

ME40064: System Modelling & Simulation

ME50344: Engineering Systems Simulation

Lecture 20

Dr Andrew Cookson
University of Bath, October 2018

LECTURE 20

Optimisation In Simulink

- Using the response optimisation toolkit in Simulink

OPTIMISATION IN SIMULINK

Response Optimisation Toolkit

The response optimisation toolkit allows the user to optimise the output of a Simulink dynamical system model/control system against a target design requirement

Target requirements can be selected for both time-domain and frequency-domain

Built-in target time-domain target requirements include step response, reference signal tracking, signal bounds

Custom target requirements can also be specified by the user

In this tutorial we will look at how to specify a step-response characteristic and optimise our model parameters for this characteristic

OPTIMISATION IN SIMULINK

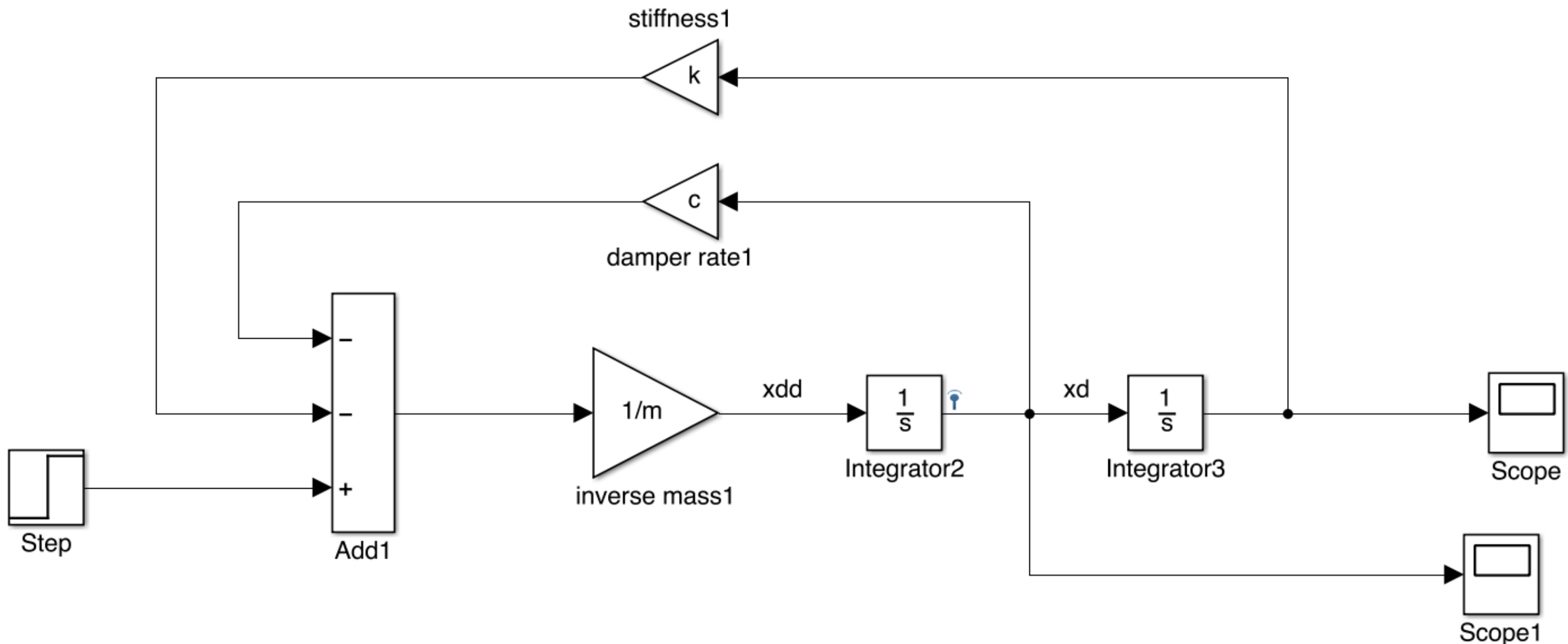
Step Response Optimisation

Open up your mass-spring-damper system model

OPTIMISATION IN SIMULINK

Step Response Optimisation

Open up your mass-spring-damper system model

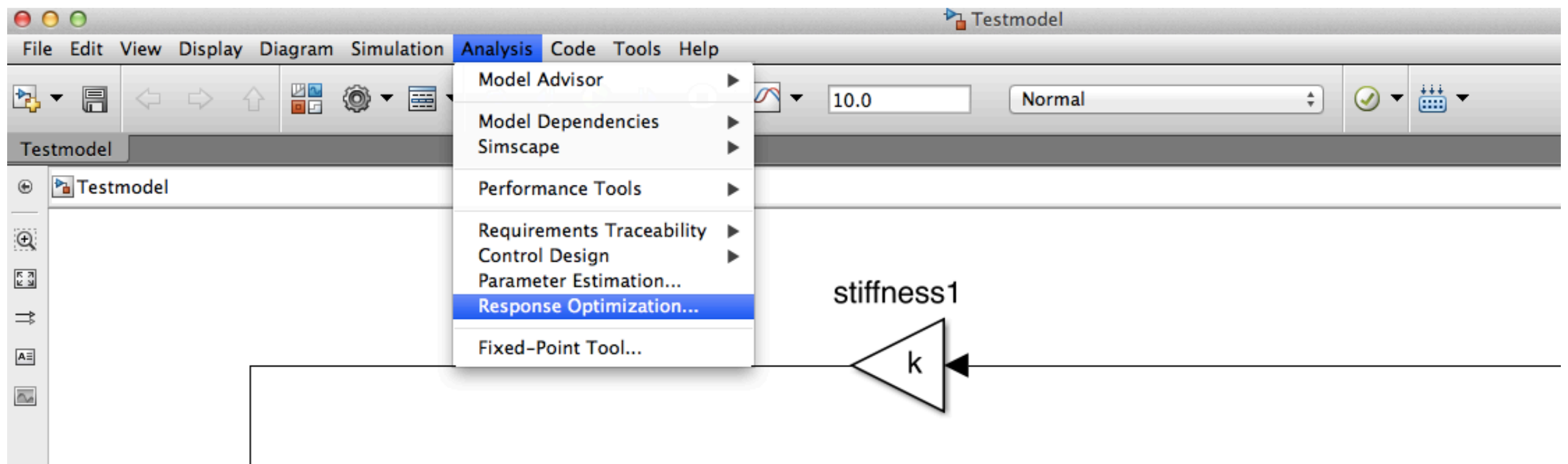


Set the variables $m = 250$, $c=1000$, $k=20000$ in the Matlab command line as before

OPTIMISATION IN SIMULINK

Step Response Optimisation

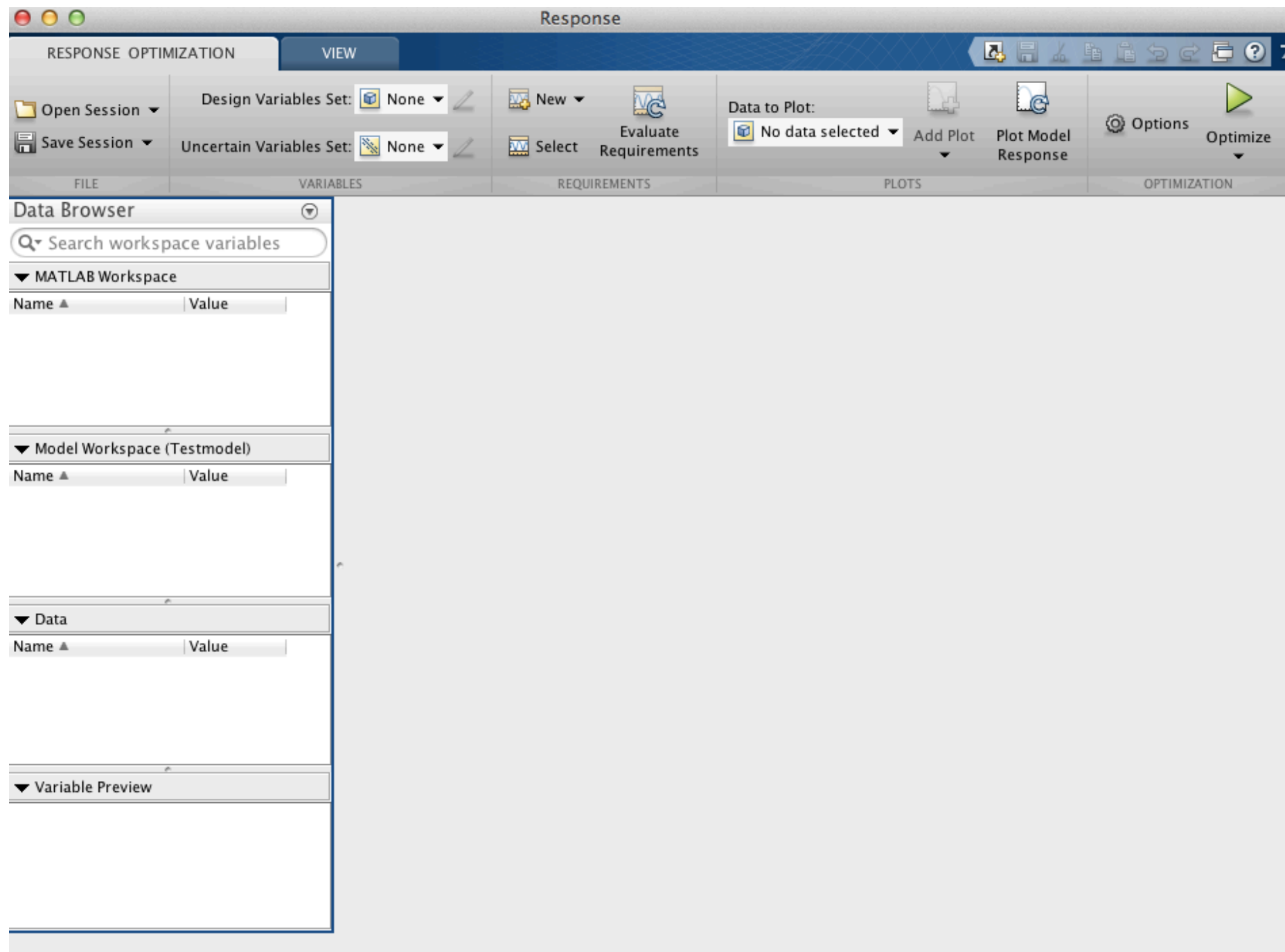
Select the Response Optimisation toolkit from the Menu: Analysis



