COUPLED TANKS
Installation & Commissioning

33-041-IC

(For use with MATLAB)

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: www.feedback-instruments.com

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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.

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CAUTION - RISK OF DANGER

Refer to accompanying documents

CAUTION - RISK OF ELECTRIC SHOCK

CAUTION - ELECTROSTATIC SENSITIVE DEVICE

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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.

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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.

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

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Table of Contents

Manual overview

This manual serves as a set of installation instructions for the Coupled Tanks Setup. Firstly, it explains which elements belong to the setup and how they are connected. The software installation process is described, and finally the details of how the Coupled Tanks System is controlled with the PC in the Matlab environment are presented. Precautions are underlined.

Required manuals and equipment

The following equipment and manuals are required for the use of the Coupled Tanks 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 PCI1711 card

5 Coupled Tanks – Mechanical and Electronic Units

6 Software installation CDs

7 '*Installation & Commissioning'* manual

8 '*Control Experiments'* manual

9 '*Matlab Guide*' manual

The following equipment is supplied by Feedback Instruments as 33-041 (Coupled Tanks System):

1 33-230 - Coupled Tanks rig with Software Pack

2 Advantech PCI card with cables and connector box

Packing List

Unpack the items and remove all packing and securing material. Apart from software installation CD's you should have the following items:

1) 33-230 – Coupled Tanks rig with Tanks and Pumps mounted
2) 1 SCSI cable
3) Connector box
4) LPT 25 way cable

Unit assembly

Connect the unit according to Figure 1 and the following instructions.

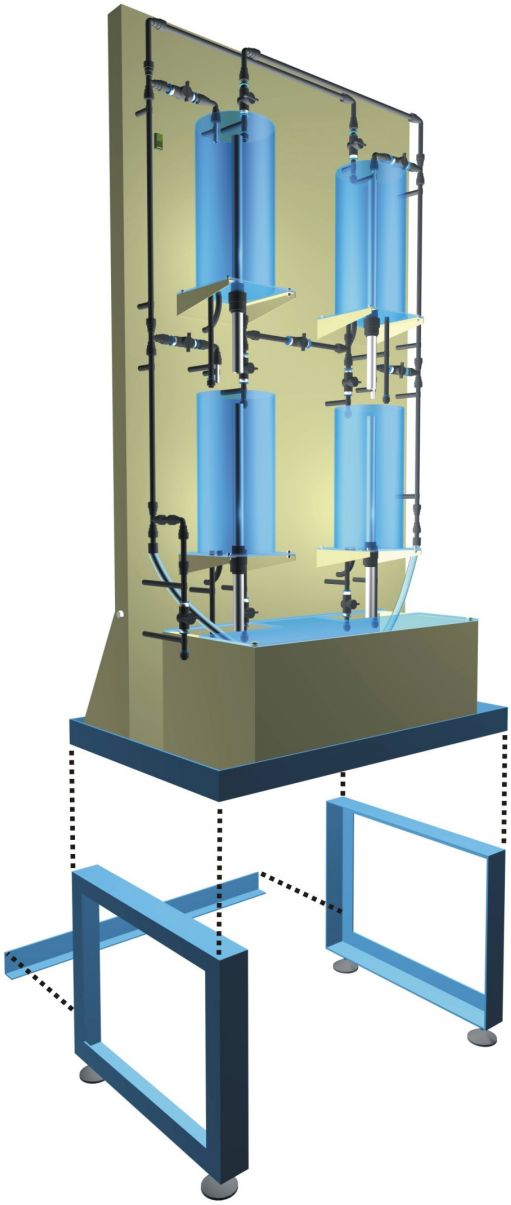

Figure 1 Assembled Coupled Tanks unit

- Assemble the bottom stand for the Coupled Tanks if necessary. Use the supplied screws to attach the legs to the rig.

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.

During the installation of the Advantech PCI-1711 card make sure you follow the instructions given in this section. This will ensure that common installation problems are avoided.

