

Towards a UVM-based Solution for Mixed-signal Verification

Alexander W. Rath, Sebastian Simon, Volkan Esen,
Wolfgang Ecker

Infineon Technologies AG



Agenda

- Introduction
- Idea of Analog Transactions
- Constraint Random Analog Stimulus
- Monitoring Analog Behavior
- Checking Analog Transactions
- Example
- Summary and Outlook

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Introduction

- In today's chip design, analog parts shifted to digital design, because digital circuits scale better with new technologies
- This leads to mixed signal designs
- Historically, digital and analog parts are verified using totally different strategies
 - Analog parts are verified using network simulators
 - Digital parts are verified using event driven simulators

Introduction

- Digital Verification has become highly sophisticated
 - Constraint random stimulus
 - Self-checking testbenches
 - Functional coverage
 - Unified Verification Methodology (UVM)
- Analog Verification has not gone through the same evolution
 - Testbenches use directed stimulus and checking
 - Waveforms are checked using “eye-balling”

Introduction

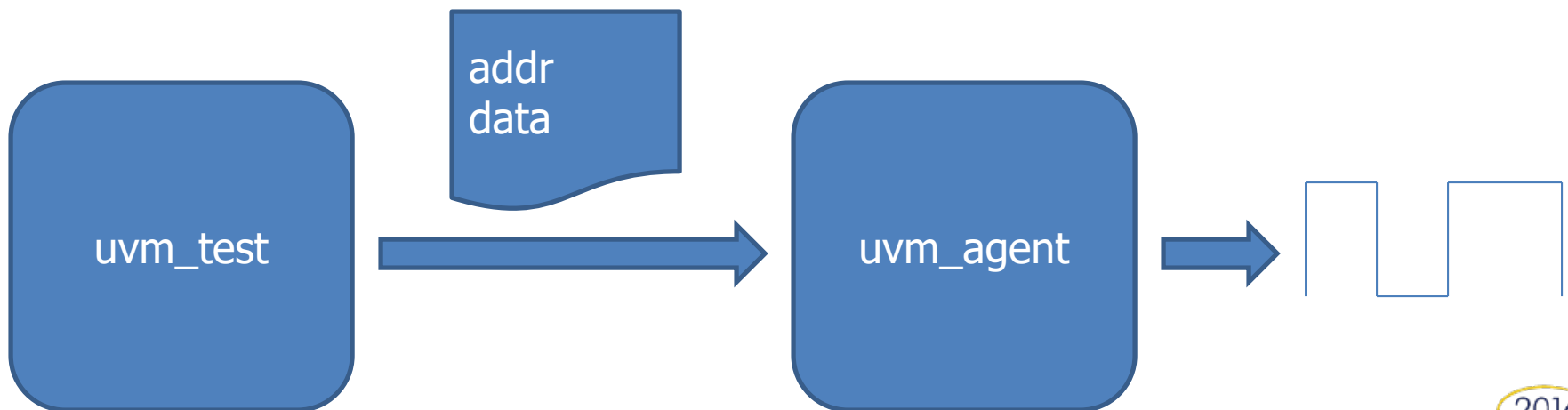
- In our research, we target to leverage this discrepancy
- We show, how the aforementioned techniques from the digital verification can be mapped to and used in analog verification

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Idea of Analog Transactions

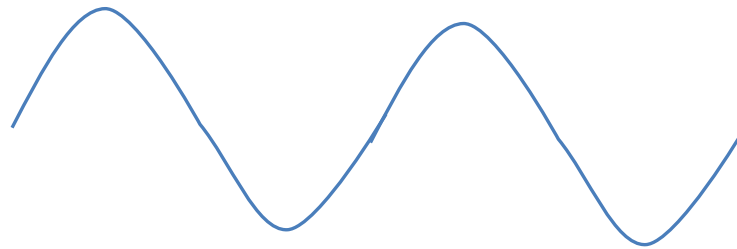
- Transactions are data structures
 - Containing potentially randomized fields
 - Providing abstraction from the protocol's details
- The protocol is implemented separately in a driver



Idea of Analog Transactions

- How to transfer this approach to analog?
- Idea: Replace the term “protocol” by “shape”
- Signals can be of different shapes

