Mathematica® Link for LabVIEW®

User's Guide

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Table of Contents

1 Introduction

Greetings, and thank you for purchasing *Mathematica* Link for LabVIEW. As you grow to understand the structure and organization of the Link, we are sure you will discover an ever-increasing number of workflow advantages that can be realized by combining the complementary strengths of LabVIEW and *Mathematica*.

Where to Begin...?

Everyone comes to *Mathematica* Link for LabVIEW with different backgrounds, requirements, and expectations. Indeed, the way you initially use this toolkit will likely depend on your background and existing workflow. However, because the *Mathematica* Link for LabVIEW is a flexible conduit for information transfer between *Mathematica* and LabVIEW, a diverse range of workflow scenarios are possible.

For example, if you have extensive LabVIEW experience, you may choose to call *Mathematica*'s MathKernel as a subprocess of LabVIEW – passing algebraic equations, symbolic expressions and real-time data to *Mathematica* for in-depth processing and manipulation. On the other hand, if you are more familiar with *Mathematica*'s interactive notebook interface, you may prefer to call LabVIEW VIs (virtual instruments) from *Mathematica*, acquiring data directly into a notebook for interactive computation and analysis using *Mathematica*'s advanced tools.

Perhaps you are most interested in reporting and visualization. *Mathematica* is the ideal tool for generating publication-quality graphics for your LabVIEW reports. Or maybe you want to take advantage of *Mathematica*'s interactivity while fine-tuning the control function for your LabVIEW RT application.

Any of these application approaches is a perfectly suitable implementation of the tools contained herein. However, more powerful solutions are possible by utilizing *Mathematica* Link for LabVIEW as the central axis in a combined *Mathematica*–LabVIEW workflow. In this context, the greatest benefits from the synergy between these two powerful applications are realized. (An exploration of a hybrid *Mathematica*–LabVIEW workflow is presented in the Advanced Topics and Examples section, beginning on page 116.) Before we explore specific solutions and the steps necessary to realize them, additional background discussions are in order.

LabVIEW and *Mathematica* – Added Power and Flexibility through a Synergistic Union

LabVIEW and *Mathematica* have two important features in common. First, they are both high-level programming languages that allow custom applications to be written efficiently. Second, programs written with these languages can be run on a variety of operating system/hardware configurations - specifically, under Windows or Windows NT operating systems on computers that use Intel microprocessors or their clones, under MacOS on the Apple Macintosh or other computers based on Motorola 68K or PowerPC microprocessors, and with UNIX on Sun, Hewlett-Packard, and other workstations.

LabVIEW and *Mathematica* both allow fast development of custom portable applications, but each offers a completely different user interaction paradigm and workflow. Interestingly, this is precisely why these two applications can be viewed as extremely complementary. Because their user interfaces are somewhat antithetical, different aspects of a complex problem can be addressed with the user interface that is most suitable to the given task. For instance, in cases where interactive problem-solving or symbolic manipulation is necessary, *Mathematica*'s textual command-line interface is ideal. However, once a solution (or component of a larger system) has been well-defined, LabVIEW's RAD (rapid application development) tools, built-in GUI elements and graphical programming language provide a robust environment for high-efficiency deployment. Combining these two diverse user interfaces interactively yields completely new solution opportunities that are inaccessible using either program alone.

The *Mathematica* Front End

If you are a LabVIEW programmer and are new to *Mathematica*, it is important to understand that the *Mathematica* user interface is completely text-based. *Mathematica* programs are text files and are entered by typing function-like command lines. The *Mathematica* front end is an application—separate from the number-crunching kernel —that is in charge of user interaction. The front end is where the command lines are usually typed, but this is not merely a terminal window. The purpose of the front end is to provide a user-friendly working environment. The front end is used to generate documents called "notebooks" in which you can place much more than the sequence of command lines intended for the kernel. Notebooks are divided into cells that are organized in a hierarchical structure. You can edit, comment on, and organize your notebooks in whatever way that best supports the requirements of your work. A notebook's structure can be loosely designed in any style that stimulates your creativity, or it can also be very rigorously organized.

Thus, you can see that the *Mathematica* front end is similar to a word processor, but it is a word processor connected to the kernel by *MathLink*. (It should be noted that the *Mathematica* kernel can also be accessed directly through a terminal window, or used with an array of different front ends. One example is the *Mathematica* Link for Microsoft Word, which enables Microsoft Word to act as an alternative front end.)

LabVIEW Panels and Diagrams

In contrast with *Mathematica*, the LabVIEW interface is purely graphical. LabVIEW programs, which are referred to as "Virtual Instruments" (VIs), have two separate parts, the front panel and the diagram. The front panel of a VI is usually the only part visible at run-time. It is composed of controls and indicators like those on the front panel of a real scientific instrument. The diagram is the context where the algorithm is actually implemented. As the name of this part of the VI suggests, the diagram is not simply text, like the source files of conventional programming languages. Rather, the diagram graphically represents the flow of data to and from various terminals (that is, diagram representatives of the front panel controls and indicators), and external data sources. Data migrates from inputs to outputs along a network of lines, or "wires" in LabVIEW terminology. The nodes of the network are represented by operators or control structures that are found in any programming language. The major difference between LabVIEW and conventional languages such as C or Fortran is that the program step order of execution cannot be anticipated from the diagram layout as it can be from the instruction order of a source file. It is the availability of the input data from a computation step that will initiate its execution. This data-flow model makes LabVIEW algorithms parallel in nature even if the series of computing steps must be computed sequentially by the CPU. Furthermore, on platforms that support it, LabVIEW takes advantage of the multithreading capabilities of the host operating system (Windows, UNIX) to further overcome the limitations of sequential computing.

Mathematica and LabVIEW - Diverse Computing Capabilities

While the differences between the *Mathematica* and LabVIEW user interaction models are profound, differences between these programs are not restricted entirely to their user interfaces. Several differences can also be uncovered in each program’s computing capabilities. Each language has its specificity, which makes it more (or less) appropriate for particular families of computing problems.

Mathematica is a general-purpose system for doing mathematics. It is a rich programming language that allows a problem to be interactively explored in many different ways. Its underlying architecture is based on transformation rules and pattern matching, which in turn provides powerful symbolic capabilities. Often *Mathematica* programs comprise a large set of definitions or rules that are applied at evaluation time. In most cases, the evaluation of a *Mathematica* program will last no longer than just a few seconds. When an evaluation is running in the kernel, you still can interact with the front end, but you cannot start another evaluation until the one that is currently running is completed. However, it is possible to connect your front end to several kernels simultaneously. You can, for instance, assign the evaluation of cells containing complex commands to a remote kernel running on a system with a fast CPU while you keep your local kernel for less intensive interactive evaluations. A *Mathematica* “session” is a series of inputs and the corresponding outputs returned by a kernel.

Conversely, many LabVIEW programs are designed to run indefinitely until you stop them. Due to the data-flow model, many tasks occur simultaneously during execution. It is the programmer’s responsibility to prioritize tasks through time delays so that there is adequate resources for higher priority operations. Moreover, since LabVIEW is specifically oriented toward data acquisition and instrumentation, VIs often interact with hardware located either inside the computer (acquisition boards, for example) or at remote locations (connected via one or more communication interfaces). Typically a LabVIEW program is required to interact with one or more specialized devices at run-time.

Data acquisition and instrumentation applications often require various instruments to be synchronized with one another, or with real-world events such as triggers or user interaction. The pseudo-parallel structure of LabVIEW diagrams and their timing functions, as well as their ability to make use of dedicated hardware timers, allow VIs to simultaneously manage all of these events.

Mathematica Link for LabVIEW - Practical Implementations

In the opening paragraphs, we briefly discussed different ways of using the *Mathematica* Link for LabVIEW package. Here, we will expand on this further.

1. Run *Mathematica* as a subprocess of LabVIEW

Initially, it may be easiest to visualize implementations where *MathLink* is used to run the *Mathematica* kernel as a subprocess of a LabVIEW application. A particular computation step of your application may be easier to access or to implement in *Mathematica* than in LabVIEW. Perhaps you need to access one of *Mathematica's* sophisticated functions, or even the specialized, domain-specific capabilities of dedicated third-party, add-on package. Either way, the time spent building a communication link between LabVIEW and *Mathematica* will be recovered by the time saved in using the *Mathematica* programming language rather than LabVIEW for this particular step.

2. Run a LabVIEW VI as a subprocess of *Mathematica*

Running the MathKernel as a subprocess of LabVIEW is often the easiest place to begin. However, operating LabVIEW VIs or entire LabVIEW applications from within the *Mathematica* notebook can also be extremely valuable in the conduct of your R&D projects. If you are not yet used to interacting with your instruments from within *Mathematica* notebooks, this use of *Mathematica* Link for LabVIEW may sound less natural to you. Yet, when instruments are operated from within a notebook, *Mathematica* becomes a kind of electronic laboratory notebook offering a convenient way to automatically document your experiments – simply save your notebook at the end of each session to make a comprehensive record your entire session.

3. LabVIEW provides the GUI for your *Mathematica* applications

Like LabVIEW, *Mathematica* provides a robust application development environment. However, developing convincing, powerful GUIs in *Mathematica* can be a challenging task. On the other hand, LabVIEW's diverse set of ready-made controls and indicators makes GUI programming quick and easy. The Link gives you access to the best of both worlds–the *Mathematica*l intelligence and pattern-matching prowess of *Mathematica* with the rapid GUI integration of LabVIEW.

4. Call *Mathematica* to generate publication-quality images and reports with LabVIEW-acquired data

LabVIEW is an ideal development tool for data acquisition application development. However, if you want to export your results in printed form, your options are limited. LabVIEW's bitmap export capabilities and. html document generation is fine for on-screen review, but if you want to produce hard-copy printouts the results can be disappointing. In contrast, *Mathematica* offers a wide variety of document export options – from Postscript and .PDF formats to .WMF (Windows Metafile Format), and even AutoCAD .DXF files. Using the Link, a single experiment or project can benefit from the powerful integrated DAQ capabilities of LabVIEW while also enjoying the robust file export capabilities of *Mathematica*.

5. Add sophisticated *Mathematica* data processing and symbolic manipulation to LabVIEW applications

Admittedly, the *Mathematica*l requirements of many programs are well within the capabilities of LabVIEW. However, complex problems can call for mathematically sophisticated solutions. Sometimes it is much easier to approach a problem using symbolic representation – particularly early in the project cycle when all aspects of the problem are not well understood or completely defined. In other cases, a solution is well within LabVIEW's capabilities, but in order to try several different scenarios substantial wiring and rewiring is necessary. In the exploratory phase, the flexibility of the text-based *Mathematica* interface can provide several productivity advantages. The Link provides interactive communication to *Mathematica's* extensive library of functions – any of which can be called upon interactively, and without the need for rewiring. After the details of the solution have been determined, you can continue to call *Mathematica* in a Link-based hybrid application, or build a stand-alone LabVIEW-based solution.

6. Gain access to powerful *Mathematica* Add-on packages

There are several functions in the standard *Mathematica* packages that have no LabVIEW counterparts. In addition, there are several third-party add-on packages that may prove useful for advanced instrumentation applications. Examples include *Time Series*, *Signal and System*, *Electrical Engineering*, *Experimental Data Analyst*, and *Control System Professional*, to name a few of the titles available. The Link provides access to these powerful packages from within the LabVIEW environment.

7. Take advantage of *Mathematica's* powerful graphics

Mathematica has powerful and flexible graphical capabilities. You may be interested in making direct use of high-level *Mathematica* graphics functions such as **Plot**, **Plot3D**, **ListPlot**, and so forth. Use these capabilities to plot an analytical function describing the theoretical response of your devices. Or simply use these flexible *Mathematica* commands to generate a graphical visualization of the data you just collected. *Mathematica* also has a large set of graphical primitives that enable you to build custom graphical functions. Thus, you can use *Mathematica* Link for LabVIEW to display any kind of graphical output that you can imagine.

8. Create Electronic Laboratory Notebooks

The GUI has become the de-facto standard in the computing world in recent years. However in some circumstances, a text-based interface can be preferable to a GUI. The *Mathematica* notebook interface becomes an attractive alternative to the GUI for instruments and data acquisition systems when LabVIEW applications and data acquisition hardware can be controlled using *Mathematica* Link for LabVIEW. One or a series of *Mathematica* notebooks can function as a digital metaphor for traditional, paper-based laboratory notebooks.

Traditionally, scientists involved in research would rigorously record data in paper laboratory notebooks. In spite of the increased use of digital technology in the laboratory, this traditional recording method is still taught to graduate students. However, anyone who has done experimental research knows the limitations of this approach – after a few months it can be difficult to tell what precisely has been done. The necessity of increasing research productivity and the requirements for complying with regulations specific to quality control of laboratory practice (Good Laboratory Practice, Good Manufacturing Practice) are two reasons to find an alternative methodology. Moreover, given the growing number of digital instruments in laboratories, and the growing use of computer integrated data acquisition systems, physically pasting data produced by these systems into paper notebooks is becoming an increasingly anachronistic practice. Data can be incorporated into documents such as word processing files, but no software has been available specifically for the purpose of recording data in a notebook-type form.

Mathematica Link for LabVIEW could be used for this purpose. Given that all the features of *Mathematica* notebooks are completely described by kernel functions, it is possible to build *Mathematica* programs that automatically generate documents. In this way *Mathematica* can provide scientific computing and typesetting functionality in a single environment. *Mathematica* has a greater functionality than TeX, Fortran and other traditional scientific tools because it provides hypertext features and an active link to the kernel for evaluating *Mathematica* functions. Since the functions used to describe notebooks are kernel functions the front-end application is not needed. Thus, *Mathematica* programs could be developed to generate custom reports from within LabVIEW applications without calling the front end.

As previously mentioned, there are few commercial software packages that can be used as electronic laboratory notebooks. The functionality of the "new digital tools" is still being evaluated. Prototypes that can be tested under real laboratory conditions will be required to prove the concept. Currently *Mathematica* Link for LabVIEW does not have the full functionality of an electronic laboratory notebook. Nonetheless, it may be considered a first step in that direction. The package provides the user with the ideal unified working environment – instruments and experiments can be controlled, and results can be reported automatically.

9. Quickly build distributed LabVIEW applications

MathLink provides functions to exchange complex data in a homogeneous way, independent of the computers used and the underlying transfer protocol. Although LabVIEW provides other “native” communication options (TCP VIs, DataSockets, VI Server, and so forth), the *MathLink* libraries may also be used to distribute an application among several computers. Such applications can be written in a platform-independent way. The advantage is that you do not have to master intricate protocols such as TCP or PPC to be able to write a distributed application: *MathLink* functions take care of the details for you. Once you are comfortable with *MathLink* programming techniques, you will have the option of using the same high-level functions to provide the communications mechanism for your distributed applications.

10. Stand-Alone *Mathematica* Applications

Because *Mathematica*’s text-based interface is so flexible, users unfamiliar with the syntax of the language may experience difficulties when attempting to run applications in the standard *Mathematica* front end. By embedding kernel evaluations into the LabVIEW framework, you can build robust stand-alone GUI applications that anyone can run. For example, the neural net used to run a Khepera robot is easily computed in *Mathematica*. However, setting up the connection weight matrix can be difficult due the abstract nature and large size of the matrix. An attractive and convenient design is to build a VI where the connection between neurons is graphically represented on the front panel. The VI controls are used to set the weights of the neural net connections. At run time, all the computation parameters (connection weights and current state of the network) are passed to the *Mathematica* kernel to compute the new state of the network. (For more information and an actual example involving a Khepera robot, refer to “Khepera.pdf”. This document and other support files are installed in the `LabVIEW/user.lib/MathLink/extra/Advanced/Khepera` directory.)

10. A Powerful Synergistic Workflow

Mathematica Link for LabVIEW allows you to interact with your instruments in an entirely new way. Using a combination of both LabVIEW and *Mathematica* can create a more transparent user experience – where the tools recede, and your attention is focused directly on the problem at hand, rather than on overcoming the limitations of the tools.

To expand on this further, consider a typical example. The development of a measurement program often involves an initial stage where you write a quick LabVIEW prototype to control and interact with your instrument. This first prototype is rarely sufficient to produce high-quality data: you may need to fine-tune your acquisition strategy, redefine acquisition parameters, modify the sampling environment in some way, reposition your sensors and so on, several times before you are ready to collect useful data. Many trials yielding unusable results may pass before the final data are recorded. At this stage of the process, you need to forget the instrument as much as possible, and focus on the research itself.

Now image how useful it would be if you could run a test and acquire a sample with a single **CallInstrument[]** command. This single command would return data directly into your *Mathematica* notebook, where you could then interactively analyze the results in order to compute the parameters for the next experiment. Imagine a workflow where you simply call a new data set from your instruments on command, then interactively process, analyze, plot, manipulate, plot again, and so on...

Here is an example of a typical development loop for a hypothetical experiment:

- Choose acquisition parameters, then make a data acquisition run from within a *Mathematica* notebook.
- Analyze, process, and view the data returned by the instrument interactively using advanced *Mathematica* functions.
- Use the results from your analysis to compute a new set of values for the acquisition parameters.
- Return to the first step.

After the optimal experimental conditions are determined, you may want to take additional steps, such as:

- Saving your *Mathematica* notebook so the entire experiment can be recreated and duplicated in the future.
- Developing a stand-alone LabVIEW VI with hard-wired acquisition parameters for 100% repeatability.
- Extending the native LabVIEW functionality of your stand-alone VI by calling advanced *Mathematica* data-processing, graphing, and file export capabilities.

This hypothetical workflow exposes some of the opportunities offered by the Link, but the details and requirements of your own applications may introduce a completely different set. The key is to exploit the relative strengths of the *Mathematica* and LabVIEW user interfaces, and then realize the combined productivity benefits of both.

Programming and application examples illustrating all of the practical implications noted above are included with the *Mathematica* Link for LabVIEW package. (Programming examples are introduced in the “Getting Started“ and “Programming” chapters later in this user guide.)

Overview of *Mathematica* Link for LabVIEW

This section provides a brief description of *Mathematica* Link for LabVIEW’s functionality and multi-layered architecture.

General Functionality

Mathematica Link for LabVIEW is a bi-directional communication link. As implied in previous discussions, either application – *Mathematica* or LabVIEW – can initiate a message, or be called as a subprocess of the other. To clarify, LabVIEW can call the *Mathematica* kernel as a subprocess, and/or *Mathematica* can call a LabVIEW VI as a subprocess.

Calling *Mathematica* from LabVIEW

Using the *Mathematica* kernel from within LabVIEW is somewhat similar to using formula nodes in LabVIEW application diagrams. However, *Mathematica* Link for LabVIEW offers one important advantage: whereas a formula node resides on a VI diagram, and the VI must be stopped and restarted to change the formula, a

Mathematica string can be specified in a standard string control on a VI front panel, or generated programmatically. Changes made to the control string at runtime can be passed immediately to *Mathematica* for evaluation, so new formulae and functions can be attempted interactively, without stopping the VI.

Mathematica Link for LabVIEW provides you with a small set of high-level VIs that can be thought of as *Mathematica* nodes. For example, one of the bundled VIs evaluates *Mathematica* expressions using properly formatted strings as arguments, and injects the returned results into the VI diagram.

Other VIs are dedicated to graphical output. Integration of these VIs into your LabVIEW application is consistent with the LabVIEW interface, even for graphics, since *Mathematica* images are returned and displayed as intensity graphs. When the kernel and LabVIEW are running on the same computer the usual *Mathematica* evaluations execute quickly. However, functions that return graphics take longer than typical *Mathematica* evaluations because an intermediate PostScript interpretation step is required.

Calling LabVIEW VIs from a *Mathematica* Notebook

VIs can also be opened and run interactively from the *Mathematica* front end. The custom **VIClient.m** package (included in the Link package) interfaces with the specialized `MathLink VI Server.vi` to provide a flexible, yet easy-to-use command interface for launching, running, and disposing of VIs.

The command syntax for controlling VIs is consistent with LabVIEW terminology, past and present. LabVIEW veterans may prefer to use `victl.llb` terminology:

PreloadInstrument[]

CallInstrument[]

ReleaseInstrument[]

and so forth.

People new to LabVIEW and users comfortable with the newer VI Server terminology will likely prefer a command structure consistent with VI Server conventions:

OpenVIRef[]

RunVI[] (or CallByReference[])

CloseVIRef[]

and so on.

(More information about the **VIClient.m** package, the specialized `MathLink VI Server.vi`, and *Mathematica's* VI Server command-line syntax is presented later in this section and at various other places throughout this user guide.)

Structure of the Link

The low-level component that provides the communication link between the *Mathematica* kernel and the outside world is Wolfram's own *MathLink*. *MathLink* is a library of C functions that manage program-to-program communication. The *MathLink* protocol is responsible for all communication with the kernel, including communication with the standard *Mathematica* front end. This protocol can also be used to establish a connection between the kernel and an external *MathLink*-compatible program. (Interested parties are directed the *Mathematica* documentation for more information about *MathLink*.)

Mathematica Link for LabVIEW leverages the *MathLink* code base. The *MathLink* functions are made accessible to LabVIEW through a Code Interface Node. Several VIs are included to implement the most commonly used *MathLink* functions, but all of these VIs call a common CIN VI. Inside this single CIN VI the *MathLink* C functions are actually called. This CIN VI also includes a function to read files generated by the PostScript interpreter MLPost. (Refer to "Software Architecture" on page 62, for a more detailed description.)

High-Level Functions

The following VIs provide direct access to the most common Link functions, and are designed for users with only a minimal familiarity with *MathLink*. They provide ready-made solutions for a variety of standard applications.

MathLink VI Server.vi

This VI is a bridge between *MathLink* and the various VIs of the LabVIEW VI control library. A number of *Mathematica* functions have been designed that are strict *Mathematica* equivalents of these VIs. Thus you can use functions such as **OpenVIRef**, **OpenPanel**, **RunVI**, and others to operate your LabVIEW applications. These applications can run either on the same computer or on two different computers linked over a network.

Kernel Evaluation.vi

This VI passes a string of *Mathematica* commands (in the usual *Mathematica* syntax) to the kernel for evaluation, and returns the results to LabVIEW. You need to specify the expected data type for the result from among a finite number of data types: Boolean, Integers, Real, Complex, Strings, and lists and matrices of all these types. The result of the evaluation is returned on the indicated connector of the VI.

`Kernel Evaluation.vi` has high-level functions to manage all aspects of *Mathematica* sessions, such as printed messages, error messages, etc. You can use it as a general-purpose interface to *Mathematica* functions within the diagrams of your LabVIEW applications.

Mathematica Graphics Generators

Four VIs are provided to make *Mathematica* graphical functions available to LabVIEW. `Generic ListPlot.vi` displays a graphical representation of sets of data. `Generic Plot.vi` is used to visualize, from within LabVIEW, graphics returned by *Mathematica* commands. `Display Bitmap.vi` is similar in function to `Generic Plot.vi`, but uses *Mathematica* graphic functions to generate a .BMP (rather than a PICT) file. `Generate Graphic File.vi` illustrates how images generated in *Mathematica* can be exported to one of several different image file formats.

Development Tools

A number of VIs can help you build your own *MathLink* applications. They combine the action of several *MathLink* functions in ways frequently encountered when developing *MathLink* applications.

Data Transfer VIs

Thirty VIs are provided to transfer the most commonly used data structures (mainly lists and matrices of all kinds). They are documented and their source code is accessible, so they can be a basis for building new VIs to transfer other data structures that have not yet been implemented.

Error Handling VIs

Mathematica Link for LabVIEW follows the LabVIEW error cluster scheme for managing *MathLink* errors. All the VIs have "Error in" and "Error out" clusters. A *MathLink* `Error Manager.vi`, based on `General Error Handler.vi`, is provided to identify *MathLink* errors and take the appropriate corrective action when possible.

MathLink VIs

Forty-three of the most commonly used *MathLink* functions are implemented in *Mathematica* Link for LabVIEW.

Development Environment

A number of examples are provided to illustrate how the *MathLink* VIs can be used in various combinations in LabVIEW applications. Some of the examples are based on the standard VIs contained in the LabVIEW distribution. Others—such as the `PID Control Demo` and the `Mathematica Shape Explorer`—are entirely new VIs, developed for the package using Link components as subVIs. Some of the standard VI library examples are slightly modified to take advantage of *MathLink* functions more efficiently. Comments, guidelines, and recommendations are also provided in the VIs to accelerate the development of your own *MathLink* applications.

Some real applications to control the Khepera mobile robot are also included. Although they cannot be run without the robot, they illustrate the possibility of developing robust real-time applications with *Mathematica* Link for LabVIEW.

For basic work, you might be satisfied to use the higher-level VIs of *Mathematica* Link for LabVIEW. However, as you continue to work with *Mathematica* Link for LabVIEW, you will soon realize that it is truly an open development environment that allows you to make creative use of the respective strengths of *Mathematica* and LabVIEW. Also, depending on the application, you may wish to have an interface that is more oriented toward either *Mathematica* or LabVIEW. Once the interface has been chosen, you are still completely free to implement each step of your algorithm in the most appropriate language. In successive revisions of your application, the language that a particular step is written with may even change. For example, you may first use *Mathematica* in a phase where you want to prove a concept with minimal development cost. Later, after the algorithm has been validated, it can be valuable to rewrite the procedure in LabVIEW for speed and integration.

Thus, *Mathematica* Link for LabVIEW provides a new development framework that neither LabVIEW nor *Mathematica* can claim on its own. The portability of each of the components of this association ensures that applications written with *Mathematica* Link for LabVIEW will also be portable.

2 Installation

Mathematica Link for LabVIEW uses an innovative VI-based installer. When the installation CD is inserted, `Install.vi` automatically launches LabVIEW on the target system and begins the installation process (see Figure 1). The VI-based installer is an ideal choice for LabVIEW toolkit installation offering several distinct advantages over conventional software installers. Specifically, it can quickly and easily locate the target LabVIEW directory on your system and initiate VI Server functions to initialize VI parameters during the installation process.

In most cases, link components are automatically configured to run properly without any user intervention. While you also have the option of installing all *Mathematica* Link for LabVIEW components manually (as discussed later in this chapter), the VI-based installer offers a complete, automated solution for the majority of installations.

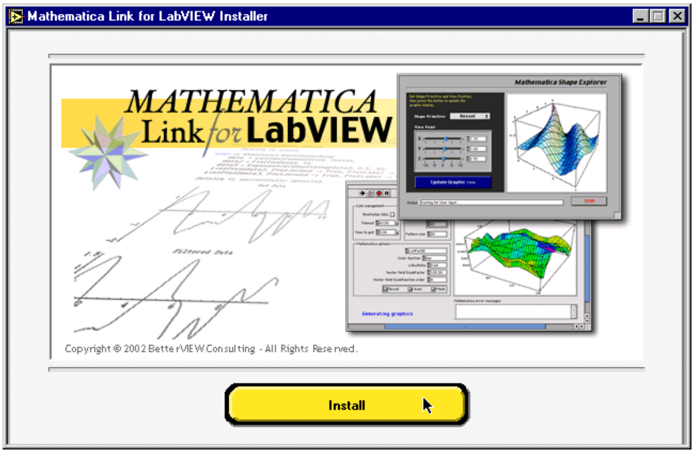

Mathematica Link for LabVIEW Installer
MATHEMATICA
Link for LabVIEW
Mathematica Shape Explorer
Update Graphic
STOP
Filtered Data
Copyright © 2002 BetterVIEW Consulting - All Rights Reserved.
Install

Figure 1. `Install.vi` VI-based installer splash screen.

The default installation assumes *Mathematica* and LabVIEW are both installed on a single target PC. The target PC drive is first scanned for installed copies of LabVIEW and *Mathematica*. After the user confirms the target path locations, the toolkit files are installed in the appropriate places within the LabVIEW and *Mathematica* file systems. The default installation is recommended whenever possible to ensure the full functionality of all *Mathematica* Link for LabVIEW components. If *Mathematica* and LabVIEW will run on different systems, and your network topology does not permit you to locate the *Mathematica* directory from inside LabVIEW using a standard file browser, you may need to install the *Mathematica* components manually. (Manual installation and other non-standard installation requirements are discussed in "Non-standard Installation Options" beginning on page 21.)

Standard Installation Procedures

This section describes the standard installation process in more detail. Since `Install.vi` was constructed using LabVIEW itself, the installation process is identical for both MacOS and Windows platforms.

System Requirements

This distribution of *Mathematica* Link for LabVIEW is designed for LabVIEW 6.0 or higher* and *Mathematica* 4.1 or higher*. *Mathematica* and LabVIEW should be installed on the same PC, or one of the applications should be installed on a second computer accessible to the first over a TCP/IP network. Any system (or combination of systems) that can run LabVIEW and *Mathematica* effectively should be appropriate for *Mathematica* Link for LabVIEW. If you are unsure about the capabilities of your system, please refer to the LabVIEW and *Mathematica* documentation for detailed system requirements.

*IMPORTANT NOTE: Neither *Mathematica* nor LabVIEW is part of the *Mathematica* Link for LabVIEW package: each must be purchased separately. For information about support for previous version of *Mathematica* and/or LabVIEW, contact BetterVIEW directly.

Windows 95/98/ME/NT/2000/XP

The components in this installation are compatible with Windows 95, 98, ME, NT (Version 3.51 or later), 2000, and XP. *Mathematica* Link for LabVIEW cannot run under Windows 3.1.

MacOS

The MacOS version of *Mathematica* Link for LabVIEW will run on MacOS 7.6, 8.x, and 9.x . Version 8.5 or higher is recommended. (MacOS X is not supported at this time, and the package has not been verified for use in the MacOSX "Classic" environment. A native OSX version is under consideration. Contact BetterVIEW directly if you are interested in native MacOSX support.)

Disk Space Requirements

The full installation requires approximately 20 MB of disk space. If you plan to use *Mathematica* on a remote computer, you may also need to install networking software.

Installing the CD-ROM version

1. *Mathematica* Link for LabVIEW is available in two formats: a CD-ROM distribution, and an electronic distribution. (For electronic distribution installation instructions, see page 20.) To install the CD-ROM version, begin by inserting the CD into the appropriate place your on your PC.

2. The VI-based installer, `Install.vi` is configured to auto-run when the CD is inserted. If LabVIEW is running when the CD is inserted, the VI will load immediately. If LabVIEW is not running, it will launch before `Install.vi` loads. If the CD auto-run capability has been disabled on your PC, simply open the CD and double-click on the `Install.vi` icon. Alternatively, you can manually open the VI from inside the LabVIEW editor.

3. Once running, `Install.vi` walks you through the necessary installation steps. Select the items to install using the large yellow checkboxes provided. If both LabVIEW and *Mathematica* will run on the same system, be sure to check both items: "Install LabVIEW Components" and "Install *Mathematica* Components".

4. After selecting the components to install, you will be asked to verify the installation paths. `Install.vi` uses more than one platform-specific search strategy to determine the most likely target paths.

However, an inappropriate path is sometimes selected if several instances of *Mathematica* or LabVIEW are installed on the target PC, or if *Mathematica* and LabVIEW are installed on different PCs, drives, or drive partitions. Be sure to verify, and if necessary, specify alternate paths before initiating the installation step.

5. Follow the instructions provided by the installer and review the online installation notes for additional information and last minute changes.

6. A Mass Compile option has been added to the exit page of the VI-based installer. Click the Mass Compile button if you would like to update the main toolkit components for the version of LabVIEW you are running. (Note: to minimize the time required, some secondary Link components are not updated by the Mass Compile function.)

7. Register your copy of *Mathematica* Link for LabVIEW by selecting the On-line Registration option on the Exit page of `Install.vi`, or by filling in the Application Library Registration Form accessed from the LabVIEW item in the Add-ons section of the *Mathematica* Help Browser (see next subsection).

8. To finish the installation, quit and restart LabVIEW. When LabVIEW restarts, you will have direct access to the Link components through the Function and Control palettes. Also, you will discover that new MathLink items have been inserted in the LabVIEW Help and Tools menus.

REBUILDING THE *MATHEMATICA* HELP INDEX

Before you can use the freshly installed *Mathematica* documentation and `Hands-on exercises`, you will also need to rebuild the *Mathematica* Help Index. Launch *Mathematica* then simply select Rebuild Help Index in the Help menu.

Installing the Electronic Distribution

If you have purchased the electronic distribution of *Mathematica* Link for LabVIEW, the first two installation steps are slightly different. Begin by expanding the compressed .zip (Windows) or .hqx (MacOS) archive. Open the resulting installer folder, and double-click on `Install.vi`. Proceed with the rest of the installation beginning with step 3 from the CD-ROM installation instructions (listed previously).

Uninstalling *Mathematica* Link for LabVIEW

No dedicated uninstaller application has been included with this package. However, *Mathematica* Link for LabVIEW components can be uninstalled manually by removing following directories and all of the items they contain:

LabVIEW/user.lib/MathLink

LabVIEW/project/MathLink

LabVIEW/menus/MathLink

LabVIEW/help/ML_Help.vi

LabVIEW/help/ML_UserGuide.pdf

Mathematica/AddOns/Applications/LabVIEW

More detailed information about the organization and file structure can be found in the section entitled "Organization of *Mathematica* Link for LabVIEW" on page 23.

Non-standard Installation Options

Most configurations can be accommodated using the VI-based installer, and whenever possible, this is the preferred installation method. The VI-based installer uses VI Server functions and *Mathematica* path information to automatically configure Link components. Still, some users may have specific requirements that are not specifically supported by the installer. The most common variations are discussed next.

LabVIEW and *Mathematica* Running on Different PCs

Some users may prefer to run *Mathematica* and LabVIEW on different PCs to distribute the processing load, or simply because the LabVIEW and *Mathematica* licenses are assigned to different PCs. If LabVIEW is installed on both PCs, simply run the installer on each PC and install only the files corresponding to the resident application. More often, LabVIEW will be installed on only one of the PCs. In this case, you may be able to run the installer on one PC and manually browse the second PC's drive to locate the target *Mathematica* directory across the network. If you want to install only the LabVIEW components or only the *Mathematica* components in a particular session, simply set the large checkboxes accordingly on the `Installation Selection` page of the installer VI. If *Mathematica* and LabVIEW components are installed in different sessions, you will be required to manually configure the Math Kernel path information in `Launch Kernel.vi`. This relatively simple procedure is discussed on page 22.

Installing *Mathematica* Link for LabVIEW components in non-standard places.

IMPORTANT NOTE: While it is possible to use `Install.vi` to install the various components of the *Mathematica* Link for LabVIEW package in any location you choose, this practice is not recommended. On-line documentation, Tool menu functionality, and direct access to Link elements from within *Mathematica* and LabVIEW are only available when the components are installed in the intended locations.

Auto-Installation to Non-standard Locations

Manually locate the preferred destinations using the file browser buttons on the installer's main installation page. Then, after acknowledging the warning dialogs, proceed with the installation.

Manual Installation

The VI-based installer has been included to automate the installation process. However, you also have the option of manually copying the files from the CD into any location on your drive. This option is convenient if you only want to install or re-install a specific component. Manual installation also provides a useful workaround if you experience a problem with the VI-based installer. If you are familiar with the organization of the LabVIEW and *Mathematica* file structures, the destinations will be somewhat self-explanatory. If you are new to either LabVIEW or *Mathematica*, refer to “Organization of *Mathematica* Link for LabVIEW” on page 23 for additional background information.

Configuring the MathKernel Path in `Launch Kernel.vi`

One of the duties performed by the VI-based installer is to set the default value of the `MathKernel Path` parameter in `Launch Kernel.vi` This enables LabVIEW to automatically negotiate a MathLink connection without user intervention. If you install the Link components manually or using separate installer sessions, the VI-based installer cannot take care of this task for you.

If you have performed a manual or non-standard installation, you must set the default MathKernel path manually. First locate the MathKernel executable in the *Mathematica* file hierarchy, and make a note of the full path. (On the Windows platform, MathKernel.exe is typically found in the top level of the *Mathematica* file system. MacOS users can usually find it inside the `Mathematica Files:Executables:PowerMac` folder.)

Next, launch LabVIEW and open `Launch Kernel.vi`. This VI can be found in `MLStart.llb`, located in the `LabVIEW/user.lib/MathLink` directory. Enter the full MathKernel path from the previous step into the `MathKernel Path` control on the front panel. Set this value as the default by right-clicking on the modified path control (option-clicking on the Mac) and selecting the Set as Default option. Save the VI to finalize the change and close the panel. Your *Mathematica* Link for LabVIEW VIs should now be configured to automatically negotiate a MathLink connection.

Organization of *Mathematica* Link for LabVIEW

The *Mathematica* Link for LabVIEW installation process creates new directories in both the *Mathematica* file system and in the LabVIEW file system. Installed Link components interact with the *MathLink* libraries installed in your system directory by the *Mathematica* installer. The *Mathematica* Link for LabVIEW file system is described in detail in this section.

The *MathLink* Subdirectory of the User.lib Directory

The majority of the *Mathematica* Link for LabVIEW distribution files are placed in the `MathLink` subdirectory of the `user.lib` folder, which is located inside the main LabVIEW directory. The `MathLink` directory contains the VI libraries `MLStart.llb` and `Tutorial.llb` and four subdirectories named `dev`, `extra`, `LabVIEW`, and `MLPost`.

`MLStart.llb` provides a collection of standard high-level VIs that can be used as limited stand-alone applications, or as the basis for further development. These VIs are described in the section “The MLStart.llb Library” on page 29.

Tutorial.llb contains the example VIs introduced in the "Getting Started" and "Programming" chapters later in this User Guide.

The dev directory contains five VI libraries: MLComm.llb, MLGets.llb, MLFast.llb, MLPuts.llb, and MLUtil.llb. Collectively, these libraries contain the VIs necessary to implement the low-level *MathLink* functions. In MLComm.llb you will find all *MathLink* functions dealing with communication management of the link. MLGets.llb and MLPuts.llb, respectively, contain *MathLink* functions for "getting" and "putting" data to and from the link. MLFast.llb contains a collection of higher-level functions used to transfer common data structures. Finally, MLUtil.llb provides VIs that are not part of *MathLink* but that are used either as subVIs of the VIs in the previous libraries, or to manage general aspects of *MathLink* sessions in LabVIEW applications.

The extra subdirectory contains additional application examples and advanced topics. Here, you will find the *Mathematica* Shape Explorer.vi, a MathLink Simulation and PID Control demo, additional graphics examples, and an advanced application tutorial. The extra folder also contains several VIs and supporting documentation for MathLink operation and control of a Khepera robot. The items in the extra folder are useful, both as quick demonstrations of the capabilities of *Mathematica* Link for LabVIEW, and as an introduction to how various components can be used in the development of larger projects.

The MLPost directory contains the MLPost application, a PostScript interpreter used for rendering *Mathematica* graphics in LabVIEW (see the section "Graphics Rendering" on page 92).

The LabVIEW subdirectory of the MathLink directory contains *Mathematica* material and additional advanced programming examples. During the standard installation, a copy of this directory is also placed in the *Mathematica* file system. The contents of the LabVIEW subdirectory is described in more detail in the section "The LabVIEW Subdirectory of the *Mathematica* Applications Directory" on page 25.

Use the readme.vi utility to browse the content of *Mathematica* Link for LabVIEW.

Each subdirectory installed in the user.lib folder also includes a dir.mnu where icons and structures of floating palettes are saved. (If you are not familiar with this LabVIEW feature, consult the LabVIEW documentation for more specific information). In addition, short descriptions of every library or VI are provided as .txt files that can be read by the readme.vi utility found in the examples directory of the standard LabVIEW distribution.

Other LabVIEW Directories Affected by *Mathematica* Link for LabVIEW Installation

The installation process also affects other directories of the LabVIEW file system:

On line version of the User's Guide.

A complete online version of this manual - the *Mathematica* Link for LabVIEW User Guide – is installed in the help directory. This document can be accessed through the MathLink item in the LabVIEW Help menu .

Run the top-level VIs and examples from the LabVIEW Tools menu.

A MathLink subdirectory is also created in the project directory of the LabVIEW file system. This allows you to launch the main VIs from this distribution directly using the MathLink item in LabVIEW's Tools menu .

Use the *MathLink* palettes to enhance your productivity.

A MathLink sub directory is also added to the LabVIEW menu directory. The file in this folder adds *Mathematica*-oriented palette sets to the Control and Function palettes. You can access the custom sets by selecting the MathLink Palette Set in the Control or Functions palette Options dialog. (For more information about setting and selecting custom palette sets, refer to the LabVIEW documentation.)

The LabVIEW Subdirectory of the *Mathematica* Applications Directory

If you intend to use *Mathematica* Link for LabVIEW to control LabVIEW applications from within *Mathematica*, it is necessary to configure your *Mathematica* installation. The configuration procedure is explained in this section.

If the VI-based installer is used to perform a standard installation (as outlined earlier in this chapter), the *Mathematica* configuration is completed automatically. A second complete copy of the user.lib/MathLink/LabVIEW directory is installed in the Applications directory of the *Mathematica* file system.

