Developing a Real-Time Motor Model for HIL Testing

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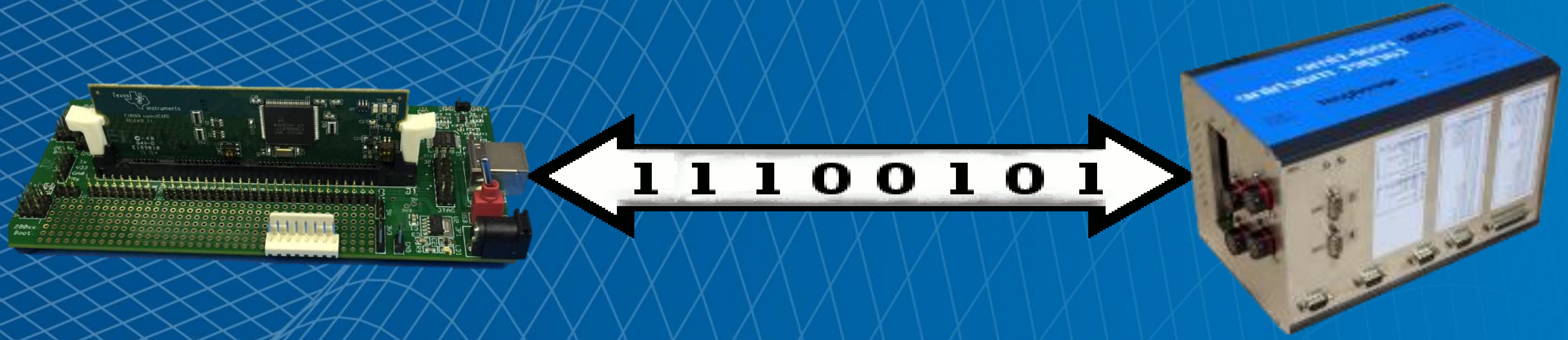

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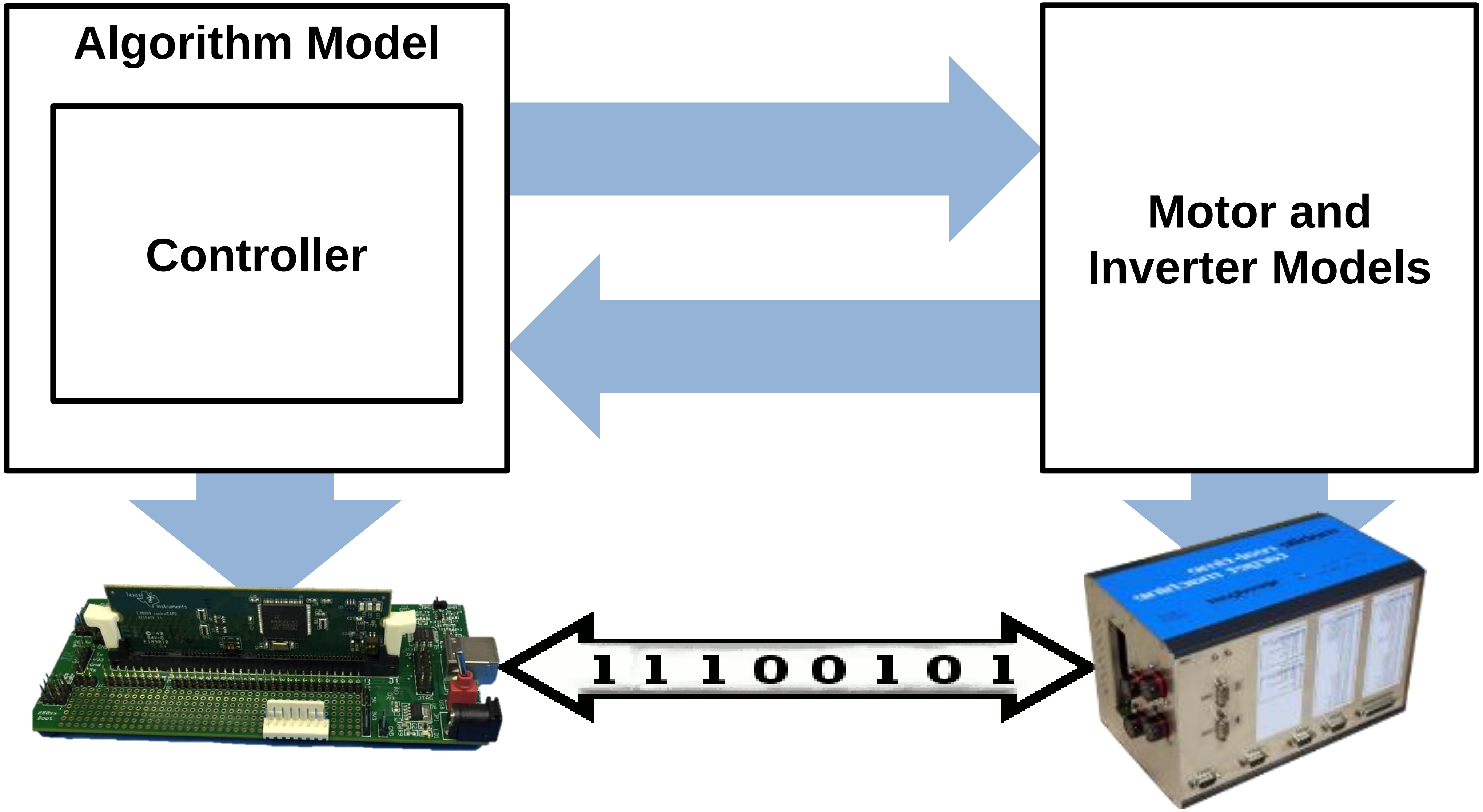
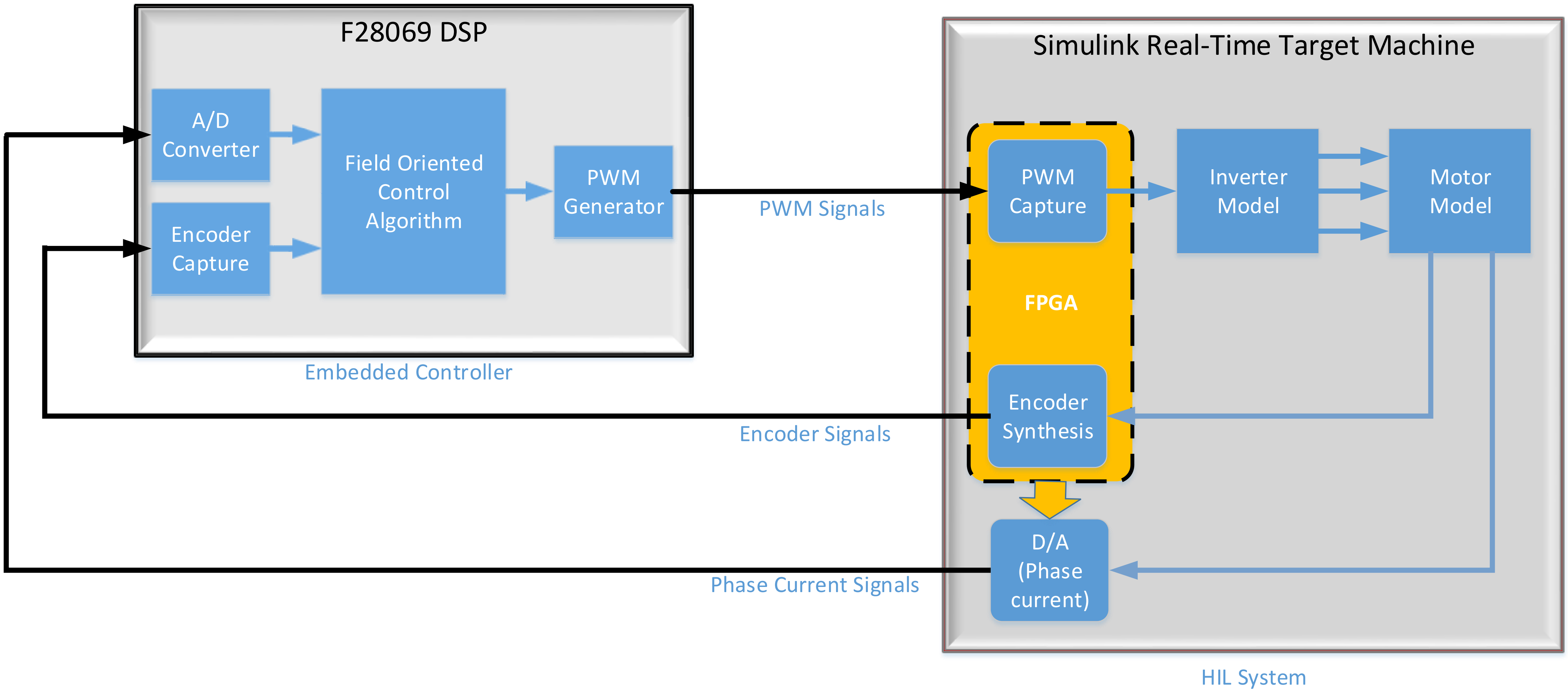


Connecting the embedded controller to the HIL system

PMSM HIL Connections Diagram



Developing a real-time motor model for HIL testing

- Modeling motor dynamics for a HIL system
- Deploying the motor model to a HIL system
- Testing an embedded motor controller with the HIL system

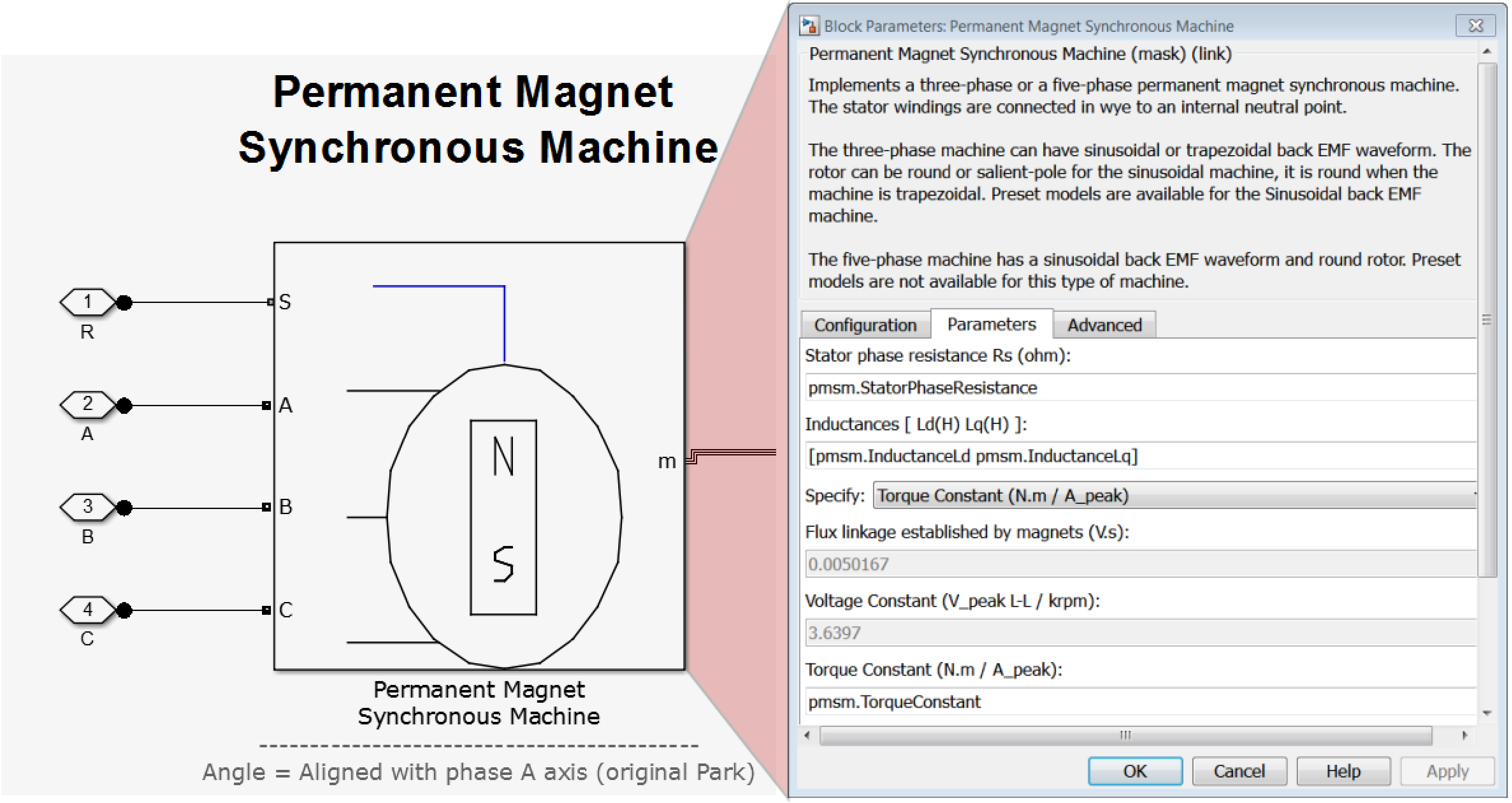
Developing a real-time motor model for HIL testing

- **Modeling motor dynamics for HIL testing**
  - **Identifying model parameters**
  - **Use testing framework to validate model**

- Deploying the motor model to a HIL system

- Testing an embedded motor controller with the HIL system

What do These Particular Models Look Like?