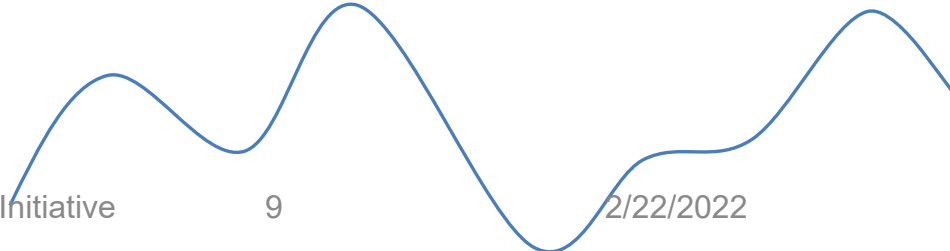
– Harmonic



– Linear

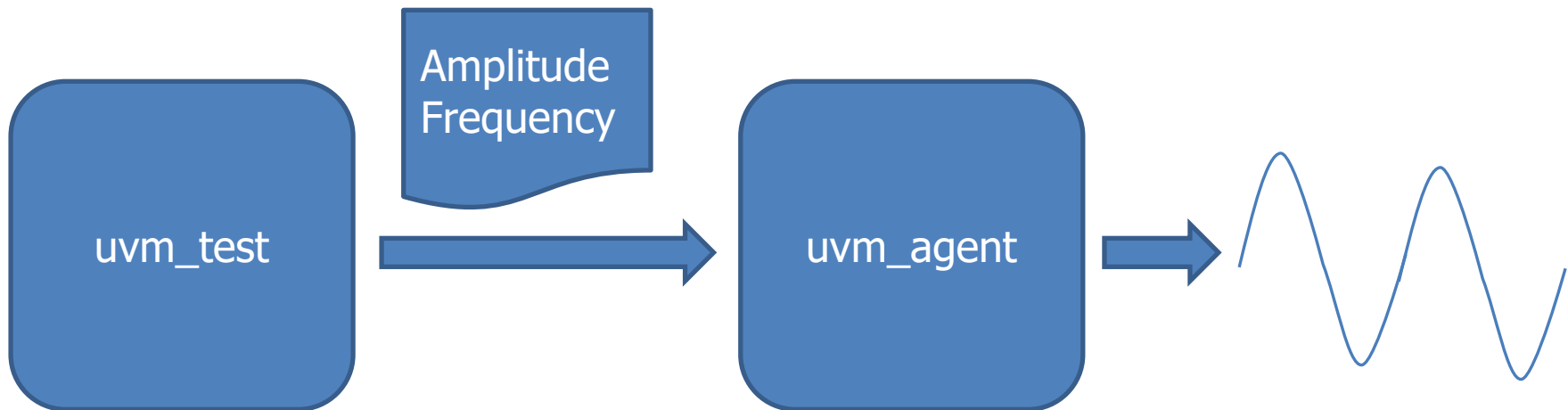


– Cubic Spline



Idea of Analog Transactions

- To name a shape is not sufficient to describe a signal
- Parameters are required → transaction



