*svlib* User Guide  
and Programmer's Reference

# About this document

## Summary

This document provides a specification and programmer's reference for the SystemVerilog utility library svlib.

## Revision information

|  |  |  |  |
| --- | --- | --- | --- |
| Rev | Date | Author | Description |
| 0.0 | 10 Feb 2014 | J Bromley | Initial release for discussion |
| 0.1 | 23 Feb 2014 | J Bromley | Working towards a first release |
| 0.2 | 02 Mar 2014 | J Bromley | All sections present, ready for initial release. Some explanatory text is still missing. |
| 0.3 |  | J Bromley | Fix issues #18, #19 and various other minor errors. Complete the text. |

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### Authorship

This document was prepared at Verilab, Inc ([www.verilab.com](http://www.verilab.com)) by Jonathan Bromley, Paul Marriott and André Winkelmann.

### Open source requirements

svlib is an open source package, so you are free to examine the source code and modify it in any way you wish. This document is provided in PDF for convenience, and therefore is not strictly open-source. The original editable document is available from the authors on request.

## Contacting the authors

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# Introduction and Overview

This document describes svlib, a utility library for SystemVerilog. It provides functionality that we have found lacking in SystemVerilog for our day-to-day verification work: string processing, operating system interface and many other useful operations.

* Section 3 describes how to integrate svlib with your simulator and your own SystemVerilog code.
* Section 4 discusses some underlying principles and conventions of svlib, to help you use it with confidence.
* Section 5 documents features of svlib that support string manipulations and operations that are not available in the base SystemVerilog language.
* Section 6 introduces the regular expression matching and substitution features.
* Section 7 gives details of the Pathname class, which makes it easy to perform common manipulations on a typical filename such as determining the directory, assembling a pathname from its directory components, finding a file's extension, etc. These operations are just specialized string functions; they do not make any access to the file system.
* Section 8 looks at svlib facilities for querying the file system. It allows you to find properties of files such as "does this file exist", "on what date was the file last modified", "can I write to this file", "is it a directory" and many others.
* Section 9 offers a collection of operating system query functions. You can easily discover the current (wall-clock) time and date, render a date in various human-readable formats, explore the OS's environment variables, get the contents of a directory as a queue of strings, and read a high-resolution (sub-microsecond) timer.
* Section 10 discusses how errors are handled in svlib. By default errors are reported on the simulation console, but you can customize the error handling in various ways and even take full responsibility for handling errors under control of your own SystemVerilog code.
* Section 11 details classes and functions that support reading and writing configuration files in .ini or YAML format, and explains how to transfer configuration data between your own custom configuration classes and svlib's internal Document Object Model (DOM) representation.
* Section 12 describes a set of utility functions that make it easier to work with SystemVerilog enumeration types.
* Section 13 describes some convenience features, provided in the form of SystemVerilog macros.
* Finally, section 14 provides a number of ready-to-run examples that show svlib facilities in practical use.

# Compiling and running code that uses *svlib*

The svlib codebase is in three distinct parts, all found in the src/ directory of the distribution:

* macros that are available for user code if you `include "svlib\_macros.svh" appropriately
* SystemVerilog code, forming a single package svlib\_pkg, that you can compile by asking your tool's analyzer (compiler) to process file svlib\_pkg.sv
* C code that is called, using the SystemVerilog DPI, by various parts of the library – currently appearing as a single file dpi/svlib\_dpi.c

To make use of svlib it is essential that you compile both svlib\_pkg.sv and dpi/svlib\_dpi.c. Users who already have a DPI flow can integrate this compilation (and linking to a shared object file) by extending their existing flow in accordance with their tool vendor's guidelines. For new users and for experimenting with svlib, however, it is usually simplest to take advantage of the tool vendor's integrated one-step compile/link/run flow. To ease this flow there is a response file svlib.f in the src/ directory.

The placeholder <svlibRoot> is used to indicate the directory in which the svlib distribution has been placed.

In the following notes for three popular SystemVerilog simulators, all trademarks are acknowledged as the property of their respective owners.

## Command line for Mentor Graphics QuestaSim

Use the qverilog one-step flow, as follows:

qverilog +incdir+<svlibRoot>/src –f <svlibRoot>/src/svlib.f \

<user\_options> <user\_files>

## Command line for Cadence Incisive

Use the irun one-step flow, as follows:

irun +incdir+<svlibRoot>/src –f <svlibRoot>/src/svlib.f \

<user\_options> <user\_files>

## Command line for Synopsys VCS

Use the vcs one-step flow, as follows. Note the additional –LDFLAGS option that is required to link with an additional C library component that VCS does not link by default. The –R option is not mandatory. It simply causes the simv executable to start running automatically when compilation and linking is done.

vcs –sverilog –R +incdir+<svlibRoot>/src –f <svlibRoot>/src/svlib.f \

–LDFLAGS –lrt \

<user\_options> <user\_files>

To simplify this, we have created a file vcs.f that contains the required ‑LDFLAGS and ‑sverilog options along with the other contents of svlib.f, allowing you to use this alternative command line:

vcs–R +incdir+<svlibRoot>/src –f <svlibRoot>/src/vcs.f \

<user\_options> <user\_files>

# A few notes about general principles of use

svlib has been designed to be as un-selfish and un-intrusive as possible for use in any SystemVerilog environment. To achieve these goals it was necessary to introduce some underlying behaviors that are common to the whole library. It is important for users to be aware of these behaviors to avoid unpleasant surprises.

## Overall structure of the library

### The package

svlib is organized as a single SystemVerilog package named svlib\_pkg. Having compiled this package using their simulator of choice, users should then import this package into their own code so that the facilities of svlib are readily available.

The package should always be imported into the scope of any module or package that needs it, just after the module or package header. Do not be tempted to put your import statement at the outermost scope, outside any module or package - this is very bad practice and should always be avoided.

### Macros

In addition to the package, svlib has a few macros that are useful or necessary when using the package features. To make these macro definitions available, users should do

`include "svlib\_macros.svh"

at the outermost ($unit) scope of their code, outside any module or package. It is safe to include this file as often as you wish, because it is protected by sentinels so that it cannot be compiled twice. Consequently it is a good idea to provide this include at the top of any file that makes use of svlib facilities.

