Static Analysis of SystemC/SystemC-AMS System and Architectural Level Models

Karsten Einwich, Thilo Vörtler
COSEDA Technologies

SYSTEMS INITIATIVE

2020
DESIGN AND VERIFICATION™
DVCON
CONFERENCE AND EXHIBITION
EUROPE

Outline

- Motivation
- Generic Concept
- Framework Implementation in SystemC
- Analyzer Examples
- Application Example
- Result Visualization
- Summary

Motivation

- Numerous properties can be analyzed/estimated statically based on structural information using simple formulas
- Static analysis is extremely fast compared to extracting the property by a dynamic simulation
- Very often complex excel sheets are used to perform static analyzes
- Difficult to maintain consistency between excel sheets and system implementation
- Supporting of different configurations, operating modes or settled states becomes extremely complex
- Increasing complexity of the structure of the system limits the excel approach

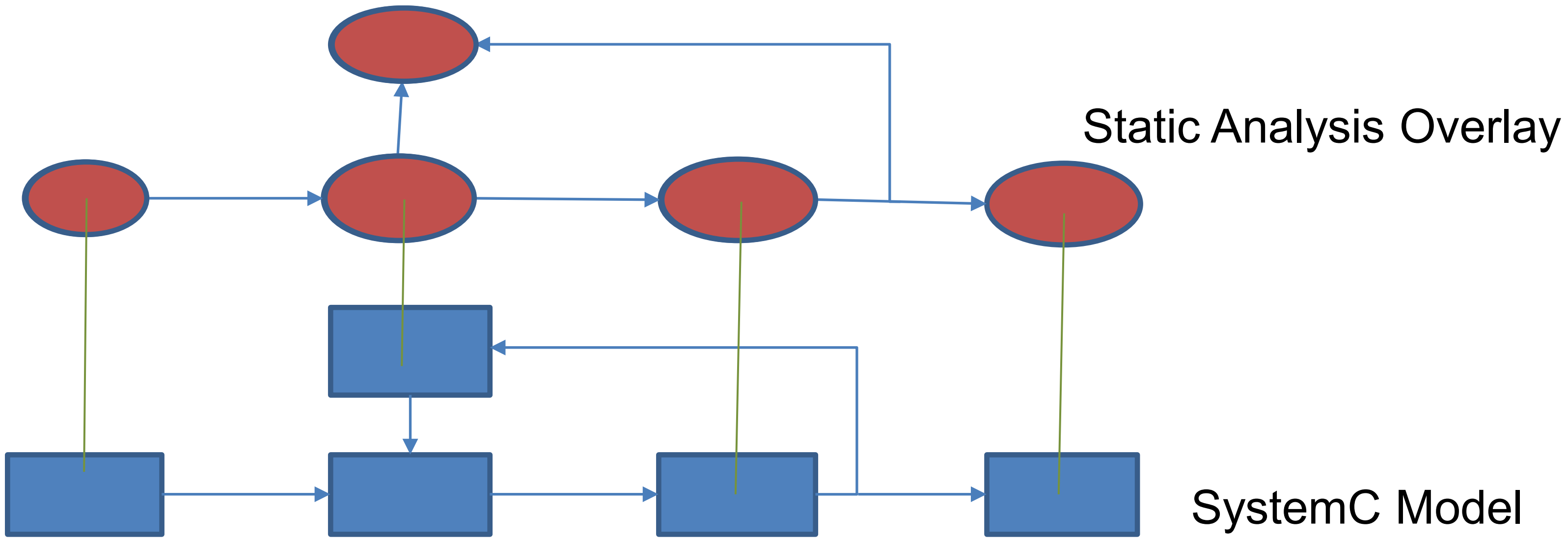
Examples for Static Analyses

- Power Consumption (in different operating modes)
- Chip Area
- Timing Analysis
- Gain / Signal level
- Noise
- Interception Points (IP2/IP3)
- …

© Accellera Systems Initiative

Generic Concept - Principle

- Attach the static properties to the modules of a SystemC/SystemC-AMS based simulation model
- Analyze the properties using the hierarchical structure, connectivity and the current state of the model



