MATLAB EXPO 2018

Design and Verification of Mixed-Signal ASICs Using MATLAB and Simulink

Aniruddha Dayalu
Principal Application Engineer –
Analog/Mixed-Signal Design

Agenda

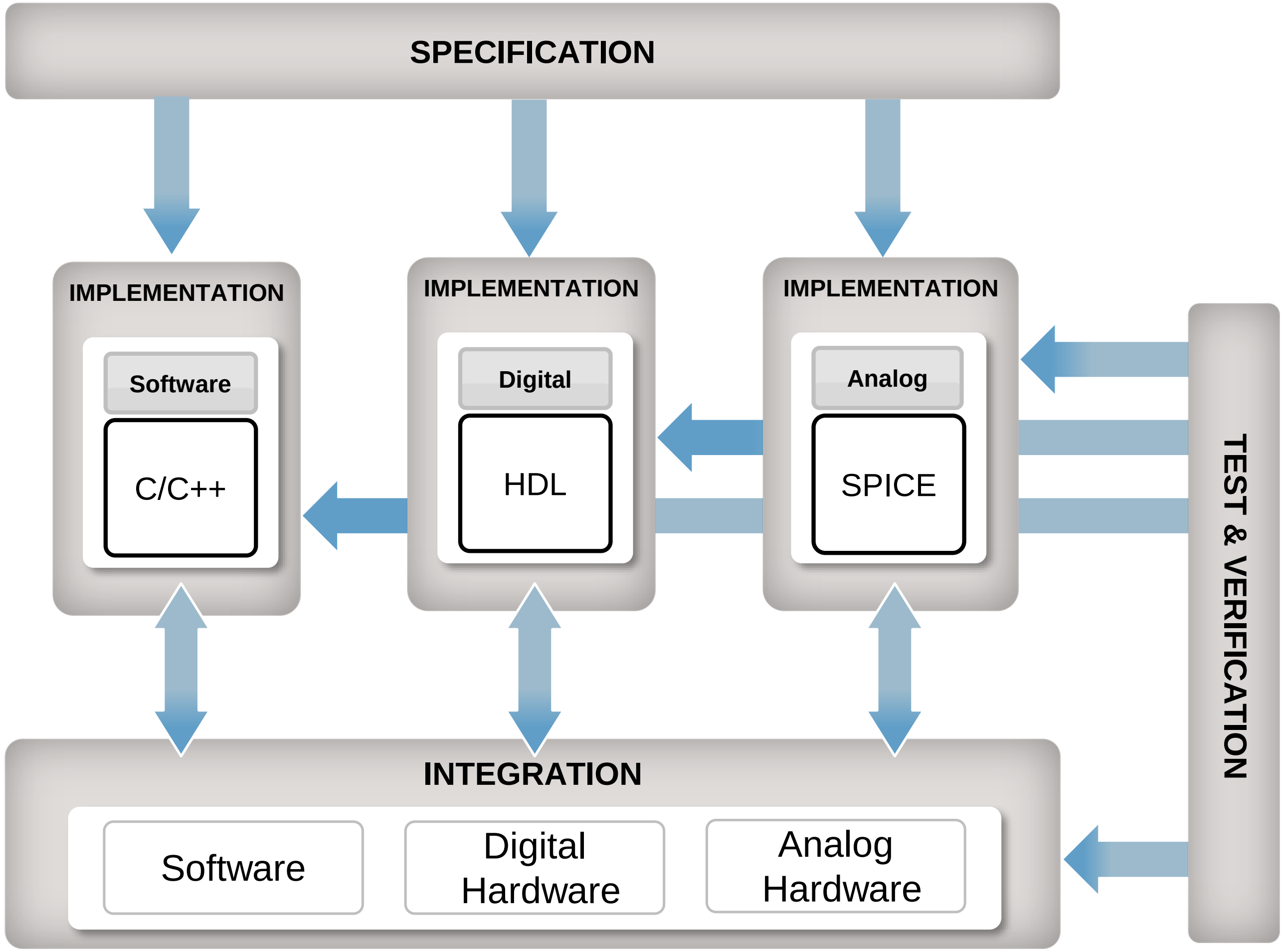
- Current Trends in Semiconductor Design and Verification
- System Level Design of Analog and Mixed-Signal Components
- Linking Behavioral to Circuit design and Verifying AMS designs
- Post-processing of simulation results
- Conclusion