## Classes or package-level functions?

Almost all svlib functionality is provided by classes defined in the package. Users can create instances of these classes (see section below) as required. However, in some situations it is more convenient simply to call a function to do some work for you, rather than going to the trouble of creating an object, populating it with your source data, calling methods on it, and finally extracting your processed data from the object. Many svlib features are available in both forms, so that you can choose whichever is more convenient for you. For more details, see the documentation for each individual feature.

## Constructing svlib objects

Many parts of svlib use SystemVerilog classes. User code must of course create new objects of these class types in order to make use of svlib features. However, in order to avoid unexpected disturbance to random stability and to improve memory management efficiency,

* **it is very important that user code should *never* directly call the constructor, new(), of any svlib class.**

All svlib objects should be created using their built-in static create method, which is documented individually for each class.

This issue is discussed in more detail in the accompanying conference paper [1]. Fortunately, all major SystemVerilog simulators now offer full support for protected constructors. Consequently, all svlib class constructors are declared protected so that it is impossible to call them from user code.

## Handling errors

Occasionally, svlib functions may give rise to internal error conditions. This is especially likely if the function calls out to the C library, and there may be issues with memory allocation, file permissions or even the existence of files, and so on. Such errors are invariably passed back for handling within SystemVerilog, but the exact details of how the error is handled are somewhat under the programmer's control. The default behavior is for svlib to throw an assertion-style error, but more subtle control is available. See section 9 for details.

## Internal hidden features of svlib

Some features of svlib are designed to remain hidden from the user. This is done so that the package can maintain consistency of data on the C and SystemVerilog sides of the DPI. However, SystemVerilog does not provide any means to enforce this hiding in the language.

To help users to avoid accidentally breaking this encapsulation, the hidden aspects of svlib are placed in a separate package svlib\_private\_base\_pkg. User code should *never* import this package directly, and should *never* attempt to use any of the data, functions, classes or DPI imports in it.

## Naming conventions

As far as possible, a consistent naming scheme has been used throughout svlib. The naming scheme has been designed with an emphasis on consistency, so that it is easier to remember or guess what a given feature is called. We have also tried to keep names as short as possible for convenience, but sometimes this has not been possible - perhaps because of conflicts with SystemVerilog keywords or other commonly-used packages such as the UVM, or perhaps in order to keep some set of names unique across the whole package.

### Classes

Almost all svlib classes have short names that begin with an uppercase letter and are otherwise all-lowercase. For example, the class that represents a regular expression is Regex. There are a few exceptions. In particular, the configuration features have several classes that are named with a prefix cfg, such as cfgNode.

### Class methods

Methods of svlib classes are given names that are as short as possible while striving to remain memorable. Where a name is naturally made up of multiple words, the name is spelled in camelCase (no underscores, all but the first word capitalized). A typical example is the addNode function of class cfgNode.

### Prefixes for package-level functions

Many svlib functions fall naturally into groups. For example, there are several package-level functions concerned with operating system interaction. Those functions all have names beginning with the prefix sys, separated from the main part of the name by an underscore as in sys\_dayTime.

# String manipulation

The SystemVerilog language provides a number of string operations natively. However, experience has shown that the built-in set is not sufficient for many practical string processing tasks, and svlib provides a further set of operations to help meet these requirements.

String operations are, in most cases, available in two different forms, and a programmer is free to choose whichever form is more appropriate to their needs.

The first form is straightforward functions on string values, often (but not always) returning a string result. These functions are defined in the svlib package and consistently have names that begin with the prefix str\_.

The second form is methods of an object of class Str (note the uppercase S). The Str class is a wrapper for a SystemVerilog string, allowing a string to be passed around by reference and making some sequences of operations more convenient.

The obvious drawback to using Str objects rather than simple functions is that an object must be constructed before any operation is performed. This drawback is often outweighed by the efficiency and convenience of being able to offer a Str object, by reference, to many successive operations. As already noted, programmers are free to choose the representation that is most convenient for them. In practice, if you need to do just one operation on a string, the package level functions are likely to be most convenient. If you plan to do many successive operations on the same string, it's usually best to create a Str object and work on that.

## The Str class

### Methods that manage a Str object and its contents

static function Str create(string s = "");

function void set (string s);

function string get ();

function Str copy ();

function int len ();

As mentioned earlier, users must never invoke the new constructor of any svlib class. To construct a Str object you must call the Str::create() method. Optionally, you can pass to this method the initial value of the string.

At any time after creation you can update the contents of a Str object by using its set method, providing the new string value as argument. get returns the object's current contents as a native SystemVerilog string. len yields the length of the string.

copy creates and returns a completely new Str object having the same contents as the invoking object.

### Enumeration types

These two enumerations are used to specify various optional behaviors of some methods. side\_enum is used to specify which "side" of a string is to take part in various operations, notably the trim and pad operations. origin\_enum is used to specify which end of a string. START specifies the leftmost end of a string, END specifies the rightmost end. Further details of these options are described in the next sub-section.

### Appending a string to the end of an existing Str object

function void append(string s);

This function modifies the existing string contents of a Str object by appending the specified string to it, using simple string concatenation.

### Finding occurrences of a substring

function int first (string substr, int ignore=0);

function int last (string substr, int ignore=0);

first() searches for the first (leftmost) occurrence of the string substr within the object`s string contents. It returns the character position, within the original string, of the leftmost character of the sought substring. If the search is unsuccessful (there is no occurrence of substr within the original string) then the function returns ‑1. The search is an exact literal match; no wildcard or regular expression matching is performed.

Argument ignore specifies where the search is to begin. The default value (ignore=0) causes the whole string to be scanned, and the first match returned. If ignore is greater than zero, the search will begin at the specified character position. Regardless of the value of ignore, the return value after a successful match is the absolute start position of the match within the original string.

last behaves in a similar way, but it begins its scan from the rightmost end of the string, and therefore returns the last possible match if the sought substring occurs more than once in the original string. For last, the ignore argument specifies the number of characters at the rightmost end of the string that are to be ignored – it acts as though the last ignore characters were simply not present.

