to the right directory.
PLCE_NO_MEMORY	Not enough memory was available to load the shared library module or allocate the module-specific PLC structures.
PLCE_MISSING_FUNCS	The shared library module loaded successfully but is missing either the _plc_open( ) or _plc_close( ) function.
PLCE_OPEN_CONFIG	Could not open the Soft PLC Config File. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.
PLCE_INVAL_SOFTPLC	No match for "PLC xxx" in the Soft PLC Config File.
PLCE_WRONG_TYPE	Soft PLC is defined as a different master/slave type in the config file than what is specified in the physical PLC parameters.
PLCE_OPEN_POINTCFG	Could not open the Soft PLC Point-configuration file.
PLCE_PARSE_IDENT	Indicates invalid white space or missing symbols while trying to parse the additional module arguments for the physical PLC.

Ethernet Protocol Errors

PLCE_MISSING_HOST	No hostname was specified in *destination* when trying to connect to an Ethernet-based PLC in **master** mode.
PLCE_UNKNOWN_HOST	An Ethernet hostname was specified but could not be resolved.
PLCE_BAD_TCP_PORT	A TCP/IP port was specified but was not in the range 1-65535.
PLCE_OPEN_SOCKET	Could not open a UNIX socket to establish the PLC connection. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.
PLCE_CONNECT	PLCIO failed to connect to the remote PLC. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.
PLCE_COMM_SEND	An error occurred while sending data during the handshake with the PLC. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.
PLCE_COMM_RECV	An error occurred while waiting for data during the handshake with the PLC. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.
PLCE_BIND	Failed to open a local TCP/IP port for **slave** communication. Usually occurs if the port is already in use. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.
PLCE_MULTICAST	Failed to register the application as a member of a multicast group. Verify that the system supports Multicast Networking. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.

Serial Protocol Errors

PLCE_SERIAL_PARAM	The specified baud rate or style was either unsupported, or the syntax was invalid.
PLCE_OPEN_SERIAL	PLCIO failed to open the serial device for communication. The UNIX *errno* is stored in *plc_open_ptr->j_errno*.

Application Example

```
#include <plc.h>

int main(int argc, char *argv[])
{
  PLC *ptr;

  /* Open access to PLC using the Mach2 entry in plcio.cfg */
  ptr=plc_open("PLC Mach2");
  if(ptr == NULL) {
    plc_print_error(ptr, "plc_open");
    return 1;
  }

  /* Application is now ready to perform I/O */
  ...
```

Debugging and Tracing

Errors during a plc_open( ) and any of the other PLCIO API functions can be viewed on standard output by passing the PLC object to the plc_print_error( ) function, as shown in the example above. Because plc_open( ) returns NULL on an error, plc_print_error( ) understands that specifying a NULL pointer means to display the error information from the most recent plc_open( ) attempt.

Sometimes, printing errors is not enough information to debug a problem that occurs in development. Tracing can be enabled on an individual plc_open( ) call by inserting a special symbol before the module name. This can be specified as the first letter to the plc_open( ) argument when opening a physical PLC, or specified as the first letter on the line in the plcio.cfg file when opening a soft PLC.

These symbols are:

!	Level 1	Basic tracing
@	Level 2	
$	Level 3	
*	Level 4	Most verbose, creating very large debug files

In addition to using the symbol, it is necessary to enable tracing using either the $TRACE facility in the PLCIO Configuration File (see page 14), or with plc_log_init( ) (see page 36) before these diagnostics are generated. For instance, the following opens a physical PLC (Allen-Bradley PLC-5) on the network at 192.168.1.10, sending all debugging information to the console:

```
plc_log_init(PLC_LOG_TTY);
ptr=plc_open("*abeth plc5 192.168.1.10");
```

plc_close( )

int plc_close(PLC *plc_ptr)

This function should be called when the application is finished with its communications to the PLC. PLCIO first closes the physical channel to the PLC, then frees the PLC object allocated by the plc_open( ) function. It is not necessary to call this function if the program is about to exit( ), however in some cases, resources may not be freed on the PLC side if not closed properly.

Closing a PLC does not release the shared library that was dynamically loaded by plc_open( ). PLCIO assumes that if an application does a plc_close( ), it will most likely either exit or do a plc_open( ) with the same module shortly thereafter.

Return Value

This function returns 0 if successful, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC pointer.
PLCE_DUPLICATE_CLOSE	Function called twice in a row using the same PLC object.

Application Example

```
ptr=plc_open("PLC Mach2");

...

/* Application performs I/O on the PLC */

...

if(plc_close(ptr) == -1)
  plc_print_error(ptr, "plc_close");
```

plc_read( ), plc_write( ) – Master Mode

int plc_read(PLC *plc_ptr, int j_op, char *pc_addr, void *p_data, int j_length, int j_timeout, char *pc_format)

int plc_write(PLC *plc_ptr, int j_op, char *pc_addr, void *p_data, int j_length, int j_timeout, char *pc_format)

In **master** mode (solicited communication), these functions perform basic operations on the PLC, such as reading and writing data registers, coils, strings, and so forth. Each function specifies the PLC address, application buffer, size of that buffer, a timeout (in milliseconds) for the operation to complete, and a format string describing the data structure, used only when converting between big- and little-endian byte-order.

Arguments

PLC *plc_ptr	The PLC communications object as returned from the plc_open( ) call.
int j_op	The type of operation to perform on the PLC—usually PLC_RREG for reading 2-byte registers, or PLC_WREG for writing 2-byte registers. The operations supported by a PLC are module-specific. This option is discussed in more detail for each PLC module in Chapter 5.
char *pc_addr	The target memory or I/O address for reading and writing data on the PLC. If a soft PLC is opened, then this is the name of a soft address as defined in the PLC's point-configuration file (see page 15). Otherwise, this is a physical address that corresponds to an actual memory location or I/O point on the PLC. If the first character of *pc_addr* is a ! symbol, then the address following the ! refers to a physical address on the PLC regardless if the PLC was opened as a physical or soft PLC. The soft-point table lookup is subsequently bypassed for this operation.
void *p_data	Pointer to the beginning of a buffer that either copies data from the PLC during a plc_read( ), or writes data to the PLC during a plc_write( ). This variable can point to a data array of any size (char, short, int, long, etc.), including structures of data containing different sized members. By default, PLCIO assumes the application is working with 16-bit short integers, typical of PLC communication. Each coil and input is treated as a short integer (with non-zero values treated as coil-energized).

int j_length	The length, in bytes, of the data to send during a plc_write( ), or the maximum data to retrieve during a plc_read( ). This value should be evenly divisible by the element size of its data members. When referencing a soft address, an error can occur if this value is larger than the limitation placed in the point-configuration file (see page 15). The maximum value for *j_length* is defined by the constant PLC_CHAR_MAX, or 8192 bytes.
int j_timeout	The maximum amount of time to wait for a response from the PLC, in milliseconds. Time is counted starting from when the function is called by the application. It is important to set this variable to a high value (such as 3 seconds) when working with large data sets, as PLCIO may need to split the data set into multiple transactions—each taking several tenths of a second to complete. If the timeout is reached, these functions will return -1 with the resulting error code set to PLCE_TIMEOUT. Even with an error, it is possible that the PLC has already completed the request, or it can still complete the request sometime in the future if the communications channel is slow. Applications should simply retry the request again in this situation, and they need not use plc_close( ). Use 0 to disable this timeout on a request-by-request basis.
char *pc_format	Instructs PLCIO on how to convert the data being read or written between PLC and application. This string is only used when the byte-order differs between the CPU type used by the PLC and that of the application.

There are several modes of operation for this argument:

- If set to NULL (or PLC_CVT_WORD), PLCIO assumes the data consists solely of 16-bit short integers. This default handles most PLC communications.
- If set to PLC_CVT_NONE, no translation is performed.
- If set to a string, the string describes the size and number of bytes of each different set of data members in the *p_data* buffer.

Creation of the string requires knowledge of the data buffer members in question. The string consists of a set of characters of the form "<type_id>[optional length in bytes]", where *type_id* is one of the following:

c	char	Character or Byte Data (8-bit)
i	short	Short Integer (16-bit)
j	int	Integer (32-bit for UNIX computers)
q	quad	Long-Long Integer (64-bit on UNIX computers)
r	float	Floating point (32-bit)
d	double	Double Precision Floating Point (64-bit)

Conversion Example:

For the packed structure in the following format:

```
int   a[5];     /*  5 int * 4 bytes     =  20 bytes */
char  b[10];    /*  10 char             =  10 bytes */
short c[3];     /*  3 short * 2 bytes   =  6 bytes  */
int   d;        /*  1, 4 byte integer   =  4 bytes  */
short e;        /*  1, 2 byte short     =  2 bytes  */
```

Define the *pc_format* string as: "j20c10i6j4i2".

Return Value

Function plc_read( ) returns the length in bytes of the data read into the *p_data* buffer from the PLC. 0 indicates that the operation completed but no data was received. Returns -1 on error.

Function plc_write( ) returns 0 if the operation completed successfully, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC pointer.
PLCE_NO_SUPPORT	Function not supported by this PLC module.
PLCE_INVALID_MODE	plc_write( ) called when PLC is being accessed in **slave** mode.
PLCE_INVALID_OP	Operation *j_op* not valid for this function. For instance, using PLC_RREG during a plc_write( ), and vice versa.
PLCE_INVALID_POINT	Function called with NULL or empty *pc_addr* string, and PLC is being accessed in **master** mode.
PLCE_BAD_SOFTPOINT	Address *pc_addr* was not found in the Soft Point-configuration file.
PLCE_INVALID_LENGTH	Function called with invalid *j_length* (less than 1 or greater than PLC_CHAR_MAX).
PLCE_NO_READ	Application used plc_read( ) to read from a point not marked **R** in the Soft Point-configuration file.
PLCE_NO_WRITE	Application used plc_write( ) to write to a point not marked **W** in the Soft Point-configuration file.
PLCE_CONV_FORMAT	Unknown character found in conversion string *pc_format*.
PLCE_PARSE_ADDRESS	Could not identify PLC target data location due to error in *pc_addr* semantics (misplaced parentheses, brackets, etc).
PLCE_BAD_ADDRESS	Specified address does not physically exist on the PLC.
PLCE_REQ_TOO_LARGE	Target address data size is too small for the specified *j_length*.
PLCE_BAD_REQUEST	Size *j_length* is not evenly divisible by the element size requested in *j_op*.
PLCE_ACCESS_DENIED	Remote read/write access is disallowed for this specific address.
PLCE_INVALID_DATA	The data values sent in a plc_write( ) operation were rejected by the PLC due to data type restrictions on the target address.
PLCE_COMM_SEND	A transport error occurred while sending the read/write request to the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_COMM_RECV	A transport error occurred while waiting for the response from the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_TIMEOUT	No response was received after *j_timeout* milliseconds have elapsed. *plc_ptr->j_errno* is set to ETIMEDOUT.
PLCE_MSG_TRUNC	Received a response from the PLC too small to process.

Application Example

Below is a typical example of a communication using PLCIO. This function reads ten 16-bit registers (PLC_RREG operation) from an address named “Pdata” on a generic PLC (see Soft Point-configuration file example on page 17), and saves the data to the *ai_regs* argument. It sets the transaction timeout to 3 seconds and uses PLC_CVT_WORD, telling PLCIO that the buffer contains only 16-bit words for byte-order conversion.

```
int read_from_plc(PLC *plc_ptr, short ai_regs[10])
{
  int j_length;

  j_length=plc_read(plc_ptr, PLC_RREG, "Pdata", ai_regs, 20, 3000, PLC_CVT_WORD);
  if(j_length == 20)
    return 1;  /* Completed successfully */

  /* Otherwise, there’s been a problem */
  if(j_length == -1)
    plc_print_error(ptr, "read_from_plc");
  else
    printf("Only received %d bytes from the PLC.", j_length);

  return 0;  /* Operation failed */
}
```

The following code snippet shows typical usage of the read_from_plc( ) function above. If the request fails, we check the *j_error* member of the PLC object to determine what action is necessary. Only return codes PLCE_COMM_SEND and PLCE_COMM_RECV are considered fatal communications errors, and the application should close and reopen the PLC to correct the problem. If PLCE_TIMEOUT is received, the application should simply retry the request. All other errors, such as an invalid PLC address, indicate a problem with PLCIO or the application, rather than the communications link.

```
j_status=read_from_plc(plc_ptr, ai_regs);
if(j_status == 0) {
  /* An error has occurred with the PLC request */
  if(plc_ptr->j_error == PLCE_COMM_SEND || plc_ptr->j_error == PLCE_COMM_RECV) {

    /* Communications error; close and reopen PLC */
    plc_close(plc_ptr);
    plc_ptr=plc_open(PLC_OPEN_STRING);
    if(!plc_ptr) {
      plc_print_error(plc_ptr, "Reopening PLC");
      exit(1);  /* Unrecoverable error */
    }
  } else if(plc_ptr->j_error != PLCE_TIMEOUT) {
    /* A non-timeout has occurred; something is wrong with the program */
    exit(1);
  }
}
```

See plc_error( ) on page 31 for more information on checking the returned error code of a read/write request.

Note	The plc_write( ) function cannot be used in **slave** PLC mode (unsolicited communication). Use plc_receive( ) and plc_reply( ) instead.

plc_read( ) – Slave Mode

int plc_read(PLC *plc_ptr, int j_op, char *pc_addr, void *p_data, int j_length, int j_timeout, char *pc_format)

In **slave** mode (unsolicited communication), this function waits for a write request to be received from the PLC. If a request is received within the allotted *j_timeout* milliseconds, then PLCIO will send back a successful reply to the PLC, copy the received data to *p_data*, and return control back to the application program.

This function will ignore any PLC request except a Write-Registers (PLC_SLAVE_WREGS) operation. For more fine-grained control over accepting requests and sending the reply, use the plc_receive( ) and plc_reply( ) functions instead (see page 28).

Some modules may need to keep a TCP/IP socket connected to the PLC or to a local daemon program to receive requests. This function can return error code PLCE_COMM_RECV if the connection is dropped. In this case, the *plc_ptr->j_errno* value contains the UNIX *errno* with the reason of failure.

Note	PLCIO internally implements this function as a shortcut for plc_receive( ) and plc_reply( ). Unlike plc_receive( ), the byte-order of the returned data is converted according to the *pc_format* string.

Arguments

This function takes the same arguments as in **master** PLC mode, except that the arguments *j_op* and *pc_addr* are ignored (set these arguments to 0 and NULL). Use 0 for *j_timeout* to wait indefinitely for a response from the PLC. Use 1 for *j_timeout* to poll the PLC for any pending requests without halting the application program. See “plc_read( ), plc_write( ) – Master Mode” on page 24 for more details.

Return Value

If successful, this function returns the length in bytes of the write request, as received from the PLC. It returns -1 on error.

A return value of 0 means the PLC successfully sent a 0-byte message to the application.

General Errors

PLCE_NULL	Function called with NULL PLC pointer.
PLCE_NO_SUPPORT	Function not supported by this PLC module.
PLCE_INVALID_LENGTH	Function called with invalid *j_length* (less than 1 or greater than PLC_CHAR_MAX).
PLCE_RECV_TOO_LARGE	Received an unsolicited message with a size greater than the application’s *j_length* argument.
PLCE_CONV_FORMAT	Unknown character found in conversion string *pc_format*.
PLCE_SELECT	An error occurred while managing the list of connected PLCs. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_COMM_RECV	A transport error occurred while waiting for a request from the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_COMM_SEND	A transport error occurred while sending the reply back to the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_TIMEOUT	No request was received after *j_timeout* milliseconds have elapsed. *plc_ptr->j_errno* is set to ETIMEDOUT.
PLCE_MSG_TRUNC	Received a request from the PLC too small to process.

plc_receive( )

**int plc_receive(PLC *plc_ptr, int j_op, PLCSLAVE *ps_slave, void *p_data, int j_length,
int j_timeout)**

This function is used in conjunction with plc_reply( ) to poll for unsolicited requests from the PLC. While this method is slightly more complex than plc_read( ), it gives the application greater flexibility to control responses to the PLC for many different types of requests.

In slave mode, PLCIO handles two types of requests: PLC_SLAVE_WREGS (Write-Registers request from the PLC), and PLC_SLAVE_RREGS (Read-Registers request, where the application can respond with data). In Streaming I/O mode, a third type is handled: PLC_STREAM_INPUT, in which no reply back to the PLC is required. The *j_op* argument lets applications selectively receive (or ignore) messages from the PLC by their request type.

Arguments

PLC *plc_ptr	The PLC communications object as returned from the plc_open( ) call.
int j_op	This is a bit mask of accepted types of PLC requests. PLCIO will transfer control back to the application after receiving a request that matches *j_op*. Use a bitwise-OR to poll for several types of requests at a time. Possible flags for *j_op* are:

PLC_SLAVE_WREGS	PLC is sending register data to the application.
PLC_SLAVE_RREGS	PLC is requesting to read register data from the application.
PLC_STREAM_INPUT	PLC is sending streaming input packets to the application.

In slave mode, PLCIO will automatically call plc_reply( ) with the PLC_SLAVE_NAK operation for all PLC requests that do not match a flag in *j_op*, and the request will effectively be ignored. Control only returns to the application when a request is accepted or when the timeout expires.

PLCSLAVE *ps_slave	Pointer to a locally declared structure that will get filled with information about the PLC packet received. The structure has the following members:

int j_length	Length of the incoming read/write request, in bytes. For write requests, this indicates how many bytes were written to the *p_data* buffer.
int j_type	Contains the PLC request type—one of the *j_op* flags above.
int j_offset	An offset, address, or file number that the PLC is sending to or reading from. This value is PLC-specific.
int j_ipaddr	The IP Address of the sender, in network byte-order.
int j_fileno	The destination file number. This value only pertains to messages sent by Allen-Bradley PLCs.
int j_sequence	The sequence number identifying the Streaming I/O packet.

void *p_data	Pointer to a buffer area to receive data from the PLC during a PLC_SLAVE_WREGS or PLC_STREAM_INPUT request.
int j_length	The size of the *p_data* buffer, in bytes. This sets the maximum allowed size of a Write-Registers request. If a PLC sends a request larger than this value, an error will be returned to the application.
int j_timeout	The maximum amount of time to wait for a PLC request, in milliseconds. If no accepted request has been received in the allotted time, this function will return -1 with the error code PLCE_TIMEOUT. Use 0 to disable the timeout, or 1 to poll for any available PLC requests without halting the application.

Return Value

This function returns 0 if successful, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC or PLCSLAVE pointer.
PLCE_NO_SUPPORT	Function not supported by this PLC module.
PLCE_INVALID_MODE	PLC was opened in **master** mode.
PLCE_INVALID_LENGTH	Function called with invalid *j_length* (less than 1 or greater than PLC_CHAR_MAX).
PLCE_RECV_TOO_LARGE	Received an unsolicited message with a size greater than the function's *j_length* argument. The incoming message size is stored in *plc_ptr->aj_errorval[0]*.
PLCE_SELECT	An error occurred while managing the list of connected PLCs. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_COMM_RECV	A transport error occurred while waiting for a request from the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_COMM_SEND	A transport error occurred while sending the reply back to the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_TIMEOUT	No request was received after *j_timeout* milliseconds have elapsed. *plc_ptr->j_errno* is set to ETIMEDOUT.
PLCE_MSG_TRUNC	Received a request from the PLC too small to process.

Notes

The general order of operations when accepting unsolicited requests is as follows:

- Use plc_receive( ) to poll for a request from the PLC.
- Process data involved with that request.
- Use plc_reply( ) to send a success/fail response back to the PLC.
- Repeat.

Since plc_receive( ) can receive many different types of requests, this function does not perform any byte-order conversion. Applications must check the type of message received (from the *ps_slave* variable) and explicitly call plc_conv( ) to perform the conversion.

Application Example

In the following example, check_for_plc_data( ) is defined to poll for any pending requests from the PLC and return immediately. If there is a request, the buffer and length is passed to "process_write( )". If there is a read request, the buffer is filled with words counting up from 0 and returned to the PLC. In both cases, the application issues a plc_reply( ) acknowledgment using PLC_SLAVE_ACK to notify the PLC that the request was accepted.

The code that calls check_for_plc_data( ) below must check that it returns 1 for success. If it returns 0, then the PLC has been closed due to an error.

Polls for PLC read/write requests up to 200 bytes in length. j_timeout is set to 1 to poll and immediately return.

```
int check_for_plc_data(PLC *ptr)
{
  PLCSLAVE slave;
  short ai_data[100];
  int i, j_result;

  j_result=plc_receive(ptr, PLC_SLAVE_WREGS|PLC_SLAVE_RREGS, &slave, ai_data,
                       200, 1);

  if(j_result == -1) {
    if(ptr->j_error == PLCE_TIMEOUT)
      return 1;  /* Timeout = No request was present */

    /* Unexpected error received; print and close PLC */
    plc_print_error(ptr, "check_for_plc_data: plc_receive");
    plc_close(ptr);
    return 0;
  }
```

Use plc_conv( ) after a plc_receive( ) and before a plc_reply( ) that contains data.

```
  if(slave.j_type == PLC_SLAVE_WREGS) {
    plc_conv(ai_data, PLC_TOCPU, ai_data, slave.j_length, PLC_CVT_WORD);
    process_write(ai_data, slave.j_length);
    j_result=plc_reply(ptr, PLC_SLAVE_ACK, NULL, 0, 3000);
  } else if(slave.j_type == PLC_SLAVE_RREGS) {
    if(slave.j_length > 200) {
      j_result=plc_reply(ptr, PLC_SLAVE_NAK, NULL, 0, 3000);
```

Reply with a NAK if the PLC requests more data than the size of our buffer.

```
    } else {
      /* Fill buffer with 0, 1, 2, ... */
      for(i=0;i < slave.j_length/2;i++)
        ai_data[i]=i;
      plc_conv(ptr, PLC_TOPLC, ai_data, slave.j_length, PLC_CVT_WORD);
      j_result=plc_reply(ptr, PLC_SLAVE_ACK, ai_data, slave.j_length, 3000);
    }
  }

  if(j_result == -1) {
    /* Unexpected error when sending back reply */
    plc_print_error(ptr, "check_for_plc_data: plc_reply");
    plc_close(ptr);
    return 0;
  }

  return 1;
}
```

plc_reply( )

int plc_reply(PLC *plc_ptr, int j_op, void *p_data, int j_length, int j_timeout)

This function acknowledges an unsolicited request obtained from plc_receive( ). Applications can send back an ACK or NAK to accept or reject the request, respectively. If in response to a PLC_SLAVE_RREGS message, *p_data* and *j_length* should contain the message to return to the PLC.

Arguments

PLC *plc_ptr	The PLC communications object as returned from the plc_open( ) call.
int j_op	This value can be either PLC_SLAVE_ACK or PLC_SLAVE_NAK, corresponding to accepting or rejecting the request, respectively.
void *p_data	Pointer to a buffer of data to send back to the PLC. This parameter can be NULL if *j_length* is 0.
int j_length	The size of the response buffer, *p_data*, in bytes.
int j_timeout	The maximum amount of time to allow PLCIO to send back the response, in milliseconds. See j_timeout on page 25 for more information. Warning: Do not use 1 for this value.

Return Value

This function returns 0 if successful, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC pointer.
PLCE_NO_SUPPORT	Function not supported by this PLC module.
PLCE_INVALID_MODE	PLC was not opened in **slave** mode.
PLCE_INVALID_REPLY	Function called without first getting a successful plc_receive( ).
PLCE_INVALID_LENGTH	Function called with invalid *j_length* (less than 1 or greater than PLC_CHAR_MAX).
PLCE_REPLY_TOO_LARGE	Response is too big to fit in a single reply packet for this PLC.
PLCE_COMM_RECV	A transport error occurred while sending the reply back to the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_COMM_SEND	A transport error occurred while sending the reply back to the PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.
PLCE_TIMEOUT	Response could not be sent within *j_timeout* milliseconds. *plc_ptr->j_errno* is set to ETIMEDOUT.

plc_error( )

int plc_error(PLC *plc_ptr, int j_level, char *pc_data, int j_length)

This function retrieves the error code that occurred during the last PLCIO function call associated with *plc_ptr*. This function is provided for backward compatibility—new code should test *plc_ptr->j_error* for the most recent error code and *plc_ptr->j_errno* for the accompanying UNIX *errno* code (if any).

Arguments

PLC *plc_ptr	Pointer to the PLC object that stored the error.
int j_level	Ignored—this parameter exists for backward compatibility. Set to 0 for all new applications.

char *pc_data	A pointer to a character buffer to hold a human-readable error message. PLCIO sets this message dynamically based on the actual error in runtime. Although the error code might be identical in two cases, this message is written by the actual part of the library that generated the error. It can contain additional variables that more closely describe the cause of the error.
int j_length	Length of the buffer pointed to by *pc_data*. PLCIO will not write more than *j_length* characters to this buffer, including the terminating NULL character. You can use NULL for *pc_data* and 0 for *j_length* to disable retrieval of the error message.

Return Value

This function returns one of the PLCE-prefixed constants defined at the bottom of /usr/local/include/plc.h, or 0 (PLCE_OK) if the last function call succeeded. The return value is identical to *plc_ptr->j_error*.

Notes

General error codes are listed along with the documentation for each PLCIO function call. These codes are standard across all PLC types, with error numbers ranging from 1 to 99. Other errors caused by in-transit PLC communication through the “remote” module use 100 to 199 (see page 75). Further, each module can generate its own specific error codes in the range 200 and up—see individual module documentation in Chapter 5 for details.