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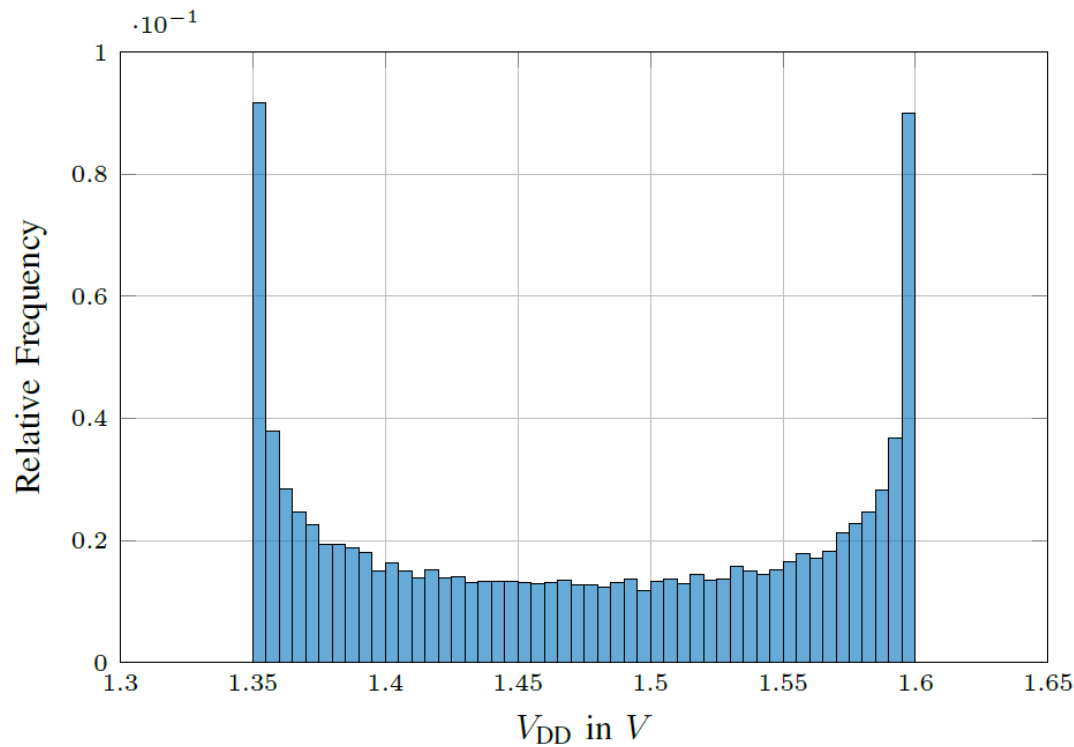
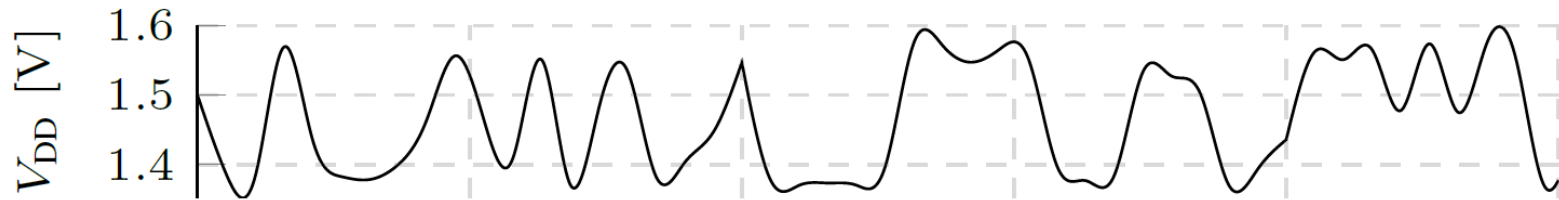
Constraint Random Analog Stimulus

- In UVM, transactions are converted to stimulus by drivers
- We follow the same principle using a generic driver for analog stimulus
- The algorithm that converts the transaction to signal level activity can be exchanged through a plug-in mechanism even at runtime
- Communication between the generic driver and the algorithm is done via a predefined API
- New algorithms implement this API

Constraint Random Analog Stimulus

```
rand_real r_num;  
r_num = new();  
void' (r_num.randomize() with {  
    r_num.minv == rtb(1.35);  
    r_num.maxv == rtb(1.6);  
    r_num.alphav == rtb(0.5);  
    r_num.betav == rtb(0.5);  
    r_num.dist_type == BETA; });
```

Constraint Random Analog Stimulus



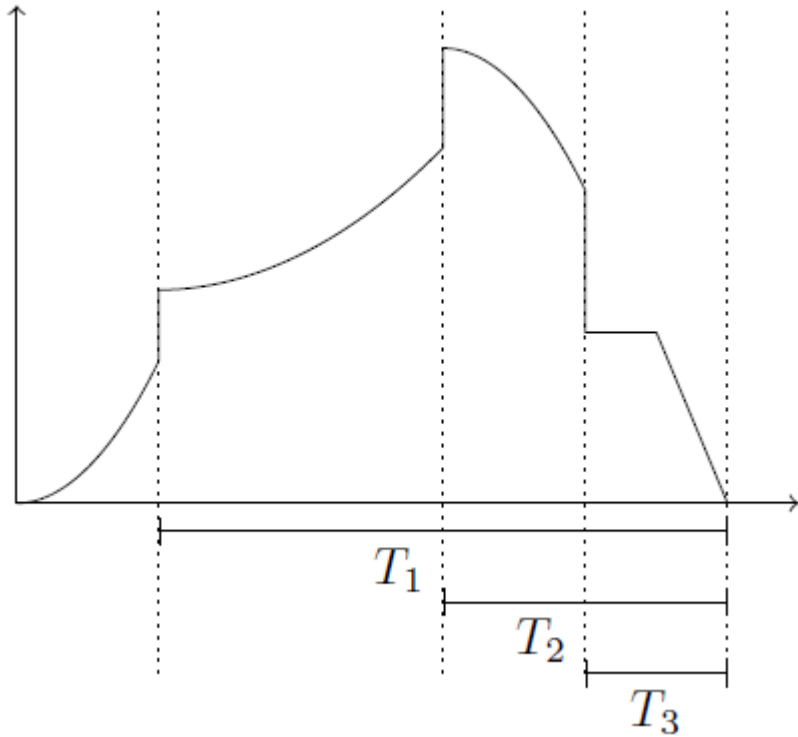
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Monitoring Analog Behavior

- We followed the same principle as in driving
- Monitoring is more complicated than driving
 - Start of transaction has to be determined
 - Single vs. Multi threaded
- This leads to a more complex algorithm API

Monitoring Analog Behavior



- Determining the times T_1 , T_2 and T_3 requires multi-threaded monitoring
- Trigger objects determine start of monitoring
 - Discontinuities
 - Threshold levels
 - Changes in frequency
 - ...

