CAPSIM® Text Mode
User's Guide

Version 6

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Introduction

Capsim has been developed by XCAD Corporation. The predecessor and original model of CAPSIM was BLOSIM. BLOSIM is a signal processing simulation program, originally developed at the University of California, Berkeley, 1985. The primary authors were D. G. Messerschmitt and D. J. Hait. Since arrival at NCSU in November 1987, the program has been extensively debugged and expanded. Capsim was completely remodeled, enhanced with new commands, and improved by XCAD Corporation as will be described shortly[1]. The person-hours spent on this task have made Capsim a vast improvement over the original in user convenience, capability and reliability (see appendix A for a comparison between Capsim V5 and Blosim v.3). In the latest version, V6, all blocks are written in XML and are transformed into C code using XSLT. Furthermore, the TCL interpreter has been incorporated into Capsim with full interaction with the block diagram topology, supporting iterative simulations. Capsim simulations can set TCL variables that are accessible to TCL scripts. TCL scripts can set and change block parameters and topology arguments. These are major enhancements to Capsim and increase its power and capabilities. They also allow parameters to be expressed in terms of mathematical expressions without limit. Also with V6 the term *star* is no longer used to refer to *blocks*. Also instead of *Galaxy* we use *HBlock* for hierarchical blocks.

About the Manual

This manual provides a tutorial introduction to ***Text Mode Capsim*** and is a complete reference manual.

The original BLOSIM tutorial [1] and reference manual[2] including the Blockgaze manual [3] have proven to be excellent guides in terms of getting students and faculty up to speed in using BLOSIM at NC State Univ. Therefore, XCAD has used all three in writing this manual. Sections were deleted or added as necessary to reflect Capsim commands and

[1]The principal authors are Sasan Ardalan of the Dept. of Electrical and Computer Engineering, North Carolina State Univertsity, Raleigh, NC , and Jim Faber, Colorado State University, Fort Collins, Co.

procedures. New sections have been added describing TCL interpreter support and scripting.

Basic CAPSIM Design

Simulation topologies are constructed from any number of blocks. Each block can be connected with input and/or output buffers over which data samples are passed. A block is described by a subroutine in C-code. A hierarchical block called an *HBlock* is described by a "topology file", which is a readable text file description of connected blocks and sub-HBlocks.

By connecting blocks together as a block diagram, one can create very large simulations. Since multiple instances of the same block or HBlock can be used, the system is completely hierarchical; simulations can be designed and proven in pieces. Since block design is constrained by certain rules, several engineers can contribute their designs to a library of blocks and HBlocks which can be readily transported.

References

[1] D. J. Hait and D. G. Messerschmitt, *A BLOSIM Tutorial ,* UC Berkeley
[2] D. J. Hait and D. G. Messerschmitt, *BLOSIM Reference Manual,* UC Berkeley
[3] D. G. Messerschmitt, *BLOCKGAZE User's Manual (in print),* UC Berkeley

Capsim Text Mode Tutorial

1.0 A CAPSIM Text Mode Tutorial

1.1 Introduction

This tutorial introduces you to CAPSIM, a signal processing simulation program. CAPSIM can be used to design simulations for a large number of signal processing and communications applications, with a minimum of programming overhead. The sections below will guide you through the use of CAPSIM, without graphics, to create a few very simple simulations. This tutorial parallels and enhances [1] to cover the new features and capabilities of CAPSIM.

In this tutorial, whenever you are asked to type in text at your terminal or workstation, the text is shown in **bold-faced type.** This is to prevent you from confusing it with CAPSIM's output messages, which are shown in a normal font. Naturally, when you use CAPSIM, everything will be displayed on your terminal in the same type style.

1.2 Invoking CAPSIM

Before you start, you should make sure that CAPSIM has been installed in an appropriate directory on your system . To invoke the non-graphical CAPSIM, type

% **capsim -b**

from the Shell. The system will respond

Capsim Topology file: universe.t

followed by the prompt

Capsim[1]>

CAPSIM is now ready to accept commands. Notice that the command number appears with the Capsim prompt. In the following we will ignore the number although it will appear on the terminal. Capsim has a history mechanism for recalling commands and the command number will come in handy.

1.3 Blocks, HBlocks, and the Universe

In CAPSIM, you construct simulations out of a number of building blocks. These building blocks, known as *blocks*, correspond to small pieces of simulation programming. Each block has inputs and/or outputs over which data samples are passed. By connecting these blocks together in a way analogous to creating a block diagram, you can execute very large simulations. Since blocks can be used from simulation to simulation, you can use CAPSIM to build up a library of blocks that is suited to your own application needs. To help get you started, CAPSIM is supplied with a large library of blocks object code that is automatically loaded into memory when CAPSIM is invoked.

You can also combine building blocks together to form larger building blocks, which can in turn be used to create more advanced simulations. Building blocks that are created out of smaller ones in this way are known as *HBlocks*. These concepts will become clearer as we go on.

The collection of blocks and HBlocks in a simulation is collectively known as the *universe*. When you first invoke CAPSIM, the universe is empty. To create a CAPSIM simulation, you must first bring copies of the blocks and HBlocks that you are going to use into the universe. You can then connect these blocks and HBlocks together; that is, you specify the way data samples are to flow between them. The names of the blocks and HBlocks, and the specification of how they are

interconnected, is known as a *topology*. A topology can be stored in a file, so that the arrangement of the universe can be saved for later simulations. Once you have created a universe, either by creating it with CAPSIM commands or loading its topology from a file, you can run the simulation to get the desired results. A *universe* is the top level of a simulation hierarchy.

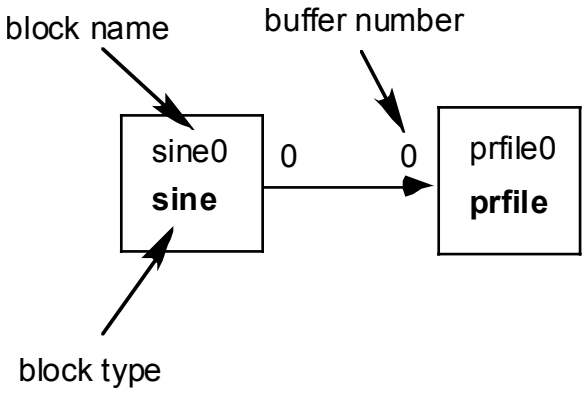


Figure 1.1

1.4 The Standard Block Library

To get started, the first thing you should do is see what blocks can be created out of CAPSIM's standard library. To do this type

```
Capsim> display s
```

CAPSIM will display a list of *modules* that were loaded as part of its standard library. A block can be created by specifying the appropriate module. Find the modules **impulse** and **prfile** in this list. You should realize that even though these program segments are in the standard library, there is nothing special about them. They are identical in format to the code you will be writing yourself later on.

1.5 Parameters

Before you actually use one of these blocks, let's talk a bit about *parameters*. A parameter is a value that you specify to affect the way the block works. For example, the library module **impulse** is used to generate an impulse data sequence, that is, a 1 sample followed by a number of 0 samples. This number of trailing 0's is not fixed anywhere in the program for **impulse**, but is specified by a parameter to an **impulse** block. In fact, you can create several blocks based on **impulse**, with each block having a different parameter value. In this manner, simulation programming can be written in a very general manner, with parameters not set until the time they are used.

HBlocks can also take parameters. In this case, the HBlock holds the parameter values so that the blocks which make up the HBlock can use them. A special parameter type called *arg* is used by the block to tell the HBlock which parameter the block needs. For example, if our **impulse** block above has a parameter of **arg 3**, it means that the number of 0 samples is equal to the value of the third parameter to the HBlock in which **impulse** is contained. Just before the simulation is executed, the value of this third parameter will be copied to **impulse**.

The programming for the block specifies how many parameters the block expects there to be, what their types are (floating-point, integer, etc), and how they are to be used. Also the prompt for the parameter is specified in the block code by the block programmer. **Impulse** blocks take only one parameter of type integer, and use this parameter to send out the proper number of 0 samples. Note that if the number of parameters specified or the type of parameters specified are incorrect CAPSIM will not generate an error message until the simulation is run.

1.6 Using Blocks

Now you are ready to create a block.

```
Capsim> block impulse0 impulse
```

This block requires parameters. To enter the parameters for a block make sure that the block is the Current Block and then type:

```
Capsim> chp
```

CAPSIM will respond by prompting you for all the parameters.

```
Enter 1 new parameter(s):
0:   Number of generated samples:
     param int 128  ?==> 10
```

Impulse0 is the name of the block you are creating, while **impulse** is the library module which contains its programming. Blocks may have a name composed of any alphanumeric string of reasonable length, as long as no other blocks or HBlocks in this universe have the same name. One could also use the command **block source impulse**, or **block impulse**. In the first case the block's name is **source**. In the second case, Capsim automatically assigns a name **impulse0**. That is, it appends a 0 to the name of the block to create a new name. If we issue another **block impulse** command, the new block's name will be **impulse1** and so on.

CAPSIM keeps track of the most recently created block, and displays it after appropriate commands. The Current Block is used by some of the other CAPSIM commands, as we shall see later.

Current Block: block impulse0 impulse (lib)

In a likewise manner, create the block **prfile0**. Use the default parameter for **prfile**, stdout:

```
Capsim> block prfile0 prfile
Capsim> chp

Enter 2 new parameter(s):
0:   Name of output file::
     param file stdout  ?==>Hit a return
     param file stdout
1:   Print output control (0/Off, 1/On)
     param int 1 ? ==>Hit a return
     param int  1
```

Here, rather than specifying a value for the parameter of **prfile**, you have told **prfile** to use its internal default value for the first parameter. **Prfile** is a block that takes data samples from its inputs and places them in the file specified by the first parameter. The default value for this first parameter is the standard output. Default parameter values are specified by the block's programmer, and are included as a convenience to the user. Hit return if the default is O.K.

1.7 Making Connections

Now you have a block that will generate data samples, and another block which will consume data samples. To inform CAPSIM how the blocks will relate to one and other you must tell CAPSIM how the blocks are to be connected. To connect the output of **impulse0** to the input of **prfile0**, type

```
Capsim>  connect  impulse0  prfile0  data
```

In this command, you are telling CAPSIM to connect the first output of **impulse0** (output number 0) to the first input of **prfile0** (input number 0) and to name this connection **data**. The naming of the connection (**data** in this example) is optional. Each block can have a large number of inputs and outputs (the exact number is implementation dependent). CAPSIM will allow you to connect any block's output to any block's input, as long as both blocks exist and the desired input or output is not already connected. Errors are not flagged until the simulation is run. The number of connections that a block has, and how they are used, is specified by the block's programmer. **Impulse** (as well as **impulse0**) is designed to put output samples on one output connection. If you connect anything to its inputs, or connect its outputs to more than one other block, you will get an error. CAPSIM will not give you this error, however, until you attempt to run the simulation. It will then appear as a *user error code*. We will talk about this later.

1.8 Checking the Universe

Now you have a universe consisting of two blocks connected together. To see if CAPSIM's view of the universe agrees with your own, type

```
Capsim>  display a
```

CAPSIM will print every block or HBlock in the universe, and all the connections between them. The parameters for each block or HBlock

are printed *before* the block or HBlock itself; this corresponds exactly to the way that parameters are first placed on the Parameter Stack, and then transferred to the next block or HBlock created. Here is a what is displayed after entering the **display a** command.

```
Capsim-> display a
*****************************************************
        parent HBlock  UNIVERSE

arg -1 (none)

param int 10
block impulse0 impulse

param file stdout  "Name of output file"
param int 1  "Print output control (0/Off, 1/On)"
block prfile0 prfile

connect impulse0 0 prfile0 0    data

*****************************************************
 Current Block:  impulse0  (block: impulse)
```

1.9 Running the Simulation

Now you can see if your simulation will work correctly. To run, type

```
Capsim>  run
```

If you did everything right, the **impulse0** block should pass data samples on to the **prfile0** block, which then displays them on the standard output:

```
Output from Prfile 'prfile0'
data
1.000000
0.000000
0.000000
0.000000
0.000000
0.000000
```

```
0.000000
0.000000
0.000000
0.000000
0.000000
```

Note that, as expected, there are 10 "0" samples after the 1.

