TA Manual for the Controls Lab

BY **Justin Pearson**

Humble graduate student
January 2017

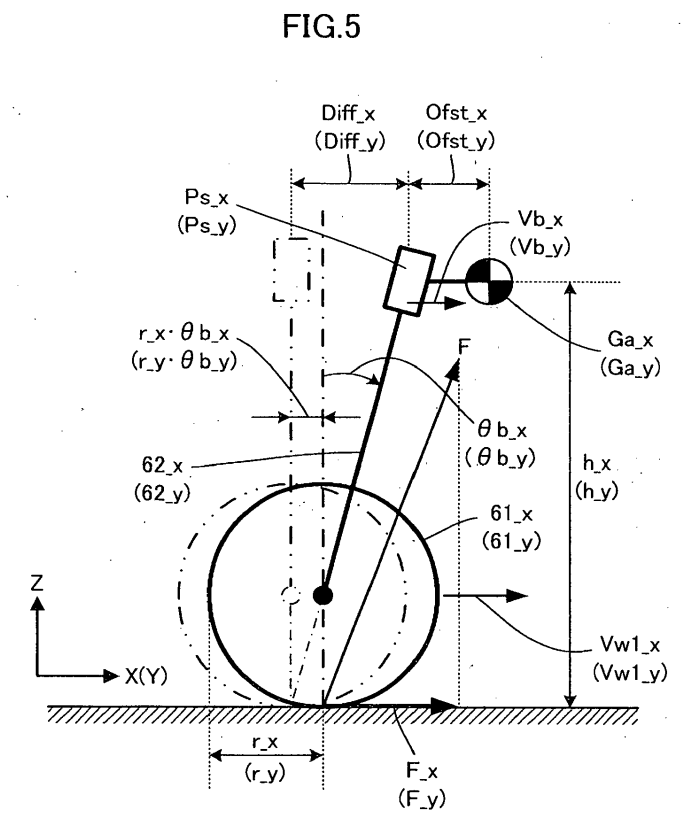

Figure 1: Inverted pendulum type vehicle.
United States Patent 8,744,688

This document lives at
`https://github.com/justinpearson/UCSB-Quanser-Inverted-Pendulum-Lab-Manual`

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TA Manual for the UCSB ECE Controls Lab

This document guides Teaching Assistants in setting up the Quanser inverted pendulum hardware in Harold Frank Hall 3120A that we use in the controls classes (ECE 147) in the Electrical and Computer Engineering department at the University of California, Santa Barbara.

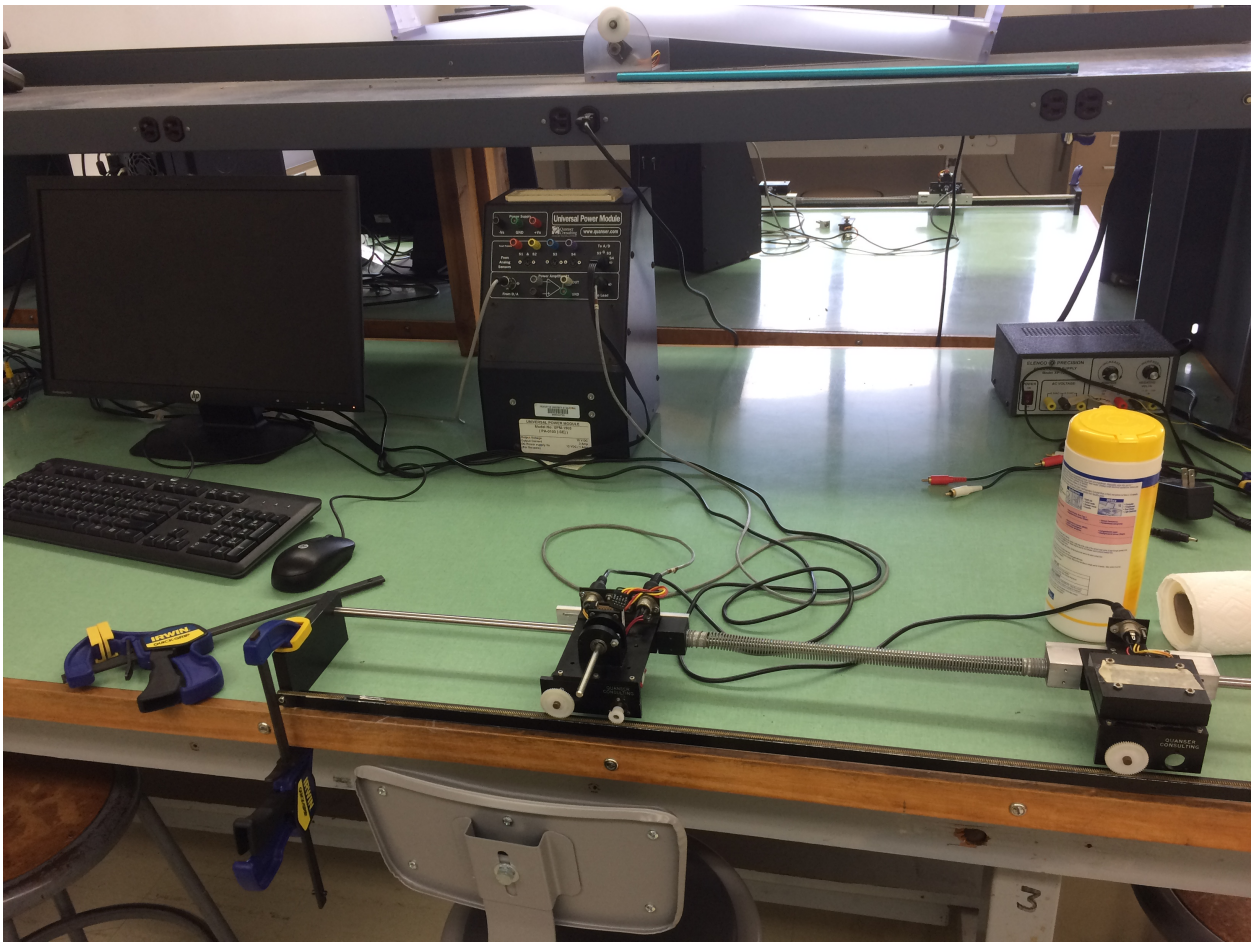


Figure 1: A Quanser pendulum setup in Harold Frank Hall 3120A

By Justin Pearson, Jan 2017

This lab manual is dedicated to the legions of Graduate Students who struggled to set up this hardware the day before their first lab.

It is also dedicated to Paul Gritt, Avery Juan, and Raul Ramirez for diligently and patiently maintaining these labs against the destructive force of countless students over the years.

This file lives at

- https://github.com/justinpearson/UCSB-Quanser-Inverted-Pendulum-Lab-Manual

and also

- http://ece.ucsb.edu/~jppearson/ECE147C/Lab0/Lab0_ForStudents.tar.gz

If you improve it, please send me a GitHub pull request so we can help future generations of TAs. Thanks.

Instructions

1. Set up the hardware as described in the document `hardware_setup.odg` / `pdf`. In the process, you will run the Matlab Simulink files:

- `read_sensors.mdl` (reads motor-cart & springy-cart angle sensors)
- `read_sensors_and_run_motor.mdl` (same, but also writes voltage to motor)

The mdl file `read_sensors_and_run_motor.mdl` runs for 10 seconds. It sends a 1-Hz sinusoidal voltage to the motor and records the encoders of the motor-cart and springy-cart. Upon completion, the simulation dumps the sensor data into the Matlab workspace.

2. In Matlab R2011b, run the Matlab script `do_correlation_method.m`. You will need to edit the script a bit to reflect your own data. This script uses the "correlation method" (taught in the first week of ECE147C) to find the magnitude and phase of the "motor voltage to encoder angle" transfer function evaluated at the frequency that you 1-Hz.
3. Compare your result with the results in `do_correlation_method/do_correlation_method.html`, which shows an example run when I did it. The html file was made by using Matlab to "publish" the Matlab script `do_correlation_method.m`.

Building the PDF of this documentation (Mac)

Running the script `make-lab-manual.sh` produces the pdf `lab-manual.pdf`, which contains

- this document (`README.md`)
- the slides to set up the hardware `hardware_setup.pdf`
- the m-file `do_correlation_method.m`

This `lab-manual.pdf` is meant to be printed out and kept in the Controls Lab.

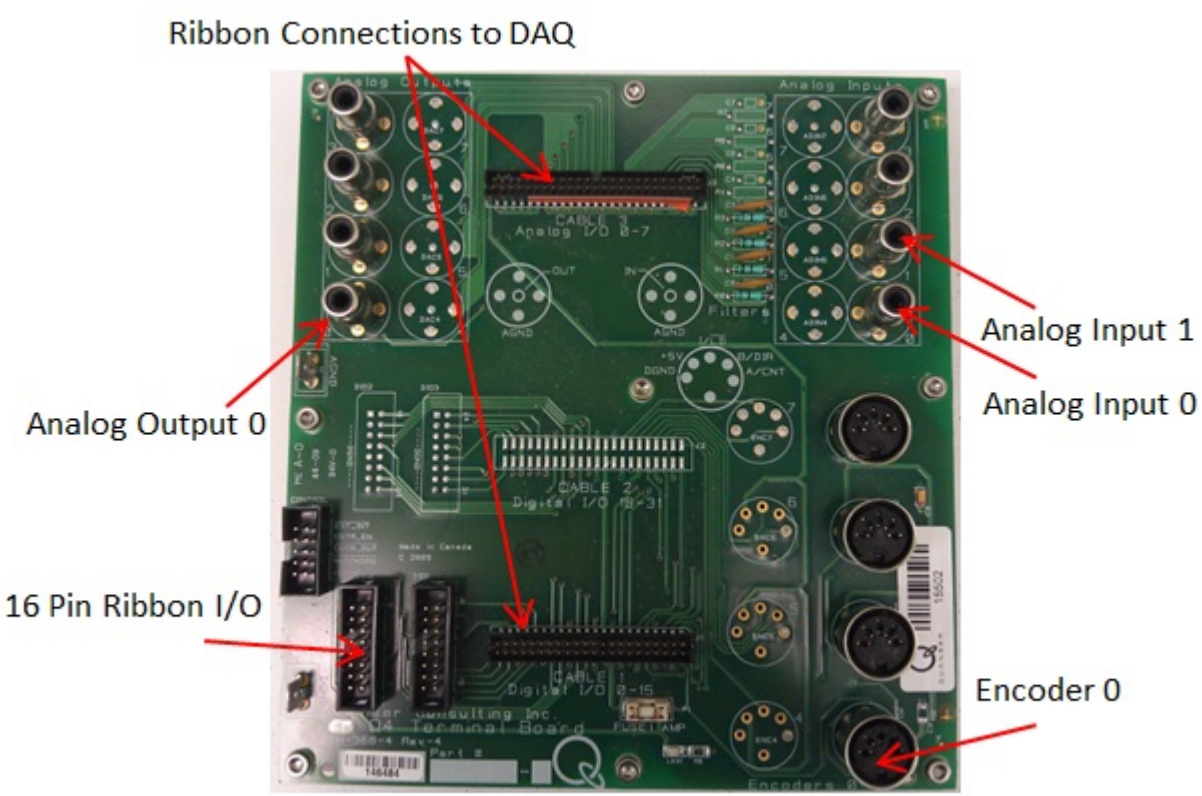
Here is a typical terminal output:

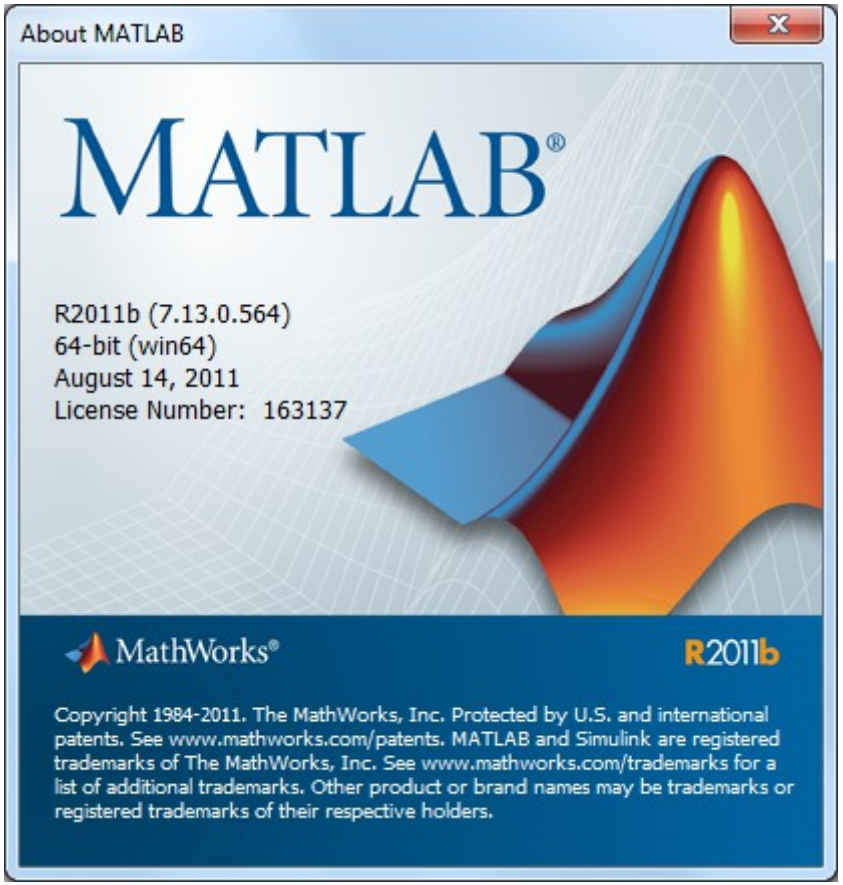
```
$ ./make-lab-manual.sh

Creating lab-manual.pdf.
Assuming you're on a Mac with LibreOffice, pandoc, xelatex, wkhtmltopdf, and Automator.
==========================================
hardware_setup.odg to pdf...
convert /Users/justin/Projects/TA-Guide-to-UCSB-Controls-Lab/UCSB-Quanser-Inverted-Pendulum-Lab-Manual/h
Overwriting: /Users/justin/Projects/TA-Guide-to-UCSB-Controls-Lab/UCSB-Quanser-Inverted-Pendulum-Lab-Mar
==========================================
README.md to .tex...
```

```
==========================================
README.tex to .pdf...
This is XeTeX, Version 3.14159265-2.6-0.99996 (TeX Live 2016) (preloaded format=xelatex)
 restricted \write18 enabled.
entering extended mode
This is XeTeX, Version 3.14159265-2.6-0.99996 (TeX Live 2016) (preloaded format=xelatex)
 restricted \write18 enabled.
entering extended mode
==========================================
Matlab-published m-file html to pdf...
Loading pages (1/6)
Counting pages (2/6)
Resolving links (4/6)
Loading headers and footers (5/6)
Printing pages (6/6)
Done
==========================================
Concatenating pdf...
==========================================
Clean up...
```

