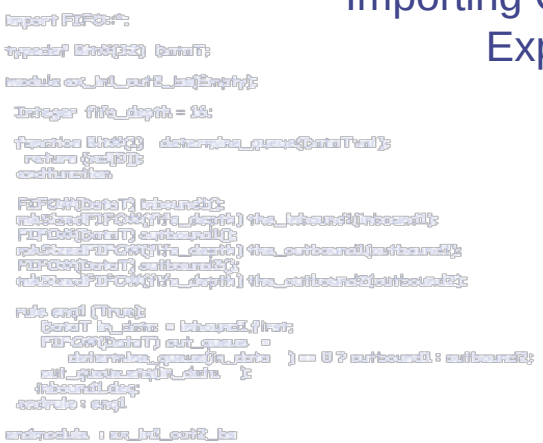
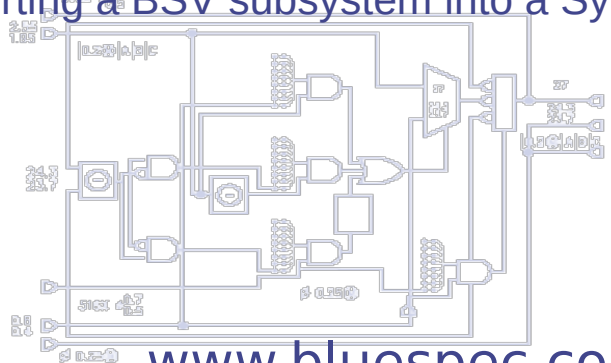
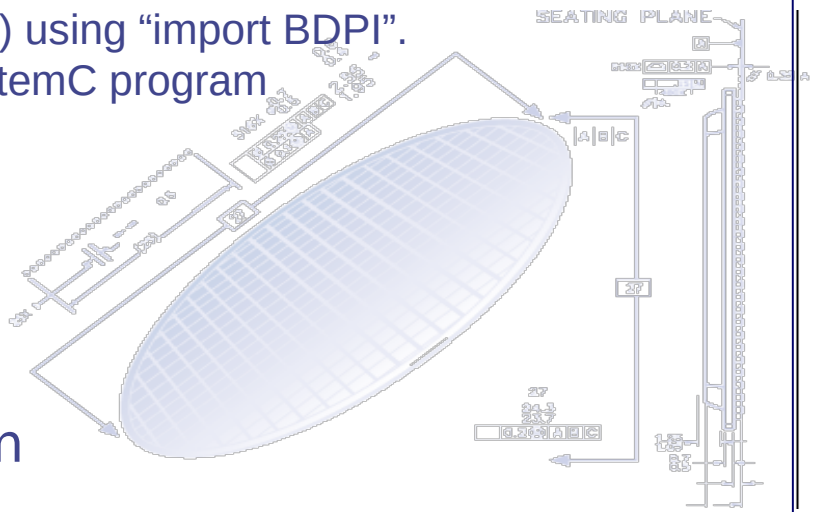
BSV Training

Lec_Interop_C

Importing C code into BSV (for simulation only) using “import BDPI”.
Exporting a BSV subsystem into a SystemC program







