

# High-Performance Semiconductors

- » Magnetic Sensor Integrated Circuits
- » Power Integrated Circuits



## Automotive ASIC Model Based Design

*Jamie Haas*

*Director of Design Engineering*

*Advanced Sensor Technology Business Unit*





# Sensor Applications



- **Automotive**
  - **Steering**
  - **Engine**
  - **Transmission**
  - **Hybrid/Electric Motor**
  - **Seat Belt**
  - **More!**
- **Consumer Applications**
- **Industrial Controls**
- **Current Sensing**





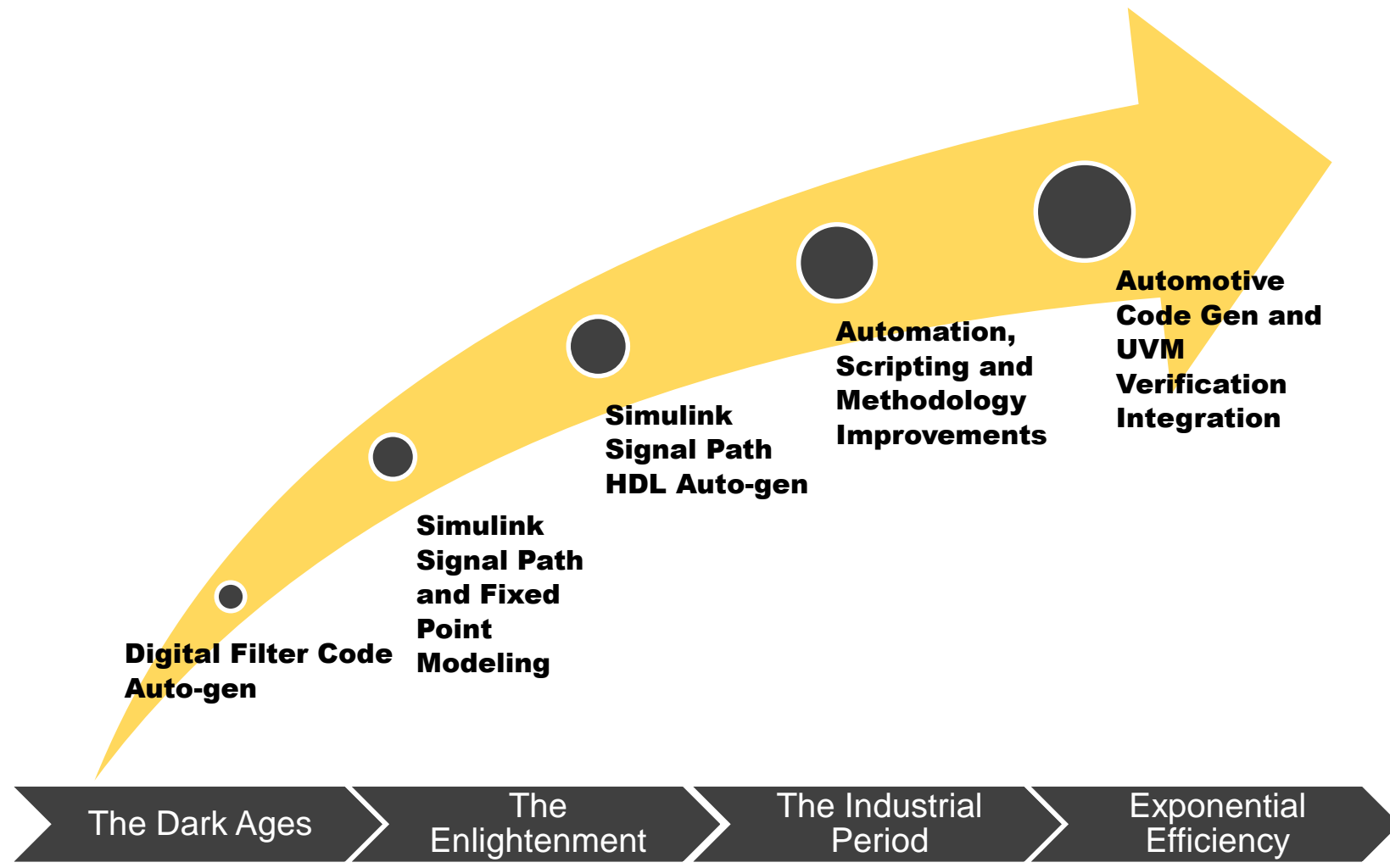
## An Overview of Allegro's MBD Success

- ❑ **We Started taking a serious look at Simulink MBD for ASIC Development in 2014**
- ❑ **Team Adoption hit the “knee” of the curve in 2015**
- ❑ **A total of 8 device digital control systems and signal paths auto generated from Simulink**
  - ❑ Interpolation engines
  - ❑ Digital filters
  - ❑ Signal Processing Algorithms
  - ❑ Digital PLL's
  - ❑ Digital Sigma Delta DAC's
- ❑ **Silicon Evaluation has demonstrated ZERO bugs from auto generated code to date.**



