

Precision Modular Servo - Control Experiments

33-008-1C

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Control in a MATLAB[®] Environment

Precision Modular Servo

Control Experiments



Feedback

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**Precision Modular Servo
Control Experiments**

Preface

Notes



Precision Modular Servo Control Experiments

Preface

THE HEALTH AND SAFETY AT WORK ACT 1974

We are required under the Health and Safety at Work Act 1974, to make available to users of this equipment certain information regarding its safe use.

The equipment, when used in normal or prescribed applications within the parameters set for its mechanical and electrical performance, should not cause any danger or hazard to health or safety if normal engineering practices are observed and they are used in accordance with the instructions supplied.

If, in specific cases, circumstances exist in which a potential hazard may be brought about by careless or improper use, these will be pointed out and the necessary precautions emphasised.

While we provide the fullest possible user information relating to the proper use of this equipment, if there is any doubt whatsoever about any aspect, the user should contact the Product Safety Officer at Feedback Instruments Limited, Crowborough.

This equipment should not be used by inexperienced users unless they are under supervision.

We are required by European Directives to indicate on our equipment panels certain areas and warnings that require attention by the user. These have been indicated in the specified way by yellow labels with black printing, the meaning of any labels that may be fixed to the instrument are shown below:



CAUTION -
RISK OF
DANGER



CAUTION -
RISK OF
ELECTRIC SHOCK



CAUTION -
ELECTROSTATIC
SENSITIVE DEVICE

Refer to accompanying documents

PRODUCT IMPROVEMENTS

We maintain a policy of continuous product improvement by incorporating the latest developments and components into our equipment, even up to the time of dispatch.

All major changes are incorporated into up-dated editions of our manuals and this manual was believed to be correct at the time of printing. However, some product changes which do not affect the instructional capability of the equipment, may not be included until it is necessary to incorporate other significant changes.

COMPONENT REPLACEMENT

Where components are of a 'Safety Critical' nature, i.e. all components involved with the supply or carrying of voltages at supply potential or higher, these must be replaced with components of equal international safety approval in order to maintain full equipment safety.

In order to maintain compliance with international directives, all replacement components should be identical to those originally supplied.

Any component may be ordered direct from Feedback or its agents by quoting the following information:

- | | |
|------------------------|----------------------------|
| 1. Equipment type | 2. Component value |
| 3. Component reference | 4. Equipment serial number |

Components can often be replaced by alternatives available locally, however we cannot therefore guarantee continued performance either to published specification or compliance with international standards.



CE DECLARATION CONCERNING ELECTROMAGNETIC COMPATIBILITY

Should this equipment be used outside the classroom, laboratory study area or similar such place for which it is designed and sold then Feedback Instruments Ltd hereby states that conformity with the protection requirements of the European Community Electromagnetic Compatibility Directive (89/336/EEC) may be invalidated and could lead to prosecution.

This equipment, when operated in accordance with the supplied documentation, does not cause electromagnetic disturbance outside its immediate electromagnetic environment.

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**Precision Modular Servo
Control Experiments**

Contents

Note

In this manual "Input" refers to input from the plant to the I/O Board in the computer, and "output" refers to output to the plant from the I/O Board.



1 Introduction

The 33-008C Precision Modular Servo is a system designed to explore the techniques of servo motor control, with a set of hardware sufficiently precise to allow fine control of motor position and speed.

Various inputs are available to measure the state of the system. These include:

Digital Input (2 channels available)

Digital Input from the 33-300 Digital Encoder to measure the angle of rotation (and hence position) of the motor. The mechanical set provides for one unit of rotation of the encoder to one of the motor, so no scaling is involved at this point. Calculation of the rate of change of this position gives the motor speed.

Analogue Input (6 channels available)

Analogue Input from the GT150X, which gives a varying voltage proportional to motor speed.

Analogue input from the IP150H Input Potentiometer giving a varying voltage proportional to angular displacement.

Analogue input from the OP150K Output Potentiometer giving a varying voltage proportional to angular displacement.

Note that only the last two inputs are not used in the control experiments described in this manual.

Analogue Output (2 channels available)

Control Output is exercised by two analogue output channels to the 33-301



The 33-301 Interface Unit has 8 channels for input/output to / from the I/O Board. These are related to the channel numbers in the Advantech PCL812 (EISA) and PCI1711 (PCI) Boards as shown in Table 1.

33-301 Channel No.	PCL812 / PCI 1711 Channel No.	Input or Output (to / from I/O board)
AD1	10	Analogue Input Channel
AD2	11	Analogue Input Channel
AD3	12	Analogue Input Channel
AD4	13	Analogue Input Channel
AD5	14	Analogue Input Channel
AD6	15	Analogue Input Channel
DA1	0	Analogue Output Channel
DA2	1	Analogue Output Channel

Table 1: 33-301 - PCL812 / PCI1711 Channel Numbers Relationships



2 Safety Instructions

Read these instructions carefully



Ensure you are acquainted with the safety Instructions in the Preface to this Manual



In the event of an unexpected or erratic operation, the control effort should immediately be discontinued by switching off the power supply to the equipment



All users of this equipment should be familiar with and trained in good Laboratory Practice where electrical machinery is used.



When running any control experiment ensure that the Real Time control program is running before switching on the power supply unit



**Precision Modular Servo
Control Experiments**

Safety Instructions - [Read This](#)

Notes



3 Building the model and controlling execution

Building the Model

Build Options

Before initiating the subsequent automatic build process (that is using Real Time Workshop to generate, compile and link the actual C code to run the control model), it is necessary to ensure that the build options are set correctly.

Start MATLAB

Enter into the MATLAB Command Window

ModularCalib

You can also open it from the MATLAB File menu, or double click its icon before starting MATLAB.

To this end, select **Tools** from the Simulink model menu bar and then selecting **Real-Time Workshop** followed by **Options** from the pull-down menu. The **Simulation Parameters** window appears as shown in Figure 3-1.

From this window , click on the **Real-Time Workshop** tab

If you have followed the installation sequence described in the Installation manual 33-000C, the Simulation Parameters window should look exactly as in Figure 3-1.

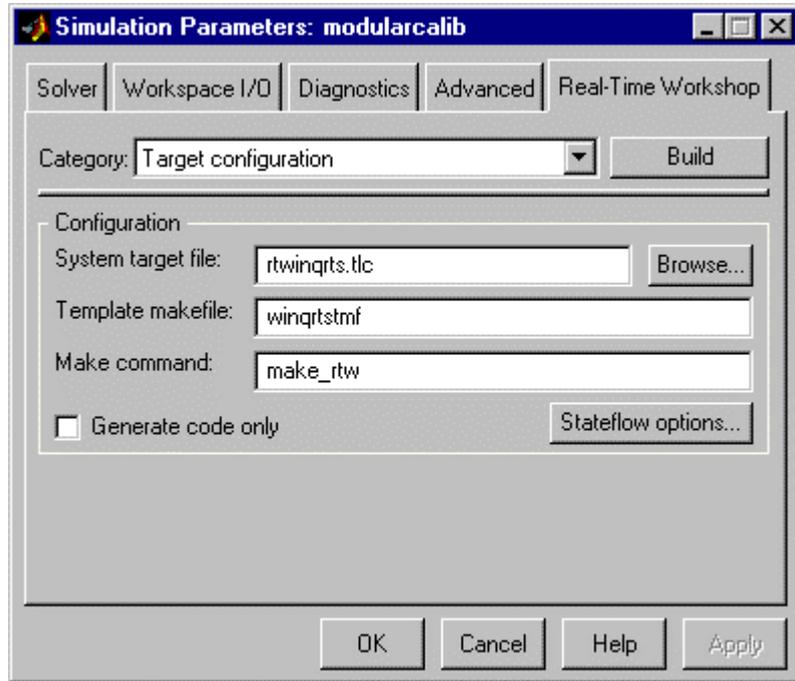


Figure 3-1: Simulation Parameter Options

Non standard Installations

If the text in the

System target file

Template makefile

Make command

edit boxes is not the same as shown in Figure 3-1, then follow the following sequence

Click on the **Browse** button.

From the resulting **System Target File Browser** window, select

rtwinqrts.tlc Real-Time Windows Target with
QRTS Extensions

as shown in Figure 3-2.

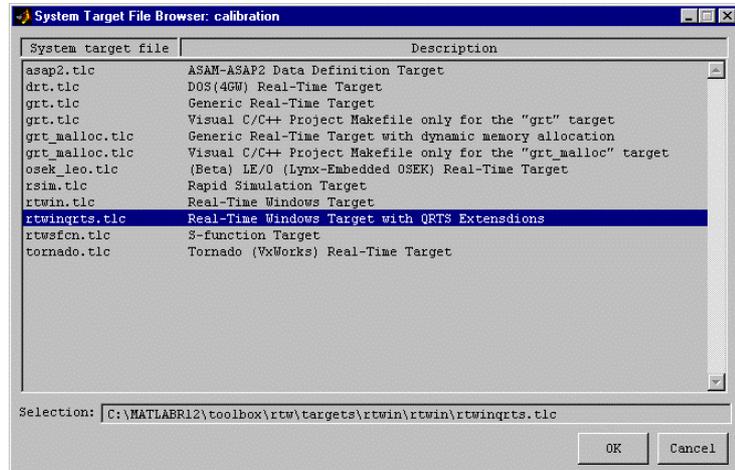


Figure 3-2: System Target File Browser

When the Simulation Parameters window is correctly set up, click the **Build** tab.