Each PLCIO function call clears the error variables in *plc_ptr* before doing anything else. The *plc_ptr->j_error* value is set only when an error occurs and can be retrieved by the application until the next PLCIO function is called. The *plc_ptr->ac_errmsg[80]* variable contains a dynamic, human-readable error message set by PLCIO for the specific error. Some errors also set *plc_ptr->j_errno* and *plc_ptr->aj_errorval[0…8]* to reveal more detailed information for the application (these are documented specifically). In these cases, *j_errno* corresponds to the UNIX *errno* variable at the time the error occurred, and *aj_errorval[0…8]* contains additional values relating to the error in question.

Diagnosing Errors

Applications should use the following procedure for error checking:

- **PLCE_TIMEOUT.** Applications should first check for this non-fatal error after every function call. If received, applications should retry the call until it succeeds. Timeouts can occur from having the *j_timeout* parameter set too low in read/write requests or from poor network conditions. A timeout means that the underlying transport protocol is still active, but the PLC could not complete your request in the allotted time.

  Even when this error is returned, the PLC might still complete the request and send back a response. On most PLCs, PLCIO tags each transaction with a sequence number. On a retry, it ignores the responses from a prior sequence number. This ensures that all transactions are in sync with the application and that the latest response by the PLC is returned.

- **PLCE_COMM_SEND/RECV.** These errors occur when the underlying transport protocol (usually TCP/IP) becomes broken. Both send and receive errors can happen during a single read or write request. Applications should call plc_close( ) and plc_open( ) to close and reopen the link to the PLC, respectively.

Note	Some unsolicited modules listen for PLC connections on a local TCP/IP port. In these cases, no error might be returned for dropped connections, as it is PLCIO’s job to manage connections until a valid request reaches the application.

- **Other.** All other codes should be considered fatal errors, and the application should either exit or deal with these errors as they appear during development.

If tracing is enabled, all errors are logged to the file specified by $TRACE in plcio.cfg, or to the file specified in the plc_log_init( ) call. See $TRACE Keyword on page 14 for more information.

plc_print_error( )

void plc_print_error(PLC *plc_ptr, char *pc_string)

This function will print the current PLCIO error associated with *plc_ptr* to standard output, along with the error number and message. Its intent is to be used as a debugging aid during development.

Arguments

PLC *plc_ptr	Pointer to the PLC object that stored the error.
char *pc_string	A small string to display before the error message, like in the UNIX *perror()* function. This can be used to track which line in the application caused the error.

Return Value

This function returns no value.

plc_conv( )

int plc_conv(PLC *plc_ptr, int j_type, void *p_buf, int j_len, char *pc_format)

This function performs byte-order conversion on a data buffer *p_buf* for communication between PLC and application. This function is usually called internally by the PLCIO library during a plc_read( ) and plc_write( ), however, applications need to use this function explicitly to handle unsolicited communication with plc_receive( ) and plc_reply( ).

Arguments

PLC *plc_ptr	The PLC communications object as returned from the plc_open( ) call.	
int j_type	One of the following constants:	
	PLC_TOPLC	The buffer is being sent from the application to the PLC. This should be used before sending data via a plc_reply( ) call.
	PLC_TOCPU	The buffer is being sent from the PLC to the application. This should be used after receiving data from a plc_receive( ) call.
void *p_buf	Pointer to a buffer containing the data to be translated.	
int j_len	Length of the data in the *p_buf* buffer, in bytes.	
char *pc_format	This format string tells PLCIO how to convert the buffer. Refer to “char *pc_format” on page 25 for details on this argument.	

Return Value

This function returns 0 if successful, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC pointer.
PLCE_CONV_FORMAT	Unknown character found in conversion string *pc_format*.
PLCE_INVALID_LENGTH	Function called with invalid *j_length* (less than 1 or greater than PLC_CHAR_MAX).

plc_validaddr( )

int plc_validaddr(PLC *plc_ptr, char *pc_addr, int *pj_size, int *pj_domain, int *pj_offset)

This function checks the syntax of the address *pc_addr* and verifies that it is valid, without performing any communication to the PLC. If valid, it returns whatever PLC-specific knowledge it has regarding the address in the *pj_size*, *pj_domain*, and *pj_offset* variables.

This function can be used with either physical or soft PLC addressing, depending on how the PLC was opened. It can also be used in either **master** or **slave** mode.

Arguments

PLC *plc_ptr	The PLC communications object as returned from the plc_open( ) call.
char *pc_addr	The target memory or I/O address to validate on the PLC. This can be either a physical or soft address depending on how the PLC was opened.
int *pj_size	A pointer to an integer that gets the element or point size associated with *pc_addr*. For instance, this will return 0 for bit/coil data types, 2 for 16-bit words, and 4 for double words. Set this to NULL if you do not need the information.
int *pj_domain	A pointer to an integer that gets a PLC-specific domain or file number associated with *pc_addr*. This number can be used to identify groups of addresses in the PLC. Set this to NULL if you do not need the information.
int *pj_offset	A pointer to an integer that gets a PLC-specific offset associated with *pc_addr*. Set this to NULL if you do not need the information.

Return Value

This function returns 0 if successful, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC pointer.
PLCE_NO_SUPPORT	Function not supported by this PLC module.
PLCE_INVALID_POINT	Function called with NULL or empty *pc_addr* string.
PLCE_BAD_SOFTPOINT	Address *pc_addr* was not found in the Soft Point-configuration file.
PLCE_PARSE_ADDRESS	Could not identify PLC target data location due to error in *pc_addr* semantics (misplaced parentheses, brackets, etc).
PLCE_BAD_ADDRESS	Specified address does not physically exist on the PLC.
PLCE_ACCESS_DENIED	Remote read/write access is disallowed for this specific address.

Note Some modules might not associate a size, domain, or offset with an address. If this is the case, the module will always set these integers to 0.

plc_fd_set( )

int plc_fd_set(PLC *plc_ptr, fd_set *ps_readset, int *pj_nfds)

This function is used in conjunction with select( ) to poll for unsolicited PLC activity alongside other file descriptors or PLC modules in the application. Call this function in the same place where the UNIX FD_SET( ) function would normally be called. When called, the PLCIO module associated with *plc_ptr* will add one or more of its internal file descriptors to *ps_readset*—a pointer to an *fd_set* structure—for later use as the *readfds* argument to select( ). This function can be called as many times as necessary to add file descriptors for all opened PLC modules.

If select( ) returns a positive count, the function plc_fd_isset( ) (see below) can be called for each opened PLC module to determine if a PLC event has occurred. If plc_fd_isset( ) returns 1, then plc_read( ) or plc_receive( ) can be called (with the *j_timeout* argument set to 1) to immediately process the PLC event.

If a pointer to an integer is passed in for *pj_nfds*, it will be updated with one plus the maximum file descriptor number being used. This value can then be passed directly as the *nfds* argument to select( ).

This function can only be used in **slave** or **Streaming I/O** mode.

Special Considerations

PLCIO acts as a miniature server when listening for requests from PLCs. In this regard, it does all the things a normal server does: listen for connections, accept input, and handle closed connections. plc_fd_isset( ) will return true if there is activity that must be handled by the plc_read( ) or plc_receive( )

function, even if this activity is not enough to generate a full request. Therefore it is important to set the *j_timeout* argument to 1, so that the application will not block waiting to receive the rest of a partial request. PLCE_TIMEOUT errors returned from plc_read( ) or plc_receive( ) should be treated as a normal occurrence.

Application Example

The following example demonstrates how to poll a PLC in unsolicited mode while also waiting for keyboard input (on file descriptor *fd_kbd*) to come in:

```
FD_SET s_readset;
int j_nfds, j_result;

/* Main Loop */
while(1) {
  FD_ZERO(&s_readset);

  /* Add fd_kbd to the read set */
  FD_SET(fd_kbd, &s_readset);
  j_nfds=fd_kbd+1;

  /* Add PLCIO module FDs to the read set */
  if(plc_fd_set(plc_ptr, &s_readset, &j_nfds) == -1) {
    plc_print_error(plc_ptr, "plc_fd_set");
    exit(1);
  }

  /* Wait for input from either the PLC or the keyboard */
  j_result=select(j_nfds, &s_readset, NULL, NULL, NULL);
  if(j_result == -1) {
    perror("select");
    exit(1);
  }

  /* Check for keyboard input */
  if(FD_ISSET(fd_kbd, &s_readset))
    process_keyboard_input(fd_kbd);

  /* Check for PLC input */
  if(plc_fd_isset(plc_ptr, &s_readset)) {
    j_result=plc_receive(plc_ptr, PLC_SLAVE_WREGS|PLC_SLAVE_RREGS, &slave, ai_data,
                         200, 1);  /* Read the input with very little timeout */
    if(j_result == -1) {
      if(plc_ptr->j_error == PLCE_TIMEOUT)
        continue;  /* Normal situation: no request has been received yet */

      /* Otherwise we had a receive error */
      plc_print_error(plc_ptr, "plc_receive");
      continue;  /* Wait for more input */
    }

    plc_conv(plc_ptr, PLC_TOCPU, ai_data, slave.j_length, PLC_CVT_WORD);
    process_plc_input(ai_data, slave.j_length);
  }
}
```

Return Value

This function returns 0 if successful, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC pointer or *ps_readset* pointer.
PLCE_NO_SUPPORT	Function not supported by this PLC module.
PLCE_INVALID_MODE	PLC was opened in **master** mode.

plc_fd_isset( )

int plc_fd_isset(PLC *plc_ptr, fd_set *ps_readset)

This function is called to check whether *ps_readset* contains a file descriptor in use by the PLCIO module *plc_ptr*. It should only be called after select( ) returns a positive count. If plc_fd_isset( ) returns 1, then plc_read( ) or plc_receive( ) can be called (with *j_timeout* set to 1) to process any pending events and retrieve the next request from the PLC without blocking the application.

See plc_fd_set( ) above for more details.

Return Value

This function returns 1 if *ps_readset* contains a file descriptor in use by the PLCIO module *plc_ptr*, 0 if no file descriptor matches, or -1 if an error has occurred.

General Errors

PLCE_NULL	Function called with NULL PLC pointer or *ps_readset* pointer.
PLCE_NO_SUPPORT	Function not supported by this PLC module.
PLCE_INVALID_MODE	PLC was opened in **master** mode.

plc_set_cfgfname( )

void plc_set_cfgfname(const char *pc_path, const char *pc_file)

This function changes the path and filename that PLCIO uses to search for the PLCIO Configuration File and other related point configuration files on the system. The variable *pc_path* defaults to "/usr/local/cti/plcio/data/" for UNIX systems and "C:\Program Files\PLCIO\plcio\data\" for Windows systems. The variable *pc_file* defaults to "plcio.cfg".

To properly override the defaults, this function should be called before the first call to plc_open( ). Also be advised that the new *pc_path* string must end with a / character if on UNIX, or a \ character if on Windows.

Arguments

const char *pc_path	Specifies the new path to use for configuration information, up to 255 characters. Set this to NULL to leave the current path unchanged.
const char *pc_file	Specifies the new configuration filename to use, up to 63 characters. Set this to NULL to leave the current filename unchanged.

Return Value

This function returns no value.

plc_log_init( )

void plc_log_init(const char *pc_logfile)

This function sets the name of the logfile used by PLCIO for tracing and debugging PLC communications (see $TRACE Keyword on page 14). An application can change this value at any time during program execution—any open PLCs will write to the new file immediately. If a full path is not specified in *pc_logfile*, then the logfile is opened using the current working directory.

The *pc_logfile* argument can take two special keywords: PLC_LOG_NONE and PLC_LOG_TTY. PLC_LOG_NONE disables all writing to a logfile, just as if plc_log_init( ) was never called or $TRACE was never specified. PLC_LOG_TTY sets the logfile to the program's running terminal, if one exists.

An application can use plc_log_init( ) prior to opening a soft PLC in order to bypass reading the $TRACE keyword. However, if the logfile is set back to PLC_LOG_NONE, then the $TRACE keyword will go into effect as soon as the application opens the next soft PLC.

Return Value

This function returns no value.

Application Example

```
int main(int argc, char *argv[])
{
  PLC *ptr;

  /* Set trace file to the user's terminal */
  plc_log_init(PLC_LOG_TTY);

  /* Open access to PLC */
  ptr=plc_open("abeth plc5 192.168.1.10");

  ...
}
```

Global Variables

The PLCIO library only exports the following global variables to application programs:

j_plcio_open_timeout

This variable provides a means of overriding the built-in timeout for connecting to a PLC with the plc_open( ) call. Normally, this value is preset based on the module being used, or specified in the Timeout field in the PLCIO Configuration File (see page 13 for details).

Set this variable to a number greater than zero to specify a timeout in milliseconds. Setting it to -1 disables the timeout. Setting it to 0 turns off the override (this is the default).

This variable is used by PLCIO only at the time plc_open( ) is called.

j_plcio_ipaddr

This global variable tells PLCIO to bind new TCP or UDP sockets to a specific IP Address (or Ethernet interface) when listening for unsolicited requests. It is only referenced during the plc_open( ) step when opening a PLC for slave communication. The default value for *j_plcio_ipaddr* is INADDR_ANY (0), which means to listen for unsolicited requests on all available Ethernet interfaces. The value specified must be one of the IP Addresses assigned to the system (in network byte-order), or the plc_open( ) call will fail.

The following code snippet demonstrates how to listen for incoming connections only to 192.168.1.1:

```
#include <arpa/inet.h>   /* Use <winsock.h> instead if on Windows */
#include <plc.h>

int main(int argc, char *argv[])
{
  PLC *ptr;

  /* Listen for messages only for ethernet interface 192.168.1.1 */
  j_plcio_ipaddr=inet_addr("192.168.1.1");

  /* Open the PLC for slave communication */
  ptr=plc_open("abeth");

  ...
}
```

j_plcio_ipaddr is reserved specifically for the application to set and is not modified by the library.

j_plcio_logsize

This variable specifies the maximum size of the logfile (in bytes) before rotation occurs. If this variable is zero or negative, then logfile rotation is disabled. Note that if the $LOGSIZE keyword is specified in the plcio.cfg file, then the *j_plcio_logsize* variable will be updated by PLCIO every time a soft PLC is opened. See $LOGSIZE Keyword on page 15 for more information.

plcio_version

This read-only variable allows the application to determine the version and release date of the currently running PLCIO library. The variable points to a string that reads like “4.1.0 - 06/15/2007” (month/date/year), except it is instead filled with the correct version number and date.

plc_open_ptr

This variable points to a temporary PLC object that acts as a substitute for *plc_ptr* when plc_open( ) returns NULL on error. It can be used to determine the cause of error, either by calling plc_print_error(plc_open_ptr, “plc_open”) or by checking the error directly using *plc_open_ptr->j_error* and *plc_open_ptr->ac_errmsg*. All data in this variable is cleared on each successive call to plc_open( ). See plc_open( ) on page 21 for more details.

5 PLC MODULES

PLC manufacturers use a variety of proprietary communication protocols. Even in a single company numerous different PLC models can be deployed, each with their own spin on performing a similar task. This chapter explains how to configure PLCIO to access a specific supported PLC.

Introduction

PLCIO uses dynamically loadable modules to communicate with a specific PLC model. Having loadable modules minimizes the resident memory overhead, loading only the parts of PLCIO that a program is specifically going to use.

These shared objects are installed in /usr/local/cti/lib, the same directory where libplc.so.1 resides. They are named libplcxxx.so (.sl on HP-UX or .dll on Windows), where “xxx” is the name of the module. Modules are loaded when plc_open( ) is called, and they remain in memory until the program exits.

Each of the following sections covers a specific PLC module, its parameters to the plc_open( ) function, and any additional errors that can be returned by the PLCIO API.

Syntax

In the plc_open( ) parameters for each module, the following conventions are used:

phrase	- Phrases with no markings are to be inserted verbatim.
<argument>	- Words marked <> are to be replaced with an argument (don’t type the <>).
<arg1|arg2>	- Argument must be either “arg1” or “arg2”.
[argument]	- Parameters in [ ] brackets are optional and may be omitted.

abdf1 – Allen-Bradley PLC5/SLC500 over Serial (DF1)

This module supports sending solicited PCCC messages to an Allen-Bradley PLC over a serial interface using the DF1 protocol. It can be used to read and write registers and coils on a PLC-5 or SLC 5/00 series PLC.

Open Parameters

Master: abdf1 [plc5|slc500] <device>[:baud:bits:parity:stopbits:flowctrl] <remote node> [bcc|crc] [Local=Node#]

<device> is a UNIX serial device name, such as “/dev/ttyS0” on Linux or “COM1” on Windows. The colon-separated serial parameters are optional and, if not specified, default to the most common DF1 configuration: “19200:8:N:1”. The optional argument “plc5” or “slc500” can be used to instruct the module to use PLC-5 or SLC 500 Typed Reads and Writes in making requests to the PLC, respectively. If omitted, it will default to PLC-5 messaging.

<remote node> is a required parameter with an integer value from 0 to 254 that addresses the destination PLC node on the DF1 network. For serial I/O links that only connect to a single PLC, use node 0 as the destination.

The optional parameter [bcc|crc] selects what type of checksumming is to be used by PLCIO. The DF1 protocol defines two types of checksums for data transmissions: BCC (block check character) and CRC (cyclic redundancy check). Both methods guard against noise on the serial line and automatically force a retransmission of data if the message is received corrupted. However, BCC is weaker in that it cannot detect when NUL bytes (00 hex) are randomly added anywhere in the message. This selection must match what is configured for the serial port’s settings on the PLC. If omitted, the more capable CRC method is used by default.

The optional parameter [Local=Node#] allows the PLCIO application to select the source node to use on the DF1 network. Valid source nodes are from 0 to 254. If omitted, the default node 0 is used.

PLCIO does not support unsolicited requests over the serial DF1 protocol.

Timeout

The default timeout for connecting to an Allen-Bradley PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
/* Connect to a PLC-5 on device ttyS0 */
plc_open("abdf1 /dev/ttyS0 0");

/* Connect to a SLC 5/00 on node 4 of a DF1 network using 9600 baud */
plc_open("abdf1 slc500 /dev/ttyS0:9600 4");

/* Use BCC checksumming instead of CRC, with source node 1 */
plc_open("abdf1 /dev/ttyS0 0 bcc Local=1");
```

Point Addressing

Syntax: <type><file number>:<starting register #>[/coil | .suffix]

<type> refers to one of the Valid Data Types below. <file number> can be 0 to 99 and refers to a specific array of similarly-typed registers in the PLC’s memory. Files 0 through 7 are hard-defined by the PLC to be a specific data type (shown below), and files 8 to 99 can be user-defined for any type on the PLC.

Hard-defined File Numbers

0 – Output	4 – Timer
1 – Input	5 – Counter
2 – Status	6 – Control
3 – Byte	7 – Integer

Valid Data Types

O – Output	C – Counter	A – ASCII
I – Input	R – Control	ST– String
S – Status	N – Integer	L – Long Int.
B – Byte	D – BCD	
T – Timer	F – Floating Pt.	

Using <file number> with Outputs, Inputs, and Status is disallowed, as these data types can only be assigned to file numbers 0, 1, and 2 respectively.

Also, when using PLC-5 messaging, the <starting register #> and [/coil] values for Outputs and Inputs must be specified in **octal**, while all other file numbers must use values specified in decimal. When using SLC 5/00 messaging, all values must be specified in decimal.

For [/coil], special keywords can be used to retrieve data about timers (T), counters (C), and controls (R). Keywords /EN, /TT, and /DN are supported for timers. Keywords /CU, /CD, /DN, /OV, /UN, and /UA are supported for counters. And last, keywords /EN, /EU, /DN, /EM, /ER, /UL, /IN, and /FD are supported for controls.

For [.suffix], keywords .CTL, .PRE, and .ACC are supported for timers (T) and counters (C). Additionally, keywords .CTL, .LEN, and .POS are supported for controls (R).

The *abdf1* module supports the following *j_op* operations for the plc_read( ) and plc_write( ) functions:

PLC_RREG	PLC_WREG	- Read/write word registers (2 bytes per element)
PLC_RLONG	PLC_WLONG	- Read/write floating-point registers (4 bytes per element)
PLC_RCOIL	PLC_WCOIL	- Read/write coils (2 bytes per bit)
PLC_RBYTE	PLC_WBYTE	- Read/write string registers (1 byte per element, 82 max)
PLC_RCHAR	PLC_WCHAR	- Read/write ASCII registers (1 byte per element)
PLC_RLONGINT	PLC_WLONGINT	- Read/write long-word registers (4 bytes per element)

When reading and writing registers, data is packed in the buffer one element after another. With coils (single boolean bits), each 2-byte word determines if a single coil is energized (non-zero) or de-energized (zero). The PLC_WCOIL command can only write one coil at a time.

Addressing Examples

N7:0	Addresses the first integer register.
N10:50	Addresses register 50 (byte 100) of file 10 (using Integer data type).
F12:50	Addresses register 50 (byte 200) of file 12 (using Floating-Point data type).
I:3	Addresses register 3 (byte 6) of file 1 ("I" type is always file 1).
I:3/5	Addresses the 6th coil (bit 5) in register 3 of file 1 (the "3" is an octal number).
T4:0.ACC	Addresses the accumulator in timer 0 of file 4.
R6:2/EN	Addresses the enable bit in control 2 of file 6.

Programming Examples

Example 1: This writes the decimal values "50, 100, 150" to N7:0, N7:1, and N7:2.

```
short ai_data[3]={50, 100, 150};
j_result=plc_write(ptr, PLC_WREG, "N7:0", ai_data, 6, 3000, PLC_CVT_WORD);
```

Example 2: This reads a single coil from I:2/10 (reading coils returns 2 bytes per coil) into ai_buffer[0].

```
short ai_buffer[5];
j_result=plc_read(ptr, PLC_RCOIL, "I:2/10", ai_buffer, 2, 3000,
                  PLC_CVT_WORD);
```

Additional Errors

PLCE_DF1_PCCC_ERROR	210	A PLC error occurred during a PCCC command. The error-status byte is stored in *plc_ptr->aj_errorval[0]*, and the extended status (if any) is stored in *plc_ptr->aj_errorval[1]*.

abeth – Allen-Bradley PLC5/SLC500 over Ethernet

This module supports sending solicited PCCC messages to an Allen-Bradley PLC over Ethernet. It can be used to read and write registers and coils on a PLC-5 or SLC 5/00 series PLC.

Open Parameters

Master:	abeth [plc5|slc500] <address>[:port]
Slave:	abeth

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the PLC's Ethernet interface on the network. PLCIO will attempt to connect to this host using TCP port 2222, or [port] if specified. The optional argument "plc5" or "slc500" can be used to instruct the module to use PLC-5 or SLC 500 Typed Reads and Writes in making requests to the PLC, respectively. If omitted, it will default to PLC-5 messaging.

Timeout

The default timeout for connecting to an Allen-Bradley PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Unsolicited Communication

If no parameters are given after the "abeth", then this module will be opened in **slave** (unsolicited) mode. The module will open TCP port 2222 on the local system to listen for connections from a PLC. Applications can change the local bind address (normally INADDR_ANY) by setting the global variable *j_plcio_ipaddr* to a new address in network byte-order before each plc_open( ) call.

In unsolicited mode, this module can accept PLC-2 Unprotected, PLC-5 Typed, and SLC 500 Typed Reads and Writes simultaneously from multiple PLCs. The plc_reply( ) function will send a reply back to the PLC in the style of messaging that was received.

Note	Only one unsolicited receiver may run on a single local address. This is a limitation of TCP/IP in that only one application may bind to a given TCP port.

Open Examples