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 driver software has been installed correctly. A PCI-1711 device driver 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).

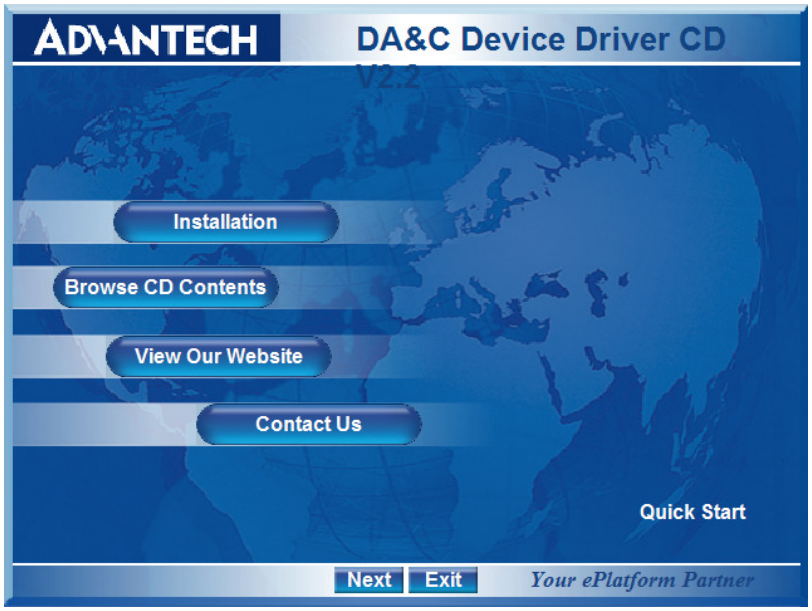

Figure 3 Installation Menu

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).

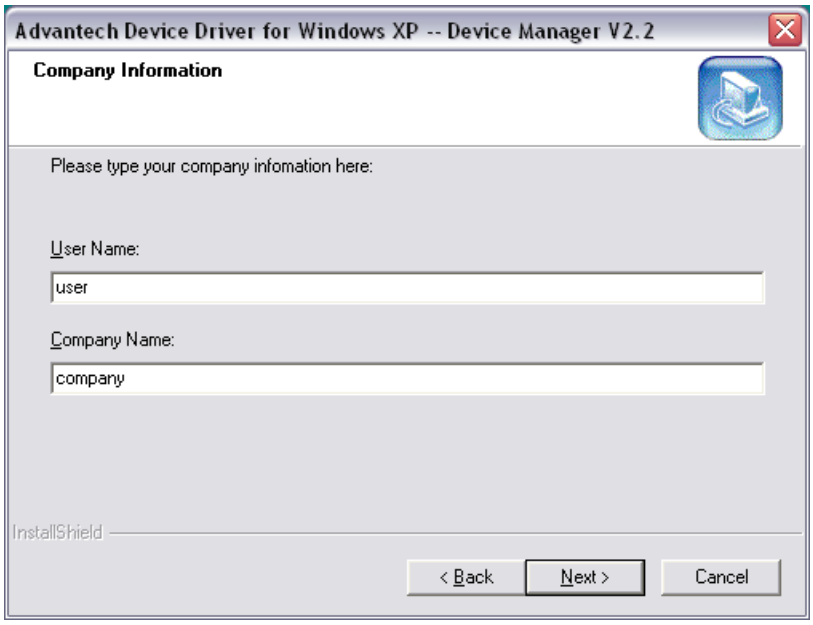

Figure 7 User Information Window

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.

