MathWorks

Speeding up Simulink

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Agenda

- Typical use cases
- Accelerator mode
- Performance Advisor
- Fast Restart and parsim
- Incremental workflows
- Solver Profiler

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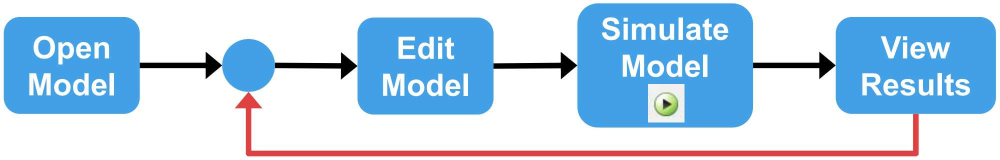
Typical simulation use cases

Edit-Sim-Repeat

Tune-Sim-Repeat

Multi-Sim

Edit-Sim-Repeat



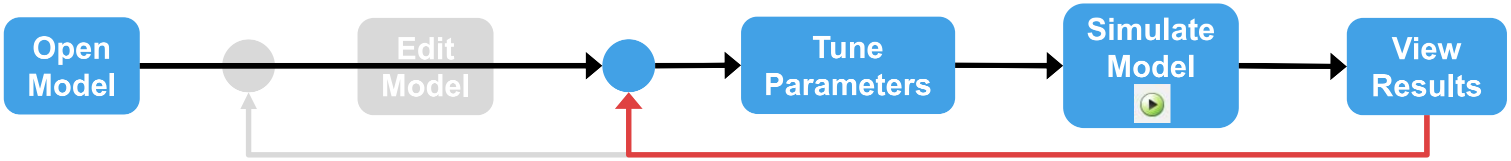
Tune-Sim-Repeat

Multi-Sim

Edit-Sim-Repeat

Tune-Sim-Repeat

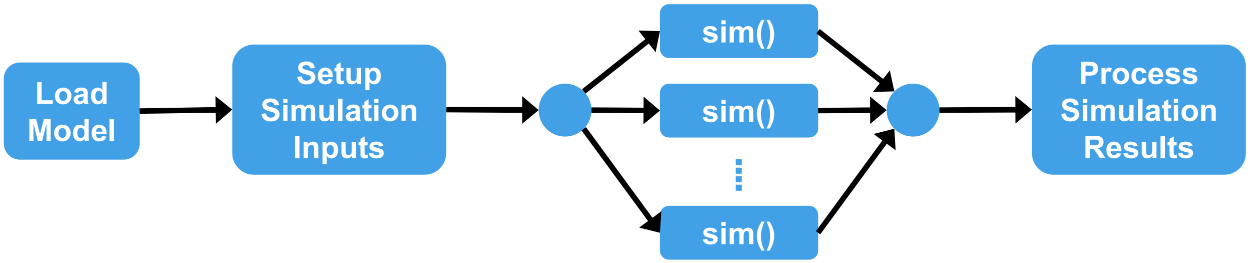
Multi-Sim



Edit-Sim-Repeat

Tune-Sim-Repeat

Multi-Sim



Load Model

Setup Simulation Inputs

sim()

sim()

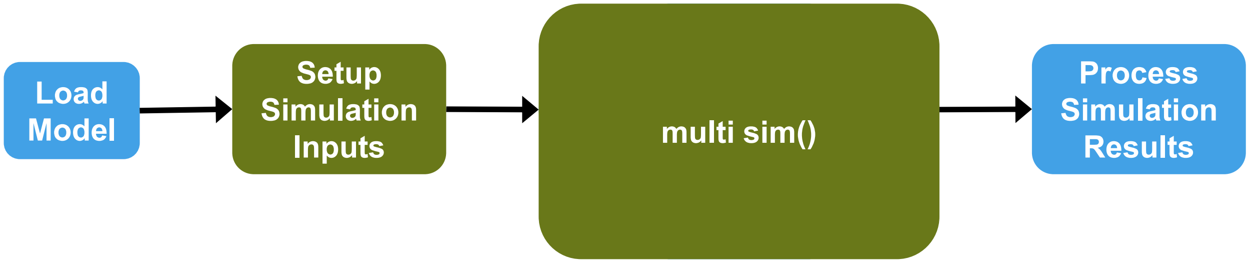
sim()

Process Simulation Results

Edit-Sim-Repeat

Tune-Sim-Repeat

Multi-Sim



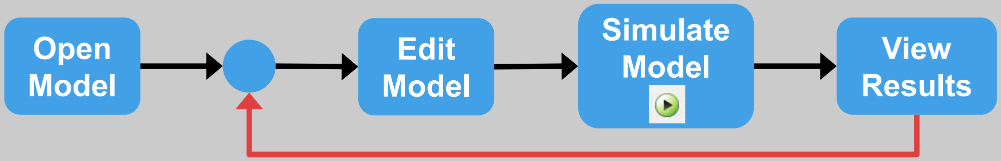
Load Model

Setup Simulation Inputs

multi sim()

Process Simulation Results

Edit-Sim-Repeat



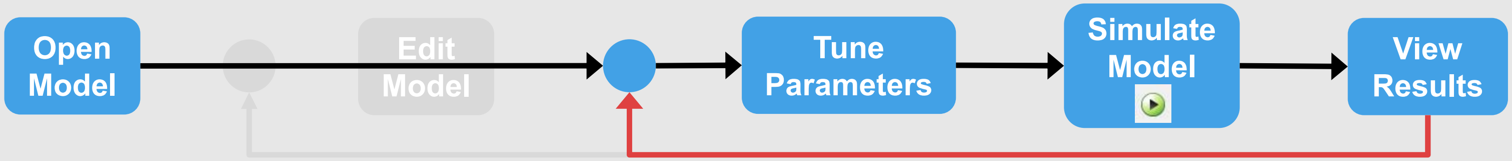
Open Model

Edit Model

Simulate Model

View Results

Tune-Sim-Repeat



Open Model

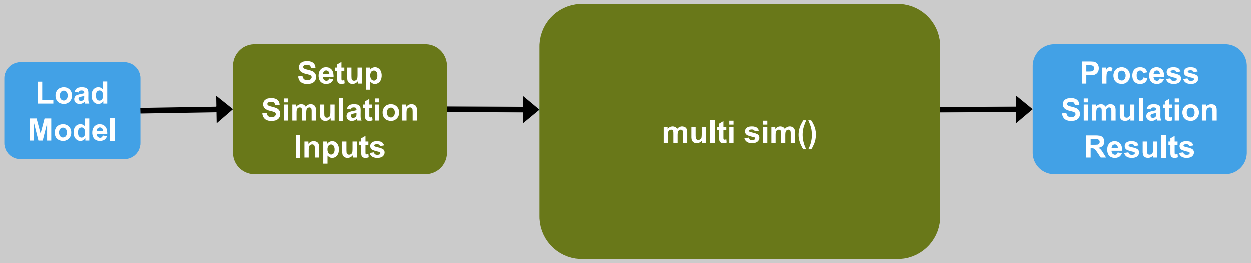
Edit Model

Tune Parameters

Simulate Model

View Results

Multi-Sim



Load Model

Setup Simulation Inputs

multi sim()

Process Simulation Results

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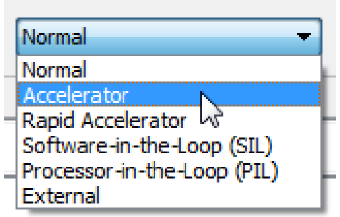
Accelerator Mode

Why would Simulink speed up?

- JIT compiles (or generates C-code for) portions of the model
- Running compiled code has less overhead



Normal

Normal
Accelerator
Rapid Accelerator
Software-in-the-Loop (SIL)
Processor-in-the-Loop (PIL)
External

What's the tradeoff?

- There is overhead to generate code
- Some run time diagnostics are disabled, e.g., inf/nan checking
- May not speedup all models

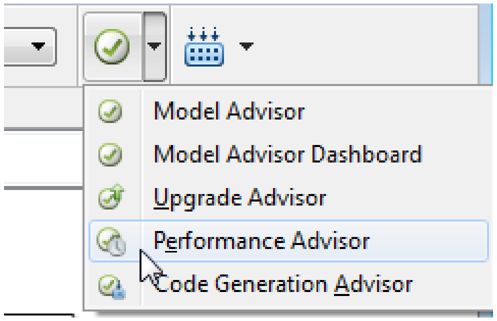
Introduced before **R**2006**a**

Help Search: how acceleration modes work

Performance Advisor

Why would Simulink speed up?

- Checks your model for speedup options
- Validates its own advice, only applies changes that:
  - give the same answer
  - and improve speed



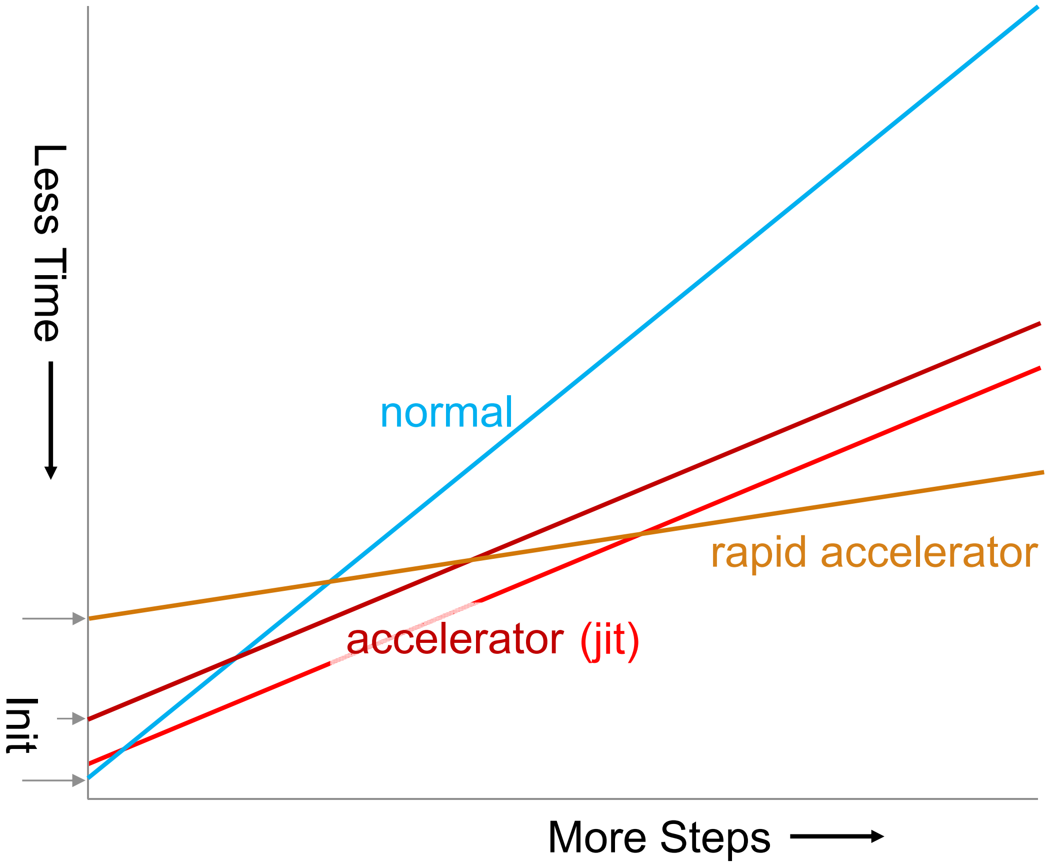
What's the tradeoff?