When running *Mathematica* and LabVIEW on different systems, the LabVIEW directory containing the VIClient.m file is the only component of the distribution that must be placed on the computer running *Mathematica*. If LabVIEW is also installed on the computer that will run *Mathematica*, simply use the installer VI to automatically install the `LabVIEW` directory. On the other hand, if LabVIEW is not installed on the PC where the *Mathematica* components will run, manual installation is necessary as described next.

Exchanging the package among computers under different operating systems.

Manual installation of the *Mathematica* components involves manually copying the `user.lib/MathLink/LabVIEW` directory into the target *Mathematica* directory. If you need to exchange files across platforms—for example, between a Windows system and a Macintosh or UNIX system— the easiest method is often via a TCP/IP network. (TCP/IP is required to use *MathLink* in multi-platform configurations–for example, *Mathematica* running on a UNIX or Macintosh machine and LabVIEW running on a Windows system). After the network connection is established, you can then transfer files using FTP (File Transfer Protocol), an email attachment, or any native file transfer options your network topology permits. *Mathematica* packages and notebooks are platform-independent ASCII text files that must be transferred in ASCII mode.

Manually configuring *Mathematica*.

Mathematica application packages must be placed in specific subdirectories of the `Applications` directory located inside the `Add-ons` directory of the main *Mathematica* directory. In order to configure your system correctly, place the entire `LabVIEW` directory, and all of its contents, into the .../*`Mathematica`*`/AddOns/Applications` directory. Next, launch *Mathematica* and select Rebuild Help Index in the Help menu. This will add a new item named LabVIEW in the AddOns section of the *Mathematica* help browser. Manual installation of the *Mathematica* components is now complete.

LabVIEW Settings

The following LabVIEW settings can have a significant influence on the performance of *Mathematica* Link for LabVIEW. (These settings can be found in the Performance & Disk section of the Options dialog box – consult the LabVIEW documentation for more details.)

Memory

Deallocate memory as soon as possible: You may want to consider using this option when generating high-resolution graphics, particularly when system memory resources are limited. Activate this option if a first attempt to generate a graphic results in a warning message stating that the available memory is low and more memory cannot be allocated to LabVIEW.

Compact memory during execution (Macintosh only): This option can also help in coping with memory-shortage problems, especially with graphics-intensive applications.

Cooperation Level (Macintosh Only)

In most typical *Mathematica* Link for LabVIEW configurations, the *Mathematica* kernel and your LabVIEW application will share the same CPU. If performance is an issue, it can be critically important to adjust the time yielded by each application to the other. If you need good performance on the LabVIEW side, and only require short evaluation periods for the *Mathematica* kernel, you should set the cooperation level to “low".

In some cases you may need to interact with the two applications at the same time. For instance, if you want to control a VI from within a *Mathematica* notebook, you may need to switch back and forth frequently between the *Mathematica* front end and LabVIEW. In this situation, setting the cooperation level to “high” may improve the response of your application significantly. When the cooperation level is set to “low”, switching from LabVIEW to another application occurs much more slowly. Thus, setting the cooperation to a high level may be advisable even though it can impact the execution speed of your LabVIEWapplication.

3 Getting Started

Immediate Gratification

If you are interested in immediate, hands-on interaction with *Mathematica* Link for LabVIEW, there are a couple of options available to you. If you would first like to see the *Mathematica* kernel operating as a sub-process of LabVIEW, experiment with the `Mathematica Shape Explorer.vi` or the `PID Control Demo`. Both of the demos can be accessed via the MathLink -> Extras menu of the LabVIEW Tools menu (see Figure 2).

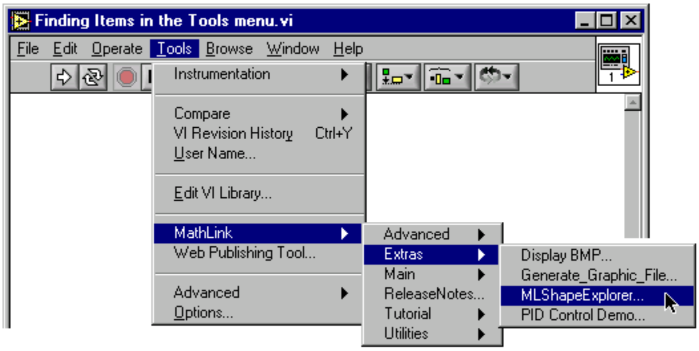


Figure 2. Accesssing MathLink items in the LabVIEW Tools menu.

Readers interested in calling LabVIEW VIs from inside a *Mathematica* notebook are directed to the hands-on tutorials installed with the *Mathematica* files. After *Mathematica* Link for LabVIEW has been installed, you can access the tutorials from the AddOns section of the *Mathematica* Help Browser (see Figure 3).

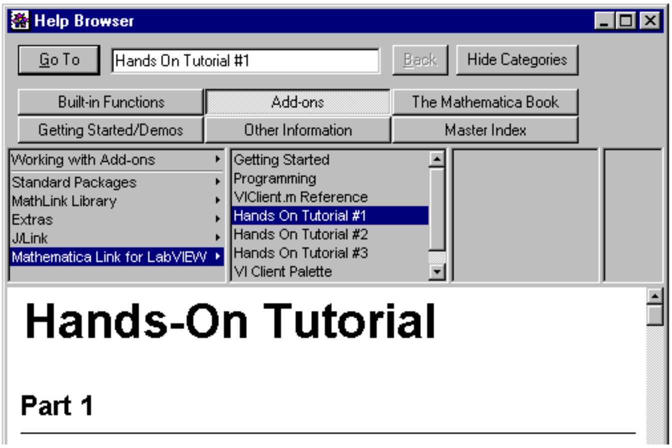


Figure 3. Accesssing the Hands-on Tutorials from the *Mathematica* Help Browser.

Alternatively, you can find the raw tutorial notebook files – **HandsOn_Part1.nb**, **HandsOn_Part2.nb**, and **HandsOn_Part3.nb**, in the following *Mathematica* subdirectory:

…\AddOns\Applications\LabVIEW\Documentation\English\

(Note: This material can also be found in the LabVIEW file system, inside the `user.lib\MathLink\LabVIEW\Documentation` subdirectory.)

If you have any difficulty locating and running these items, review the previous Installation chapter to ensure that the *Mathematica* Link for LabVIEW components have been installed and configured properly.

These introductory materials are intended to get you working with the Link components immediately, but provide very little background information. Additional insight into Link components and operations is provided in the text that follows.

The MLStart.llb Library

In this section you will learn to use the four top-level VIs of `MLStart.llb`:

- `Kernel Evalution.vi`
- `Generic ListPlot.vi`
- `Generic Plot.vi`

- `MathLink VI Server.vi`

Understanding these VIs will give you a glimpse into the fundamental capabilities of *Mathematica* Link for LabVIEW.

`Kernel Evalution.vi` can be used within LabVIEW diagrams to request a computation step from the *Mathematica* kernel.

`Generic ListPlot.vi` provides the *Mathematica* data visualization tools for LabVIEW data sets from within LabVIEW applications.

`Generic Plot.vi` can be used to plot, from within LabVIEW, analytical functions specified in *Mathematica* syntax.

`MathLink VI Server.vi` is the tool that controls LabVIEW VIs and applications from within *Mathematica* notebooks.

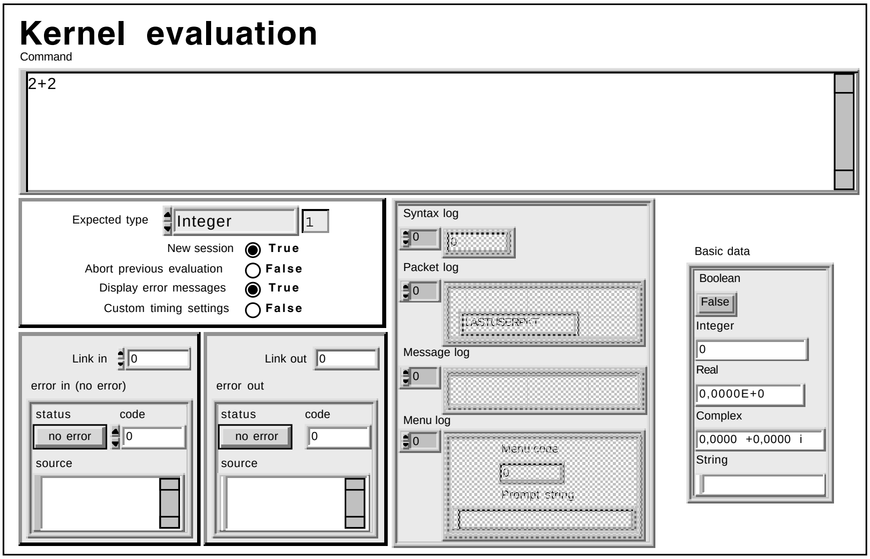
Next, we will look at each of these VIs individually.

Kernel Evaluation.vi

`Kernel Evalution.vi` allows you to send computation requests to *Mathematica's* kernel as strings. You can type *Mathematica* commands in this VI's "Command" box just as you would from within a *Mathematica* notebook. However, it is also necessary to specify the data type that you expect as the result of the computation.

The result of the computation is sent to the appropriate element of one of the three clusters positioned on the right side of the front panel. In Figure 4 only the "Basic data" cluster is displayed. Two other clusters—"1D Arrays" and "2D Arrays"—which are used to collect lists and matrices of data, are not visible in the operational mode depicted in the figure.

Figure 4. The `Kernel Evaluation.vi` front panel.



Kernel evaluation

Command

2+2

Expected type Integer 1

New session ● True

Abort previous evaluation ○ False

Display error messages ● True

Custom timing settings ○ False

Link in 0

error in (no error)

status no error code 0

source

Link out 0

error out

status no error code 0

source

Syntax log 0 0

Packet log 0 LASTUSERPKT

Message log 0

Menu log 0 Menu code 0 Prompt string

Basic data

Boolean False

Integer 0

Real 0,0000E+0

Complex 0,0000 +0,0000 i

String

Use of Kernel Evaluation.vi

This VI can be used either as a main application, or as a subVI in larger applications. Some advanced settings to optimize its performance are discussed later.

Basic Operation

The default values of the controls are set so that you can run the VI immediately. If you worked through the hands-on exercises introduced at the beginning of this chapter, you have already used this VI to compute the result of **2+2.** If you skipped over the tutorial exercises, type **2+2** into the "Command" box and run this VI now to verify your installation of *Mathematica* Link for LabVIEW. (If you experience difficulties, refer to the Troubleshooting notes at the end of this discussion.)

The initial evaluation will take slightly longer than subsequent runs because the *Mathematica* kernel must be launched on the first run. However, once the evaluation is completed, the result is displayed in the "Basic data" cluster on the right. In this case it appears under "Integer", since the "Expected type" was set to "Integer", as is appropriate for the expected result of **2+2**.

Next, you can try a simple operation that returns a string. In the "Command" box type "**MathLink for "<>"LabVIEW"**. Select "String" in the "Expected type" list and run the VI again. The expected concatenated string appears in the "String" box in the "Basic data" cluster.

You can also perform a computation involving a more complex data type. For example, enter **Range[10]^2** with "1D Integers" selected. The "Basic data" cluster disappears and the "1D Arrays" cluster becomes visible. This feature limits the number of objects that are present at any one time on the front panel.

CUSTOM SETTINGS

New session. A sequence of requests issued by `Kernel Evaluation.vi` constitutes a *Mathematica* session. Since definitions are retained throughout the session, it is sometimes helpful to restart the kernel as a means of removing conflicting definitions, or simply as a way to free memory. "New session" is the way to restart the kernel. Its default value is "True", so that a new session is automatically started when the VI is run for the first time. But, after completion, "New session" is reset to "False" so that subsequent evaluations will be performed within the same session. You can, however, manually or programmatically set this control to "True" in order to quit and restart the kernel.

Abort previous evaluation. This control is used to abort a running evaluation. `Kernel Evaluation.vi`—and any other VI sending computations to the *Mathematica* kernel for that matter—should not be permitted to lock out the user with an infinite or very long evaluation. There is a time out control implemented: if the time out is exceeded, then no result is returned. This means that the indicator corresponding to the selected data type will not be updated and this may be easily overlooked. Another way to see that no result was returned is to determine whether a new packet was added to the "Packet log" indicator (see "Logs Description" on page 36, for details).

When such a situation occurs, it is useful to be able to abort the running calculation before sending the next one. Set "Abort previous evaluation" to "True" in this case. An instruction to abort the computation will be sent to the kernel before the next command. Make sure that there is an evaluation running before sending an abort command, otherwise the kernel may quit (see "Troubleshooting" on page 37). As an example of this feature, send the following command to the kernel: **While[True]**. Nothing will be returned. Afterwards send **Names["System`*"]** with the "Abort" button turned on and with "1D Strings" selected as the expected data type.

Display error messages. When this control is set to “True”, error messages will be displayed in a dialog box with a single OK button. Otherwise no dialog box is displayed, which is preferable when you want to programmatically control how the error is handled.

Custom timing settings. Built-in timings should ensure smooth behavior of this VI. However, depending on your configuration and your computations, it might be necessary to refine the timing settings. When this control is set to “True”, a pop-up window appears in which three delays can be tuned. “Delay to quit” is the time required by *Mathematica* to quit, and is used when you start a new session. It is then necessary to allow some time after closing the link before attempting to launch the kernel again. “Delay to launch” is used when starting the kernel, and “Delay to evaluate” is the evaluation time out. Its default value is 60 seconds, which should be sufficient for most applications.

Use as a SubVI

Two simple examples using `Kernel Evaluation.vi` as a subVI are included in `Tutorial.llb`. They are `Good PrimeQ.vi` and `Bad PrimeQ.vi`. Both VIs test an integer to determine whether it is a prime number, but (as per their names) one implementation is better than the other one. Let us examine `Bad PrimeQ.vi` first.

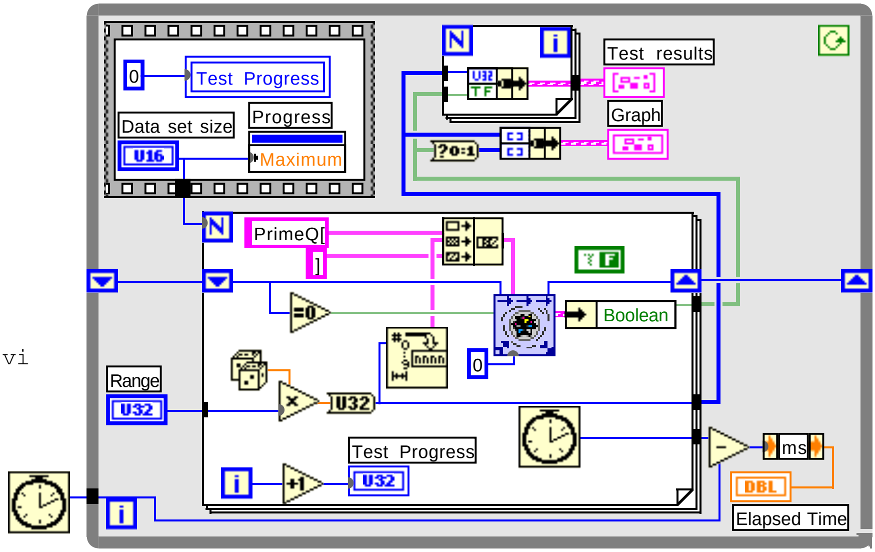


Figure 5. `Bad PrimeQ.vi` diagram.

Open the diagram of `Bad PrimeQ.vi`. Before running the VI, make sure that your kernel is not still connected to `Kernel Evaluation.vi`. In order to close the connection, run `Close All Links.vi` (this VI can be found in `MLUtil.llb`, or can be accessed via the LabVIEW **`Tools`** menu under MathLink -> Utilities -> Close All Links...).

In `Bad PrimeQ.vi`, each number is tested separately with the comparatively trivial *Mathematica* command, **PrimeQ[number]**. The command is sent for evaluation to the kernel repeatedly for as many times as the length of the list. This somewhat inefficient design results in longer than necessary processing times – a feature particularly noticeable on slower, legacy PC equipment. (For example, in testing, a Windows PC with a Pentium processor running at 166 MHz took approximately 0.4 seconds for each element of the list.)

The general structure of `Bad PrimeQ.vi` uses an uninitialized shift register to store the current link reference number. When the VI is run for the first time, 0 is the shift register value. A test is implemented with this criterion to check whether or not a new session must be started.

Now examine the `Good PrimeQ.vi` diagram, as illustrated in Figure 6, and run this VI. Again, before running the VI, make sure that your kernel is not still connected to `Bad PrimeQ.vi`. In order to close the connection, run `Close All Links.vi` (found in `MLUtil.llb`, or accessible from the LabVIEW **`Tools`** menu). Although `Good PrimeQ.vi` is similar to `Bad PrimeQ.vi`, because it uses an uninitialized shift register to manage the session, the command it sends to the kernel is very different. One evaluation only is sent:

PrimeQ/{random numbers}.

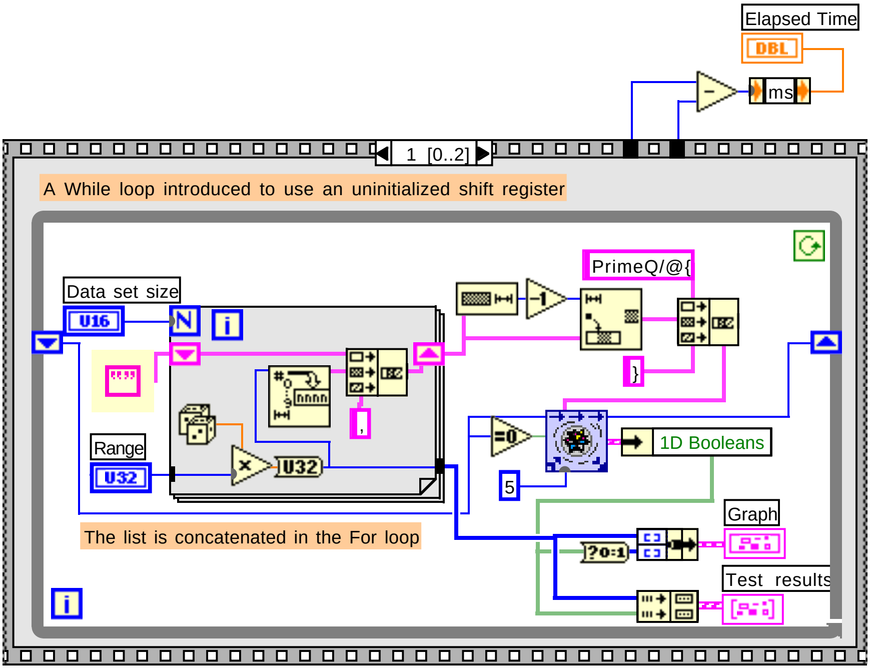


Figure 6. The `Good PrimeQ.vi` diagram.

Because there are fewer *MathLink* transactions, `Good PrimeQ.vi` is more efficient than `Bad PrimeQ.vi` – however, more effort is required to properly format the command string. In order to quit, again run `Close All Links.vi` (found in `MLUtil.llb` or accessible from the LabVIEW **`Tools`** menu.)

Logs Description

Most packets received by LabVIEW are recorded in the log clusters. If you are unfamiliar with *MathLink*, you only need to know that data are sent over the link wrapped in packets. The “Packet log” maintains an up-to-date accounting of packets received from the kernel. You can ensure that the results of the previous request are returned by the kernel prior to sending the next evaluation simply by monitoring the size of the “Packet Log”. For a more detailed description of this cluster, see “**Packet Parser.vi**” on page 89.

Numerical Data Types Compatibility

In contrast to *Mathematica*, numerical data type definitions have been relaxed in the initialization of `Kernel Evaluation.vi` to make handling numbers easier. In *Mathematica* integers, reals, rationals, and complex numbers are distinct because different *Mathematica*l properties hold for each of these types of numbers. In LabVIEW the difference is not that dramatic—LabVIEW operators can handle the three kinds of numbers without differentiation. For instance, the number "2" is an integer and nothing else for *Mathematica.* In LabVIEW it could be an integer, a real, or a complex number.

In addition, determining the correct data type that results from an evaluation can be a tricky or even impossible exercise. What would be the expected data type of **I^2** or **1/2**? In *Mathematica,* evaluating the first one returns an integer and evaluating the second one returns a rational. But for LabVIEW, the first one could be a complex number and the second could still be regarded as a real number. Because of situations like this, data type definitions were relaxed so as to allow coercion of *Mathematica* data types into LabVIEW when possible without loss of information. The following table shows the authorized correspondences between *Mathematica* evaluation types and those you can select on the `Kernel Evalution.vi` front panel.

***Mathematica* type**	**Valid `Kernel Evaluation.vi` types**
Integer	Integer, Real, Complex
Rational	Real, Complex
Real	Real, Complex
Complex	Complex

Whatever the type of your result, you can select "Complex" in `Kernel Evalution.vi`. But if your evaluation returns a real number in *Mathematica* and you select "Integer" on the `Kernel Evalution.vi` front panel, then you will be notified that the result of your evaluation does not match the expected data type. This rule can easily be extrapolated to lists and matrices of numbers.

Troubleshooting

1. **LabVIEW cannot find the *Mathematica* kernel.** If you are prompted to locate a *MathLink* application to launch, this generally means that your installation is not properly configured. One way to solve the problem is to locate the kernel that you want and launch it manually, however this is only a temporary solution. Another option is to locate and open `Launch Kernel.vi`, then set the MathKernel file path explicitly, as outlined on page 22. If you are not comfortable with setting this parameter manually, reinstalling *Mathematica* Link for LabVIEW using the VI-based installer should alleviate further difficulties. (See Chapter 2).

2. **The *Mathematica* kernel is already launched.** You are notified of this situation by a specific *MathLink* error message. You must quit your *Mathematica* kernel before running `Kernel Evaluation.vi` again. You can either quit it manually or run `Close All Links.vi` (found in `MLUtil.llb` and accessible from the LabVIEW **`Tools`** menu.)

3. **The data type is incorrect.** There are a number of situations that can result in an unexpected data type. For instance, if you evaluate **10**, a symbol **Null** is returned instead of the integer that you may have expected. Similarly, if you attempt to evaluate **Table[Sqrt[i], {i, 10}]**, expecting a list of real numbers, you may be surprised to get an error message saying that the returned data type does not match the expected type. You must specify that you want the numerical value of this list (using the *Mathematica* **N[ ]** command) to return a list of real numbers.

4. **The *Mathematica* kernel has quit.** If you send an abort message to the kernel while no evaluation is running it makes the kernel quit.

5. **You want to use a remote kernel.** `Kernel Evaluation.vi` cannot launch a remote kernel. You can open a link to a remote kernel and use `Kernel Evaluation.vi` on this link. For details on opening links, consult "**Getting Connected**" on page 75.

Generic Plot.vi and Generic ListPlot.vi

`Generic Plot.vi` and `Generic ListPlot.vi` are a pair of VIs designed to fulfill the most common needs of *Mathematica* graphics presentation within a LabVIEW application. There are two important areas where *Mathematica* can complement LabVIEW's built-in data visualization tools. These are functions that plot analytical functions, which we refer to as "Plot functions", and functions to visualize lists of data, which we refer to as "ListPlot functions". The VI that calls all Plot functions is named `Generic Plot.vi`, and the one that calls all ListPlot functions is named `Generic ListPlot.vi`.

Rendering graphics in *Mathematica* is somewhat more complicated than evaluating a command that returns data, since it is necessary to use an ancillary application named MLPost. *Mathematica* graphics are PostScript graphics, which must be interpreted by a PostScript interpreter application in order to be rendered on a computer monitor. In the usual *Mathematica* configuration (i.e., the notebook front end interacting with the kernel), the kernel returns the PostScript code to the front end before it is displayed in the notebook. Since neither LabVIEW nor the kernel can interpret PostScript code, it is necessary to call an external PostScript interpreter to generate a bitmap version of the graphic that can be displayed in a LabVIEW window. MLPost is the PostScript interpreter that performs this task. It is operated through a *MathLink* connection directly managed from within LabVIEW. The VIs of `MLStart.llb` take care of these issues for you, but you should be aware of the function of MLPost, since you will see that this application is launched when graphics are generated. You can consult "**Graphics Rendering**" on page 92 for a more detailed description of these issues. Another consequence of the use of MLPost is that there is a significant delay in the generation of graphics. Also note that the first call to MLPost takes additional time because the application must be launched.

To integrate *Mathematica* graphics into LabVIEW VI front panels, the bitmap images generated by MLPost are converted to a format compatible with a specially-customized LabVIEW intensity graph. A copy of this customized intensity graph named `Graphics Window.ctl` can be found in `MLStart.llb`.

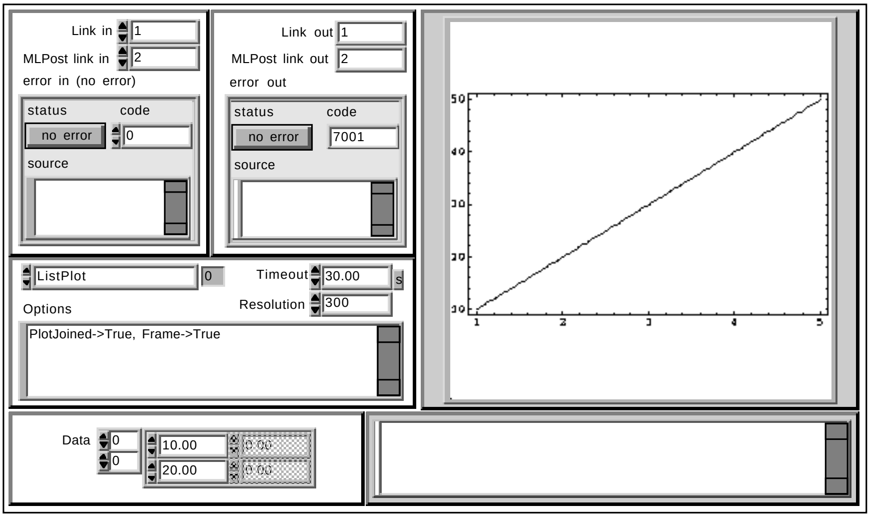
Use of Generic ListPlot.vi

Like `Kernel Evaluation.vi`, this VI can also function either as a main application or as a subVI. Some advanced settings to optimize its performance are discussed later in this section.

Basic Operation

To run `Generic ListPlot.vi,` you will need to understand some of the controls on the front panel shown in Figure 7. Above the box labeled "Options" there is a pop-up control that can be used to select the type of graphics you want to make with your data. Each type corresponds to a particular *Mathematica* function: **ListPlot**, **ListContourPlot**, **ListDensityPlot**, and **ListPlot3D**. (Refer to the *Mathematica* documentation for an introduction to these functions if you are not already familiar with them.) Each function uses a data array as its first argument, followed by a series of options. Data are passed to the VI as a LabVIEW array named "Data", located below the "Options" box: options are passed as a string. The controls, "Timeout" and "Resolution", will be discussed later in "Advanced Settings" on page 41.

Fill the first column of the "Data" control with some data as shown in Figure 7. To run the VI, first make sure that the *Mathematica* kernel is not running by quitting it if necessary. You can either quit it manually or use `Close All Links.vi`, (found in `MLUtil.llb` and accessible from the LabVIEW **`Tools`** menu). Now click the Run button. Soon an elementary plot will be rendered. Since this operation needs to launch both the kernel and MLPost it may take longer than expected. (On slower, older PCs, this may take as long as 20 or 30 seconds.)



Link in 1
MLPost link in 2
error in (no error)
status: no error
code: 0
source:

Link out 1
MLPost link out 2
error out
status: no error
code: 7001
source:

ListPlot 0
Timeout 30.00 s
Resolution 300
Options
PlotJoined->True, Frame->True

Data 0 0
10.00 0.00
20.00 0.00

Figure 7. `Generic ListPlot.vi` front panel.

If this step was successful, you can add additional plot options to the evaluation. Plot options should be typed in the “Options” box, with commas used for separation if several options are used in sequence. However, option sequences should not be enclosed in braces, as they are in the usual *Mathematica* syntax – nor should option sequences be enclosed in quotation marks. Here are examples:

- Correct:
  PlotJoined->True, Frame->True, PlotLabel->"My Plot"
- Incorrect:
  {PlotJoined->True, Frame->True, PlotLabel->"My Plot"}

An Important Note about Aspect Ratio

When using `Generic ListPlot.vi` the last item in the “Options” box should always be AspectRatio-> 1. This ensures that the *Mathematica* image will completely fill the LabVIEW intensity graph. If this step is neglected, residual data may fill the unused portions of the intensity graph, compromising the aesthetic quality of the visual presentation.

Feel free to experiment with your own data sets, but remember that not all of the four **ListPlot** functions accept data with the same format.

ListPlot is the most versatile, since it accepts data with two different formats. For instance, **ListPlot[{y1, y2, ..., yn}]** plots **y1, y2,..., yn** at **x** values 1, 2, ..., *n*. Yet, you can specify custom **x** values using the alternative format for the data list: **ListPlot[{{x1, y1}, {x2, y2} ...,{xn, yn}}]**.

Experiment with `Illustrate ListPlot.vi` to see how different data structures are used by various functions for data visualization.

In `Tutorial.llb`, you will find a VI named `Illustrate ListPlot.vi`. This VI illustrates how different kinds of data structures are used by the different ListPlot functions. Run this VI and consult its diagram.

ADVANCED SETTINGS

Resolution. The bitmap version of the *Mathematica* PostScript graphics is a square matrix of color values. The “Resolution” indicator is used to control the size of this matrix. It specifies, in pixels, the size of a side of the bitmap image. A low value will result in a crude rendering and a high value uses a considerable amount of memory (the picture size grows as the square of the resolution parameter). The setting of this parameter is partly determined by the size of the control in which the picture is displayed. For example, a value of 300 ensures a nice display on the `Generic ListPlot.vi` front panel. The same quality is achieved with a value of 200 in the smaller box of `ListPlot Benchmark.vi` (see “Performance Evaluation” on page 42).

Timeout. This control specifies the maximum time that the VI will wait for the result of a *Mathematica* evaluation, so that you can avoid being trapped in a long or infinite *Mathematica* evaluation. If you do not mind waiting a long time, give this parameter a high value. A high value will not delay the evaluation: the result will be returned as soon as it is available from the *Mathematica* kernel. If the time out is exceeded before graphics are returned, the execution of the VI will stop and nothing will be displayed.

Note that the time out applies only to the *Mathematica* kernel’s evaluation time. It does not include the time required by MLPost to interpret the PostScript. In order to estimate a reasonable value for the time out parameter, you can make tests in the *Mathematica* front end to gauge the time required for the computation of graphics that are similar to the ones you plan to visualize in LabVIEW.

Performance Evaluation

Since rendering graphics can be computationally time-consuming, a tool has been provided in `Tutorial.llb` to help you analyze how long it will take on your hardware configuration: its name is `ListPlot Benchmark.vi`.

`ListPlot Benchmark.vi.` is designed to generate a sequence of graphical outputs, the number of which is set by an "Iteration" control on the front panel. Data are generated by sinusoidal functions and arranged in a matrix having "Line" lines and "Column" columns. You can control the resolution of the display with the "Resolution" slider, and there is also a control to select the type of plot you want to generate. All of the graphics that are generated are stored in a buffer and are displayed sequentially, once when they are computed and a second time after the last iteration is completed. The second display sequence indicates how the display step will perform on your system.

To get an idea of the time it takes the *Mathematica* kernel to create the graphics, go to the *Mathematica* front end and execute the following example commands:

```
l = Table[Cos[i] Sin[j], {i, 20}, {j, 20}];
Timing@ListContourPlot[l]
```

Close any link that may still be open with `Close All Link.vi`. Create the same graphics with `ListPlot Benchmark.vi`, and compare the time needed to render the graphics with the time that was needed by *Mathematica*.

The most time-consuming step in the graphics rendering process is the PostScript interpretation, and how long it takes depends on the complexity of the graphic. Use `ListPlot Benchmark.vi` with increasing numbers of columns and lines at a fixed resolution. You will see that the iteration time depends more on the size of the data set being plotted than on the resolution of the display. Also note that some kinds of graphics are more complex than others. For instance, given 20 lines, 20 columns, and a 200–pixel resolution, it will take about twice as long to evaluate **ListContourPlot** or **ListPlot3D** as it will to evaluate **ListDensityPlot**.

Use as a SubVI

ListPlot Benchmark.vi is an example of the use of Generic ListPlot.vi as a subVI of an upper–level VI. Figure 8 shows how Generic ListPlot.vi can be used in this context.

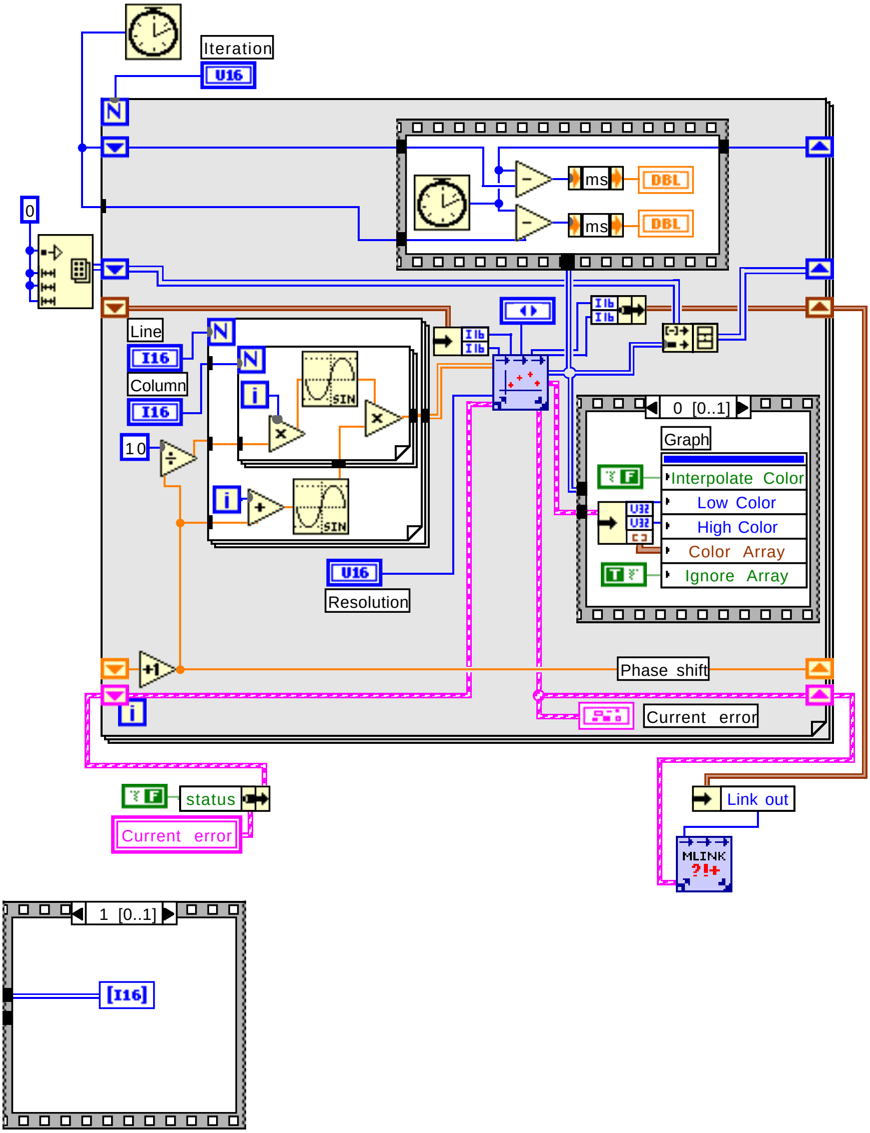


Figure 8. The ListPlot Benchmark.vi diagram.

Nothing is particularly challenging in this implementation except perhaps the link management scheme. The simplest situation is one where you have LabVIEW, MLPost, and the *Mathematica* kernel running on the same machine with no other link active. Use an uninitialized shift register for each link number so as to initialize the connection when the VI is run for the first time. Then use the current link numbers in subsequent evaluations. Since both the link to *Mathematica* and the link to MLPost work in concert to render graphics, you can bundle them together and use a single shift register for both of them.

Generic Plot.vi

`Generic Plot.vi` is very similar to `Generic ListPlot.vi`. It too can function as either as a stand-alone application or as a subVI. Some advanced settings to optimize its performance will be discussed later in this section.

BASIC OPERATION

`Generic Plot.vi` is a close relative of `Generic ListPlot.vi`. The main difference between the two is that `GenericPlot.vi` does not use a list of data as an argument. In order to provide the same level of flexibility as the *Mathematica* syntax, the commands are passed as strings to this VI—just as they are with `Kernel Evaluation.vi` (discussed earlier in this chapter). You can use this VI to send any sequence of commands that would return graphics from the kernel.

The “Command” box is used to type in the sequence of *Mathematica* commands, so there is no need to have a separate window for options. Options can be typed directly into the appropriate place in the command string.

Although the name of this VI refers to plot functions, keep in mind that there is little limitation to the form that plot functions may take. Any functions that return graphical output can be typed here. This includes low-level graphics primitive commands such as:

Show@Graphics@{Dashing[{0.5, 0.5}],Line[{{-1, -1},{1, 1}}]}

or higher level command such as:

ListPlot[Table[Sin[i], {i, 0, 10Pi, Pi/5}]].

`Generic Plot.vi` is a general-purpose graphics generator that contains, as a special case, the functionality of `Generic ListPlot.vi`.

Examine the contents of the "Command" box in Figure 9. Two graphics named **p** and **q** are generated first. Next,

Show@GraphicsArray[{{p}, {q}}]

produces the picture displayed in the figure.

Note: Intermediate commands must end in a semicolon to avoid a premature exit from the evaluation.

AN IMPORTANT NOTE ABOUT ASPECT RATIO

When using `Generic Plot.vi` the last item in the "Command" box should always be **AspectRatio->1** . This ensures that the *Mathematica* image will completely fill the LabVIEW intensity graph. If this step is neglected, residual data may fill the unused portions of the intensity graph, compromising the aesthetic quality of the visual presentation.

ADVANCED SETTINGS

The "Timeout" and "Resolution" controls are analogous to the ones found in `Generic ListPlot.vi`. Review "Advanced Settings" on page 41, for a detailed description.

PERFORMANCE EVALUATION

Record the time required to evaluate the following commands from the standard *Mathematica* front end:

- **Plot3D[Sin[x y], {x, 0, 2Pi}, {y, 0, 2}]**
- **ListPlot[Range[10]]**

Close all the links that may still be open with `Close All Link.vi` and run `Plot Benchmark.vi`. In this way you can evaluate the same commands and compare the evaluation time to appreciate how `Generic Plot.vi` performs on your system.

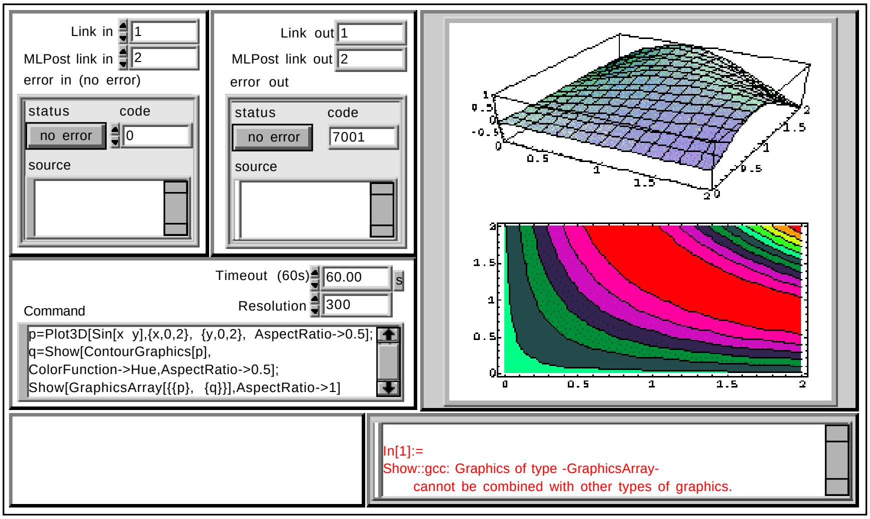


Figure 9. The `Generic Plot.vi` front panel.

Link in 1

MLPost link in 2

error in (no error)

status code

no error 0

source

Link out 1

MLPost link out 2

error out

status code

no error 7001

source

Timeout (60s) 60.00 s

Resolution 300

Command

```
p=Plot3D[Sin[x  y],{x,0,2},  {y,0,2},  AspectRatio->0.5];
q=Show[ContourGraphics[p],
ColorFunction->Hue,AspectRatio->0.5];
Show[GraphicsArray[{{p},  {q}}],AspectRatio->1]
```

```
In[1]:=
Show::gcc: Graphics of type -GraphicsArray-
     cannot  be  combined  with  other  types  of  graphics.
```

Use as a SubVI

`Plot Benchmark.vi` is an example of the use of `GenericPlot.vi` as a subVI. `Generic Plot.vi` can be wired into a diagram in very much the same way as `Generic ListPlot.vi`. Thus, see the discussion pertaining to `Generic ListPlot.vi` under “Use as a SubVI” on page 43.