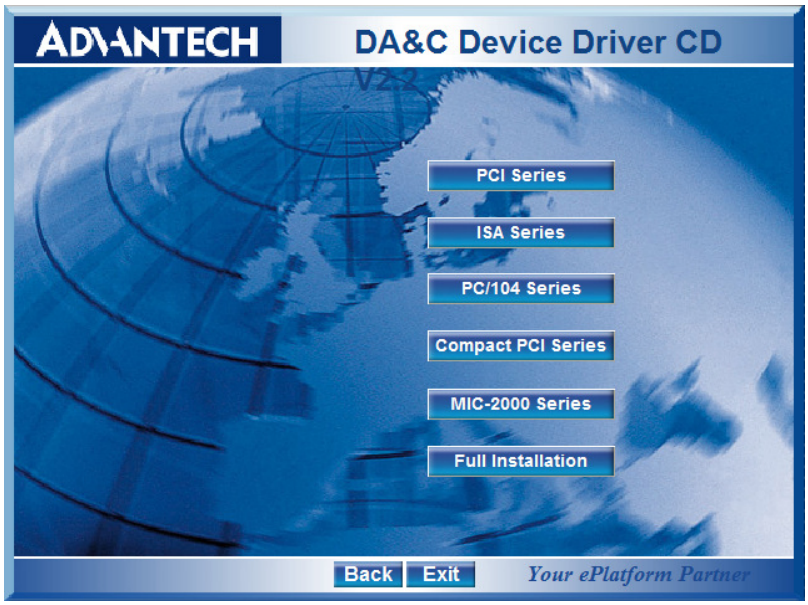

Figure 11 Main Menu

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

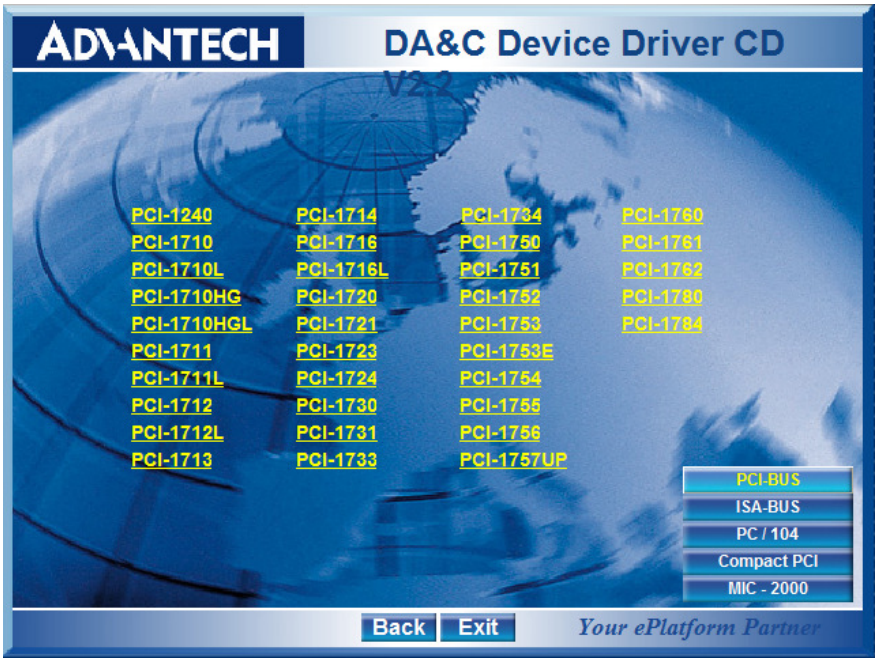

Figure 12 Card Choice Menu

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

This section refers only to the users upgrading the Advantech software. Refer to the previous section for first installation instructions.

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).

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 ADS1711.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*.

