

LabVIEW™ Data Storage

Introduction

This document describes the formats in which you can save data. This information is most useful to advanced users, such as those using shared libraries (DLLs) or code interface nodes (CINs) and those using the file I/O functions for reading and writing binary data to files. This document describes the following concepts:

- How LabVIEW stores data in memory
- How LabVIEW converts binary data for file storage on disk
- Relationship of type descriptors to data storage

How LabVIEW Stores Data in Memory

This section describes how LabVIEW stores data in memory for controls, indicators, wires, and other objects.

Boolean Data

LabVIEW stores Boolean data as 8-bit values. If the value is zero, the Boolean value is FALSE. Any nonzero value represents TRUE.

Numeric Data

Refer to the *Numeric Data Types* in the *LabVIEW Help* for more information about numeric data types.

Byte Integer

Byte integer numbers have 8-bit format, signed and unsigned.

Word Integer

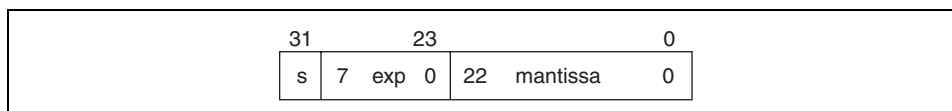
Word integer numbers have 16-bit format, signed and unsigned.

Long Integer

Long integer numbers have 32-bit format, signed and unsigned.

Single

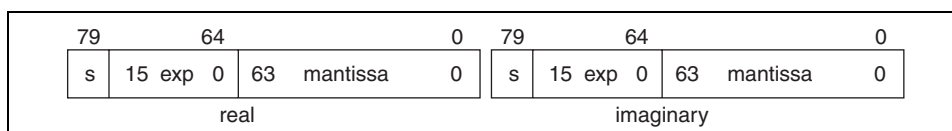
Single-precision floating-point numbers have 32-bit IEEE single-precision format.



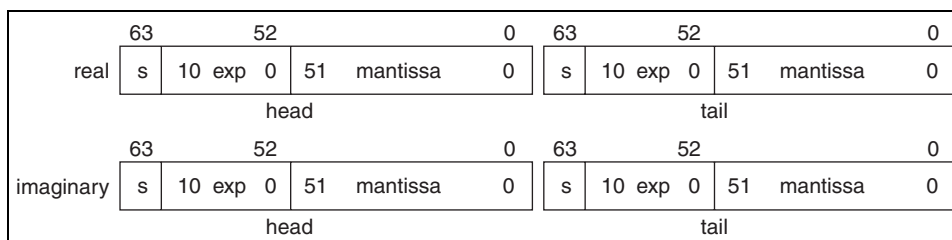
Complex Extended

Complex extended-precision floating-point numbers consist of real and imaginary values in IEEE extended-precision format. In memory, the size and precision of extended-precision numbers vary depending on the platform, as described in the following sections:

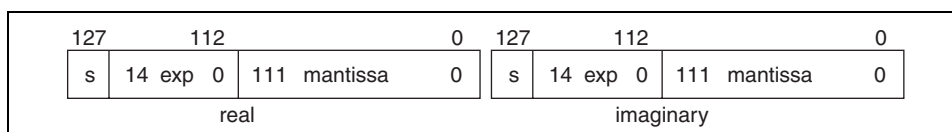
- **Windows and Linux** – Extended-precision floating-point numbers have 80-bit IEEE extended-precision format.



- **Mac OS** – Extended-precision floating-point numbers are represented as two double-precision floating-point numbers added together, called the Apple double-double format.



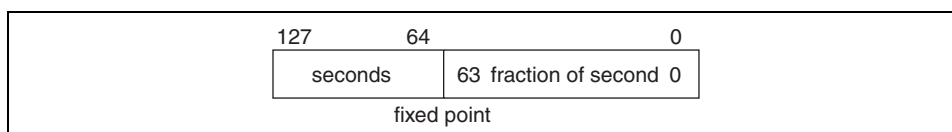
- **Sun** – Extended-precision floating-point numbers have 128-bit IEEE extended-precision format.



Note For floating point and complex numbers, s is the sign bit (0 for positive, 1 for negative), exp is the biased exponent (base 2), and mantissa is a number in the [0,1] range.