`Plot Benchmark.vi` has several features that have not been discussed yet. First, it has a message box that displays *Mathematica* messages. This is accomplished by a small algorithm that extracts the last message generated by the kernel from within the message string returned by `Generic Plot.vi`.

A “New session” button has also been introduced. When its value is “True”, all active links are closed and two new links are opened to MLPost and the *Mathematica* kernel. This strategy is somewhat crude, but it is extremely easy to implement when no other links are being used by an application.

Troubleshooting

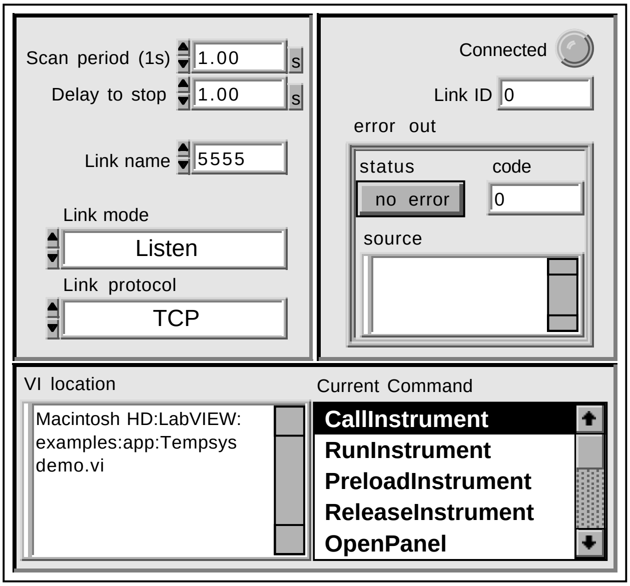
You are prompted to locate MLPost. This means that MLPost has not been found. It is likely that the file structure of the `MathLink` subdirectory of the `user.lib` directory has been changed. You can either fix it as described in "**The MathLink Subdirectory**" on page 23, or you can reinstall *Mathematica* Link for LabVIEW to correct the problem.

The plot does not match the command. Sometimes the graphics displayed by the VI are inconsistent with the sequence of commands that were sent. This may occur when an error condition is encountered—the graphic is not returned by the kernel, but rather is queued on the link as a result of the error. (Note: graphics queued on the Link will typically display during the next execution). If you encounter this problem, the best solution is to reinitialize the links by running `Close All Links.vi` (from `MLUtil.llb` or the **`Tools`** `menu)`, then rerun `Generic Plot.vi`.

MathLink VI Server.vi

`MathLink VI Server.vi` is a general-purpose utility that controls LabVIEW VIs and applications from within a *Mathematica* notebook. You typically would run this VI on the computer that is connected to your instruments. The VI works in combination with the `VIClient.m` package to provide "VI Server-like" control of LabVIEW VIs from within a *Mathematica* notebook.

`MathLink VI Server.vi` first opens a link in Listen mode and waits for *Mathematica* to connect. The `VIClient.m` package provides the function **ConnectToServer[ ]** on the *Mathematica* side, which automates the connection step. This connection, when established, is not specific to the LabVIEW application; the link can be used to run any VI or application saved on a volume accessible to the computer where `MathLink VI Server.vi` is running. It can even manage several VIs simultaneously.



Scan period (1s) 1.00 s
Delay to stop 1.00 s
Link name 5555
Link mode Listen
Link protocol TCP
Link ID 0
error out
status: no error
code: 0
source
VI location: Macintosh HD:LabVIEW: examples:app:Tempsys demo.vi

Figure 10. The `MathLink VI Server.vi` front panel.

The `VIClient.m` package's main functions are basic: to load a VI into memory, to release it after use, to manipulate its front panel, and to run it. The basic function set does not allow arguments to be passed to a VI, nor can data be collected after the VI's execution. However, another function based on the similarly named VI Server function, **CallByReference[ ]**, allows parameter passing through VI controls, as well as the return of VI indicator values after execution. (The **CallByReference[ ]** command will be discussed in more detail later in this section.)

Front Panel Organization

The `MathLink VI Server.vi` front panel is divided into three areas, as shown in Figure 10. In the upper-left area are the controls used to set the connection parameters. They include the protocol used, the connection mode, and the default link name.

The link status indicators can be found in the upper-right area. An LED titled "Connected" indicates whether the link is connected. An error cluster is used in a standard way to report errors, and a digital indicator displays the current link number.

In the lower part of the front panel, two boxes provide feedback on the current VI's operation. The "VI location" box displays the path or name of the VI being operated, and the current operation is highlighted in the "Current command" box.

Using MathLink VI Server.vi

The material in this section is an extension to the material introduced in **Hands-on Tutorial #1** and **#2** (as noted at the beginning of this chapter). If you haven't worked through these exercises, you may want to look at them before continuing.

`MathLink VI Server.vi` operates in a three-phase operational sequence: First, you must connect to it. Second, you need to declare **Instrument** objects in *Mathematica*. Finally, you have to use the functions of the `VIClient.m` package to operate LabVIEW applications. We will explore each phase sequentially next.

GETTING CONNECTED TO THE SERVER

The first step in connecting to the VI server is to load the `VIClient.m` package. The following command will load the package:

In[1]:=

```
<<LabVIEW`VIClient`
```

The `VIClient.m` package has a function that automates the connection to `MathLink VI Server.vi`. It is named **ConnectToServer**. When queried, *Mathematica* returns the following information about **ConnectToServer**:

In[2]:=

```
?ConnectToServer
```

```
ConnectToServer[linkname, opt] is used to
  establish a connection to the MathLink VI
  Server.vi. Linkname is an optional
  argument. When it is not specified, the
  default linkname is set to "5555" and the
  default protocol used is "TCP".
```

Mathematica and LabVIEW run on a single PC configured to use TCP/IP.

If the TCP protocol is properly configured on your machine, and if *Mathematica* and LabVIEW are running on the same machine, use the following procedure to get connected. Open `MathLink VI Server.vi` and click the Run button without changing any control value. Then go back to the standard *Mathematica* front end to establish the connection.

In[3]:=

```
link = ConnectToServer[ ]
```

Out[3]=

```
LinkObject[5555, 2, 2]
```

This output depends on your system configuration. In particular the address of your local machine can be joined to the link name. In this case the first argument of LinkObject is of the form 5555@machine address.

Running *Mathematica* and LabVIEW on different systems over a TCP/IP network.

If you are running LabVIEW on a remote machine with TCP, you should specify the address of that machine with the **LinkHost** option for **ConnectToServer** (see below)**.** You can also specify the machine address in the link name using a name of the form 5555@machine address.

Running *Mathematica* and LabVIEW under the same platform using the local protocol.

If your machine is not configured to use TCP/IP, use the local protocol. On the `MathLink VI Server.vi` front panel select the local protocol with the “Link protocol” control. The local procotol is “FileMap” on Windows systems and “PPC” on Macintosh systems. Then click the Run button without changing any other control value. Go back to the standard *Mathematica* front end to establish the connection with the following command.

```
link = ConnectToServer[ LinkProtocol->Automatic]
```

Generally, an appropriate choice of options needs to be specified to make the connection possible. If you experience difficulties in your first attempts, try using the local protocol as noted in the previous paragraph. For more details about the options needed to open a link, consult “**Getting Connected**” on page 75.

The next command reveals that the options for **ConnectToServer** (introduced above) have the same names as those for **LinkOpen**, but they have different values.

In[4]:=

```
Options[ConnectToServer]
```

Out[4]=

```
{LinkMode -> Connect, LinkProtocol -> TCP,
 LinkHost -> }
```

Note: On a MacOS computer when the `MathLink VI Server.vi` is run, LabVIEW may hang. To solve the problem see pages 75 and 27.

Note also that **ConnectToServer** returns a **LinkObject** just as **LinkOpen** does. The main difference between the two functions is that **ConnectToServer** has default option values that allow the remote control of a LabVIEW application by *Mathematica*. Be aware, however, that the default value of the **LinkHost** option is an empty string as it is for **LinkOpen**. This is because relevant values depend on your specific network configuration. To establish an operational *MathLink* link, you must connect the link with the **LinkConnect** function after declaring the link with the **LinkOpen** function. **ConnectToServer** proceeds to this connection step before returning the **LinkObject**. Thus, the **LinkObject** returned by **ConnectToServer** must not be connected again—such as would be the case if **LinkOpen** returned it.

Instrument Declaration

Once the connection has been established you must describe the instrument—or more specifically, the VI you intend to operate. A function named **DeclareInstrument** is provided for this purpose. It returns an object of the type **Instrument**. This function usually requires three arguments. The first is the path (including filename) to the VI you want to run. The second is a list describing the controls of the target VI, as well as their values. The last argument is used to describe the indicators that you want to read. These topics will be discussed in "The CallInstrument Function and Related Functions"on page 56. For right now, we will only use the smallest set of arguments needed to declare an instrument. The VI we will use in this section is `Frequency Response.vi`, a standard example in the LabVIEW distribution.

The instrument declaration step takes the following form:

In[5]:=

```
inst = DeclareInstrument["HD:LabVIEW:examples:apps:
freqresp.llb:Frequency Response.vi"]
```

Out[5]=

```
Instrument[HD:LabVIEW:examples:apps:freqresp.llb:Frequency
Response.vi, Frequency Response.vi, {}, {}]
```

The preceding example specifies the VI path information for a typical Macintosh configuration. When you reproduce this command on your PC, do not forget to modify the path so that it leads to `Frequency Response.vi` in your file system. For example, here is its adaptation for a typical Windows configuration:

Confused by the doubled path delimiters? This *Mathematica* for Windows convention will be discussed further in a moment.

```
inst = DeclareInstrument["C:\\LabVIEW\\examples\\
apps\\freqresp.llb\\Frequency Response.vi"]
```

As mentioned previously, the result returned by **DeclareInstrument** is an **Instrument** object. This indicates that your **DeclareInstrument** arguments are valid. A formal verification of the function arguments is conducted by the **DeclareInstrument** function before returning the resulting **Instrument** (consult “**The VIClient.m Package**” on page 201 for details). The output in the preceding example may not appear on your system; in fact the output that you do get may be different from what you normally receive. For instance, in the example output, the path string has at least one path delimiter character. This delimiter may be not the one you expect from the operating system under which *Mathematica* is running. Since the LabVIEW application you are controlling may be remotely implemented, the path name separator used by **DeclareInstrument** may not have the same value as the system variable **$PathnameSeparator**. **DeclareInstrument** has an option named **PathnameSeparator** that you can use to adjust this effect to your liking. As an example, the next command declares, on a Macintosh or other type of machine, a VI located on a UNIX machine with the **PathnameSeparator** set to a “/”.

In[6]:=

```
inst2 = DeclareInstrument["~/readme.vi",
PathnameSeparator->"/"]
```

Out[6]=

```
Instrument[~/readme.vi, readme.vi, {}, {}]
```

In Windows, the path separator is the backslash character, “\”. This is a potential source of confusion, since “\” is also a control character used by *Mathematica* to format strings. For instance, “`\t`” is a tab and “`\r`” is a carriage return. The string “\\” represents a single \ because the first \ is the *Mathematica* control character that specifies the interpretation of the second one. This is familiar to users who run *Mathematica* under Windows, but might be puzzling to people used to running *Mathematica* on other operating systems. To illustrate further, here is another declaration example for a VI located on a Windows machine:

In[7]:=

```
inst3 = DeclareInstrument["C:\\LABVIEW\\README.VI",
PathnameSeparator->"\\"]
```

Out[7]=

```
Instrument[C:\LABVIEW\README.VI, README.VI,

 {},{}]
```

BASIC OPERATION

The `VIClient.m` package has a large number of functions that perform basic operations on remote VIs. In order to maintain both backward compatibility, and consistency with evolving LabVIEW nomenclature, each function is defined by two different terminology sets. The first terminology set is analogous to the VIs of `victl.llb`. Long-time LabVIEW users with experience using the functions in `victl.llb` should feel comfortable using the corresponding `Mathematica` terminology. The other function set is patterned after the VI Sever. Users coming to LabVIEW after the release of version 5.0 will likely be more comfortable with the VI Server-compatible function set. The functions sets are completely inter-changeable, so feel free to use the function set which is most comfortable for you. Alternatively, if you have no experience with either the traditional `victl.llb` VIs (LabVIEW 4.1 and earlier), or VI Server functions (LabVIEW 5.0 and above), you are encouraged first to have a look at the examples provided with LabVIEW.

The advantage of using declared instruments is that you can now use a variable to refer to the instrument. Note, however, that to operate the instrument you need information both about the **Instrument** itself, and about the link where the instrument will be addressed. None of the basic operations return data (data exchange will be addressed a little later in this discussion), so to acknowledge the receipt of your instructions, the VI server will send you a message saying that the operation was completed or that an error occurred.

Start by loading a VI from disk into memory.

In[8]:=

```
OpenVIRef[link, inst]
```

or alternatively (using the `victl.llb` terminology):

```
PreloadInstrument[link, inst]
```

Mathematica will respond with:

```
Frequency Response.vi loaded
```

While this command is being processed nothing is visible unless you use LabVIEW tools to inspect VIs that are in memory (the VI hierarchy tool or the Unopened subVIs item of the Windows menu).

You can now display the VI front panel.

In[9]:=

```
OpenPanel[link, inst]
```

```
Frequency Response.vi: panel displayed
```

Now you should see the VI panel and you can make an attempt to run the VI.

In[10]:=

```
RunVI[link, inst]
```

or alternatively (using the `victl.llb` terminology):

```
RunInstrument[link, inst]
```

```
Frequency Response.vi running
```

Next, you can close the panel.

In[11]:=

```
ClosePanel[link, inst]
```

```
Frequency Response.vi: panel closed
```

The last operation that you can do with the basic functions of the `VIClient.m` package is to release a VI from memory.

In[12]:=

```
CloseVIRef[link, inst]
```

or alternatively (using the `victl.llb` terminology):

```
ReleaseInstrument[link, inst]
```

```
Frequency Response.vi released
```

Now go into LabVIEW to make sure that `Frequency Response.vi` has been removed from the VI hierarchy.

To gain further understanding of these tools it might be useful to enter some commands that give rise to errors. Start by declaring an instrument that is not on the hard drive.

In[13]:=

```
fooinst = DeclareInstrument[":foo.vi"]
```

Out[13]=

```
Instrument[:foo.vi, foo.vi, {}, {}]
```

In[14]:=

```
OpenPanel[link, fooinst]
```

```
Error 1004
Error 1004 occurred at VI not in memory.

Possible reasons:
LabVIEW: The VI is not in memory.
```

This is a very reasonable reply: the VI has not been loaded. So, you can try to load it.

In[15]:=

```
OpenVIRef[link, fooinst]
```

```
Error 7
Error 7 occurred at VI not found at path.

Possible reasons:
LabVIEW: File not found.
OR
NI-488: Non-existent board.
```

Here again, you can rely on the error message returned to *Mathematica*.

SERVER REMOTE SHUTDOWN

The last basic function of the package is named **ServerShutdown**, and it is used to close the link and stop the remote VI server. Since it is not instrument specific, its only argument is a link to the server.

There is no specific button on the server panel to stop the VI. The reason is that only the client should be able to decide when the service is not needed anymore. There is no indication on the `MathLink VI Server.vi` panel that it is currently used by someone when it is connected. Stopping the server in LabVIEW is not advisable, although it is possible with the Abort button on the VI's toolbar. If you use this method, make sure to close the link manually, either with `Close All Links.vi`, or with `MLClose.vi`.

Here is the correct way to use **ServerShutdown** to close the link.

In[16]:=

```
ServerShutdown[link]
```

Out[16]=

```
Server stopped
```

THE CALLINSTRUMENT FUNCTION AND RELATED FUNCTIONS

The aforementioned basic functions do not allow execution parameters to be passed to and from LabVIEW. However, VI Server and the `victl.llb` have more general methods that are capable of passing control values to VIs and collecting indicator values. The `VIClient.m` package taps into this functionality with 2 interchangeable functions: **CallInstrument—**consistent with `victl.llb` terminology, and **CallByReference—**consistent with VI Server terminology. We will look at these interchangeable functions in context next.

First, before we can call a VI to exchange data, we must declare it. And if we want to access the controls and read the indicators, we also must declare the controls and indicators of interest in the **DeclareInstrument** command. Apart from the path to the VI, two other arguments are necessary. The first argument is a list of controls: each control must be described by its name, data type, and value. The indicators that you want to read are specified in the second list. Naturally, you do not have to provide indicator values (these will be returned at run-time), however, you must provide the name and type for each indicator of interest. Here is an extension of the example used in the previous section:

In[17]:=

```
inst = DeclareInstrument["HD:LabVIEW:examples:apps:
freqresp.llb:Frequency Response.vi", {{"Amplitude", DBL,
1.5}, {"Number\nof Steps", I32, 20 }}, {{"Current
Frequency", DBL}}]
```

Out[17]=

```
Instrument[HD:LabVIEW:examples:apps:freqresp.llb:
Frequency Response.vi, Frequency Response.vi,

 {{Amplitude, DBL, 1.5},

 {Number
of Steps, I32, 20}},

 {{Current Frequency, DBL}}]
```

Important note: control and indicator names must be entered as they appear on the VI diagram.

Read this output carefully. The second control is named "**Number\nof Steps**". Why is it necessary to place the "**\n**" between "**Number**" and "**of**"? The answer lies in the VI diagram. Whereas the control label is written on a single line on the front panel, it is written on two lines in the diagram. If you do not introduce the "**\n**", the *Mathematica* newline character, in the control name, `Call Instrument.vi` will not recognize it.

You can easily query *Mathematica* to access the list of data types supported by the **DeclareInstrument** function.

In[18]:=

```
SupportedTypes[]
```

Out[18]=

```
{EXT, DBL, SGL, I32, I16, I8, U32, U16, U8,

 CXT, CDB, CSG, EXTList, DBLList, SGLList,

 I32List, I16List, I8List, U32List, U16List,

 U8List, CXTList, CDBList, CSGList,

 EXTMatrix, DBLMatrix, SGLMatrix, I32Matrix,

 I16Matrix, I8Matrix, U32Matrix, U16Matrix,

 U8Matrix, CXTMatrix, CDBMatrix, CSGMatrix,

 Boolean, BooleanList, BooleanMatrix, String,

 StringList, StringMatrix}
```

These are all the types of LabVIEW numbers, strings, and booleans, plus one-dimensional and two-dimensional arrays of these types of data. If you are not familiar with these data types, each one is briefly documented on line. Information for each data type can also be obtained using the *Mathematica* query operator. Here is an example.

In[19]:=

```
?CXT
```

```
LabVIEW data type: complex extended-precision
  floating point number.
```

You can also refer to the LabVIEW documentation for more details.

Now connect to the VI server once again. Go into LabVIEW, run `MathLink VI Server.vi`, then go back to *Mathematica* to get connected and to call the instrument. Type the following commands:

In[20]:=

```
link = ConnectToServer[ ]
```

Out[20]=

```
LinkObject[5555, 3, 2]
```

In[21]:=

```
CallByReference[link, inst]
```

or alternatively (using the `victl.llb` terminology):

```
CallInstrument[link, inst]
```

```
Frequency Response.vi successfully operated.
```

Out[21]=

```
1000.
```

When you need to run a VI several times with **CallByReference**, use **OpenVIRef** first.

Before the result is returned you will observe the VI loading (actually, you will hear the disk drive). You will see it briefly running and then it will be released from memory. This behavior is described in the `Call Instrument.vi` on-line documentation.

If you preload the VI or open a VI reference first, the VI is less likely to vanish at completion. (The rules defining when and how VIs are closed and unloaded from memory is beyond the scope of this discussion. Refer to VI Server topics in the LabVIEW documentation for more information.)

To open a VI reference or ‘preload’ the VI before calling it by reference, use the following command sequence:

In[22]:=

```
OpenVIRef[link, inst]
```

or alternatively (using the `victl.llb` terminology):

```
PreloadInstrument[link, inst]
```

Mathematica responds with:

```
FrequencyResponse.vi loaded
```

Continue with:

In[23]:=

```
OpenPanel[link, inst]
```

```
FrequencyResponse.vi: panel displayed
```

In[24]:=

```
CallByReference[link, inst]
```

or alternatively (using the `victl.llb` terminology):

```
CallInstrument[link, inst]
```

After the VI terminates, *Mathematica* responds with:

```
Frequency Response.vi successfully operated.
```

Out[24]=

```
1000.
```

Since you will use the **CallByReference** and/or the **CallInstrument** functions to operate VIs, you need a convenient way to interactively edit instrument values. Three functions are provided for this.

- **SetControls**: The function used to change the value of a list of declared controls.
- **AddControls**: The function used to add new controls to a declared instrument ‘s current list of controls.
- **AddIndicators**: This function is the same as **AddControls**, except that it applies to indicators.

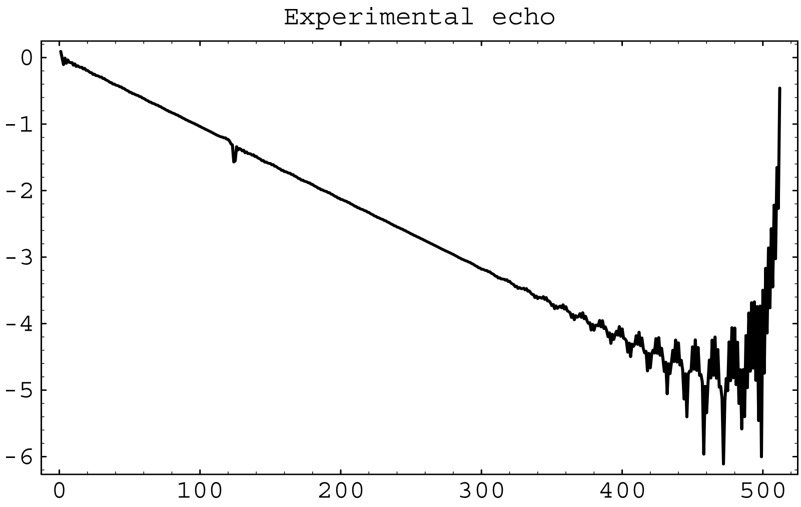
Test these functions in conjunction with the **CallByReference** function. To make the exercise more fun, use a different example VI. (Remember to set the path appropriately for your own file system.)

```
In[25]:=

    echo =
    DeclareInstrument["HD:LabVIEW:examples:analysis:
    dspxmpl.llb:Echo Detector"]

Out[25]=

    Instrument[HD:LabVIEW:examples:analysis:
    dspxmpl.llb:Echo Detector, Echo Detector, {}, {}]

In[26]:=

    OpenVIRef[link, echo]

    Echo Detector loaded

In[27]:=

    RunVI[link, echo]

    Echo Detector running

In[28]:=

    echo = AddControls[echo, {"Samples", U16, 1}]

Out[28]=

    Instrument[HD:LabVIEW:examples:analysis:
    dspxmpl.llb:Echo Detector, Echo Detector,

     {{Samples, U16, 1}}, {}]

In[29]:=

    echo = AddControls[echo, {"Frequency", DBL, 45.0}];

In[30]:=

    echo = AddIndicators[echo, {"Echogram", DBLList}];

In[31]:=

    echo

Out[31]=

    Instrument[HD:LabVIEW:examples:analysis:
    dspxmpl.llb:Echo Detector, Echo Detector,

     {{Samples, U16, 1}, {Frequency, DBL, 45.}},

     {{Echogram, DBLList}}]

In[32]:=

    data = CallByReference[link, echo][[1]];
```

Echo Detector successfully operated.

In[33]:=

```
ListPlot[data, PlotJoined->True, Frame->True, PlotLabel->"Experimental echo"];
```



Thus, you now have access to experimental data from within *Mathematica* notebooks. Close the link with **ServerShutdown**.

In[34]:=

```
ServerShutdown[link]
```

Server stopped

Consult “**The VIClient.m Package**” on page 201 for a more detailed description of `VIClient.m` package functions.

Main Limitations of VIClient.m Functions

- From within *Mathematica* you can only operate VI controls belonging to a limited set of data types: numbers of all kinds, strings, booleans, and lists and matrices of these basic data types. You cannot, for instance, set the value of a cluster control. However, you still can run these VIs with the current values of the controls (default values or values set manually). Moreover, the ‘to array’ and ‘from array’ functions usually make it easy to convert clusters into list of numerical data.
- Many LabVIEW applications can be considered as process monitoring applications. They continue to run and monitor a process

until the operator stops them (by clicking a Stop button, for instance). There is no function in the `VIClient.m` package to dynamically collect the data recorded by these kinds of applications. It is possible to run them, but no data will be returned, and the application needs to be stopped manually. In this kind of situation, you should introduce a small *MathLink* subVI in your application to manage communication with *Mathematica* at run time. Examples are provided in "Process Monitoring with *MathLink*" on page 107.

- It is not possible to stop the VI server in LabVIEW if it has not been connected. To stop it, go into *Mathematica* and connect yourself to the server, then shut it down.

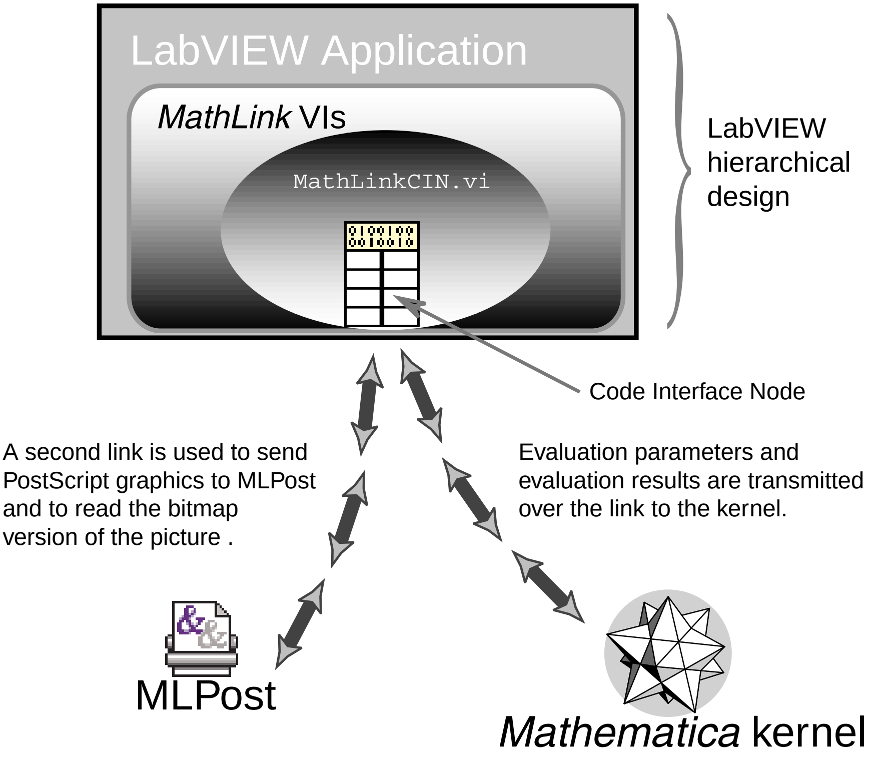
MathLink and *Mathematica* Link for LabVIEW

In order to use *Mathematica* Link for LabVIEW effectively, a basic understanding of its foundations is helpful. In this section, the global architecture of the package is described. A brief introduction to the differences between *Mathematica* and LabVIEW with respect to data management is also necessary to understand how data are transferred between *Mathematica* and LabVIEW using *Mathematica* Link for LabVIEW.

Software Architecture

Mathematica Link for LabVIEW is a straightforward LabVIEW translation of the C functions of the *MathLink* library. Each *MathLink* VI implements a single *MathLink* function. So, for instance, you will find in your distribution `MLOpen.vi`, `MLPutInteger.vi`, and so on. However, not all of the VIs of your *Mathematica* Link for LabVIEW distribution are *MathLink* VIs. Several libraries provide utilities or high-level VIs, which have no direct *MathLink* counterparts.

All the VIs implementing *MathLink* functions make use of a subVI named `MathLinkCIN.vi`. `MathLinkCIN.vi` is the only VI in the distribution that contains a LabVIEW Code Interface Node (CIN). This CIN can be regarded as the heart of the software, since this is the interface point where *MathLink* functions are called. To some extent, this VI can be viewed as a *Mathematica*–LabVIEW translator. *Mathematica* can maintain a dialog with the C program through *MathLink*. This C program can also carry on a dialog with LabVIEW through a Code Interface Node. Thus, *Mathematica* and LabVIEW can exchange information through *MathLink* and a Code Interface Node.



A second link is used to send PostScript graphics to MLPost and to read the bitmap version of the picture .

Evaluation parameters and evaluation results are transmitted over the link to the kernel.

Figure 11. The global structure of *Mathematica* Link for LabVIEW.

The global structure of *Mathematica* Link for LabVIEW is illustrated in Figure 11. A LabVIEW application can use *MathLink* functions by using VIs that implement those *MathLink* functions. These VIs themselves call the CIN-containing VI, `MathLinkCIN.vi`. The external C code is where the actual *MathLink* functions are called.

Three Sets of Data Types

In order to avoid confusion, you must keep in mind that, when you use *Mathematica* Link for LabVIEW, three programming languages are working together, each having its own set of data types.

Mathematica data are mainly expressed as compound expressions composed of atoms belonging to a limited set of atomic data types. The types are **Symbol**, **String**, **Integer**, **Real**, **Rational**, and **Complex**. Note that **Number** is not one atomic type, but rather, the union of the last four types. (Refer to sections A.1.4 and A.1.5 of "**The *Mathematica* Book**", by S. Wolfram [6] for more details.)

Similarly, LabVIEW has its own set of elementary data types. This set is much larger (26 elementary types) than the *Mathematica* set of atomic types. (Consult the LabVIEW documentation for an exhaustive list of LabVIEW elementary data types.) Regarding complex data types, LabVIEW handles them either as "Arrays", "Clusters", or any combination of both (cluster of arrays, array of clusters, and so on). Arrays are multidimensional, but must contain elements of identical type, whereas clusters are a means of combining data of different types into a single structure.

Data are transferred between *Mathematica* and LabVIEW by a layer of C code having its own data structures and types. Any textbook on the C programming language will give you details about C data types. But you do not need to have any experience programming in C to use *Mathematica* Link for LabVIEW—the data you exchange over the link between *Mathematica* and LabVIEW are transparently handled by *MathLink* functions.

Polymorphism

When designing your programming project, you have to consider the kind of relationships you will define between the elementary programs written with the language you are using, and the data that they manipulate. Some languages allow you to build programs capable of using several types of data as arguments; the data type they return depends on the kind of argument they are supplied. Programs that have this feature are said to be "polymorphic". Nonpolymorphic programs are "typed" programs.

LabVIEW, *Mathematica*, and C approach the issue of polymorphism in very different ways. *Mathematica* is polymorphic by nature. Among the simplest of *Mathematica* programs is the function **f**, defined by

```
f[x_] := x
```

Although it looks trivial, the fact that a programming language can allow the definition of such a function is quite remarkable. It can use anything as an argument and, thus, return any kind of data. In *Mathematica* you can use pattern matching to restrict function definitions to particular patterns. But be careful; patterns are not data types. (Patterns represent a much subtler notion, which is part of the foundation of symbolic computation.) Even so, you can shape patterns so that they fit some types of data. For example,

```
g[x_Integer] := x^2
h[x_^n_Integer] := n
SetAttributes[h, HoldAll]
```

The definition of **g** uses a pattern to limit its evaluation to integers, and when it executes, it returns an integer. Thus, defined this way, **g** is a typed function. Is the same also true for **h**? Certainly not. The pattern used to define **h** ensures that only integers will be returned by this function, but the kind of arguments it can use does not fit a single type of data. The pattern only specifies that it must be something with an integer power: the "something" can really be anything. Try it with x = 2, 2.5, a/b, 2/3, "foo", or whatever else you can dream up. (The final command, **SetAttributes[h, HoldAll]**, is present so that the argument of **h** will not be evaluated before the integer **n** is extracted.)

Polymorphism in LabVIEW can be misleading if you do not pay careful attention to it. As you may know, many LabVIEW functions are polymorphic. To illustrate this point, simply refer to the on-line description of the `Add operator` function: the inputs can be any type of number, a number and an array of numbers, and so forth. The data type that is returned depends on the data types of the inputs. The fact that most built-in functions are polymorphic to varying degrees does not mean that they share this feature with LabVIEW *programs*, that is VIs. VIs are not polymorphic. When you build a VI, you have to specify the types of all the controls and indicators you use: your inputs and outputs. This also applies to complex data structures such as arrays and clusters. Even the polymorphic VI feature introduced in LabVIEW 6 requires duplicate versions of a VI to be constructed—one for each data type supported. Here again, it is also worth noting that there is no way in LabVIEW to programmatically control the data structure of the inputs and outputs of a VI. You cannot add an indicator at run time or a dimension to a front panel array, or an element to a cluster control. Thus, we can say that despite the polymorphism of its built-in functions, and some recent additions to simulate polymorphic behavior, LabVIEW remains a typed language.

The C language is not polymorphic at all (although the object-oriented language C++ is). When defining a function in C, you need to carefully specify the type of each argument as well as the type of the value returned by the function. To understand how strict the various *MathLink* functions definitions are, consult **Section A.11 - "Listing of C Functions in the MathLink Library"** in "**The *Mathematica* Book**" [6].

Type Casting

Another notion, “type casting”, also deserves clarification. Type casting is a mechanism to coerce a variable of one type into another type. Type casting provides a conversion mechanism for the data; that is, a transformation of the data from one type to another. For instance, you can cast a real value into an integer type, but this process is not reversible, since the number has been rounded during the first conversion. When a function is polymorphic it does not need to use type casting, since the function is defined for different data types. However, many LabVIEW functions are still not polymorphic, so type casting can occur frequently, especially for numerical variables. LabVIEW notifies you that type casting will occur by way of coercion dots on the diagram. Type casting can be kept to a minimum by eliminating coercion dots wherever possible.

Elementary Data Type Conversion Table

The following table shows the most natural correspondences between the elementary data types of the three languages.

Mathematica	*MathLink*	**LabVIEW**
Integer	short integer, integer, long integer	I8, I16, I32, U8, U16, U32
Real	double, long double	SGL, DBL, EXT
Complex	*Mathematica* expression	CSG, CDB, CXT
Rational	*Mathematica* expression	SGL, DBL, EXT
String	string	abc
Symbol	string	abc

In this version of *Mathematica* Link for LabVIEW, extended precision numbers are converted to double precision numbers and word integers (16-bit format) are converted to long integers (32-bit format) for *MathLink* transactions. While this should prove adequate for the majority of practical implementations, future versions of the Link may introduce additional data formats.

Peculiarities of *Mathematica* Link for LabVIEW

Every effort was made during the development of *Mathematica* Link for LabVIEW to retain 100% compatibility with the original *MathLink* functions. However, differences between LabVIEW and the C language make minor adaptations of some *MathLink* features unavoidable. Specifically, *MathLink* VIs differ from their C counterparts with respect to link identification, the way they deallocate memory, and the way they report function values. `MLOpen` uses front panel lists to specify its options. Also, VIs are not installable in *Mathematica*.

Link in and Link out

No special MLINK data type has been defined in this distribution. Links are simply identified by an I16 integer. Most VIs have both a "Link in" control and a "Link out" control that can be used to force data dependency and "chain" *MathLink* session VIs across the diagram. The "Link out" value is the same as the "Link in" value. Both can be used to create an artificial data dependency to ensure proper sequencing of operations—a standard LabVIEW convention used with several built-in functions and libraries of the standard LabVIEW distribution (File I/O, VI Server functions, TCP, UDP, PPC, etc.).

Function Value

Many *MathLink* functions return an integer that is used to indicate a possible error. This integer is returned in a particular indicator named "value" that all *MathLink* VIs have on their front panel. In the *MathLink* VI diagrams, the integer error code returned by the *MathLink* function call is checked by `ErrorClusterMaker.vi`. In case it matches a value indicating an error, `ErrorClusterMaker.vi` will build an error cluster indicating that an error occured (see "Introduction to Error Management", page 68 and "Error Management Tools", page 84).

Disown Functions

MathLink has a set of functions to free memory after arrays of data have been read: `MLDisownIntegerList`, `MLDisownString`, and so forth. Since these memory management issues would have looked somewhat out of place in the LabVIEW environment, the disown functions are automatically called whenever they are required in the CIN. This means that you can get lists of any kind of data safely without concerning yourself with memory management. Although it is clearly specified in the *MathLink* documentation that you must call `MLDisownString` after a call to `MLGetString`, in LabVIEW you can read your string with `MLGetString` and forget the disown function. This also applies to all of the functions that you use to get arrays of any type.

MLOpen Arguments

The original prototype of MLOpen is MLINK MLOpen(argc, argv). It is difficult to use that model to build a LabVIEW VI. Actually the four arguments of MLOpen are the link mode, the link protocol, the link name, and the link host. Two menus help you select the mode and the protocol you want to use and two string controls specify the name and address of a remote partner.

MLOpen returns an integer in "Link out". The convention is that, in the case of an error, 0 will be returned instead of a NULL pointer.

Noninstallable VIs

LabVIEW programs using *MathLink* are not installable in *Mathematica*.

Introduction to Error Management

Error management in *MathLink* is a three-step process. First, most *MathLink* functions return an integer value that can give you an indication of the result (successful or not) of the execution. When zero is returned, it means that an error occurred. You then have to call the MLError function to know precisely which error occurred. (Alternatively, you can call MLErrorMessage, for a user-friendly description that is more useful than numerical error codes.)

Second, once you know precisely what happened, you can conduct the most appropriate corrective action. Finally, you need to reactivate the link with MLClearError.

LabVIEW also has a well-defined strategy for managing errors. (If you are not familiar with this topic, you may also want to refer to LabVIEW's documentation.) A short overview of LabVIEW error management is presented next.

In LabVIEW, error management in sequential I/O operations—such as file manipulations or any kind of communication—relies mainly on error clusters (Error In.ctl and Error Out.ctl) located in the "Error Cluster" area of the Control menu. These clusters comprise three elements: a boolean named "status" indicates whether an error occurred, an integer is used to report the error code, and a string field named "source" is used to report where the error occurred.

There are two families of I/O VIs, depending on their use of error clusters; some use error clusters (VIs of DAQ libraries, VIs of tcp.llb), and some do not (VIs of the GPIB libraries, `Serial.llb,` and so on). Those that do not use error clusters only return error codes, and it is your responsibility to manage them safely. On the other hand, VIs that take advantage of error clusters have an extremely clear error-management scheme. They first check the cluster status. If a pre-existing error is detected, no other operation is undertaken in the VI. "Error in" and "Error out" clusters are thus used to chain the VIs that implement the sequence of operations. At the end of the sequence, you can simply wire one of the LabVIEW error handlers to programmatically control error management. Doing so ensures that not more than one error can accumulate during a sequence of operations, thereby simplifying troubleshooting operations.

All *Mathematica* Link for LabVIEW VIs employ error clusters except those that do not return error codes (`MLClose.vi` and `MLReady.vi`, for instance). You should always wire a `MathLink Error Manager.vi` at the end of the *MathLink* operation chain; this is where `MLError` and related functions are called.

4 Programming *Mathematica* Link for LabVIEW

The Link Structure Revisited

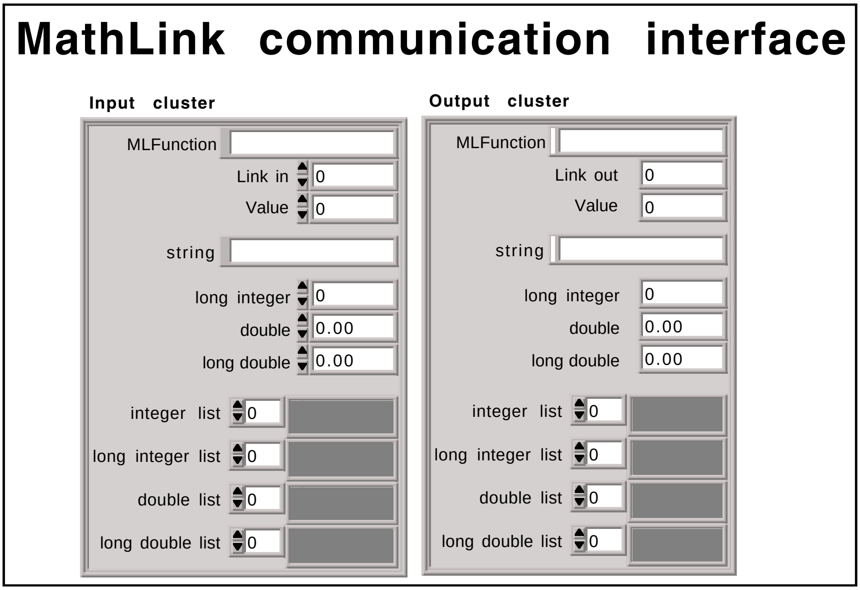
The structure of the link between *Mathematica* and LabVIEW was introduced in Chapter 3. In this first section on Link programming, the organization of *Mathematica* Link for LabVIEW components is described in more detail to help *MathLink* programmers develop their own applications.