```
plc_open("abeth host.domain:2222");  /* Use gethostbyname(), PLC-5 (default) */
plc_open("abeth slc500 10.0.0.2");   /* Direct IP address, SLC 500 messaging */
plc_open("abeth");                   /* Open local port for slave mode */
```

Point Addressing

Point addressing and programming examples are exactly like those explained for the *abdf1* module. Refer to the "abdf1 – Allen-Bradley PLC5/SLC500 over Serial (DF1)" section on page 40 for more information.

Additional Errors

PLCE_DF1_PCCC_ERROR	210	A PLC error occurred during a PCCC command. The error-status byte is stored in *plc_ptr->aj_errorval[0]*, and the extended status (if any) is stored in *plc_ptr->aj_errorval[1]*.
PLCE_DF1_BAD_ADDR	211	Received a PCCC request for an invalid or unsupported address.
PLCE_DF1_BAD_MSG	212	Received a corrupted multi-part PCCC request from the PLC in unsolicited mode.

cip – Allen-Bradley Logix 5000 Family over EtherNet/IP

This module supports reading and writing data to a ControlLogix, CompactLogix, FlexLogix, or SoftLogix PLC using the Common Industrial Protocol (CIP) encapsulated by EtherNet/IP. Applications can access PLC variables directly by using the tag names stored for each object.

Open Parameters

Master: cip <address>[:port] [Path=<route>|Slot=#] [FwdOpen|LateFwdOpen] [Interval=#] [LoadTags]

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the EtherNet/IP interface on the Logix PLC rack. PLCIO will attempt to connect to this host using TCP port 44818, or [port] if specified.

[Path=<route>] is an optional parameter that specifies a comma-separated route, from the EtherNet/IP interface to the PLC's CPU, through the CIP network (see Routes below for examples). For configurations where the CPU is located on the same rack as the EtherNet/IP card, the simpler [Slot=#] parameter can be used instead, where # refers to the slot number of the CPU on the rack (slots are numbered starting from 0). "Slot=n" is equivalent to "Path=1,n". If either [Path=<route>] or [Slot=#] is not specified, then the rack is scanned and the first CPU detected is used.

[FwdOpen] or [LateFwdOpen] are optional parameters that instruct PLCIO to create a CIP connection to the target CPU, rather than use unconnected messaging to send requests. Connected messaging reserves a transport connection to the CPU, which increases reliability at the expense of having a slightly longer round-trip latency (unconnected messages may be ignored by the CPU whenever its maximum number of connections are reached). The difference between using [FwdOpen] and [LateFwdOpen] is that [LateFwdOpen] will use connected messaging only after reading all tag information (when the [LoadTags] option is specified), thus speeding up the initial plc_open( ) step. Not all CPUs support connected messaging.

[Interval=#] is an optional parameter that sets the Requested Packet Interval (RPI) value in the CIP connection. It is only used during connected messaging, and denotes the longest delay anticipated between two subsequent PLCIO requests, in milliseconds. If the target CPU does not receive a request within 4 times this value, then the target CPU will consider the connection to have been dropped, and all further requests will be ignored. This value should be set as low as possible in order for the target CPU to drop broken connections from its list in a timely manner. [Interval=#] defaults to 16 seconds, permitting a delay of up to one minute between requests. An optional *us*, *ms*, or *s* can be appended to the number to specify microseconds, milliseconds, or seconds, respectively.

[LoadTags] is an optional parameter that reads all tags, programs, and user-defined structures from the PLC when plc_open( ) is called. It is used by programs to display the contents of all PLC tags or to extract structure data (such as member names, data types, and byte-offset information) for a particular tag. On PLCs with thousands of tags defined, this option can delay plc_open( ) by upwards of 60 to 180 seconds. If this is the case, you can override the default timeout by specifying a timeout value in the PLCIO Configuration File (see page 13) or by setting the *j_plcio_open_timeout* global variable (see page 37) prior to calling plc_open( ).

This module cannot be used for unsolicited requests. Use the *enip* module instead.

Timeout

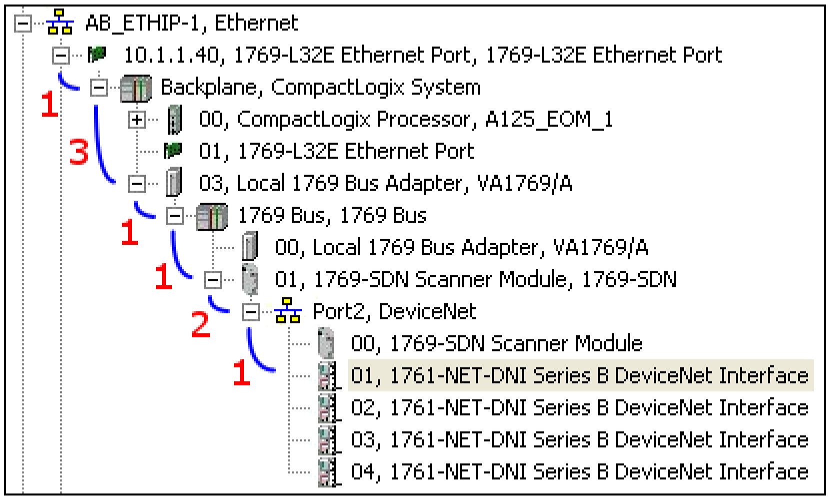
The default timeout for connecting to a Logix 5000 family PLC is 5 seconds if [LoadTags] is not specified, otherwise 60 seconds. This can be changed in the PLCIO Configuration File.

Routes

The connection path ([Path=<route>] parameter) determines where requests are routed on the CIP network once they reach the EtherNet/IP interface. Up to 16 pairs of comma-separated values can be specified. Each pair consists of two numbers: the outgoing port on the device, and the target node or address on the device's network. For instance, the route from the EtherNet/IP device usually starts out with “1,n”, where port 1 refers to the connection to the backplane, and “n” is the target slot number on the backplane.

Ports range from 0-65535, and target nodes range from 0-255. Port names can be used in place of port numbers—for instance, the term “Backplane” always refers to port 1, and terms “A” through “Z” refer to ports 2 through 27, respectively. When communicating via an Ethernet Bridge such as 1756-ENBT, the target node can be an IP Address. A path such as “Path=Backplane,6,A,10.1.1.40,Backplane,8” breaks down as “Slot 6 of initial Logix rack (where ENBT card is located) → EtherNet/IP 10.1.1.40 → Slot 8 of secondary Logix rack”. Only one IP Address can be specified in a connection path.

The connection path to the CPU can be determined by using the RSWho utility in the RSLinx software application from Rockwell Automation. The following example shows the CIP route from an EtherNet/IP device located at IP Address 10.1.1.40, to a CPU behind a DeviceNet scanner. The resulting [Path=<route>] parameter can be entered as “Path=1,3,1,1,2,1”.


```
AB_ETHIP-1, Ethernet
  10.1.1.40, 1769-L32E Ethernet Port, 1769-L32E Ethernet Port
    Backplane, CompactLogix System
      00, CompactLogix Processor, A125_EOM_1
      01, 1769-L32E Ethernet Port
      03, Local 1769 Bus Adapter, VA1769/A
        1769 Bus, 1769 Bus
          00, Local 1769 Bus Adapter, VA1769/A
          01, 1769-SDN Scanner Module, 1769-SDN
            Port2, DeviceNet
              00, 1769-SDN Scanner Module
              01, 1761-NET-DNI Series B DeviceNet Interface
              02, 1761-NET-DNI Series B DeviceNet Interface
              03, 1761-NET-DNI Series B DeviceNet Interface
              04, 1761-NET-DNI Series B DeviceNet Interface
```

Open Examples

```
plc_open("cip host.domain:44818");      /* Auto-detect CPU on the rack */
plc_open("cip 10.0.0.2 Slot=2");        /* Direct IP address, CPU in 3rd slot */
plc_open("cip 10.0.0.2 Path=1,2,2,1"); /* Extended route through CIP network */
```

Point Addressing

Syntax: [program name:]<tag name>[.bit][(offset)]

The most common way to address a tag is by simply using its name. Tags on the Logix PLCs have a data type and size associated with them. When addressing a 2-byte INT tag, for instance, you will only be able to read and write at most 2 bytes. If a tag describes an array of data items, array indexes can be specified using “[#]” after the tag name, where # is the index of the array (you can specify up to three array dimensions: e.g. tagname[10][5][2] or tagname[10,5,2]). Likewise, if a tag describes a structure, then members of that structure can be accessed using “tagname.member”. Tag names are not case-sensitive.

Using [(offset)], it is possible to read and write starting at some number of bytes from the beginning of the start of the tag. This can be used interchangeably with array indexes—for instance, “tagname[10](3)” addresses the 4th byte from the beginning of “tagname[10]”.

It is also possible to read from or write to a single boolean bit in a tag. Use the [.bit] suffix after the tag name to specify the bit number to access, starting from 0. For example, “tagname.12” refers to the fifth bit of the second byte of “tagname”.

The optional [program name:] parameter restricts tag name lookup to only those tags in the specified program. If no program name is specified, then only tags in the global scope are addressed.

Addressing Examples

Assuming the following structure in the PLC's memory:

```
Structure Name: Device
{
  Length   SINT
  Points   INT[10]
  Timer    TIMER
}
```

the following addresses are legal:

device	Addresses the entire structure of data.
device.length	Addresses the 1-byte length member.
device.points	Addresses the entire *points* array.
device.points[6]	Addresses the 12th and 13th byte of the *points* array.
device.points[6].2	Addresses the third bit of the 12th byte in the array.
device.timer(2)	Addresses *timer* starting with the third byte in the object.
device.points[9](1)	Addresses the second byte of the *points[9]* index.
Program:device	Addresses the *device* tag included in program name *Program*.
Local:0:I.Data[6]	Addresses the 7th byte in the local array of PLC inputs.

Because a tag includes information about the type and size, the *j_op* parameter of the plc_read( ) and plc_write( ) functions is ignored.

Application Examples

Structure elements in PLC memory are aligned according to their members' sizes. An normal Integer (INT) must always begin on a 2-byte boundary, and a Double Integer (DINT) must begin on a 4-byte boundary. Arrays also must begin on a 4-byte boundary. The following PLC structure:

```
Structure Name: Object
  Flags    BOOL[32]
  Input    INT[3]
  Output   INT[2]
  Data     SINT[40]
```

is represented in C as:

```
struct Object {
  unsigned int Flags;
  short Input[3];
  short __pad1;    /* 2-byte pad since Output begins on a 4-byte boundary */
  short Output[2];
  char Data[40];
};
```

This structure could be referenced in an application using the following C code:

```
struct Object data;
int j_len;

j_len=plc_read(plc_ptr, 0, "Object", &data, sizeof(data), 3000, "j4i12c40");
```

Note When accessing structures using CIP, be sure to include a *pc_format* string that fully describes its members. See the 'showcip' utility below for ways to generate a format string based on a structure's data type.

The showcip Utility

The ‘showcip’ utility in the PLCIO “examples/” directory can be used as an aid for defining C structures for applications that use a Logix family PLC. Note that applications need not use #pragma to pack PLC-based structures, since all alignment is stricter on the PLC than in C. However, sometimes special *__pad* variables need to be inserted in various places in C structures to cover the cases where alignment is forced on the PLC.

This program can be used to display the current data value of a tagname, list all available tags, programs, or structures, and display the C-style structure definition for a particular tagname. It accepts these options:

```
Usage: showcip [options] hostname[:port] [tagname]
Options:
   -b           Display data values in Binary
   -d           Display data values in Decimal
   -o           Display data values in Octal
   -x           Display data values in Hexadecimal
   -n #         Make the "Tag Name" column # characters wide
   -a #         Make the "Alias For" column # characters wide
   -t #         Make the "Type" column # characters wide
   -v #         Make the "Value" column # characters wide
   -c slot      Specify slot number of CPU in rack
   -l logfile   Specify the name of the logfile for debugging
   -e           Expand all arrays during display
   -s           Show C-style structure definition for [tagname]
   -V           Increase verbosity; can be used up to 4 times
```

Additional Errors

PLCE_CIP_COMM_ERROR	200	A communications error occurred while routing the CIP command to the PLC. The error-status byte is stored in *plc_ptr->aj_errorval[0]*. The 2-byte routing-error code is stored in *plc_ptr->aj_errorval[1]*.
PLCE_CIP_CPU_SLOT	201	Failed to auto detect the slot number where the CPU resides on the rack. Specify “Slot=#” explicitly to correct the problem.
PLCE_CIP_BAD_TAG	202	Received a PLC error or malformed packet while requesting data type and size information for each tag at startup.
PLCE_CIP_RPI_EXCEEDED	204	Attempted to send a request after 4 times the RPI value has elapsed when using connected messaging.

cipab – Allen-Bradley PLC5/SLC500 over EtherNet/IP

This module supports sending solicited PCCC messages using the Common Industrial Protocol (CIP) encapsulated by EtherNet/IP. It can be used to send Typed Reads and Writes to a PLC-5 or SLC 5/00 series PLC either directly to a PLC's EtherNet/IP interface slot or via a Logix gateway over EtherNet/IP.

Open Parameters

Master: cipab [plc5|slc500] <address>[:port] [Path=<route>] [FwdOpen] [Interval=#]

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the EtherNet/IP interface on the network. PLCIO will attempt to connect to this host using TCP port 44818, or [port] if specified. The argument "plc5" or "slc500" can be specified to instruct PLCIO to use PLC-5 or SLC 5/00 Typed Reads and Writes in making requests to the PLC, respectively. If omitted, it will default to PLC-5 messaging.

The [Path=<route>] argument is optional. If specified, then this module will communicate through a Logix gateway to reach the PLC. In this mode, <address> is the IP Address of the EtherNet/IP module on the Logix rack, and <route> is a comma-separated route, from the EtherNet/IP interface to the PLC, through the CIP network. See section Routes under the *cip* module on page 43 for examples.

[FwdOpen] is an optional parameter that instructs PLCIO to create a CIP connection to the target CPU, rather than use unconnected messaging to send requests. Connected messaging reserves a transport connection to the CPU, which increases reliability at the expense of having a slightly longer round-trip latency (unconnected messages may be ignored by the CPU whenever its maximum number of connections are reached). Not all CPUs support connected messaging.

[Interval=#] is an optional parameter that sets the Requested Packet Interval (RPI) value in the CIP connection. It is only used during connected messaging, and denotes the longest delay anticipated between two subsequent PLCIO requests, in milliseconds. If the target CPU does not receive a request within 4 times this value, then the target CPU will consider the connection to have been dropped, and all further requests will be ignored. This value should be set as low as possible in order for the target CPU to drop broken connections from its list in a timely manner. [Interval=#] defaults to 16 seconds, permitting a delay of up to one minute between requests. An optional *us*, *ms*, or *s* can be appended to the number to specify microseconds, milliseconds, or seconds, respectively.

This module cannot be used for unsolicited requests. Use the *enip* module instead.

Timeout

The default timeout for connecting to an Allen-Bradley PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
/* This example opens a PLC-5-style connection to a PLC with a built-in EtherNet/IP
   interface. The default port 44818 is assumed: */

plc_open("cipab host.domain");

/* This example routes SLC 5/00-style messaging to a PLC connected through a
   DeviceNet controller populated in slot 4 on a Logix rack, via port B (port 3),
   at node 2: */

plc_open("cipab slc500 10.0.0.2 Path=1,4,3,2");
```

Point Addressing

Point addressing and programming examples are exactly like those explained for the *abdf1* module. Refer to the "abdf1 – Allen-Bradley PLC5/SLC500 over Serial (DF1)" section on page 40 for more information.

Additional Errors

PLCE_CIP_COMM_ERROR	200	A communications error occurred while routing the CIP command to the PLC. The error-status byte is stored in *plc_ptr->aj_errorval[0]*. The 2-byte routing-error code is stored in *plc_ptr->aj_errorval[1]*.
PLCE_CIP_RPI_EXCEEDED	204	Attempted to send a request after 4 times the RPI value has elapsed when using connected messaging.
PLCE_DF1_PCCC_ERROR	210	A PLC error occurred during a PCCC command. The error-status byte is stored in *plc_ptr->aj_errorval[0]*, and the extended status (if any) is stored in *plc_ptr->aj_errorval[1]*.

cipdh – Allen-Bradley PLC5/SLC500 via DH+ over EtherNet/IP

This module supports sending solicited PCCC messages using the Common Industrial Protocol (CIP) encapsulated by EtherNet/IP. It uses Typed Reads and Writes for messaging to a PLC-5 or SLC 5/00 series PLC on Data Highway Plus network via a 1756-DHRIO interface card on a ControlLogix gateway.

Open Parameters

Master: cipdh [plc5|slc500] <address>[:port] Path=<route>,<port>,<node> [Interval=#]

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the EtherNet/IP interface on the network. PLCIO will attempt to connect to this host using TCP port 44818, or [port] if specified. The argument "plc5" or "slc500" can be used to instruct the module to use PLC-5 or SLC 5/00 Typed Reads and Writes in making requests to the PLC, respectively. If omitted, it will default to PLC-5 messaging.

The "Path=<route>,<port>,<node>" parameter specifies a comma-separated route, from the EtherNet/IP interface to the PLC's CPU, through the CIP network (see section Routes under the *cip* module on page 43 for examples). The route must end with <port> (the port on the DHRIO card—either A or B), and <node> (the node number of the PLC on the Data Highway Plus network, in decimal digits—not octal). For instance, if the PLC is node 6 on port B of the DHRIO card, and the card is in slot 2 on the ControlLogix rack, the path to use is "Path=1,2,B,6".

[Interval=#] is an optional parameter that sets the Requested Packet Interval (RPI) value in the CIP connection. It denotes the longest delay anticipated between two subsequent PLCIO requests, in milliseconds. If the target CPU does not receive a request within 4 times this value, then the target CPU will consider the connection to have been dropped, and all further requests will be ignored. This value should be set as low as possible in order for the target CPU to drop broken connections from its list in a timely manner. [Interval=#] defaults to 16 seconds, permitting a delay of up to one minute between requests. An optional *us*, *ms*, or *s* can be appended to the number to specify microseconds, milliseconds, or seconds, respectively.

This module cannot be used for unsolicited requests. Use the *enip* module instead.

Timeout

The default timeout for connecting to an Allen-Bradley PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
/* The following example opens a PLC-5-style connection to a PLC. The PLC is
   located on node 7, off port A of the DHRIO card in slot 4 on the rack: */

plc_open("cipdh host.domain:44818 Path=1,4,A,7");

/* This example uses SLC 5/00-style messaging to a PLC with an EtherNet/IP address
   of 10.0.0.2. The PLC is located on node 14 (decimal), off port B of the DHRIO
   card in slot 3 on the rack: */

plc_open("cipdh slc500 10.0.0.2 Path=1,3,B,14");
```

Point Addressing

Point addressing and programming examples are exactly like those explained for the *abdf1* module. Refer to the "abdf1 – Allen-Bradley PLC5/SLC500 over Serial (DF1)" section on page 40 for more information.

Additional Errors

PLCE_CIP_COMM_ERROR	200	A communications error occurred while routing the CIP command to the PLC. The error-status byte is stored in *plc_ptr->aj_errorval[0]*. The 2-byte routing-error code is stored in *plc_ptr->aj_errorval[1]*.
PLCE_CIP_RPI_EXCEEDED	204	Attempted to send a request after 4 times the RPI value has elapsed.
PLCE_DF1_PCCC_ERROR	210	A PLC error occurred during a PCCC command. The error-status byte is stored in *plc_ptr->aj_errorval[0]*, and the extended status (if any) is stored in *plc_ptr->aj_errorval[1]*.

cipio – Streaming I/O over EtherNet/IP

This module allows reading inputs and setting outputs directly on an I/O Bus Terminal, such as the Beckhoff BK9105 or the Phoenix Contact FL IL 24 BK ETH/IP-PAC, using the Common Industrial Protocol (CIP) encapsulated by EtherNet/IP. Multicast Network support must be enabled on the UNIX system in order to receive streaming inputs.

Open Parameters

Stream: cipio <address>[:port] Input=<bytes>[,interval,conc] Output=<bytes>[,interval,conc]

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the EtherNet/IP interface on the network. PLCIO will attempt to connect to this host using TCP port 44818 or [port], if specified.

The "Input=<bytes>" and "Output=<bytes>" parameters must be specified. These parameters set the size of the streaming input and output packets for each plc_receive( ) and plc_write( ). Packet sizes directly correlate to the number and types of I/O modules available on the device, however, different model devices could allocate more data or pack structures differently for the same amount of I/O than others. Consult the device manufacturer's documentation for the correct values to be used here.

An optional packet interval may be specified in *interval* for both input and output. With inputs, the interval determines how often the I/O device will send an input packet to the PLCIO application. The output interval, on the other hand, generally informs the I/O device how often the PLCIO application will send an output packet. The application is free to send updates faster than the output interval. However, if the remote device does not receive an output packet within 4 times the output interval, the device will close the connection and reset its outputs back to power-on defaults.

Packet intervals are specified in milliseconds. An optional *us*, *ms*, or *s* can be appended to the number to specify microseconds, milliseconds, or seconds, respectively. The default intervals for both input and output is 1 second.

Note	The I/O device terminates the connection if no output packets are received within 10 seconds of the connection being opened, regardless of the output interval specified.

An optional connection endpoint may be specified in *conc* for both input and output. This parameter addresses the instance on the device that processes input and output packets, which can vary between device models. Consult the device manufacturer's documentation for the correct values to be used here. The default input and output connection endpoints are 101 and 102, respectively.

Timeout

The default timeout for connecting to an I/O Bus Terminal is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
plc_open("cipio 10.0.0.2 Input=6 Output=8");  /* 3 input words, 4 output words */
plc_open("cipio 10.0.0.2 Input=6,2s Output=8");  /* Two seconds between inputs */
plc_open("cipio 10.0.0.2 Input=6,2s Output=8,1s,100");  /* Set output endpoint */
```

Communications

Communications with an I/O device are different than with a PLC, in that each packet received contains the entire input state of the device. This includes all digital and analog inputs and also the state of other on-board modules, such as timers or counters. Similarly, each packet sent must contain the entire output state, which is refreshed to all digital and analog outputs on the device when received. In order to change the state of a single output, the PLCIO application must also fill in the previous values of all other outputs in the output packet.

The data buffer in an input and output packet is composed of an array of 16-bit words. Although the behavior may differ across device models, each I/O module on the device will generally register one or more 16-bit words in either the input or output buffer. The application programmer must determine, through experimentation or documentation, the location (offset) and size of each I/O module in the buffer.

All I/O packets are transmitted over UDP with no acknowledgment of receipt. Due to the nature of UDP, packets can sometimes (although rarely) be duplicated, received in reverse order, or lost altogether. PLCIO makes no decision regarding packet order and forwards all received packets to the application for further analysis. An application wanting to detect lapses in packet ordering can monitor the *j_sequence* member of the returned PLCSLAVE object (see below). For output packets, however, there is no way to detect when a single packet fails to reach its destination.

If no output packets reach their destination within 4 times the specified output interval, the remote device will close the connection. This state can be detected by the PLCIO application because it will no longer be receiving input packets in the requested packet interval. In this state, the only way to resume connectivity is to close and reopen the I/O device.

To receive input packets, call either the plc_read( ) function with *j_op* set to 0 and *pc_addr* set to NULL, or the plc_receive( ) function with *j_op* set to PLC_STREAM_INPUT. plc_reply( ) should not be called after a received packet. The PLCSLAVE object returned from plc_receive( ) will have its *j_type* member set to PLC_STREAM_INPUT and its *j_sequence* member filled in from the EtherNet/IP layer.

Send an output packet by calling the plc_write( ) function with *j_op* set to 0 and *pc_addr* set to NULL. Because no acknowledgment is emitted upon receipt, the *j_timeout* field is not applicable.

Multicast Networking

I/O devices generally use Multicast Networking to transmit input packets. For PLCIO to receive streaming input, the UNIX system must be configured to subscribe to and receive Multicast packets.

On systems with multiple Ethernet interfaces, Multicast packets by default are only received on the interface corresponding to the default gateway. If a different interface is desired for communication, then a specific route must be added for Multicast: network 224.0.0.0 with subnet mask 240.0.0.0. Here is an example on how to do this in Linux for interface “eth1” (note that this is temporary until the system is rebooted—consult your system documentation on how to make this permanent):

```
route add –net 224.0.0.0 netmask 240.0.0.0 dev eth1
```

Programming Examples

Example 1: This sends a output packet of six 16-bit words to the remote I/O:

```
short ai_data[6]={0, 0, 0, 0x3fff, 0, 0x0001};
j_result=plc_write(ptr, 0, NULL, ai_data, 12, 0, PLC_CVT_WORD);
```

Example 2: This code demonstrates receiving an input packet using plc_read( ) with a 3-second timeout:

```
short ai_buffer[6];
j_result=plc_read(ptr, 0, NULL, ai_buffer, 12, 3000, PLC_CVT_WORD);
```

Example 3: This code demonstrates receiving an input packet using plc_receive( ):

```
static int j_last_sequence;
PLCSLAVE slave;
short ai_buffer[6];

j_result=plc_receive(ptr, PLC_STREAM_INPUT, &slave, ai_buffer, 12, 3000);

/* If successful, convert each 16-bit word to host byte-order */
if(j_result != -1)
  plc_conv(ptr, PLC_TOCPU, ai_buffer, slave.j_length, PLC_CVT_WORD);

/* Print a warning if we had data loss */
```

```
if(slave.j_sequence != 0 && slave.j_sequence != j_last_sequence+1)
  fprintf(stderr, "Warning: Wrong packet order in the input stream.\n");

/* Remember current sequence number */
j_last_sequence = slave.j_sequence;
```

Warning	If the application exits without calling plc_close( ), the remote I/O device continues to wait for packets until the output interval timeout elapses. The application cannot reconnect during this time.

Additional Errors

PLCE_CIP_COMM_ERROR	200	A communications error occurred while opening the CIP connection. The error-status byte is stored in *plc_ptr->aj_errorval[0]*. The 2-byte routing-error code is stored in *plc_ptr->aj_errorval[1]*.
PLCE_CIP_IO_ADDR	203	During plc_open( ), the remote I/O device failed to provide a valid IP Address for sending output packets or a Multicast Address for receiving input packets.
PLCE_CIP_RPI_EXCEEDED	204	Attempted to send an output packet after 4 times the output interval has elapsed.

cipioslv – Streaming I/O Receiver over EtherNet/IP

This module allows a PLCIO application to be on the receiving end of an EtherNet/IP implicit messaging connection, simulating the appearance of an I/O Bus Terminal from the PLC's point of view. This module requires the *enipd* daemon to be running on the local computer in order to receive EtherNet/IP connections from the PLC.

Open Parameters

Stream: cipioslv <address>[:port] <input ID> <output ID> [Multicast=<dest_address>]

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the Ethernet interface where the *enipd* daemon is listening for connections on the local computer. If multicast packets are required and there is more than one Ethernet interface in the system (see below), specify the IP Address assigned to the interface on the local computer that is connected to the PLC. PLCIO will attempt to connect to this host using TCP port 315, or [port] if specified. The *enipd* daemon should be running on the local computer prior to starting the PLCIO application. This module will not work if you connect to an *enipd* daemon on a remote computer.

The <input ID> and <output ID> parameters must be specified. These parameters set the connection endpoints, or Assembly Instances, for both input and output packets (inputs and outputs are specified from the PLC's point of view). There can be several EtherNet/IP I/O connections running on the same computer, each addressed through *enipd* by a unique combination of Input ID and Output ID.

Note	It is possible to communicate between two PLCIO applications on two different computers using EtherNet/IP. One application is configured to act as the PLC (master) using the *cipio* module, and the other is configured to act as the I/O Bus Terminal (slave) using *cipioslv*. Use the same Input and Output IDs in the plc_open( ) parameters of both modules.

Note	Some PLCs have the Input ID and Output ID terms swapped compared to the EtherNet/IP standard. If the PLC's connection fails, try swapping the <input ID> and <output ID> parameters on the plc_open( ) line.

The "Multicast=<dest_address>" parameter is optional. This parameter sets the target multicast IP Address to use when sending Input packets to the PLC. Any multicast address from 224.0.0.0 to 239.255.255.255 is allowed. If this parameter is not specified, then PLCIO will pick a random address in the local-use area between 239.192.0.0 and 239.192.255.255 at the time the plc_open( ) call is made.

