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Analog Transaction Level Modeling for Verification of Mixed-Signal-Blocks

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Agenda

- Introduction
- Idea of Analog Transactions
- FOURIER transformation-based stimulus
- Cubic Spline based stimulus
- Examples applications
- Summary and Outlook

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- **Introduction**
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Introduction

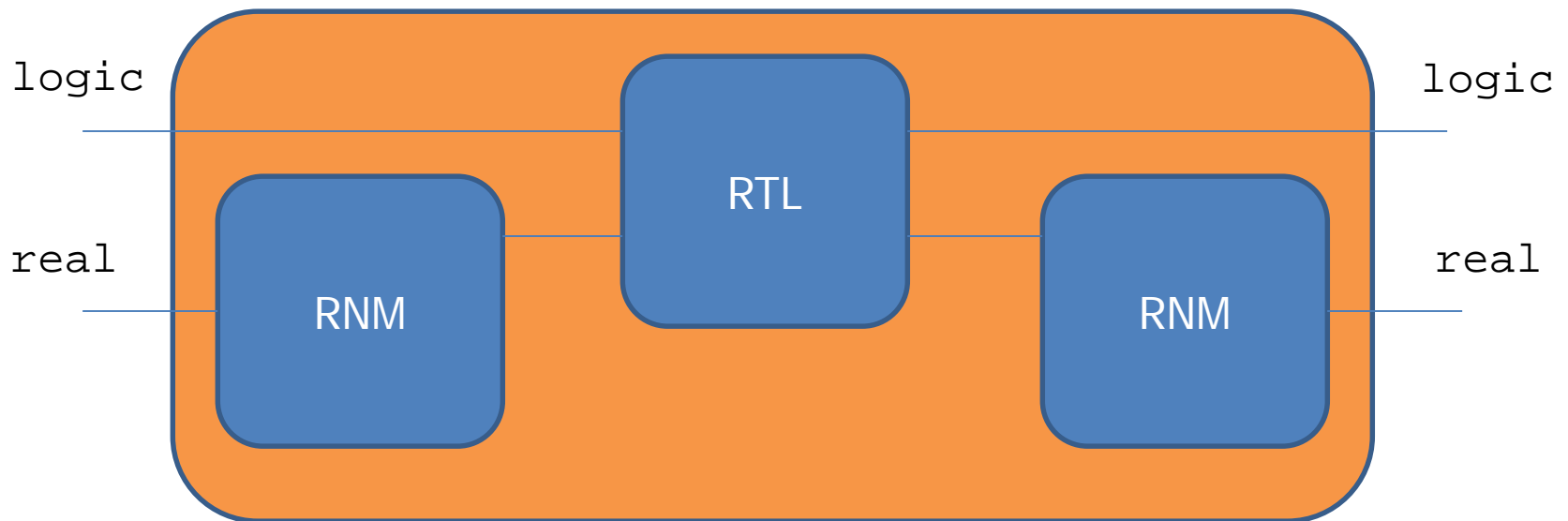
- Many design are mixed-signal designs
- Historically, digital and analog circuits are verified using different strategies
 - Analog circuits are verified using SPICE netlists and network simulators
 - Digital circuits are functionally verified using RTL models and event driven simulators
 - Digital verification strategies have become high sophisticated
 - Constrained random, functional coverage, UVM...

Introduction

- There are two DUT styles
 - RTL + AMS
 - Verilog AMS
 - SystemC AMS
 - RTL + real-number models (RNMs)
 - Analog circuits are represented using behavioral models
 - VHDL or SystemVerilog
 - Discrete Time Modeling

Introduction

- Resulting DUT
 - Has digital and real-valued pins
 - Shows analog and digital behavior
 - How will you verify such a DUT?