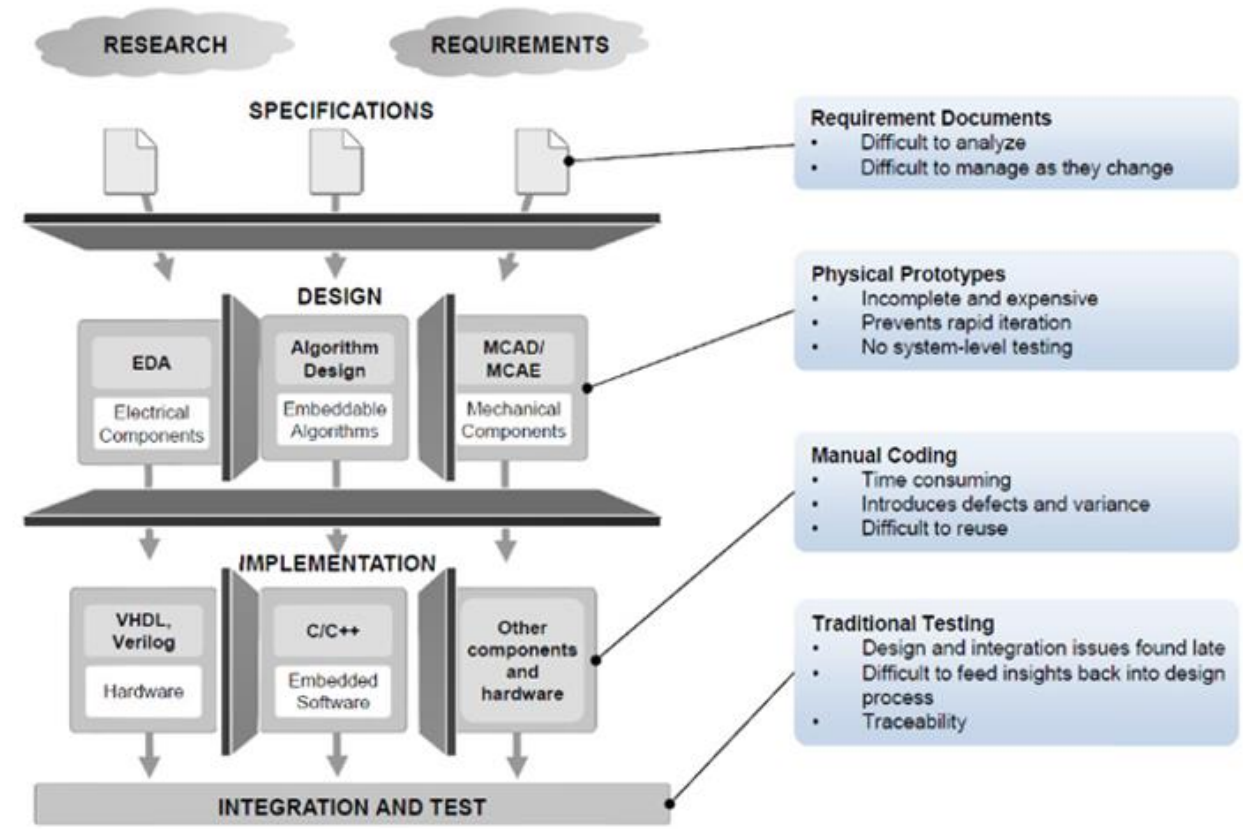


# The Evolution of Allegro's Model Based Design (MBD) Flow



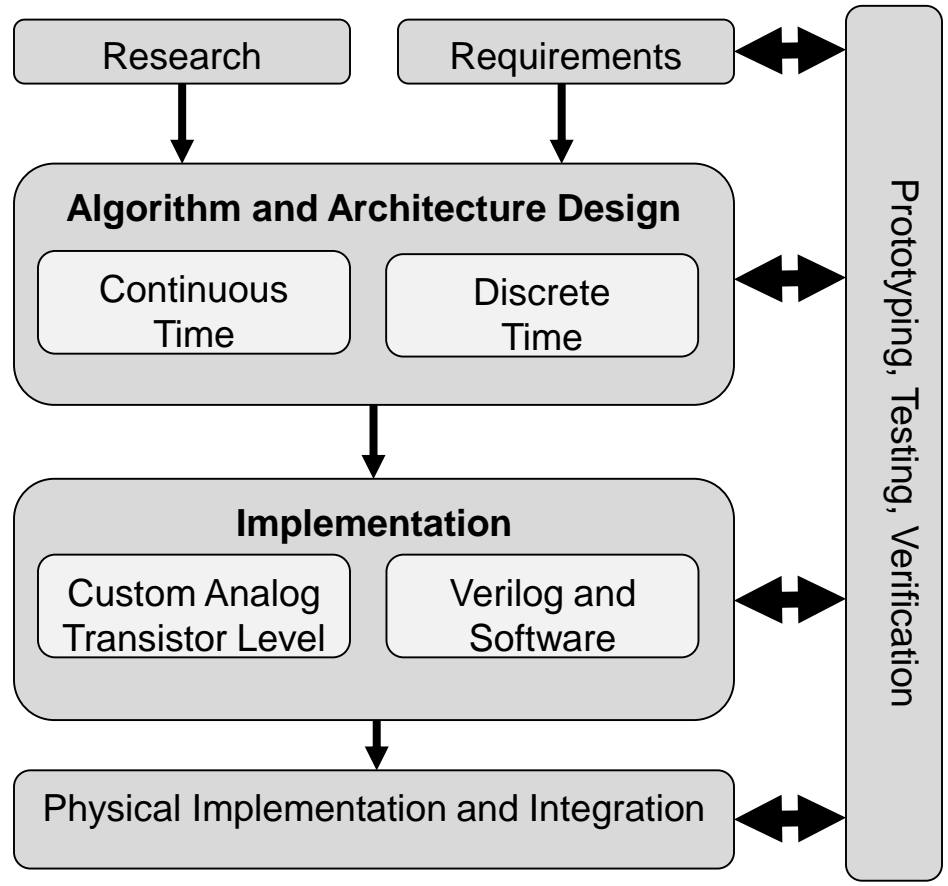


# “The Dark Ages” Traditional ASIC Design





# The Enlightenment: Model Based Design



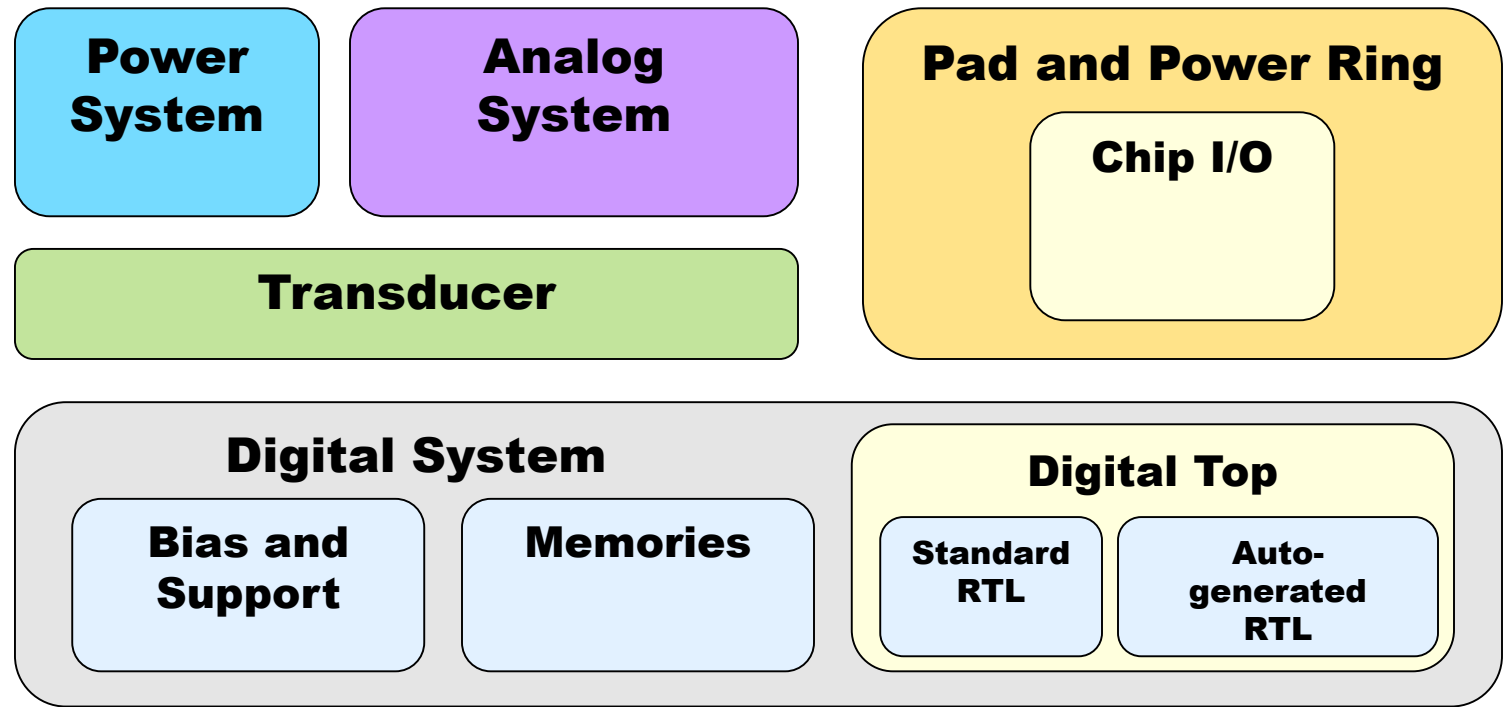
- Architecture and Algorithm Design Evolve into Executable Specifications**
- Front load testing and verification**
- Development is “parallelized”**
- Continuous Equivalency Testing is utilized**
- .... And of course auto-generated production code**



