Transaction Level Modeling with SystemC

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Outline

- Abstraction Levels
- SystemC Communication Mechanism
- Transaction Level Modeling of the AMBA AHB/APB Protocol
- Generic Transaction Level Channel
Abstraction Levels:

- **Transaction Level**
  - **Layer 3: Message Layer**
    - Model (un-)timed functionality
    - Point-point communication
  - **Layer 2: Transaction Layer**
    - Analyze SoC architecture, early SW development
    - Estimated timing
  - **Layer 1: Transfer Layer**
    - Cycle true but faster than RTL
    - Detailed analysis, develop low-level SW

- **Pin Level**
  - **Layer 0: Register Transfer Level**
# SystemC Language Architecture

## Methodology-specific channels

### Elementary Channels
- Signal, Timer, Mutex, Semaphore, FIFO, etc.

### Data Types
- 4-valued logic (0, 1, X, Z)
- 4-valued logic-vectors
- Bits and bit-vectors
- Arbitrary-precision integers
- Fixed-point numbers
- C++ user-defined types
- C++ built-in types (int, char…)

### Time
- Concurrency
- Modules
- Processes
- Interfaces
- Ports
- Channels
- Events
- Event-driven sim. kernel

## C++ Language Standard
SystemC Communication Mechanism: How?

- Separate Functionality from Communication
  - Functionality: implemented in Modules
  - Communication: implemented in Channels

- Interface Method Calls (IMC)
  - The collection of a fixed set of communication Methods is called an Interface
  - Channels implement one or more Interfaces
  - Modules can be connected via their Ports to those Channels which implement the corresponding Interface (sc_port<interface> )
Module1::process()
{
    port->write(42);
}

Module2::process()
{
    x = port->read();
}
Hierarchical Channel

Channels can be hierarchical, i.e. they can contain processes, ports, modules and channels.
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Transaction-Level Modeling of the AMBA AHB/APB Protocol

- Background
  - implemented in the spirit of “simple_bus”
    (transfers modeled via dedicated interface methods)

- Requirements
  - cycle-accurate (Layer 1)
  - optimal simulation speed
  - ease of use (blocking interface)
  - integration of low-level models (non-blocking interface)
  - enable SW debugging (debug interface)
Hierarchical Channel

Channels can be hierarchical, i.e. they can contain processes, ports, modules and channels.
TLM Bus Model (Layer 1, simplified)
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Bus → {Arbiter, Decoder, Slave}: Interface Method Call
AHB Master-Bus Interface

- **Blocking**
  - `bool burst_read(id, data, start_address, burst_length, burst_mode, num_bytes);`
  - `bool burst_write(id, data, start_address, burst_length, burst_mode, num_bytes);`

- **Non-Blocking**
  - `void request(id);`
  - `bool has_grant(id);`
  - `void init_transaction(id, read_mode, address, ...);`
  - `void set_data(id, data);`
  - `bool response(id, status);`
  - `...`

Note that such interfaces are always protocol-specific
AHB Interfaces (cont’d)

- Direct Bus Interface (Debugging)
  - bool direct_read(address, data, num_bytes);
  - bool direct_write(address, data, num_bytes);

- Bus-Slave Interface
  - void set_data(data);
  - void control_info(burst_mode, transfer_type, ...);
  - void read(address, num_bytes);
  - void write(address, num_bytes);
  - bool response(status);
  - ...

AMBA AHB Components

- AHB bus with external arbiter and decoder
- Interconnection matrix for AMBA multilayer support
- AHB bus monitor
- Processors (ARM 926, ARM 946)
- Pin Level adaptors
- Example masters and slaves
- Example AHB platforms
AMBA APB Components

- AHB-APB bridge with APB bus
- APB bus monitor
- Pin Level adaptors
- APB peripherals
  - Remap and pause controller
  - Interrupt controller
  - APB timer
- Example AHB/APB platforms
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Generic Transaction-Level Channel

- **Background**
  - Developed by Nokia and Synopsys in cooperation with TI and Sonics for OCP

- **Requirements**
  - Point-to-point connection (module ↔ generic channel ↔ module)
    - Data passing and synchronization
  - Interface independent of communication protocol
    - Protocol to be implemented by the user
    - Can be used for Layers 1, 2, and 3
Generic TL Channel: A Building Block for easy Transaction-Level Modeling

Recap interface method calls (IMCs)

Interface methods are executed in the context of the calling process.
Generic TL Channel: A Building Block for easy Transaction-Level Modeling

How to implement concurrent behavior (pipelining, split transfers, ...) with IMCs?

More events are needed when
- module needs to wait for channel to be ready
- channel needs to wait for module to collect data
Generic TL Channel: A Building Block for easy Transaction-Level Modeling

The generic channel is a building block that eases implementing data passing and synchronization of initiator and target.

It is not a ready-made implementation of any communication protocol.
Generic Channel Interface (simplified)

- **Initiator ("Master")**
  - `TdataCl* GetDataCl();`
  - `bool MputRequest*();`
  - `bool MgetResponse*(bool release);`
  - `void Mrelease(time);`

- **Target ("Slave")**
  - `TdataCl* GetDataCl();`
  - `bool SgetRequest*(bool release);`
  - `bool SputResponse*();`
  - `void Srelease(time);`

**TdataCl:**
- template parameter
- depends on application and communication protocol being used
Flow of Events

```c
data = port->GetDataCl();

data = port->GetDataCl();
```

Master | Slave

```c
data->input = 42;
MputWriteRequestBlocking();

SgetRequestBlocking(true);
int mem = data->input;
if (mem != 0)
data->response = true;
else
data->response = false;
SputResponseBlocking();

MgetResponseBlocking();
if (data->response) ...
```

data type is likely to depend on the protocol
The bus protocol has to be implemented by the user; is it not part of the generic interface.
Summary

- **Abstraction Levels**
  Transaction Level comprises multiple Layers (Message, Transaction, Transfer)

- **SystemC Communication Mechanism**
  Interface Method Calls (IMC)

- **Transaction Level Modeling of the AMBA Protocol**
  Efficient implementation based on IMCs

- **Generic Transaction Level Channel**
  Building Block for easy Transaction Level Modeling
Further information

- **SystemC and Transaction-Level Modeling**
  - OSCI website: www.systemc.org
  - “System Design with SystemC”

- **Generic Transaction-Level Channel White Paper**
  - www.ocpip.org/data/systemc.pdf

- **AMBA models**
  - www.synopsys.com