ECE 147C
Getting started with the hardware & software
Justin Pearson
2014.04.07

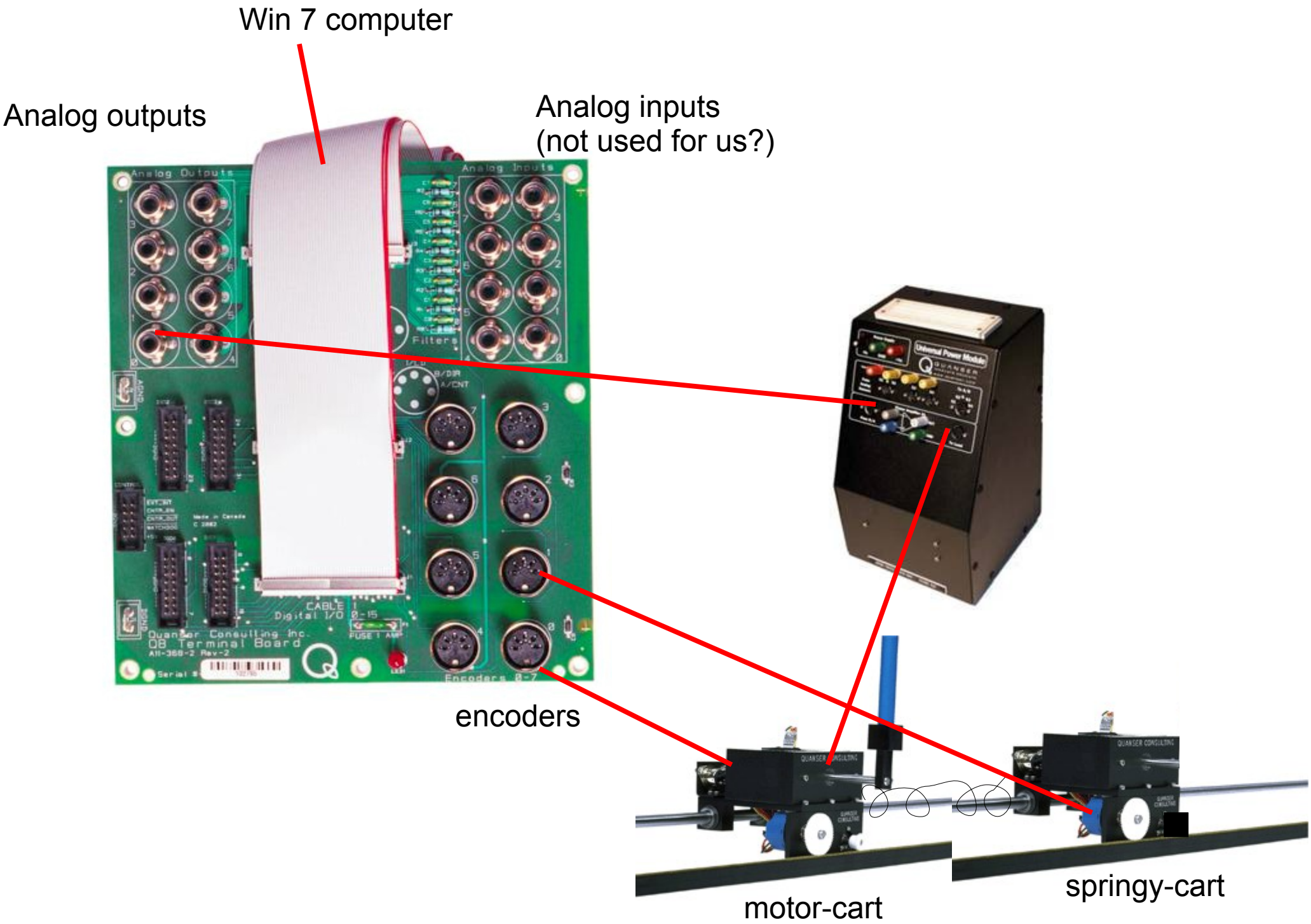
Our current setup: Windows 7,
MATLAB R2011B,
Quanser Q4 terminal board





http://www.clemson.edu/ces/crb/ece495/past_projects/MagnaDoodle/Fall2013Websites/Team%2017/Images/P1_F2_Quanser%20Q4%20HIL%20Board%20Connections.jpg

Hardware setup


Win 7 computer
Analog outputs
Analog inputs
(not used for us?)
encoders
motor-cart
springy-cart

How to build a simple Simulink model to read the encoders

MATLAB R2011b

File Edit Debug Parallel Desktop Window Help

Current Folder: C:\Users\jppearson\Documents\MATLAB

Shortcuts How to Add What's New

Current Folder

« Users ▸ jppearson ▸ Documents ▸ MATLAB ▸

Name

- ece147b_lab0_v0_quarc_win64
- ece147b_lab0_v1_quarc_win64
- ece147b_lab0_v2_quarc_win64
- ece147b_lab0_v3_quarc_win64
- slprj
- ece147b_lab0_v0.rt-win64
- ece147b_lab0_v1.rt-win64
- ece147b_lab0_v2.rt-win64
- ece147b_lab0_v3.rt-win64

Details

Select a file to view details

Command Window

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

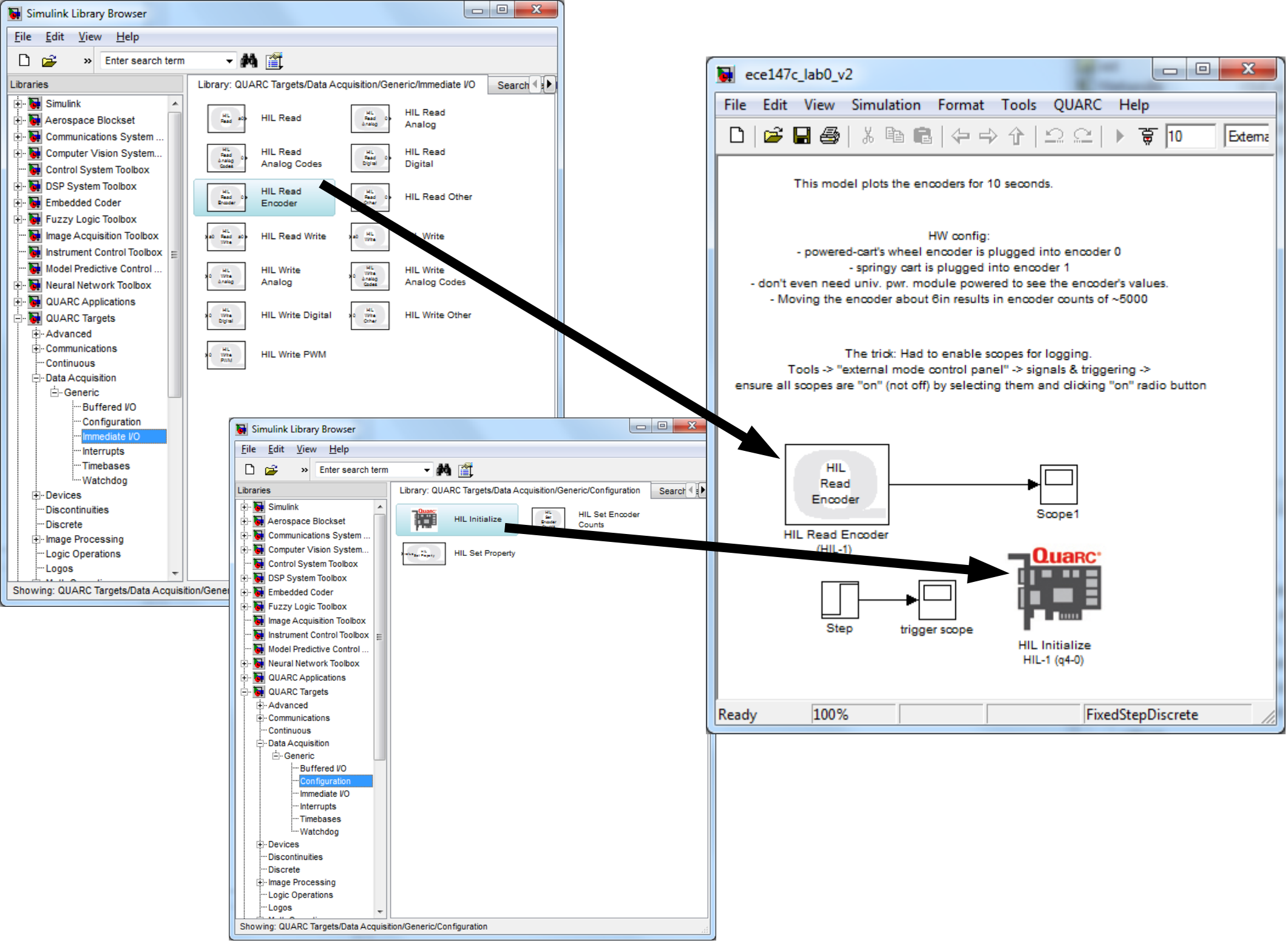
```
>> mex -setup

Welcome to mex -setup.  This utility will help you set up
a default compiler.  For a list of supported compilers, see
http://www.mathworks.com/support/compilers/R2011b/win64.html

Please choose your compiler for building MEX-files:

Would you like mex to locate installed compilers [y]/n?

Select a compiler:
[1] Microsoft Visual C++ 2010 in c:\Program Files (x86)\Microsoft Visual Studio 10.0

[0] None

Compiler: 1

Please verify your choices:

Compiler: Microsoft Visual C++ 2010
Location: c:\Program Files (x86)\Microsoft Visual Studio 10.0

Are these correct [y]/n?

*************************************************************************
  Warning: MEX-files generated using Microsoft Visual C++ 2010 require
           that Microsoft Visual Studio 2010 run-time libraries be
           available on the computer they are run on.
           If you plan to redistribute your MEX-files to other MATLAB
           users, be sure that they have the run-time libraries.
*************************************************************************


Trying to update options file: C:\Users\jppearson\AppData\Roaming\MathWorks\MATLAB\R2011b\mexopts.bat
From template:              C:\PROGRA~1\MATLAB\R2011b\bin\win64\mexopts\msvc100opts.bat

Done . . .

*************************************************************************
  Warning: The MATLAB C and Fortran API has changed to support MATLAB
           variables with more than 2^32-1 elements.  In the near future
           you will be required to update your code to utilize the new
           API. You can find more information about this at:
           http://www.mathworks.com/support/solutions/en/data/1-5C27B9/?solution=1-5C27B9
           Building with the -largeArrayDims option enables the new API.
*************************************************************************

>>
```

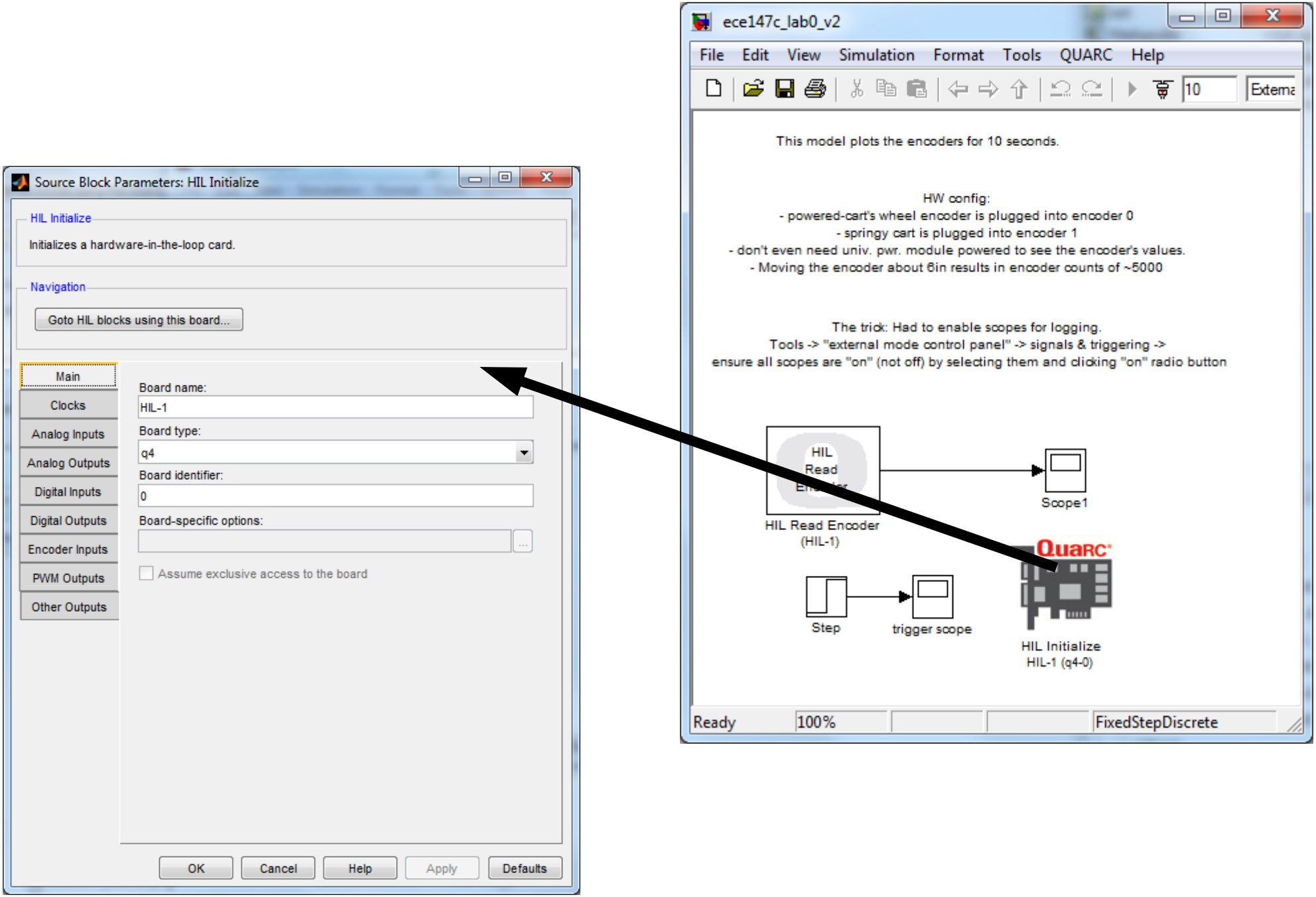
Name

ans

Start

OVR


Simulink Library Browser
File Edit View Help
Enter search term
Libraries
Library: QUARC Targets/Data Acquisition/Generic/Immediate I/O
Search
Simulink
Aerospace Blockset
Communications System ...
Computer Vision System...
Control System Toolbox
DSP System Toolbox
Embedded Coder
Fuzzy Logic Toolbox
Image Acquisition Toolbox
Instrument Control Toolbox
Model Predictive Control ...
Neural Network Toolbox
QUARC Applications
QUARC Targets
Advanced
Communications
Continuous
Data Acquisition
Generic
Buffered I/O
Configuration
Immediate I/O
Interrupts
Timebases
Watchdog
Devices
Discontinuities
Discrete
Image Processing
Logic Operations
Logos
HIL Read
HIL Read Analog
HIL Read Analog Codes
HIL Read Digital
HIL Read Encoder
HIL Read Other
HIL Read Write
HIL Write
HIL Write Analog
HIL Write Analog Codes
HIL Write Digital
HIL Write Other
HIL Write PWM
Showing: QUARC Targets/Data Acquisition/Generic/Immediate I/O
Simulink Library Browser
File Edit View Help
Enter search term
Libraries
Library: QUARC Targets/Data Acquisition/Generic/Configuration
Search
HIL Initialize
HIL Set Encoder Counts
HIL Set Property
Showing: QUARC Targets/Data Acquisition/Generic/Configuration
ece147c_lab0_v2
File Edit View Simulation Format Tools QUARC Help
10
This model plots the encoders for 10 seconds.
HW config:
- powered-cart's wheel encoder is plugged into encoder 0
- springy cart is plugged into encoder 1
- don't even need univ. pwr. module powered to see the encoder's values.
- Moving the encoder about 6in results in encoder counts of ~5000
The trick: Had to enable scopes for logging.
Tools -> "external mode control panel" -> signals & triggering ->
ensure all scopes are "on" (not off) by selecting them and clicking "on" radio button
HIL Read Encoder
HIL Read Encoder (HIL-1)
Scope1
Step
trigger scope
QUARC
HIL Initialize
HIL-1 (q4-0)
Ready
100%
FixedStepDiscrete