- Takes time run the analysis
- Not comprehensive
  - Trading off fidelity for speed is not part of performance advisor

Help Search: performance advisor

R2012b

Rough Comparison of Simulation Modes



Accelerator is faster

- Unless your simulations are short

- With JIT, accelerator is faster than normal mode in many more cases

Rapid-accelerator has the least per-step overhead but the most init overhead

Just-In-Time Accelerator Mode Introduced in R2016b

Questions

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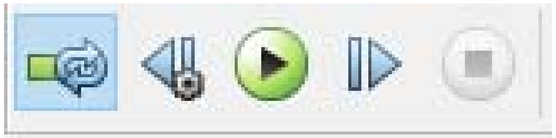
Fast Restart



Why would Simulink speed up?

- Avoids recompile between simulation runs
- Works with Accelerator mode

What's the tradeoff?

- Cannot edit the model when in fast restart mode

Help Search: fast restart

R2014b

parsim

R2017b
R2017a

Why would Simulink speed up?

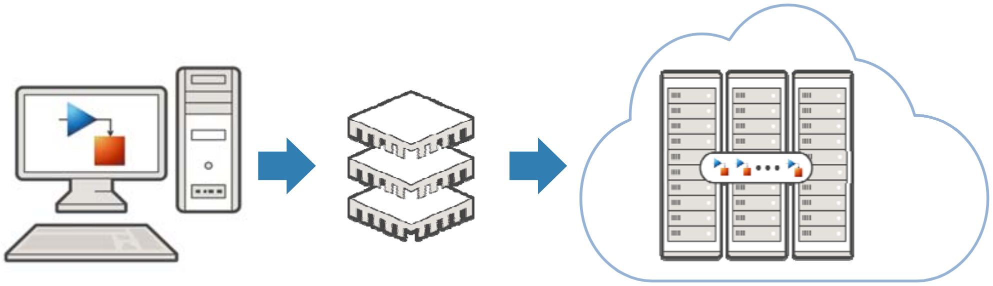
- Runs simulations in parallel using MATLAB Parallel Computing
- Parallelization details are automatically handled
  - if your model works with **`sim`** ...

    … it works with **`parsim`**

What’s the tradeoff?

- Overhead of setting up parallel pool
- Overhead of starting simulations on the workers
- Needs scripting in MATLAB

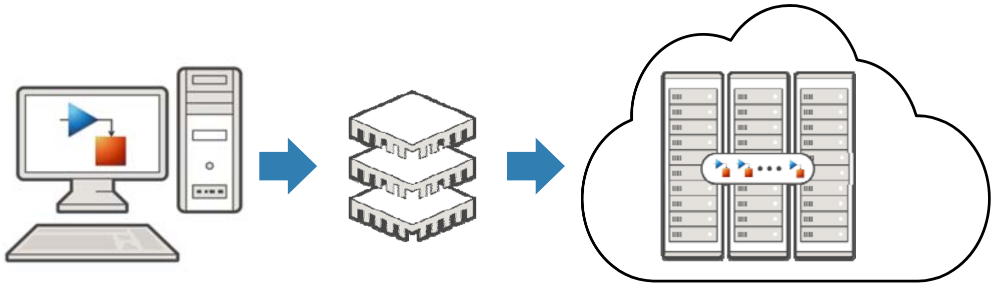
```
for i = 10000:-1:1
    in(i) = Simulink.SimulationInput('my_model');
    in(i) = in(i).setVariable('my_var', i);
end
out = parsim(in);
```



Help Search: parsim

`parsim` : Benefits

```
for i = 10000:-1:1
    in(i) = Simulink.SimulationInput('my_model');
    in(i) = in(i).setVariable('my_var', i);
end
out = parsim(in);
```



Desktop Multicore Cluster

parsim manages the details of running parallel simulations

… so you can focus on the design tasks

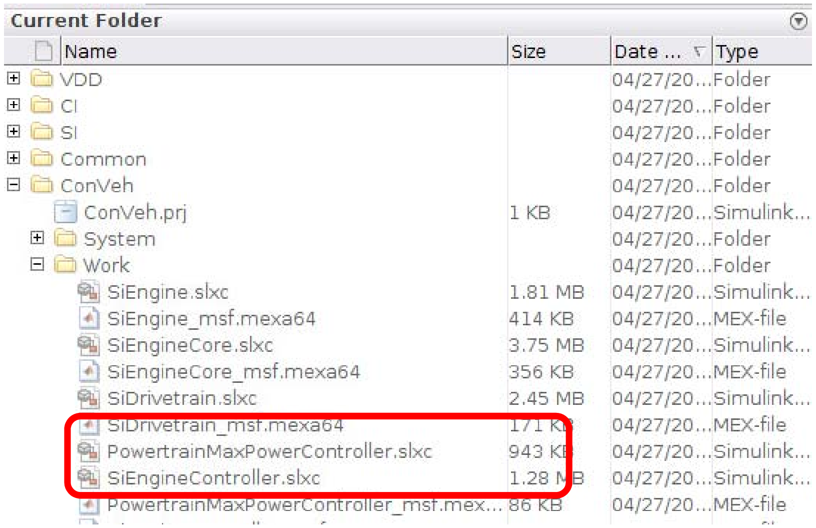
parsim: automates book-keeping details (1)

- Handles cross platform details
  - Use parsim from a Windows desktop to run simulations on Linux Cluster

- Handles model dependencies
  - MATLAB Code, Libraries, S-Functions, …

- Integrated with Simulink Cache

- Leverages model reference parallel build

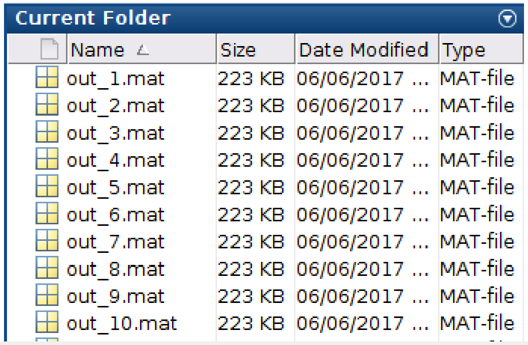


Current Folder

Name	Size	Date ...	Type
⊞ VDD		04/27/20...	Folder
⊞ CI		04/27/20...	Folder
⊞ SI		04/27/20...	Folder
⊞ Common		04/27/20...	Folder
⊟ ConVeh		04/27/20...	Folder
ConVeh.prj	1 KB	04/27/20...	Simulink...
⊞ System		04/27/20...	Folder
⊟ Work		04/27/20...	Folder
SiEngine.slxc	1.81 MB	04/27/20...	Simulink...
SiEngine_msf.mexa64	414 KB	04/27/20...	MEX-file
SiEngineCore.slxc	3.75 MB	04/27/20...	Simulink...
SiEngineCore_msf.mexa64	356 KB	04/27/20...	MEX-file
SiDrivetrain.slxc	2.45 MB	04/27/20...	Simulink...
SiDrivetrain_msf.mexa64	171 KB	04/27/20...	MEX-file
PowertrainMaxPowerController.slxc	943 KB	04/27/20...	Simulink...
SiEngineController.slxc	1.28 MB	04/27/20...	Simulink...
PowertrainMaxPowerController_msf.mex...	86 KB	04/27/20...	MEX-file

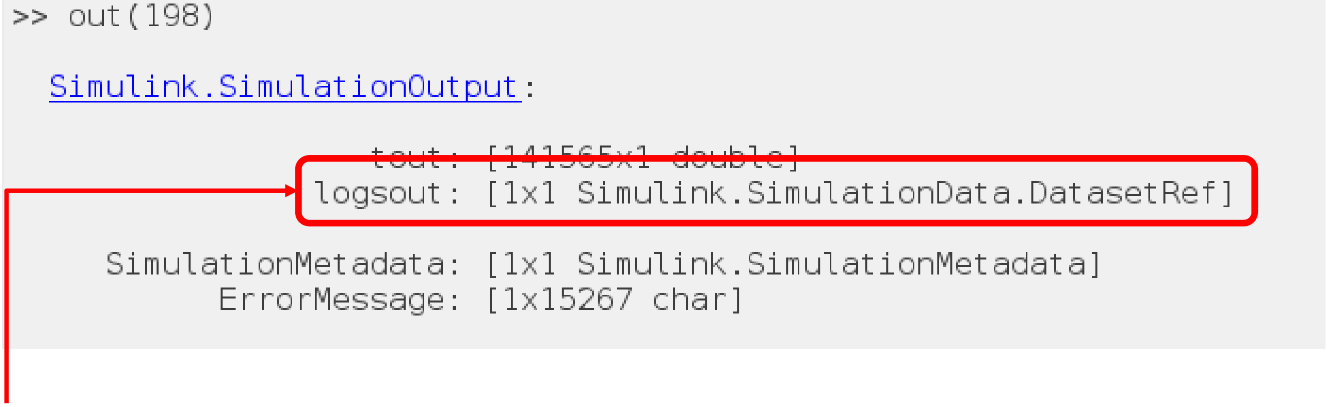
parsim: automates book-keeping details (2)

- Brings back log files from the workers
  - Appends run id to make them unique



Current Folder

Name	Size	Date Modified	Type
out_1.mat	223 KB	06/06/2017 ...	MAT-file
out_2.mat	223 KB	06/06/2017 ...	MAT-file
out_3.mat	223 KB	06/06/2017 ...	MAT-file
out_4.mat	223 KB	06/06/2017 ...	MAT-file
out_5.mat	223 KB	06/06/2017 ...	MAT-file
out_6.mat	223 KB	06/06/2017 ...	MAT-file
out_7.mat	223 KB	06/06/2017 ...	MAT-file
out_8.mat	223 KB	06/06/2017 ...	MAT-file
out_9.mat	223 KB	06/06/2017 ...	MAT-file
out_10.mat	223 KB	06/06/2017 ...	MAT-file

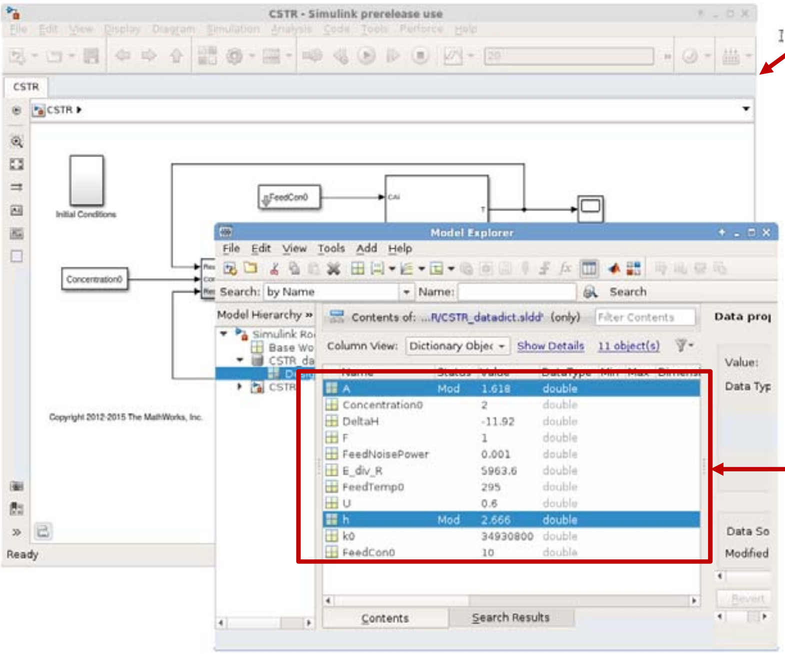


```
>> out(198)

  Simulink.SimulationOutput:

                  tout: [141565x1 double]
               logsout: [1x1 Simulink.SimulationData.DatasetRef]

    SimulationMetadata: [1x1 Simulink.SimulationMetadata]
          ErrorMessage: [1x15267 char]
```