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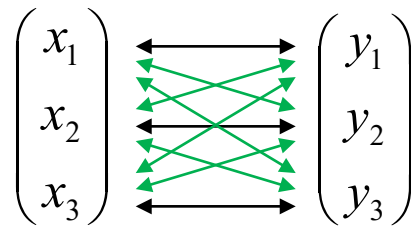
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Checking Analog Transactions

- In order to check for functional correctness of the DUT, transactions must be compared – possibly inside of a scoreboard
- In UVM, transactions are compared bitwise, field by field
- This does not work for analog transactions
 - When comparing analog behavior, a certain fuzziness is allowed
 - Real-valued numbers can suffer from round-off errors which affect direct comparison
 $5 == 5.0000000000000001$

Checking Analog Transactions

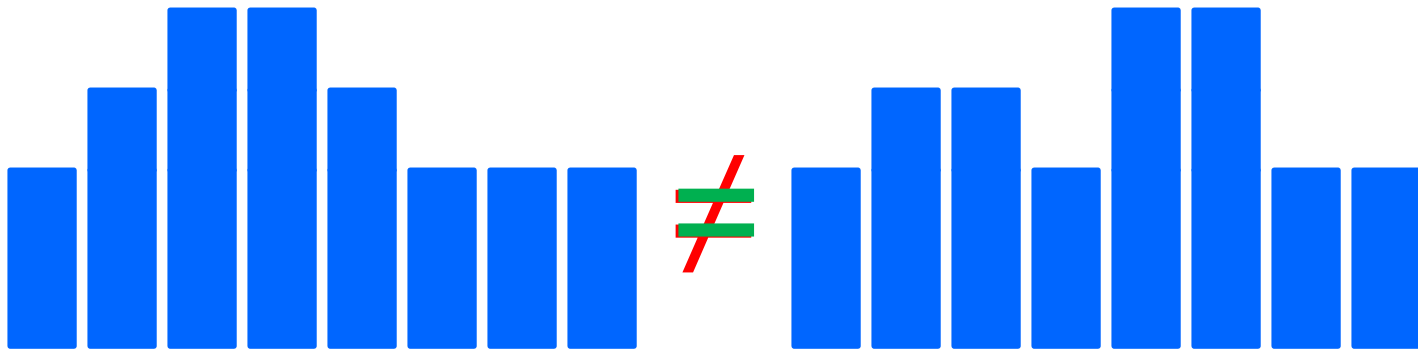
- Similarity can be measured by several metrics (Pearson correlation, cosine similarity, Euclidean distance, ...)
- **Deficiency:** bin-by-bin measures do not necessarily match perceptual similarity well



- Leveraging cross-bin measures in order to obtain more meaningful results
→ **Earth Mover's Distance**

Checking Analog Transactions

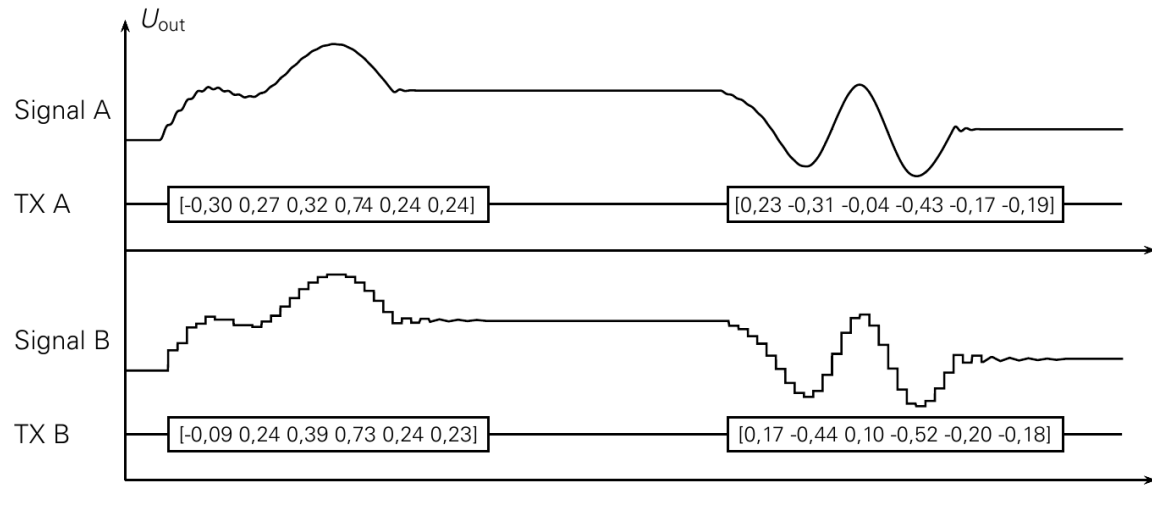
- Approach to measure the distance between two distributions
- Visualization: transportation of soil from one pile to another