Surface Mount PMSM Equations

Electrical Model

$$v_d = Ri_d - L_q p\omega_r i_q + L_d \frac{d}{dt} i_d$$

$$v_q = Ri_q + p\omega_r (L_d i_d + \lambda) + L_q \frac{d}{dt} i_q$$

$$\omega_e = p\omega_r$$

$$T_e = 1.5p\left[\lambda i_q + \left(L_d - L_q\right) i_d i_q\right]$$

$$T_e = K_t i_q \ \left(assumes\ round\ rotor, L_d = L_q\right)$$

Mechanical Model

$$\frac{d}{dt}\omega_r = \frac{1}{H}\left(T_e - sgn(\omega_r) J_0 - b\omega_r - T_{load}\right)$$

Required Parameters

Electrical Model

$$v_d = Ri_d - L_q p\omega_r i_q + L_d \frac{d}{dt} i_d$$

$$v_q = Ri_q + p\omega_r (L_d i_d + \lambda) + L_q \frac{d}{dt} i_q$$

$$\omega_e = p\omega_r$$

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Mechanical Model

$$\frac{d}{dt}\omega_r = \frac{1}{H}(T_e - sgn(\omega_r)J_0 - b\omega_r - T_{load})$$

Mapping parameters to PMSM model

R

L_d, L_q

λ

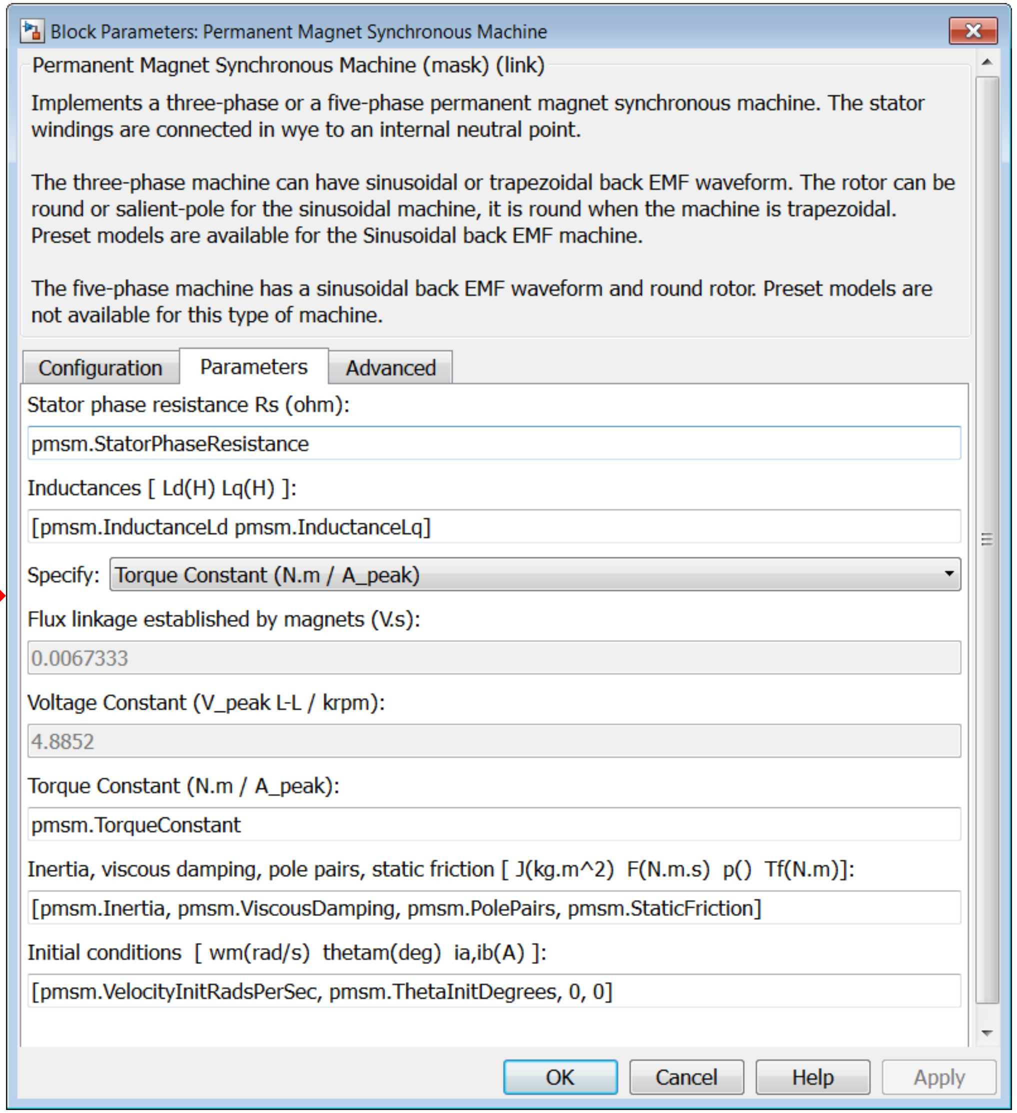
K_t

H

b

p

J_0



Tests to Characterize Motor and Load

Motor Tests	Parameters Identified	Identification method
Back EMF Test	Number of Pole Pairs (p) Flux Linkage Constant (λ) Torque Constant (K_t)	Calculation
Friction Test	Viscous Damping Coefficient (b) Coulomb Friction (J_0)	Curve fitting
Coast Down Test	Rotor Inertia (H)	Curve fitting
DC Voltage Step Test	Resistance (R) Inductance (L)	Parameter estimation

- For more details watch this video: parameterizing and verifying a permanent magnet synchronous motor.

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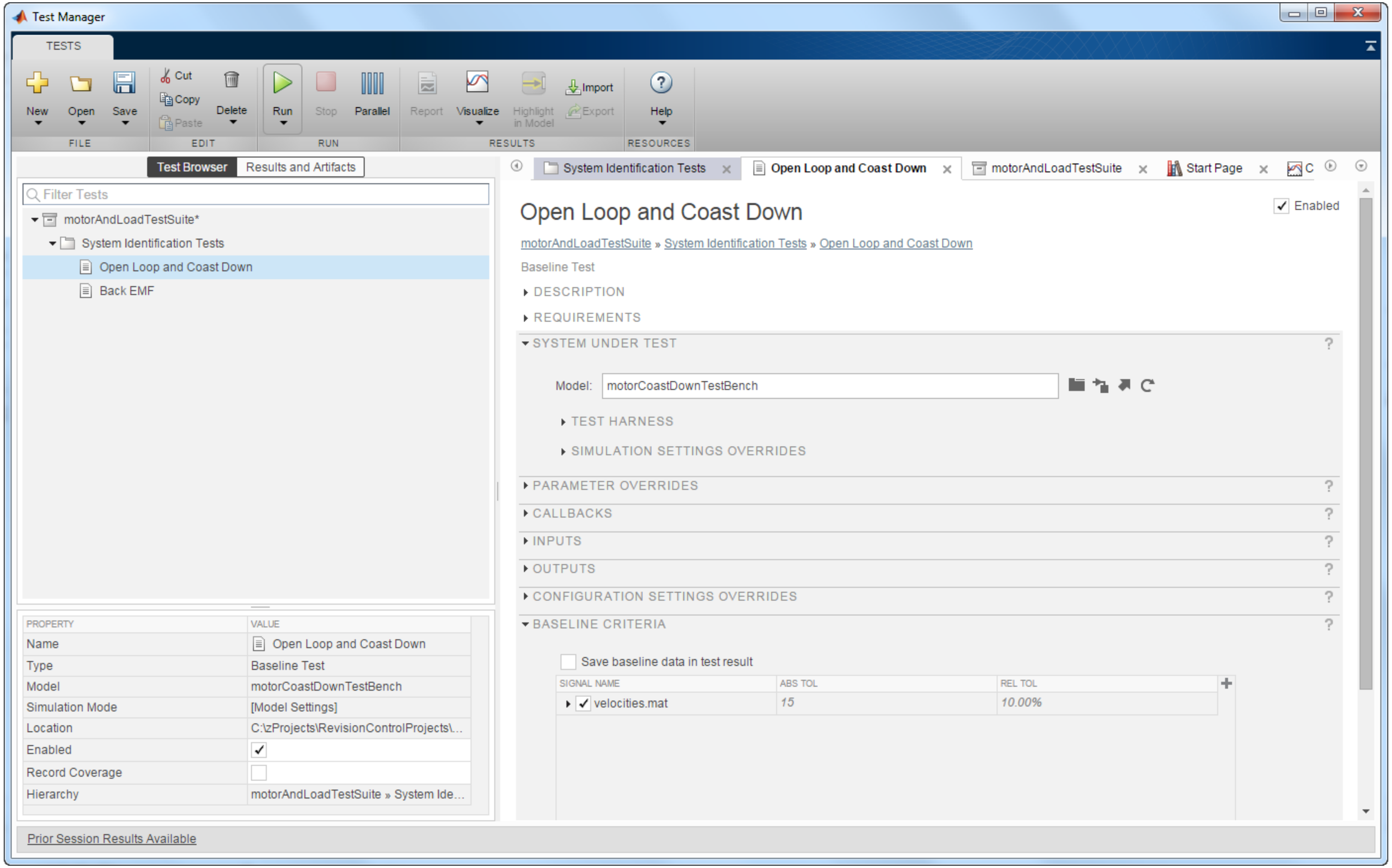
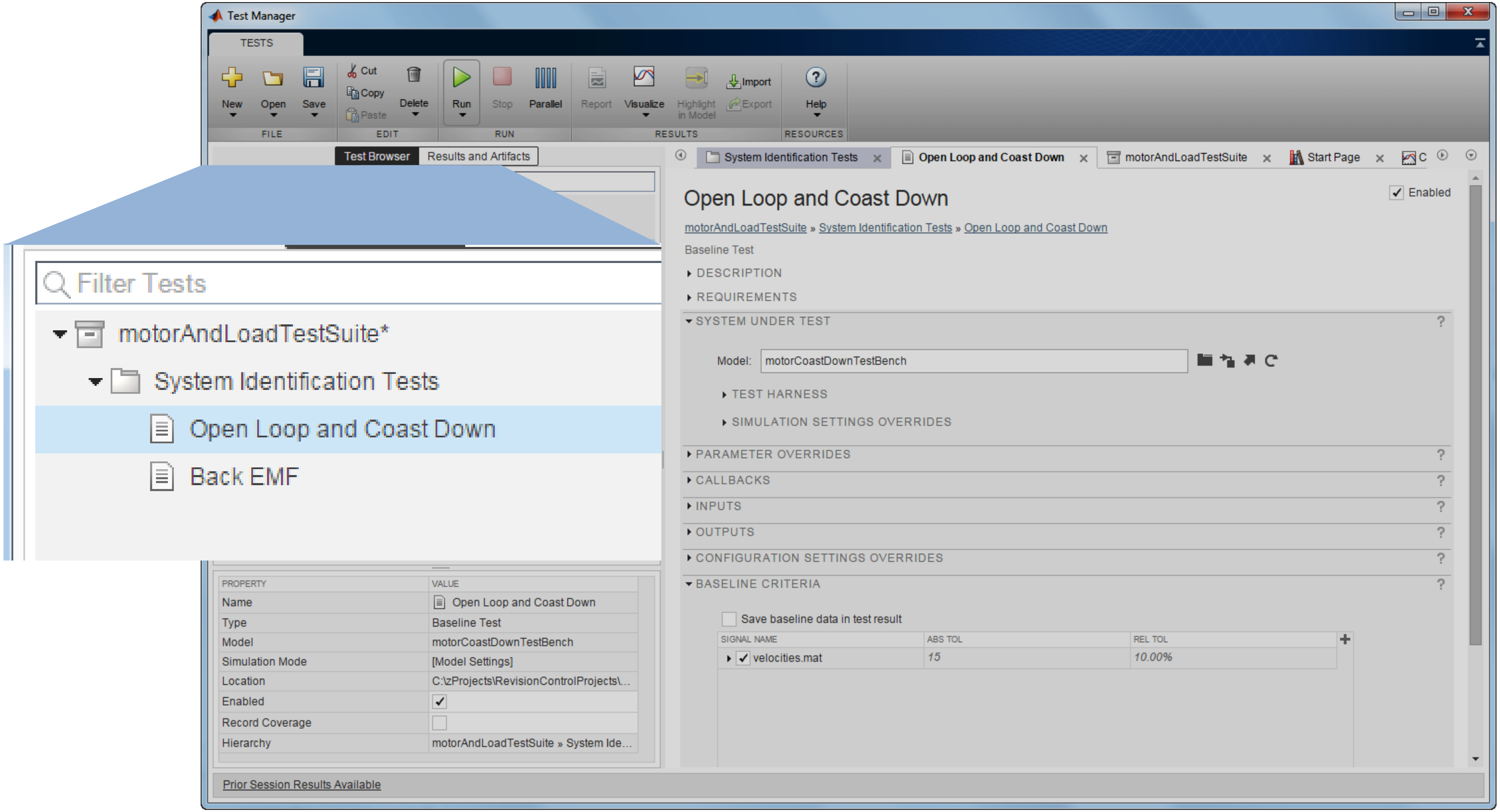
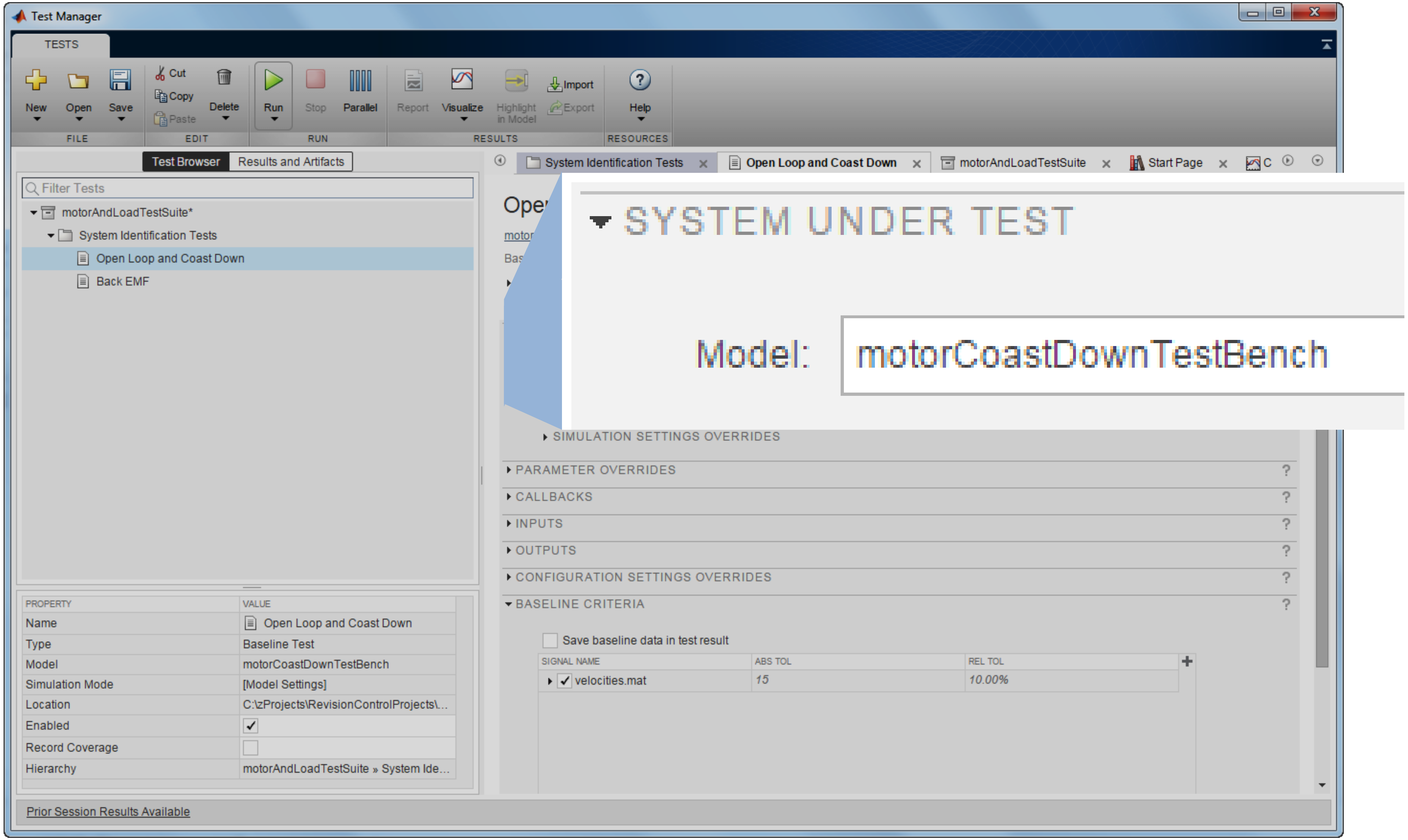
Simulink Test Framework