1.10 Changing the Parameters

Suppose that once you have created a block or HBlock, you wish to change its parameters. You can do this with the **chp** command. This command will cause CAPSIM to prompt the user for the parameters of the Current Block. For example, let us say that you want the **impulse0** block to produce 20 zero's after the 1, rather than 10. First, you must make **impulse0** the Current Block. The **forward, back** and **to** commands allow you to move around within the universe by changing the Current Block.

Capsim> **to impulse0**

Now that **impulse0** is the Current Block, we can go ahead and change its parameter value.

Capsim> **chp**

You can verify the change you just made by typing **display a,** which shows the contents of the entire universe. If your universe is very large it is often more convenient to use the **info** command, which tells you about the Current Block only:

```
Capsim> info
Parent: UNIVERSE
Name:  (impulse0)
Type: BLOCK
File: impulse.s (library)
Status: Modified library

Parameters:
 0:   Number of generated samples   (int) 20
Inputs:
(None)
Outputs:
 0: prfile0 (prfile) 0 data
```

Try to run again:

```
Capsim> run
```

Now the impulse sequence should contain 20 zero samples.

1.11 Saving the Universe

To save the universe that you have created, use the **store** command:

```
Capsim> store
```

Since you did not specify a file name, CAPSIM will store this universe in the default topology file, which is "universe.t". You will now be able to run this simulation at a later time without having to rebuild the universe, simply by loading "universe.t".

To save the universe that you have created under any name, use:

```
Capsim> store topology_name
```

where **topology_name** is the name of the topology that is created to store the information.(a post-fix .t will be added to the file name by CAPSIM).

1.12 Creating an HBlock (Hierarchical Block)

Now that you have a familiarity with the basic commands of CAPSIM, you are ready to build more advanced simulations. We mentioned before that blocks can be combined to form HBlocks, which can then be connected in the same way that blocks are to form a universe. Specifying the topology of an HBlock is identical to specifying the topology of a universe, with one exception: since an HBlock will be connected to other blocks or HBlocks, you must specify what the inputs and outputs of an HBlock are. In fact, a universe is just an HBlock with no outputs or inputs.

Armed with this information, let us create a simple HBlock: a one-pole IIR filter. To specify the topology for this HBlock, we will need blocks that add, multiply, and delay samples. Also, since in CAPSIM connections can only be made between two blocks or HBlocks, we will need a block that implements the fork operation; that is, a block that takes data samples from one block and sends copies of them to two or more other blocks. This block is called a node in CAPSIM. By using the **display s** command to look at the library, we see that the blocks **add**, **delay**, **gain**, and **node** are the blocks we are looking for.

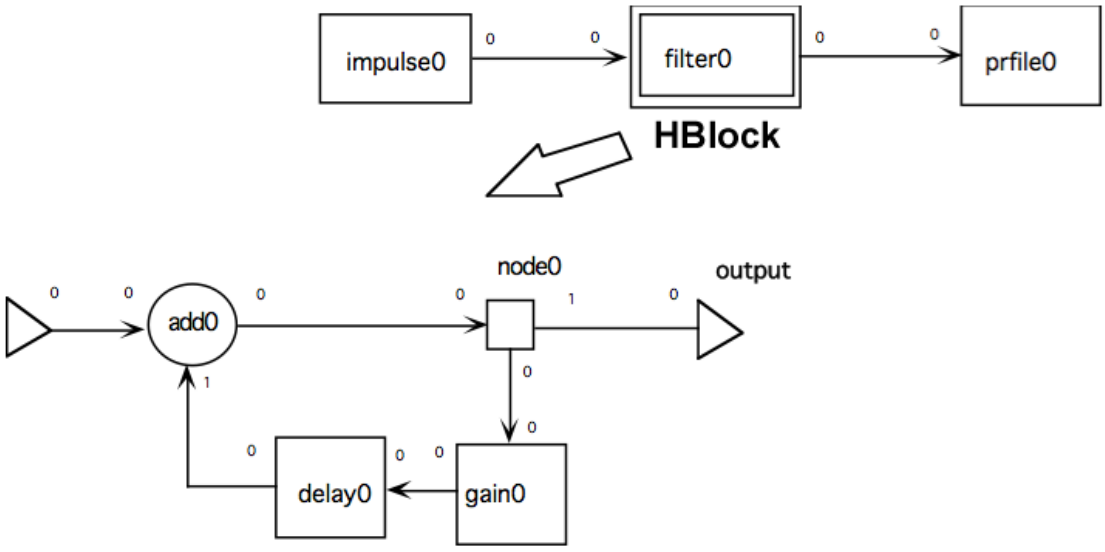


Figure 1.2

First, let's clear out the universe so we can start from scratch:

```
Capsim>  new
```

The universe is now empty. **Be very careful when you use this command, as there is no turning back once you have destroyed the universe.** In this example we will use the alternate method of pre-specifying the parameters. Now specify what blocks you will need, by issuing the appropriate commands (notice that we let Capsim automatically assign names to the blocks):

```
Capsim> arg 0 float 0.9 "Filter Pole"
Capsim> block  add
Capsim> block delay
Capsim> block node
Capsim> block  gain0  gain
Capsim>chp
   Enter 1 new parameters:
0:Gain factor
 param float 1 ?==> arg 0
Capsim>display a

*******************************************************
       parent HBlock  UNIVERSE  (universe.t)
```

```
arg 0 float 0.9 (0.900000)  "Filter Pole"

block add0 add (*)

param int 1  "Enter number of samples to delay"
block delay0 delay (*)

block node0 node (*)

(arg 0) param float 0.9  "Filter Pole"
block gain0 gain (*)


*****************************************************
```

In the above sequence of commands, the first command specifies that the HBlock has one parameter which is refered to as **arg 0**. Its type is floating point and its default value is 0.9. Furthermore, when the HBlock is used as a block, the prompt *Filter Pole* will appear in response to the **chp** command. Of course the HBlock can have more arguments. In this example only one is required. Rather than specifying a floating-point value for the **gain0** gain parameter, an *arg* parameter has been specified. As we mentioned before, this means that the actual value to be used for the coefficient will be taken from the parameters to the HBlock you are now creating. When a copy of this HBlock is created for a simulation, it must be given one parameter, of type floating point, which will specify the value of the filter's pole. The **0** means parameter 0 that is, the first parameter. In this way, you can use an HBlock many times, perhaps to simulate a cascade of first-order filters, with each copy of the HBlock using a different coefficient value.

Now make the connections:

```
Capsim> connect  input  add0
```

Samples that are directed to the 0 input of this HBlock will be directed to the 0 input of **add0**.

```
Capsim> connect add0  node0
Capsim> connect  node0    gain0
Capsim> connect gain0  delay0
Capsim>  connect  delay0   add0
Capsim> connect node0  output
```

Output samples for this HBlock will be taken from output 1 of **node0**.
The specification for a one-pole filter, with one input and one output, is now complete. You should now store this topology, so that we can use it later. Be sure to specify a file name, otherwise CAPSIM will store this HBlock in the file "universe.t", overwriting what we put in there before.

```
Capsim>  store  filter.t
```

It may be worthwhile at this point to show what happens when we try to run a simulation on a universe with inputs or outputs.

```
Capsim>  run
 <Error  42>  Top  level  contains   input/output
connections
```

You are now ready to use the HBlock you have created in a simulation. In the case of the filter, you can obtain its impulse response by connecting its input to an **impulse** block and its output to a **prfile** block, and running the result. First, clear the universe again:

```
Capsim> new
```

Now, load the universe that was created previously, containing **impulse0** and **prfile0**:

```
Capsim>  load  universe
```

The universe now contains the two blocks you need (**impulse0** and **prfile0**). Of course, their connections are incorrect, but you can easily take care of that.
First, let's use the **HBlock** command to create the HBlock:

Capsim> **HBlock filter**

This command is similar to the **block** command, except that now the **filter** argument represents the file where the HBlock's topology can be found, rather than the name of a library block. You can call this HBlock anything you'd like, subject to the same rules that exist for blocks (i.e., no other block or HBlock in this universe can have the same name). Also note that Capsim will automatically assign a name filter0 to the HBlock.

Now you can change the HBlock's parameter using the **chp** command. A good test value for a pole is 0.90:

```
Capsim> chp
 Enter 1 new parameters:
0: Filter Pole
  param float 0.9 ?==>0.9
```

Before you can connect up the universe, you need to remove the connection that exists between **impulse0** and **prfile0** (if you don't believe that this connections exists, use the **display a** to see what CAPSIM

thinks). To remove it, use the **disconnect** command, whose syntax is identical to the **connect** command:

```
Capsim>  disconnect impulse0  prfile0
```

Now proceed with the necessary connections, just as you did before:

```
Capsim> connect impulse0  filter0
Capsim> connect filter0   prfile0
```

It would probably be a good idea at this point to do a *display a* to make sure everything looks good:

```
Capsim>  display  a
```

Everything looks like it's ready. Use the run command to run the simulation:

```
Capsim>  run
```

If you did everything correctly up until now, CAPSIM should print twenty samples of the impulse response of the filter. You should now store this filter so that you can use it in future simulations (put it in "universe.t"):

```
Capsim>  store universe
```

You can now leave CAPSIM by issuing the **quit** command.

```
Capsim> quit
```

1.13 Additional Hints

By now, you have all the information you need to construct any simulation you desire. A complete list of CAPSIM's commands is given in Chapter 3; it includes a few commands that we have so far left out. In particular,

you may find the **alias** and **unalias** commands useful. These allow you to redefine CAPSIM's commands, so that you can save on keystrokes.

When CAPSIM stores a topology in a file, it stores it as the sequence of commands necessary to create the specified universe. Thus, the topology file can be printed or edited like any other text file. You can also create universes from the editor, and use CAPSIM only to run the simulations. To do this, invoke CAPSIM with a valid topology file specified:

```
% capsim  myuniverse.t
```

When invoked in this way, CAPSIM builds the universe according to **myuniverse.t**, automatically executes a **run** command, and then exits. The -l option,

```
% capsim -l myuniverse.t
```

causes CAPSIM to initially load myuniverse.t and enter into the interactive mode.

When CAPSIM starts up, it looks for a file named **.capsimrc**, first in your current directory, and then in your home directory. If this file is found, commands are read from it and executed before CAPSIM prints the prompt. You may want to use this file to set up search paths for blocks and HBlocks with the **path** command, to define aliases, or to turn off the Current Block display.

More information about CAPSIM can be found in chapter 2.

Capsim Text Mode Reference

2.0 CAPSIM Text Mode Reference

2.1 Introduction

The following reference manual is derived from and parallels the original UC Berkeley manual[2] and includes more commands and a number of enhancements. Additions and changes have been made as necessary.

In CAPSIM, simulations are constructed out of a variety of building blocks. Each building block, known as a block, represents a small segment of object code that executes a part of the simulation. Blocks are linked together by specifying the flow of data between them, in the same way that you might wire together individual components in an actual system. Once the system is built, CAPSIM can then simulate it by executing each block independently, and transferring data samples between them as needed.

Blocks can also be combined into larger, more complicated blocks. Once the structure of these larger blocks, which are called HBlocks, is defined, they can be interconnected in the same way as blocks. This approach to simulation allows you to simulate large, complicated systems without much of the overhead associated with single-application simulation programming. Also, because of the standardized nature of each block, simulation code written by different programmers can be effortlessly tied together.