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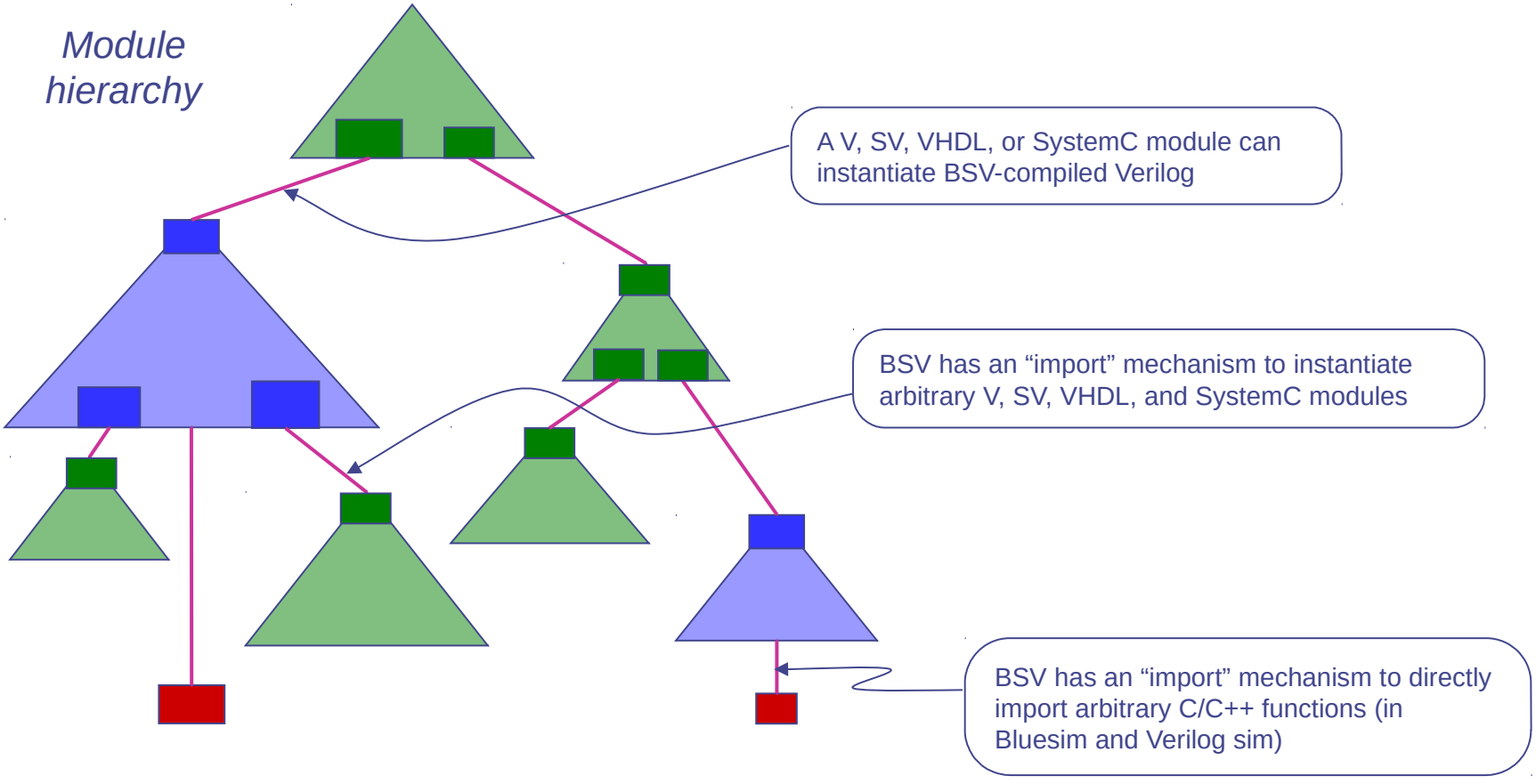
BSV interoperates with V, SV, VHDL, SystemC, and C/C++



Legend

- V (Verilog), SV (SystemVerilog), VHDL, or SystemC (event-driven)
- BSV
- C, C++

Plugging C/C++ into BSV

Motivations for importing C/C++

- Many applications begin life as C/C++ models:
  - When you are creating a HW accelerator for an existing SW program
  - When you are trying to choose the best algorithm before going to HW implementation

  As you incrementally develop your BSV implementation, you may wish to reuse C/C++ components temporarily (or even permanently, for the testbench)

- When you add a new “primitive” to BSV by importing Verilog, you may also want to import a corresponding C model for running in Bluesim
  - In fact, all BSV “primitives” are imported this way—the knowledge is not built into the compiler

Importing C

- You declare a BSV function prototype (i.e., just the types) which is then implemented in C
- Example:

```
// C code
#include <stdio.h>
#include <stdlib.h>

unsigned int rand32()
{
    return (unsigned int) rand();
}
```

```
// file Import_Decls.bsv      Note: BSV, not Classic
package  Import_Decls;

import "BDPI" rand32 =
    function ActionValue #(Bit#(32)) bsv_rand32();

endpackage
```

```
mkTest :: Module Empty
mkTest =
  module
    myFIFO :: FIFO (Bit 32) <- mkSizedFIFO 9

    rules
      "fill": when True ==> do
        x <- bsv_rand32
        myFIFO.enq  x

      "empty": when True ==> do
         myFIFO.deq
         $display "Number %d" myFIFO.first
```