Real Time Workshop will now generate, compile and link the code necessary to run the model.

After selecting **Real-Time Workshop / Build** for `c:\MatlabR12\Feedback\Modular\`, the following files will be automatically generated and saved in the directory `c:\MATLABR12\Feedback\Modular\`.

*modularcalib.bat, modularcalib.c,
modularcalib.dt, modularcalib.h,
modularcalib.mk,
modularcalib.obj, modularcalib.prm,
modularcalib.reg, modularcalib.rwd,
wadapt.bat, wadapt.c, wadapt.dt,
wadapt.h, wadapt.mk, wadapt.obj, wadapt.prm,
wadapt.reg, wadapt.rwd, wpos.bat wpos.c,
wpos.dt, wpos.h, wpos.mk, wpos.obj, wpos.prm,
wpos.reg, and wpos.rwd*

Execution of the model

To connect to the target and execute the control program, follow the following sequence, using the wpos model as an example

Select **Tools** from the Simulink model menu bar.

Select **External Mode Control Panel** from the pull-down



menu. The window shown in Figure 3-3 appears.
Click on the `Connect` button.

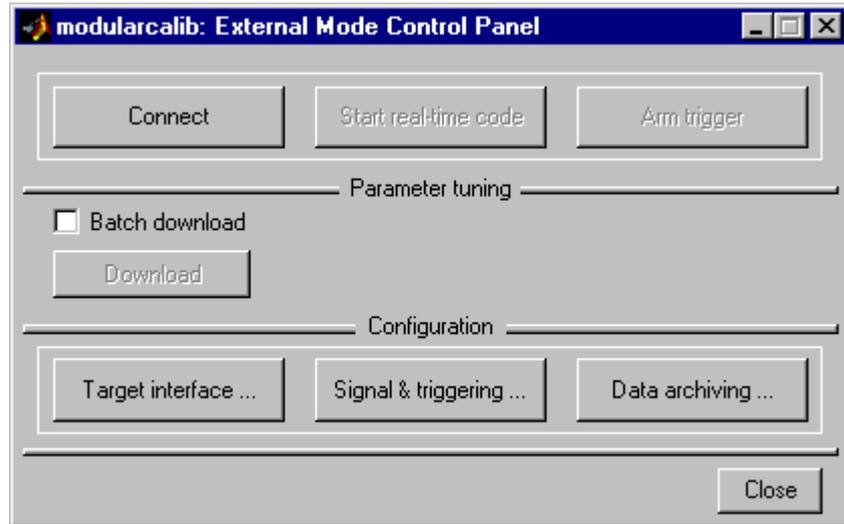


Figure 3-3: External Mode Control Panel

The `Connect` Button changes to `Disconnect` and the `Start real-time code` button is made available.

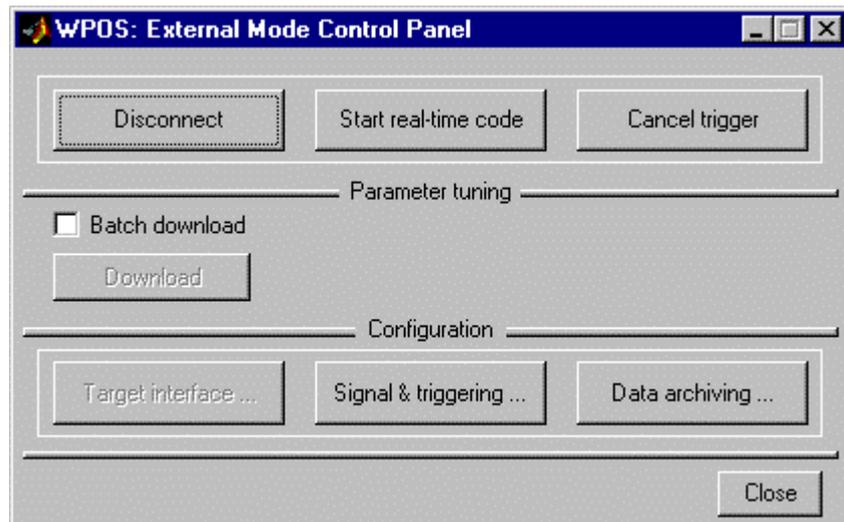


Figure 3-4: External Mode Control Panel

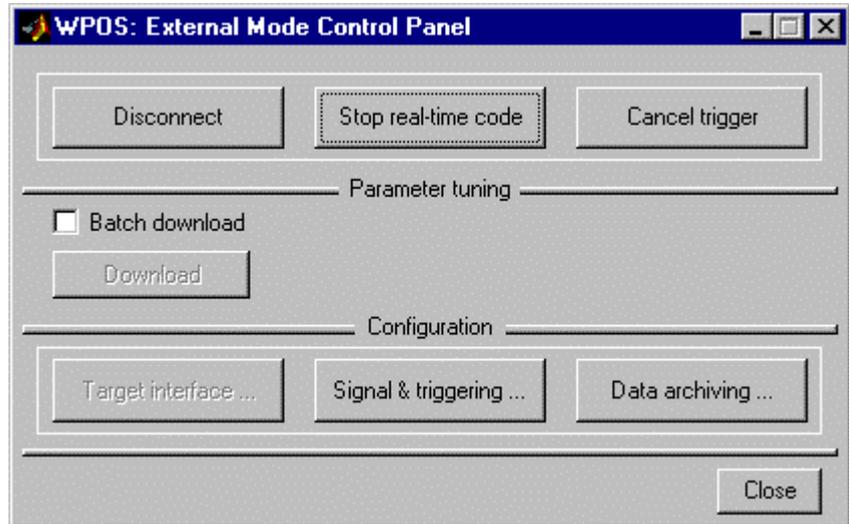


Figure 3-5: External Mode Control Panel

Control Program Execution

Starting

To **begin** execution of the real time Control Program, click the

`Start real-time code` button

The control software is now active (the Advantech hardware adapter has been started)

Switch on the power switch on the Modular Servo Power Supply Unit

Stopping

To **stop** execution of the real-time target click either the

`Stop real-time code` button or the
`Disconnect` button shown in Figure 3-5.

Switch off the power switch on the Modular Servo Power Supply Unit

In the External Mode Control Panel, the check box

`batch download`

under the

`Parameter tuning`

group title, controls the behaviour of the parameter tuning.



If the

batch download

check box is enabled, then the new parameters will not be downloaded automatically to the real-time target until you click the

Download

button .

This feature is useful in a situation where you need to change *multiple* parameters and desire that all of these changes take effect instantaneously. Note, however, that there are some limitations to this capability.

**Changing
Real Time
Parameters**

To change parameters follow the following sequence

Switch off the power switch on the Modular Servo Power Supply Unit

In the External Mode Control Panel (Figure 3-5) click:

Stop real time code

Double Click the Simulink Block containing the parameters, make the changes, and then in the External Mode Control Panel click:

Start real time code

Switch on the power switch on the Modular Servo Power Supply Unit

Note

Some of the parameters can be changed during program execution, others dealing with *changes to the model* will necessitate a new system build and new C code generation.

Real Time Workshop will inform you if a new build is necessary.



4 Calibration

Before starting any of the control experiments it is necessary to first calibrate the analogue input and output, using the 33-301 Analogue Control Interface unit. You will need a digital voltmeter for this.

To start the modularcalib program follow the procedure outlined below:

Start MATLAB

Type the following commands into the MATLAB command window

```
Modularcalib
```

You can also open it from the MATLAB File menu, or double click its icon before starting MATLAB.

The RTWT block diagram appears and is shown in Figure 4-1.

