# A Transaction-Oriented UVM-based Library for Verification of Analog Behavior

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# 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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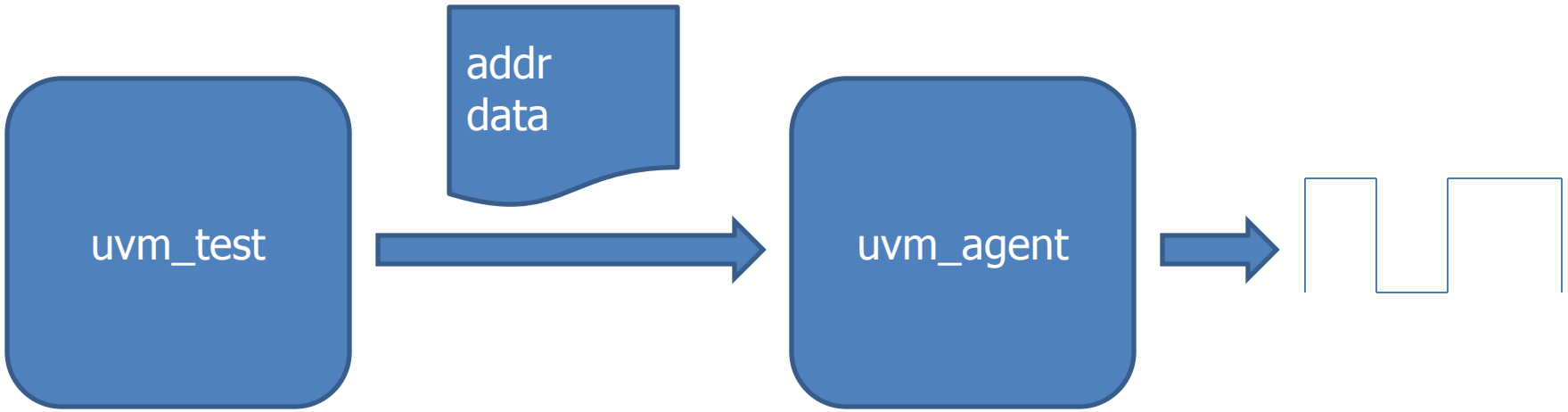
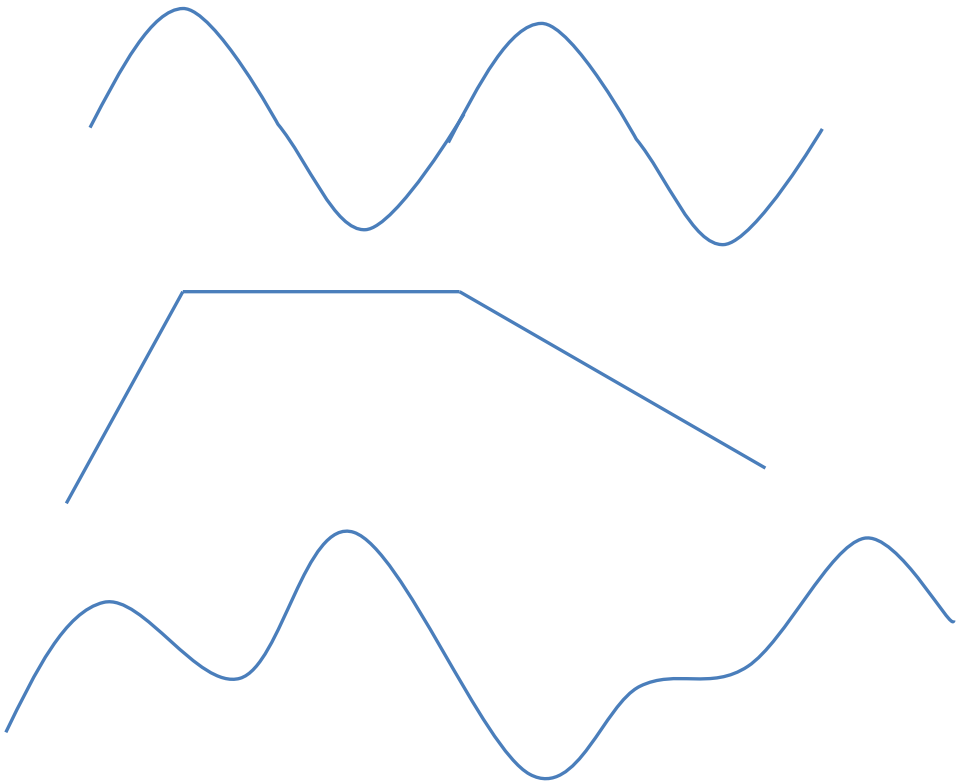
# Idea of Analog Transactions