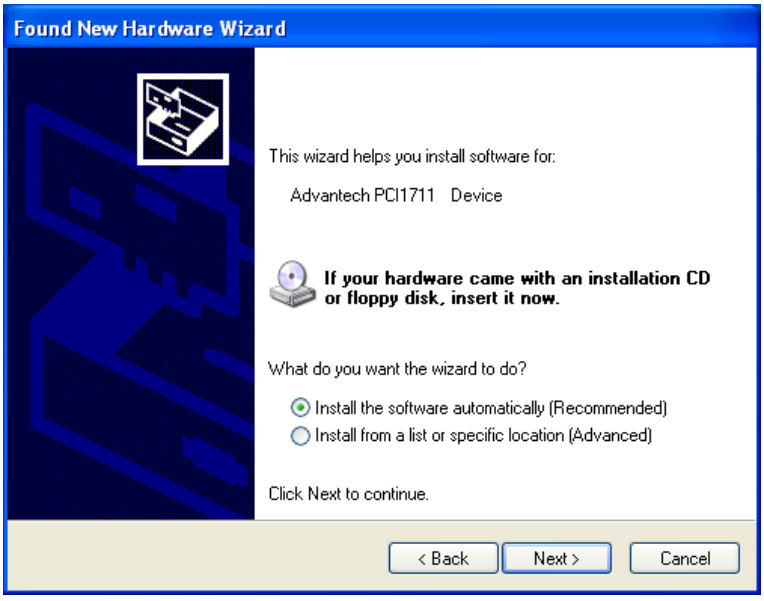

Figure 16 Install New Driver

Windows should find the PCI1711 driver and install it.

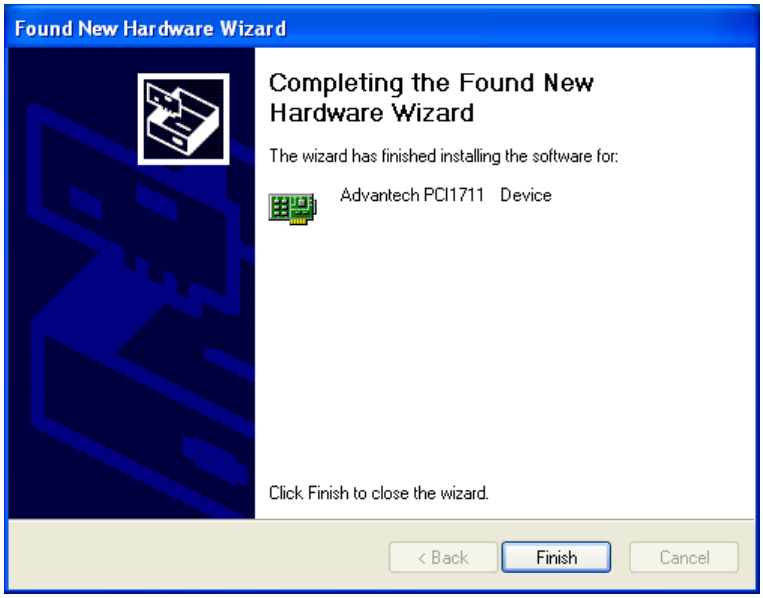

Figure 17 Driver Installation Completed

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

Coupled Tanks System software installation

After installing the Advantech software and PCI1711 card you are ready to install the Coupled Tanks software.