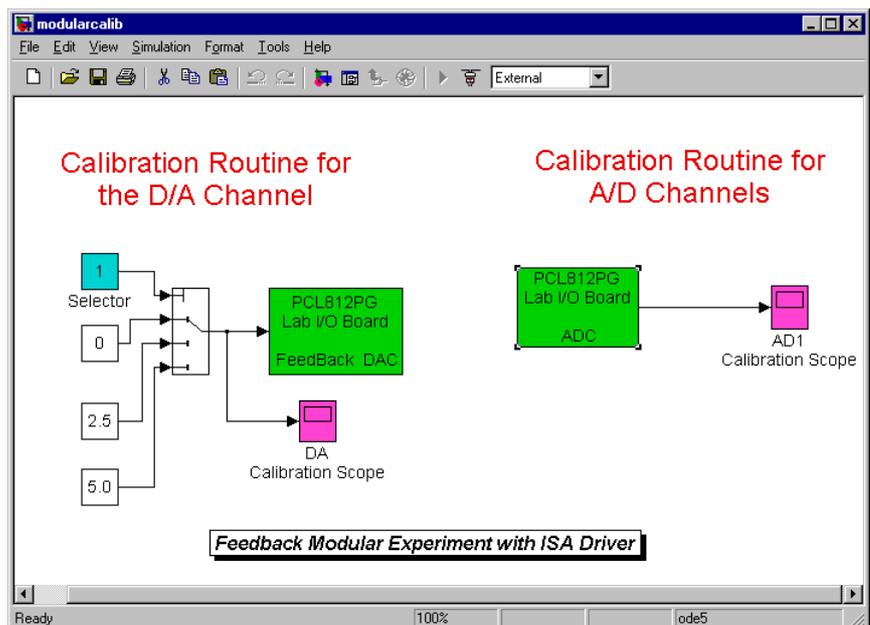


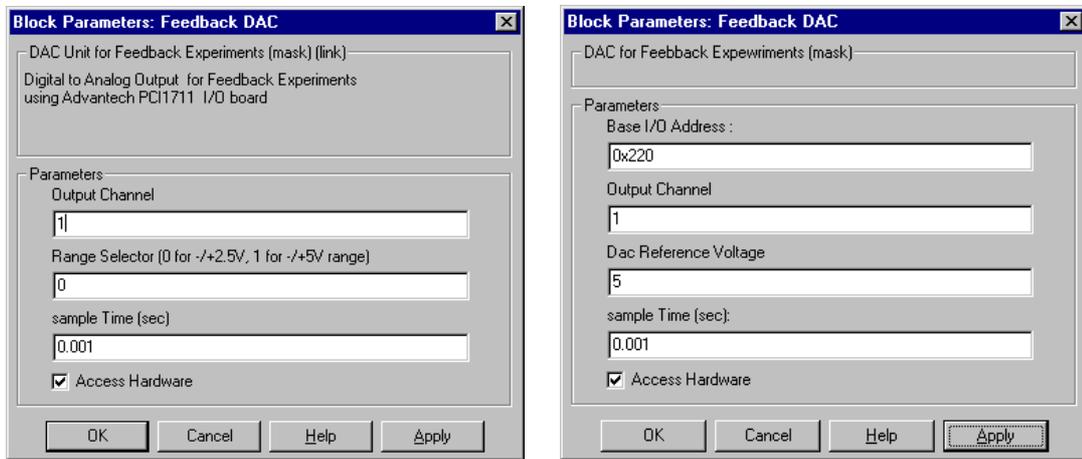
Figure 4-1: RTW Block diagram for calibration



The installation procedure described in the accompanying manual 33-008-0C shows the following channels on the 33-301 being used. Table 1 gives the equivalent PCL812 / PCI1711 channel

Input	AD1, AD2	PCL812 / PCI1711 Channels 10
Output	DA1	PCL812 / PCI 1711 Channel 0

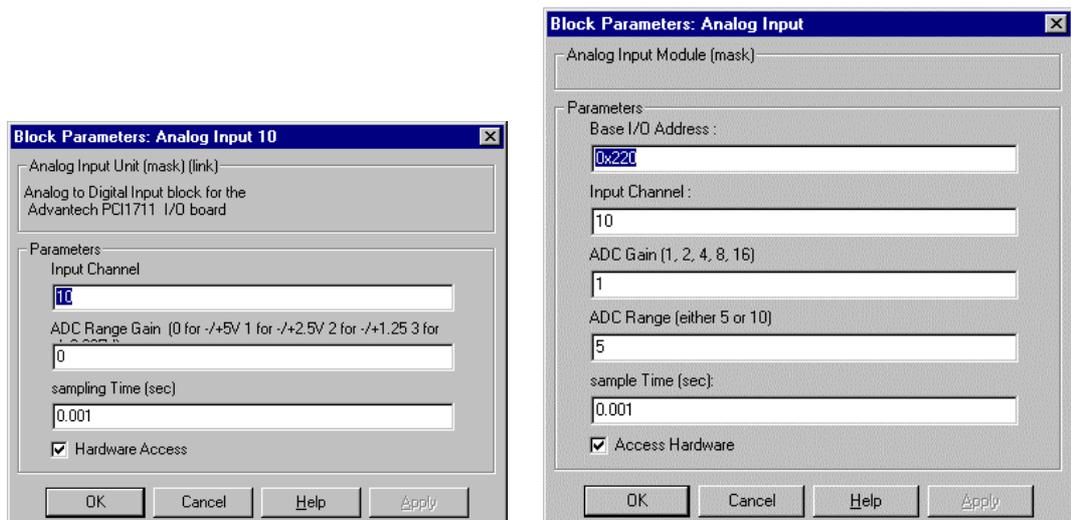
Double click the green blocks in Figure 4-1 to check that the base address (If ISA) and the channel assignments of your board are correct., as shown in Figure 4-2, and Figure 4-3.



PCI

ISA

Figure 4-2: Channel DA1



PCI

ISA

Figure 4-3: Channel AD1



Note

Always check, in the following assignments, that the channel numbers which are actually wired, correspond with the correct channels in the RTW model.

D/A Channel calibration

Start the Modularcalib program, as follows:

From the Simulink Title bar select

```
Tools
  Real Time Workshop
  Build Model
```

After successfully Building the model select:

```
Tools
  External Mode Control Panel
```

and then `Connect` and `Start` the real time program

Double click the DA calibration scope.

Set the light blue **Selector** block to 1 by double clicking the block and entering 1 in the edit box.

Connect a voltmeter to DA1 of the 33-301 Interface Module.

Adjust the "OFFSET" (lower) potentiometer located below DA1 until the voltmeter reads - 2.5 volts. The motor should rotate.

Set the light blue **Selector** block to 3 by double clicking the block and entering 3 in the edit box. The motor should rotate.

Adjust the "GAIN/ATTN" (upper) potentiometer located below DA1 until the voltmeter reads + 2.5 volts.

Set the light blue **Selector** block to 2 by double clicking the block and entering 2 in the edit box. The motor should be stationary. If it is not, set it to be stationary by adjusting the set zero potentiometer on the 150C Pre-amplifier.



Note that if the D/A channels are not calibrated precisely, the motor may turn slightly when no voltage is written to the D/A channel. This effect may be offset by making small adjustments to the "Set Zero" dial on the PA150C preamplifier.

A/D Channels calibration

Remove any wires connected to AD1 on the 33-301.. Connect DA1 to AD1.

- 1 Set the light blue **Selector** block to 1 by double clicking the block and entering 1 in the edit box.
- 2 Adjust the "OFFSET" (lower) potentiometer located below AD1 until the AD1 calibration scope shows -2.5V.
- 3 Set the light blue **Selector** block to 3 by double clicking the block and entering 1 in the edit box.
- 4 Adjust the "GAIN/ATTN" (upper) potentiometer located below AD1 until the AD1 calibration scope shows +2.5V volts.

Repeats steps 1 to 4 if necessary until no further adjustments are required. Disconnect DA1 and AD1.

Re-connect any wires originally connected to AD1.



5 Experiment 1 - Position Control

Introduction

In this experiment the rotor position of a DC servo motor is forced to track a time varying reference trajectory, utilising a standard proportional derivative (PD) controller of the form

$$u = K_p (q_d - q) + K_r \frac{d}{dt} (q_d - q)$$

where $q(t)$ represents the actual angular position of the rotor. For this experiment the reference trajectory for the rotor is a sine wave of the form

$$q_d = \sin(t)$$

The **amplitude** and **frequency** can be changed during by entering new values into the edit boxes in the Desired Rotor Angular Displacement window shown in Figure 5-6.

The **Position Feedback Gain** (K_p) and the **Velocity Feedback Gain** (K_v) can be modified by double clicking on the light blue Control Design block in Figure 5-1 and entering values into the edit boxes shown in Figure 5-4.



Precision Modular Servo Control Experiments

Experiment 1 - Position Control

Experiment

Start the experiment by entering into the MATLAB command window

```
wpos
```

You can also open it from the MATLAB File menu, or double click its icon before starting MATLAB.

The Real Time Workshop / Simulink model appears as shown in Figure 5-1.