Generic Concept – Mapping to SystemC

- Static properties are represented by a class derived from a static analyzer attribute base class which is derived from the SystemC **sc_core::sc_attribute**
- The SystemC standard mechanism is used to **attach** the attributes to objects of class **sc_core::sc_module**
- The **ports** of the module are categorized as in- or outport and **referenced** to the static property
- The attached properties are analyzed using the **SystemC hierarchy exploration** methods (e.g. get_parent_object) and for analyzing the connectivity the port base class method get_interface
- The static property contains a **callback to calculate and propagate** the property value in dependency of pre-decessor values and the current module state

Generic Concept – Classes of Analyzers

- Analyzers can be principally categorized in three categories:
  1. Hierarchic Analyzer
     - Analyzes and combines properties of a hierarchic level and propagates them through the hierarchy
     - Examples: Power, Chip Area
  2. Dataflow analyzer
     - Analyzes/combines values along a datapath
     - Examples: gain, noise, IP2/IP3
  3. Equation system based Analyzer
     - An equation system is setup and solved based on the system structure, the properties representing contributions to the equation system
     - Examples: Settled value, AC-analysis
- The presented framework supports directly analyzers of class 1 and 2

Framework Implementation– Attribute Base Class

```
class cos_analyzer_attr_base : public sc_core::sc_attribute<cos_analyzer_value>
{
public:
    cos_analyzer_attr_base(sc_core::sc_module* parent);

    //access to number of predecessors / sucessors for a dataflow analysis
    unsigned long get_number_of_inports() const;
    unsigned long get_number_of_outports() const;

    //predecessor/successor value access/ propagation
    template<class T>
    void set_outport_value(const T& val,long o);

    template<class T>
    T get_inport_value(unsigned long i);

    template<class T>
    T get_module_value() const;

    //value callback function to propagate the value
    virtual void value_function(){}

};
```

Framework Implementation– Analyzer Base Class

```
class cos_static_analyzer_base
{
public:
    virtual void analyze() = 0; //callback to perform the analysis

    //start dataflow analysis
    void analyze_datapath(const std::vector<std::string>& starting_points);

    void analyze_hierarchy();  //start hierarchic analysis


    //utility functions for generic analysis result access

    //for hierarchic analyzis
    const vector<tree_analysis_result_element>& get_tree_analysis_result();

    //for dataflow analyzis
    const vector<std::vector<cos_analyzer_attr_base*> >& get_clusters();


    //callback function to recognize attributes which belong to
    //a concrete analyzer
    virtual bool is_type(cos_analyzer_attr_base*) = 0;
};
```

Analyzer Example – Power Analyzer

- Calculates/Estimates the power consumption in the current system state
- A power analyzer sums the annotated power values of one hierarchy level and attaches it to the corresponding instance of the next hierarchy level
- -> Hierarchic Analyzer

© Accellera Systems Initiative

Analyzer Example – Power Analyzer - Attribute

```
class cos_analyzer_attr_power : public cos_analyzer_attr_base

public:
            cos_analyzer_attr_power(sc_core::sc_module* mod, double val);

            void set_value(double val);
            double get_value() const;

            //datastructure to hold the values for the analysis
            struct cos_budget_value : public cos_value_base
            {
                        double value=0.0;
            } value;

         //call back function for calculating the power
            void value_function(cos_value_base&) override;

};

void cos_analyzer_attr_power::value_function(cos_value_base& previous)
{
       auto res=dynamic_cast<cos_power_value*>(&previous);
       //sum power values
       res->value+=this->get_value();
}
```

