SystemC Headstart

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Version 2

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Introduction

The Doulos SystemC Headstart Kit

The Doulos SystemC™ Headstart Kit helps you to get started with SystemC. The kit is intended to help with the basic questions such as

- How do I install SystemC?
- How do I create a SystemC project using my particular compiler and operating system (OS)?
- Is it possible to co-simulate SystemC and a hardware description language (HDL)?
- What problems might I encounter, and how should I solve them?

The Headstart Kit includes a simple example design but is not intended to teach SystemC itself. There is a tutorial on our website at

http://www.doulos.com/knowhow/systemc/tutorial

which covers the basics, but to be able to use SystemC for a real project, you would be wise to take proper training: see

http://www.doulos.com/content/training/systemc_fundamental_training.php

For a thorough reference, you can download the SystemC Language Reference Manual via the Open SystemC Initiative (OSCI) website, http://www.systemc.org - you'll need to register first.

For a handy pocket-sized reference (well, for those with fairly large pockets!) see our SystemC Golden Reference Guide. The Golden Reference Guide is included on our SystemC training courses, or you can buy one by following the links from

http://www.doulos.com/webshop/

Now let's start at the beginning, with SystemC installation.

Installing SystemC

SystemC can be installed on a range of operating systems and with various C++ compilers. This section gathers together our experience for both Linux and Windows based systems.

Whatever platform or compiler you are using, make sure you read the INSTALL and RELEASENOTES files which are part of the SystemC distribution.

At the time of writing, the version of the SystemC library is 2.2.0.

Linux Install

```
0. make sure you are running as root

1. Download systemc-2.2.0.tgz to a convenient place, e.g.
/usr/local/src

2. uncompress

   gunzip systemc-2.2.0.tgz
```

Note: users of the Firefox web browser may find that Firefox itself has uncompressed the file. In that case the previous step may not work - you'll just have to rename systemc-2.2.0.tgz to systemc-2.2.0.tar and carry on.

```
3. untar the file

   tar -xf  systemc-2.2.0.tar

This creates a directory

   /usr/local/src/systemc-2.2.0

containing all the installation files.

5. Create a directory to which you will install. The default is
/usr/local/systemc-2.2.0

   mkdir /usr/local/systemc-2.2.0

6. cd /usr/local/src/systemc-2.2.0

7. mkdir objdir

8. cd objdir

9. Check that g++ is available:

which g++

10. If g++ is not available in your path, set the environment variable
CXX
```

cshell syntax:

```
setenv CXX /path/to/g++
```

bash syntax:

```
export CXX=/path/to/g++
```

(obviously replace "/path/to/g++" with the actual path where the g++ executable is located).

11. run configure by typing:

```
    ../configure
```

Note: If you prefer to install to a different location than /usr/local/systemc-2.2.0, then type

```
    ../configure --prefix=/my_other_path_to/systemc-2.2.0
```

12. run make to create libraries

```
    make debug
```

Note: "debug" ensures that debugging symbols are included in the library which is useful during development. If you don't care about debugging within the library, just type

```
    make
```

Note: If you intend to do memory profiling (e.g. with valgrind) then you may prefer to use the pthreads library. The SystemC library can be compiled with QuickThreads (the default) or POSIX Threads (pthreads). pthreads has better tool support for debugging and profiling, but runs slightly slower. To choose pthreads, type

```
    make pthreads
```

13. do final install

```
    make install
```

14. With the Makefile structure we suggest below, each user will then need to set the entries in Makefile.defs to the location of SystemC, and also set TARGET_ARCH.

Visual C++ 2005 Express Edition Install

For Visual C++ 2003. NET, you can simply follow the instructions in the INSTALL file supplied with SystemC.

For Visual C++ 2005 Express Edition, it is necessary to follow slightly modified instructions - but first you must install the Windows Platform SDK as a separate step.

Installing the Windows Platform SDK

Note: this is only needed for Visual C++ 2005 Express Edition - it is not needed for Visual C++ .NET 2003, or for Visual C++ 2008 Express Edition.

```
1. Download the windows Platform SDK from Microsoft. These notes use
the Windows Server 2003 Platform SDK SP1 which was supplied as a CDROM
image in the file

    5.2.3790.1830.15.PlatformSDK_Svr2003SP1_rtm.iso

2. Burn an image of the onto a CD

3. Autoruns from CD

4. Welcome to the Setup Wizard
  Next

5. End User License Agreement
  I agree
  Next

6. User Information
  <your name>
  <your company>
  Next

7.  Select an Installation Type
  Typical
  Next

8. Select an Installation Location
  (leave at default C:\...)
  Next

9. Begin Installation
  Next

10. Finish
```

Now carry on and install SystemC.