Automatically get references to logged files

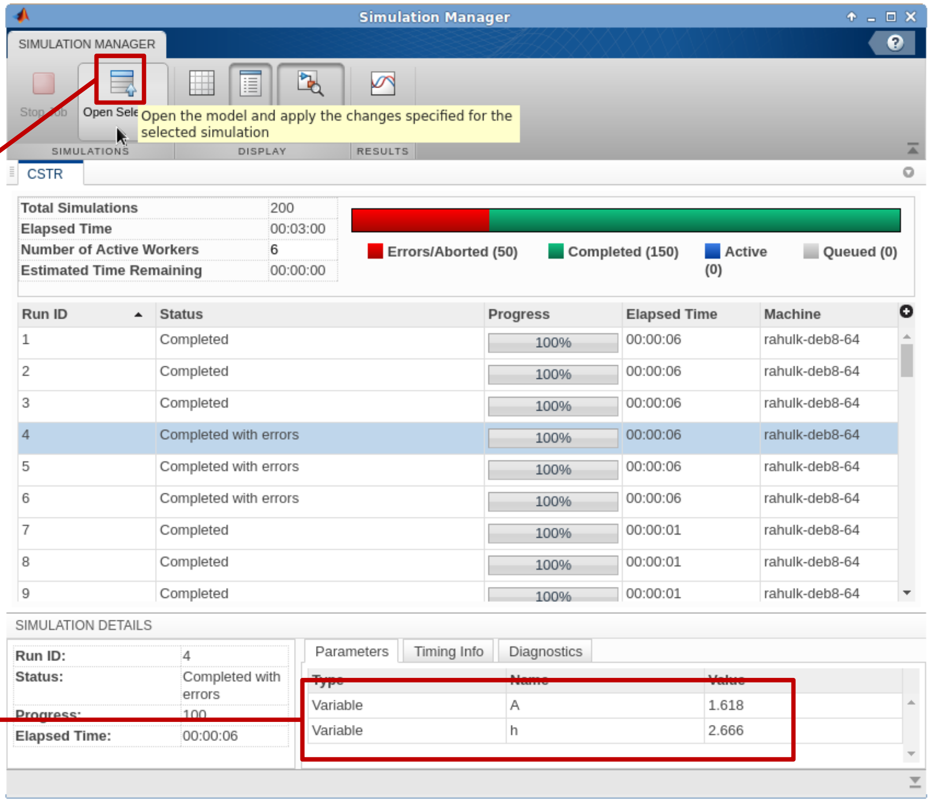
parsim: automates book-keeping details (3)

- Show progress and error diagnostics
  - Setups up model to run locally to debug



Contents of: ...R/CSTR_datadict.sldd' (only)

Name	Status	Value	DataType	Min	Max	Dimensi
A	Mod	1.618	double			
Concentration0		2	double			
DeltaH		-11.92	double			
F		1	double			
FeedNoisePower		0.001	double			
E_div_R		5963.6	double			
FeedTemp0		295	double			
U		0.6	double			
h	Mod	2.666	double			
k0		34930800	double			
FeedCon0		10	double			



Open the model and apply the changes specified for the selected simulation

Total Simulations	200
Elapsed Time	00:03:00
Number of Active Workers	6
Estimated Time Remaining	00:00:00

🟥 Errors/Aborted (50) 🟩 Completed (150) 🟦 Active (0) ⬜ Queued (0)

Run ID	Status	Progress	Elapsed Time	Machine
1	Completed	100%	00:00:06	rahulk-deb8-64
2	Completed	100%	00:00:06	rahulk-deb8-64
3	Completed	100%	00:00:06	rahulk-deb8-64
4	Completed with errors	100%	00:00:06	rahulk-deb8-64
5	Completed with errors	100%	00:00:06	rahulk-deb8-64
6	Completed with errors	100%	00:00:06	rahulk-deb8-64
7	Completed	100%	00:00:01	rahulk-deb8-64
8	Completed	100%	00:00:01	rahulk-deb8-64
9	Completed	100%	00:00:01	rahulk-deb8-64

SIMULATION DETAILS

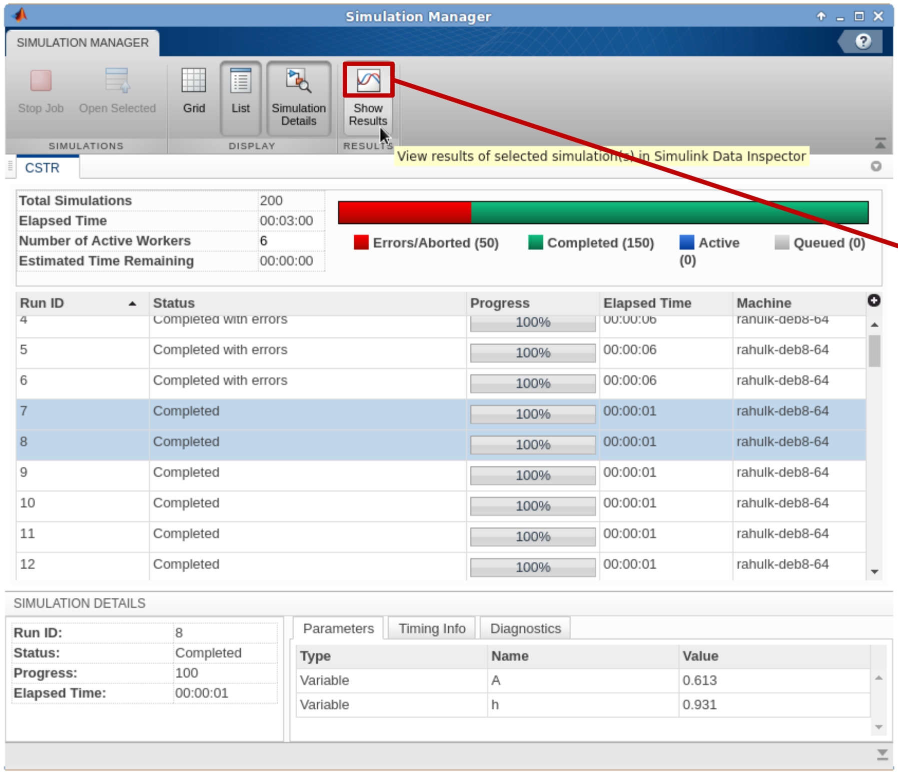
Run ID:	4
Status:	Completed with errors
Progress:	100
Elapsed Time:	00:00:06

Parameters | Timing Info | Diagnostics

Type	Name	Value
Variable	A	1.618
Variable	h	2.666

R2017b

Visualizing Results



View results of selected simulation(s) in Simulink Data Inspector

Total Simulations	200
Elapsed Time	00:03:00
Number of Active Workers	6
Estimated Time Remaining	00:00:00

🟥 Errors/Aborted (50) 🟩 Completed (150) 🟦 Active (0) ⬜ Queued (0)

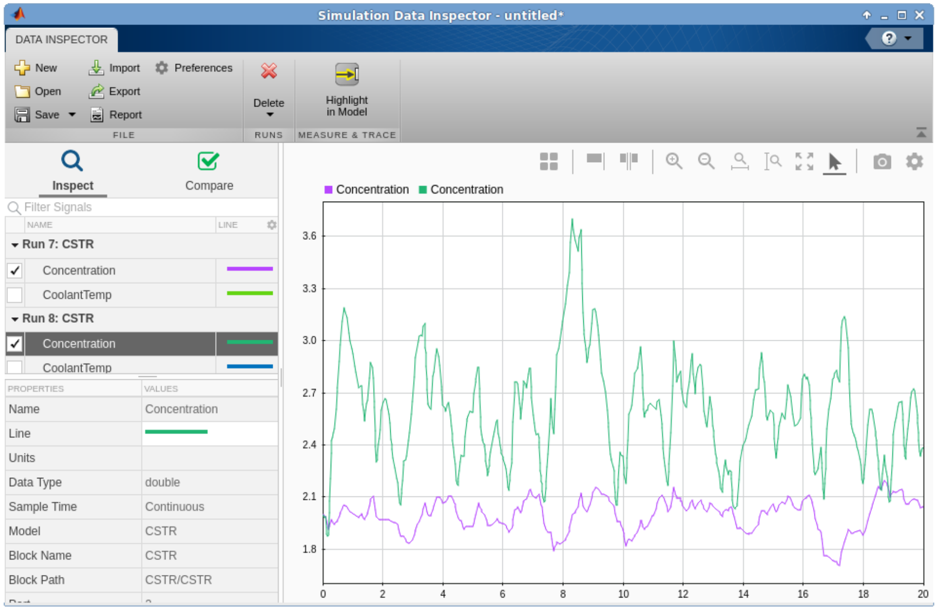
Run ID	Status	Progress	Elapsed Time	Machine
4	Completed with errors	100%	00:00:06	rahulk-deb8-64
5	Completed with errors	100%	00:00:06	rahulk-deb8-64
6	Completed with errors	100%	00:00:06	rahulk-deb8-64
7	Completed	100%	00:00:01	rahulk-deb8-64
8	Completed	100%	00:00:01	rahulk-deb8-64
9	Completed	100%	00:00:01	rahulk-deb8-64
10	Completed	100%	00:00:01	rahulk-deb8-64
11	Completed	100%	00:00:01	rahulk-deb8-64
12	Completed	100%	00:00:01	rahulk-deb8-64

SIMULATION DETAILS

Run ID:	8
Status:	Completed
Progress:	100
Elapsed Time:	00:00:01

Parameters | Timing Info | Diagnostics

Type	Name	Value
Variable	A	0.613
Variable	h	0.931



NAME	LINE
Run 7: CSTR	
☑ Concentration	
□ CoolantTemp	
Run 8: CSTR	
☑ Concentration	
□ CoolantTemp	

PROPERTIES	VALUES
Name	Concentration
Line	
Units	
Data Type	double
Sample Time	Continuous
Model	CSTR
Block Name	CSTR
Block Path	CSTR/CSTR

parsim : customization(1)

- TransferBaseWorkspaceVariables

```
outs = parsim(inps, ’TransferBaseWorkspaceVariables’,’on’, …)
```

- UseFastRestart

```
outs = parsim(inps, ’UseFastRestart’,’on’, …)
```

`parsim` : customization(2)

- SetupFcn

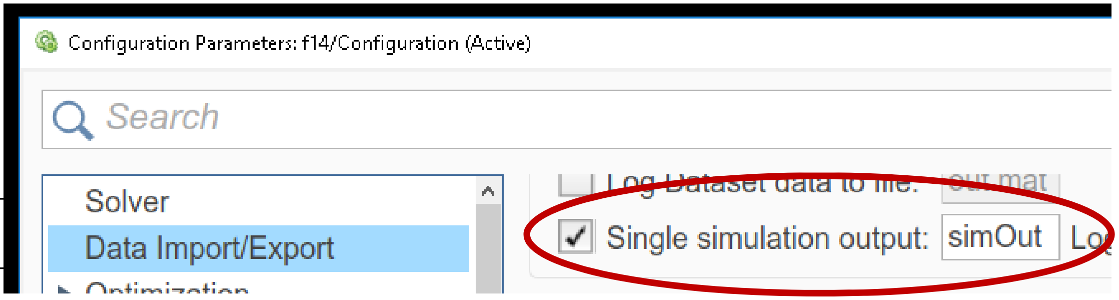
```
setupFcn = @()addpath(’myProjectDir’)
outs = parsim(inps, ’SetupFcn’,setupFcn, …)
```