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

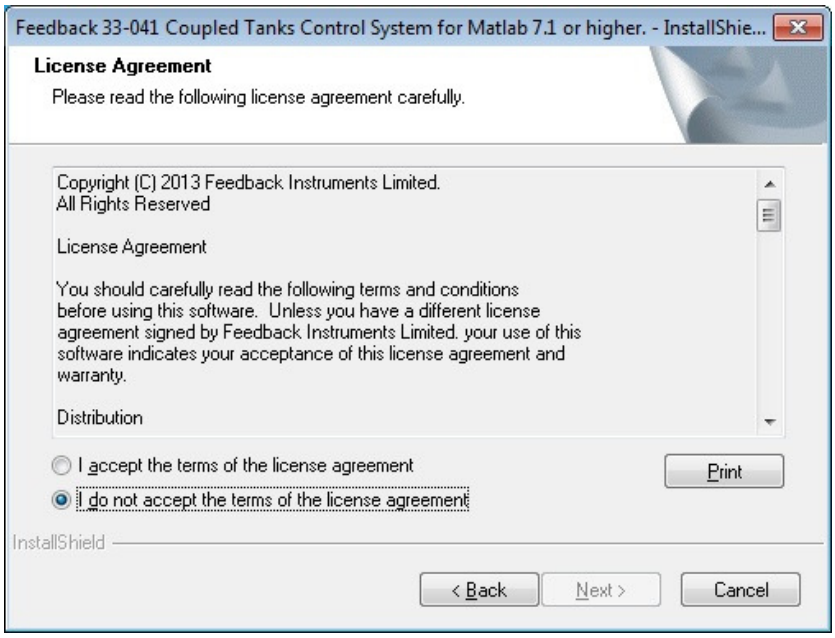

Figure 18 License Agreement window

2. If you accept the agreement select the appropriate option and click Next.

3. Click ‘Next’ to continue. The license agreement window will appear. If you accept the terms select the appropriate tick box and click ‘Next’ to continue.