OPTIMISATION IN SIMULINK

Step Response Optimisation

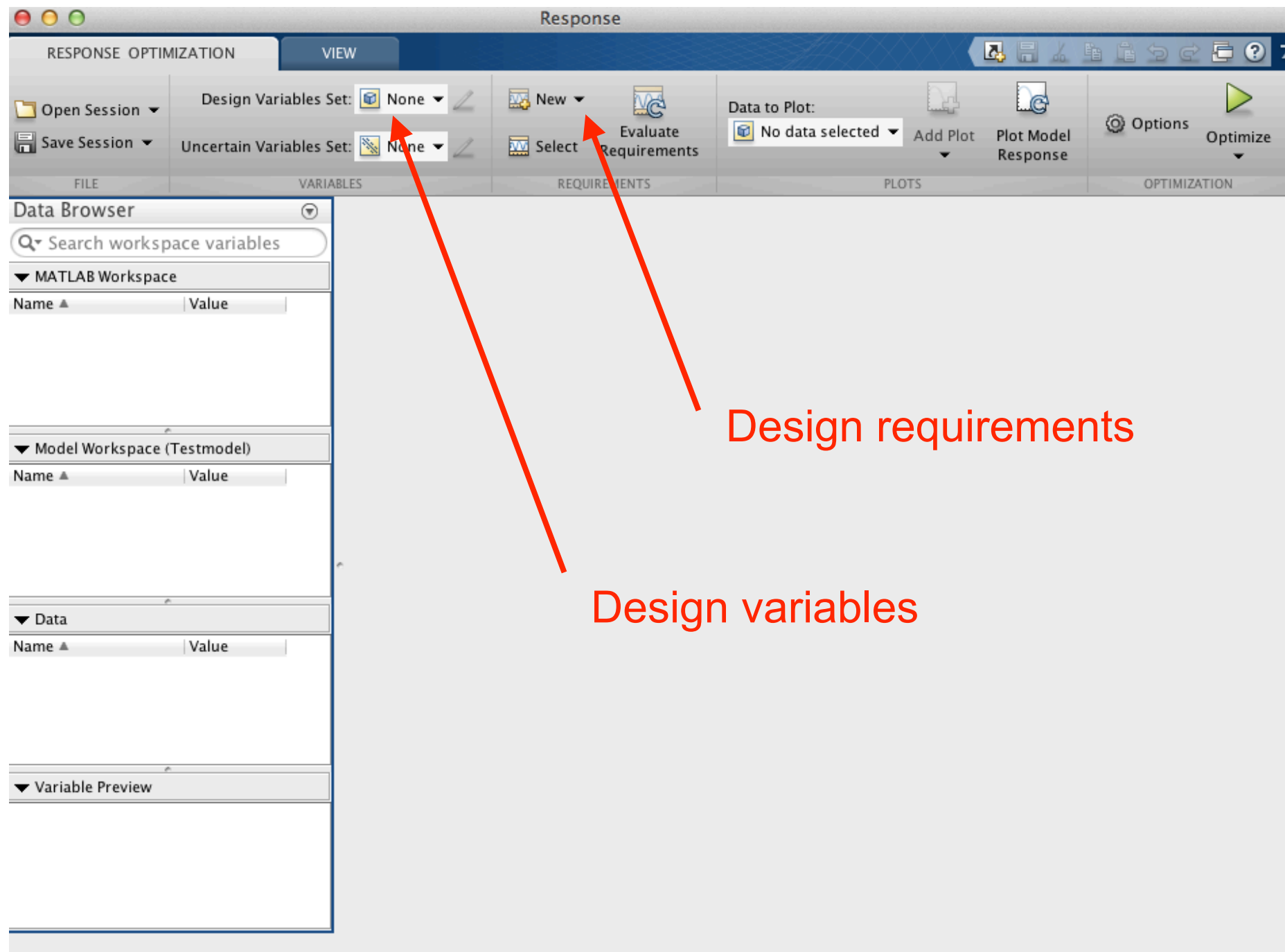
The following window should open:



OPTIMISATION IN SIMULINK

Step Response Optimisation

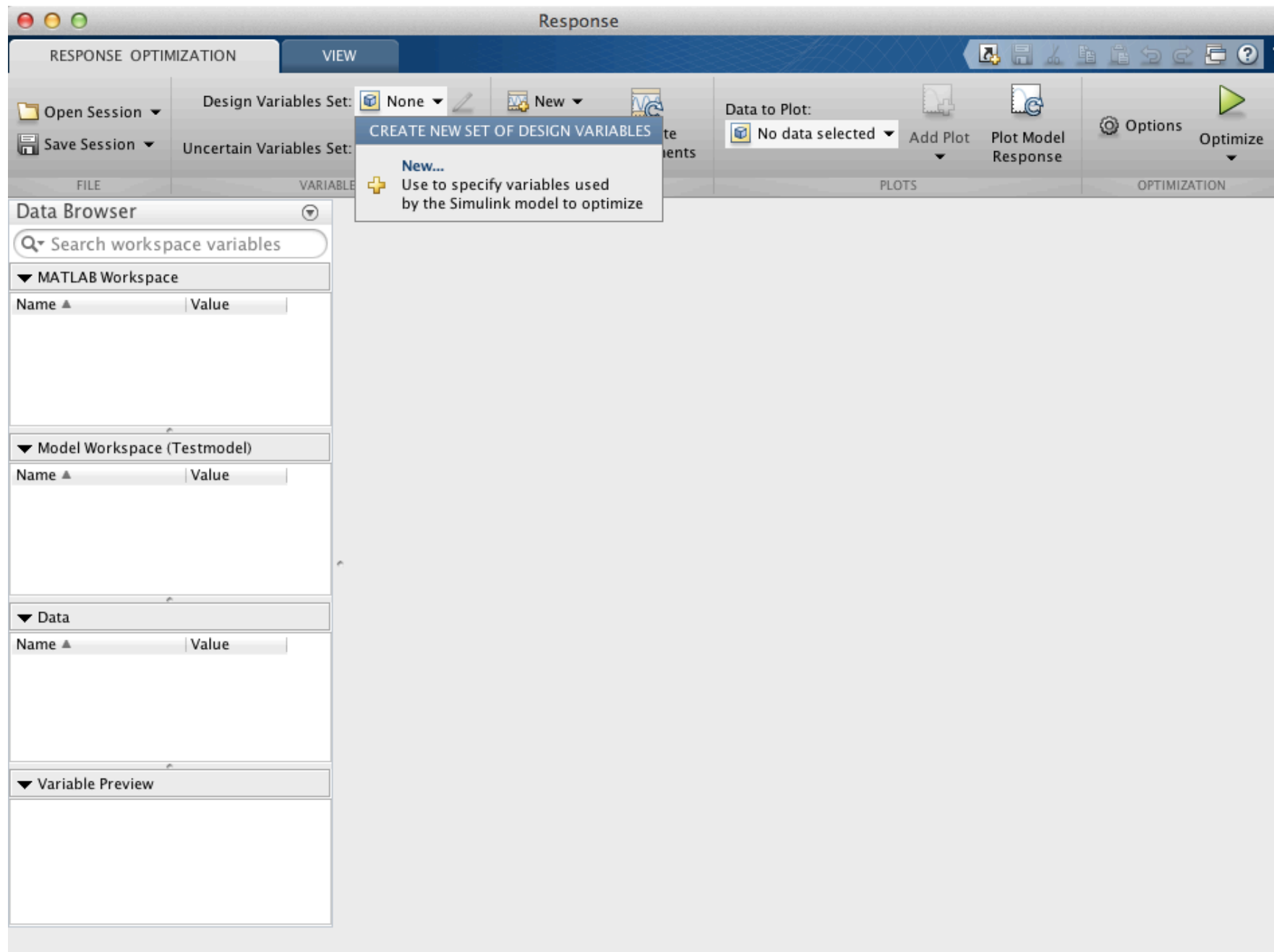
The following window should open:



OPTIMISATION IN SIMULINK

Step Response Optimisation

Set the design variables - these are the parameters in the model that the optimiser can vary to meet the design requirement