Time Stamp

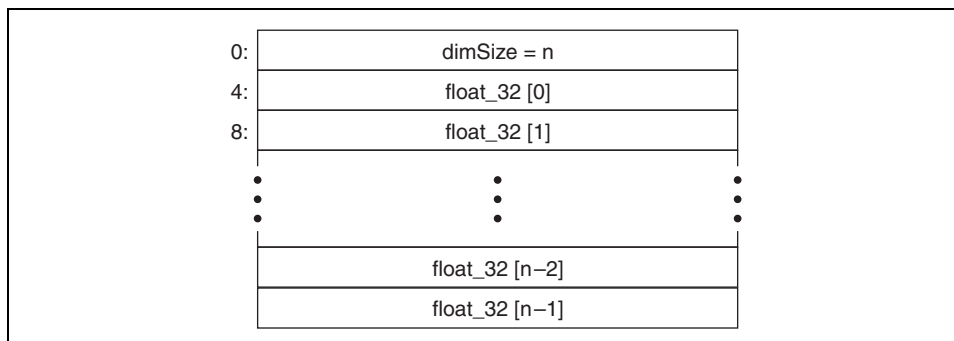
LabVIEW stores a time stamp as a cluster of four integers, where the first two integers (64 bits) represent the time-zone-independent number of complete seconds that have elapsed since 12:00 a.m., January 1, 1904, Universal time. The next two integers (64 bits) represent the fractions of seconds.



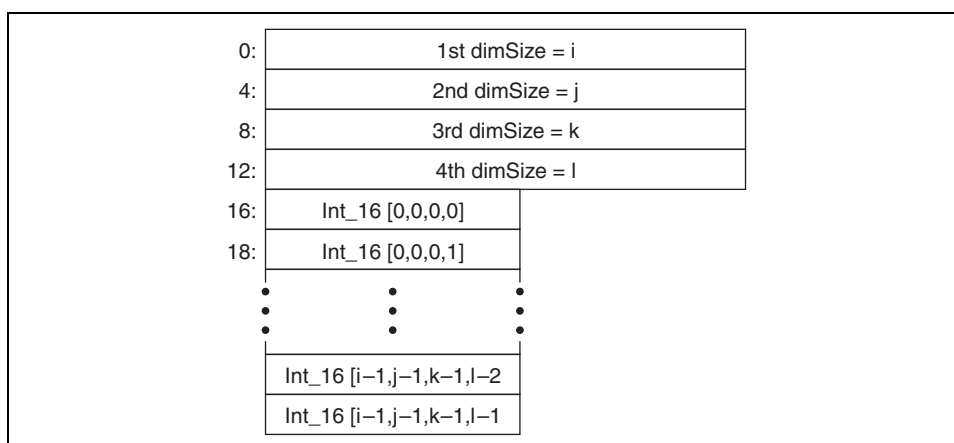
Arrays

LabVIEW stores arrays as handles, or pointers to pointers, that contain the size of each dimension of the array in 32-bit integers followed by the data. If the handle is 0, the array is empty. Because of alignment constraints of certain platforms, a few bytes of padding might follow the dimension size so that the first element of the data is correctly aligned. If you write DLLs or CINI, refer to the *Alignment Considerations* section of Chapter 4, *Programming Issues for CINI*, of the [Using External Code in LabVIEW](#) manual for more information.

The following illustration shows a 1D array of single-precision floating-point numbers. The decimal numbers to the left represent the byte offsets of locations in memory where the array begins.

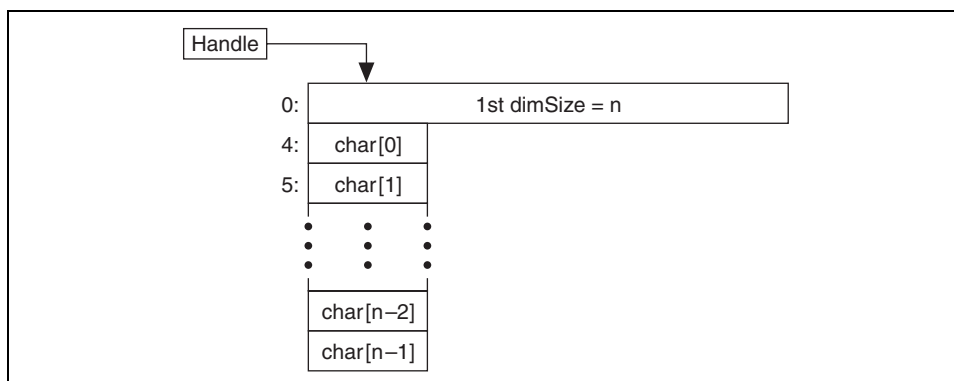


The following illustration shows a 4D array of 16-bit integers.