# ASIC Sensor Components



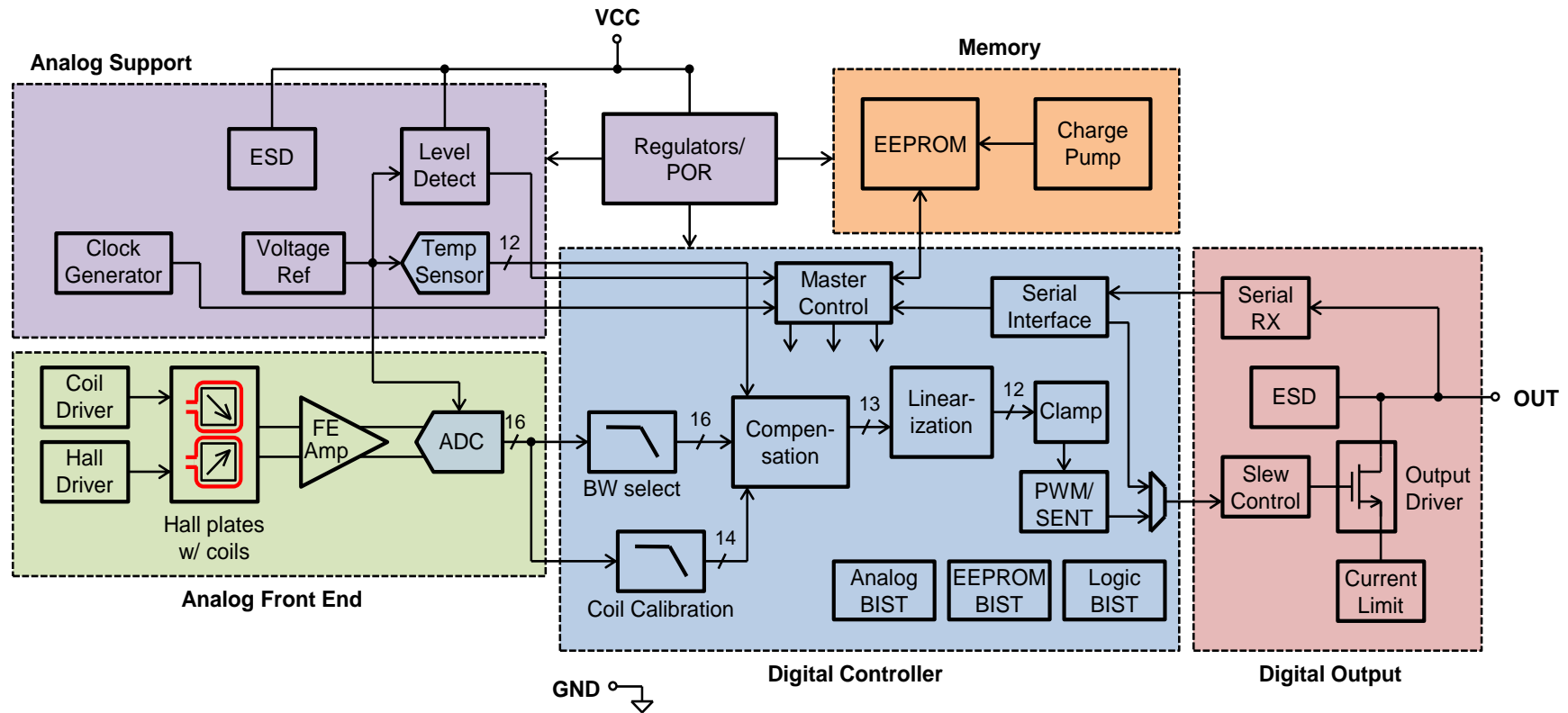
# Mixed Signal ASIC Components







# Precision Automotive Magnetic Sensor



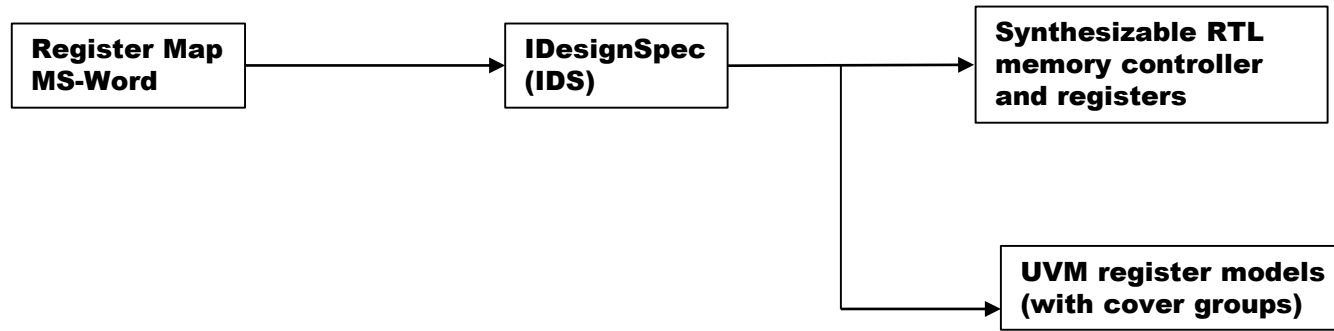


## ASIC Sensor Simulink Modeling

- How do we handle the memory (EEProm configuration)
  
- Simulink Model Types
  - Spec Model
  - HDL Gen: Stateflow
  - HDL Gen: Matlab Function
  - Validation Model



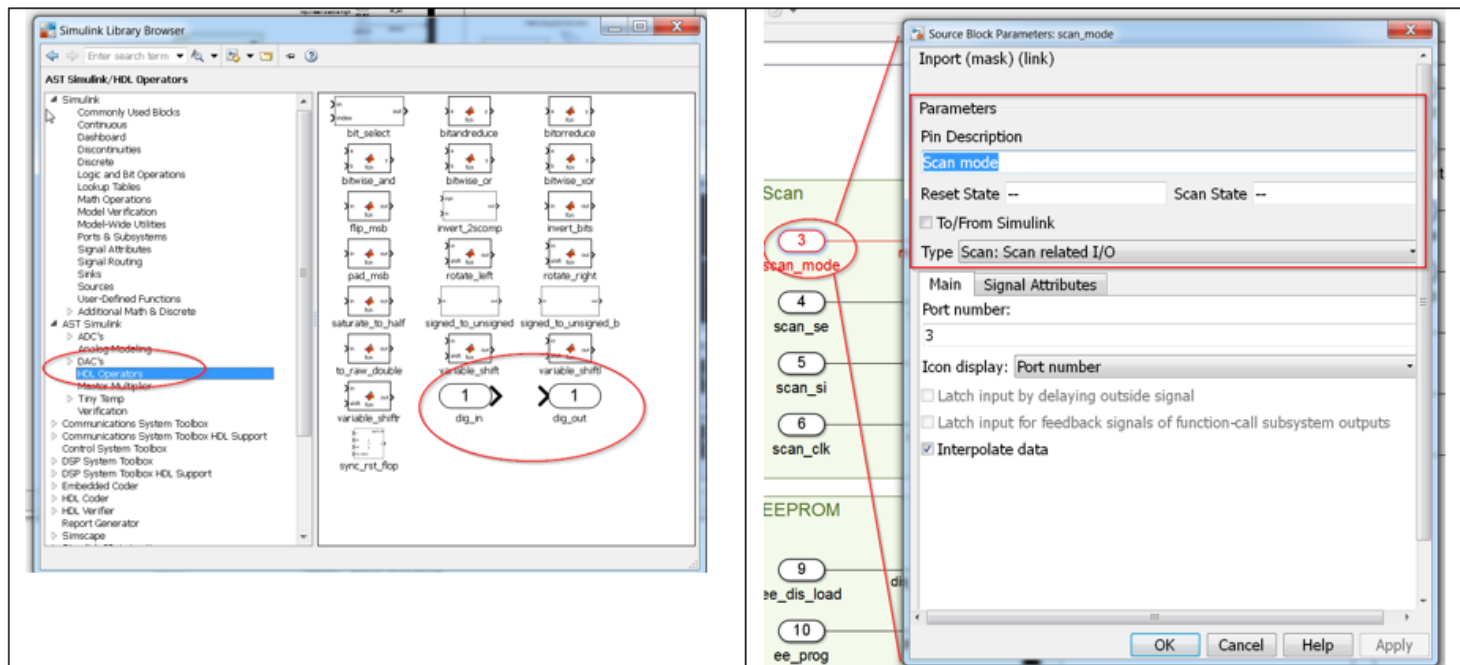
## Memories: Automatic Register Generation



- ❑ **The Word based register map is the single point for documenting all registers**
- ❑ **RTL is generated using the Agnisisys IDesignSpec tool**
- ❑ **Register models required by DV (Design Verification) are generated using the Agnisisys IDesignSpec tool**



# Memories: Link Simulink Model to Memory Map

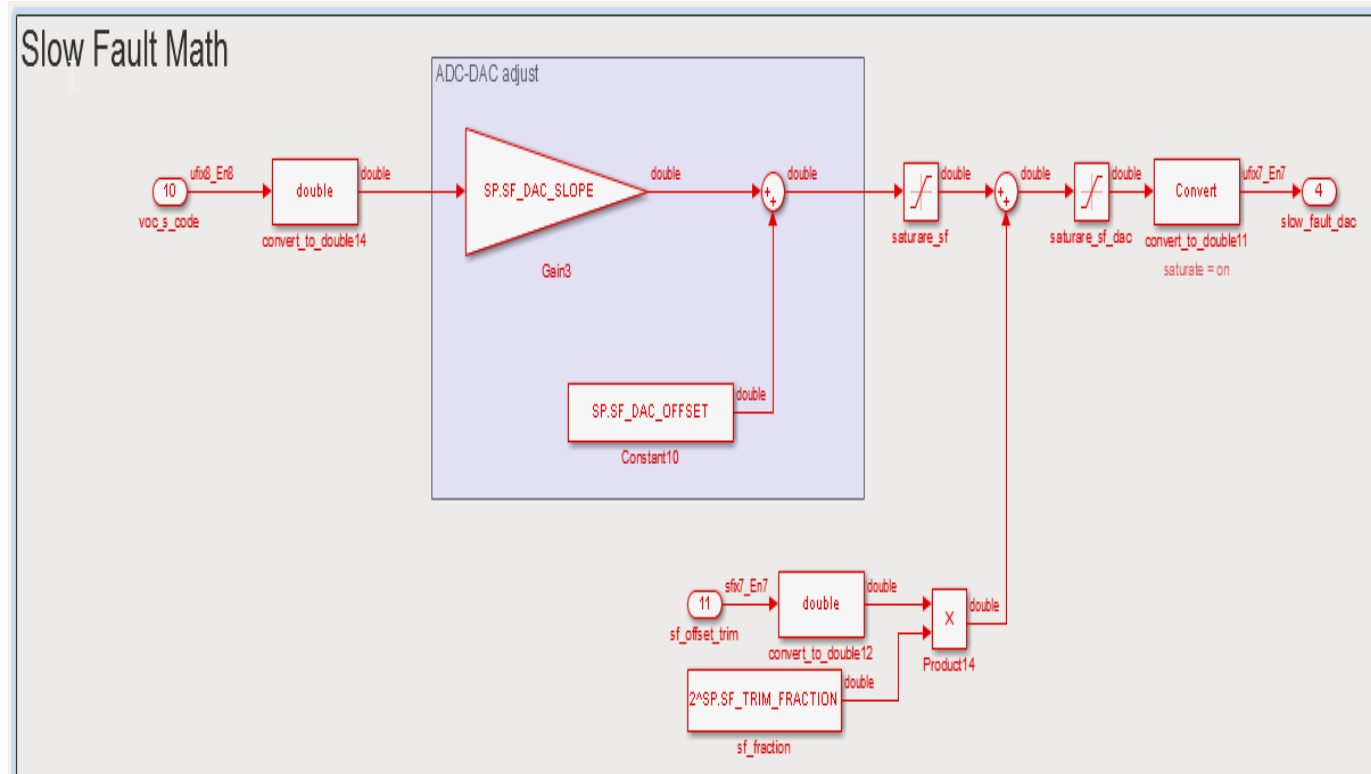


The image shows two windows from the Simulink environment. On the left is the 'Simulink Library Browser' showing the 'AST Simulink/HDL Operators' section. The 'HDL Operators' folder is expanded, and the 'dsg\_in' and 'dsg\_out' blocks are circled in red. On the right is the 'Source Block Parameters: scan\_mode' dialog. The 'Parameters' section is highlighted with a red box, showing 'Scan mode' as the pin description and 'Type: Scan: Scan related I/O'. A red circle highlights the '3' in the 'Port number' field, which is also circled in red in the 'Scan' block list on the left. Other parameters like 'Reset State', 'Scan State', and 'Interpolate data' are also visible.