4. After launching the setup program, the program installation manager dialog will appear on the screen. (Figure 19)

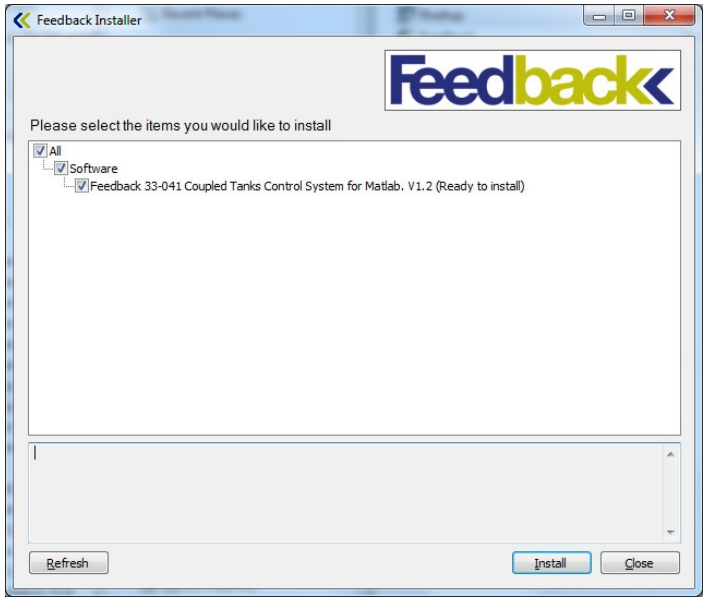

Figure 19 Program Installation Manager

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

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

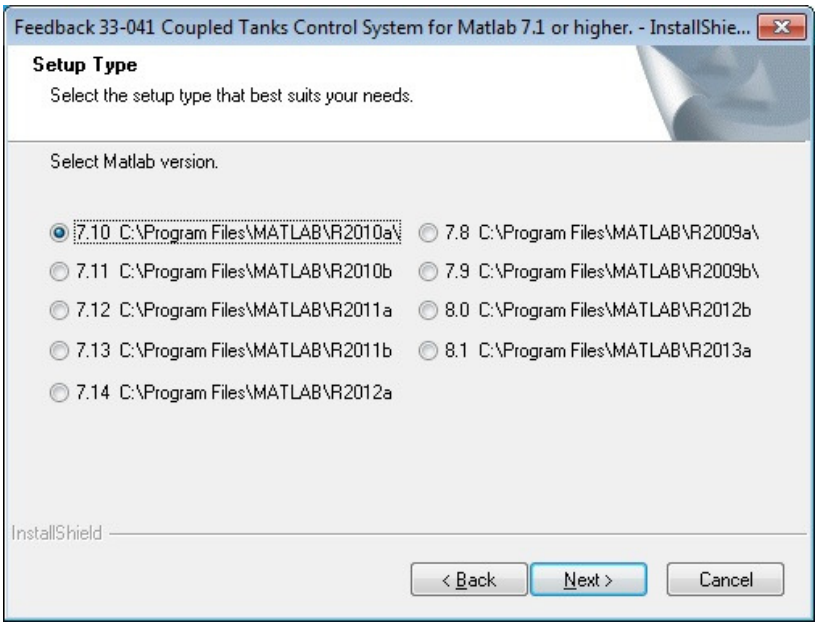

Figure 20 Matlab version choice window

6. Click 'Install' to proceed. The Coupled Tanks Calibration File window will appear (Figure 21).

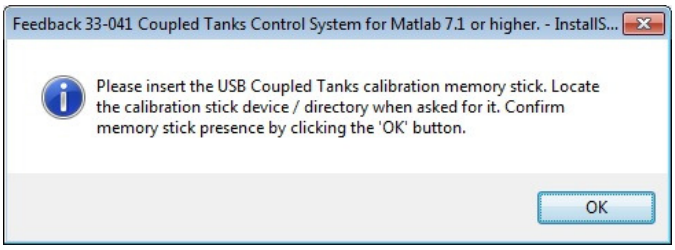

Figure 21 Coupled Tanks Calibration File window

7. Click ‘OK’. Insert the USB memory stick supplied with the coupled tacks into a spare USB socket. Follow the on screen instructions.

8. Next the Choose Folder window will open (Figure 22). Navigate to the USB memory stick and click ‘OK’ to continue.

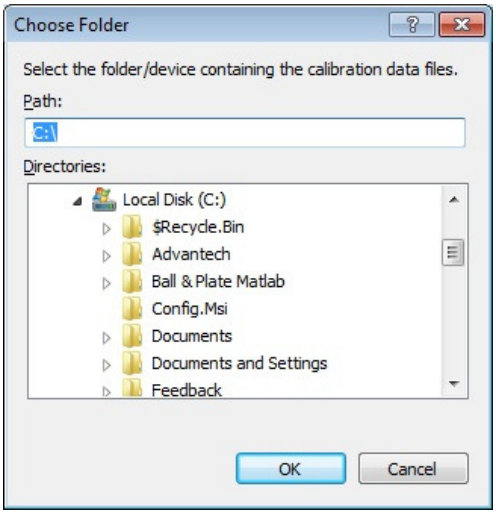

Figure 22 Choose Folder window

9. When the files have been copied to the system a window will open. Click ‘OK’ to continue.

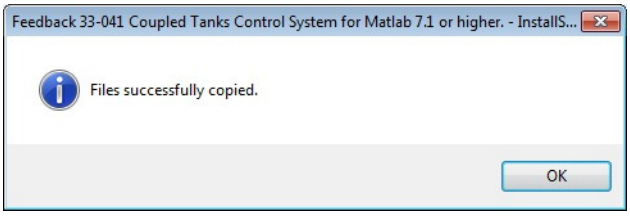

Figure 23 Files successfully copied window

10. When install an ‘Installation Complete’ window will appear (Figure 24).

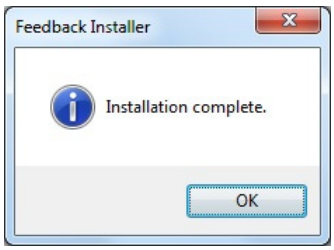

Figure 24 Installation Complete window

11. When software is installed the ‘Program Installation Manager’ will show the software is installed (Figure 25). Click ‘Close’ the installation manager.