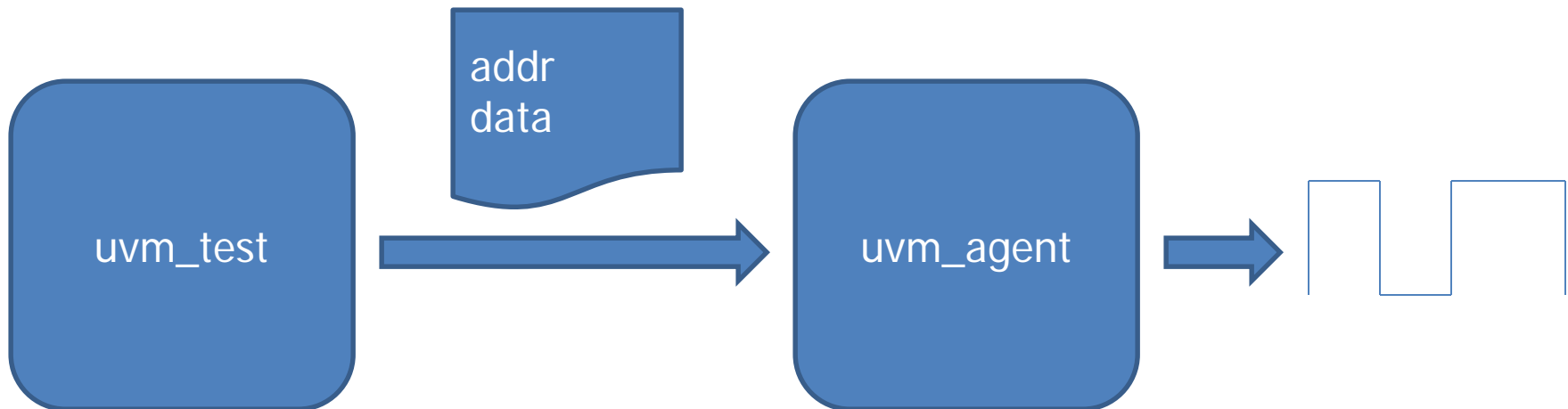


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Idea of analog transactions

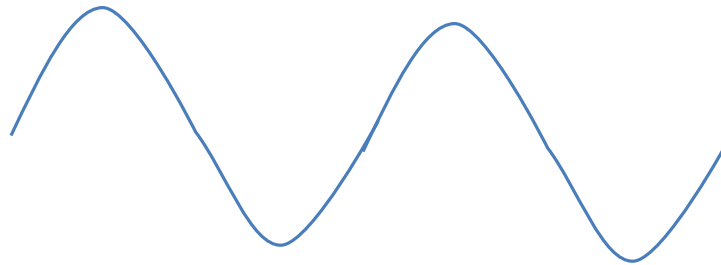
- Transactions are data structures
 - Containing potentially randomized fields
 - Providing abstraction from the protocol's details
- The protocol is implemented separately in a driver