- ❑ **Custom Inports and Outports with attributes where created**
- ❑ **Additional attributes are used by Matlab Report Generator for automated document generation**



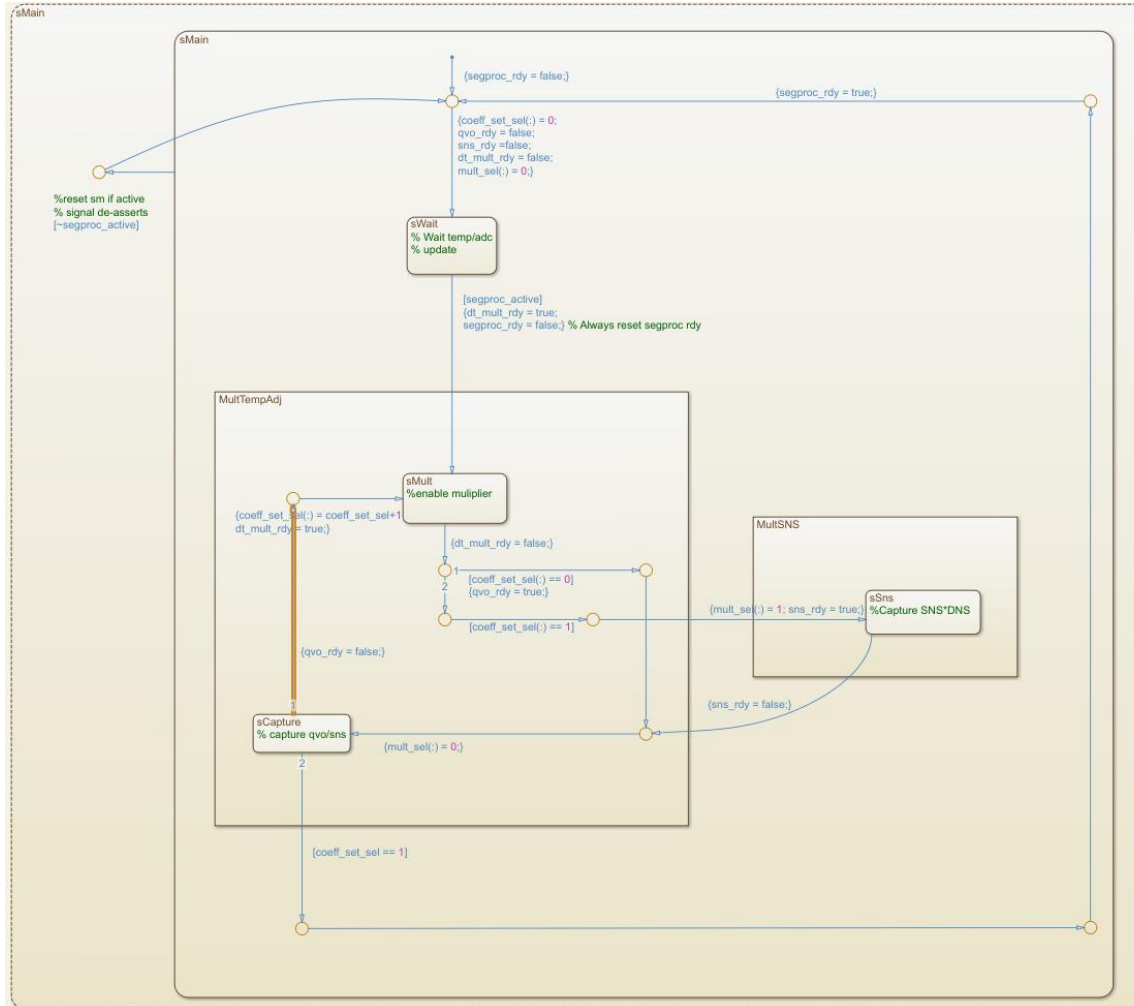
# Simulink Spec Model



- ❑ **A Spec Model is the “golden model” of what you are trying to achieve.**
  - ❑ **Easy to read**
  - ❑ **Simple as possible**
- ❑ **Requirements are linked to the spec models**
- ❑ **Avoid**
  - ❑ **HDL optimizations**
- ❑ **Keep data types as doubles where possible**
- ❑ **Using DPI-C , System Verilog models are created from the spec models**



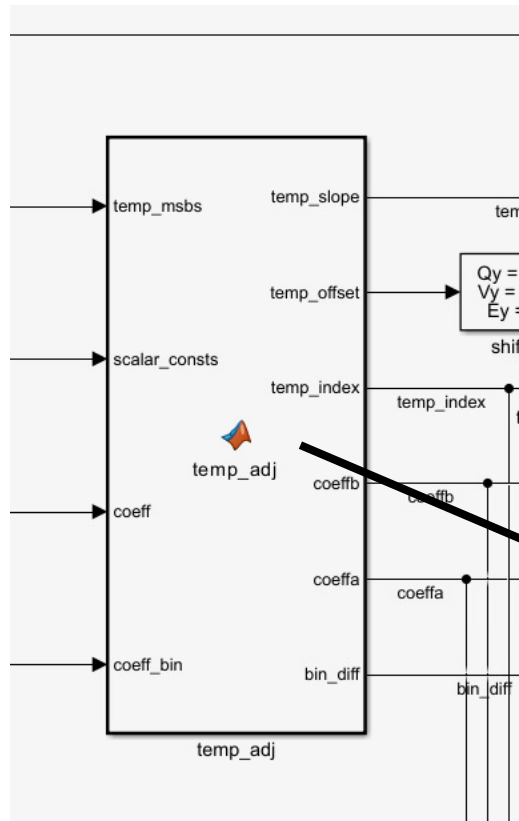
# The Power of Stateflow



- ❑ **Stateflow is a universal tool**
  - ❑ **Stateflow allows for efficient control logic design that is self documenting and translates to efficient RTL(\*\*)**
    - ❑ **SAR ADC Controller**
    - ❑ **Multiplier Sharing**
- ❑ **Stateflow can be used as a verification driver (handles asynch events)**
- ❑ **Stateflow can be used to model analog switched capacitor charge transfer!**
- ❑ **Stateflow charts can be embedded within Stateflow charts**