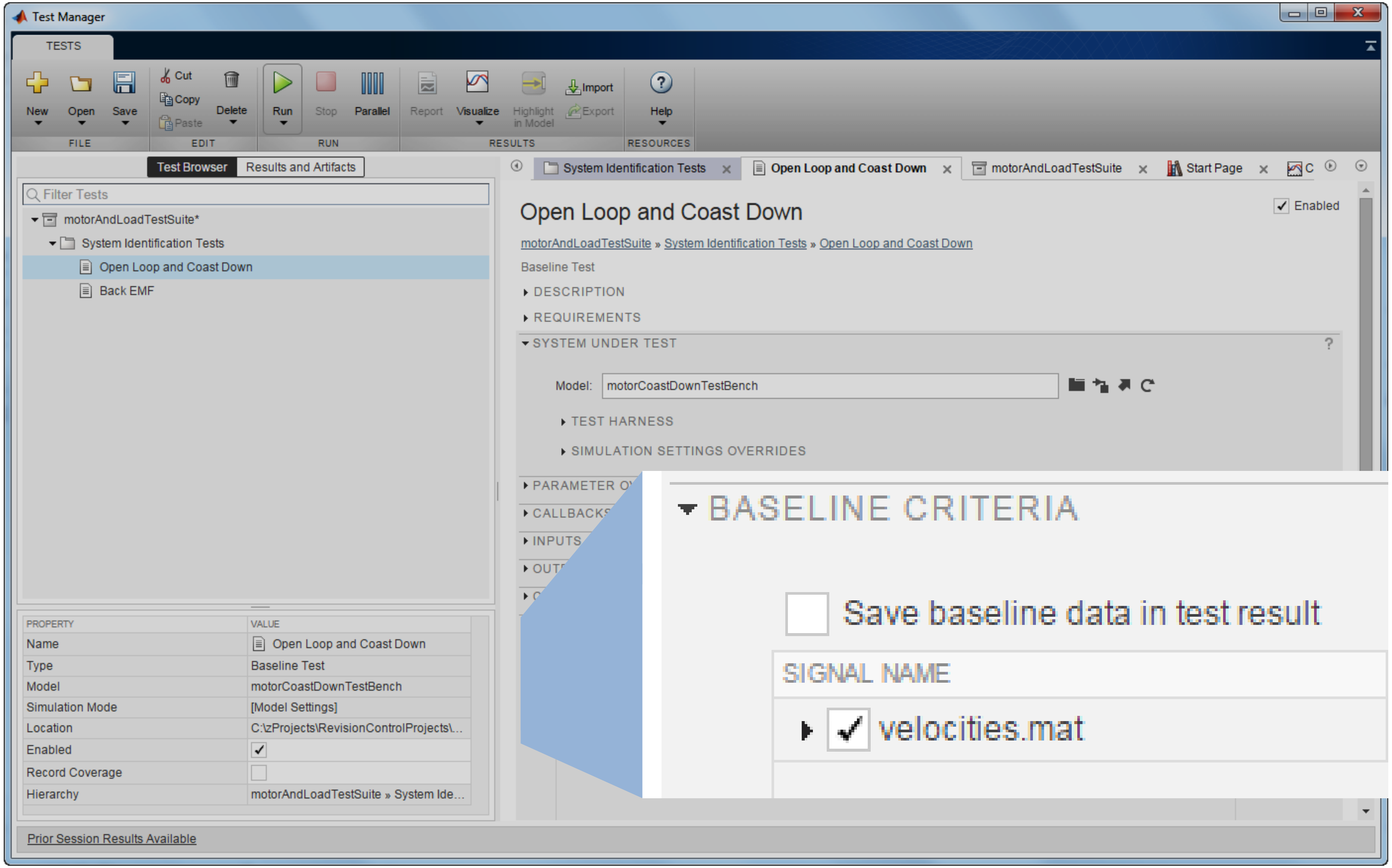
Suite of Tests to Run



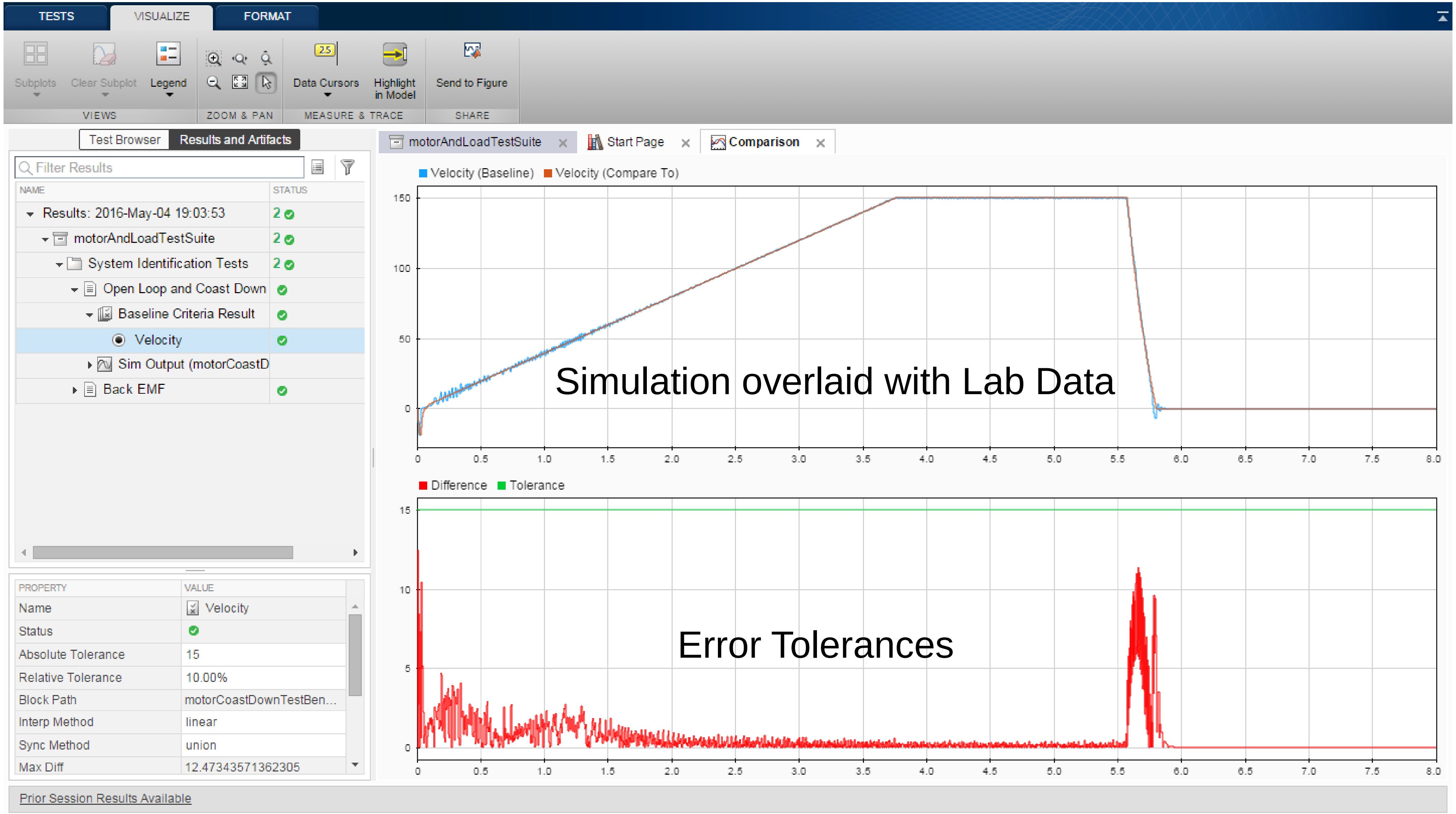
Model to be Tested



Baseline Results for Comparison



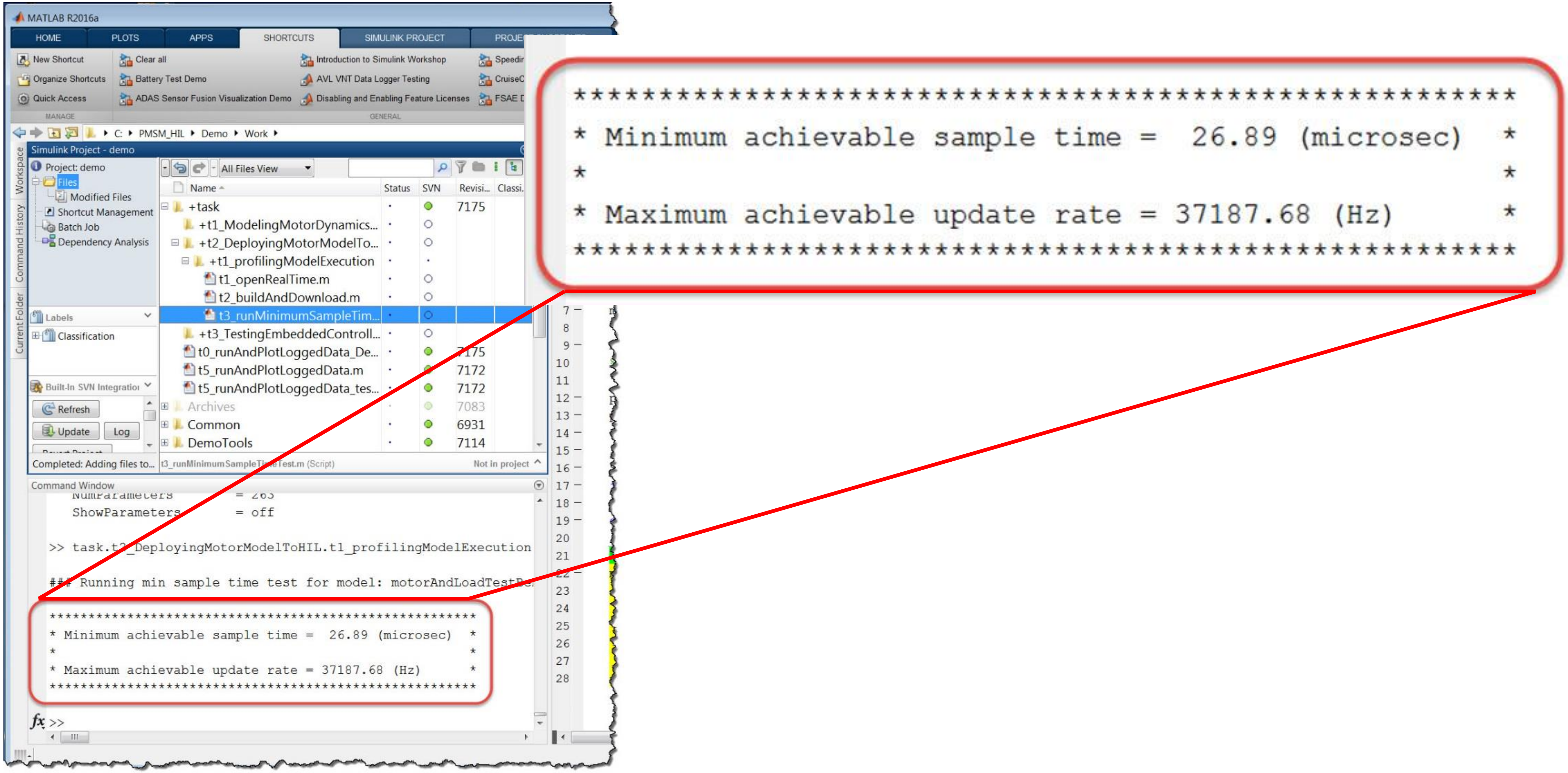
Open Loop Coast Down Test Results



Developing a real-time motor model for HIL testing

- Modeling motor dynamics for HIL testing
- **Deploying the motor model to a HIL system**
  - **Profiling model execution on HIL system**
  - **Integrating model into HIL system**
- Testing an embedded motor controller with the HIL system