Idea of analog transactions

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

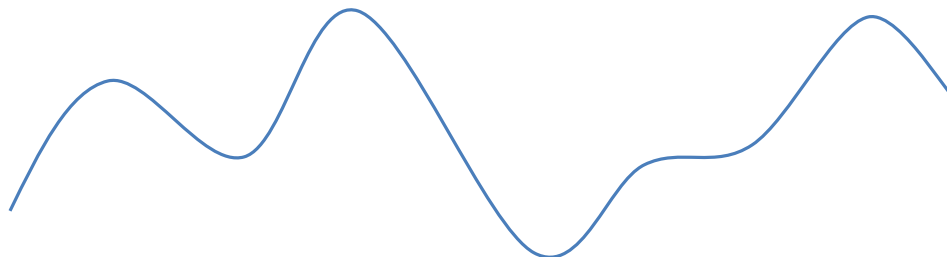
- Harmonic



- Linear

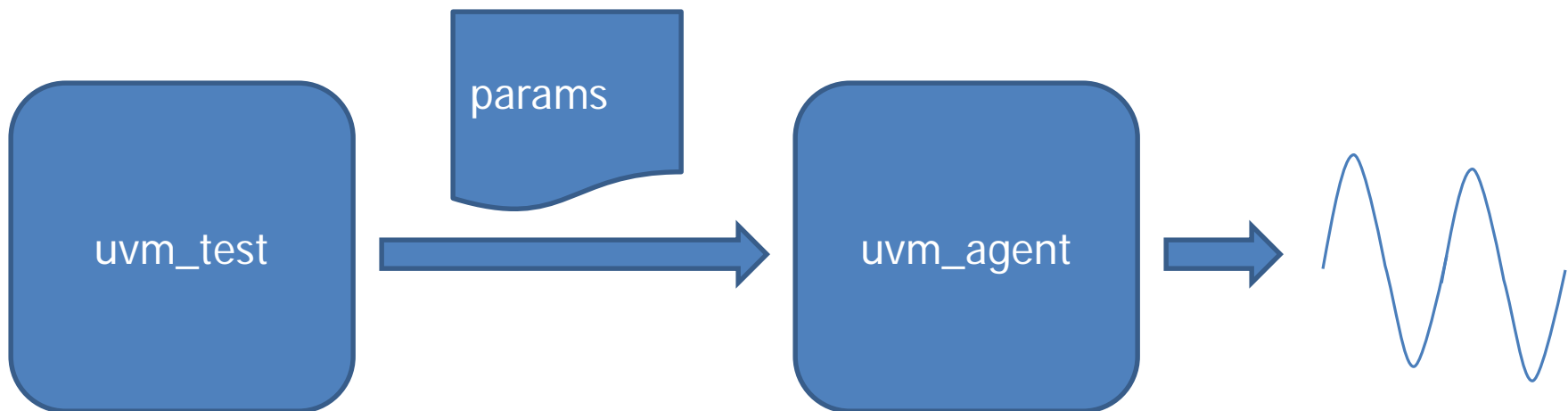


- Cubic Spline



Idea of analog transactions

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



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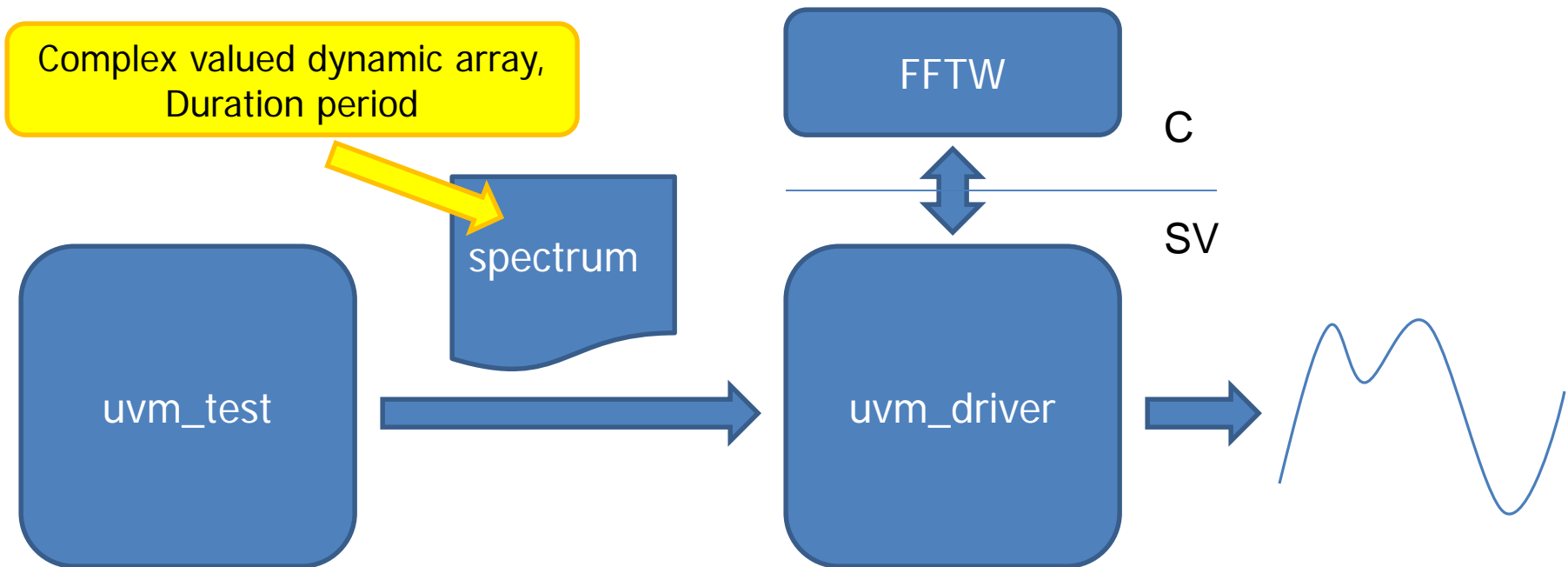
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Fourier transformation-based stimulus