Strings

LabVIEW stores strings as a pointer to a structure that contains a 4-byte length value followed by a 1D array of byte integers (8-bit characters), as shown in the following illustration. If the handle, the pointer to the structure, is NULL, LabVIEW treats the string as an empty string, which is the same as a string with length value of zero. Because LabVIEW uses the length value to determine the end of the string and not a terminating character, you can embed all characters that include the NULL character, ASCII character 0, in the string at any point. When passing LabVIEW strings to external code that expects a C string, the embedded NULL characters cause that code to interpret the string as terminating at the first NULL character.



Paths

LabVIEW stores paths as handles, or pointers to pointers, that contain the path type and number of path components in 16-bit integers followed by the path components. The path type is 0 for an absolute path, 1 for a relative path, and 3 for a Universal Naming Convention (UNC) path. A UNC path occurs on Windows only and has \\<machine name>\<share name> rather than a drive letter as its first component. Any other value of path type indicates an invalid path. Each path component is a Pascal string (P-string) in which the first byte is the length, in bytes, of the P-string not including the length byte.

The following illustrations show how LabVIEW stores representative paths for each platform.

Windows C:\temp\data.txt	Macintosh Volume:Folder:File	Unix /usr/temp/file
0: 0	0: 0	0: 0
2: 3	2: 3	2: 3
4: 1	4: 6	4: 3
5: "C"	5: "Volume"	5: "usr"
6: 4	11: 6	8: 4
7: "temp"	12: "Folder"	9: "temp"
11: 8	18: 4	13: 4
12: "data.txt"	19: "File"	14: "file"

Clusters

LabVIEW stores cluster elements of varying data types according to the cluster order. To set cluster order, right-click the cluster border and select Cluster Order from the shortcut menu. LabVIEW stores scalar data directly in the cluster. LabVIEW stores arrays, strings, and paths indirectly. The LabVIEW cluster stores a handle that points to the location in memory where the data is stored. Because of alignment constraints of certain platforms, a few bytes of padding might follow the dimension size so that the first element of the data is correctly aligned. If you write DLLs or CINs, refer to the *Alignment Considerations* section of Chapter 4, *Programming Issues for CINs*, of the [Using External Code in LabVIEW](#) manual for more information.

The following illustrations show a cluster that contains a single-precision, floating-point number, an extended-precision, floating-point number, and a handle to a 1D array of 16-bit unsigned integers, respectively.

- Windows and Linux**

0:	SGL float
4:	EXT float
14:	Handle to Array

- Mac OS**

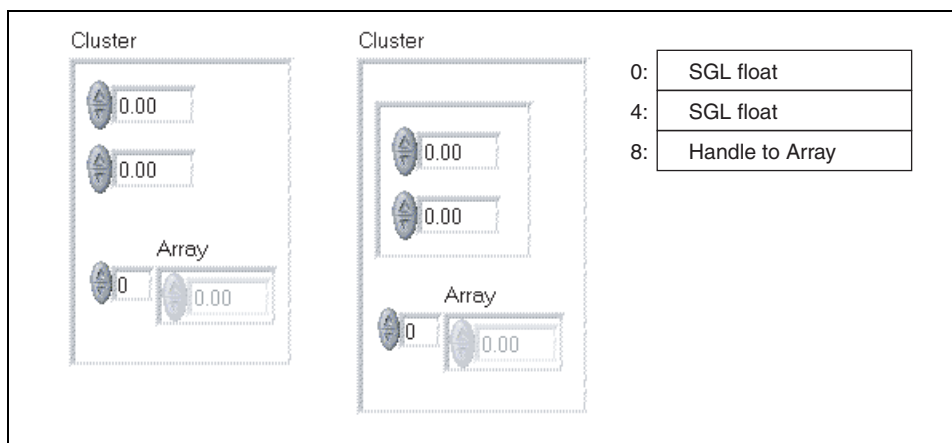
0:	SGL float
4:	EXT float
16:	Handle to Array

- Sun

0:	SGL float
4:	Padding
8:	EXT float
24:	Handle to Array

LabVIEW stores embedded clusters directly – meaning that LabVIEW stores the data as if the data were not embedded in the subcluster. LabVIEW stores only arrays, strings, and paths indirectly.