Installing SystemC with Visual C++ 2005 EE

Make sure you are logged in as administrator, or you have administrator privileges.

0. After download, you should have a file called something like:

```
 systemc-2[1].2.0.tgz
```

1. Extract this file to C: using e.g. 7-zip.

2. Extract to C: (archive creates top level systemc-2.2.0 dir in c:)

3. add environment variables

my computer > properties > advanced > environment variables

In the System variables section, click

```
New (only if the variable doesn't exist yet...)
variable name SYSTEMC
variable value C:\systemc-2.2.0\msvc80
OK OK OK
```

4. Copy c:\systemc-2.2.0\msvc71 to c:\systemc-2.2.0\msvc80

5. Launch Microsoft Visual C++ 2005 Express Edition and open the systemC workspace:

```
   C:\systemc-2.2.0\msvc80\SystemC\systemc.sln
```

(Note: don't double-click on it as that may automatically launch the wrong version of VC++, if you have more than one installed)

Let the tool convert it to the new project format.

6. Make sure that the Platform SDK is installed (see elsewhere) and that the paths are in the project settings

i.e.

```
    (i). Tools > Options
      Click the Projects Tab
      Select VC++ Directories

    (ii). Select Executable Files
      add
      C:\Program Files\Microsoft Platform SDK\Bin

    as the first path

    (iii). Select Include Files
      Set the first path to
      C:\Program Files\Microsoft Platform SDK\Include

    (iv). Select Library Files
      Set the first path to
      C:\Program Files\Microsoft Platform SDK\lib
```

(v). Click OK

Note: the settings above apply *per user*.

7. Select menu Build> Batch Build

Select All
Build

(takes a few minutes!)

You'll get a lot of warnings. If you don't like them, set the macro _CRT_SECURE_NO_DEPRECATE in the macro settings for the project.

Note: the following settings apply *per user*.

8. In VC++.NET, Select Tools -> Options . . . and the Projects and Solutions -> VC++ Directories tab

9. Select show directories for: Library files

10. Select the 'New' icon and enter: $(SYSTEMC)\SystemC\debug

11. Select show directories for: Include files

12. Select the 'New' icon and enter: $(SYSTEMC)\..\src

Note: you should remove any Library and Include directories from old versions of SystemC you may have installed previously.

13. Click OK

Visual C++ 2008 Express Edition Install

Make sure you are logged in as administrator, or you have administrator privileges.

0. After download, you should have a file called something like:

systemc-2[1].2.0.tgz

1. Extract this file to C: using e.g. 7-zip.

2. Extract to C: (archive creates top level systemc-2.2.0 dir in c:)

3. add environment variables

my computer > properties > advanced > environment variables

In the System variables section, click

New (only if the variable doesn't exist yet...)
variable name SYSTEMC
variable value C:\systemc-2.2.0\msvc90
OK OK OK

4. Copy c:\systemc-2.2.0\msvc71 to c:\systemc-2.2.0\msvc90

5. Launch Microsoft Visual C++ 2005 Express Edition and open the systemC workspace:

C:\systemc-2.2.0\msvc90\SystemC\systemc.sln

(Note: don't double-click on it as that may automatically launch the wrong version of VC++, if you have more than one installed)

Let the tool convert it to the new project format.

6. Select menu Build> Batch Build

Select All
Build

(takes a few minutes!)

You'll get a lot of warnings. If you don't like them, set the macro
_CRT_SECURE_NO_WARNINGS
in the macro settings for the project.

Note: the following settings apply *per user*.

7. In VC++.NET, Select Tools -> Options . . . and the
Projects and Solutions -> VC++ Directories tab

8. Select show directories for: Library files

9. Select the 'New' icon and enter: $(SYSTEMC)\SystemC\debug

```
10. Select show directories for: Include files
```

```
11. Select the 'New' icon and enter: $(SYSTEMC)\..\src
```

Note: you should remove any Library and Include directories from old versions of SystemC you may have installed previously.

```
12. Click OK
```

SystemC Projects

Building on Linux

One of the most straightforward ways to build SystemC projects on Linux is to use Gnu make. The system we use at Doulos has the feature that dependencies are automatically generated - that is if you edit a header file, and a source file depends on that header, the source will automatically be recompiled.

