

A Cross-domain Heterogeneous ABV-Library for Mixed-signal Virtual Prototypes in SystemC/AMS

Muhammad Hassan¹ (muhammad.hassan@dfki.de) Thilo Vörtler², Karsten Einwich² Rolf Drechsler^{1,3} Daniel Große^{1,4} ¹Cyber-Physical Systems, DFKI GmbH, Bremen, Germany ²COSEDA Technologies GmbH, Dresden, Germany ³Institute of Computer Science, University of Bremen, Bremen, Germany ⁴Institute of Complex Systems, Johannes Kepler University, Linz, Germany



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- Motivation
- Challenges
- Contribution
- Conclusion and outlook

Smart Devices







Heterogeneous System on Chip



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Virtual Prototypes





Modern VP-based Verification Environment



Poor quality Testsuite and VP



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AMS VP Verification – Challenge





Big problem!

Practical system-level assertions library!

Contribution: System-level Assertions Library

- System-level assertions library for heterogeneous systems
 - SystemC/AMS + TLM
 - Follows SystemVerilog Assertions (SVA) closely
- Application Programming Interface
 - Intuitive
 - User-friendly
 - Expressive
- Complex behaviors
 - Analog-to-digital
 - Digital-to-analog ...
- Software/Hardware interactions
- Industrial Case Studies
 - ARM V8 based CPU using ARM Fast Models
 - Temperature control system

Outcome: High-quality verified DUV





SystemVerilog Assertions Standard

• SystemVerilog Assertions (SVA)



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Building blocks

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Mainly for digital systems!

System-level Assertions Library - Architecture



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Intelligence



Assertion Example

Required behavior



- b is true 2 cycles after a is true
- SystemVerilog assertion



- System-level assertions library
 - 1. sequence $a_b = a | delay(2) | b$;
 - 2. property example_prop = a_b;
 - 3. example_prop.default_sampling(clk.posedge_event());
 - 4. ASSERT_PROPERTY (example_prop);

Boolean Layer and Lambda Functions

- Boolean layer
 - Describes the atomic behavior of signals
 - Lambda functions are supported
 - Define complex functionality inside an assertion

```
1. expr<std::function<int(void)>> lambda { []() {
```

```
2. return calc_average();
```

3. } };

```
4. auto expr_lambda = lambda < 3.0;
```

5. ASSERT_PROPERTY (expr_lambda);

Operator	Name
+= -= /= *= &= =	Binary assignment operators
< <= > >=	Binary relational operators
+ - * =	Binary arithmetic operators
&& == !=	Binary logical operators
+ - ! ++	Unary operators

Supported boolean operators



Sequence Layer and More ...

- Sequence layer
 - Builds on top of boolean layer
 - Specifies temporal relationship between boolean expressions
 - Support for delay () and repeat ()
- // delay (value) and repeat (value)
 sequence seqr1 = expr_a | delay (3) | expr_b | repeat (2)
- 3. //repeat (min_value, max_value)
- 4. sequence seqr2 = expr_a | delay (2,3) | expr_b | repeat (1,3)

delay	Specifies delay from current sampling point until the next
and	Sequence and operation
or	Sequence or operation
repeat	Repetition operator
	Sequence continue operator

Description

Operator

Supported sequence operators



Property Layer and Implications



- Property layer
 - · General behaviors to be specified
 - An implication built up from several sequences

antecedent - > * consequent
where - > * is overlapping implication operator

- 1. expr expr1 = a_int < 42;
- 2. sequence expr2 = true | delay(1,2) | expr_a + expr_b;
- 3. property non_overlap = expr1 ->* expr2;
- 4. ASSERT_PROPERTY (non_overlap);

Not supported – non-overlapping assertion!*

* One can use delay(...) operator

Experimental Evaluation – Case Study

- Temperature control system
 - Software + digital hardware + analog
 - SystemC/AMS + TLM
 - Time dataflow model
 - Electrical linear network
 - An ARM V8 based CPU using ARM Fast Models – Linux OS + SW
 - 4 ADT7420 temperature sensors discrete event model
 - AMBA bus to connect temperature sensors and ARM processor
 - An environment model (Thermal_Network)
 - A heater model





Experimental Evaluation – Scenario



- Booting a Linux operating system on the ARM processor,
- A control SW is executed on top of Linux. The control SW continuously measures (monitors) the temperature sensor output,
- If the SW detects that the temperature value falls below a programmed threshold value, it switches the heater to ON state,
- Otherwise, when the temperature exceeds a certain programmed threshold, the heater is switched to OFF state

Assertion description

When the temperature of Room 1 t_r1 (SystemC TDF signal) is above the threshold t_t (SW-controlled TLM register value), the heater has to be switched off (*heater_sw*) within 1 ms.



Assertion description

When the temperature of Room 1 t_r1 (SystemC TDF signal) is above the threshold t_t (SW-controlled TLM register value), the heater has to be switched off (*heater_sw*) within 1 ms.

➡

auto heater_off = (t_r1 > t_threshold) ->* (true | delay(1_SC_MS) | (heater_sw==false));
 heater_off.default_sampling(1_SC_MS);

Experimental Evaluation – Simulation Results



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