- Harmonic signals are important in many applications
 - Amplifiers
 - Filters
 - ...
- They are described using a spectrum
 - The spectrum is the parameter set
 - Spectrum can be used as sequence item
- Signals are derived from spectra by inverse Fourier Transformation

Fourier transformation-based stimulus

- Implementation of DFT algorithm
 - Difficult in SystemVerilog
 - Inefficient in SystemVerilog
 - We used FFTW (www.fftw.org) via DPI-C



Fourier transformation-based stimulus

- Sequence item:

```
`uvm_create(req);
```

```
req.c[0].re = 0.0;
```

```
req.c[0].im = 0.0;
```

req.c is the complex valued dynamic array

```
foreach(req.c[i])
```

```
begin
```

```
if(i inside {[5:20]})
```

```
req.c[i].re = real'($urandom_range(1))/10.0;
```

```
else
```

```
req.c[i].re = 0.0;
```

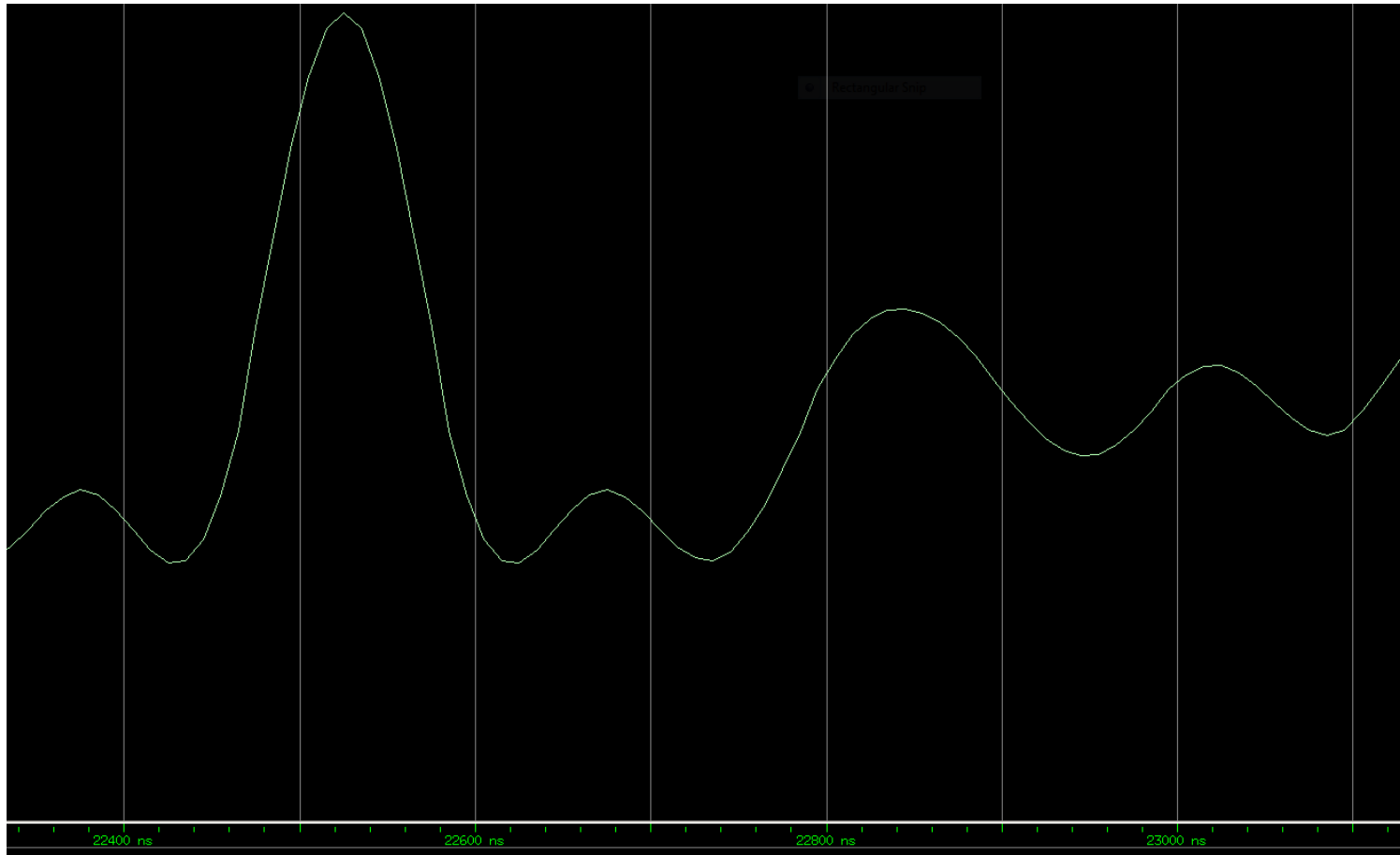
```
req.c[i].im = 0.0;
```

```
end
```

```
`uvm_send(req);
```

Fourier transformation-based stimulus

- Resulting signal:



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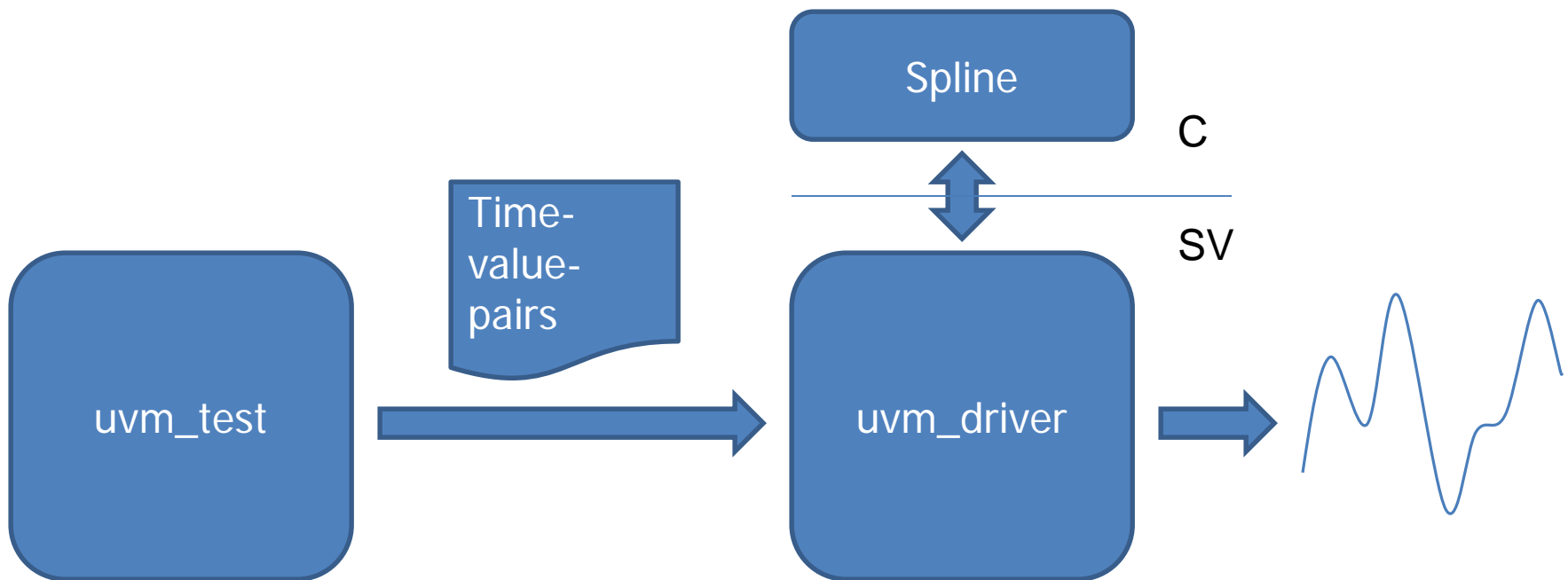
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Cubic Spline based stimulus