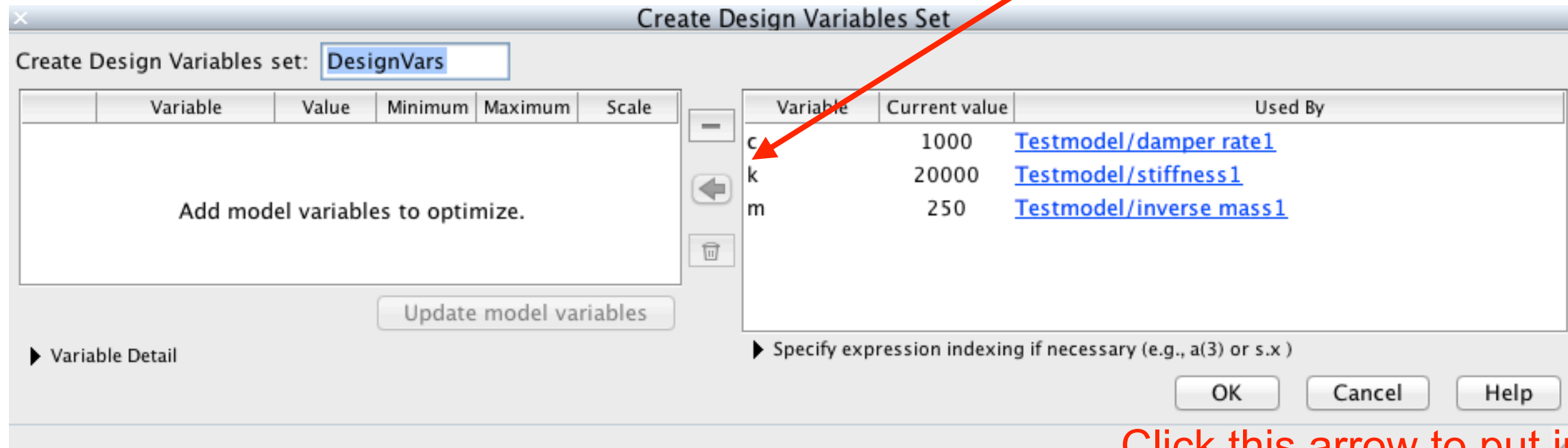


OPTIMISATION IN SIMULINK

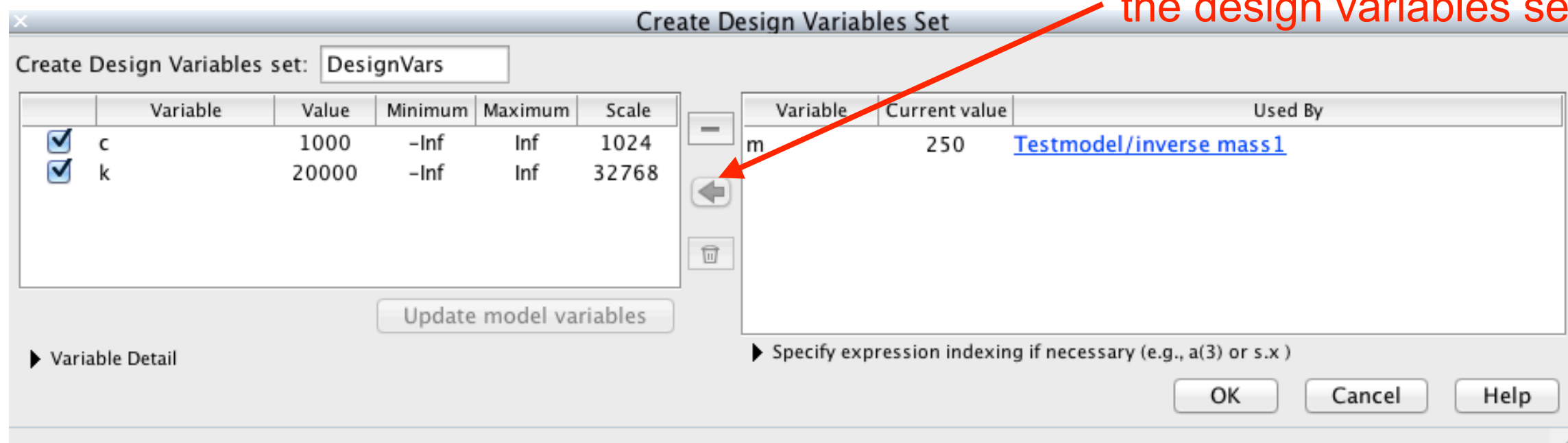
Step Response Optimisation

Set the design variables - these are the parameters in the model that the optimiser can vary to meet the design requirement

Select c and k - we assume m to be fixed



Click this arrow to put in the design variables set



OPTIMISATION IN SIMULINK

Step Response Optimisation

Can set upper and lower bounds on the feasible values for the design variables

Upper bound - maximum allowed value of c

Lower bound - minimum allowed value of k

Create Design Variables Set

Create Design Variables set:

	Variable	Value	Minimum	Maximum	Scale
<input checked="" type="checkbox"/>	c	1000	-Inf	Inf	1024
<input checked="" type="checkbox"/>	k	20000	-Inf	Inf	32768

Update model variables

Variable Detail

Variable	Current value	Used By
m	250	Testmodel/inverse mass 1

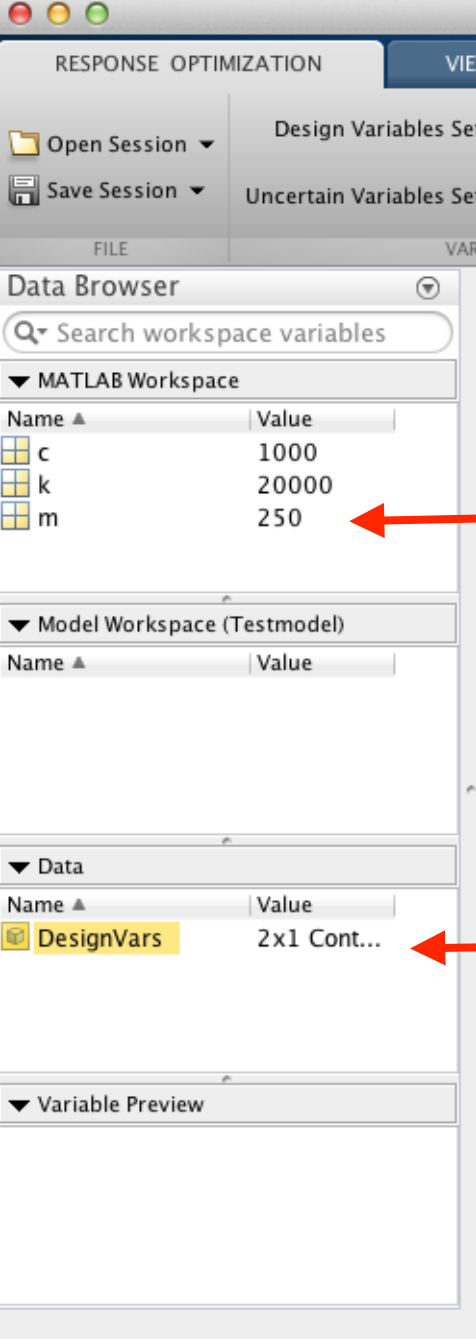
Specify expression indexing if necessary (e.g., a(3) or s.x)

OK Cancel Help

OPTIMISATION IN SIMULINK

Step Response Optimisation

These variables can now all be seen in the Data Browser on the left of the window



The screenshot shows the 'RESPONSE OPTIMIZATION' window in Simulink. On the left is the 'Data Browser' panel. It has a search bar 'Search workspace variables'. Below it are three expandable sections: 'MATLAB Workspace', 'Model Workspace (Testmodel)', and 'Data'. The 'MATLAB Workspace' section is expanded, showing a table with two columns: 'Name' and 'Value'. It lists three variables: 'c' with value 1000, 'k' with value 20000, and 'm' with value 250. A red arrow points from the text 'Workspace variables' to this table. The 'Data' section is also expanded, showing a table with 'Name' and 'Value' columns. It lists one variable: 'DesignVars' with value '2x1 Cont...'. A red arrow points from the text 'Design variables' to this entry. The 'Model Workspace (Testmodel)' section is collapsed. At the bottom is a 'Variable Preview' section, also collapsed.