### Split and join operations

function string sjoin (qs elements);

function qs split (string splitset="", bit keepSplitters=0);

**NOTE**: the type name qs is internally defined within svlib to mean "queue of strings", but it is **not** available to user code. If you need a type name to represent queue-of-strings you should define your own; it will be fully compatible (*type-equivalent*) to qs. Alternatively you can simply declare variables that are queues of strings, and use them as argument and result variables.

The sjoin method (unfortunately it cannot be called join because that is a SystemVerilog keyword) uses the contents of the Str object as a "joiner" to assemble the elements of a queue of strings into a single string. It can be convenient for creating comma-separated lists, for example.

The split method takes the existing contents of the Str object (which remains unaltered) and breaks it into a queue of strings, using *single character* split-markers ("splitters"). The argument splitSet is a string, but it is treated as a set of individual characters; the string contents of the object will be split at every occurrence of any character in the set.

If splitset is the empty string (the default) then the result is a queue of single-character strings, with each element being one character of the original string.

If keepSplitters is true (1) and splitset is not the empty string, then the split characters will appear in their appropriate positions as individual members of the result queue. If keepSplitters is false (the default) the split characters wlll not appear in the result.

### Extracting substrings and the replace operation

function string range (int p, int n, origin\_enum origin=START);

function void replace(string rs, int p, int n, origin\_enum origin=START);

Method range provides a more versatile and consistent version of the SystemVerilog native string's substr operation. It does not suffer from substr's confusing and irregular behavior when one of the boundaries falls outside the string. In section 4.3 you can find details of how to use the p, n and origin arguments to specify a slice of a string in a consistent way. range simply returns the substring thus specified, as a regular SystemVerilog string.

Method replace identifies a substring in exactly the same way, and then replaces that substring with the replacement string rs, modifying the Str object's contents. The replace method is sufficiently flexible that it can do duty for various operations that are sometimes provided as separate functions. In particular:

* part of a string can be deleted (removed) by specifying an empty string for rs
* the append operation (which *is* provided separately, because it is so common) can be rewritten as   
  s.replace(append\_string, 0, 0, Str::END);
* similarly, a prefix can be added to an existing string thus:   
  s.replace(prefix\_string, 0, 0, Str::START);

There is *no* requirement for the replacement string rs to have the same length as the slice of original string that it is replacing.

### Adding and removing spaces at the start and end of a string

function void trim (side\_enum side=BOTH);

function void pad (int width, side\_enum side=BOTH);

Method trim removes leading and/or trailing white space from a string, modifying the existing contents of the Str object. Argument side specifies which end of the string is to have whitespace trimmed. If side is Str::LEFT, white space is removed from the left (leading) end of the string; RIGHT removes trailing space; BOTH removes whitespace from both ends. Finally, if NONE is specified, the function has no effect.

Whitespace is any of space, tab, newline, carriage-return, and nonbreaking space (ASCII code 160).

If the string consists entirely of whitespace and side is not NONE, the result will be an empty string.

Method pad adds enough leading and/or trailing spaces (always using the space character) to make the resulting string exactly width characters long. If the string is already larger than width, it is not changed (so the result can sometimes be *larger* than width). If side is NONE, the string is unchanged. Otherwise, spaces are added to the specified end of the string as required. If side is NONE, equal numbers of spaces are added to both sides (with one extra space on the right side if necessary). This method is useful for aligning text for printing in tabular format.

### Rendering a string as a SystemVerilog string literal

function string quote ();

This method returns the text that would be required to represent the object's string contents as a SystemVerilog string literal. The Str object's contents are not updated.

Quoting is performed by replacing special characters (backslash, double-quote, control characters etc) with their backslash-escaped equivalents, using the usual escape sequences such as \" and \n. The more general \xNN notation is used where necessary. Finally, the entire string is surrounded by a pair of string quotes ("). The result is always a complete, legal SystemVerilog string literal.

This function is intended to be useful for writing SystemVerilog programs that will write out SystemVerilog source code. It may also be useful when writing files in formats such as comma-separated value (CSV).

## Package-level string functions

function string str\_sjoin(qs elements, string joiner);

function string str\_trim(string s, Str::side\_enum side=Str::BOTH);

function string str\_pad(

string s, int width, Str::side\_enum side=Str::BOTH);

function string str\_quote(string s);

function string str\_replace(

string s, string rs,

int p, int n, Str::origin\_enum origin=Str::START);

Sometimes it is inconvenient to create and populate a Str object simply in order to peform one or two operations on it. To ease this, svlib provides a few string operations as package-level functions rather than class methods. In each case the function performs exactly the same actions as the corresponding method of class Str (without the str\_ prefix). In fact, these functions populate a Str object with the argument string s, perform the operation and return the appropriate result. The performance overhead is very small, because the library maintains a pool of Str objects ready for such operations.

## Specifying a string range

svlib uses a single consistent way of specifying substring ranges (slices of a string). It is used explicitly in methods range and replace of class Str (and the corresponding package-level functions str\_range and str\_replace), and is also used implicitly elsewhere. It has been designed to avoid some of the difficulties that are presented by the substr operation of SystemVerilog's native string type.

### Boundary is a position between characters

We do *not* specify string ranges in terms of character numbers, because this leads to awkward discontinuities when handling zero-length string slices. The boundary of a string slice is specified in terms of a position *between characters*. To illustrate this, consider the five-character string "Hello":

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Character number (index) | | | | | | | | | | | | **0** | | **1** | | **2** | | **3** | | **4** | |  | |  | |  | |  | |  | |
|  | |  | |  | |  | |  | |  | | **H** | | **e** | | **l** | | **l** | | **o** | |  | |  | |  | |  | |  | |
|  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |
|  | | … | | -4 | | -3 | | -2 | | -1 | | 0 | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | | … | |
|  | |  | |  | |  | |  | |  | | Boundary position relative to Str::START | | | | | | | | | | | |  | |  | |  | |  | |

Using this approach, we have a consistent way to specify the boundary position of a substring using argument p, with the origin argument specified as Str::START (the default). We also have a straightforward interpretation of boundary positions that are negative, or greater than the string's length.

