# Using Simulink in Signal Processing Applications

# **Basic Simulink blocks discussed**

- How to:
  - 1) Specify configuration parameters
  - 2) Read data in from workspace
  - 3) Read data in from multimedia file
  - 4) Listen to a sound file
  - 5) Save data to multimedia file
  - 6) Save data to workspace
  - 7) Specify IIR/FIR discrete filter characteristics
  - 8) Specify internal input data
  - 9) Plot using Scope blocks
  - 10) Implement the LMS algorithm in Simulink
  - 11) Implement the RLS algorithm in Simulink
  - 12) Plot the filter coefficients using the vector scope
  - 13) Plot multiple data streams on the same figure
  - 14) Generate spectrum and spectrogram plots
  - 15) Generate frequency response plot from filter coefficients
  - 16) Listen to processed audio signals



# Required choice for discrete implementation

🍓 Configuration Parameters: a	ale1/Configuration (Active)	×
Select:	Simulation time	
Solver	Start time: 0.0 Stop time: inf	
Data Import/Export		
Optimization	Colver options	
		-
Sample Time	Type: Roxed-step	_
Data Validity	Fixed-step size (fundamental sample time):	
Type Conversion		
Connectivity		
Saving	Periodic sample time constraint: Unconstrained	
-Hardware Implementati	Tasking mode for periodic sample times: Auto	
Ģ-Simulation Target	Automatically handle rate transition for data transfer	
Symbols	Higher priority value indicates higher task priority	
LCustom Code	Specify completing used for simulation	_
⊡-Real-Time Workshop	Specify sample time used for simulation	
Report		
Comments		
Symbols		
Custom Code		
Debug		
·····Interface		

## 2) How to read data from the workspace

Select Simulink →Sources →From Workspace

		A 11 110					
🙀 Simulink Library Browser					_		
File Edit View Help							
Enter search term 💽 🗛 📺							
Libraries	Library: Simul	ink/Sources	Search Results	: (none)	Most Frequer		
Simulink     Commonly Used Blocks     Continuous	լլեմ	, Band-Limited White Noise	<b>^</b> \\\}	Chirp Sign	al		
Discret:		Clock	1	Constant			
Logic and Bit Operations Lookup Tables Math Operations	J.L.	Counter Free- Running	<sup>11</sup> 71/1>	Counter Li	mited		
····Model Verification ····Model-Verification	12:34	Digital Clock	fil Demofilier (Polisier)	Enumerate Constant	d		
Ports & Subsystems Signal <i>A</i> ttributes	u title d m at >	From File	sim Ia	From Works	space		
Signal Routing Sinks	Ð	Ground		In1			
	∭}	Pulse Generato	i	Ramp			
<ul> <li></li> <li></li></ul>	$\square$	Random Number	<i>///</i>	Repeating Sequence			
···· ₩ Control System Toolbox		Repeating Seq uence Interpol.		Repeating Sequence	Stair		
Embedded Coder	Sput Sput	Signal Builder		Signal Generator			
Showing: Simulink/Sources							

🙀 Source Block Parameters: From Workspace

-From Workspace

Read data values specified in matrix or structure format from MATLAB's workspace.

Matrix format can be used only for one-dimensional signals. Each row of the matrix has a time stamp in the first column and a vector containing the corresponding data sample in the subsequent column(s).

Structure format can be used for either one-dimensional or multidimensional signals:

- var.time=[TimeValues]
- var.signals.values=[DataValues]
- var.signals.dimensions=[DimValues]

Parameters
Data:
simin
Sample time:
1/8000
🗖 Interpolate data
Enable zero-crossing detection
Form output after final data value by: Setting to zero
OK Cancel Help

### **INPUT DATA FORMAT**

- 1) Data must be formatted as ynn2=[timesample,datasample], format: N×2
- 2) Need to define –timesample- with the correct sampling frequency

X



3) How to read .wav file

Select DSP System Toolbox → Signal Processing Sources → From Multimedia File

	🙀 Source Block Parameters: From Multimedia File 🛛 🗙					
	From Multimedia File					
E	On Windows, reads video frames and/or audio samples from a compressed or uncompressed multimedia file. Multimedia files can contain audio, video, or audio and video data.					
-	On non-Windows platforms, reads video frames and/or audio samples from an uncompressed AVI file.					
)	Video functionality requires a Video and Image Processing Blockset license.					
	Main Data Types Parameters File name: [3420\FallFY11\Apps2\audio1.wav Browse					
	Inherit sample time from file					
'	Number of times to play file: inf					
	Outputs					
	Output end-of-file indicator					
	Samples per audio frame: 1024					
	OK Cancel Help					