The system consists of two files. One file is shared across many projects, and is called Makefile.defs. Each project then contains an individual Makefile

The Makefile

Here is the code of a typical project Makefile

```
EXTRACFLAGS = -DDEBUG_SYSTEMC
EXTRA_LIBS =
MODULE = run
SRCS = $(wildcard *.cpp)

OBJS = $(SRCS:.cpp=.o)

include ~/Makefile.defs
```

EXTRA_CFLAGS may be used to add additional flags to the basic flags set in Makefile.defs.

EXTRA_LIBS may be used to add extra library commands (for example including the SystemC Verification Library by adding -lscv).

MODULE is the name of the executable program - it has '.x' appended to it by Makefile.defs, so the final executable above will be called run.x

SRCS is a list of source (.cpp) files. GNU Make has the feature of using a wildcard, shown above - however you can just type in a list of files instead.

OBJS creates a list of object files for each source - you don't have to edit this.

The final line includes the default settings. Makefile.defs may be placed anywhere - in this example it is in the user's home directory.

Makefile.defs

The following page lists the contents of Makefile.defs

```
## Variable that points to SystemC installation path
SYSTEMC = /usr/local/systemc-2.2.0

## edit this to gccsparcOS5 for solaris
TARGET_ARCH = linux

CC     = g++
OPT    = -O0
DEBUG  = -g

SYSDIR = -I $(SYSTEMC)/include

INCDIR = -I. -I.. $(SYSDIR)
LIBDIR = -L. -L.. -L$(SYSTEMC)/lib-$(TARGET_ARCH)

## Build with maximum gcc warning level
CFLAGS = -Wall -Wno-deprecated -Wno-return-type -Wno-char-subscripts \
$(DEBUG) $(OPT) $(EXTRACFLAGS)

LIBS   =  -lstdc++ -lm $(EXTRA_LIBS) -lsystemc

EXE    = $(MODULE).x

.PHONY: clean

$(EXE): $(OBJS) $(SYSTEMC)/lib-$(TARGET_ARCH)/libsystemc.a
	$(CC) $(CFLAGS) $(INCDIR) $(LIBDIR) -o $@ $(OBJS) $(LIBS) 2>&1 | c++filt

## based on http://www.paulandlesley.org/gmake/autodep.html
%.o : %.cpp
	$(CC) $(CFLAGS) $(INCDIR) -c -MMD -o $@ $<
	@cp $*.d $*.P; \
	sed -e 's/#.*//' -e 's/^[^:]*: *//' -e 's/ *\\$$//' \
	-e '/^$$/ d' -e 's/$$/ :/' < $*.d >> $*.P; \
	rm -f $*.d


clean:
	-rm -f $(OBJS) *~ $(EXE) *.vcd *.wif *.isdb *.dmp *.P *.log

-include $(SRCS:.cpp=.P)
```

Normally you only need to edit this file once, to set up the variables SYSTEMC and TARGET_ARCH. After that it "just works"...

Usage

Just type

```
gmake
```

to create an executable and

```
gmake clean
```

if you want to delete all created files (including the executable itself).

Building with Visual C++ 2003 .NET

Visual C++ 2003. NET requires you to set up a project as follows:

Each time you set up a SystemC project in Microsoft Visual C++, you must take the following steps:

1. Select menu File->New->Project...

2. Select Win32 Console Project

3. Set the *Location* to be the path to the directory **above** the directory that contains your C++ files

Set the *Project name* to be the name of the directory that contains your C++ files

Click on OK

4. The Win32 Application Wizard will appear. Select Application Settings

Tick Empty Project
Click on Finish

5. Select menu Project->Add Existing Item...

6. Select all your C++ source files, then click on Open

7. Select menu Project->Properties

8. Select C/C++ then select Language

9. Set Run Time Type Info to *Yes (/GR)*

10. Select Linker then select Input

11. In the Additional Dependencies type systemc.lib

12. Click on OK

Building with Visual C++ 2005 EE

These instructions assume you have set up the Include and Library directories correctly for SystemC, and the Include directories for the Windows Platform SDK - remember these settings need to be carried out per user.

