Digital Pendulum
Installation & Commissioning

33-936IC

Feedback Instruments Ltd., Park Road, Crowborough, East Sussex, TN6 2QX, UK
Telephone: +44 (0) 1892 653322, Fax: +44 (0) 1892 663719
E-mail: feedback@feedback-instruments.com website: http://www.feedback-instruments.com

Manual: 33-936IC Ed03-1 122013
Feedback Part No. 1160-33936IC

Product Use

All users must familiarise themselves with the following information.

This product is marked as CE compliant. This means that it complies with the relevant European Directives for this product. In particular the Directives cover Low Voltage, EMC, Machinery, Pressure and electronic waste disposal.

The equipment, when used in normal or prescribed applications and within the parameters set for its mechanical and electrical performance, should not cause any danger or hazard to health or safety.

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.

This equipment is designed for use by students as part of the learning process who must be under the supervision of a suitably qualified and experienced person in a laboratory environment where safety precautions and good engineering practices are applied.

By the nature of its intrinsic teaching functionality, parts are visible and accessible that might normally be covered up or encased in an industrial or domestic product. For this reason students attention should be drawn to the need to operate the equipment only in the manner prescribed in the accompanying documentation and supervisors must make students aware of any particular risk. The equipment should not be operated by any person alone.

We are required 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 meanings 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

Compliance with the EMC Directive

This equipment has been designed to comply with the essential requirements of the Directive. However, because of the intrinsic teaching function it cannot be electromagnetically shielded to the same extent as equipment designed for industrial or domestic use. For this reason the equipment should only be operated in a teaching laboratory environment where electromagnetic emissions in the immediate area might not be expected to cause adverse effects. In the same way users should be aware that operating the equipment near to an electromagnetic source may cause the experimental results to be outside the range expected.

The Waste Electrical and Electronic Equipment Directive (WEEE)

If this equipment is disposed of it must be in accordance with the regulations regarding the safe disposal of electronic and electrical items and not placed with ordinary domestic or industrial waste.

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 teaching capability of the equipment, may not be included until it is necessary to incorporate other significant changes.

Component Replacement

In order to maintain compliance with the Directives all replacement components must be identical to those originally supplied.

Operating Conditions

WARNING:

This equipment must not be used in conditions of condensing humidity.

This equipment is designed to operate under the following conditions:

Operating Temperature	10°C to 40°C (50°F to 104°F)
Humidity	10% to 90% (non-condensing)

ACKNOWLEDGEMENTS

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Manual overview

This manual explains how to install and test the pendulum equipment. The basic steps described are: assembly and adjustment of the mechanical unit, installation of the PC interface card and its software drivers, installation of the Pendulum control software, interconnection and basic system testing. An overview of how the pendulum is interfaced and controlled with the PC and Matlab environment is given to help the user produce his own controller design.

Required manuals and equipment

The following equipment and manuals are required for the use of the Digital Pendulum Control system:

1 PC with Windows XP, Windows Vista or Windows 7.

2 Matlab V7.6 (R2008a) 32 bit or later with Simulink (32 bit Windows operating system), or Matlab V8.0 (R2012b) 64 bit or later with Simulink (64 bit Windows operating system).

3 Matlab Toolboxes:
- Real Time Workshop with Real Time Windows Target
- System Identification Toolbox (necessary to perform identification exercises)
- Control System Toolbox (necessary to perform controller synthesis)

The Real-Time Windows Target must be activated by opening the Matlab Command Window and typing:

>> rtwintgt –setup *(note the "space" before the "-")*

Press the "enter" key to execute the above command.
Similarly, if various C Compilers have been installed, they must be deselected by typing:

>> mex –setup *(note the "space" before the "-")*

Press the "enter" key to execute the above command.
At the next prompt select the "0". This ensures that the system will only attempt to compile models with the default compiler.

4 Advantech PCI-1711 card with drivers

5 33-005 Digital Pendulum Control System – Mechanical Unit and Digital Controller

6 Feedback 33-936 software installation CDs

7 '*Installation & Commissioning*' manual

8 '*Control Experiments*' manual

9 '*Matlab Guide*' manual

The following equipment is supplied by Feedback Instruments:

1 33-200 - Digital Pendulum Mechanical Unit
2 33-201 - Digital Pendulum Controller

and either:

3 33-936 - Digital Pendulum Control System Software including Advantech PCI-1711 card

or

4 33-936I - Digital Pendulum Control System Software excluding Advantech PCI-1711 card

Composite products:

1 33-005 – Includes: 33-200, 33-201 and 33-936
2 33-005I – Includes: 33-200, 33-201 and 33-936I

Mechanical assembly

Unpack the items and remove the securing material. You should have the following items:

1. Track for the cart to move on, with motor and toothed belt
2. Two legs with adjustable feet to support the track
3. Pendulum cart with mounting points for the pendulum arms and an attached ribbon cable
4. Two pendulum arms with weights attached
5. 1 x 2mm and 1 x 6mm Allen keys

Figure 1 shows the assembled Digital Pendulum Mechanical Unit.

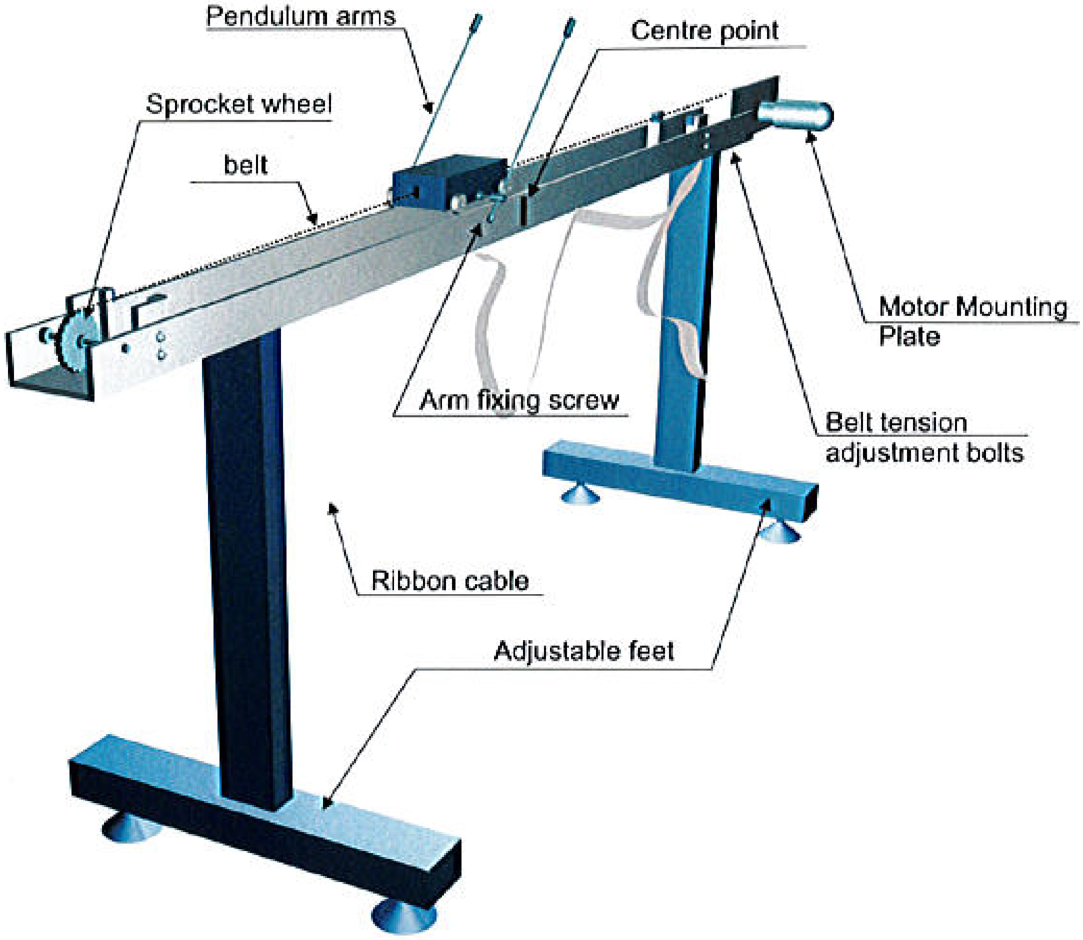

Figure 1 Digital Pendulum Mechanical Unit

Place the Digital Pendulum Mechanical Unit on a level surface with the motor on the left when viewed from the front and allow sufficient room for the controller box and the PC and mouse. Ensure that the pendulum arms are clear of any obstructions when executing a complete revolution, and are not able to make contact with any observers.

Using the 6 mm Allen key provided, remove the 8 bolts attached to the track at the leg mounting positions and fix the legs to the track with these bolts. Tighten the bolts securely.

Use the adjustable feet (it is only necessary to adjust one of the four) to ensure that the pendulum system is stable on the surface. Slacken off the adjustable foot locking nut and rotate the foot until the system is perfectly stable. Tighten the locking nut.

Insert one of the pendulum arms into one of the two mounting positions on the cart from the bottom and loosely tighten the securing screw on to the flat part of the pendulum arm with the 2mm Allen key provided. Push the arm upwards until the end of the flat is reached and tighten the securing screw. Repeat for the other pendulum arm on the other side of the cart.

Ensure that the pendulum cart is free to move on the track and that the drive belt is attached to the cart at both ends and goes over the sprocket wheels at each end of the track. If the belt is slack, use the 6mm Allen key to slacken off the belt tension adjustment bolts and move the motor mounting plate until the belt is taut. Tighten the adjustment bolts.

Finally, clip the ribbon cable to the pendulum left hand leg using the attached clips.

Advantech PCI1711 card installation guide

It is assumed that a PC is available with Matlab, Simulink, Real-Time Workshop and Real-Time Windows Target correctly installed and functioning.

Make sure you follow the instructions given in this section during the installation of the Advantech PCI-1711 card. This will ensure that you avoid common installation problems.

You must have administrator privileges on the PC before you can carry out this software installation.

Install the software supplied with the PCI-1711 card first. The PCI-1711 card must not be installed until the software has been installed correctly. A PCI-1711 device driver of version 2.2 or higher is recommended.

Installing from a CD – new installation

Ensure that you have the latest drivers (Universal 32-bit DLL Drivers V2.2 and device manager V2.4). If not, download the files from the Advantech website and refer to the procedure above for installation.

1. Insert the CD supplied with the PCI-1711 card into the PC. The installation programme will automatically start. The following window will open (Figure 2).