- CleanupFcn

```
cleanupFcn = @()rmpath(’myProjectDir’)
outs = parsim(inps, ’CleanupFcn’,cleanupFcn, …)
```

SimulationOutput object

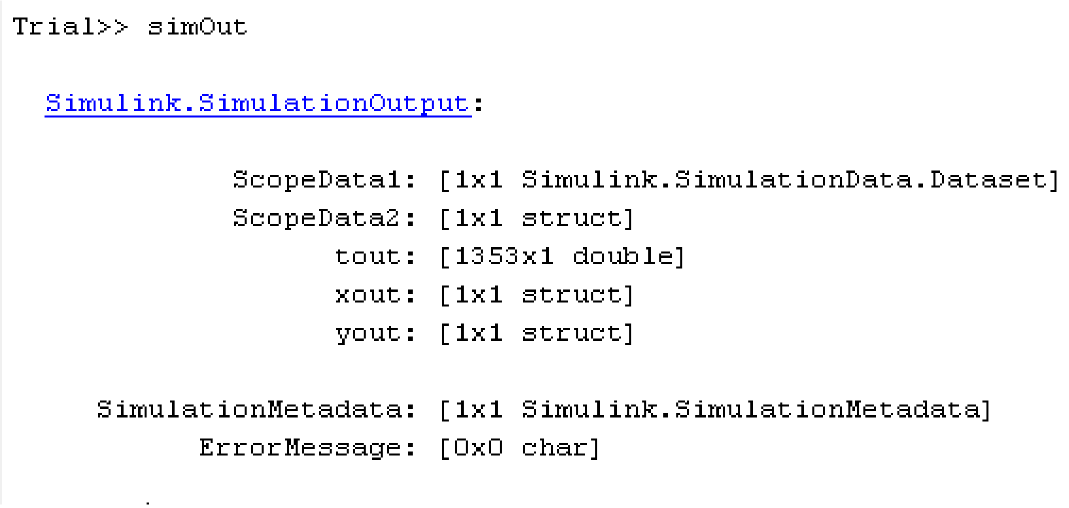
```
simOut = sim('model',
```



Configuration Parameters: f14/Configuration (Active)

□ Log Dataset data to file: out.mat

☑ Single simulation output: simOut



```
Trial>> simOut

  Simulink.SimulationOutput:

              ScopeData1: [1x1 Simulink.SimulationData.Dataset]
              ScopeData2: [1x1 struct]
                    tout: [1353x1 double]
                    xout: [1x1 struct]
                    yout: [1x1 struct]

      SimulationMetadata: [1x1 Simulink.SimulationMetadata]
            ErrorMessage: [0x0 char]
```

- Contains all logged simulation data
- Use dot notation to access the data
- Introduced in R2009a

SimulationInput object

A SimulationInput object ‘**simInp**’ encapsulates all input to one simulation

```
simOut = sim(simInp)
```

Array of **simInps** encapsulate all inputs to multiple simulations

```
simOuts = sim(simInps)
```

* Simulations are run *sequentially*

```
simOuts = parsim(simInps)
```

Simulations are run in **parallel** if MATLAB parallel computing tools are available, *serially* otherwise

SimulationInput Object

```
SimulationInput with properties:

          ModelName: 'sldemo_suspn_3d
       InitialState: [0x0 Simulink.Si
      ExternalInput: []
    ModelParameters: [1x1 Si      ink.Si
    BlockParameters: [0x0 Simuli
          Variables: [1x2 Sim      k.Si
          PreSimFcn: []
         PostSimFcn: []
         UserString: ''
```

Specify MATLAB functions to run before and after each s cus p

Add a brief UserString describing these changes for easy reference

r block as externa model

Change variables in base workspace, data dictionary, or model workspace

PreSimFcn

- Use PreSimFcn to offload parameter computations to parallel workers

```
for i = 10:-1:1
    in(i) = Simulink.SimulationInput(i);
    in(i).PreSimFcn = @(inp) myPreSimFcn(inp, i);
end

function simInp = myPreSimFcn(rawSimInp, runId)
    prmValue = expensiveComputation(runId);
    simInp = rawSimInp.setBlockParameter( …
      [rawSimInp.ModelName,’/my_block’], ’prmName’, prmValue);
end
```

PostSimFcn

- use PostSimFcn to post-process raw simulation outputs in parallel
- reduce data returned back from workers

```
>> inps = Simulink.SimulationInput(‘myModel’);
>> …
>> inps.PostSimFcn = @(out) myPostSimFcn(out);
>> outs = parsim(inps);
>> outs(i).result

function simOut = myPostSimFcn(rawSimOut)
    simOut.result = expensivePostProc(rawSimOut.lotsOfLogsOut);
end
```

Questions

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- Typical use cases
- Accelerator mode
- Performance Advisor
- Fast Restart and parsim
- Incremental workflows
- Solver Profiler

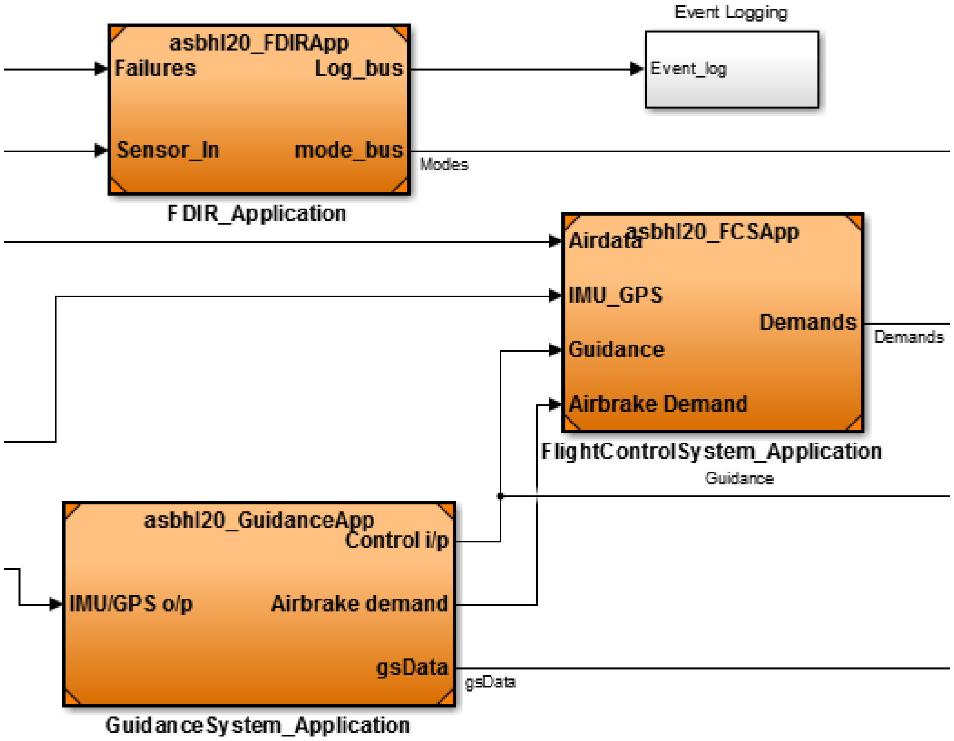
What is an incremental workflow?

Only perform an action when necessary;

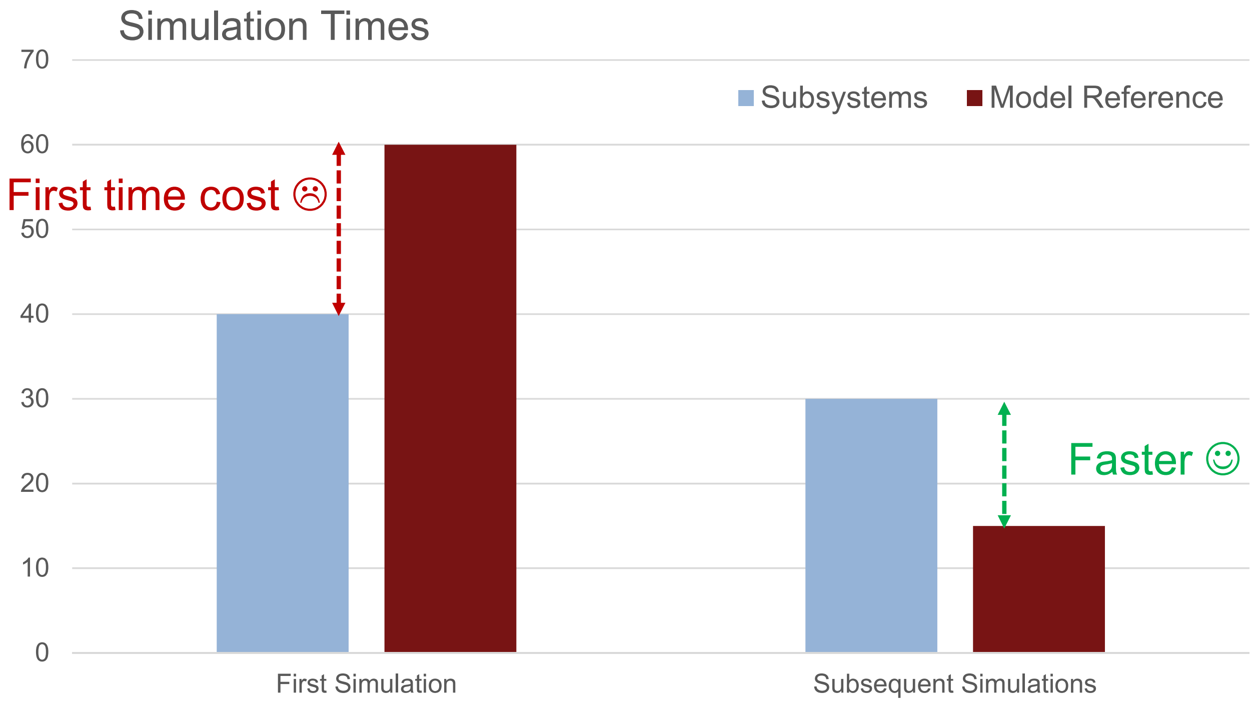
reuse and cache as much as possible

Model reference: incremental workflows

- Incremental Loading
- Incremental Update Diagram
- Incremental Code Generation
- Selective acceleration

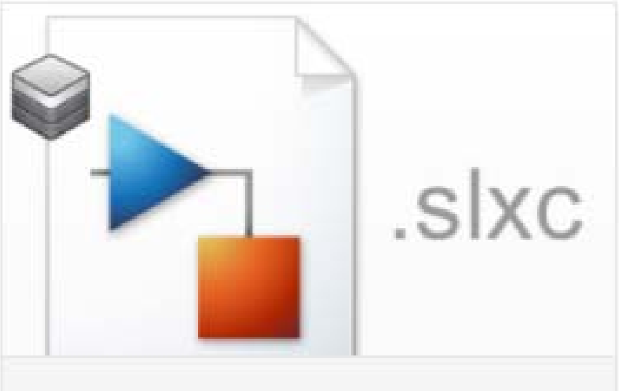


Model Reference: Performance

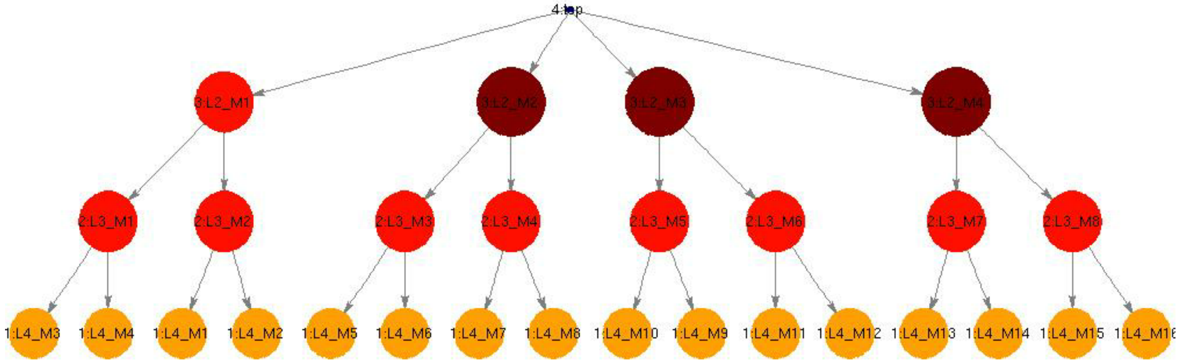


How to reduce first time cost?