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



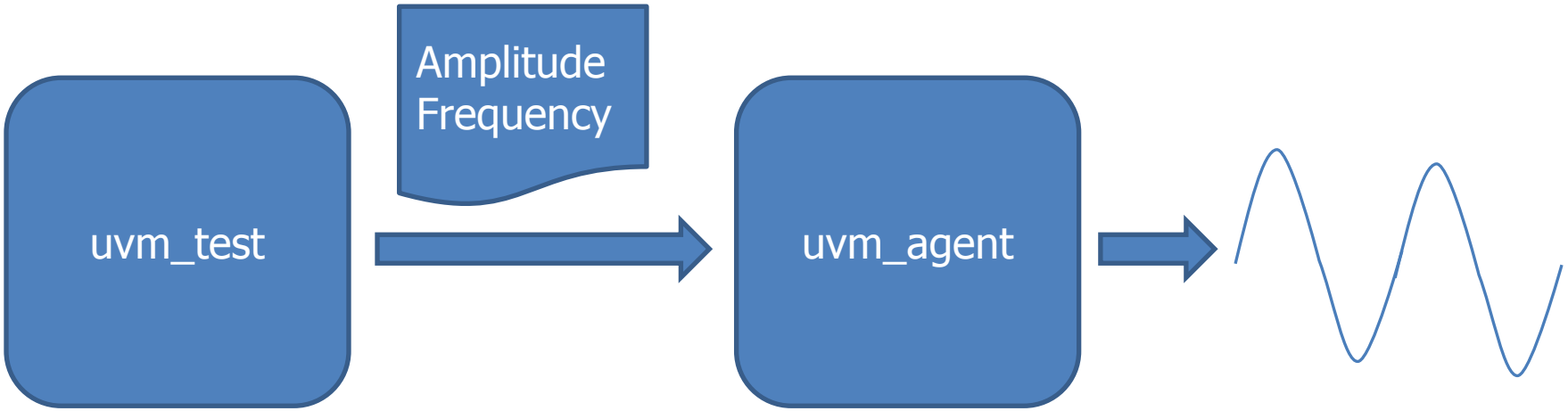
# Idea of Analog Transactions

- 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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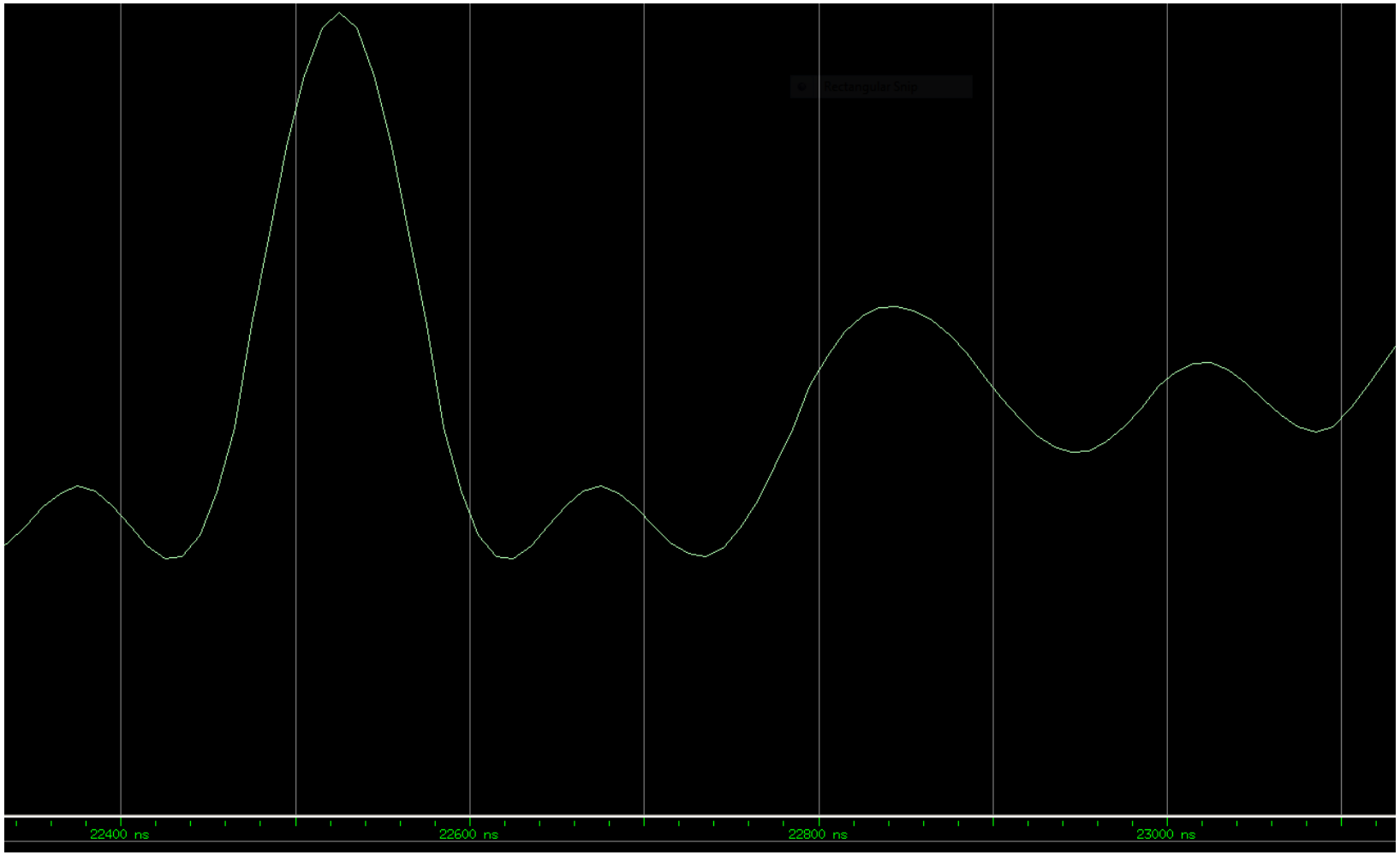
# Constraint Random Analog Stimulus

- 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

- **pure virtual function void** pre_process( a_uvm_data_structure data_str);