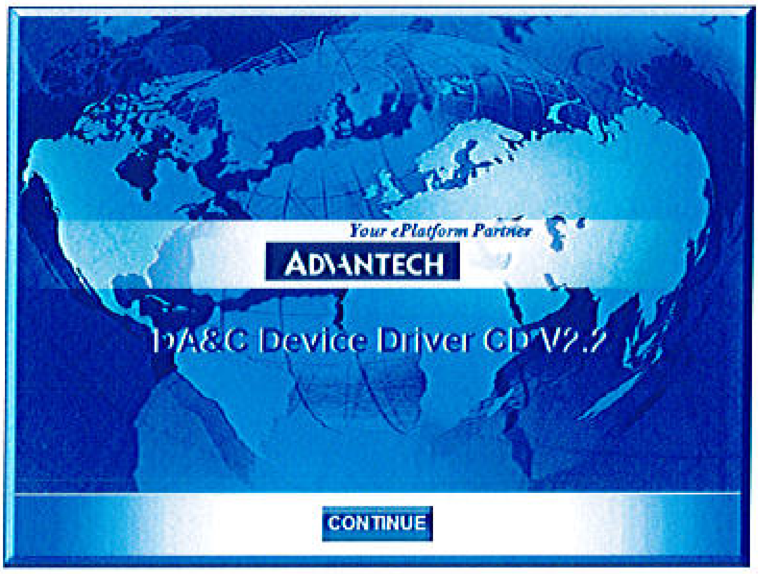

Figure 2 Initial Installation Window

2. Press 'CONTINUE' to enter the installation menu (Figure 3).

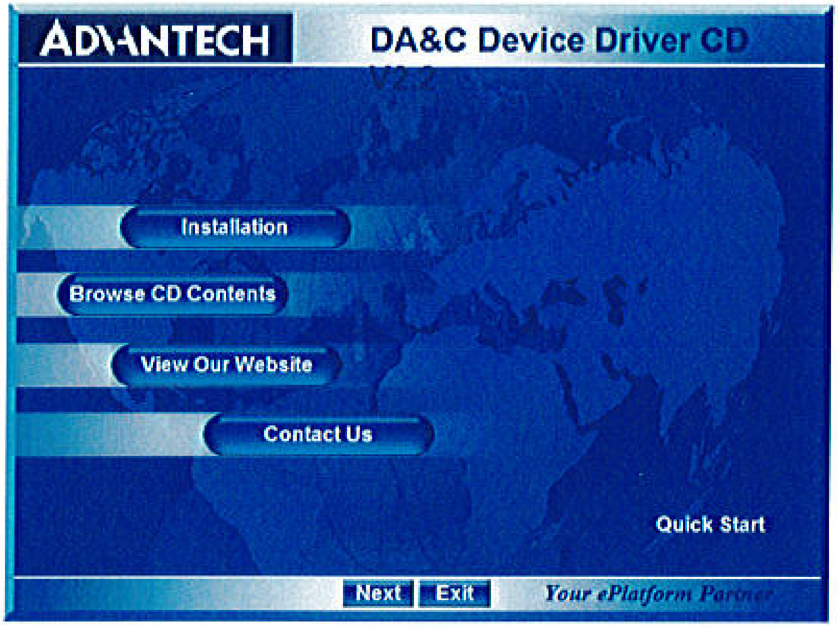

Figure 3 Installation Menu

3. To install the software select 'Installation'. The following window will appear (Figure 4)

Figure 4 Installation Element Selection Window

4. Select 'Device Manager'. The following window will open (Figure 5).

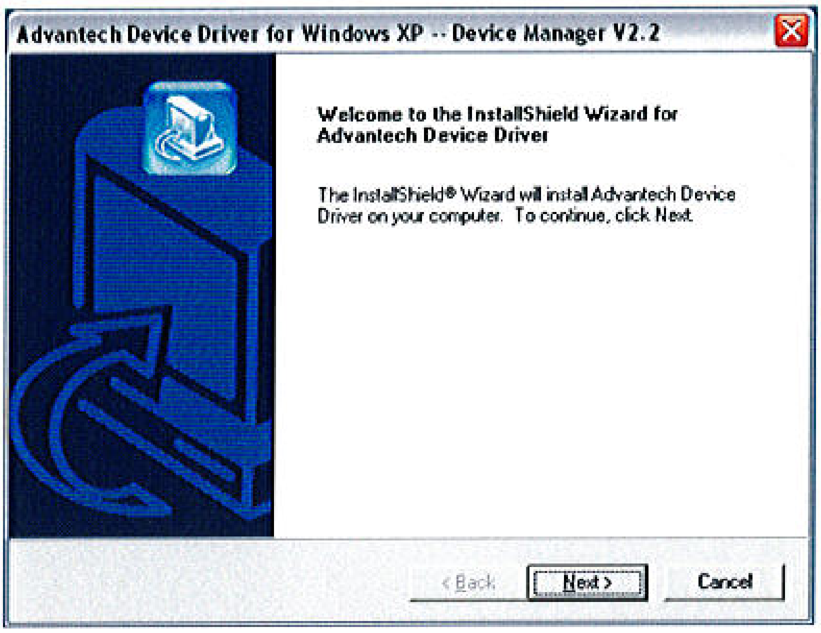

Figure 5 Device Manager Installation Window

5. Press 'Next' to continue to the License Agreement window presented in Figure 6.

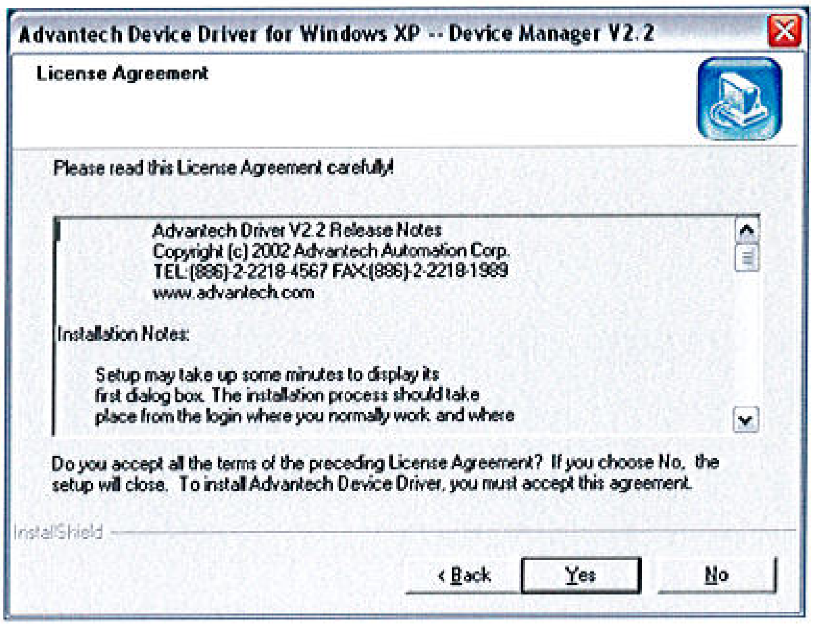

Figure 6 License Agreement Window

6. Read the terms of the license agreement and press 'Yes' if you accept. The User information window will appear (Figure 7).

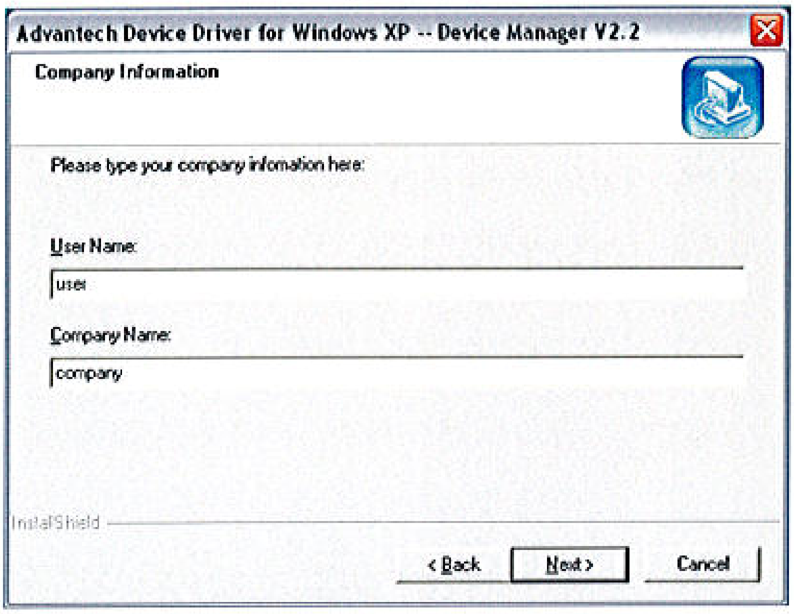

Figure 7 User Information Window

7. Fill the fields with proper information and press 'Next'. The Destination Folder information window will appear (Figure 8).

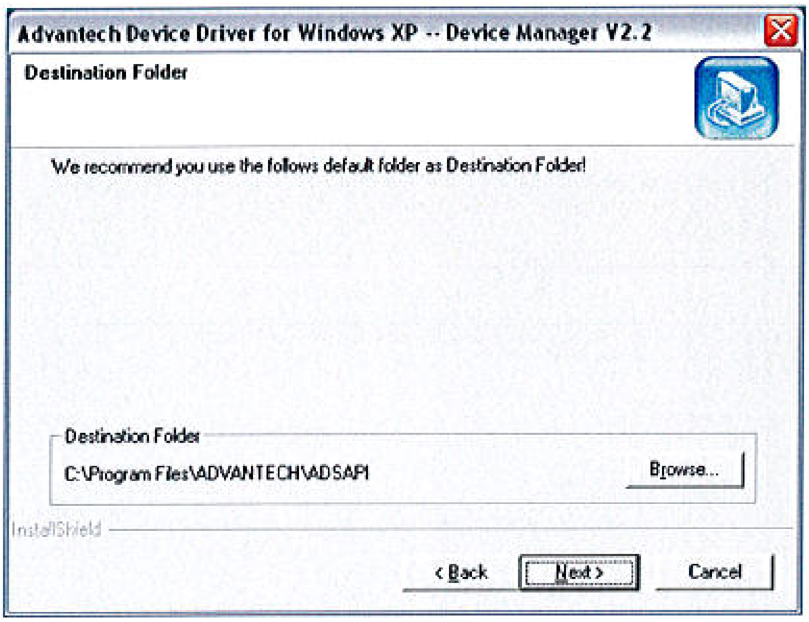

Figure 8 Destination Folder Window

8. Choose the destination folder and press 'Next'. The Setup Type information window will appear (Figure 9).

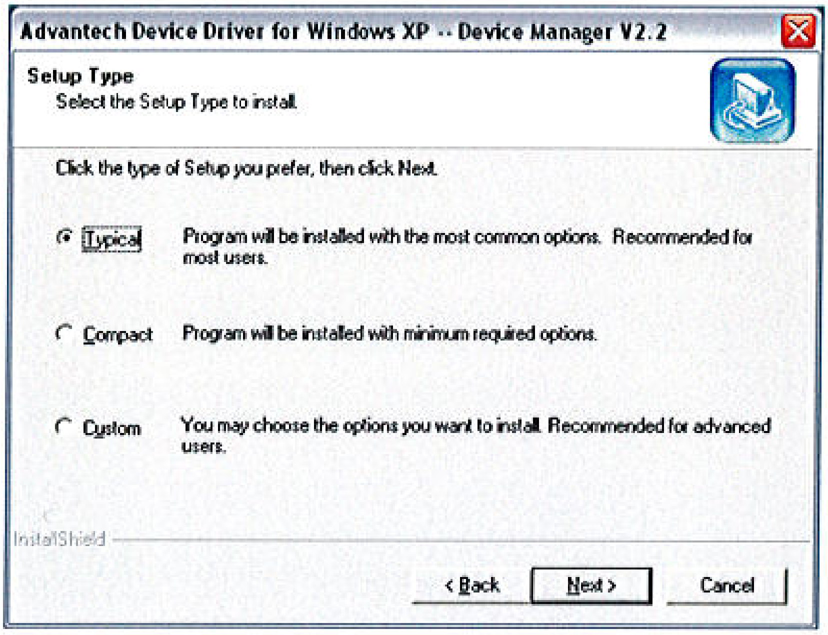

Figure 9 Setup Type Window

9. Select the Typical Setup and press 'Next'. The Program Folder information window will appear (Figure 10).

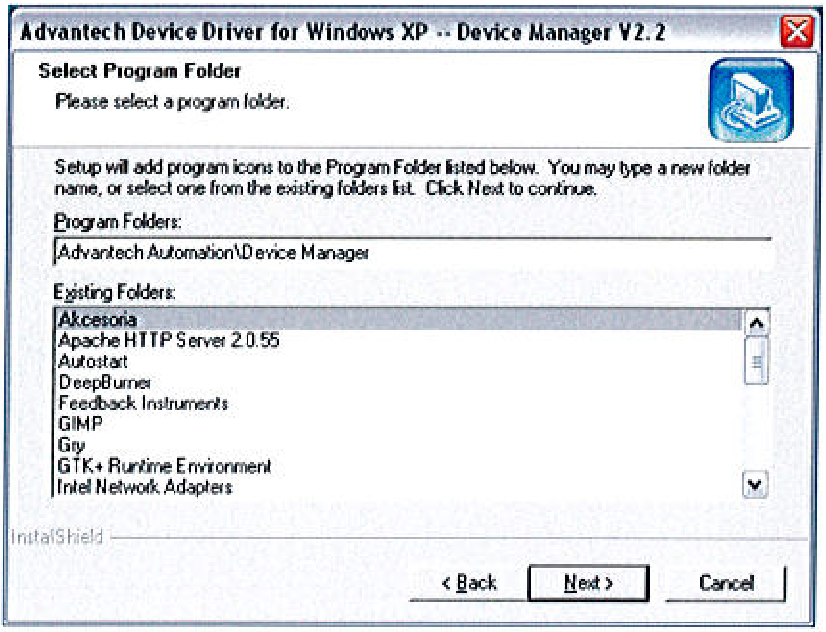

Figure 10 Program Folder Selection Window

10. Select the Program Folder and click 'Next' to proceed. The setup information window will appear. Click 'Next' to continue the setup. The necessary files will be copied and the Device Manager installation will finish.
11. Return to the main installer menu (Figure 4). To install the card driver select 'Individual Driver'. The menu appears as shown in Figure 11.