The following illustration shows two different clusters that store data the same way.



Waveform

LabVIEW stores waveforms exactly like clusters.

Refnum

LabVIEW stores refnums as a signed 32-bit integer.

Variant

LabVIEW stores variants as a handle to a LabVIEW internal data structure. The variant data type is made up of 4 bytes.

Flattened Data

LabVIEW converts data from the format in memory to a form more suitable for writing to or reading from a file. This more suitable format is called *flattened* data.

Because LabVIEW stores strings, arrays, and paths in handles (pointers to pointers in separate regions of memory), clusters that contain these strings and arrays are noncontiguous. In general, LabVIEW stores data in tree form. For example, LabVIEW stores a cluster as a double-precision, floating-point number and a string as an 8-byte floating-point number followed by a 4-byte handle to the string. LabVIEW does not store the string data adjacent to the extended-precision, floating-point number in memory. Therefore, to write the cluster data to disk, LabVIEW must get the data from two different places. With a cluster that contains many strings, arrays, and/or paths, LabVIEW stores the data in many different places.

When you save data to a file, LabVIEW *flattens* the data into a single string before saving it. Flattening data makes the data from an arbitrarily complex cluster contiguous rather than stored in several places. When LabVIEW loads data from a file, it must perform the reverse operation. It must read a single string and *unflatten* it into its internal, possibly noncontiguous, form.

LabVIEW normalizes the flattened data to a standard form so VIs that run on any platform can use the data. LabVIEW stores flattened numeric data in *big endian* form (most-significant byte first), and it stores flattened extended-precision, floating-point numbers as 16-byte quantities using the Sun extended-precision format described earlier in this application note.



Note When writing data to a file for use by an application that was not created using LabVIEW or when reading data from a file produced by an application that was not created using LabVIEW, you can transform the data into *little endian* (least-significant byte first) or *big endian* form after flattening or before unflattening. Windows applications typically expect numeric data to be in little endian form.

Use the Flatten to String and Unflatten from String functions, described in the *LabVIEW Help*, to flatten and unflatten data just as LabVIEW does internally when LabVIEW saves and loads data.

The flattened form of a piece of data does not encode the type of the data. LabVIEW stores this information in a type descriptor. Refer to the [Type Descriptors](#) section of this document for more information about type descriptors. The Unflatten From String function requires you to wire a data type as an input so the function can decode the string properly.

Use the variant data type to work with data independently of data type instead of flattening the data when you write to memory and unflattening the data when you read from memory. Use the Variant functions, described in the *LabVIEW Help*, to create and manipulate variant data. Refer to the *Handling Variant Data* section of Chapter 5, *Building the Block Diagram*, of the [LabVIEW User Manual](#) for more information about using the variant data type.

Booleans and Numerics

The flattened form of any numeric type and Boolean type stores the data only in big endian format. For example, a 32-bit integer with a value of -19 is flattened to FFFF FFED. A double-precision floating-point number with a value equal to 1/4 is flattened to 3FD0 0000 0000 0000. A Boolean value of TRUE is any nonzero value. A Boolean value of FALSE is 00.

The flattened form for extended-precision numbers is the Sun 128-bit extended-precision, floating-point format. When you save extended-precision numbers to disk, LabVIEW stores them in this format.

Strings and Paths

Because strings and paths have variable sizes, a flattened 32-bit integer that records their length in bytes precedes the flattened form. For example, a string type with value ABC is flattened to 0000 0003 4142 43. For strings, the flattened format is similar to the format the string takes in memory.

However, paths do not have a length value preceding them when LabVIEW stores them in memory, so this value comes from the actual size of the data in memory and prefixes the value when LabVIEW flattens the data. This length is preceded by four characters: PTH0.

For example, a path with value C:\File is flattened to 5054 4830 0000 000B 0000 0002 0163 0466 696C 65.

5054 4830 indicates PTH0. 0000 000B indicates 11 bytes total. 0000 is the type. 0002 is the number of components. 0163 indicates the letter C as a Pascal string. 0466 696C 65 indicates the word File as a Pascal string.