Profiling model execution on the HIL system



Process to Integrate Model into a HIL System

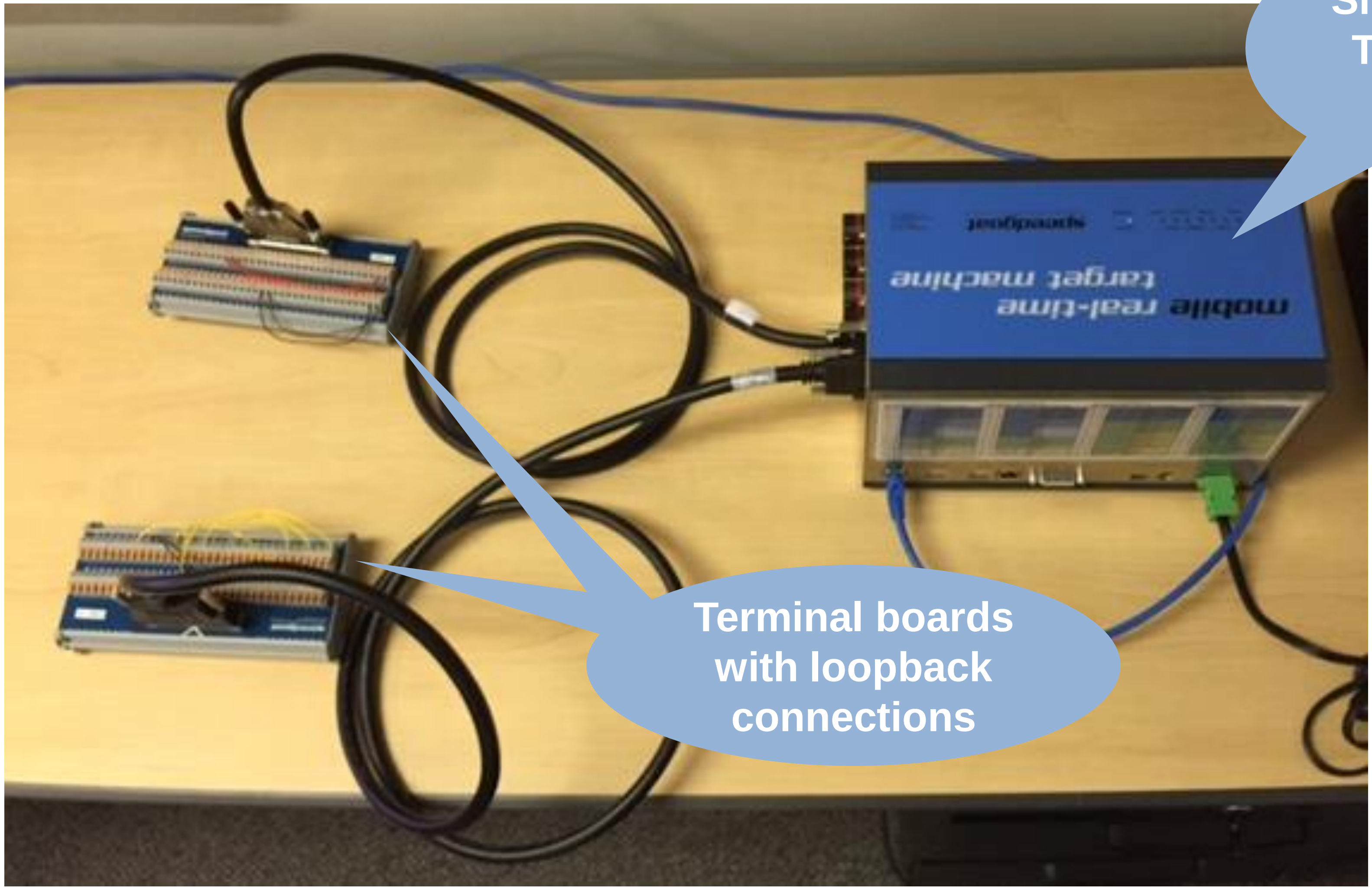
- Step 1 – Speedgoat Only
- Step 2 – Speedgoat with Loopback
- Step 3 – Speedgoat with C2000

