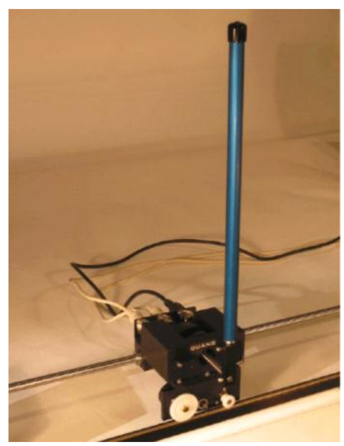
ASEIL Quanser Controls Lab, Bu-212E

Running Linear Inverted Pendulum Experiment

Contents

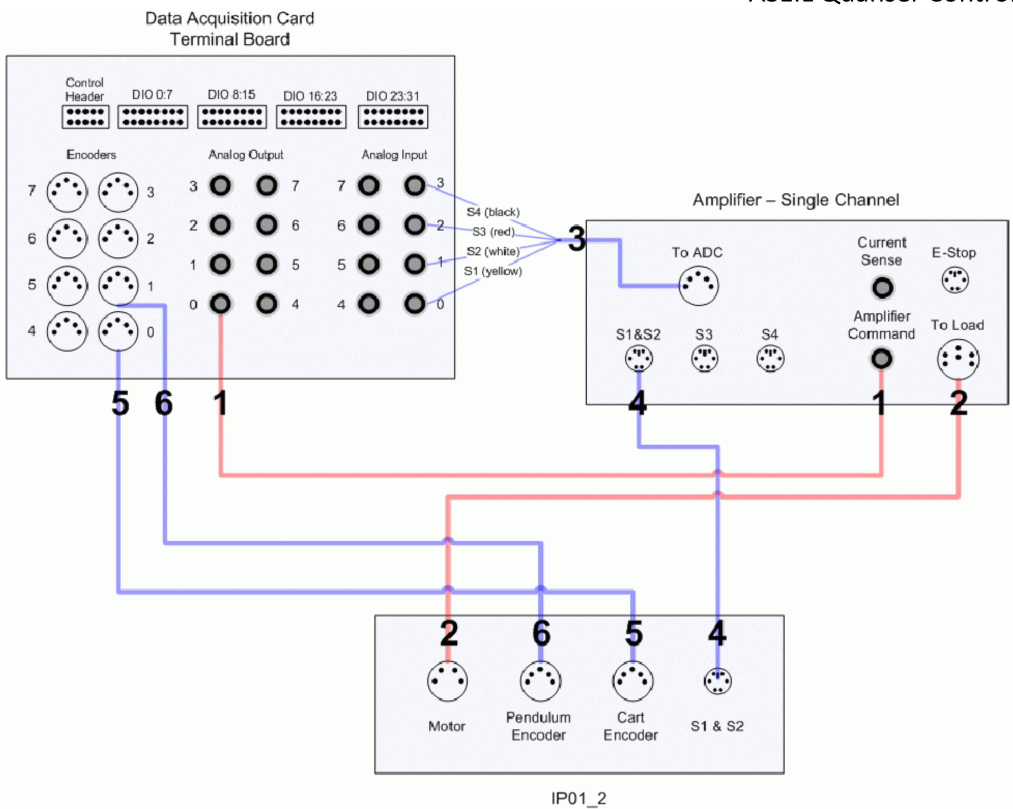
Purpose

The goal of this experiment is to design, implement and test a Liner-Quadratic-Regulator-based control system that keeps a single inverted pendulum (SIP) balanced and tracks the linear car to a commanded position



Physical Setup

Make sure everything is connected according to the following wiring diagram (note, this experiment does not necessarily require a 8-channel DAQ board as shown in the figure, but can also utilize a 2-channel DAQ board)



Procedures

Step 1: Starting MATLAB

Start MATLAB and change the active directory to:

C:\Users\Public\Desktop\QUARC\Linear Labs with Manuals\Exp05-SIP-LQR\Lab Design Files

Step 2: Selecting Compiler

Type the following into the MATLAB command line and press enter

```
>> mex -setup
```