Arrays

Flattened 32-bit integers that record the size, in elements, of each of the dimensions of an array precede the data for a flattened array. The slowest varying dimension is first, followed successively by the faster varying dimensions, just as the dimension sizes are stored in memory. The flattened data follows immediately after these dimension sizes in the same order in which LabVIEW stores them in memory. The following example shows a 2D array of six 8-bit integers.

{ {1, 2, 3}, {4, 5, 6} } is flattened to 0000 0002 0000 0003 0102 0304 0506.

The following example shows a flattened 1D array of Boolean variables.

{T, F, T, T} is flattened to 0000 0004 0100 0101. The preferred value for TRUE is 01.

Clusters

A flattened cluster is the concatenation, in cluster order, of the flattened data of its elements. For example, a flattened cluster of a 16-bit integer of value 4 (decimal) and a 32-bit integer of value 12 is 0004 0000 000C.

A flattened cluster of a string ABC and a 16-bit integer of value 4 is 0000 0003 4142 4300 04.

A flattened cluster of a 16-bit integer of value 7, a cluster of a 16-bit integer of value 8, and a 16-bit integer of value 9 is 0007 0008 0009.

Waveforms

LabVIEW flattens waveforms exactly like clusters.

Refnums

LabVIEW stores the majority of flattened refnums as flattened 32-bit integers, which represent an internal LabVIEW data structure. Refer to the [Booleans and Numerics](#) section for more information about how LabVIEW flattens 32-bit integers.

You can classify the remaining refnums by their refnum type code. Refer to the [Type Descriptors](#) section to determine the type code.

Type codes 0xE, 0xF and 0x15 are refnums that store their data as a flattened string. Refer to the [Strings and Paths](#) section of this document for more information about how LabVIEW flattens strings. This string contains the value of the refnum tag, and can be empty (4 bytes of zero).

Type codes 0x1A, 0x1C, and 0x1D concatenate, in the following order:

1. A flattened string for the name in the refnum tag. This string is empty (4 bytes of zero) if the refnum does not have a tag.
2. A flattened string that contains information specific to the refnum. This string can be empty (4 bytes of zero).
3. A flattened string that contains information specific to the refnum. This string can be empty (4 bytes of zero).
4. A flattened 32-bit signed integer that contains information specific to the refnum.
5. A flattened string that contains information specific to the refnum. This string can be empty (4 bytes of zero).

Type Descriptors

LabVIEW associates each wire and terminal on the block diagram with a data type. LabVIEW keeps track of this type with a structure in memory called a *type descriptor*. This type descriptor is a sequence of 16-bit integers that can describe any data type in LabVIEW. Numeric values are written in hexadecimal format, unless otherwise noted.

The generic format of a type descriptor is

<length> <type code>

Some type descriptors have additional information following the type code. Arrays and clusters are structured or aggregate data types because they include other types. For example, the cluster type contains additional information about the type of each of its elements.

The first word (16 bits) in any type descriptor is the length, in bytes, of that type descriptor, including the length word. The second word (16 bits) is the type code. LabVIEW reserves the high-order byte of the type code (the *xx* in the following tables) for internal use. When comparing two type descriptors for equality, you should ignore this byte. Two type descriptors are equal even if the high-order bytes of the type codes are not.

The type code encodes the actual type information, such as single-precision or extended-precision, floating-point number, as listed in Tables 1 and 2. These type code values might change in future versions of LabVIEW.

Data Types

Tables 1 and 2 list numeric and nonnumeric data types, type codes, and type descriptors.

Table 1. Scalar Numeric Data Types

Data Type	Type Code (numbers in hexadecimal)	Type Descriptor (numbers in hexadecimal)
8-bit Integer	01	0004 <i>xx</i> 01
16-bit Integer	02	0004 <i>xx</i> 02
32-bit Integer	03	0004 <i>xx</i> 03
Unsigned 8-bit Integer	05	0004 <i>xx</i> 05
Unsigned 16-bit Integer	06	0004 <i>xx</i> 06
Unsigned 32-bit Integer	07	0004 <i>xx</i> 07
Single-Precision Floating-Point Number	09	0004 <i>xx</i> 09
Double-Precision Floating-Point Number	0A	0004 <i>xx</i> 0A
Extended-Precision Floating-Point Number	0B	0004 <i>xx</i> 0B
Single-Precision Complex Floating-Point Number	0C	0004 <i>xx</i> 0C
Double-Precision Complex Floating-Point Number	0D	0004 <i>xx</i> 0D
Extended-Precision Complex Floating-Point Number	0E	0004 <i>xx</i> 0E
Enumerated 8-bit Integer	15	<nn> <i>xx</i> 15 <k> <k pstrs>
Enumerated 16-bit Integer	16	<nn> <i>xx</i> 16 <k> <k pstrs>
Enumerated 32-bit Integer	17	<nn> <i>xx</i> 17 <k> <k pstrs>