The Use of MathLinkCIN.vi

`MathLinkCIN.vi` is the central component in the *Mathematica* Link for LabVIEW package. Its front panel is shown in Figure 12. It is a simple VI that has two clusters: a control cluster for input called "Input cluster"and an indicator cluster "Output cluster". These clusters are identical and have been designed to pass data used by *MathLink* functions. `MathLinkCIN.vi` is saved in `MLComm.llb`.

Use keyboard shortcuts to hide the front panel of `Copyright Notice.vi`.

The `Copyright Notice.vi` is a subVI of `MathLinkCIN.vi`. It is thus executed once every time the CIN is called. Since the graphic displayed by the `Copyright Notice.vi` subVI changes randomly at run time, it can be used to visually monitor the link activity. Note, however, that this display of graphics may use some CPU time and be limiting in some circumstances. There are two ways to hide the front panel of `Copyright Notice.vi`. It can be closed by the keyboard shortcut Control+w (command+w on the Macintosh), or you can simply unselect the option "Show front panel when loaded" in the VI setup menu.



MathLink communication interface

Input cluster

MLFunction

Link in 0

Value 0

string

long integer 0

double 0.00

long double 0.00

integer list 0

long integer list 0

double list 0

long double list 0

Output cluster

MLFunction

Link out 0

Value 0

string

long integer 0

double 0.00

long double 0.00

integer list 0

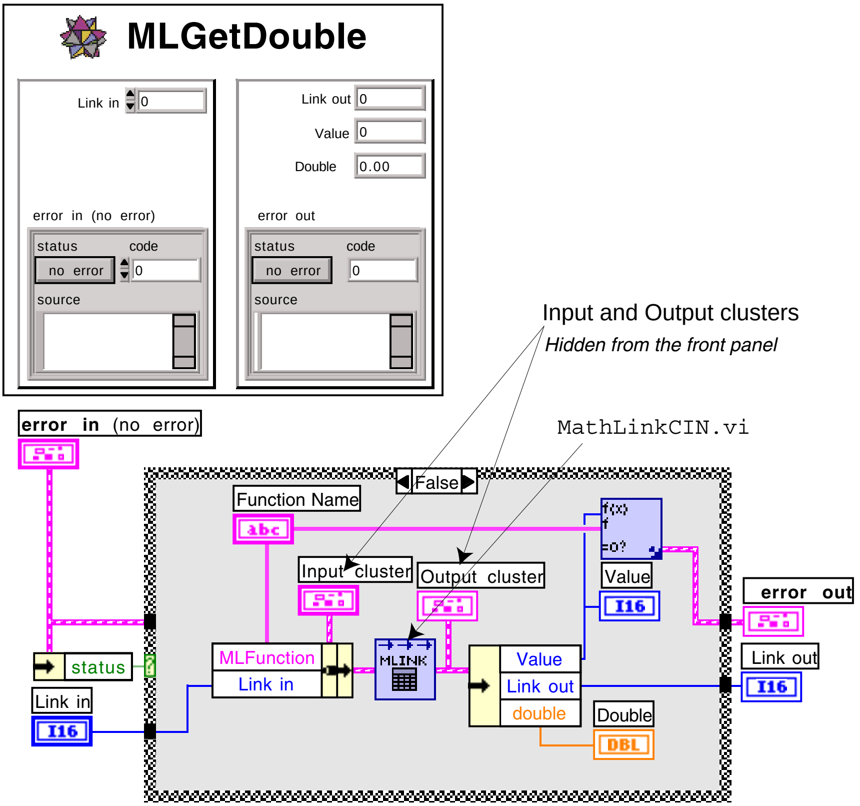
long integer list 0

double list 0

long double list 0

Figure 12. The `MathLinkCIN.vi` front panel.

The `MLGetDouble.vi` diagram can help in understanding how `MathLinkCIN.vi` is called by VIs that implement *MathLink* functions. None of the *MathLink* VIs use all the elements of the clusters of `MathLinkCIN.vi`. Rather, they use only certain cluster elements, depending on the kinds of data that they manipulate. Look at Figure 13 to see how `MLGetDouble.vi` calls `MathLinkCIN.vi`. You can see that the "Input cluster" and "Output cluster" are not visible on the front panel, yet they are used to call the `MathLinkCIN.vi` subVI. Similarly, all the *MathLink* VIs use the same two clusters, although they are hidden from the front panel.



Input and Output clusters

Hidden from the front panel

MathLinkCIN.vi

Figure 13. The MLGetDouble.vi diagram and front panel.

Library Contents

Conceptually, the VIs distributed with *Mathematica* Link for LabVIEW can be classified into three generalized categories:

1. Low-level communication, data transfer, and utility VIs.
2. Medium-level VIs constructed from combinations of low-level VIs, and designed to automatically administer most of the Link activities transparently. The medium-level VIs can be used as simple, stand-alone applications, or can be used as the basis for further development.
3. Tutorial and example VIs demonstrating specific Link programming techniques in various practical contexts.

Low-Level VIs

The low-level VIs can be found in the `dev` subfolder of the `LabVIEW\user.lib\MathLink directory`. They are organized into .llb libraries, and are grouped as follows :

- **`MLComm.llb`**: This library contains all *MathLink* functions devoted to link management (the functions that do not transfer data). `MathLinkCIN.vi` is also located in this library.
- **`MLFast.llb`**: This library is a collection of higher-level functions used to transfer common data structures for which no *MathLink* function is available, including functions to transfer booleans, lists of strings, matrices of complex numbers, etc.
- **`MLGets.llb`**: This library contains all *MathLink* functions used by LabVIEW to read data from the link, such as `MLGetString`, `MLGetLongInteger`, etc.
- **`MLPuts.llb`**: This library contains all *MathLink* functions used by LabVIEW to send data over the link, such as `MLPutString`, `MLPutDouble`, etc.
- **`MLUtil.llb`**: This library is a collection of utilities used by many of the other VIs in this distribution.

Medium-Level VIs

The medium-level VIs can be found in **`MLStart.llb`** at the top level of the `LabVIEW\user.lib\MathLink directory`. Four of the VIs in this library can be used immediately as top-level VIs as you start working with *Mathematica* Link for LabVIEW. These are `Kernel Evaluation.vi`, `Generic ListPlot.vi`, `Generic Plot.vi`, and `MathLink VI Server.vi`. There are also some lower-level utilities in this library that can be useful when developing custom *MathLink* applications.

Tutorial and Example VIs

A variety of example VIs are included along with the core *Mathematica* Link for LabVIEW VIs. These examples are intended to demonstrate the low and medium-level VIs in action. Several examples can be found in **`Tutorial.llb,`** located at the top level of the `LabVIEW\user.lib\MathLink` directory. Additional examples including applied graphics utilities, a simple PID control demo, a mobile robotic control example, and a sophisticated hybrid workflow demo can be found inside the **Extras** subfolder of the LabVIEW\user.lib\MathLink directory. The examples will be discussed in more detail at the end of this chapter.

Although the locations of the various files within the LabVIEW file hierarchy are given here, it should be noted that the VIs can also be easily accessed from the LabVIEW Tools menu, or from MathLink tab of the User Libraries located at the bottom of the LabVIEW Functions palette. For additional information about the structure and organization of *Mathematica* Link for LabVIEW components, refer to Chapter 3.

Getting Connected

Open Link.vi in Tutorial.llb is a very simple program that conducts a *MathLink* session. It opens a link, connects to the other partner, and then closes the link—not a very sophisticated or useful VI, but one that embodies a basic function. We will use this VI to experiment with the various methods to open a link.

Opening a link is the very first event of a link's life cycle. This is when the link comes into existence. Instructions for opening a link are generally mandatory for both sides of the link, and they must be consistent. (There is one exception to this rule, which is when the link is opened in Launch mode—see "Connections in Launch Mode" on page 81).

The Open Link.vi front panel has three areas, as illustrated in Figure 14. The controls in the "MLOpen parameters" area specify the three parameters used to open a link. In the "Link status" area you will find Link ID—an indicator revealing the integer used to identify the recently opened link. There are also two "LEDs" that respectively indicate whether the link is open and connected. Finally, there is a large button with red letters that you can click to close the link.

Connection between Homogeneous Systems

The procedure for opening a link varies depending on whether or not LabVIEW and *Mathematica* are both running on the same OS platform (e.g., Windows or Macintosh). This section first describes how to open a link when both applications are running on the same platform. (Opening a link across different platforms is discussed a little later.)

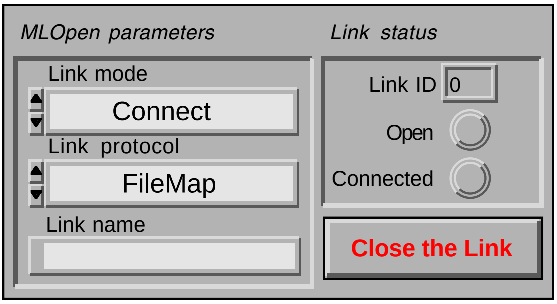


Figure 14. The `Open Link.vi` front panel.

Listen and Connect Modes

The “Link mode” parameter is used with “Link name” to help each member of the link find the other. When the “Link mode” parameter is set to “Listen”, it indicates that `Open Link.vi` is initiating the link connection, and thus should wait for the *MathLink* partner to connect to it. In contrast, when the “Link mode” parameter is set to “Connect”, `Open Link.vi` is responsible for locating the other partner that is waiting in Listen mode. Launch mode will be explained later (see page 81).

Be careful here: the link mode terminology can be misleading. “Listen” and “Connect” do not dictate the status or direction of communication on the link. The partner opening a link in Connect mode is not relegated to a client role, for instance. Once both sides have found each other, they can freely exchange data on a peer-to-peer basis independent of how the connection was originally established.

In order to establish a connection between *Mathematica* and LabVIEW, you must first create a link. In the *Mathematica* notebook, type:

In[1]:=

```
link = LinkOpen["link1", LinkMode->Listen]
```

Out[1]=

```
LinkObject[link1, 2, 2]
```

You can consider this initial step as a kind of link declaration. The link is now available to anybody who wishes to connect to it. At this stage however, a link connection has yet to be made. You will be unable to send data on the link until a connection is made. We can verify that no connection exists using **LinkConnectedQ**:

In[2]:=

```
LinkConnectedQ[link]
```

Out[2]=

```
False
```

Our next task is to connect the link:

In[3]:=

```
LinkConnect[link]
```

Out[3]=

```
LinkObject[link1, 2, 2]
```

Initially, this instruction should hang. The indicated output will not appear until the following steps are performed. This is logical since the link is now waiting for a partner to make a connection. The partner on the LabVIEW side will be `Open Link.vi`. This VI's default parameter values are set to Connect for "Link mode" and the appropriate local protocol for "Link protocol".

The local protocol is platform dependent.

The local protocol is the default communication protocol used by the *Mathematica* kernel and the notebook front end. It depends on the hardware platform you are using. On Windows, a proprietary protocol named FileMap is used. On Macintosh systems, the local protocol is PPC, and UNIX applications communicate through pipes. You should refer to the user's guide for your *Mathematica* installation to learn more about the system-specific protocols that you can use.

On the `Open Link.vi` front panel, type "**link1**" in the "Link name" box to match the link name that was declared in *Mathematica*. Organize your application windows so that you can see both the VI front panel and the *Mathematica* notebook simultaneously, and then run the VI. You can observe as the link is first opened on the front panel of `Open Link.vi`. After a second or two, the connection is made, and the **LinkConnect** command that was hanging in *Mathematica* is finally evaluated. The expected output then appears in your *Mathematica* notebook.

The Macintosh PPC browser.

On a Macintosh, if you omit the link name, a window appears to prompt you to locate the link to which to connect. You should choose "**link1**" on the machine running your *Mathematica* kernel.

Now you can go back to the *Mathematica* front end to make sure that the connection is established. Query the link by using **LinkConnectQ**.

In[4]:=

```
LinkConnectedQ[link]
```

Out[4]=

```
True
```

The last step of our tutorial is to close the link. The only problem that you may have with closing links is forgetting to do it.

In[5]:=

```
LinkClose[link]
```

Do not forget to close the link on both sides! Go to `Open Link.vi` and click the red “Close the link” button.

On a Macintosh click on the Finder or in the application menu to get out of LabVIEW.

Now repeat the procedure, but this time, type “**link2**” in the “Link name” box, set “Link mode” to Listen, and run the VI. Then open the link in Connect mode within the *Mathematica* notebook. Two things will change. First, LabVIEW tells you that it is listening. Second, if you wait too long before switching to *Mathematica*, you will note that LabVIEW is hanging while the LabVIEW evaluation waits in the CIN for the connection.

The following sequence of commands connects *Mathematica* to the open LabVIEW link:

In[1]:=

```
link = LinkOpen["link2", LinkMode->Connect]
```

Out[1]=

```
LinkObject[link2, 4, 2]
```

In[2]:=

```
LinkConnect[link]
```

Out[2]=

```
LinkObject[link2, 4, 2]
```

As before, do not forget to close the link on *both* sides.

In[3]:=

```
LinkClose[link]
```

Link Names

You may have noticed that the *Mathematica* commands we used in the previous sections assigned a value to the “Link name” parameter, while LabVIEW did not – the “Link name” control of the “MLOpen parameters” area remained empty. The result of this omission is that you have to manually locate the link to which you wish to connect. You can omit this step by providing a consistent link name to both sides of the link. If one side of the link can find a partner hosting a link with a complementary link mode value (Connect or Listen), and an identical link name, the connection step will occur automatically.

The possible values for link names depend on the protocol used to open a link. (More details about link names can be found in Wolfram’s “`The` *`MathLink`* `Reference Guide`”.)

Connecting Two Macintosh Machines over a Network

When you run *Mathematica* and LabVIEW on separate Macintoshes over a network, the sequence of instructions for opening a link is the same as just described. However, you will need turn on the “Program Linking” option in the Sharing Setup control panel of the Macintosh that is opening the link in Listen mode.

Connecting Two Windows Machines over a Network

When opening a link between two Windows machines over a network, you have to use the TCP procotol. See the next section.

Connection between Heterogeneous Systems over a Network

The preceding section dealt with the connection of *Mathematica* and LabVIEW when both run on the same type of machine. This section describes the connection procedure when LabVIEW and *Mathematica* are running on machines of heterogeneous types (Windows, UNIX, and Macintosh).

The TCP Protocol

Many scenarios require that several processes communicate in a heterogeneous environment. For example, you may wish run LabVIEW applications on the Windows computer dedicated to the control of your instruments while running the *Mathematica* front end from your favorite Macintosh desktop environment. At the same time you might run your *Mathematica* kernel on a fast UNIX CPU. The TCP protocol must be used for a distributed application that involves several processes running on several computers.

The TCP protocol is flexible, and you can use it in the same way that you use the local protocol described in the previous section. When using TCP, however, the link name must be a positive integer (a port number), and you must specify the IP address or name (e.g., `praline` or `praline.wolfram.com)` for the machine to which you want to connect.

Example

We can reproduce the connection sequence explained in the preceding section using the TCP protocol. Use `Open Link.vi` and choose the TCP protocol. Specify a link name such as **3000@machine.domain**. This must be the address of the machine where the *Mathematica* kernel is running. In *Mathematica* you use almost the same sequence of commands given in the previous section, except that you must give option values consistent with the use of the TCP protocol. In particular, you have to use the **LinkProtocol** option.

In[1]:=

```
link = LinkOpen["3000@praline",
                LinkProtocol->"TCP",
                LinkMode-> Connect]
```

Out[1]=

```
LinkObject[LabVIEW, 4, 2]
```

In[2]:=

```
LinkConnect[link]
```

Out[2]=

```
LinkObject[LabVIEW, 4, 2]
```

Once again, do not forget to close the link on both sides.

In[3]:=

```
LinkClose[link]
```

Connections in Launch Mode

Launch mode allows you to initiate a process from within another *MathLink* program. A typical use of Launch mode is to have a *Mathematica* front end start the *Mathematica* kernel. All the top-level VIs of the `MLStart.llb` can open a link to the *Mathematica* kernel in Launch mode.

The purpose of Launch mode is to allow automation of the connection process. Launch mode is an exception to the typical use of `MLOpen`—in Launch mode, a subsidiary process is initiated by a parent process. In this instance, the subsidiary process does not need to open a link. Thus, you have only one call to `MLOpen` in the parent process.

Since Launch mode starts a process, its arguments must provide an identification of this process. The link name is given in a special form to indicate the process name. Launch mode has platform-specific properties detailed in the following sections.

Windows

The value of "Link name" should be a path to the application you want to launch. Directories in Windows paths are separated by the back slash character `\`.

If your hard drive is named "C" and your application is named "app.exe", the following table gives some examples of valid paths.

Path	Points to
C:\app.exe	app.exe located at the top level of C
C:\APPS\app.exe	app.exe located inside a directory named "APPS", which is on C
app.exe	app.exe in the current directory
..\app.exe	app.exe in the directory containing the current directory

You can place such paths in the "Link name" box when starting applications. See the diagram of `Launch Kernel.vi` for an example of an implementation of this instruction.

Macintosh

The value of “Link name” should be a path to the application you want to launch. Directories in Macintosh paths are separated by colons.

If your hard drive is named “HD” and your application is named “app”, the following table gives some examples of valid paths.

Path	Points to
HD:app	app located at the top-level of HD
HD:Applications:app	app located inside a folder named “Applications”, which is on HD
:app	app in the current folder
::app	app in the folder containing the current folder

You can place such paths in the “Link name” box when starting applications. Open `Launch Kernel.vi` and examine its diagram for an example of an implementation of this instruction.

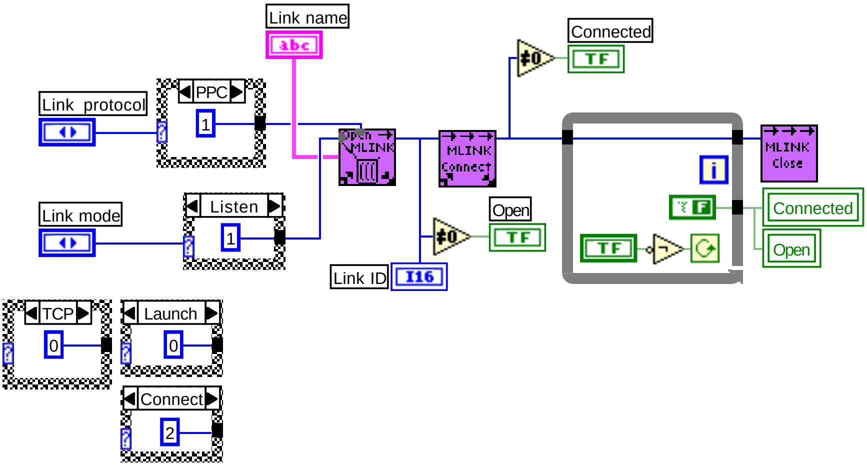
The Open Link.vi Diagram

In Figure 15, you can see how the three *MathLink* VIs are chained together by the link identifier. You can also see what is wired to the “Link name”, “Link mode”, and “Link protocol” connectors of `MLOpen.vi`. (Note: This is the Macintosh version of the VI. In the Windows diagram, “FileMap” is used instead of “PPC”.)

Monitoring Link Activity

Since *MathLink* applications involve inter-task communication, a common operation that occurs in any *MathLink* program is monitoring link activity. When a link is connected but no transaction is pending, it is necessary to monitor potential requests from the link. On the receiver side, a transaction is always triggered by incoming data, which can be detected by the `MLReady` instruction. However, calling `MLReady` in a **while** loop might not be necessary, since the possibility of errors also needs to be tested. The simultaneous use `MLReady` and `MLError` is the core structure that allows link activity to be monitored.

Figure 15. The `Open Link.vi` diagram.



Link monitoring requires two timing parameters to be integrated smoothly within an application. A timeout is required to avoid getting trapped in an infinite loop. Depending on the application and particular context, you will want to choose between a finite or an infinite value for this parameter. The other timing parameter is the link-scanning period. Since LabVIEW's diagrams are cooperative multitasking systems, it is necessary to slow down all tasks that are not priorities. The strategic use of the `wait` function allows the introduction of a hierarchy in task priorities (refer to LabVIEW documentation for more information on this subject). When monitoring a link, it is necessary to balance the fast processing of incoming data with the overall CPU load.

Link Monitor.vi

The main structure of `Link Monitor.vi` illustrated in Figure 16 is a **while** loop. Three conditions can be used to exit the loop:

1. `MLReady returns 1`: there is something ready to be read on the link.
2. `MLError does not equal MLEOK`: an error occurred on the link.
3. `Timeout exceeded.`

Since these three conditions are not equivalent, it is necessary to inform downstream VIs of a possible error. This is the purpose of the "Proceed?" indicator. The link can be read only when this indicator returns "True".

When an infinite loop is necessary, it is possible to eliminate the timeout parameter by setting its value to +∞ with the LabVIEW built-in constant.

`Link Monitor.vi` should not be used between `MLOpen` and `MLConnect`, because it can be used only on connected links.

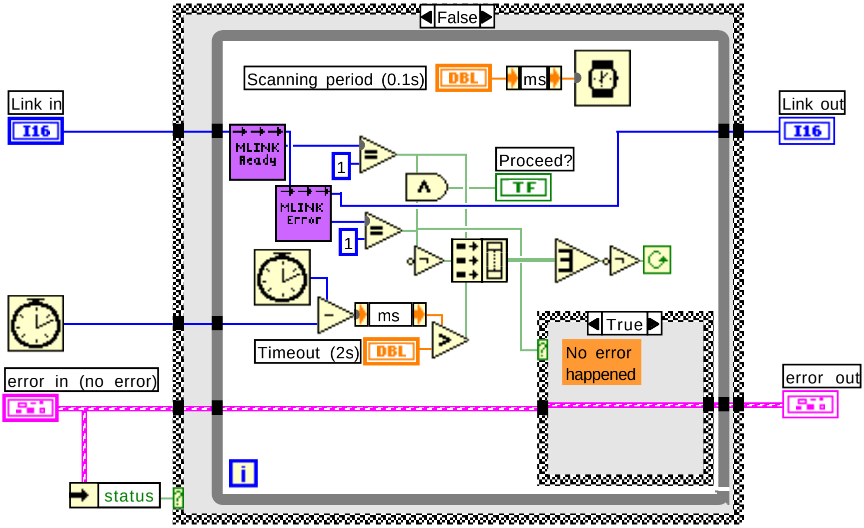


Figure 16. The `Link Monitor.vi` diagram.

Error Management Tools

Mathematica Link for LabVIEW uses globals and custom error manager VIs to track and control error processing. In this section we will discuss the integrated error-handling capabilities of *Mathematica* Link for LabVIEW, along with a short introduction to potential error sources.

Four Error Types and the ErrorOffset.gbl Global Variable

Four kinds of errors may occur in *Mathematica* Link for LabVIEW:

- *Mathematica* errors
- *MathLink* errors
- *Mathematica* Link for LabVIEW errors
- LabVIEW errors

Mathematica errors are easy to handle, since they always generate messages. *Mathematica* is extremely robust, and error messages are automatically generated. The task at hand is to collect these messages and dispatch them accordingly (see the "Packet Parser.vi" section on page 89). *MathLink* errors are more subtle—most *MathLink* functions simply return a value of zero when a problem occurs. After this error signal, you must use `MLError` to identify the error code. Special error codes that do not conflict with *MathLink* nor with LabVIEW have been introduced to tag *Mathematica* Link for LabVIEW errors. Finally, LabVIEW has its own set of built-in error codes.

One global variable, `ErrorOffset.gbl` (located in `MLUtil.llb`), is used to map *MathLink* and *Mathematica* Link for LabVIEW error codes into LabVIEW's user-defined error space. The default offset value has been set to 7000. Keep in mind, however, that this value could interfere with other custom LabVIEW applications that might be running simultaneously. In case of conflict, open `ErrorOffset.gbl` and set the offset value accordingly to map *Mathematica* Link for LabVIEW errors into a non-conflicting range.

MathLink Error Manager.vi

`MathLink Error Manager.vi,` shown in Figure 17, is intended to be placed at the end of a *MathLink* session. Its job is to check for and ascertain the identity of any *MathLink* error that may have occured, display the corresponding error message, possibly take a corrective action, and then clear the error.

This VI first reads the incoming error cluster to detect a possible *MathLink* error. Two criteria are used for this purpose: the status value and the code value. It is a good idea to start by testing the status flag of the incoming error cluster. When it is set to "False", no error was detected, and we can proceed to the next VI. Should the status flag be set to "True", it does not necessarily mean that the error originated in a

MathLink function. It could have come from any other function, including one from `MLUtil.llb`. Nevertheless, *MathLink* function code errors have a specific value: the value set in `ErrorOffset.gbl`. Thus, a *MathLink* error is detected by a double condition: the status is “True” and the code is 7000.

`MathLink Error Manager.vi` uses two main arguments, the link number and an error cluster. The “Display dialog” check box is an optional argument.

If a *MathLink* error is detected, you must identify it precisely by using `MLError.vi`, which returns a specific *MathLink* error code, not just a generic error flag. Finally, the link is reactivated, if possible, by `MLClearError.vi`.

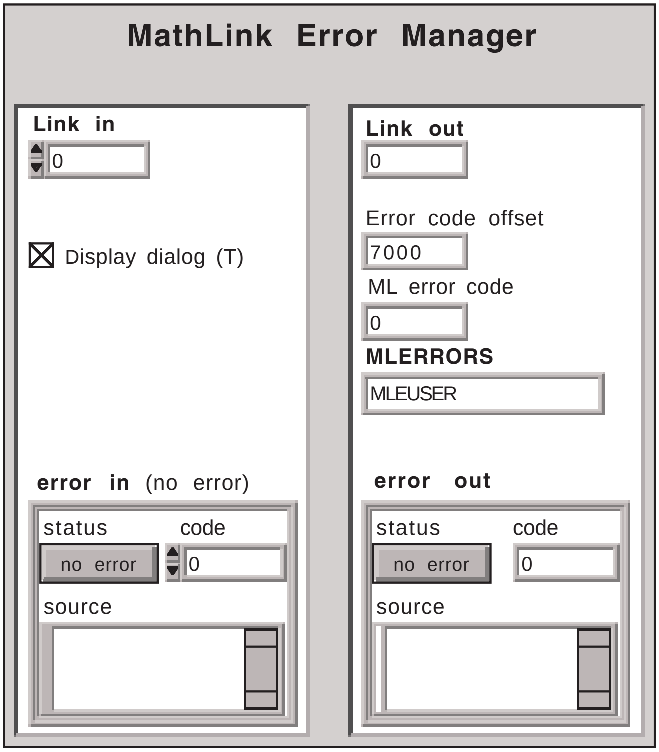
The last action of `MathLink Error Manager.vi` is to call `General Error Handler.vi`. Lists of user-defined error codes and error messages are wired to `General Error Handler.vi` to cover both *MathLink* errors and *Mathematica* Link for LabVIEW errors. The “Display dialog” check box is wired to the error handler to control the display of error messages. Uncheck this box when you want the program to process errors without informing the user.

In some cases, `MathLink Error Manager.vi` performs a corrective action in response specific errors:

- `MLClose` for `MLEUNKNOWN` error
- `MLClose` for `MLEDEAD` error
- `MLNewPacket` for `MLEGETSEQ` error

Error Cluster Maker.vi

Once a MathLink function has been sent to the link, you must check whether or not it returns a nonzero value and bundle the error cluster accordingly. A dedicated VI, `Error Cluster Maker.vi`, has been designed for this purpose. It is located in `MLUtil.llb`. It is a general utility not specific to MathLink that can be used with functions returning either a zero or nonzero value when an error occurs. As noted previously, MathLink functions return zero in response to an error. However, many non-MathLink functions return their error codes directly, and for these functions, a value of zero usually means that no error occurred. A check box on the front panel specifies which values indicate an error. Its default value is “True”, which specifies that a return value of zero indicates an error according to MathLink convention. The last input is the function name, whose value will be sent in the source field of the “error out” cluster in the event of an error.



MathLink Error Manager

Link in: 0

☒ Display dialog (T)

error in (no error)
status: no error
code: 0
source:

Link out: 0

Error code offset: 7000

ML error code: 0

MLERRORS: MLEUSER

error out
status: no error
code: 0
source:

Figure 17. The `MathLink Error Manager.vi` front panel.

`Error Cluster Maker.vi` compares the function value with the check box “Error=0” boolean value to compute the value of the “status” element of the “error out” cluster. Whatever the value of “Error=0”, the offset value is added to the function value, and the result is sent to the “code” element of “error out”. Finally, the function name is sent in the source field only when an error is detected. `Error Cluster Maker.vi` is used by most of the VIs of the *Mathematica* Link for LabVIEW libraries.

Code And Messages.vi

`Codes And Messages.vi` is used as a subVI of `MathLink Error Manager.vi` to collect *MathLink* and *Mathematica* Link for LabVIEW error codes and messages.

The Art of Packet Management

What are packets and when should you be concerned about them? This depends very much on the way you use *Mathematica* Link for LabVIEW. When you use it to get control of a LabVIEW application from within a *Mathematica* notebook, you will not see evidence of packets. Nor will you have to consider packets when you use *MathLink* to exchange data between two separate LabVIEW applications. You will encounter packets only when you use the *Mathematica* kernel as a subprocess of a LabVIEW application.

At this point, it should be noted that several of the VIs bundled with *Mathematica* Link for LabVIEW, including the top-level VIs in MLStart.llb, take care of packet management for you. If your own applications can be built on top of these VIs, the following discussion is mostly academic. On the other hand, if you want to get the most out of *Mathematica* Link for LabVIEW and take control of the low-level details of your *MathLink* applications, a working understanding of packet management is necessary.

Packets are special *Mathematica* functions used by the kernel when it is operated in *MathLink* mode. *MathLink* mode is automatically turned on when you open a link to the kernel in Launch mode.

Some users may consider *Mathematica* Link for LabVIEW the ideal tool for extending the set of *Mathematica*l functions available to LabVIEW applications. In this context, the *Mathematica* kernel is launched to perform as a subsidiary process of LabVIEW applications. *Mathematica* is run in *MathLink* mode and thus returns evaluation results wrapped in packets. If you plan to develop your own LabVIEW applications that use the *Mathematica* kernel to work on nontrivial computations, you need to understand how to process packets in your application. The sequence of commands will be different from the ones you would use in a *Mathematica* notebook.

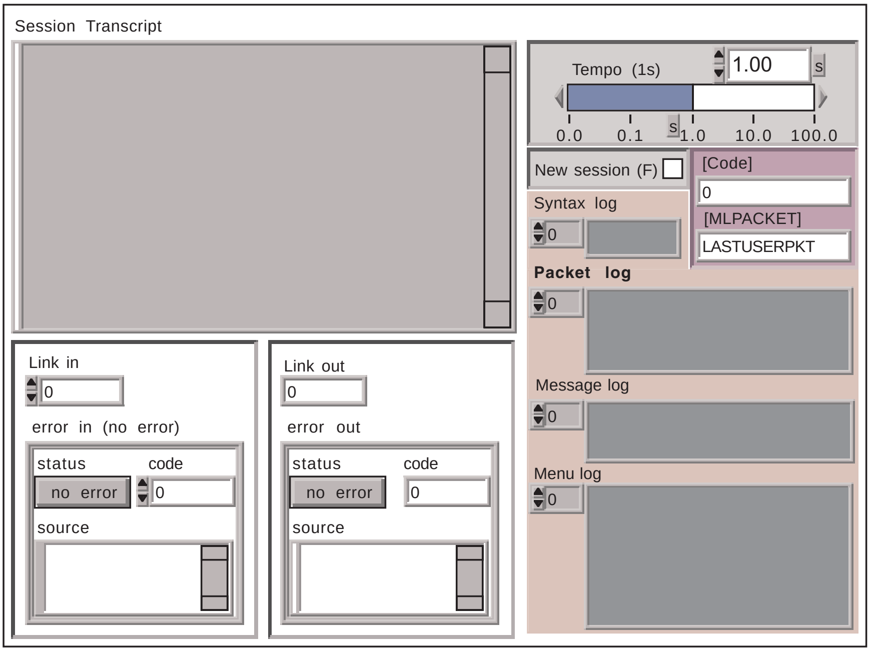
On the other hand, when using the *Mathematica* kernel from a standard *Mathematica* notebook, you don't need to worry about packets, which are handled by the front-end application. The standard front end distributed with the *Mathematica* kernel is a separate program that launches the kernel and interacts with it through *MathLink*. If you have not used this front end, spend some time becoming familiar with it before starting the development of your LabVIEW application. The standard notebook front end should not be regarded as the only option for interacting with the kernel: it is only one well-developed representative from a general family of external programs that can be used for this purpose. The kernel and *MathLink* have been designed to facilitate the control of the kernel by external programs. The links to Microsoft Excel and to Microsoft Word are two examples that were developed by Wolfram Research for users who need to use *Mathematica* functions from within these popular Microsoft software packages.

Although generic *Mathematica* front ends can be defined as applications that use *MathLink* to run the kernel, such applications can be very different from one another. Even the front ends developed by Wolfram Research vary in the functions they provide. In `Tutorial.llb`, `Basic Front End.vi` provides functionality similar to the terminal window of the Macintosh or Windows versions of the kernel. It can handle any *Mathematica* expression as input, it can return results as well as error messages, but it cannot display graphics. You will see later that the interface of this VI, although simple, can be more user-friendly than the terminal window of the kernel (see "Basic Front End.vi" on page 94).

If you develop a LabVIEW application to run the *Mathematica* kernel, recognize that you are actually developing a front end. Rather than focusing on the data you expect as result of the evaluation of your command line, you have to proceed with the careful and safe management of packets in mind. `Packet Parser.vi`, provided with this distribution, has been designed to simplify the development process.

Packet Parser.vi

`Packet Parser.vi` shown in Figure 18 is a general utility upon which any LabVIEW front end can be built. As soon as you send a command to the *Mathematica* kernel from within a LabVIEW application, packets will be returned. The job of `Packet Parser.vi` is to sort them out and process them properly when possible. There are two classes of packets: packets that LabVIEW can process on a systematic basis (those that return a single data type) and packets that require a custom LabVIEW application to handle them (those that return *Mathematica* expressions). `Packet Parser.vi` will process packets of the first type and pass on to downstream VIs those that require custom treatment.



Tempo (1s): 1.00 s

[Code]: 0

[MLPACKET]: LASTUSERPKT

Syntax log: 0

Packet log: 0

Message log: 0

Menu log: 0

Link in: 0

error in (no error): status no error, code 0

Link out: 0

error out: status no error, code 0

Figure 18. The `Packet Parser.vi` front panel.

The main structure of `Packet Parser.vi` is a state machine with three frames. Frame 1 is the initial frame in which the link is monitored for the number of seconds set in the “Tempo” control. During this time, the link is regularly scanned to detect either errors or incoming data. If a packet arrives with no error, the state machine jumps to frame 2. Otherwise, it jumps to frame 0, which is the exit frame. In frame 2, first `MLNextPacket` is called, and the result is time-stamped and saved in the Packet log and also displayed in the “Packet” and “Packet code” boxes. The custom processing of each packet type is discussed in the next section.

Packet Processing

The following table describes the action taken by `Packet Parser.vi` for all possible kinds of *MathLink* packets.

Packet type	Action	Comment
ILLEGALPKT		An error occurred. This should be processed by MathLink Error Manager.vi.
CALLPKT	MLNewPacket	Not supported.
EVALUATEPKT	MLNewPacket	This type of packet should not be returned by the kernel to LabVIEW.
RETURNPKT		This should be processed outside of Packet Parser.vi
INPUTNAMEPKT	MLGetString	Appended to the session transcript.
ENTERTEXTPKT	MLNewPacket	This type of packet should not be returned by the kernel to LabVIEW.
ENTEREXPRPKT	MLNewPacket	This type of packet should not be returned by the kernel to LabVIEW.
OUTPUTNAMEPKT	MLGetString	Appended to the session transcript.
RETURNTEXTPKT	MLGetString	Appended to the session transcript.
RETURNEXPRPKT		Should be processed outside of Packet Parser.vi.
DISPLAYPKT	MLGetString	Appended to Graphics.
DISPLAYENDPKT	MLGetString	Appended to Graphics. Graphics saved in temporary file, and cleared.
MESSAGEPKT	MLGetSymbol, MLGetString	Appended to the Message log.
TEXTPKT	MLGetString	Appended to the session transcript.
INPUTPKT	See diagram below	
INPUTSTRPKT	See diagram below	
MENUPKT	MLGetLongInteger, MLGetString	Appended to the Menu log.
SYNTAXPKT	MLGetLongInteger	Appended to the Syntax log.
SUSPENDPKT	MLNewPacket	Not supported.
RESUMEPKT	MLNewPacket	Not supported.
BEGINDLGPKT	MLNewPacket	Not supported.
ENDDLGPKT	MLNewPacket	Not supported.

The INPUTPKT case is managed by the diagram shown in Figure 19. The INPUTSTRPKT case is processed similarly to the INPUTPKT case.

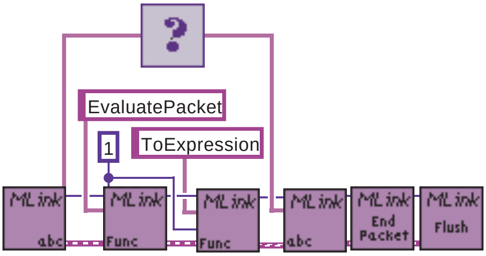


Figure 19. `INPUTPKT` processing.

The "New session" Check Box

Check the "New session" check box to empty all the logs before the VI is run. For a log set consisting only of the current *Mathematica* session, you should enable this option whenever the *Mathematica* kernel is reinitialized.

Graphics Rendering

When *Mathematica* graphics are returned to LabVIEW from the kernel, the packet of types `DISPLAYPKT` or `DISPLAYENDPKT`s are sorted by `Packet Parser.vi`. After the packet `DISPLAYENDPKT` has been read, the graphic is written in a temporary file by the `MakeGraphTempFile.vi` from `MLUtil.llb`. The temporary file generated by this VI is named `mmagraphtemp` and is located in the LabVIEW temporary folder.

The next step is to visually render the contents of this file. As explained in the section "**Structure of the Link**" on page 13, it is necessary to interpret the PostScript information in order to generate a LabVIEW-compatible bitmap version of the picture. Rendering *Mathematica* graphics from inside a LabVIEW VI is a two step process. First, the PostScript expression of the graphics has to be converted to a bitmap form. Second, the bitmap description of the graphics must be read into the VI front panel. To accomplish this second step, a temporary LabVIEW-compatible bitmap is generated and read in for display on the LabVIEW front panel. The entire graphics-file processing chain is handled by `Graphics Viewer.vi` and its subVIs.

If the `mmagraphtemp` file cannot be found, an empty picture is displayed and nothing more is done. Otherwise, a subVI named `Pictify.vi` is called. This VI manages the MLPost operations. In particular, it detects whether or not MLPost has been launched on the basis of the value of "MLPost Link in". A value of zero means that the application has not yet been launched. The other arguments of this VI are the name of the bitmap temporary file (its default value is `mmapicttemp`) and the dimensions (the number of columns and rows) of the bitmap graphic.

Once the bitmap file has been generated, the next step is to read it. This is achieved by `Read Bitmap.vi` which calls a particular function implemented in `MathLinkCIN.vi`. This is the only function of this CIN that is not a true *MathLink* function.

One of the arguments passed to `Read Bitmap.vi` is "Link in", which is used mainly to allow sequencing of graphic-processing steps through data dependency. Note, however, that no *MathLink* operations are conducted here. The number of lines and columns of the picture as well as the path to the bitmap file are other required arguments. The picture is returned as a matrix of color values along with the color palette for the image.

The picture is displayed in a custom intensity graph named `GraphicsWindow.ctl`, found in `MLStart.llb`. The information returned by `Read Bitmap.vi` in the "Color palette" cluster must be wired to the corresponding items of an intensity graph property node. Both temporary files that were generated in the course of generating the graphic are deleted after being processed.