- Harmonic signals are not always appropriate
- Other possible options are Cubic Splines
- Cubic spline interpolation is a method of connecting points smoothly
- Idea:
 - The test randomly selects some points
 - The driver connects them in a smooth way

Cubic Spline based stimulus

- Cubic spline algorithm, we also implemented in C and connected to via DPI-C



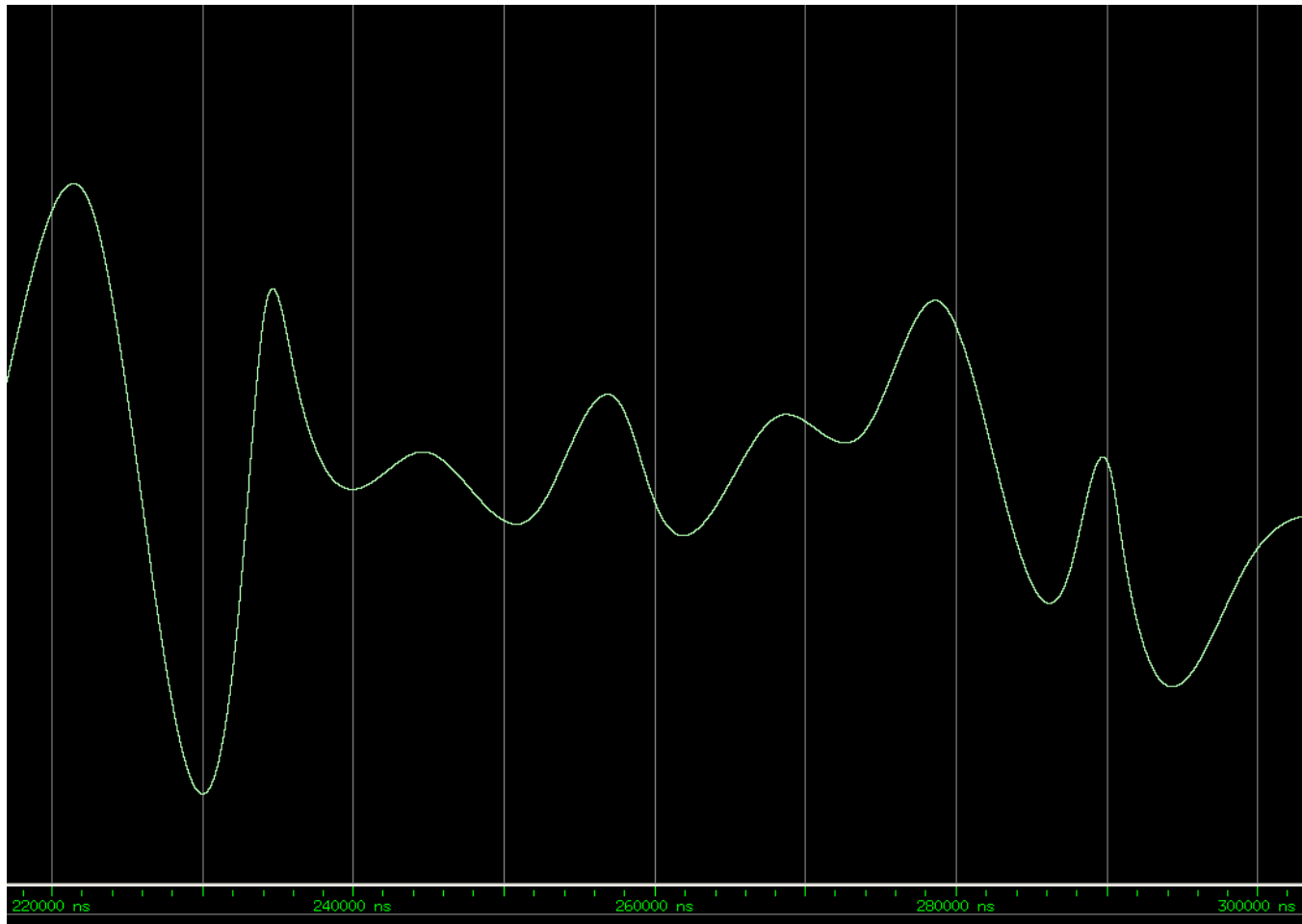
Cubic Spline based stimulus

- Sequence item:

```
`uvm_create(req);  
req.points.push_back(point'({0.0, 0.0}));  
  
repeat(100)  