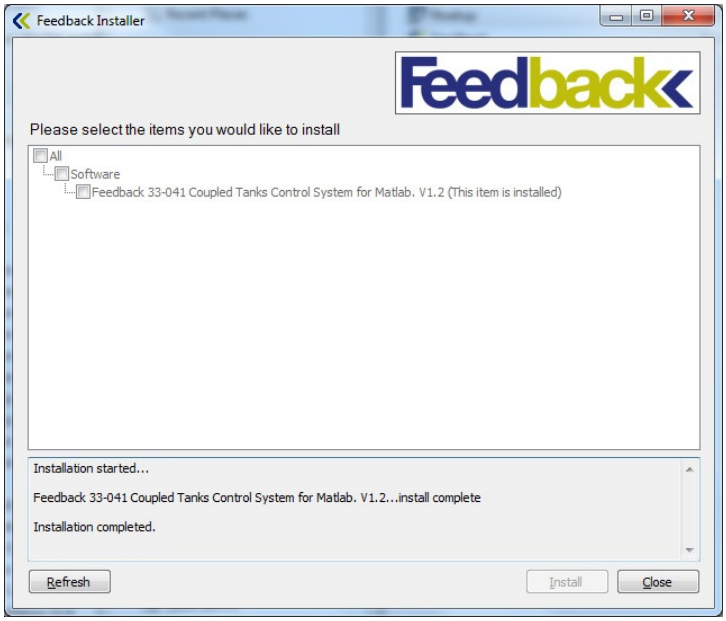

Figure 25 Program Installation Manager window

PC and Coupled Tanks connection

With all of the software installed you are ready to connect the PC to the hardware. The following elements have to be connected to complete the setup:

1. PC containing the PCI-1711 card
2. Cable connector box
3. Coupled Tanks PSUPA (Power Supply Power Amplifier)

Refer to the connection schematic presented in Figure 26 and follow the steps below.