Challenges in ASIC Design Workflow

Limited design abstractions

Design trade-offs difficult

Slow design iterations

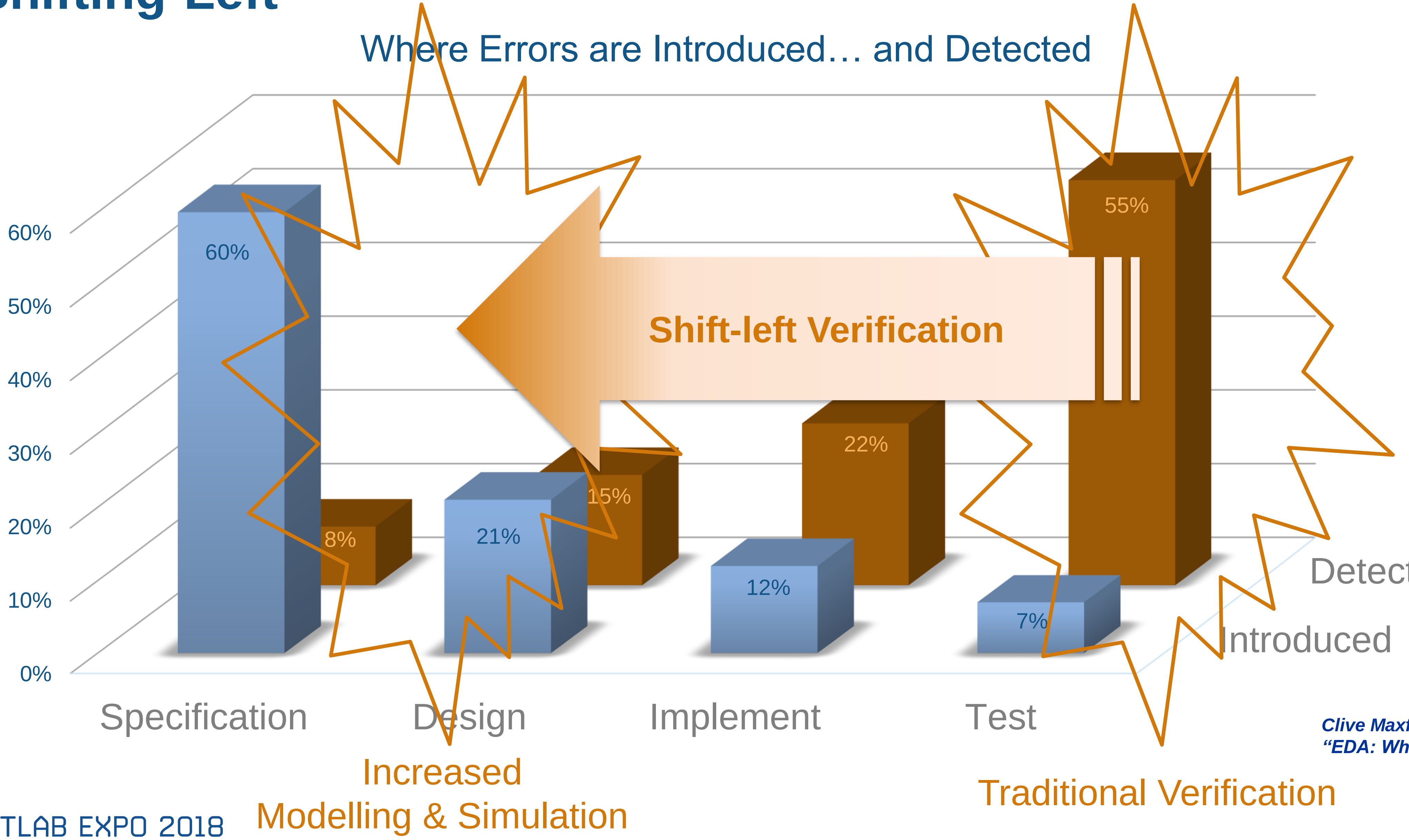


Specification isolated from verification

Multiple, disconnected tools

Disconnected teams

Shifting-Left



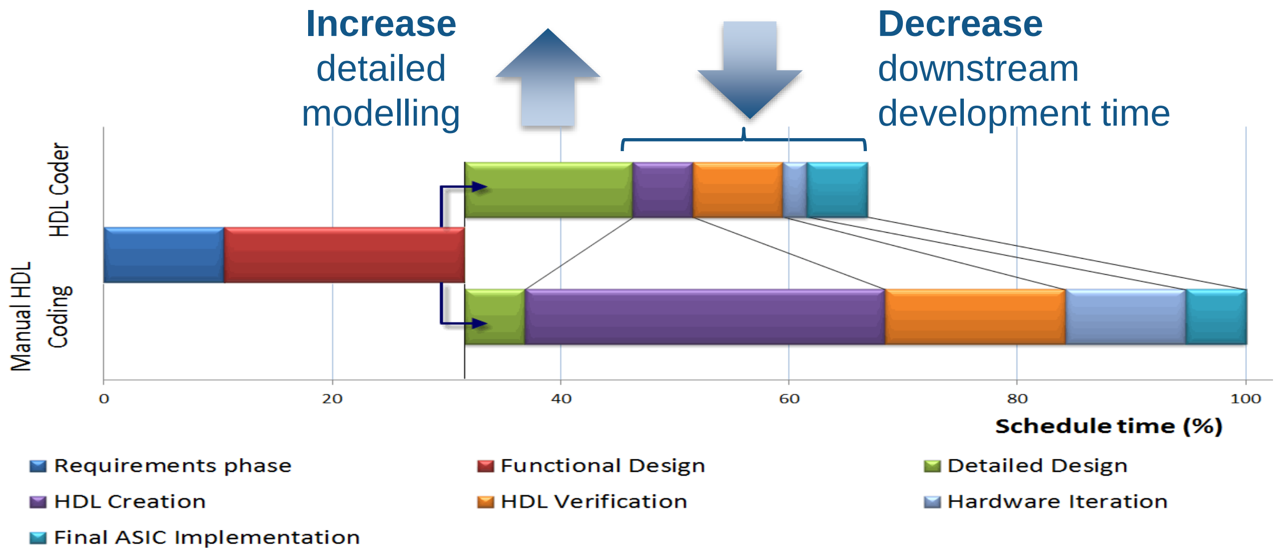
Clive Maxfield and Kuhoo Goyal
"EDA: Where Electronics Begins"

Why Model-Based Design: Achieving the Shift-Left

Reduce overall development time

- All studies point to benefits of top-down design
- Shorter design iteration cycle by 80%
- Improved product quality

Customer Study: Benefit of MBD flow



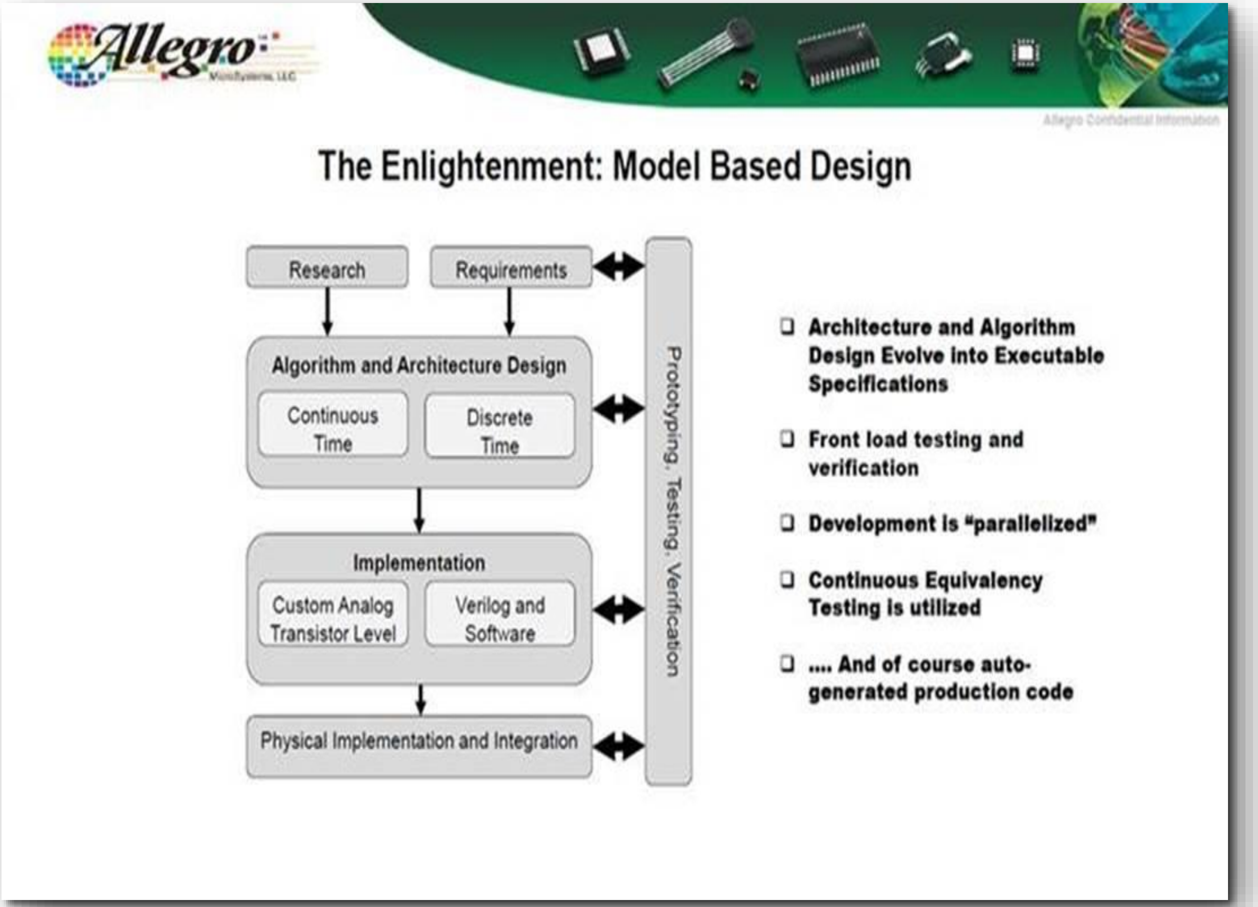
EE Times - Top-down verification guides mixed-signal designs
K. Kundert and H. Chang, Partners, Designer's Guide Consulting

"Top-Down Mixed-Signal Design
In order to address these challenges, many design teams are either looking to, or else have already implemented, a top-down design methodology. In a top-down approach, the architecture of the chip is defined as a block diagram and simulated and optimized using a system simulator such as ***MATLAB or Simulink****. From the high-level simulation, requirements for the individual circuit blocks are derived."*

Customer Successes - Allegro

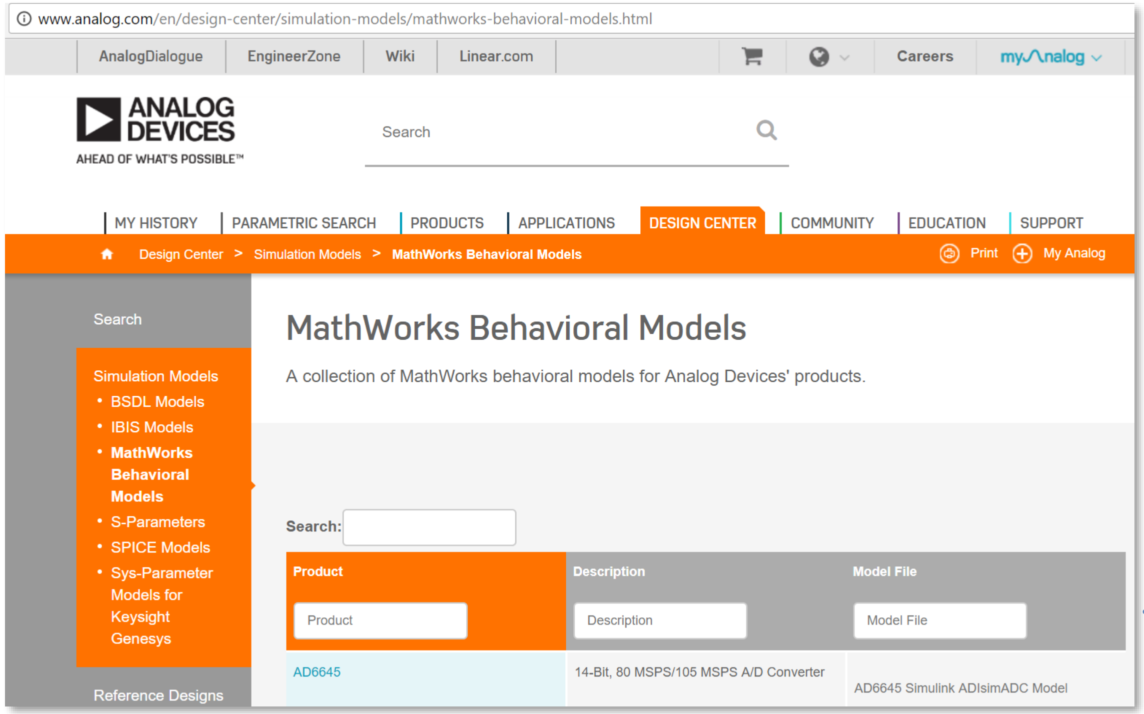
Allegro designs ASIC using Simulink:

- Interpolation engines
- Digital filters
- Signal Processing Algorithms
- Digital PLL's
- Digital Sigma Delta DAC's
- MATLAB EXPO Link