begin  
  random_value = (-1.0)**$urandom_range(1)* real'($urandom_range(4000))  
  / 1000.0;  
  
  random_time = real'($urandom_range(10000000,500000)) / 1000.0;  
  
  old_time = req.points[$].x;  
  
  req.points.push_back(point'({old_time + random_time, random_value}));  
end  
  
`uvm_send(req);
```

Cubic Spline based stimulus

- Resulting signal:



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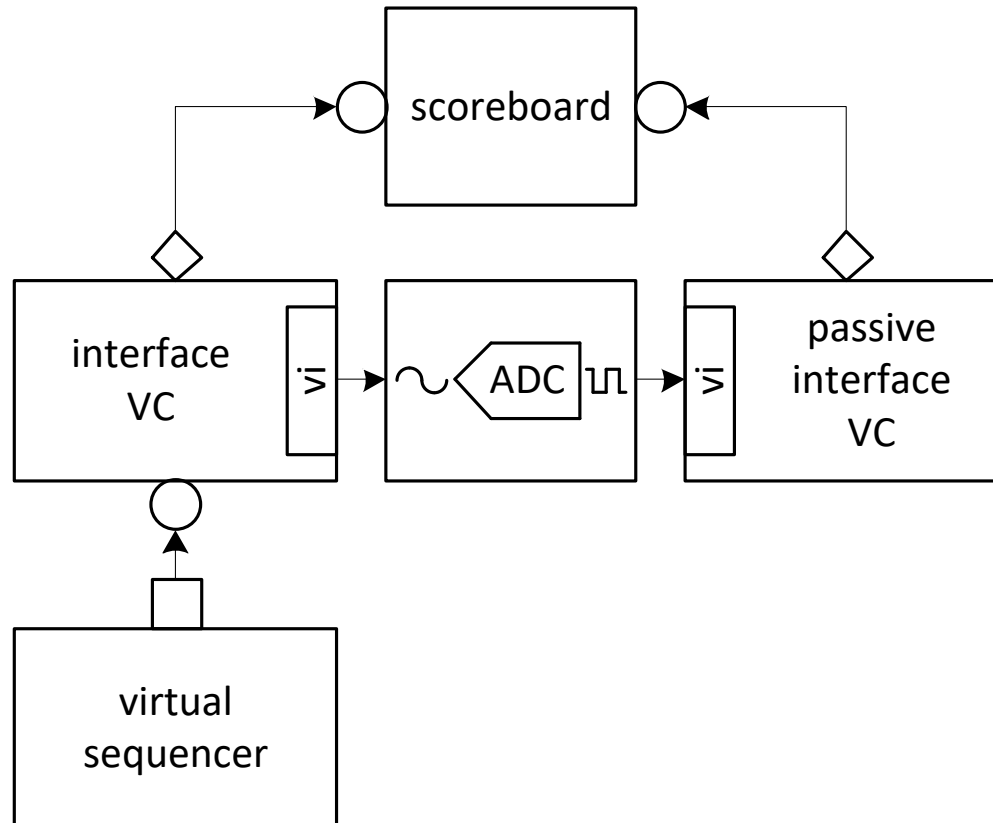
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Example applications