Name	Value
c	1000
k	20000
m	250

Workspace variables

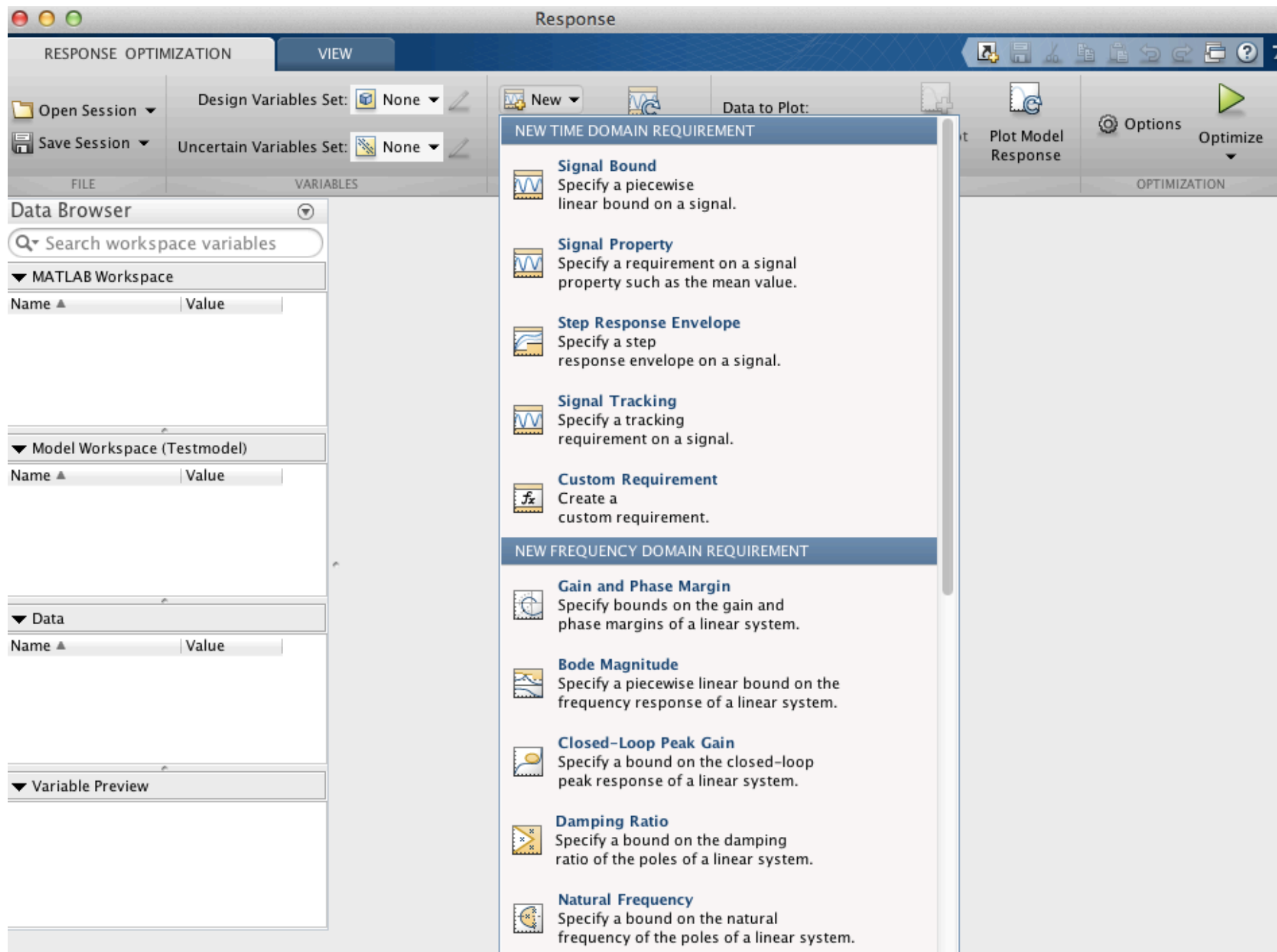
Name	Value
DesignVars	2x1 Cont...

Design variables

OPTIMISATION IN SIMULINK

Step Response Optimisation

Select the Step Response Envelope from the design requirement drop down list



OPTIMISATION IN SIMULINK

Step Response Optimisation

Step Response Envelope menu:

Create Requirement

Step Response Envelope

Specify a step response envelope on a signal.

Name:

▼ Specify Step Response Characteristics

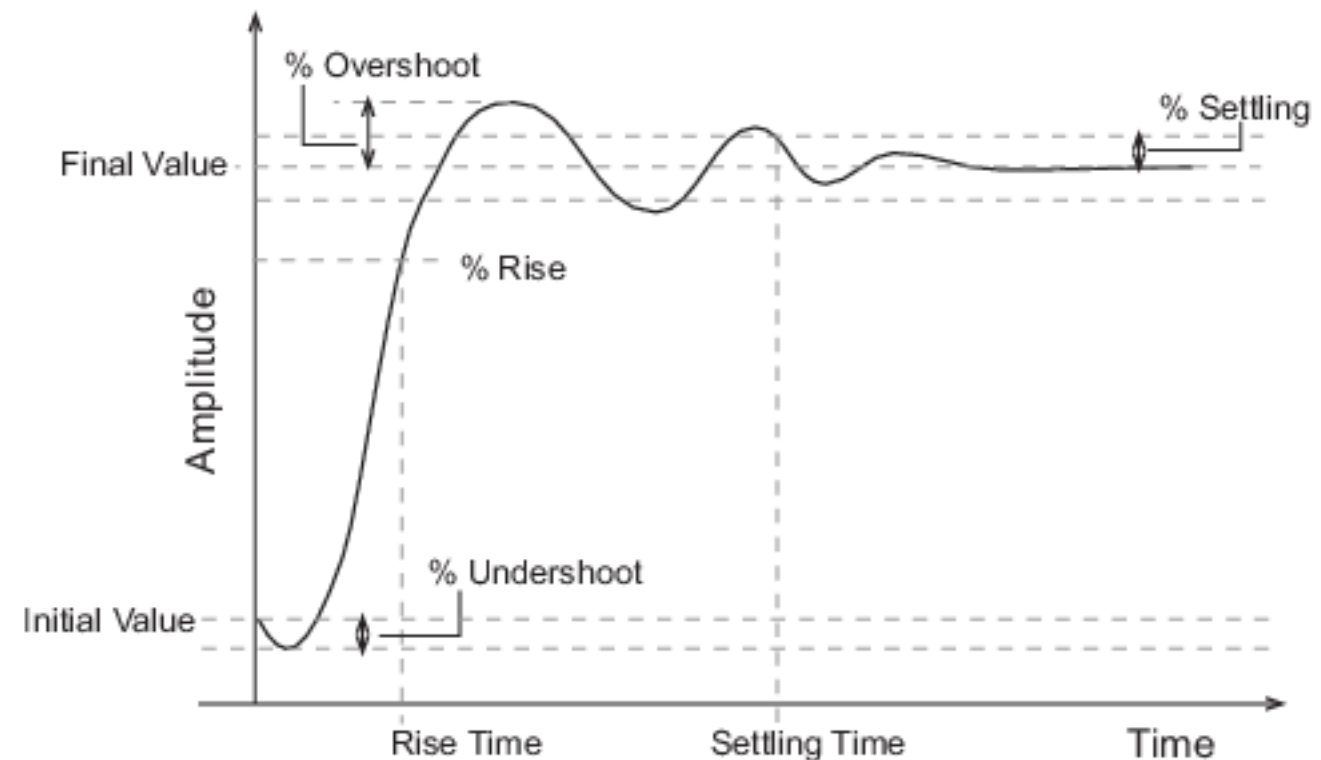
Initial value:	<input type="text" value="0"/>	Final value:	<input type="text" value="1"/>
Step time :	<input type="text" value="0"/> seconds		
Rise time :	<input type="text" value="5"/> seconds	% Rise:	<input type="text" value="80"/>
Settling time :	<input type="text" value="7"/> seconds	% Settling:	<input type="text" value="1.0000"/>
% Overshoot:	<input type="text" value="10.0000"/>	% Undershoot:	<input type="text" value="1"/>

▼ Select Signals to Bound

Signal
<div>Create a signal logging definition so that it can be used in requirements.</div>

☒ Create Plot

OK Cancel Help



OPTIMISATION IN SIMULINK

Step Response Optimisation

Initial value: Input level before the step occurs

Step time: Time at which the step takes place

Final value: Input level after the step occurs

Rise time: The time taken for the response signal to reach a specified percentage of the step's range. The step's range is the *difference* between the *final* and *initial* values.

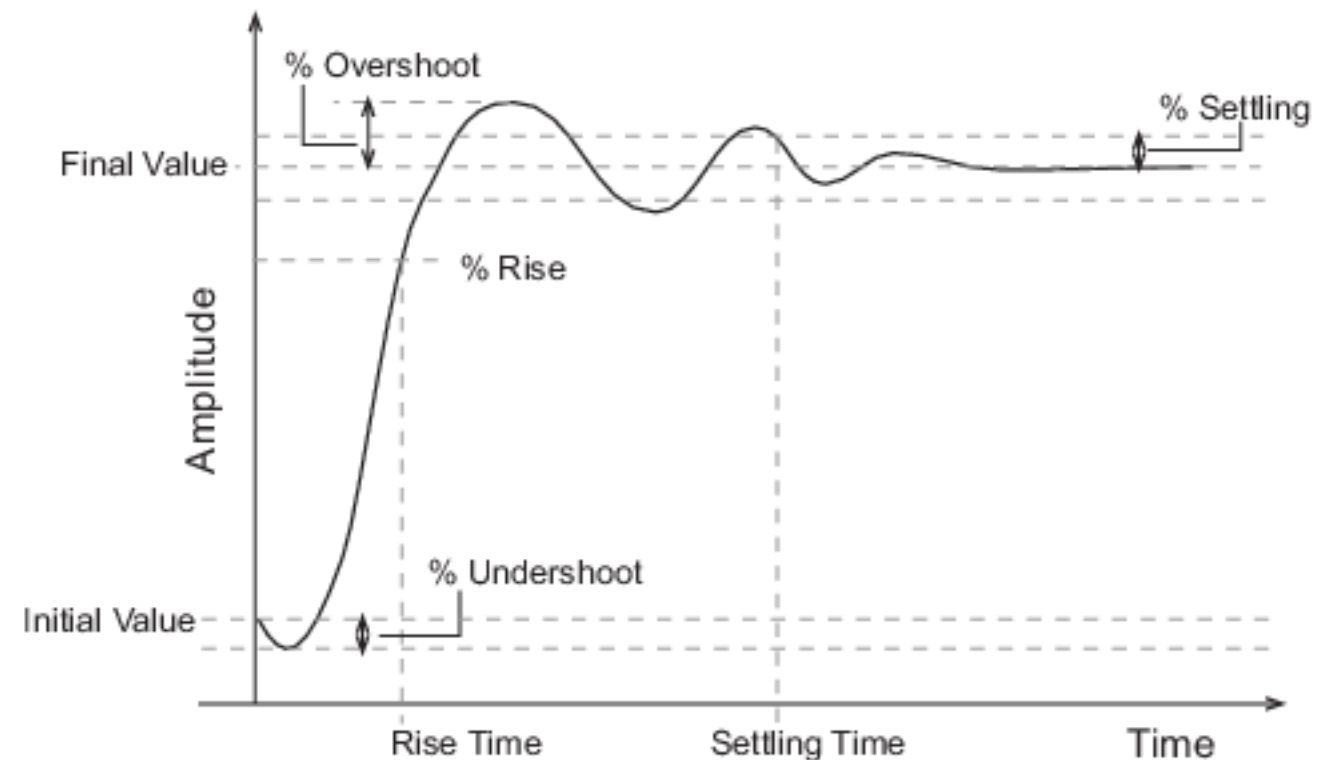
% Rise: The percentage used in the *rise time*.