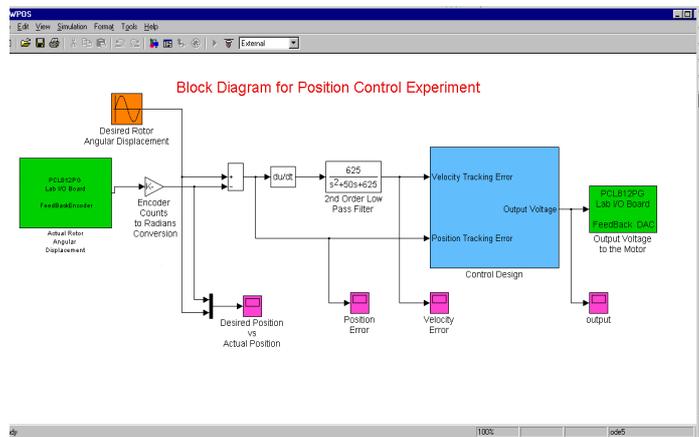
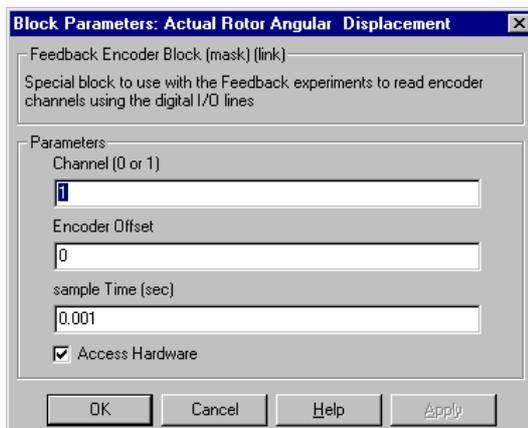


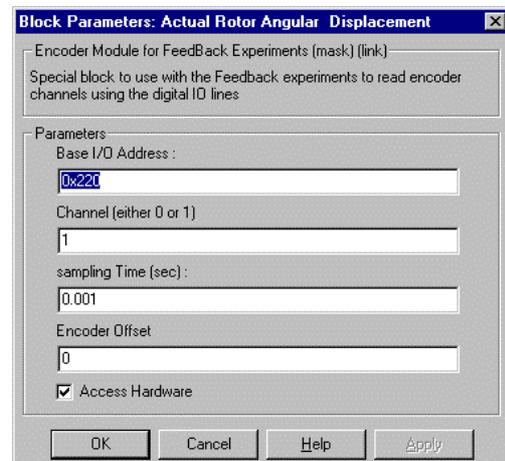
Figure 5-1

The green block on the left is the input block from the 33-300 Feedback Digital encoder. Signals from this are sent via the wide ribbon cable to the I/O board.

Double click this to show its parameters shown in Figure 5-2 (PCI and ISA)



PCI



ISA

Figure 5-2



Precision Modular Servo Control Experiments

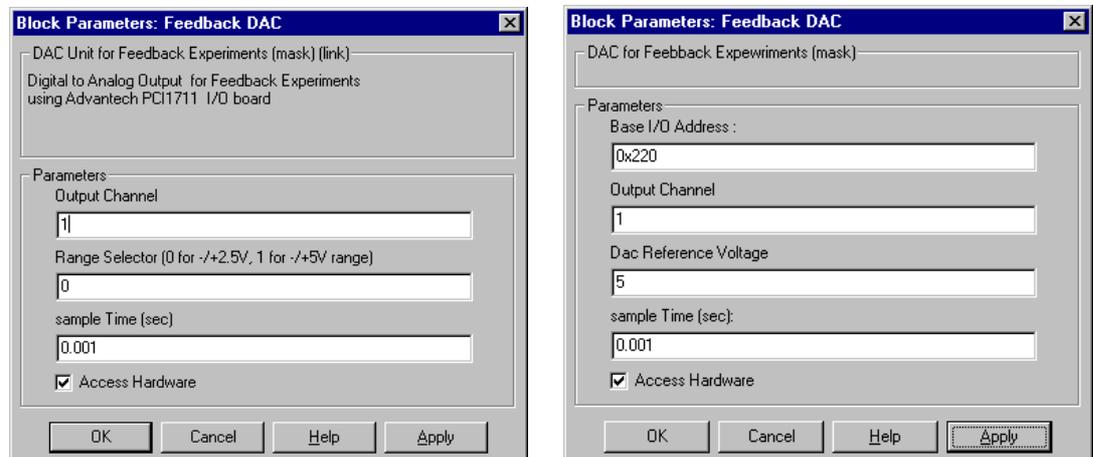
Experiment 1 - Position Control

Enter the correct base address if the default value is incorrect (ISA only), and check that the channel number is set to one.

The green block on the right is the output block to the 33-300 Feedback Digital encoder. Signals are sent via the narrow ribbon cable to the 33-301 channel DA2.

Double click this to show its parameters shown in Figure 5-3.

Figure 5-3 shows the channel assignments for the analogue output channel, PCI and ISA.



PCI

ISA

Figure 5-3

Enter the correct base address if the default value is incorrect, and check that the channel number is set to zero.

Double click on the light blue block to show its parameters, shown in Figure 5-4.

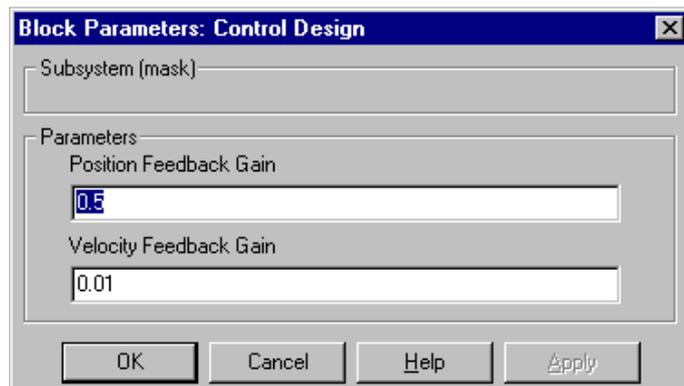


Figure 5-4



Precision Modular Servo Control Experiments

Experiment 1 - Position Control

Right click the mouse and select **Look** under **mask** to reveal the structure of the control block shown in light blue. The window shown Figure 5-5 in appears.

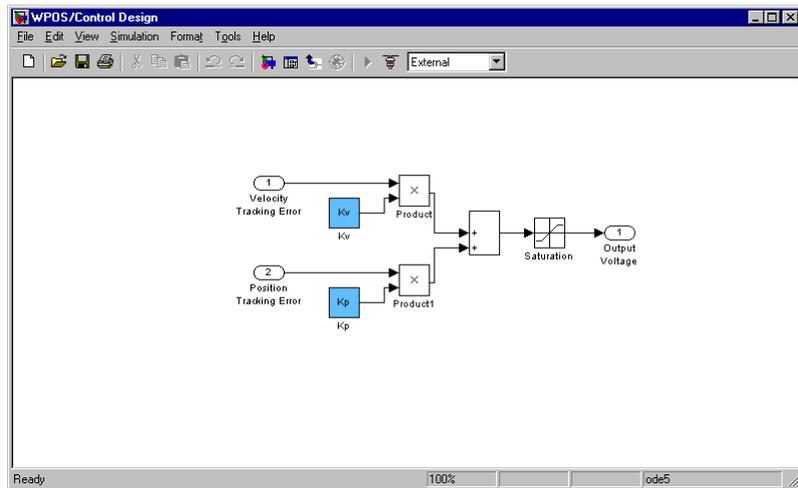


Figure 5-5

Double click the sine block to show the parameters of the sine wave reference trajectory, shown in Figure 5-6.

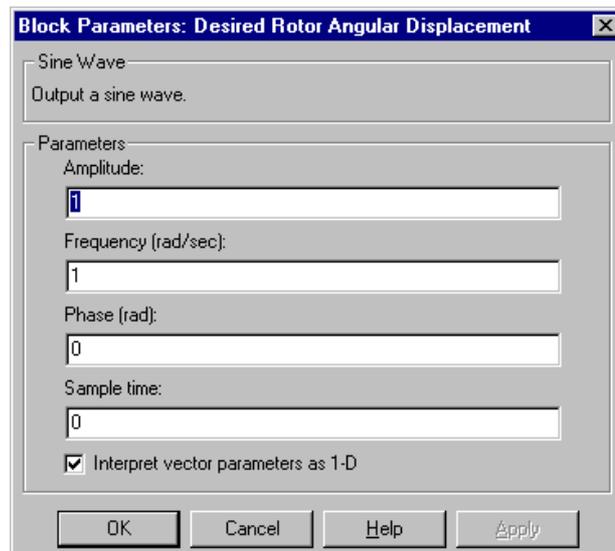


Figure 5-6

Start the real time program and open the four Simulink scopes shown in Figure 5-1.



Typical results

Figure 5-7, Figure 5-8, Figure 5-9, and Figure 5-10 show typical results for a sine wave varying set point.