# Flexibility of Matlab Function Block



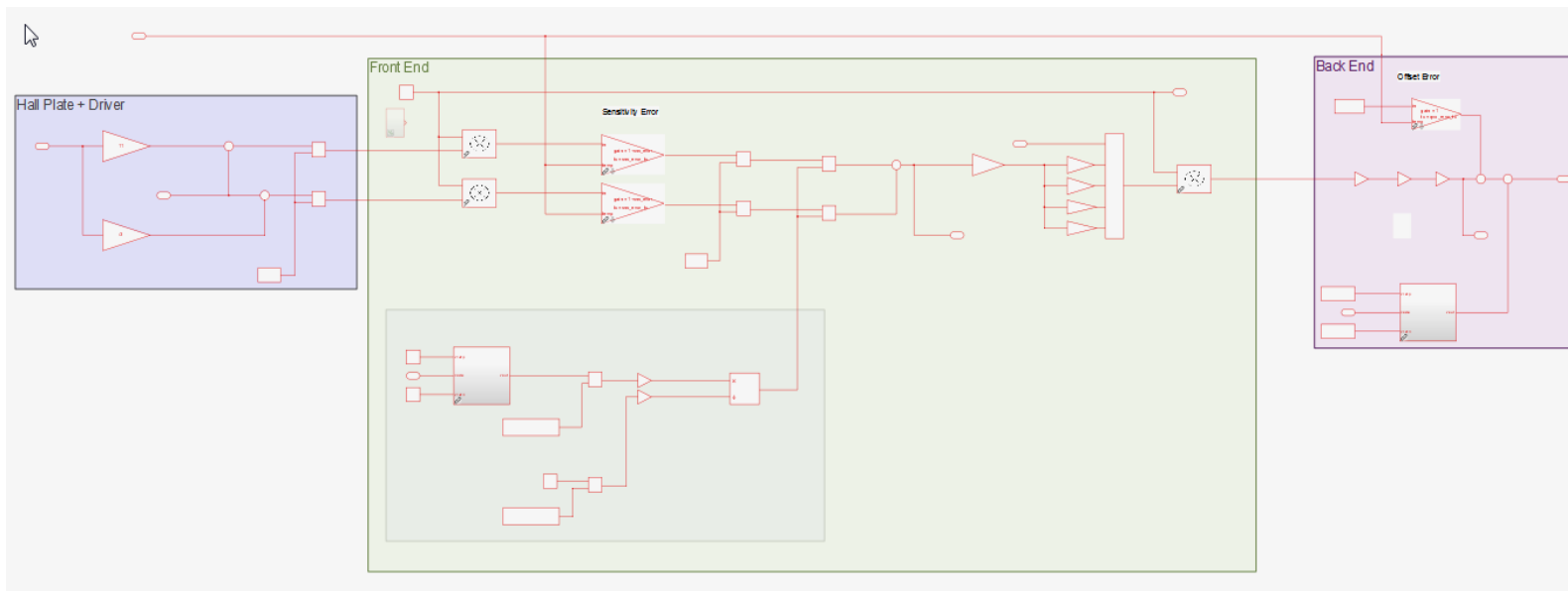
```

Editor - Block: segment_processor/fixd_point_coeff_temp_calc/temp_adj
fixd_point_coeff_temp_calc/temp_adj x +
1 function [temp_slope,temp_offset,temp_index,coefffb,coefffa,bin_diff] = temp_
2 %#codegen
3
4
5 temp_slope = fi(0,0,9,4);
6 temp_offset = fi(0,0,4,0);
7 temp_index = fi(0,0,2,0);
8
9 bin_diff = fi(0,0,3,0);
10
11 for i = 0:3
12     if temp_msbs >= coeff_bin(i+1) && temp_msbs < coeff_bin(i+2) || ...
13        i==0 && temp_msbs < coeff_bin(i+1) || ...
14        i==3 && temp_msbs >= coeff_bin(i+2)
15         temp_index = fi(i,0,2,0);
16         bin_diff = fi(coeff_bin(i+2)-coeff_bin(i+1),0,3,0);
17         temp_slope = scalar_consts(bin_diff+1);
18         temp_offset = fi(coeff_bin(i+1),0,4,0);
19     end
20 end
21
22 if bin_diff == 0
23     bin_diff = fi(0,0,3,0);
24 end
25 if bin_diff > 6
26     bin_diff = fi(6,0,3,0);
27 end
28
29
30 coefffa = coeff(temp_index+1);
31 coefffb = coeff(temp_index+2);
32
33
    
```

- Code generation is not limited to Simulink fixed point and Stateflow**
- Many functions and operations are more efficiently written as a Matlab function**
- Floating point functions**
  - coder.approximate**
- Simulink is your canvas**



## Simulink Validation Model



- ❑ **A validation model generates “evidence” that specific requirements are met**
  - ❑ **Automated regressions require that a pass/fail criteria be used**
  
- ❑ **Asserts are your friend!**
  - ❑ **We hope to see the asserts pass through to the auto generated HDL very soon!**

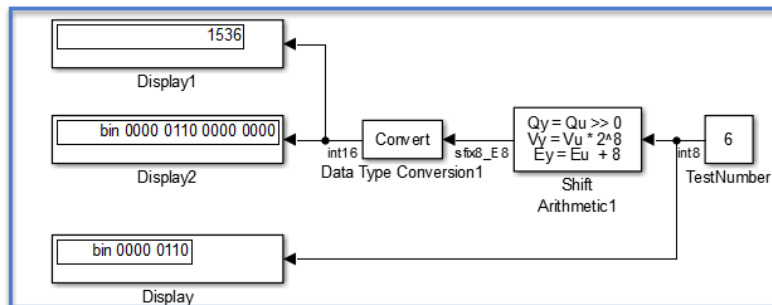
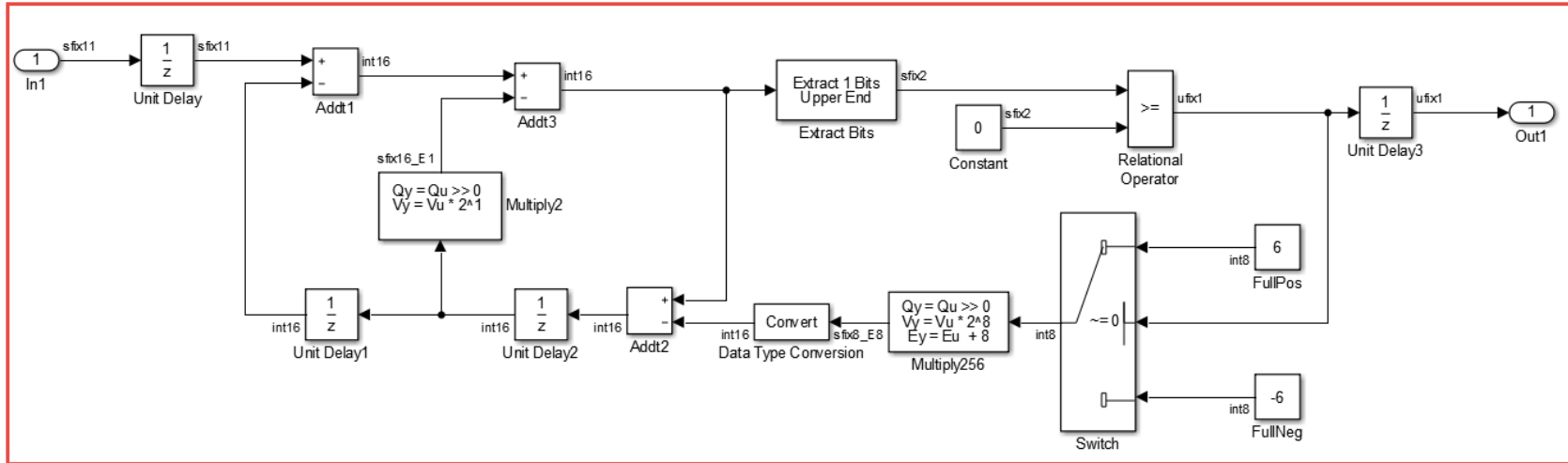