Settling time: The time taken until the response signal settles within a specified region around the final value. This *settling region* is defined as the final step value *plus or minus* the *specified percentage of the final value*.

% Settling: The percentage used in the *settling time*.

% Overshoot: The amount by which the response signal can exceed the final value. This amount is specified as a percentage of the step's range. The step's range is the difference between the final and initial values.

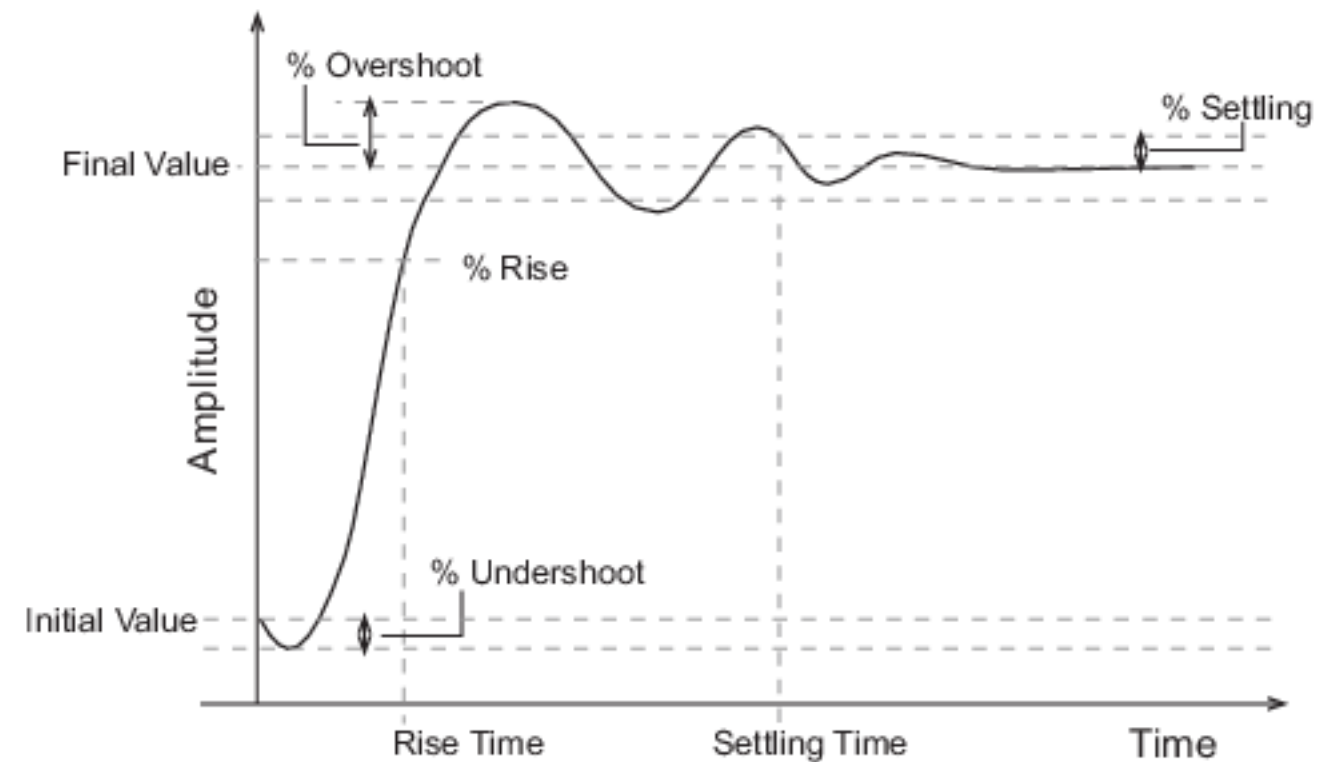
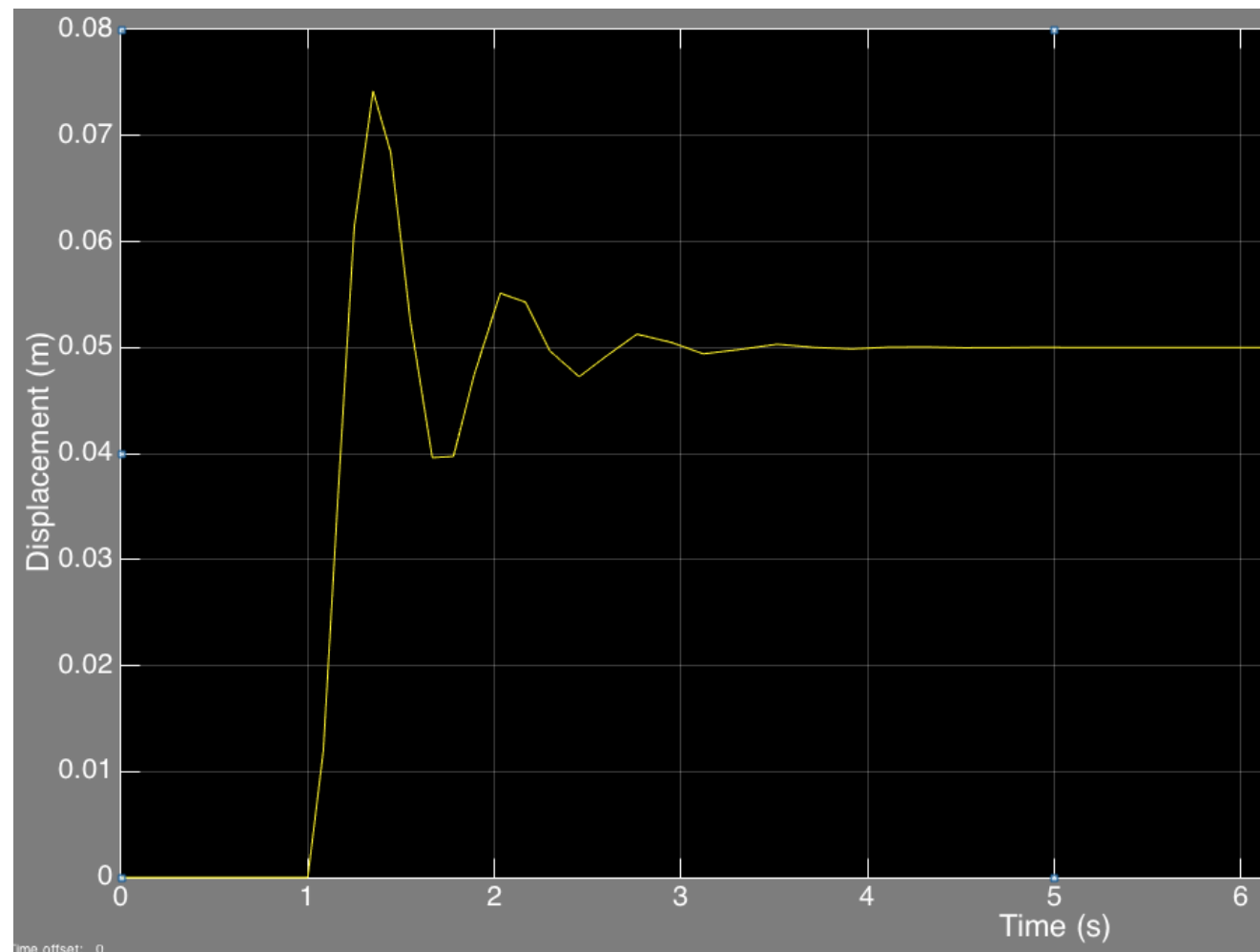
% Undershoot: The amount by which the response signal can undershoot the initial value. This amount is specified as a percentage of the step's range. The step's range is the difference between the final and initial values.