This reference manual gives a complete list of CAPSIM's capabilities, and thus is not intended as an introductory guide. If you are not

[2] D. J. Hait and D. G. Messerschmitt, *BLOSIM Reference Manual,* UC Berkeley

familiar with CAPSIM, it is suggested that you read chapter 1 prior to reading this chapter.

2.2 The CAPSIM Environment

As we mentioned before, a CAPSIM simulation consists entirely of blocks and their interconnections. A block can be a *block,* in which case it refers to simulation programming, or it can be a *HBlock*, which means that the block's function is described in terms of more primitive blocks and the interconnections between them. For example, a digital filter can be implemented as a block by writing simulation programming for it, or as an HBlock by specifying an interconnection of multipliers, adders, and delays, each of which is a block.

Blocks in CAPSIM always refer to a file that contains the programming for the block. The file may be either compiled object code, a C program in the proper format, or BLOCKGAZE source code [3]. The name of this file must be specified when the block is created. In addition, before a block can be executed during a simulation, one copy of the compiled code must be loaded into memory. CAPSIM sets up the private data structures that allow many blocks to share this one copy.

Included with CAPSIM is a large standard library of commonly used block object modules. This library has already been linked to the object code for CAPSIM and is automatically loaded into memory when CAPSIM starts up. Blocks whose object modules are part of the standard library are known as *library blocks*. Since library blocks don't actually reference files, you specify a *module* name rather than a file name when you create a library block.

While each block refers to a simulation program segment, every HBlock has associated with it a specification of what blocks it contains and how they are interconnected. This specification is known in CAPSIM as a *topology,* and is stored in a *topology file*. As with blocks, the topology file for an HBlock must be specified at the time the HBlock is created.

[3]D. G. Messerschmitt, *STARGAZE User's Manual (in print),* UC Berkeley

An HBlock can be built out of other HBlocks as well as blocks. In this way, we can consider every block in CAPSIM to have a place in a hierarchy. This hierarchy can be represented as a tree structure, with each node of the tree being a CAPSIM block (a block or a HBlock). If a node is a HBlock, it has a number of child nodes, each of which corresponds to a block that is part of that HBlock. At the leaves of the tree are the blocks, which have no children. Thus, each block in CAPSIM has a *parent HBlock*, that is, the HBlock of which it is a part.

At the very top, or root, of the tree is a node whose children are the top-level blocks of the simulation. This node is called the *universe*. It is a HBlock, because like any other HBlock, it contains a number of blocks. Unlike any other HBlock, however, the universe has no input or output connections. In addition, the universe does not have to be explicitly created by the user; it is automatically created by CAPSIM when the system starts up, and is initialized to be empty.

CAPSIM allows you to display and edit only one HBlock at a time, known as the *current parent HBlock*. When CAPSIM starts up, the current parent HBlock is the universe. By using the **up** and **down** commands (see below), you can move up and down the CAPSIM hierarchy, displaying and changing blocks at different levels independently.

Just as each HBlock has a topology file associated with it, the universe has its own topology file. This universe topology file specifies which blocks are to be included at the top level of the CAPSIM simulation, and how they are to be interconnected. The default universe topology file is named universe.t.

2.3 Running CAPSIM

To start up Text Mode CAPSIM, type the command **capsim** from the Shell:

% **capsim -b**

If your path is not setup type **`./capsim -b`**.

Invoked in this way, CAPSIM works interactively. If instead, you specify a file,

```
% capsim file.t
```

CAPSIM will run non-interactively, by loading the file as the universe topology, executing a **run** (see below), and exiting. Note that the file name **must** end in ".t".

Other command options to CAPSIM are:

```
% capsim -l file.t
```

Load the specified topology file, and then prompt for interactive commands.

When CAPSIM starts up, it will check the current directory, and then your home directory, for a file named *.capsimrc*. This file, if it exists, should contain valid CAPSIM commands, one per line. CAPSIM will read this file and execute the commands in it before displaying the prompt (or before loading and executing the specified topology, if invoked non-interactively). If any command in the *.capsimrc* file is in error, CAPSIM will terminate prematurely. If CAPSIM is invoked with the -l option, the .capsimrc commands are read *before* the -l file is loaded. To leave CAPSIM, the **exit** command and the **quit** command work identically:

```
Capsim> exit
Capsim> quit
```

2.4 Creating Blocks

The **block** command is used to create a block instance and places it in the current parent HBlock. The first argument to this command is always the name of the block to be created (the name you wish to give the block). A block may have any name that is an alphanumeric string of reasonable length. No two blocks in the same HBlock (or universe) may have the same name.

The second argument to **block** tells CAPSIM the library name of the block. If you need a block that does not already exist in your library you will have to add it using precapsim (see section on precapsim).

For example,

```
Capsim>block source sine
```

will create the block called source which produces a sinusoid.

Capsim also allows for the automatic naming of blocks. Thus

```
Capsim>block sine
```

will produce the block named sine0. The index attached to the block is equal to the number of instances of that block.

2.5 Creating HBlocks (Hierarchical Blocks)

To create a HBlock, use the **HBlock** command:

```
Capsim> HBlock name topfile.t
```

The HBlock's name is *name*; the same rules apply as for blocks. *Topfile*.**t** is a topology file (the ".t " suffix is mandatory).

The **HBlock** command searches for the specified topology file in the directories in the HBlock path search list (see **path** below). Once found, that file is used to create the internal structure of the new HBlock. Since new blocks and HBlocks may be part of this structure, the **HBlock** command may have to load in many other topologies or block object code, and thus may take a few seconds to complete.

If any errors are found in either the specified topology file or the topology file of one of the HBlock's children, a brief error message is printed, with the name of the offending file, and the line number where the error occurred. The HBlock whose topology file generated the error is cleared of all blocks. In addition, that HBlock and all its ancestors (HBlocks that contain it, and HBlocks that contain an HBlock that contains it, etc.) are given the designation bad. This designation is printed every time a bad HBlock is displayed (a simulation will not run when the universe contains bad HBlocks). An HBlock can only become good again when it is rebuilt from within CAPSIM, or when its file is fixed and it is reloaded (this usually requires leaving CAPSIM).

Capsim also allows for the automatic naming of HBlocks. Thus

```
Capsim>HBlock filter.t
```

will produce the HBlock named filter0. The index attached to the HBlock is equal to the number of instances of that HBlock.

2.6 Parameters

A parameter is a variable argument to a block or an HBlock that can be set from within CAPSIM prior to running a simulation. Blocks access the values of their parameters through special subroutine calls (these calls are part of the programming automatically generated by the XSLT script *blockgen.xsl* that generates C code). An HBlock does not directly use the values of its parameters, but instead passes the values on to the blocks and HBlocks of which it is composed. Simply by changing the parameters values, many copies of a single block or HBlock can be used in very different ways. For example, a ten-pole IIR filter can have its tap values defined in terms of parameters, so that the same filter can be used from application to application.

CAPSIM maintains a data structure internally called the *Parameter Stack*. Parameters are set by placing the values on the Parameter Stack, and then copying them to the appropriate block or HBlock. After the values are copied, the Parameter Stack is cleared. The copying is done automatically when a block or HBlock is created, so usually you specify what the parameters are before you create the block or HBlock. This is not necessary, however. After the block or HBlock is created use the **chp** command described below to change the blocks parameters. This is the preferred method.

The **param** command places a parameter value of the specified type on the Parameter Stack. The command must take one of the following forms:

```
Capsim> param int integer
```

The parameter is an integer value.

```
Capsim> param float floating-point
```

The parameter is a floating-point value.

```
Capsim> param array size value1 value2 ...
```

The parameter is an array of values. The first number gives the size of the array and must be an integer. The rest of the numbers list the contents of the array, which may be floating-point. **An array may not contain more than ten elements.**

```
Capsim> param file file name
```

The parameter is the name of a file, which may be any UNIX file name.

```
Capsim> param function function.c
```

The parameter is the name of a function. The function name must have a ".c" appended to it, indicating that the function will be found in the file function.c.

```
Capsim>  param  default
```

The block is to use a default value for this parameter. **This default value must be set within the block program.**

```
Capsim>  param arg  n
```

The parameter value is to be obtained from the *nth* parameter of the block's parent HBlock. The value is copied just before the simulation is run.

Note: arg n must be defined using the **arg** command prior to being referenced by block parameters.

To display the contents of the Parameter Stack, type

```
Capsim> display p
```

To change the parameters of a block or HBlock that has already been created, use the **chp** command:

```
Capsim> chp
```

chp (<pindex> <pval>)
If no arguments : User is prompted for new values for parameters of the current block. A <return> during prompt leaves value unchanged. If "default" is entered at prompt, the value from the block model is used. If "arg n" is entered (n is a non-negative integer), the value of parent parameter n is used. See command "arg". If "arg -1" is entered, the current block value is maintained, but no longer referenced to the parent.

<pindex> is the integer index of a defined parameter. This option allows you to rapidly access a parameter without going through all parameters. Type **info** to get a listing of the parameters.

<pval> : A given value string is interpreted according to the previously declared parameter type. If pval == "default", the value from the block model is used. If pval == "arg n", the value of parent parameter n is used. If pval == "arg -1", the current block value is maintained, but no longer referenced to the parent.

This will copy the contents of the Parameter Stack into the parameters of the Current Block, and clear the Parameter Stack. The user is prompted for the parameters in a sequential manner.

Example:

```
 Current Block:  sine0  (block: sine)
Capsim[7]-> chp
 Enter 5 new parameters:
0: Number of samples to generate
  param int 1000 ?==>
1: Magnitude
  param float 1 ?==>
2: Sampling Rate
  param float 8000 ?==>
3: Frequency
  param float 200 ?==>
4: Phase degrees
  param float 0 ?==>
```

2.7 HBlock Arguments

The **arg** command establishes a model for an HBlock parameter. In fact it can be used to set a global parameter for the universe. For example, the number of samples to generate and consume is the same for a several source blocks. Instead of specifying the same number of samples for each block, the parameter *arg 0* is specified. Using the **arg** command the value and prompt for *arg 0* is set. Then if the number of samples was changed, only *arg 0* is modified. Otherwise, the parameter for each block must be changed individually.

arg <argnum> <argtype> <argval>
(<"promptString">)

<argnum> : normally, a non-negative integer.
If negative, signals that HBlock has no parameters.
<argtype>
int : argval is an integer.
float : argval is a float value.
file : argval is a file name string.
NULL : deletes this argument definition.

<"prompt"> : String describing arg. It must be in quotes!
This is transcribed to the corresponding parent
HBlock block parameter.

When an HBlock is the current block, the **chp** command will cause the above prompt for each parameter to appear.