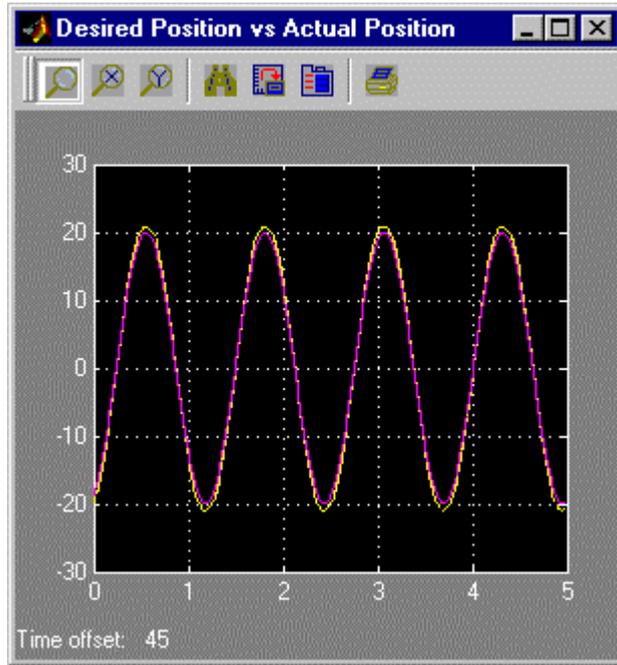


Figure 5-7

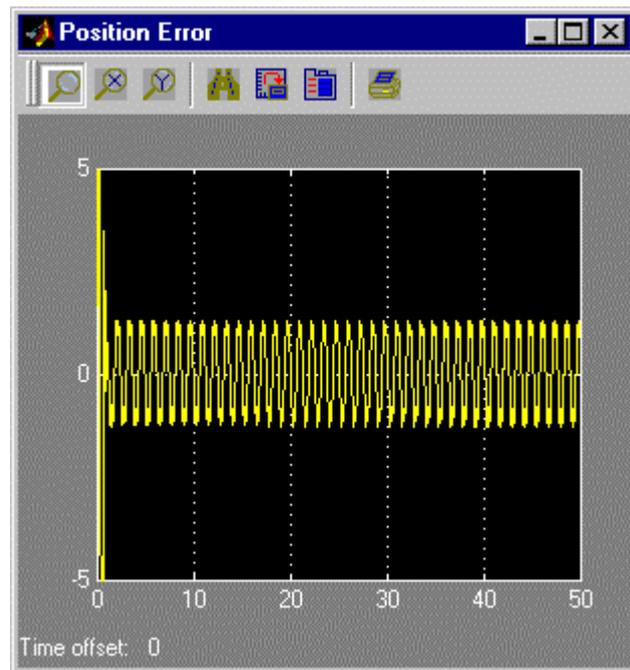


Figure 5-8

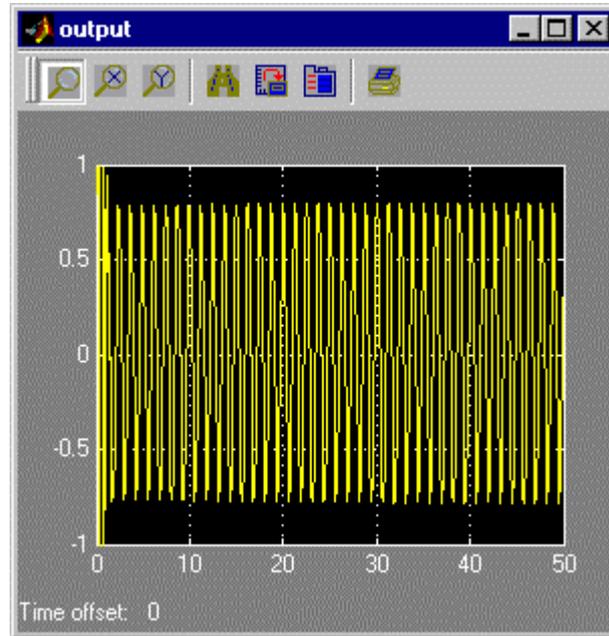


Figure 5-9

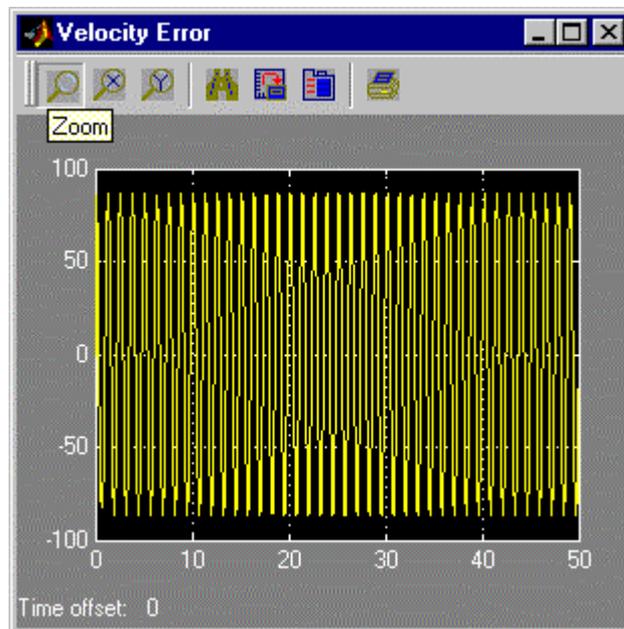


Figure 5-10



6 Experiment 2 - Velocity Control

Introduction

In this experiment the rotor velocity is regulated to a constant reference velocity feedback controller as shown below

$$u = K_v(v_d - v) + load$$

where $v(t)$ represents the actual rotor velocity, v_d represents the constant desired rotor velocity in rotations per minute (rpm), and $Load$ represents the known torque load.

For this experiment the reference rotor velocity can be set by double clicking on the orange **Desired RPM** box in the block diagram shown in Figure 6-1, and entering values into the edit box in the window which appears.

The **Velocity Feedback Gain** (K_v) and the **Load Torque** ($Load$) can be modified by double clicking on the light blue Control design block in Figure 6-1 and changing the values in the edit boxes shown in Figure 6-4.



Experiment

Start the experiment by entering into the MATLAB command window

```
wvel
```

You can also open it from the MATLAB File menu, or double click its icon before starting MATLAB.

The Real Time Workshop / Simulink model appears as shown in Figure 6-1.

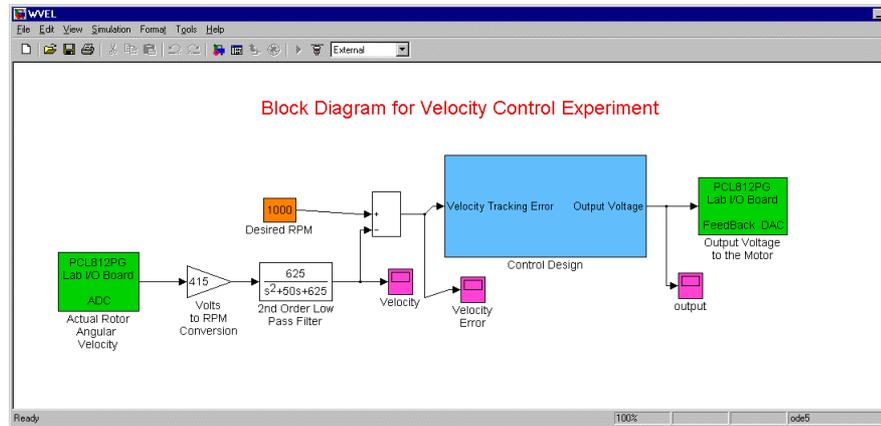
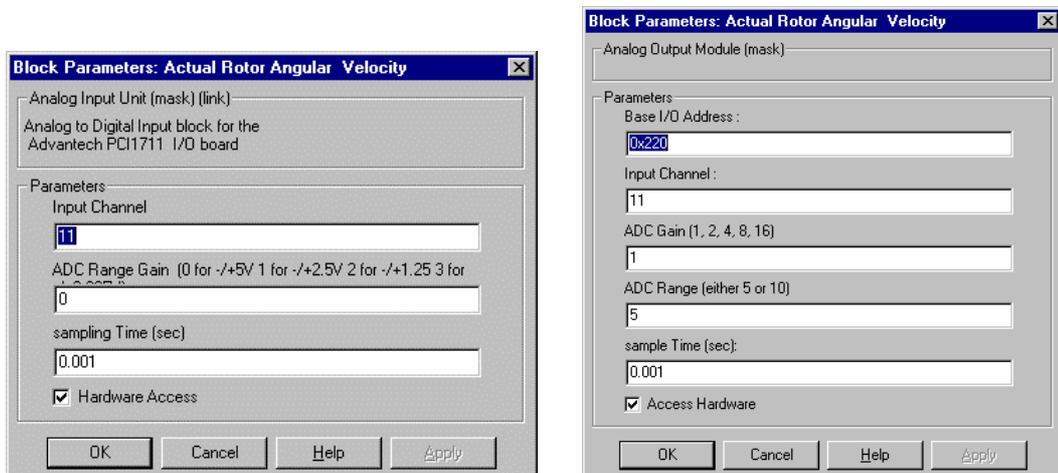


Figure 6-1

The green block on the left is the speed input block from the GT150X tachogenerator.. Signals from this are sent via the *narrow* ribbon cable to the I/O board.

Double click this to show its parameters shown in Figure 6-2.