Source Block Parameters: HIL Initialize
HIL Initialize
Initializes a hardware-in-the-loop card.
Navigation
Goto HIL blocks using this board...
Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs
Board name:
HIL-1
Board type:
q4
Board identifier:
0
Board-specific options:
Assume exclusive access to the board
OK
Cancel
Help
Apply
Defaults
ece147c_lab0_v2
File Edit View Simulation Format Tools QUARC Help
10
This model plots the encoders for 10 seconds.
HW config:
- powered-cart's wheel encoder is plugged into encoder 0
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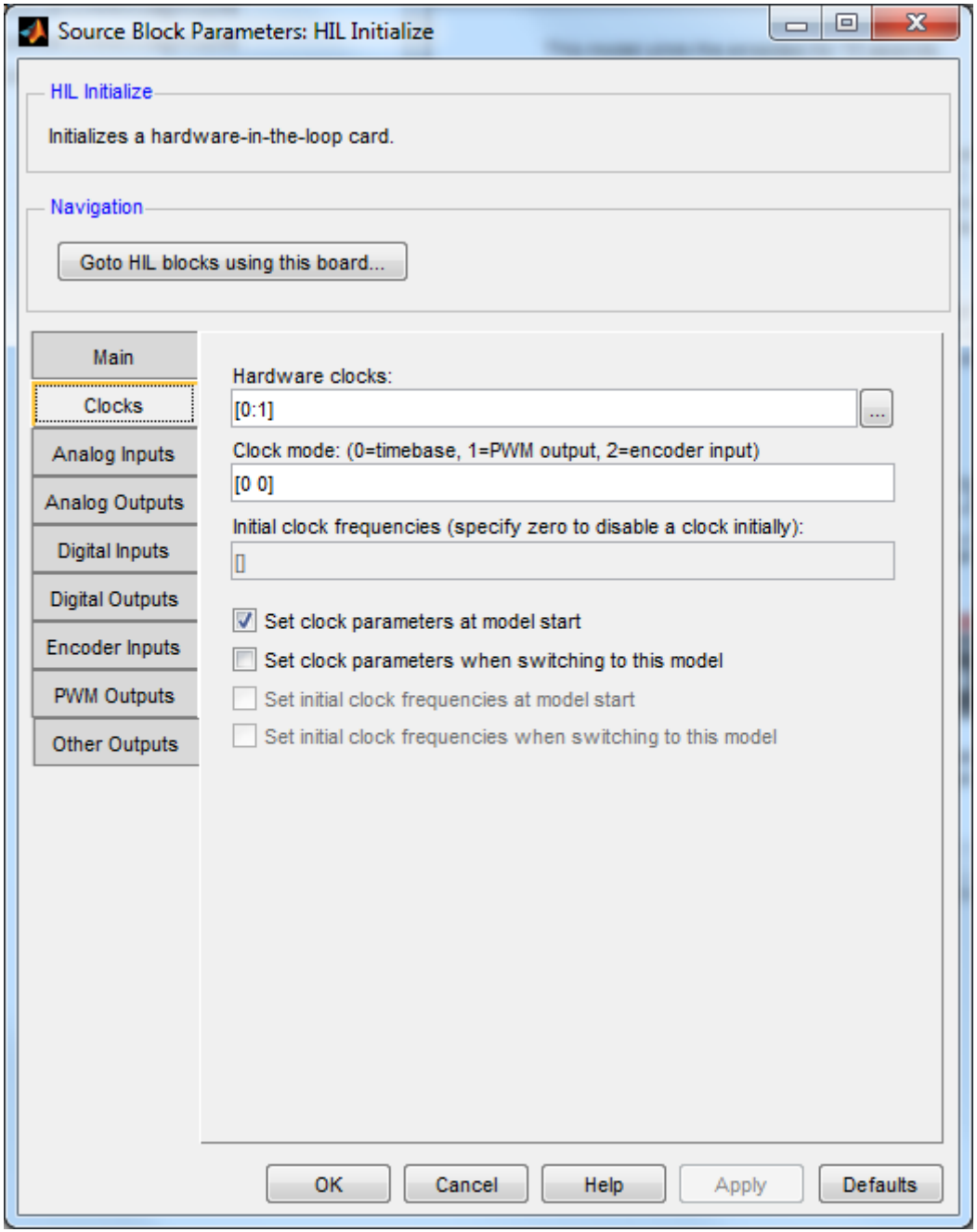
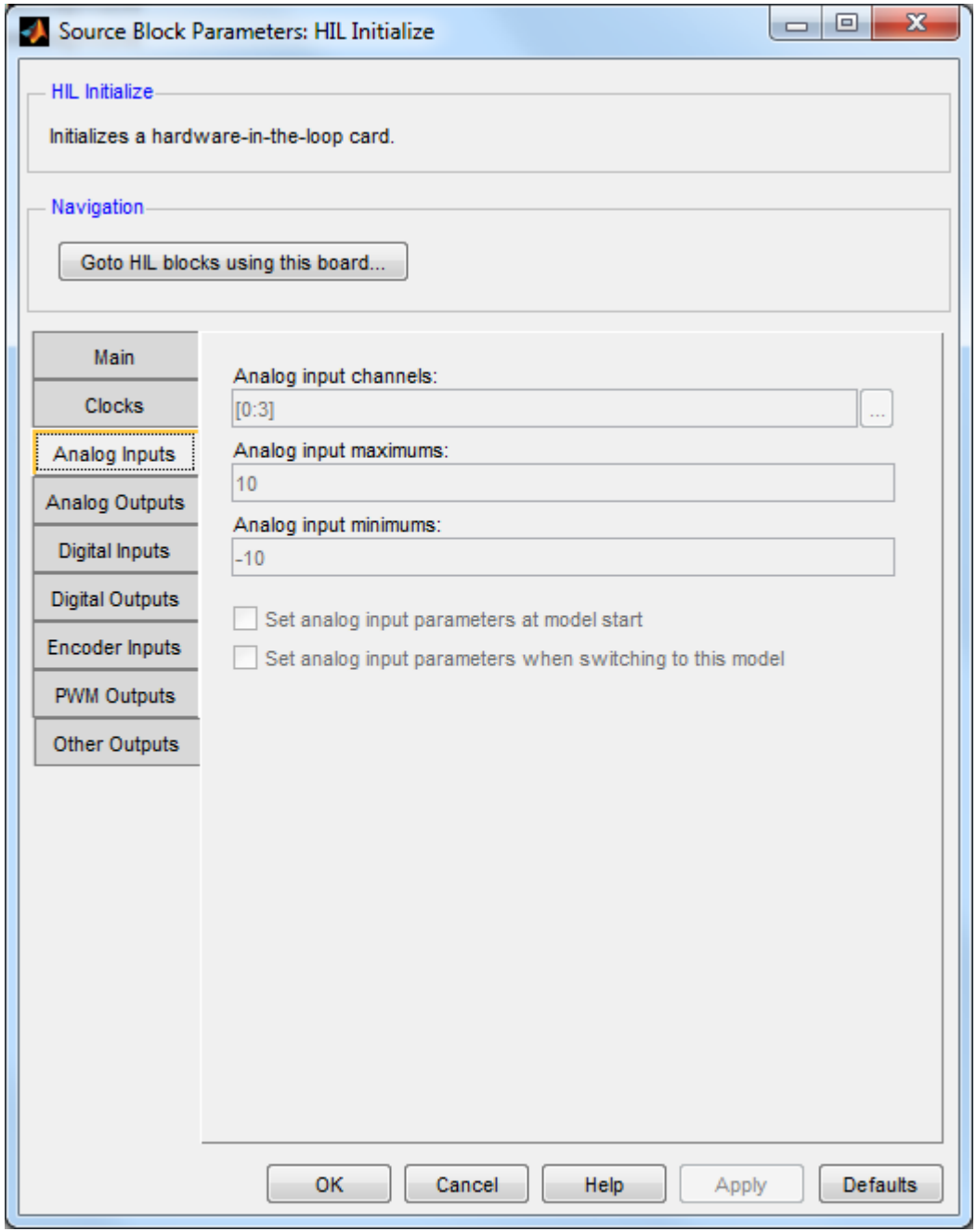
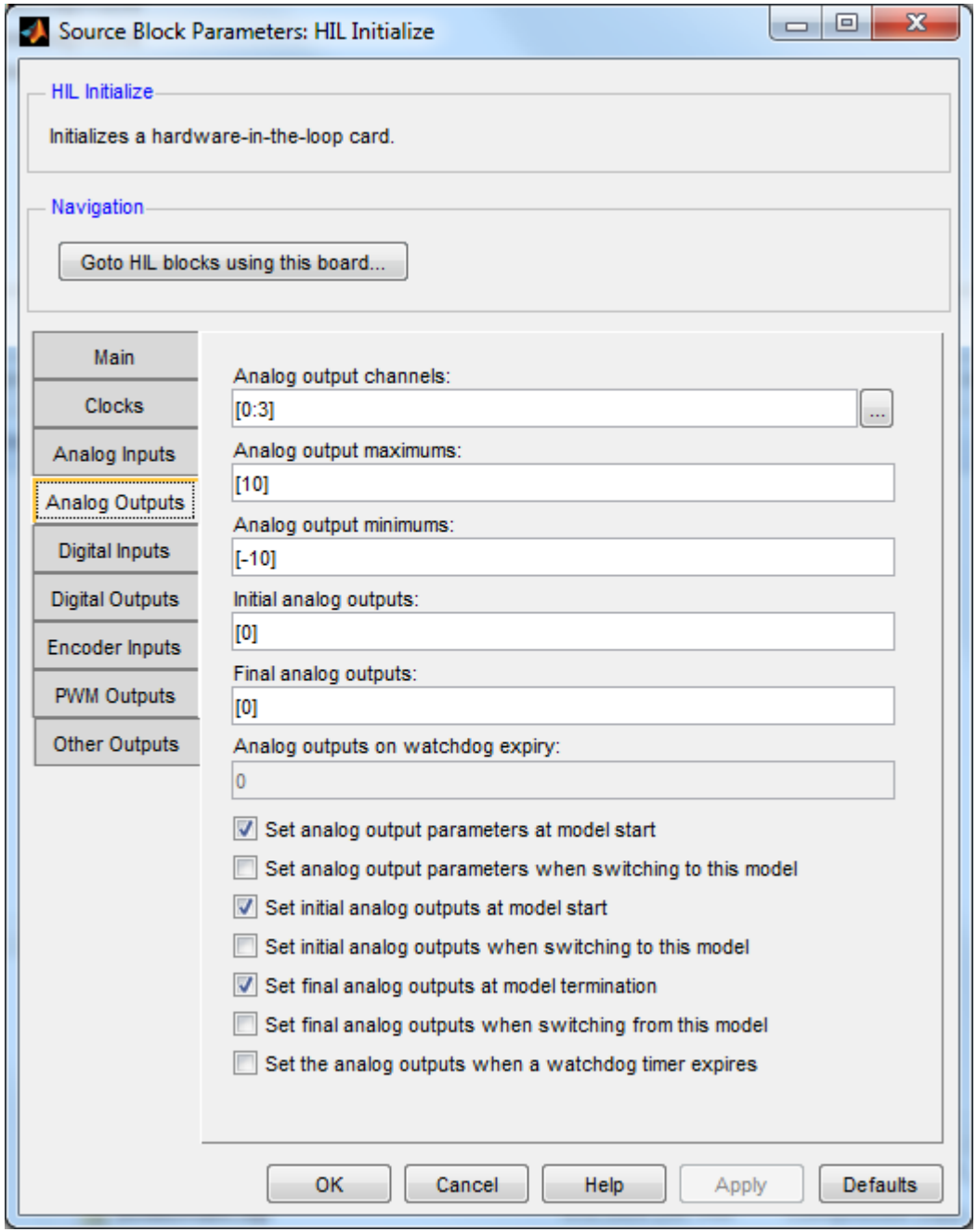
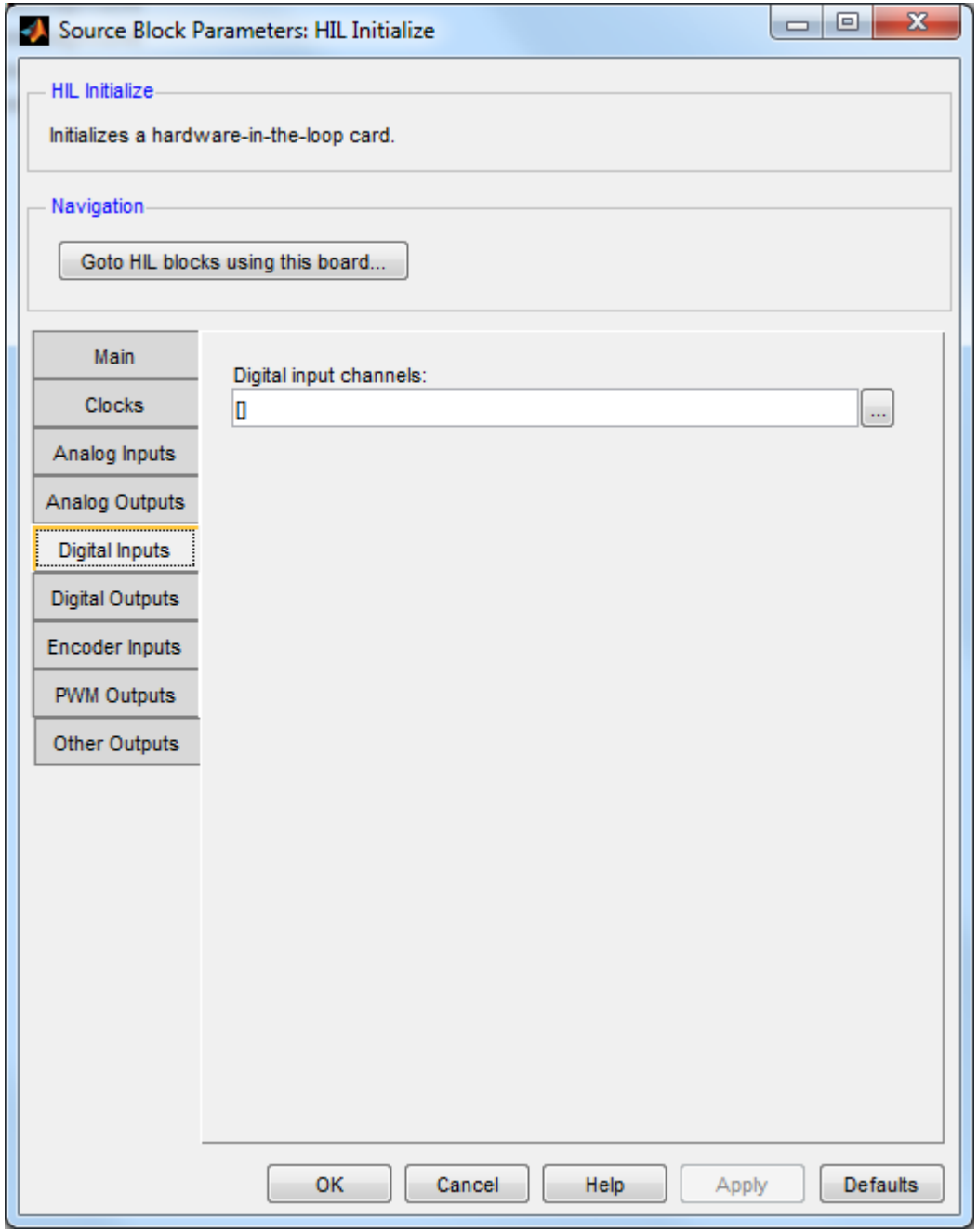
HIL Read Encoder (HIL-1)
Scope1
Step
trigger scope
HIL Initialize HIL-1 (q4-0)
Ready
100%
FixedStepDiscrete