Other Graphics Examples

The notes above pertain specifically to `Generic Plot.vi` and `Generic ListPlot.vi`—the two primary graphics examples found in `MLStart.llb`. These examples take advantage of `MLPost`, a stand-alone executable that converts *Mathematica's* PostScript files into bitmap files. While `MLPost` is perhaps the easiest way to display *Mathematica* graphics on a VI front panel, other graphic options are available. For example, *Mathematica* graphics export capabilities can be accessed directly using standard *Mathematica* commands, as illustrated by `Generate MM Graphics File.vi` and `Display BMP.vi`. (These and other graphics examples can be found in the `Extras` subdirectory of `LabVIEW\user.lib\MathLink` folder, or alternatively can be accessed via the LabVIEW Tools menu, or through the `MathLink` tab on the `Functions` palette.)

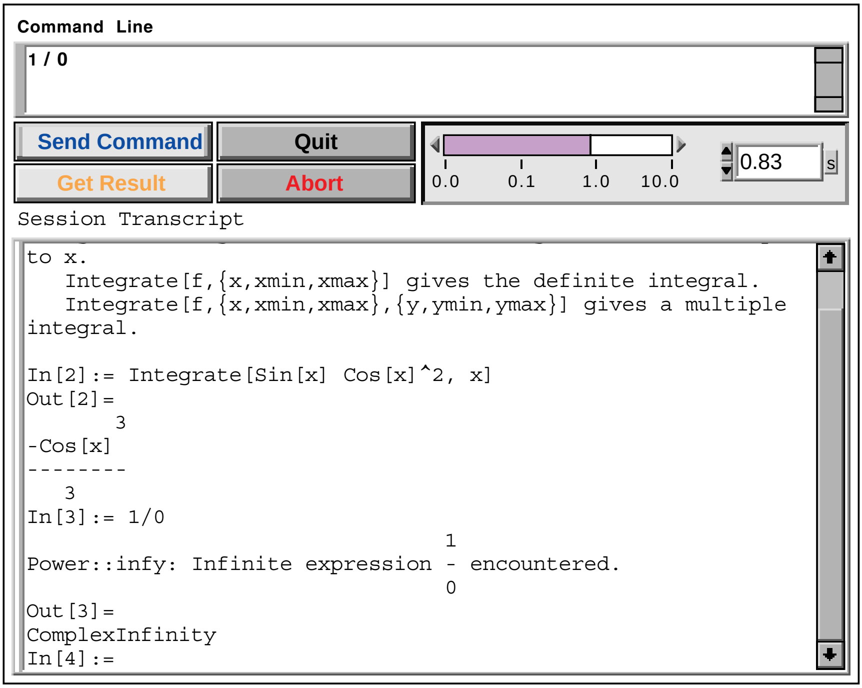
Commented Programming Examples

As indicated earlier in this chapter, several simple examples have been provided to illustrate applied uses for *MathLink* functions in LabVIEW applications. All of these examples are contained either in `Tutorial.llb` or the `Extras` subdirectory of `LabVIEW\user.lib\MathLink` folder. However, you may find it more convenient to access these examples through the LabVIEW Tools menu.

Basic Front End.vi

`Basic Front End.vi` shown in Figure 20 and Figure 21 is an interesting programming example mainly because it illustrates an alternative method to program a *MathLink* application. As detailed in the section "Packet Parser.vi" on page 89, custom applications are required to process *Mathematica* expressions returned by the kernel. One way to side-step this requirement is to return all evaluation results from the kernel in the form of strings. The advantage of this approach is that a systematic treatment of command results can be implemented. However, the drawback is the information returned by the kernel cannot be used directly in subsequent computations since the data types are lost in the *MathLink* transaction.

As you can see in Figure 20, `Basic Front End.vi` offers a text interface to the kernel, similar to the kernel window. This VI can be used to control the kernel as a rudimentary front end. When you run the VI, you are prompted to locate the *Mathematica* kernel that you want to launch. In the "Command Line" box you can type any *Mathematica* command. Click the "Send Command" button to have the command evaluated. The result will be displayed in the "Session Transcript" window. The "Get Result" button is used to fetch a result that may not have come back before the time out has elapsed. The slider on the right is used to set the length of the time out interval, and the "Abort" button can be used to abort a running evaluation. Finally, "Quit" releases the kernel and stops the execution of the VI.



Command Line

```
1 / 0
```

Session Transcript

```
to x.
   Integrate[f,{x,xmin,xmax}] gives the definite integral.
   Integrate[f,{x,xmin,xmax},{y,ymin,ymax}] gives a multiple
integral.

In[2]:= Integrate[Sin[x] Cos[x]^2, x]
Out[2]=
       3
-Cos[x]
--------
   3
In[3]:= 1/0
                                 1
Power::infy: Infinite expression - encountered.
                                 0
Out[3]=
ComplexInfinity
In[4]:=
```

Figure 20. The `Basic Front End.vi` front panel.

The block diagram for `Basic Front End.vi` is revealed in Figure 21. We will discuss it briefly here, but you may also want to interact with it directly from within LabVIEW.

First, notice the sequence structure at the top of the figure. This is where the terminal is initialized, and also where the link is opened: `MLNextPacket` is used to establish the connection. The first packet emitted by the kernel will be `INPUTNAMEPKT`. Next, `MLGetString` is used to read the string “In[1]:=” which is the packet content.

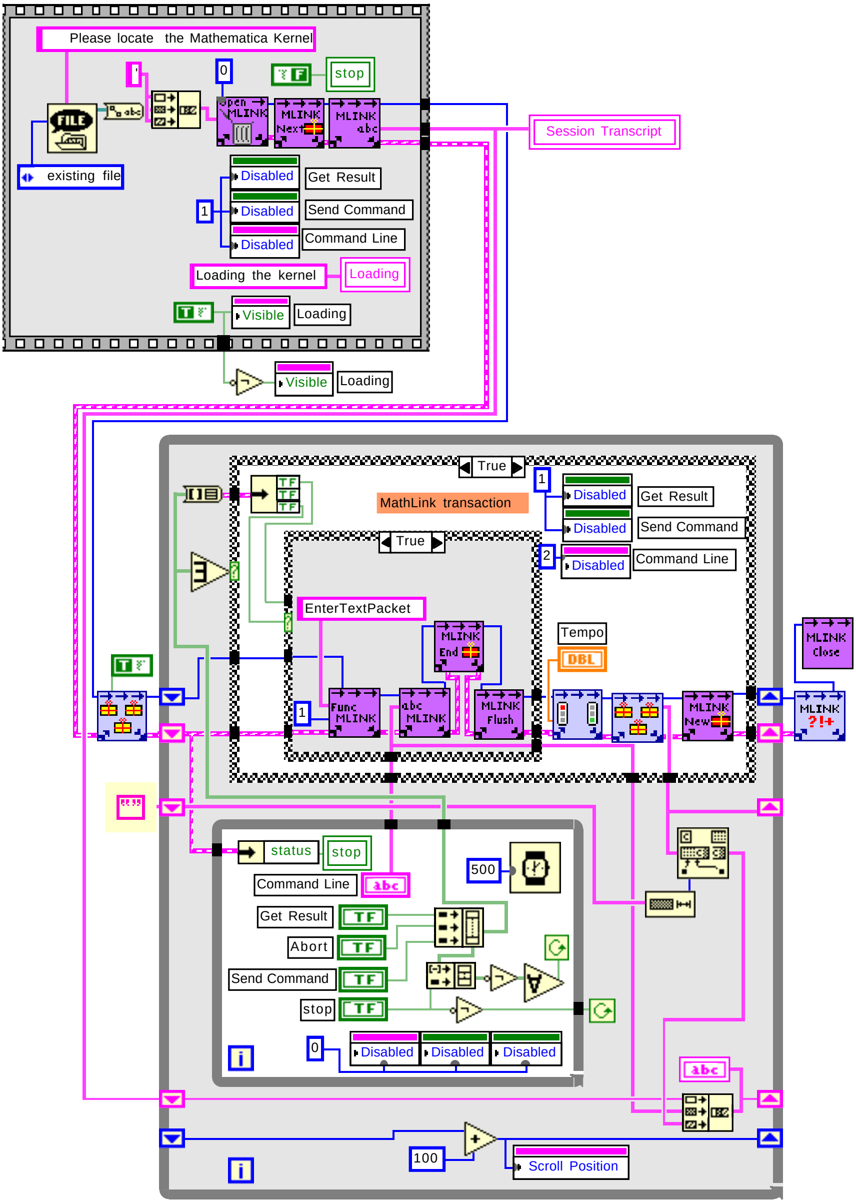


Figure 21. The `Basic Front End.vi` diagram.

When the program completes the initialization step, `Packet Parser.vi` is used to reinitialize the session. This step is necessary to purge all packet logs that may have accumulated during initialization, or that may possibly remain from previous runs.

Two loops are nested. The smaller loop is used to monitor user interaction. The program exits this loop when the user clicks one of the four buttons. The nested case structures correspond to the four possible actions: “Send Command”, “Get Result”, “Abort”, and “Quit”.

Of particular interest is the frame corresponding to the “Send Command” action. The command is passed as a string wrapped in `ENTERTEXTPKT`. This ensures that the evaluation result will be returned as `RETURNTEXTPKT`, that is, as a string. After sending the command over the link, `Link Monitor.vi` is used to detect the incoming result until the time out period elapses. The returned string is collected by `Packet Parser.vi`. The final step is to split the string returned by `Packet Parser.vi`, and to extract the part generated by the last evaluation.

This approach is interesting since it overcomes the difficulty of parsing the different kinds of packets returned by the kernel. However, the limitation of this treatment, as noted previously, is that the results can be displayed, but no further computation can be performed on them.

Basic *MathLink* Programming

Thus far, we have been investigating the VIs specific to *Mathematica* Link for LabVIEW. *MathLink* functions were rarely used alone. Rather, higher-level VIs that perform somewhat generic functions were the focus of the discussions to this point. One drawback of the top-level VIs of `MLStart.llb` is that they have many subVIs – these ready-made solutions may be overkill if you have a very specific *MathLink* objective in mind. The VIs presented in the following section introduce you to basic *MathLink* functions that can be used to build smaller, focused applications. When carefully applied, the functions presented here may prove to be somewhat more efficient than the top-level VIs in the `MLStart.llb` library.

For the examples in this tutorial, LabVIEW and *Mathematica* must run on the same computer. The link will use the default local protocol. The next two VIs are “bare-bones” applications that exchange data between LabVIEW and *Mathematica*. They can be found in the MathLink -> Tutorial submenu of the LabVIEW Tools menu.

Simple Data Server.vi

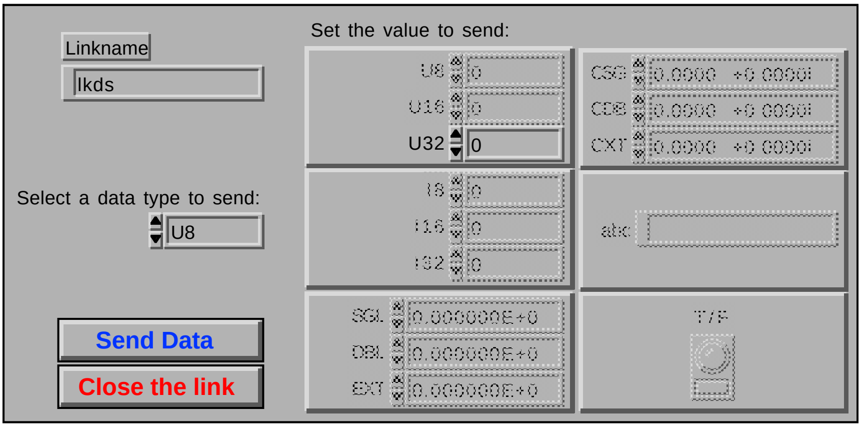
`Simple Data Server.vi` is a stripped-down application designed to send data to *Mathematica*. Its front panel is depicted in Figure 22; its diagram appears in Figure 23.

Operation of Simple Data Server.vi

Upon opening `Simple Data Server.vi`, you will find the following items on its front panel:

- A button labeled "Send Data". The function of this button is easy to guess: it sends data on the link.
- A button labeled "Close the link" – even easier to guess – closes the link.
- A ring control labeled "Select a data type to send". This parameter is used to select the kind of data you want to transmit. Most elementary data types—including all numeric data (integer, real, and complex numbers), strings, and boolean types—are available here.

Next, notice the controls located in the center of the panel and to the right. Also notice that only the currently selected data type is editable – all others are grayed out.



Linkname: lkds

Select a data type to send: U8

Set the value to send:

U8: 0
U16: 0
U32: 0
I8: 0
I16: 0
I32: 0
SGL: 0.000000E+0
DBL: 0.000000E+0
EXT: 0.000000E+0
CSG: 0.0000 +0.0000i
CDB: 0.0000 +0.0000i
CXT: 0.0000 +0.0000i

Figure 22. `Simple Data Server.vi` front panel.

You first have to open the link in Listen mode in *Mathematica*—the link will be opened in Connect mode in LabVIEW. (Note: this default behavior cannot be programmatically modified when running this VI.)

The default value of the link name is set to “lkds” in the VI. Use this same default link name when opening the link in *Mathematica*.

In[1]:=

```
link = LinkOpen["lkds", LinkProtocol->"FileMap", LinkMode->Listen]
```

Out[1]=

```
LinkObject[lkds, 2, 2]
```

In[2]:=

```
LinkConnect[link]
```

Out[2]=

```
LinkObject[lkds, 2, 2]
```

You can now run `Simple Data Server.vi`. Select the type of the data you wish to send on the link using the ring control; note that the corresponding control becomes active. Set the value of the data in the control and click the Send Data button.

You can now return to *Mathematica* and try to collect the data that you have just sent. A good practice is to make sure that something is ready to be read before you actually attempt to read it. **LinkReadyQ** is the query command that serves this purpose.

In[3]:=

```
LinkReadyQ[link]
```

Out[3]=

```
True
```

True should be returned. Since something is waiting, you just have to read it.

In[4]:=

```
LinkRead[link]
```

Out[4]=

```
0.2 + 0.03 I
```

In place of the output shown in this example, you should see the data you sent. You should now try to send *several* pieces of data at once from the LabVIEW side. Select the data types you wish to test and click the Send Data button as many times as you want. Then go back to the *Mathematica* notebook and repeat the previous sequence of instructions. (Be sure that there is something to read before reading it.)

In[5]:=

```
If[LinkReadyQ[link], LinkRead[link], Print["The link is
empty"]]
```

Out[5]=

```
1
```

In[6]:=

```
If[LinkReadyQ[link], LinkRead[link], Print["The link is
empty"]]
```

Out[6]=

```
2
```

In[7]:=

```
If[LinkReadyQ[link], LinkRead[link], Print["The link is
presently empty."]]
```

Out[7]=

```
3
```

In[8]:=

```
If[LinkReadyQ[link], LinkRead[link], Print["The link is
presently empty."]]
```

```
The link is presently empty.
```

The output is dependent on the data you sent and may be different from those illustrated here.

Making sure that the link is ready before reading it is a wise precaution: **LinkReadyQ[link]** is included in the **If** statement for this purpose. Keep in mind that if nothing is ready to be read, the **LinkRead** command will hang until something arrives. It is important to understand this because **LinkRead** cannot be aborted. A hanging, unabortable **LinkRead** command is undesirable because you increase the likelihood of collecting data whose origin you do not know.

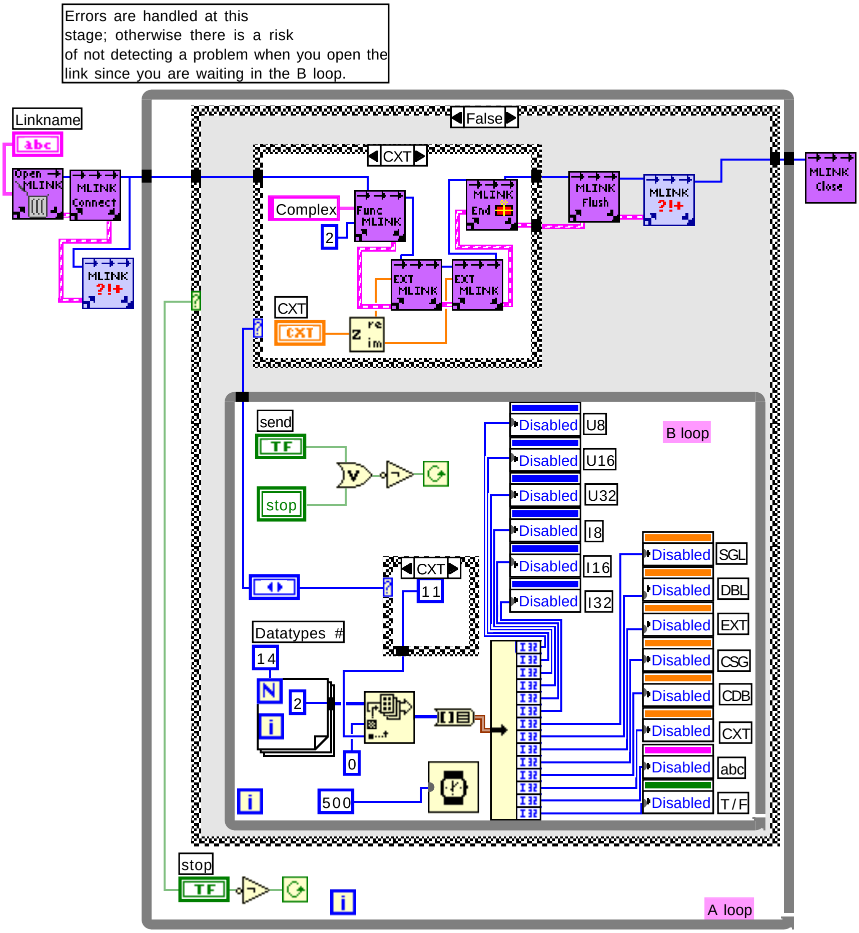


Figure 23. `Simple Data Server.vi` diagram.

Now it is time to inspect the block diagram to see how this VI is implemented. Remember to close the link before moving on to the next section. Don't forget : the link must be closed by both partners. In the *Mathematica* notebook simply use the **LinkClose** command.

In[9]:=

```
LinkClose[link]
```

In LabVIEW, click the "Close the link" button and the VI stops.

SIMPLE DATA SERVER.VI DIAGRAM

The `Simple Data Server.vi` diagram has all the basic features necessary to establish a session and write data on a link. First, the link is opened and a connection is made. Any errors that may have resulted from a previous sequence are processed at this stage to avoid sending data over a malformed link connection.

There is one main execution loop that terminates when the user presses the Stop button. The only command lying outside of this main loop is `MLClose`. Inside the main loop is a nested user interface loop to poll user action. When this inner UI loop terminates, the data flow is directed to a case structure where a series of *MathLink* commands are executed in accordance with the user's choice. Pay particular attention to the complex number transmission depicted in the figure. Complex numbers are transmitted as functions because of their internal representation in *Mathematica*.

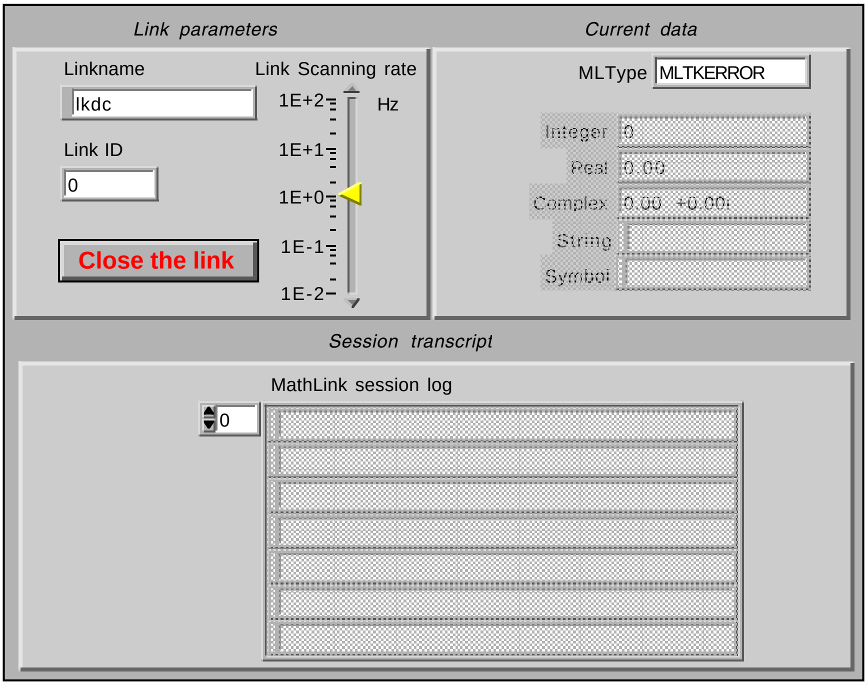
After the type-specific case structure executes, data are flushed using the `MLFlush` command, and `MathLink Error Manager.vi` processes any errors that may have occurred.

Simple Data Client.vi

The `Simple Data Server.vi` demonstrates (albeit in the simplest terms) how to pass parameters from LabVIEW to *Mathematica*, but suppose you prefer to move data in the other direction? In this case, you will be more interested in `Simple Data Client.vi`. We will explore `Simple Data Client.vi` next.

OPERATION OF SIMPLE DATA CLIENT.VI

In this tutorial you will read data from a link into LabVIEW. The VI front panel (shown in Figure 24) has three areas. The area in the upper left region is used to provide information related to the link itself, such as its name, its ID number, and the scanning frequency. A second area, directly to the right of the first, is used to display information related to the data currently read from the link. At the top is a specific *Mathematica* Link for LabVIEW control named “MLType”. It reveals the data type of the last data read on the link (as it is defined in the `mathlink.h` file). Below this indicator, are five indicators that are grayed out in the figure. When in use, the indicator that corresponds to the current data type becomes active and displays the current data. The third area at the bottom of the panel is used to display a transcript of the *MathLink* session.



Linkname: lkdc

Link ID: 0

MLType: MLTKERROR

Integer: 0

Real: 0.00

Complex: 0.00 +0.00i

String:

Symbol:

Figure 24. `Simple Data Client.vi` front panel.

Once again, we will initiate the link connection in *Mathematica* to prevent LabVIEW from hanging. Use the following expressions in *Mathematica* to open the link and establish the connection:

In[1]:=

```
link = LinkOpen["lkdc", LinkProtocol->"FileMap", LinkMode->Listen]
```

Out[1]=

```
LinkObject[lkdc, 2, 2]
```

In[2]:=

```
LinkConnect[link]
```

Out[2]=

```
LinkObject[lkdc, 2, 2]
```

Then go to LabVIEW and run `Simple Data Client.vi`. Since the link names match, you should not need to locate the link manually. After you have started the client, the second output should appear. You are now ready to send data to LabVIEW. Once again, this step is particularly easy in *Mathematica*, since the instruction for doing this job is the same regardless of the kind of data you wish to send. If possible, organize your application windows so that you can keep an eye on the VI front panel while you are writing commands in the *Mathematica* notebook. Then, execute the following command:

In[3]:=

```
LinkWrite[link, 123456, True]
```

Now look at the VI front panel to see what has happened. The indicator named “Integer” is now active and displays the number. The “MLType” indicator is now indicating `MLTKINT`, which is the *MathLink* integer type. Try to send more data such as:

In[4]:=

```
LinkWrite[link, 1.23456, False]
```

Since the option to flush the data was set to “False” (the last parameter sent), you will notice that nothing has happened on your VI front panel. Now try to send something like this:

In[5]:=

```
LinkWrite[link, 2.34567, True]
```

With a “True” value for the flush option, notice that your data has now reached the VI client. The data are displayed one after the other in the “Real” indicator. If you miss something, you can make sure that the data actually arrived by inspecting the session transcript.

Now try to send some other kinds of data:

In[6]:=

```
LinkWrite[link, "Hello World", True]
LinkWrite[link, Symbol, True]
LinkWrite[link, 2.5 + 3 I, True]
```

Note that complex numbers are actually sent as functions. This is consistent with their internal representation in *Mathematica*, which you can display with this command:

In[9]:=

```
FullForm[2.5+ 3 I]
```

Out[9]//FullForm=

```
Complex[2.5, 3]
```

Note however that this behavior cannot be generalized for sending any kind of function. To demonstrate, try this:

In[10]:=

```
LinkWrite[link, Sin[x], True]
```

The function was read, but nothing appeared on the VI front panel as a result. It is not identified as a readable data type in this VI. Instead you are notified that something arrived that could not be handled by the data client.

As an interesting experiment, execute this command.

In[11]:=

```
LinkWrite[link, Sin[Pi], True]
```

Can you explain why the VI correctly read this expression? If you are unable to explain this, but are intrigued by this behavior, refer to the sections related to expression evaluation in "The *Mathematica* Book" by Stephen Wolfram.

Finally, you will want to close the link. Type this command and observe the result:

In[12]:=

```
LinkClose[link]
```

Notice the effect this last step has on the VI front panel. Obviously, a problem was detected since an error message is presented. You will also notice the VI stops executing very soon after you acknowledge this error message. We will investigate the reasons for this behavior further in the next section.

SIMPLE DATA CLIENT.VI DIAGRAM

Now let us turn our attention to this VI's diagram. The first step involves initializing the indicators' attributes. This takes place in the sequence structure on the left of Figure 25. In frame 2 of this sequence, the link is opened and connected. When these steps are complete, execution proceeds to the main loop. Here, execution is locked in a link-scanning loop where continuous calls are made to `MLReady`. This loop prevents the VI from hanging by blocking read attempts until the other partner has sent something over the link. When link data is detected, execution proceeds to the next step.

The scanning rate depends on your application. You can use the vertical slide to set a variable scanning rate manually. Each time `MLReady.vi` is executed (i.e., each time the scanning loop is executed), the picture displayed on the `Copyright Notice.vi` front panel is updated. You can visualize the scanning frequency by observing the changes to this picture.

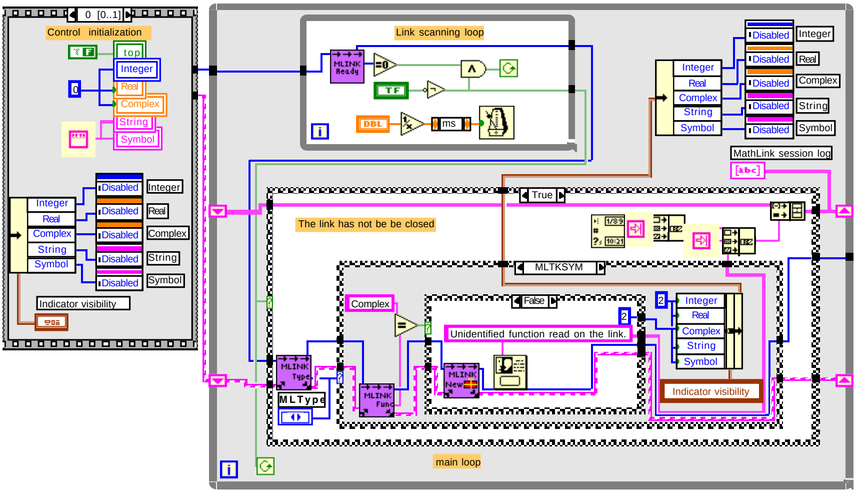


Figure 25. `Simple Data Client.vi` diagram.

When data are received, the scanning loop terminates, and the `MLGetType` instruction is executed. The nature of the data read determines which instruction is called—to be specific, the data type “announced” by `MLGetType`, determines which frame of the case structure is required to read the data. The implementation details for the cases devoted to the common data types such as `MLTKINT`, `MLTKREAL`, `MLTKSYM`, and `MLTKSTR` are somewhat self-evident. However, the `MLTKFUNC` case is a bit more sophisticated. This case can accept only “Complex” as a valid function name. If the function name is “Complex”, then its two arguments are read by `MLGetLongDouble.vi` and collected in a single complex number by the appropriate conversion function. However, if another function was sent, it is necessary to notify the user that an invalid function was returned. Under these circumstances, it is also necessary to discard any remaining packet data.

(See the *MathLink Reference Guide* for more details about packets.) Finally, if the data read was of type MLTKERROR, the VI handles this error and stops execution.

Practical Application Examples

So far, the examples presented have focused on the low-level details of initiating a link connection, or on ready-made communication utilities. While these examples are useful for understanding the underlying structure and the semantics of *Mathematica* Link for LabVIEW, they are somewhat removed from the high-level, real-world applications most users are hoping to build. In this section, we will present a few simple, yet practical, examples of how various components from the package can be applied to real-world data acquisition, analysis, and control system challenges.

Process Monitoring with *MathLink*

Earlier in this chapter, we discovered how to call LabVIEW VIs from inside a *Mathematica* notebook. As you may recall, this involved `MathLink VI Server.vi` on the LabVIEW side, and a custom *Mathematica* package called `VIClient.m.` Unfortunately, the functions provided in the `VIClient.m` package do not permit direct, real-time process monitoring using a remote LabVIEW application. This is because the **CallByReference** and **CallInstrument** functions can only read LabVIEW data after completion of the VI run. However, with modest effort, it is not difficult to customize an existing LabVIEW application to make it capable of passing data to *Mathematica*.

The model we will use to demonstrate the technique is based on `Temperature System Demo.vi`, one of the numerous examples provided with LabVIEW. The original VI can be found in the `apps` directory in `tempsys.llb`. The modified, *MathLink* version of this VI is named `MathLink Temperature.vi`. You can find a copy of this VI in `Tutorial.llb`.

OPERATION OF MATHLINK TEMPERATURE.VI

After opening `MathLink Temperature.vi`, you may notice that its front panel is identical to the original. (The VI's diagram is shown in Figure 26.) To make this demonstration as simple as possible, no option has been provided for setting connection parameters interactively—it will be assumed that you are running *Mathematica* and LabVIEW on the same computer, and that the protocol used is the default local protocol.

Open the link in *Mathematica*.

In[1]:=

```
link = LinkOpen["5678", LinkMode->Listen]
```

Out[1]=

```
LinkObject[5678, 2, 2]
```

In[2]:=

```
LinkConnect[link]
```

Out[2]=

```
LinkObject[5678, 2, 2]
```

In LabVIEW, run `MathLink Temperature.vi`. The connection establishes itself automatically. The function of the VI is to return the most recent temperature history to *Mathematica* upon request.

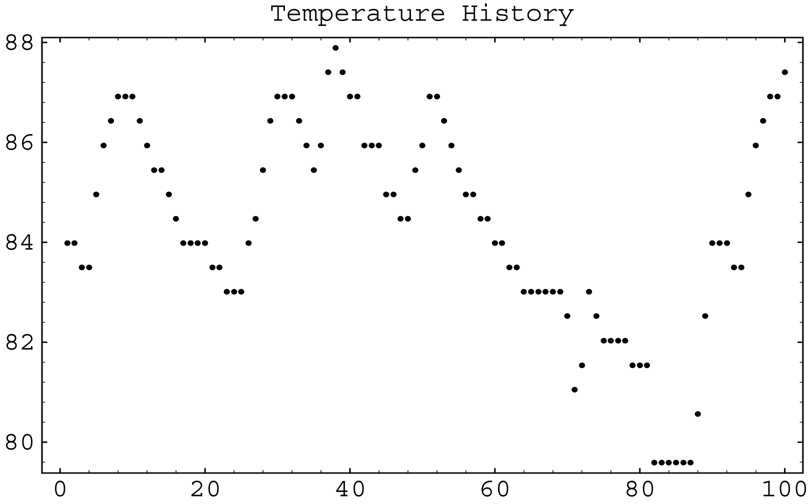
Now, let us define the function used to query LabVIEW for the data. Our query will be composed of three parts: First, it is necessary to send a short message to say that we want the data. Second, we need to read the link. Finally, we want to plot the data. All three objectives can be met like this:

In[3]:=

```
ReadChart[link_] := (LinkWrite[link, "top"];
ListPlot[LinkRead[link],
Frame->True, Axes->False, PlotLabel-
>"TemperatureHistory"])
```

In[4]:=

```
ReadChart[link];
```



The result? Live LabVIEW data (from a continuously running VI) returned to a *Mathematica* notebook on request.

CLOSING THE LINK GRACEFULLY

Before closing the link in *Mathematica,* first stop the data acquisition in LabVIEW by switching off the Acquisition button. This will close the link at the LabVIEW end. Then return to *Mathematica* and close the link there using:

In[5]:=

```
LinkClose[link];
```

MATHLINK TEMPERATURE.VI DIAGRAM

Each time the main loop of `MathLink Temperature.vi` is executed, `MLReady` is called to check whether a data request has been received from *Mathematica*. Since the **ReadChart** function queries the graph by sending the string “top” to the VI, `MLReady` checks whether the string “top” has been written on the link. The decision to use a string to pass the message to LabVIEW is arbitrary since the string is simply read and discarded by `MathLink Temperature.vi` anyway. (Another alternative would be to pass an integer to query the graph.)

Note that because we used this simple mechanism, we do not need to call `MLGetType` or identify the string elsewhere. This tutorial is intended to be as simple as possible, and as a result the VI is not very robust—it could easily be misled if anything other than a string is received. However, even with this simple structure, it works fine.

After the message string “top” is discarded to clear the link, the data buffer can be sent over the link. Then the link is flushed, and any potential errors processed. One common pitfall to avoid in process monitoring applications is attempting to write the data over the link as soon as they are available. Since packets cannot be stacked in large numbers in the link, this practice invariably result in a VI that hangs quickly. It is preferable to create a buffer in the LabVIEW application where data are saved before being sent to *Mathematica*. The recommended practice is to send the contents of this buffer in a single packet over the link when a request is detected.

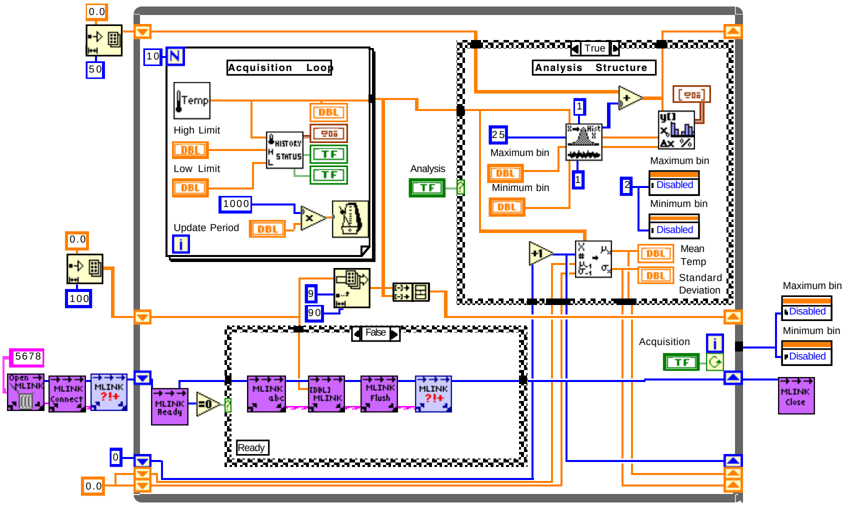
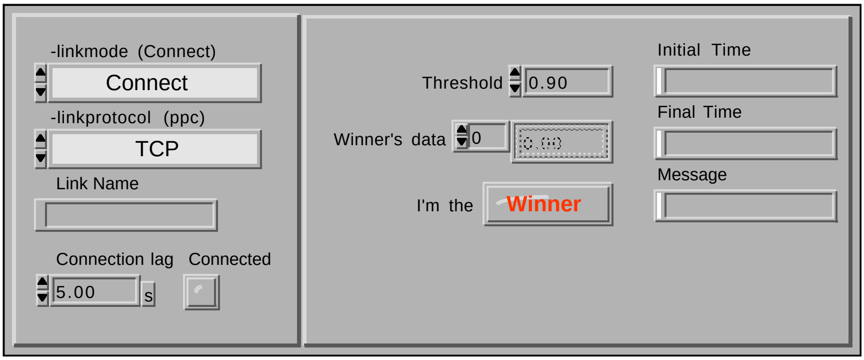


Figure 26. The `MathLink` `Temperature.vi` diagram.

Distributed LabVIEW Applications Based on *MathLink*

In Chapter 1, the notion of using *Mathematica* Link for LabVIEW to distribute LabVIEW applications across several computers was introduced. Admittedly, several robust networking options have been introduced in recent versions of LabVIEW. However, if you are looking for a consistent protocol for all of your LabVIEW and *MathLink* applications, the following example may be of interest to you.



-linkmode (Connect) Connect

-linkprotocol (ppc) TCP

Connection lag 5.00 s

Threshold 0.90

Winner's data 0

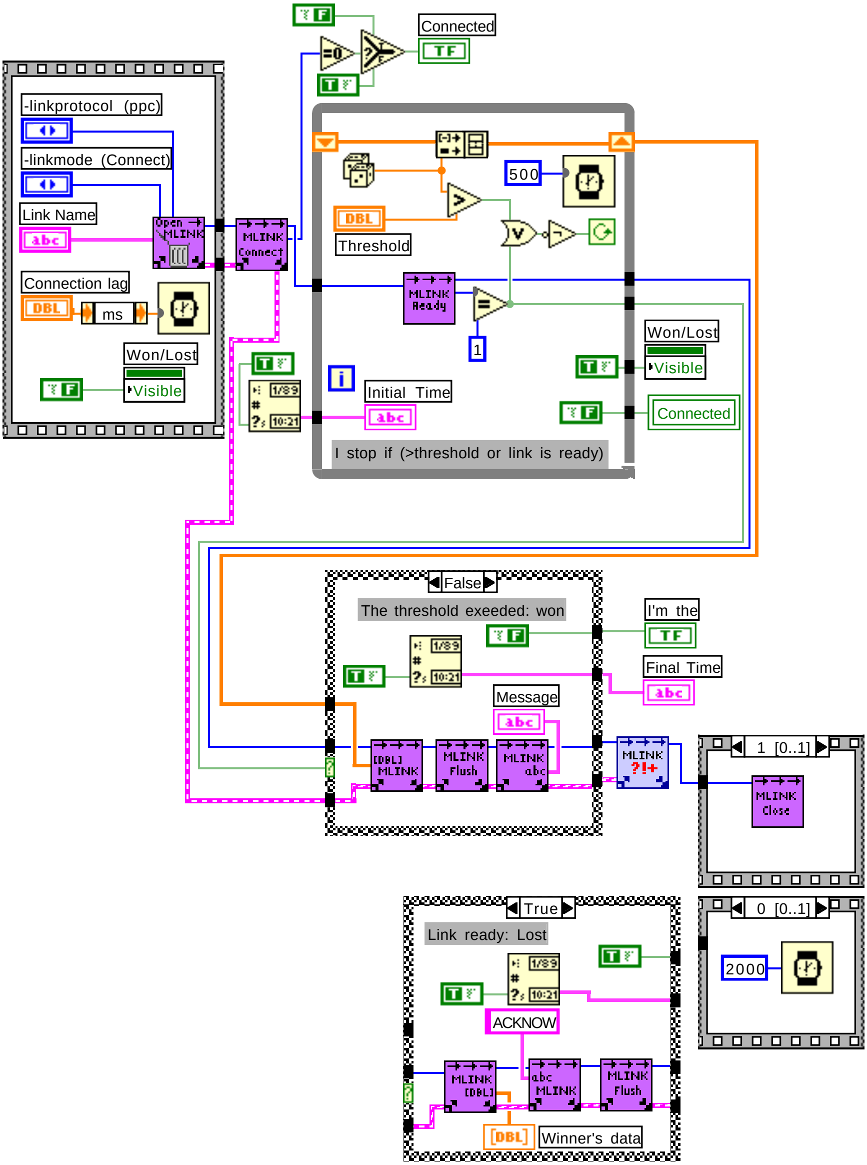
Figure 27. The `Distributed.vi` front panel.

In `Tutorial.llb`, you will find `Distributed.vi`, whose front panel is shown in Figure 27. (For the VI diagram, see Figure 28.) Use a copy of this VI on each of two different computers on which *Mathematica* Link for LabVIEW is installed. (Before proceeding, ensure that your LabVIEW and *Mathematica* Link for LabVIEW licenses allow this.)

The computers should be able to exchange data over a network. Choose consistent link parameters before running the application: both applications must use the same protocol and identical link names. The first application you will run must be in Listen mode, the other must be in Connect mode. Note also that when using the TCP protocol, you must specify the IP address of the host since there is no field corresponding to the **LinkHost** option. To achieve this, use a link name of the form number@IPaddress. (For more details on opening a link, see “Getting Connected” on page 75.) Once both applications are running, the status of the link is indicated by the “Connected” indicator.

After a connection has been established, each partner starts to generate random numbers. The first one to reach a given threshold (set in the “Threshold” control) sends a signal to the other. To make this competition fair, give the same threshold to both partners. The winner will send its data to the loser, which will stop the execution of the application.

Figure 28. The `Distributed.vi` diagram.