Analog Devices – Builds Simulink Behavioral Models

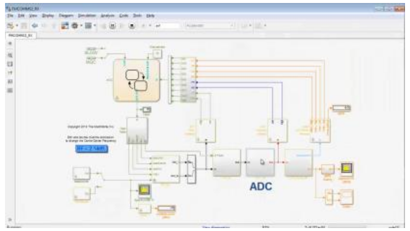
http://www.analog.com/en/design-center/simulation-models/mathworks-behavioral-models.html

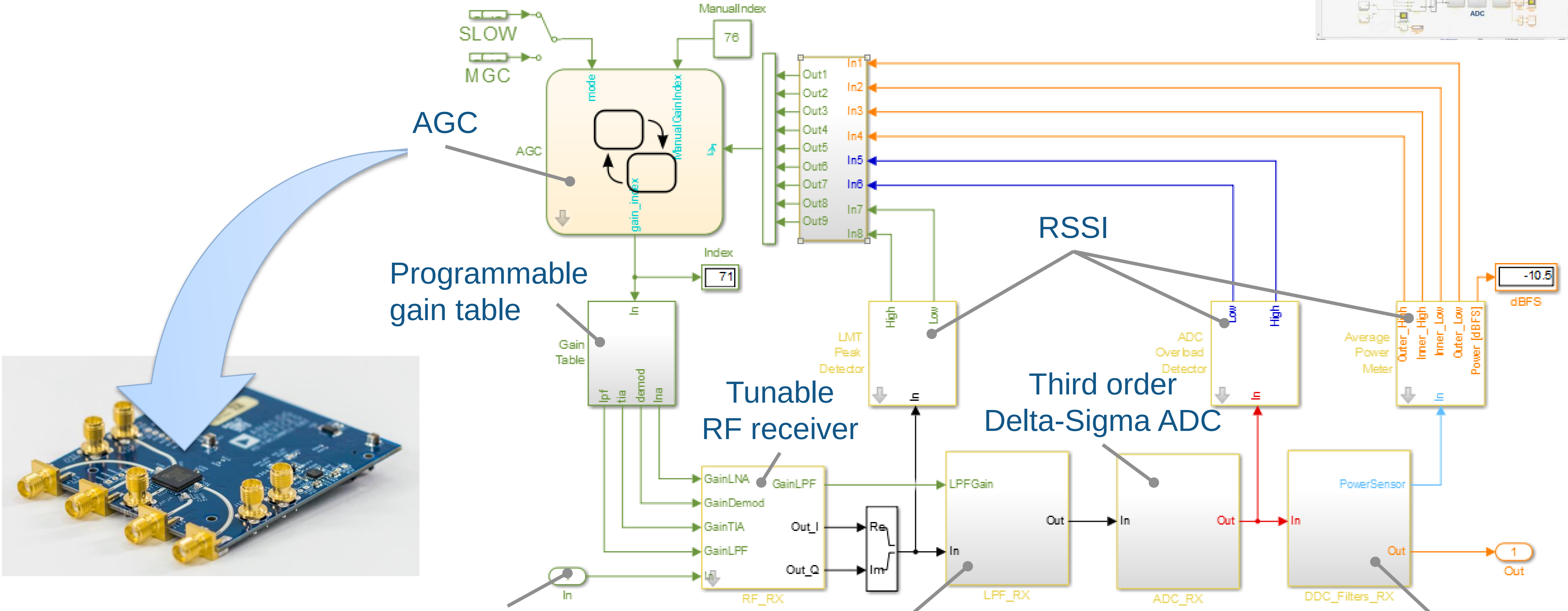


Product	Description	Model File
AD6645	14-Bit, 80 MSPS/105 MSPS A/D Converter	AD6645 Simulink ADIsimADC Model • AD6645 Simulink ADIsimADC Model
AD7403	16-Bit, Isolated Sigma-Delta Modulator	AD7403 Simulink ADIsimADC Model • AD7403 Simulink ADIsimADC Model • AD7403 MatLab Model • MathWorks Simulink Model of AD7403
AD9136	Dual, 16-Bit, 2.8 GSPS, TxDAC+® Digital-to-Analog Converter	AD9136 Simulink ADIsimDAC Model • AD9136 Simulink ADIsimDAC Model
AD9144	Quad, 16-Bit, 2.8 GSPS, TxDAC+® Digital-to-Analog Converter	AD9144 Simulink ADIsimDAC Model • AD9144 Simulink ADIsimDAC Model
AD9211	10-Bit, 200 MSPS/250 MSPS/300 MSPS, 1.8 V Analog-to-Digital Converter	AD9211 Simulink ADIsimADC Model • AD9211 Simulink ADIsimADC Model
AD9214	10-Bit, 65/80/105 MSPS, +3.3V A/D Converter	AD9214 Simulink ADIsimADC Model • AD9214 Simulink ADIsimADC Model
AD9215	10-Bit, 65/80/105 MSPS 3 V A/D Converter	AD9215 Simulink ADIsimADC Model • AD9215 Simulink ADIsimADC Model
AD9216	10-Bit, 65/80/105 MSPS Dual A/D Converter	

Multi-Domain Modeling: AD9361 Agile RF Transceiver

https://www.mathworks.com/hardware-support/analog-devices-rf-transceivers.html





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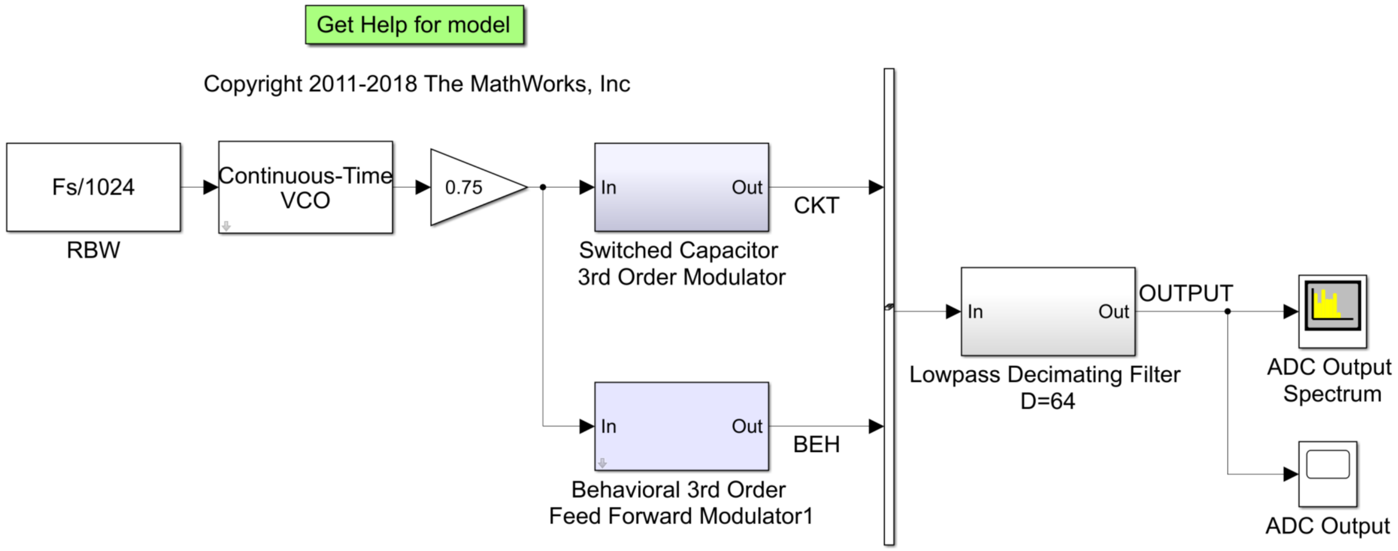
Modeling Mixed-Signal Systems in Simulink: Example Library

https://www.mathworks.com/programs/mixed-signal/index.html

10 Gbps digital communications system with timing and noise impairments

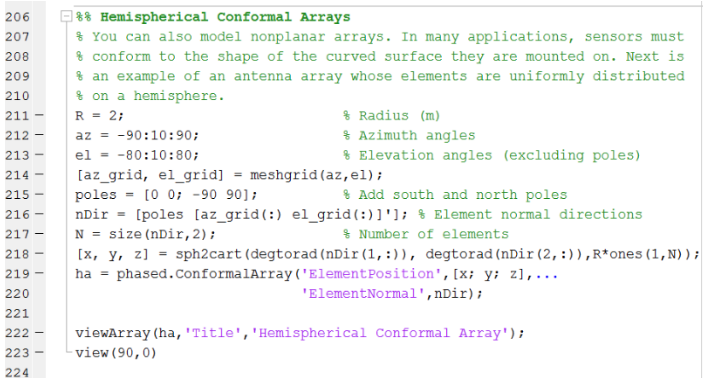
Fractional-N Frequency Synthesis with Analog (Post Phase Detector) Error Correction

Circuit Level and Behavioral Sigma Delta ADC

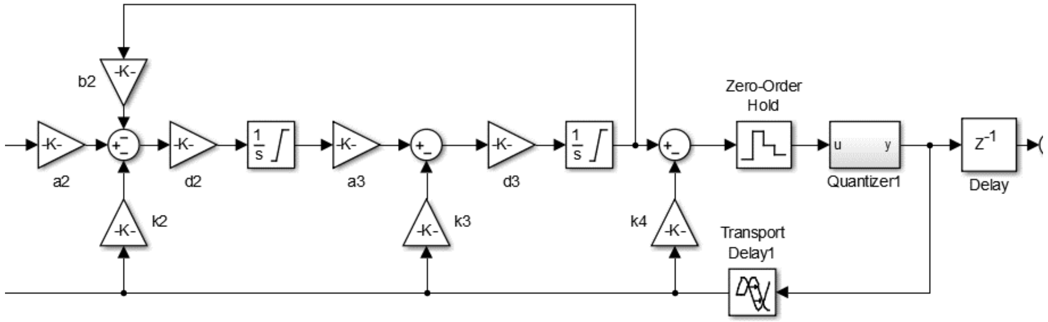


How much time does it take to build such a Simulink model?