Timeout

The default timeout for connecting to the ENIP daemon is 5 seconds. This can be changed in the PLCIO Configuration File.

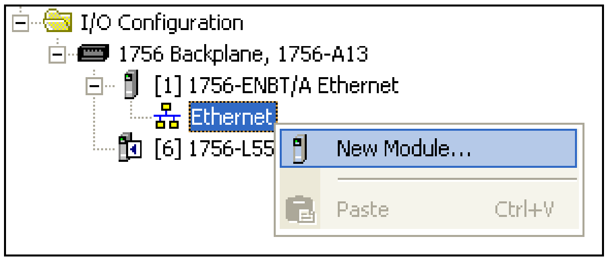
Open Examples

```
/* Connect to local enipd daemon using Input ID 100 and Output ID 101 */
plc_open("cipioslv localhost 100 101");

/* If the local computer is multi-homed with several IP Addresses in use,
this example uses the Ethernet interface attached to 10.0.0.15, using Input
ID 1 and Output ID 2 */
plc_open("cipioslv 10.0.0.15:315 1 2");

/* This example uses a specific multicast target IP Address */
plc_open("cipioslv localhost 100 101 Multicast=239.192.4.1");
```

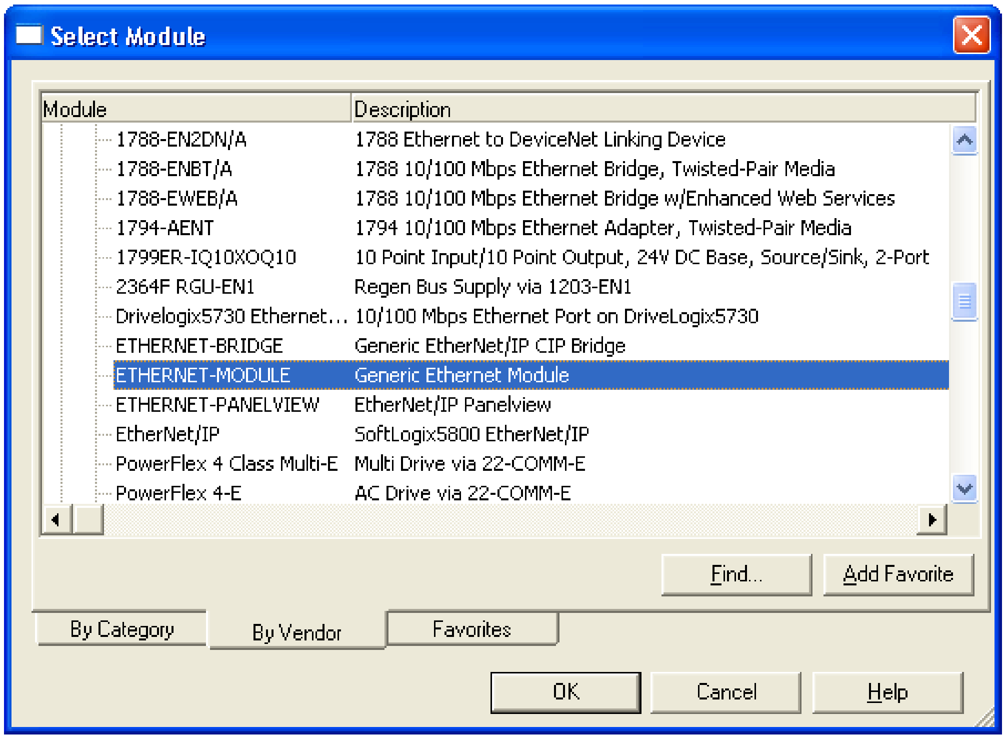
Configuring the PLC

This section demonstrates how to use RSLogix5000 to set up an Allen-Bradley Logix-family PLC to communicate to PLCIO using EtherNet/IP implicit messaging.

First, open your PLC project in RSLogix5000. In the Controller Organizer, locate your EtherNet/IP device under I/O Configuration, and right-click the Ethernet item to add a New Module.



Under Allen-Bradley, select ETHERNET-MODULE and click OK.



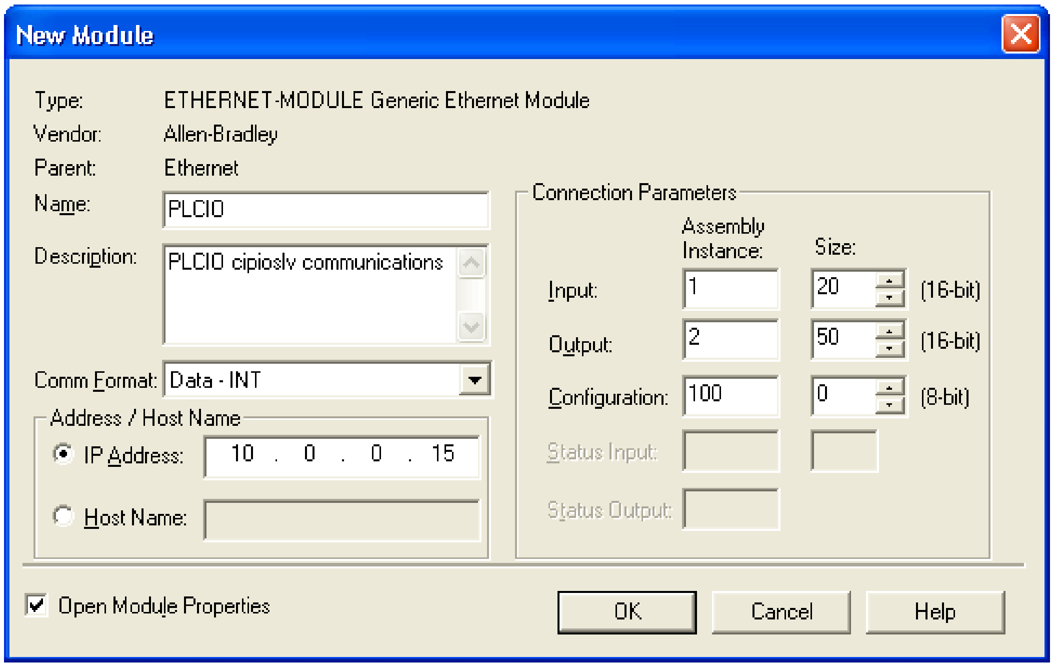
Module	Description
1788-EN2DN/A	1788 Ethernet to DeviceNet Linking Device
1788-ENBT/A	1788 10/100 Mbps Ethernet Bridge, Twisted-Pair Media
1788-EWEB/A	1788 10/100 Mbps Ethernet Bridge w/Enhanced Web Services
1794-AENT	1794 10/100 Mbps Ethernet Adapter, Twisted-Pair Media
1799ER-IQ10XOQ10	10 Point Input/10 Point Output, 24V DC Base, Source/Sink, 2-Port
2364F RGU-EN1	Regen Bus Supply via 1203-EN1
Drivelogix5730 Ethernet...	10/100 Mbps Ethernet Port on DriveLogix5730
ETHERNET-BRIDGE	Generic EtherNet/IP CIP Bridge
ETHERNET-MODULE	Generic Ethernet Module
ETHERNET-PANELVIEW	EtherNet/IP Panelview
EtherNet/IP	SoftLogix5800 EtherNet/IP
PowerFlex 4 Class Multi-E	Multi Drive via 22-COMM-E
PowerFlex 4-E	AC Drive via 22-COMM-E

Next, fill in the Name and Description the same as you would for a standard I/O Bus Terminal. Select any non-status communications format (INT, DINT, REAL, etc.) that matches the data type you intend to transmit. Type in the IP Address of the target computer that is running PLCIO.

In the Connection Parameters box, choose a new, unique Input and Output ID (Assembly Instance) for the target computer. This ID combination must match the <Input ID> and <Output ID> specified in the plc_open( ) parameters of your PLCIO application.

Next, type in the size of the expected Input and Output packets (specified in units of bytes, 16-bit words, or 32-bit words depending on the data type). The Input size must match exactly how many bytes are written by your application’s plc_write( ) functions, or the packets will be ignored by the PLC.

The Configuration parameter is not used with PLCIO. Pick any instance number for this field here, and enter in a size of 0. When finished, click OK.


New Module

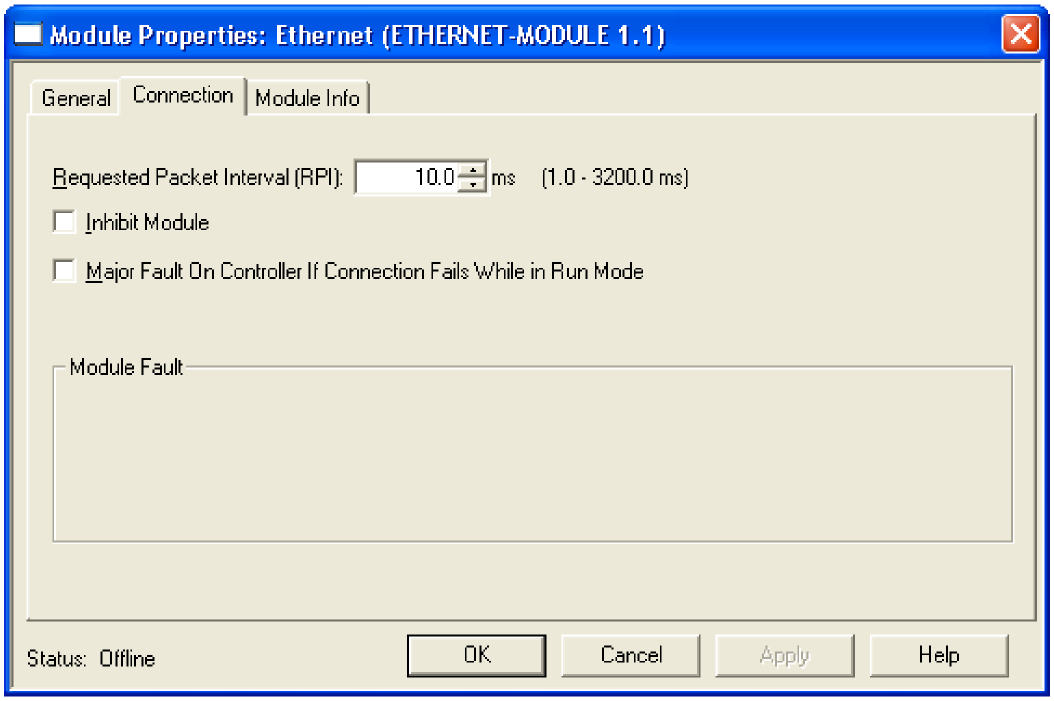
Type: ETHERNET-MODULE Generic Ethernet Module
Vendor: Allen-Bradley
Parent: Ethernet
Name: PLCIO
Description: PLCIO cipioslv communications
Comm Format: Data - INT
Address / Host Name
● IP Address: 10 . 0 . 0 . 15
○ Host Name:

Connection Parameters

	Assembly Instance:	Size:	
Input:	1	20	(16-bit)
Output:	2	50	(16-bit)
Configuration:	100	0	(8-bit)
Status Input:			
Status Output:			

☑ Open Module Properties

Next, select a reasonable RPI (Requested Packet Interval) for this communications channel and click OK. The RPI denotes how often the PLC will send output data to PLCIO, and how often it expects to receive input data from PLCIO. The PLCIO application must attempt to do a plc_write( ) once every RPI in order to keep the connection established. If the PLC does not receive a message within 4 times the specified RPI, then the PLC will close and reopen the connection to *enipd*.


Module Properties: Ethernet (ETHERNET-MODULE 1.1)

Requested Packet Interval (RPI): 10.0 ms (1.0 - 3200.0 ms)
☐ Inhibit Module
☐ Major Fault On Controller If Connection Fails While in Run Mode
Module Fault

Status: Offline

After clicking OK, the new PLCIO tag will be available in the list of Controller Tags on the PLC. You can view the input and output data on the PLC side by monitoring tags PLCIO:I and PLCIO:O, respectively. Data will be available only when the connection from the PLC to your PLCIO program is fully established.

Note	It is possible to communicate between two PLCIO applications on two different computers using EtherNet/IP. One application is configured to act as the PLC (master) using the *cipio* module, and the other is configured to act as the I/O Bus Terminal (slave) using *cipioslv*. Use the same Input and Output IDs in the plc_open( ) parameters of both modules.

Communications

To receive output packets from the PLC, call either the plc_read( ) function with *j_op* set to 0 and *pc_addr* set to NULL, or the plc_receive( ) function with *j_op* set to PLC_STREAM_INPUT. plc_reply( ) should not be called after a received packet. The PLCSLAVE object returned from plc_receive( ) will have its *j_type* member set to PLC_STREAM_INPUT and its *j_sequence* member filled in from the EtherNet/IP layer.

Send an input packet to the PLC by calling the plc_write( ) function with *j_op* set to 0 and *pc_addr* set to NULL. Because no acknowledgment is emitted upon receipt, the *j_timeout* field is not applicable.

Since *cipioslv* exists on the EtherNet/IP network as a slave I/O device, the master PLC controls when connections are opened or closed. *enipd* will send notifications to your PLCIO application whenever there is a change in connection state. These notifications are automatically managed by PLCIO in the background during calls to the plc_read( ) or plc_receive( ) functions. If plc_write( ) is used when no connection is established, the error PLCE_NO_ENDPOINT is returned. This error can be safely ignored without needing to call plc_close( ). Writes will again succeed as soon as the PLC reconnects to *enipd*.

Multicast Networking

This module transmits input packets to the master PLC using a target multicast IP Address. As UNIX systems only need Multicast Networking enabled to subscribe to and receive Multicast packets, no special configuration is required to use *cipioslv* to send multicast packets.

On systems with multiple Ethernet interfaces, Multicast packets by default are only sent on the interface corresponding to the default gateway. If a different interface is desired for communication, then a specific route must be added for Multicast: network 224.0.0.0 with subnet mask 240.0.0.0. Here is an example on how to do this in Linux for interface “eth1” (note that this is temporary until the system is rebooted—consult your system documentation on how to make this permanent):

```
route add –net 224.0.0.0 netmask 240.0.0.0 dev eth1
```

Note	If the <address> parameter on the *cipioslv* plc_open( ) string specifies a hostname or IP Address other than localhost (127.0.0.1), then the interface associated with that address will automatically be used for sending multicast packets, and no *route* command is required.

Caveats

Some PLCs such as the Allen-Bradley Logix family ignore Multicast packets sent with the *Don’t Fragment* bit turned on in the IP Packet header. This bit is disabled automatically by software when running *cipioslv* on Linux systems, however other UNIX and Windows systems will need special configuration applied to disable this bit.

This bit is controlled by the Path MTU Discovery logic in the kernel. Here is the procedure for turning off Path MTU Discovery for various systems.

<u>Solaris:</u>

```
ndd –set /dev/ip ip_path_mtu_discovery 0
```

HP-UX 10.xx:

```
nettune -s udp_pmtu 0
```

HP-UX 11.xx:

```
ndd -h ip_pmtu_strategy 0
```

Windows:

Set registry key HKEY_LOCAL_MACHINE\System\CurrentControlSet\Services\Tcpip\Parameters\EnablePMTUDiscovery to 0.

Programming Examples

Example 1: This sends an input packet of six 16-bit words to the PLC:

```
short ai_data[6]={0, 0, 0, 0x3fff, 0, 0x0001};
j_result=plc_write(ptr, 0, NULL, ai_data, 12, 0, PLC_CVT_WORD);
```

Example 2: This code demonstrates receiving an output packet using plc_read( ) with a 3-second timeout:

```
char ac_buffer[10];
j_result=plc_read(ptr, 0, NULL, ac_buffer, 10, 3000, PLC_CVT_NONE);
```

Example 3: This code demonstrates receiving an output packet using plc_receive( ):

```
PLCSLAVE slave;
short ai_buffer[6];

j_result=plc_receive(ptr, PLC_STREAM_INPUT, &slave, ai_buffer, 12, 3000);

/* If successful, convert each 16-bit word to host byte-order */
if(j_result != -1)
  plc_conv(ptr, PLC_TOCPU, ai_buffer, slave.j_length, PLC_CVT_WORD);
```

Additional Errors

PLCE_ENIP_INIT_ERROR	201	An error occurred during the handshake to the ENIP daemon. The reason is stored in *plc_ptr->aj_errorval[0]* as follows: 1: The version of *enipd* running is too old. 4: Invalid EtherNet/IP parameters specified. 5: Input/Output ID already in use by another application.

cipmlx – Allen-Bradley MicroLogix over EtherNet/IP

This module supports sending solicited PCCC messages to an Allen-Bradley MicroLogix PLC using the Common Industrial Protocol (CIP) encapsulated by EtherNet/IP. It uses SLC 5/00 Protected Typed Reads and Writes for messaging directly to a PLC's EtherNet/IP interface slot or via a 1761-NET-ENI module.

Open Parameters

Master: cipmlx <address>[:port]

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the EtherNet/IP interface on the network. PLCIO will attempt to connect to this host using TCP port 44818, or [port] if specified.

This module cannot be used for unsolicited requests. Use the *enip* module instead.

Timeout

The default timeout for connecting to an Allen-Bradley PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
plc_open("cipmlx host.domain:44818");  /* Use gethostbyname() */
plc_open("cipmlx 10.0.0.2");           /* Direct IP address */
```

Point Addressing

Point addressing and programming examples are exactly like those explained for the *abdf1* module. Refer to the "abdf1 – Allen-Bradley PLC5/SLC500 over Serial (DF1)" section on page 40 for more information.

Additional Errors

PLCE_CIP_COMM_ERROR	200	A communications error occurred while routing the CIP command to the PLC. The error-status byte is stored in *plc_ptr->aj_errorval[0]*. The 2-byte routing-error code is stored in *plc_ptr->aj_errorval[1]*.
PLCE_DF1_PCCC_ERROR	210	A PLC error occurred during a PCCC command. The error-status byte is stored in *plc_ptr->aj_errorval[0]*, and the extended status (if any) is stored in *plc_ptr->aj_errorval[1]*.

enip – Allen-Bradley Unsolicited over EtherNet/IP

This module allows PLCIO to receive unsolicited communication from Allen-Bradley Logix PLCs using the EtherNet/IP protocol. During a plc_open( ), the module connects to a specialized UNIX daemon, *enipd*, which acts as a Connection Manager for EtherNet/IP. Up to 64 separate applications (nodes) can listen on the receiving end of a single *enipd* process, and these applications do not need to be on the same computer as *enipd*. This gives PLCs great flexibility in controlling the destination of their Read/Write commands to the application.

ENIP Daemon

The *enipd* daemon handles receiving both Read and Write PCCC messages via EtherNet/IP. The binary executable can be found in the bin/ directory of the install path after PLCIO is installed. Also included is a sample RC script located in the same directory, "enipd.rc", which can be manually modified to automatically start the daemon on system boot (see your UNIX administration guide for more details).

The *enipd* application forks itself into the background, so simply execute 'enipd' to run the program.

```
Usage: enipd [options] [app-port] [plc-port]
Default APP port is 315. Default PLC port is 44818.

Options:
   -h host     Binds sockets to a specific local Host/IP#
   -l logfile  Sends error & log messages to 'logfile'
   -s logsize  Rotate logfile after reaching 'logsize' bytes
   -v          Increase verbosity; maximum -vvv
   -V          Display version information and exit
   -w delay    Delay responses to PLC by 'delay' ms (0-999; default=10)
```

Note	Due to issues with the TCP stack in some models of ControlLogix, it is recommended to keep the "-w" option set at 10 milliseconds or higher to avoid stalls caused by the *enipd* daemon responding too quickly to an EtherNet/IP message.

Open Parameters

Slave: enip <address>[:port] <channel ID>

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the system running the *enipd* daemon. PLCIO will attempt to connect to this host using TCP port 315, or [port] if specified. The *enipd* daemon should be running on the target computer prior to starting the PLCIO application.

<channel ID> refers to a user-selected node number. Each application that connects to the *enipd* daemon must register its own unique number for receiving messages. PLCs wishing to send to a specific PLCIO application must reference this same Channel ID in their MSG instruction configuration. Channels 0-65535 are valid IDs, though most PLCs can only send to nodes 1-63.

When setting up the MSG instruction on the PLC side, there are a few important notes to consider. First, the *enip* module only supports the following message types: PLC2 Unprotected Reads/Writes, PLC5 Typed Reads/Writes, and SLC Typed Reads/Writes. Second, if the choice is available, select the communication method "CIP With Source ID", and fill in the Channel ID (as selected above) in the "Source Link" field. The CIP Path should end with the IP Address where the *enipd* daemon is running. The Destination Link and Destination Node fields should both be set to 0. On some PLCs, the Source Link and Destination Link values may need to be swapped.

Note	Some Logix PLCs do not utilize a Channel ID for the message destination. In this case the ID defaults to zero, and only one PLCIO application can receive messages from such PLCs per *enipd* daemon instance.

This module cannot be used to send solicited requests to a PLC.

Timeout

The default timeout for connecting to the ENIP daemon is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
plc_open("enip localhost 3");         /* Connect to enipd using node 3 */
plc_open("enip 192.168.0.15:315 7");  /* Specify address:port explicitly */
```

Additional Errors

PLCE_ENIP_INIT_ERROR	201	An error occurred during the handshake to the ENIP daemon. The reason is stored in *plc_ptr->aj_errorval[0]* as follows: 1: The version of *enipd* running is too old. 2: Invalid Channel ID specified. 3: Channel ID already in use by another application.
PLCE_DF1_BAD_ADDR	211	Received a PCCC request for an invalid or unsupported address.
PLCE_DF1_BAD_MSG	212	Received a corrupted multi-part PCCC request from the PLC.

fins – Omron CS/CJ-series CPUs over Ethernet

This module supports sending reads and writes using the FINS protocol to an Omron PLC over Ethernet via TCP, UDP, or EtherNet/IP using the Common Industrial Protocol (CIP).

Open Parameters

Master: fins [cs|cj|cv] [tcp|udp|enip] <address>[:port] [Path=<route>] [Interval=#] [Symbols=<disk>]

<address> is an IP Address (192.168.1.10) or a Hostname of the FINS or EtherNet/IP interface on the network. An optional argument—“cs”, “cj”, or “cv”—can be specified to instruct PLCIO to use CS/CJ or CV memory-addressing mode in data requests. If omitted, then PLCIO will auto-detect the best messaging mode based on the type of target CPU (PLC) in the rack. A second optional argument—“tcp”, “udp”, or “enip”—instructs PLCIO to use TCP port 9600, UDP port 9600, or EtherNet/IP (TCP) port 44818 respectively when connecting to the PLC. If omitted, the *fins* module defaults to using TCP. The optional [port] argument can be used to override the Ethernet port selection.

The [Path=<route>] argument is optional and only has meaning for EtherNet/IP communication. If specified, then this module will communicate through a Logix gateway to reach the PLC. In this mode, <address> is the IP Address of the EtherNet/IP module on the Logix rack, and <route> is a comma-separated route, from the EtherNet/IP interface to the PLC, through the CIP network. See section Routes under the *cip* module on page 43 for examples.

[Interval=#] is also an optional argument that only has meaning for EtherNet/IP communication. This parameter sets the Requested Packet Interval (RPI) value in the CIP connection. It is only used during connected messaging, and denotes the longest delay anticipated between two subsequent PLCIO requests, in milliseconds. If the target CPU does not receive a request within 4 times this value, then the target CPU will consider the connection to have been dropped, and all further requests will be ignored. This value should be set as low as possible in order for the target CPU to drop broken connections from its list in a timely manner. [Interval=#] defaults to 16 seconds, permitting a delay of up to one minute between requests. An optional *us*, *ms*, or *s* can be appended to the number to specify microseconds, milliseconds, or seconds, respectively.

The Omron PLC stores its symbol table in a file called SYMBOLS.SYM in one of three possible disk areas: the Memory card, the EM file, and Comment memory. PLCIO will attempt to read the symbol table from those three disks (in that order) until it is discovered. Sometimes it is necessary to instruct PLCIO to read only from a specific disk, for instance if the Memory card contains an outdated version of the table. The optional [Symbols=<disk>] argument tells PLCIO to read from a specific disk area, where <disk> is one of three keywords:

Disk	Symbol Table Area
Card	Memory Card
EM	EM File
Comment	Comment Memory

PLCIO does not support unsolicited requests from an Omron PLC.