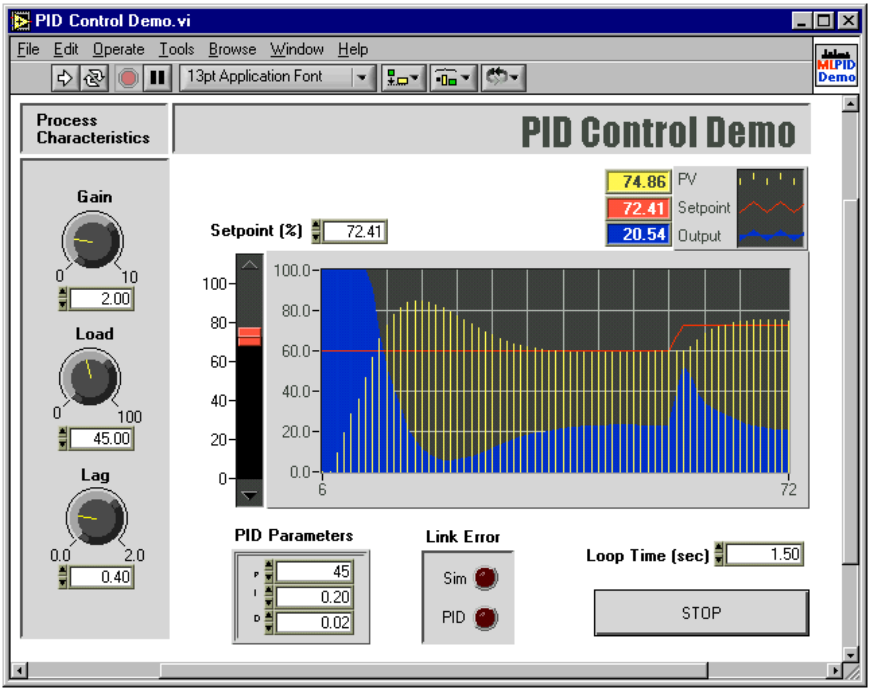
This very simple example illustrates the flexibility of *Mathematica* Link for LabVIEW in developing distributed LabVIEW applications.

Process Simulation and Control Applications Based on *MathLink*

Mathematica Link for LabVIEW offers interesting opportunities for the development and testing of process simulation and control applications. While variable and unpredictable communication intervals limit the run-time practicality of *MathLink* to systems that respond slowly, the combination of advanced *Mathematica* functions, and LabVIEW's RAD (rapid application development) tools makes for a potent simulation and prototyping platform. Ideally, you can take advantage of the combined strengths of *Mathematica* and LabVIEW while designing your system. Then you can use what you have learned to optimize your solution for 100% G, pure *Mathematica*, or LabVIEW RT deployment.

The PID Control Demo included in the `Extras` subdirectory of the `LabVIEW\user.lib\MathLink` folder is a simplified demonstration of this potential. The front panel for this VI is depicted in Figure 29.

The basic equations used for this example were derived from "Process Control Systems" 4th edition, by F. G. Shinskey. All dynamic plant simulation and the PID control calculations are passed to *Mathematica* for evaluation. In this instance, LabVIEW functions primarily as an interactive GUI. The LabVIEW panel tracks changes to process characteristics, as well as setpoint and PID tuning parameter changes. The dynamic effects of these user-initiated changes are reflected in the scrolling process response graph that dominates the panel.



Gain 2.00

Load 45.00

Lag 0.40

Setpoint (%) 72.41

74.86 PV

72.41 Setpoint

20.54 Output

PID Parameters

P 45

I 0.20

D 0.02

Loop Time (sec) 1.50

Figure 29. The `PID Control Demo.vi` front panel.

OPERATION OF THE PID CONTROL DEMO.VI

Open the `PID Control Demo.vi` from the LabVIEW Tools menu. Run the VI and observe the graph as the output is manipulated to bring the process variable up to the `Setpoint(%)` value. Experiment with different setpoints, then try changing the `Process Characteristics` on the left, and the `PID Parameters` on the bottom of the panel. When you are finished experimenting, press `Stop` in the lower right corner.

Since *Mathematica* must process both the simulation and control calculations on each loop iteration, there is a limit to how quickly the control loop can run. If you find that you are encountering *MathLink* errors—as revealed by the Link Error indicators on the panel—simply increase the `Loop Time (sec)` parameter.

PID CONTROL DEMO.VI DIAGRAM

The `PID Control Demo.vi` block diagram (see Figure 30) is based on a state machine structure. `Kernel Evaluation.vi` (introduced previously in Chapter 3) is responsible for all *MathLink* transactions. In the PID processing case of the state machine (the “Call PID” case depicted in the figure), an updated process variable (PV) value is read from an “encapsulated data VI” (or “LV2-style global”, as this structure is popularly called). This PV value is then passed to the PID subVI, and on to the graph. The PID subVI combines this updated PV value with the front-panel `Setpoint` and `PID Parameter` settings. Using these values, a *Mathematica* command string is constructed, and sent to *Mathematica* for evaluation. The output from the PID subVI is plotted on the graph, and assuming no *MathLink* error has occurred, the `Update Sim` case of the state machine is called next. The `Update Sim` case uses methods similar to those outlined above to construct a second *Mathematica* command string. This second string is used by *Mathematica* to calculate a new PV value in preparation for the next “Call PID” cycle.

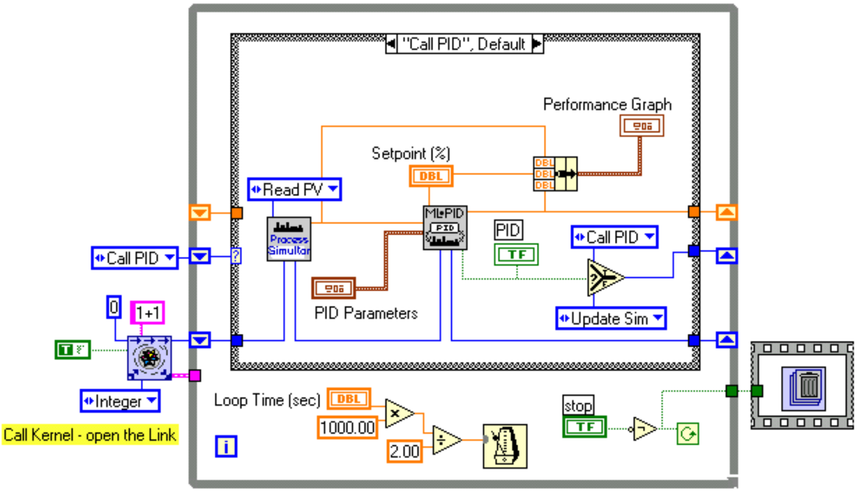


Figure 30. The `PID Control Demo.vi` diagram.

When the VI is operating as intended, the `Call PID` and the `Update Sim` cases are called in a regular, alternating sequence. However, if a *MathLink* error is detected in either case of the state machine, the same case is repeated to prevent erroneous data from destabilizing the controller. While this automatic error recovery mechanism is adequate for spurious errors, a series of consecutive errors will adversely affect the integrity of the controller. If MathLink errors are degrading performance, try increasing the value of `Loop Time (sec)` until errors are no longer detected. (Informal testing suggests the default setting of 1.5 seconds should be more than adequate for the majority of PCs.)

Admittedly, this is a very simple example. Mathematically speaking, there is nothing here that couldn't be implemented directly with native LabVIEW formula nodes. However, one advantage of processing the calculations using *MathLink* functions rather than LabVIEW formula nodes is that you have the option of modifying the equations interactively at run-time. This offers a greater degree of interactivity than standard formula node methods, which require you to stop the VI in order to edit the contents of the node.

This simple example suggest opportunities for more sophisticated simulation and control strategies, and many interesting variations could be explored simply by extending this basic framework. Furthermore, advanced *Mathematica* library functions and add-on packages can be introduced into the LabVIEW workflow. Using this basic framework, you can readily experiment mathematically sophisticated simulation and control strategies that lie beyond LabVIEW's inherent mathematical capabilities.

Advanced Topics and Examples

By now it should be clear that *Mathematica* Link for LabVIEW is a flexible package that offers many different ways to build hybrid applications based on *Mathematica*, LabVIEW, and *MathLink*. In fact, it is usually possible to develop a variety of different solutions for the same application challenge. For example, one possible solution might use a LabVIEW GUI and send a computation to the *Mathematica* kernel using `Kernel Evaluation.vi` as demonstrated by `GoodPrimeQ.vi` and the `PID Control Demo.vi`. Another implementation could use a *Mathematica* notebook as an alternative interface to instruments operated through `MathLink VI Server.vi`. This implementation would be similar to the `Echo Detector` example presented in "The CallInstrument Function and Related Functions" on page 56. A third implementation could be derived from the method used to interact with `MathLink Temperature.vi`. It might even use customized *MathLink* transactions to enhance the data transfer rate. Depending on your application, several other implementations might also be possible, however it is important to realize that the implementation strategy you choose will determine the mode of user interaction, the performance level, the development cost, and to some extent, the type and accuracy of the data collected. In order to make the best use of *Mathematica* Link for LabVIEW it is necessary to examine more complex examples than those used previously to illustrate the basics of *MathLink* programming.

Unfortunately, LabVIEW and *Mathematica* users are a diverse group of individuals. Each scientific discipline uses its own hardware, signal sources, and mathematical methods. Therefore it is extremely difficult to present advanced examples that offer an adequate degree of detail while remaining comprehensible to all. Still, it is presumed that the majority of *Mathematica* Link for LabVIEW users will be pursuing advanced topics, so the following examples have been included in an attempt to reveal the possibilities. It is hoped these examples will be easy to understand and accessible to the largest possible audience while still providing an adequate level of technical detail.

The following advanced application examples capitalize more fully on the combined strengths of *Mathematica* and LabVIEW. We will introduce these examples only briefly in this text—for a more in-depth examination, you are directed to the programming examples and electronic documentation found in your LabVIEW file system in the `\user.lib\MathLink\Extra\Advanced` folder. Hopefully, the ideas and techniques introduced by these examples will serve as a useful primer for your own advanced *MathLink* explorations.

Case Study: Development of a Complex Application Using *Mathematica* Link for LabVIEW

Combining micromagnetic and microtopographic observations of a thin magnetic film into a single graphic display

In the opening chapter, *Mathematica* Link for LabVIEW was cast as the central player in a hybrid, exploratory workflow. This example graphically illustrates the power of this concept. In this exercise, we will follow a typical *Mathematica* Link for LabVIEW workflow while developing a complex hybrid application. The tutorial material provided for this example is designed to guide you through the steps taken by Leon Abelmann, Steffen Porthum, and Thijs Bolhuis from the Information Storage Technology Group of the MESA Research Institute at the University of Twente (The Netherlands). The tutorial recreates the workflow used by these intrepid researchers as they developed this real-world *Mathematica* Link for LabVIEW application.

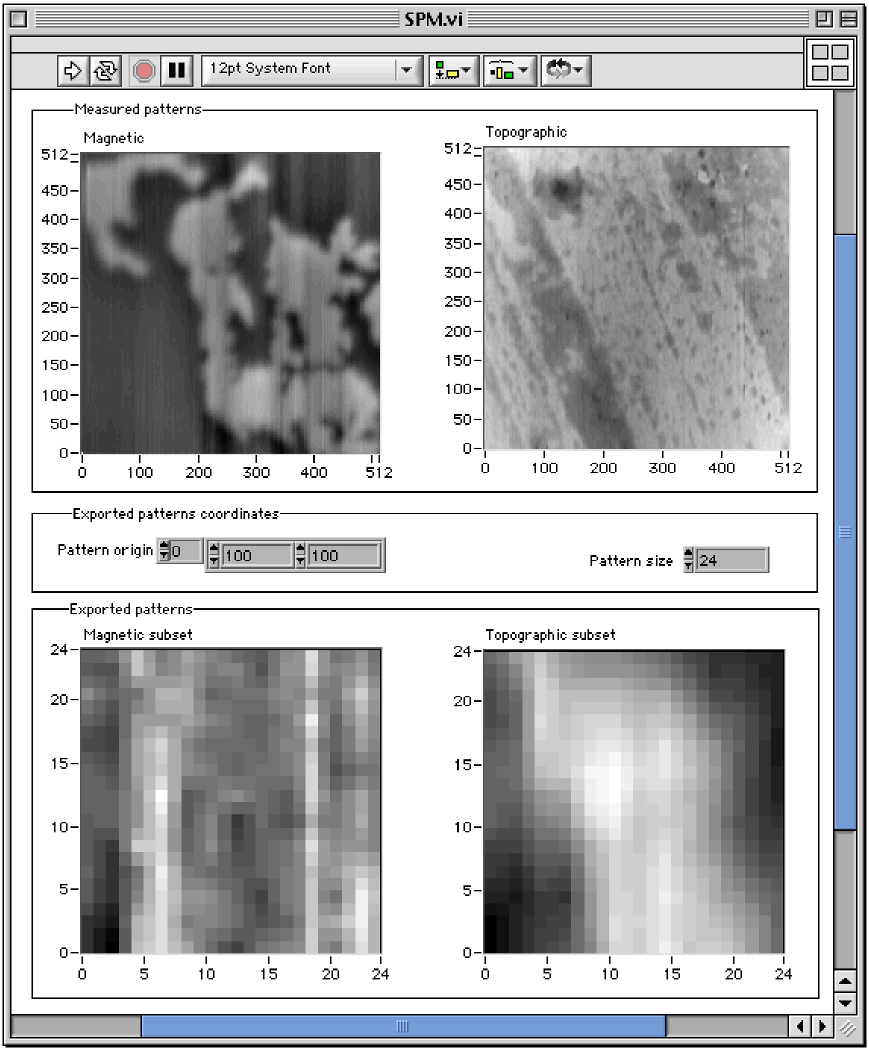
OVERVIEW

A thin magnetic film is observed with a scanning probe microscope. A LabVIEW application called `SPM.vi` (see Figure 31) is used to acquire both topographic and magnetic patterns of a region under inspection. The topographic/magnetic separation is achieved with the microscope using a two step process—that is, each line in the raster scan pattern is passed over twice. On the first pass, topographical information is recorded. Magnetic force data is acquired during a second pass, for which the tip is raised to a user-selected "lift height." The lift height (typically 20-200 nm) is added point-by-point to the stored topographical data, thus keeping the tip-sample separation constant and preventing the tip from interacting with the surface. These two-pass measurements are taken for every scan line to produce separate topographic and magnetic force images of the same area. Within a LabVIEW application, *Mathematica* is called to generate a custom 3D plot where the magnetic pattern is superimposed over the topographic data.

HANDS-ON TUTORIAL

The hands-on tutorial included in the `Complex` subdirectory of the `user.lib\MathLink\Extra\Advanced` folder will guide you through the process of building this application for yourself. The tutorial is divided in two main sections. First, you will operate the `SPM.vi` from within *Mathematica* using the `MathLink VI Server.vi`. Later, you will build a sophisticated LabVIEW application that calls the *Mathematica* kernel to produce the custom graphics that are the final objective of the tutorial. Each section is divided into exercises designed to approximate the different steps required to build a real application. It is thus highly recommended that you complete the exercises in the prescribed order. For more information, and to get started on this tutorial, begin by opening `Advanced Tutorial.nb`. You will find this notebook along with the other components for this exercise in the LabVIEW`\user.lib\MathLink\Extra\Advanced\Complex` folder.

Figure 31. `SPM.vi` front panel



Pattern origin 0 100 100

Pattern size 24

Mobile Robotic Experiments

The examples described next were developed for a small mobile robot named **Khepera** (see Figure 32). **Khepera** has sensors and actuators, and can be operated via a standard computer serial port. Therefore, it has many features in common with instruments used in other fields, and serves as an adequate model for experimentation. The goal of the example applications is to specify a target trajectory for the robot, and then to analyze the actual trajectory traveled from the data collected.

The mobile robot Khepera is not part of *Mathematica* Link for LabVIEW.

Before we get started, it is important to note that the **Khepera** LabVIEW driver (used as a subVI in the supplied examples) is not included with *Mathematica* Link for LabVIEW. Therefore, you will not be able to run and interact with the examples unless you have a **Khepera** robot. **Khepera** and its LabVIEW driver are commercially available from K-Team S.A. For additional information please consult the Appendix on page 209.

With the exception of the proprietary **Khepera** driver VIs, and the robot itself, all other material pertaining to the demonstrations (VIs, packages, and documenting notebooks) can be found in the `Khepera` subdirectory of the `\user.lib\MathLink\Extra\Advanced` folder, which can be found inside your main LabVIEW folder . To continue with supplied exercises, locate and open the Khepera.pdf document in the `Khepera` subdirectory.

This concludes the formal discussions of the programming examples included with *Mathematica* Link for LabVIEW. The next chapter will look more closely at the individual VIs included in the package.

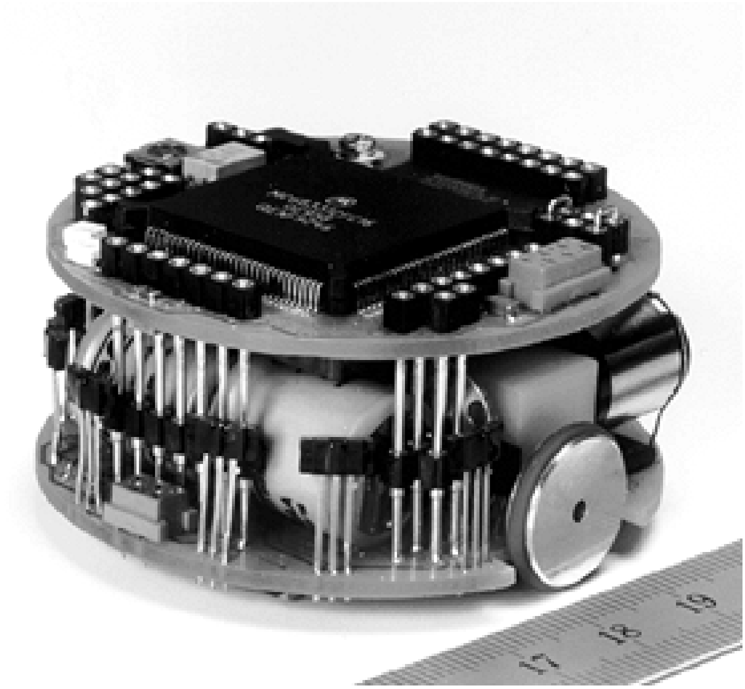


Figure 32. The Khepera robot

5 Reference Guide

This chapter provides in-depth reference material for *Mathematica* Link for LabVIEW developers. Each and every component subVI—that is, all the library VIs found in the `dev` subdirectory of the `LabVIEW\user.lib\MathLink` directory, plus all of the `MLStart.llb` VIs—are documented in a style consistent with the LabVIEW reference manuals. Different sections correspond to the different libraries. In addition, the final section of this chapter documents the `VIClient.m` package is some detail.

Most VIs of the distribution have a common set of controls and indicators. Since it would be redundant to reproduce the description of these common objects wherever they appear, these common items will be discussed first.

As already mentioned (page 67), all VIs used to conduct *MathLink* operations have a "Link in" control to receive the link ID number . This number identifies the link over which all data transactions will be performed. There is also a "Link out" indicator, which always has the same value as "Link in". This indicator can be used to create artificial data dependencies that control the execution sequence of the VI diagram. (Refer to the LabVIEW documentation for more information about controlling data flow through artificial data dependency.) Most *MathLink* functions return an integer value indicating the error status of the operation: nonzero values indicate that everything was OK. This value is returned, when applicable, in a dedicated indicator named "Value". (Consult "**The *Mathematica* Book**" and "**The *MathLink* Reference Guide**" for more details about *MathLink* error codes.) Finally, as noted on page 68, *Mathematica* Link for LabVIEW conforms to the classical LabVIEW error management conventions. VIs have "error in" and "error out" clusters that are used to report errors to the error handler VI. These clusters are standard front panel objects, and can be accessed through the Arrays and Clusters submenu of the default view.

Next we will look at descriptions for these common elements. Keep in mind that these items will not be repeated for each VI in which they appear. Consult LabVIEW's on line documentation for a complete description of the "error in" and "error out" clusters if you are unfamiliar with their usage.

I16 **Link in**
Link identifier.

I16 **Value**
A nonzero value indicates that no error occurred.

I16 **Link out**
The link over which the function name was received (same as the input link). This is used to create data dependency between MathLink VIs.

Mathematica Link for LabVIEW VIs can all be accessed with custom palettes and views. The top level palettes are represented in Figure 33 and Figure 34.

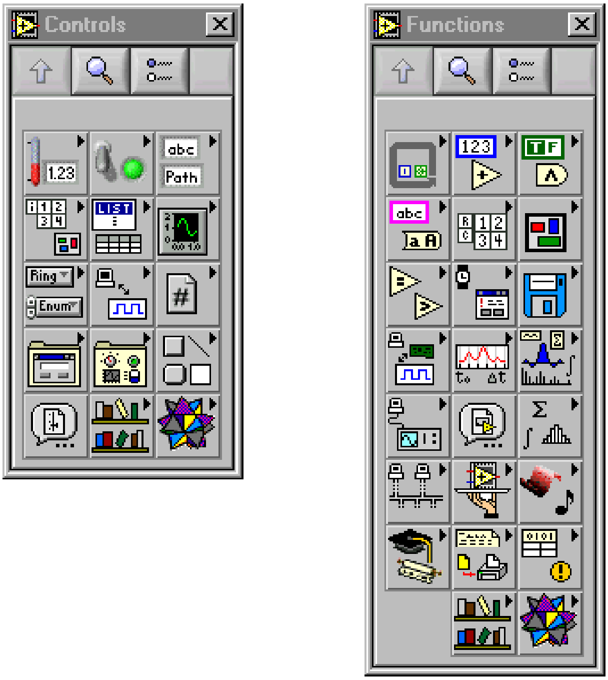


Figure 33. The control and function palettes of the *MathLink* view.

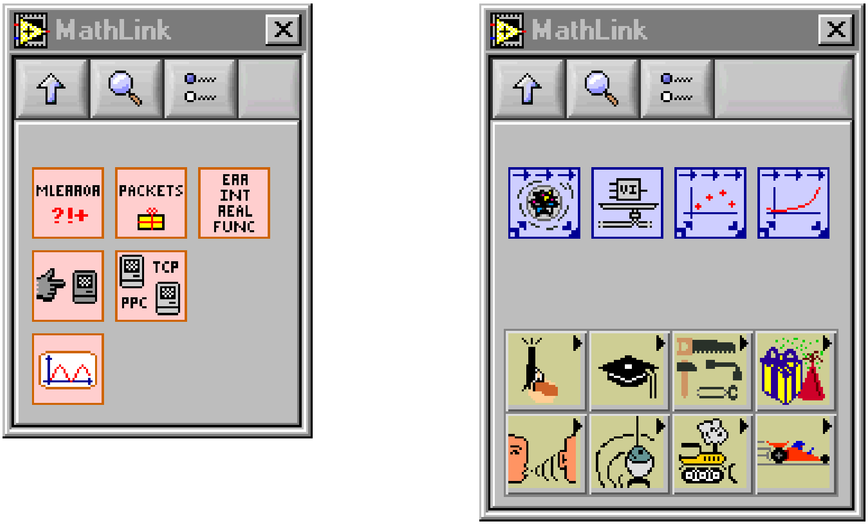
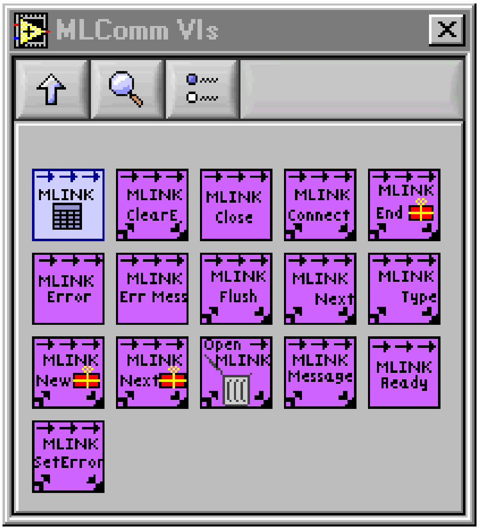


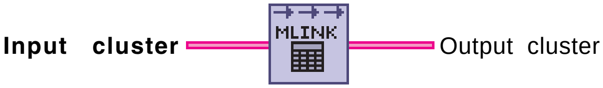
Figure 34. *Mathematica* Link for LabVIEW main control and function palettes.

MLComm.llb



VIs

MathLinkCIN.vi



MathLinkCIN.vi

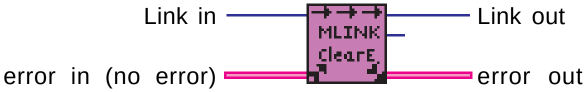
MathLinkCIN.vi is the interface to the C code. This VI is not intended to be used directly.

This VI is the only one of the distribution containing a CIN.
The input and output clusters have the same structure. They provide all possible kinds of data to be used by MathLink functions as arguments or returned by these functions. The only argument specific to this VI is the MLFunction name, which is used by the CIN to properly read all its arguments.

Warning:
Integers of any type are passed in the long integer field.

See “InputClusterTemplate.ctl” and “OutputClusterTemplate.ctl” on page 134 for a description of the input and output clusters.

MLClear Error.vi

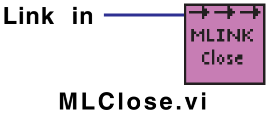


MLClearError.vi

MLClearError.vi clears any error on the "Link in" and reactivates the link, if possible.

This function can be used at the end of a complicated operation. If an error is detected, you can proceed to corrective action if possible and then call MLClearError.vi to activate the link again.

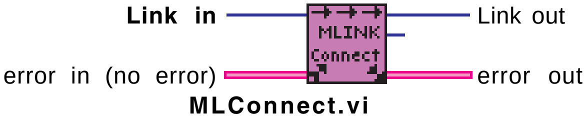
MLClose.vi



MLClose.vi closes a MathLink connection.

A program must close all links that it has opened before terminating. When MLClose.vi is called, any buffered outgoing data are flushed, that is, sent to the other partner (if its end of the link is still open).

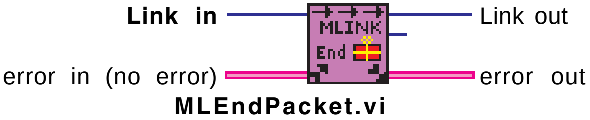
MLConnect.vi



MLConnect.vi is used to connect each side of a link together.

After a link is opened by both sides, the connection is not yet established. There are two ways to make this connection. You can write something on the link and read it from the other side. This action will connect both partners if they have not been connected yet. Or you can use MLConnect without transmitting anything on the link. This solution is preferable when the first emitting partner is not predictable.

MLEndPacket.vi

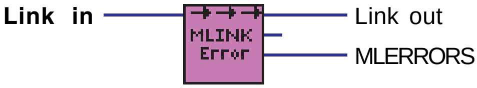


MLEndPacket.vi marks the end of an expression sent to "Link in".

Once all the pieces of a packet have been sent using MLPutFunction.vi, MathLink requires you to call MLEndPacket.vi to ensure synchronization and consistency.

Warning:
MLEndPacket.vi does not actually send the expression on the link. You still need to flush the link before the link is read by the other partner.

MLError.vi



MLError.vi

MLError.vi returns an integer code identifying the most recent MathLink error that occurred on "Link in".

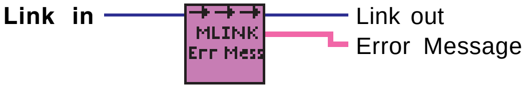
The description of the different types of errors can be found in the mathlink.h file of your MathLink developer kit. If no error has occurred on the link, then MLError.vi returns zero (MLEOK).

Use MLErrorMessage.vi to get a detailed description of the error, and use MLClearError.vi to clear the link when possible.

I32 **Error**
A nonzero value indicates that no error occurred.

◀▶ **MLERRORS**
MathLink error types as they are defined in the mathlink.h

MLErrorMessage.vi



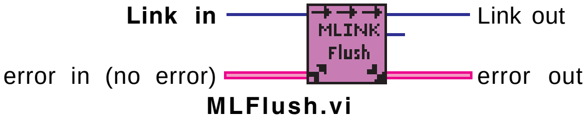
MLErrorMessage.vi

MLErrorMessage.vi returns a text string describing the most recent error that occurred on "Link in".

Warning:
Error messages displayed by the MathLink Error Manager.vi are coded in the MLConstant.gbl global variable. They should however match one another.

abc **Error Message**
The description of the error as it is reported in the mathlink.h file.

MLFlush.vi

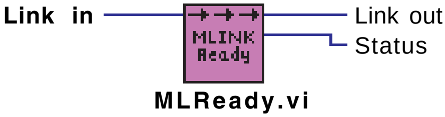


MLFlush.vi immediately transmits any data buffered for sending over the connection.

MathLink usually buffers the data before they are written on the link. To make sure that all necessary data have been sent and are thus available to the other partner, it is necessary to call MLFlush.vi. Only after doing this does it make sense to call MLReady.vi and wait for the data to be returned by the other side of the link.

Warning:
MLFlush.vi should not be confused with MLEndPacket.vi which is related to the expression structure. MLFlush.vi is a buffer management function: it has nothing to do with expression or data structures.

MLReady.vi

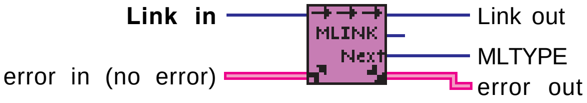


MLReady.vi tests whether there are data ready to be read from "Link in".

It is analogous to the Mathematica function LinkReadyQ. It is often called in a loop as a way of polling a MathLink connection. It will always return immediately and will not block.

I16 **Status**
This indicator is zero when no data is available for reading. A nonzero value indicates that data are ready to be read.

MLGetNext.vi



MLGetNext.vi

MLGetNext.vi returns the type of the next element in the expression currently being read from "Link in".

The "next" element always means an element that has not yet been examined by any MathLink get call. If the preceding element has been examined, but not completely read, it will be discarded.

Warnings:
1. To check the type of a partially read element without advancing to the following element, call MLGetType.vi.

2. The integer type code is returned on both the long integer field and the value field of the output cluster. The value can still be used for error checking since MLTKERROR = 0. The long integer is converted into a defined type by MLType Ident.vi.

I16 **Type code**

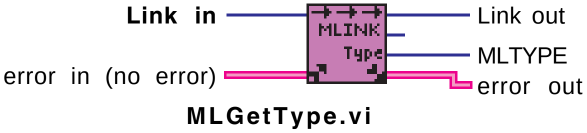
These are the valid type codes:

0	MLTKERROR
89	MLTKSYM
83	MLTKSTR
73	MLTKINT
82	MLTKREAL
70	MLTKFUNC

MLTYPE

These are the MathLink data types:
MLTKSTR Mathematica string
MLTKSYM Mathematica symbol
MLTKINT integer
MLTKREAL real number
MLTKFUNC composite expression
MLTKERROR error getting type

MLGetType.vi



MLGetType.vi returns the type of the current element in the MathLink data stream.

The difference between MLGetType.vi and MLGetNext.vi is that MLGetNext.vi always looks ahead to a fresh data element, that is, one that has not been examined by any get call. MLGetType.vi will stay at the data element that was last accessed, if it was not read completely. Therefore, MLGetType.vi can be called several times for the same element.

Warnings
1. To check the type of the next element in the current data stream, call MLGetNext.vi.

2. The integer type code is returned on both the long integer field and the value field of the output cluster. The value can still be used for error checking since MLTKERROR = 0. The long integer is converted into a defined type by MLType Ident.vi.

I16

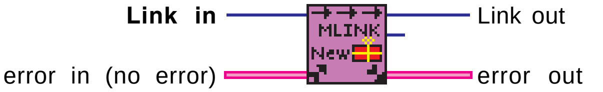
Type code
These are the valid type codes:

0	MLTKERROR
89	MLTKSYM
83	MLTKSTR
73	MLTKINT
82	MLTKREAL
70	MLTKFUNC

◂▸

MLTYPE
These are the MathLink data types:
MLTKSTR Mathematica string
MLTKSYM Mathematica symbol
MLTKINT integer
MLTKREAL real number
MLTKFUNC composite expression
MLTKERROR error getting type

MLNewPacket.vi

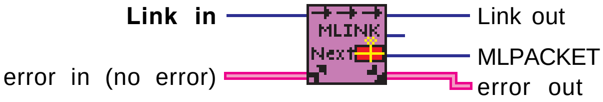


MLNewPacket.vi

MLNewPacket.vi discards the remaining data in the expression currently being read from "Link in".

MLNewPacket.vi works even if the head of the current top-level expression is not a standard packet type. MLNewPacket.vi does nothing if you are already at the end of a packet.

MLNextPacket.vi



MLNextPacket.vi

MLNextPacket.vi reads the head of the expression currently waiting to be read form "Link in".

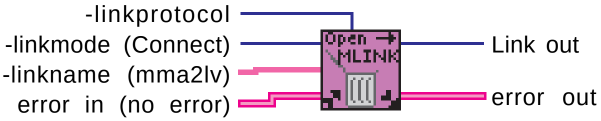
It returns an integer code corresponding to the packet type. See the MathLink.h file for the definition of the integer codes. If the head of the current expression does not match any of the defined packet types, MLNextPacket.vi returns zero.

Warning:
The integer packet code is returned simultaneously on the "Value" and the "long integer" elements of the CIN output cluster. It is read on "Value" for error checking and the value returned on "long integer" is converted into a packet type by MLPacket Ident.vi.

I16 **Packet code**
The integer code of the packet type. Zero is returned when the packet head is not defined.

MLPACKET
The packet types are defined in the mathlink.h file. The most common packets are these:
INPUTPKT input packet
RETURNPKT return packet
MESSAGEPKT message packet
INPUTNAMEPKT input name packet
OUTPUTNAMEPKT output name packet

MLOpen.vi



MLOpen.vi

MLOpen.vi opens a MathLink connection.

MLOpen.vi returns an integer that is used subsequently to identify the link. Zero is returned if an error occurred.

Warning:
This function does not have any value other than the "Link out" indicator. This is the value that is used to check for possible errors.

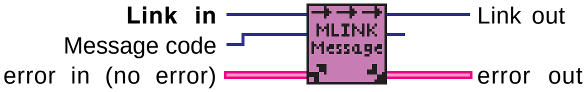
◀▶ **-linkmode (Connect)**
The connection mode.

◀▶ **-linkprotocol**
Data transport mechanism.

abc **-linkname (mma2lv)**
Name of communication partner (a command line or port

I16 **Link out**
The number used to identify the link created by MLOpen.vi.

MLPutMessage.vi



MLPutMessage.vi

MLPutMessage.vi sends a request to Mathematica to interrupt the current calculation.

The nature of the interrupt request is a MathLink implementation which varies from version to version. See the mathlink.h file for details.

I32 **Message code**
The MLInterruptMessage constant. See the mathlink.h file for details.

Controls

InputClusterTemplate.ctl

InputClusterTemplate.ctl

InputClusterTemplate.ctl is a type definition used by all the VIs of the MathLink libraries to send data on the link.

InputClusterTemplate.ctl is a control cluster containing every kind of data that can be sent on a link. This control is used by MathLinkCIN.vi and by all other VIs implementing MathLink functions. Note however that it is hidden from the front panel of all VIs except MathLinkCIN.vi.

Warning:
Integers are transmitted through the long integer field.

Input cluster
In this cluster are collected all possible kinds of data that can be communicated to the CIN. Not all are used together. For a given MLFunction call only a limited set of data is used. The other variables are passed but not used.

abc **MLFunction**
The name of the MathLink function called.

I16 **Link in**
The link identifier.

I16 **Value**
Not used as input.

abc **string**
The field used to send strings.

I32 **long integer**
The field used to send integers and long integers.

DBL **double**
The field used to send doubles.

EXT **long double**
The field used to send long doubles.

[I16] **integer list**
The field used to send lists of integers.

[I32] **long integer list**
The field used to send lists of long integers.

[DBL] **double list**
The field used to send lists of doubles.

[EXT] **long double list**
The field used to send lists of long doubles.

OutputClusterTemplate.ctl

Output

OutputClusterTemplate.ctl

OutputClusterTemplate.ctl is a type definition used by all the VIs of the MathLink librairies to collect data from the link.

OutputClusterTemplate.ctl is an indicator cluster containing every kind of data that can be received from a link. This indicator is used by MathLinkCIN.vi and by all other VIs implementing MathLink functions. Note, however, that it is hidden from the front panel of all VIs except MathLinkCIN.vi.

Warning:
Integers are transmitted through the long integer field.

Output cluster
In this cluster are collected all possible kinds of data that can be communicated to the CIN. Not all are used together. For a given MLFunction call, only a limited set of data is used. The other variables are passed but not used.

abc **MLFunction**
The name of the MathLink function called.

I16 **Link out**
The link identifier.

I16 **Value**
The integer value returned by the function.

abc **string**
The field used to read strings.

I32 **long integer**
The field used to read integers of any format.

DBL **double**
The field used to read doubles.

EXT **long double**
The field used to read long doubles.

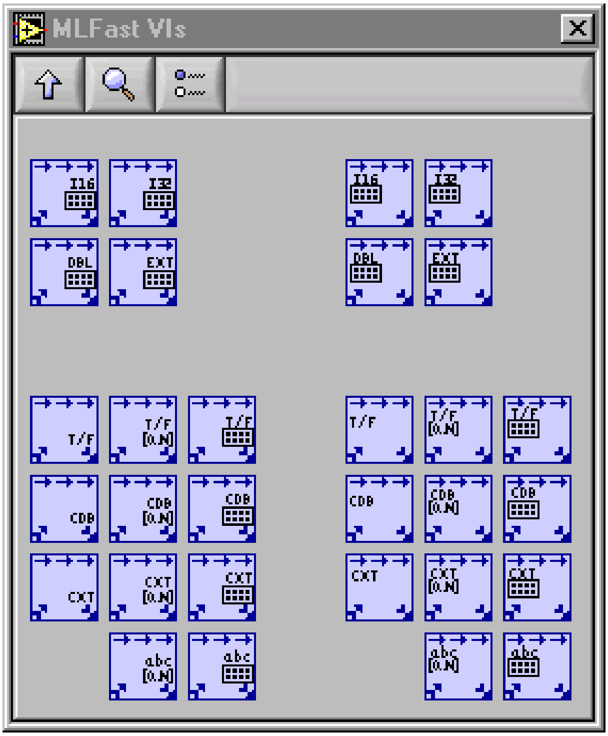
[I16] **integer list**
The field used to read lists of integers.

[I32] **long integer list**
The field used to read lists of long integers.

[DBL] **double list**
The field used to read lists of doubles.

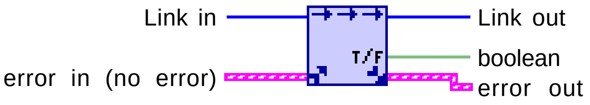
[EXT] **long double list**
The field used to read lists of long doubles.

MLFast.llb



VIs

GetBoolean.vi



GetBoolean.vi

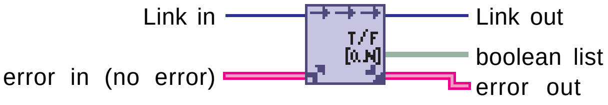
This VI reads a boolean on the link.

The result of MLGetSymbol.vi is compared to "True" and the result is displayed in the boolean indicator.

Warning:
If a symbol which other than "True" or "False" is read from the link, "False" is returned. You have to make sure that "True" and "False" are the only possible symbols sent over the link before calling GetBoolean.vi.

TF **boolean**
The boolean read on the link.

GetBooleanList.vi



GetBooleanList.vi

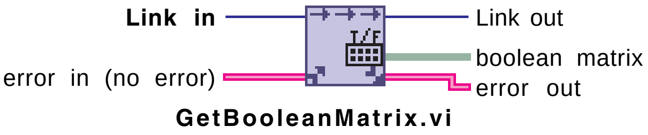
This VI reads a list of booleans from the link.

Since there are no MathLink functions for transferring arrays of Booleans, the list is read as a function, List[elem 1, elem 2, ..., elem n]. In a "For" loop, the result of MLGetSymbol.vi is compared to "True" and the result is displayed in the boolean indicator.

Warnings:
1. If a symbol other than "True" or "False" is read from the link, "False" is returned. You have to make sure that "True" and "False" are the only possible symbols sent over the link before calling GetBooleanList.vi.
2. Due to the structure of this VI, its performance is limited. If you need to send a large number of booleans, you should probably try to send them in a numerical format and convert them in LabVIEW later.

[TF] **boolean list**
The list of booleans read from the link.

GetBooleanMatrix.vi



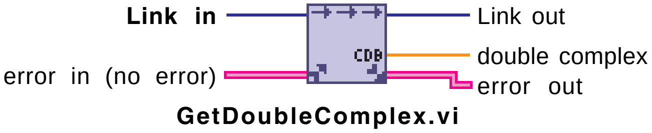
GetBooleanMatrix.vi reads a matrix of booleans from the link.