To create a SystemC project:

1. Launch Visual C++ 2005 Express Edition

2. Select menu File > New > Project...

The New Project dialogue appears

3. In the Project Types: pane, highlight Win32

4. In the Templates: pane, highlight Win32 Console Application

5. Set the *Location:* to be the path to the directory **above** the directory that contains your C++ files

6. Set the *Project name:* to be the name of the directory that contains your C++ files

7. Click on OK

The Win32 Application Wizard appears

8. Click on Application Settings

9. Make sure Application Type: is set to Console, and that Empty Project is ticked

10. Click Finish

11. Add your files by selecting Project > Add Existing Items

12. Highlight all your .h and .cpp files, and click Add

To disable warnings:

13. Select menu Project > Properties

The Property Pages dialogue appears.

14. Browse in the tree at the left to Configuration Properties + C/C++ + Preprocessor

15. In the Preprocessor Definitions, append
   ;_CRT_SECURE_NO_DEPRECATE
to any existing macros

and click Apply

16. Select Configuration Properties + C/C++ + Code Generation and change the Runtime Library to Multi-threaded Debug (/MTd)

17. Select Configuration Properties + C/C++ + General and set Detect 64 bit Portability Issues to No

18. Select Configuration Properties + C/C++ + Command Line and add the option

```
    /vmg
```

in the Additional Options: pane at the bottom

19. Select Configuration Properties + Linker + Input and in the Additional Dependencies: line add

```
   systemc.lib
```

20. Click OK

Now you can build your project - the quickest way to build and run is Ctrl + F5.

Note - the settings above apply to one configuration - the debug configuration by default. You may need to repeat them for the Release configuration if you want to use Release mode.

Building with Visual C++ 2008 EE

These instructions assume you have set up the Include and Library directories correctly for SystemC - remember these settings need to be carried out per user.

To create a SystemC project:

1. Launch Visual C++ 2008 Express Edition

2. Select menu File > New > Project...

The New Project dialogue appears

3. In the Project Types: pane, highlight Win32

4. In the Templates: pane, highlight Win32 Console Application

5. Set the *Location:* to be the path to the directory **above** the directory that contains your C++ files

6. Set the *Project name:* to be the name of the directory that contains your C++ files

7. Click on OK

The Win32 Application Wizard appears

8. Click on Application Settings

9. Make sure Application Type: is set to Console, and that Empty Project is ticked

10. Click Finish

11. Add your files by selecting Project > Add Existing Items

12. Highlight all your .h and .cpp files, and click Add

To disable warnings:

13. Select menu Project > Properties

The Property Pages dialogue appears.

14. Browse in the tree at the left to Configuration Properties + C/C++ + Preprocessor

15. In the Preprocessor Definitions, append
   ;_CRT_SECURE_NO_WARNINGS
to any existing macros

and click Apply

16. Select Configuration Properties + C/C++ + Code Generation and change the Runtime Library to Multi-threaded Debug (/MTd)

17. Select Configuration Properties + C/C++ + General and set Detect 64 bit Portability Issues to No

18. Select Configuration Properties + C/C++ + Command Line and add the option

```
    /vmg
```

in the Additional Options: pane at the bottom

19. Select Configuration Properties + Linker + Input and in the Additional Dependencies: line add

```
   systemc.lib
```

20. Click OK

Now you can build your project - the quickest way to build and run is Ctrl + F5.

Note - the settings above apply to one configuration - the debug configuration by default. You may need to repeat them for the Release configuration if you want to use Release mode.

Example Projects

This section shows three example projects. The first is plain C++; the second is an example of co-simulation with VHDL; and the final version is essentially the same as the first, but in a more "C++-ish" style of coding.

The examples are supplied in two versions - one has windows line endings and is in the archive headstartfiles.zip.

The other has unix line endings, and is in the file headstartfiles.tar.gz.

To use the Window files unzip the archive using an unzip program.