Source Block Parameters: HIL Initialize
HIL Initialize
Initializes a hardware-in-the-loop card.
Navigation
Goto HIL blocks using this board...
Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs
Hardware clocks:
[0:1]
Clock mode: (0=timebase, 1=PWM output, 2=encoder input)
[0 0]
Initial clock frequencies (specify zero to disable a clock initially):
[]
Set clock parameters at model start
Set clock parameters when switching to this model
Set initial clock frequencies at model start
Set initial clock frequencies when switching to this model
OK
Cancel
Help
Apply
Defaults


Source Block Parameters: HIL Initialize
HIL Initialize
Initializes a hardware-in-the-loop card.
Navigation
Goto HIL blocks using this board...
Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs
Analog input channels:
[0:3]
Analog input maximums:
10
Analog input minimums:
-10
Set analog input parameters at model start
Set analog input parameters when switching to this model
OK
Cancel
Help
Apply
Defaults


Source Block Parameters: HIL Initialize
HIL Initialize
Initializes a hardware-in-the-loop card.
Navigation
Goto HIL blocks using this board...
Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs
Analog output channels:
[0:3]
Analog output maximums:
[10]
Analog output minimums:
[-10]
Initial analog outputs:
[0]
Final analog outputs:
[0]
Analog outputs on watchdog expiry:
0
Set analog output parameters at model start
Set analog output parameters when switching to this model
Set initial analog outputs at model start
Set initial analog outputs when switching to this model
Set final analog outputs at model termination
Set final analog outputs when switching from this model
Set the analog outputs when a watchdog timer expires
OK
Cancel
Help
Apply
Defaults


Source Block Parameters: HIL Initialize
HIL Initialize
Initializes a hardware-in-the-loop card.
Navigation
Goto HIL blocks using this board...
Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs
Digital input channels:
[]
OK
Cancel
Help
Apply
Defaults

Source Block Parameters: HIL Initialize

HIL Initialize

Initializes a hardware-in-the-loop card.

Navigation

Goto HIL blocks using this board...

Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs

Digital output channels:
[]

Digital output configuration (0=open-collector, 1=totem-pole):
[]

Initial digital outputs:
[1]

Final digital outputs:
[1]

Digital outputs on watchdog expiry (0=low, 1=high, 2=tristate, 3=same):
[2]

- [ ] Set digital output parameters at model start
- [ ] Set digital output parameters when switching to this model
- [x] Set initial digital outputs at model start
- [ ] Set initial digital outputs when switching to this model
- [x] Set final digital outputs at model termination
- [ ] Set final digital outputs when switching from this model
- [ ] Set the digital outputs when a watchdog timer expires

OK | Cancel | Help | Apply | Defaults

Source Block Parameters: HIL Initialize

HIL Initialize

Initializes a hardware-in-the-loop card.

Navigation

Goto HIL blocks using this board...

Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs

Encoder input channels:
[0:3]

Encoder quadrature: (0=none, 1=1X, 2=2X, 4=4X)
[4]

Encoder filter frequency in Hertz:
(1/60e-9)/1

Initial encoder counts:
[0]

- [x] Set encoder input parameters at model start
- [ ] Set encoder input parameters when switching to this model
- [x] Set initial encoder counts at model start
- [ ] Set initial encoder counts when switching to this model

OK | Cancel | Help | Apply | Defaults

Source Block Parameters: HIL Initialize

HIL Initialize

Initializes a hardware-in-the-loop card.

Navigation

Goto HIL blocks using this board...

Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs

PWM output channels:
[]

Mode: (0=duty cycle, 1=frequency, 2=period, 3=one-shot, 4=time, 5=encode
[0]

Frequency in Hz (mode 0, 3 and 4) or duty cycle (modes 1 and 2):
(1/60e-9)/1024

Configuration (0=unipolar, 1=bipolar, 2=paired, 3=complementary)
[]

Alignment (0=leading-edge, 1=trailing-edge, 2=center-aligned):
[]

Polarity (0=active low, 1=active high):
[]

Leading-edge deadband (seconds):
[]

Trailing-edge deadband (seconds):
[]

Initial PWM outputs:
[0]

Final PWM outputs:
[0]

OK | Cancel | Help | Apply | Defaults

Source Block Parameters: HIL Initialize

HIL Initialize

Initializes a hardware-in-the-loop card.

Navigation

Goto HIL blocks using this board...

Main
Clocks
Analog Inputs
Analog Outputs
Digital Inputs
Digital Outputs
Encoder Inputs
PWM Outputs
Other Outputs

Other output channels:
[]

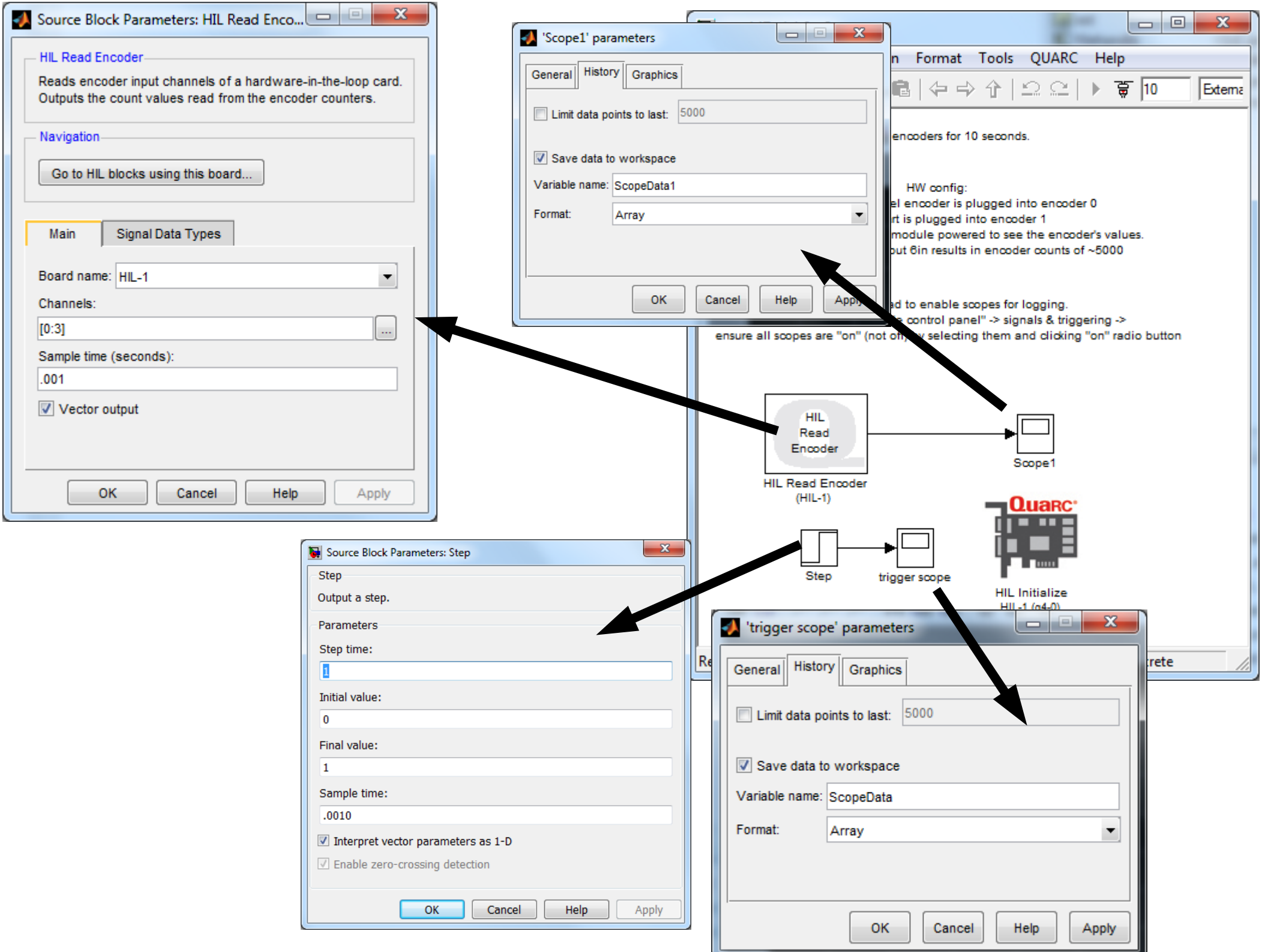
Initial other outputs:
[]

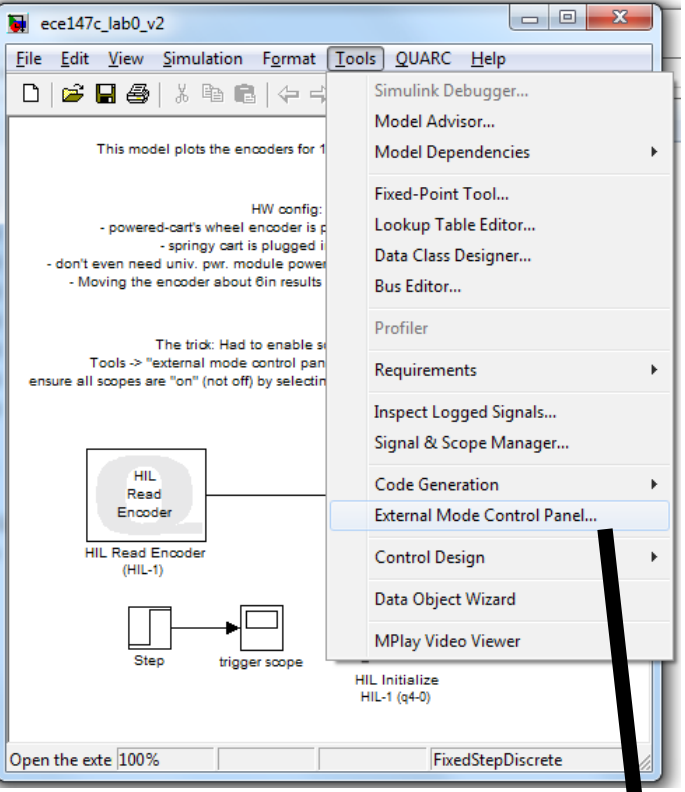
Final other outputs:
[]

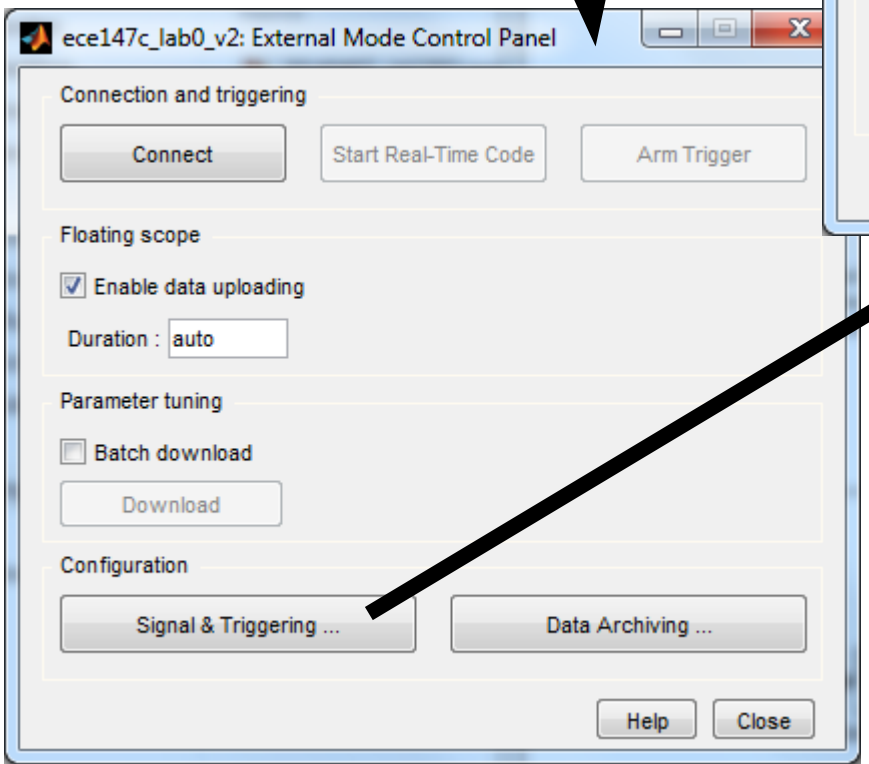
Other outputs on watchdog expiry:
[]