OPTIMISATION IN SIMULINK

Step Response Optimisation

With the existing parameters, under a step input force = 1000N at $t=1$ s, this model responds with the following displacement curve:



We will proceed to specify a tighter bound on this step function response

OPTIMISATION IN SIMULINK

Step Response Optimisation

We will set the following values of the target step function response:

Initial value: 0.0

Step time: 1.0

Final value: 0.05

Rise time: 0.25

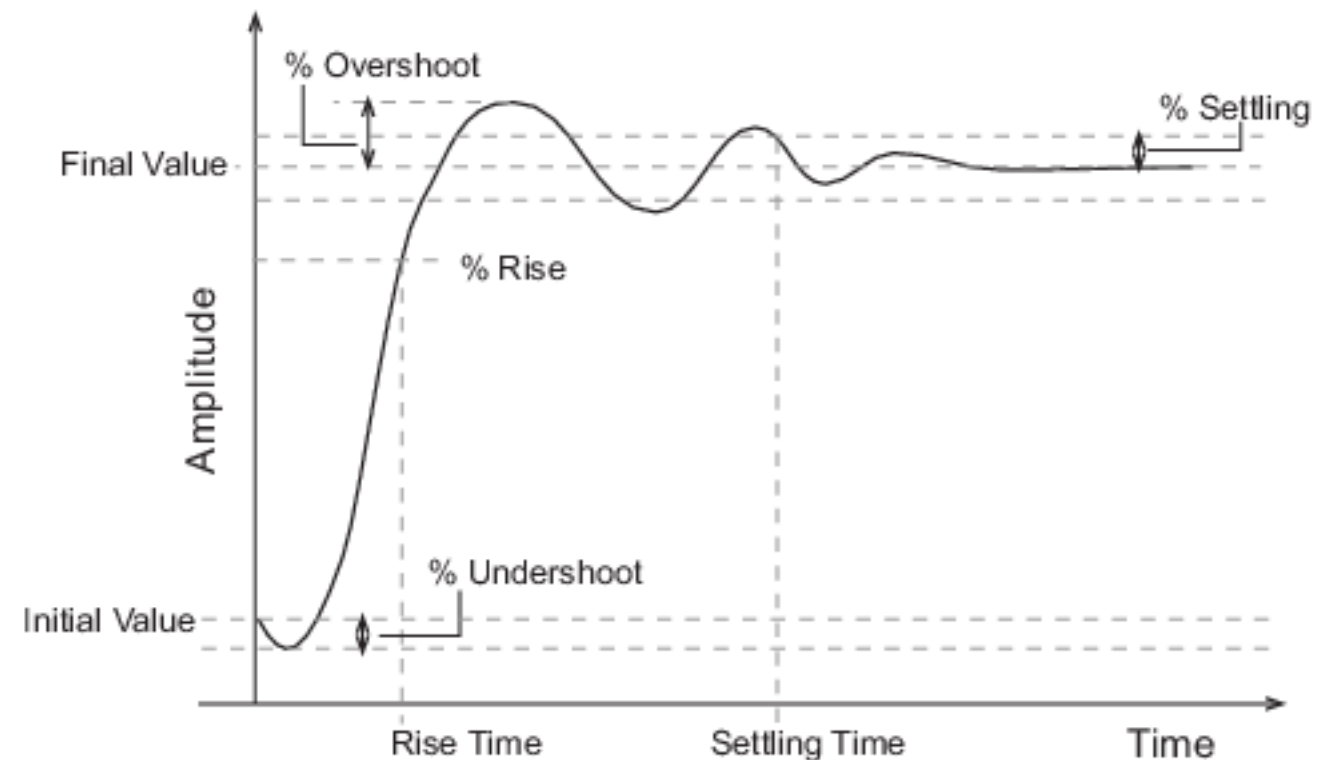
% Rise: 75%

Settling time: 2

% Settling: 2%

% Overshoot: Currently the overshoot is at 50% - set a target overshoot of 10%

% Undershoot: 2%



OPTIMISATION IN SIMULINK

Step Response Optimisation

We will set the following values of the target step function response:

Create Requirement
Step Response Envelope
Specify a step response envelope on a signal.

Name:

▼ Specify Step Response Characteristics

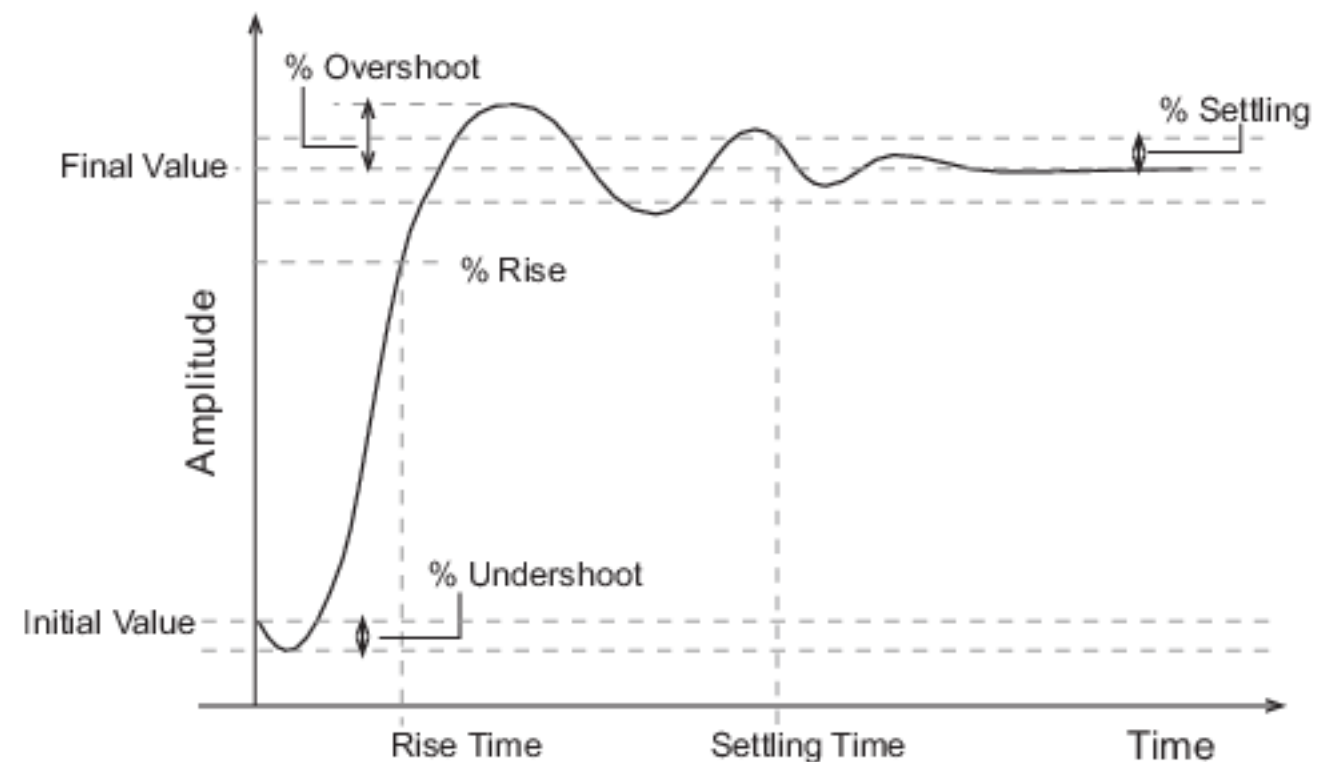
Initial value:	<input type="text" value="0"/>	Final value:	<input type="text" value="0.0500"/>
Step time :	<input type="text" value="1"/> seconds		
Rise time :	<input type="text" value="0.2500"/> seconds	% Rise:	<input type="text" value="75"/>
Settling time :	<input type="text" value="2"/> seconds	% Settling:	<input type="text" value="1000000000000002"/>
% Overshoot:	<input type="text" value="10.0000"/>	% Undershoot:	<input type="text" value="2"/>

▼ Select Signals to Bound

Signal
Create a signal logging definition so that it can be used in requirements.