# Simulink Code Generation for Digital (and Analog ?!)



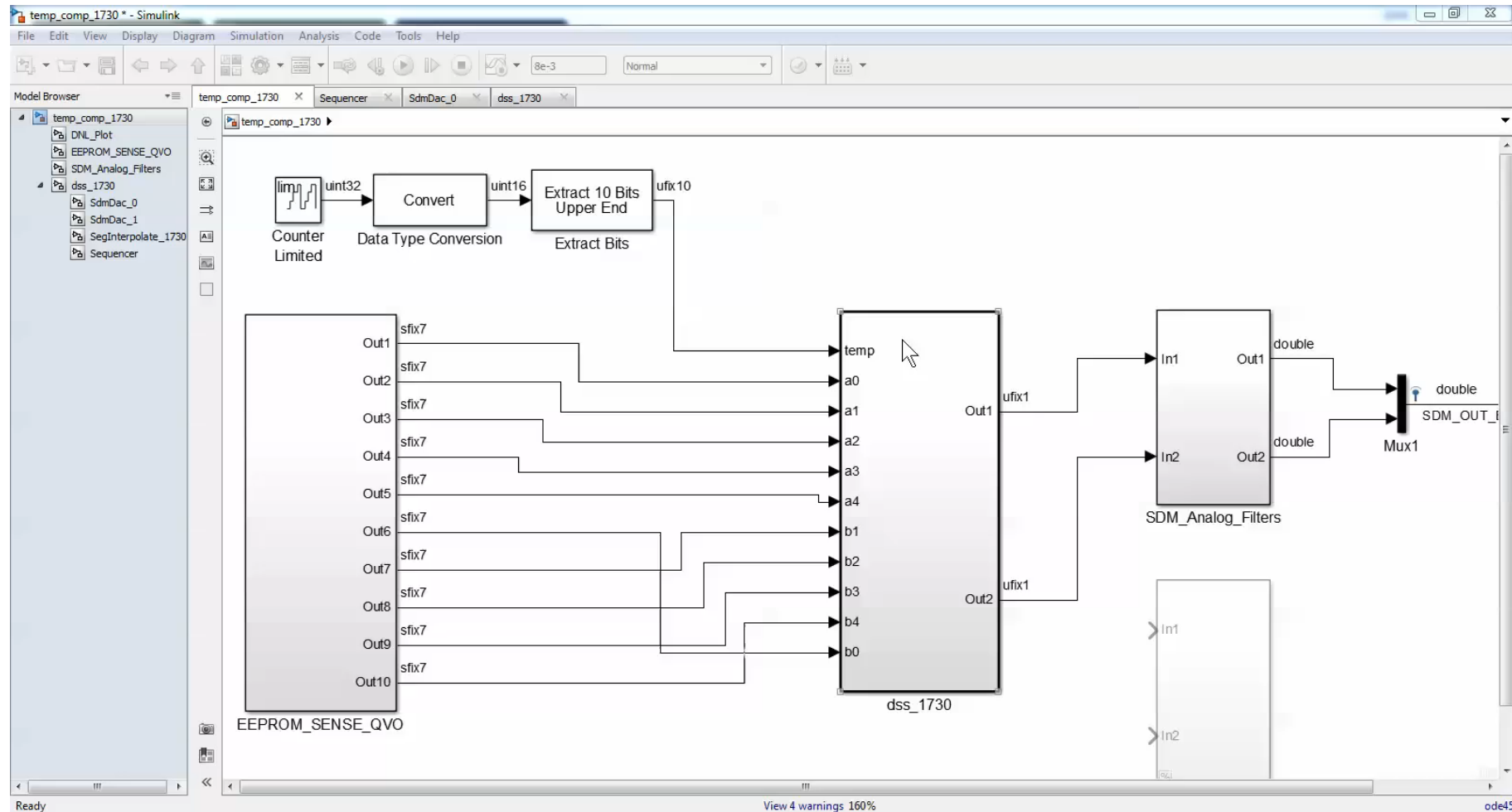
# Digital Example: SDM DAC



- ❑ Fixed Point Modeling is VERY powerful in Simulink
  - ❑ Fixed point optimization and area/accuracy tradeoffs are rapidly analyzed

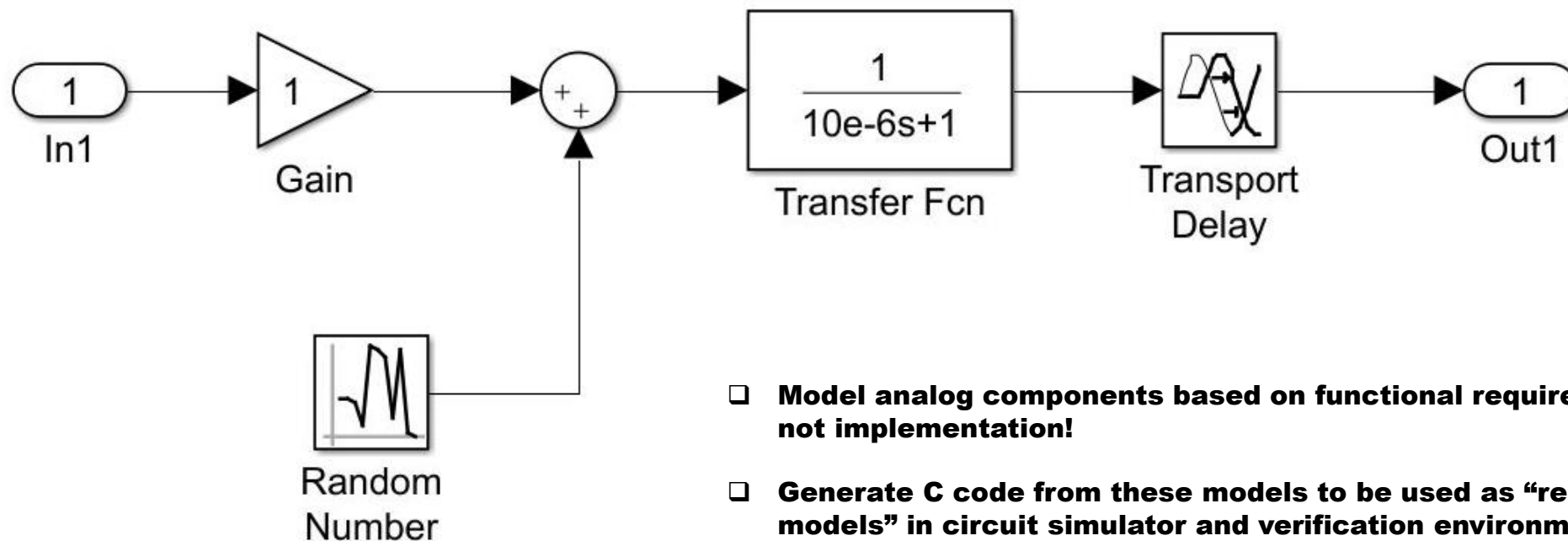


# Digital DAC: Code Generation Video





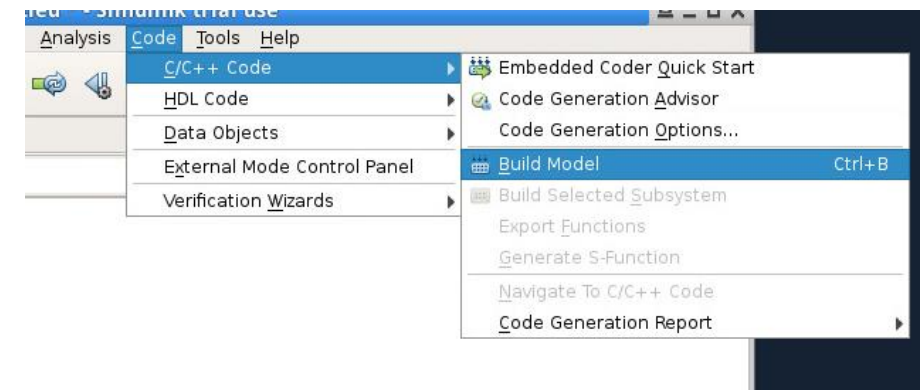
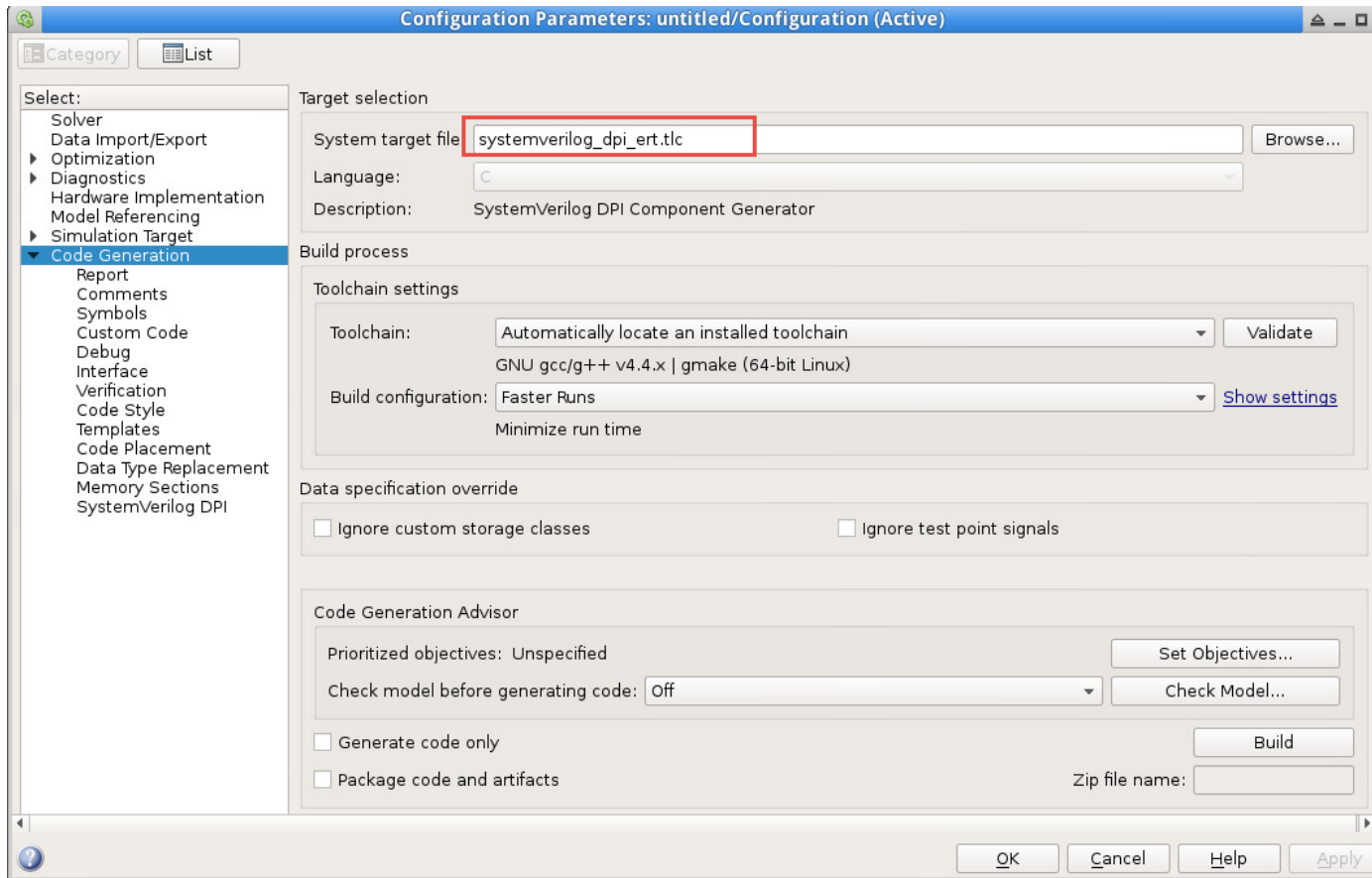
## Simulink Analog Models using DPI-C: Passive Filter with Noise and Delay