Alternatively we can specify the boundary relative to the string's Str::END (the rightmost position). In this case, the interpretation of different p argument values is modified, with p counting leftwards from the right-hand (end) character boundary:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Character number (index) | | | | | | | | | | | | **0** | | **1** | | **2** | | **3** | | **4** | |  | |  | |  | |  | |  | |
|  | |  | |  | |  | |  | |  | | **H** | | **e** | | **l** | | **l** | | **o** | |  | |  | |  | |  | |  | |
|  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  | |
|  | | … | | 9 | | 8 | | 7 | | 6 | | 5 | | 4 | | 3 | | 2 | | 1 | | 0 | | -1 | | -2 | | -3 | | … | |
|  | |  | |  | |  | |  | |  | | Boundary position relative to Str::END | | | | | | | | | | | |  | |  | |  | |  | |

Once again, we have a straightforward interpretation of out-of-range values for p. With origin specified as Str::END, however, we can specify trailing (suffix) parts of the string without needing to worry about exactly how long the string is.

### Interpretation of the length argument (n)

Having established a starting (boundary) point for our string range, we now need to consider the length of slice that we wish to take. The interpretation of this argument n is not in any way affected by the origin value. It specifies how far to move from the p-specified boundary in order to find the second boundary of our substring. Positive values of n describe movement to the right. Negative values describe movement to the left.

# Regular expression processing

svlib supports regular expression matching and substitution within strings.

This document does not describe how to write regular expressions. svlib uses the "extended regular expression" dialect of the C library's POSIX-compliant regular expression subsystem, and you can find full details of how to write regular expressions in this dialect by consulting the man-page man 7 regex or any of the numerous online regular expression tutorials. The regex dialect is in almost all respects the same as that used by the Unix/Linux command egrep.

After a regular expression match has succeeded, there are many different things that a user might wish to do with the results. To support this variety of needs, regular expressions in svlib are invariably represented as an object of class Regex. You can call the query functions in a Regex object to find out about the matches that were discovered by the last match attempt, and perform substitution operations.

Often, you need to apply the same expression multiple times to a given string – typically because you want to locate not just the first, but every occurrence of a match within the string. To make this more efficient and convenient, regular expression matching works not on a native SystemVerilog string, but on a Str object (see section ).

The basic steps in performing a regular expression match are:

* Construct a Str object containing the string that you wish to examine. (In practice it's likely that this object already exists because you have already been working on the string in question.)
* Construct a Regex object and set it up to contain your chosen regular expression, together with options such as case sensitivity and end-of-line handling.
* Call the test method of the Regex object to perform the match, returning information about whether the match succeeded (found a match) or failed.
* Call other methods of the Regex object to retrieve more detailed results such as matches corresponding to parenthesized groups, or to perform substitution operations.

Convenience functions exist to simplify some of these steps in situations where only standard matching operations are required.

First we describe the more flexible approach in which objects are created explicitly. Later in this section we cover the package-level convenience functions.

## Constructing and configuring a Regex object

static function Regex Regex::create(string re="", int opts=0);

function void setRE(string re);

function void setOpts(int opts);

To perform regular expression matching it is first necessary to construct a Regex object and set it up appropriately. This is done in the usual way by means of the Regex class's static create method (see section ):

Regex myRE = Regex::create();

The newly created object should then be set up with your desired regular expression and options so that searches can later be performed. Setup is accomplished using the setRE and setOpts methods. Alternatively, it is possible to pass in the regular expression string and options values as arguments of the create method.

### Setting the regular expression

The regular expression that you wish to use is of course a string itself. By calling the setRE method of an existing Regex object you can set up the object's regular expression string.

Suppose, for example, that you wish to search for a string of any three uppercase letters. Having created the Regex object as shown above, you would then supply the regular expression string thus:

myRE.setRE("[A-Z]{3}");

Some care is required when specifying the regular expression string. Many regular expressions require backslash-escapes to indicate special characters, or to remove special regex meaning from characters such as $ or square brackets. Because the expression is typically specified as a string literal, you must be aware that SystemVerilog quoted strings also use backslash as an escape character. This usually means that you need to specify each backslash twice. For example, a regex matching one or more dollar-signs is \$+ but to write that as a SystemVerilog string literal you must specify "\\$+" as in the following example:

myRE.setRE("\\$+");

Within a quoted string literal, SystemVerilog uses the double backslash to denote a single backslash character. There is one especially unpleasant case of this backslash escape problem. Suppose you wish to write a regex that matches a single backslash character. The regular expression you need is \\ (two backslashes) - but to express that as a SystemVerilog string literal requires *four* consecutive backslashes!

### Configuring matching options

Before you use a regular expression, you can configure some optional features of its operation. The current version of svlib supports POSIX-standard extended regular expressions, which have only two such optional features: case insensitivity, and end-of-line matching. By default, matching is case-sensitive and end-of-line within a string is treated like any other character. By calling a Regex object's setOpts method you can configure these two options, passing an integer value that is the logical OR of a series of bit flags. The available flags are:

* NOCASE for case-insensitive matching; zero for case-sensitive matching
* NOLINE to enable special treatment of end-of-line; zero for no special treatment

If NOCASE is enabled, then matching makes no distinction between upper and lower-case letters, either in the regular expression itself or in the string being tested.

If NOLINE is enabled, end-of-line characters are treated specially in the following ways:

* The match-any-character wildcard '.' (period) will not match an end-of-line character.
* The anchors ^ (start) and $ (end) will match not only the beginning and end of the whole string being tested, but also the beginning and end of any physical line in the string. ^ will match the anchor point just after any end-of-line, and $ will match the anchor point just before any end-of-line.

The options flags may be changed at any time, and will affect any match operations performed subsequently; they do not affect the stored match values for a match that has already been performed.

### Setting and configuring the regular expression at creation

As you can see from the create function prototype, creation and setup can be performed together by supplying the regular expression string and the options value as optional arguments to create.