PCI

ISA

Figure 6-2



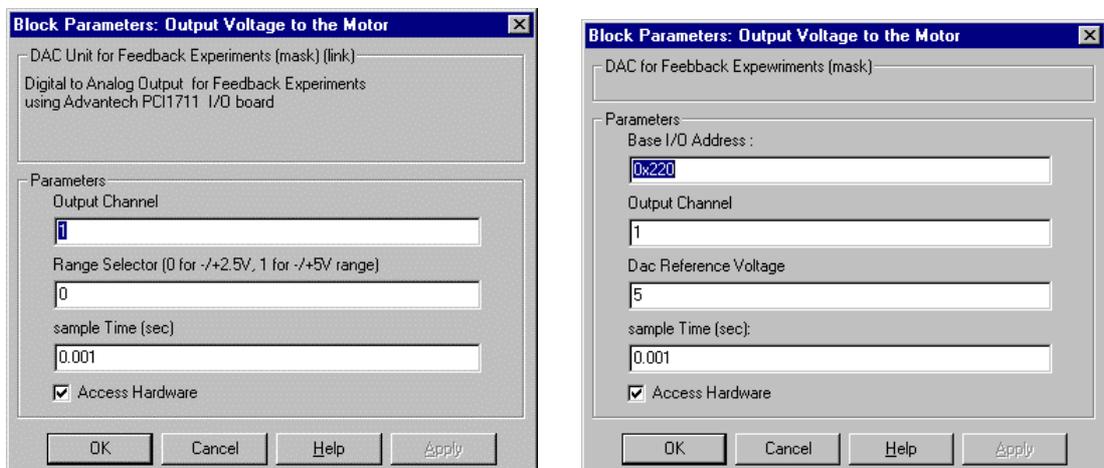
Precision Modular Servo Control Experiments

Experiment 2 - Velocity Control

Enter the correct base address if the default value is incorrect, and check that the channel number is set to eleven..

The green block on the right is the output block to the 33-300 Feedback Digital encoder. Signals are sent via the narrow ribbon cable to the 33-301 channel DA2.

Double click this to show its parameters shown in Figure 6-3.



PCI

ISA

Figure 6-3

Enter the correct base address if the default value is incorrect, and check that the channel number is set to one.

Double click on the light blue block to show its parameters, shown in Figure 6-4.

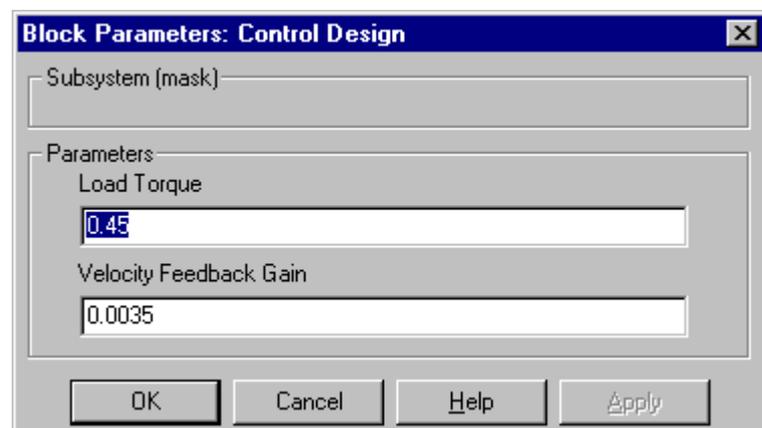


Figure 6-4



Right click the mouse and select `Look` under `mask` to reveal the structure of the control block shown in light blue. The window shown in Figure 6-5 appears.

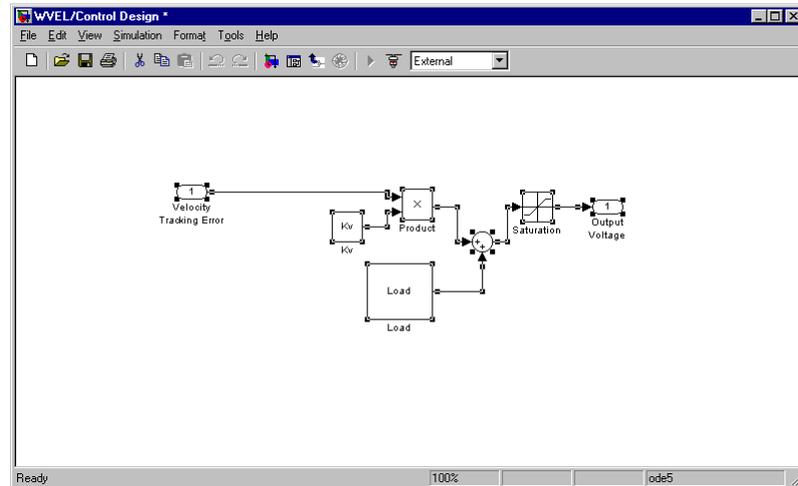


Figure 6-5

Start the real time program and open the three Simulink scopes shown in Figure 6-1.



Typical results

Figure 6-6, Figure 6-7 and Figure 6-8 show typical results for a set point of 1000 rev/min.

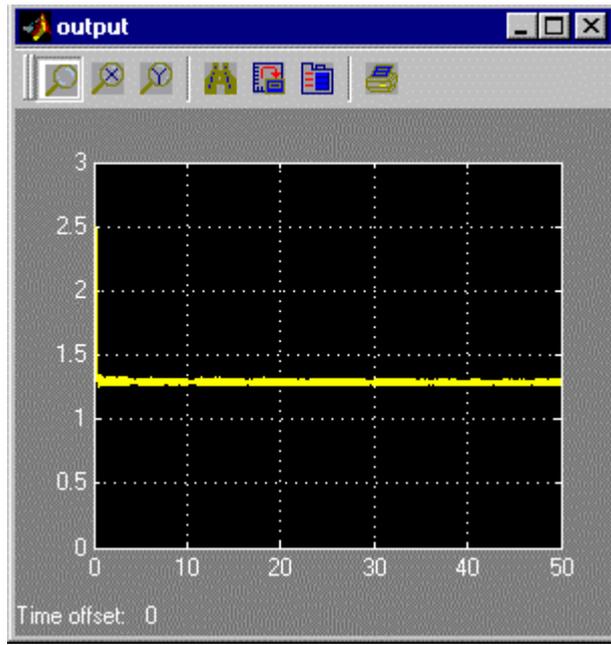


Figure 6-6

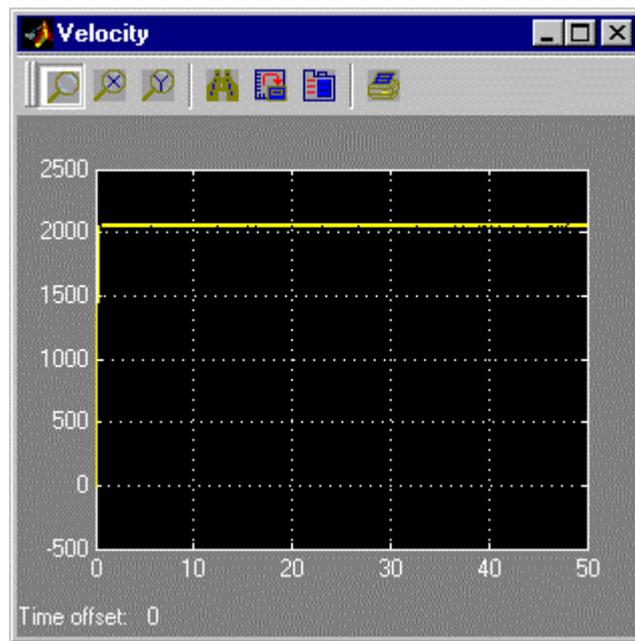


Figure 6-7

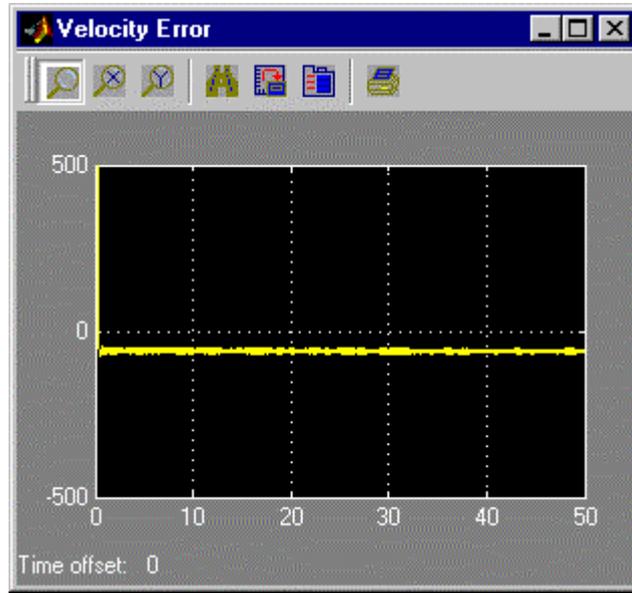


Figure 6-8



7 Experiment 3 - Adaptive Control

Introduction

In this experiment a reference model adaptive controller is used having the form

$$u = K_p(q_d - q) + K_v \frac{d}{dt}(q_d - q) + \int \Gamma_1 \left[\frac{d^2}{dt^2} q_d + \frac{d}{dt}(q_d - q) \right] [K_p(q_d - q) + K_v \frac{d}{dt}(q_d - q)] \\ + \int \Gamma_2 \left[\frac{d}{dt} q_d + (q_d - q) \right] [K_p(q_d - q) + K_v \frac{d}{dt}(q_d - q)] + \int \Gamma_3 [K_p(q_d - q) + K_v \frac{d}{dt}(q_d - q)]$$

This controller is used to force the rotor position of the DC servomotor to follow a time varying reference trajectory despite the fact that the rotor inertia, damping and load torque are unknown.