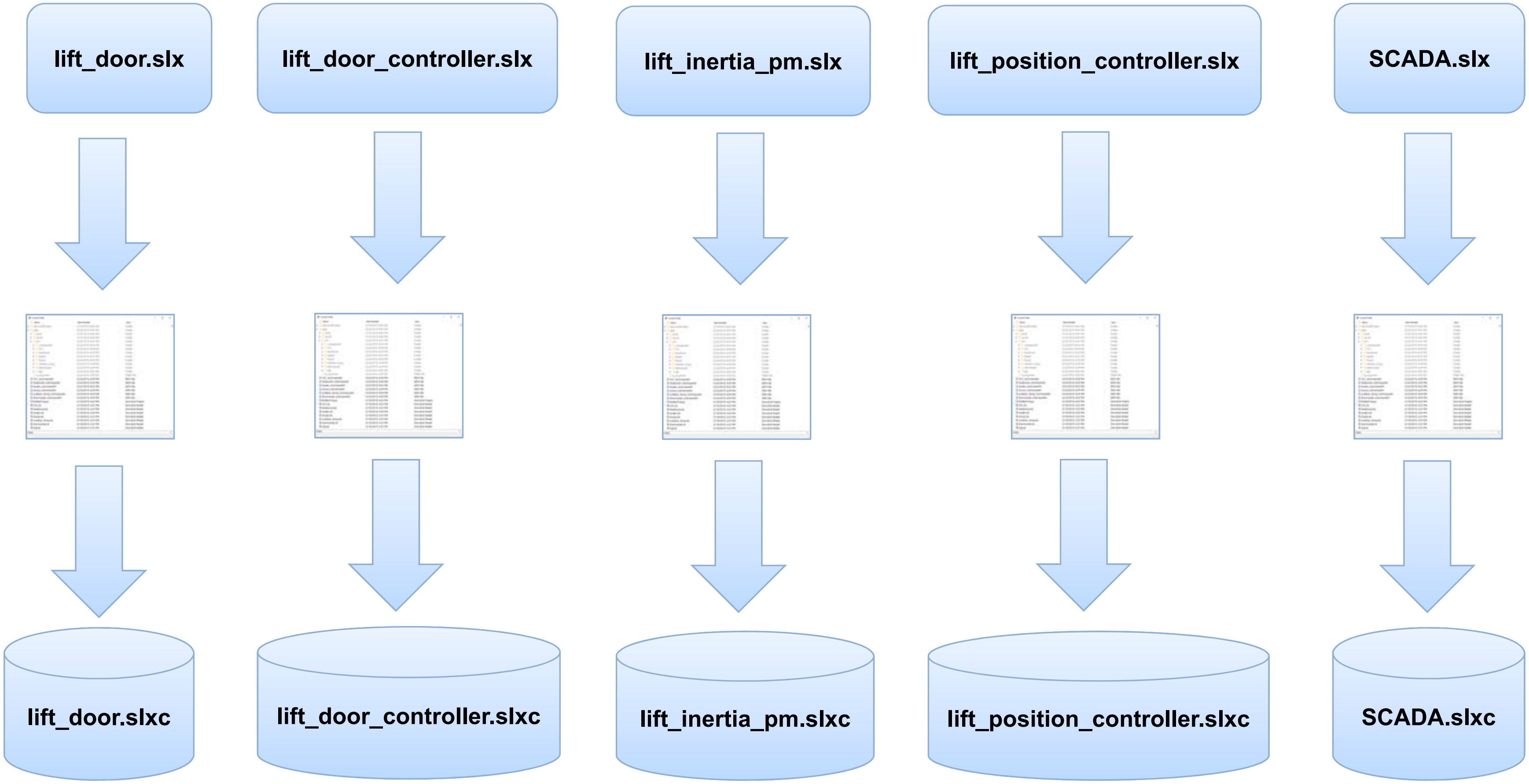
Simulink Cache



Parallel Model Reference Build



Simulink Cache



lift_door.slx

lift_door_controller.slx

lift_inertia_pm.slx

lift_position_controller.slx

SCADA.slx

lift_door.slxc

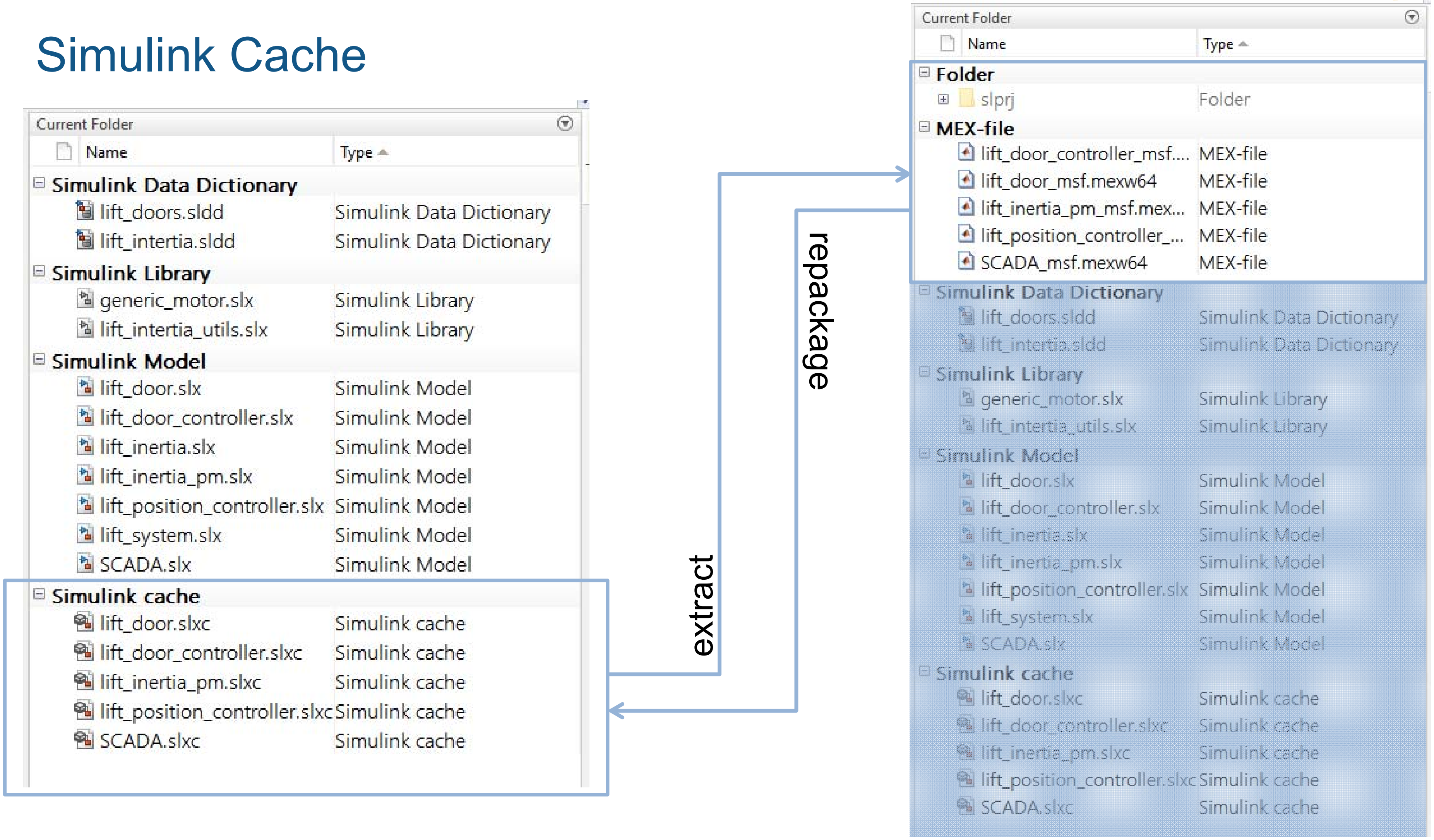
lift_door_controller.slxc

lift_inertia_pm.slxc

lift_position_controller.slxc

SCADA.slxc

Simulink Cache



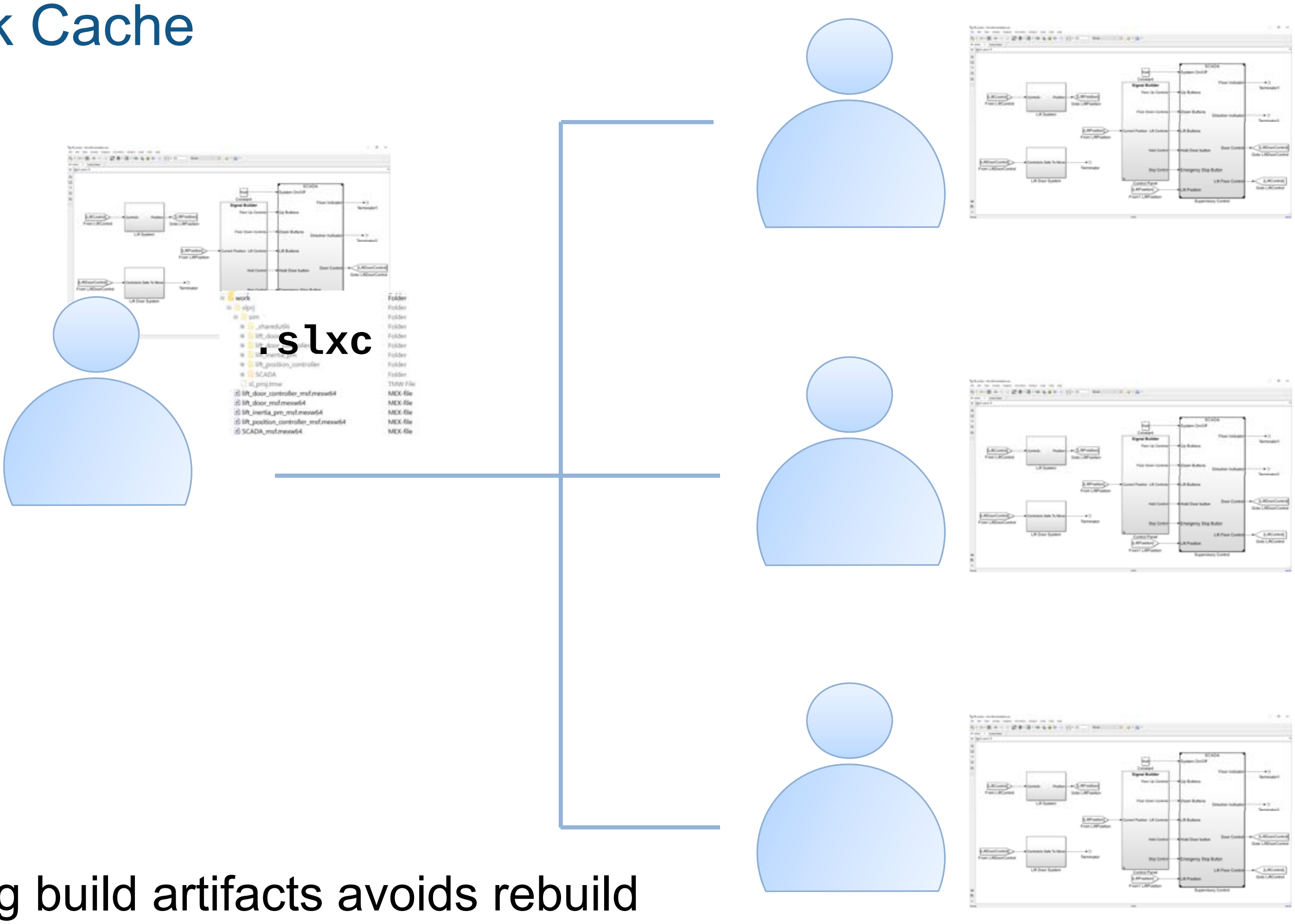
Current Folder

Name	Type
Simulink Data Dictionary	
lift_doors.sldd	Simulink Data Dictionary
lift_intertia.sldd	Simulink Data Dictionary
Simulink Library	
generic_motor.slx	Simulink Library
lift_intertia_utils.slx	Simulink Library
Simulink Model	
lift_door.slx	Simulink Model
lift_door_controller.slx	Simulink Model
lift_inertia.slx	Simulink Model
lift_inertia_pm.slx	Simulink Model
lift_position_controller.slx	Simulink Model
lift_system.slx	Simulink Model
SCADA.slx	Simulink Model
Simulink cache	
lift_door.slxc	Simulink cache
lift_door_controller.slxc	Simulink cache
lift_inertia_pm.slxc	Simulink cache
lift_position_controller.slxc	Simulink cache
SCADA.slxc	Simulink cache

Current Folder

Name	Type
Folder	
slprj	Folder
MEX-file	
lift_door_controller_msf....	MEX-file
lift_door_msf.mexw64	MEX-file
lift_inertia_pm_msf.mex...	MEX-file
lift_position_controller_...	MEX-file
SCADA_msf.mexw64	MEX-file
Simulink Data Dictionary	
lift_doors.sldd	Simulink Data Dictionary
lift_intertia.sldd	Simulink Data Dictionary
Simulink Library	
generic_motor.slx	Simulink Library
lift_intertia_utils.slx	Simulink Library
Simulink Model	
lift_door.slx	Simulink Model
lift_door_controller.slx	Simulink Model
lift_inertia.slx	Simulink Model
lift_inertia_pm.slx	Simulink Model