## Providing a string for testing against the RE

function void Regex::setStr(Str s);

function void Regex::setStrContents(string s);

The string to be tested by the regular expression must be supplied as a Str object (see section ). Give your Regex object a reference to this Str object by calling the Regex object's setStr or setStrContents method. As described later, there are alternative ways to achieve this that may be more convenient in some situations.

You can call these methods at any time. They do not affect the regular expression string or the options that have been configured for the Regex object, nor do they disturb the stored matches from any earlier match attempts. However, the next match attempt will of course apply to the new string.

If you do not already have a Str object containing your test string, it is convenient to construct the Str object implicitly by passing a regular SystemVerilog string to the setStrContents method:

myRE.setStrContents("the string you wish to test");

Of course, any string expression is appropriate as the argument - it does not have to be a literal.

## Testing the string against the RE

function int test(Str s, int startPos=0);

function int retest(int startPos);

To discover whether a regular expression matches a string, call the test or retest methods. The difference is that test allows you to pass in a new Str object containing the string you wish to test, avoiding the need to invoke setStr or setStrContents. By contrast, retest performs a further match test on the existing Str object held by the Regex. In both cases, the startPos argument specifies the starting point of the match.

The result value is 1 if the match succeeded, zero if there was no match or if there was some error. Error handling is described in section 5.6 below.

Matching always ignores the first startPos characters of the string. This allows multiple matches to be found by repeatedly calling retest with progressively increasing startPos values until it returns zero indicating that there are no further matches.

## Retrieving matches and sub-matches

After using a Regex object to perform a successful match, you can call methods of the object to get information about the various matches and sub-matches that were found by the match attempt.

function int getMatchCount();

function string getMatchString(int m);

function int getMatchStart (int m);

function int getMatchLength(int m);

With the exception of getMatchCount, these methods extract and return the match specified by the argument m. A value of zero indicates the whole regular expression match. Values between 1 and 9 correspond to strings that matched sub-expression groups in the regular expression, numbered in left-to-right order of their opening left parenthesis in the usual way.

* getMatchCount returns the number of matches provided by the regular expression. If the most recent match failed, this function returns zero. Otherwise it returns the total number of available matches and submatches (i.e. one larger than the number of capturing groups in the regex). Note that this information is based on the syntax of the regex, and is *not* influenced by what it matched. It always reports the number of *possible* matches, and of course some of those matches may be empty or nonexistent depending on exactly what was matched. If you call this method on a Regex object that has never been used to do a match, it will return ‑1.
* getMatchString returns the matching string itself (a slice of the original string).
* getMatchStart returns the left-most character position of the match.
* getMatchLength returns the number of characters in the match.

If you call any of these functions on a Regex object whose most recent match was unsuccessful, or if you supply a value of m that is larger than the number of sub-matches in the original regular expression, then there will be no error, but:

* getMatchString returns an empty string.
* getMatchStart returns -1.
* getMatchLength returns zero.

getMatchString(m) is always exactly equivalent to calling the range method on the Str object containing the string that was searched:

range(getMatchStart(m), getMatchLength(m))

## Substitution (search-and-replace)

function int Regex::subst(string substStr, int startPos = 0);

function int Regex::substAll(string substStr, int startPos = 0);

The Regex class supports substitution, in which the part of a string that matched your regular expression is replaced with some other string. As usual in regular expression search-and-replace, the replacement string can contain matches and sub-matches taken from the regular expression.

Methods subst and substAll are called on an existing Regex object, whose source string, regular expression and options must already have been set up.

subst finds and replaces the first match within the Regex object's source string, starting from startPos. substAll finds and replaces every match, again starting from character position startPos. The source string is updated to reflect the substitutions, and (as usual) can be retrieved as a Str object using the getStr method, or as a SystemVerilog string using getStrContents.

The replacement string substStr can be a simple string value. However, it can also contain placeholders that will be replaced with match values taken from the corresponding regular expression match. These placeholders, often indicated by markers such as \1 in common regex dialects, are indicated in svlib using a dollar sign followed by a single digit. $0 refers to the whole match that was found by the regular expression (you can also write $\_ or $& if you prefer; they mean exactly the same thing). Sub-matches (up to a maximum of nine) are indicated by $1..$9. A dollar sign followed by any other character (including $ itself) is replaced with the character after the $ - so, for example, $R would be replaced by a single letter R, and $$ by a single dollar sign.

## Errors in regular expression matching

function int Regex::getError();

function string Regex::getErrorString();

function void Regex::userErrorHandling(bit suppressAssertions);

If the regular expression is valid (syntactically legal) but did not match anything in the input string, then there is no error condition and the retest method returns zero to indicate that there was no match. Subsequent calls to getMatchCount will return zero.

However, it is sometimes possible for regex matching to give rise to error conditions. The most likely reason is that the regular expression string itself is ill-formed and cannot be used, perhaps because it contains unmatched parentheses or other illegal features. Much more rarely, there may be internal errors in the regular expression processor such as memory overflow. In all these cases, svlib has no choice but to yield an error. The matching process will return zero, just as for an unsuccessful match, but it will also cause an assertion-style error unless you have configured the Regex object to suppress errors using the userErrorHandling method.

Regardless of the user error handling configuration, the getError and getErrorString methods can be called to get information about the error (if any) from the most recent match operation. If called before any match operation has been performed, these methods cause the regex to be tested for legality, and return a corresponding result. If the regular expression is valid and matching proceeded without memory overflow or other internal errors, getError will return zero. A nonzero result indicates that there was an error, and getErrorString can then be called to obtain a more verbose human-readable description of the error.

# File pathname manipulation

Create a Pathname object, optionally setting it to contain a given file path:

static function Pathname create(string s = "");

Update a Pathname object with a new path value:

function void set (string path);

function void append (string tail);

function void appendPN (Pathname tailPN);

Extract various components of a pathname, always returning a simple string:

function string get ();

function string dirname (int backsteps=1);

function string extension ();

function string basename ();

function string tail (int backsteps=1);

function string volume ();

Query whether a pathname is absolute (begins with /) or not:

function bit isAbsolute ();

Create a new Pathname object with identical contents to the invoking object:

function Pathname copy();

The Pathname class provides a convenient way to store and manipulate a file name. As the filename is manipulated, its integrity is maintained.