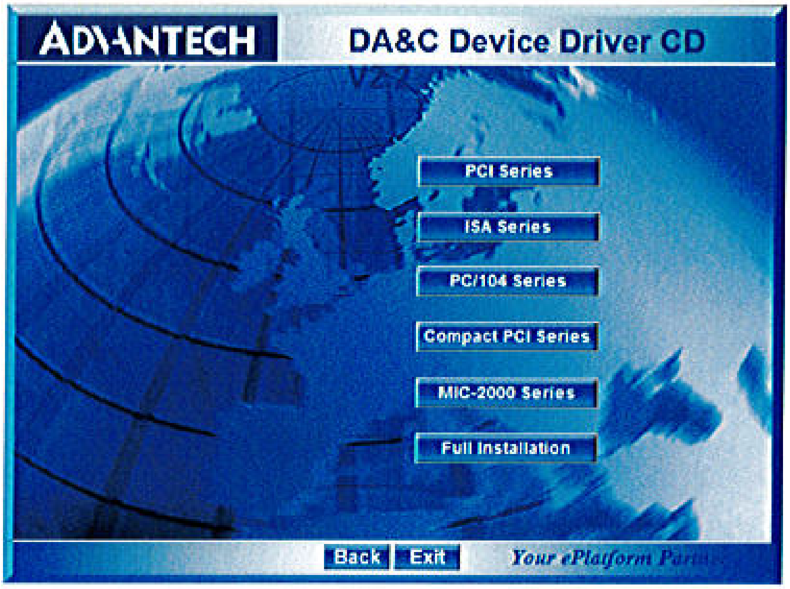

Figure 11 Main Menu

12. Select the 'PCI Series'. The card choice window will open (Figure 12).

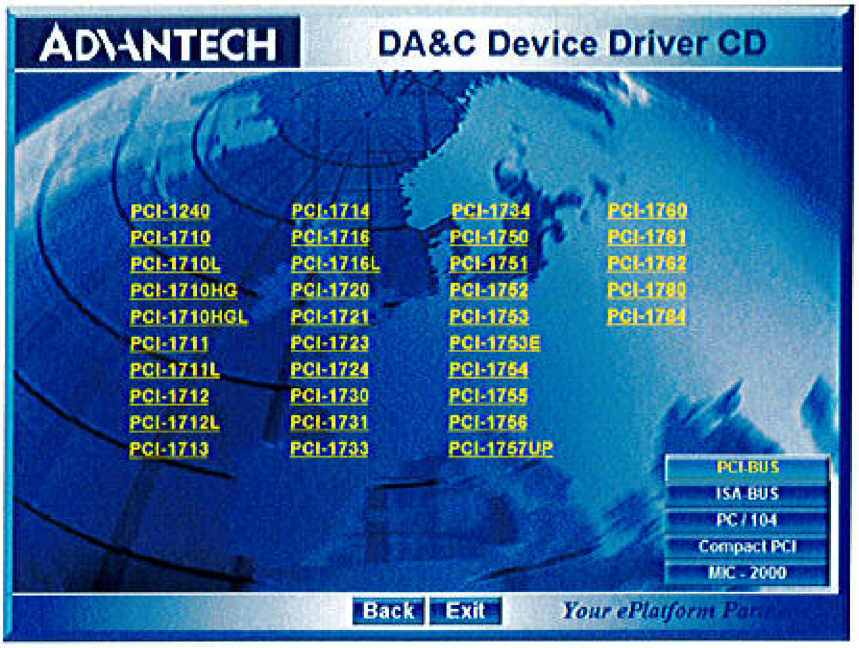

Figure 12 Card Choice Menu

13. Select the 'PCI-1711'. The driver installer will open in a new window (Figure 13).

Figure 13 PCI-1711 Driver Installation window

14. Click 'Next' to proceed. Select the Typical installation (Figure 14) and click 'Next' to continue to the setup information window.

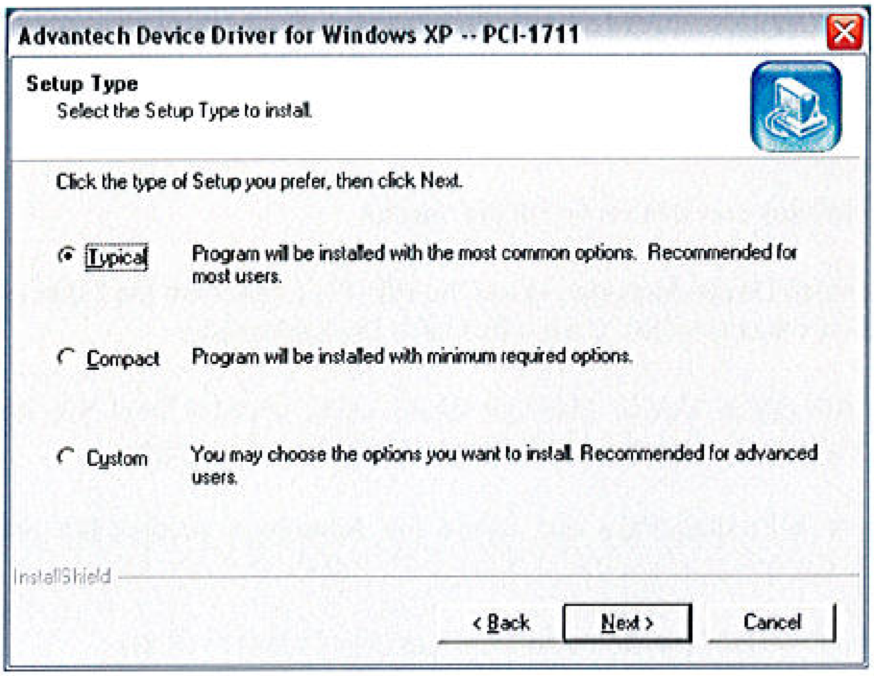

Figure 14 Setup Type window

15. Click 'Next' to proceed with the installation. The necessary files will be copied and the installer will finish.

16. Turn the PC off and use any free PCI slot to insert the PCI-1711 into. Restart the PC. During the start up Windows will automatically install the driver for the PCI-1711.

17. To check that the card has installed correctly, navigate from the Start → All Programs menu to Advantech and run the Device Manager. The PCI-1711 card should show as active in the 'Supported Devices' window. Exit the device manager.

Upgrading and installing downloaded files

The latest version of software can be downloaded from the Advantech website if you have an older version. You will need to download and install both the device driver (Universal 32-bit DLL Drivers V2.2 or higher, PCI1711.exe) and device manager (V2.4 or higher, DevMgr.exe).

First uninstall any previous version of the drivers:

Run Advantech Device Manager, select the PCI-1711 card from the list of supported devices then select Remove. Close Advantech Device Manager.

Uninstall Advantech Device Manager either using uninstall from the Advantech Program Menu entry or from Control Panel - Add/Remove programs.

Navigate to c:\Program Files and delete the Advantech subdirectory and all its contents.

Navigate to C:\windows\system32\drivers and delete ADS1711S.sys.

Do NOT reboot the PC.

Now run the device manager installation DevMgr.exe first, then run the device driver installation PCI1711.exe.

Reboot the PC.

The new hardware will be detected. When asked if Windows can connect to Windows Update to search for software select *No, not this time.*

Figure 15 New Hardware Wizard

At the next screen select *install the software automatically.*

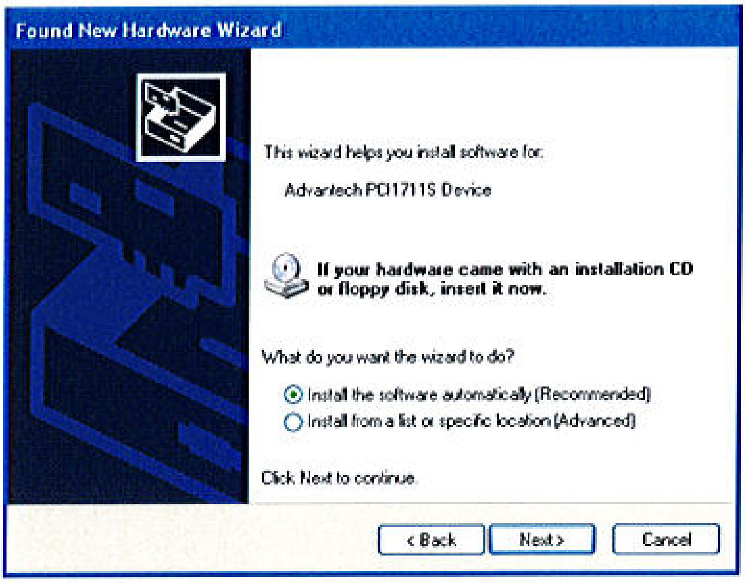

Figure 16 Install New Driver

Windows should find the PCI1711S driver and install it.

Figure 17 Driver Installation Completed

Installation is now complete. To check that the card has installed correctly, navigate from the Start → All Programs menu to Advantech and run the Advantech Device Manager. The PCI-1711 card should show as active in the 'Supported Devices' window. Exit the device manager

Pendulum software installation

After installing the Advantech software and PCI-1711 card you are ready to install the Pendulum workshop software.

1. Close Matlab. Run the fbsetup programme from the CD. The following window will open (Figure 18).

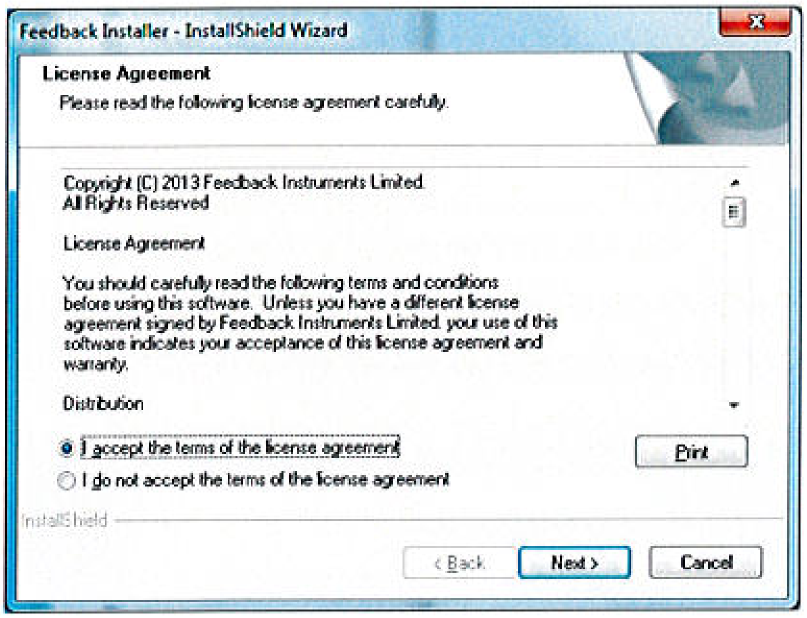

Figure 18 Installation window

2. If you accept the agreement select the appropriate option and click Next.
3. After launching the setup program, the program installation manager dialog will appear on the screen (Figure 19).