lift_position_controller.slx	Simulink Model
lift_system.slx	Simulink Model
SCADA.slx	Simulink Model
Simulink cache	
lift_door.slxc	Simulink cache
lift_door_controller.slxc	Simulink cache
lift_inertia_pm.slxc	Simulink cache
lift_position_controller.slxc	Simulink cache
SCADA.slxc	Simulink cache

Simulink Cache



work	Folder
slprj	Folder
sim	Folder
_sharedutils	Folder
lift_door	Folder
lift_door_controller	Folder
lift_inertia_pm	Folder
lift_position_controller	Folder
SCADA	Folder
sl_proj.tmw	TMW File
lift_door_controller_msf.mexw64	MEX-file
lift_door_msf.mexw64	MEX-file
lift_inertia_pm_msf.mexw64	MEX-file
lift_position_controller_msf.mexw64	MEX-file
SCADA_msf.mexw64	MEX-file

- Sharing build artifacts avoids rebuild

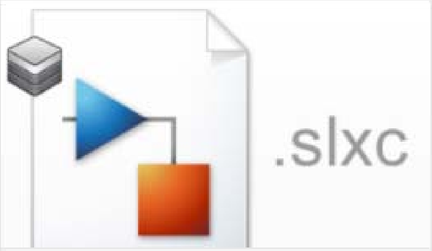
Simulink Cache

Why would Simulink speed up?

- Sharing build artifacts reduces first time cost
- Integrated into Simulink Projects and parsim

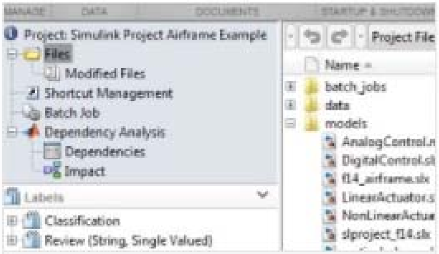
What's the tradeoff?

- Extra work needed to manage `.slxc` files
  - If Simulink Projects is not used



Simulink Cache

Get simulation results faster by using shared model artifacts



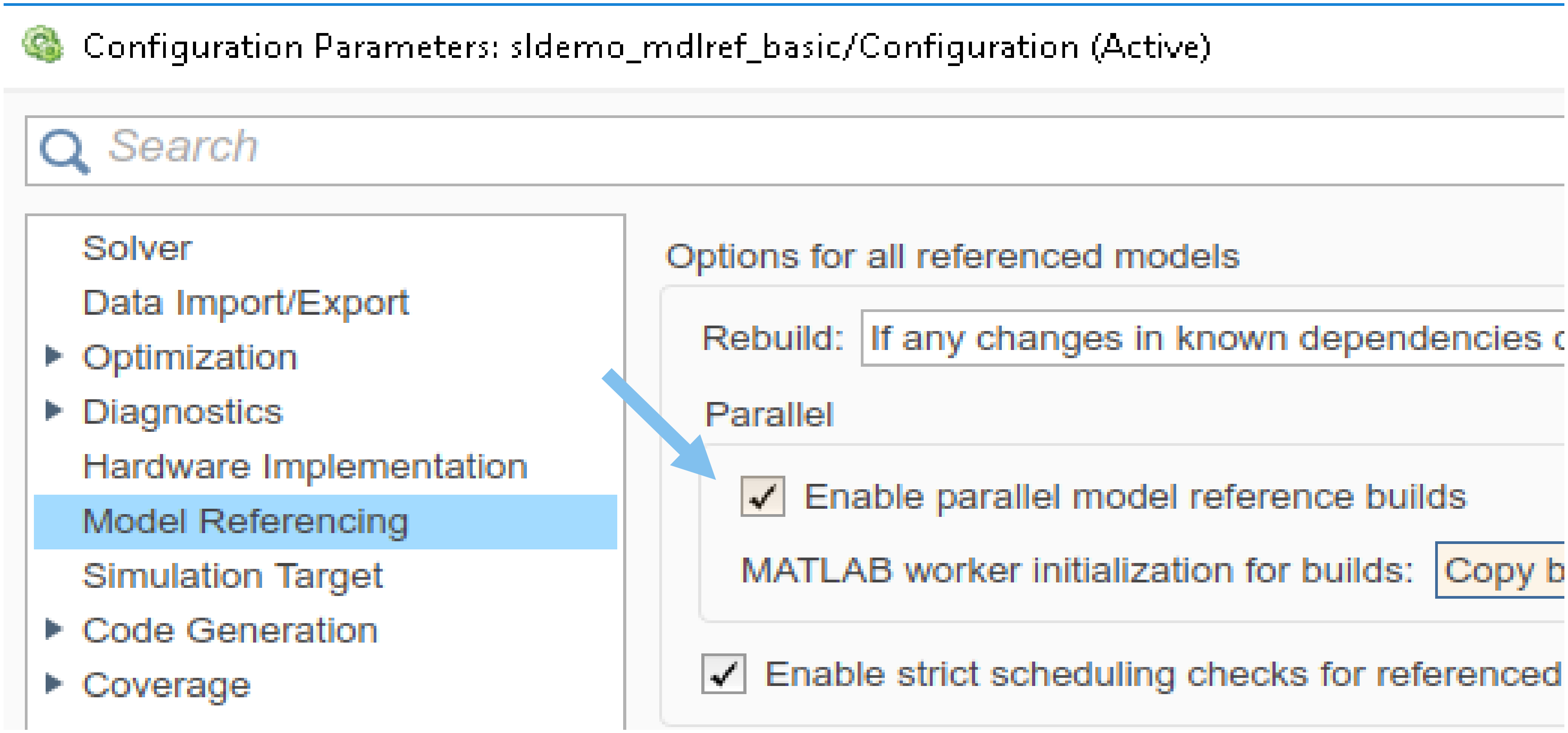
Managing Projects

Develop and share applications as code, executables, or software components.

Help Search: simulink cache

R2017a

Parallel Model Reference Builds



Configuration Parameters: sldemo_mdlref_basic/Configuration (Active)

Options for all referenced models

Rebuild: If any changes in known dependencies c

Parallel

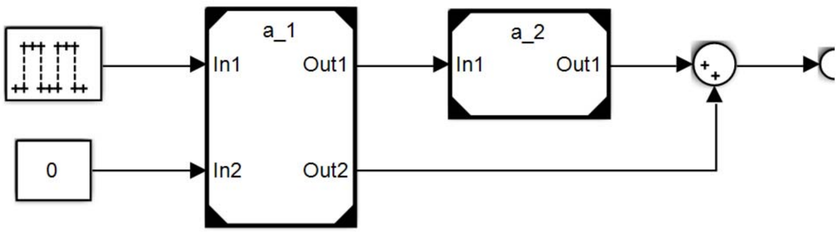
☑ Enable parallel model reference builds

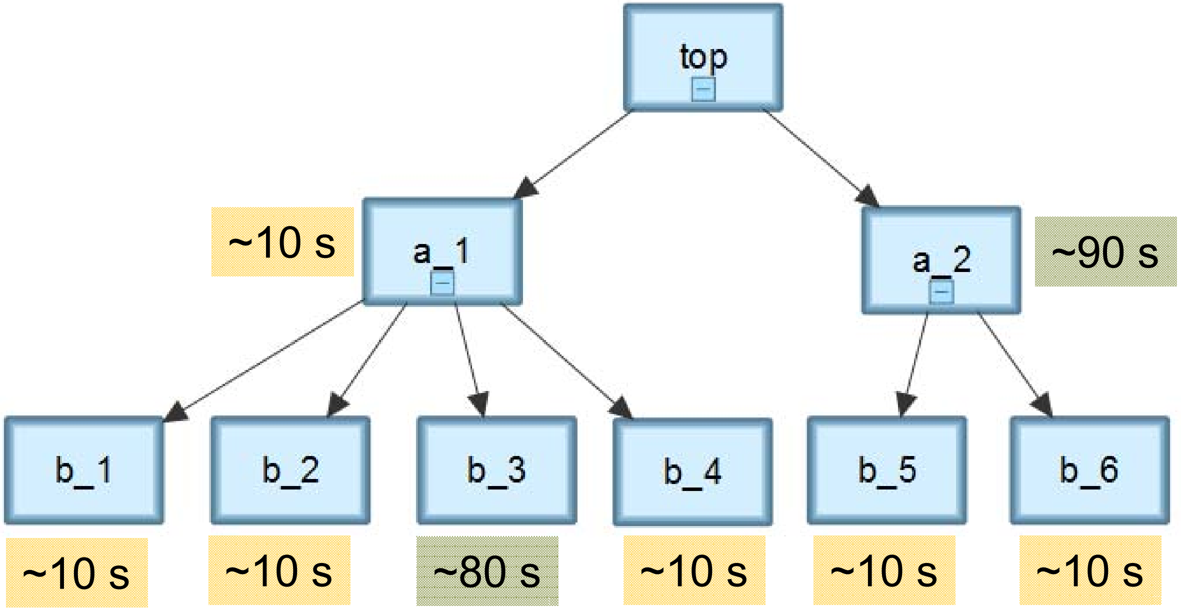
MATLAB worker initialization for builds: Copy b