- Work += distance x amount: $A = \sum_{i=1}^n \sum_{j=1}^n d_{ij} f_{ij}$
- Find minimum flow which equalizes distributions
→ optimization problem has to be solved

Checking Analog Transactions

- Analyzing one pair of transactions results in exactly one value s_{EM} for the Earth Mover's Distance



- Range: $0 \leq s_{EM} \leq 1$ (where 1 implies a full match)
- Basic idea for regression:** defining a lower bound for s_{EM}
- Once s_{EM} falls below this bound, the regression test fails and the regarding transactions can be examined

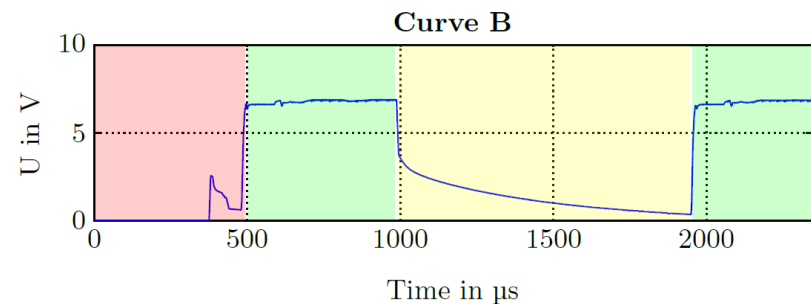
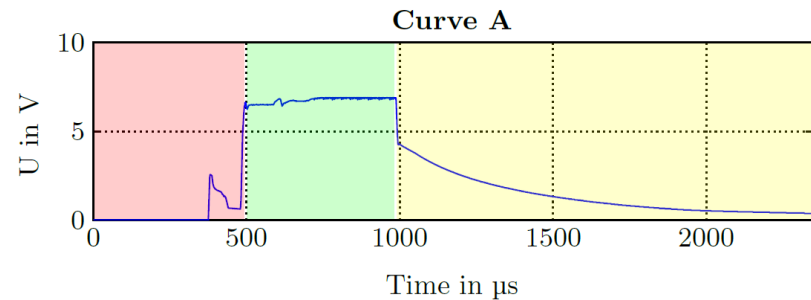
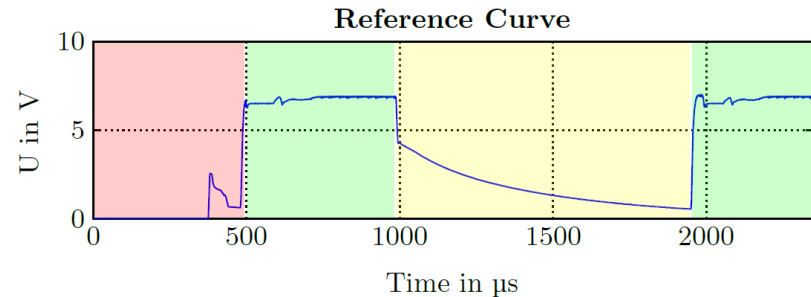
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Example

- Observed signal: PMU-related voltage
- Four different signal phases are automatically detected by analog monitors
- Forced failure scenarios:
 - Curve A: stuck-at-sleep
 - Curve B: modified external cap

Signals	Phase1	Phase2	Phase3	Phase4
RefvsRef	100%	100%	100%	100%
RefvsA	99%	99%	99%	53%
RefvsB	99%	99%	88%	99%



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Summary and Outlook

- We presented a possible definition for analog transactions
- We showed, how this definition can be used to accomplish stimulation, monitoring and checking of analog circuitry or models

Questions?