I/O for Step 1: Speedgoat Only

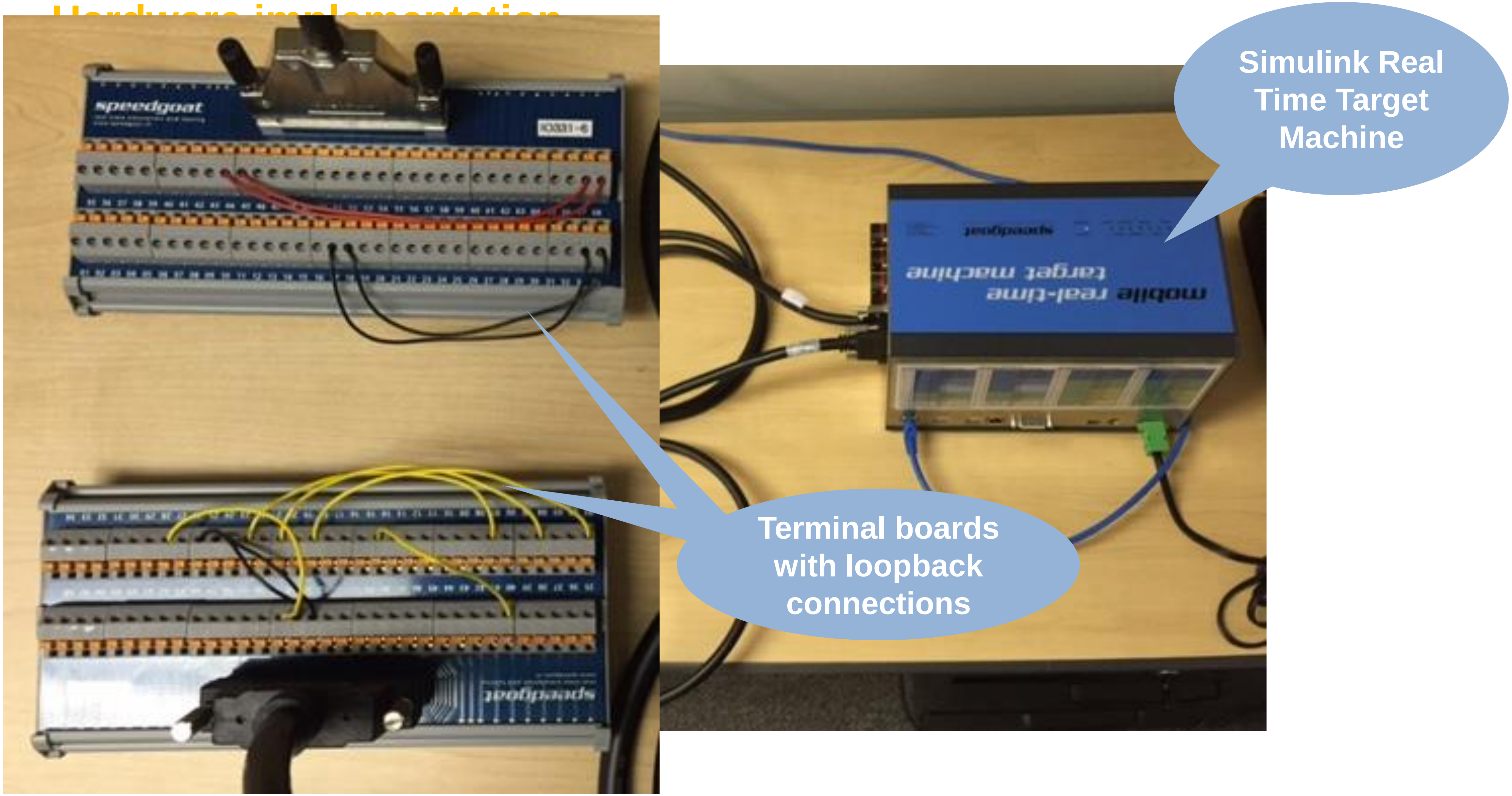
- Hardware implementation

Simulink Real Time Target Machine

I/O for Step 2: Speedgoat with Loopback
- Hardware implementation

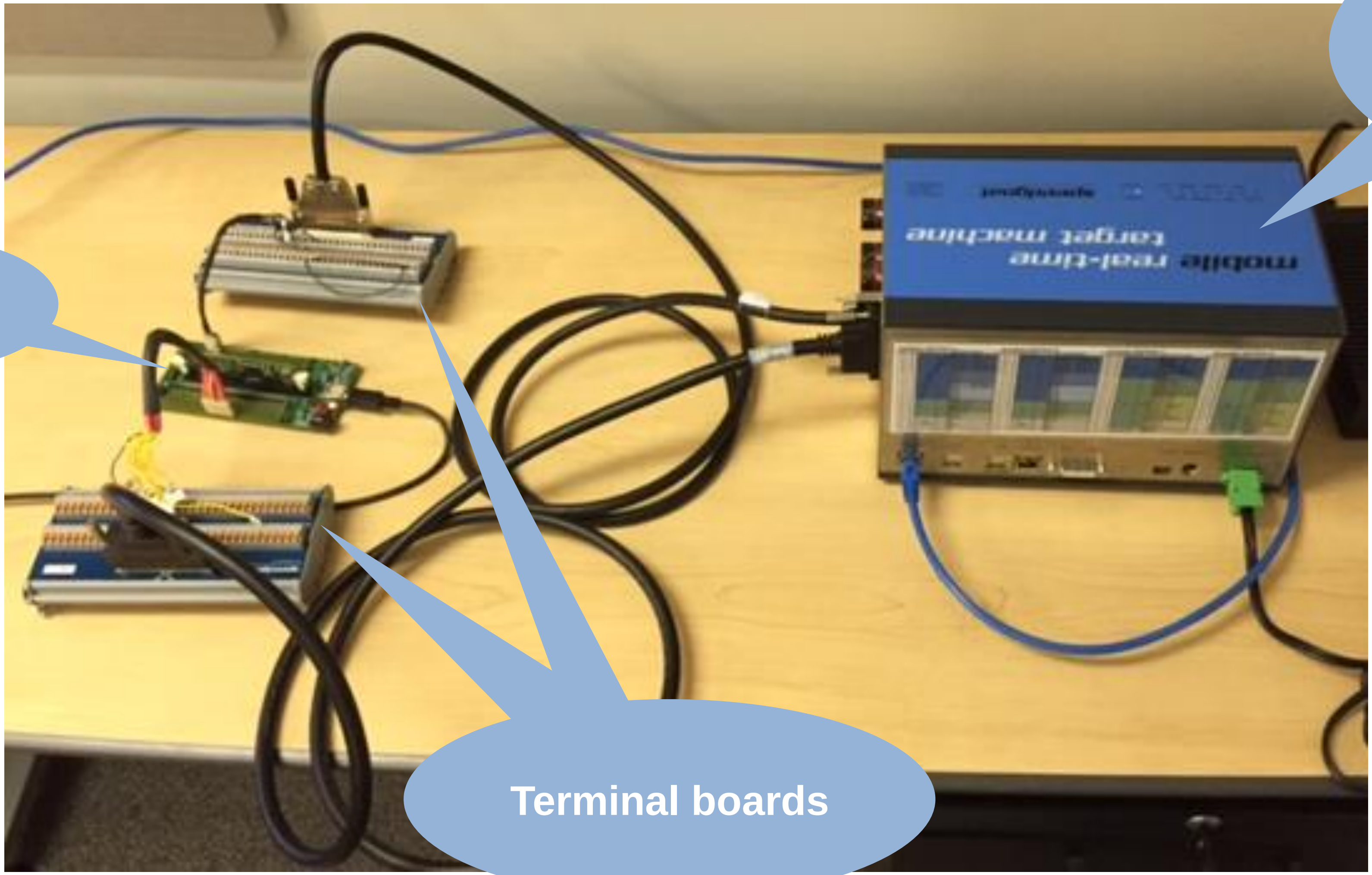


I/O for Step 2: Speedgoat with Loopback

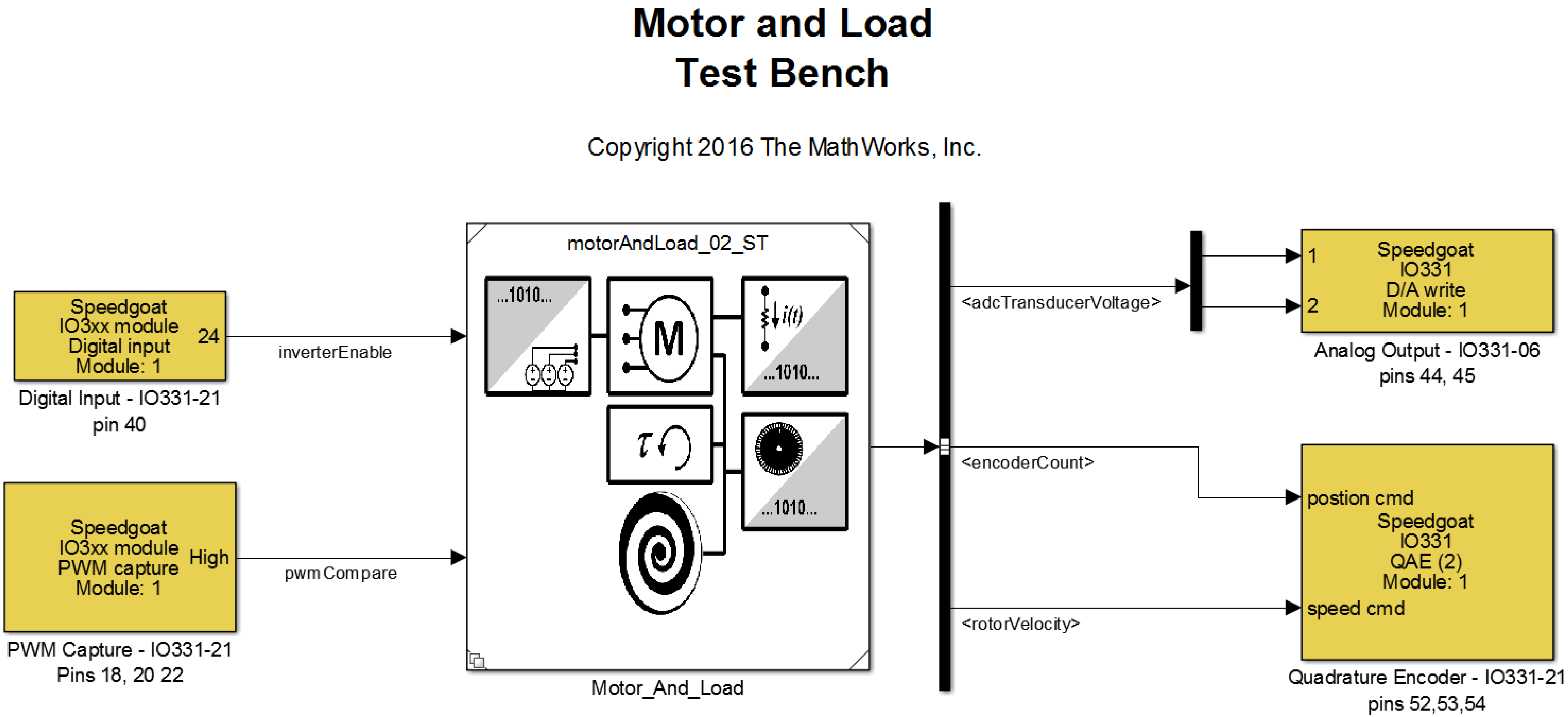


I/O for Step 3: Speedgoat with C2000

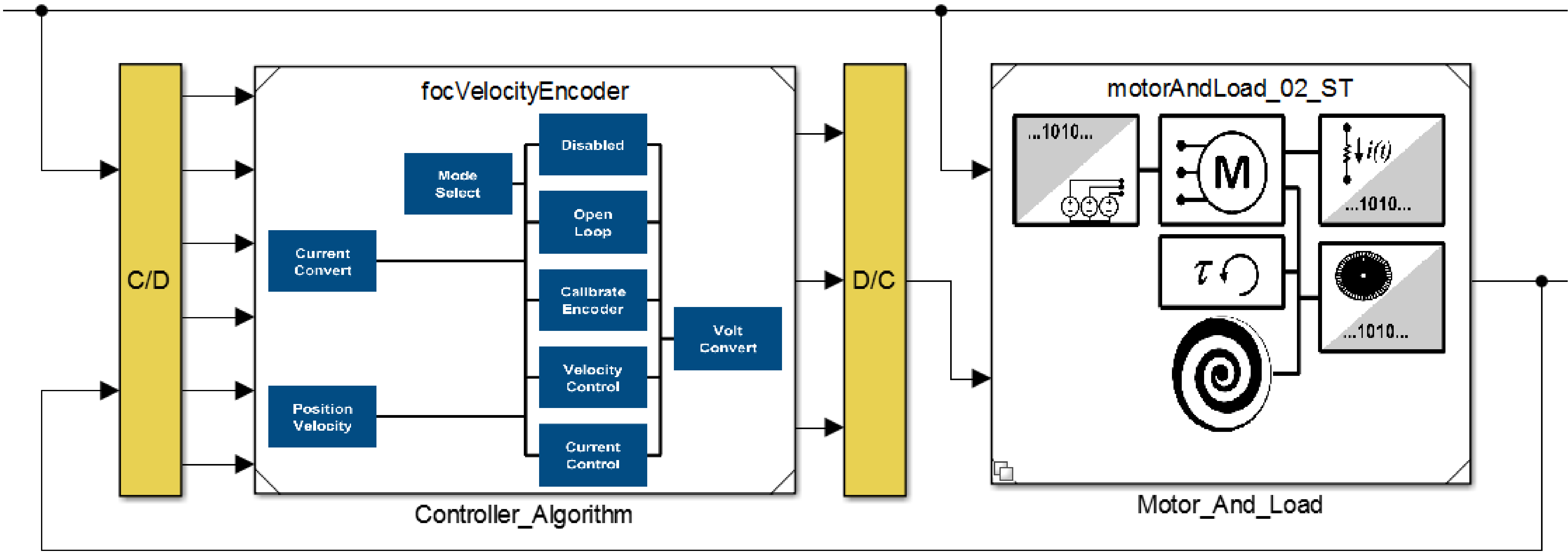
- Hardware implementation



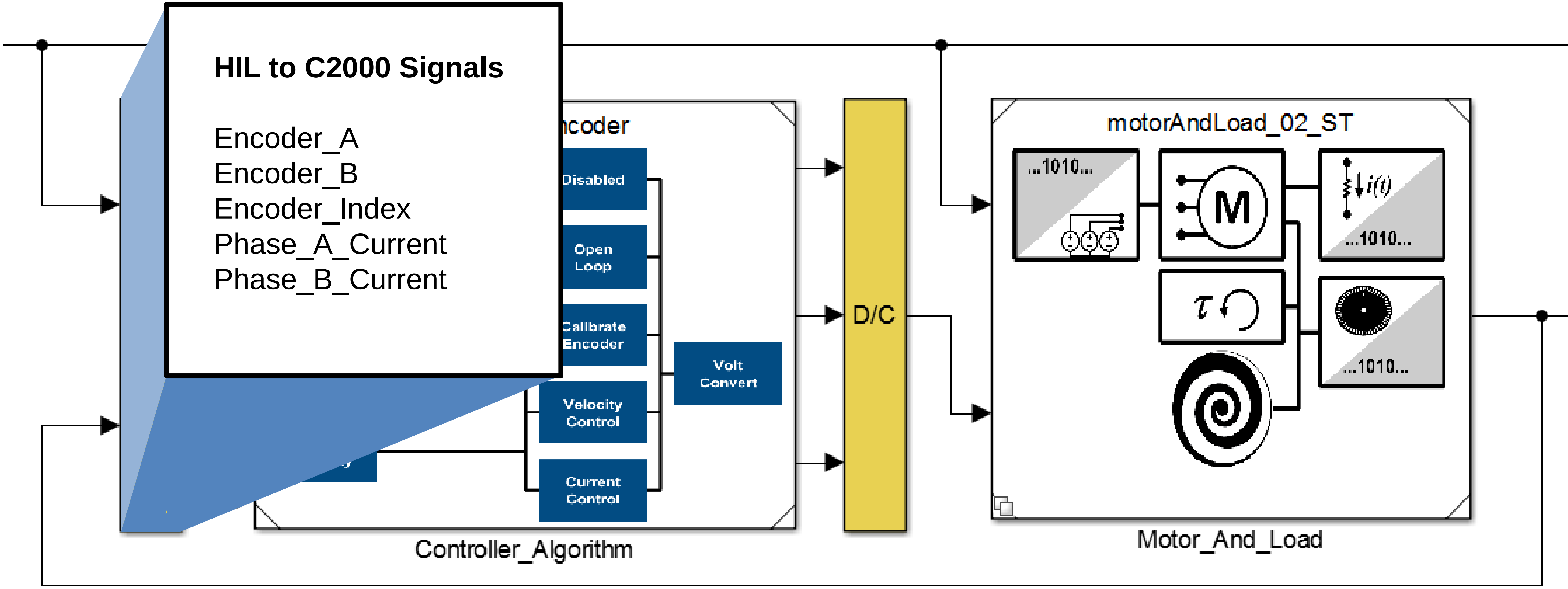
Model For Final HIL Integration



Baseline – Model and Controller on Speedgoat



Adding I/O to Interfaces



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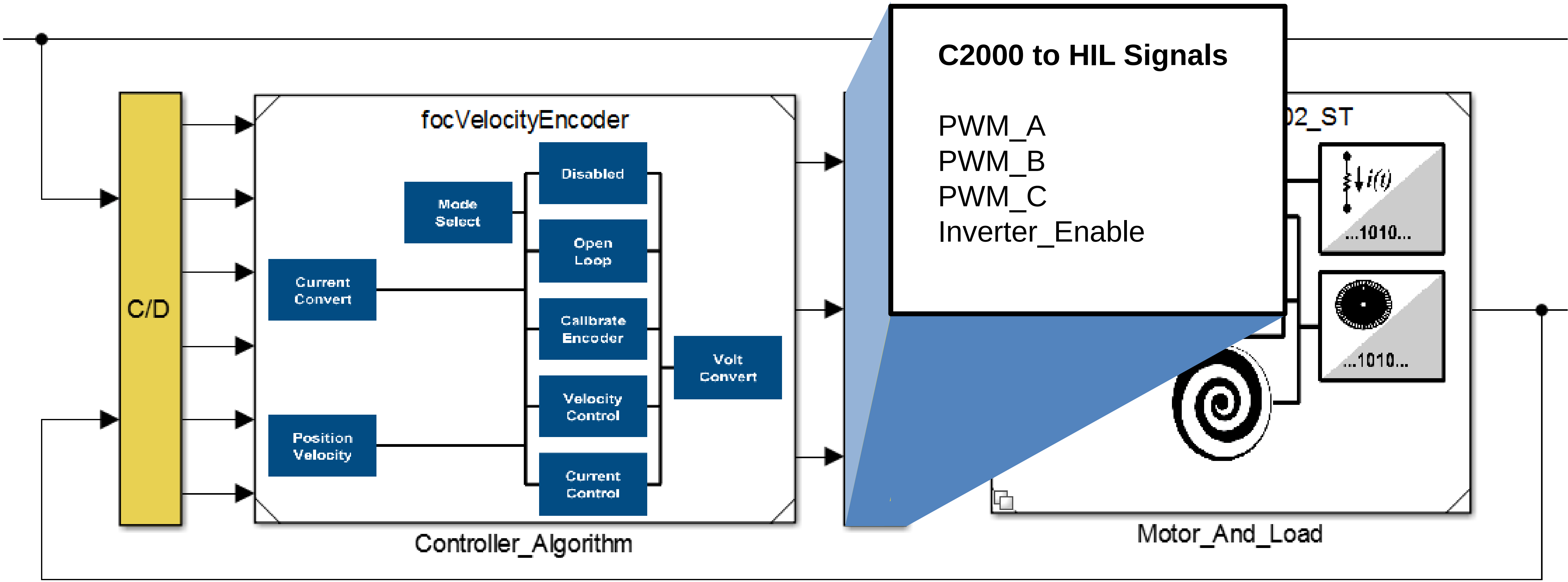

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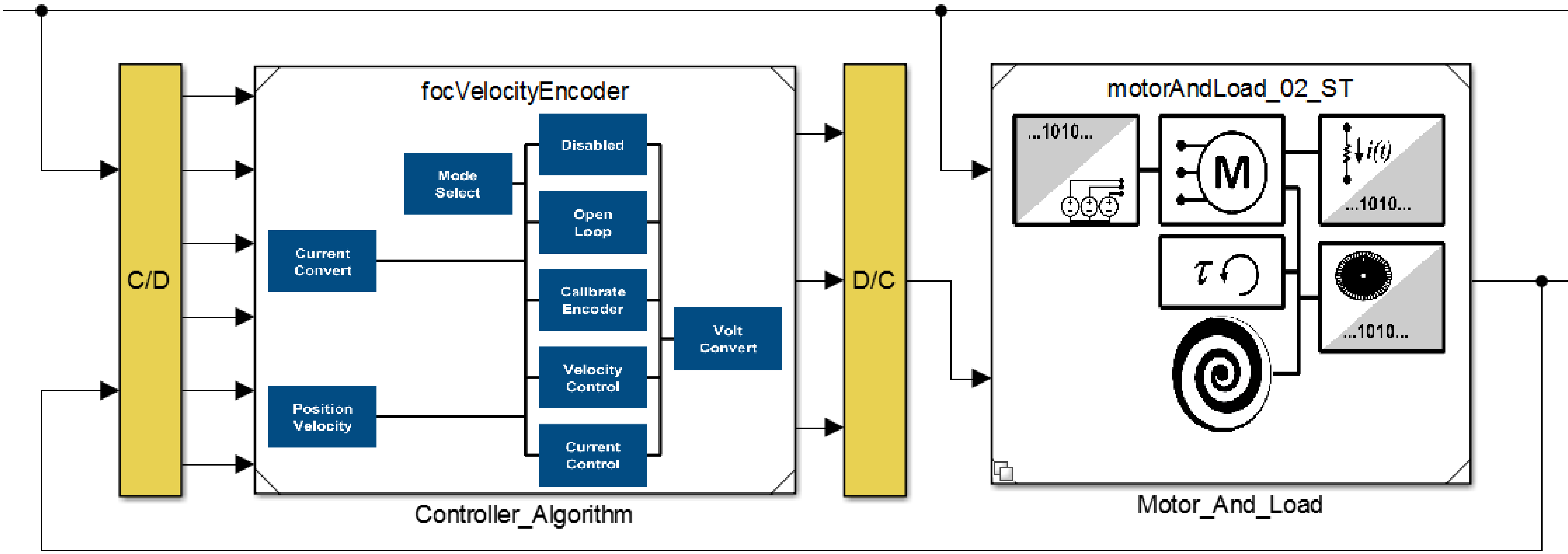