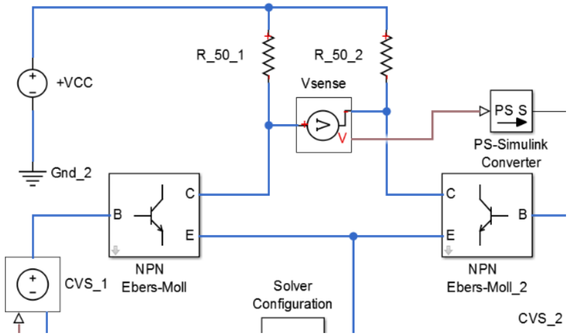
Mixed-Signal Systems Require Different Modeling Approaches



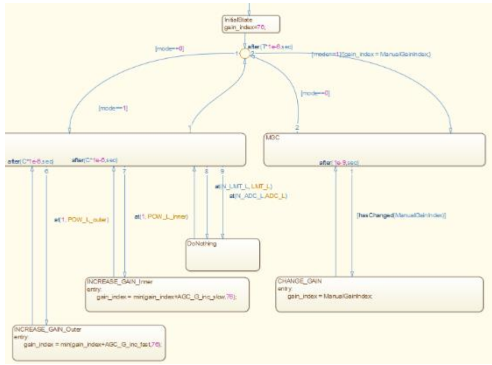
Algorithms



Behavioral Models

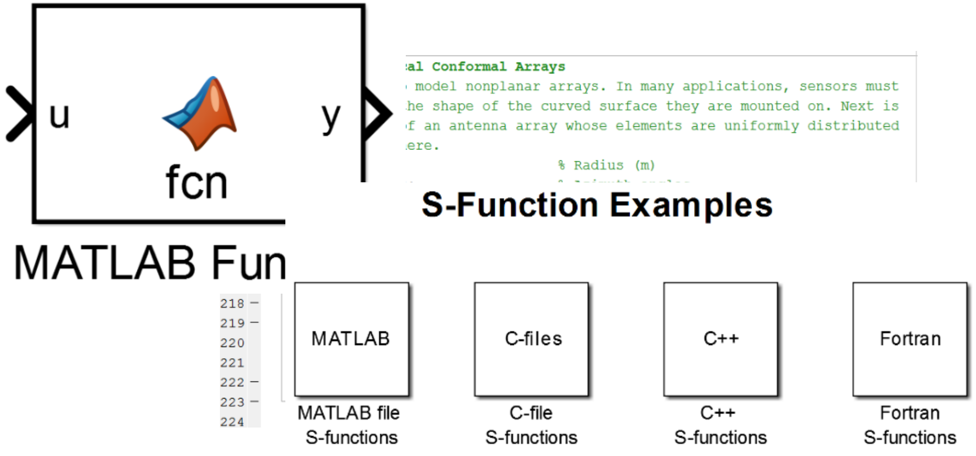


Analog Circuits

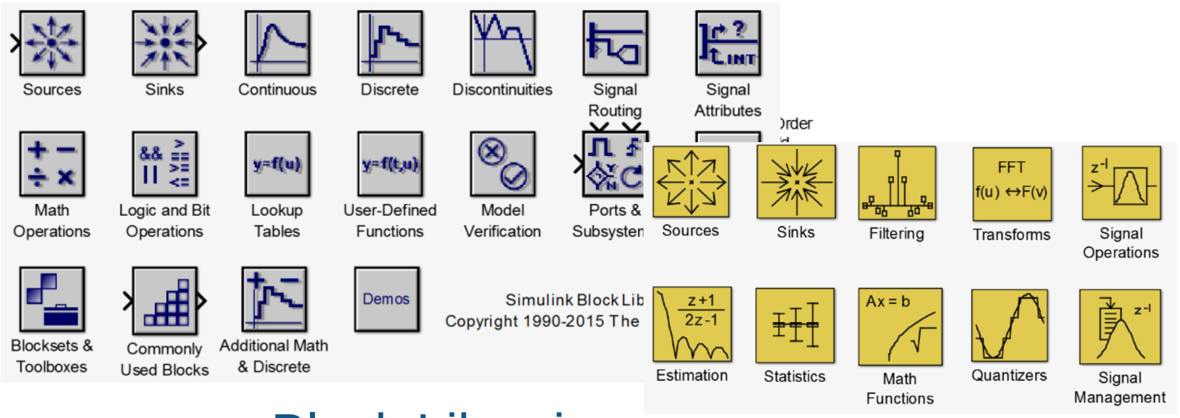


Control Logic

Simulink is the Platform for Mixed-Signal System Design

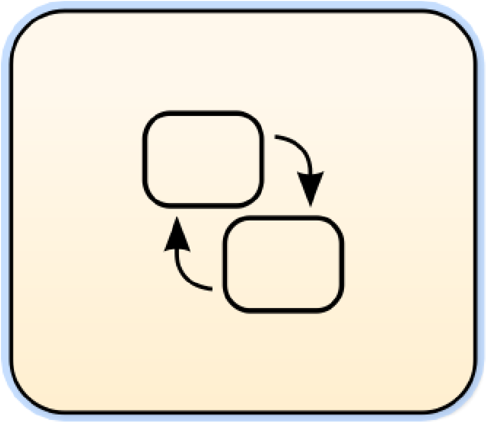


MATLAB & C Code Integration



Block Libraries

Simscape Electrical and Physical Modeling



Stateflow

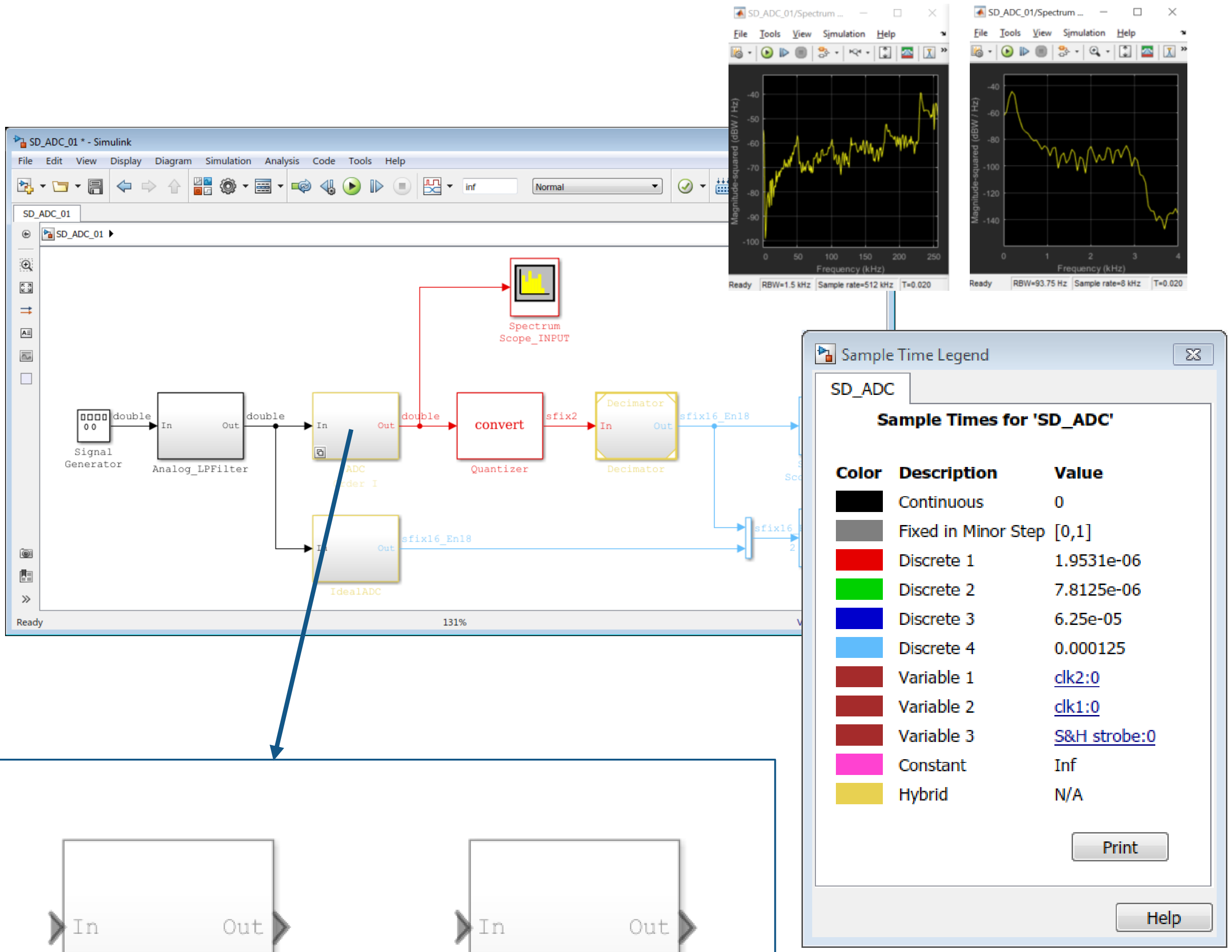
Fast Simulation and Large Scale Modeling with Simulink