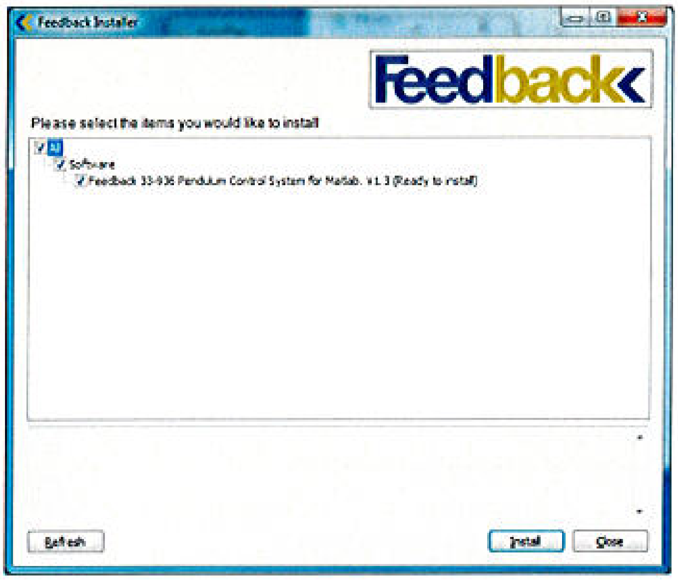

Figure 19 Program Installation Manager window

Tick the software to be installed. Click the 'Install' button.

4. The Matlab version choice window will appear (Figure 20).

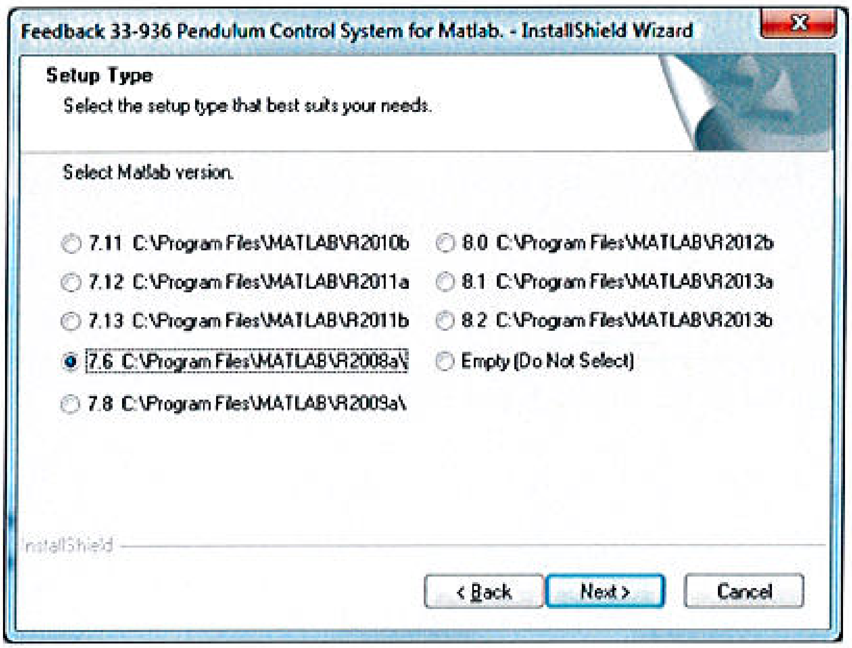

Figure 20 Matlab version choice window

5. Select the Matlab version and click 'Next' to proceed.

6. The software will begin installing. When install an 'Installation Complete' window will appear (Figure 21).

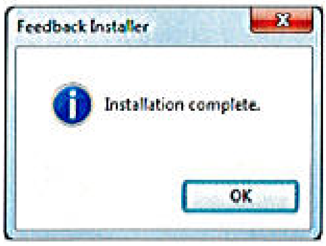

Figure 21 Installation Complete window

7. When software is installed the 'Program Installation Manager' will show the software is installed (Figure 22). Click 'Close' the installation manager.

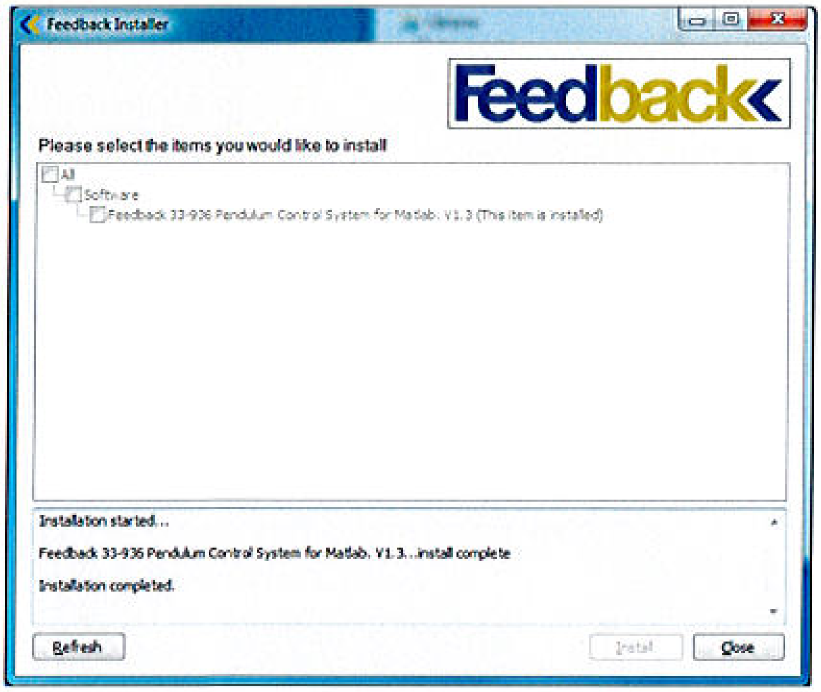

Figure 22 Program Installation Manager window

8. Two folders will be available after the installation. 'Real-time models' folder in which the Maglev Real Time applications are loaded and 'Simulation models' folder in which all of the model simulations files are placed.

PC and pendulum connection

With all of the software installed you are ready to finish the connections of the hardware. Four elements have to be connected to complete the setup:

1. PC with the PCI-1711 card
2. Feedback SCSI Cable Adaptor
3. Digital Pendulum Controller
4. Digital Pendulum Mechanical Unit

Refer to the connection schematic presented in Figure 23 and follow the steps below.

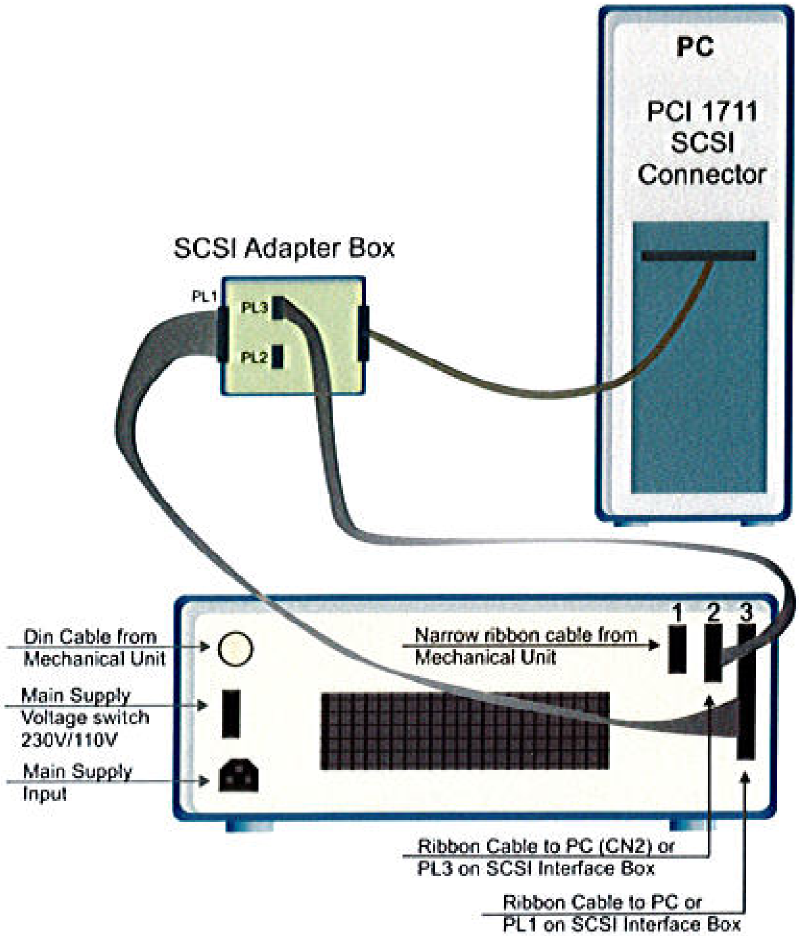

Figure 23 Connection diagram

1. Connect one end of the SCSI cable into the PCI-1711 SCSI connector at the rear of the PC. Connect the other end of the cable into the Feedback SCSI Cable Adaptor box.

2. Connect one end of the wide ribbon cable to the Cable Adaptor box PL1 port and the other end to the Digital Pendulum Controller Unit port 3.

3. Connect one end of the medium sized ribbon cable to the Cable Adaptor box PL3 port and the other end to the Digital Pendulum Controller Unit port 2.

4. The Pendulum Mechanical Unit is equipped with a narrow ribbon cable. Insert the free end of the cable into port 1 of the Digital Pendulum Controller Unit port 1.

5. The Pendulum Mechanical Unit is equipped with a circular 3-pin DIN connector. Insert the DIN connector into the Digital Controller DIN port. Connect the green earth cable to the tab provided below the DIN port.

6. Make sure the Digital Pendulum Controller **power switch is turned off.** Check that the voltage selector is set correctly for your area. Connect the unit to the mains supply using the IEC power cable.

WARNINGS

Do not switch on or press the green start button of the digital controller unit yet. Before you turn the controller on you must be sure that the PCI-1711 card is initialised correctly.

It is safe to press the green start controller button only when your Simulink control application is connected to the external interface and correctly initialised.

Make sure that all of the pendulum mechanical unit bolts are tightened securely.

Always start the simulation with the pendulum placed in the middle of the rail.

Keep clear of the working pendulum and ensure that it will not accidentally come into contact with other objects

Location of Simulink model files

The example Simulink models supplied are stored in two subdirectories. Their location can be selected during installation. The default locations are:

C:\ProgramData\Feedback Instruments\33-936 Pendulum\Examples\Real-time models
C:\ProgramData\Feedback Instruments\33-936 Pendulum\Examples\Simulation models

These models can be edited, saved, built etc. as required. A protected copy of the example models is saved so that these copies can be used to reinstate the original models when required. The default locations of the protected examples are:

C:\ProgramData\Feedback Instruments\33-936 Pendulum\Example backup\Real-time models
C:\ProgramData\Feedback Instruments\33-936 Pendulum\Example backup\Simulation models

To reinstate the original models, delete all files within the *Examples\Real-time models* and *Examples\Simulation models* directories and copy in the contents of the *Example backup\Real-time models* and *Example backup\Simulation models* directories respectively.

Load Matlab and the menu system using the Windows Start menu or by double clicking on the desktop icon (Figure 24).

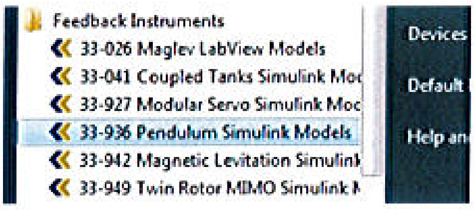

Figure 24 Start menu

Matlab will run and the Simulink model menu will open (Figure 25).