# 4) How to listen to a sound file

Select DSP System Toolbox → Signal Processing Sinks → To Audio Device



# 5) Save data to a multimedia file

Select DSP System Toolbox → Signal Processing Sinks → To Multimedia File

### **Output to Wave device**

Need to define file name! 🗟 Sink Block Parameters: To Multimedia File	×
To Multimedia File	
Writes video frames and/or audio samples to a multimedia file. On Windows, audio and video compressors are also available to compress audio and/or video streams in the output file. If the specified output file exists, it will be overwritten.	
Video functionality requires a Computer Vision System Toolbox license.	
Parameters	
File name: output.wav Browse	
File type: WAV	
Audio compressor: None (uncompressed)	
Audio data type: Determine from input data type	
OK Cancel Help Apply	



## 6) Save data to workspace

Select DSP System Toolbox

→ Signal Processing Sinks → Signal To Workspace

## 7) Specify IIR/FIR Filter characteristics

Select Simulink → Discrete → Discrete Filter



## 8) Specify internal input data

# Specific parameters specified within each block



→ White Gaussian Noise

→ Sinewave

→ Uniform Random Noise



Select

Simulink

 $\rightarrow$  Sources

## 9) Plot data using Scope blocks

Select Simulink → Sinks



## 10) Implement the LMS algorithm (adaptive noise canceller application shown)



Function Block Parameters: LMS Filter	Normalized LMS
LMS Filter	
Adapts the filter weights based on the chosen algorithm for filtering of the input signal.	configuration parameters
Select the Adapt port check box to create an Adapt port on the block. When the input to this port is nonzero, the block continuously updates the filter weights. When the input to this port is zero, the filter weights remain constant.	
If the Reset port is enabled and a reset event occurs, the block resets the filter weights to their initial values.	
Main Fixed-point	
Parameters	
Algorithm: Normalized LMS	
Filter length: 50	
Specify step size via: Dialog	
Step size (mu): 0.7	
Leakage factor (0 to 1): 1	- Leakage=1 ⇔ no leakage
Initial value of filter weights: 0	
Adapt port	
Reset port: None	<ul> <li>Check to allow filter coef</li> </ul>
Output filter weights	adaptation based on external
	non-zero value
OK Cancel Help Apply	Check if you want to get the filter coefficient values out



# 11) Implement the RLS algorithm (adaptive noise canceller application shown)



Call the RLS algorithm from: DSP System Toolbox → Filtering → Adaptive Filters → RLS

Function Block Parameters: RLS Filter	
RLS filter (mask) (link)	RLS
Computes filter weights based on the exponentially weighted recursive least-squares (RLS) algorithm for adaptive filtering of the input signal.	configuration parameters
Select the Adapt port check box to create an Adapt port on the block. When the input to this port is nonzero, the block continuoulsy updates the filter weights. When the input to this port is zero, the filter weights remain constant.	J
If the Reset port is enabled and a reset event occurs, the block resets the filter weights to their initial values.	
Parameters	
Filter length:	
<u>65</u>	
Specify forgetting factor via: Dialog	
Forgetting factor (0 to 1):	
1.0	A value of 1 specifies an infinite
Initial value of filter weights:	memory.
Initial input variance estimate:	
Adapt port	Check to allow filter coef
Beset nort: None	adaptation based on external
✓ Output filter weights	non zero input value
	Check if you want to get the
	filter coefficient values out
OK Cancel Help Apply	

#### 🙀 Sink Block Parameters: Vector Scope

#### -Vector Scope

Display a vector or matrix of time-domain, frequency-domain, or user-specified data. Each column of a 2-D input matrix is plotted as a separate data channel. 1-D inputs are assumed to be a single data channel.

For frequency-domain operation, input should come from a source such as the Magnitude FFT block, or a block with equivalent data organization.

Scope Properties       Display Properties       Axis Properties       Line Properties         Parameters       Input domain:       User-defined            Horizontal display span (number of frames):       1											
File	k2/¥e Axes	- ctor Scor Channe	pe Is Windo	- ow Help	-	-		-	-		<u>×</u> لا
Amplitude	1 0.8 0.6 0.4 0.2 0				+ + + + + + + + + + + + + + + + + + + +						
9	0	) 2 Frame: 5	: 4	4 Е	) 8 W	10 eight coeffic	12 ients	14	16 1	18 20	D