☑ Enable strict scheduling checks for referenced

Parallel Model Reference Builds

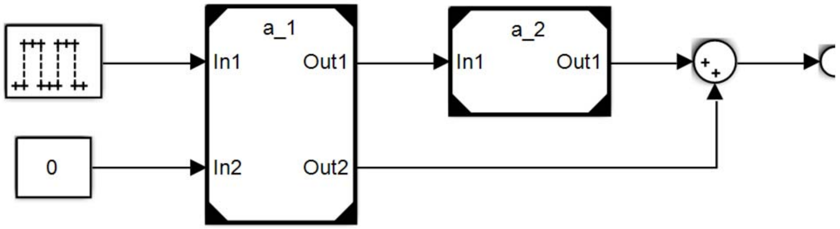
top

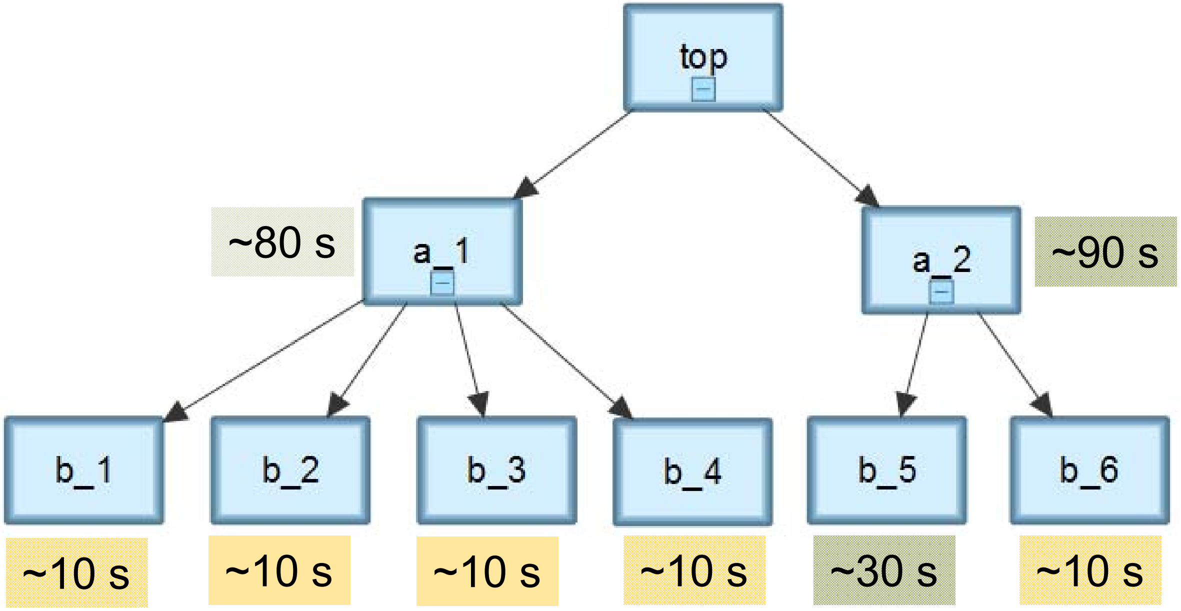




Parallel Model Reference Builds

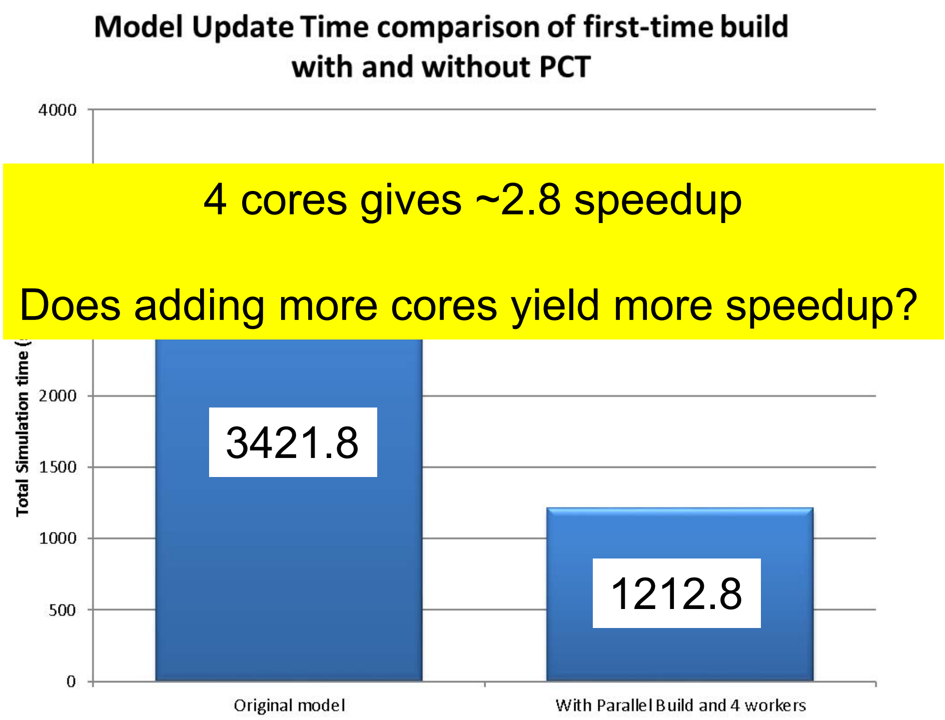
top





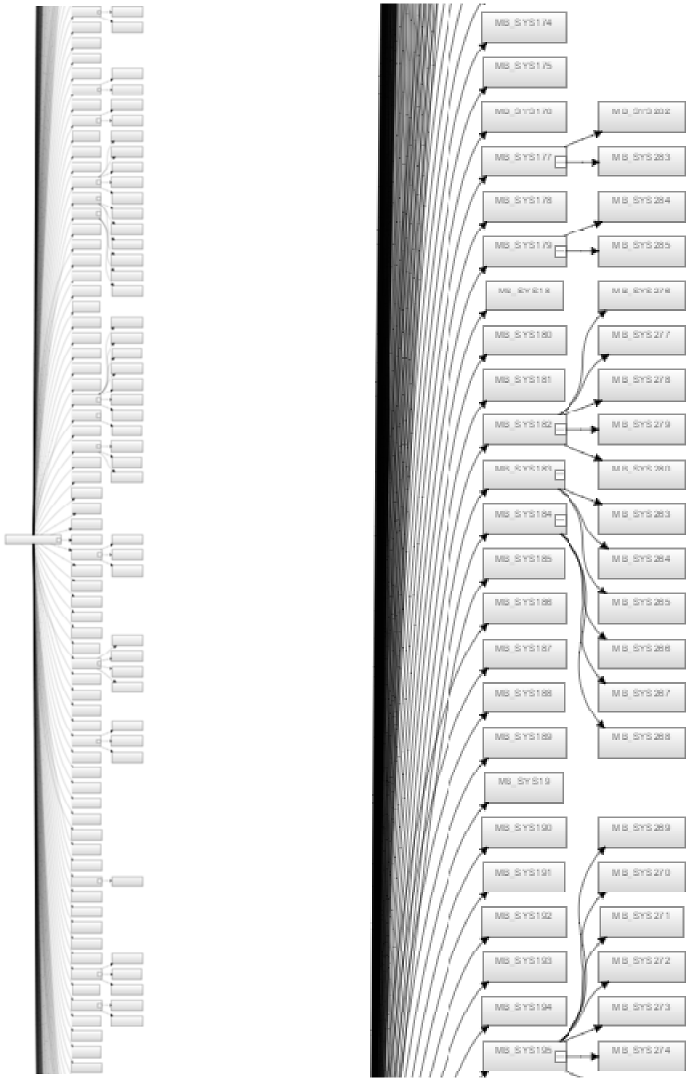
Model Reference Parallel Build
User example

- Approximately 400 referenced models

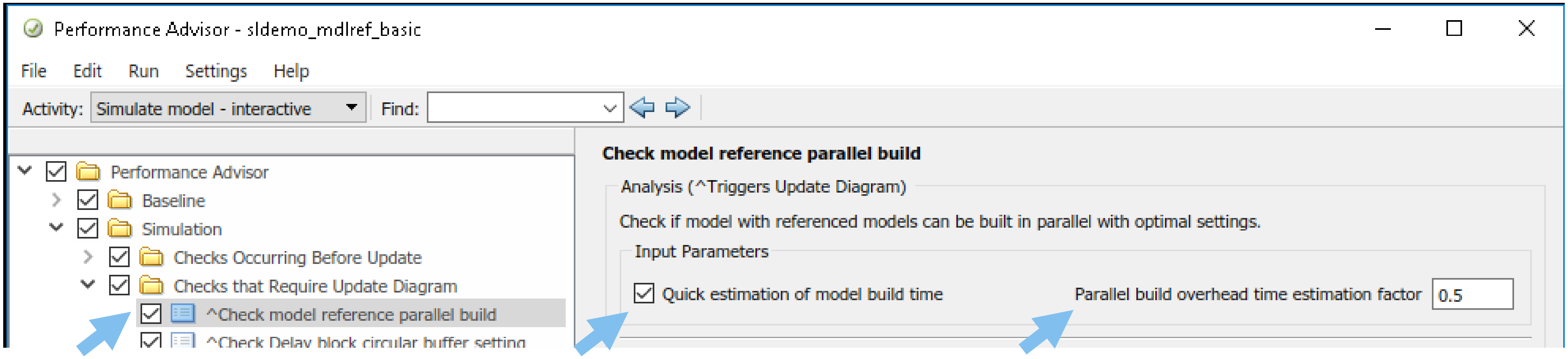


4 cores gives ~2.8 speedup

Does adding more cores yield more speedup?



Performance Advisor: Check model reference parallel build



Performance Advisor - sldemo_mdlref_basic

Activity: Simulate model - interactive

Find:

- ☑ Performance Advisor
  - ☑ Baseline
  - ☑ Simulation
    - ☑ Checks Occurring Before Update
    - ☑ Checks that Require Update Diagram
      - ☑ ^Check model reference parallel build
      - ☑ ^Check Delay block circular buffer setting

Check model reference parallel build

Analysis (^Triggers Update Diagram)

Check if model with referenced models can be built in parallel with optimal settings.