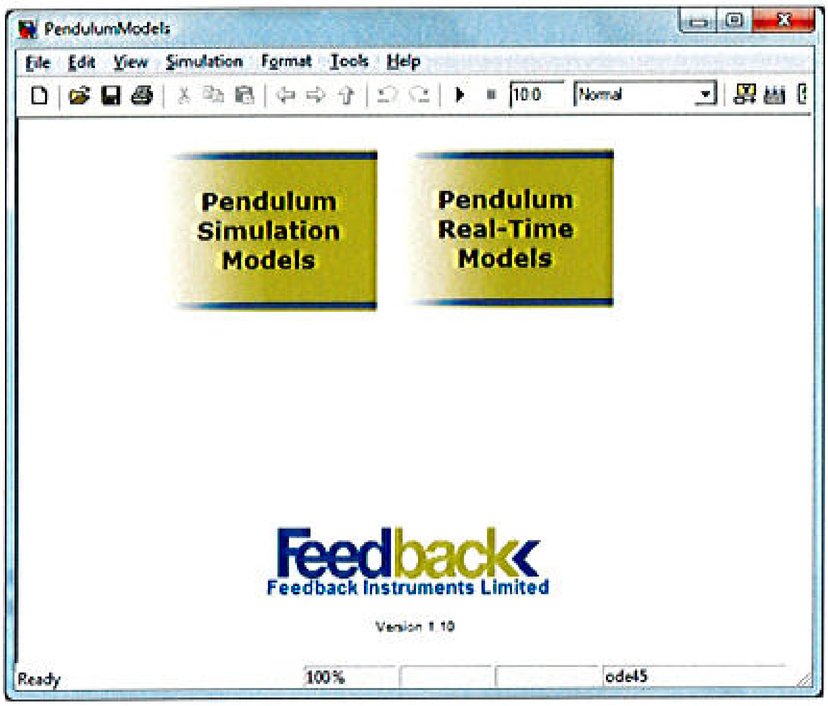

Figure 25 Simulink model menu

To run a real-time model for example, double click on the 'Pendulum Real-Time Models' block in the main menu. A sub-menu containing all of the real-time models will open. Double click the required model, for example Cart Control. The Simulink model window will open.

Refer to '*Running a Simulink Pendulum controller*' section for more information if necessary.

Pendulum Mechanical Unit description

The main element of the Pendulum Mechanical Unit is a cart with two pendulums travelling on a rail. The cart position is controlled by the toothed belt which is driven by a DC motor with a velocity proportional to the control voltage applied to the motor (Figure 26).

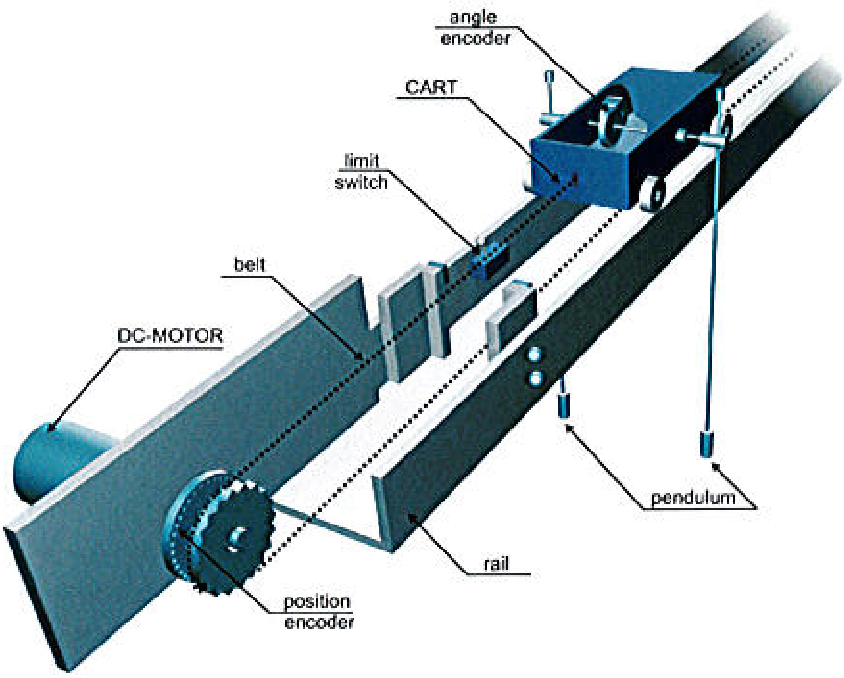

Figure 26 Pendulum Mechanical Unit

The movement of the cart on the rail is bounded mechanically. Additionally, safety limit switches are mounted at either end of the track which cut power to the motor when the cart crosses them.

The cart relative position and relative pendulum angle can be measured by the optical encoders (Figure 26). An optical encoder consists of a light source, light detector and a slit disk placed between them. This way the relative position with respect to the initial point can be measured by counting the pulses on the light detector. Refer to further sections of this manual for explanation on how the encoder pulses are counted.

Because the relative position and angle are measured every time the simulation is started, the cart has to be placed in the zero position with the pendulum not moving before the simulation is started.

Control system

The Pendulum Control System is organized as shown in the schematic presented in Figure 27.

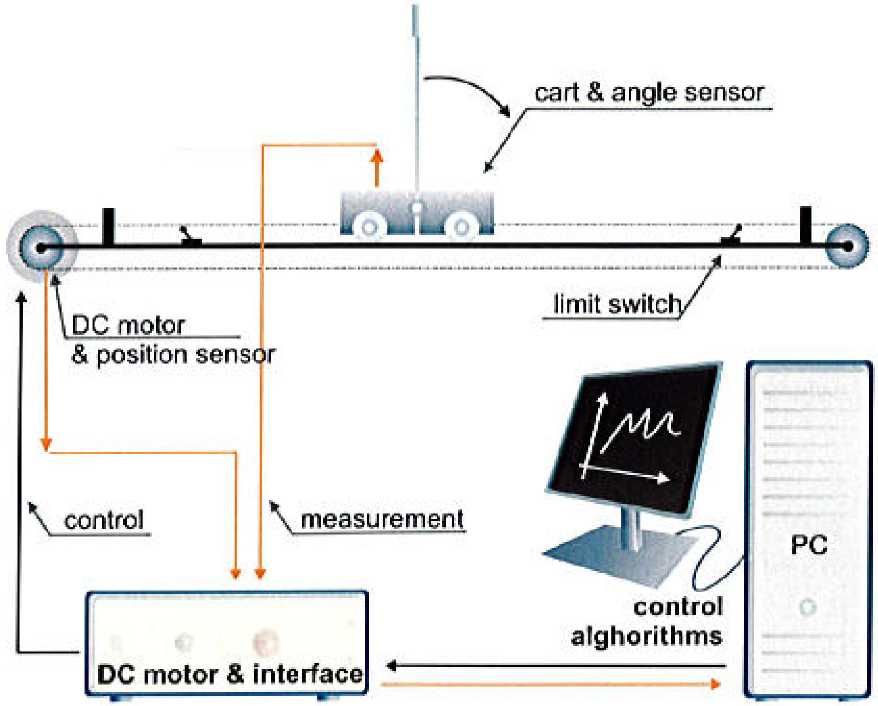

Figure 27 Control System Schematic

The PC with Advantech card and Matlab and Simulink environment serve as the main control unit. The control signal, which is a voltage between –2.5 V and 2.5 V, is transferred to the Digital Pendulum Controller, which drives the DC motor.

The cart position and the pendulum angle encoder signals are transferred to the Digital Pendulum Controller and then to the PC, where all of the control algorithms are placed in the Simulink environment. From the Simulink point of view the pendulum is seen as the following model presented in Figure 28:

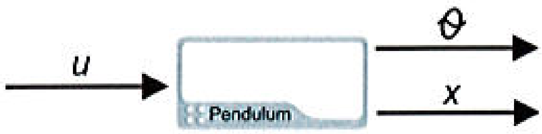

Figure 28 Pendulum model

Computer control

Advantech and Mathworks cooperation lead to significant simplification of control of the systems such as the Digital Pendulum Unit. To design a controller you do not have to build a Real Time application from the very beginning. The framework is already provided for you. You can design arbitrary controllers in the Simulink environment, execute them in real-time using the Real Time workshop and control an external process using PCII/O cards. For those not familiar with computer control systems some basic information is given here.

The digital control diagram presented in Figure 29 is used for that purpose.

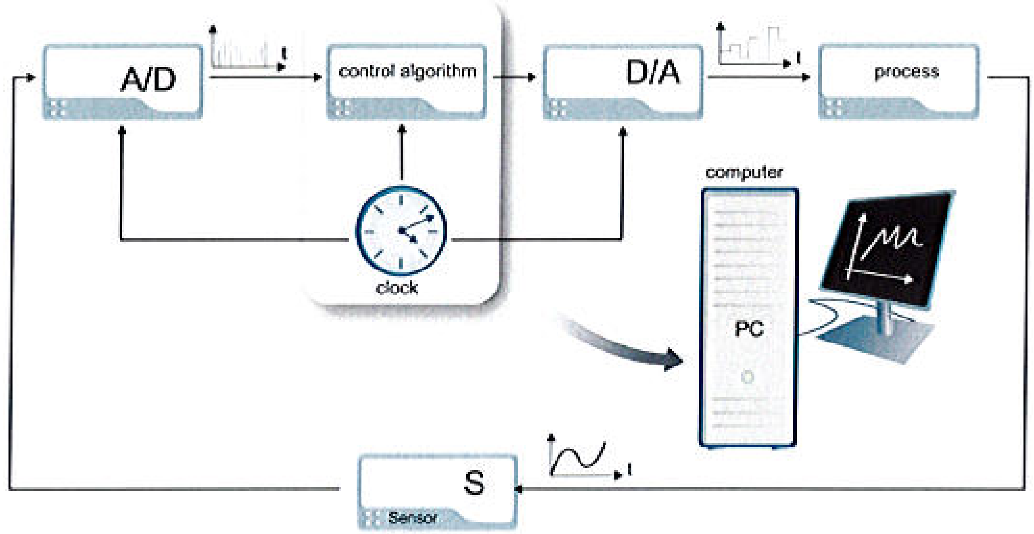

Figure 29 Computer Control System Diagram

The system consists of four main elements:

1. PC with a clocked control algorithm
2. A/D and D/A converters – serving as an interface between the PC and external environment
3. The controlled process
4. Sensors

The control algorithm and the converters operate according to the time pulses distributed by the clock. The distance between consecutive time pulses is called the sampling time. Usually the sampling time is constant however some special applications use intermittent sampling. The clock delivers an interrupt and the interrupt service routine - ISR is called during which the A/D delivers the discrete representation of the measurement returned by the sensor and based on that the algorithm calculates the value of the control signal. At the end of the ISR that value is updated and set by the D/A converter to be held for the next sampling interval.

The same control scheme is used for the Digital Pendulum System.

Running a Simulink Pendulum controller

After software installation two folders should be available, in which Simulink files are placed. One of them includes files for simulation only and the other for external Pendulum real-time control applications.

The files prepared for model simulations can be used in the same way as any normal simulation experiment conducted in Simulink.

Testing the real-time control system

The easiest way to test the newly installed system is to run one of the model files supplied. *CartControl.mdl* is suitable for this purpose (Figure 30).

