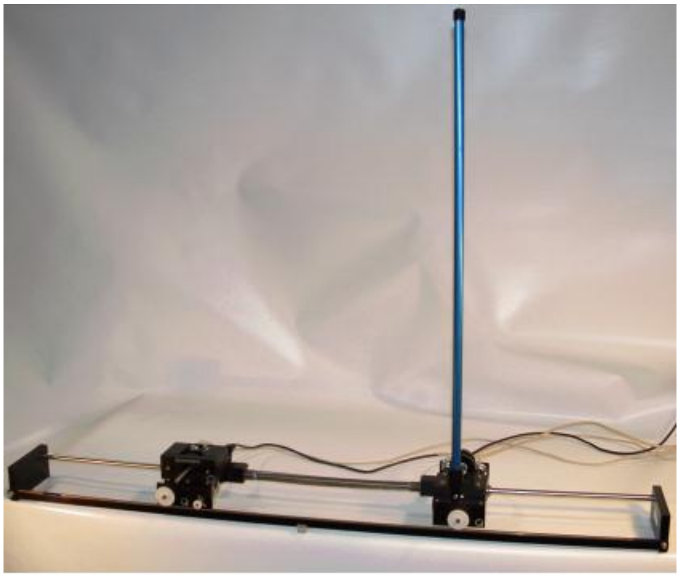
ASEIL Quanser Controls Lab, Bu-212E

Running Linear Flexible Joint Cart + Single Inverted Pendulum Experiment

Contents

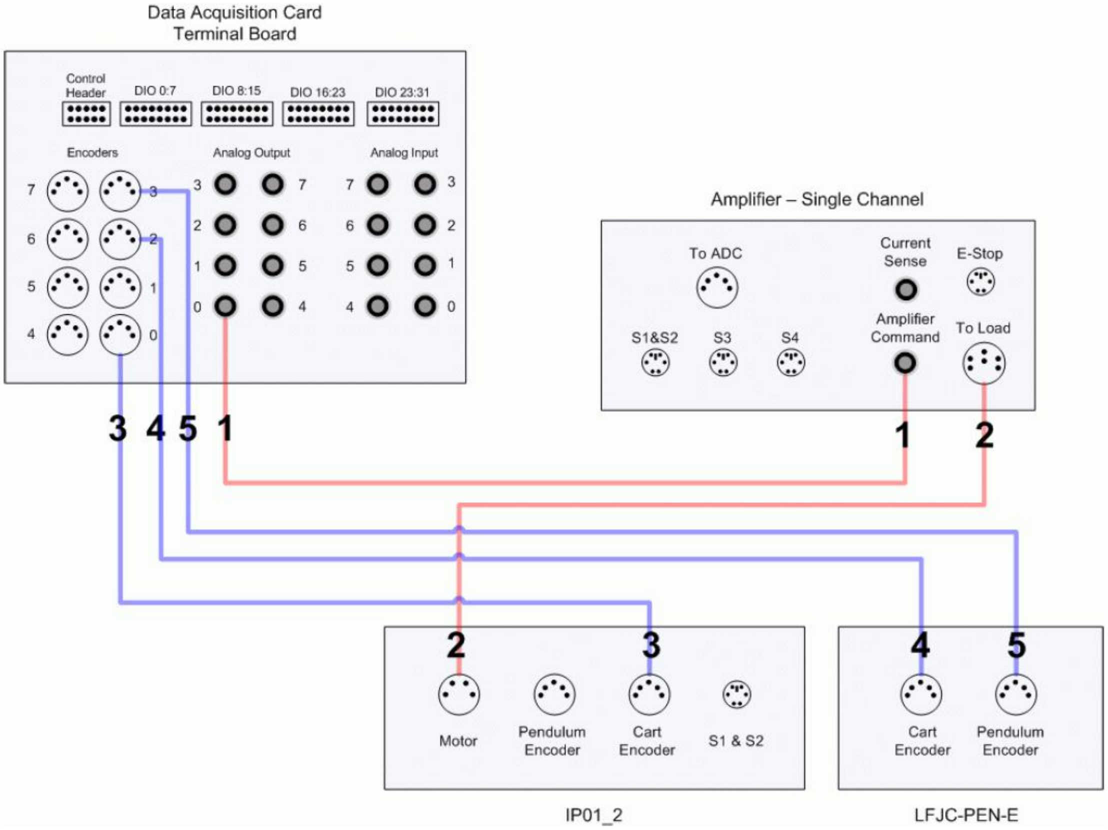
Purpose

The goal of this experiment is to design, implement and test a Liner-Quadratic-Regulator-based control system that balances a single inverted pendulum (SIP) on a spring-driven linear cart (LFJC-PEN-E) while minimizing the induced vibrations due to the elastic linkage