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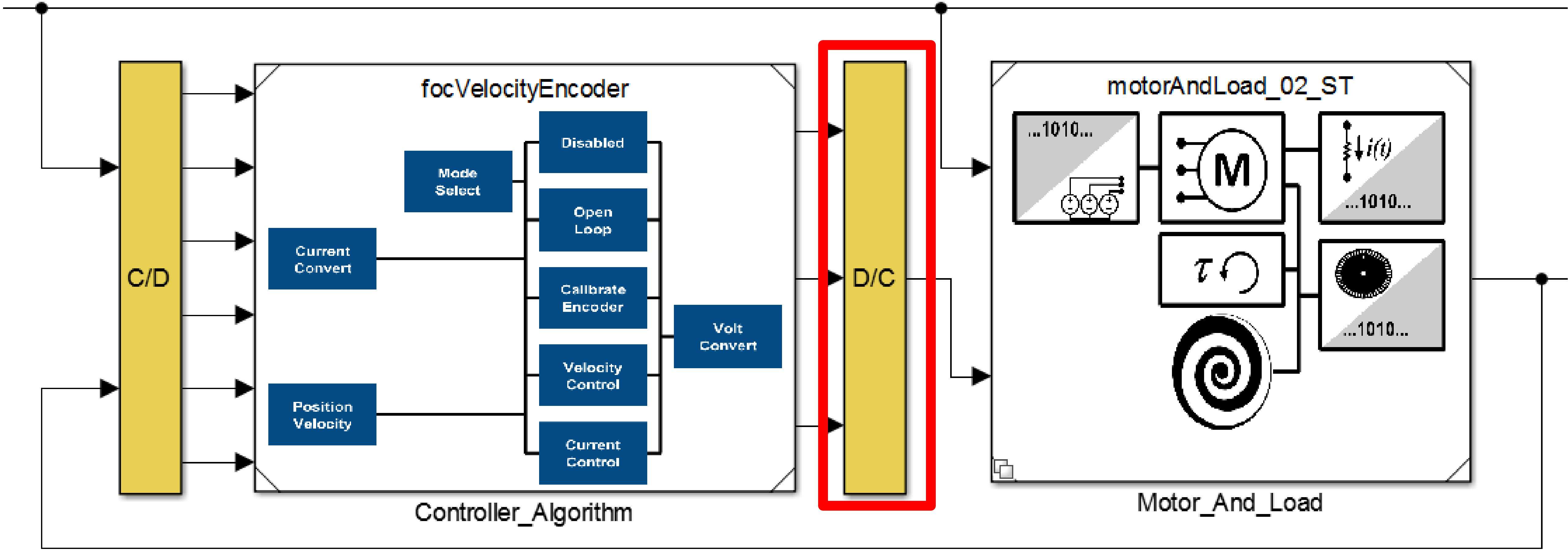
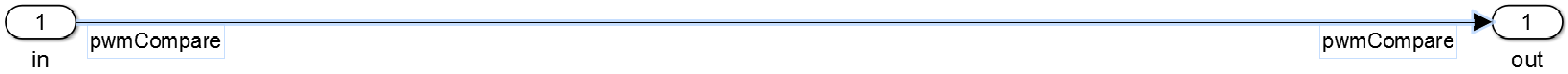
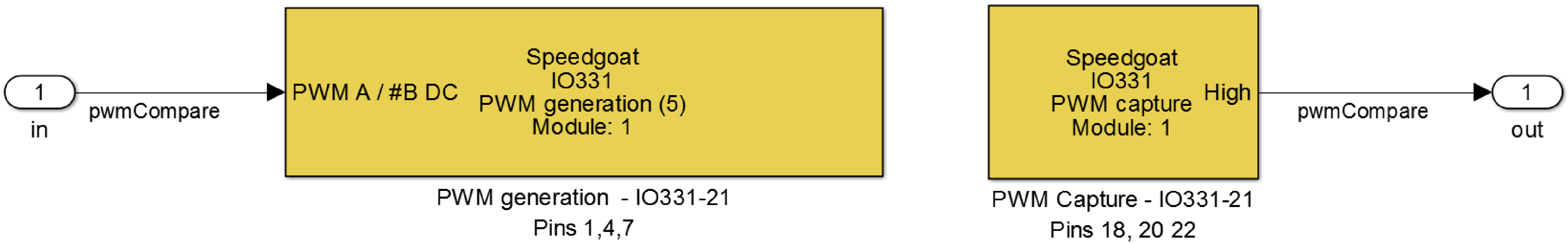


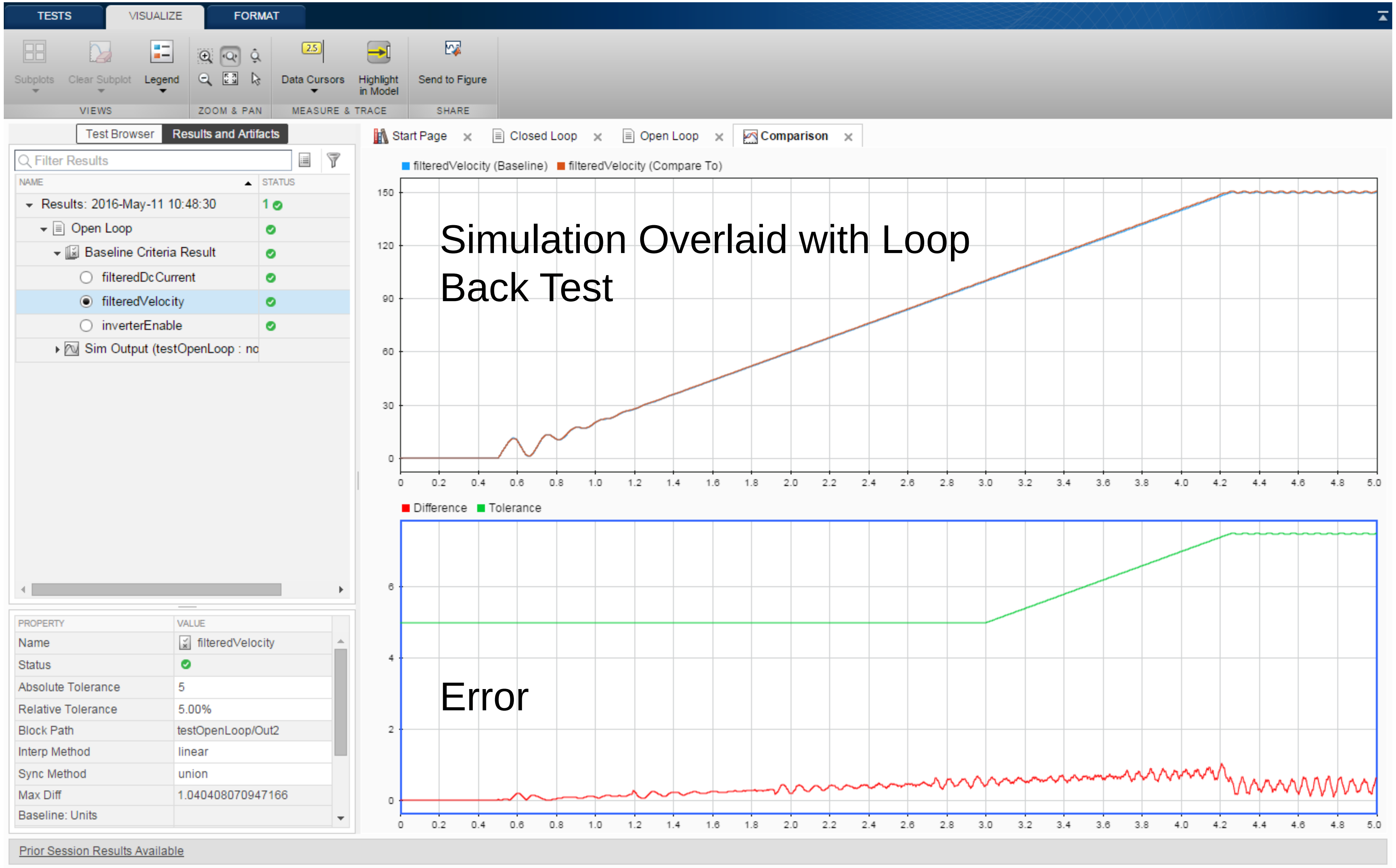
I/O for Step 1: Speedgoat Only



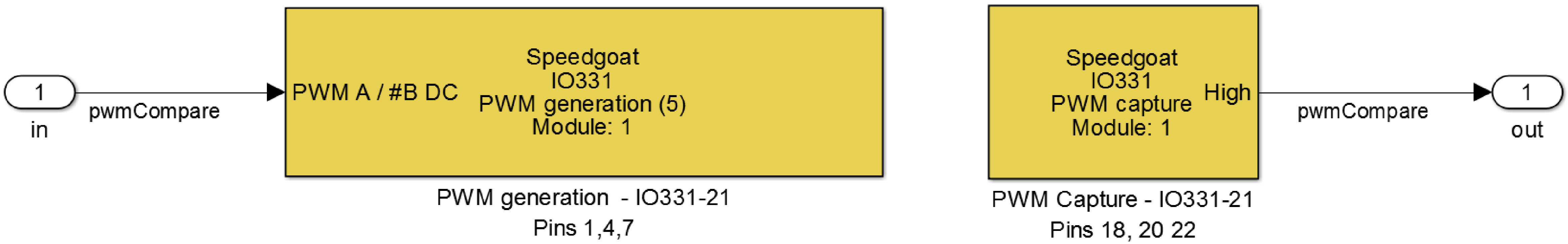
I/O for Step 2: Speedgoat with Loopback



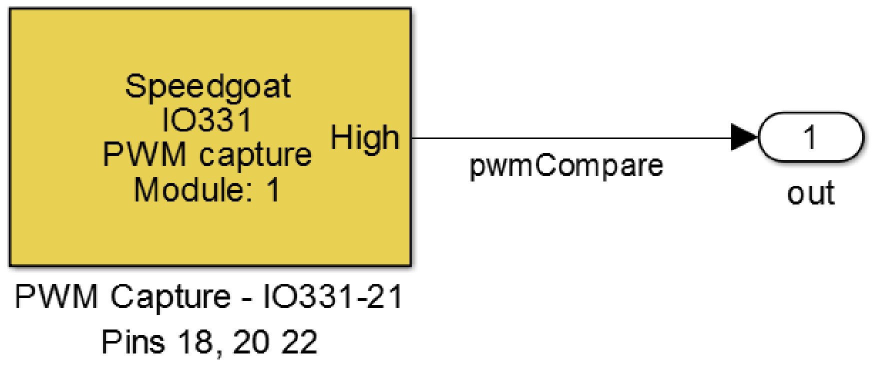
Validating Loop Back Performance with Simulink Test



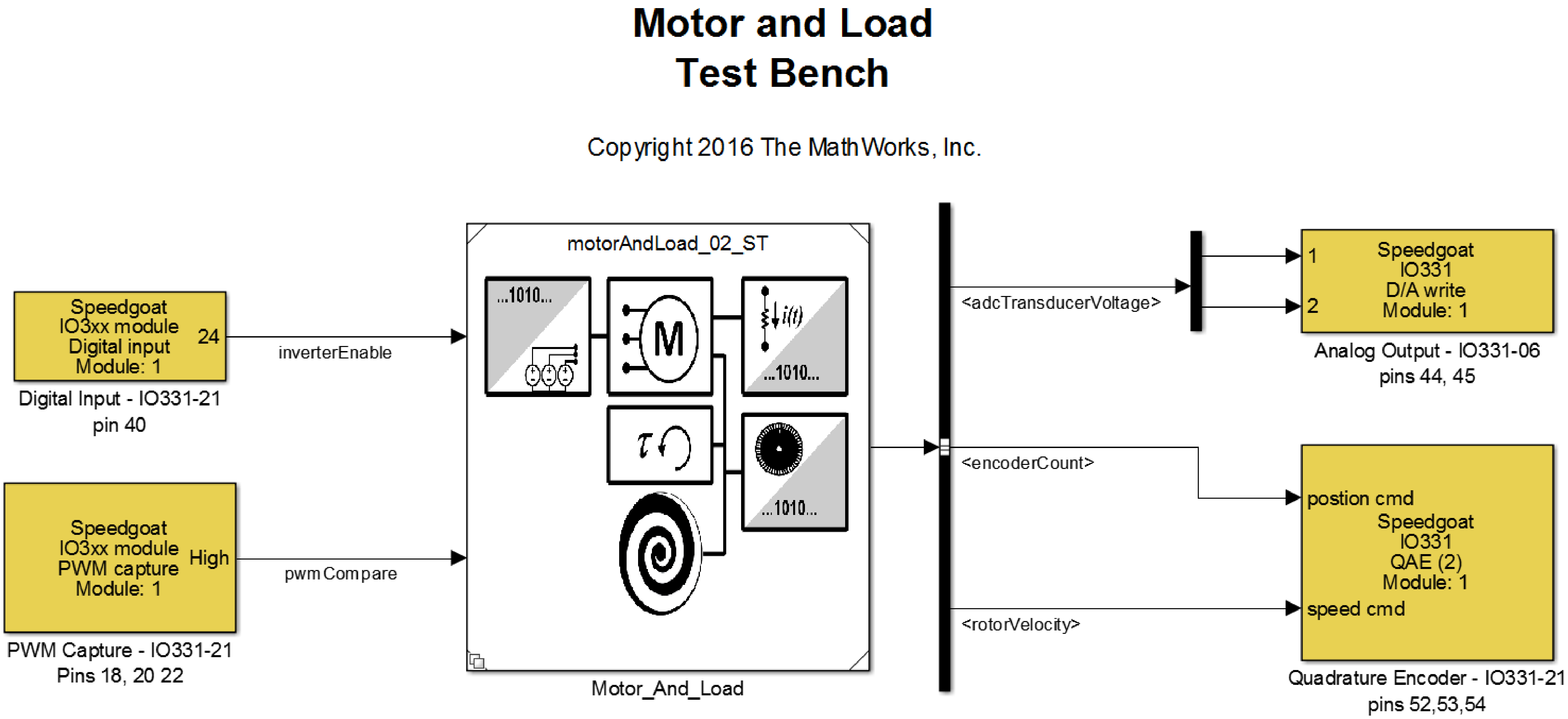
I/O for Step 2: Speedgoat with Loopback



I/O for Step 3: Speedgoat with C2000



Model Ready for HIL



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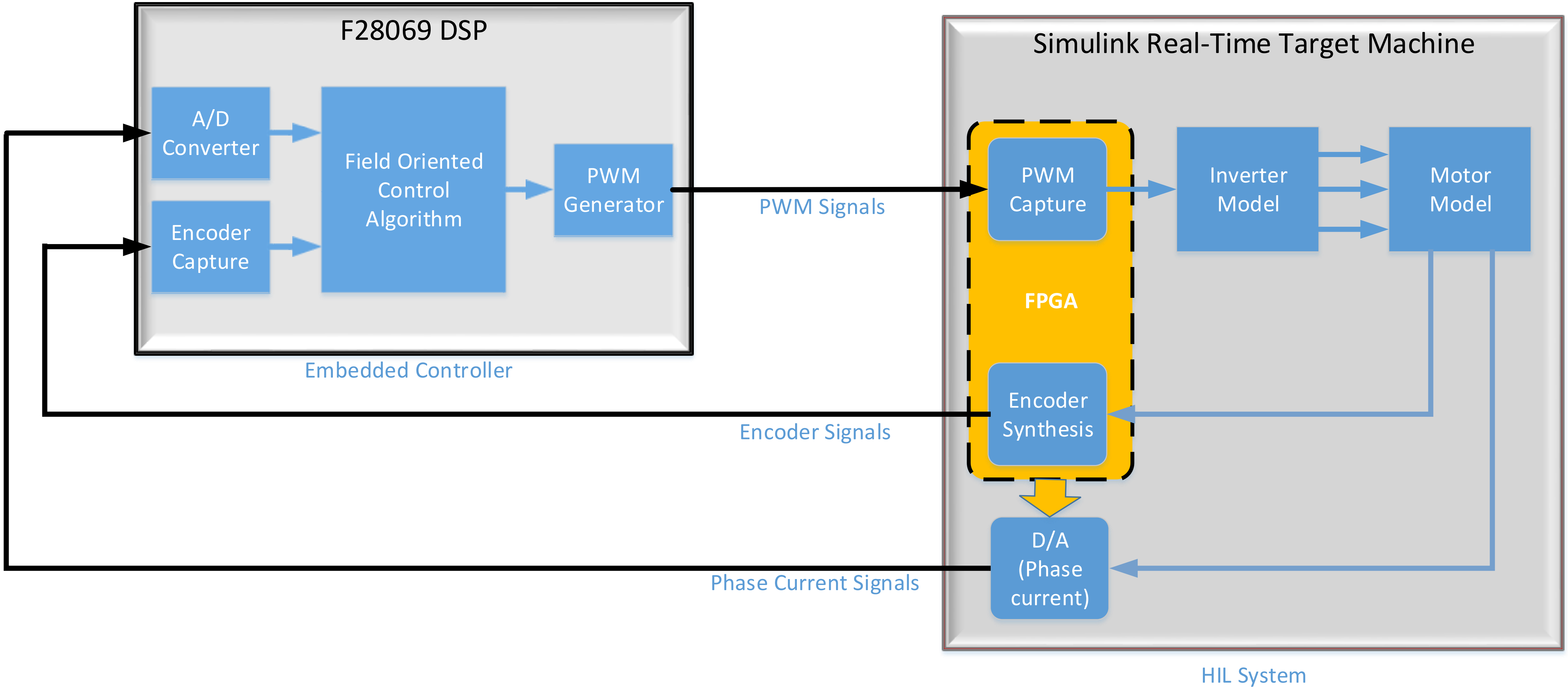
- **Testing an embedded motor controller with the HIL system**
  - **Connecting the embedded controller to the HIL system**
  - **Comparing HIL and Simulation test results**