Adaptive update laws are utilised to compensate for the unknown constant parameters (see[1] for further details with regard to the structure of the controller).

The reference trajectory selected is a sine wave of the form

$$q_d = \sin(t)$$

The **Amplitude** and **Frequency** of the reference trajectory can be modified by double clicking on the orange **Desired Rotor Angular Displacement** block shown in Figure 7-1 and entering the new values into the edit boxes.

The feedforward adaptive estimate gains (i.e. **Load Adaptive Gain**, **Damping Adaptive Gain**, **Inertia Adaptive Gain**, and the feedback gains (i.e. **Position Feedback Gain** (K_p), **Velocity Feedback Gain** (K_v), can be modified by double clicking on the light blue Control design block and entering new values into the edit boxes as shown in Figure 7-4.



Precision Modular Servo Control Experiments

Experiment 3 - Adaptive Control

Experiment

Start the experiment by entering into the MATLAB command window

```
wadapt
```

You can also open it from the MATLAB File menu, or double click its icon before starting MATLAB.

The Real Time Workshop / Simulink model appears as shown in Figure 7-1.

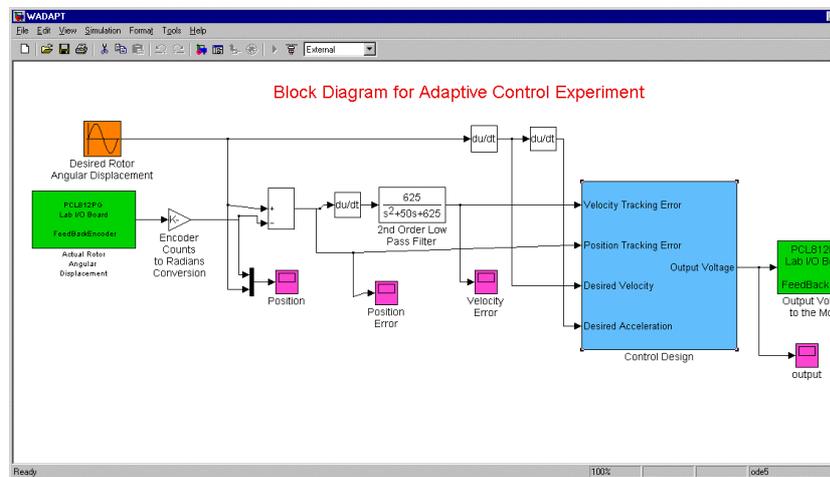
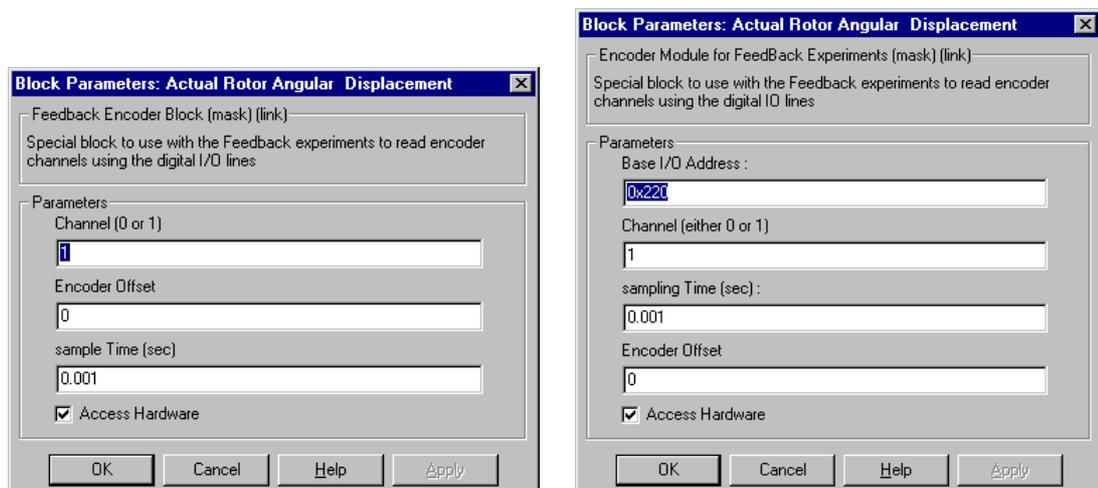


Figure 7-1

The green block on the left is the speed input block from the GT150X tachogenerator.. Signals from this are sent via the *narrow* ribbon cable to the I/O board. Double click this to show its parameters shown in Figure 7-2.



PCI

ISA

Figure 7-2



Precision Modular Servo Control Experiments

Experiment 3 - Adaptive Control

Enter the correct base address if the default value is incorrect, and check that the channel number is set to eleven.

The green block on the right is the output block to the Feedback. Signals are sent via the narrow ribbon cable to the 33-301 channel DA2.

Double click this to show its parameters shown in Figure 7-3.

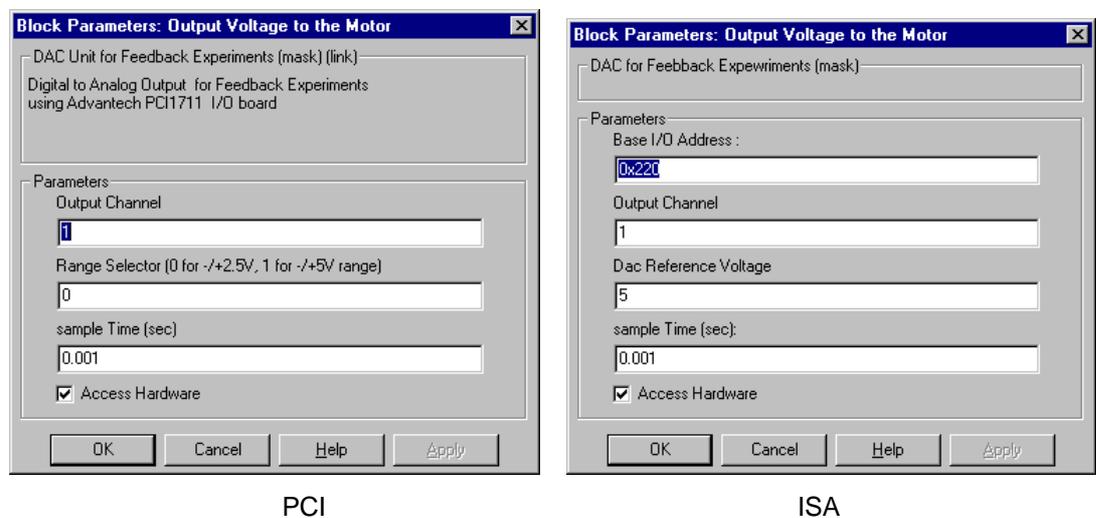


Figure 7-3

Enter the correct base address if the default value is incorrect, and check that the channel number is set to one.

Double click on the light blue block to show its parameters, shown in Figure 7-4.

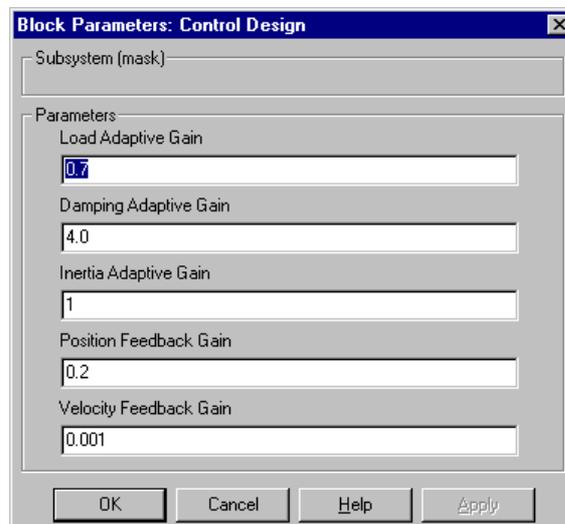


Figure 7-4



Precision Modular Servo Control Experiments

Experiment 3 - Adaptive Control

Right click the mouse and select **Look** under **mask** to reveal the structure of the control block shown in light blue. The window shown in Figure 7-5 appears.