This will load the compiler into MATLAB. You must answer Y(es), 1, and Y(es) to the questions asked

```
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/R2011a/win64.html

Please choose your compiler for building MEX-files:

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

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

[0] None
```

```
Compiler: 1

Please verify your choices:

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

Are these correct [y]/n? y

Done . . .
```

Step 3: Setup File Editing

Next, edit the setup m-file to ensure proper parameters are set:

```
>> edit setup_lab_ip01_2_lfjc_sip.m
```

Ensure the correct cart is chosen (IP01 vs. IP02) and the correct pendulum length (12” vs. 24”). Make any desired changes to limit parameters and save the m-file

```
% ############### USER-DEFINED IP01 or IP02 with SIP CONFIGURATION
% Type of motorized cart: set to 'IP01', 'IP02'
% CART_TYPE = 'IP01';
CART_TYPE = 'IP02';
% if IP02: Type of Cart Load: set to 'NO_LOAD', 'WEIGHT'
IP02_LOAD_TYPE = 'NO_LOAD';
% IP02_LOAD_TYPE = 'WEIGHT';
% Type of single pendulum: set to 'LONG_24IN', 'MEDIUM_12IN'
PEND_TYPE = 'LONG_24IN';
% PEND_TYPE = 'MEDIUM_12IN';
% Turn on or off the safety watchdog on the cart position: set it to 1 or 0
X_LIM_ENABLE = 1;        % safety watchdog turned ON
% X_LIM_ENABLE = 0;       % safety watchdog turned OFF
% Safety Limits on the cart displacement (m)
X_MAX = 0.25;             % cart displacement maximum safety position (m)
X_MIN = - X_MAX;         % cart displacement minimum safety position (m)
% Turn on or off the safety watchdog on the pendulum angle: set it to 1 or 0
ALPHA_LIM_ENABLE = 1;        % safety watchdog turned ON
% ALPHA_LIM_ENABLE = 0;       % safety watchdog turned OFF
```

Step 4: Running a Setup File

Run the setup file to load the setup variables into MATLAB workspace

```
>> run setup_lab_ip01_2_sip.m
```

The setup script is finished when it displays the calculated gain values:

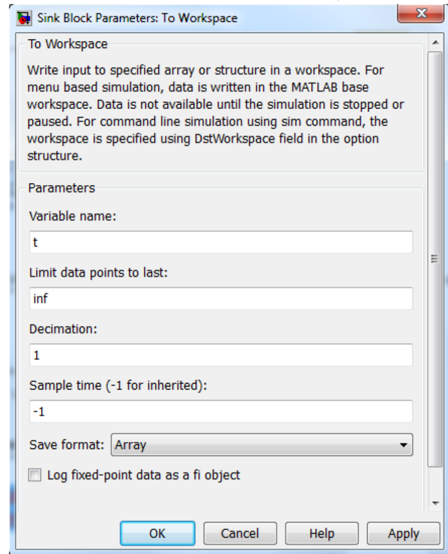
```
K(1) = -44.7214 V/m     (Cart position)
K(2) = 200.8014 V/rad   (Pendulum angle)
K(3) = -49.7681 V.s/m   (Cart speed)
K(4) = 27.3761 V.s/rad  (Pendulum angular velocity)
```