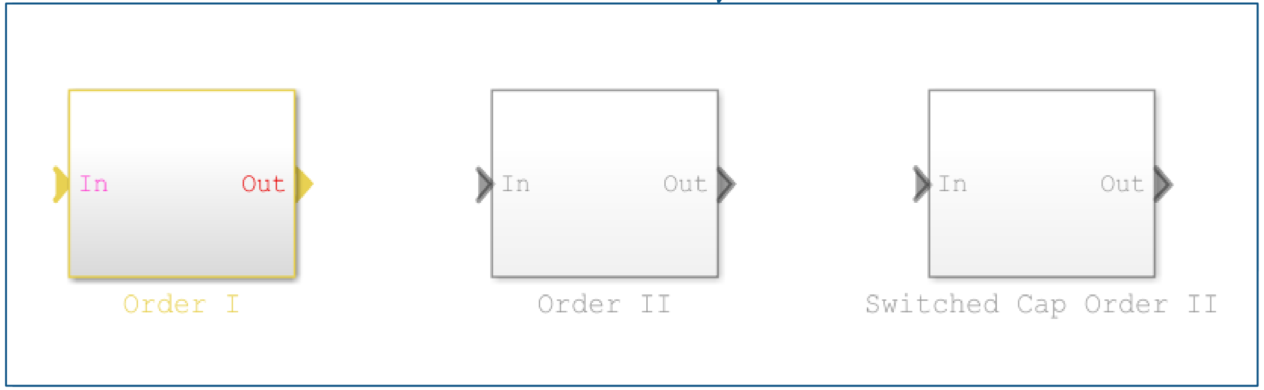
Continuous and discrete time simulation

- Multi-rate schedulers and ODE solvers
- Multi-core parallel simulations
- Solver profiler and accelerator

Scale up adoption across large organizations

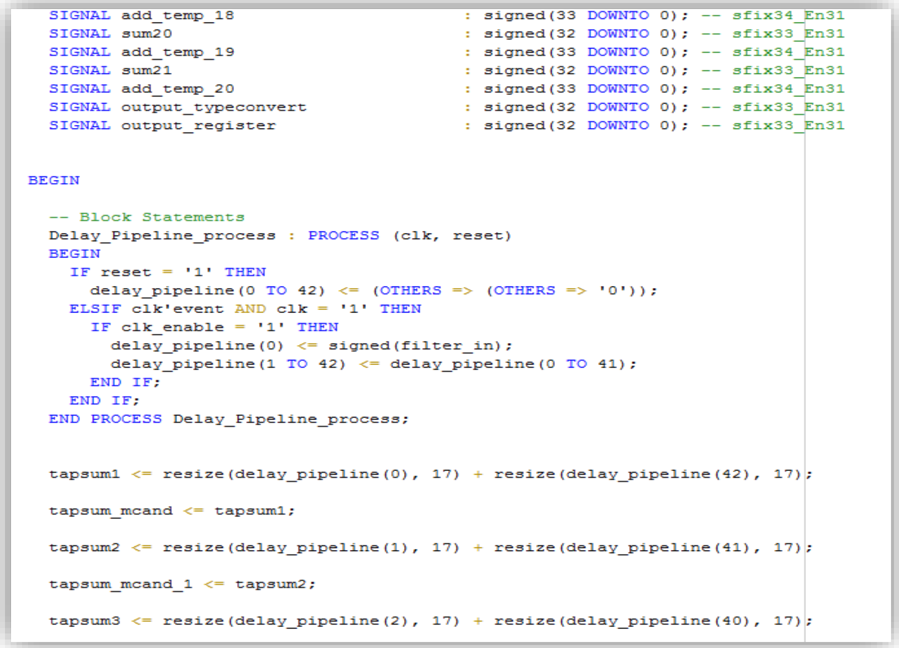
- Variants and model management
- Build libraries of components
- Model encryption