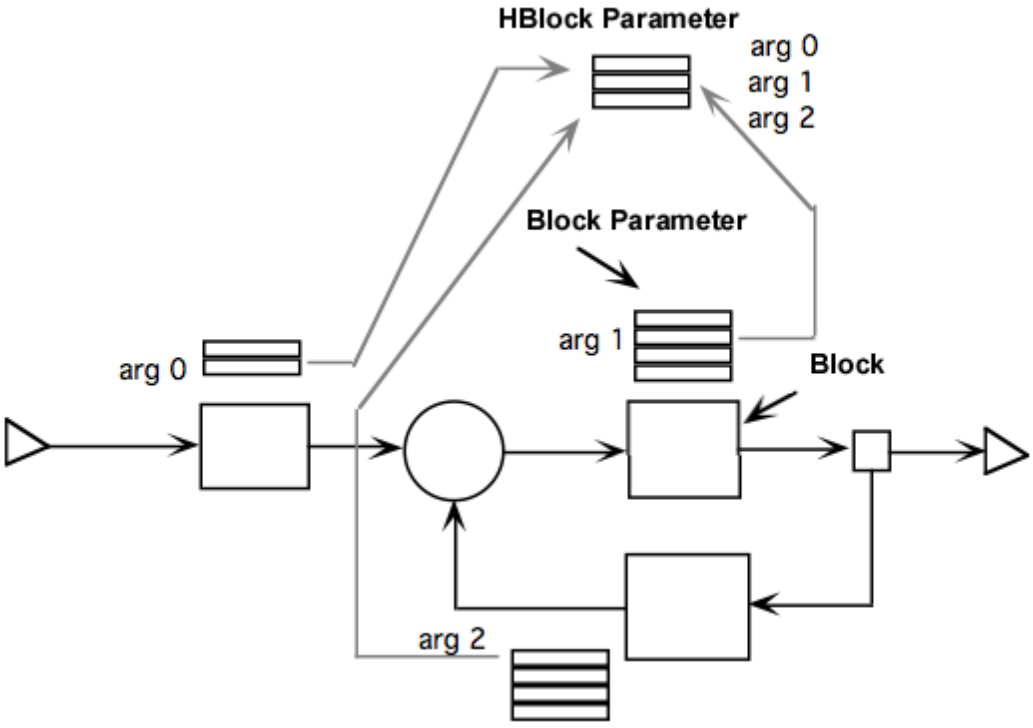


Figure 2.1 This figure shows how block parameters relate to HBlock parameters.

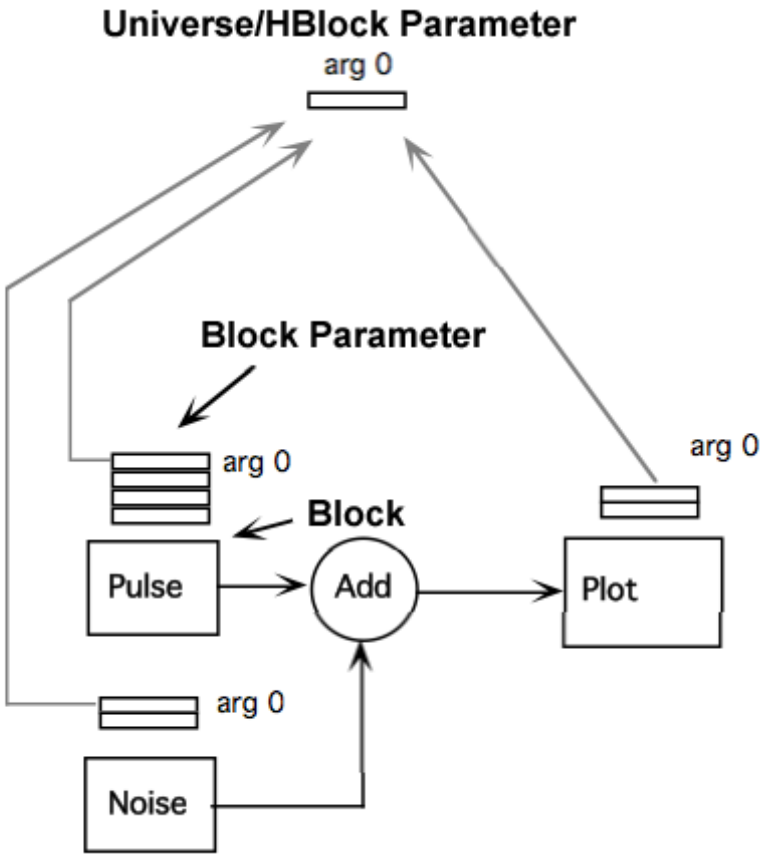


Figure 2.2 Illustration of how global parameters can be handled in Capsim.

2.8 Connecting, Disconnecting and Naming Connections

To connect two blocks (blocks or HBlocks) together, use the **connect** command:

```
Capsim> connect block1 outnumber block2 innumber signal_name
```

This causes a data connection to be created, allowing data samples to move from the *outnumber* output of *block1* to the *innumber* input of *block2*. Data samples can only move from *block1* to *block2*, not in the reverse direction. The *signal_name* is used by blocks such as the plot block to automatically generate legends and also is part of the information displayed by the **info** command. If no signal name is specified CAPSIM creates one itself of the form: *blockname//output_number.dat*.

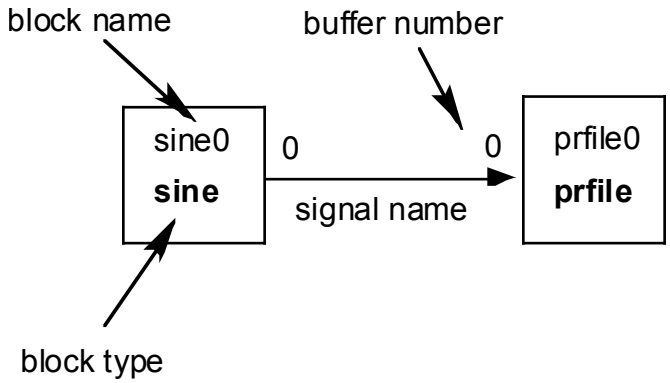


Figure 2.3 Connections.

To connect a block to the output of the block's parent HBlock, use this form of the **connect** command:

```
Capsim> connect block1 outnumber output galoutnumber
```

This will direct data samples from the *outnumber* output of *block1* out through the *galoutnumber* output of *block1's* parent HBlock.

Similarly,

```
Capsim> connect input galinnumber block2 innumber
```

causes data samples that arrive at this HBlock's *galinnumber* input to be directed to the *innumber* input to *block2*.

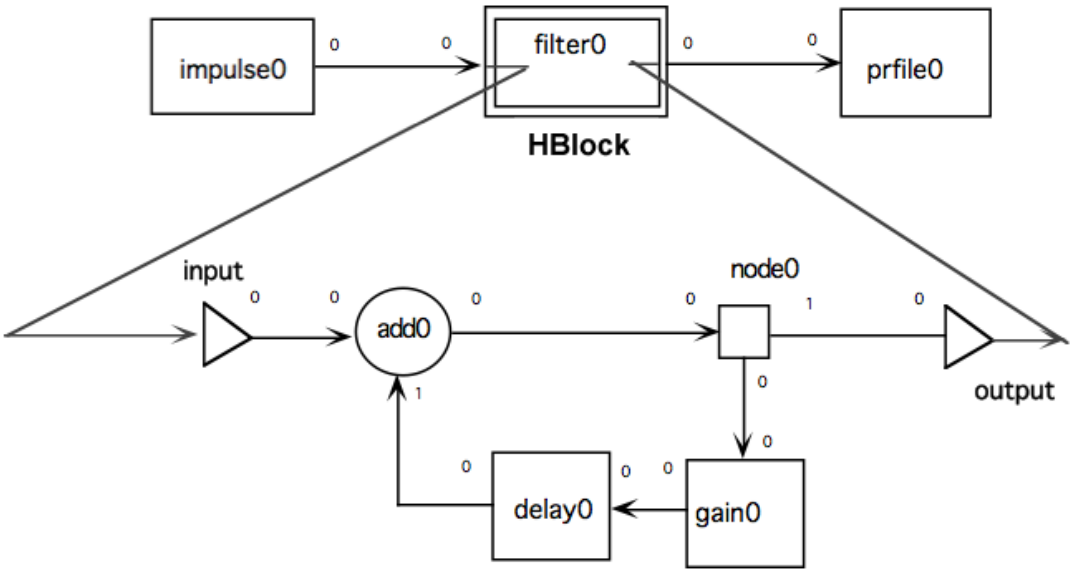


Figure 2.4 **Connect input add0** and **connect node output** command.

Disconnect has an identical syntax, and is used to remove a data link between two blocks:

```
Capsim> disconnect block1 outnumber block2 innumber
Capsim> disconnect block1 outnumber output galoutnumber
Capsim> disconnect input galinnumber block2 innumber
```

It is an error to connect to or disconnect from blocks that do not exist.

It is not necessary to specify the buffers in the connect and disconnect commands.. Capsim will automatically assign them. For example you can type,

```
Capsim> connect source filter
```

In this case the next highest output buffer number of source is connected to the next highest input buffer of filter. This is the usual method for connections. If buffer numbers are specified then they will be used.

The **name** command is used to provide a name for the connection.

```
Capsim>name <toblkname> <innum> <signalName>
```

The connection is verified as existing, "toblkname" cannot be "output".

2.9 Running a Simulation

To run a simulation, use the **run** command:

```
Capsim> run
```

A simulation will not run if any one of the following conditions is present:

(1) The universe contains bad blocks.
(2) The universe is empty.
(3) A block within the universe is connected to input or output.

In addition, a *block error code* will be generated if one of the following conditions is true:

(1) A block has an incorrect number of input or output connections.
(2) A block has an incorrect number of parameters, or one of its parameters is of the wrong type.
(3) A block uses an *arg* parameter that has not been properly set in the block's parent HBlock.

If there are no errors, the simulation will halt when no block has data samples left on any of its input buffers. **Thus, any blocks in the universe that are sources of data samples must eventually stop, otherwise the simulation will continue indefinitely.**

2.10 The Current Block

If the current parent HBlock is not empty, it will have a *Current Block* associated with it. The Current Block is used by several other CAPSIM commands. When **block** or **HBlock** is used to create a new block, that block becomes the new Current Block.

After appropriate commands, the Current Block is displayed after each command is executed, in one of the following formats:

Current Block: block *blockname blockfile*
Current Block: block *blockname libblockname* (lib)
Current Block: HBlock *HBlockname HBlockfile*

2.11 Moving About

To change the Current Block, use the **forward**, **back**, and **to** commands:

```
Capsim>  forward
Capsim> back
Capsim>  to name
Capsim>  to  (partial  name)
```

CAPSIM places the blocks that are in the current parent HBlock on a list according to the order in which they were created. You can view this ordering by using the **display a** command (see below). The **forward** command will cause the block that is listed after the existing Current Block to become the new Current Block. Likewise,the **back** command will cause the block that is listed before the existing Current Block to become the new Current Block. The **to** command searches in a forward direction until it finds a block with a name that matches the name or partial name you provide. If the search reaches the end of the list, it starts again at the beginning until it reaches the Current Block. A message is printed if no match is found for the *name* pattern.

To move through the block hierarchy, use the **up** and **down** commands:

```
Capsim> up
Capsim> down
```

The **up** command causes CAPSIM to move the current parent HBlock up one level. The last block that was created in the new parent HBlock becomes the Current Block. If the current parent HBlock is the universe, **up** will print an error message. Similarly, the **down** command causes the

Current Block to become the new parent HBlock. This command is in error if the Current Block is a block.