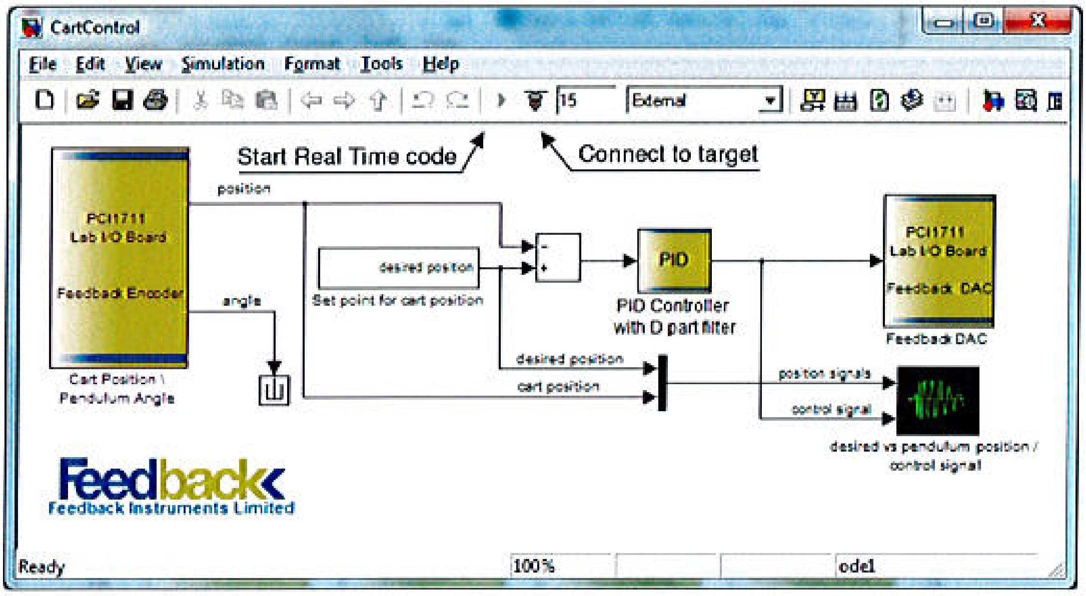

Figure 30 PID Cart Control

The models can be run by double clicking on the desktop icon or navigating using either the Windows *start* menu:

Start menu → All Programs → Feedback Instruments → Feedback 33-936 Pendulum Simulink Models

The top level menu will open (Figure 31).

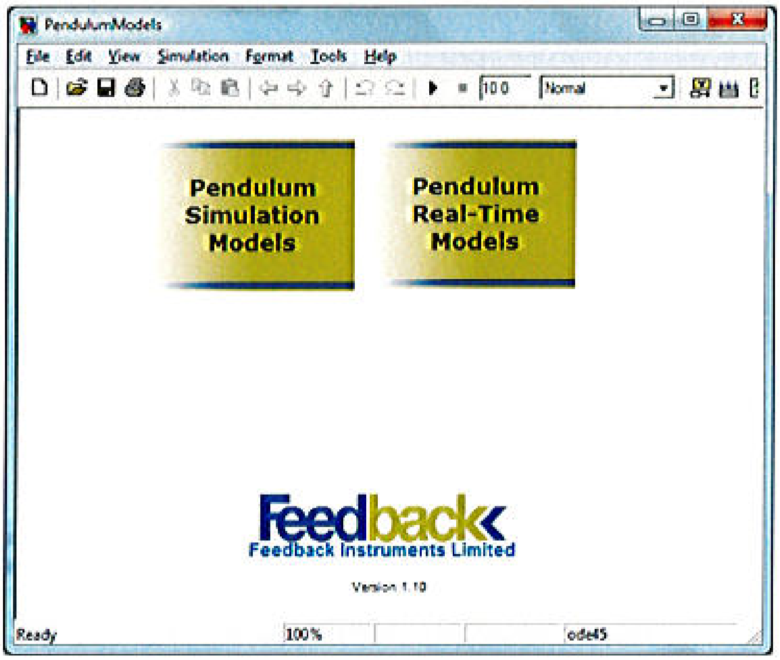

Figure 31 Model category window

To run a real-time model for example, double click on the 'Pendulum Real-Time Models' block in the main menu. A sub-menu containing all of the real-time models will open. Double click the required model, for example Cart Control. The Simulink model window will open (Figure 30).

The simulation parameters are already set. If you want to make your own applications you have to use the same simulation parameters like solver options for example. Thus it is easiest to use one of the existing applications and modify it as necessary without changing the simulation parameters.

Refer to the following sections to see how the model can be compiled and run.

Adding an I/O card to the Matlab installed boards list

If you have carried out a fresh install of the PCI-1711 card drivers, you will need to add the board to the list of installed boards that Matlab uses. The easiest way to do this is to carry out the following instructions.

In the Simulink CartControl window, identify the Feedback DAC block. Right click on this block and select *Look under mask*. A new window will open showing the Simulink blocks that comprise the DAC block. Identify the *Analogue Output* block and double click on it. A dialog box will pop up asking whether you wish to add the board to the list of installed boards (Figure 32). Select yes.

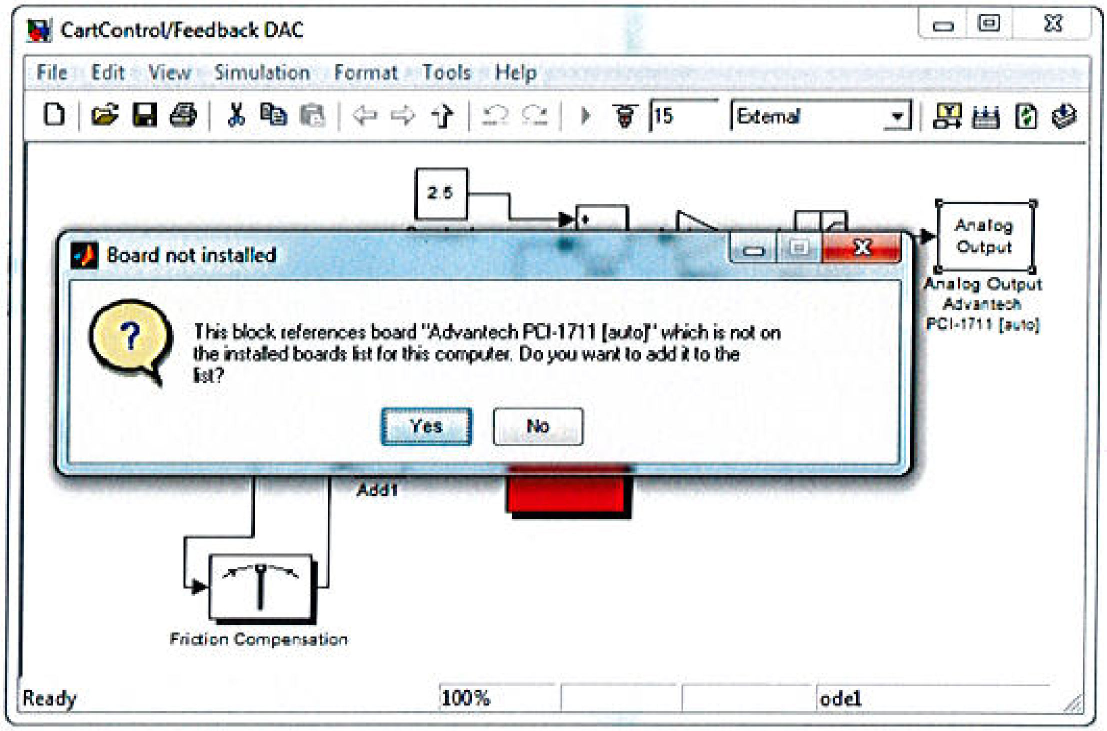

Figure 32 Adding an I/O Board to the Matlab Installed Boards List

The block parameter dialogue box for the PCI-1711 card will open. Cancel this dialogue then close the CartControl/Feedback DAC window. The PCI-1711 card is now correctly registered on the Matlab installed boards list.

Compiling a model

The real-time models provided with the Feedback 33-936 software must be built before they can be executed in real-time. The Real-Time Workshop generates C code from the model which must be compiled and linked to form an application which can be executed on the Real-Time Windows Target. Matlab uses the Open Watcom compiler (part of the standard Matlab install) to compile models for the Real Time Windows Target and no additional compiler is required. The Open Watcom compiler compiles the C code to an executable that runs with the Real-Time Windows Target kernel.

To compile the CartControl model, select the *Tools* menu then *Real-Time Workshop* and *Build Model* (Figure 33).

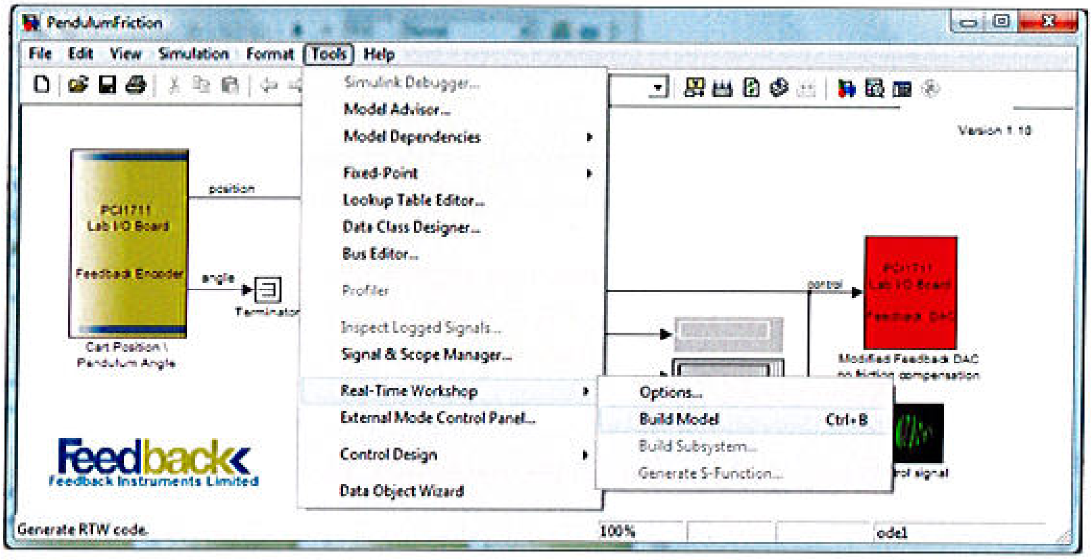

Figure 33 Building a model

Go to the Matlab command window to observe the progress of the build. When the build is complete, check that it was successful (i.e. no error messages were displayed in the Matlab command window).

Running a real-time model

You are now ready to run the CartControl application to test that the hardware and software has been installed correctly.

IMPORTANT

The analogue output of the PCI-1711 card is scaled from 0V to 5V and defaults to 0V output before it is initialised by a Simulink model. The motor driving the cart is scaled so that 0V gives full power to move the cart left, 2.5V gives zero power and 5V gives full power to move the cart to the right. Therefore, if the Digital Pendulum Controller is switched on and the green start button is pressed, the cart motor will be driven hard to the left into the mechanical end-stop. To prevent this, a valid model should be connected to the target first which will initialise the PCI-1711 card and set its output to 2.5V.

Similarly, when driving the PCI-1711 card output manually using the Advantech Device Manager Test facility, the output of the card (Channel 0) should be set to 2.5V before pressing the green start button to enable the Pendulum Controller.

The following sequence is very important and should always be followed when preparing to execute a real-time model to avoid the condition described above.

1. **Make sure that before you run the application, the Digital Pendulum Controller POWER switch is ON but the green START pushbutton is OFF (the green pushbutton lamp is not illuminated). If necessary, press the red STOP pushbutton.**

2. **Place the cart in the centre of the track (over the marker) and stop the pendulum from swinging.**

3. **Connect the application with the target by pressing the** *Connect to Target* **button** (Figure 30) **The application will not run yet but the PCI-1711 card will be initialised correctly. Now press the green START pushbutton on the Digital Pendulum Controller unit.**

4. **If the area around the pendulum is clear you can start the application by pressing the** ***Start Real Time Code*** **button** (Figure 30)**.**

5. **When the simulation is complete, press the red STOP switch on the Digital Pendulum Controller.**

6. **If you wish to stop a simulation part way through, press the red STOP switch on the Digital Pendulum Controller first. Then stop the simulation using the Simulink controls. To restart, follow the steps above again.**

Follow the sequence above and run the cart control model. During the simulation the cart should move gently back and forth according to a sinusoidal reference signal. You can open the scopes to see how the position and angle signals vary but **note that the scope has to be opened before the application is started.**

More information on *CartControl.mdl* is given in the '*Control Experiments*' manual.