For example, consider the following sequence of activity. First, the path to a certain directory is stored in a Pathname object. Note the doubled path-separator "//" in the middle of the name string, and the absence of separator after the final directory name component. Both these features are completely legal, but can easily confuse simple string-based processing of pathnames:

Pathname pn = Pathname::create("/user/jb//myDir");

This step creates an object of Pathname type, with the given path already saved in it. Next, we append a further path to the current value of pn:

pn.append("subDir/myFile.txt");

If this string were simply appended to the original path name, the result would be nonsense because there was no / separator at the end of the original path. However, the Pathname object understands this, and correctly concatenates the directory components – as we can see by asking the Pathname object to provide the new path as a string:

$display(pn.get()); // *displays* /user/jb/myDir/subDir/myFile.txt

Note that the doubled separator has been correctly flattened to a single forward-slash, and a separator has been correctly added between the two directory components.

Other manipulations will always return a string, without affecting the stored path value. For example, suppose we wished to find only the trailing filename part of this path, and its extension:

$display(pn.tail()); // *displays* myFile.txt

$display(pn.extension()); // *displays* .txt

$display(pn.get()); // *displays* /user/jb/myDir/subDir/myFile.txt

Given this behavior, if you wish to use any of these functions to modify a Pathname object you will need to use the set method to update your object with the modified value. In the following example, we use the dirname method to back up 2 levels of path hierarchy:

pn.set( pn.dirname(2) );

$display(pn.get()); // *displays* /user/jb/myDir

## Detailed descriptions of the methods

set updates the object with a new pathname. The pathname is normalized (multiple separators are collapsed to a single separator, and any trailing separator is removed).

get returns the pathname as a string, in the normalized form.

tail returns the last component of the pathname, and dirname returns the path with the last component removed. Both methods take an optional backsteps argument (default = 1) specifying how many components to back up:

$display(pn.tail(3)); // *displays* myDir/subDir/myFile.txt

extension returns the part of the pathname after the last period character in the last component, including the period character itself. If there is no period character in the last component, extension returns an empty string. basename returns the pathname with the extension, if any, removed.

isAbsolute returns a bit indicating whether the pathname is absolute.

volume returns the first component of an absolute pathname or, for a relative pathname, what the first component would be if the pathname were to be made absolute. On Unix and Linux platforms, volume invariably returns the single character /.

append and appendPN update the object's pathname by appending a pathname to its tail. They have the same behavior, but updatePN takes a second Pathname object as its argument. If the added pathname is absolute, then the original pathname is discarded and the updated pathname becomes the same as the argument.

## Restrictions and special cases

The relative-directory path components . and .. are not treated specially in any way. This design decision allows users to specify relative paths with no risk of the Pathname object corrupting the user's original intent.

Shell special characters such as ~, and environment variables such as $LD\_LIBRARY\_PATH, get no special treatment and are not expanded. They simply remain in the path as component strings.

For the purposes of backstep processing by dirname and tail, the volume indicator / of a relative pathname is treated as a distinct pathname component. For example:

pn.set("/short/absolute/path");

$display(pn.dirname(2)); // "/short"

$display(pn.dirname(3)); // "/"

$display(pn.dirname(4)); // ""

If the backstep argument supplied to dirname or tail is negative or zero, dirname returns the entire path (exactly like get) and tail returns the empty string. If the backstep argument is greater than the number of components, dirname returns the empty string and tail returns the entire path.

## Important note

The Pathname object and its methods *never* make any access to the file system. They merely process strings in a special way that conforms to file naming conventions. You are free to manipulate a completely imaginary, non-existent filename if you wish.

# Querying properties of files

## Struct definitions for file properties

The following struct definitions are useful for extracting file properties (such as "is this file a directory") from the file mode value returned by the file\_mode function described later in this section.

typedef struct packed {

bit r;

bit w;

bit x;

} sys\_fileRWX\_s;

typedef struct packed {

bit setUID;

bit setGID;

bit sticky;

sys\_fileRWX\_s owner;

sys\_fileRWX\_s group;

sys\_fileRWX\_s others;

} sys\_filePermissions\_s;

typedef enum bit [3:0] {

fTypeFifo = 4'h1,

fTypeCharDev = 4'h2,

fTypeDir = 4'h4,

fTypeBlkDev = 4'h6,

fTypeFile = 4'h8,

fTypeSymLink = 4'hA,

fTypeSocket = 4'hC

} sys\_fileType\_enum;

typedef struct packed {

sys\_fileType\_enum fType;

sys\_filePermissions\_s fPermissions;

} sys\_fileMode\_s;

typedef struct {

longint mtime;

longint atime;

longint ctime;

longint size;

int unsigned uid;

int unsigned gid;

sys\_fileMode\_s mode;

} sys\_fileStat\_s;

## Query functions

Each of these package-level functions interrogates a file to find certain properties such as timestamp or file kind. The file is specified by its string pathname. If the file does not exist, a default value (usually zero) is returned, and an error is thrown as described in section 9.

All these functions (except file\_accessible) also take an argument asLink. This argument controls the functions' behavior if the path specifies a symbolic link. If asLink is false (the default), then the symbolic link is followed and the query function examines the file that is referenced by that symbolic link. However, if asLink is set (true), the query function examines the symbolic link itself.

function automatic longint file\_mTime(string path, bit asLink=0);

function automatic longint file\_aTime(string path, bit asLink=0);

function automatic longint file\_cTime(string path, bit asLink=0);

function automatic longint file\_size(string path, bit asLink=0);

function automatic sys\_fileMode\_s file\_mode(string path, bit asLink=0);

function automatic bit file\_accessible(

string path, sys\_fileRWX\_s mode = 0);

file\_mTime/aTime/cTime query the file's timestamps: modification time, accessed time, and creation time.

file\_size returns the file's size in bytes.

file\_mode returns a sys\_fileMode\_s struct (see section 7.1) containing various properties of the file such as its permissions, group and user ownership, and its file type. In particular, it may be useful to query whether a file is or is not a directory:

sys\_fileMode\_s fMode;

fMode = file\_mode("maybe/directory");

if (fMode.fType == fTypeDir)

$display("It's a directory");

file\_accessible allows you to determine whether the current running process is able to access a file in different ways. For example, to determine if you are able to read a file, you need to arrange that the r bit of the sys\_fileRWX\_s argument is set:

if (file\_accessible("maybe/readable", '{r:1, w:0, x:0}))

$display("OK to read that file");

As a special case, if *none* of the access mode bits are set (the default), the function queries whether the file exists:

if (file\_accessible("maybe/exists"))

$display("the file exists");

To get a list of all files in a directory, see function sys\_fileGlob described in section 8.