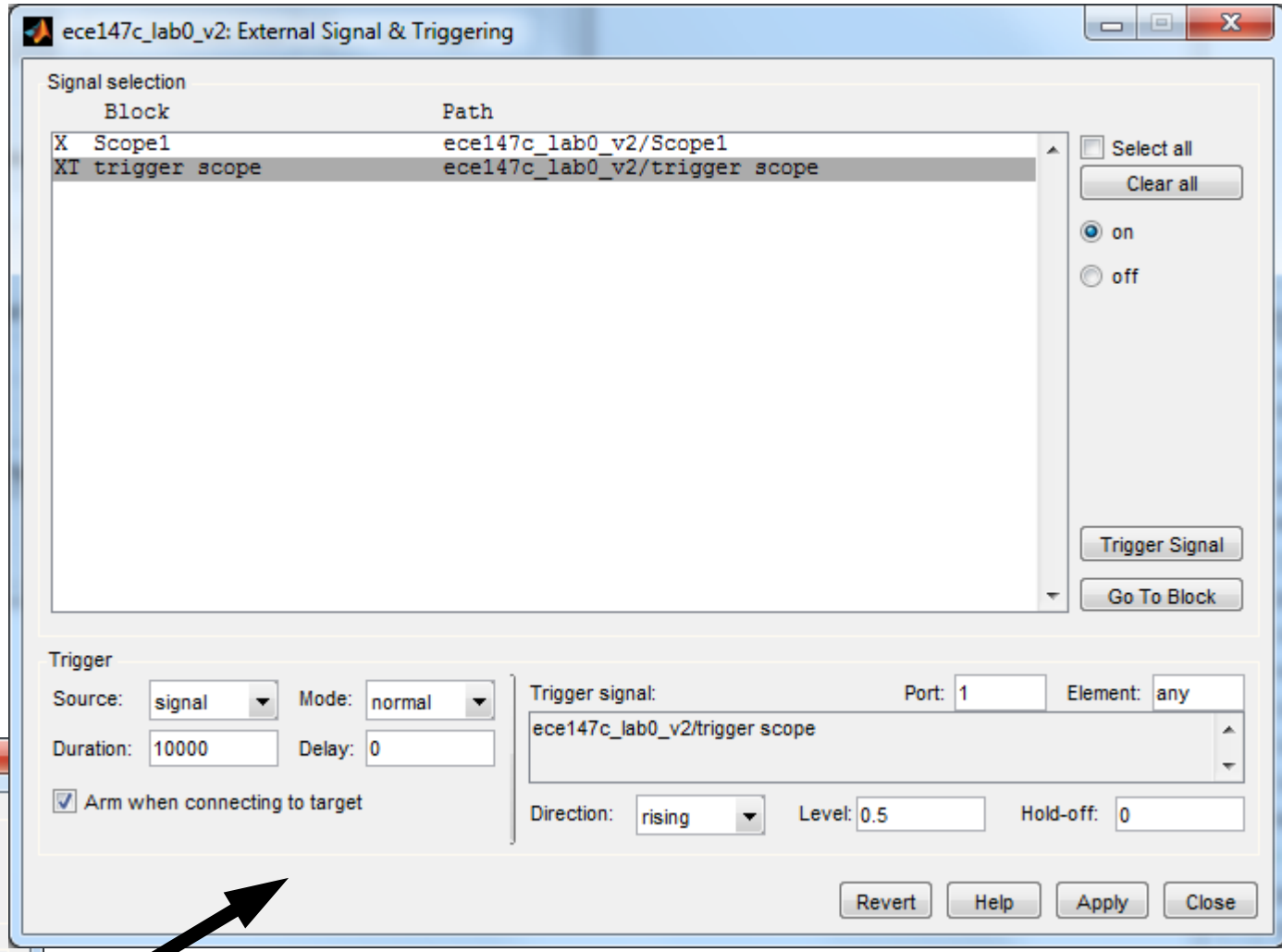
- [ ] Set initial other outputs at model start
- [ ] Set initial other outputs when switching to this model
- [ ] Set final other outputs at model termination
- [ ] Set final other outputs when switching from this model
- [ ] Set the other outputs when a watchdog timer expires

OK | Cancel | Help | Apply | Defaults


Source Block Parameters: HIL Read Enco...
HIL Read Encoder
Reads encoder input channels of a hardware-in-the-loop card.
Outputs the count values read from the encoder counters.
Navigation
Go to HIL blocks using this board...
Main
Signal Data Types
Board name: HIL-1
Channels:
[0:3]
Sample time (seconds):
.001
Vector output
OK
Cancel
Help
Apply
'Scope1' parameters
General
History
Graphics
Limit data points to last: 5000
Save data to workspace
Variable name: ScopeData1
Format: Array
OK
Cancel
Help
Apply
Format
Tools
QUARC
Help
10
encoders for 10 seconds.
HW config:
HIL Read Encoder
Scope1
HIL Read Encoder
(HIL-1)
Step
trigger scope
HIL Initialize
Source Block Parameters: Step
Step
Output a step.
Parameters
Step time:
1
Initial value:
0
Final value:
1
Sample time:
.0010
Interpret vector parameters as 1-D
Enable zero-crossing detection
OK
Cancel
Help
Apply
'trigger scope' parameters
General
History
Graphics
Limit data points to last: 5000
Save data to workspace
Variable name: ScopeData
Format: Array
OK
Cancel
Help
Apply


ece147c_lab0_v2
File Edit View Simulation Format Tools QUARC Help
Simulink Debugger...
Model Advisor...
Model Dependencies
Fixed-Point Tool...
Lookup Table Editor...
Data Class Designer...
Bus Editor...
Profiler
Requirements
Inspect Logged Signals...
Signal & Scope Manager...
Code Generation
External Mode Control Panel...
Control Design
Data Object Wizard
MPlay Video Viewer
HIL Read Encoder
HIL Read Encoder (HIL-1)
Step
trigger scope
HIL Initialize HIL-1 (q4-0)
Open the exte
100%
FixedStepDiscrete


ece147c_lab0_v2: External Mode Control Panel
Connection and triggering
Connect
Start Real-Time Code
Arm Trigger
Floating scope
Enable data uploading
Duration : auto
Parameter tuning
Batch download
Download
Configuration
Signal & Triggering ...
Data Archiving ...
Help
Close


ece147c_lab0_v2: External Signal & Triggering
Signal selection
Block
Path
X Scope1
ece147c_lab0_v2/Scope1
XT trigger scope
ece147c_lab0_v2/trigger scope
Select all
Clear all
on
off
Trigger Signal
Go To Block
Trigger
Source: signal
Mode: normal
Duration: 10000
Delay: 0
Arm when connecting to target
Trigger signal:
Port: 1
Element: any
ece147c_lab0_v2/trigger scope
Direction: rising
Level: 0.5
Hold-off: 0
Revert
Help
Apply
Close

ece147c_lab0_v2

File Edit View Simulation Format Tools QUARC Help

Start Real-Time Code
Connect To Target Ctrl+T
Configuration Parameters... Ctrl+E
Normal
Accelerator
Rapid Accelerator
Software-in-the-Loop (SIL)
Processor-in-the-Loop (PIL)
✓ External

HIL Read Encoder (HIL-1)
Scope1
Step
trigger scope
HIL Initialize HIL-1 (q4-0)

Show the active configuration paramete 100%

Configuration Parameters: ece147c_lab0_v2/Configuration (Active)

Select:
- Solver
- Data Import/Export
- Optimization
- Diagnostics
- Hardware Implementation
- Model Referencing
- Simulation Target
- Code Generation
  - Report
  - Comments
  - Symbols
  - Custom Code
  - Debug
  - Interface
  - QUARC

Target selection

System target file: quarc_win64.tlc [Browse...]

Language: C

Description: QUARC Win64 Target

Build process

TLC options:

Makefile configuration

☑ Generate makefile

Make command: make_rtw

Template makefile: quarc_default_tmf

Code Generation Advisor

Select objective: Unspecified

Check model before generating code: Off [Check model ...]

☐ Generate code only [Build]

OK Cancel Help Apply

Configuration Parameters: ece147c_lab0_v2/Configuration (Active)

Select:
- Solver
- Data Import/Export
- Optimization
- Diagnostics
- Hardware Implementation
- Model Referencing
- Simulation Target
- Code Generation
  - Report
  - Comments
  - Symbols
  - Custom Code
  - Debug
  - Interface
  - QUARC

Software environment

Target function library: C89/C90 (ANSI)

Shared code placement: Auto

☑ Support non-finite numbers

Data exchange

☐ MAT-file logging

Interface: External mode

Host/Target interface

Transport layer: quarc MEX-file name: quarc_comm

MEX-file arguments: '-w -d %d -uri %u'

Memory management

☐ Static memory allocation

OK | Cancel | Help | Apply

Configuration Parameters: ece147c_lab0_v2/Configuration (Active)

Select:

- Solver
- Data Import/Export
- Optimization
- Diagnostics
- Hardware Implementation
- Model Referencing
- Simulation Target
- Code Generation
  - Report
  - Comments
  - Symbols
  - Custom Code
  - Debug
  - Interface
  - QUARC

- [ ] MAT-file logging
- [ ] Stop the model if an overrun occurs
- [ ] Allow use of fast system timer (experimental)
- [x] Allow console output (printing to stdout)
- [ ] Support dynamic reconfiguration
- [ ] Show compilation times
- [ ] Debug version
- [ ] Enable heap checking (debug version only)

Assertions: Stop model with an error

Minimum thread priority: 2

Stack size: 0

Model affinity: []

OK | Cancel | Help | Apply

Configuration Parameters: ece147c_lab0_v2/Configuration (Active)

Select:
- Solver
- Data Import/Export
- Optimization
- Diagnostics
- Hardware Implementation
- Model Referencing
- Simulation Target
- Code Generation
  - Report
  - Comments
  - Symbols
  - Custom Code
  - Debug
  - Interface
  - QUARC

Simulation time

Start time: 0.0 Stop time: 10

Solver options

Type: Fixed-step Solver: discrete (no continuous states)

Fixed-step size (fundamental sample time): 0.001

Tasking and sample time options

Periodic sample time constraint: Unconstrained

Tasking mode for periodic sample times: Auto

☐ Automatically handle rate transition for data transfer

☑ Higher priority value indicates higher task priority

OK Cancel Help Apply

Configuration Parameters: ece147c_lab0_v2/Configuration (Active)

Select:

- Solver
- Data Import/Export
- Optimization
- Diagnostics
- Hardware Implementation
- Model Referencing
- Simulation Target
- Code Generation
  - Report
  - Comments
  - Symbols
  - Custom Code
  - Debug
  - Interface
  - QUARC

Embedded hardware (simulation and code generation)

Device vendor: Generic

Device type: Unspecified (assume 32-bit Generic)

Number of bits

char:	8	short:	16	int:	32
long:	32	float:	32	double:	64
native:	32	pointer:	32		

Largest atomic size

integer: Char

floating-point: None

Byte ordering: Unspecified

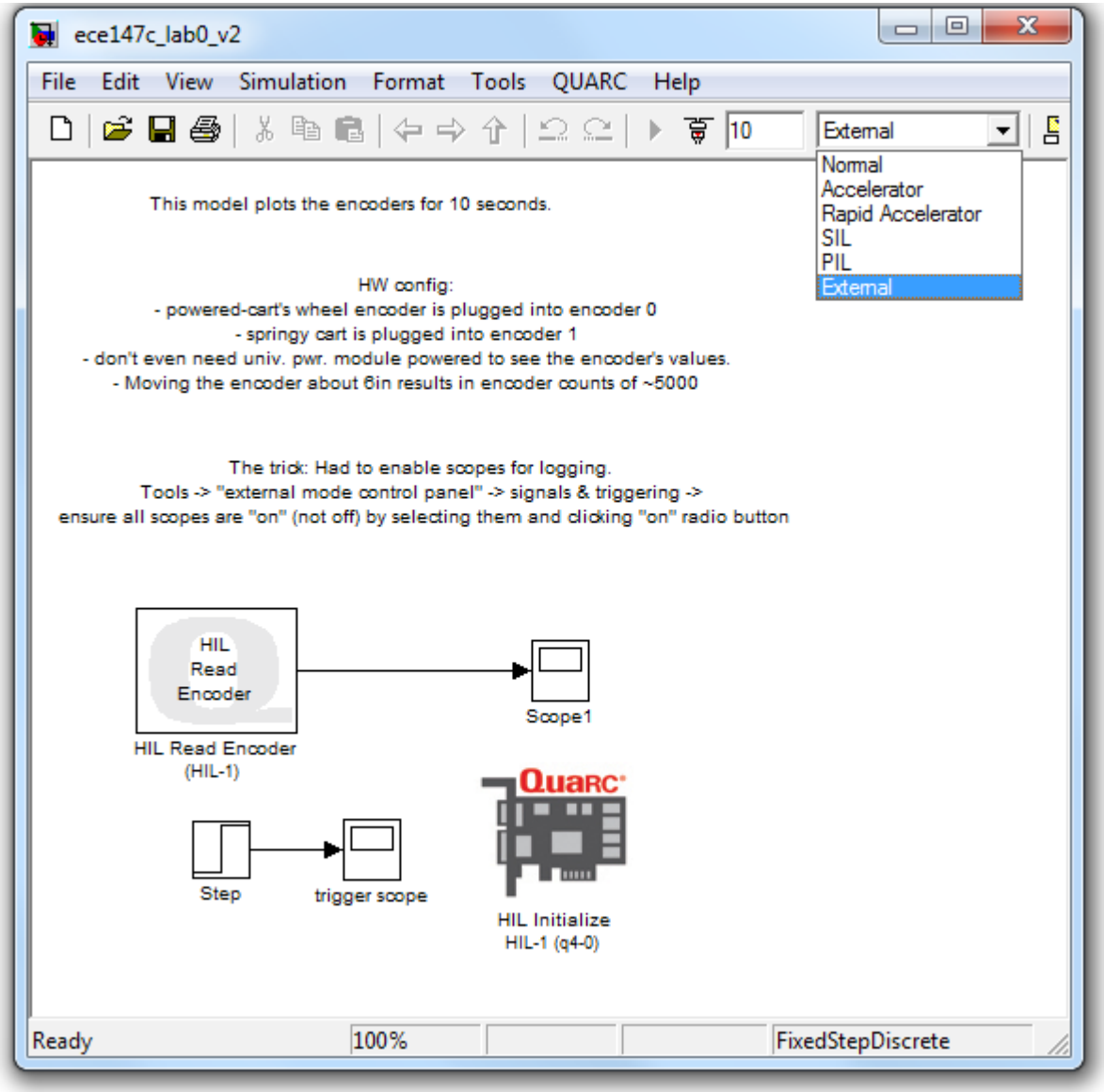
Signed integer division rounds to: Undefined