  - For preparation, like opening connections to external tools
- **pure virtual function real** get_real(**real** x);
  - Computes the signal values
- **virtual function void** post_process();
  - Closing connections etc.

# Constraint Random Analog Stimulus



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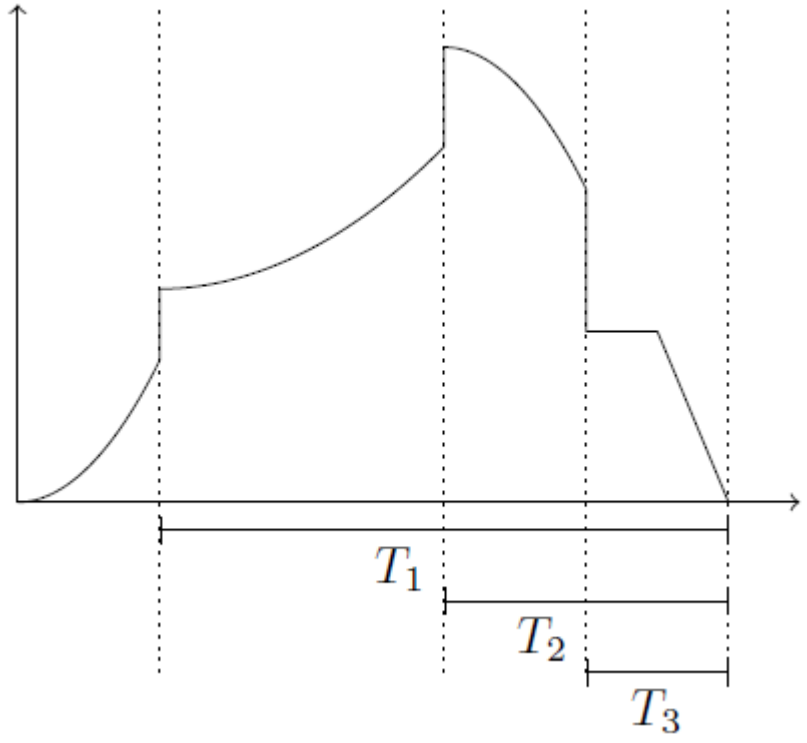
# Monitoring Analog Behavior