Physical Setup

Make sure everything is connected according to the following wiring diagram (note, this experiment requires a 8-channel DAQ board, not 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\Exp11 - LJFC+SIP\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 LFJC-plus-SIP-IP01-or-IP02 CONFIGURATION #####
% Type of motorized cart: set to 'IP01', 'IP02'
% CART_TYPE = 'IP01';
CART_TYPE = 'IP02';
% Type of IP01 or IP02 Cart Load: set to 'NO_WEIGHT', 'WEIGHT'
%IP01_2_WEIGHT_TYPE = 'NO_WEIGHT';
IP01_2_WEIGHT_TYPE = 'WEIGHT';
% Type of LFJ Cart: set to 'LFJC-PEN-E'
LFJC_TYPE = 'LFJC-PEN-E';
% Type of LFJC Load: set to 'NO_WEIGHT', 'ONE_WEIGHT', 'TWO_WEIGHT'
%LFJC_WEIGHT_TYPE = 'NO_WEIGHT';
% LFJC_WEIGHT_TYPE = 'ONE_WEIGHT';
LFJC_WEIGHT_TYPE = 'TWO_WEIGHT';
% Type of single pendulum: set to 'LONG_24IN'
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 IP01 or IP02 cart displacement (m)
X_MAX = 0.15; % 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
% Safety Limits on the pendulum angle (deg)
global ALPHA_MAX ALPHA_MIN
ALPHA_MAX = 15; % pendulum angle maximum safety position (deg)
ALPHA_MIN = - ALPHA_MAX; % pendulum angle minimum safety position (deg)
```

```
% Amplifier Gain used: set VoltPAQ to 1
K_AMP = 1;
% Amplifier Type: set to 'VoltPAQ' or 'Q3'
AMP_TYPE = 'VoltPAQ';
% AMP_TYPE = 'Q3';
% Digital-to-Analog Maximum Voltage (V); for Q8/Q4/MultiQ cards set to 10
VMAX_DAC = 10;
% ##### END OF USER-DEFINED LFJC-plus-SIP-IP01-or-IP02 CONFIGURATION #####
```

Step 4: Running a Setup File

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

```
>> run setup_lab_ip01_2_lfjc_sip.m
```

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