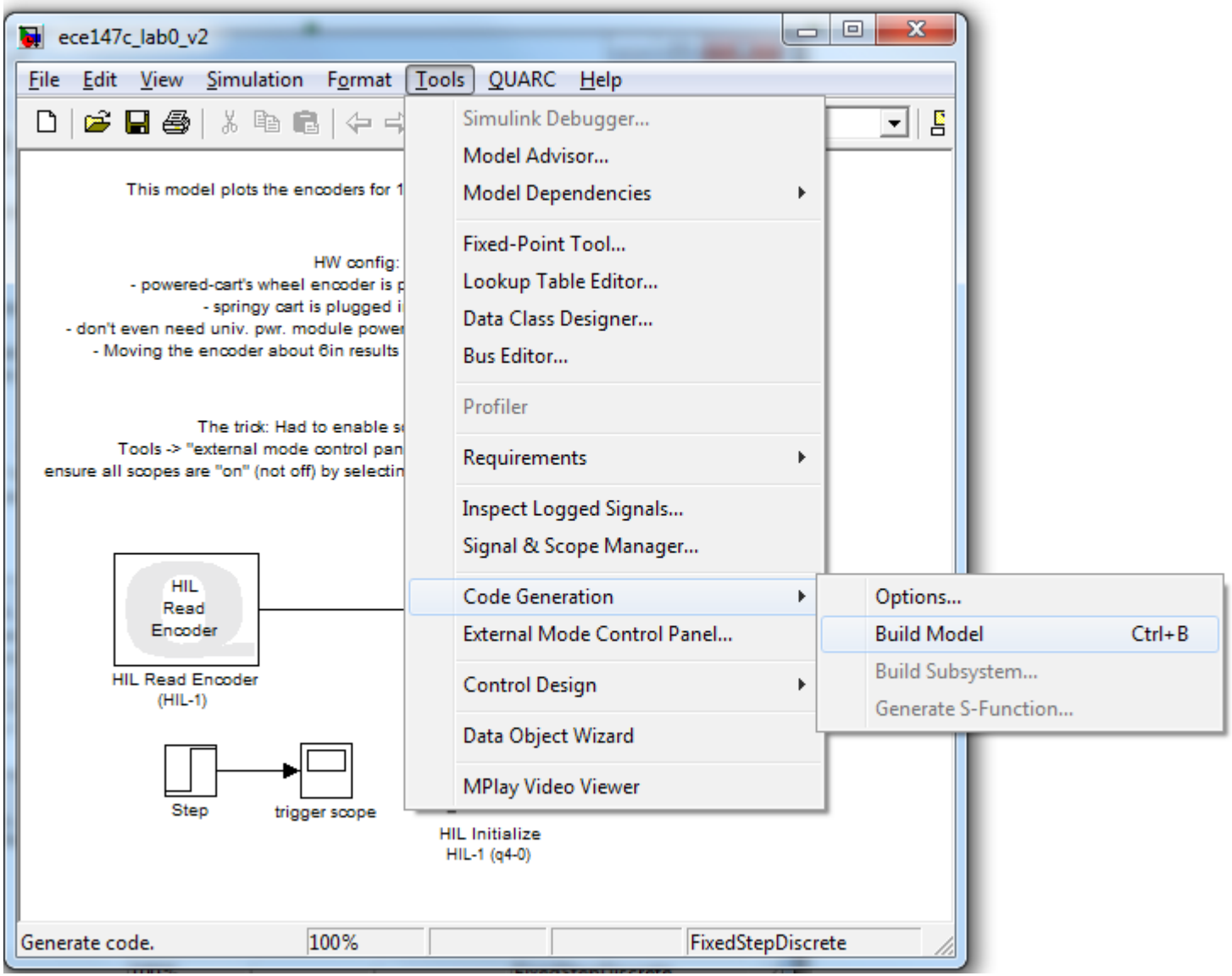
☑ Shift right on a signed integer as arithmetic shift

Emulation hardware (code generation only)

☑ None

OK | Cancel | Help | Apply


ece147c_lab0_v2
File Edit View Simulation Format Tools QUARC Help
10
External
Normal
Accelerator
Rapid Accelerator
SIL
PIL
External
This model plots the encoders for 10 seconds.
HW config:
- powered-cart's wheel encoder is plugged into encoder 0
- springy cart is plugged into encoder 1
- don't even need univ. pwr. module powered to see the encoder's values.
- Moving the encoder about 6in results in encoder counts of ~5000
The trick: Had to enable scopes for logging.
Tools -> "external mode control panel" -> signals & triggering ->
ensure all scopes are "on" (not off) by selecting them and clicking "on" radio button
HIL Read Encoder
HIL Read Encoder (HIL-1)
Scope1
Step
trigger scope
QuaRC
HIL Initialize HIL-1 (q4-0)
Ready
100%
FixedStepDiscrete


ece147c_lab0_v2
File Edit View Simulation Format Tools QUARC Help
Simulink Debugger...
Model Advisor...
Model Dependencies
Fixed-Point Tool...
Lookup Table Editor...
Data Class Designer...
Bus Editor...
Profiler
Requirements
Inspect Logged Signals...
Signal & Scope Manager...
Code Generation
External Mode Control Panel...
Control Design
Data Object Wizard
MPlay Video Viewer
Options...
Build Model Ctrl+B
Build Subsystem...
Generate S-Function...
This model plots the encoders for 1
HW config:
- powered-cart's wheel encoder is p
- springy cart is plugged i
- don't even need univ. pwr. module power
- Moving the encoder about 6in results
The trick: Had to enable s
Tools -> "external mode control pan
ensure all scopes are "on" (not off) by selectin
HIL Read Encoder
HIL Read Encoder (HIL-1)
Step
trigger scope
HIL Initialize HIL-1 (q4-0)
Generate code.
100%
FixedStepDiscrete

MATLAB R2011b

File Edit Debug Parallel Desktop Window Help

Current Folder: X:\ECE147C_AdvancedDigitalControlLab_Hespanha_Spr2014\Labs\Tools

Shortcuts How to Add What's New

Current Folder

« Labs ▸ Tools ▸

Name

- ece147c_lab0_v2_quarc_win64
- slprj
- .~lock.asdf.odp#
- .~lock.lab0_v2_setup.odg#
- 20140407_142203.png
- 20140407_142323.png
- 20140407_142353.png
- 20140407_142412.png
- 20140407_142430.png
- 20140407_142501.png
- 20140407_142511.png
- 20140407_142523.png
- 20140407_142655.png
- 20140407_142758.png
- 20140407_142822.png
- 20140407_143557.png
- 20140407_143632.png
- 20140407_143637.png
- 20140407_143646.png
- 20140407_143651.png
- 20140407_143701.png
- 20140407_143704.png
- 20140407_143714.png
- 20140407_143718.png
- 20140407_144614.png
- 20140407_144619.png
- 20140407_144634.png
- 20140407_144641.png
- 20140407_144647.png
- 20140407_144658.png
- 20140407_144852.png
- 20140407_144951.png
- asdf.odp
- bodeomatic.zip
- ece147c_lab0_v2.rt-win64
- lab0_v2_setup.odg
- manipulate_bode.fig
- manipulate_bode.m

Details

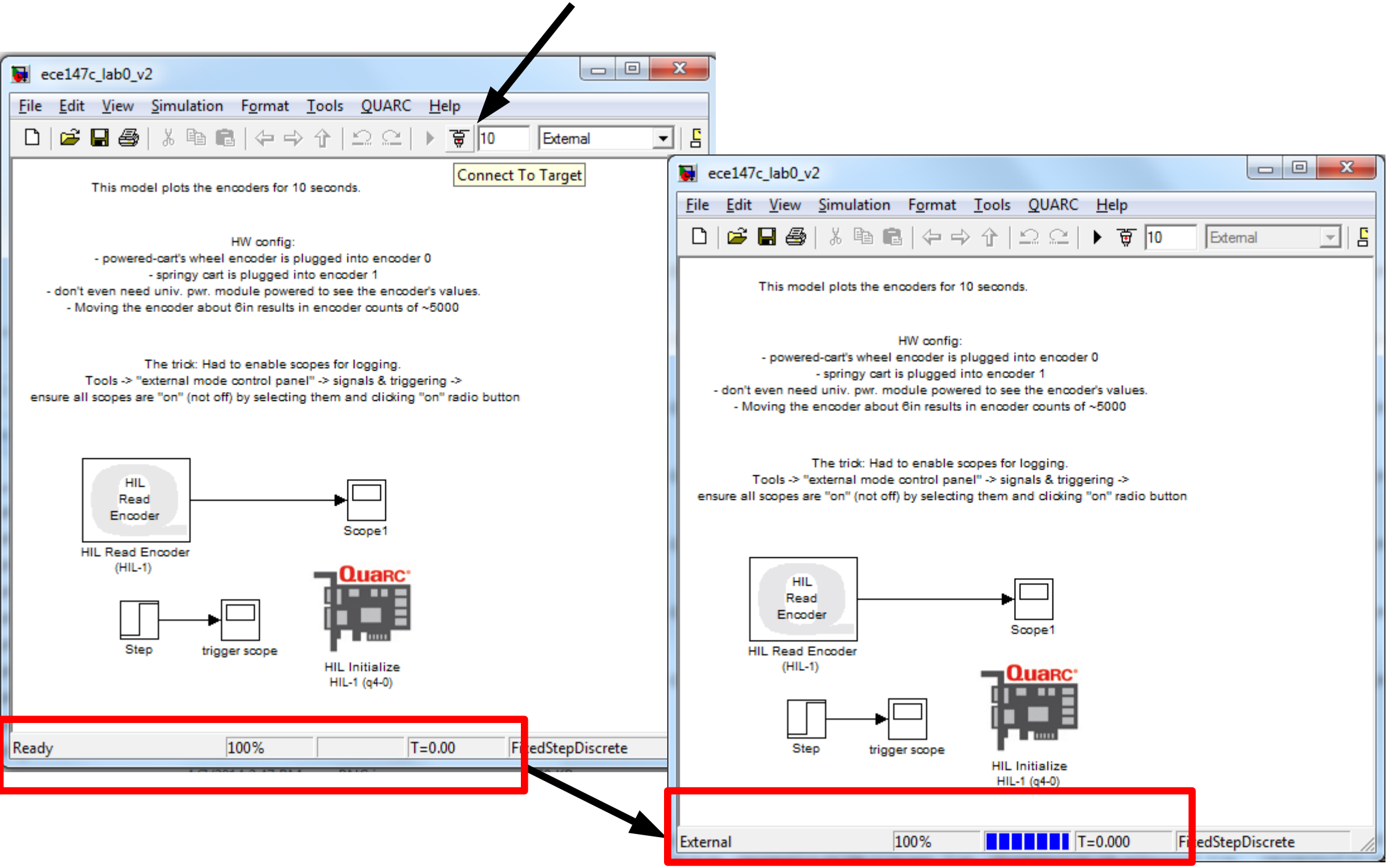
Select a file to view details

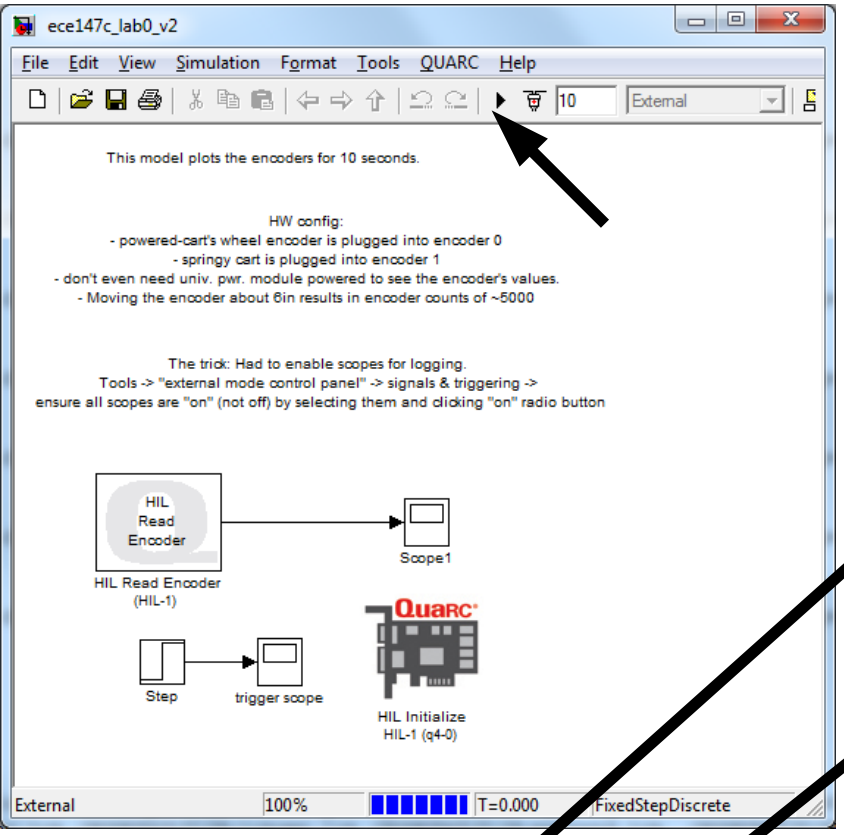
Command Window

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

```
### Generating TLC interface API.
.......................
### Creating data type transition file ece147c_lab0_v2_dt.h
.### Creating project marker file: rtw_proj.tmw
.
### Processing Template Makefile: C:\Program Files\Quanser\QUARC\quarc\R2009a\quarc_win64.tmf
### Creating ece147c_lab0_v2.mk from C:\Program Files\Quanser\QUARC\quarc\R2009a\quarc_win64.tmf
### Building ece147c_lab0_v2: .\ece147c_lab0_v2.bat

X:\ECE147C_AdvancedDigitalControlLab_Hespanha_Spr2014\Labs\Tools\ece147c_lab0_v2_quarc_win64>call "c:\Program Files (x86)\Microsoft Visual Studio 10.0\VC\vcvarsall.bat" x86_
Setting environment for using Microsoft Visual Studio 2010 x64 cross tools.

Microsoft (R) Program Maintenance Utility Version 10.00.30319.01
Copyright (C) Microsoft Corporation.  All rights reserved.

### Compiling ece147c_lab0_v2.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab0_v2:1" -DVERBOSE  -DUSE_RTMODEL /wd4100 -DMODEL=ece147c_lab0_v2 -DRT -DNUMST=1  -DTID01EQ=0 -DNCSTATES=0  -D
ece147c_lab0_v2.c
### Compiling ece147c_lab0_v2_data.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab0_v2:1" -DVERBOSE  -DUSE_RTMODEL /wd4100 -DMODEL=ece147c_lab0_v2 -DRT -DNUMST=1  -DTID01EQ=0 -DNCSTATES=0  -D
ece147c_lab0_v2_data.c
### Compiling ece147c_lab0_v2_main.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab0_v2:1" -DVERBOSE  -DUSE_RTMODEL /wd4100 -DMODEL=ece147c_lab0_v2 -DRT -DNUMST=1  -DTID01EQ=0 -DNCSTATES=0  -D
ece147c_lab0_v2_main.c
### Compiling rtGetInf.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab0_v2:1" -DVERBOSE  -DUSE_RTMODEL /wd4100 -DMODEL=ece147c_lab0_v2 -DRT -DNUMST=1  -DTID01EQ=0 -DNCSTATES=0  -D
rtGetInf.c
### Compiling rtGetNaN.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab0_v2:1" -DVERBOSE  -DUSE_RTMODEL /wd4100 -DMODEL=ece147c_lab0_v2 -DRT -DNUMST=1  -DTID01EQ=0 -DNCSTATES=0  -D
rtGetNaN.c
### Compiling rt_nonfinite.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab0_v2:1" -DVERBOSE  -DUSE_RTMODEL /wd4100 -DMODEL=ece147c_lab0_v2 -DRT -DNUMST=1  -DTID01EQ=0 -DNCSTATES=0  -D
rt_nonfinite.c
### Compiling C:\PROGRA~1\MATLAB\R2011b\rtw\c\src\rt_sim.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab0_v2:1" -DVERBOSE  -DUSE_RTMODEL /wd4100 -DMODEL=ece147c_lab0_v2 -DRT -DNUMST=1  -DTID01EQ=0 -DNCSTATES=0  -D
rt_sim.c
    rc  /r ece147c_lab0_v2.auto.rc
Microsoft (R) Windows (R) Resource Compiler Version 6.1.7600.16385
Copyright (C) Microsoft Corporation.  All rights reserved.

### Linking ...
    C:\PROGRA~1\MATLAB\R2011b\sys\perl\win32\bin\perl C:\PROGRA~1\MATLAB\R2011b\rtw\c\tools\mkvc_lnk.pl ece147c_lab0_v2.lk ece147c_lab0_v2.obj ece147c_lab0_v2_data.obj ece14
    link /RELEASE  /INCREMENTAL:NO /NOLOGO -subsystem:console,5.02 /NODEFAULTLIB:libc.lib /NODEFAULTLIB:libcmt.lib /NODEFAULTLIB:msvcrtd.lib  /NODEFAULTLIB:libcd.lib /NODEFA
### Created executable ece147c_lab0_v2.rt-win64
### Downloading ece147c_lab0_v2 to target 'shmem://quarc-target:1' ...
### Model ece147c_lab0_v2 has been downloaded to target 'shmem://quarc-target:1' (65536 bytes)
>>
>> % yay, no errors :)
```