# 12) Plot filter coefficients using the vector scope → DSP System Toolbox → Signal Processing Sinks → Vector Scope

×

EC4440.MPF -

🙀 Sink Block Parameters: Vector Sc	ope			×	
-Vector Scope					
Display a vector or matrix of time-domain, frequency-domain, or user-specified data. Each column of a 2-D input matrix is plotted as a separate data channel. 1-D inputs are assumed to be a single data channel.					
For frequency-domain operation, Magnitude FFT block, or a block w	input shoi /ith equiva	uld come from a alent data organ	source such ization.	as the	
Scope Properties Display Prop	perties	Axis Properties	Line Pro	perties	
☑ Inherit sample increment from	n input				
X-axis title: weight coefficients					
X display limits User-defined				•	
Minimum X-limit (samples): 0					
Maximum X-limit (samples): 20					
Minimum Y-limit: -0.2					
Maximum Y-limit: 1.2					
Y-axis label: Amplitude					
	ОК	Cancel	Help	Apply	

## 13) Plot multiple data streams on the same figure



### Simulink → Commonly used Blocks → Vector Concatenate → Scope

## 14) Generate spectrum and spectrogram plots → Specta.mdl (provided in course material)



### Blocks used in specta.mdl

Function Block Parameters: Periodogram         Periodogram (mask) (link)         Power spectral density and mean-square power spectrum estimation via the periodogram method and Welch's averaged, modified periodogram method.	Selector Select or reorder specified elements of a multidimensional input signal. The index to each element is identified from an input port or this dialog. You can choose the indexing method for each dimension by using the			
Parameters	"Index Option" parameter.			
Measurement: Power spectral density	Parameters			
Window: Hamming	Number of input dimensions: 1			
Window sampling: Periodic	Index mode: Zero-based			
Inherit FFT length from input dimensions				
FFT length: 1024	Index     Option     Index     Output Size       1     Index vector (dialog)     Image: 0:511     Inherit from "Index"			
Number of spectral averages:				
2 Inherit sample time from input	Input port size: 1024			
	OK Cancel Help Apply			
OK Cancel Help Apply				

### Blocks used in specta.mdl, cont'

Function Block Parameters: Buffer1	🙀 Sink Block Parameters: Matrix Viewer
Buffer Convert scalar samples to a frame output at a lower rate. You can a optional overlap. For calculation of sample delay, see the rebuffer_c	Matrix Viewer Display a matrix as an image, scaling the colormap to the specified input data range. Colormap must be an Nx3 matrix of RGB values. Type "help graph3d" at the MATLAB prompt for a list of predefined colormaps.
Parameters         Output buffer size (per channel):         512         Buffer overlap:         500	Image Properties       Axis Properties         Parameters       Colormap matrix: jet(256)         Minimum input value:       -70
Initial conditions: -70 Treat Mx1 and unoriented sample-based signals as: M channels (t OK Cancel Help Apply	Maximum input value: 15
	OK Cancel Help Apply

# 15) Frequency response plot generated from filter coefficients

The frequency response for the model  $|1/A(e^{j\omega})|^2$  can be computed in dB from the filter coefficients by using the following blocks (this implementation leads to a frequency response plot identical to that given by *freqz.m*).

Note: The spectrum scope uses the periodogram to compute the spectrum expression which results in a discrepancy between simulink & freqz.m results.



## 16) Listen to audio signals (Batch mode from Simulink)

a) send data to workspace

b) create a subsystem which plays the data

#### Simulink $\rightarrow$ Ports & Subsystems 🙀 Simulink Library Browser → Subsystem File Edit View Help Enter search term I 🐴 📺 » Libraries Library: Simulink/Ports & Subsystems Search Results: (none) r un cu on-c an runcuon-can 🖬 Simulink ٠ 0.1 Split Subsystem …Commonly Used Blocks Continuous 11 🗘 If Action $\{f_{jk}, j \in D\}$ If Oul1 de a Subsystem Discontinuities Discrete In1 Model …Logic and Bit Operations "Lookup Tables" Math Operations Model Variants Out1 Model Verification viodel-Wide Utilities Subsystem Subsystem Subsystem 0.1 Ports & Subsystems Examples Examples Signal Attributes Switch Case Actcase: 🖸 cm(a) ! ] Signal Routing Switch Case c din. i ion Subsystem Sinks Triggered -Sources ₽ Trigger Subsystem User-Defined Functions Additional Math & Discrete Variant While Iterator while C ... I: Ou 🗄 🔂 Communications System ... Subsystem Subsystem 🔁 Computer Vision System Showing: Simulink/Ports & Subsystems Cor 09/03/11

EC4440.MPF - Simulink Introduction

### c) Remove subsystem input/output ports

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File	Edit	View	Simu	lation	Form	at To	ols
Help							
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	(	1			<b>→</b> (	1	
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 	2						
FITOD.	76						//





### d) Code audio play action by accessing system block properties



### e) In-code audio play commands