- We tested the approach in two applications
 1. Model of an ADC
 - To test and refine our approach
 2. Automotive motor that drives wipers or window lifts

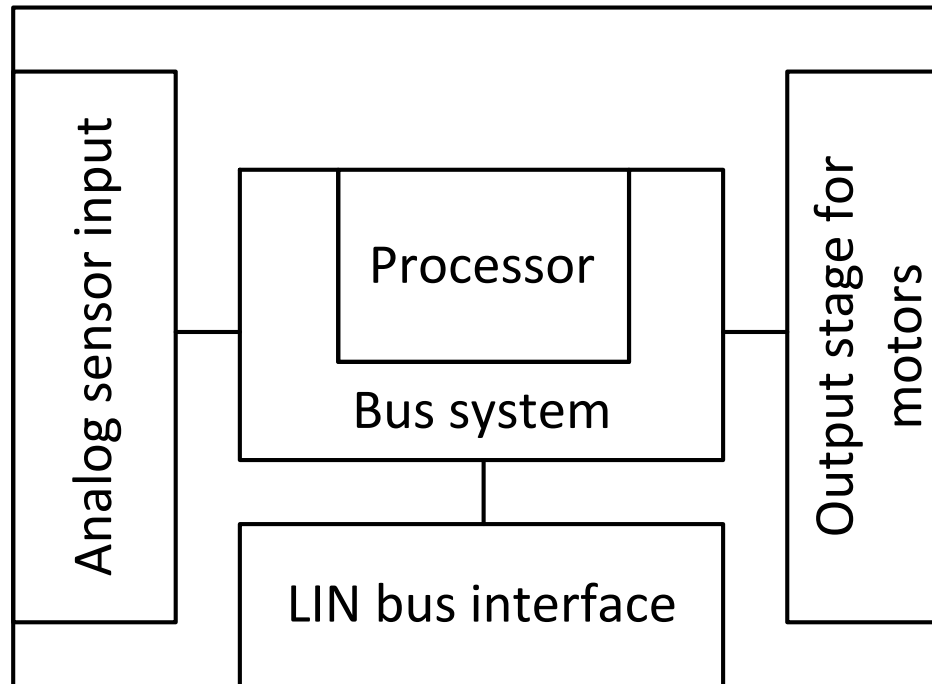
Example applications

- ADC:



Example applications

- Motor driver



- We used our methodology to inject random spikes

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Summary and Outlook

- We gave a possible definition for analog transactions
- We showed two possible realizations regarding stimulation of a DUT
 - Fourier transformation based
 - Cubic spline based
- We presented two applications

Summary and Outlook

- Analog transaction can be used also for other things
 - Monitoring
 - Checking
 - Scoreboarding
 - Coverage collection
- Abstraction in stimulus generation
- AMS layer
- We will show those in other papers

**Thank you for your attention!
Questions?**