Since there are no MathLink functions for transferring arrays of booleans, the matrix is read as a compound Mathematica expression, List[List[elem 1, elem 2, ..., elem n], ...]. In two nested "For" loops, the result of MLGetSymbol.vi is compared to "True", and the result is displayed in the boolean indicator.

Warnings:
1. If a symbol other than "True" or "False" is read from the link, "False" is returned. You have to make sure that "True" and "False" are the only possible symbols sent over the link before calling GetBooleanMatrix.vi.
2. Due to the structure of this VI, its performance is limited. If you need to send a large number of booleans, you should probably try to send them in a numerical format and convert them in LabVIEW later.

[TF] **boolean matrix**
The matrix of booleans read from the link.

GetDoubleComplex.vi



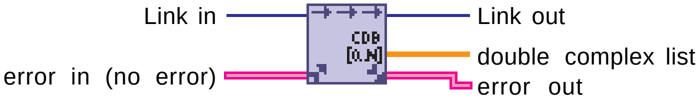
GetDoubleComplex.vi reads a complex number from the link.

This VI is based on MLGetDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a complex number data structure, it is your responsibility to ensure that the array will fit the data structure when using this VI. Inconsistent incoming data read by this VI lead to an MLEGSEQ MathLink error.

CDB **double complex**
The complex number read from the link.

GetDoubleComplexList.vi



GetDoubleComplexList.vi

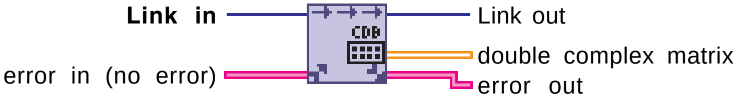
GetDoubleComplexList.vi reads a list of complex numbers from the link.

This VI is based on MLGetDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a list-of-complex-numbers data structure, it is your responsibility to ensure that the array fits this data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[CDB] **double complex list**
The list of double complex numbers read from the link.

GetDoubleComplexMatrix.vi



GetDoubleComplexMatrix.vi

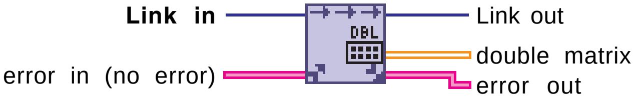
GetDoubleComplexMatrix.vi reads a matrix of complex numbers from the link.

This VI is based on MLGetDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a matrix-of-complex-numbers data structure, it is your responsibility to ensure that the array fits this data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[CDB] **double complex matrix**
The matrix of complex numbers read from the link.

GetDoubleMatrix.vi



GetDoubleMatrix.vi

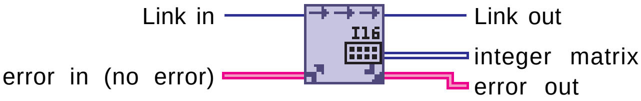
GetDoubleMatrix.vi reads a matrix of double precision numbers from the link.

This VI is based on MLGetDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a matrix-of-real-numbers data structure, it is your responsibility to ensure that the array fits the data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[DBL] **double matrix**
The matrix of double precision numbers read from the link.

GetIntegerMatrix.vi



GetIntegerMatrix.vi

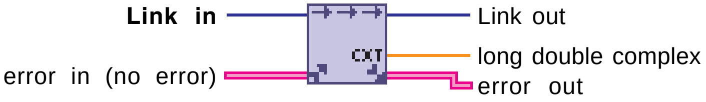
GetIntegerMatrix.vi reads a matrix of integers from the link.

This VI is based on MLGetIntegerArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a matrix-of-integers data structure, it is your responsibility to ensure that the array fits the data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[I16] **integer matrix**
The matrix of integers read from the link.

GetLongDoubleComplex.vi



GetLongDoubleComplex.vi

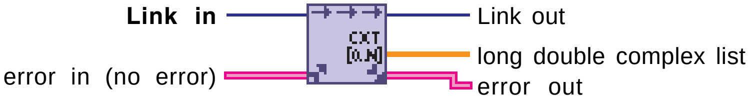
GetLongDoubleComplex.vi reads a complex number from the link.

This VI is based on MLGetLongDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a complex number data structure, it is your responsibility to ensure that the array fits the data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

CXT **long double complex**
The complex number read from the link.

GetLongDoubleComplexList.vi



GetLongDoubleComplexList.vi

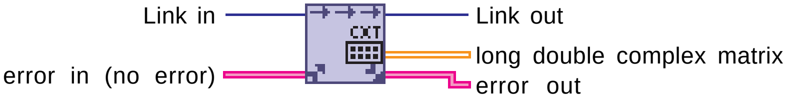
GetLongDoubleComplexList.vi reads a list of complex numbers from the link.

This VI is based on MLGetLongDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a list-of-complex-numbers data structure, it is your responsibility to ensure that the array fits the data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[CXT] **long double complex list**
The list of complex numbers read from the link.

GetLongDoubleComplexMatrix.vi



GetLongDoubleComplexMatrix.vi

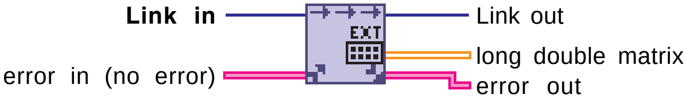
GetLongDoubleComplexMatrix.vi reads a matrix of complex numbers from the link.

This VI is based on MLGetLongDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a matrix-of-complex-numbers data structure, it is your responsibility to ensure that the array fits the data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[CXT] **long double complex matrix**
The matrix of complex numbers read from the link.

GetLongDoubleMatrix.vi



GetLongDoubleMatrix.vi

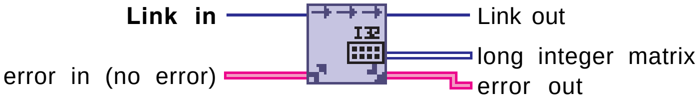
GetLongDoubleMatrix.vi reads a matrix of extended precision numbers from the link.

This VI is based on MLGetLongDoubleArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a matrix-of-real-numbers data structure, it is your responsibility to ensure that the array fits the data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[EXT] **long double matrix**
The matrix of extended precision numbers read from the link.

GetLongIntegerMatrix.vi



GetLongIntegerMatrix.vi

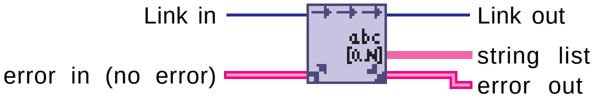
GetLongIntegerMatrix.vi reads a matrix of integers from the link.

This VI is based on MLGetLongIntegerArray.vi.

Warning:
Since there is no MathLink function to verify that the incoming array fits a matrix-of-integers data structure, it is your responsibility to ensure that the array fits the data structure when using this VI. Inconsistent incoming data read by this VI can lead to a MLEGSEQ MathLink error.

[I32] **long integer matrix**
The matrix of long integers read from the link.

GetStringList.vi



GetStringList.vi

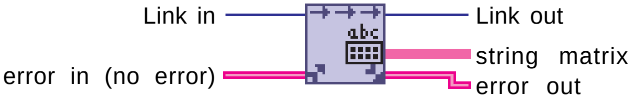
GetStringList.vi reads a list of strings from the link.

Since there is no MathLink function for transferring arrays of strings, the list is read as a function, List[elem 1, elem 2, ..., elem n]. MLGetString is called sequentially in a "For" loop.

Warning:
Due to the structure of this VI, its performance is limited. If you need to send large arrays of strings, you should probably try to send them as a single string and split it in LabVIEW after collection.

[abc] **string list**
The list of strings read from the link.

GetStringMatrix.vi



GetStringMatrix.vi

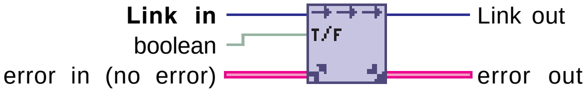
GetStringMatrix.vi reads a matrix of strings from the link.

Since there is no MathLink function for transferring arrays of strings, the list is read as compound Mathematica expression, List[List[elem 1, elem 2, ..., elem n], ...]. MLGetString is called sequentially in two nested "For" loops.

Warning:
Due to the structure of this VI, its performance is limited. If you need to send large arrays of strings, you should probably send them as single strings and split them in LabVIEW after collection.

[abc] **string matrix**
The matrix of strings read from the link.

PutBoolean.vi

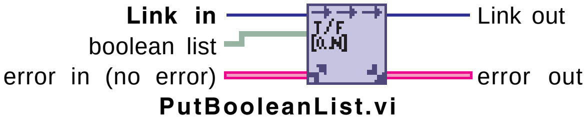


PutBoolean.vi

PutBoolean.vi writes a boolean over the link.

TF **boolean**
The boolean value sent over the link.

PutBooleanList.vi

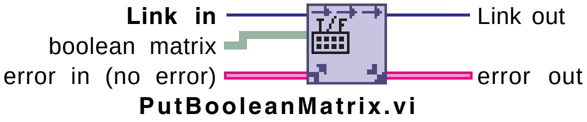


PutBooleanList.vi writes a list of booleans over a link.

Warning:
Since there is no MathLink function for transferring arrays of booleans, the list is passed as List[elem 1, elem 2 ...]. Consequently, the performance of this VI is limited. If you need to send large lists of booleans, you should try to code them in a numerical format and convert them in Mathematica afterwards.

[TF] **boolean list**
The list of boolean values that will be sent over the link.

PutBooleanMatrix.vi



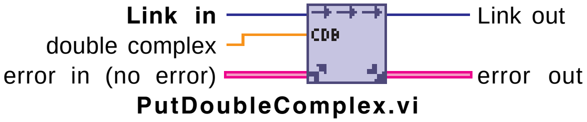
PutBooleanMatrix writes a matrix of booleans over the link.

Since there is no MathLink function for transferring arrays of booleans, the matrix is read as a compound Mathematica expression List[List[elem 1, elem 2, ..., elem n], ...]. In two nested For loops, "True" or "False" is sent by the MLPutSymbol function according to the value of the current matrix element.

Warning:
Due to the structure of this VI, its performances is limited. If you need to send large numbers of booleans, you should probably try to send them in a numerical format and convert them in Mathematica afterwards.

[TF] **boolean matrix**
The matrix of booleans to write over the link.

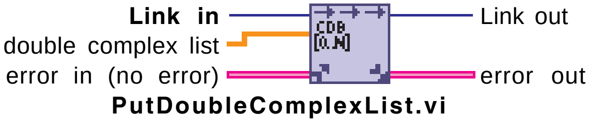
PutDoubleComplex.vi



PutDoubleComplex.vi can be used to write a complex number over the link.

CDB **double complex**
The complex number sent over the link.

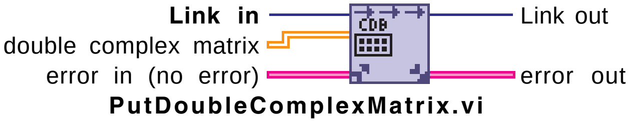
PutDoubleComplexList.vi



PutDoubleComplexList.vi can be used to write a list of complex numbers over the link.

[CDB] **double complex list**
The list of complex numbers sent over the link.

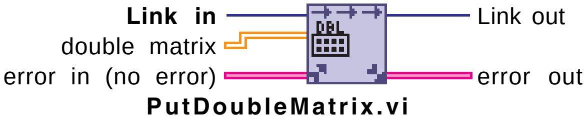
PutDoubleComplexMatrix.vi



PutDoubleComplexMatrix.vi sends a matrix of complex numbers over a link.

[CDB] **double complex matrix**
The matrix of complex numbers sent over the link.

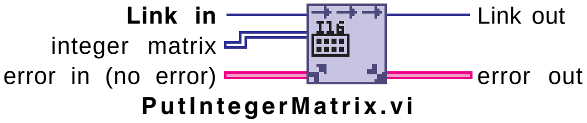
PutDoubleMatrix.vi



PutDoubleMatrix.vi sends a matrix of doubles over the link.

[DBL] **double matrix**
The matrix of doubles sent over the link.

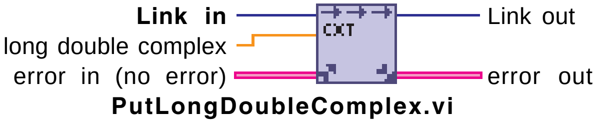
PutIntegerMatrix.vi



PutIntegerMatrix.vi sends a matrix of integers over the link.

[I16] **integer matrix**
The matrix of integers sent over the link.

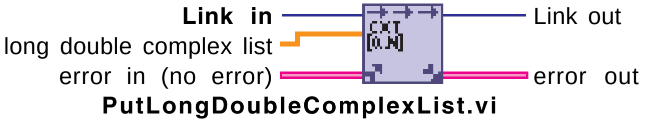
PutLongDoubleComplex.vi



PutLongDoubleComplex.vi sends a complex number over the link.

CXT **long double complex**
The complex number sent over the link.

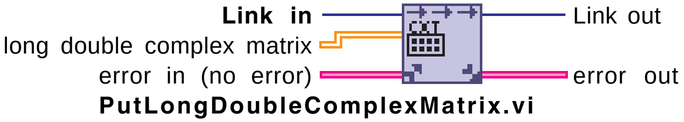
PutLongDoubleComplexList.vi



PutLongDoubleComplex.vi sends a list of complex numbers over the link.

[CXT] **long double complex list**
The list of complex numbers sent over the link.

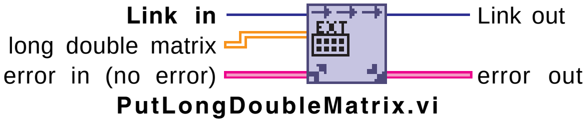
PutLongDoubleComplexMatrix.vi



PutLongDoubleComplex.vi sends a matrix of complex numbers over a link.

[CXT] **long double complex matrix**
The matrix of complex numbers sent over the link.

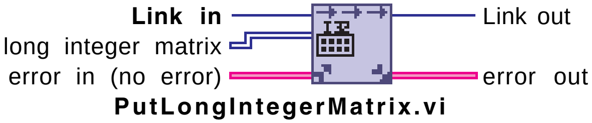
PutLongDoubleMatrix.vi



PutLongDoubleMatrix.vi sends a matrix of long doubles over a link.

[EXT] **long double matrix**
The matrix of long doubles sent over the link.

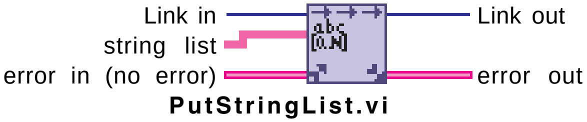
PutLongIntegerMatrix.vi



PutLongIntegerMatrix.vi sends a matrix of long integers over the link.

[I32] **long integer matrix**
The matrix of long integers sent over the link.

PutStringList.vi

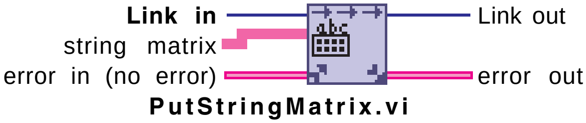


PutStringList.vi sends a list of strings over the link.

Warning:
Since there is no MathLink function for transferring an array of strings, the list is written as a function, List[elem1, elem2, ...]. MLPutString is called sequentially in a For loop. Due to this structure, the performance of this VI is limited. If you need to send a large array of strings, you should send it as a single string and split it in Mathematica after collection.

[abc] **string list**
The list of strings sent over the link.

PutStringMatrix.vi

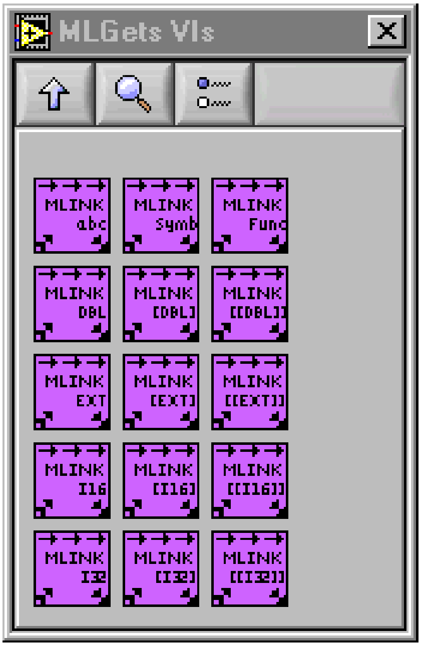


PutStringMatrix.vi sends a matrix of strings over the link.

Warning:
Since there is no MathLink function for transferring an array of strings, the list is written as a function, List[List[elem1, elem2, ...], ...]. MLPutString is called sequentially in two nested For loops. Due to this structure, the performance of this VI is limited. If you need to send a large matrix of strings, you should send it as a single string and split it in Mathematica after collection.

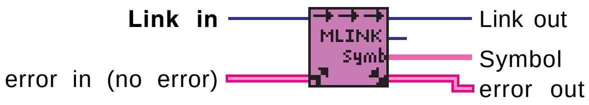
[abc] **string matrix**
The matrix of strings sent over the link.

MLGets.llb



VIs

MLGetSymbol.vi



MLGetSymbol.vi

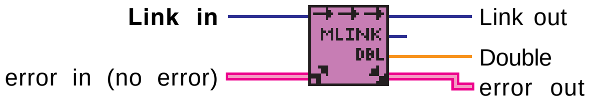
MLGetStymbol.vi receives a Mathematica symbol from "Link in" and displays it in the "Symbol" indicator.

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
This VI does not require the user to call MLDisownSymbol after it has been used since this step is achieved in the CIN.

abc **Symbol**
The Mathematica symbol read on the link.

MLGetDouble.vi



MLGetDouble.vi

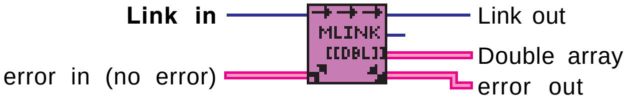
MLGetDouble.vi reads a real number from "Link in" and assign it to the "Double" indicator.

The "Value" indicator returns a nonzero value if the operation was successful of zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
MLGetReal and MLGetFloat functions are not provided in this distribution. MLGetDouble should be used instead.

DBL **Double**
The double read on the link.

MLGetDoubleArray.vi



MLGetDoubleArray.vi

MLGetDoubleArray.vi gets an array of real numbers from "Link in".

The data themselves are returned in the "Double list". The parameters used to describe the data structure are returned in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
You do not need to call any Disown function after using this VI since this step is achieved in the CIN.

Double array
The array of real numbers read on the link. This cluster contains both the raw data and the parameters used to describe the data structure.

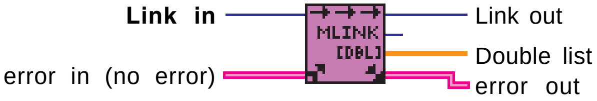
[DBL] **Double list**
The list of doubles read on the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2],...} are List\eolComplex\eol.)

I32 **Depth**
The array depth (Example: 2 for a 3 x 3 matrix.)

MLGetDoubleList.vi



MLGetDoubleList.vi

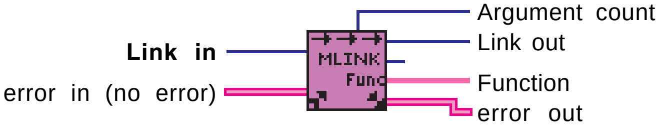
MLGetDoubleList.vi reads a list of real numbers from "Link in" and assigns it to the "Double list" indicator.

The "Value" indicator returns a nonzero value if the operation was successful of zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
The user does not have to call MLDisownDoubleList after using this VI since this step is achieved in the CIN.

[DBL] **Double list**
The list of doubles read on the link.

MLGetFunction.vi



MLGetFunction.vi

MLGetFunction.vi reads a Mathematica function name and argument count from "Link in".

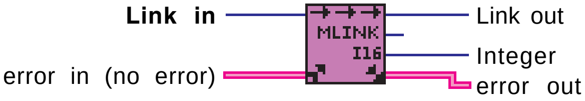
See the MathLink documentation for more details.

Warning:
The user does not have to call MLDisownSymbol after using this function as specified in the MathLink documentation, since this is achieved in the CIN.

abc **Function**
The name of the function read from "Link in".

I32 **Argument count**
The number of arguments of the function read from "Link in".

MLGetInteger.vi



MLGetInteger.vi

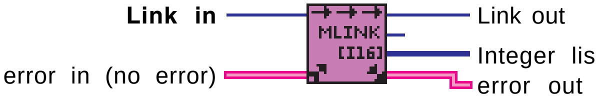
MLGetInteger.vi reads an integer number from "Link in" and assigns it to the "Integer" indicator.

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warnings:
1. This function is not an actual call to MLGetInteger. The number is read from the link through an MLGetLongInteger call and coerced in this VI into an I16.
2. MLGetShortInteger is not provided with this distribution. MLGetLongInteger should be used instead.

I32 **Integer**
The integer read from the link.

MLGetIntegerList.vi



MLGetIntegerList.vi

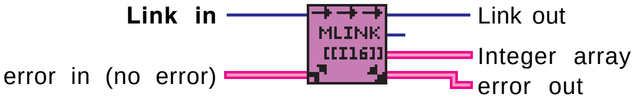
MLGetIntegerList.vi reads a list of integers from "Link in" and assigns it to the "Integer list" indicator.

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
The user does not have to call MLDisownIntegerList after using this VI since this step is achieved in the CIN.

[I16] **Integer list**
The list of integers read on the link.

MLGetIntegerArray.vi



MLGetIntegerArray.vi

MLGetIntegerArray.vi gets an array of integers from "Link in".

The data are returned in the "Integer list". The parameters used to describe the data structure are returned in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
You do not need to call any disown function after using this VI since this step is achieved in the CIN.

Integer array
The array of integers read on the link. This cluster contains both the raw data and the parameters used to describe the data structure.

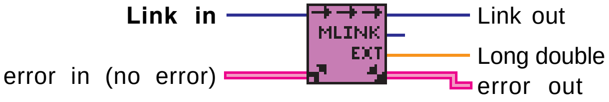
[I16] **Integer list**
The list of integers read on the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2],...} are List\eolComplex\eol.)

I32 **Depth**
The array depth. (Example: 2 for a 3 x 3 matrix.)

MLGetLongDouble.vi



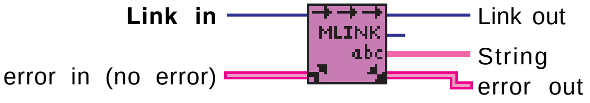
MLGetLongDouble.vi

MLGetLongDouble.vi calls MLGetDouble.vi to read a real number from "Link in" and assigns it to the "Long double" indicator.

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

EXT **Long double**
The real number read on the link.

MLGetString.vi



MLGetString.vi

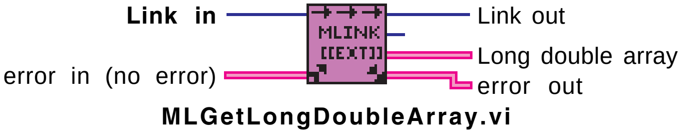
MLGetString.vi reads a Mathematica character string from "Link in" and displays it in the "String" indicator.

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
This VI does not require the user to call MLDisownString after it has been used since this step is achieved in the CIN.

abc **String**
The string read on the link.

MLGetLongDoubleArray.vi



MLGetLongDoubleArray.vi calls MLGetDoubleArray.vi to get an array of real numbers from "Link in".

The data are returned in the "Long double list". The parameters used to describe the data structure are returned in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warnings:
You do not need to call any Disown function after using this VI since this step is achieved in the CIN.

Long double array
The array of real numbers read on the link. This cluster contains both the raw data and the parameters used to describe the data structure.

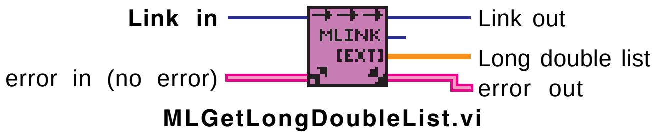
[EXT] **Long double list**
The list of real numbers read on the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2],...} are List\eolComplex\eol.)

I32 **Depth**
The array depth. (Example: 2 for a 3 x 3 matrix.)

MLGetLongDoubleList.vi



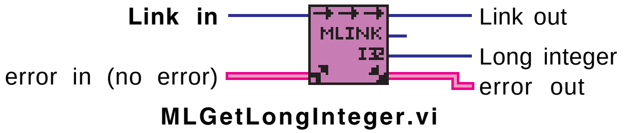
MLGetLongDoubleList.vi calls MLGetDoubleList.vi to read a list of real numbers from "Link in" and assigns it to the "Long double list" indicator.

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
The user does not have to call MLDisownLongDoubleList after using this VI since this step is achieved in the CIN.

[EXT] **Long double list**
The list of long doubles read on the link.

MLGetLongInteger.vi

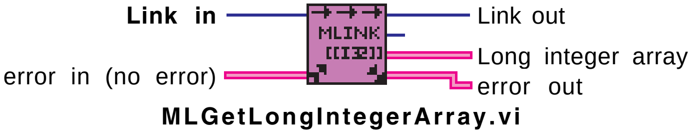


MLGetLongInteger.vi reads an integer number from "Link in" and assigns it the "Long integer" indicator.

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

I32 **Long integer**
The long integer read from the link.

MLGetLongIntegerArray.vi



MLGetLongIntegerArray.vi gets an array of long integers from "Link in".

The data are returned in the "Long integer list". The parameters used to describe the data structure are returned in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful,or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
You do not need to call any disown function after using this VI since this step is achieved in the CIN.

Long integer array
The array of long integers read on the link. This cluster contains both the raw data and the parameters used to describe the data structure.

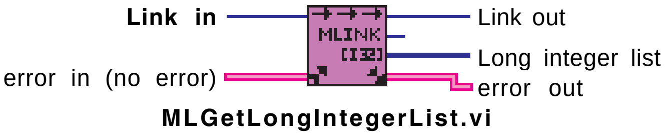
[I16] **Long integer list**
The list of long integers read on the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2],...} are List\eolComplex\eol.)

I32 **Depth**
The array depth. (Example: 2 for a 3 x 3 matrix.)

MLGetLongIntegerList.vi



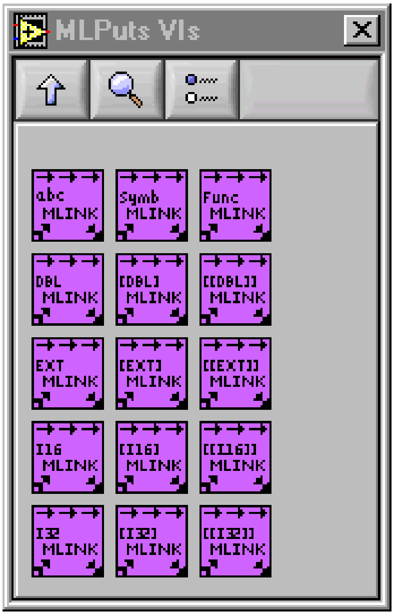
MLGetLongIntegerList.vi reads a list of integers from "Link in" and assigns it to the "Long integer list" indicator.

The "Value" indicator returns a non-zero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
The user does not have to call MLDisownLongIntegerList after using this VI since this step is achieved in the CIN.

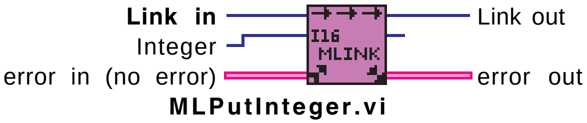
[I32] **Long integer list**
The list of long integers read on the link.

MLPuts.llb



VIs

MLPutInteger.vi



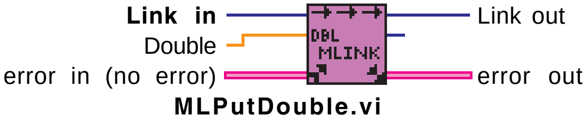
MLPutInteger.vi writes an integer to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
This VI does not implement the actual MathLink function MLPutInteger. It calls MLPutLongInteger and coerces the I16 to an I32 before sending it over the link.

I32 **Integer**
The integer to write on the link.

MLPutDouble.vi



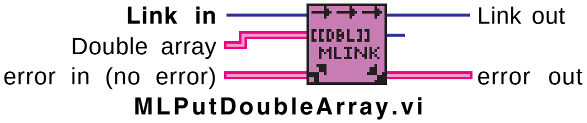
MLPutDouble.vi writes a real number to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
MLPutReal and MLPutFloat functions are not provided in this distribution. MLPutDouble should be used instead.

DBL **Double**
The double to write on the link.

MLPutDoubleArray.vi



MLPutDoubleArray.vi writes an array of doubles to "Link in".

The data are returned in the "Double list". The parameters used to describe the data structure are returned in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Double array
The array of doubles written to the link. This cluster contains both the raw data and the parameters used to describe the data structure.

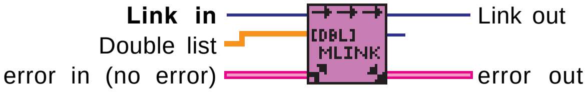
[DBL] **Double list**
The list of doubles written to the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2],...} are List\eolComplex\eol.)

I32 **Depth**
The array depth. (Example: 2 for a 3 x 3 matrix.)

MLPutDoubleList.vi



MLPutDoubleList.vi

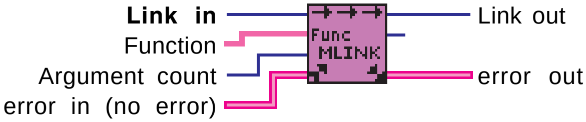
MLPutDoubleList.vi writes a list of real numbers to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
In LabVIEW it is not necessary to specify the list length as a separate argument of this function.

[DBL] **Double list**
The list of doubles to write to the link.

MLPutFunction.vi



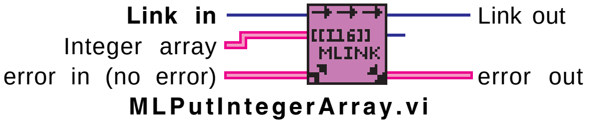
MLPutFunction.vi

MLPutFunction.vi writes a Mathematica function to "Link in".

The function argument values will be sent after MLPutFunction.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

abc **Function**
The name of the Mathematica function to write to the link.

MLPutIntegerArray.vi



MLPutIntegerArray.vi writes an array of integers to "Link in".

The data are put in the "Integer list". The parameters used to describe the data structure are returned in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Integer array
The array of integers written to the link. This cluster contains both the raw data and the parameters used to describe the data structure.

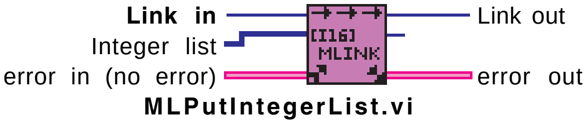
[I16] **Integer list**
The list of integers written to the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2], ...} are List\eolComplex\eol.)

I32 **Depth**
The array depth. (Example: 2 for a 3 x 3 matrix.)

MLPutIntegerList.vi



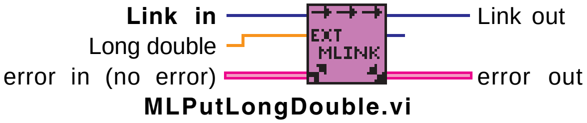
MLPutIntegerList.vi writes a list of integers to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
In LabVIEW it is not necessary to specify the list length as a separate argument of this function.

[I16] **Integer list**
The list of integers to write to the link.

MLPutLongDouble.vi

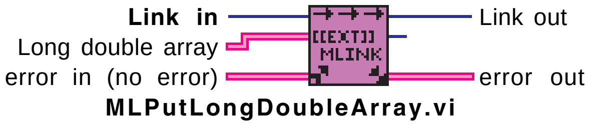


MLPutLongDouble.vi calls MLPutDouble.vi to write a real number to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

EXT **Long double**
The long double written on the link.

MLPutLongDoubleArray.vi



MLPutLongDoubleArray.vi calls MLPutDoubleArray.vi to write an array of long doubles to "Link in".

The data are put in the "Long double list". The parameters used to describe the data structure are returned in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Long double array
The array of long doubles written to the link. This cluster contains both the raw data and the parameters used to describe the data structure.

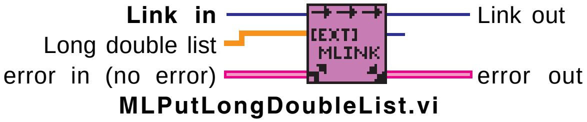
[EXT] **Long double list**
The list of long doubles written to the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2], ...} are List\eolComplex\eol.)

I32 **Depth**
The array depth. (Example: 2 for a 3 x 3 matrix.)

MLPutLongDoubleList.vi



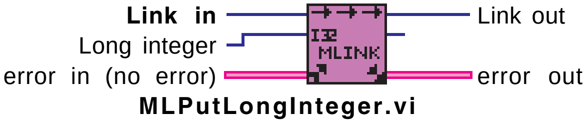
MLPutLongDoubleList.vi calls MLPutDouble.vi to write a list of real numbers to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
In LabVIEW it is not necessary to specify the list length as a separate argument of this function.

[EXT] **Long double list**
The list of long doubles to write to the link.

MLPutLongInteger.vi

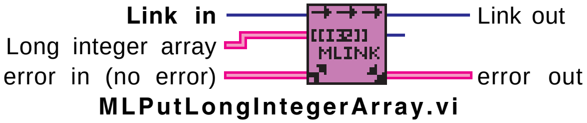


MLPutLongInteger.vi writes a long integer to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

I32 **Long integer**
The long integer to write to the link.

MLPutLongIntegerArray.vi



MLPutLongIntegerArray.vi writes an array of integers to "Link in".

The data are put in the "Long integer list". The parameters used to describe the data structure are written in the "Dimensions", "Heads", and "Depth" indicators.
The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Long integer array
The array of integers written to the link. This cluster contains both the raw data and the parameters used to describe the data structure.

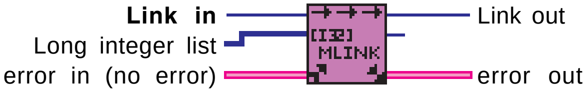
[I16] **Long integer list**
The list of integers written to the link.

[I32] **Dimensions**
The number of elements in each dimension.

abc **Heads**
The Mathematica function name describing the data structure. (Example: the heads of {Complex[a1,b1], Complex[a2,b2], ...} are List\eolComplex\eol.)

I32 **Depth**
The array depth. (Example: 2 for a 3 x 3 matrix.)

MLPutLongIntegerList.vi



MLPutLongIntegerList.vi

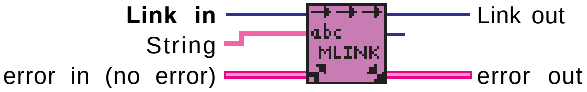
MLPutLongIntegerList.vi writes a list of integers to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

Warning:
In LabVIEW it is not necessary to specify the list length as a separate argument of this function.

[I32] **Long integer list**
The list of integers to write to the link.

MLPutString.vi



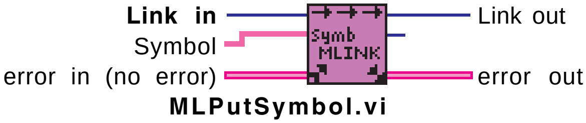
MLPutString.vi

MLPutString.vi writes a string to "Link in".

The "Value" indicator returns a non-zero value if the operation was successful, and 0 if an error occurred. In this case, the error can be identified with MLError.

abc **String**
The string to write to the link.

MLPutSymbol.vi

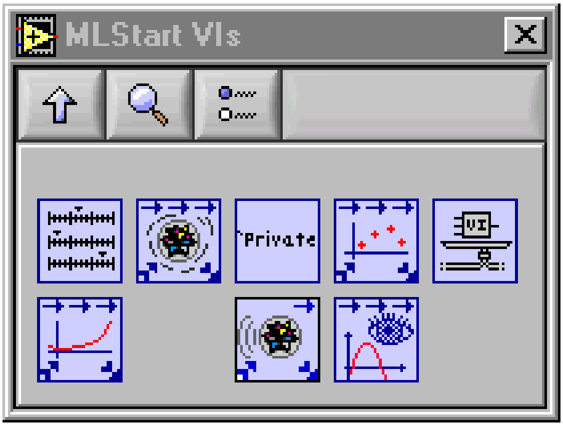


MLPutSymbol.vi writes a Mathematica symbol to "Link in".

The "Value" indicator returns a nonzero value if the operation was successful or zero if an error occurred. In this case, the error can be identified with MLError.

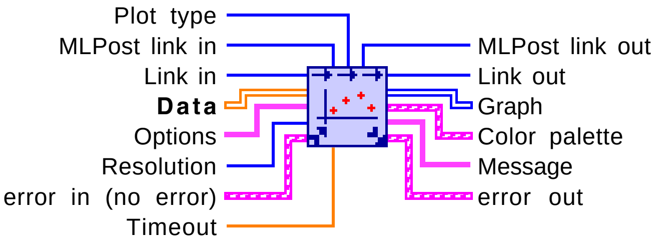
Symbol
The Mathematica symbol to write to the link.

MLStart.llb



VIs

Generic ListPlot.vi



Generic ListPlot.vi

Generic ListPlot.vi can be used to plot a data set. It calls one of the Mathematica ListPlot functions (ListPlot, ListContourPlot, ListDensityPlot, ListPlot3D) according to the value of the "Plot type" control.
See your Mathematica documentation for a detailed description of these functions.

Warning:
To avoid sending an empty array over the link if the "Data" control is empty, it is automatically filled with {{0},{0}} before being sent.

[DBL]

Data

The data to plot. Their format depends on the function you select. ListPlot accepts data as either a list or an n x 2 matrix. The other three functions require the data to be passed as a matrix of heights. See the Mathematica book for details.

Warnings:
1. If you attempt to send an empty matrix,
Generic ListPlot.vi will automatically fill it with {{0},{0}} to ensure normal behavior of the data transfer over the link.
2. If you send any matrix having invalid dimensions, a

U16

Resolution

Graphics dimensions. Graphics are returned in a square window. Resolution is the size of the square side expressed in the number of pixels.

DBL

Timeout

The maximum time allowed to Mathematica for generating the graphics.

I16

MLPost link in

The number of the link to MLPost.

abc

Options

The list of options. The series of options should be comma delimited but not enclosed in braces. (Example:
PlotRange->{0, 10}, PlotLabel-> "plotlabel")

◀▶

Plot type

Use this control to specify the type of the plot you want to generate.

[I16]

Graph

The graph generated by Mathematica. You can wire this data set to an intensity graph or to the customized type definition GraphicsWindow.ctl. Color display can be controlled by wiring the color palette to the corresponding attribute node.

Color palette

The color palette of the picture. These data are wired to the corresponding attribute node items of "graph".

I16

MLPost link out

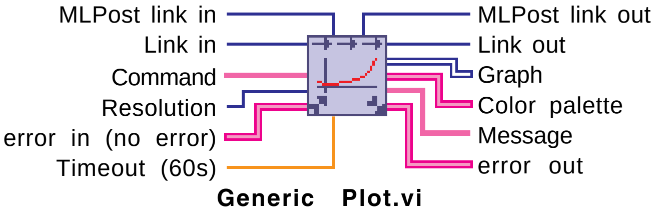
Same as MLPost link in. Use it to sequence MLPost operations.

abc

Message

The messages returned by the kernel. All the messages generated during the Mathematica session are returned here.

Generic Plot.vi



Generic Plot.vi can be used to generate any kind of Mathematica graphics. The "Command" box is used to type the Mathematica command to generate the graphics, just as you would type it in a Mathematica notebook.

See your MathLink for LabVIEW documentation for more details and your Mathematica documentation for graphics command reference.

U16 **Resolution**
Graphics dimensions. Graphics are returned in a square window. Resolution is the size of the square side expressed in the number of pixels.

DBL **Timeout (60s)**
The maximum time allowed to Mathematica for generating the graphics.

I16 **MLPost link in**
The number of the link to MLPost.

abc **Command**
A Mathematica command that returns a graphic.

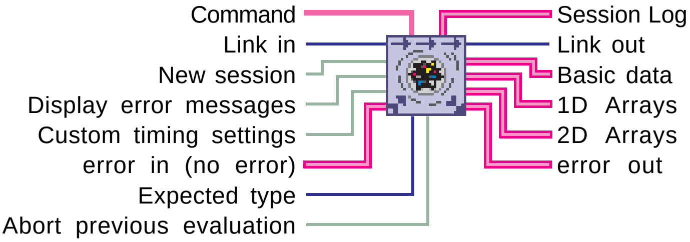
[I16] **Graph**
The graph generated by Mathematica. You can wire this data set to an intensity graph or to the customized type definition GraphicsWindow.ctl. Color display can be controlled by wiring the color palette to the corresponding attribute node.

Color palette
This cluster is used to specify the color mapping of "Graph".

I16 **MLPost link out**
Same as "MLPost link in". Use it to sequence MLPost

abc **Message**
The messages returned by the kernel. All the messages generated during the Mathematica session are returned here.