To use the Unix/Linux programmes, untar and unzip the files as follows:

```
gunzip headstartfiles.tar.gz
tar -xf headstartfiles.tar
```

In either case, you will get a folder headstart, containing three subfolders:

```
dut_systemc

dut_systemc_cppstyle

dut_vhdl
```

and a file

```
Makefile.defs
```

SystemC Example Project

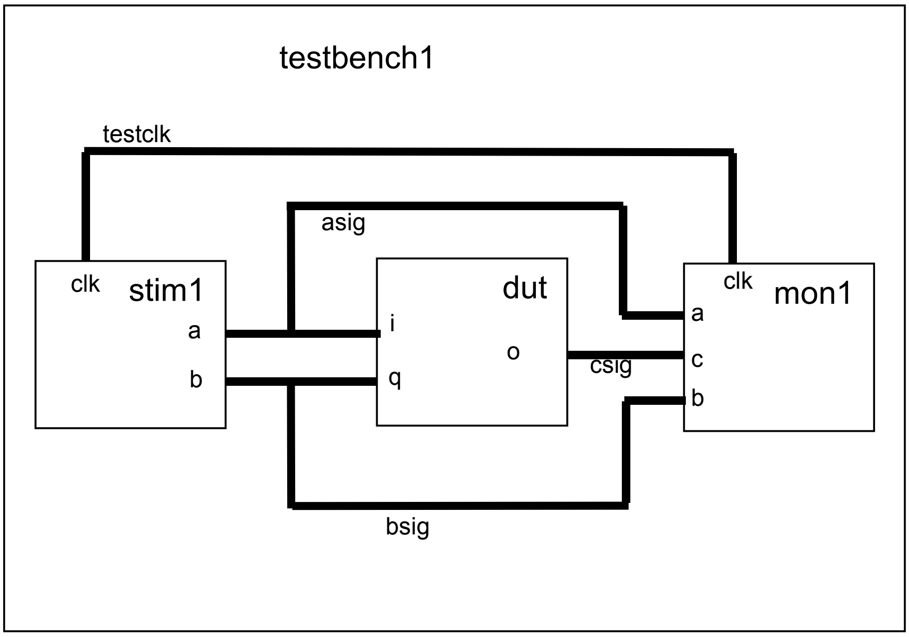
This is in the directory

```
    dut_systemc
```

The example consists of a very simple device under test (DUT) which is instanced, together with a stimulus and monitor, in a top level module.

Description

Here is a diagram



The thick black lines represent channels, three sc_signals and one sc_clock. The module testbench1 is instanced inside the function sc_main().

The device under test is a very simple algorithm as follows, it implements as sum-of-squares.

```
o = i * i + q * q
```

The implementation uses two instances of a multiplier, and one instance of an adder. Of course there are many other ways of implementing such a function, but this example was deliberately written to use hierarchy (instances) within the dut.

Compiling (Linux)

Make sure you edit `headstart/Makefile.defs` so that the variables `SYSTEMC` and `TARGET_ARCH` are correct.

```
cd headstart/dut_systemc/

gmake

./run.x
```

The program should run, and lots of numbers appear!

Compiling (Visual C++ 2005 EE)

Make sure you've set up your environment correctly, especially the variable SYSTEMC.

Double-click on the file

```
    headstart\dut_systemc\dut_vc2005\dut_2005.sln
```

Visual C++ should start. The quickest way to run is to use Ctrl-F5, which builds and runs the program.

The program should run, and lots of numbers appear!

Compiling (Visual C++ 2008 EE)

Make sure you've set up your environment correctly, especially the variable SYSTEMC.

Double-click on the file

```
    headstart\dut_systemc\dut_vc2008\dut_2008.sln
```

Visual C++ should start. The quickest way to run is to use Ctrl-F5, which builds and runs the program.

The program should run, and lots of numbers appear!

SystemC Example Project (C++-ish)

This is in the directory

```
dut_systemc_cppstyle
```

The only difference between this example and the previous example is the style of coding. If you are an experienced C++ programmer, you may have noticed that SystemC makes a number of macros available, such as SC_MODULE and SC_CTOR.

This version of the example replaces those macros with traditional C++ constructs. Also all instances are made using pointers - and this allows forward declaration of the modules rather than inclusion of header files.

SystemC Example Project (VHDL DUT)

This is in the directory

```
    dut_vhdl
```

Description

The DUT is replaced by a VHDL implementation - but the surrounding testbench, stimulus, and monitor are still SystemC.