Designing controllers

In this section more information is given on the design of controllers.

It is best to start your own controller design by using an existing application and removing its content apart from two essential interface blocks (Figure 34), which are the Encoder input block (Cart Position/Pendulum Angle) and the DAC output block (Feedback DAC). By doing this, all of the simulation parameters that are needed for the Real Time application will be set.

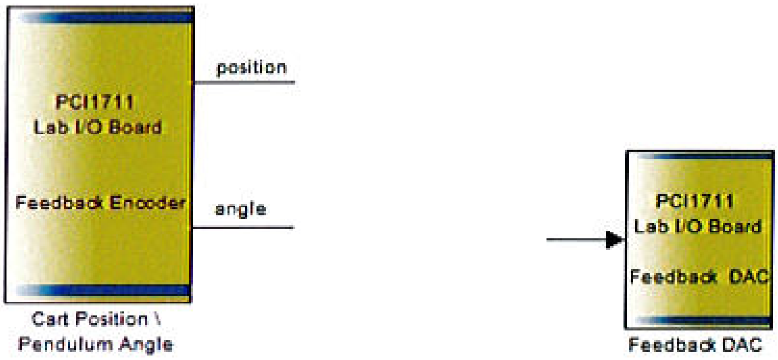

Figure 34 External Interface Blocks

The *Feedback encoder* block has two outputs. The upper output is the cart position in metres and the lower output is the pendulum angle measured in radians. You should not need to modify these blocks. Modifications may cause serious problems with control applications.

Whenever the simulation is started the initial cart and pendulum position are set as a reference. Thus before starting the application the cart must be set at the zero point (centre of the track) and the pendulum must hang vertically with as little movement as possible

It is best if you start by modifying the control parameters of existing applications or design your own simple algorithms to become familiar with the pendulum set-up.

Reading the encoders and setting the control signal

In this section the contents of the two blocks that interface with the external equipment, namely the '*Feedback encoder block'* and the '*Feedback DAC block*' are described (Figure 34).

PCI-1711 I/O Block – Feedback Encoder

- This is a universal Feedback block, which reads two 16-bit values from the encoder interface (two HCTL2016 ICs) and transforms them into relative position and relative angle.
- The block has two outputs which are both updated even if only one of them is used (connected) in the experiment. If one of the outputs is not used it is connected to a terminator.

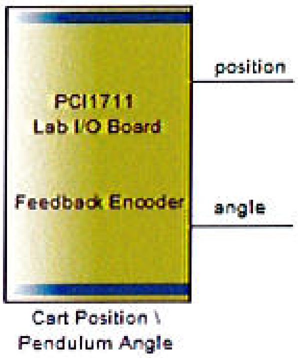

Figure 35 Encoder Interface Block

- There are three parameters for this block: sample time, channel one and channel two offsets. Channel one refers to the first encoder output and channel two to the second encoder output.
- By double clicking on this block we can change the above parameters (see Figure 36).

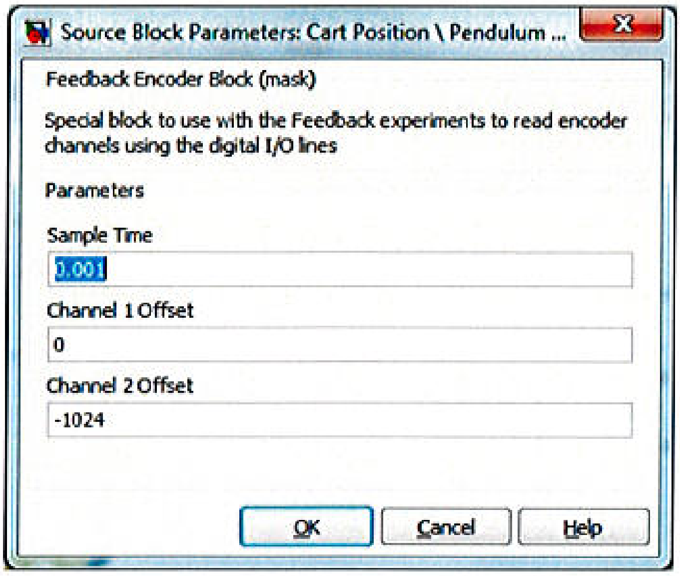

Figure 36 Feedback Encoder Block Parameters

- Choose "*Look under Mask*" to see the subsystems (Figure 37).

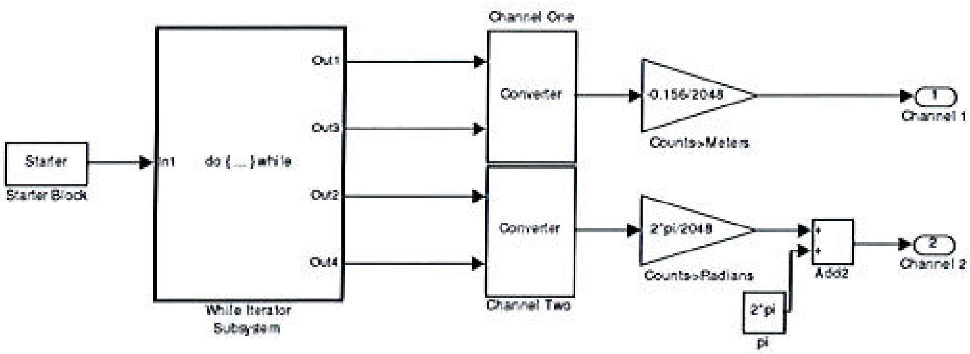

Figure 37 Feedback Encoder Block - Look Under Mask

- The *"While iterator subsystem"* reads low and high byte for the two encoders. These bytes are then converted into one 16-bit word for each encoder and we get two 16-bit words in the output of the block. We use the *"while iterator subsystem"* because we have to perform a lot of operations in the shortest time possible. These operations are necessary because every HCTL2016 encoder has an 8-bit output and reading a 16-bit word can only be done the following way:

1) prepare to read high byte: set !OE line to low and SEL line to low,
2) read high byte,
3) prepare to read low byte: set SEL line to high,
4) read low byte,
5) set !OE line to high (Figure 38).

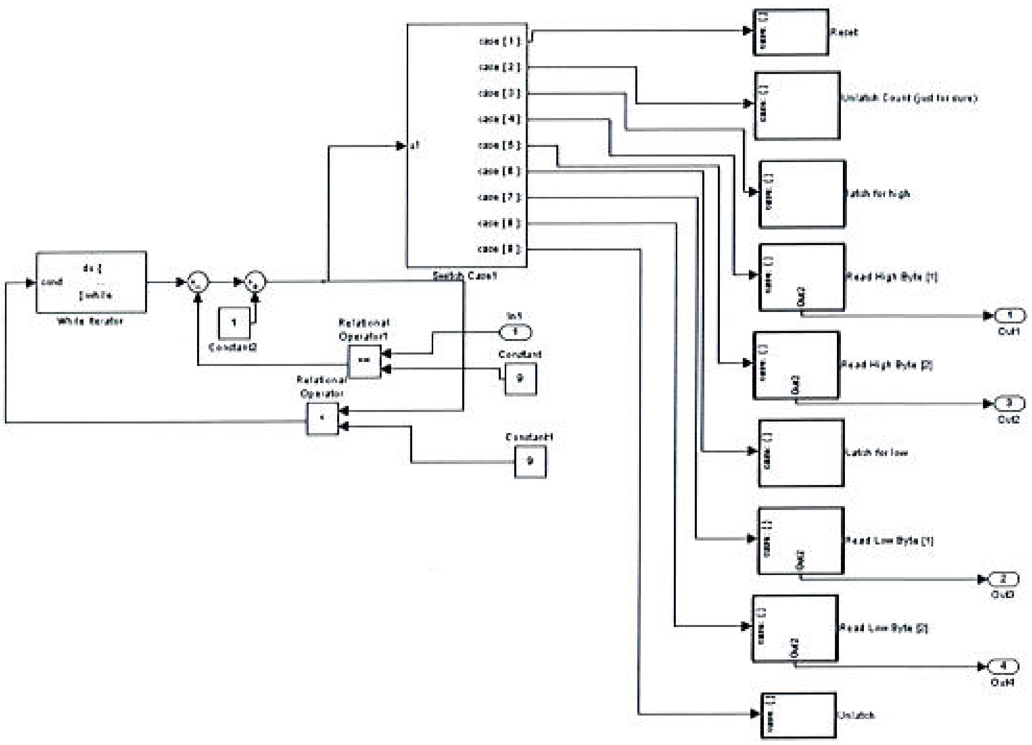

Figure 38 Feedback Encoder Block - Reading Values From Encoders

- Digital Output or Digital Input blocks are placed in the Action blocks presented in Figure 38.
- This block uses two S-functions: Starter and Converter. These are very simple functions and can be found in *C:\ProgramData\Feedback Instruments\33-936 Pendulum\src.*
- If the PCI-1711 card experiment is run for the first time we can double click on the Digital Output block and register the PCI-1711 card in Matlab environment (Figure 39).

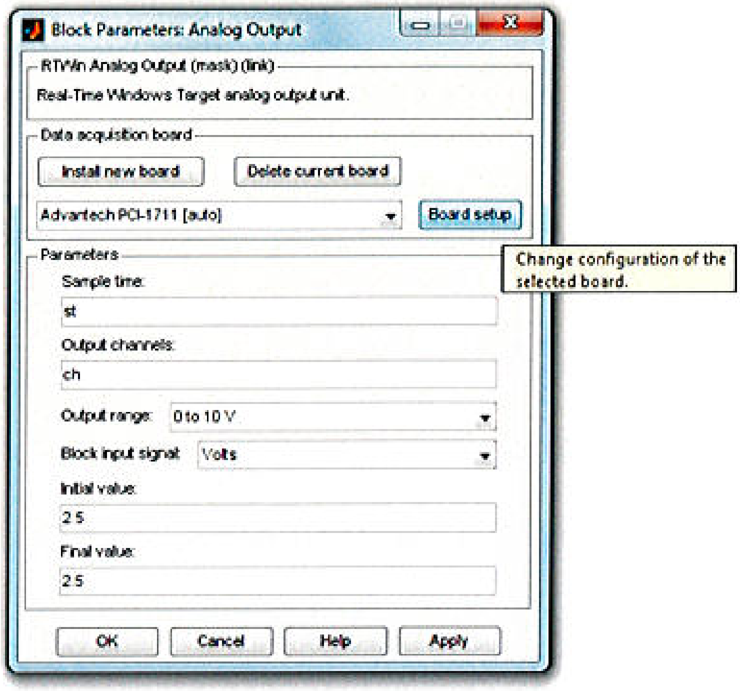

Figure 39 Selecting the I/O Card

PCI 1711 I/O Block – Feedback DAC

- This is a universal Feedback block which sends the input value to PCI-1711 analogue output.
- There is one input to this block. The block reads the value from this input and sends it to the analogue output of the PCI-1711 card (Figure 40).

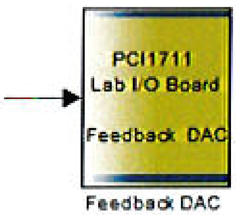

Figure 40 Feedback DAC Block

- There are two parameters available: sample time and output channel. We can choose between 1 or 2 for output channels. This is because the PCI-1711 has two analogue output channels. Channel 1 is connected to the cart motor.
- By double clicking on this block we can change the above parameters (Figure 41).