Step 5: Running a Simulink Model

Run or double-click the following file to load the Simulink model

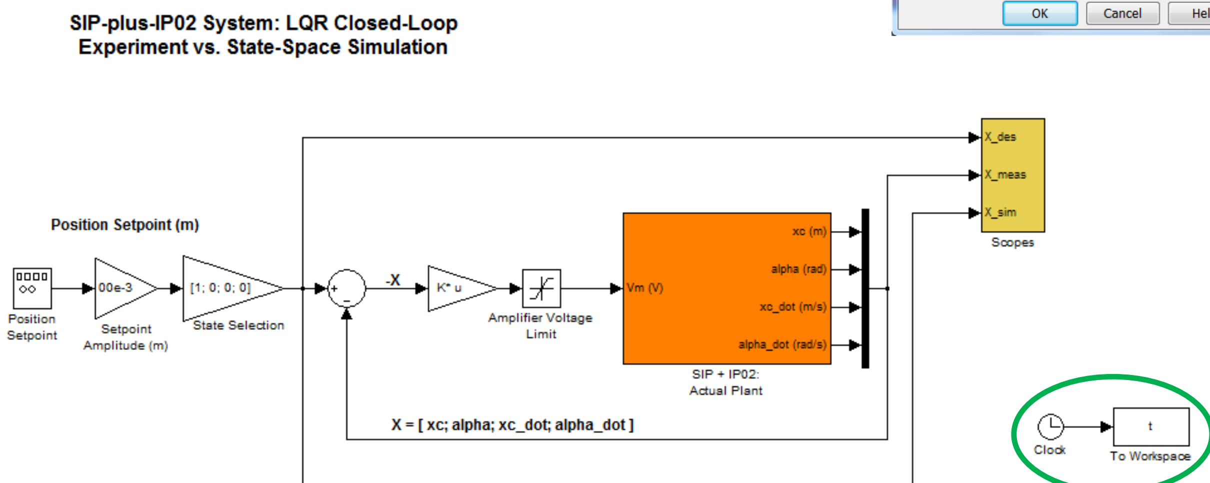
```
>> run q_sip_lqr_ip02.mdl
```

If you wish to extract data from the experiment for later analysis with MATLAB, the Simulink model has to be modified to export data into the workspace. If you do not need this functionality, go to Step 7.



Step 6: Setup Sending the Outputs to Workspace

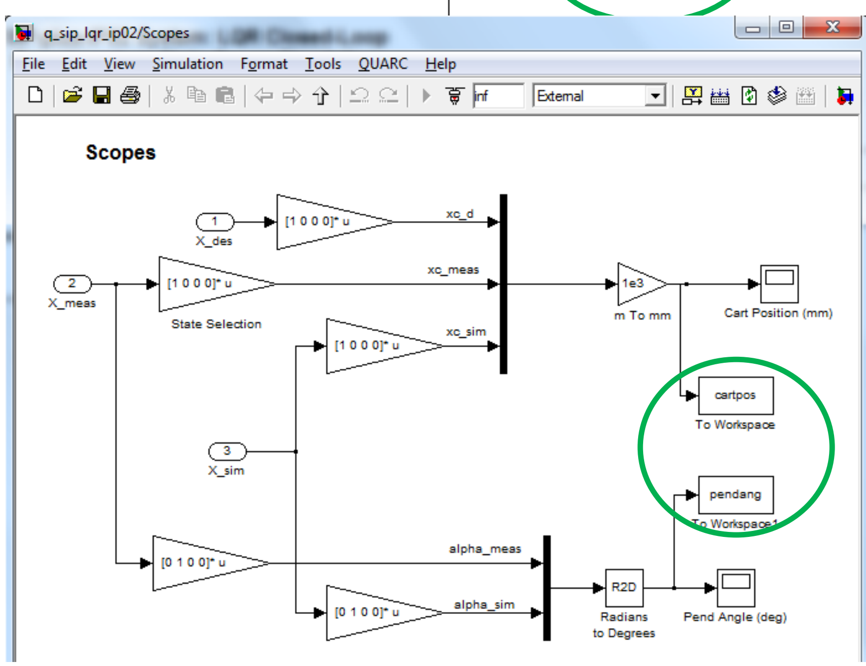
First, on the top-level system layout, add a clock source connected to a workspace sink.



Open the workspace sink, choose a variable name, and ensure the save format is "array."

Next, double-click the "Scopes" functional block and add branches from the scopes to two workspace sinks:

Again, choose variable names for each workspace sink and ensure the save format is "array."

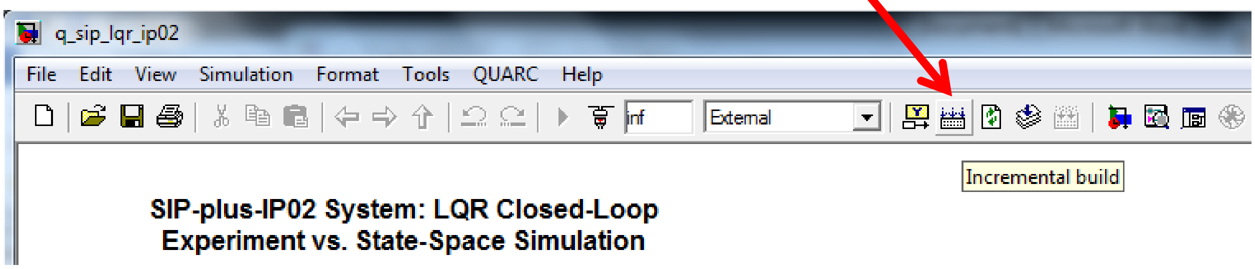


Step 7: Running Experiment

In Simulink, under the Quarc menu, choose Options, then find the Code Generation options. Confirm the operating system matches the computer (Win64 for HP / Win32 for Dell)