Table 1. Scalar Numeric Data Types (Continued)

Data Type	Type Code (numbers in hexadecimal)	Type Descriptor (numbers in hexadecimal)
Single-Precision Physical Quantity	19	<nn> xx19 <k> <k base-exp>
Double-Precision Physical Quantity	1A	<nn> xx1A <k> <k base-exp>
Extended-Precision Physical Quantity	1B	<nn> xx1B <k> <k base-exp>
Single-Precision Complex Physical Quantity	1C	<nn> xx1C <k> <k base-exp>
Double-Precision Complex Physical Quantity	1D	<nn> xx1D <k> <k base-exp>
Extended-Precision Complex Physical Quantity	1E	<nn> xx1E <k> <k base-exp>
n=length; x=reserved; k=number; k pstrs=number of Pascal strings; k base-exp=number of base-exponent pairs. Refer to the <i>Physical Quantity</i> section of this document for more information about physical quantities.		

Table 2. Nonnumeric Data Types

Data Type	Type Code (numbers in hexadecimal)	Type Descriptor (numbers in hexadecimal)
Boolean	21	0004 xx21
String	30	0008 xx30 <dim>
Path	32	0008 xx32 <dim>
Pict	33	0008 xx33 <dim>
Array	40	<nn> xx40 <k> <k dims> <element type descriptor>
Cluster	50	<nn> xx50 <k> <k element type descriptors>
Waveform	54	<nn> xx54 <waveform type> <element type descriptors>
Refnum	70	<nn> <refnum type code><specific type code information>
Variant	53	<nn> xx53
n=length; x=reserved; k=number; k pstrs=number of Pascal strings; k base-exp=number of base-exponent pairs. A dim is a 32-bit integer. Refer to the following sections of this document for examples of data and type descriptors..		

The minimum value in the size field of a type descriptor is 4, as shown in Table 1. However, any type descriptor can have a name (a Pascal string) appended, in which case the size field is larger by the length of the name rounded up to a multiple of two.

Enumerated 8-Bit Integer

In the following example of an enumerated 8-bit integer for the items *am*, *fm*, and *fm stereo*, each group of characters represents a 16-bit word. The space enclosed in quotation marks (" ") represents an ASCII space.

```
0016 0015 0003 02a m02 fm 09f m" " st er eo
```

0016 indicates 22 bytes total. 0015 indicates an enumerated 8-bit integer. 0003 indicates there are three items.

Physical Quantity

In the following example of a double-precision physical quantity with units m/s, each group represents a 16-bit word.

000E 001A 0002 0002 FFFF 0003 0001

000E indicates 14 bytes total. 001A indicates this is a double-precision physical quantity. 0002 indicates two base-exponent pairs. 0002 denotes the seconds base index. FFFF (-1) is the exponent of seconds. 0003 denotes the meters base index. 0001 is the exponent of meters.



Note LabVIEW stores all physical quantities internally in terms of base units, regardless of the units used to display them.

Table 3 shows the nine bases that are represented by indexes 0 through 8 for radians through candela.

Table 3. Base Units

Quantity Name	Unit	Abbreviation	Base Value
plane angle	radian	rad	0
solid angle	steradian	sr	1
time	second	s	2
length	meter	m	3
mass	kilogram	kg	4
electric current	ampere	A	5
thermodynamic temperature	kelvin	K	6
amount of substance	mole	mol	7
luminous intensity	candela	cd	8

String, Path, and Pict Data Types

The string, path, and pict data types have a 32-bit length, similar to the array dimension size. Although the only value currently encoded is FFFFFFFF (-1), which indicates variable sized. Currently, all strings, paths, and pict are variable sized. The actual length is stored with the data.

Array and Cluster Data Types

Notice the array and cluster data types each have their own type code. They also contain additional information about the data types of their elements and the dimensionality for arrays or number of elements for clusters.