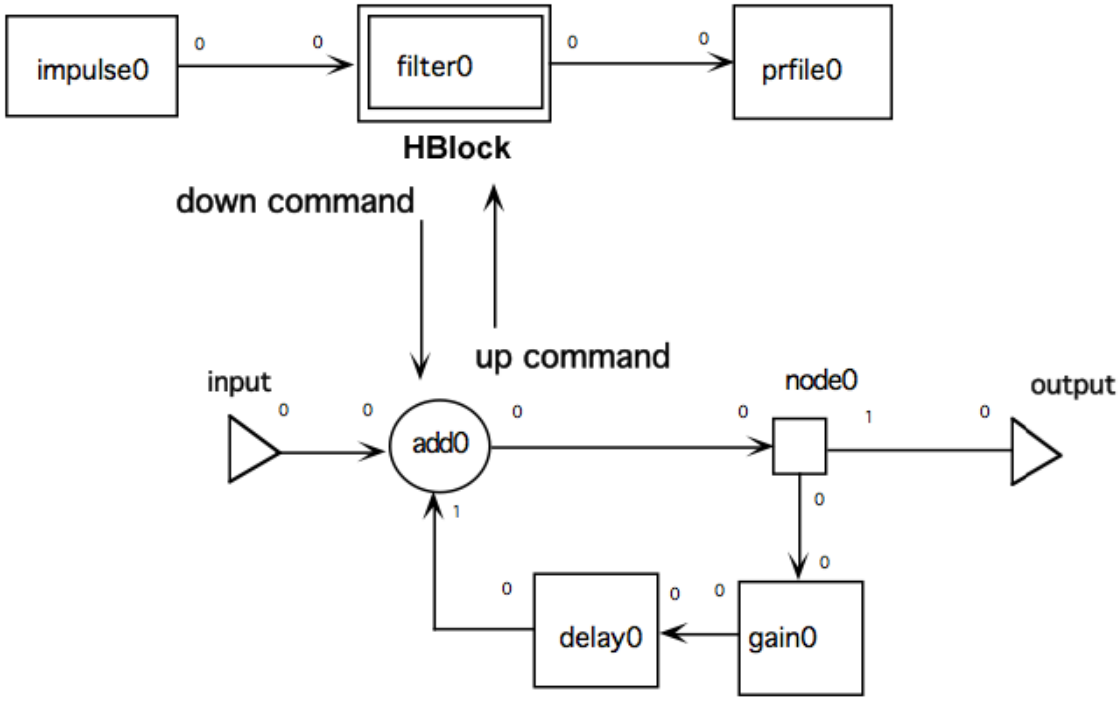


Figure 2.5 The **up** and **down** commands.

2.12 Display, Info, and Man

The **display** command is used to print information about the current state of the CAPSIM environment. We have already seen the **display on** and **display off** commands, which control the display of the Current Block, and the **display p** command, which displays the contents of the Parameter Stack.

To display the complete topology of the current parent HBlock, type:

```
Capsim> display a
```

This will print the name of each block and HBlock, what values their parameters are set to, and how they are interconnected. This information is displayed in terms of the commands that would have to be given to CAPSIM to generate the existing universe. Thus, a block named

"myblock0" with an integer parameter set to 23 would be displayed as follows:

```
param int 23
block myblock0 myblock
```

Example:

```
Capsim[6]-> display all
*****************************************
**********
        parent HBlock  zzhist  (zzhist.t)

arg -1 (none)

param int 1000  "Number of samples to
generate"
param float 1  "Magnitude"
param float 8000  "Sampling Rate"
param float 200  "Frequency"
param float 0  "Phase degrees"
block sine0 sine

param float -1.2  "Start"
param float 1.2  "Stop"
param int 100  "Number of bins"
param file none  "File to store result (none
is default)"
param int 1000  "Number of points"
block hist0 hist

connect sine0 0 hist0 0

*****************************************
**********
 Current Block:  sine0  (block: sine)
```

To see what blocks are in the standard block library, use the **display s** command:

```
Capsim> display s
```

This will print out the module name of each library block.

The **display g** command shows which HBlock topology files CAPSIM knows about:

```
Capsim> display g
```

These are topology files that have previously been used in an **HBlock** command, or have been loaded by CAPSIM.

To display the name of the Current Block while the automatic display is turned off, use **display** without an argument:

```
Capsim> display
```

The **info** command gives more complete information about the Current Block. It lists what values its parameters have, and what its connections are:

```
Capsim> info
```

Example:

```
Current Block:  sine0  (block: sine)
Capsim[5]-> info
Parent:  zzhist
Name:  sine0  (sine0)
Type:  BLOCK
File:  sine.s (library)
Parameters:
 0: Number of samples to generate  (int)
1000
 1: Magnitude  (float) 1
 2: Sampling Rate  (float) 8000
 3: Frequency  (float) 200
 4: Phase degrees  (float) 0
Inputs:
 (none)
Outputs:
 0:  hist0 (hist) 0     sine0:0
```

If a detailed knowledge of exactly how the block is operating is required then the **man** command is used. The **man** command gets the source file (".s" or ".t") for the current block. To get a specific source file **man** may also be issued with an argument that is a file name.

```
Capism> man [filename.s, filename.c, filename.t ]
```

To get on-line help type **man command**. For example **man chp**. To get a summary of the commands type **man capsim**.

Note: In all cases paths must be setup to the block., HBlock, and documentation files using the path command. It is a good idea to place the path to documentation in the .capsimrc startup file.

2.13 Loading and Storing

The **load** command causes CAPSIM to try to load a topology from a file:

```
Capsim>  load
Capsim>  load  file
```

If no file is specified, and the currently displayed HBlock is the universe, CAPSIM loads the default universe file (**universe.t**, if no other is specified with the -t option). If the currently displayed HBlock is not the universe, CAPSIM tries to load the file associated with this HBlock.

The **load** command acts recursively; that is, if any HBlocks are part of the loaded topology, their topologies are also loaded. During the load, if any topology files are in error, the name of the offending file and the line number are printed along with the appropriate error message. HBlocks that could not be loaded, or that contain HBlocks that could not be loaded, are given the designation bad. A universe containing bad HBlocks can not be run (see the **HBlock** command above).

To store a HBlock, use the store command:

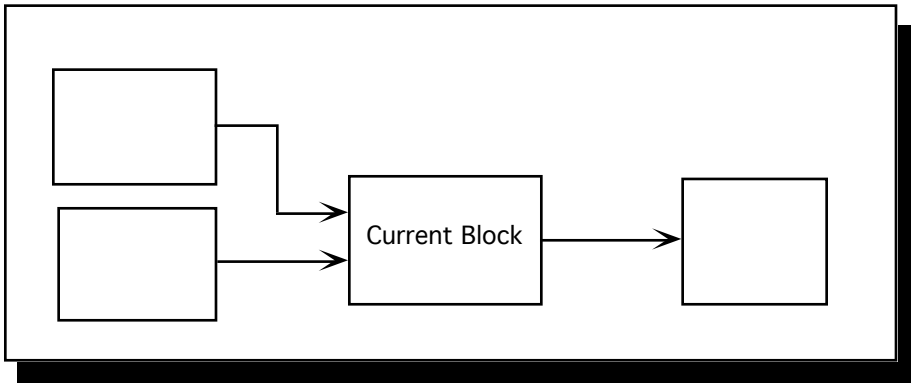
```
Capsim> store
Capsim> store file
```

If no file is specified, the rules are the same as for **load**. Note that **store** is different from load in that it *only* stores the topology of the currently displayed HBlock, not the topology of any of its children.

2.14 Removing Blocks

The **remove** command first disconnects the *Current Block* from all blocks to which it is connected. The Current Block is then removed. If the parent HBlock is not empty, another block becomes the Current Block. Therefore, first use the **to** command to go to the desired block (making it the Current Block) then use the command:

```
Capsim> remove
```



Topology Before Remove Command

Topology After Remove Command

Figure 2.6

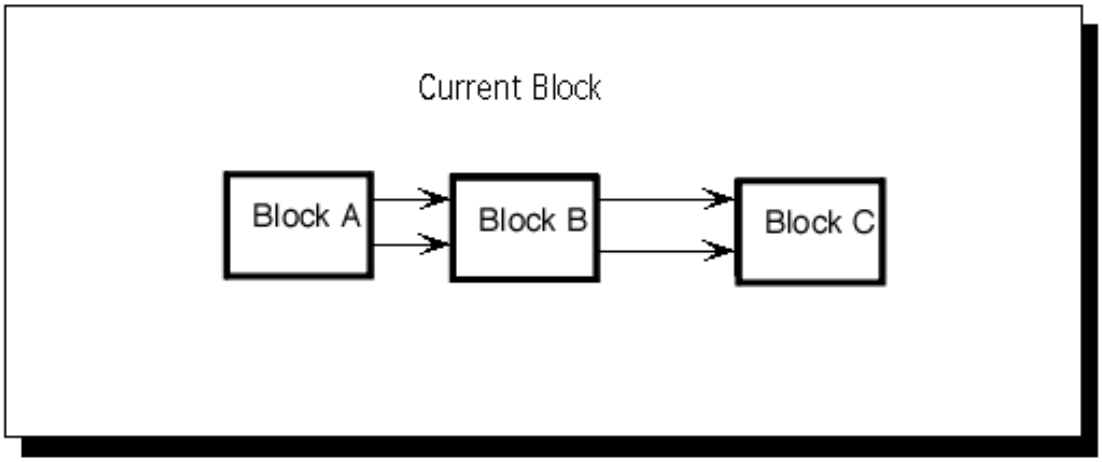
The **new** command removes every block in the parent HBlock:

```
Capsim>  new
```

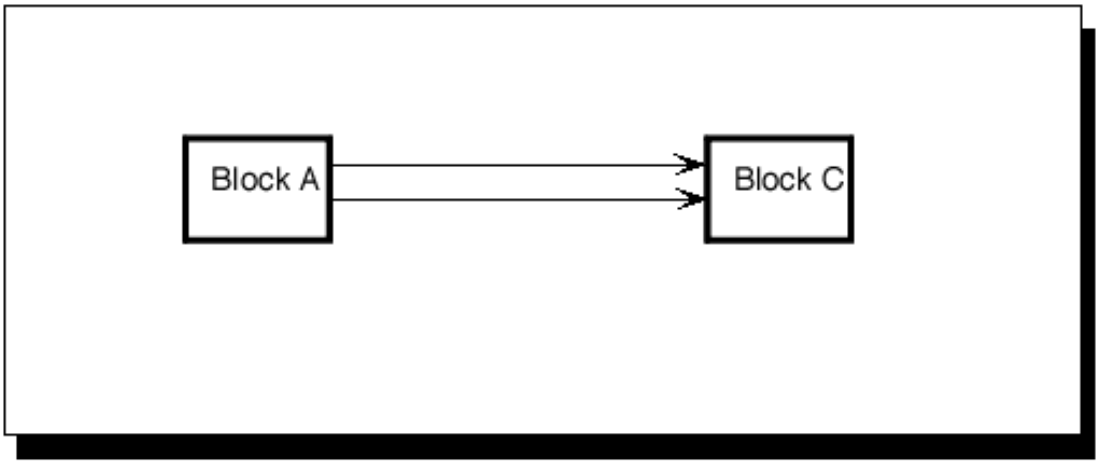
2.15 Deleting Blocks

The **delete** command removes the *Current Block* from the current HBlock but not the connections. All block connections are restored "through" the block; i.e., connections with the matching i/o numbers are remade. Unmatched connections are removed. If the current block is a HBlock, all sub-HBlocks are removed.

```
Capsim> delete
```



Topology Before Delete Command



Topology After Delete Command

Figure 2.7

2.16 Inserting Blocks

The **insert** command is used to insert the *Current Block* before(-) or after (+) a block into a connection. Connections are restored to the next available ports in the current block.

```
Capsim> insert <+/-> <blkname> <connum>
```

HBlock "input" and "output" are valid block names.