☒ Create Plot

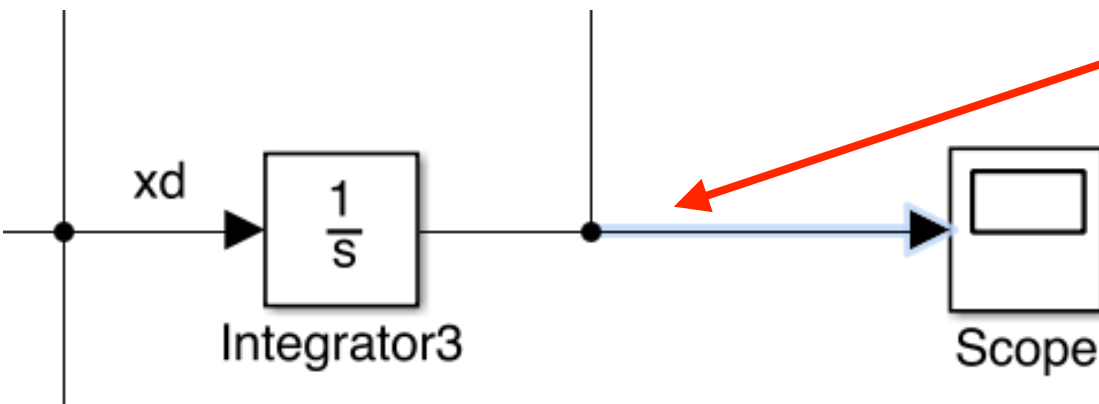
OK Cancel Help



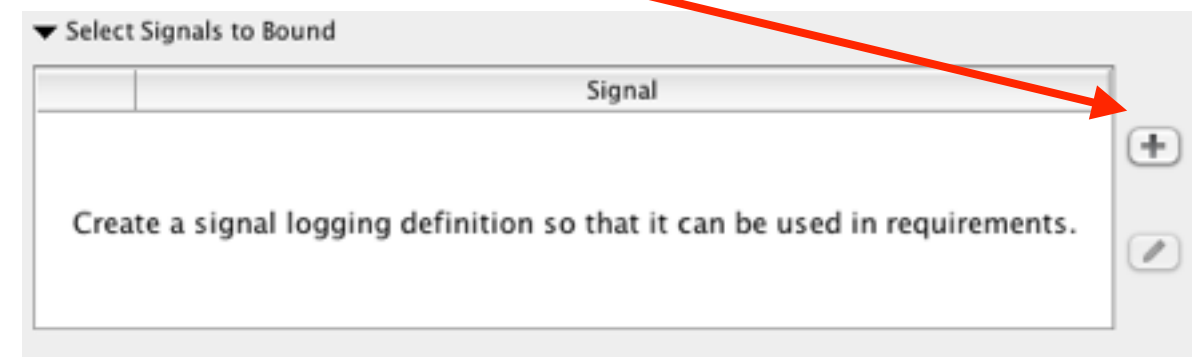
OPTIMISATION IN SIMULINK

Step Response Optimisation

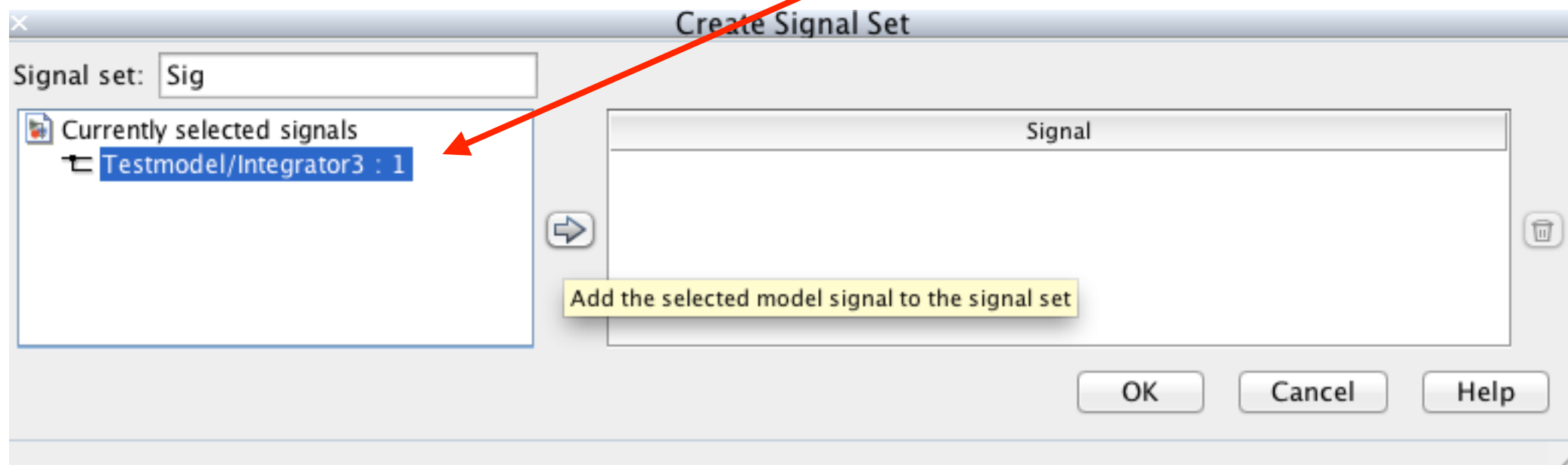
Now have to set a signal to bound - in this case the displacement



Select the correct signal in the Simulink model



This will now appear in this list

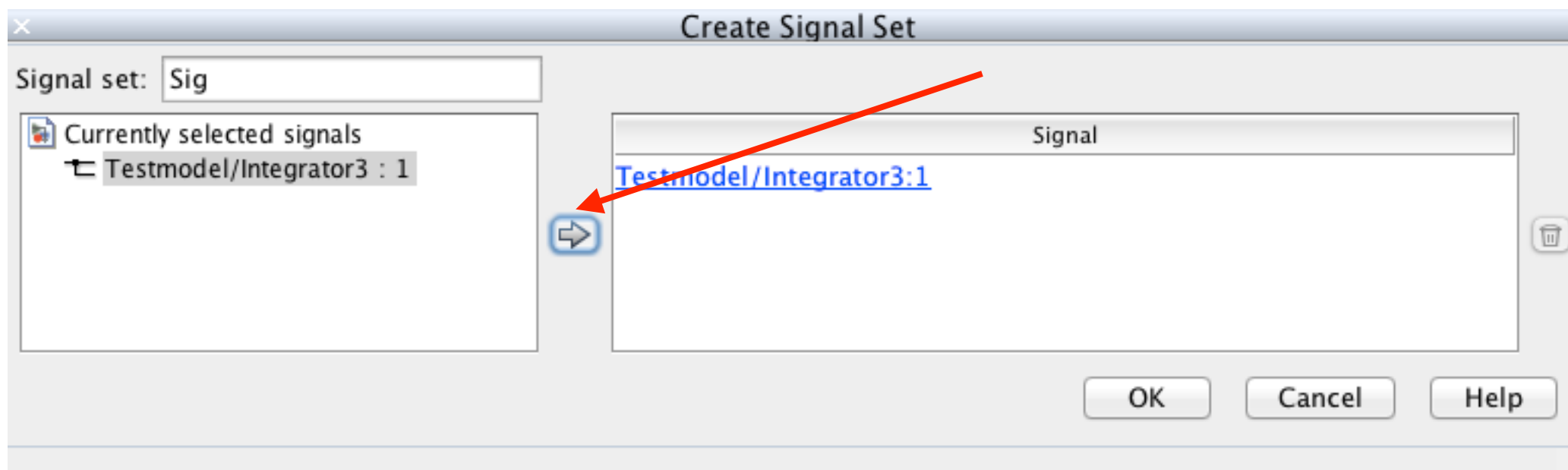


OPTIMISATION IN SIMULINK

Step Response Optimisation

Now have to set a signal to bound - in this case the displacement

Click the arrow to move it into the right hand box



OPTIMISATION IN SIMULINK

Step Response Optimisation

The Response Settings menu is now:

The screenshot shows the 'Create Requirement' dialog box for 'Step Response Envelope'. The dialog has a title bar 'Create Requirement' and a subtitle 'Step Response Envelope'. Below the subtitle is the instruction 'Specify a step response envelope on a signal.'.

The 'Name' field is set to 'tepRespEnvelope'.

Under the 'Specify Step Response Characteristics' section, the following fields are visible:

- Initial value: 0
- Final value: 0.0500
- Step time: 1 seconds
- Rise time: 0.2500 seconds
- % Rise: 75
- Settling time: 2 seconds
- % Settling: 2.0000
- % Overshoot: 10.0000
- % Undershoot: 2

Under the 'Select Signals to Bound' section, there is a list box with the following signal:

	Signal
<input checked="" type="checkbox"/>	Sig (Testmodel/Integrator3:1)

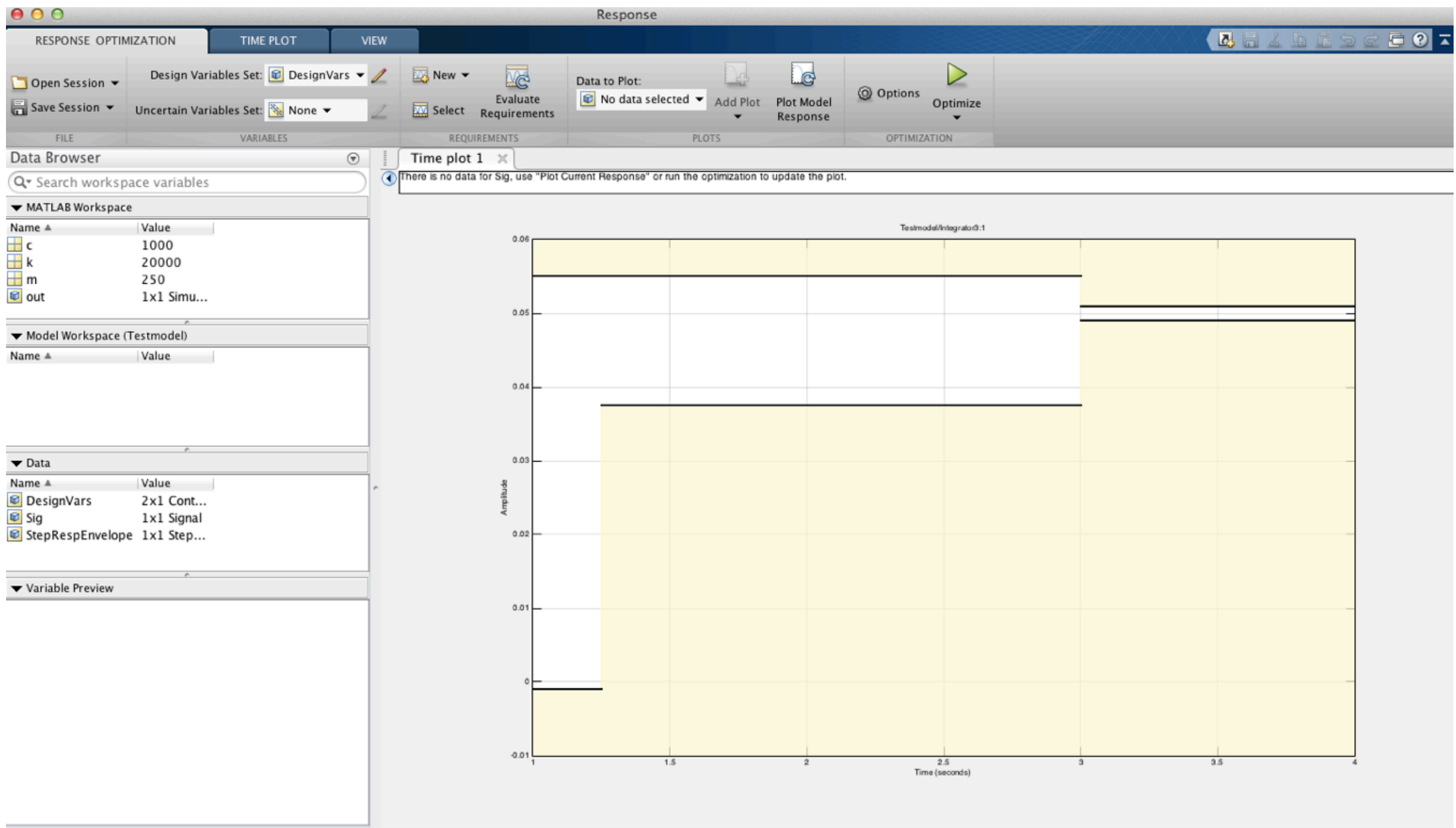
At the bottom of the dialog, there is a checkbox for 'Create Plot' which is checked, and three buttons: 'OK', 'Cancel', and 'Help'.