Analyzer Example – Power Analyzer - Implementation

```
class cos_static_analyzer_power :
                public cos_static_analyzer_base
{
public:
     //perform analyzis
     void analyze() override;

 //print results to shell
 void print_results(std::ostream& str=std::cout);

private:

  //callback for type recognition
  bool is_type(cos_analyzer_attr_base*) override;
};
```

```
void cos_static_analyzer_power::analyze()
{
   this->analyze_hierarchy(); //perform hierarchic analysis
}

bool cos_static_analyzer_power::is_type(cos_analyzer_attr_base* attr)
{
    return (dynamic_cast<cos_analyzer_attr_power*>(attr)!=NULL);
}

void cos_static_analyzer_power::print_results(std::ostream& str)
{
  auto& result=this->get_tree_analysis_result();
  double overall_power=
       result[0]->get_value<cos_analyzer_attr_power::cos_power_value>().value;

  str << "Overall power: " << overall_power << " W" << std::endl;
  for(auto& modp : result)
  {
    double mod_value=
            modp->get_value<cos_analyzer_attr_power::cos_power_value>().value;

    str << "\t" << modp->get_object()->name() << " :\t"  << mod_value << " W"
        << std::endl;
} }
```


© Accellera Systems Initiative

Application Example – Attaching Attributes

- The Framework supports different mechanism for attaching the attributes (for details see paper)
- Simplest way is to attach the attribute in the module constructor

```
SC_MODULE(temp_sensor)
{
…
    SC_CTOR(temp_sensor)
    {
      pattr=new cos_analyzer_attr_power(this);
      pattr->set_value(1e-3); //set power consumption to 1mW
    }

}
…
    cos_analyzer_attr_power* pattr=NULL;
};
```


SYSTEMS INITIATIVE

2020 DESIGN AND VERIFICATION™ DVCON CONFERENCE AND EXHIBITION EUROPE

Application Example – Starting Analyzis in sc_main

- An analysis can be started/re-started any timeafter DUT instantiation

```
int sc_main(int argc, char* argv[])
{
    …
    dut_tb* i_dut_tb;
    i_dut_tb = new dut_tb("i_dut_tb");
    …
    cos_static_analyzer_power panalyzer;
    panalyzer.analyze();
    panalyzer.print_results();
    …
}
```