Start

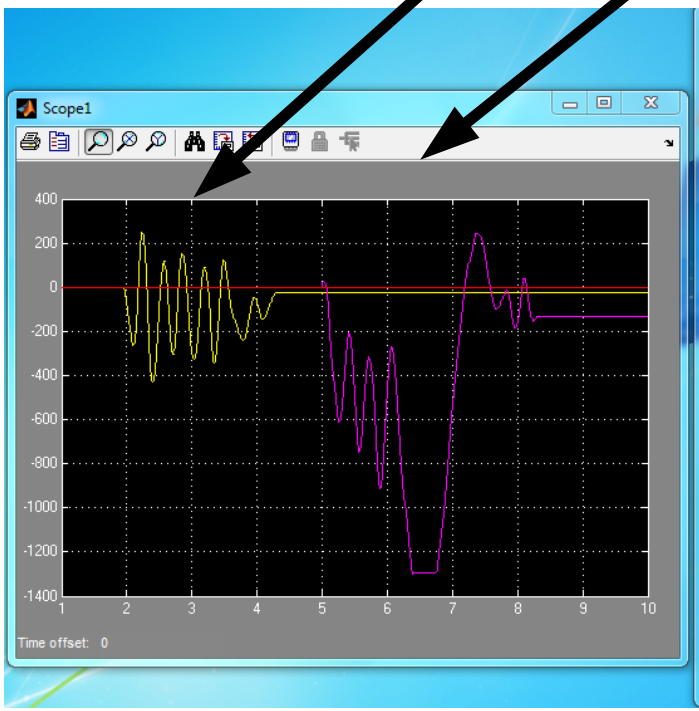

ece147c_lab0_v2
File Edit View Simulation Format Tools QUARC Help
10
External
Connect To Target
This model plots the encoders for 10 seconds.
HW config:
- powered-cart's wheel encoder is plugged into encoder 0
- springy cart is plugged into encoder 1
- don't even need univ. pwr. module powered to see the encoder's values.
- Moving the encoder about 6in results in encoder counts of ~5000
The trick: Had to enable scopes for logging.
Tools -> "external mode control panel" -> signals & triggering ->
ensure all scopes are "on" (not off) by selecting them and clicking "on" radio button
HIL Read Encoder
HIL Read Encoder (HIL-1)
Scope1
Step
trigger scope
HIL Initialize HIL-1 (q4-0)
Ready
100%
T=0.00
FixedStepDiscrete
ece147c_lab0_v2
File Edit View Simulation Format Tools QUARC Help
10
External
This model plots the encoders for 10 seconds.
HW config:
- powered-cart's wheel encoder is plugged into encoder 0
- springy cart is plugged into encoder 1
- don't even need univ. pwr. module powered to see the encoder's values.
- Moving the encoder about 6in results in encoder counts of ~5000
The trick: Had to enable scopes for logging.
Tools -> "external mode control panel" -> signals & triggering ->
ensure all scopes are "on" (not off) by selecting them and clicking "on" radio button
HIL Read Encoder
HIL Read Encoder (HIL-1)
Scope1
Step
trigger scope
HIL Initialize HIL-1 (q4-0)
External
100%
T=0.000
FixedStepDiscrete

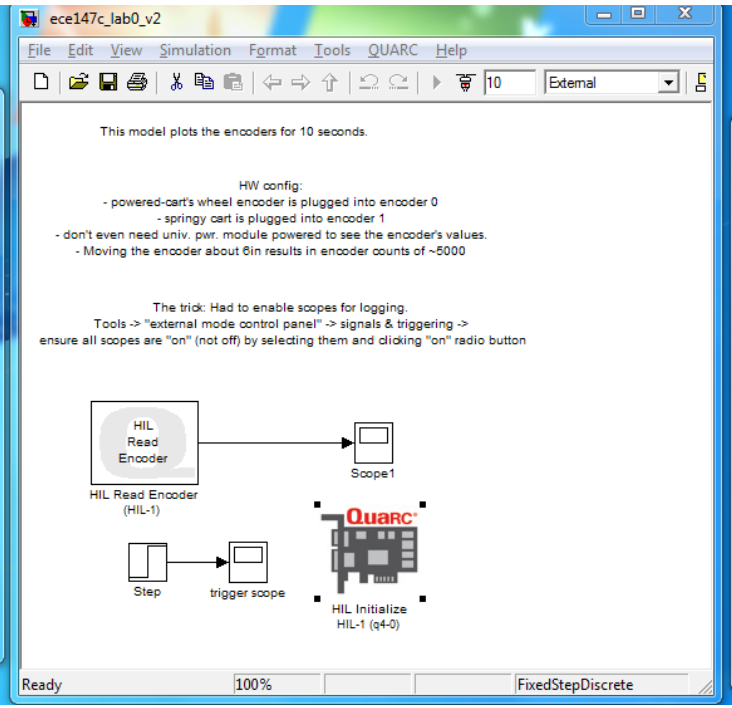


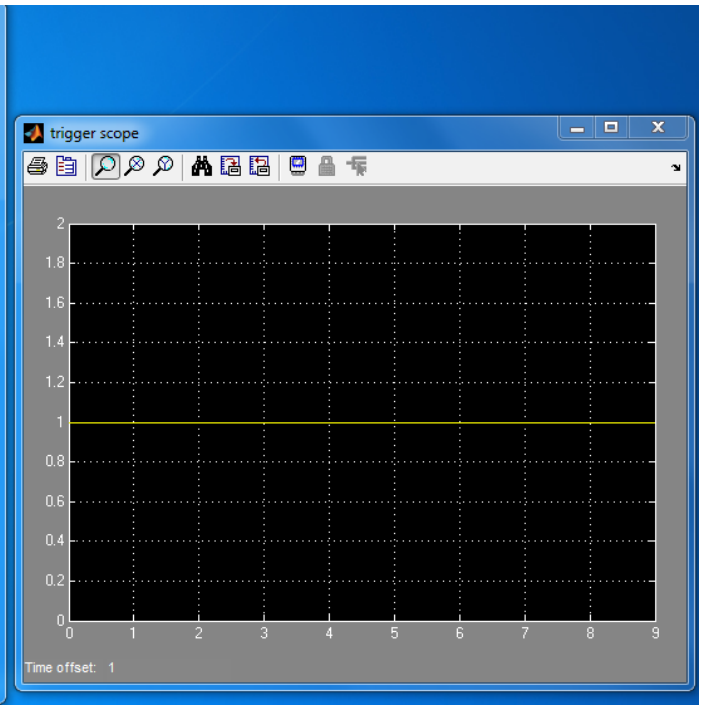
Wiggle motor-cart's wheel encoder

Wiggle springy-cart's wheel encoder

Note: doesn't show 3 encoders??



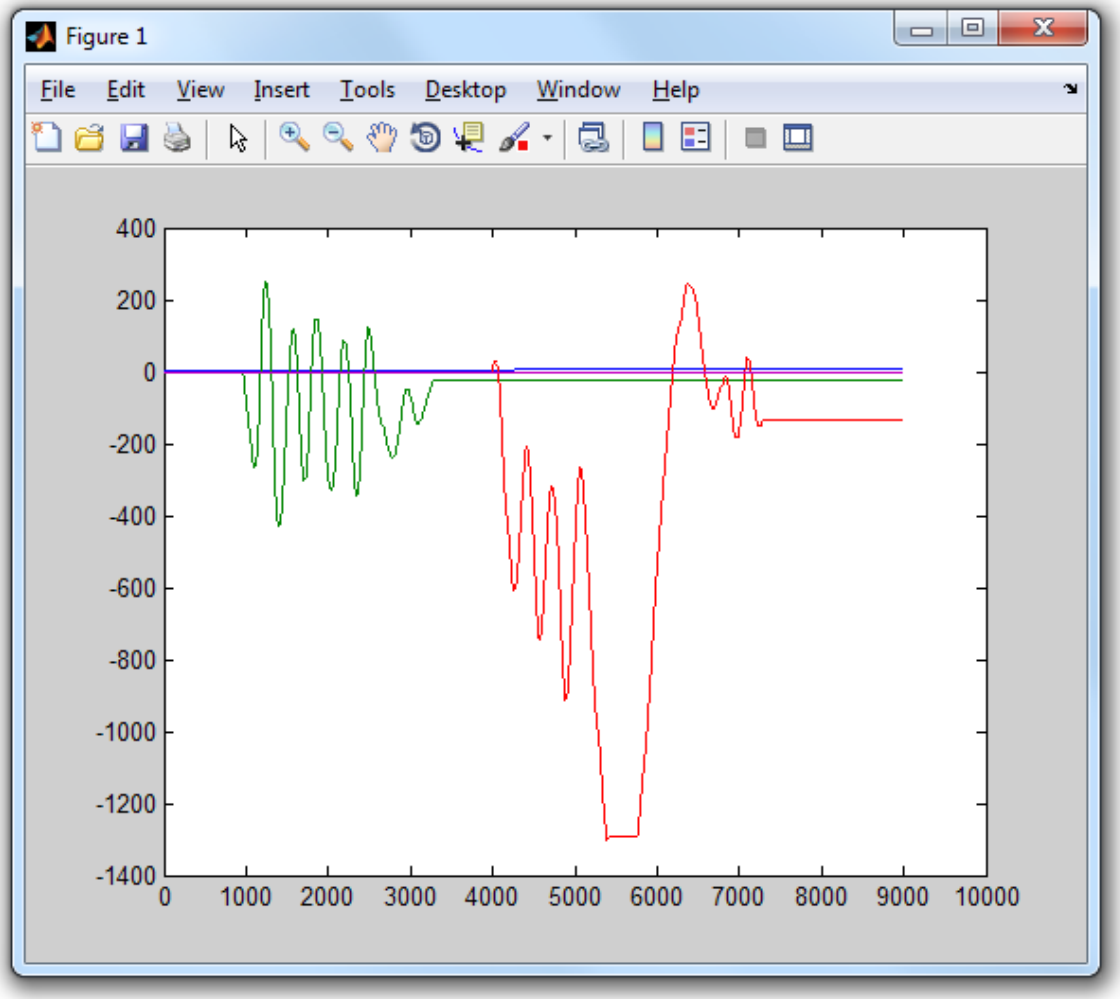




Command Window

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

```
>> whos
  Name                Size              Bytes  Class     Attributes

  ScopeData        9001x2              144016  double
  ScopeData1       9001x5              360040  double

>> plot(ScopeData1)
>>
```



Next: move motor

ece147c_lab0_v3

File Edit View Simulation Format Tools QUARC Help

10 External

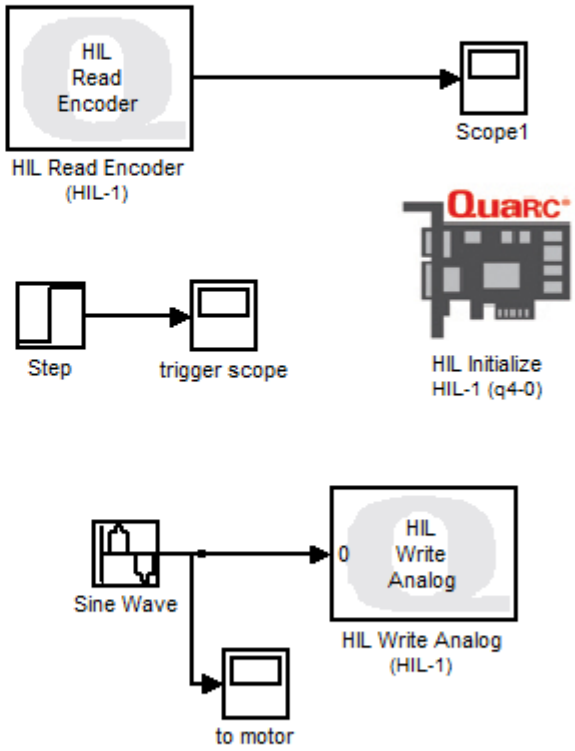
Move cart slightly

This model sends a sine wave command to the motor.