The signal(s) to bound are now listed here

OPTIMISATION IN SIMULINK

Step Response Optimisation

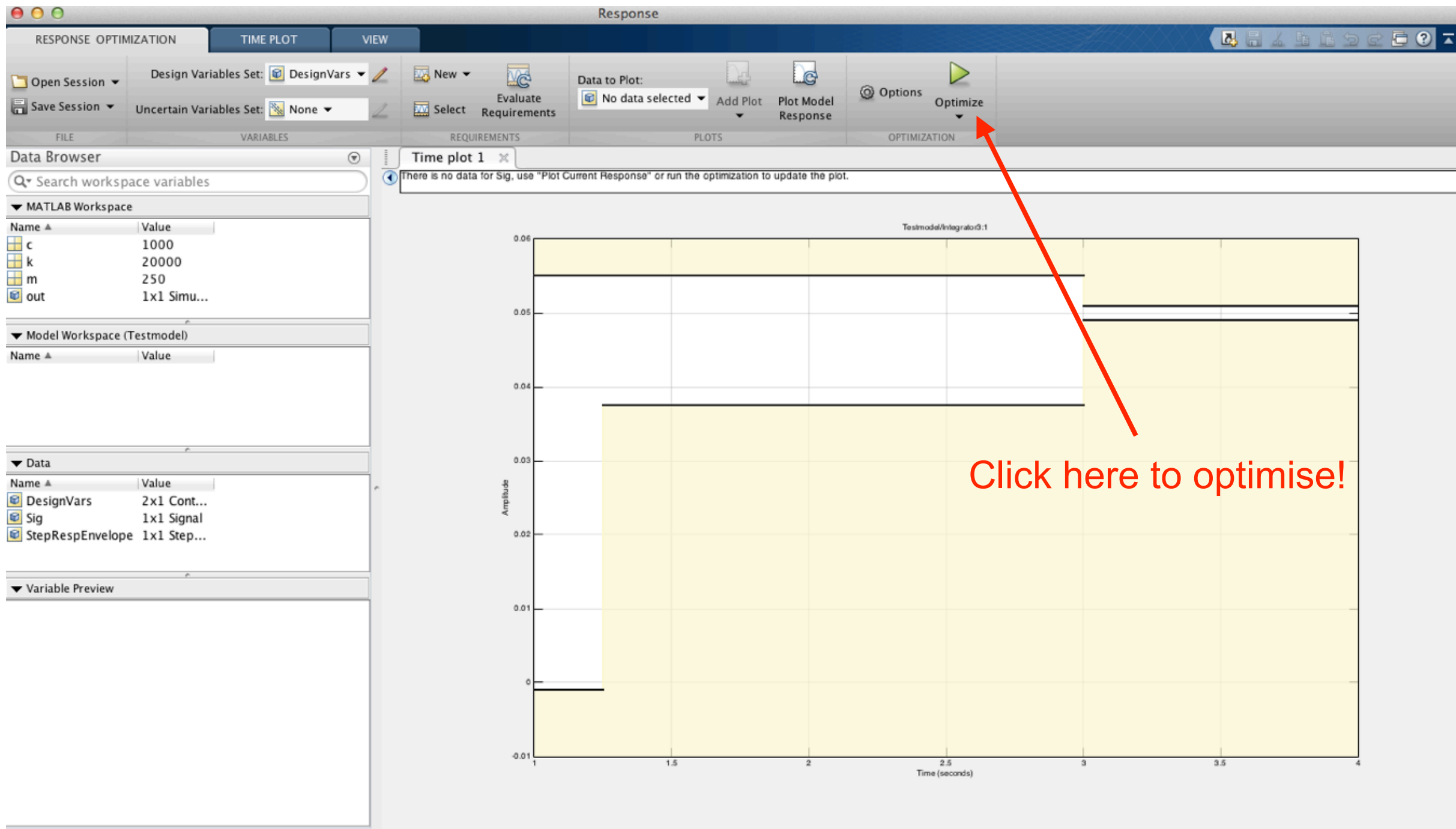
Click OK and we can now see a graphical representation of the specified signal bounds



OPTIMISATION IN SIMULINK

Step Response Optimisation

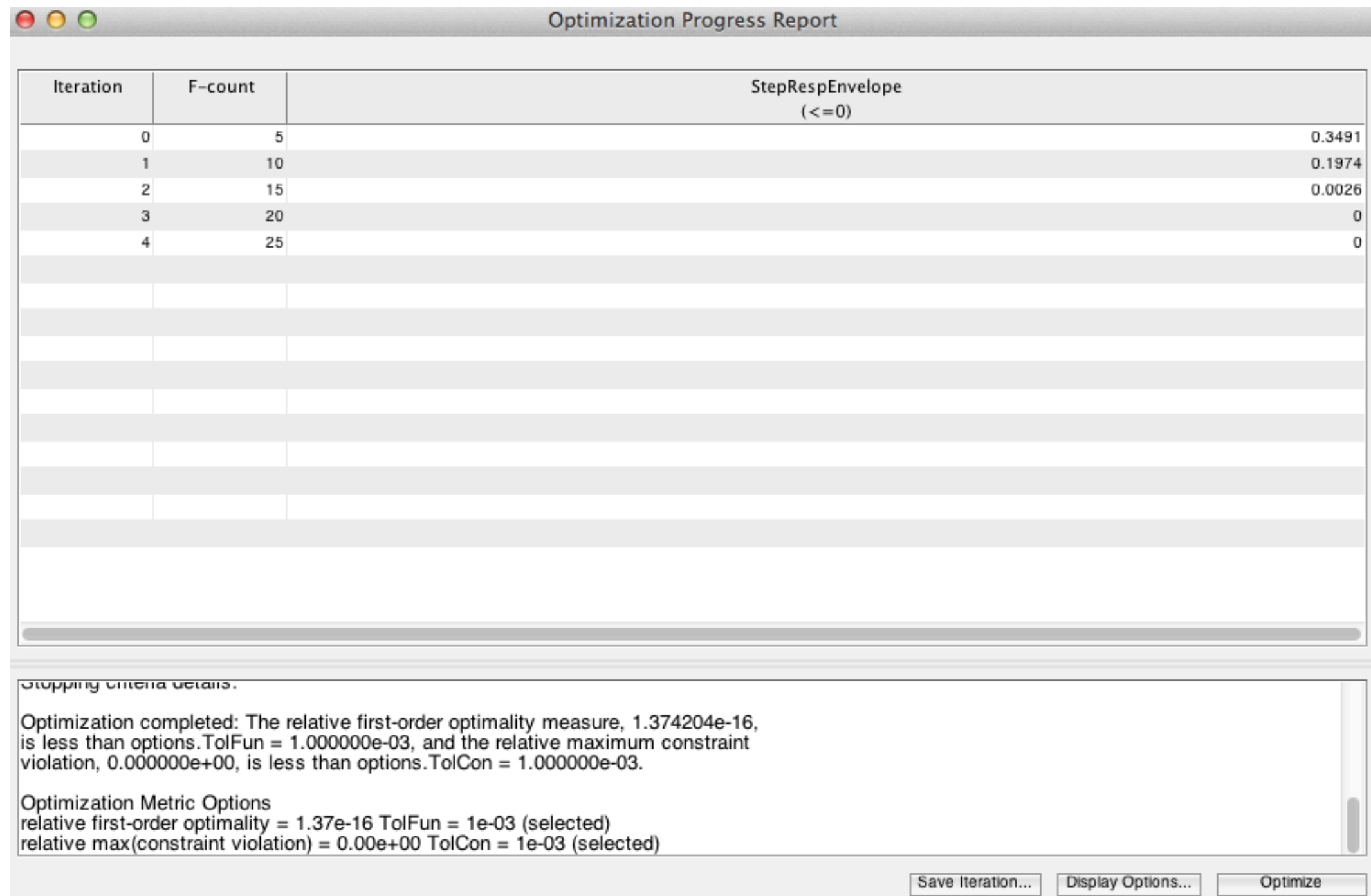
Click optimise to run the optimisation process



OPTIMISATION IN SIMULINK

Step Response Optimisation

Optimisation progress report shows the details of the convergence behaviour



OPTIMISATION IN SIMULINK

Step Response Optimisation

This plots shows the final step response signal that fits within the specified bounds