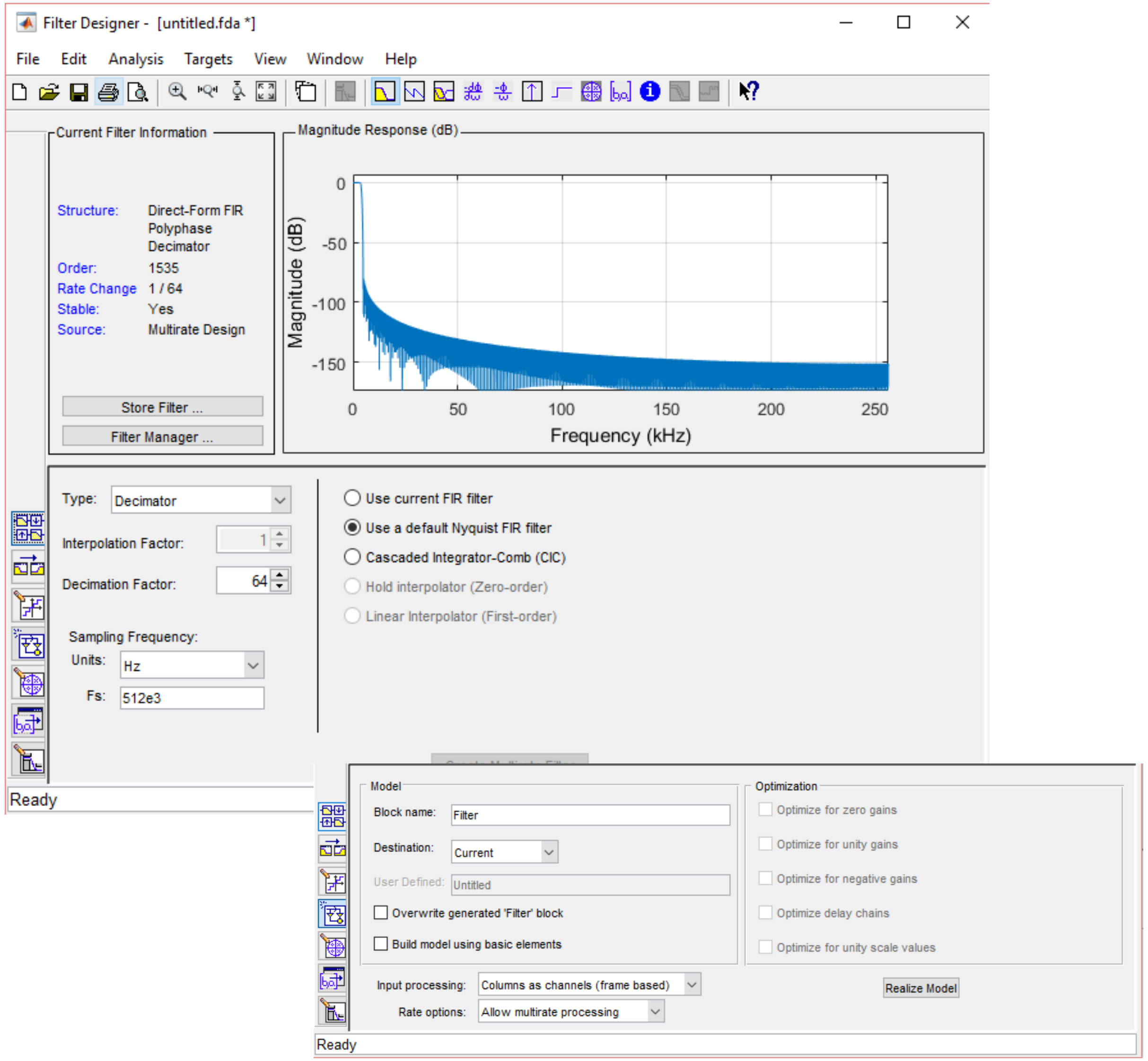


Start with Designing and Implementing Digital Filters

- Realize model with basic Simulink blocks
- Export coefficients to MATLAB
- Create multi-rate filters
- Generate synthesizable HDL code



```
  SIGNAL add_temp_18                    : signed(33 DOWNTO 0); -- sfix34_En31
  SIGNAL sum20                          : signed(32 DOWNTO 0); -- sfix33_En31
  SIGNAL add_temp_19                    : signed(33 DOWNTO 0); -- sfix34_En31
  SIGNAL sum21                          : signed(32 DOWNTO 0); -- sfix33_En31
  SIGNAL add_temp_20                    : signed(33 DOWNTO 0); -- sfix34_En31
  SIGNAL output_typeconvert             : signed(32 DOWNTO 0); -- sfix33_En31
  SIGNAL output_register                : signed(32 DOWNTO 0); -- sfix33_En31


BEGIN

  -- Block Statements
  Delay_Pipeline_process : PROCESS (clk, reset)
  BEGIN
    IF reset = '1' THEN
      delay_pipeline(0 TO 42) <= (OTHERS => (OTHERS => '0'));
    ELSIF clk'event AND clk = '1' THEN
      IF clk_enable = '1' THEN
        delay_pipeline(0) <= signed(filter_in);
        delay_pipeline(1 TO 42) <= delay_pipeline(0 TO 41);
      END IF;
    END IF;
  END PROCESS Delay_Pipeline_process;


  tapsum1 <= resize(delay_pipeline(0), 17) + resize(delay_pipeline(42), 17);

  tapsum_mcand <= tapsum1;

  tapsum2 <= resize(delay_pipeline(1), 17) + resize(delay_pipeline(41), 17);

  tapsum_mcand_1 <= tapsum2;

  tapsum3 <= resize(delay_pipeline(2), 17) + resize(delay_pipeline(40), 17);
```



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- ✓ Current Trends in Semiconductor Design and Verification
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- ▪ **Linking Behavioral to Circuit design and Verifying AMS designs**
- ▪ Post-processing of simulation results
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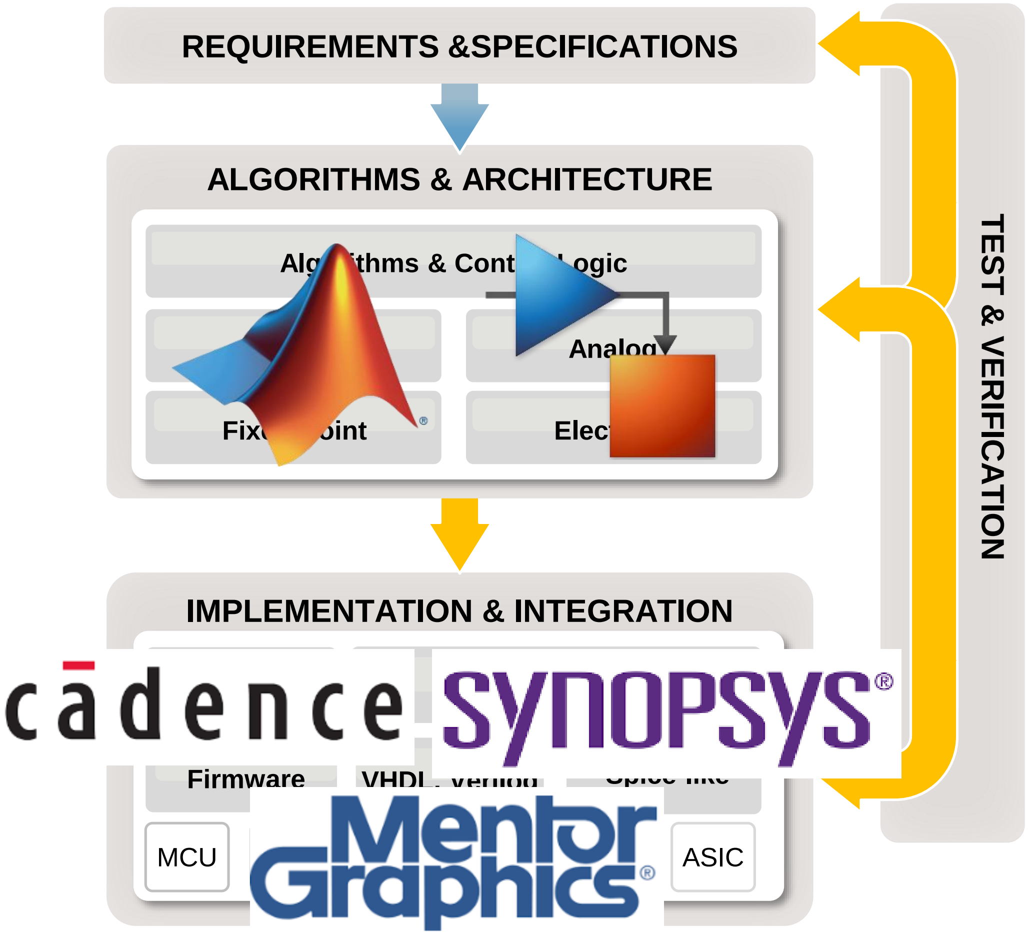
Linking System-Level Algorithms and Circuit-Level Implementation

Design methodologies are true differentiators:

- Innovate more rapidly
- Achieve faster design cycles
- Introduce fewer errors
- Understand the system and its implementation

Linking MathWorks and EDA tools:

- Suitable for analog, digital or mixed-signal systems
- Target system-level and circuit-level designers



EDA Workflow Integration: Co-simulation

Algorithm Development
System Design & Architecture

RTL Co-Simulation

- Cadence Incisive
- Mentor Graphics QuestaADMS
- Synopsys VCS

Analog Co-Simulation

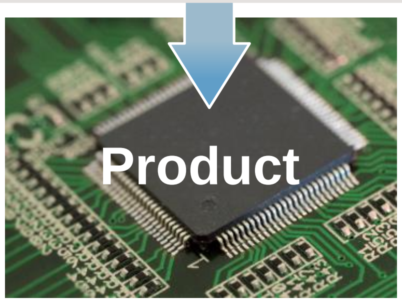
- Cadence Virtuoso
- Cadence Pspice

RTL Simulator

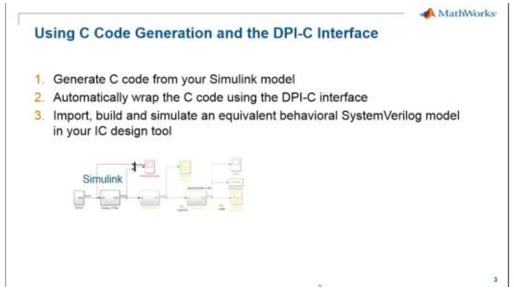
FPGA In-the-Loop

SPICE Simulator

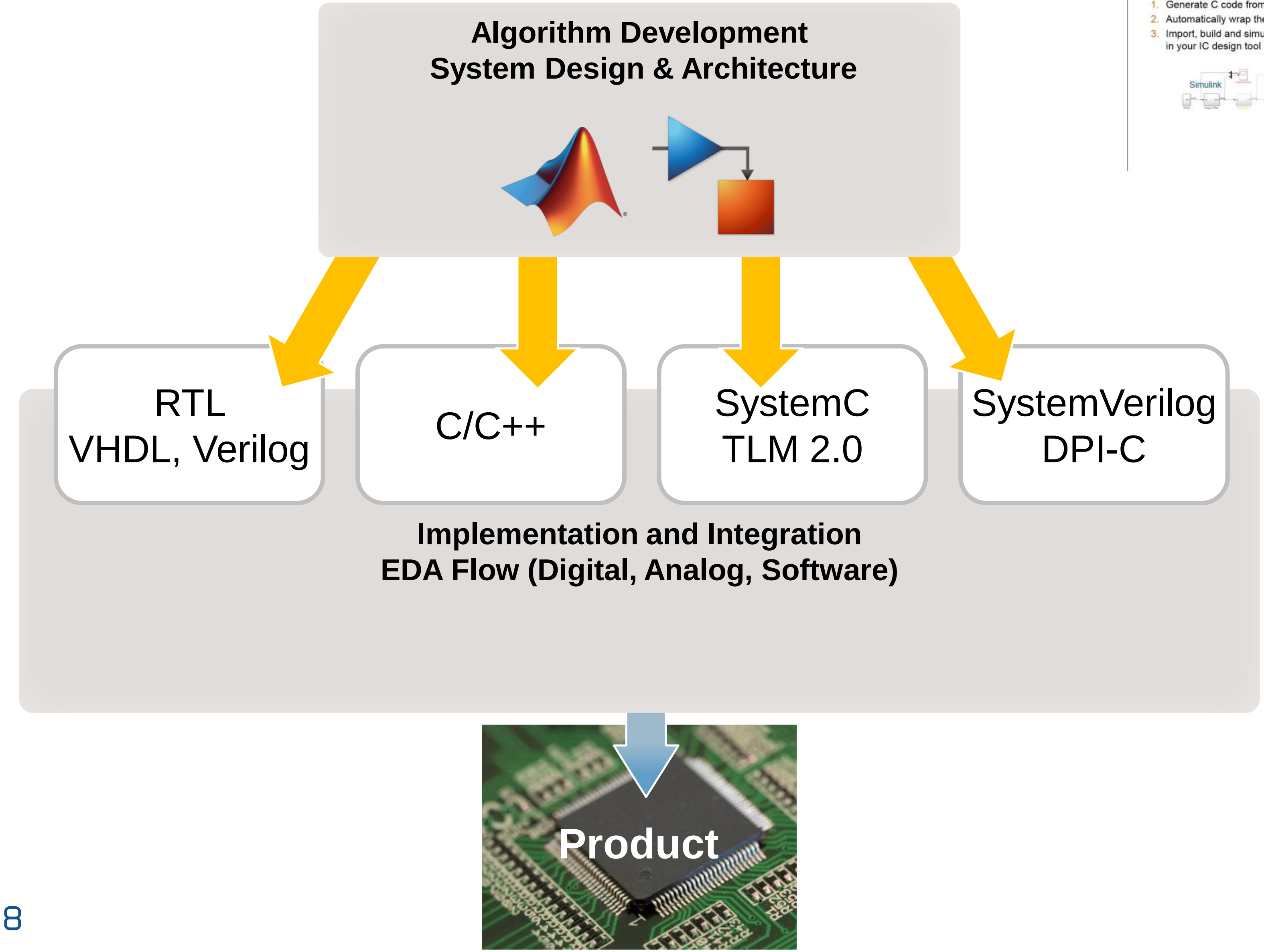
Implementation and Integration
EDA Flow (Digital, Analog, Software)