# Operating system queries

## Wall-clock time and human-readable time formatting

function automatic longint sys\_dayTime();

function automatic string sys\_formatTime(

input longint epochSeconds,

input string format

);

All times returned by the file timestamp query functions are in the usual Unix format of seconds since the beginning of 1970 (the "epoch"). In a similar way, sys\_dayTime returns the current wall-clock time in that same format.

sys\_formatTime uses the C library's time formatting features to create human-readable time strings from any seconds-since-1970 epoch time. The format string works rather like the format string for $sformatf or $display (it can include arbitrary plain text along with its %X format placeholders) but the format placeholders are very different. They are described in full by the Unix/Linux man page man 3 strftime.

## High-resolution timer

function automatic longint unsigned sys\_nsTime();

sys\_nsTime returns the highest available resolution real-time clock, scaled to nanoseconds. The exact resolution of this clock is not guaranteed, although 256ns resolution appears to be common on x86 Linux systems. It may be useful for performance measurements.

## Directory queries

function automatic qs sys\_fileGlob(string wildPath);

function automatic string sys\_getCwd();

sys\_getCwd returns the full path of the current working directory.

sys\_fileGlob returns a queue of strings containing all files that match the shell glob pattern wildPath, using the normal shell wildcard characters \* and ?. It provides a convenient way to determine the files that exist in a certain directory.

## Environment variables

function automatic string sys\_getEnv(string envVar);

function automatic bit sys\_hasEnv(string envVar);

sys\_getEnv returns the value of the chosen environment variable, or the empty string if the variable does not exist. sys\_hasEnv returns 1 if the chosen environment variable exists, 0 if it does not. Note that an empty string result from sys\_getEnv is ambiguous, because it is possible (and, indeed, quite useful) to define an environment variable that has no value.

# svlib error management

function automatic svlibErrorManager error\_getManager();

function automatic void error\_userHandling(bit user, bit setDefault=0);

function automatic int error\_getLast(bit clear = 1);

function automatic string error\_text(int err=0);

function automatic string error\_details();

function automatic string error\_fullMessage();

function automatic qs error\_debugReport();

# Document Object Model

virtual class svlibCfgBase extends svlibBase;

pure virtual function cfgObjKind\_e kind();

virtual function string getName(); return nam

virtual function string getLastErrorDetails(); return las

virtual function cfgError\_e getLastError(); return las

virtual function string kindStr();

endclass

virtual class cfgScalar extends svlibCfgBase;

pure virtual function string str();

pure virtual function bit scan(string s);

endclass

virtual class cfgNode extends svlibCfgBase;

pure virtual function string sformat(int indent = 0);

pure virtual function cfgNode childByName(string idx);

function cfgNode lookup(string path);

virtual function void addNode(cfgNode nd);

virtual function cfgNode getFoundNode(); return foundNode;

virtual function string getFoundPath(); return foundPath;

virtual function cfgNode getParent(); return parent;

endclass

# Utilities for enumeration types

class EnumUtils #(type ENUM = int);

static function ENUM EnumUtils::from\_name (string s);

static function int EnumUtils::pos (BASE b);

static function bit EnumUtils::has\_name (string s);

static function bit EnumUtils::has\_value (BASE b);

static function qe EnumUtils::all\_values ();

static function ENUM EnumUtils::match(BASE b, bit requireUnique = 0);

static function int EnumUtils::maxNameLength();

endclass

The EnumUtils class provides various utility methods designed to help with manipulation of enumerated types and their values. The class is parameterized for the enumerated type it will manipulate, and the type parameter ENUM *must* be overridden with an actual enumerated type in your code; if you try to use the default int parameterization there will be many elaboration-time errors. Ideally the ENUM parameter should have no default type; this would lead to much clearer error messages if a user forgets to provide appropriate type parameterization. However, not all simulators support this feature at the time of writing.

In practice it is usually easiest to create a typedef to give a simple short name for a type-overridden specialization of EnumUtils, as in the following example:

// User's enumeration type

typedef enum logic [3:0] {

RED = 4'b1010, GREEN = 4'b0101, ANY = 4'bxxxx

} shade\_enum;

// Typedef for specialization of EnumUtils

typedef EnumUtils#(shade\_enum) shadeUtils;

The BASE type used in some methods of EnumUtils is a placeholder for the underlying integral data type of the enum. In our example it is logic [3:0].

## All methods of EnumUtils are static

Because the EnumUtils class provides services related to an enumerated *type*, there is no reason for the class ever to be instanced. All its methods are static and can be called, with an appropriate class scope prefix, even when no object of the corresponding class type has been created.

Because of the need to use the class's name as a scope prefix, it is usually easiest to create a typedef to give a simple short name for each type-overridden specialization of EnumUtils, as in the following example:

// User's enumeration type

typedef enum logic [3:0] {

RED = 4'b1010, GREEN = 4'b0101, DF = 4'b11x1

} shade\_enum;

// Typedef for specialization of EnumUtils

typedef EnumUtils#(shade\_enum) shadeUtils;

The BASE type used in some methods of EnumUtils is a placeholder for the underlying integral data type of the enum. In our example it is logic [3:0].