- 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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# 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 == 5.00000000000001

# Checking Analog Transactions

- Fuzziness is hard to quantify
- As a first attempt, we used the cosine similarity to compare transactions

$$r(X,Y) = \frac{\sum_{i=0}^{n-1} X_i Y_i}{\sqrt{\sum_{i=0}^{n-1} (X_i)^2 \sum_{i=0}^{n-1} (Y_i)^2}}$$

- $X$ and $Y$ are the transactions and $X_i$ and $Y_i$ are their parameters
- $r$ is between -1 and 1

# Checking Analog Transactions

- Examples with $X = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}$:
- $Y = \begin{pmatrix} 2 \\ 4 \\ 6 \end{pmatrix} \Rightarrow r = 1$
- $Y = -\begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} \Rightarrow r = -1$
- $Y = \begin{pmatrix} 3 \\ 0 \\ -1 \end{pmatrix} \Rightarrow r = 0$
- $Y = \begin{pmatrix} 1.2 \\ 1.8 \\ 3.3 \end{pmatrix} \Rightarrow r \approx 0.996$

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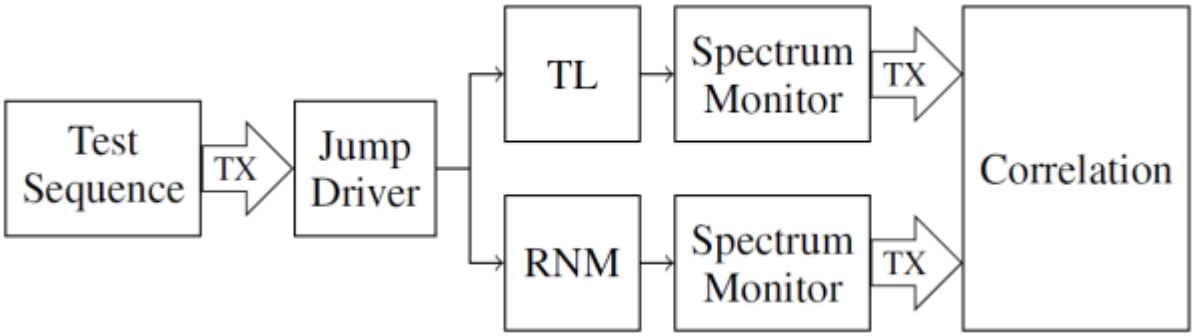
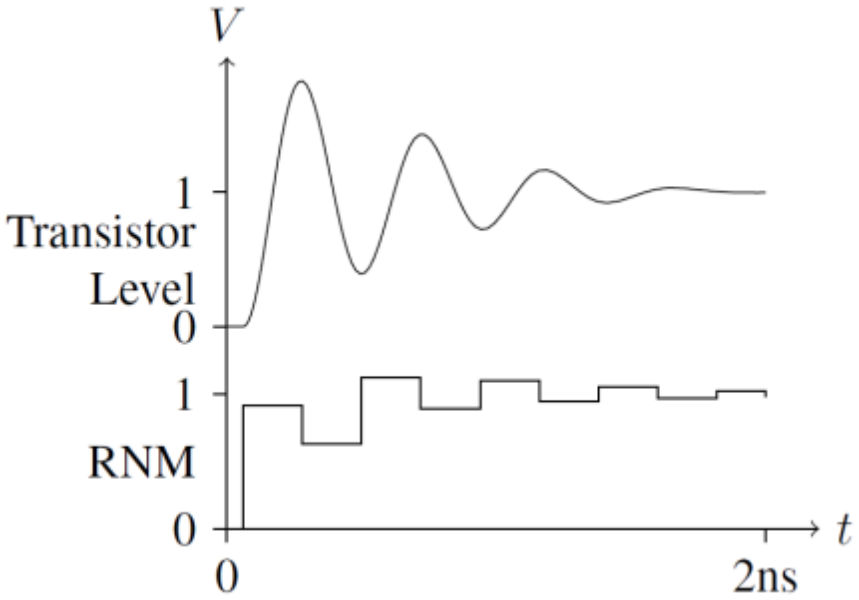
# Example

- Voltage Regulator




- Unmodified TL
  - $\bar{r} = 0.89$
- Oscillation frequency reduced by factor 0.5
  - $\bar{r} = 0.24$

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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

Thanks for attention!
Questions?