EDA Workflow Integration: Model Export


Using C Code Generation and the DPI-C Interface

1. Generate C code from your Simulink model
2. Automatically wrap the C code using the DPI-C interface
3. Import, build and simulate an equivalent behavioral SystemVerilog model in your IC design tool



Two Complementary Verification Approaches

Analog / Digital co-simulation

- Test your IP within the context of a full system simulation
- Use the visualization and analysis capabilities of Simulink and MATLAB
- Test each module independently of other modules
- Validate the IP behavioral model and speed up system-level simulation

SystemVerilog (DPI-C) code generation

- Fast simulation using the native SystemVerilog API
- HDL simulator independent
- Real number models for analog and digital IPs
- Most suitable for testbench generation and IC verification (regression tests)

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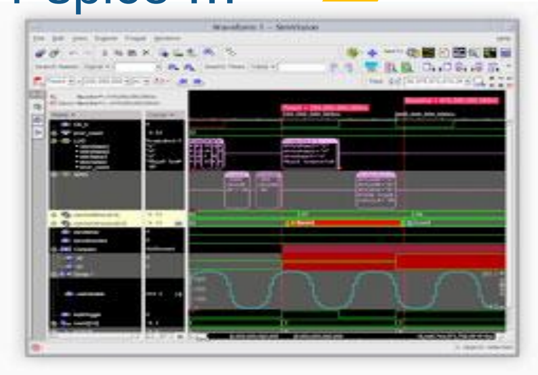
Post-Processing of Simulation Results with MATLAB

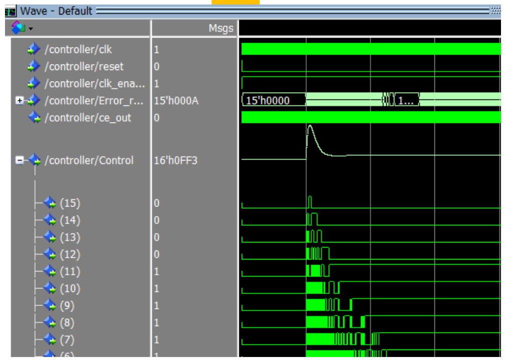
- Analyze all kinds of simulation results in MATLAB
- Import files from Spectre, HSPICE, Eldo, Questa ADMS, etc

Functions, Measurements, and Visualization

Signal Processing, Statistical analysis, Model fitting, RF Analysis, Sensitivity Analysis, Monte Carlo, …

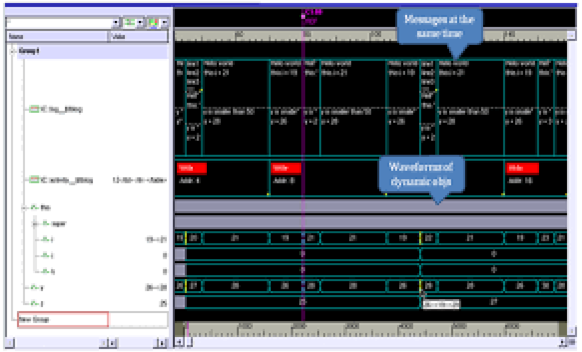
Cadence Virtuoso, Spectre, Pspice …





Mentor Graphics QuestaADMS, Eldo, QuestaSim, …

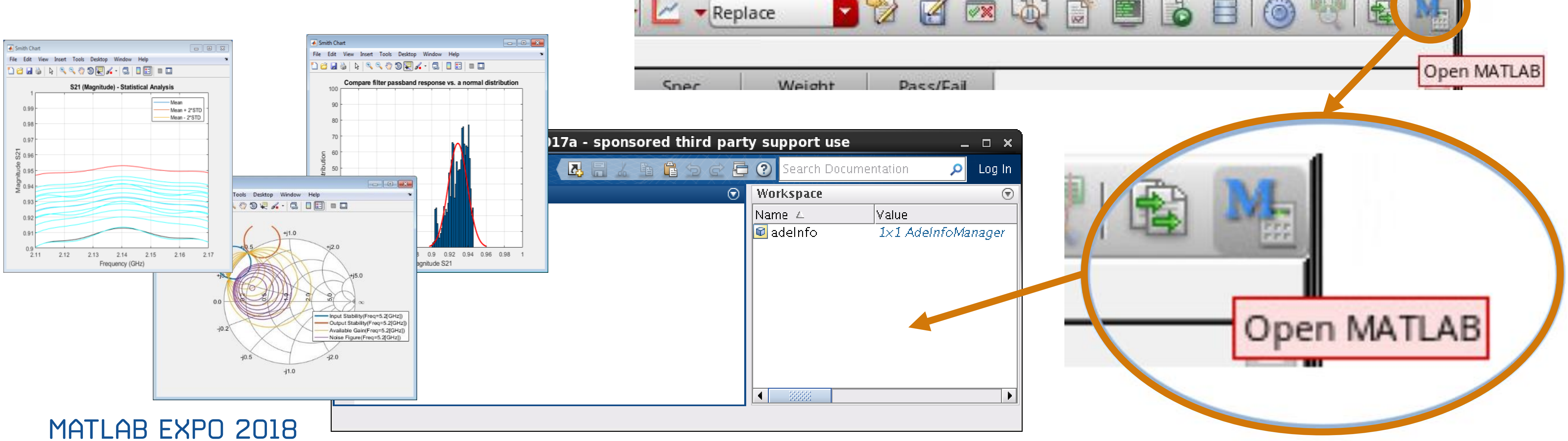
Synopsys VCS, HSPICE, …



Cadence MathWorks Integration for Advanced Data Analytics

- Cadence ADE XL interface to MATLAB in latest MMSIM
  - Enables Simulation data to be seamlessly transferred into MATLAB Environment
  - Leverage MATLAB advanced data analysis capabilities to post-process and verify simulation results
  - [Cadence Newsroom Link]

Cadence Virtuoso ADE-XL



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Design and Verification of Mixed-Signal Systems with MathWorks

- Use many trusted functions for algorithmic design
  ► **You don’t have to be a modeling guru**

- Anticipate implementation impairments in Simulink
  ► **Iterate more rapidly in a truly mixed-signal simulation environment**

- Build and reuse system-verification test-benches through your development process
  ► **Reduce the verification effort**

- Use MATLAB for the analysis and visualization of your circuit simulation results
  ► **Automate the large scale analysis of data and gain deeper insights**

Call to Action – MathWorks Resources

- Semiconductor solutions
- User stories
- Technical Articles

Faster Digital System Design

MATLAB and Simulink products can help improve the process for DSP, FPGA, ASIC, and SoC semiconductor design. Engineers use an extensive library of signal processing algorithms, data visualization functions, and an interactive user interface which makes the development of digital systems faster than using lower level languages such as C or C++.

Broadcom Develops Low-Cost 3G Semiconductor Product

"MATLAB is an ideal environment for developing and understanding our algorithms. Simulink integrates well with MATLAB and lets us produce a design that looks very similar to what we end up with ultimately in hardware."