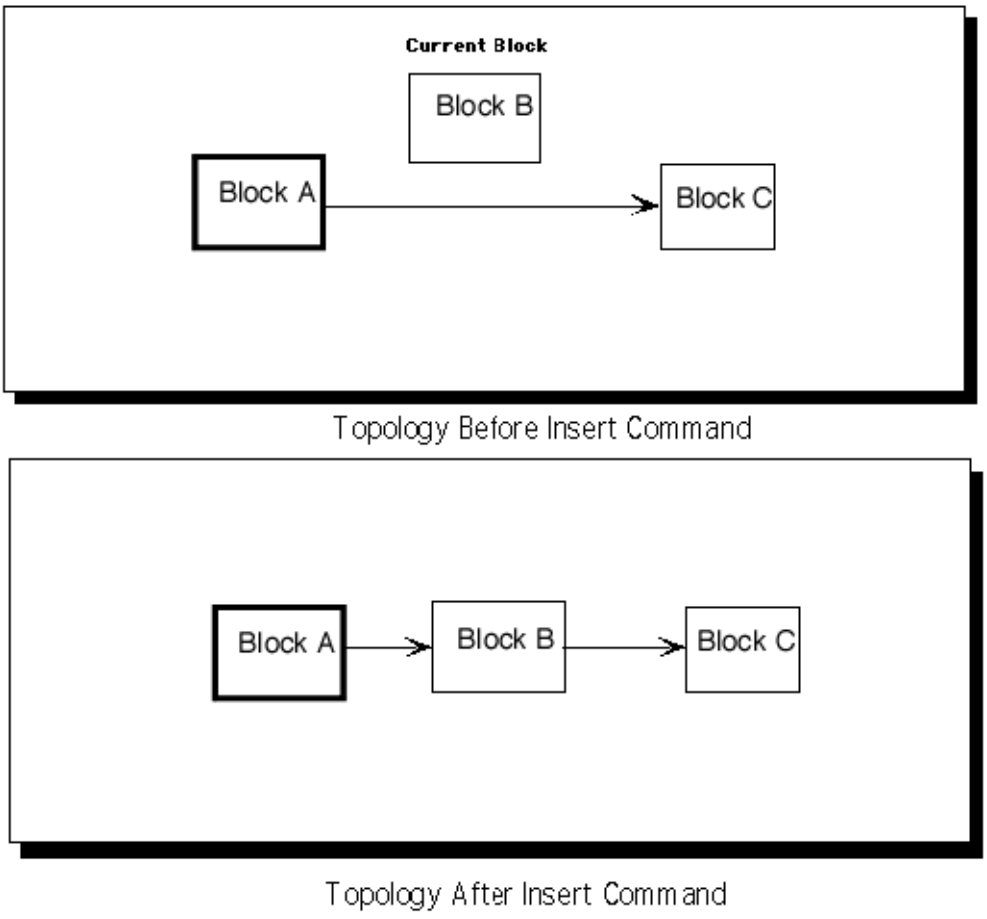


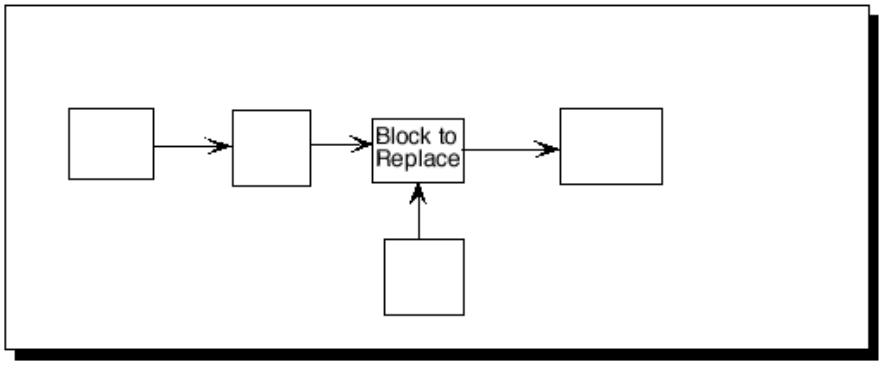
Figure 2.8

2.17 Replacing Blocks

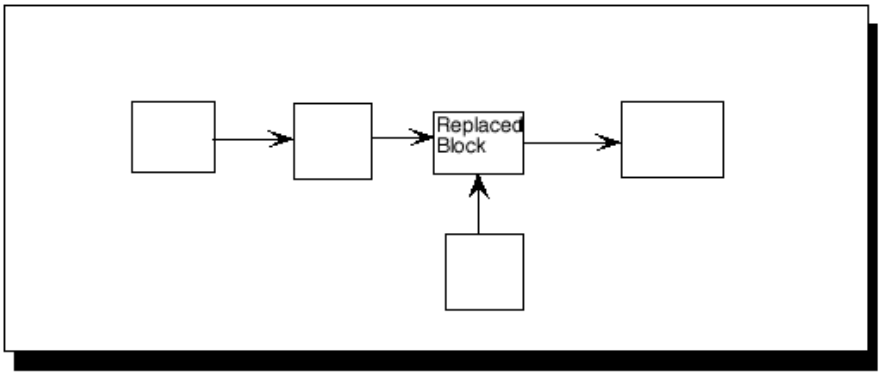
The **replace** command allows the user to replace a block (Current Block) with another block. First make the block to be replaced the current block. Then issue the command:

```
Capsim>replace (<name>) <modelname>
```

"modelname" must be a defined block or HBlock type. If "name" is supplied, it must be unique. A default name is generated if "name" is not given. All parameters are overwritten from the model.



Topology Before Replace Command



Topology After Replace Command

Figure 2.9

2.18 Search Paths

By default, CAPSIM only searches in the current working directory for block and HBlock files. You can use the **path** to specify alternate paths to search in. This allows you to keep all your blocks in a set of directories, and HBlocks in a different set.

```
Capsim> path s pathname
```

adds *pathname* to the list of directories that are searched when CAPSIM looks for a block file, and

```
Capsim> path g pathname
```

adds *pathname* to the list of directories that are searched for HBlocks.

A path to online documentation may also be specified.

```
Capsim> path d pathname
```

2.19 Aliases

CAPSIM contains an alias facility. When a command is presented to CAPSIM, each word that makes up the command is checked to see if it is an alias for a string. If so, the string is substituted for the alias before the command is executed. For example, if "pint" is an alias for "param int", then

```
Capsim> pint 20
```

is equivalent to

```
Capsim> param int 20
```

To set an alias, use the **alias** command:

```
Capsim>  alias  alias  substitution
```

To remove the substitution, use **unalias**:

```
Capsim> unalias alias
```

The alias expansion is disabled when setting or unsetting aliases, in order to avoid some disturbing situations.

To display what aliases are currently active, type **alias** without an argument:

```
Capsim> alias
```

2.10 The Shell Command

To execute a UNIX shell command from within capsim type **sh command**. For example to edit a topology type **sh vi test.t**. To get a directory of topologies type **sh ls *.t** .

It is a good idea to define a number of aliases in the .capsimrc file such as:
alias ls sh ls
alias date sh date.

2.19 History

The command shell has a simple history mechanism, similar to UNIX: "!!" means repeat last command, "!5" means repeat command 5, "!ab"means repeat the latest command beginning with characters "ab", etc. The accessible commands can be viewed by typing "display h". Command indices are shown with the prompt.

2.20 Inform

The **inform** command is to specify the Title, Author, Date, and Description of the universe or HBlock.

To display the title/author/date/description type:

```
Capsim> inform p
```

To change the information use the following commands:

```
Capsim> inform title This is the title
Capsim> inform author First Name Last Name etc.
Capsim> inform date July 20 1990
Capsim> inform descrip Description of the
topology
```

In the above, the underlined character indicates a required character for each command. This can be used to shorten the command. For example, all of the following commands are valid:

```
Capsim> inform t This is the title
Capsim> inform tit This is the title
Capsim> inform  des This is a description
Capsim> inform  de This is a description
```

The information supplied by the inform command will be stored at the top of a universe/HBlock as follows:

```
#-------------------------------------------------------
#Title:
#Author:
#Date:
#Description:
#-------------------------------------------------------
```

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Capsim TCL Interpreter

3.0 Capsim TCL Interpreter

3.1 Introduction

Capsim V6 has scripting support using a built in TCL interpreter. A major goal of adding TCL scripting is to support iterative simulations and to support TCL command interface to numerical packages such as LAPACK.

The TCL commands support all of the Capsim commands with the addition of new commands to refer to parameters by name and to change their value. Also Capsim blocks can return values from simulations via TCL variables.

3.2 TCL Script

The best way to see the power of TCL scripting is to review a TCL script for creating a table of BER (bit error rate) versus SNR (signal to noise ratio) in the simulation of a QPSK digital link.

```
#
# TCL Script that tabulates the BER for various SNR's
# The sys-ete-ber.t topology implements a
# QPSK digital communications link
# The number of bits is different for each SNR
# The script demonstrates coupling of two different
# paramters per simulation.
# The script stores the results of each run in a list.
# At the end of the iteration loop the results are
# tabulated.
#
# Author: Sasan Ardalan
# June 25th, 2006
#

new


set snr { -2 0 2 5  7 }
set bits { 10000 10000 100000 100000 10000000 }


capload sys-ete-snr.t
```

```
set berResults [list {}]
foreach snrVal  $snr numbits $bits {

    #
    # for each value of SNR $snr and corresponding
    # number of bits $bits set the parameters
    # in the topology. The number of bits is a global
    # parameter in arguments.
    # to change the SNR we first make the set SNR block
    # the current block. We then set the parameter
    # using the Capsim TCL command parambyname
    #
    arg 3 int $numbits  "number of bits"
    to setsnr0
    parambyname snr $snrVal

    run

    #
    # when the simulation is run, at the end of the
    # simulation the ecountfap0 block stores the BER in
    # the TCL variable $ecountfap0_ber
    #

    puts -nonewline "$snrVal : $numbits "
    puts "BER=$ecountfap0_ber"

    # gather the results in a list for each simulation

    lappend berResults [list $snrVal $ecountfap0_ber ]


}

#
# Create a table of BER versus SNR
#
puts [ llength $berResults ]
puts -nonewline SNR
puts -nonewline "\t"
puts   BER

foreach value $berResults {
   puts  -nonewline [lindex $value 0]
   puts  -nonewline "\t"
   puts   [lindex $value  1]

}
```

In the above script the key points are that once a topology is loaded, *sys-ete-snr.t* in this case, we can access any block parameter by name. We can also access the topology arguments. Furthermore, once a simulation is run, blocks can store their results in TCL variables. In this case the BER is stored in the variable *$ecountfap0_ber*.

The results of the simulation are:

```
SNR  BER
-2   0.05677
0    0.023237
2    0.005626
5    0.000220
7    5.000000e-06
```

Another important aspect of TCL scripts is that TCL commands including mathematical expressions can be used to set parameter values prior to running a simulation.

Finally, using TCL scripting algorithms can be developed for optimization of designs. In addition, sensitivity studies can be performed where the sensitivity of overall system performance to parameter variation can be analyzed.

Here is another Capsim TCL script example. Figure 3.1 shows the topology for *iirtest.t*. A sine wave is generated and filtered by an IIR low pass filter. Its rms value is calculated using the *stats* block. The TCL script changes the frequency parameter in the sine block (freq), runs a simulation, and retrieves the measured RMS value of the filter output from the *stats* block. The *stats0* block returns the RMS value as a TCL variable *stats0_rms*.