- Model analog components based on functional requirements, not implementation!**
- Generate C code from these models to be used as “real number models” in circuit simulator and verification environment**
- This will allow for traceability and equivalence checking under the ISO26262 Automotive Specification.**
- Analog designers will feel a strong attraction to SimElectronics. Leave the implementation for the circuit simulator (Cadence, etc.)**



# Generate the System Verilog / C-code Model



Select “systemverilog\_dpi\_ert.tlc”

Files to be generated

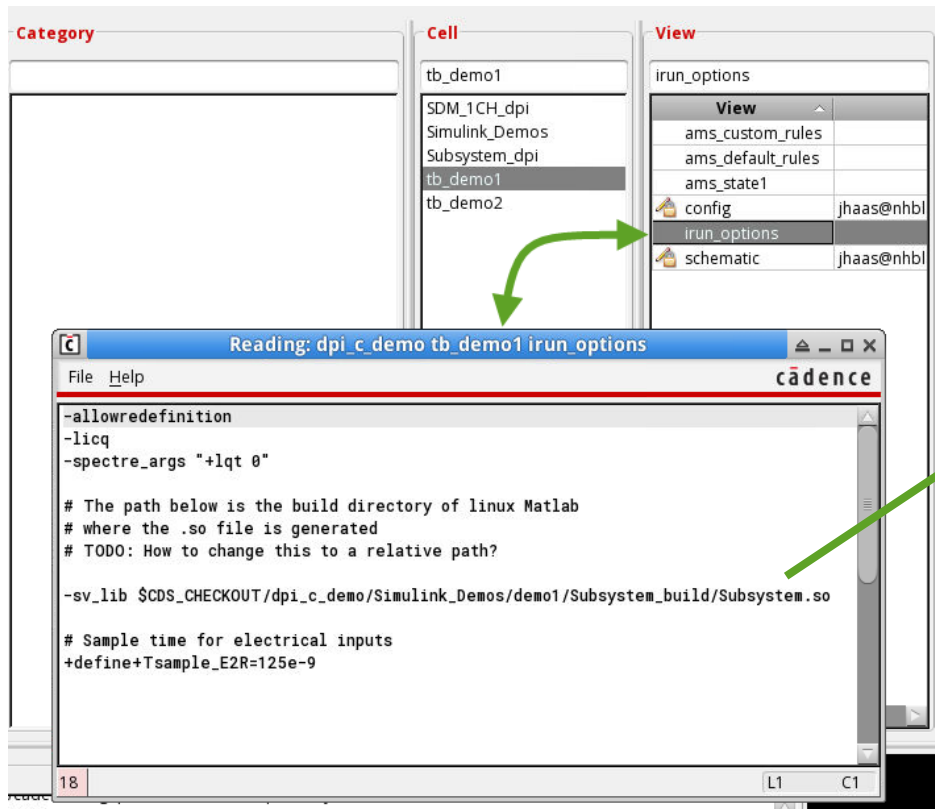
Model\_name.sv “wrapper”

Model\_name.so



# The System Verilog Wrapper and the System Object Functions

□ Within AMS Options, add the path to the `irun_options` file



The image shows the Cadence AMS Options dialog box with the 'View' tab selected. The 'irun\_options' file is highlighted in the 'View' list. Below it, a terminal window displays the contents of the 'irun\_options' file:

```

-allowredefinition
-licq
-spectre_args "+lqt 0"

# The path below is the build directory of linux Matlab
# where the .so file is generated
# TODO: How to change this to a relative path?

-sv_lib $CDS_CHECKOUT/dpi_c_demo/Simulink_Demos/demo1/Subsystem_build/Subsystem.so

# Sample time for electrical inputs
+define+Tsample_E2R=125e-9
    
```

```

// File: /home/jhaas/Subsystem_build/Subsystem_dpi.sv
// Created: 2015-11-11 23:18:45
// Generated by MATLAB 8.6 and HDL Verifier 4.7

`timescale 1ns / 1ns

module Subsystem_dpi(
    input clk,
    input clk_enable,
    input reset,
    input real Subsystem_U_In1,
    output real Subsystem_Y_Out1
);

   chandle objhandle=null;
    // Declare imported C functions
    import "DPI-C" functionchandle DPI_Subsystem_initialize(chandle existhandle);
    import "DPI-C" function void DPI_Subsystem_output(input chandle objhandle, input real Subsystem_U_In1, inout real Subsystem_Y_Out1);
    import "DPI-C" function void DPI_Subsystem_update(input chandle objhandle, input real Subsystem_U_In1);
    import "DPI-C" function void DPI_Subsystem_terminate(input chandle objhandle);

    initial begin
        objhandle = DPI_Subsystem_initialize(objhandle);
    end

    always @(posedge clk or posedge reset) begin
        if(reset == '1'b1) begin
            objhandle = DPI_Subsystem_initialize(objhandle);
        end
        else if(clk_enable) begin
            DPI_Subsystem_output(objhandle, Subsystem_U_In1, Subsystem_Y_Out1);
            DPI_Subsystem_update(objhandle, Subsystem_U_In1);
        end
    end
endmodule
    
```

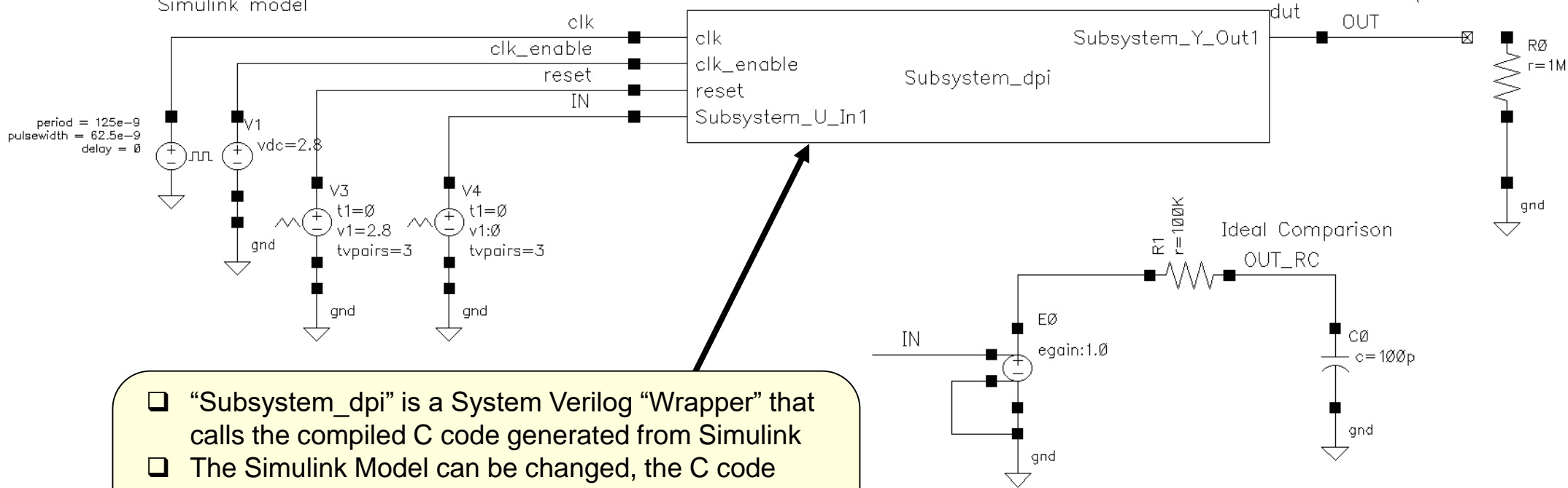


# Cadence AMS Test Bench

Note:  
Sample Clock must match  
discrete sample period of  
Simulink model

Model with s-domain first order filter  
( $\tau = 10e-6$ )