Array

The type code for an array is 40. A word that contains the number of dimensions of the array immediately follows the type code. Then, for each dimension, a 32-bit integer contains the size in elements of that dimension. Finally, after all of the dimension sizes, the type descriptor for the element appears. The element type can be any type except an array. Currently all sizes are FFFFFFFF (−1), which means the array dimension size is variable. LabVIEW stores the actual dimension size, which is always greater than or equal to zero, with the data. The following example is a type descriptor for a 1D array of double-precision floating-point numbers:

```
000E 0040 0001 FFFF FFFF 0004 000A
```

000E is the length of the entire type descriptor, including the element type descriptor. The array is variable sized, so the dimension size is FFFFFFFF. Notice the element type descriptor (0004 000A) appears exactly as it does for a scalar of the same type.

The following example is a type descriptor for a 2D array of Boolean values:

```
0012 0040 0002 FFFF FFFF FFFF FFFF 0004 0021
```

Cluster

The type code for a cluster is 50. A word that contains the number of items in the cluster immediately follows the type code. The type descriptor for each element in *cluster order* follows this word. For example, consider a cluster of two integers – a 16-bit signed integer and an 32-bit unsigned integer:

```
000E 0050 0002 0004 0002 0004 0007
```

000E is the length of the type descriptor including the element type descriptors.

Because array and cluster type descriptors contain other type descriptors, they might become deeply nested. For example, the following is a type descriptor for a multiplot graph. The numeric types can vary.

```
0028 0040 0001 FFFF FFFF... 1D array of  
001E 0050 0001... 1 component cluster of  
0018 0040 0001 FFFF FFFF... 1D array of  
000E 0050 0002... 2 component cluster of  
0004 000A... double-precision floating-point number  
0004 0003... 32-bit integer
```

Waveform

The type code for a waveform is 54. A word that contains the type of waveform immediately follows the type code. The type descriptor of the cluster of the waveforms elements follows this word. There are five categories of waveforms:

- Analog
- Digital
- Digital Table
- Time Stamp
- Dynamic

- a. The following table lists the types of analog waveforms.

Table 4. Types of Analog Waveforms

Type	Subtype Code
8-bit signed	14
16-bit signed	2
32-bit signed	15
Double-Precision	3
Single-Precision	5
Extended-Precision	10
8-bit unsigned	11
16-bit unsigned	12
32-bit unsigned	13
Complex Single-Precision	16
Complex Double-Precision	17
Complex Extended-Precision	18

For example, consider a double-precision waveform:

0086 0054 0003...size of waveform, followed by type and subtype code

0080 0050 0005...size of cluster, cluster code, and number of elements

<type descriptor of time stamp>

<type descriptor of dt >

<type descriptor of array of element type>

<type descriptor of unused error cluster>

<type descriptor of attributes>

The type descriptor of the other types of analog waveforms is similar to the double-precision waveform. The difference is a different type for the array element and a different subtype.

- b. Digital: The digital waveform is the only type of waveform that has a subtype code 8.

For Example,

00B6 0054 0008...size of digital waveform, type code and subtype code

00B0 0050 0005...size of cluster, cluster code and number of elements

<type descriptor of time stamp>

<type descriptor of dt >

<type descriptor of digital table>

<type descriptor of unused error cluster>

<type descriptor of attributes>

- c. Digital Table: The digital table is the only data type with a waveform type code and a subtype code of 7.

For example,

003E 0054 0007...size of digital table, type code and subtype code

0038 0050 0002...size of cluster, cluster code and number of elements.

<type descriptor of transitions>

<type descriptor of data>

- d. Time Stamp: The time stamp has a subtype code of 6. The time stamp is a 128-bit fixed-point number. LabVIEW stores a time stamp as a cluster of four integers where the first two integers (64 bits) represent the number of whole seconds after 12:00 a.m., January 1, 1904, Universal time. The next two integers (64 bits) represent the fractions of seconds.

001C 0054 0006

0016 0050 0004

0004 0003,

0004 0003,

0004 0003,

0004 0003

- e. Dynamic: The dynamic data type has a subtype code of 9. Dynamic waveform is a cluster of an array of analog waveforms.

For Example,

009C 0054 0009...size of dynamic waveform, type code subtype

0096 0050 0001...cluster of one element

0090 0040 0001 FFFF FFFF...array of one element

<type descriptor of an analog waveform>