Input Parameters

☑ Quick estimation of model build time

Parallel build overhead time estimation factor: 0.5

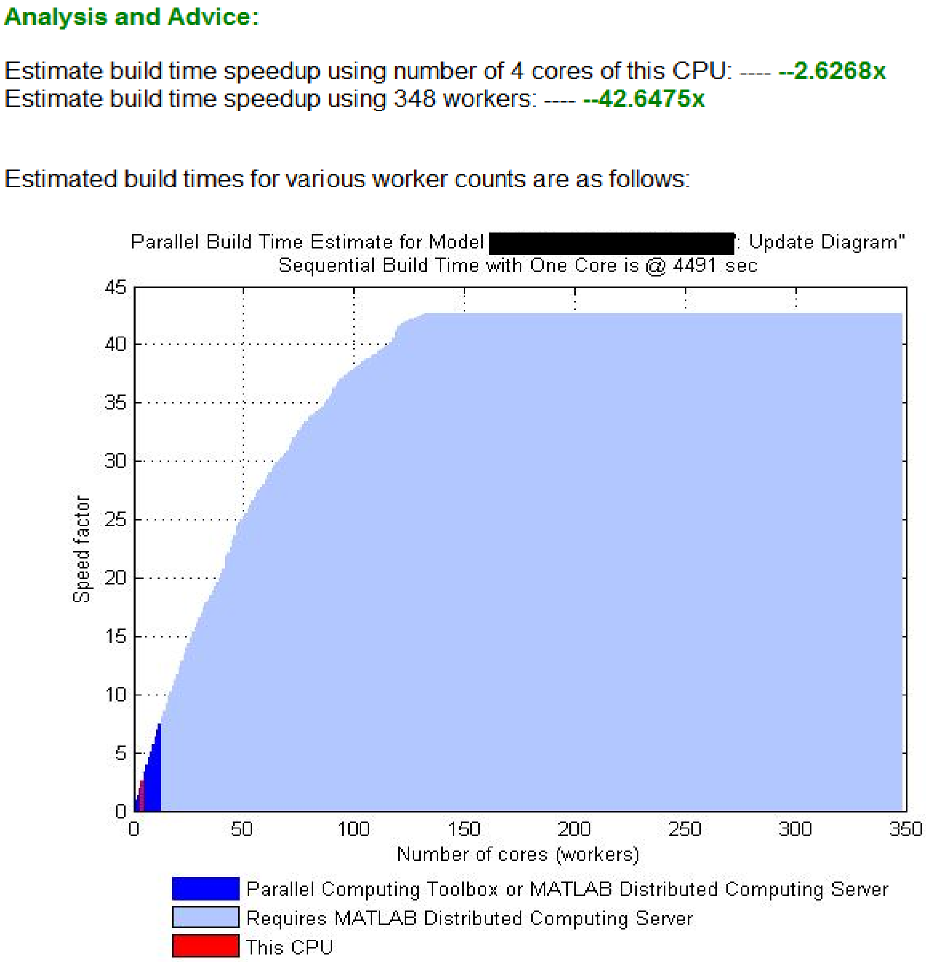
Performance Advisor: Check model reference parallel build

- Performance Advisor estimates the speedup with more cores

- The estimated speed up with 4 cores is ~2.6
  - Close to the measured value ~2.8

- Given ~120 cores, the estimated speed up is ~42

  => Build time goes from ~3400s to ~80s



Analysis and Advice:

Estimate build time speedup using number of 4 cores of this CPU: ---- **--2.6268x**
Estimate build time speedup using 348 workers: ---- **--42.6475x**

Estimated build times for various worker counts are as follows:

Parallel Build Time Estimate for Model [redacted]: Update Diagram"
Sequential Build Time with One Core is @ 4491 sec
Speed factor
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250
300
350
Number of cores (workers)
Parallel Computing Toolbox or MATLAB Distributed Computing Server
Requires MATLAB Distributed Computing Server
This CPU

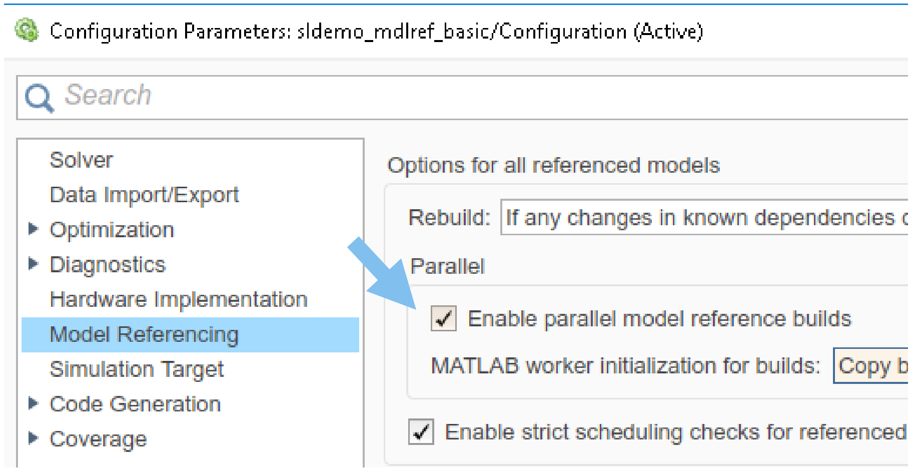
Model Reference Parallel Build

Why would Simulink speed up?

- Model reference targets are built in parallel
- Use Performance Advisor to check if your large models can benefit from this option

What's the tradeoff?

- Speedup is model dependent
- Requires MATLAB Parallel Computing



Configuration Parameters: sldemo_mdlref_basic/Configuration (Active)

Options for all referenced models

Rebuild: If any changes in known dependencies c

Parallel

☑ Enable parallel model reference builds

MATLAB worker initialization for builds: Copy b

☑ Enable strict scheduling checks for referenced

R2012b

Help Search: model reference parallel build

Questions

Agenda

- Typical use cases
- Accelerator mode
- Performance Advisor
- Fast Restart and parsim
- Incremental workflows
- Solver Profiler

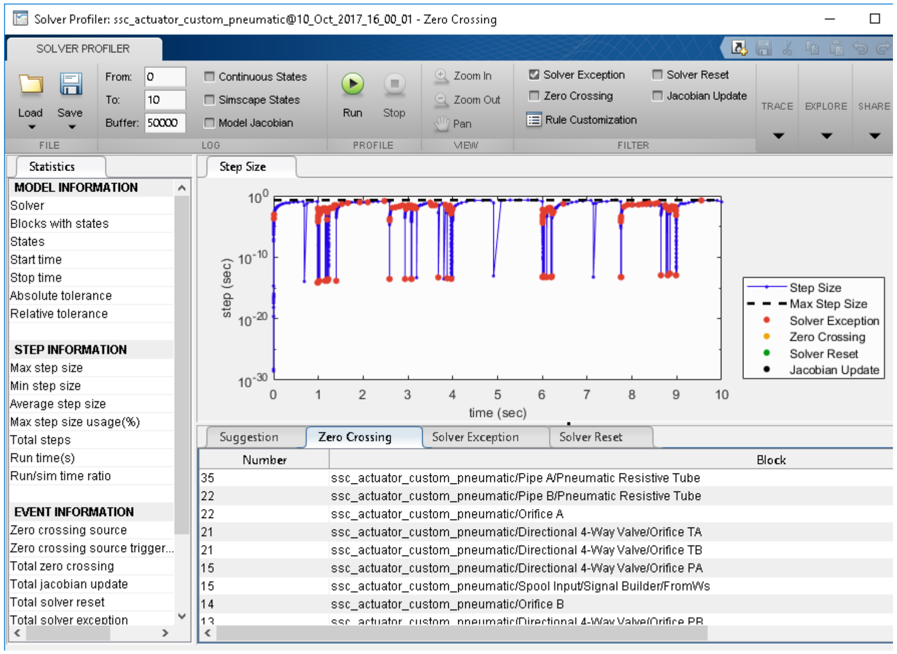
Solver Profiler

Why would Simulink speed up?

- Identifies parts of the model causing solver to slow down
  - too many resets
  - too many zero crossings etc.

What's the tradeoff?

- Profiling overhead
- Requires domain knowledge to optimally fix the issues identified by the Solver profiler.



Solver Profiler: ssc_actuator_custom_pneumatic@10_Oct_2017_16_00_01 - Zero Crossing

From: 0
To: 10
Buffer: 50000

□ Continuous States
□ Simscape States
□ Model Jacobian

☑ Solver Exception
□ Zero Crossing
□ Solver Reset
□ Jacobian Update
Rule Customization

MODEL INFORMATION
Solver
Blocks with states
States
Start time
Stop time
Absolute tolerance
Relative tolerance

STEP INFORMATION
Max step size
Min step size
Average step size
Max step size usage(%)
Total steps
Run time(s)
Run/sim time ratio

EVENT INFORMATION
Zero crossing source
Zero crossing source trigger...
Total zero crossing
Total jacobian update
Total solver reset
Total solver exception

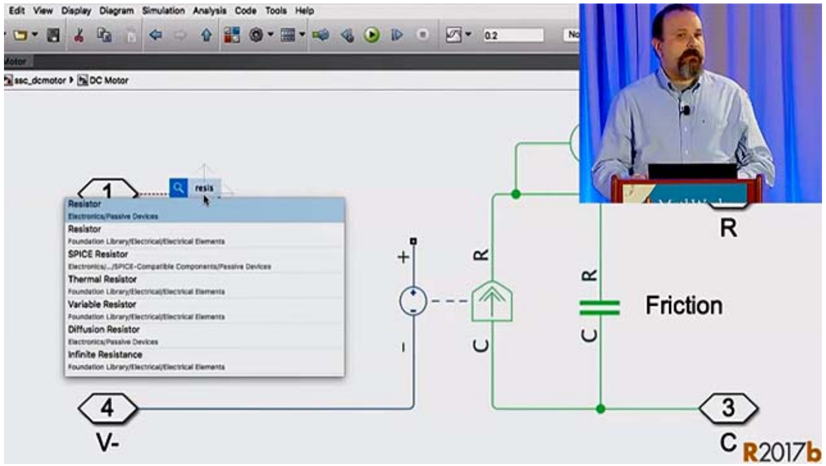
Number	Block
35	ssc_actuator_custom_pneumatic/Pipe A/Pneumatic Resistive Tube
22	ssc_actuator_custom_pneumatic/Pipe B/Pneumatic Resistive Tube
22	ssc_actuator_custom_pneumatic/Orifice A
21	ssc_actuator_custom_pneumatic/Directional 4-Way Valve/Orifice TA
21	ssc_actuator_custom_pneumatic/Directional 4-Way Valve/Orifice TB
15	ssc_actuator_custom_pneumatic/Directional 4-Way Valve/Orifice PA
15	ssc_actuator_custom_pneumatic/Spool Input/Signal Builder/FromWs
14	ssc_actuator_custom_pneumatic/Orifice B
13	ssc_actuator_custom_pneumatic/Directional 4-Way Valve/Orifice PB

Help Search: solver profiler

R2016a

Summary

Use Case	Recommended Features	
Edit-Sim-Repeat	Normal mode Accelerator mode	Smart Editing Model Reference Simulation Data Inspector Solver Profiler
Tune-Sim-Repeat	Performance Advisor Fast Restart Accelerator + Fast Restart	
Multi-Sim	parsim parsim + Accelerator + Fast Restart parsim + Rapid Accelerator + Up-To-Date-Check-Off	


Edit View Display Diagram Simulation Analysis Code Tools Help
0.2
Motor
ssc_dcmotor ▸ DC Motor
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Electronics/Passive Devices
Resistor
Foundation Library/Electrical/Electrical Elements
SPICE Resistor
Electronics/.../SPICE-Compatible Components/Passive Devices
Thermal Resistor
Foundation Library/Electrical/Electrical Elements
Variable Resistor
Foundation Library/Electrical/Electrical Elements
Diffusion Resistor
Electronics/Passive Devices
Infinite Resistance
Foundation Library/Electrical/Electrical Elements
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R2017b

[Editing at the Speed of Thought with Simulink]

Learn about the latest smart editing features that have been added to Simulink to increase your modeling speed.

Thank you