The example has been written so that it will work with Mentor ModelSim/Questa, and Cadence Incisive Unified Simulator. These simulators can both set and recognise special macros - here is the top level (main.cpp) showing the use of the macros

```
#include "systemc.h"
#include "testbench.h"

#ifdef MTI_SYSTEMC

// export top level to modelsim
SC_MODULE_EXPORT(testbench);

#elif NCSC

// export top level to Cadence Incisive
NCSC_MODULE_EXPORT(testbench);

#else

// top level instanced in sc_main for use with OSCI
// reference simulator
int sc_main(int argc, char * argv[])
{
  testbench testbench1("testbench");
  sc_start();
  return 0;
}
#endif
```

The macro MTI_SYSTEMC is set by Modelsim. SC_MODULE_EXPORT tells Modelsim the top level of the design.

NCSC and NCSC_MODULE_EXPORT perform the same function for Incisive.

The code for the dut looks like this

```
#ifdef MTI_SYSTEMC

#include "systemc.h"

class SumOfSquares : public sc_foreign_module
{
  public:
    sc_in<sc_bv<8> > i;
    sc_in<sc_bv<8> > q;
    sc_out<sc_bv<17> > o;

    SumOfSquares(sc_module_name nm, const char* hdl_name)
      : sc_foreign_module(nm, hdl_name),
      i("i"),
      q("q"),
      o("o")
      {}

    ~SumOfSquares()
      {}

};

#elif NCSC

#include "systemc.h"
class SumOfSquares : public ncsc_foreign_module
{
  public:

    sc_in<sc_bv<8> > i;
    sc_in<sc_bv<8> > q;
    sc_out<sc_bv<17> > o;

    SumOfSquares(sc_module_name nm) : ncsc_foreign_module(nm),
      i("i"),
      q("q"),
      o("o")
      {}

    const char* hdl_name() const
    {
      return "SumOfSquares";
    }

};

#else

// ... SystemC Implementation omitted

#endif
```

Mentor uses a special class sc_foreign_module; Cadence uses a special class ncsc_foreign_module.

Compiling

To compile and simulate these designs, you will need either Modelsim/Questa, or Incisive, and you will require the correct licence features to compile and simulate both VHDL and SystemC.

ModelSim/Questa on Windows

Make sure that the vsim executable is in your path.

Double-click headstart/dut_vhdl/scripts/start_modelsim.bat

If it doesn't work, check your path again - or alternatively edit start_modelsim.bat so that it uses the full path to vsim, rather than just the name "vsim".

Modelsim should run, compile, simulate, and display waveforms. You'll see that the dut is shown in a different colour as it comes from VHDL.

ModelSim/Questa on Linux

Make sure that the `vsim` executable is in your path.

```
cd headstart/dut_vhdl/script
./start_modelsim.bat
```

If it doesn't work, check that `vsim` is in your path by typing

```
which vsim
```

which should return the path.

Also check the script is executable

```
chmod +x start_modelsim.bat
```

Modelsim should run, compile, simulate, and display waveforms. You'll see that the dut is shown in a different colour as it comes from VHDL.

Incisive on Linux

Execute the script as follows

```
cd headstart/dut_vhdl/script
./start_ncsim.csh
```

If it doesn't work: check which version of Incisive you have installed. If it is an older version, edit the script so that it says:

```
#!/bin/csh
ncsc_run -GNU -top testbench -access +rwc -v93 -gui *.cpp dut.vhd
```

This is because the irun command was only introduced in later versions.

To view waveforms, edit the `start_ncsim.csh` script and add the option `-gui`.

Cleaning up (Linux)

You can run the script `clean.csh` to tidy up the files, e.g.

```
cd headstart/dut_vhdl/script
./clean.csh
```

Notes on co_simulation

The examples above are for two particular tools - you can of course carry out co-simulation in most simulators - for instance Aldec Riviera, Synopsys VCS-MX, Synopsys System Studio, CoWare Platform Architect and so on. On a Doulos training course, we try wherever possible to supply the tools you normally use in your day-to-day work.

Conclusion

This short guide, together with the files included, will help you get started with the initial steps for using SystemC - installing the library, creating projects, compiling, and even co-simulation with and HDL.

For more information on SystemC training and other resources, see http://www.doulos.com

If you have any queries about this Headstart Kit, you can email info@doulos.com with your questions.