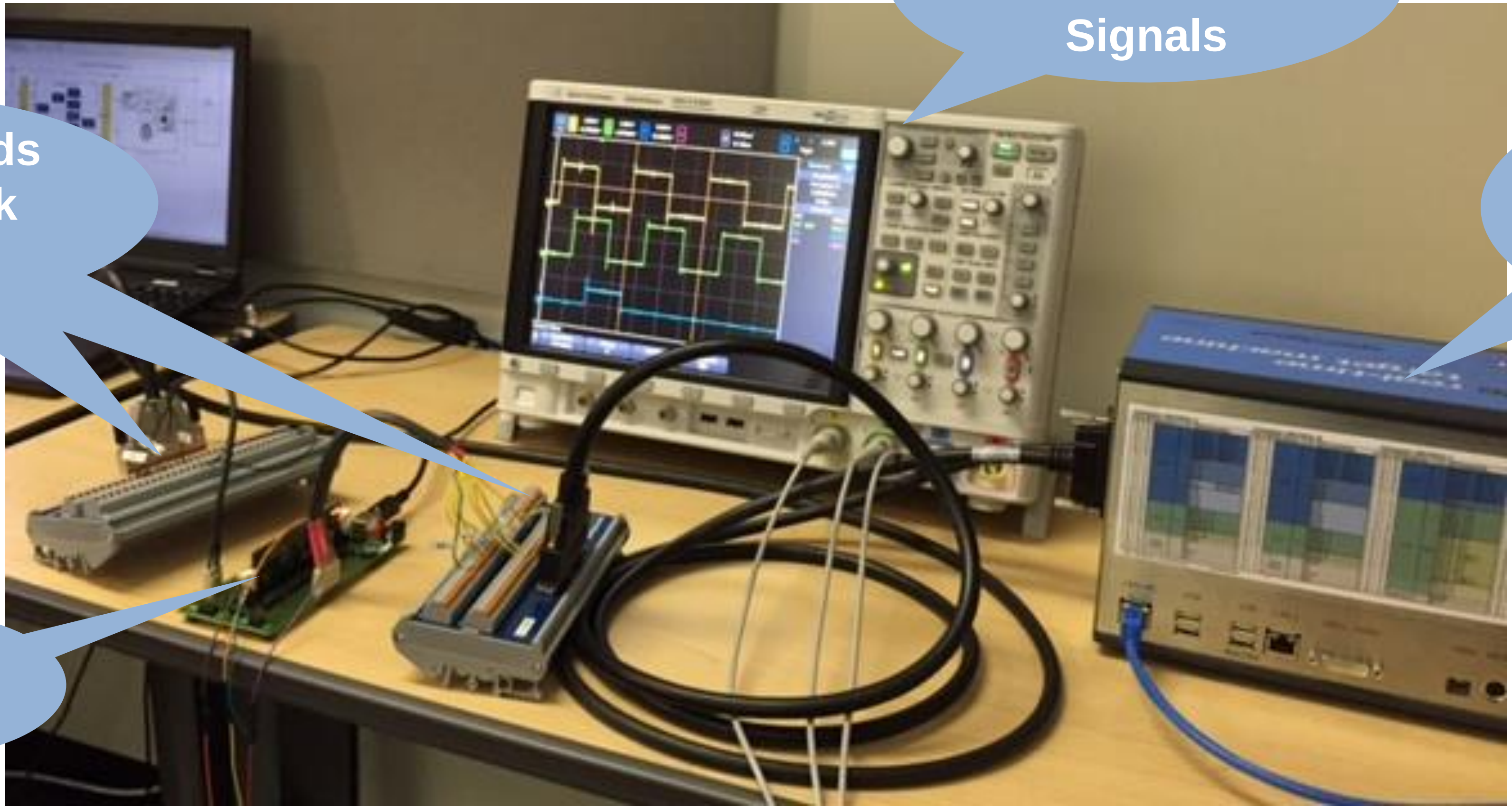
Connecting the embedded controller to the HIL system