Timeout

The default timeout for connecting to an Omron PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
/* The following example connects with TCP to 10.1.1.72 using CS/CJ-style
   addressing mode */

plc_open("fins cs 10.1.1.72");
```

```
/* This example connects to a PLC using CV-style addressing over EtherNet/IP.
   Read/write requests will be assumed to be issued to the PLC within once
   per minute. */

plc_open("fins cv enip host.domain Interval=60s");
```

Point Addressing

Address Syntax:	<memory area>[bank_]<offset>[.bit]
Symbol Syntax:	<symbol name>

The *fins* module supports two styles of point addressing: by direct address or by symbol name. Direct addressing gives the application access to any contiguous memory area (or extended memory bank) available on the PLC. Alternatively, any symbol name previously programmed into the PLC can also be used. When given a name, PLCIO will perform a simple search through the PLC's symbol table to determine what starting address to use in the subsequent read/write request. The symbol's type, size, or array length has no bearing on how many bytes can be read from this starting address.

The <offset> argument in the direct address specifies the starting element in the memory area. For instance, since memory area D is comprised of word elements each 2 bytes long, specifying an offset of 10 really makes a request that begins with the 20th byte (counting from zero) in the memory area.

The optional [bank_] argument can be specified for memory area E only (extended memory). This denotes what extended memory bank should be accessed for the read/write request. The number of banks available on the PLC depends on how much memory is installed on the CPU and whether external memory cards are currently in use. If no bank is specified when accessing the E memory area, then the bank that is currently active on the CPU is automatically used.

Based on the style of memory addressing (CS/CJ or CV mode) selected, some memory areas may support bit-level addressing. The optional [.bit] syntax can be specified to use a starting bit number that the read or write request will address. Since only word-addressable (2-byte) memory areas support bit addressing, the specified starting bit must be between 0 and 15.

PLCIO can read or write multiple bits at a time in bit-addressing mode. During a read request, each bit is returned as a separate byte—1 if the bit is turned on, or 0 if the bit is turned off. Similarly, during a write request, PLCIO can turn on or off several bits at once using 1 or 0 respectively for each byte in the request.

The following table shows the available memory areas in CS/CJ or CV mode, along with the number of elements available in the area, the element size, and whether the area supports bit-level addressing:

CS/CJ Addressing Mode

Memory Area	Index	Number of Elements	Element Size	Supports Bit Addressing
Controller I/O	CIO	6144	2	Yes
Work Area	W	512	2	Yes
Holding Area	H	512	2	Yes
Auxiliary Area	A	960	2	Yes
Timers	T	4096	2	-
Counters	C	4096	2	-
Data Memory	D	32768	2	Yes
Extended Memory	E	32768	2	Yes (Bank access only)
Task Flag	TK	32	1	-
Index Register	IR	16	4	-
Data Register	DR	16	2	-

CV Addressing Mode

Memory Area	Index	Number of Elements	Element Size	Supports Bit Addressing
Controller I/O	CIO	2556	2	Yes
Auxiliary Area	A	960	2	Yes
Timers	T	2048	2	-
Counters	C	2048	2	-
Data Memory	D	32768	2	-
Extended Memory	E	32768	2	-
Data Register	DR	3	2	-

The length of all read/write requests must be a multiple of the element size of the target memory area. The element size for bit-level addressing is always 1.

Word values are stored in big-endian format on the PLC. That is, the hexadecimal value 0x8144 is stored in PLC memory as byte 81 followed by byte 44. Use the PLC_CVT_WORD conversion constant in plc_read( ) and plc_write( ) to automatically convert word values to your local system's endianness.

Double-word data types, such as DINT and UDINT, are stored in memory with the least-significant word followed by the most-significant word. That is, the hexadecimal value 0x11223344 is stored in memory as 33 44 11 22. PLCIO offers no automatic conversion for this data type. To read the value of double integers, first read four bytes using the PLC_CVT_WORD conversion constant, and then add (65536 × the value of the second word) to the first word.

Note Controller I/O (CIO) memory is the only area that is addressed by number only. That is, to access CIO element 30, use the string "30" by itself. The phrase "CIO" should not be specified in the address string.

Addressing Examples

10	Access CIO Area element 10 (bytes 20 and 21).
50.12	Access CIO Area element 50 starting with bit 12 (decimal).
T5	Access Timer word number 5 (bytes 10 and 11).
D4000	Access Data Memory word number 4000 (bytes 8000 and 8001).
A6.02	Access Auxiliary Area element 6 starting with bit 2.
E4	Access the currently active bank of Extended Memory, element 4.
E0_4	Access bank 0 of Extended Memory, element 4.
E2_1600.03	Access bank 2 of Extended Memory, element 1600 bit 3.

Because FINS addresses are just element-sized offsets into memory areas, the *j_op* parameter of the plc_read( ) and plc_write( ) functions is ignored.

Programming Examples

Example 1: This writes the decimal words "50, 100, 150" to bytes 200-205 of the Data Memory area.

```
short ai_data[3]={50, 100, 150};
j_result=plc_write(ptr, 0, "D100", ai_data, 6, 3000, PLC_CVT_WORD);
```

Example 2: This reads 12 bits starting at CIO Area word 15, bit 8. This returns 12 bytes—one for each bit from CIO 15.08 through CIO 16.03.

```
char ac_data[12];
j_result=plc_read(ptr, 0, "15.08", ac_data, 12, 3000, PLC_CVT_NONE);
```

Example 3: This reads a DINT (double-word) value from a symbol called "counter" stored on the PLC.

```
int j_counter;
unsigned short ai_data[2];

j_result=plc_read(ptr, 0, "counter", ai_data, 4, 3000, PLC_CVT_WORD);
j_counter=ai_data[0] + 65536*ai_data[1];
```

Additional Errors

PLCE_FINS_PLC_ERROR	210	A PLC error occurred while sending a request. The 2-byte error code is stored in *plc_ptr->aj_errorval[0]*.
PLCE_FINS_BANK	211	An attempt was made to read from or write to an Extended Memory bank that does not exist on the PLC.
PLCE_FINS_SYMBOL_TABLE	212	An error occurred while downloading the symbol table from the PLC.
PLCE_FINS_TCP_NODE	213	There are no TCP connections available on the FINS gateway.

hostlink – Omron C/CS/CJ-series CPUs over Serial

This module supports sending reads and writes using the Host Link protocol to on Omron PLC over a serial interface. Standard Host Link commands are used when communicating to a C-series CPU, and FINS commands encapsulated in Host Link are used when communicating to a CS- or CJ-series CPU.

Open Parameters

Master: hostlink [c|cs|cj|cv|fins] <device>[:baud:bits:parity:stopbits:flowctrl] <node> [NoRetry] [Symbols=<disk>]

<device> is a serial device name, such as "/dev/ttyS0" on Linux or "COM1" on Windows. The colon-separated serial parameters are optional and default to the Host Link standard if not specified: "9600:7:E:2". <node> is the node number of the device on the serial bus, which must be between 0 and 31.

An optional argument—"c", "cs", "cj", "cv", or "fins"—can be specified to change the type of messaging and/or memory-addressing mode in data requests. Specifying "c" instructs PLCIO to use C-mode messaging, which is the default messaging mode in the Host link protocol and also carries the most restrictions on point addressing. The other four arguments instruct PLCIO to send FINS commands encapsulated in the Host Link protocol. Specifying "cs", "cj", and "cv" instructs PLCIO to use CS/CJ or CV memory-addressing mode, while specifying "fins" will allow PLCIO to auto-detect the best messaging mode based on the type of target CPU (PLC) in the rack.

[NoRetry] is an optional argument that controls how PLCIO responds in the case that a corrupted response is received from the PLC. When not specified, PLCIO will continue to resend the command until either a successful response is received or the timeout is reached. When [NoRetry] is specified, PLCIO will immediately return with a PLCE_COMM_RECV error with *j_errno* set to EPROTO. This allows the PLCIO application to, for instance, update the plc_write() buffer with newer data when resending the request.

The Omron PLC stores its symbol table in a file called SYMBOLS.SYM in one of three possible disk areas: the Memory card, the EM file, and Comment memory. When FINS mode is enabled, PLCIO will attempt to read the symbol table from those three disks (in that order) until it is discovered. Sometimes it is necessary to instruct PLCIO to read only from a specific disk, for instance if the Memory card contains an outdated version of the table. The optional [Symbols=<disk>] argument tells PLCIO to read from a specific disk area, where <disk> is one of three keywords:

Disk	Symbol Table Area
Card	Memory Card
EM	EM File
Comment	Comment Memory

PLCIO does not support unsolicited requests from an Omron PLC.

Timeout

The default timeout for connecting over Host Link is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
/* Connect to node 0 on /dev/ttyS0 using C-mode addressing */
plc_open("hostlink /dev/ttyS0 0");

/* Connect to node 4 using FINS commands encapsulated in Host Link.
   Also, do not automatically retry commands on packet corruption */
plc_open("hostlink fins /dev/ttyS0:9600:7:E:2 4 NoRetry");
```

Point Addressing

Address Syntax: <memory area>[bank_]<offset>[.bit]

Symbol Syntax: <symbol name>

The *hostlink* module supports two styles of point addressing: by direct address or by symbol name. Direct addressing gives the application access to any contiguous memory area (or extended memory bank) available on the PLC. Alternatively, in FINS mode, any symbol name previously programmed into the PLC can also be used. When given a name, PLCIO will perform a simple search through the PLC's symbol table to determine what starting address to use in the subsequent read/write request. The symbol's type, size, or array length has no bearing on how many bytes can be read from this starting address.

The <offset> argument in the direct address specifies the starting element in the memory area. For instance, since memory area D is comprised of word elements each 2 bytes long, specifying an offset of 10 really makes a request that begins with the 20th byte (counting from zero) in the memory area.

The optional [bank_] argument can be specified for memory area E only (extended memory). This denotes what extended memory bank should be accessed for the read/write request. The number of banks available on the PLC depends on how much memory is installed on the CPU and whether external memory cards are currently in use. If no bank is specified when accessing the E memory area, then the bank that is currently active on the CPU is automatically used.

Based on the style of memory addressing (CS/CJ or CV mode) selected, some memory areas may support bit-level addressing. The optional [.bit] syntax can be specified to use a starting bit number that the read or write request will address. The starting bit must be between 0 and 15.

PLCIO can read or write multiple bits at a time in bit-addressing mode (FINS mode only). During a read request, each bit is returned as a separate byte—1 if the bit is turned on, or 0 if the bit is turned off. Similarly, during a write request, PLCIO can turn on or off several bits at once using 1 or 0 respectively for each byte in the request.

The following table shows the available memory areas in C, CS/CJ, or CV mode, along with the number of elements available in the area, the element size, and whether the area supports bit-level addressing:

C Addressing Mode

Memory Area	Index	Number of Elements	Element Size	Supports Bit Addressing
Controller I/O	CIO	6144	2	-
Holding Area	H	512	2	-
Auxiliary Area	A	960	2	-
Timers	T	2048	2	-
Counters	C	2048	2	-
Data Memory	D	10000	2	-
Extended Memory	E	10000	2	-

CS/CJ Addressing Mode

Memory Area	Index	Number of Elements	Element Size	Supports Bit Addressing
Controller I/O	CIO	6144	2	Yes
Work Area	W	512	2	Yes
Holding Area	H	512	2	Yes
Auxiliary Area	A	960	2	Yes
Timers	T	4096	2	-
Counters	C	4096	2	-
Data Memory	D	32768	2	Yes
Extended Memory	E	32768	2	Yes (Bank access only)
Task Flag	TK	32	1	-
Index Register	IR	16	4	-
Data Register	DR	16	2	-

CV Addressing Mode

Memory Area	Index	Number of Elements	Element Size	Supports Bit Addressing
Controller I/O	CIO	2556	2	Yes
Auxiliary Area	A	960	2	Yes
Timers	T	2048	2	-
Counters	C	2048	2	-
Data Memory	D	32768	2	-
Extended Memory	E	32768	2	-
Data Register	DR	3	2	-

The length of all read/write requests must be a multiple of the element size of the target memory area. The element size for bit-level addressing is always 1.

Word values are stored in big-endian format on the PLC. That is, the hexadecimal value 0x8144 is stored in PLC memory as byte 81 followed by byte 44. Use the PLC_CVT_WORD conversion constant in plc_read( ) and plc_write( ) to automatically convert word values to your local system's endianness.

Double-word data types, such as DINT and UDINT, are stored in memory with the least-significant word followed by the most-significant word. That is, the hexadecimal value 0x11223344 is stored in memory as 33 44 11 22. PLCIO offers no automatic conversion for this data type. To read the value of double integers, first read four bytes using the PLC_CVT_WORD conversion constant, and then add (65536 × the value of the second word) to the first word.

Note Controller I/O (CIO) memory is the only area that is addressed by number only. That is, to access CIO element 30, use the string "30" by itself. The phrase "CIO" should not be specified in the address string.

Addressing Examples

10	Access CIO Area element 10 (bytes 20 and 21).
50.12	Access CIO Area element 50 starting with bit 12 (decimal).
T5	Access Timer word number 5 (bytes 10 and 11).
D4000	Access Data Memory word number 4000 (bytes 8000 and 8001).
A6.02	Access Auxiliary Area element 6 starting with bit 2.
E4	Access the currently active bank of Extended Memory, element 4.
E0_4	Access bank 0 of Extended Memory, element 4.
E2_1600.03	Access bank 2 of Extended Memory, element 1600 bit 3.

Because FINS addresses are just element-sized offsets into memory areas, the *j_op* parameter of the plc_read( ) and plc_write( ) functions is ignored.

Programming Examples

Example 1: This writes the decimal words "50, 100, 150" to bytes 200-205 of the Data Memory area.

```
short ai_data[3]={50, 100, 150};
j_result=plc_write(ptr, 0, "D100", ai_data, 6, 3000, PLC_CVT_WORD);
```

Example 2: In FINS mode. this reads 12 bits starting at CIO Area word 15, bit 8. This returns 12 bytes—one for each bit from CIO 15.08 through CIO 16.03.

```
char ac_data[12];
j_result=plc_read(ptr, 0, "15.08", ac_data, 12, 3000, PLC_CVT_NONE);
```

Example 3: In FINS mode, this reads a DINT (double-word) value from a symbol called "counter" stored on the PLC.

```
int j_counter;
unsigned short ai_data[2];

j_result=plc_read(ptr, 0, "counter", ai_data, 4, 3000, PLC_CVT_WORD);
j_counter=ai_data[0] + 65536*ai_data[1];
```

Additional Errors

PLCE_HOSTLINK_PLC_ERROR	200	A Host Link error occurred while sending a request. The 1-byte error code is stored in *plc_ptr->aj_errorval[0]*.
PLCE_HOSTLINK_BANK	201	An attempt was made in C-mode to read from or write to an Extended Memory bank that does not exist on the PLC.
PLCE_FINS_PLC_ERROR	210	A PLC error occurred in the FINS protocol layer while sending a request. The 2-byte error code is stored in *plc_ptr->aj_errorval[0]*.
PLCE_FINS_BANK	211	An attempt was made in FINS mode to read from or write to an Extended Memory bank that does not exist on the PLC.
PLCE_FINS_SYMBOL_TABLE	212	An error occurred while downloading the symbol table from the PLC.

modeth – Modbus+ over Ethernet

Modbus+ Ethernet supports master and slave communication over TCP/IP with the Quantum models available from Modicon, including a variety of other devices that support the Modbus+ communication standard, such as the Wago 750-842. Unsolicited communication over UDP is a supported feature of the Wago models only.

Open Parameters

Master:	modeth <address>[:port] [route]
Slave:	modeth

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the PLC's Ethernet interface on the network. PLCIO will attempt to connect to this host using TCP port 502, or [port] if specified. [route] is an optional parameter from 1 to 255 that specifies where messages will be directed inside the PLC.

Timeout

The default timeout for connecting to a Modicon PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Unsolicited Communication

If no parameters are present, then this module will be opened in **slave** (unsolicited) mode. The module will open both TCP and UDP 502 on the local system to listen for connections from a PLC. Applications can change the local bind address (normally INADDR_ANY) by setting the global variable *j_plcio_ipaddr* to a new address in network byte-order prior to each plc_open( ) call.

Note Only one unsolicited receiver may run on a single local address. This is a limitation of TCP/IP in that only one application may bind to a given local port.

Open Examples

```
plc_open("modeth host.domain:502 1");  /* Use gethostbyname(), route 1 */
plc_open("modeth 10.0.0.2 1");         /* Direct IP address */
plc_open("modeth");                    /* Open local port for slave mode */
```

Point Addressing

Both 5- and 6-digit addressing formats are accepted by this module (for instance, 40001 and 400001 are assumed to be identical). Each address refers to a single register in the PLC's data memory, with addresses numbered starting from 1. The first digit of the address corresponds to one of 4 accessible register domains, as shown below:

Register Domains	Data Size	Access
0 – Coils (Outputs)	Boolean	R/W
1 – Inputs	Boolean	R
3 – Input Registers	16-bit Registers	R
4 – Output Registers	16-bit Registers	R/W

The modeth module supports 4 different *j_op* operations to the plc_read( ) and plc_write( ) functions:

PLC_RREG	PLC_WREG	- Read/write 16-bit registers (domains 3 and 4)
PLC_RCOIL	PLC_WCOIL	- Read/write coils (domains 0 and 1)

Each element packed into the plc_read( ) or plc_write( ) is 16 bits in size, regardless if the PLC data size is a boolean value or a register. For boolean values, a single coil is energized if the 16-bit value is nonzero, and de-energized if zero. The PLC_WCOIL command can write only one coil per call to plc_write( ).

Addressing Examples

40001	Addresses the first 16-bit Output Register using PLC_RREG or PLC_WREG.
00003	Addresses the 3rd coil (output) using PLC_RCOIL or PLC_WCOIL.
300257	Addresses the 257th 16-bit Input Register (bytes 512-513) using PLC_RREG.

plc_validaddr( ) can be used to validate the syntax of a Modicon address. The *pj_size* argument returns 0 for boolean addresses and 2 for 16-bit registers. The *pj_domain* argument returns the domain number, which can be 0, 1, 3, or 4. The *pj_offset* argument returns the zero-based word offset. For example, address “40266” returns 2, 4, and 265, respectively.

Programming Examples

Example 1: This writes the decimal values “50, 600, -1800” to addresses 40260-40262:

```
short ai_data[3]={50, 600, -1800};
j_result=plc_write(ptr, PLC_WREG, "40260", ai_data, 6, 3000, PLC_CVT_WORD);
```

Example 2: This reads a single coil from 10008 (reading coils returns 2 bytes per coil) into ai_buffer[0].

```
short ai_buffer[5];
j_result=plc_read(ptr, PLC_RCOIL, "10008", ai_buffer, 2, 3000,
                  PLC_CVT_WORD);
```

Additional Errors

PLCE_MOD_PLC_ERROR	202	A PLC error occurred during a read or write request. The error-status byte is stored in *plc_ptr->aj_errorval[0]*.

modrtu – Modbus RTU over Serial

Modbus RTU supports master communication with a variety of devices and PLC's over a serial interface.

Open Parameters

Master: modrtu <device>[:baud:bits:parity:stopbits:flowctrl] <node>

<device> is a serial device name, such as "/dev/ttyS0" on Linux or "COM1" on Windows. The colon-separated serial parameters are optional and default to the Modbus RTU standard if not specified: "9600:8:N:1". <node> is the node number of the device on the serial bus, which must be between 1 and 247.

PLCIO does not support unsolicited requests from a Modbus RTU device.

Timeout

The default timeout for connecting to a Modbus RTU device is 500 milliseconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
/* Connect to node 1 using serial device ttyS0 */
plc_open("modrtu /dev/ttyS0 1");

/* Example showing serial parameters */
plc_open("modrtu /dev/ttyS0:9600:8:N:1 1");
```

Point Addressing

Both 5- and 6-digit addressing formats are accepted by this module (for instance, 40001 and 400001 are assumed to be identical). Each address refers to a single register in the PLC's data memory, with addresses numbered starting from 1. The first digit of the address corresponds to one of 4 accessible register domains, as shown below:

Register Domains	Data Size	Access
0 – Coils (Outputs)	Boolean	R/W
1 – Inputs	Boolean	R
3 – Input Registers	16-bit Registers	R
4 – Output Registers	16-bit Registers	R/W

The modeth module supports 4 different *j_op* operations to the plc_read( ) and plc_write( ) functions:

PLC_RREG	PLC_WREG	- Read/write 16-bit registers (domains 3 and 4)
PLC_RCOIL	PLC_WCOIL	- Read/write coils (domains 0 and 1)

Each element packed into the plc_read( ) or plc_write( ) is 16 bits in size, regardless if the PLC data size is a boolean value or a register. For boolean values, a single coil is energized if the 16-bit value is nonzero, and de-energized if zero. The PLC_WCOIL command can write only one coil per call to plc_write( ).

Addressing Examples

40001	Addresses the first 16-bit Output Register using PLC_RREG or PLC_WREG.
00003	Addresses the 3rd coil (output) using PLC_RCOIL or PLC_WCOIL.
300257	Addresses the 257th 16-bit Input Register (bytes 512-513) using PLC_RREG.

plc_validaddr( ) can be used to validate the syntax of a Modbus address. The *pj_size* argument returns 0 for boolean addresses and 2 for 16-bit registers. The *pj_domain* argument returns the domain number, which can be 0, 1, 3, or 4. The *pj_offset* argument returns the zero-based word offset. For example, address "40266" returns 2, 4, and 265, respectively.

Programming Examples

Example 1: This writes the decimal values “50, 600, -1800” to addresses 40260-40262:

```
short ai_data[3]={50, 600, -1800};
j_result=plc_write(ptr, PLC_WREG, "40260", ai_data, 6, 3000, PLC_CVT_WORD);
```

Example 2: This reads a single coil from 10008 (reading coils returns 2 bytes per coil) into ai_buffer[0].

```
short ai_buffer[5];
j_result=plc_read(ptr, PLC_RCOIL, "10008", ai_buffer, 2, 3000,
                  PLC_CVT_WORD);
```

Additional Errors

PLCE_MOD_PLC_ERROR	202	A PLC error occurred during a read or write request. The error-status byte is stored in *plc_ptr->aj_errorval[0]*.

remote – Remote PLC Concentrator/Multiplexer

This module connects over Ethernet to a PLC Concentrator daemon running on the local PC or a remote host. This daemon, called *plciod*, allows multiple PLCIO applications to share a single physical connection with a PLC, regardless if that PLC is connected via Ethernet or Serial I/O. Read/write requests issued through this module have the same behavior and error codes as if they were issued directly to the PLC.

The *remote* module provides three primary benefits to existing PLCIO applications:

- *plciod* makes only a single connection to a PLC, freeing up resources on the PLC side. This is useful when a server has many PLCIO applications running and the PLC limits the number of available connections.
- *plciod* can be used as a migration tool to let applications run on a new server without physically disconnecting the PLC from the old server.
- The *remote* module allows UNIX applications to communicate with a PLC (if supported by PLCIO) connected to a Windows system, and vice versa.

PLCIO Daemon

The *plciod* daemon is an intelligent concentrator that can accept up to 1000 simultaneous PLCIO connections on the network. Each read and write request received by the daemon is served in a round-robin fashion and passed directly on to the PLC. If a second request comes in from the same application before the first request is processed, then *plciod* assumes the application timed out and ignores the first request. No data is cached between consecutive requests; every request is sent directly to the PLC.

plciod itself is a PLCIO application that makes its own direct connection to the PLC on startup. If that connection fails or becomes interrupted, then *plciod* automatically retries every 10 seconds until successful. If applications using the *remote* module are consistently receiving PLCE_TIMEOUT error codes, check the logs produced by *plciod* to verify that it is still connected to the PLC and serving requests.

Running *plciod* requires two arguments: the TCP/IP port for registering the service, and the PLCIO module + parameters for the destination PLC (i.e. what is normally specified in the plc_open( ) call). Once registered, PLCIO applications can connect to *plciod* using the chosen TCP/IP port. *plciod* will automatically fork itself into the background when started.

```
Usage: plciod [options] port "plc module & args"
Options:
   -h host      Binds sockets to a specific local host or IP
   -l logfile   Sends error & log messages to 'logfile'
   -r secs      Delay in seconds to reconnect to PLC; default=0
   -s secs      Delay in seconds between successive reconnects; default=10
   -S logsize   Rotate logfile after reaching 'logsize' bytes
   -t ms        Maximum timeout in milliseconds per PLC request; default=60000
   -v           Increase verbosity; maximum -vvvv
   -V           Display version information and exit
```

Open Parameters

Master: remote <address>:<port> [Node=#]

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) that can be resolved using the UNIX function gethostbyname( ). PLCIO will attempt to connect to this host using the specified TCP/IP <port>. Once connected, read and write requests can be issued as though the application itself was communicating with the PLC.

[Node=#] is an optional parameter that is only used when *plciod* is connected to a serial interface. This option allows different PLCIO applications to share the same serial device through *plciod*, yet address different PLCs over the serial bus. This value specifies the destination node of the remote PLC for messages sent only by this PLCIO application.

This module does not support unsolicited communication.

Warning	The *cip* module, when running with the [LoadTags] option, only reads the list of available tags at startup. If you upload a new program to the PLC, *plciod* should be restarted for the new tag names to take effect. Otherwise, tag names will refer to old memory locations, and writes to these locations can cause irrecoverable errors on the PLC.

Timeout

The default timeout for connecting to *plciod* is 5 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
/* This example connects to plciod running on localhost port 2000: */

plc_open("remote localhost:2000");

/* This example connects to a remote host running plciod with the abdf1
   module, using remote node 8 on the DF1 network: */

plc_open("remote 10.1.1.60:3000 Node=8");
```

Error Handling

plciod makes requests to the PLC on behalf of your application, forwarding back all responses and error codes—except for a select few. Communications errors PLCE_COMM_SEND, PLCE_COMM_RECV, and PLCE_MSG_TRUNC are handled internally by *plciod*. When received, *plciod* will automatically close and reconnect to the PLC on the remote side, requeuing any pending requests that fail (after servicing other requests via round-robin) until the specified timeout elapses.

Because of this, *plciod* will never forward a PLCE_COMM_SEND, PLCE_COMM_RECV, or PLCE_MSG_TRUNC error to your application. Instead, any such errors received are the result of a communications problem between PLCIO and *plciod*, and the application should call plc_close( ) and plc_open( ) as usual to correct the problem. Additionally, protocol errors can occur when sending requests to the *plciod* daemon, which are different than the forwarded errors that occur between *plciod* and the PLC. These error codes are given a special range between 100 and 199 and can happen with any destination PLC type (see Additional Errors below).

Additional Errors

PLCE_REMOTE_PROTO	100	A protocol error occurred when communicating to *plciod*. The reason is stored in *plc_ptr->aj_errorval[0]* as follows: 1: The operation failed. 2: Bad request length from PLCIO. 3: Invalid username/password specified. 4: Authentication required first. 5: A remote PLCIO error occurred.

s5inat – Siemens Step5 over Ethernet via INAT Echolink

This module provides Ethernet communication to a Siemens Step5 PLC routed through an INAT Echolink. It uses the S5-AP protocol to communicate with the PLC. Each packet is prefixed with the INAT PLC Header to allow for recovering from network interruptions and timeouts. The application is given full access to read and write directly to memory areas including data blocks, timers, counters, flags, and I/O points on the CPU.