Step 8: Building Simulation

Close the options window and click incremental build icon on the toolbar

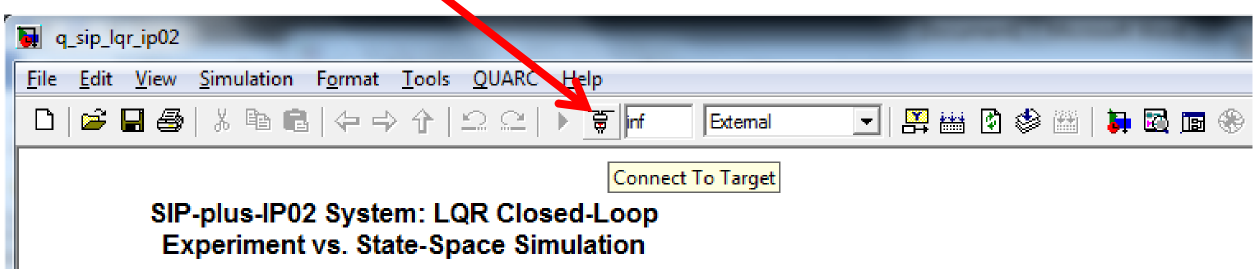


The build is finished when the following message appears in the MATLAB command window

```
### Model q_sip_lqr_ip02 has been downloaded to target 'shmem://quarc-target:1'
(66048 bytes)
>>
```

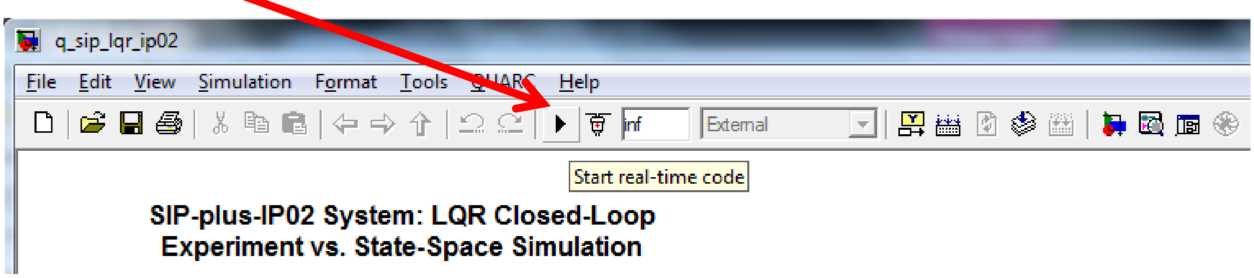
Step 9: Connecting Simulation to the Model

Connect the simulation to the model



Step 10: Starting Simulation

Start the program



The pendulum must be manually positioned upright to initiate the control system. Move it upright slowly, watching the pendulum angle scope to ensure the angle is correct. The control system will take over once the pendulum has been upright for approximately one second.

Step 11: Consolidating Data after (between) Experiment(s)

If data was output to the MATLAB workspace consolidate data into a single vector

```
>> OutputData=[t cartpos(:,2) pendang(:,1)]
```

The output data should be saved to another folder (as a .mat file), because rebuilding the code clears the MATLAB workspace.

References

[1] Quanser Inc., *IP01 and IP02 User Manual*.
[2] Quanser Inc., *IP02 - Self-Erecting Single Inverted Pendulum (SESIP) – Linear Experiment #6: PV and LQR Control - Student Handout*.
[3] Quanser Inc., *IP02 – Self-Erecting Single Inverted Pendulum (SESIP) – Linear Experiment #6: PV and LQR Control – Instructor Manual*.