Application Example - Result

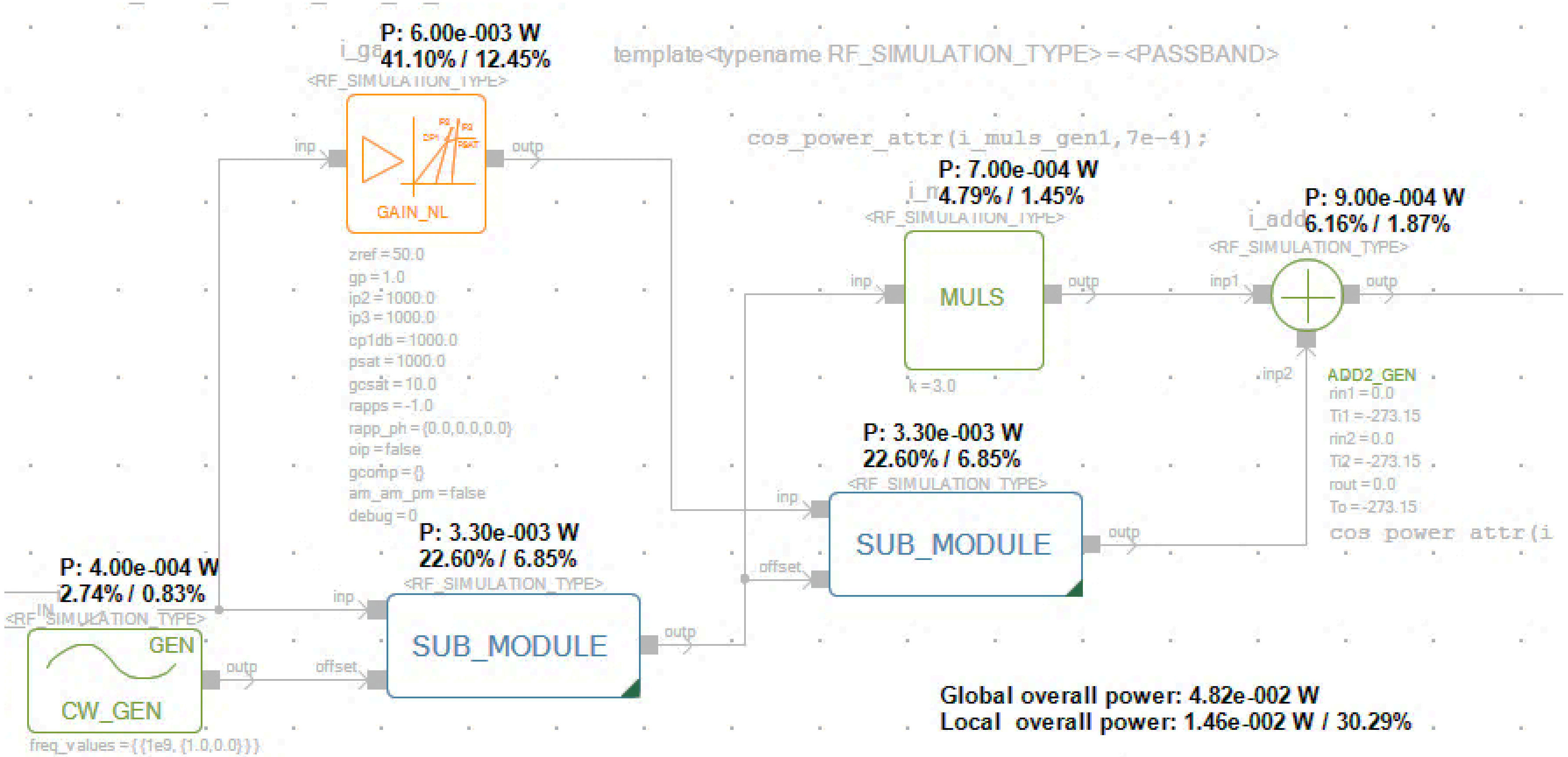
```
Overall power: 4.31e-002W
       i_hierarchic_toplevel                    :    4.31e-002 W
       i_hierarchic_toplevel.i_cw_top_start_1 :    3.00e-003 W
       i_hierarchic_toplevel.i_cw_top_start_2 :    2.00e-003 W
       i_hierarchic_toplevel.i_gain_nl_gen1   :    5.00e-004 W
       i_hierarchic_toplevel.i_gain_nl_gen2   :    1.00e-003 W
       i_hierarchic_toplevel.i_muls_gen1      :    5.00e-004 W
       i_hierarchic_toplevel.i_sub_module1    :    3.30e-003 W
       i_hierarchic_toplevel.i_sub_module2    :    3.30e-003 W
```