Open Parameters

Master: s5inat <address>:<port>

<address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the Echolink on the network. <port> must match a TCP/IP port that is configured as an active connection on the Echolink (see Configuring the Echolink below). The <port> field is required.

PLCIO does not support unsolicited requests from a Siemens Step5 PLC.

Timeout

The default timeout for connecting to the INAT Echolink is 6 seconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
plc_open("s5inat 192.168.0.2:1024");  /* Connects to port 1024 on the Echolink */
```

Point Addressing

Syntax: <type>[X|B|Y|W|D]<offset>[.bit]
or: DB<data block number>.DW<word offset>[.bit]

<type> refers to one of the Data Types listed below. <offset> refers to either a byte- or word-offset from the beginning of the data area, based on the Addressing mode for that type. [X|B|Y|W|D] refers to an optional element size, which can be either Boolean (1 bit), Byte (“B” or “Y”), Word (2 bytes), or Double-Word (4 bytes) long. Except for “X”, this parameter is ignored by PLCIO.

If the “X” (boolean) type is present, then the address must contain a [.bit] suffix corresponding to the specific bit being accessed: from 0 to 7 for byte-addressed data, or from 0 to 15 for word-addressed data. Boolean bits can be read or written only one at a time—the lowest bit of byte 0 in the read/write buffer determines if a single bit is energized (1) or de-energized (0).

The [X|B|Y|W|D] specifier is prohibited on Timer and Counter data types.

Data Types	Addressing	Allowed Offsets	Size (in bytes)
I – Inputs	byte	0 to 127	128
Q – Outputs	byte	0 to 127	128
F – Flags	byte	0 to 255	256
T – Timers	word	0 to 255	512
C – Counters	word	0 to 255	512

For Data Block access, the format “DB#.DW” is used, where # is the data block number from 1 to 255. <word offset> is a starting word offset into the data block memory, which can be a number from 0 to 255. The maximum size that can be defined for a data block is 4096 bytes (2048 words).

Warning	Writing a single bit to the Step5 PLC is not an atomic operation. If a PLC program simultaneously toggles a bit on the same byte accessed by your application, then the bit changed by the PLC can become lost.

Addressing Examples

I10	Accesses the Input Data segment starting with byte 10.
FW200	Accesses the Flag Data segment starting at offset byte 200.
F200.4	Accesses only the 5th boolean bit of byte 200 in the Flag Data segment.
FW201	Accesses the Flag Data segment starting at offset byte 201. Note: Reading a word at offset 201 will give you half of the word at 200 and the other half at 202.
T6	Accesses Timer Data starting with word 6.
DB3	Accesses the entire Data Block 3.
DB3.DW10	Accesses Data Block 3 starting at word 10.
DB3.DW10.15	Accesses only the last (16th) boolean bit of word 10 in Data Block 3.

Because Step5 addresses are just offsets into a large segment of data, the *j_op* parameter of the plc_read( ) and plc_write( ) functions is ignored.

Programming Examples

Example 1: This writes the decimal words "50, 100, 150" to bytes 200-205 of the Flag Data segment.

```
short ai_data[3]={50, 100, 150};
j_result=plc_write(ptr, 0, "FW200", ai_data, 6, 3000, PLC_CVT_WORD);
```

Example 2: This reads 16 bytes (8 words) of data starting at word-offset 20 (byte 40) in Data Block 12.

```
short ai_data[5];
j_result=plc_read(ptr, 0, "DB12.DW20", ai_data, 16, 3000, PLC_CVT_WORD);
```

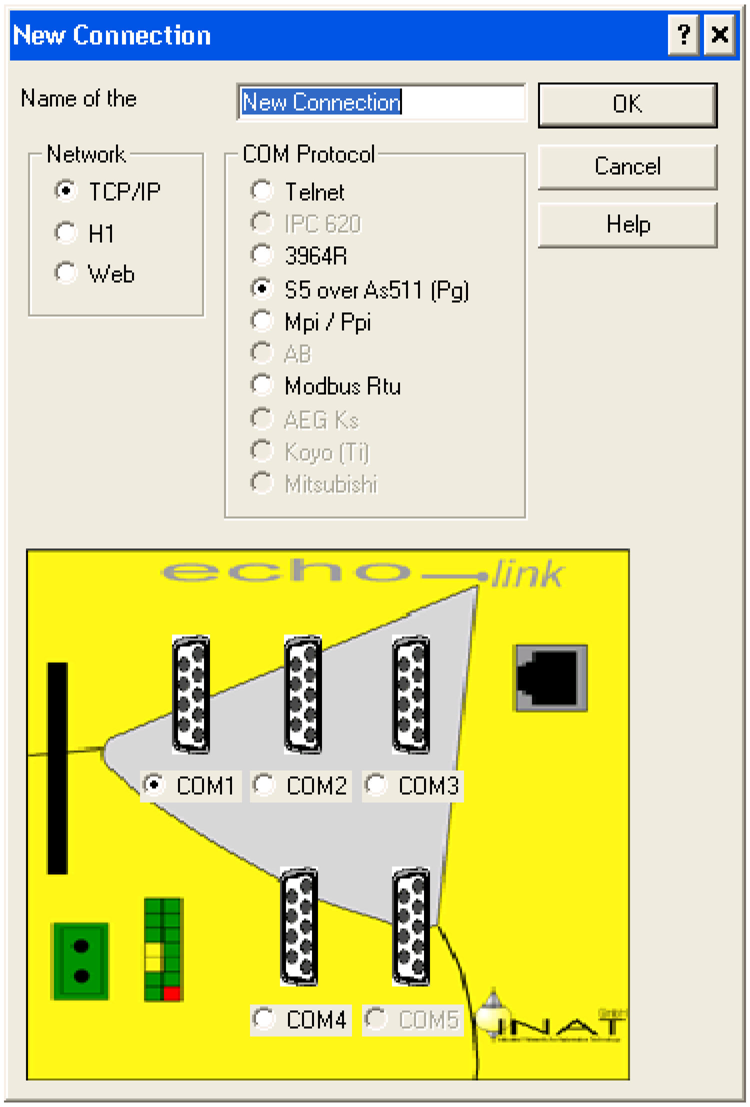
Example 3: This reads a single boolean bit 6 from byte 4 of the Input Data segment. The data returned is a single byte reading 1 if on, or 0 if off.

```
char c_onoff;
j_result=plc_read(ptr, 0, "I4.6", &c_onoff, 1, 3000, PLC_CVT_NONE);
```

Configuring the Echolink

The following examples show how to properly configure the INAT Echolink to pass PLCIO traffic to the Step 5 PLC. Consult the INAT Echolink manual for more information.

First, run the INAT Parameterization program on a Windows terminal to connect to the Echolink. Select "New…" from the "Connection" menu. On this screen, type in a connection name and choose the correct COM port for the PLC. Then select TCP/IP and "S5 over As511 (Pg)" as shown below, and click OK.

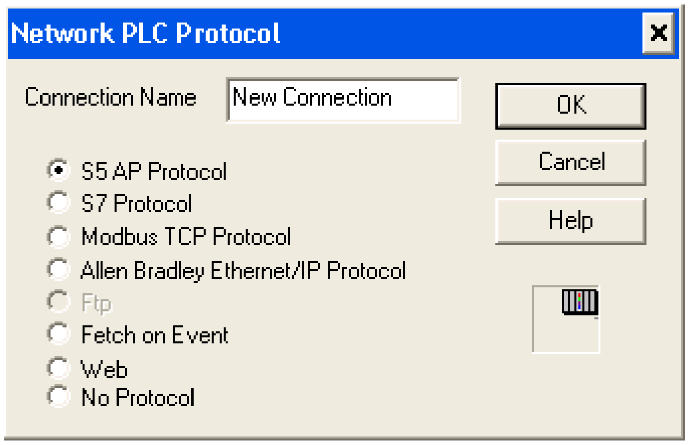

New Connection

Name of the: New Connection

Network: [✓ TCP/IP] H1 Web

COM Protocol: Telnet, IPC 620, 3964R, [✓ S5 over As511 (Pg)], Mpi / Ppi, AB, Modbus Rtu, AEG Ks, Koyo (Ti), Mitsubishi

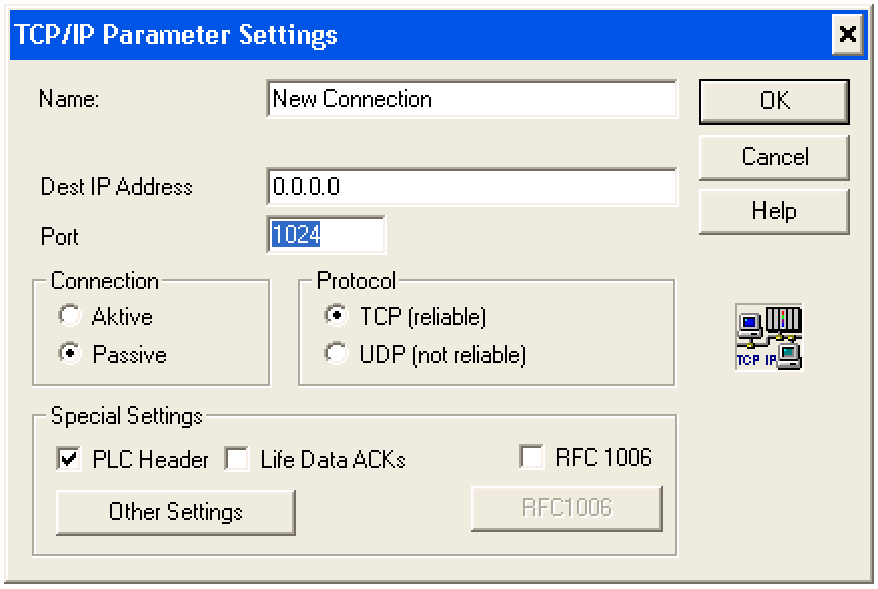
Select the "S5 AP Protocol" as shown below, then click OK.


Network PLC Protocol

Connection Name: New Connection

[✓ S5 AP Protocol]
S7 Protocol
Modbus TCP Protocol
Allen Bradley Ethernet/IP Protocol
Ftp
Fetch on Event
Web
No Protocol

On this screen, choose a TCP/IP port number for your connection. This port number must be unique on the Echolink and can range from 1024 to 65535. This number must match the one used in the plc_open( ) syntax. Change the check boxes to match the screen shown below, and click on "Other Settings".


TCP/IP Parameter Settings

Name: New Connection

Dest IP Address: 0.0.0.0

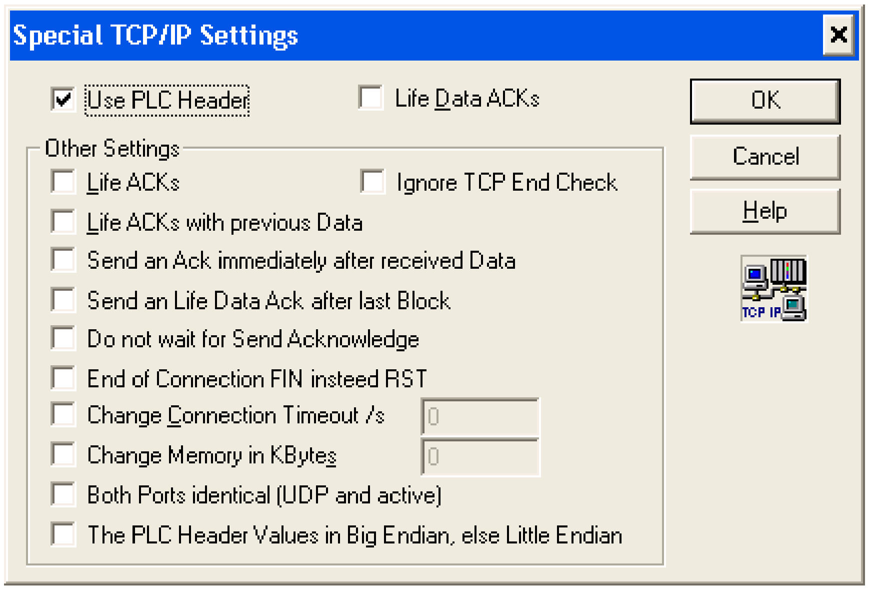
Port: 1024

Connection: Aktive [✓ Passive]

Protocol: [✓ TCP (reliable)] UDP (not reliable)

Special Settings:
- ✓ PLC Header
- ☐ Life Data ACKs
- ☐ RFC 1006

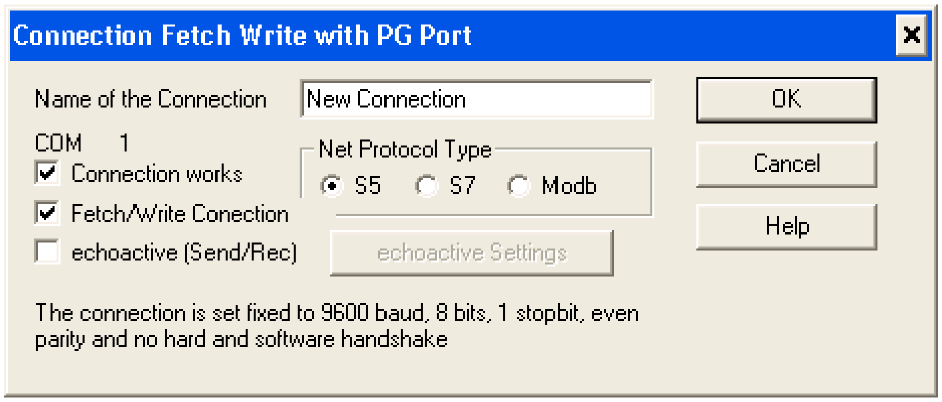
On this menu, change the check boxes to match the screen shown below, then click OK. Click OK once more to advance to the next screen.


Special TCP/IP Settings

- ✓ Use PLC Header
- ☐ Life Data ACKs

Other Settings:
- ☐ Life ACKs
- ☐ Ignore TCP End Check
- ☐ Life ACKs with previous Data
- ☐ Send an Ack immediately after received Data
- ☐ Send an Life Data Ack after last Block
- ☐ Do not wait for Send Acknowledge
- ☐ End of Connection FIN insteed RST
- ☐ Change Connection Timeout /s: 0
- ☐ Change Memory in KBytes: 0
- ☐ Both Ports identical (UDP and active)
- ☐ The PLC Header Values in Big Endian, else Little Endian

On this last screen, make sure “Connection works” and “Fetch/Write Connection” are both selected, and that the “Net Protocol Type” is set to S5 (as shown below). Click OK to create the connection.


Connection Fetch Write with PG Port

Name of the Connection: New Connection

COM 1

- ✓ Connection works
- ✓ Fetch/Write Conection
- ☐ echoactive (Send/Rec)

Net Protocol Type: [✓ S5] S7 Modb

The connection is set fixed to 9600 baud, 8 bits, 1 stopbit, even parity and no hard and software handshake

After clicking OK, the new port is available for access using PLCIO.

Additional Errors

PLCE_S5_PLC_ERROR	200	A PLC error occurred while sending a request. The 1-byte error code is stored in *plc_ptr->aj_errorval[0]*.
PLCE_S5_UNDEF_BLOCK	202	An attempt was made to read from or write to a non-existing Data Block on the PLC.

step5 – Siemens Step5 over Serial (AS511)

This module communicates with a Siemens Step5 PLC over a serial interface using the AS511 protocol. The application is given full access to read and write directly to memory areas including data blocks, timers, counters, flags, and I/O points on the CPU.

Open Parameters

Master:	step5 <device>[:baud:bits:parity:stopbits:flowctrl]

<device> is a UNIX serial device name, such as "/dev/ttyS0" on Linux or "COM1" on Windows. The colon-separated serial parameters are optional and default to the AS511 standard if not specified: "9600:8:E:1".

PLCIO does not support unsolicited requests from a Siemens Step5 PLC.

Timeout

The default timeout for connecting to the Siemens Step5 PLC is 500 milliseconds. This can be changed in the PLCIO Configuration File.

Open Examples

```
plc_open("step5 /dev/ttyS0");  /* Connects to a PLC on device ttyS0 */
plc_open("step5 /dev/ttyS0:9600:8:E:1");  /* Example with parameters */
```

Point Addressing

Syntax:	<type>[X|B|Y|W|D]<offset>[.bit]
or:	DB<data block number>.DW<word offset>[.bit]

<type> refers to one of the Data Types listed below. <offset> refers to either a byte- or word-offset from the beginning of the data area, based on the Addressing mode for that type. [X|B|Y|W|D] refers to an optional element size, which can be either Boolean (1 bit), Byte ("B" or "Y"), Word (2 bytes), or Double-Word (4 bytes) long. Except for "X", this parameter is ignored by PLCIO.

If the "X" (boolean) type is present, then the address must contain a [.bit] suffix corresponding to the specific bit being accessed: from 0 to 7 for byte-addressed data, or from 0 to 15 for word-addressed data. Boolean bits can be read or written only one at a time—the lowest bit of byte 0 in the read/write buffer determines if a single bit is energized (1) or de-energized (0).

The [X|B|Y|W|D] specifier is prohibited on Timer and Counter data types.

Data Types	Addressing	Allowed Offsets	Size (in bytes)
I – Inputs	byte	0 to 127	128
Q – Outputs	byte	0 to 127	128
F – Flags	byte	0 to 255	256
T – Timers	word	0 to 255	512
C – Counters	word	0 to 255	512

For Data Block access, the format "DB#.DW" is used, where # is the data block number from 1 to 255. <word offset> is a starting word offset into the data block memory, which can be a number from 0 to 255. The maximum size that can be defined for a data block is 512 bytes (256 words).

Warning	Writing a single bit to the Step5 PLC is not an atomic operation. If a PLC program simultaneously toggles a bit on the same byte accessed by your application, then the bit changed by the PLC can become lost.

Addressing Examples

I10	Accesses the Input Data segment starting with byte 10.
FW200	Accesses the Flag Data segment starting at offset byte 200.

F200.4	Accesses only the 5th boolean bit of byte 200 in the Flag Data segment.
FW201	Accesses the Flag Data segment starting at offset byte 201. Note: Reading a word at offset 201 will give you half of the word at 200 and the other half at 202.
T6	Accesses Timer Data starting with word 6.
DB3	Accesses the entire Data Block 3.
DB3.DW10	Accesses Data Block 3 starting at word 10.
DB3.DW10.15	Accesses only the last (16th) boolean bit of word 10 in Data Block 3.

Because Step5 addresses are just offsets into a large segment of data, the *j_op* parameter of the plc_read( ) and plc_write( ) functions is ignored.

Programming Examples

Example 1: This writes the decimal words “50, 100, 150” to bytes 200-205 of the Flag Data segment.

```
short ai_data[3]={50, 100, 150};
j_result=plc_write(ptr, 0, "FW200", ai_data, 6, 3000, PLC_CVT_WORD);
```

Example 2: This reads 16 bytes (8 words) of data starting at word-offset 20 (byte 40) in Data Block 12.

```
short ai_data[5];
j_result=plc_read(ptr, 0, "DB12.DW20", ai_data, 16, 3000, PLC_CVT_WORD);
```

Example 3: This reads a single boolean bit 6 from byte 4 of the Input Data segment. The data returned is a single byte reading 1 if on, or 0 if off.

```
char c_onoff;
j_result=plc_read(ptr, 0, "I4.6", &c_onoff, 1, 3000, PLC_CVT_NONE);
```

Additional Errors

PLCE_S5_PLC_ERROR	200	A PLC error occurred while sending a request. The 1-byte error code is stored in *plc_ptr->aj_errorval[0]*.
PLCE_S5_UNDEF_BLOCK	202	An attempt was made to read from or write to a non-existing Data Block on the PLC.

step7 – Siemens Step7 over Ethernet

This module communicates with a Siemens Step7 PLC, allowing the application to read and write directly to memory areas and I/O points on the CPU. It can connect to a S7-200/300/400/1200/1500-series CPU either directly using the built-in Ethernet port or via an Ethernet module (such as CP-343) connected to the CPU.

Open Parameters

Master:	step7 [s7-200|s7-300|s7-400|s7-1200|s7-1500] <address>[:port] [Rack=#] [Slot=#]
Slave:	step7 slave <port>

For master mode, <address> is an IP Address (192.168.1.10) or a Hostname (a30c2001) of the PLC's Ethernet interface on the network. PLCIO will attempt to connect to this host using TCP port 102, or [port] if specified. The optional argument "s7-200", "s7-300", "s7-400", "s7-1200", or "s7-1500" can be used to select the target PLC type. If omitted, then PLCIO communicates using messaging common to any S7-300/400/1200/1500-series CPU.

[Rack=#] is an optional parameter, where # specifies the rack number where the CPU is located (racks are numbered starting from 0). If this option is used, then [Slot=#] must also be specified. If left unspecified, then rack 0 is assumed. This option can not be used on an S7-200 PLC.

[Slot=#] is an optional parameter, where # specifies the slot number of the CPU on the rack (slots are numbered starting from 1). If unspecified, racks 0 and 1 are scanned and the first CPU that is detected is used. Usually 300-series CPUs are located in slot 2 and 400-series CPUs are located in slot 3. This option can not be used on an S7-200 PLC.

Note	Only one application can connect to a S7-200 series PLC at any one time. If PLCIO is connected, then the S7 programming software will not be able to connect to or monitor the PLC. There is no such limitation with 300- to 1500-series CPUs.

Timeout

The default timeout for connecting to the Siemens Step7 PLC is 5 seconds. This can be changed in the PLCIO Configuration File.

Unsolicited Communication

If the "slave" and <port> parameters are present, then Step7 will be opened in **slave** (unsolicited) mode. This module will open the specified TCP port on the local system to listen for connections from Step7 PLCs. The port can be any number from 1 to 65535 (only superusers on UNIX can open ports between 1 and 1023). As only one application can listen on a single port, each message from Step7 can be directed to a specific PLCIO program. Applications can change the local bind address (normally INADDR_ANY) by setting the global variable *j_plcio_ipaddr* to a new address in network byte-order before each plc_open( ) call.

To support unsolicited communication, a Step7 PLC must manually open a TCP/IP connection to the selected <port> on the UNIX computer. Each packet must be hand-crafted to include a 6-byte header at the beginning using this format (words below are 2 bytes each in Big-Endian byte-order):

WORD	length	- Length of the data portion of the message (not including this 6-byte header).
WORD	offset	- User-defined offset; this could act as a message type. It can be set to anything.
WORD	sequence	- A sequence number, starting from 1 and counting by 1 for each packet sent.
[Message data follows]		

PLCIO in turn responds with the following structure through the TCP/IP connection:

WORD	length	- Length of the data portion of the response (not including this 6-byte header).
WORD	error	- Error status, explained below.
WORD	sequence	- A sequence number, mirroring what was sent in the above request.

[Response data follows]

In the above structures, *length* can be from 0 to 1454 (the maximum size of a TCP/IP packet). Zero-length messages are accepted. Return *error* status codes for the PLC are:

0 – No error	Operation was a success.
1 – Failure	Request failed due to bad parameters, or message was rejected by the application with PLC_SLAVE_NAK.
2 – Retry	Link down or application not responding. PLC should retry sending this message until it succeeds.

The PLC should resend its message with the **same** *sequence* number only if it does not receive a response from PLCIO in the allotted time. Otherwise, the PLC should always increment the *sequence* number to mark the beginning of a new transaction, regardless of the *error* code received.

Open Examples

```
plc_open("step7 host.domain:102");  /* Master mode: Utilizes gethostbyname() */
plc_open("step7 10.0.0.8 Slot=3");  /* Master mode: Use CPU in slot #3 */
plc_open("step7 s7-200 10.0.0.42"); /* Master mode: Connect to a S7-200 */
plc_open("step7 slave 2000");       /* Unsolicited mode: Listens on port 2000 */
```

Point Addressing

Syntax:	<type>[X|B|W|D|S]<byte offset>[.bit]
or:	DB<data block number>.DB[X|B|W|D|S]<byte offset>[.bit]

<type> refers to one of the Data Types listed below. <byte offset> specifies an offset from the beginning of the data area, from 0 to 65535. [X|B|W|D|S] refers to an optional element size, which can be either Boolean (1 bit), Byte, Word (2 bytes), Double-Word (4 bytes), or String (1 byte) long. Except for "X", this parameter is ignored by PLCIO. The byte offset does not need to be evenly divisible by the element size used.

If the "X" (boolean) type is present, then the address must contain a [.bit] suffix corresponding to the specific bit being accessed: from 0 to 7. Boolean bits can be read or written only one at a time—the lowest bit of byte 0 in the read/write buffer determines if a single bit is energized (1) or de-energized (0).

The [X|B|W|D] specifier is prohibited on Timer and Counter data types. These types are referenced by word offset rather than byte offset, and requests to these must use a byte-length that is a multiple of 2.

Data Types

I – Input Data	M – Memory Area
Q – Output Data	T – Timer Data
PI – Peripheral Input	C – Counter Data
PQ – Peripheral Output	DB – Data Block

When accessing Data Blocks, the format "DB#.DB" is used, where # is the data block number from 1 to 65535.

Addressing Examples

I10	Accesses the Input Data segment starting with byte 10.
MW200	Accesses the Memory Area segment starting at offset byte 200.
MX200.4	Accesses only the 5th boolean bit of byte 200 in the Memory Area.
MW201	Accesses the Memory Area segment starting at offset byte 201. Note: Reading a word at offset 201 will give you half of the word at 200 and the other half at 202.
T6	Accesses Timer Data starting with word 6.
DB3	Accesses the entire Data Block 3.
DB3.DBW10	Accesses Data Block 3 starting at offset byte 10.
DB3.DBX10.0	Accesses only the first bit of byte 10 in Data Block 3.

Because Step7 addresses are just offsets into a large segment of data, the *j_op* parameter of the plc_read( ) and plc_write( ) functions is ignored.

Programming Examples

Example 1: This writes the decimal words “50, 100, 150” to main memory words 100, 101, and 102.