Importing C: arguments and results

- There is a 1-to-1 correspondence between the arguments and result in the BSV prototype and in the C function.
- Allowed arguments types
  - any type that is in the Bits typeclass
  - String
  - polymorphic types
- Allowed result types:
  - any type that is in the Bits typeclass
  - Action
  - ActionValue t where t is in the Bits typeclass
  - polymorphic types (and polymorphic ActionValue t types)

- For “small” types (<= 64b), the corresponding C argument or result is the nearest C scalar integer type adequate to contain it (char, short, long, long long)

- For “larger” types and polymorphic types, the C function receives a “void *” pointer to the storage for that value
  - This storage contains the “raw bits” of the BSV representation
  - For return types that are passed using “void *” like this, the “void *” pointer is passed as the first argument of the C function, not returned as the C function value

- Details and examples in the Reference Guide, Sec. 16

Recommendation: arguments and results

- Although the 'import C' arguments and results can be of arbitrary type, it's usually too much effort, and too error-prone, and too non-portable to exploit this capability
  - The representation of C types varies across C compilers and across target architectures (insertion of padding for word alignment, little- and big-endianness, etc.

- **Recommendation**:

  a) Stick to just a few standard, highly portable types: 32b and 64b scalars, and arrays/vectors thereof.
     - In the C code, use standard types declared in <stdint.h>: uint32_t, int32_t, uint64_t, int64_t, and arrays of those types
     - In the BSV code, correspondingly, use UInt 32, Int 32, UInt 64, Int 64, and Vector n t of those types

  b) In both the C code and the BSV code, write functions to convert from "native" types (enums, structs, unions) to standard types (a) and back.
     - Being purely in C and BSV, such conversion functions are easy to write and very predictable and reliable
     - E.g., convert a struct to and array of uint32_t or uint64_t
     - E.g., convert a C pointer to a uint64_t (pointers may not fit in uint32_t)

  c) In both the C code and the BSV code, use these functions on arguments and results so that only these standard types (a) are passed between C and BSV

Linking in the imported C function(s)

- Compilation of an “import BDPI” produces intermediate “.ba” files

```
# bsc -u -sim DUT.bsv
checking package dependencies
compiling DUT.bsv
Foreign import file created: compute_vector.ba
code generation for mkDUT starts
Elaborated Bluesim module file created: mkDUT.ba
code generation for mkTB starts
Elaborated Bluesim module file created: mkTB.ba
```

- In the link stage (for Bluesim or Verilog sim, you supply these .ba files and the C file

```
# bsc -sim -e mkTB -o bsim mkTB.ba mkDUT.ba compute_vector.ba vectors.c
Bluesim object created: mkTB.{h,o}
Bluesim object created: mkDUT.{h,o}
Bluesim object created: schedule.{h,o}
User object created: vectors.o
Bluesim binary file created: bsim
```

When you compile for Verilog sim, bsc generates the appropriate “VPI”-like linkage files that allows your Verilog simulator to import the C code (for most popular simulators like VCS, NCSim, Modelsim, iVerilog, CVC, etc.)

Importing C++ (as opposed to C)

The BSV “import BDPI” mechanism can only directly invoke C functions (it assumes function linkage conventions for C, and C++ typically has different linkage conventions).

C++ has an ‘extern “C”’ construct that tells the C++ compiler to compile a function with C linkage instead of C++ linkage. That function, in turn, can freely call C++ functions.

Thus, the following example illustrates the idiom for calling C++ from BSV:

- We using “import BDPI” to invoke a function myMainC_function() which has C linkage
- This, in turn, calls the desired C++ function myMainCPP_function():

```
// File foo.cpp   (C++)

// This is the C++ function we would like to invoke from BSV
int myMainCPP_function(int a, int b) {
   … C++ code …
}

extern ”C” {  // This is the function imported into BSV
   void myMainC_function (int a, int b)
   {
        return myMainCPP_function (a, b);
   }
}
```