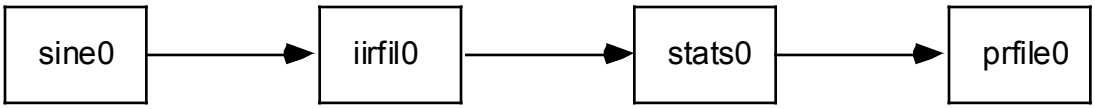

Figure 3.1 *iirtest* Topology

```
#
# TCL Script that iterates a number of
simulations
# The iirtest topology is a sine wave filtered by
a low pass IIR filter
# The filtered samples are processed by the
"stats" block which computes the
# RMS value.
# The script stores the results of each run in a
list.
```

```
# At the end of the iteration loop the results
are tabulated.
#
# Author: Sasan Ardalan
# June 25th, 2006
#



new
capload iirtest

#turn the printer probe off
to prfile0
parambyname control 0

set freq 0
to sine0
set results [list {}]
for { set i 0}  { $i < 10 } { incr i} {
   set freq [expr $freq+1000]
   puts $freq
   parambyname freq $freq
   run
   puts $stats0_sigma
   lappend results [list $freq $stats0_sigma]


}
puts -nonewline Freq
puts -nonewline "\t"
puts   RMS

foreach value $results {
   puts  -nonewline [lindex $value 0]
   puts  -nonewline "\t"
   puts   [lindex $value  1]

}
```

The results of the simulation are:

```
Freq    RMS
1000    0.68096101284
2000    0.690733492374
3000    0.672446846962
4000    0.152041137218
```

```
5000    0.038574591279
6000    0.027747457847
7000    0.0252503212541
8000    0.0251301862299
9000    0.0249269343913
10000   0.0243778862059
```

The *iirtest.t* topology is provided below. Note that the *freq* parameter that changes the frequency of the sine wave generator block is highlighted (the TCL command **parambyname** is used to change the frequency):

```
arg -1 (none)

param int 128    num_of_samples   "total number of samples
to output"
param float 1    magnitude   "Enter Magnitude"
param float 32000    fs   "Enter Sampling Rate"
param float 1000    freq   "Enter Frequency"
param float 0    phase   "Enter Phase"
param float 1    pace_rate   "pace rate to determine how
many samples to output"
param int 128    samples_first_time   "number of samples on
the first call if paced"
block sine0 sine

param file stdout    file_name   "Name of output file"
param int 1    control   "Print output control (0/Off,
1/On)"
param int 0    bufferType   "Buffer type:0= Float,1=
Complex, 2=Integer"
block prfile0 prfile

param int 0    skip   "Points to skip"
param file stat.dat    stat_file   "File to store results"
block stats0 stats

param int 3    desType
"1=Butterworth,2=Chebyshev,3=Elliptic"
param int 1    filterType
"1=LowPass,2=HighPass,3=BandPass,4=BandStop"
param float 32000    fs   "Sampling Frequency, Hz"
param float 0.1    pbdb   "Enter Passband Ripple in dB's"
param float 35    sbdb   "Enter Stopband Attenuation in
dB's"
param float 3400    fpb   "Passband Freq.
Hz/LowPass/HighPass Only"
param float 4400    fsb   "Stopband Freq.
Hz/LowPass/HighPass Only"
param float 220    fpl   "Lower Passband Freq.
Hz/BandPass/BandStop Only"
param float 3400    fpu   "Upper Passband Freq.
Hz/BandPass/BandStop Only"
param float 10    fsl   "Lower Stopband Freq.
Hz/BandPass/BandStop Only"
param float 4400    fsu   "Upper Stopband Freq.
Hz/BandPass/BandStop Only"
param file tmp    name   "Filter name"
block iirfil0 iirfil
```

```
connect sine0 0 iirfil0 0
connect prfile0 0 stats0 0
connect iirfil0 0 prfile0 0
```

3.2 Capsim TCL Command Summary

In the following summary of TCL commands, most commands are exactly the same as the Capsim commands with the following exceptions:

To store a topology the TCL command is *capstore* instead of *store*.
To load a capsim topology the TCL command is *capload* instead of *load*.
The Capsim command *info* in TCL is *getinfo*.

TCL Commands:

display	[g or s]
block block_model	block_model,or block block_name
replace block_model	block_model,or block block_name
HBlock block_model	block_model, or HBlock block_name
chp	[param number] [paramvalue]
connect [port]	blockNameSrc [port] blockNameDest
disconnect [port]	blockNameSrc [port] blockNameDest
run	
new	
to	path_to_block
capstore	[file_name]
capload	file_name
arg	argnum argtype argval "argprompt"
up	
down	
back	
forward	
setCellInc increase buffer	integer (number of cells allocated to FIFO)
setMaxSeg	integer (Maximum number of cell increments, setting too high may cause memory over flow. Too low results in buffer over flow)
path	[sgd] thePath

remove	
delete	
insert	<-,+> <specifiedBlockName> <i,o number>
signame	name_to inNum sigName
inform	field info
makecontig	
state	
getinfo	
man	block
parambyname	name value

Capsim Command Summary

4.0 CAPSIM COMMAND SUMMARY

Capsim (Capture and Simulate) is an interactive, sampled data simulation package. The program is controlled via commands which come either from user input or from topology (~.t) files. The command shell has a simple history mechanism, similar to UNIX: "!!" means repeat last command, "!5" means repeat command 5, "!ab"means repeat the latest command beginning with characters "ab", etc. The accessible commands can be viewed by typing "display h". Command indices are shown with the prompt. There is also a simple aliasing utility for the first word of a command. See "alias" below. The commands listed below are grouped by function. There is a documentation file for each command. To view any of these while Capsim is active, type (e.g.) "man block".

capsim	print this documentation file
block	create a block current bloc
HBlock,	create an HBlock current block
replace	change the current block model type
store	save current HBlock into a topology file
load	load a topology file into current HBlock
connect	block buffer connection
disconnect	block buffer disconnection
inform	Update and/or display info, author, date etc.
insert	insert current block into an old connection
name	give a name to the buffer connection
remove,	remove current block from HBlock
delete,	remove current block but restore any connections
new	remove all blocks in current HBlock
quit, exit	leave capsim with/without change confirmation
param, chp	block parameter specification, change
arg	HBlock parameter-model specify
up, down,	movement between topology levels
forward, back	movement between blocks in the current HBlock
to	move to the block with name matching a string
display	status display (several options)
path	create search path(s) to various file groups
alias, unalias	define simple strings for various commands
man, sh	manual (file) reference; perform a shell command
< *filename*	get commands from the file *filename*.
inform	specify title/author/date/description of universe/HBlock

alias, unalias : Define or undefine alias strings for commands.

alias (<shortWord> <commandString>)
: if no arguments are given, all currently defined alias pairs are printed.

<shortWord> : A single word, which will imply "commandString". A subsequent use of "shortWord" on the Capsim command line will be expanded to "commandString". Only the latest alias of "shortWord" is kept.

<commandString> : An arbitrary number of words. The first word MUST be a legitimate Capsim command word.

unalias <shortWord>
: eliminate "shortWord" as a keyword.

---

arg : Establish a model for an HBlock parameter.

arg <argnum> <argtype> <argval> (<"promptString">)

<argnum> : normally, a non-negative integer.
If negative, signals that HBlock has no parameters.
<argtype>
int : argval is an integer.
float : argval is a float value.
file : argval is a file name string.
NULL : deletes this argument definition.

<"prompt"> : String describing arg. It must be in quotes!
This is transcribed to the corresponding parent HBlock block parameter.

up, down, forward, back, to

These commands are used to change the current block (CB).
The current HBlock (CG) is always the parent of CB.

up : up one level, if CG is not the top level.
CB = CG. CG = CG's parent.
down : down one level, if CB is a HBlock.
CG = CB. CB = CB's child.
forward : CB = CB's forward sibling. This will wrap around.
back : CB = CB's backward sibling. This will wrap around.

to <arg>: movement via pattern match to block name. Compound arguments are allowed. Matching proceeds until failure. Partial patterns will work.
<args>
* : move to top level.
. : move up, if possible. ("to ." = "up")
/ : move down, if possible. ("to /" = "down")
"pat" : move forward to match "pat", if possible.

---

param, chp : Set parameters, change parameters.

param <ptype> <pval>
<ptype>
int : pval is an integer.
float : pval is a float value.
file : pval is a file name string.
function : pval is a function name string ending in ".c".
array : pval is a sequence of numbers.
The first is an integer denoting the array size.
Then follows that number of float values.
arg : pval is an integer, denoting the index of the
HBlock parameter to reference. See command "arg".
default : (no pval) ptype and pval retrieved from block model.

chp (<pindex> <pval>)
no arguments : User is prompted for new values for parameters of the current block. A <return> during prompt leaves value unchanged. If "default" is entered at prompt, the value from the block model is used. If "arg n" is entered (n is a non-negative integer), the value of parent parameter n is used. See command "arg". If "arg -1" is entered, the current block value is maintained, but no longer referenced to the parent.
<pindex> : integer index of defined parameter.
<pval> : A given value string is interpreted according to the previously declared parameter type. If pval == "default", the value from the block model is used. If pval == "arg n", the value of parent parameter n is used. If pval == "arg -1", the current block value is maintained, but no longer referenced to the parent.

---

connect, disconnect : control block data buffer connection.
insert : put current block between old connection.
name : name the signal for a connection.

The connect and disconnect commands have several allowed formats, with different degrees of io number interpolation.
("blkname" is the block instance name or "input" or "output".)

connect

1) connect <fromblkname> <outnum> <toblkname> <innum> (<signalName>)
: This is a complete specification, as in ~.t files
It will be verified as being available.
A one word signal name is optional; a default name is created, but not displayed.
2) connect <fromblkname> <toblkname>
: outnum and innum are chosen as "lowest available".
3) connect <fromblkname> -1 <toblkname> <innum>
4) connect <fromblkname> <outnum> <toblkname> -1

5) connect <fromblkname> -1 <toblkname> -1
: If an io number is -1, the lowest available is chosen.

disconnect

1) disconnect <fromblkname> <outnum> <toblkname> <innum>
: This is a complete specification to remove a previous connection. It will be verified as existing.

2) disconnect <fromblkname> <toblkname>
: outnum is set as "highest available connection to toblk". If fromblkname is "input", innum is "highest from input".

3) disconnect <fromblkname> -1 <toblkname> <innum>
4) disconnect <fromblkname> <outnum> <toblkname> -1
: if an io number is set to -1, it is interpolated.

insert <+/-> <blkname> <connum>
: The current block is to be inserted before (-) or after (+) block "blkname", into connection "connum". The named block, and the specified connection must exist. ("input" and "output" are valid block names.) Connections are restored to the next available ports in the current block. Signal names are propagated if available.

name <toblkname> <innum> <signalName>
: The connection is verified as existing. "toblkname" cannot be "output".

remove, delete, : remove current block(s) from current HBlock new

remove : remove current block from current HBlock. All block connections are removed. If the current block is a HBlock, all sub-HBlocks are removed.

delete : remove current block from current HBlock. All block connections are restored "through" the block; ie, connections with the matching i/o numbers are remade. Unmatched connections are removed. If the current block is a HBlock, all sub-HBlocks are removed.

new : delete all blocks in the current HBlock and any sub-HBlocks. There is a prompt for user verification if there have been any changes in the current HBlock, or any sub-HBlocks.

---

display, info : Display information about several things.

info : Display information about the current block.

display <option>: Display has several options. Only the first character of the option word is actually referenced.

<option>

none : Display information about the current block.

a(ll) : Display the current HBlock topology. The format is very similar to that of a stored topology file. A "(*)" after a block name means that it has been changed, ie, the corresponding topo file is out of date. This is cleared if the HBlock is stored.

s(tars) : Show all currently known blocks.

g(alaxies) : Show all currently known blocks.

h(istory) : Show the command history array.

quit, exit : Leave capsim with/without change confirmation.

quit : Prompt for verification, if there have been any changes in the current universe. The changes are noted by HBlock of occurrence. Changes can be cleared by storing appropriate HBlocks.
exit : Unconditional exit.

---

block, HBlock : create a new block or HBlock block;
replace : replace the current block; leave connections.

block (<name>) <modelname>
HBlock (<name>) <modelname>
: "modelname" must be a defined block/HBlock type.
See command "display s", or "display g".
If "name" is supplied, it must be unique.
A default name is generated from "modelname"
if "name" is not given.
If no "param" commands have been previously issued,
default parameters are created from the model.
Else, any non-conforming parameters are overwritten.

replace (<name>) <modelname>
: "modelname" must be a defined block or HBlock type.
If "name" is supplied, it must be unique.
A default name is generated if "name" is not given.
All parameters are overwritten from the model.

---

store, load : store or load current HBlock.

store (<modelname>)
: If "modelname" is not given, the current HBlock is stored in the current directory under name "currentHBlockName.t"
If "modelname" is given, the HBlock is stored in the current directory under name "modelname.t"
Additionally, if the current HBlock is the top level, the HBlock is renamed as "modelname".

load (<modelname>)
: If "modelname" is not given, the current HBlock name is used. The HBlock path list (see command "path g") is used to locate the file "modelname.t". This file is then loaded into the current HBlock. All sub-HBlocks are also loaded as necessary. User verification is sought if the overwritten HBlocks have any changes in them. The HBlock name is changed to "modelname" if new.