Kernel Evaluation.vi



Kernel Evaluation.vi

Kernel Evaluation.vi can be used within a LabVIEW application to send computations to the local Mathematica kernel.
To run the VI you need to type a Mathematica command and specify the data type expected from the evaluation result.
See the on-line descriptions of the various front-panel objects and your Mathematica Link for LabVIEW user's guide for details.

abc **Command**
Type here the Mathematica command you want to evaluate.

◂▸ **Expected type**
Select here the type of the data you expect to be returned as a result of the evaluation.

TF **New session**
Use this control to quit the kernel and start it again.

TF **Display error messages**
When this control is set to "True", error messages will be displayed to the operator. You should switch this option to "False" when you wish a program to manage errors.

TF **Custom timing settings**
Set this control to "True" when you want to fine-tune the timing of the kernel operations.

TF **Abort previous evaluation**
Use this control to abort an evaluation that is still running, before proceeding to the next evaluation.

Basic data
Elementary data types are bundled in this cluster.

TF **Boolean**

I32 **Integer**

DBL **Real**

CDB **Complex**

abc **String**

1D Arrays
The five types of lists supported by Kernel Evaluation.vi are bundled in this cluster.

[TF] **1D Booleans**

[I32] **1D Integers**

[DBL] **1D Reals**

[CDB] **1D Complex**

[abc] **1D Strings**

2D Arrays
The five types of matrices supported by Kernel Evaluation.vi are bundled in this cluster.

[TF] **2D Booleans**

[I32] **2D Integers**

[DBL] **2D Reals**

[CDB] **2D Complex**

[abc] **2D Strings**

Session Log
The log of the main packet types recorded during the current Mathematica session.

Message log
The log of messages.
Warning: Note that the message texts are not displayed in this log since they are returned as TEXTPKTs. Here you find only the message name as

abc **Display string**
This field is the result of the concatenation of "symbol", "::", and "tag". Its only purpose is to provide a Mathematica-like display. "symbol" and "tag" are also invisible elements of this cluster and can be unbundled

Menu log
The log of MENUPKTs.

I32 **Menu code**
A number to specify a particular menu. See the mathlink.h file for details.

abc **Prompt string**
The menu prompt string. See the mathlink.h file for details.

I32 **Syntax log**
The log of SYNTAXPKT integer values.

I32 The position at which the syntax error was detected.

Packet log
The log of packets received.

MLPACKET

◀▶ **MLPACKET**
The packet types are defined in the mathlink.h file. The most common packets are:
INPUTPKT input packet
RETURNPKT return packet
MESSAGEPKT message packet
INPUTNAMEPKT input name packet

abc **Time**
The date and time when the packet was received.

MathLink VI Server.vi

MathLink VI Server.vi

Use this VI in conjunction with the functions provided in the VIClient.m package. When the connection is established, you can control LabVIEW applications from within your Mathematica notebook.

This VI is strongly on the victl.llb VIs. See the Mathematica Link for LabVIEW documentation for more details.

I32 **Link name**
The current link name. Its default value, 5555, matched the default value of the link name opened by the ConnectToServer function of the VIClient package.
Note that this name is a number, whereas the link names are ultimately passed as a string in MLOpen because the TCP protocol, which is the default protocol of this VI, requires a number as a link name. Numbers are also valid names with

◂▸ **Link mode**
The connection mode.

◂▸ **Link protocol**
Data transport mechanism.

DBL **Scan period (1s)**
This is used to set the link scanning-period. When the server is idle, that is not processing an input command, the VI will monitor incoming commands every "Scan period" seconds.

DBL **Delay to stop**
When the server is shut down remotely, it is better to wait for a while to let the other partner read the acknowledgment message before closing the link. Depending on the protocol used and your network configuration, you may need to

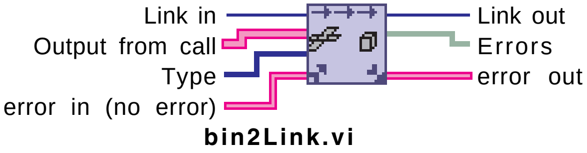
abc **VI location**
This is the location of the currently operated VI. It can be either a VI name (when the VI is already in memory) or a VI path (when it must be loaded first).

TF **Connected**
When switched to "True", this LED indicates that the link is connected.

I32 **Current command**
The command currently processed.

I16 **Link ID**
The number of the link currently operated.

bin2Link.vi



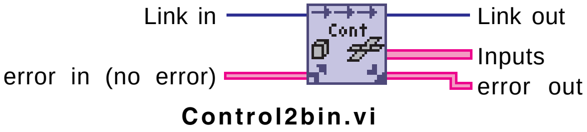
bin2Link.vi is a subVI of MathLink VI Server.vi. It is used to unflatten the binary strings returned by Call Instrument.vi.

[I16] **Type**
The series of data type index. (Position in the case

Output from call
This is the output read from Call Instrument.vi. See the description of Call Instrument.vi in the LabVIEW on-line help.

[TF] **Errors**
The list of possible errors resulting from the conversion of the flattened data to numerical data.

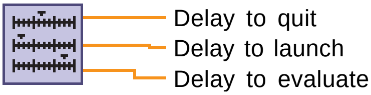
Control2bin.vi



Control2bin.vi is used to flatten incoming control values to pass them to Call Instrument.vi. This VI is a subVI of MathLink VI Server.vi.

Inputs
An array of clusters containing a control name, a type descriptor, and flattened data. You can get the type descriptor and the flattened data from the "Flatten to String" function. This cluster will be wired to the connector labeled "inputs" of the Call Instrument.vi

Delay Settings.vi



Delay Settings.vi

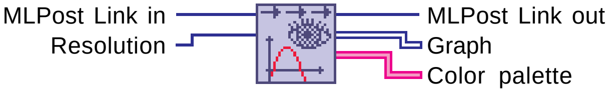
Delay Settings.vi is used to set up the three delays introduced to schedule Kernel Evaluation.vi operations.
If it appears that the default values of these controls are adaptated to your configuration, edit the VI to change the default values of the controls. See the on-line help of each control for more details.

DBL **Delay to evaluate**
The maximum time allowed to the kernel for evaluating a command.

DBL **Delay to launch**
The time that Mathematica needs when it is launched, before it can reply to external requests.

DBL **Delay to quit**
This delay is the time necessary to the kernel when it quits the current link, to be available for a new connection. If this delay is too short the kernel file will not be found.

Graphics Viewer.vi



Graphics Viewer.vi

Graphics Viewer.vi is a utility to render Mathematica graphics in LabVIEW. This VI is not intended to be used on a stand-alone basis, but rather as a subVI of higher level VIs that generate Mathematica graphics. It uses a two-step process. First, MLPost is run to make a bitmap version of the Mathematica graphics file. Then Read Bitmap.vi is called to convert the bitmap file into LabVIEW data.
See your Mathematica Link for LabVIEW user's guide for more details.

I16 **Resolution**
The side length of the square picture measured in pixels.

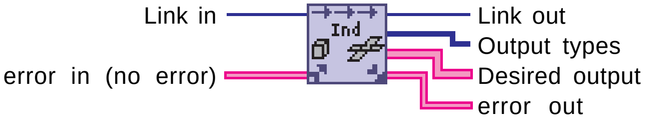
I16 **MLPost Link in**
This control is used to sequence the execution of Graphics Viewer.vi by data dependency. Note that Graphics Viewer.vi does not conduct any operation on the link to the Mathematica

Color palette
The color palette of graphics returned by Graphics Viewer.vi. When this VI is used as a subVI, it is necessary to wire this data structure to the corresponding attribute node of the graph of the upper-level VI to control the color display.

I16 **MLPost Link out**
This indicator is used to sequence the execution of Graphics Viewer.vi by data dependency.

[I16] **Graph**
The graph generated by Mathematica. You can wire this data set to an intensity graph or to the customized type definition GraphicsWindow.ctl. Color display can be controlled by wiring the color palette to the corresponding attribute node.

Indicator2bin.vi



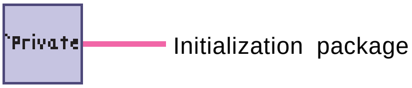
Indicator2bin.vi

Indicator2bin.vi is used to flatten incoming indicator descriptions to pass them to Call Instrument.vi. This VI is a subVI of MathLink VI Server.vi.

[I16] **Output types**
The series of positions in supported types of data read from the link.

Desired output
An array of clusters containing a control name, a type descriptor, and flattened data. You can get the type descriptor and the flattened data from the "Flatten to String" function. This cluster is wired to the "Desired output" cluster

Kernel Initialization.vi

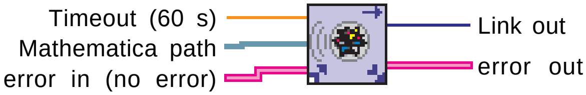


Kernel Initialization.vi

Kernel Initialization.vi is only used to send the initialization package to the Mathematica kernel when it is launched by Kernel Evaluation.vi, Generic ListPlot.vi, and Generic Plot.vi.

abc **Initialization package**
This package is used to initialize the kernel when it is launched by Kernel Evaluation.vi, Generic ListPlot.vi, and Generic Plot.vi of Mathematica Link for LabVIEW. It contains a single function EvaluateUserInput which ensures a compatibility between Mathematica data types and LabVIEW

Launch Kernel.vi



Launch Kernel.vi

Launch Kernel.vi opens a link in launch mode to the Mathematica kernel. It is used as a subVI of Kernel Evaluation.vi, Generic ListPlot.vi, and Generic Plot.vi.

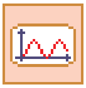
DBL **Timeout (60 s)**
The time required by the kernel to evaluate the initialization package.

Mathematica path
Edit the VI and type here the path to the Mathematica kernel on your system. Reset the default value of the control to be this path. This will automate the launch of the kernel.

I16 **Link out**
The number of the newly opened link.

Controls

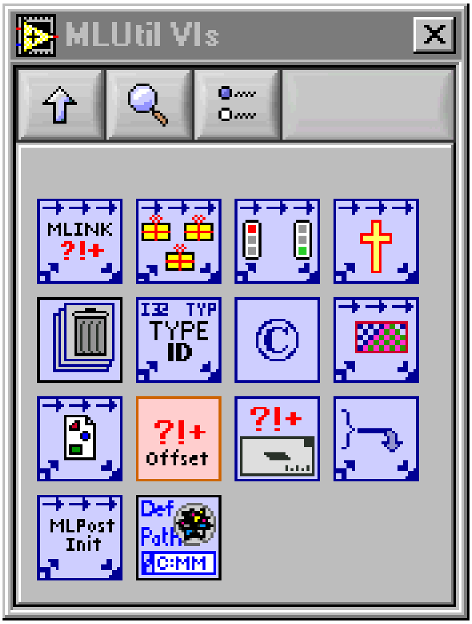
GraphicsWindow.ctl



GraphicsWindow.ctl

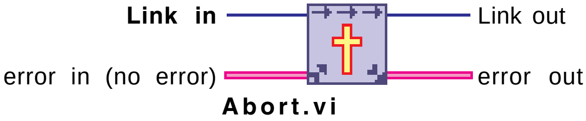
A custom control to display Mathematica graphics. It is a square intensity graph.

MLUtil.llb



VIs

Abort.vi



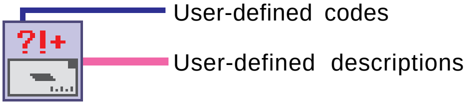
Abort.vi should be used to abort the computation running on the Mathematica kernel connected to "Link in".

Close All Links.vi

Close All Links.vi

Close All Links.vi closes links 1 to 100. It should be used to reinitialize Mathematica Link for LabVIEW.

Codes And Messages.vi



Codes And Messages.vi

Codes And Messages.vi returns valid error codes, merging together the values of the MathLink for LabVIEW errors, the MathLink error codes and messages, and the global error offset. Messages are sorted in increasing order by error codes.

[I32] **User-defined codes**
The sorted series of error codes.

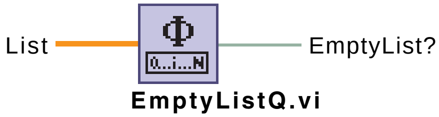
[abc] **User-defined descriptions**
The sorted series of error messages in error code order.

Copyright Notice.vi

Copyright Notice.vi

Copyright Notice.vi contains a copyright notice. It is a subVI of MathLinkCIN.vi. The picture will change on a random basis each time a MathLink function is called to give an indication of the link activity. This windows can be hidden with the standard keyboard shortcut to close a window.

EmptyListQ.vi

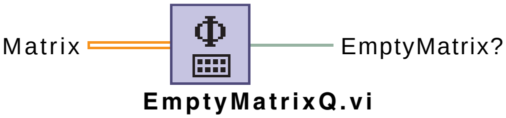


EmptyListQ.vi returns "True" if the incoming list is empty.

[CDB] **List**
The list that should be tested for emptiness.

TF **EmptyList?**
"True" when the incoming list length equals zero, "False" otherwise.

EmptyMatrixQ.vi

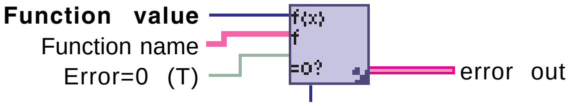


EmptyMatrixQ.vi returns "True" if the incoming matrix is empty.

[DBL] **Matrix**
The matrix that should be tested for emptiness.

TF **EmptyMatrix?**
"True" if both dimensions equal zero, "False" otherwise.

ErrorClusterMaker.vi



ErrorClusterMaker.vi

ErrorClusterMaker.vi is used to transform a function value into an error cluster.
This VI is a small utility is used by many VIs of this distribution to build error clusters. It checks whether the value returned by the function is zero or not. If the return value is zero, the status flag is turned to "True" and the name of the function responsible for this zero value is placed in the corresponding field of the error cluster.

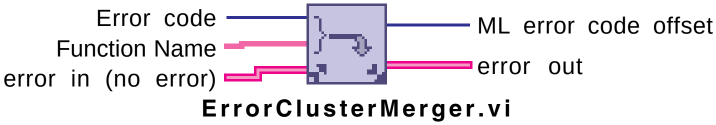
I16 **Function value**
This is the integer returned the upstream function. Errors may be indicated by a zero or nonzero value, depending on the function. For MathLink functions, a zero value indicates that an error has occurred.

abc **Function name**
This is the name of the function that returned the "Function value".

TF **Error=0 (T)**
Set this box to "False" if the function values indicating an error are nonzero values.

I16 **Error code offset**
A arbitrary value to shift the error code into the area reserved for user-defined error codes (between 5000 and 9999).

ErrorClusterMerger.vi



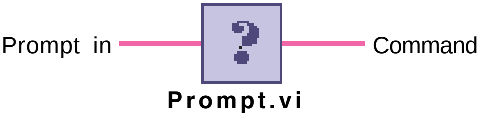
ErrorClusterMerger.vi is a small utility used to check that the incoming error cluster does not indicate a previous error. If an error occurred, the error cluster is not modified. Otherwise, the error code and source are inserted in the outgoing error cluster.

I16 **Error code**
This is the error code to be added to the global error offset before insertion in the code field of the outgoing error

abc **Function name**
This is the name of the VI to be included in the source field of the outgoing error cluster.

I16 **ML error code offset**
A arbitrary value to shift the error code into the area reserved for user-defined error codes (between 5000 and

Prompt.vi

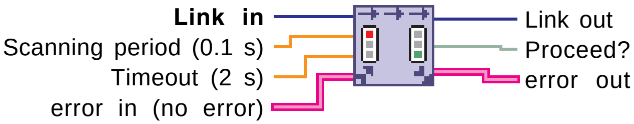


Prompt.vi is used to collect the user input in a pop-up panel. It is used by Packet Parser.vi for INPUTPKT and INPUTSTRPKT processing.

abc **Prompt in**
Wire the message used to promt the user here.

abc **Command**
The command typed by the user.

Link Monitor.vi



Link Monitor.vi

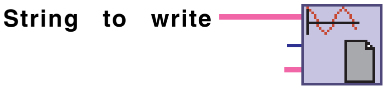
Link Monitor.vi should be used whenever you want to make sure that something is ready to be read on the link before calling the reading function. You can view it as a higher level MLReady function.
This VI structure is a "While" loop which is exited if one of the following conditions is true:
1. MLReady returns 1.
2. MLError returns anything other than MLEOK.
3. Timeout exceeded.

DBL **Scanning period (0.1 s)**
This is the time the VI will wait between two successive calls of MLReady and MLError. The default value is 100 ms.

DBL **Timeout (2 s)**
This control should be used to set the time you are willing to spend in the loop. When the timeout is exceeded, the VI stops.

TF **Proceed?**
This indicator should be used to direct the execution of the downstream VIs. When "Proceed" returns "False", it means either that the link is not ready or that an error occurred.

MakeGraphTempFile.vi



MakeGraphTempFile.vi

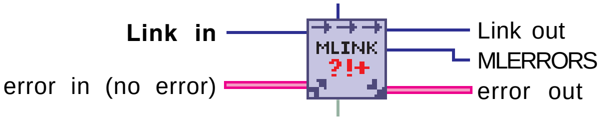
MakeGraphTempFile.vi writes a PostScript file passed as a string to a temporary file. This VI is a subVI of Packet Parser.vi.

abc **String to write**
The PostScript file to write. It is passed as a string.

◀▶ **Default directory**
The directory where the file will be placed. The default value of this setting is the Temp directory. The other possible value is the LabVIEW default directory.

abc **Temp file name**
The name of the PostScript temporary file.

MathLink Error Manager.vi



MathLink Error Manager.vi

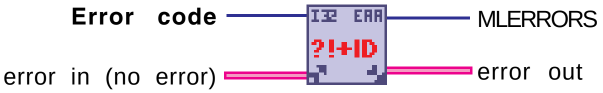
The function of MathLink Error Manager.vi is to detect a MathLink error, correct it when possible, display the corresponding error message, and transmit the information to one of the LabVIEW error handlers. The operations conducted by this VI can be divided into four steps:
1. Get the MathLink error code and put it in the error cluster. If no error occurred, the code returned is zero.
2. When an error is detected, the error message describing the error is added into the source field of the error cluster.
3. The error is cleared.
4. A corrective action is taken when possible.

TF **Display dialog (T)**
Check this box when you want to display errors in a dialog box with a single "OK" button. If you want a program to control error processing, do not select this option.

I16 **Error code offset**
A arbitrary value to shift the error code into the area reserved for user-defined error codes (between 5000 and

◂▸ **MLERRORS**
MathLink error types as they are defined in the mathlink.h

MLERROR Ident.vi



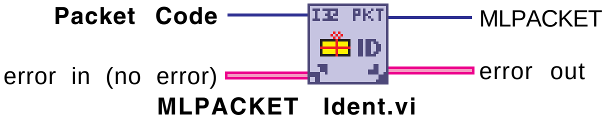
MLERROR Ident.vi

MLERROR Ident.vi identifies the incoming MathLink error code. The integer error code is converted to its corresponding value in the MLERRORS.ctl custom control.

I32 **Error code**
This field is the integer MathLink error code returned by MLError.vi.

◂▸ **MLERRORS**
MathLink error types as they are defined in the mathlink.h

MLPACKET Ident.vi



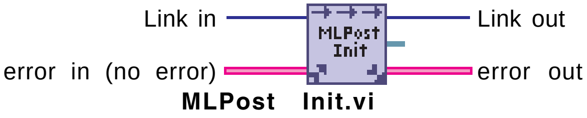
MLPACKET Ident.vi converts a packet integer code into a MathLink packet type.

This VI is used as a subVI of MLNextPacket and other packet handling functions. Its function is to make the conversion between the integer returned by the function and the type of the packet as it is described in the mathlink.h file.

I32 **Packet Code**
The integer packet code as returned by MLNextPacket.

◀▶ **MLPACKET**
The packet type as defined in the mathlink.h file.

MLPost Init.vi



MLPostInit.vi is a VI that launches MLPost when necessary, that is when the "Link in" is zero.
To launch MLPost, MLOpen is called in Launch mode and the packets returned by MLPost are discarded up to the return packet used to indicate a possible error.

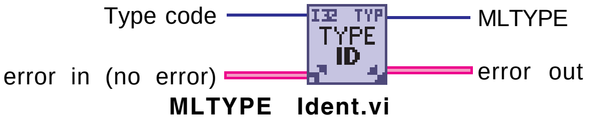
Warning:
MLPost path is computed on your installation relative to the path to MLPost Init.vi. Do not change the file organization of MathLink for Labview. This would make impossible to launch MLPost automatically.

I16 **Link in**
MLPost link. When this link is zero, MLPost is launched. Otherwise nothing happens in this VI.

I16 **Link out**
The MLPost link: it can be either the same link as "Link in" or the number of the newly created link if "Link in" was zero.

MLPost path
This is the path to MLPost used by MLOpen.vi to automatically launch the program.

MLTYPE Ident.vi



MLTYPE Ident.vi converts an integer type code into a MathLink data type. This VI implements the definition of the different types as they appear in the mathlink.h file of your Mathematica distribution.

Type code

This field is the integer returned by MLGetType and MLGetNext functions. Valid type codes are these:

0	MLTKERROR
89	MLTKSYM
83	MLTKSTR
73	MLTKINT
82	MLTKREAL
70	MLTKFUNC

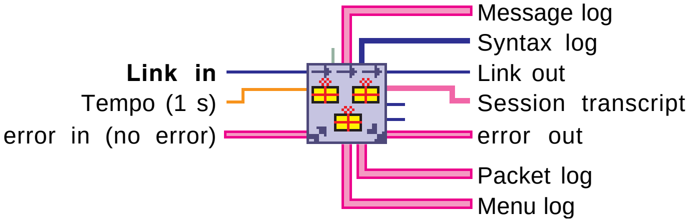
MLTYPE

The MathLink data types are these:

MLTKSTR	Mathematica string
MLTKSYM	Mathematica symbol
MLTKINT	integer
MLTKREAL	real number
MLTKFUNC	composite expression
MLTKERROR	error getting type

They are defined in the mathlink.h file.

Packet Parser.vi



Packet Parser.vi

The job of Packet Parser.vi is to record all incoming packets that it can handle in dedicated logs and to identify the incoming packets that LabVIEW cannot handle in a generic way. The packets that remain untouched by this VI are the packets that return Mathematica expressions (RETURNPKT and RETURNEXPRPKT).

Special cases
Graphics:
Graphics are returned as DISPLAYPKT and DISPLAYENDPKT, which contain strings. These strings are not appended to the session transcript but to a dedicated string indicator named "Graphics", which is not visible on the front panel. After the DISPLAYENDPKT has been read, this string is written in a temporary file by MakeGraphTempFile.vi (see the description of MakeGraphTempFile.vi for further details). Once the file is written, the "Graphics" indicator is reinitialized.
Inputs:
The INPUTPKT and INPUTSTRPKT also receive special treatment. Once the prompt string is read, Prompt.vi is called to collect the user input as a string, which in turn is sent to the kernel wrapped in the suitable packet type.
Discarded packets:
Since the VI is intended to analyze the packets returned to LabVIEW by the kernel, some types of packets are unlikely ever to be seen by this VI. They are CALLPKT, EVALUATEPKT, ENTEREXPRPKT, SUSPENDPKT, RESUMEPKT, BEGINDLGPKT, ENDDLGPKT, and the user defined packets FIRSTUSERPKT and ENDUSERPKT. These packets are discarded by an MLNewPacket call.
ILLEGALPKT:
This packet is just passed downstream to the error-handling VIs.

I16 **Link in**
The link on which the incoming packets will be received.

DBL **Tempo (1 s)**
This indicator is used to slow down the parsing of packets. After analyzing each packet, the VI halts for the number of seconds indicated in "Tempo" to let the next packets arrive in the incoming buffer.

TF **New session (F)**
If you set the control to "True", all logs will be reinitialized.

I16 **Code**
The packet integer code. See the mathlink.h file for

◀▶ **MLPACKET**
The packet types as they are defined in the mathlink.h file.

abc **Session transcript**
An indicator where all text packets are concatenated (TEXTPKT, INPUTNAMEPKT, OUTPUTNAMEPKT, and

Message log
The log of messages. Note that the messages texts are not displayed in this log since they are returned as TEXTPKT. Only the message name as symbol::tag is found here.

- abc **symbol**
- abc **tag**

Display string
This field results of the concatenation of "Symbol", "::", and "Tag". Its only purpose is to provide a Mathematica-like display. The "Symbol" and "Tag" are also elements of this cluster and can be unbundled separately if necessary.

Menu log
The log of MENUPKTs.

Menu code
A number to specify a particular menu. See the mathlink.h file for code definitions.

Prompt string
The menu prompt string. See the MathLink documentation for details.

Syntax log
The log of SYNTAXPKT integer values.

The position at which the syntax error was

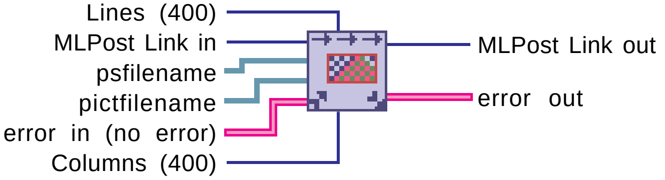
Packet log
The log of packets received.

MLPACKET

MLPACKET
The packet types are defined in the mathlink.h file. The most common packets are these:
INPUTPKT input packet
RETURNPKT return packet
MESSAGEPKT message packet
INPUTNAMEPKT input name packet

Time
The date and time when the packet was received.

Pictify.vi



Pictify.vi

Pictify.vi calls MLPost with suitable arguments to make a bitmap copy of a PostScript file generated by Mathematica graphics functions.
You should not be concerned with MLPost link management. Pictify.vi will automatically launch MLPost when necessary.

Warning:
MLPost error handling is rather crude. You will always be notified of MLPost errors with dialog boxes. In case of error on the MLPost link, Pictify.vi will close the link to MLPost, which should make MLPost quit if the link to this utility is still active. If a subsequent call to MLPost results in several repeated errors saying that it is not possible to launch MLPost again, then you should quit MLPost manually.

I16 **MLPost Link in**
The current MLPost link identifier.

psfilename
The path to the PostScript file to read.

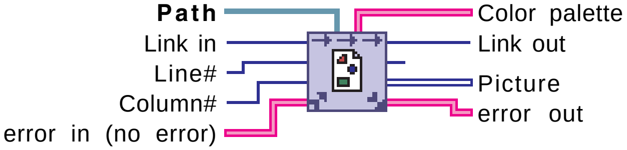
pictfilename
The path to the bitmap file that will be written.

U16 **Columns (400)**
The bitmap picture width expressed in the number of pixels.

U16 **Lines (400)**
The bitmap picture height expressed in the number of pixels.

I16 **MLPost Link out**
The current MLPost link number. It should be the same as the incoming link, but if an error occurred on this link, the MLPost link number is reset to zero.

Read Bitmap.vi



Read Bitmap.vi

Read Bitmap.vi is a function to read a bitmap file. It returns the picture as a list of data suitable for display in an intensity graph. The color palette of the file is also returned in the palette indicator to control the color palette of the intensity graph.

Read Bitmap.vi first loads the specified bitmap file. It then stretches or compresses the graphic to fit within a hypothetical window of the specified width and height. However, it preserves the aspect ratio. For example, if you specify that you want a 400 x 400 bitmap, but the bitmap is twice as wide as it is high, then the bitmap will be stretched or compressed so that it is 400 pixels wide (exactly the width specified) but only 200 pixels high to maintain the aspect ratio. The window you see on screen is actually a representation of the 400 x4 00 hypothetical window, so extra white space appears above or below the picture.

Read Bitmap.vi calls the only function of the MathLinkCIN.vi code interface not which is not a MathLink function.

I16 **Link in**
Link identifier. No operations are conducted on the link by this VI. You can, however, use this connector to sequence the execution of this VI by data dependency.

I16 **Line#**
The picture height.

I16 **Column#**
The picture width.

Path
The path to the bitmap file to read.

[I16] **Picture**
The raw data of the picture. The format is suitable for wiring into an intensity graph.

Color palette
The color palette of the picture. These data should be wired to the corresponding attribute node items of the graph where the data are displayed.

Globals

ErrorOffset.gbl

ErrorOffset.gbl

This global variable is used to shift MathLink and Mathematica Link for LabVIEW error codes into the area reserved for user-defined error codes. The valid data range for user-defined error codes is 5000 to 9999. See the General Error Handler.vi documentation for more details on this topic.

I16 **Error code offset**
Set this control to a different value to avoid if you notice conflicts with other user-defined error codes used by other LabVIEW applications.

MLConstants.gbl

MLConstants.gbl

The constants defined in the mathlink.h header file are reported here so that they can be accessed by Mathematica Link for LabVIEW. They are the type codes, packet codes, error codes, and corresponding error messages. Note that in the mathlink.h file error messages are not defined but are only mentioned as comments to error codes. Error messages should be retrieved by MLErrorMessage in a MathLink program. However, since having a hard copy of these messages in LabVIEW allows errors to be handled in a way more consistent with LabVIEW programming style, this MathLink programming guideline has been violated in this distribution.

[I32] **Type codes**
The various integers codes of the elements in a MathLink data stream.

[I16] **Error codes**
MathLink integer error codes as they are defined in the mathlink.h file.

[I32] **Packet codes**
The integer codes of the packet types declared in the mathlink.h file.

[abc] **Error messages**
The messages describing the various MathLink errors. The order of these messages corresponds to the error code order in the "Error codes" list.

User-defined Errors.gbl

User ?!+

User-defined errors.gbl

Mathematica Link for LabVIEW error codes and error messages.

[I32] **User-defined codes**
Mathematic Link for LabVIEW error codes.

[abc] **User-defined descriptions**
Mathematica Link for LabVIEW error messages.

[abc] **Source**
Location of VIs using the corresponding error codes and

Controls

LinkMode.ctl

LinkMode.ctl

An enumeration control corresponding to the three possible values of the "linkmode" parameter of MLOpen.

◂▸ **-linkmode (Connect)**
The connection mode.

LinkProtocol.ctl

TCP PPC

LinkProtocol.ctl

An enumeration control corresponding the three possible values of the "linkprotocol" parameter of MLOpen.

◂▸ **-linkprotocol (TCP)**
Data transport mechanism.

MLERRORS.ctl

MLERRORS.ctl

MLERRORS.ctl is the type definition of MathLink errors. The definition of the error types can be found in the mathlink.h file. Some errors are also detailed in the MathLink reference guide.

MLERRORS
MathLink error types as they are defined in the mathlink.h

MLPACKETS.ctl

MLPACKETS.ctl

MLPACKETS.ctl is the type definition of MathLink packets. The definition of the packet types can be found in the mathlink.h file. Some packets are also detailed in the MathLink reference guide.

MLPACKET
The packet types are defined in the mathlink.h file. The most common packets are these:
INPUTPKT input packet
RETURNPKT return packet
MESSAGEPKT message packet
INPUTNAMEPKT input name packet
OUTPUTNAMEPKT output name packet

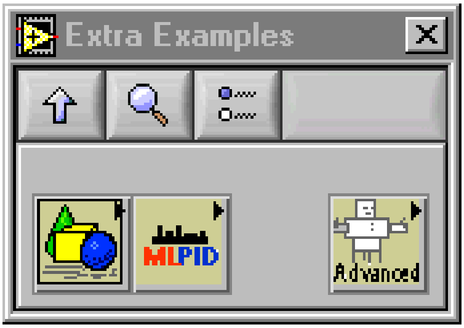
MLTYPES.ctl

MLTYPES.ctl

MLTYPES.ctl is the type definition for MathLink data types. MathLink data types are defined in the mathlink.h file. They are also documented in the MathLink reference guide.

MLTYPE
These are the MathLink data types:
MLTKSTR Mathematica string
MLTKSYM Mathematica symbol
MLTKINT integer
MLTKREAL real number
MLTKFUNC composite expression
MLTKERROR error getting type

Extra Examples



Extra and advanced VI programming examples can be accessed via the Extra Examples palette. More information about these examples can be found in Chapter 4 of this manual – "Programming *Mathematica* Link for LabVIEW".

The VIClient.m Package

Instrument Declaration and Editing

Instrument

Instrument is an object in which the data structure used by functions to operate remote VIs is saved. **DeclareInstrument**, **AddControls**, **AddIndicators**, and **SetControls** return an **Instrument** object.

Valid **Instrument** objects have the following pattern:

Instrument[path_String, viname_String, controls_List, indicators_List]

where **path** is the access path to the VI up to but not including the VI's name, **viname** is the name of the VI to operate, **control** is a list of the form **{name_String, type_, value_}**, and **indicator** is a list of the form **{name_String, type_}**.

The lists of controls and indicators are not necessarily the lists of all of the controls and indicators of the VI. You should list in the control and indicator lists only the controls that you want to set a value in and the indicators that you want to read.

The authorized data types are collected in a list returned by **SupportedTypes**[], which is a public function that you can access when the package has been loaded. The **SupportedTypes[]** elements are themselves documented symbols. They are analogous to LabVIEW data types.

ValidValueQ

ValidValueQ[type, value] is a low-level utility used to check that the type is valid and that **value** has the type **type**. It is usually not necessary to use this function except when you have difficulty declaring an instrument with the **DeclareInstrument** function.

The validity check performed by **ValidValueQ** is close to LabVIEW data coercion rules. The following table summarizes validity conditions.

Instrument Data Type	*Mathematica* Data Type
I8, I16, I32	Integers
U8, U16, U32	Nonnegative integers
EXT, DBL, SGL	Reals or integers
CXT, CDB, CSG	Complex, reals, or integers
String	String
Boolean	Either “True” or “False”
XXXLists	Nonempty list of elements of type XXX
XXXMatrix	Nonempty matrix of elements of type XXX

Observe that this validity check is not very strict. For each type of number, the different formats correspond to different precisions and data ranges. However, the number is not compared to the data range of its type. This does not matter very much, since the only possible problem is having an invalid coercion (exactly the sort of problem that can happen in LabVIEW diagrams). Another important point to remember is that lists and matrices cannot be empty.

DeclareInstrument

DeclareInstrument[path, controls, indicators] is a function that declares an instrument after checking that a new **Instrument** object is valid and can be built based on its arguments.

First, the path is verified. To be valid the path must contain at least one **PathnameSeparator** character. The default value for this parameter is **$PathnameSeparator**: this is the delimiter for the host system where *Mathematica* is run. You may, however, need to change this value, since the path should be valid for the system where LabVIEW is running. Three values are supported: “**:**”, “/”, and “\\” for the Macintosh , UNIX, and Microsoft operating systems, respectively. If the path is valid, the VI’s name (the final string of the path following the last **PathnameSeparator** character), will be stripped off the path. Second, the control list is verified. Its structure is compared to the general control pattern, and the control value and control type are verified to be consistent. The same kind of verification is conducted on indicators, except that indicators do not have values to verify.

DeclareInstrument is fairly flexible. If for any reason you do not need to declare controls or indicators, use one of the following forms:

- **DeclareInstrument[path]**
- **DeclareInstrument[path, indicators]**
- **DeclareInstrument[path, controls]**
- **DeclareInstrument[path, controls, indicators]**

Since controls and indicators do not have the same pattern, this definition set is not ambiguous.

Instrument-Editing Functions

When an instrument has a large number of controls, using **DeclareInstrument** to change a control value or to add another indicator to the indicator list can be tedious. Instrument-editing functions are provided to help you with this task.

SetControls[instrument, {controlname, controlvalue}] can be used to change a control value in a declared instrument. You cannot change the control type.

SetControls[instrument, {{controlname, controlvalue}...}] can be used to change the values of several controls in a declared instrument. You cannot change the control types.

AddControls[instrument, {name, type, value}] can be used to add a new control to the control list of a declared instrument.

AddControls[instrument, {{name, type, value}...}] can be used to add several new controls to the control list of a declared instrument.

AddIndicators[instrument, {name, type }] can be used to add a new indicator to the indicator list of a declared instrument.

AddIndicators[instrument, {{name, type }...}] can be used to add several new indicators to the indicator list of a declared instrument.

Note that these three functions all work by making a new instrument declaration. In particular, the validity of the new values you enter is checked. If the **Instrument** object was saved in a variable, the modified instrument is not saved in the same variable. When a new instrument object is created by the instrument-editing functions, it is your responsibility to save it in an appropriate place.

VI Server Management

Two operations let you manage the VI server from within *Mathematica*, the connection step and the remote shutdown.

Connection

ConnectToServer is the function that is used to make the connection with `MathLink VI Server.vi`. The default values of its arguments match the default values of its LabVIEW partner. The normal operation mode is to run the VI server first to open a link in Listen mode using the appropriate platform-specific protocol (FileMap for Windows, PPC for MacOS) using the link name "5555". Then you can use the minimal (empty) argument set of **ConnectToServer**. **ConnectToServer[]** will return a **LinkObject** that you can save in a variable so that all VI operating functions can use it.

If for some reason the default settings do not work with your configuration you can use different options or even a different link name, to get connected. **ConnectToServer** has the same options as **LinkOpen**. Refer to **LinkOpen** documentation and to "Getting Connected" on page 75 for more details on this topic.

Shutdown

The **ServerShutdown** function is provided to close the link to the server. This function sends a message to a running VI server. When received, the message is acknowledged, and the server will close the link and stop. When the acknowledgment is received by *Mathematica*, it closes its side of the link.

A VI server should not be stopped from the LabVIEW side, since the LabVIEW operator theoretically has no means of knowing whether or not the connection is going to be used. It is the client's responsibility to release the link.

Basic VI Operations – Background

Mathematica Link for LabVIEW was originally developed before the introduction of LabVIEW's VI Server—that powerful VI control technology that permits advanced control of all aspects of VI operations. Before VI Server, the `victl.llb` offered a small collection of control functions—features that are now integrated into the VI Server. Previous versions of *Mathematica* Link for LabVIEW relied exclusively on the `vict.llb` functions to dynamically call VIs from a

Mathematica notebook. However, newcomers to LabVIEW may be unfamiliar with `victl.llb` terminology, and therefore will prefer to access the same functionality using VI Server terminology.

In order to provide backward compatibility with older versions of *Mathematica* Link for LabVIEW, while at the same time supporting the current nomenclature, some of the functions that follow are offered in two different formats:

- functions consistent with legacy `victl.llb` terminology
- functions consistent with the current VI Server terminology

The function sets are completely interchangeable, so use the function set that feels most natural to you. Also, feel free to mix and match the functions from both sets in any way that seems most appropriate.

Basic VI Operations – VI Server Nomenclature

The following functions permit you to perform simple VI operations using familiar VI Server terminology. These functions are not designed to pass control values to the instrument, nor can you read indicator values from the VI. (A function that permits parameter passing is discussed later in this section.)

- **OpenVIRef[link, instrument]** opens a VI Reference and loads a VI into memory.
- **GetVIState[link, instrument]** returns the VI execution state (broken, idle, or running) and the panel window state (closed, open, or open and active).
- **RunVI[link, instrument]** runs a VI that is in memory with its front panel open. Similar to VI Server's "Run VI" method.
- **CloseVIRef [link, instrument]** unloads a VI that was loaded using **OpenVIRef.**

All these functions correspond to VI Server terminology. Refer to the LabVIEW documentation for more details.

Basic VI Operations – `victl.llb` Nomenclature

The same four functions are now presented in their `victl.llb` form. Once again, you cannot send control values to the instrument, nor can you read indicator values from the VI using these functions. (This will be discussed later in this section.)

- **PreloadInstrument[link, instrument]** loads a VI into memory.
- **GetInstrumentState[link, instrument]** returns the VI execution state (broken, idle, or running) and the panel window state (closed, open, or open and active).
- **RunInstrument[link, instrument]** runs a VI that is in memory with its front panel open.
- **ReleaseInstrument[link, instrument]** unloads a VI that was loaded using **PreloadInstrument.**

All these functions correspond to VIs of `victl.llb`. Refer to LabVIEW Version 4 documentation for more details about `victl.llb`.

Basic VI Operations – Front Panel Control

The following front panel control functions are equivalent using either VI Server or `victl.llb` terminology:

- **OpenPanel[link, instrument]** displays the front panel of a loaded VI.
- **ClosePanel[link, instrument]** closes a VI front panel.

Advanced VI Operations

CallIByReference (VI Sever terminology), or **CallInstrument** (`victl.llb` terminology) are the only functions that use the control and indicator lists of **Instrument** objects. **CallByReference[link, instrument]** , or alternatively, **CallInstrument[link, instrument]** will load, run, and release the VI if it is not in memory yet. Otherwise, it is only run, and you have to release it after use with a **CloseVIRef** or **ReleaseInstrument** function.

Verbose is an option for **OpenVIRef, PreloadInstrument**, **CloseVIRef, ReleaseInstrument**, **OpenPanel**, **ClosePanel**, **RunVI, RunInstrument**, and **CallByReference, CallInstrument**. It specifies whether the acknowledgment message read from the link should be displayed. If a large number of such instructions are processed, displaying messages can hinder the results of operations.

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Appendix

To purchase the Khepera mobile robot to run the examples described in this manual, order item number MLLV4/4 from K-Team.

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Index