## Detailed descriptions of the methods

### Lookup based on string name

Although SystemVerilog allows you to determine the string name of the label corresponding to a value of enumerated type, using its .name method, there is no built-in means to go the other way: given a string, find the enumeration value that it matches. svlib provides support for this requirement.

hasName allows you to determine whether a given string name is one of the set of available enumeration labels of a given type. For example, given the type declaration shade\_enum in section 11 above:

* shadeUtils::hasName("rubbish") returns zero, because the label is not one of the names of type shade\_enum
* shadeUtils::hasName("RED") returns 1, because the name RED exists in the type shade\_enum
* shadeUtils::fromName("RED") returns the value RED (4'b1010)
* shadeUtils::fromName("rubbish") returns the value 4'bxxxx, the default (initialization) value of a member of the enum. Any attempt such as this to find the value from a non-existent name will yield the enum's default value. This may or may not be a legal value of the enum. It will be 'x if the enum is 4-state and '0 if the enum is 2-state.

### Lookup based on underlying value

Although it is always possible in SystemVerilog to cast an integral value to an enumeration, such casting can sometimes yield a non-existent enumeration value. Function hasValue easily allows you to check whether a given integral value is a member of the value-set of an enumeration type, yielding 1 if the specified value exists in the enumeration, and zero if it does not exist.

The values of an enumerated type are not always specified in ascending numerical order. Occasionally, a value's position (rank) in the specified order may be of interest. To discover the rank order of an enumeration value within the type, use method pos on either the enumeration or its underlying numeric value. For example, in our type shade\_enum, value GREEN (4'b0101) is the second value in the list, and therefore has rank 1. Consequently:

* shadeUtils::pos(GREEN) returns 1
* shadeUtils::pos(4'b0101) returns 1
* shadeUtils::pos(4'b0011) returns ‑1, because the value 4'b0011 does not appear in our enumerated type.

Ranks are numbered from 0 to N-1 where N is the number of enumeration values in the type. The pos method returns ‑1 when its argument value does not appear in the enumerated type.

### Getting a list of all values in the enumerated type

The allValues method returns a queue of values of the enumerated type, containing all the enumerated values in their declaration order. The placeholder type name qe stands for "queue of enumerations" so, given the declarations already supplied, the following code fragment would be legal:

shade\_enum se[$];

se = shadeUtils::allValues();

foreach (se[i]) $display("se[%0d] = %s", i, se[i].name);

The results would be

se[0] = RED

se[1] = GREEN

se[2] = DF

Note that the placeholder type qe is *not* visible to user code; you must instead create your own type that is a queue of the required enumeration type.

### Wildcard matching of a value to an enumeration

The ability to put X or Z values in enumerations can occasionally be useful to indicate that certain bit positions in the enumeration are don't care. However, the usefulness of this trick is limited because it's awkward to find whether a given integral value matches one of your enums. The match function can help with this task. Given any integral value, it determines which enumeration matches it, using ==? wildcard matching between your integral value (on the left) and the enumeration values (on the right). Sometimes a value can match more than one enumeration. If this occurs, match will return the first match in the list – unless you specify unique matching by setting the requireUnique argument to 1.

If no match is found, or if requireUnique has been specified and there is more than one match:

* match returns the argument value b, cast to the enum type
* the function throws an error, which (as usual) can be handled by the user if per-process user error handling has been specified as described in section 9.

For example, suppose we have opcodes for a simple microprocessor, defined by this enum:

typedef enum logic [7:0] {

ADD = 8'b00\_xxx\_xxx, // 2-bit opcode, two 3-bit register addresses

SUB = 8'b01\_xxx\_xxx, // similar

...

SHIFT = 8'b11\_xxx\_00x, // 3-bit reg adrs, 1-bit shift direction

...

} opcode\_enum;

Now we observe the processor's instruction register, and we wish to decide which opcode is present. A simple match operation won't work, because of the varying bit positions of the wildcard Xs. However, the match method of EnumUtils will do the job, effectively scanning through all possible enum values and comparing them with the instruction value using ==? comparison:

bit [7:0] instruction;

opcode\_enum opcode;

// pick value out of the instruction register somehow

instruction = ...;

// find which opcode it represents

opcode = EnumUtils#(opcode\_enum)::match(instruction);

Note that in this example we have directly used the appropriate specialization of EnumUtils, without creating any named typedef. Either method is appropriate; you are free to choose whichever is clearer or more convenient in your code.

# Utility macros

The library provides a small number of utility macros.

## foreach\_enum

It is sometimes useful to iterate over the set of values in an enumerated type. Although this is not difficult to do in SystemVerilog, the required code pattern is somewhat clumsy and obscures the intent of the code. To ease this problem, svlib offers a macro that provides iteration over an enumeration in a similar style to a foreach-loop.

typedef enum {FIRST = 1, SECOND = 5, THIRD = 3} ordinal\_enum;

...

`foreach\_enum(ordinal\_enum, value)

$display("%s has integral value %0d", value.name, value);

The variable (value in this example) is declared, locally, as a variable of the enum type, just as the iteration variable in a foreach-loop is declared locally. You can choose any name you wish for this variable, so long as it is a legal SystemVerilog identifier. The output from this example will be:

FIRST has integral value 1

SECOND has integral value 5

THIRD has integral value 3

Like any other loop construct, foreach\_enum can be used with begin..end. Additionally, you can provide a third argument which is a locally declared variable of int type; this variable simply counts from 0 to num-1 (where num is the number of named values in the enumeration type):

`foreach\_enum(ordinal\_enum, value, j) begin

if (j==0)

$display("Skipping the first value");

else

$display("Value at position %0d is %s(%0d)",

j, value.name, value);

end

The output from that example is:

Skipping the first value

Value at position 1 is SECOND(5)

Value at position 2 is THIRD(3)

## foreach\_line

The foreach\_line macro is simply syntactic sugar for looping over every line in a plain-text file. The file is assumed to have been already opened for reading, and the macro does not close the file when it's done. The macro acts like a foreach loop, and locally declares two new variables: one string to hold each line in turn, and one int to hold the line number within the file. Each line is presented *with* its trailing end-of-line character, if any (you can easily remove that character with the str\_trim function).

int fileID;

fileID = $fopen("some\_text\_file", "r");

if (fileID == 0) ... // failed to open the file – error

// Now the file is open, we can scan the lines in it

`foreach\_line(fileID, line, lineNum) begin

$display("Line %2d: \"%s\"", lineNum, line);

end

# Worked examples