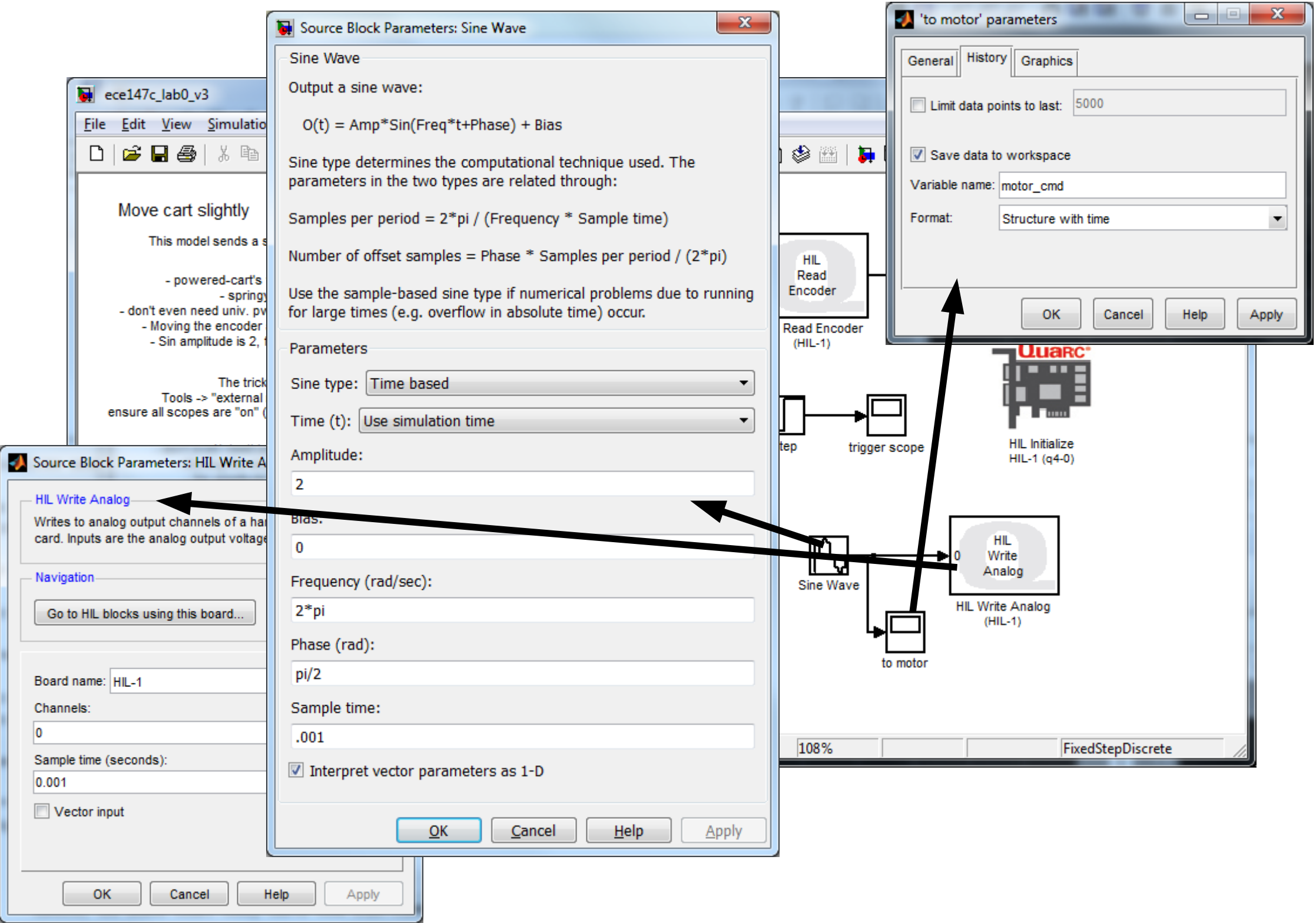
HW config:
- powered-cart's wheel encoder is plugged into encoder 0
- springy cart is plugged into encoder 1
- don't even need univ. pwr. module powered to see the encoder's values.
- Moving the encoder about 6in results in encoder counts of ~5000
- Sin amplitude is 2, freq is 2*pi. Results in very small 3" wiggles

The trick: Had to enable scopes for logging.
Tools -> "external mode control panel" -> signals & triggering ->
ensure all scopes are "on" (not off) by selecting them and clicking "on" radio button

Note: this is also reqd to add a new scope



Ready 108% FixedStepDiscrete


ece147c_lab0_v3
File Edit View Simulatio
Move cart slightly
This model sends a s
- powered-cart's
- springy
- don't even need univ. pw
- Moving the encoder
- Sin amplitude is 2,
The trick
Tools -> "external
ensure all scopes are "on" (
Source Block Parameters: HIL Write A
HIL Write Analog
Writes to analog output channels of a ha
card. Inputs are the analog output voltage
Navigation
Go to HIL blocks using this board...
Board name: HIL-1
Channels:
0
Sample time (seconds):
0.001
Vector input
OK Cancel Help Apply
Source Block Parameters: Sine Wave
Sine Wave
Output a sine wave:
O(t) = Amp*Sin(Freq*t+Phase) + Bias
Sine type determines the computational technique used. The parameters in the two types are related through:
Samples per period = 2*pi / (Frequency * Sample time)
Number of offset samples = Phase * Samples per period / (2*pi)
Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.
Parameters
Sine type: Time based
Time (t): Use simulation time
Amplitude:
2
Bias:
0
Frequency (rad/sec):
2*pi
Phase (rad):
pi/2
Sample time:
.001
Interpret vector parameters as 1-D
OK Cancel Help Apply
'to motor' parameters
General History Graphics
Limit data points to last: 5000
Save data to workspace
Variable name: motor_cmd
Format: Structure with time
OK Cancel Help Apply
HIL Read Encoder
Read Encoder (HIL-1)
trigger scope
HIL Initialize HIL-1 (q4-0)
Sine Wave
HIL Write Analog
HIL Write Analog (HIL-1)
to motor
108%
FixedStepDiscrete

MATLAB R2011b

File Edit Debug Parallel Desktop Window Help

Current Folder: X:\ECE147C_AdvancedDigitalControlLab_Hespanha_Spr2014\Labs\Tools

Shortcuts How to Add What's New

Current Folder

« Labs ▸ Tools ▸

Name

- ece147c_lab0_v2_quarc_win64
- ece147c_lab0_v3_quarc_win64
- slprj
- .~lock.lab0_v2_setup.odg#
- 20140407_142203.png
- 20140407_142323.png
- 20140407_142353.png
- 20140407_142412.png
- 20140407_142430.png
- 20140407_142501.png
- 20140407_142511.png
- 20140407_142523.png
- 20140407_142655.png
- 20140407_142758.png
- 20140407_142822.png
- 20140407_143557.png
- 20140407_143632.png
- 20140407_143637.png
- 20140407_143646.png
- 20140407_143651.png
- 20140407_143701.png
- 20140407_143704.png
- 20140407_143714.png
- 20140407_143718.png
- 20140407_144614.png
- 20140407_144619.png
- 20140407_144634.png
- 20140407_144641.png
- 20140407_144647.png
- 20140407_144658.png
- 20140407_144852.png
- 20140407_144951.png
- 20140407_145134.png
- 20140407_145300.png
- 20140407_145401.png
- 20140407_150651.png
- 20140407_151409.png
- 20140407_151632.png

Details

Select a file to view details

Command Window

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

```
### Generating TLC interface API.
..........................
### Creating data type transition file ece147c_lab0_v3_dt.h
.### Creating project marker file: rtw_proj.tmw
.
### Processing Template Makefile: C:\Program Files\Quanser\QUARC
### Creating ece147c_lab0_v3.mk from C:\Program Files\Quanser\QU
### Building ece147c_lab0_v3: .\ece147c_lab0_v3.bat

X:\ECE147C_AdvancedDigitalControlLab_Hespanha_Spr2014\Labs\Tools
Setting environment for using Microsoft Visual Studio 2010 x64 c

Microsoft (R) Program Maintenance Utility Version 10.00.30319.01
Copyright (C) Microsoft Corporation.  All rights reserved.

### Compiling ece147c_lab0_v3.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab
ece147c_lab0_v3.c
### Compiling ece147c_lab0_v3_data.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_lab
ece147c_lab0_v3_data.c
### Compiling ece147c_lab0_v3_main.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_
ece147c_lab0_v3_main.c
### Compiling rtGetInf.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_
rtGetInf.c
### Compiling rtGetNaN.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_
rtGetNaN.c
### Compiling rt_nonfinite.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_
rt_nonfinite.c
### Compiling C:\PROGRA~1\MATLAB\R2011b\rtw\c\src\rt_sim.c
    cl -Ox -DNDEBUG  -DEXT_MODE -DMODEL_URI="shmem://ece147c_
rt_sim.c
    rc  /r ece147c_lab0_v3.auto.rc
Microsoft (R) Windows (R) Resource Compiler Version 6.1.7600.
Copyright (C) Microsoft Corporation.  All rights reserved.

### Linking ...
    C:\PROGRA~1\MATLAB\R2011b\sys\perl\win32\bin\perl C:\PROG
    link /RELEASE  /INCREMENTAL:NO /NOLOGO -subsystem:console
### Created executable ece147c_lab0_v3.rt-win64
### Downloading ece147c_lab0_v3 to target 'shmem://quarc-targ
### Model ece147c_lab0_v3 has been downloaded to target 'shmem
>>
```

ece147c_lab0_v3

File Edit View Simulation Format Tools QUARC Help

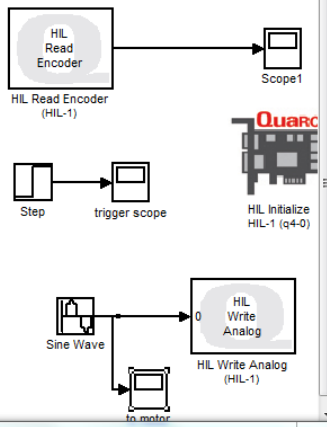
Move cart slightly

This model sends a sine wave command to the motor.

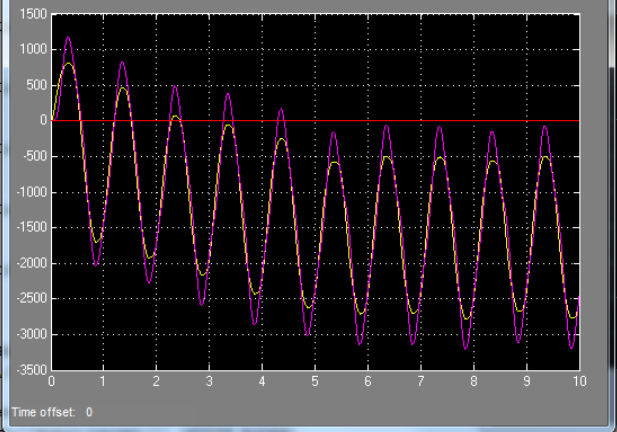
HW config:
- powered-cart's wheel encoder is plugged into encoder 0
- springy cart is plugged into encoder 1
- don't even need univ. pwr. module powered to see the encoder's values.
- Moving the encoder about 6in results in encoder counts of ~5000
- Sin amplitude is 2, freq is 2*pi. Results in very small 3" wiggles

The trick: Had to enable scopes for logging.
Tools -> "external mode control panel" -> signals & triggering ->
ensure all scopes are "on" (not off) by selecting them and clicking "on" radio button

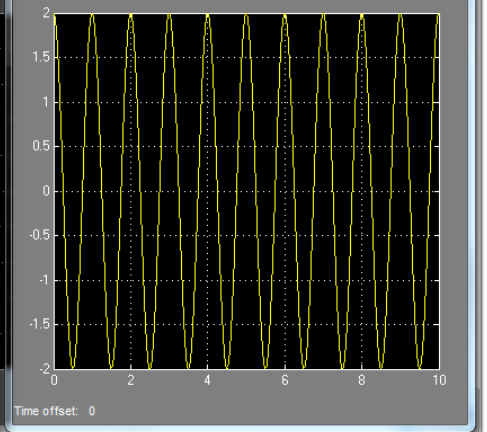
Note: this is also reqd to add a new scope



Scope1



to motor



Start

OVR

3:47 PM
4/7/2014

Troubleshooting:
- is Universal power module on?
- Is analog output cable connecting analog output 0 to UPM's "From D/A"?
- Is cable from UPM's "To Load" to motor-cart's motor plug?
- Is simulink "HIL Write Analog" block set to same channel as the board's analog output?

Correlation Method Example / Sanity Check

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- ECE 147C
- 2014.04.06

Contents

- Compute intermediate vars
- Correlation method
- Sanity check: Gain
- Sanity check: Phase

You should run ece147c_lab0_v3.mdl (in the same dir as this file) before running this file.
The simulation produces variables: encoders, motor_cmd, trigger_signal.

```
assert( exist('encoders','var') && exist('motor_cmd','var') && exist('trigger_signal','var') )
```

Compute intermediate vars

```
u     = motor_cmd.signals.values(:,1);
y     = encoders.signals.values(:,2);
T     = length(y); % number of samples
Omega = 2*pi*0.001; % sine block into motor_cmd has freq 2pi rad/sec & 0.001 sec/sample; Omega is in rad/sample
a     = 2; % amplitude of the motor_cmd sine wave block
```

Your input u should be a cosine, ie, its first element should be its amplitude.

```
assert( abs(u(1)-a) < 1e-3 ) % roughly
```

Correlation method

From the notes, for a fixed $\Omega \in [0, \pi]$ and given data $y(k) \in R, k = 1, \ldots, T$, the relationship between y and the transfer function H is

$$K_\Omega := \frac{1}{T}\sum_{k=1}^{T} e^{-j\Omega k} y(k) = \frac{\alpha}{2} H(e^{j\Omega})$$

```
x=exp(-i*Omega*[1:T]);
K = 1/T*(x*y)
H = K*2/a
```

```
K =

 -4.6560e+002 -4.9713e+002i


H =

 -4.6560e+002 -4.9713e+002i
```

That value of H is one point on the bode plot. It has magnitude and phase

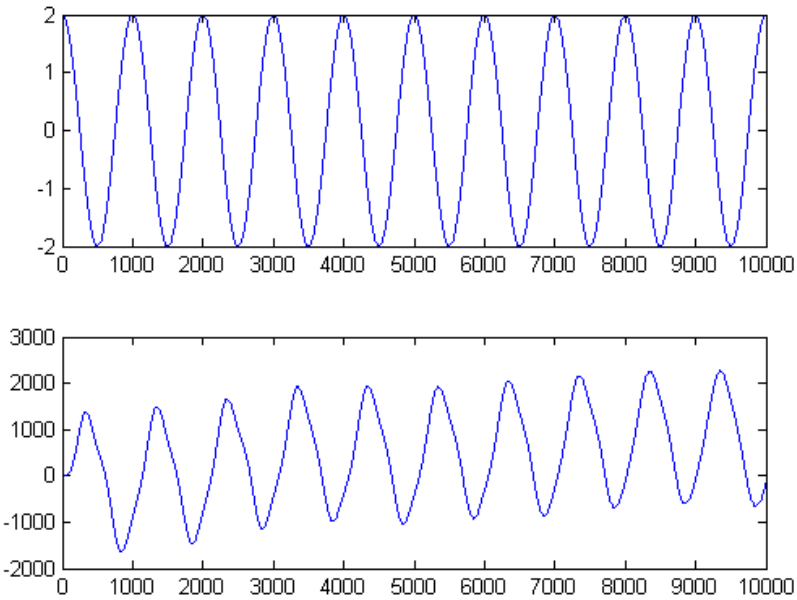
```
abs(H) % gain (unitless)
angle(H) % phase shift (rad)
```

```
ans =

  681.1236


ans =

   -2.3235
```

Sanity check: Gain

Estimate how much the plant amplified u to y, and compare it to the gain at this frequency $H(e^{j\Omega})$.

```
figure
subplot(2,1,1); plot(u)
subplot(2,1,2); plot(y)
```



Looks like about a swing of 4 for u and 2900 for y, hence:

```
2900/4
```

```
ans =

   725
```

Pretty close to abs(H).

Sanity check: Phase

Looking at the plot, it looks like u hits a peak at sample 8000 and y hits a peak at 8350.
Hence the phase should something like

```
- 350 * Omega % 350 samp * Omega rad/samp
```

```
ans =

   -2.1991
```

Pretty close to angle(H).

Could we have done better by throwing away the initial transient? Be careful to throw away starting at an index where u is at its peak (still a cosine)!

```
y = y(3000:end);
T = length(y);
x=exp(-i*Omega*[1:T]);
K = 1/T*(x*y)
H = K*2/a
abs(H)
angle(H)
```

```
K =

 -4.7915e+002 -4.9374e+002i


H =
```

```
 -4.7915e+002 -4.9374e+002i

ans =

  688.0183

ans =

   -2.3412
```

Not a big improvement. Our initial test was pretty long. If it had been shorter, we might've gained more from tossing the initial data.

Published with MATLAB® 7.13