© Accellera Systems Initiative

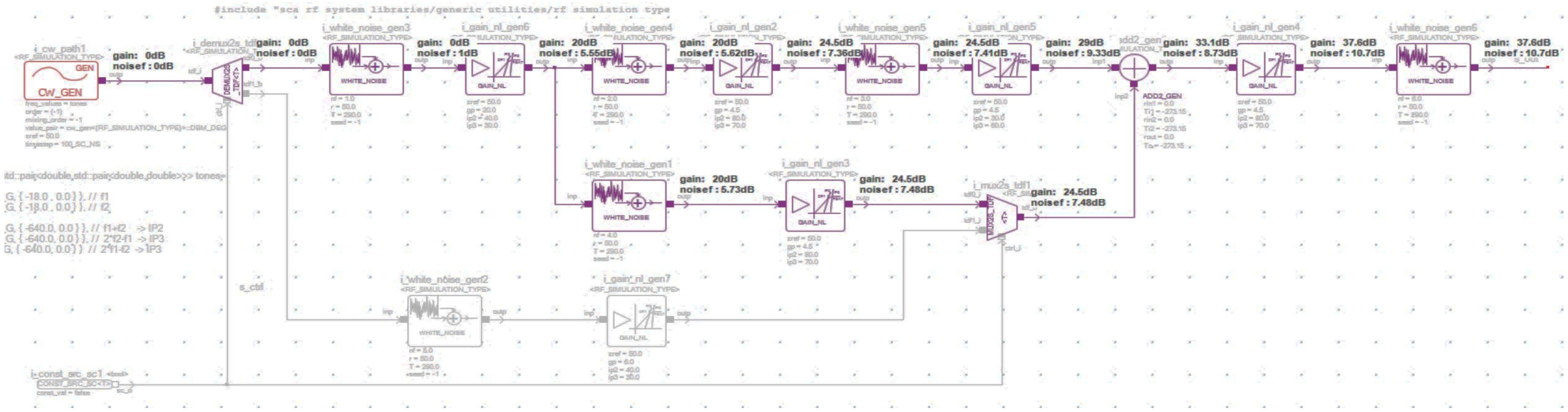
Result Visualization

- The framework supports the creation of properitary formats for result backannotation to schematics
- Allows coloring in dependency of the result
- Visualization of signal pathes, pathes with now influence or side pathes with influence

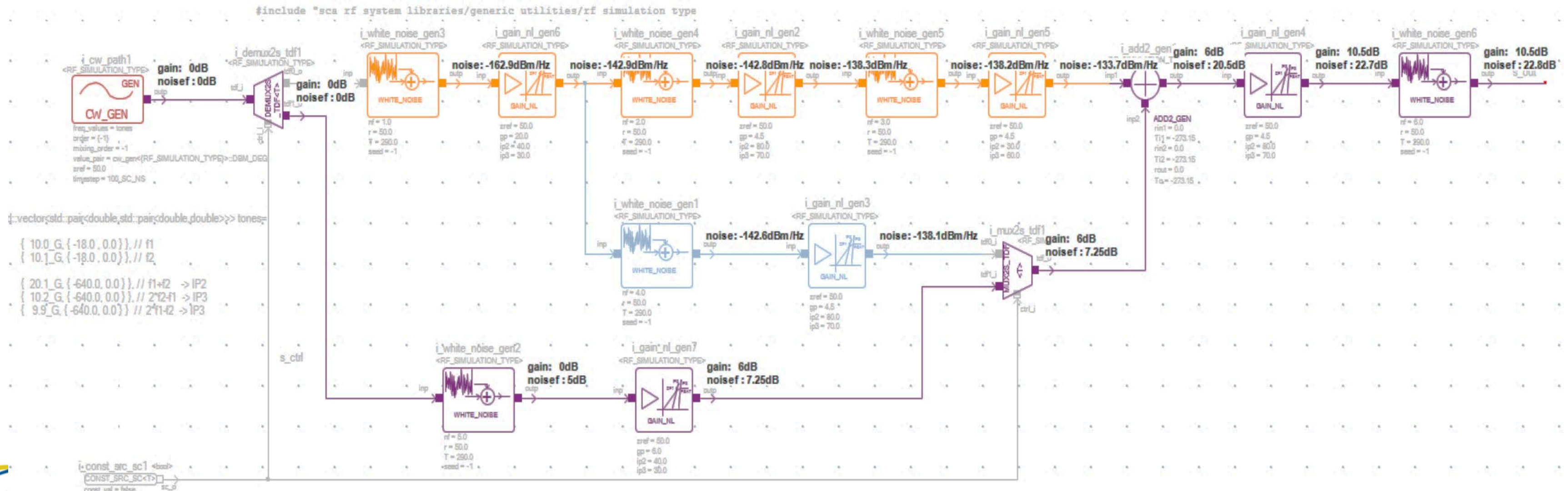
Result Visualization – Example Power Analysis



Result Visualization – Noise figure for two states



Control signal : 0



Control signal : 1

© Accellera Systems Initiative

Summary

- Static analyzis is a powerfull method to estimate system properties
- Especially suited for design space exploration
- Can be used to calculate expected „ideal“ values
- The introduced framework allows to establish consistency between static analyzis and the model and thus also to the implementation
- The framework supports the analyzis in dependency of the current system state and thus the calculation of the properties for this configurations
- The results can be backannotated and visualized in schematics

© Accellera Systems Initiative

Questions