```
short ai_data[3]={50, 100, 150};
j_result=plc_write(ptr, 0, "MW200", ai_data, 6, 3000, PLC_CVT_WORD);
```

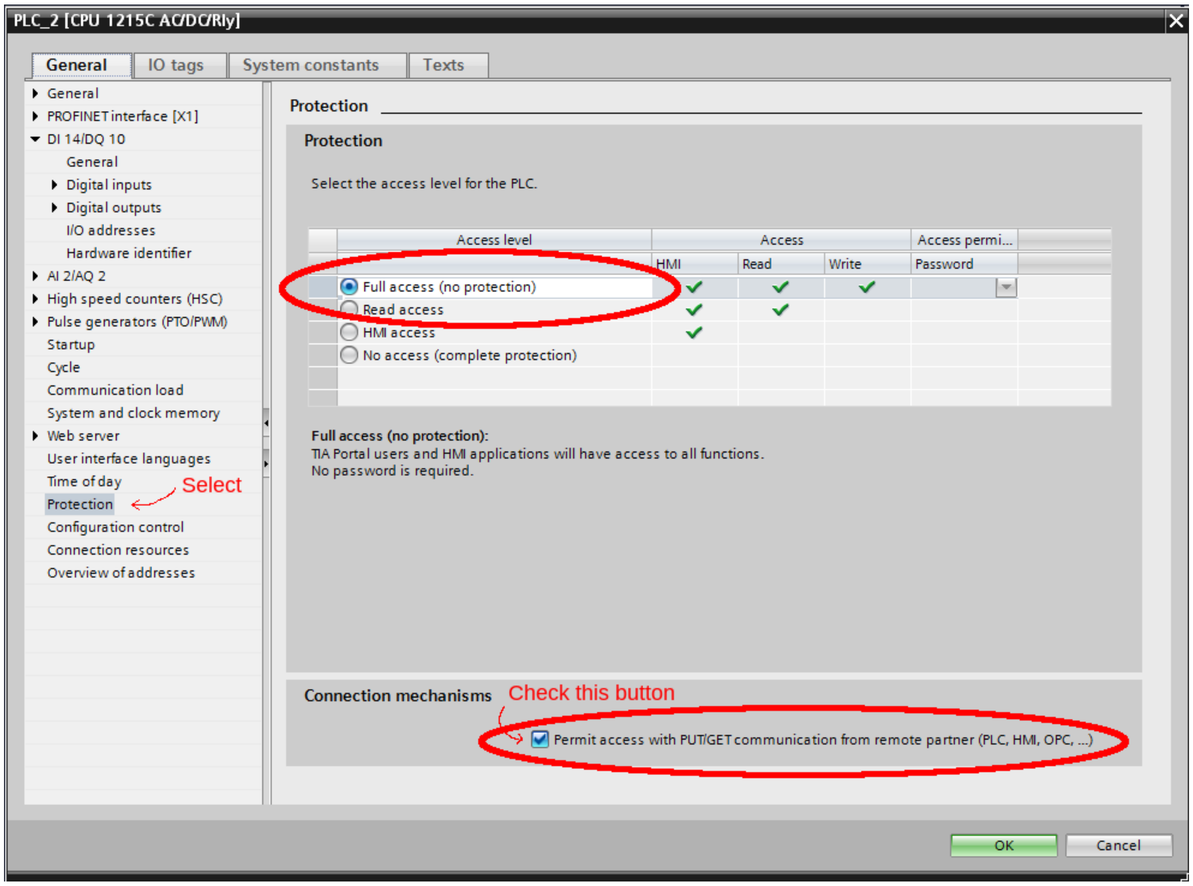
Example 2: This reads a single boolean bit 6 from byte 4 of the Input Data segment. The data returned is a single byte reading 1 if on, or 0 if off.

```
char c_onoff;
j_result=plc_read(ptr, 0, "I4.6", &c_onoff, 1, 3000, PLC_CVT_NONE);
```

Configuring for S7-1200/1500 PLCs

Specific settings must be enabled in the TIA Portal project in order for PLCIO to properly communicate to an S7-1200/1500-series PLC.

First, right-click on the PLC CPU in the project tree and select Properties. Under the General tab, select Protection. Set the access level for the PLC to “Full access (no protection)” as shown below. Also, scroll down to Connection Mechanisms and check the button that reads “Permit access with PUT/GET communication from remote partner.”



Protection

Protection

Select the access level for the PLC.

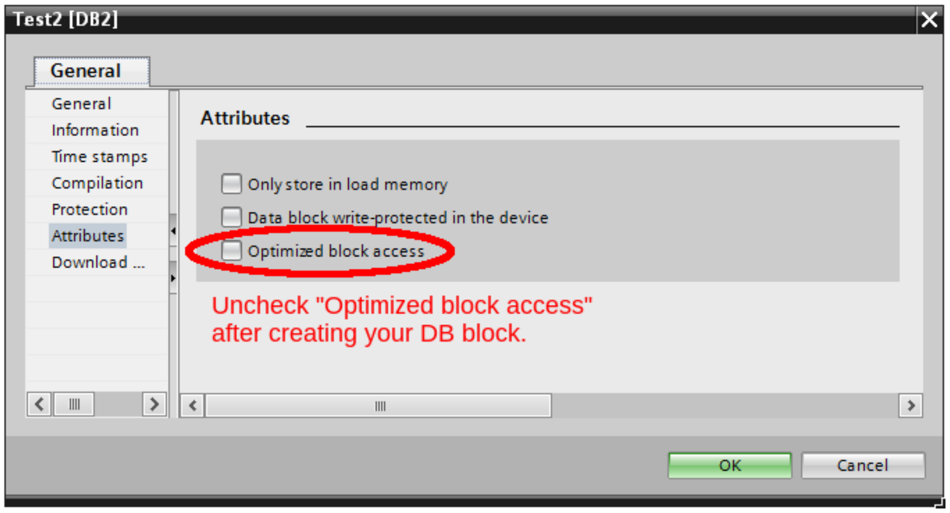
	Access level	Access			Access permi...
		HMI	Read	Write	Password
	● Full access (no protection)	✓	✓	✓	
	○ Read access	✓	✓		
	○ HMI access	✓			
	○ No access (complete protection)				

Full access (no protection):
TIA Portal users and HMI applications will have access to all functions.
No password is required.

Connection mechanisms

☑ Permit access with PUT/GET communication from remote partner (PLC, HMI, OPC, ...)

Second, in order for PLCIO to read/write to Data Blocks (DBs), each Data Block must be set to explicit addressing mode. Right-click on the data block in the project tree and select Properties. Under Attributes, uncheck “Optimized block access” as shown below. This forces the PLC to assign a byte-offset to each member of the data block individually, which can then be entered into the plc_read( ) /plc_write( ) calls.



Only store in load memory [ ]
Data block write-protected in the device [ ]
Optimized block access [ ]

Uncheck "Optimized block access" after creating your DB block.

Additional Errors

PLCE_S7_TSAP_REFUSED	200	The connection to the PLC via ISO 8073 was refused.
PLCE_S7_OPEN_ERROR	201	PLC Open-Session request failed.
PLCE_S7_PLC_ERROR	202	A PLC error occurred while sending a request. The 1-byte error code is stored in *plc_ptr->aj_errorval[0]*.
PLCE_S7_UNDEF_BLOCK	203	An attempt was made to read from or write to a non-existing Data Block, Timer, or Counter on the PLC.
PLCE_S7_CPU_SLOT	204	Wrong slot number specified, or PLCIO failed to auto-detect the slot where the CPU is located.

virtual – CTI Virtual PLC

The Virtual PLCIO module allows developers to test library functionality in their applications without requiring access to a real PLC. It emulates a PLC by providing two data buffers, RAW1 and RAW2, that can be read from or written to by the application program. These buffers are persistent in nature, allowing multiple applications on the same system to write and then later retrieve data from the same global buffer space.

One valuable feature of the Virtual PLC is the ability to develop for future devices. Often during large project development, the real PLCs are not available and application testing must be delayed until field-testing begins. By defining soft PLC points in plcio.cfg, developers can create and test-run applications using the same tag names and addresses that they would have used on the real PLC. Then when it comes time to switch, little or no code change is necessary.

Open Parameters

Master:	virtual

Open Example

```
plc_open("virtual");
```

Point Addressing

The following addresses are available:

TIMESEC	A 4-byte integer containing the current UNIX timestamp
ENVPATH	A 256-byte string buffer containing the contents of the PATH environment variable
RAW1	100 word registers (read/write)
RAW2	1000 word registers (read/write)
TIMEOUT	A 8-byte integer containing the value of the global PLCIO library variable *q_plcio_timeout* (to facilitate the 'make test' shell script)

When opening the PLC for the first time, two files: 'raw1' and 'raw2' will be created in the /tmp directory on UNIX, or C:\Windows\Temp on Windows. These contain the data for addresses RAW1 and RAW2, respectively. Stored PLC data will be available for subsequent opens as long as these two files still exist.

Byte offsets into the buffer space can be specified with the syntax "address(offset)". For instance, the address "RAW1(40)" begins with the 41st byte in the RAW1 buffer and therefore can store no more than 160 bytes (or 80 words). Byte offsets start counting from zero.

No byte-order conversion is performed on the contents during a plc_read( ) or plc_write( ). Additionally, the *j_op* parameter of a plc_read( ) and plc_write( ) is ignored.

plc_validaddr( ) can be used to determine the size and offset (in bytes) of a given point address. The *pj_domain* argument to plc_validaddr( ) will always contain a zero on return.

Programming Examples

Example 1: This reads in the entire contents of the RAW2 register.

```
short ai_data[1000];
j_result=plc_read(ptr, PLC_RREG, "RAW2", ai_data, 2000, 3000, PLC_CVT_WORD);
```

Example 2: This reads the current UNIX timestamp from the TIMESEC address.

```
int j_time;
j_result=plc_read(ptr, PLC_RLONG, "TIMESEC", &j_time, 4, 3000, "j4");
```

Note	Even though the *j_op* and *pc_format* parameters to plc_read( ) and plc_write( ) are ignored, it is good programming practice to set these anyway so that minimal code changes are required when switching to a real PLC.

Additional Errors

PLCE_VIRTUAL_TMPFILE	200	Could not open files ‘raw1’ or ‘raw2’ for read/write access. The UNIX *errno* is stored in *plc_ptr->j_errno*.

6 USER EXTENSIONS

PLCIO provides a simple modular framework for PLC communications. Each of the functions available at the API level have a back-end that talks directly to the PLC. This chapter discusses extending the module portion of PLCIO for when supporting a new PLC or communications protocol is necessary.

Introduction

Adding a module to PLCIO is as simple as creating a new C code file and adding the necessary ‘glue’ functions. All modular functions look like those on the PLCIO API level, except they have a “_plc” prefix instead of “plc”. They are auto detected by the UNIX dlopen( ) call during plc_open( ) time, and they are linked into the current PLC object under the *pfuncs* structure. A module must contain the two global functions **_plc_open( )** and **_plc_close( )** for it to be a candidate for PLCIO.

Modules should have a **#include <plclib.h>** line at the top to load in constants and other system header files internal to the PLCIO library. *plclib.h* is found in the PLCIO source tree in the lib/ directory and is not copied to /usr/local/cti/include during a ‘make install’.

We recommend that you build your module in the so/ directory and add your module to the *Makefile*, rather than build it separate from the PLCIO tree. Also, we strongly recommend starting with an existing module (other than *remote.c* or *virtual.c*) and writing your protocol using its example.

User Open

int _plc_open(PLC *plc_ptr, char *pc_ident)

This is the primary function of the module whose job is to establish a connected session with the PLC. This function is called by PLCIO after already allocating *plc_ptr* and validating whether the user requested a physical or soft PLC. The *pc_ident* argument contains a working copy of the full Open Parameters for the physical PLC. This copy can be munged for easy parsing without needing to strcpy( ) its contents into a separate buffer.

Even from the first line of _plc_open( ), you have the plc_error( ) and plc_log( ) functions available to you. Be aware that the plc_error( ) function inside a module is different than what is exported to the application in the API. This function is a macro #defined as plc_set_error(plc_ptr, …), which sets the appropriate error codes in the local *plc_ptr* variable when called. See the plc_error( ) macro on page 95 for more information.

In **Master** or **Streaming I/O** mode, _plc_open( ) must open a valid connection to the PLC or return an error if it fails. The PLCIO macro “plc_open_transport(plc_ptr, pc_device, j_baud, j_port)” is an easy way for a module to open a connection to a remote PLC via either Ethernet or Serial I/O. It does most of the error checking for you, calls plc_error( ), and returns -1 if something goes wrong.

In **Slave** mode, when you need to open a local port to accept incoming PLC connections, use the PLCIO macro “plc_open_listener(plc_ptr, j_port)” for TCP/IP ports, or “plc_open_udp(plc_ptr, j_port)” for UDP ports. This opens *j_port* and binds it to the IP Address *j_plcio_ipaddr* (global). It performs all error checking for you, similar to plc_open_transport( ).

All modules should establish a default timeout before attempting any Ethernet or Serial communication. First check that *plc_ptr->j_open_timeout* is zero (meaning that a timeout was not specified in plcio.cfg or overridden by the global *j_plcio_open_timeout*), then set the global variable *q_plcio_timeout* to “get_time( )+X” where X is the new timeout in milliseconds. Here is an example code snippet:

```
/* Set default timeout to 5 seconds */
if(!plc_ptr->j_open_timeout)
  q_plcio_timeout=get_time()+5000;
```

Implementation

Modules have sole access to the *plc_ptr->pvoid* member, so they can use this (void *) pointer to malloc( ) persistent data for the current PLC object. Store as much data as necessary to handle all communication parameters with the PLC.

Before returning successful, two *plc_ptr* variables need to be set: *plc_ptr->j_plctype* tells PLCIO the byte-order of the data as expected by the PLC. This value must be set to the ASCII character '9' (decimal 57) if it is to emulate Big-Endian (HP-UX-style) byte-order, or 'I' (decimal 73) to emulate Little-Endian (Intel-style) byte-order. Use the value 'U' (decimal 85) if no byte-order conversions are necessary (this is used in the *virtual* module, for instance).

The second variable is *plc_ptr->j_mode*, which should be set to one of the following constants:

PLC_MASTER	The PLC was opened in Master mode.
PLC_SLAVE	The PLC was opened in Slave mode.
PLC_STREAM	The PLC was opened in Streaming I/O mode.

Return Value

This function should return 0 if successful, or -1 on error.

Make sure the PLCIO error variables are set before returning -1, either by hand with plc_error( ) or via a PLCIO macro (such as when plc_open_transport( ) fails, etc).

User Close

int _plc_close(PLC *plc_ptr)

This function closes all resources previously allocated with _plc_open( ). It should safely close all file descriptors and deallocate all memory that was saved as a structure in *plc_ptr->pvoid*. The *plc_ptr* itself should **not** be freed here.

Return Value

Unless in rare circumstances, this function should always return 0 (successful). Return -1 if an error has occurred that prevents the application from closing the PLC. Be aware that most applications do not check the return value of plc_close( ).

User Read/Write

int _plc_readwrite(j_read, PLC *plc_ptr, int j_op, char *pc_addr, void *p_buf, int j_bytes)

The read/write function manages solicited (master) communication to the PLC. It is this function's responsibility to send binary requests to the PLC, receive and interpret its responses, perform any error checking or retries, and then return the data to PLCIO.

In Streaming I/O mode, this function is only called for plc_write( ) and not plc_read( ). In this case, arguments *j_op* and *pc_addr* should be ignored.

Arguments

int j_read	Determines if the application is performing a write (0) or a read (1) operation. Because these two requests are typically very closely linked, they have been merged into a single read/write function.
PLC *plc_ptr	The PLC object that is performing the request.

int j_op	Contains the specific type of operation to complete. Constants for *j_op* are defined in plc.h and include the following: PLC_RREG, PLC_WREG, PLC_RLONG, PLC_WLONG, PLC_RCOIL, PLC_WCOIL, PLC_RBYTE, PLC_WBYTE, PLC_RCHAR, and PLC_WCHAR. Return error code PLCE_INVALID_OP if the application specified an invalid *j_op*, or if PLC_WREG was used during a plc_read( ), etc. This value should only be checked if the *pc_addr* address does not contain information about the type and size of the data being examined on the PLC. If such information is already known, then you should ignore *j_op* completely.
char *pc_addr	The text address target passed by plc_read( ) and plc_write( ), which identifies the specific point, tag, or memory location to access. This address should be parsed and return a PLCE_PARSE_ADDRESS error code if there is a syntax error, or PLCE_BAD_ADDRESS if no such address exists on the PLC. Note that this is always a physical address; any soft-point lookup has already been performed by PLCIO.
void *p_buf	The application-provided buffer for receiving data on a Read, or for sending data on a Write. For a Write, PLCIO has already converted this data to the byte-order of the PLC (as specified in _plc_open( ) using the *plc_ptr->j_plctype* variable) before it calls _plc_readwrite( ). For a Read, PLCIO will look at the return value of _plc_readwrite( ) to determine the number of bytes in *p_buf* available for converting back to the application's byte-order.
int j_bytes	For a Read, this contains the total size (in bytes) of the buffer pointed to by *p_buf*. For a Write, this contains the number of bytes to send to the PLC in *p_buf*.

Implementation

The order of operations with _plc_readwrite( ) generally include the following:

- Parse the supplied *pc_addr* for a valid and/or existing address. This address is always the physical address, already translated from the Soft-Point Configuration file by PLCIO before _plc_readwrite( ) is called.
- Send a binary request to read or write data of length *j_bytes* to the PLC using the PLCIO timed-write function, tm_write( ) (see page 99). tm_write( ) automatically checks for the application's specified *j_timeout* parameter and will return an *errno* with ETIMEDOUT when time is up. Return error code PLCE_COMM_SEND if an error occurs with tm_write( ) (including ETIMEDOUT).
- Wait for the binary response from the PLC using the PLCIO timed-read function, tm_read( ) (see page 98). tm_read( ) also returns ETIMEDOUT when time is up. Return error code PLCE_COMM_RECV if an error occurs with tm_read( ).
- Parse the response from the PLC. #define and return appropriate module-specific errors so the application programmer can identify the problem in greater detail.
- Repeat the send/read requests in a loop until all data is received or written. This is usually done for large requests, when the communications protocol limits the size of each PLC command.
- Return all received data to the application by copying it to the *p_buf* buffer.

Return Value

On a Read command (*j_read* equals 1), this function should return the number of bytes actually read from the PLC, or -1 on error.

On a Write (*j_read* equals 0), this should return 0 if successful, or -1 on error.

Note	This function is only called when the PLC is opened in **master** mode. If an application uses plc_read( ) in **slave** mode, PLCIO will call plc_receive( ) followed by plc_reply( ) instead.

User Receive

int _plc_receive(PLC *plc_ptr, int j_accept, PLCSLAVE *ps_slave, void *p_buf, int j_bytes)

This function polls for unsolicited PLC requests. Its job is to manage the list of PLCs connected to PLCIO, accept new connections, and wait for messages to arrive on any of the sockets. After receiving a message, it performs error checking, determines the type of message (whether the PLC is reading or writing data), and passes the message on to PLCIO if accepted.

Arguments

PLC *plc_ptr	The PLC object that is performing the request.
int j_accept	Contains a binary mask of message types the application will accept. This value is passed directly from the *j_op* parameter in plc_receive( ). Currently, the following types of messages are defined: PLC_SLAVE_WREGS – PLC is writing data to the application. PLC_SLAVE_RREGS – PLC is reading data from the application. PLC_STREAM_INPUT – PLC is sending streaming input packets to the application. _plc_receive( ) must determine the type of message the PLC is sending and store it in *ps_slave->j_type*.
PLCSLAVE *ps_slave	This variable gets filled in by _plc_receive( ) every time a request is accepted by the PLC. Before returning successfully to PLCIO, this variable must get filled with the following information: int j_length – Length of the incoming read/write request. int j_type – The type of message received—one of the *j_accept* flags above. int j_offset – A PLC-specific offset or address pertaining to the request. int j_ipaddr – The IP Address of the sender, in network byte-order. int j_fileno – The file number associated with an Allen-Bradley address. int j_sequence – The sequence number identifying a Streaming I/O packet.
void *p_buf	An application-provided buffer that data should be copied to when accepting a PLC_SLAVE_WREGS or PLC_STREAM_INPUT request. No byte-order conversion should be performed.
int j_bytes	The total size (in bytes) of the buffer pointed to by *p_buf*. If a request is received that is larger than *j_bytes*, then a NAK reply must be sent to the PLC and _plc_receive( ) should immediately return the error code PLCE_RECV_TOO_LARGE.

Implementation

The order of operations with _plc_receive( ) generally include the following:

- Enter into a loop using the PLCIO macro tm_select( ) to poll on a list of connected file descriptors for incoming messages (see page 100). Also poll on the local file descriptor for incoming connections. If an error occurs with tm_select( ), return -1.
- Check if a PLC has attempted to connect to the server. If so, use the macro plc_accept_connection( ) to retrieve a new file descriptor to add to the list of managed PLC connections.
- Check if a request has been received from one of the PLCs. If so, use tm_read( ) to receive the request.
- Determine the message type of the incoming request, and store it in *ps_slave->j_type*. If the type is not one of the accepted types in *j_accept*, then send a NAK reply back to the PLC (telling it that the command had failed or was rejected), and continue processing messages. Do not return an error to PLCIO if the message was rejected.

- When a message is accepted, remember which PLC sent the message—you need to know what PLC to return a future plc_reply( ) to. Make sure that *p_buf* is big enough to hold the data portion, if any. Copy the data to *p_buf*, fill in the integers in *ps_slave*, and return 0 indicating success.

Managing the internal list of connected PLCs should be done transparently by _plc_receive( ). All errors regarding communications (i.e. problems accepting a new PLC connection, reading/writing on the socket, or protocol errors) should be logged using plc_log( ) if *plc_ptr->j_verbose* is > 0. None of these errors should force _plc_receive( ) to return with an error code, as these are common during normal server operations.

Only when an error or timeout occurs in tm_select( ), or when an **accepted packet** is too large for the application's *p_buf* buffer, should an error be returned to PLCIO.

Return Value

This function should return 0 if successful, or -1 on error.

User Reply

int _plc_reply(PLC *plc_ptr, int j_op, void *p_buf, int j_bytes)

This function must return a response to the last PLC that sent a successful unsolicited request. The application controls the type of response (*j_op*), in addition to any data in *p_buf* that needs to be attached to the reply packet. The application is responsible for performing any byte-order conversion on *p_buf* before calling plc_reply( ).

Arguments

PLC *plc_ptr	The PLC object that is performing the request.
int j_op	A 'success' or 'failure' answer from the application. This value can be either PLC_SLAVE_NAK indicating failure, or PLC_SLAVE_ACK indicating success. Older applications might use PLC_SLAVE_WREGS to reply to a Read-Registers request, which is incorrect terminology for plc_reply( ). Therefore, modules should treat any value that is not PLC_SLAVE_NAK as a successful acknowledgment.
void *p_buf	An application-provided buffer that contains data to transmit in the response packet. This usually only gets filled after the PLC sends a PLC_SLAVE_RREGS request, but it can be the other way as well, depending on what the PLC expects. Check that this value is not NULL before copying any data.
int j_bytes	The size (in bytes) of the response data (*p_buf*) to send back to the PLC.

Return Value

This function should return 0 if successful, or -1 on error. Unlike with _plc_receive( ), all communications errors during the reply should be returned to PLCIO.

Modules should return -1 with the error code PLCE_INVALID_REPLY if this function is called when no PLC is waiting for a response. This can happen if an application calls plc_reply( ) twice in a row.

User Validate

int _plc_validaddr(PLC *plc_ptr, char *pc_addr, int *pj_size, int *pj_domain, int *pj_offset)

This function must confirm for the application that the supplied address, *pc_addr*, is syntactically correct. Logical points are already translated to physical points by the time PLCIO calls this function. No communication with the PLC is allowed.

If additional data is known about the address, either from the syntax used in *pc_addr* or from prereading points and sizes from the PLC, then that data can be transmitted back to the application via the *pj_size*, *pj_domain*, and *pj_offset* variables. These variables are module- or PLC-specific, and not all modules need to implement all variables. Set all unsupported values to 0.

Return Value

This function should return 0 if the address is valid, or -1 on error.

Error code PLCE_PARSE_ADDRESS is appropriate for when the syntax is invalid. Error code PLCE_BAD_ADDRESS should be used only if the module has read in all addresses beforehand and knows that the address does not exist on the PLC.

User FD Set

int _plc_fd_set(PLC *plc_ptr, fd_set *ps_readset, int *pj_nfds)

This function supplies the application with a list of file descriptors that are pending for input. The PLCIO module should fill all file descriptors from connected PLCs, as well as sockets listening for connections, into *ps_readset* by calling FD_SET( ). If *pj_nfds* is not NULL, then for each file descriptor added, *pj_nfds* should be updated with the number of the file descriptor plus 1, only if the previous value is lower.

This same function is queried by PLCIO for both plc_fd_set( ) and plc_fd_isset( ) (see page 34). The behavior of a module's _plc_fd_set( ) between the two calls is identical. If no file descriptors are listening for input, then no action should be performed on *ps_readset* or *pj_nfds*.

Application Example

This example demonstrates how to add socket *fd_socket* to *ps_readset*:

```
int _plc_fd_set(PLC *plc_ptr, fd_set *ps_readset, int *pj_nfds)
{
  int fd_socket=...;  /* Fill in with actual FD */