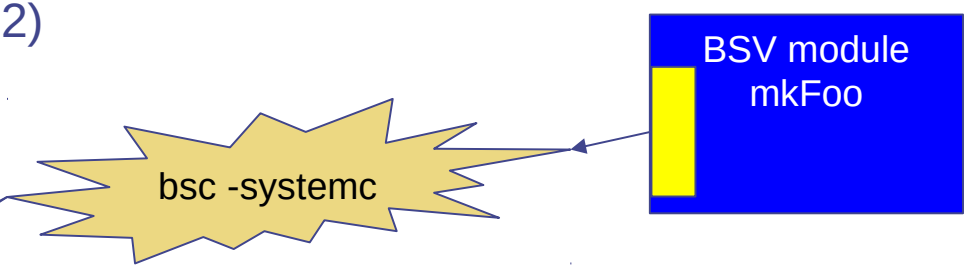
Plugging BSV into SystemC

Plugging BSV into SystemC

The *bsc* compiler directly supports, via a command-line flag, the creation of a "plug-in" into a SystemC program (User Guide Sec. 4.3.2)

```
// File mkFoo_systemc.h (SystemC)

SC_MODULE (mkFoo)
{
  public:
   sc_in<…> …;
   sc_out<…> …;
   …
  public:
   SC_CTOR (mkFoo) …
   ~mkFoo() …
}
```

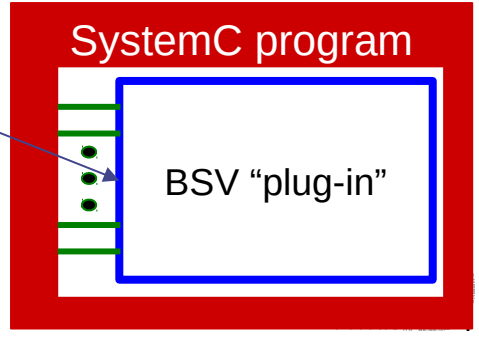


The .h file is standard SystemC. It declares mkFoo as a SystemC SC_MODULE. The sc_in and sc_out ports are SystemC signal declarations, corresponding exactly to what you would have got if you had compiled the BSV code to Verilog.
You should "#include" this .h file in your SystemC program, which can then invoke the constructor mkFoo to instantiate the module, and use the sc_in and sc_out ports to communicate with it, in the usual SystemC way.

```
// File mkFoo_systemc.cxx
// C++ code (not SystemC)
// implementing the declarations
// in the .h file

…
```

The .cxx file is compiled with your C++ compiler as usual, and linked in with the rest of your SystemC program's object files, to create the SystemC executable.

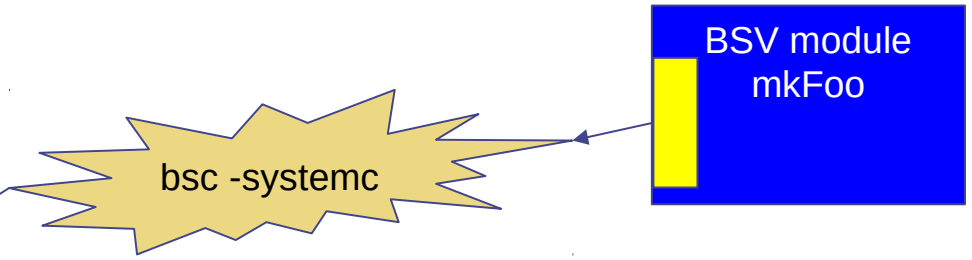


(Bluespec tests this facility with the standard OSCI SystemC simulator, but expects it to work with any SystemC simulator)

Plugging BSV into SystemC

Note: Only the .h file is intended for human readability.

Although the .cxx file is C++ source code, it is a complex translation of the cycle-level behavior of the source BSV module and does not try to mirror the BSV source structure in any recognizable way.

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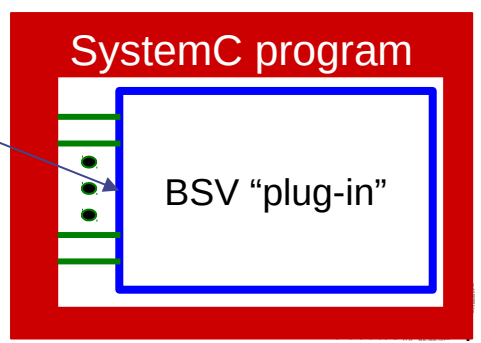

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