PMSM HIL Connections Diagram

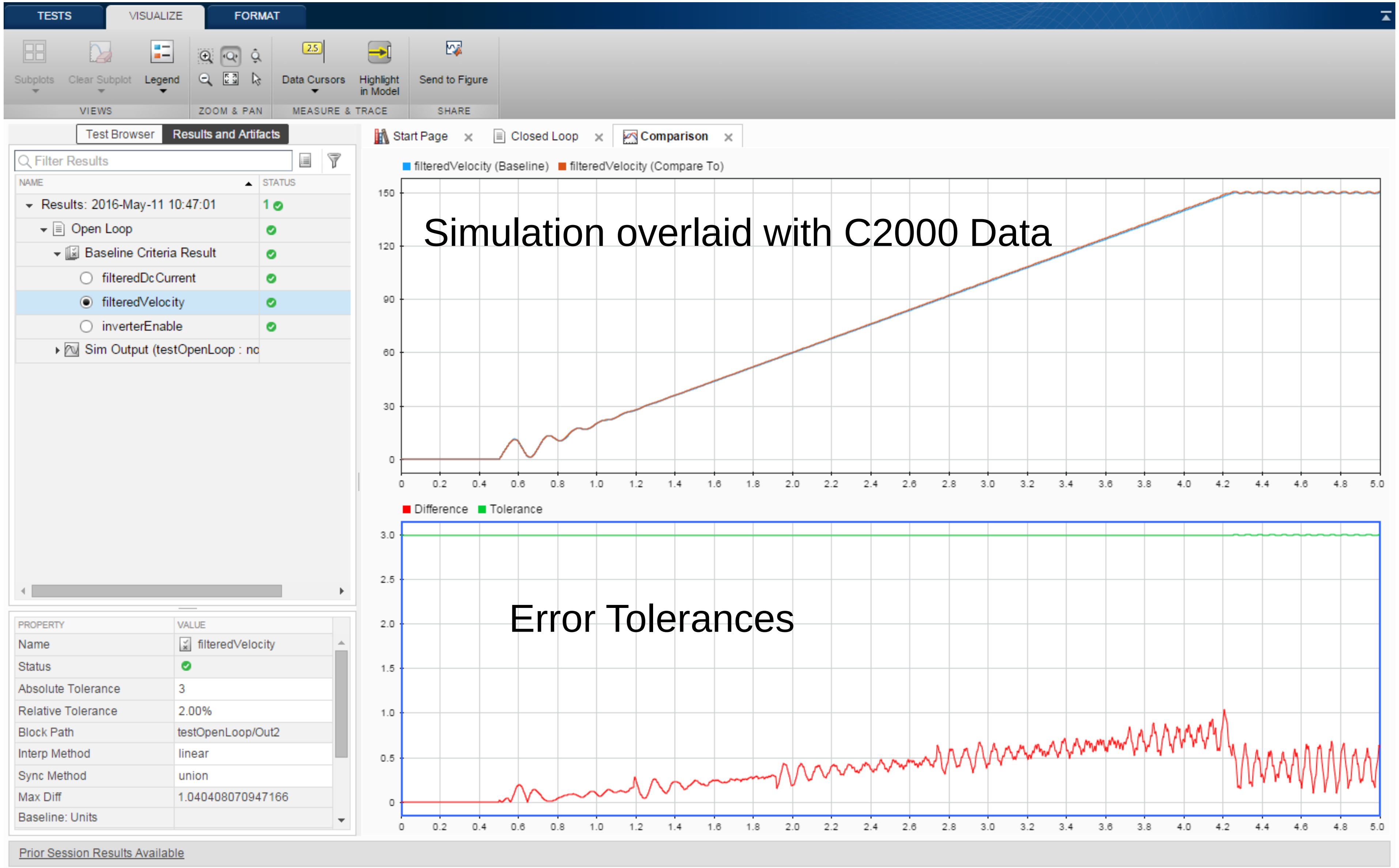


Connecting the embedded controller to the HIL system

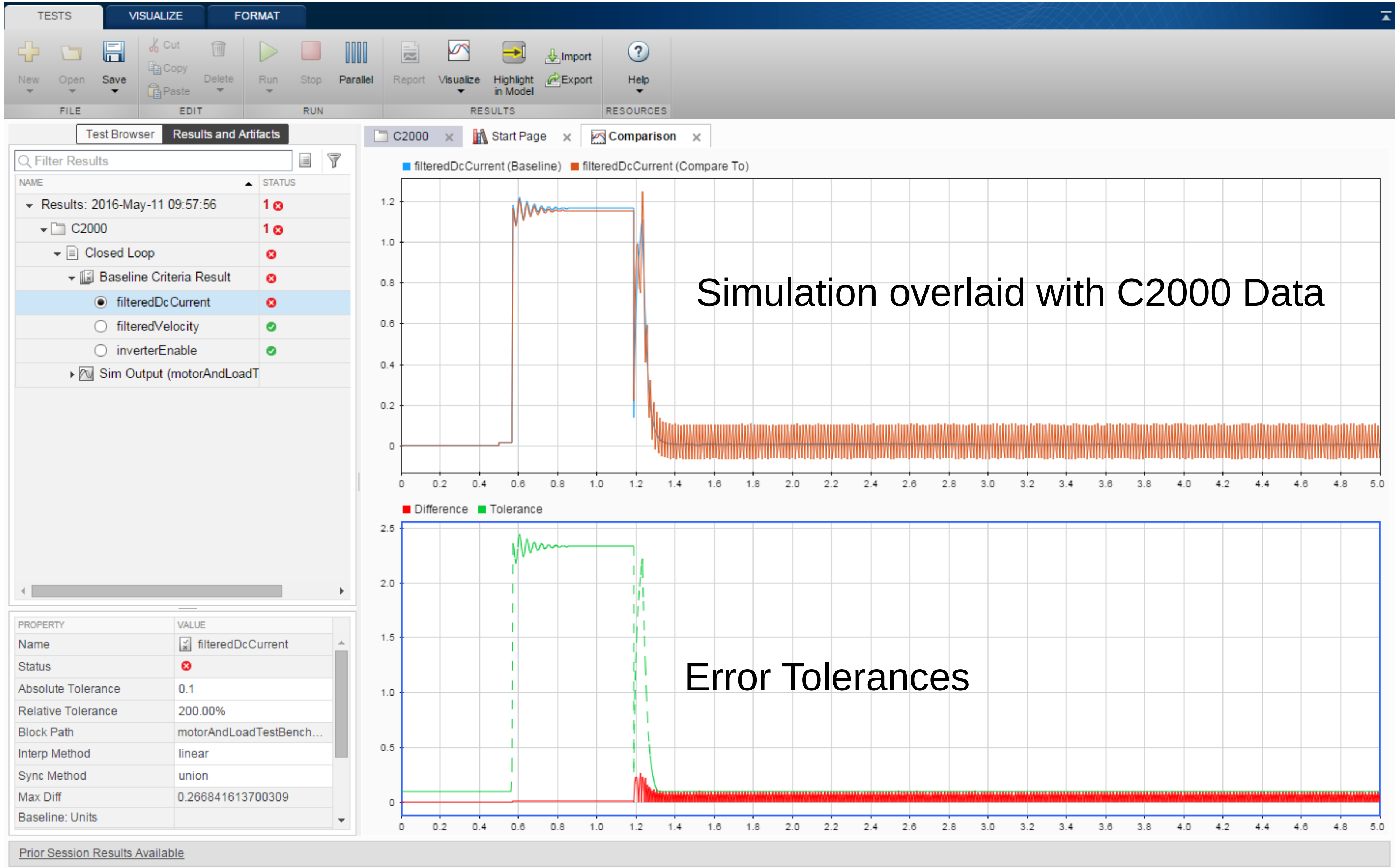
- Hardware implementation



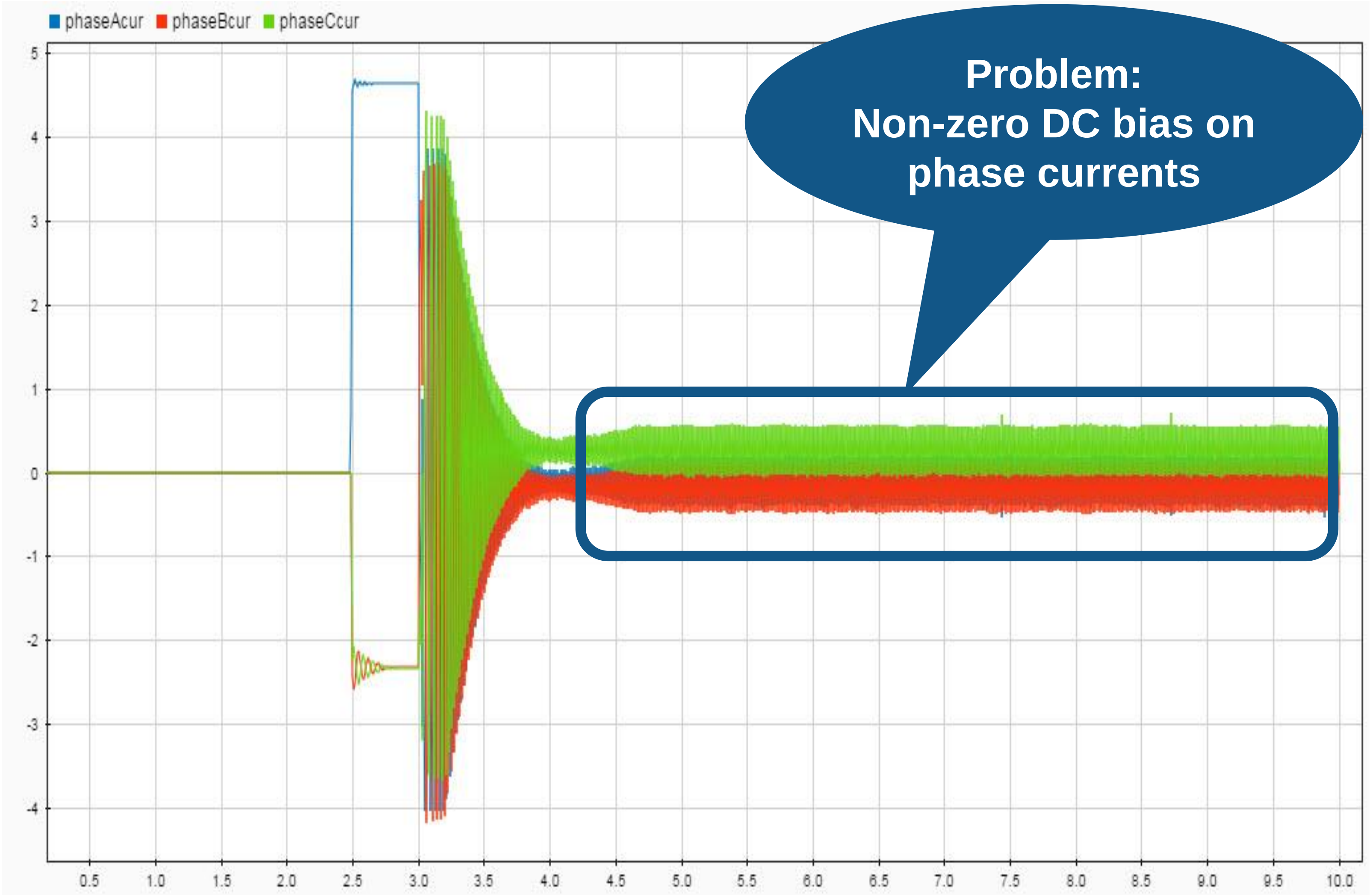
Testing Open Loop Performance: Velocity



Testing Closed Loop Performance: DC Current



Connecting the embedded controller to the HIL system
- Troubleshooting issues



Connecting the embedded controller to the HIL system

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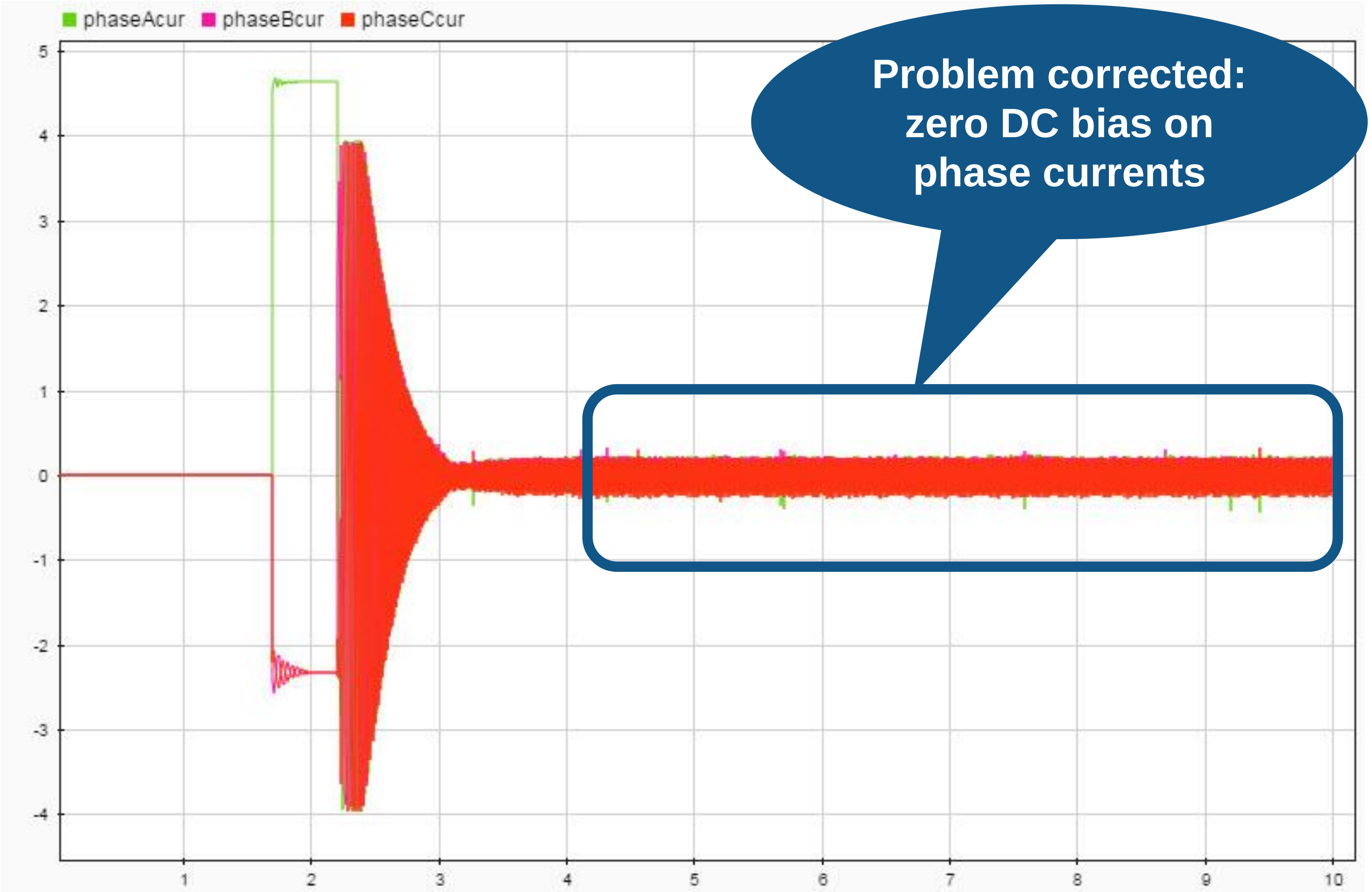

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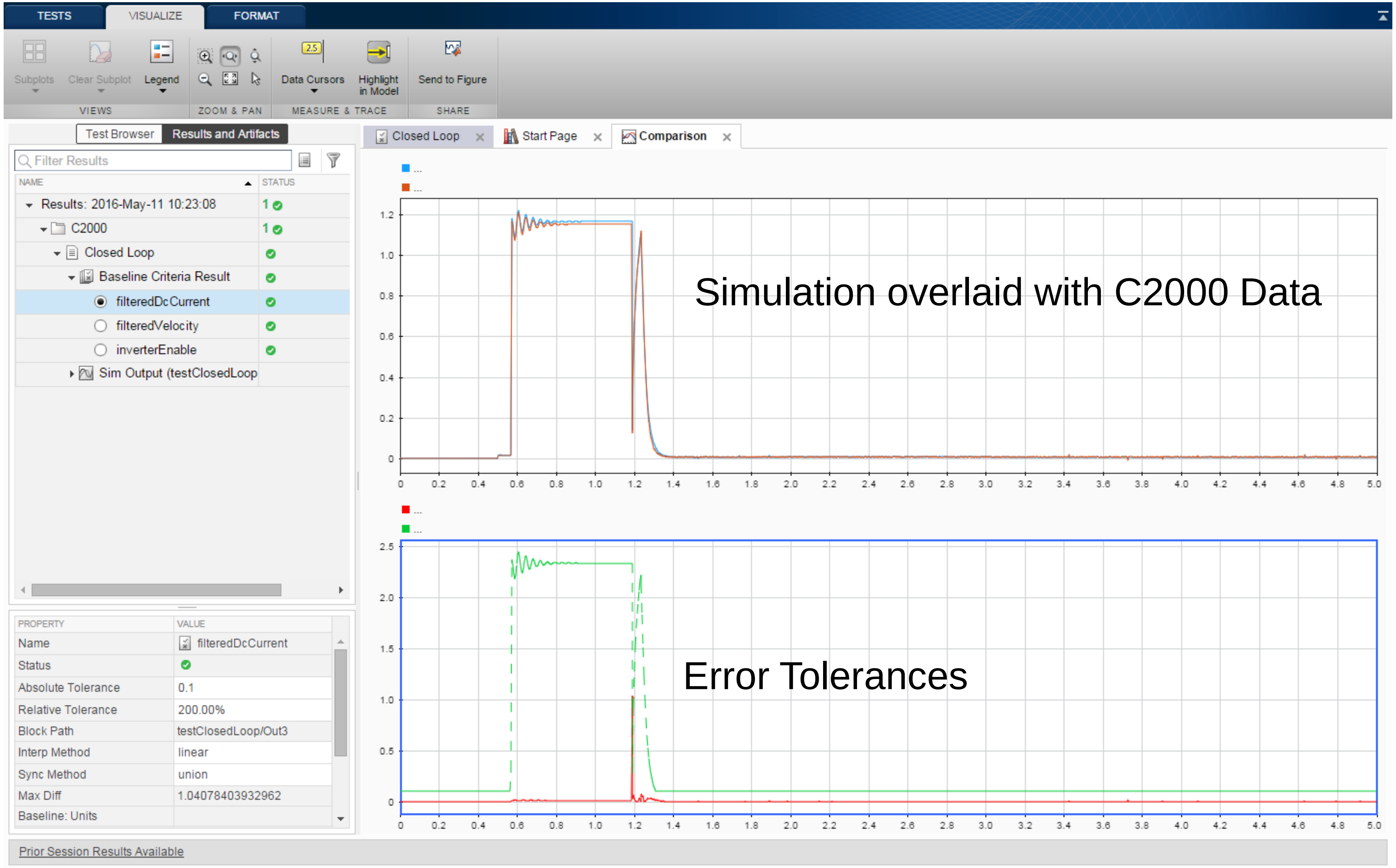

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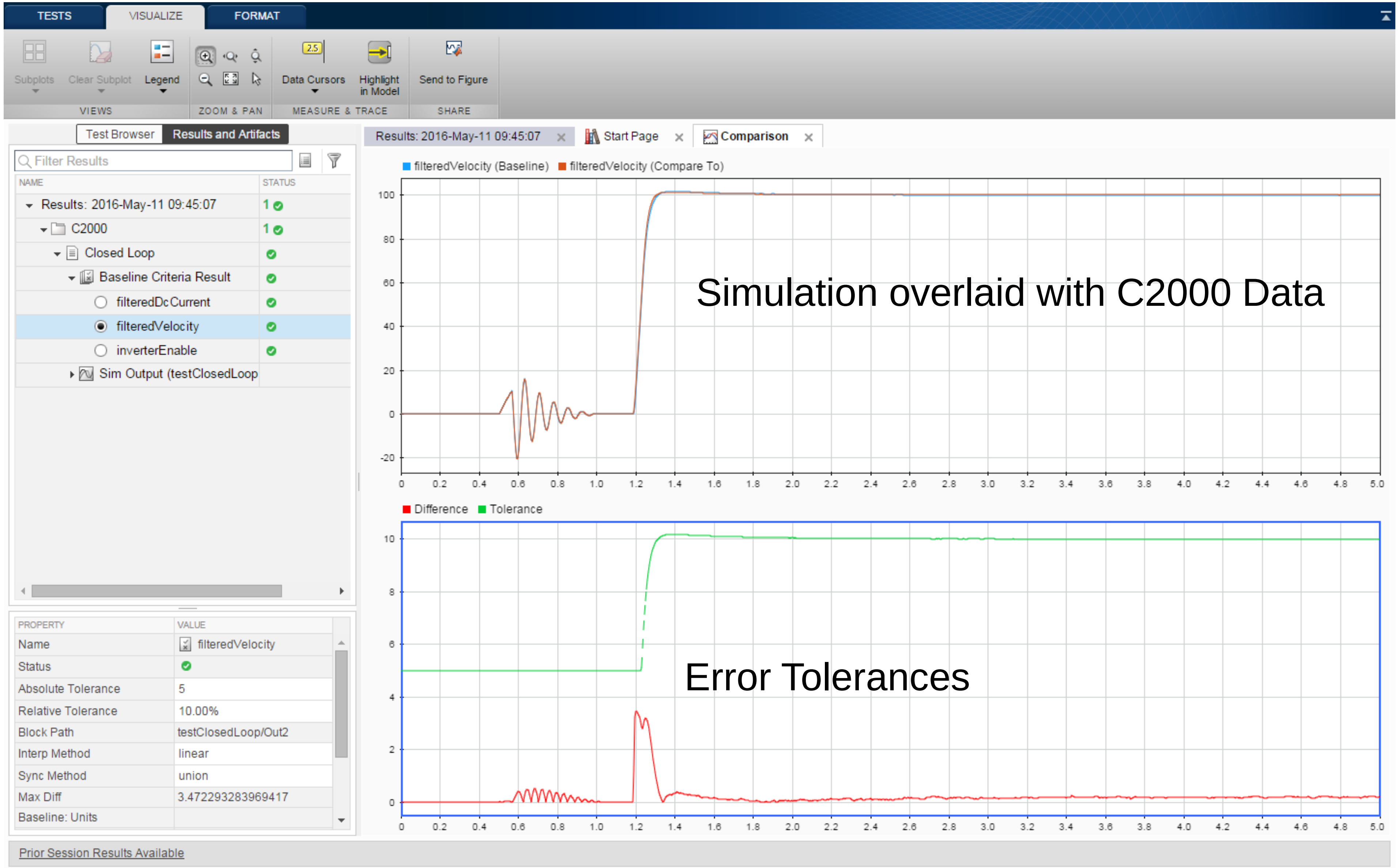

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