```
K(1) = -136.5039 V/m (Cart position)
K(2) = -725.4983 V/m (Spring extension)
K(3) = 331.6587 V/rad (Pendulum angle)
K(4) = -74.5857 V.s/m (Cart speed)
K(5) = -99.5908 V.s/m (Spring extension velocity)
K(6) = 45.7139 V.s/rad (Pendulum angular velocity)
K(7) = -20 V/(m.s) (Cart position integrator)
```

Step 5: Running a Simulink Model

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

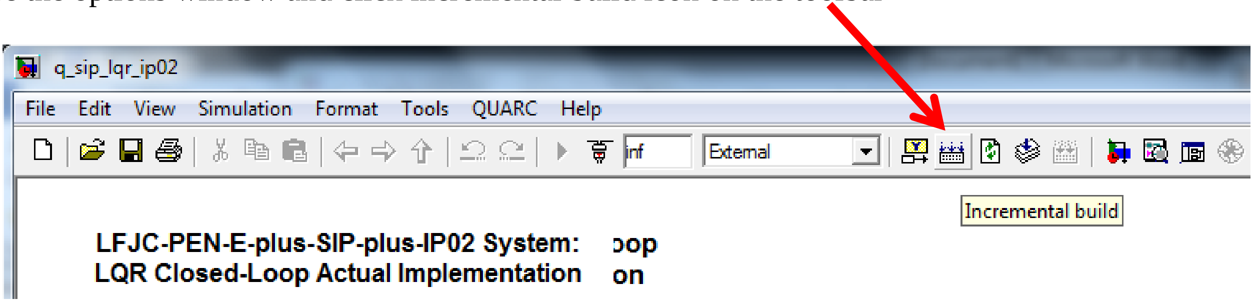
```
>> run q_lfjce_sip_ip02.mdl
```

Step 6: 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 7: Building Simulation

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

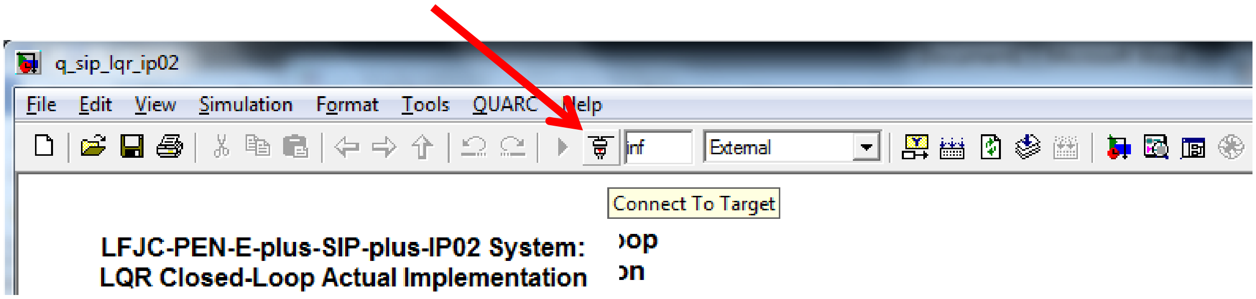


The build is finished when the following message appears in the MATLAB command window

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

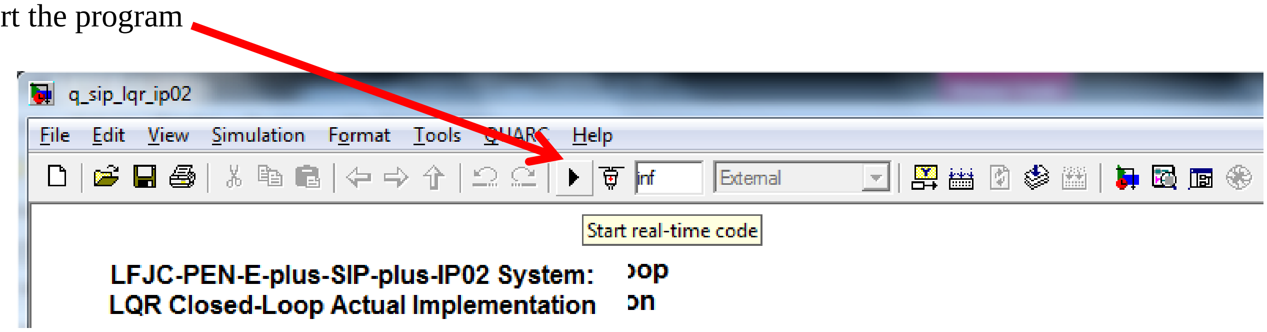
Step 8: Connecting Simulation to the Model

Connect the simulation to the model


q_sip_lqr_ip02
File Edit View Simulation Format Tools QUARC Help
inf
External
Connect To Target
LFJC-PEN-E-plus-SIP-plus-IP02 System: ›op
LQR Closed-Loop Actual Implementation ›n

Step 9: Starting Simulation

Start the program


q_sip_lqr_ip02
File Edit View Simulation Format Tools QUARC Help
inf
External
Start real-time code
LFJC-PEN-E-plus-SIP-plus-IP02 System: ›op
LQR Closed-Loop Actual Implementation ›n

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.

References

[1] Quanser Inc., *IP01 and IP02 - Linear Experiment #0: Integration with QUARC - Student Handout*.
[2] Quanser Inc., *IP01 and IP02 User Manual*.
[3] Quanser Inc., *IP01 and IP02 - Single Inverted Pendulum*.
[4] Quanser Inc., *DAQ User Manual*.
[5] Quanser Inc., *Power Amplifier User Manual*.
[6] Quanser Inc., *QUARC User Manual*, 2009 (type `doc quarc` in MATLAB to access).
[7] Quanser Inc., *IP01 and IP02 - Single Inverted Pendulum – Linear Experiment #5: LQR Control – Student Handout*.