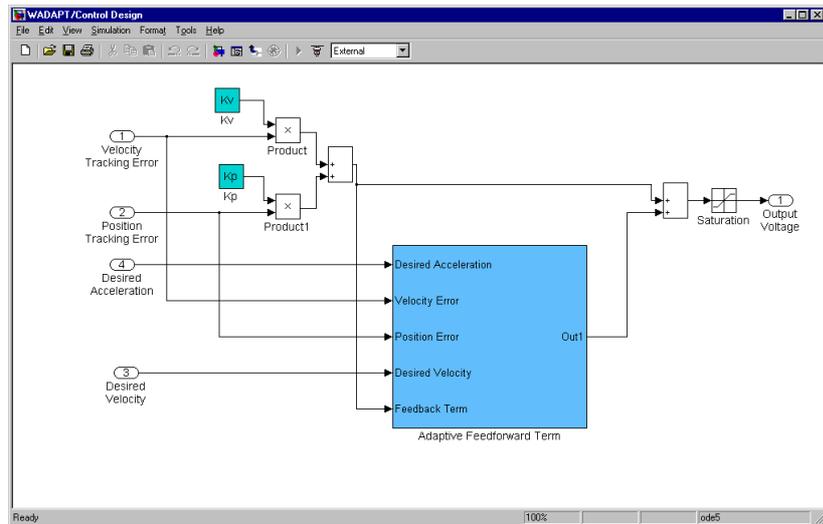


Figure 7-5

Double click on the light blue block to reveal its structure, shown in Figure 7-6.

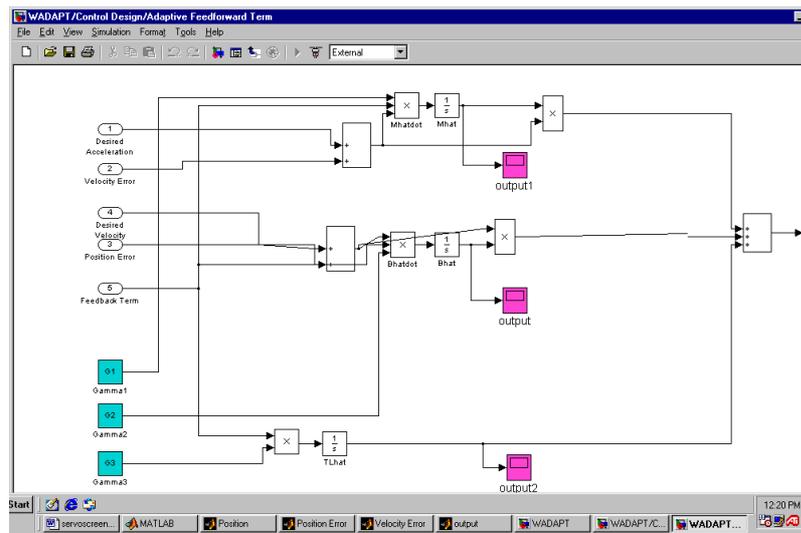


Figure 7-6

Start the real time program and open the three Simulink scopes shown in Figure 6-1.



Typical results

Figure 7-7, Figure 7-8, Figure 7-9, and Figure 7-10 show typical results for a sine wave reference trajectory. Note that Figure 7-8 shows both the actual and the desired position.

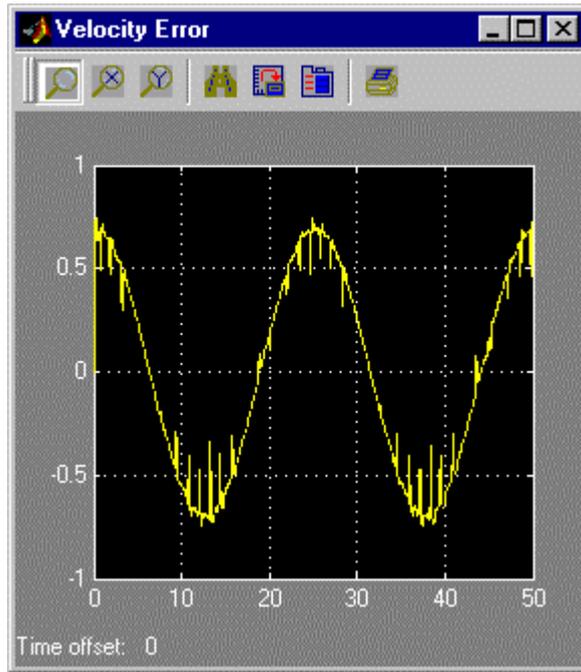


Figure 7-7

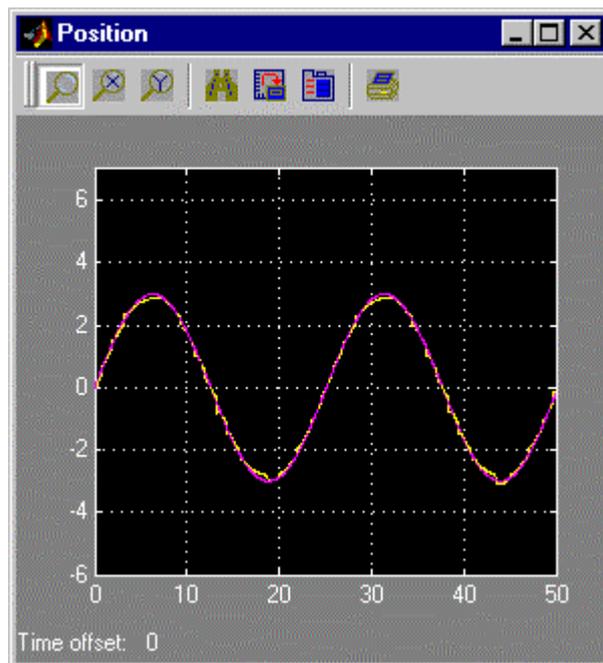


Figure 7-8

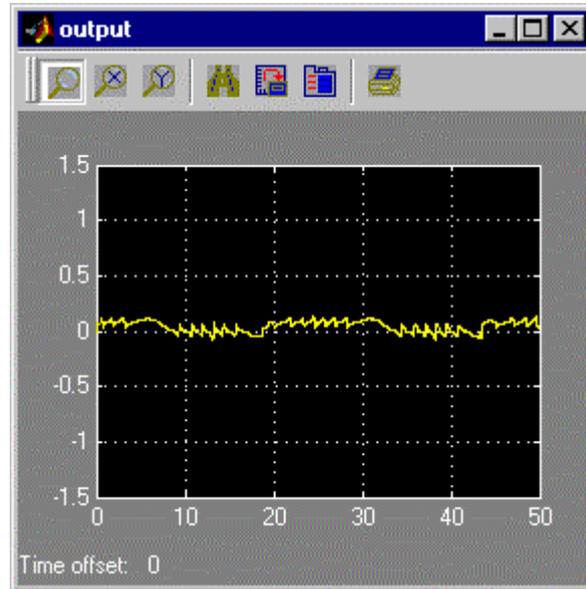


Figure 7-9

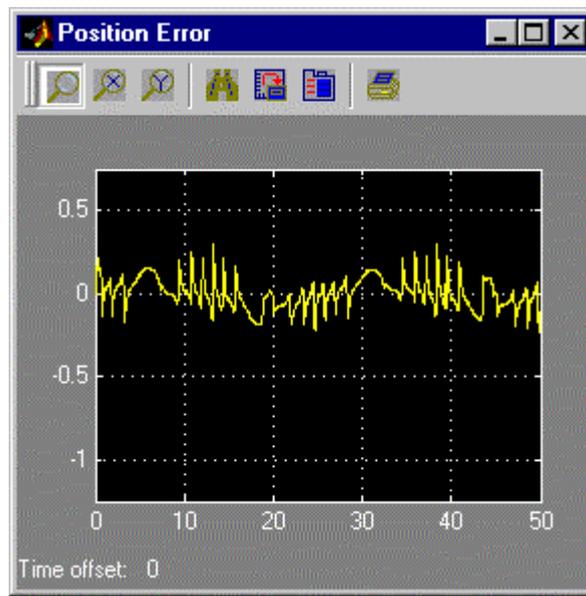


Figure 7-10



8 Customised Control

RTWT combines the powerful functionality of MATLAB, Simulink and Real-Time Workshop and allows users to implement any kind of control algorithm.

If you wish to implement a different kind of controller you may copy one of the supplied block diagrams, and simply replace the existing control blocks with customized control blocks (or subsystems).

However, before you start designing and implementing customized control algorithms, it is strongly recommended that you refer to the RTWT User's Manual and the Simulink User's Guide .

Reference

[1] D. Dawson, J. Hu, and T. Burg.
Nonlinear Control of Electric Machinery
Marcel Dekker, New York: 1998



**Precision Modular Servo
Control Experiments**

Customised Control

Notes



9 Some Common Problems

- | | | |
|------------------------|---|--|
| Calibration | 1 | If there appears to be no effect on the Simulink calibration scopes when you are adjusting the 33-301 potentiometers., the most likely cause is that you have the wrong channel number in one or more of the I/O blocks. Check that these are correct. |
| All experiments | 2 | If there appears to be no output on Simulink scopes, the most likely cause is that you have the wrong channel number in one or more of the I/O blocks. Check that these are correct. |



**Precision Modular Servo
Control Experiments**

Some Common Problems

Notes