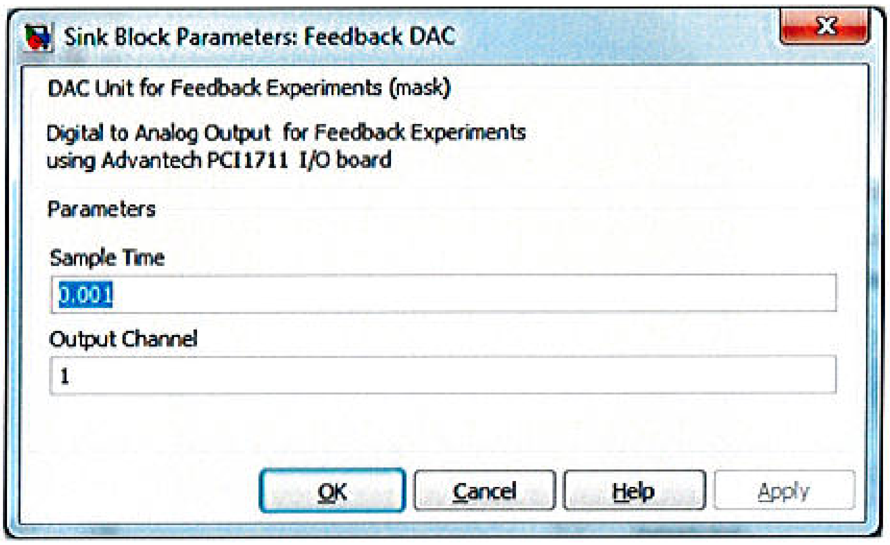

Figure 41 Feedback DAC Block Parameters

- The value, which is sent to the analogue output, is converted to the accepted range of 0V to 5V.
- Choosing "*Look under Mask*" will cause the subsystems to appear (Figure 42).

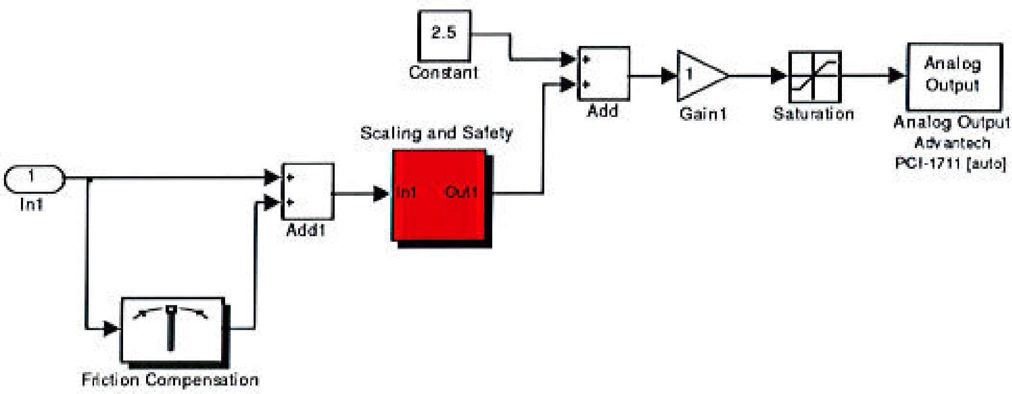

Figure 42 Feedback DAC Block - Under Mask

- If we run the PCI-1711 card experiment for the first time we can double click on the Analogue Output block and register the PCI-1711 card in the Matlab environment (Figure 43).

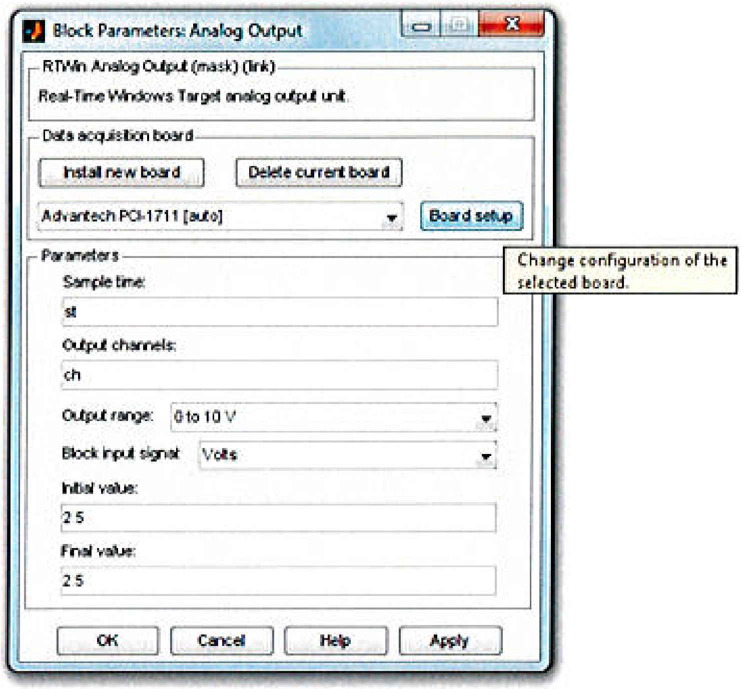

Figure 43 Feedback DAC Block - Selecting the I/O Card

Pendulum signals

- The Feedback Encoder block reads values from two encoders on the mechanical unit: cart position and pendulum angle. These two values must be scaled before we use them as controller inputs.
- Cart position should be set in metres and the scaling block converts from counts of the incremental encoder turning with the motor, to units of metres for the movement of the cart along the rails (Count->Metres gain block makes the conversion).
- Pendulum angle should be set in radians and the scaling block converts from count to radians. The offset is set to -1024 and this sets the pendulum reference position to Pi (Count->Radians gain block makes the conversion).
- The PID controller reads the values in metres and radians and gives the values already scaled to the required Volt units.

Troubleshooting

Controller runs weakly, cart motor seems to have little power

An important controller parameter is static friction (also called stiction). If your Pendulum mechanical unit is incorrectly adjusted, excessive stiction may result in poor performance. Run Exercise 3 and measure the stiction. A correctly set up mechanical unit will require approximately 0.2V to overcome stiction and cause the cart to move. Taking into account the scaling of the DAC (where 0V is full power left, 2.5V is zero and 5V is full power right), it should require around 2.7V to drive it to the right and 2.3V to the left (note that directions are viewed with the motor at the left of the track).

These results can be obtained using Exercise 3 or alternatively by driving the output of the DAC manually using the Advantech Device Manager programme, Test mode. The channel connected to the cart motor is labelled Channel 0 in the Advantech test programme.

CAUTION

When using Advantech Device Manager in Test mode, ensure that you set the output of Channel 0 to 2.5V (i.e. zero motor demand) before pressing the green START button on the Pendulum Controller Unit.

If you obtain stiction values significantly greater than ±0.2V (i.e. outside the range 2.3V to 2.7V) the controller may not function correctly. First try to reduce stiction by checking the belt tension and adjusting if necessary. When the stiction is as low as you can achieve, rerun the stiction test to obtain new values. These new stiction values can be entered into the controller model as follows. The stiction component is incorporated into the DAC Output block of each controller. Look under the mask of the DAC Output block (Figure 44) Open the Friction Compensation block and enter the new values (Figure 45). You will need to rebuild the controller model.

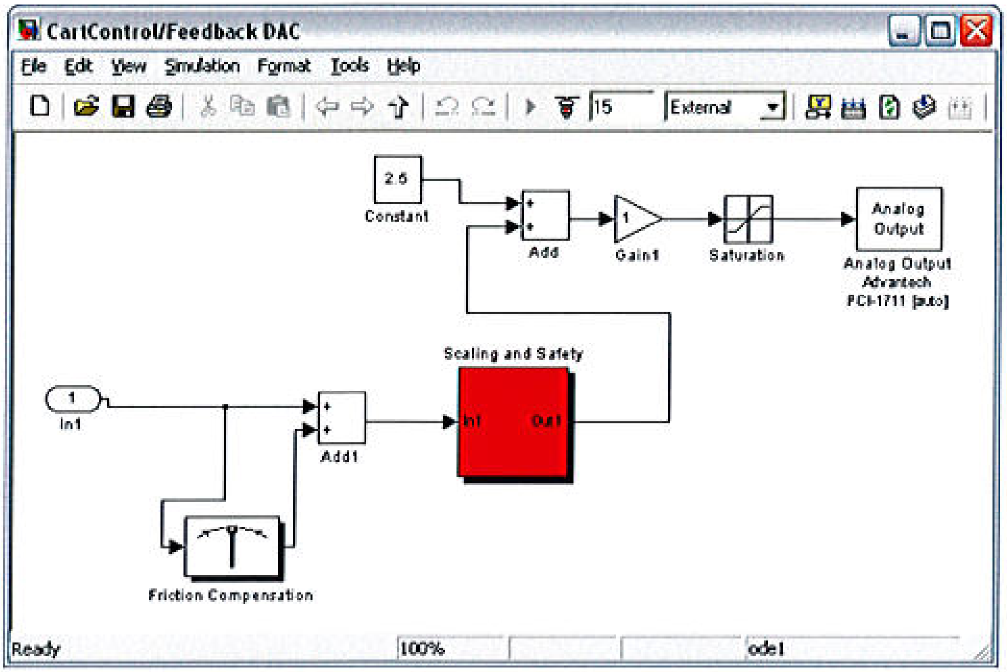

Figure 44 Look Under Mask of DAC Block

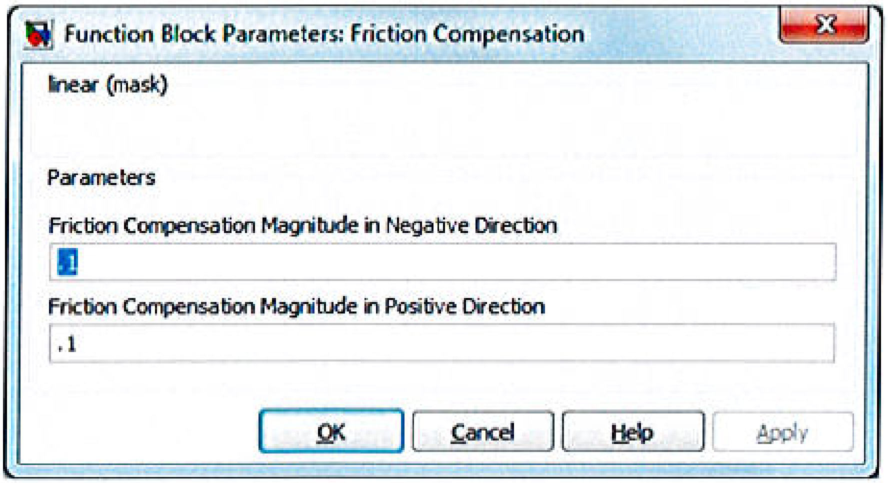

Figure 45 Entering New Stiction Values

Matlab Error message when trying to connect to target

The Matlab error message shown in Figure 46 may be appear when trying to connect to the target if the model has not been built (compiled). Refer to the section *Compiling a model* for help.

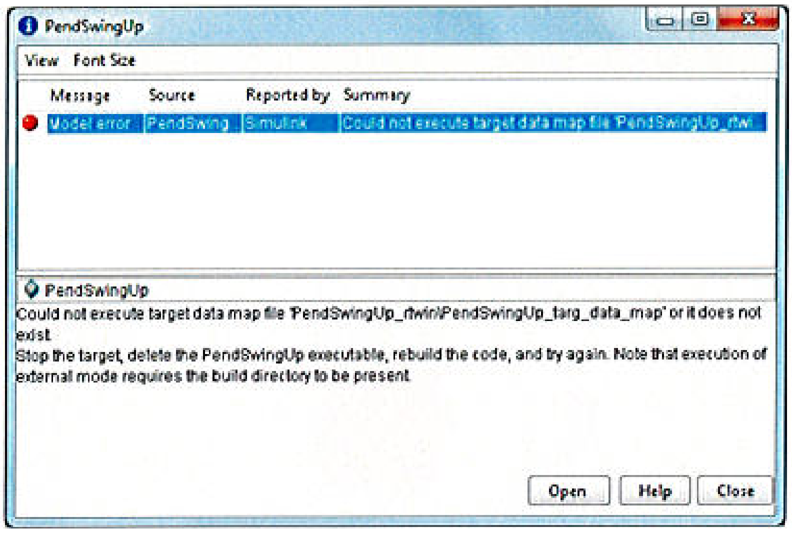

Figure 46 Matlab Error Message