  /* Add socket listener to ps_readset */
  FD_SET(fd_socket, ps_readset);
  if(pj_nfds)
    *pj_nfds=max(*pj_nfds, fd_socket+1);

  return 0;
}
```

Return Value

This function should return 0 if successful, or -1 on error.

Macros

This section describes the macros that are available for use internally within a PLCIO module. They are declared in plclib.h and are automatically linked in with PLCIO when the module is dynamically loaded. These macros provide routines and I/O-hardened versions of standard UNIX functions, making module-writing a snap. Each macro behaves the same regardless of running PLCIO on UNIX or Windows.

strspc( )

char *strspc(char **ppc_string)

This function parses a string pointed to by *ppc_string* for whitespace, returning a pointer to the next word in the list. The string pointed to by *ppc_string* will get munged up during the process, so it is important never to pass in a constant or read-only string.

This function returns NULL when there are no more words left to parse.

Application Example

This example:

```
char buf[100]="This sentence  contains   words. ";
char *r, *s=buf;

while((r=strspc(&s)))
  printf("%s\n", r);
```

displays the following text:

```
This
sentence
contains
words.
```

strsplit( )

char *strsplit(char **ppc_string, char c_delim)

This function behaves closely to strspc( ) described above, except that it parses *ppc_string* for words separated by a delimiter character *c_delim* instead of by whitespace. Unlike whitespace, which can be any number of spaces, two delimiters encountered one after another will result in a zero-length string.

Application Example

This example:

```
char buf[100]="January:1989::$420.86";
char *r, *s=buf;

while((r=strsplit(&s, ':')))
  printf("%s\n", r);
```

displays the following text:

```
January
1989

$420.86
```

get_time( )

quad get_time(void)

This function returns the 64-bit representation of UNIX time as a number of milliseconds since January 1, 1970. It can be used for sub-second timing and/or profiling.

The type “quad” is #defined to be “long long” in plclib.h.

ipaddr( )

char *ipaddr(int j_ipaddr)

This function returns the ASCII dotted-decimal representation of the integer *j_ipaddr*, in network byte-order.

plc_error( )

void plc_error(int j_error, char *pc_message, …)

void plc_set_error(PLC *plc_ptr, int j_error, char *pc_message, …)

plc_error( ) is a macro only available internally to modules and is really a shortcut #defined in plclib.h for “plc_set_error(plc_ptr, …)”. plc_set_error( ) stores an error code and message into the *plc_ptr* structure so that the application or developer can determine why the PLCIO function call failed.

j_error is the error code to set. Error codes between 1 and 99 are for general errors that can occur on any module and any PLC. Error codes between 100 and 199 are reserved for communication problems with the server side of the *remote* module. Errors starting at 200 and up are specific to your module, which can be defined and extended as the need arises. *pc_message* is a verbose English message describing how the error occurred. This message should include actual return values from the PLC related to the error in question, and it accepts standard printf( )-style substitutions to facilitate this behavior.

This function fills in *plc_ptr->j_error* with the specified error code, *plc_ptr->j_errno* with the current UNIX errno, and *plc_ptr->ac_errmsg* with the formatted *pc_message*. It clears the *plc_ptr->aj_errorval[]* array, so any changes to that array should be made after plc_error( ) is called.

Application Example

The following illustrates a common use of plc_error( ) during the _plc_open( ) routine:

```
/* Send connect request */
j_ret=tm_write(j_fd, ps_message, sizeof(struct s_message));

/* Check if we had an error */
if(j_ret == -1) {
  plc_error(PLCE_COMM_SEND,
            "Error while sending Connection Request: %s",
            strerror(errno));
  close(j_fd);
  return -1;
}
```

plc_clear_errors( )

void plc_clear_errors(PLC *plc_ptr)

This function clears the error stack associated with *plc_ptr*. It zeroes *plc_ptr->j_error, plc_ptr->j_errno, plc_ptr->aj_errorval[]*, and sets the *plc_ptr->ac_errmsg* string to “No error”.

plc_open_transport( )

int plc_open_transport(PLC *plc_ptr, char *pc_device, char *pc_baud, int j_port)

This function is used by _plc_open( ) in **Master** or **Streaming I/O** mode to establish a connection to the PLC. *pc_device* is usually a string inputted by the user, which describes either an Ethernet IP Address/Hostname and port using the syntax “address:port”, or a serial device and its parameters using the syntax “device:baud:bits:parity:stopbits:flowctrl”. All parameters after the device name (such as port or baud rate) are optional. A serial port is distinguished from an Ethernet address by the appearance of a / in the device name.

The arguments *pc_baud* and *j_port* tell PLCIO whether to let the application connect to serial devices and/or Ethernet addresses. If *pc_baud* is NULL or *j_port* is 0, then serial or Ethernet communication is disabled, respectively. Otherwise, pass in for *pc_baud* the default communication parameters for the serial device (such as “9600:8:N:1”), or pass in for *j_port* the default TCP/IP port (from 1 to 65535). A *j_port* of -1 forces the user to specify a TCP/IP port in the plc_open( ) argument.

When opening an Ethernet address, plc_open_transport( ) performs a blocking connect( ) to the requested hostname and port. When opening a serial device, plc_open_transport( ) uses open( ) to access the requested serial device, flush any pending input on the serial line, and set the chosen terminal parameters (baud rate, etc). If either method of connecting fails, plc_error( ) is called and this function returns -1.

With serial devices, plc_open_transport( ) first scans a list of currently-opened devices to look for a match. If the same device has already been opened, along with the same baud rate and communication parameters, then a reference count is incremented, and the already-opened file descriptor is returned. This allows a single PLCIO application to open paths to several different devices (distinguished by different node numbers) on the same serial bus. This logic works because only one call to any plc_*( ) function is permitted at a single time. To properly clean up serial devices, use plc_close_serial( ) instead of close( )

when exiting the module. This call ensures only the last user of the serial device closes the actual file descriptor.

Special socket options are enabled on the connected file descriptor when opening an Ethernet address. First, Nagle's algorithm for coalescing packets is disabled, allowing packets to be sent to the PLC as fast as possible. Second, the linger socket option is turned off, so that when either side abruptly closes the connection, all pending data is immediately thrown away. Third, some PLCs transmit commands using out-of-bound data, so the Out-of-bound-Inline socket option is turned on.

Return Value

This function calls plc_error( ) and returns -1 if the connection fails, otherwise it returns the newly opened file descriptor of the Ethernet socket or Serial connection.

Note	This function can also be used in a **slave** environment when connecting to a daemon process that listens for incoming PLC messages. e*nipd* is one example.

plc_open_udp_transport( )

int plc_open_udp_transport(PLC *plc_ptr, char *pc_device, int j_port)

This function is used by _plc_open( ) in **Master** or **Streaming I/O** mode to establish a UDP connection to the PLC. *pc_device* is usually a string inputted by the user, which describes an Ethernet IP Address/Hostname and optional UDP port using the syntax "address:port". j*_port* specifies the default port to use whenever the user omits it from *pc_device*. A *j_port* of -1 forces the user to specify a port in the plc_open( ) argument.

This function creates a datagram socket and binds it to the destination using connect( ). All subsequent writes will get sent to the destination.

plc_open_listener( )

int plc_open_listener(PLC *plc_ptr, int j_port)

This function is used by _plc_open( ) in **slave** mode to open a TCP/IP port on the local server to listen for PLC connections. *j_port* is the port to open, from 1 to 65535. The listen-queue size is set to the maximum the Operating System supports.

The global variable *j_plcio_ipaddr* can be set prior to calling plc_open_listener( ) to bind to a specific Ethernet IP Address (must be one of the addresses of the server, or 127.0.0.1 for localhost-only connections). The default value for *j_plcio_ipaddr* is INADDR_ANY (0). This functionality is usually reserved for the PLCIO application and should not be changed by the module unless specified in the Open Parameters.

This function is used in conjunction with plc_accept_connection( ) during a _plc_receive( ).

Return Value

This function calls plc_error( ) and returns -1 if the connection fails, otherwise it returns the newly opened file descriptor of the listening socket.

plc_open_udp( )

int plc_open_udp(PLC *plc_ptr, int j_port)

This function is used by _plc_open( ) in **slave** mode to open a UDP/IP port on the local server to listen for PLC messages. *j_port* is the port to open, from 1 to 65535. If *j_port* is 0, then the operating system will choose a random port.

The global variable *j_plcio_ipaddr* can be set prior to calling plc_open_udp( ) to bind to a specific Ethernet IP Address (must be one of the addresses of the server, or 127.0.0.1 for localhost-only messaging). The default value for *j_plcio_ipaddr* is INADDR_ANY (0). This functionality is usually reserved for the PLCIO application and should not be changed by the module unless specified in the Open Parameters.

The module should use tm_select( ) and recvfrom( ) directly on the returned file descriptor to poll for and receive incoming messages. No API macro otherwise exists to handle incoming UDP messages.

Return Value

This function calls plc_error( ) and returns -1 if the connection fails, otherwise it returns the newly opened file descriptor of the listening socket.

plc_accept_connection( )

int plc_accept_connection(PLC *plc_ptr, int j_fd, int *pj_ipaddr)

This function is called by _plc_receive( ) after a tm_select( ) indicates that a connection has arrived on the listening socket. Specify the file descriptor of the listening socket—the same descriptor returned by plc_open_listener( )—as *j_fd*. If *pj_ipaddr* is not NULL, then it will receive the integer IP Address of the remote host that was just accepted (in network byte-order).

Return Value

This function performs a non-blocking UNIX accept( ) internally, returning the file descriptor of the newly connected socket.

In rare cases, tm_select( ) will mark that *j_fd* is ready to receive a connection and accept( ) finds that no connection really exists. This could happen when a connection attempt has been made to the server but immediately closed before the server could respond. Modules should always check the return value of plc_accept_connection( ) for -1 before adding the new FD to its list of managed PLCs.

plc_close_serial( )

void plc_close_serial(int j_fd)

This function is used in _plc_open( ) and _plc_close( ) to properly close a serial port file descriptor that was opened via plc_open_transport( ).

This function scans the list of open serial ports for *j_fd*. If a match is found, it then decrements the reference count by one, signifying how many *PLC** objects still have the serial device opened. When the count reaches zero, or if *j_fd* is not found in the list, the serial entry is removed from the list (if present) and the file descriptor is closed.

tm_read( )

int tm_read(int j_fd, void *p_msg, int j_len)

This function behaves similar to the UNIX read( ) function, except that it is hardened for use in PLCIO. tm_read( ) automatically restarts itself when signals are received, obeys the *j_timeout* parameters in the PLCIO function calls, and will wait on returning any data until the expected *j_len* bytes are fully received.

tm_read( ) internally uses the global variable *q_plcio_timeout* (a 64-bit “long long” integer) to determine how many milliseconds remain in the PLCIO function call. When the application initially calls a top-level plc_( ) function, PLCIO stores the current value of get_time( ) into *q_plcio_timeout* plus the specified *j_timeout* milliseconds, (only when *j_timeout* is nonzero). This can be read or modified at any time in the PLCIO module to control how many seconds remain for PLC processing.

Return Value

Like read( ), this function will return the number of bytes read (always equal to *j_len*), or -1 on error.

Errors

In addition to those in read( ), the following values for *errno* can be returned:

EHOSTDOWN	The Ethernet or Serial connection was dropped before all *j_len* bytes have been received.

ETIMEDOUT	The total amount of time specified in the PLCIO function’s *j_timeout* variable has elapsed, and not all *j_len* bytes have been received.

If tm_read( ) returns -1, then modules should call plc_error( ) with PLCE_COMM_RECV and return -1. This macro does not call plc_error( ) itself.

tm_udp_read( )

int tm_udp_read(int j_fd, void *p_msg, int j_len)

This function behaves exactly like tm_read( ) above, except it is meant to be used on UDP connections where a packet of any length is accepted and returned to the PLCIO application. All read packets will be truncated to a maximum of *j_len* bytes.

Return Value

Like read( ), this function will return the length of the packet read (up to *j_len* bytes), or -1 on error.

Errors

In addition to those in read( ), the following values for *errno* can be returned:

ETIMEDOUT	The total amount of time specified in the PLCIO function’s *j_timeout* variable has elapsed, and not all *j_len* bytes have been received.

If tm_read( ) returns -1, then modules should call plc_error( ) with PLCE_COMM_RECV and return -1. This macro does not call plc_error( ) itself.

tm_write( )

int tm_write(int j_fd, void *p_msg, int j_len)

This function behaves similar to the UNIX write( ) function, except that it is hardened for use in PLCIO. tm_write( ) automatically restarts itself when signals are received, obeys the *j_timeout* parameters in the PLCIO function calls, and will not return until all *j*_len bytes of the data have been written on the socket.

tm_write( ) internally uses the global variable *q_plcio_timeout* (a 64-bit “long long” integer) to determine how many milliseconds remain in the PLCIO function call. When the application initially calls a top-level plc_( ) function, PLCIO stores the current value of get_time( ) into *q_plcio_timeout* plus the specified *j_timeout* milliseconds, (only when *j_timeout* is nonzero). This can be read or modified at any time in the PLCIO module to control how many seconds remain for PLC processing.

Return Value

Like write( ), this function will return the number of bytes written (always equal to *j_len*), or -1 on error.

Errors

In addition to those in write( ), the following values for *errno* can be returned:

EHOSTDOWN	The Ethernet or Serial connection was dropped before all *j_len* bytes could be written.
ETIMEDOUT	The total amount of time specified in the PLCIO function’s *j_timeout* variable has elapsed, and not all *j_len* bytes have been written.

If tm_write( ) returns -1, then modules should call plc_error( ) with PLCE_COMM_SEND and return -1. This macro does not call plc_error( ) itself.

Note	The timeout on a write( ) is checked only when the system call is about to block (due to a full output queue, which is rare). This feature lets most writes succeed even after the timeout has expired, or even if *j_timeout* is set to 1 millisecond.

tm_udp_write( )

int tm_udp_write(int j_fd, void *p_msg, int j_len)

This function behaves exactly like tm_write( ) above, except it is meant to be used on UDP connections where each tm_udp_write( ) defines a single transmitted packet.

Return Value

Like write( ), this function will return the number of bytes written (always equal to *j_len*), or -1 on error.

Notes

If tm_write( ) returns -1, then modules should call plc_error( ) with PLCE_COMM_SEND and return -1. This macro does not call plc_error( ) itself.

tm_select( )

int tm_select(int j_nfds, fd_set *ps_readset, fd_set *ps_writeset, fd_set *ps_exceptset)

This is a hardened select( ) function that automatically restarts itself when signals are received. Each argument is copied to an internal buffer before being passed on to the real select( ). Either *ps_readset*, *ps_writeset*, or *ps_exceptset* can be NULL if no reading, writing, or exceptions are requested, respectively.

tm_select( ) uses the global variable *q_plcio_timeout* (a 64-bit "long long" integer) to determine how many milliseconds remain in the PLCIO function call. When the application initially calls a top-level plc_( ) function, PLCIO stores the current value of get_time( ) into *q_plcio_timeout* plus the specified *j_timeout* milliseconds, (only when *j_timeout* is nonzero). Internally, tm_select( ) calculates the remaining time automatically and uses this as the last argument to select( ).

Return Value

Like select( ), this function will return -1 on error, 0 if the timeout specified by *j_timeout* occurred, or the number of file descriptors that are available for reading on success. If it returns -1, *errno* will be set to the error code returned by select( ).

Notes

If tm_select( ) returns -1 or 0, then modules should call plc_error( ) with PLCE_SELECT or PLCE_TIMEOUT respectively, and return -1. This macro does not call plc_error( ) itself.

tm_sleep( )

int tm_sleep(int j_msec)

This is similar to the UNIX sleep( ) function, except that it automatically restarts itself if interrupted by a signal. The *j_msec* parameter specifies how long to sleep, in milliseconds.

tm_sleep( ) checks the global variable *q_plcio_timeout* (a 64-bit "long long" integer) to determine how many milliseconds remain in the PLCIO function call. If *j_msec* is specified to be longer than the remaining time, then tm_sleep( ) only sleeps for the remaining period and a ETIMEDOUT error is returned when the time is up.

Return Value

This function returns 0 if the total amount of time in *j_msec* has elapsed, or -1 if *q_plcio_timeout* truncated the amount of time slept.

Errors

ETIMEDOUT	The total amount of time specified in the PLCIO function's *j_timeout* variable has elapsed before tm_sleep( ) could sleep the entire *j_msec* milliseconds.

tm_flush( )

void tm_flush(int j_fd)

This function flushes the input buffer on file descriptor *j_fd*. All pending bytes that have not been read will be dropped.

This function is usually used in conjunction with error handling in Serial communications. It allows the PLCIO module to start with a clean request state without needing to close and reopen the device.

Windows Programming

The PLCIO library contains a UNIX emulation layer for running under the Windows operating system. This layer allows modules to be written solely for a UNIX environment, using UNIX functions calls and file descriptors. Thus, no changes are necessary in order to compile or run any modules in Windows.

The emulation layer is available only internally in the PLCIO library and not to the application developer. Winsock function calls cannot be used within a module, as some of them are replaced with UNIX equivalents that expect file descriptors instead of Winsock handles. The global variable *errno* is emulated to contain UNIX-like error codes for all POSIX and Winsock functions. Use the strerror( ) function as usual to retrieve descriptions for each error.

Here is a list of UNIX functions supported by the emulation layer:

UNIX C Library Calls

gettimeofday( )	strerror( )	usleep( )
sleep( )	time( )	

Socket/Serial I/O

accept( )	getsockopt( )	socket( )
bind( )	listen( )	write( )
close( )	read( )	FD_CLR( )
connect( )	recvfrom( )	FD_ISSET( )
fcntl( )	select( )	FD_SET( )
getpeername( )	sendto( )	FD_ZERO( )
getsockname( )	setsockopt( )	

Data Structures

fd_set

Note The emulated select( ) call and fd_set structure support a maximum of 2048 file descriptors.

A ERROR CODES

Each function in the PLCIO Library returns an error status code in addition to the standard return value of the function. Errors can be retrieved using plc_error( ) with the PLC object *plc_ptr* as an argument, or by directly checking *plc_ptr->j_error* before the next function call.

This appendix lists all general errors returned by PLCIO (codes 1 through 99). Errors 100 through 199 are reserved for problems encountered using the *remote* module. Errors 200 and up are reserved for module-specific errors. Detailed error messages can be obtained by using the plc_error( ) function or by displaying *plc_ptr->ac_errmsg*.

Logical Name	Value	Description	Function
PLCE_OK	0	No error; the last function completed successfully.	**Any**
PLCE_OPEN_CONFIG	1	Could not open the Soft PLC Configuration file. Check that the file "plcio.cfg" exists and is readable. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_open( )**
PLCE_INVAL_SOFTPLC	2	Application requested a Soft PLC to be loaded using plc_open("PLC xxx"), however no such PLC was defined in the "plcio.cfg" file.	**plc_open( )**
PLCE_WRONG_TYPE	3	Soft PLC is defined as a different master/slave type in "plcio.cfg" than what is specified in the physical PLC parameters.	**plc_open( )**
PLCE_INVAL_MODULE	4	plc_open( ) was called with a NULL or empty *destination* string, or PLCIO could not locate the requested shared library module (.so or .sl) in the filesystem.	**plc_open( )**
PLCE_NO_MEMORY	5	Not enough memory was available to load the shared library module or allocate the module-specific PLC structures.	**plc_open( )**
PLCE_MISSING_FUNCS	6	The shared library module loaded successfully but does not contain either of the two basic PLCIO functions: _plc_open( ) and _plc_close( ).	**plc_open( )**
PLCE_OPEN_POINTCFG	7	Could not open the Soft PLC Point-configuration file referred to by "plcio.cfg". The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_open( )**
PLCE_MOD_VERSION	8	The versions of the PLCIO shared library and the requested module do not match. Verify that the PLCIO package is completely installed and the LD_LIBRARY_PATH environment variable is pointing to the right directory.	**plc_open( )**
PLCE_NULL	10	Except for plc_error( ) and plc_print_error( ), a PLCIO function was called with a NULL *plc_ptr*.	**Any**
PLCE_NO_SUPPORT	11	The requested PLCIO function is not defined for the specific PLC module being used.	**Any**
PLCE_DUPLICATE_CLOSE	12	plc_close( ) was called with a *plc_ptr* that was already closed. Note that in most cases, a Segmentation Fault may usually occur instead.	**plc_close( )**

Logical Name	Value	Description	Function
PLCE_INVALID_POINT	13	Function called with a NULL or empty *pc_addr* string with the PLC in master mode.	**plc_read( )** **plc_write( )** **plc_validaddr( )**
PLCE_INVALID_LENGTH	14	Function called with its *j_length* parameter less than 1 or greater than PLC_CHAR_MAX (8192).	**Any**
PLCE_BAD_SOFTPOINT	15	In master mode, address *pc_addr* was not found in the Soft Point-configuration file.	**plc_read( )** **plc_write( )** **plc_validaddr( )**
PLCE_NO_READ	16	Application tried to read from a point not marked **R** in the Soft Point-configuration file.	**plc_read( )**
PLCE_NO_WRITE	17	Application tried to write to a point not marked **W** in the Soft Point-configuration file.	**plc_write( )**
PLCE_CONV_FORMAT	18	Unknown character or bad element size found in conversion string *pc_format*.	**plc_read( )** **plc_write( )** **plc_conv( )**
PLCE_PARSE_ADDRESS	19	Parse error while reading point address in *pc_addr*. This could be due to misplaced parentheses, brackets, or missing or expected symbols.	**plc_read( )** **plc_write( )** **plc_validaddr( )**
PLCE_BAD_ADDRESS	20	The physical point address specified in *pc_addr* does not exist on the PLC.	**plc_read( )** **plc_write( )** **plc_validaddr( )**
PLCE_REQ_TOO_LARGE	21	Target address refers to a memory area on the PLC that is too small to hold the application's request.	**plc_read( )** **plc_write( )**
PLCE_BAD_REQUEST	22	The data size specified by *j_length* is not evenly divisible by the element size requested in *j_op*.	**plc_read( )** **plc_write( )**
PLCE_ACCESS_DENIED	23	The PLC address is configured to disallow remote read/write access by a switch in the PLC program.	**plc_read( )** **plc_write( )** **plc_validaddr( )**
PLCE_INVALID_MODE	24	Function called when PLC is being accessed in the wrong master, slave, or stream mode.	**plc_write( )** **plc_receive( )** **plc_reply( )** **plc_fd_set( )** **plc_fd_isset( )**
PLCE_RECV_TOO_LARGE	25	Received an unsolicited message with a size larger than the application's buffer size, *j_length*. The incoming message size is stored in *plc_ptr->aj_errorval[0]*.	**plc_read( )** **plc_receive( )**
PLCE_INVALID_OP	26	The operation specified by *j_op* is not valid for this function. For instance, using PLC_RREG during a plc_write( ) and vice versa.	**plc_read( )** **plc_write( )**
PLCE_INVALID_REPLY	27	Function called without first getting a successful plc_receive( ).	**plc_reply( )**
PLCE_REPLY_TOO_LARGE	28	Size of response message is too big to fit in a single reply packet for this PLC model.	**plc_reply( )**

Logical Name	Value	Description	Function
PLCE_INVALID_DATA	29	The data sent in a plc_write( ) operation was rejected by the PLC. This happens when the target point has a value/range restriction, such as BCD.	**plc_write( )**
PLCE_PARSE_IDENT	40	Syntax error while trying to parse the additional module parameters to a plc_open( ) call.	**plc_open( )**
PLCE_MISSING_HOST	41	PLCIO could not determine the target hostname or UNIX device from the plc_open( ) module parameters.	**plc_open( )**
PLCE_UNKNOWN_HOST	42	An Ethernet Hostname was specified but could not be resolved via gethostbyname( ).	**plc_open( )**
PLCE_BAD_TCP_PORT	43	A TCP/IP port was specified but was not in the range 1-65535.	**plc_open( )**
PLCE_OPEN_SOCKET	44	PLCIO could not open a UNIX socket when connecting to an Ethernet-based PLC. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_open( )**
PLCE_CONNECT	45	PLCIO could not establish a connection to the remote PLC over Ethernet. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_open( )**
PLCE_COMM_SEND	46	A transport error occurred when PLCIO tried to send data to the PLC using write( ), either via Ethernet or Serial I/O. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**Any**
PLCE_COMM_RECV	47	A transport error occurred when PLCIO tried to receive data from the PLC using read( ), either via Ethernet or Serial I/O. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**Any**
PLCE_TIMEOUT	48	A request was made to the PLC, and no response was received after *j_timeout* milliseconds have elapsed. *plc_ptr->j_errno* is set to ETIMEDOUT.	**Any**
PLCE_SERIAL_PARAM	49	The specified baud rate or style was unsupported by the underlying hardware, or the syntax was invalid.	**plc_open( )**
PLCE_OPEN_SERIAL	50	PLCIO could not open the serial device for communication. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_open( )**
PLCE_BIND	51	Failed to open a local TCP or UDP port for unsolicited communication. This usually occurs if the port is already in use. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_open( )**
PLCE_SELECT	52	An internal select( ) error occurred while managing the list of connected PLCs in unsolicited mode. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_read( )** **plc_receive( )**
PLCE_MSG_TRUNC	53	Received a communications packet from the PLC too small to process. This could be caused by a protocol error, unsupported hardware on the PLC, or hardware fault.	**Any**

Logical Name	Value	Description	Function
PLCE_MULTICAST	54	PLCIO could not register the application as a member of a multicast group. Verify that the system supports Multicast Networking. The UNIX *errno* is stored in *plc_ptr->j_errno*.	**plc_open( )**
PLCE_NO_ENDPOINT	55	Application is using Streaming I/O mode as a slave node on the network, and no master has yet established a connection.	**plc_write( )**