---

man, sh : review pertinent files; perform shell commands

man (<string>) : Find file and send to 'more' ('type' for VMS)

<string>
none : Look up base file for current block.
If block, use block paths to find "blkname.s" file.
If HBlock, use HBlock paths to find "blkname.t" file.
"name.s" : Use block paths to find "name.s" file.
"name.c" : Use block paths to find "name.c" file.
"name.t" : Use HBlock paths to find "name.t" file.
"name.x" : Converted to "name.s", and block paths used.
"name" : Use documentation paths to find "name.doc" file.

sh <string> : Perform "string" as a shell command and return to Capsim. String can be of arbitrary length, words.

---

path : Define or review that path(s) to several file directories.

path <string> (<newpath>)

<string> : Note only the first character of string is used.

s(tars) : If no "newpath" string, display all current paths to directories holding ~.s files. Else, add "newpath" to block paths.

g(alaxies) : If no "newpath" string, display all current paths to directories holding ~.t files. Else, add "newpath" to HBlock paths.

remove, delete, : remove current block(s) from current HBlock
new

remove : remove current block from current HBlock.
All block connections are removed.
If the current block is a HBlock, all sub-HBlocks
are removed.

delete : remove current block from current HBlock.
All block connections are restored "through" the
block; ie, connections with the matching i/o numbers
are remade. Unmatched connections are removed.
If the current block is a HBlock, all sub-HBlocks
are removed.

new : delete all blocks in the current HBlock and
any sub-HBlocks. There is a prompt for user
verification if there have been any changes in
the current HBlock, or any sub-HBlocks.

---

run : Run a Capsim simulation on current topology
This command can be issued while anywhere
within a topology.
There are several conditions that will cause a
run error:
- incomplete connections:
  - non-contiguous i/o buffer numbers
  - missing HBlock connections
- input/output connection(s) in top level
- improper connections for a particular block
- improper parameter values for a block

All these errors are described as they occur.

< filename : Execute commands in the file: *filename*.

This is a very useful command especially for sequential runs or parameter iteration. After a topology is entered, a series of repetitive commands which change one or more parameters and run the simulation can be executed from a file. The file itself may be created from a C program or a shell script.

Appendix A

CAPSIM Capability Improvements Over BLOSIM

Many features have been added to improve simulation design and run-time efficiency.

-program re-organization, saving 20% on executable size.

- improved scheduling algorithm.
Before a simulation is run, blocks are "scheduled" or put into an appropriate order of execution by the controller. The new algorithm selects a more efficient ordering.

- improved run-time control of data buffer size. Previously, certain buffers could grow abnormally large, requiring excessive memory usage. Buffer size is now balanced throughout the topology via an improved visitation algorithm.

- data buffer de-allocation, allowing multiple runs. Previously, multiple runs would overflow available memory.

- internal block (both block and HBlock) parameter model storage, specification, and definition. This provides consistency checking and prevents run-time errors. Additionally, the block author now specifies parameter default values and definitions.

- parameter broadcast (via "args") is possible even from the highest topology level.

- buffer signals can be named. These signal names are accessible by the block operational code, for printing, labeling, etc, and are displayed for reference.

- compilation is controlled internally for either UNIX or VMS operating systems. Allows maintenance of a single program version for use on several systems, and allows less painful installation.

- Argument numbers may be noncontiguous. However, when stored they become contiguous.

CAPSIM Convenience Improvements

Many features have been added or improved to aid the user in creating, editing and running simulations.

- on-line parameter changes with prompting; automatic type checking and compatibility enforcement for HBlock referenced parameters (args).

- on-line help descriptions for all commands.

- on-line review of block/HBlocksource files.

- command history: repeat/review of previous commands.

- command alias mechanism allows shortened commands.

- new movement command "to":
accepts full or partial name for a block or HBlock.

- change checking: prevents inadvertent exit or re-loading before
saving a modification.

- run a simulation from any location in the topology.

- improved information display format:
block modification status, parameter descriptions, signal names,HBlock argument values and descriptions.

- improved error reporting:
full block path names used; complete messages from block errors.

- simplified block creation:
automatic instance name, default parameter creation.

- simplified block connection/disconnection:
automatic default port numbering.

- re-loading of any sub-topology is possible.

- Buffer growth monitoring. This facility allows the user to monitor the growth of buffers during simulations.

- new command "replace": pin-for-pin block substitution.
HBlocks can be substituted for blocks, etc. Connections are saved, and parameters are modified automatically.

- new command "insert": put a block into an existing connection.
Useful for temporary measurement blocks, etc.

- new command "delete": remove a block, but restore connections.

- Single command to make buffer numbers contiguous.

CAPSIM Reliability Improvements

Besides the addition of new features,the original program has been extensively remodeled and re-organized. This has dramatically improved code understandability, which is important for maintenance and debugging.

- elimination of bugs through two years of personal and classroom use.

- redefinition of several key data structures.

- use of doubly linked lists.

- routines organized into more closely related source files.

- "linting" and cleanup of variables.

- improvement of "blockgaze",
a program which converts block primitive code to block compilable code
(i.e. *block.s -> block.c*).

- all added features are backward compatible with old HBlock topologies and old block primitive code.Automatic conversion takes place as necessary.

- general program logic overhaul: this is evidenced by the fact that even with all the added functionality described above,the number of source lines is *less* than original;in fact, executable size is 20% less than original.

Appendix B

Sample Capsim Session

The following is an actual Capsim session. It follows the tutorial in chapter 2. Bold letters are the keyboard inputs.

```
%capsim -b

Capsim/Blosim 3.2
Copyright (c) 1989   XCAD Corporation
All rights reserved.

        Topology File: universe.t
Capsim[0]-> display s
add         addnoise    arprocess   atod        bdata
bpf         casfil      cmux        cmxfft      cmxfftfile
cmxifft     convolve    cubepoly    cxmag       cxmult
cxphase     cxreal      dco         delay       demux
divby2      dtoa        ecount      eye         filtnyq
firfil      freqimp     gain        gauss       hist
hold        iirfil      impulse     intdmp      jitter
lconv       linecode    lpf         mixer       mulaw
mux         nl          node        null        plot
prfile      pulse       rdfile      resmpl      scatter
sdr         sine        sink        skip        slice
spectrum    sqr         sqrtnyq     stats       stcode
sum         time        toggle      transline   v29
zc          zero

 Ratio of LIBRARY Block type: 67/70


 Ratio of CUSTOM Block type: 0/70

Capsim[1]-> block impulse0 impulse
Capsim[2]-> block prfile0 prfile
Capsim[3]-> connect impulse0 prfile0
Capsim[4]-> to impulse0
 Current Block:  impulse0  (block: impulse)
Capsim[5]-> chp
 Enter 1 new parameters:
0: Enter number of samples
  param int 128 ?==>  10
Capsim[6]-> run
```

```
Output From Prfile 'prfile0'
impulse0:0
1
0
0
0
0
0
.
.
.
0
0
0
0
Capsim[9]-> info
Parent:  UNIVERSE
Name:  impulse0  (impulse0)
Type:  BLOCK
File:  impulse.s (library)
Status:  Modified
Parameters:
 0: Enter number of samples  (int) 10
Inputs:
 (none)
Outputs:
 0:  prfile0 (prfile) 0         data

Capsim[10]-> chp
 Enter 1 new parameters:
0: Enter number of samples
  param int 10 ?==>  20
Capsim[11]-> run

Output From Prfile 'prfile0'
data
1
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
Capsim[12]-> store
```

```
Capsim[13]-> new
Capsim[14]-> arg 0 float 0.9 "Filter Pole"
Capsim[15]-> block add0 add
Capsim[16]-> block delay0 delay
Capsim[17]-> chp
 Enter 1 new parameters:
0: Enter number of samples to delay
  param int 1 ?==>
Capsim[18]-> block node0 node
Capsim[19]-> block gain0 gain
Capsim[20]-> chp
 Enter 1 new parameters:
0: Gain factor
  param float 1 ?==>  arg 0
Capsim[21]-> display a
*****************************************************
        parent HBlock  UNIVERSE  (universe.t)

arg 0 float 0.9 (0.900000)  "Filter Pole"

block add0 add (*)

param int 1  "Enter number of samples to delay"
block delay0 delay (*)

block node0 node (*)

(arg 0) param float 0.9  "Filter Pole"
block gain0 gain (*)


*****************************************************
 Current Block:  gain0  (block: gain)
Capsim[22]-> connect input add0
Capsim[23]-> connect add0 node0
Capsim[24]-> connect node0 gain0
Capsim[25]-> connect gain0 delay0
Capsim[26]-> connect delay0 add0
Capsim[27]-> connect node0 output
Capsim[28]-> display a
*****************************************************
        parent HBlock  UNIVERSE  (universe.t)

arg 0 float 0.9 (0.900000)  "Filter Pole"

block add0 add (*)

param int 1  "Enter number of samples to delay"
block delay0 delay (*)

block node0 node (*)

(arg 0) param float 0.9  "Filter Pole"
block gain0 gain (*)

connect input 0 add0 0
connect add0 0 node0 0
```

```
connect delay0 0 add0 1
connect node0 0 gain0 0
connect node0 1 output 0
connect gain0 0 delay0 0

*****************************************************
 Current Block:  gain0  (block: gain)
Capsim[29]-> store filter
Capsim[30]-> run
 (Error 42) top level contains input/output terminals
 (Error 42) top level contains input/output terminals

Capsim[31]-> new
Capsim[32]-> load universe
*****************************************************
        parent HBlock  universe  (universe.t)

arg -1 (none)

param int 20  "Enter number of samples"
block impulse0 impulse (*)

param file stdout  "Name of output file"
param int 1  "Print output control (0/Off, 1/On)"
block prfile0 prfile (*)

connect impulse0 0 prfile0 0    data

*****************************************************
 Current Block:  impulse0  (block: impulse)
Capsim[40]-> to prfile0
 Current Block:  prfile0  (block: prfile)
Capsim[41]-> HBlock filter
Capsim[42]-> chp
 Enter 1 new parameters:
0: Filter Pole
  param float 0.9 ?==>
Capsim[43]-> disconnect impulse0 prfile0
Capsim[44]-> display a
*****************************************************
        parent HBlock  universe  (universe.t)

arg -1 (none)

param int 20  "Enter number of samples"
block impulse0 impulse (*)

param file stdout  "Name of output file"
param int 1  "Print output control (0/Off, 1/On)"
block prfile0 prfile (*)

param float 0.9  "Filter Pole"
HBlock filter0 filter.t (*)


*****************************************************
 Current Block:  filter0  (HBlock: filter.t)
```

```
Capsim[45]-> connect impulse0 filter0
Capsim[46]-> connect filter0 prfile0
Capsim[47]-> display a
*****************************************************
        parent HBlock  universe  (universe.t)

arg -1 (none)

param int 20  "Enter number of samples"
block impulse0 impulse (*)

param file stdout  "Name of output file"
param int 1  "Print output control (0/Off, 1/On)"
block prfile0 prfile (*)

param float 0.9  "Filter Pole"
HBlock filter0 filter.t (*)

connect impulse0 0 filter0 0
connect filter0 0 prfile0 0

*****************************************************
 Current Block:  filter0  (HBlock: filter.t)
Capsim[48]-> store test
Capsim[49]-> run

Output From Prfile 'prfile0'
filter0:0
1
0.9
0.81
0.729
0.6561
0.59049
0.531441
0.478297
0.430467
0.38742
0.348678
...
0.166772
0.150095
0.135085
Capsim[50]-> quit
%
```