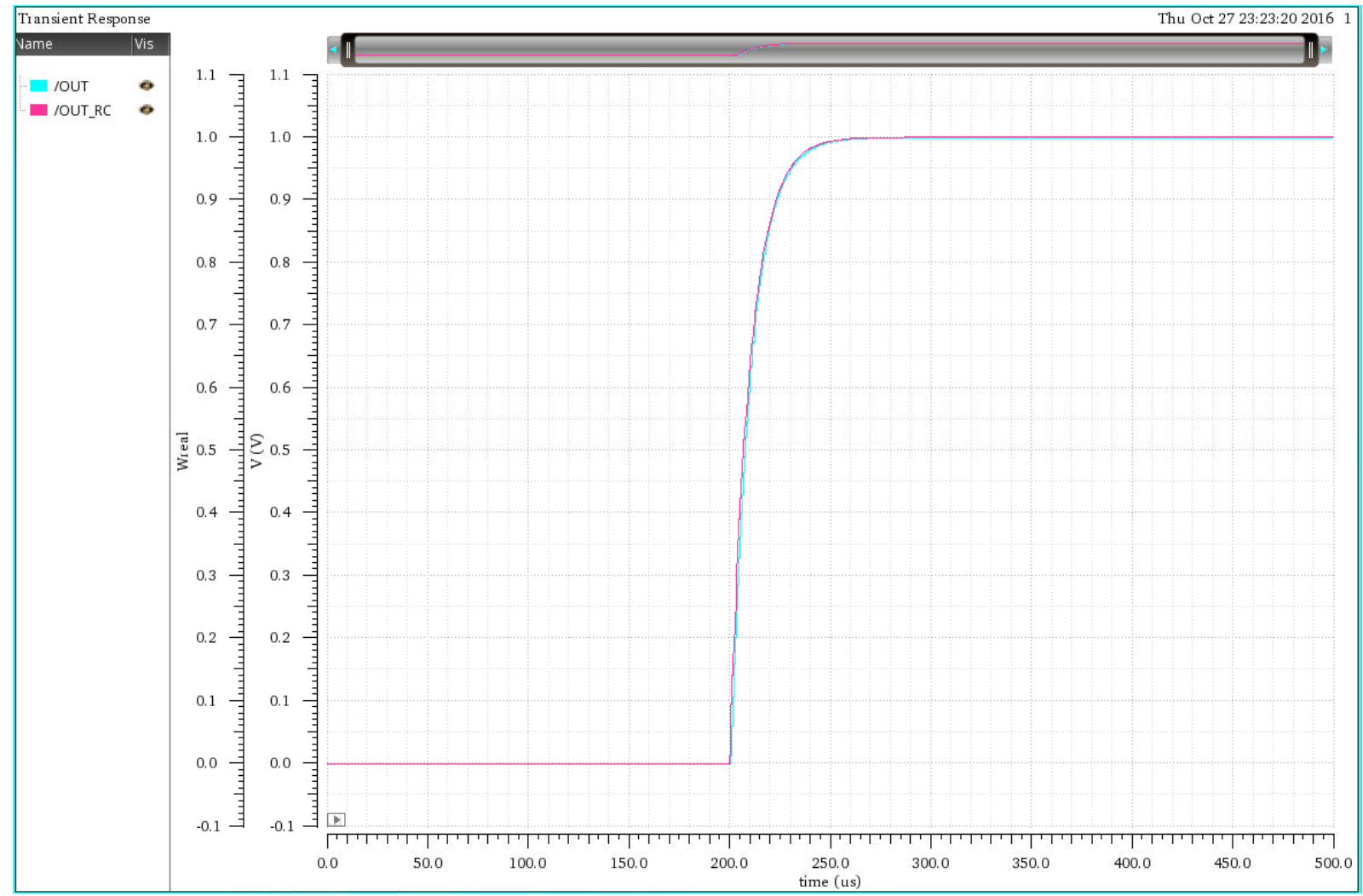
Notice:  
simulation time difference  
when this resistor is connected.  
(Still "fast" but much slower...)



- ❑ “Subsystem\_dpi” is a System Verilog “Wrapper” that calls the compiled C code generated from Simulink
- ❑ The Simulink Model can be changed, the C code regenerated and the Cadence setup needs no update!
  - ❑ Makefile is automatically called upon Simulink Code Generation



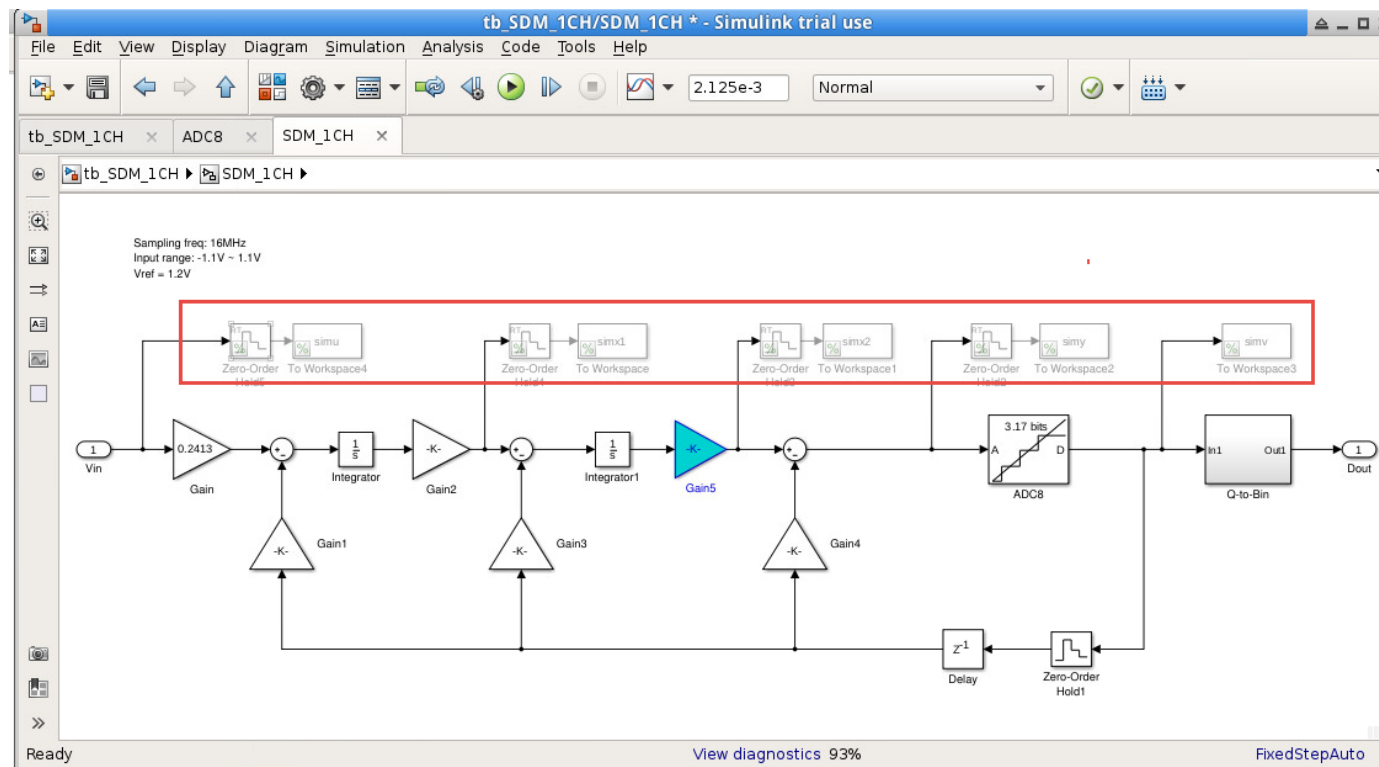
# Cadence Simulation of Simulink "C" Model and Ideal RC







# Simulink Analog Models using DPI-C: Continuous Time Sigma Delta ADC



- ❑ Make sure and "comment out" any elements in the subsystem that you do not want in the generated code.
  - ❑ Those elements are shown inside the red box.



## ASIC MBD Summary Present and Future

- ❑ Simulink and Matlab have been instrumental in the development of an agile Automotive Mixed Signal ASIC Sensor Flow
  - ❑ High level model exploration allows for accelerated insights and convergence on architecture and algorithms
  - ❑ Traditional duplication efforts (model – spec – another model) are minimized
  - ❑ Upfront models expedite the verification efforts and front load issue discovery
  - ❑ Powerful Real Time Simulation Platforms (Speed Goat) allow for testing algorithms in the lab before design team is heavily engaged!
  - ❑ Powerful modeling, automated code generation and robust traceability are paving the way for agile development in an ISO26262 world!



# Thank You!

For more information:

<http://www.allegromicro.com>

Email:

[jhaas@allegromicro.com](mailto:jhaas@allegromicro.com)