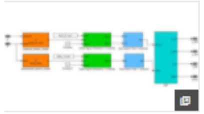
Francis Swarts, Broadcom

Behavioral Analog/Mixed-Signal Design

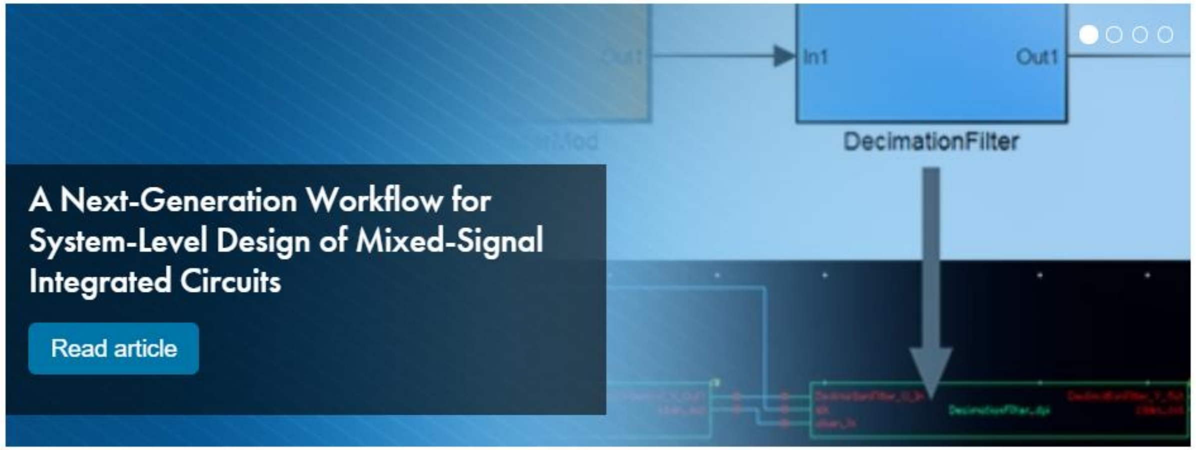
Modeling and simulating analog/mixed-signal systems in circuit-level tools is time consuming and limits the number of design alternatives engineers can evaluate. By contrast, MATLAB and Simulink provide a higher level of design abstraction and faster modeling and simulation, which enables engineers to quickly evaluate numerous design options.

Semiconductor engineers use MATLAB and Simulink models as golden references when they create transistor-level circuit models. These MATLAB and Simulink models integrate with analog/mixed-signal design tools such Cadence® Virtuoso® AMS Designer, and can also be used as behavioral verification models in production SystemVerilog test environments.

IDT-Newave Reduces Semiconductor Design Time by Months



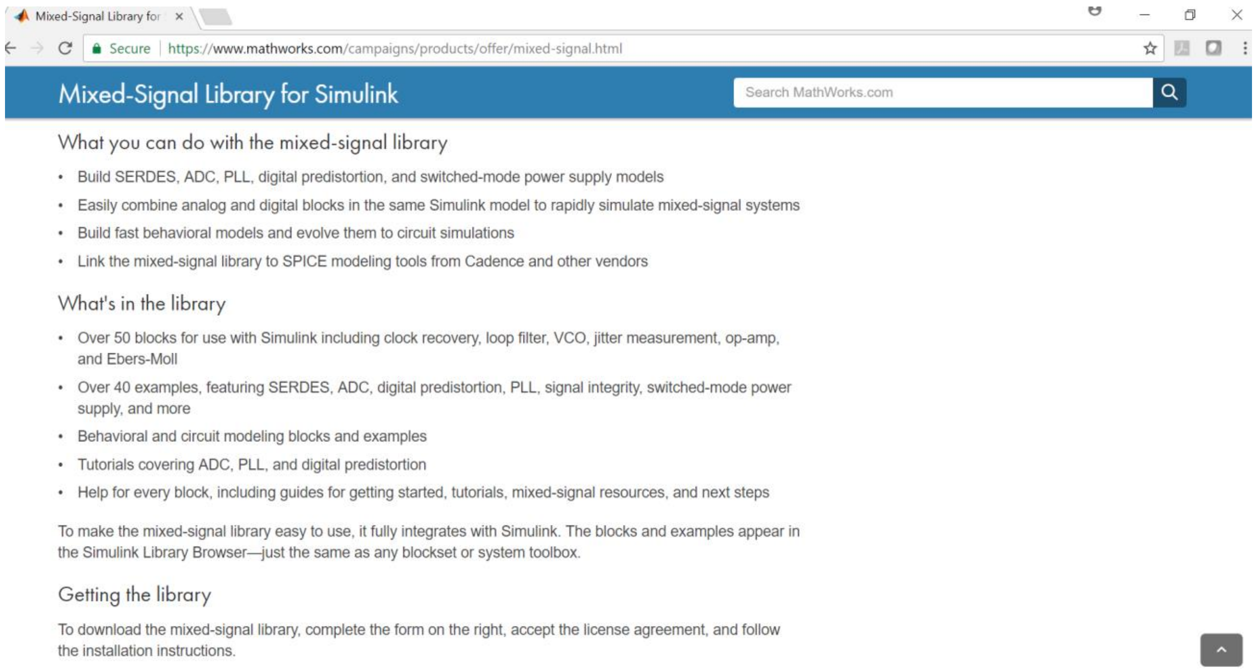
System-Level Design of Mixed-Signal ASICs Using Simulink: Efficient Transitions to EDA Environments



Call to Action – Download Mixed Signal Example Library

https://www.mathworks.com/programs/mixed-signal/index.html

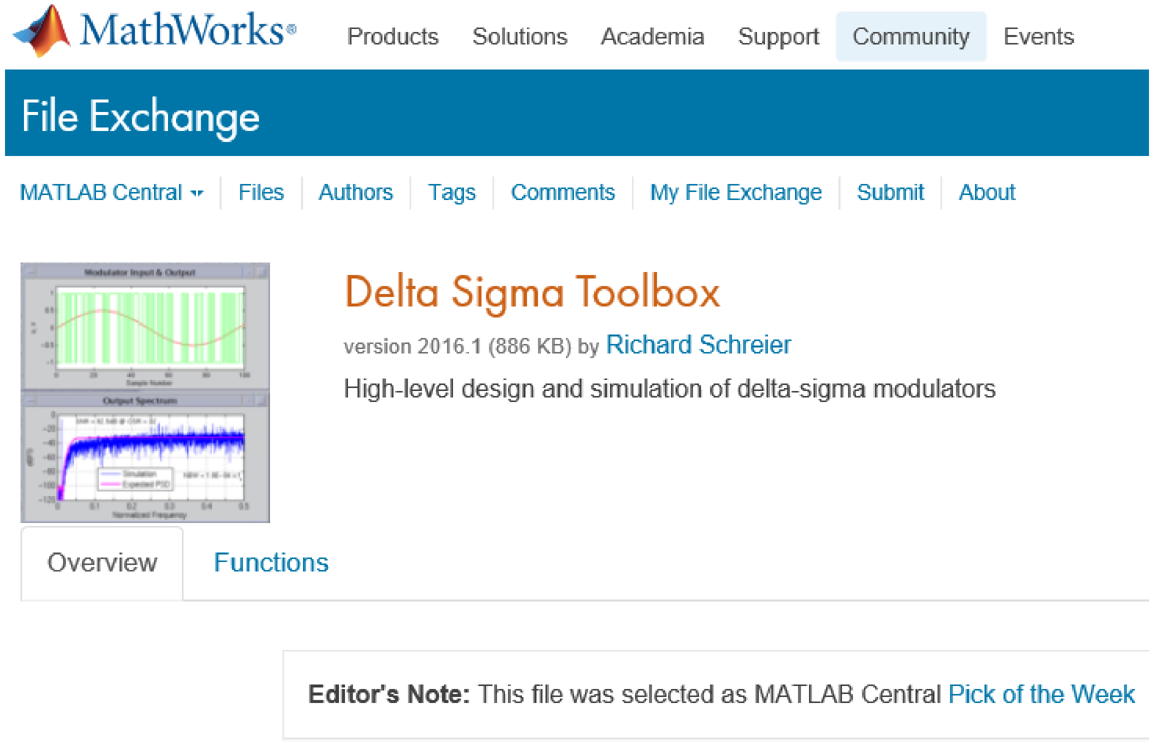
- Shorten your learning curve starting with validated examples, tutorials, best practices
  - Most popular mixed-signal examples for ADC, PLL, SerDes, and SMPS
  - Getting started with Simulink using step-by-step tutorials
  - Full documentation and latest features



Call to Action – MATLAB Central File Exchange

https://www.mathworks.com/matlabcentral/fileexchange/

- An open exchange for the MATLAB and Simulink user community
  - Get answers, challenge yourself and others, and share your knowledge
  - Tap into the knowledge and experience of over 100,000 community members and MathWorks employees.



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  - I use #MATLAB because……………………… Attending #MATLABEXPO
  - Examples
    - I use #MATLAB because it helps me be a data scientist! Attending #MATLABEXPO
    - Learning new capabilities in #MATLAB and #Simulink at #MATLABEXPO.

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