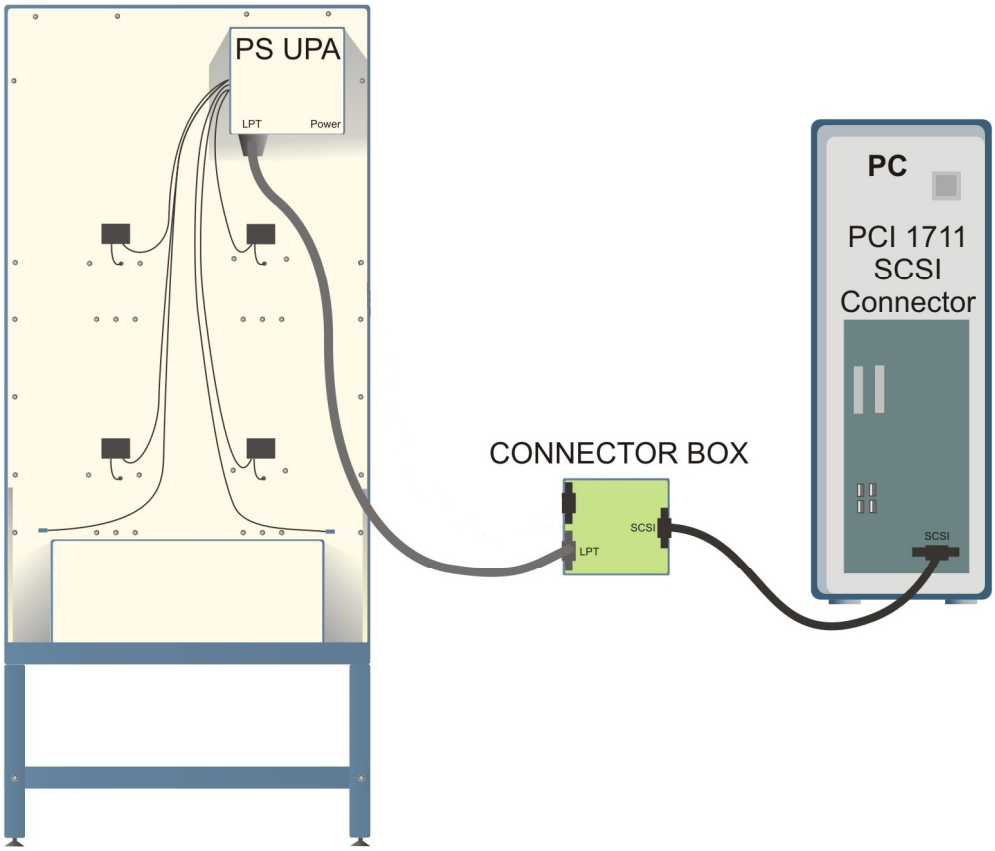

Figure 26 Connection diagram

1. Connect the PCI1711 SCSI Connector to the Feedback Cable Connector Box.

2. Use the 25 way SUB-D connector to connect the Connector Box with the proper SUB-D port of the PSUPA on the Coupled Tanks rig.

3. Connect the mains power cable into the PSUPA and plug it into your mains supply.

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\33-041 Coupled Tanks\Examples\Real-time models
C:\ProgramData\Feedback Instruments\33-041 Coupled Tanks\Examples\Simulation models

These models can be edited, saved, built etc. as required. A protected copy of the example models has been made so these copies can be used to reinstate the models within the examples directories when required. The default locations of the protected examples are:

C:\ProgramData\Feedback Instruments\33-041 Coupled Tanks\Example backup\Real-time models
C:\ProgramData\Feedback Instruments\33-041 Coupled Tanks\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 model* directories respectively.

Load Matlab and the menu system using the Windows Start menu (Figure 27).

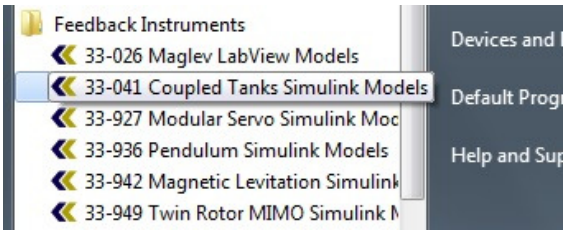

Figure 27 Start menu

Matlab will run and the Simulink model menu will open (Figure 28).

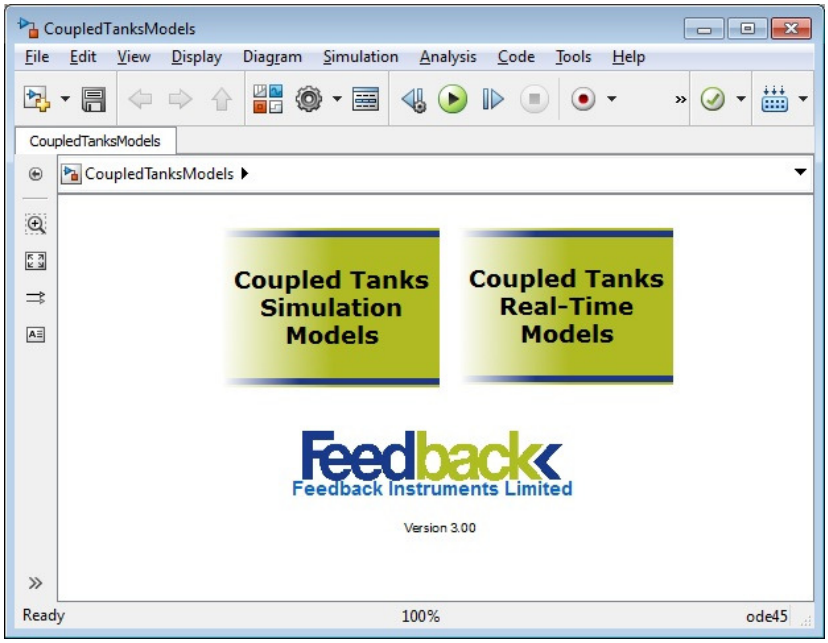

Figure 28 Simulink model menu

To run a real-time model for example, double click on the 'Coupled Tanks Real-Time Models' block in the main menu. A sub-menu containing all of the real-time models will open (Figure 29).

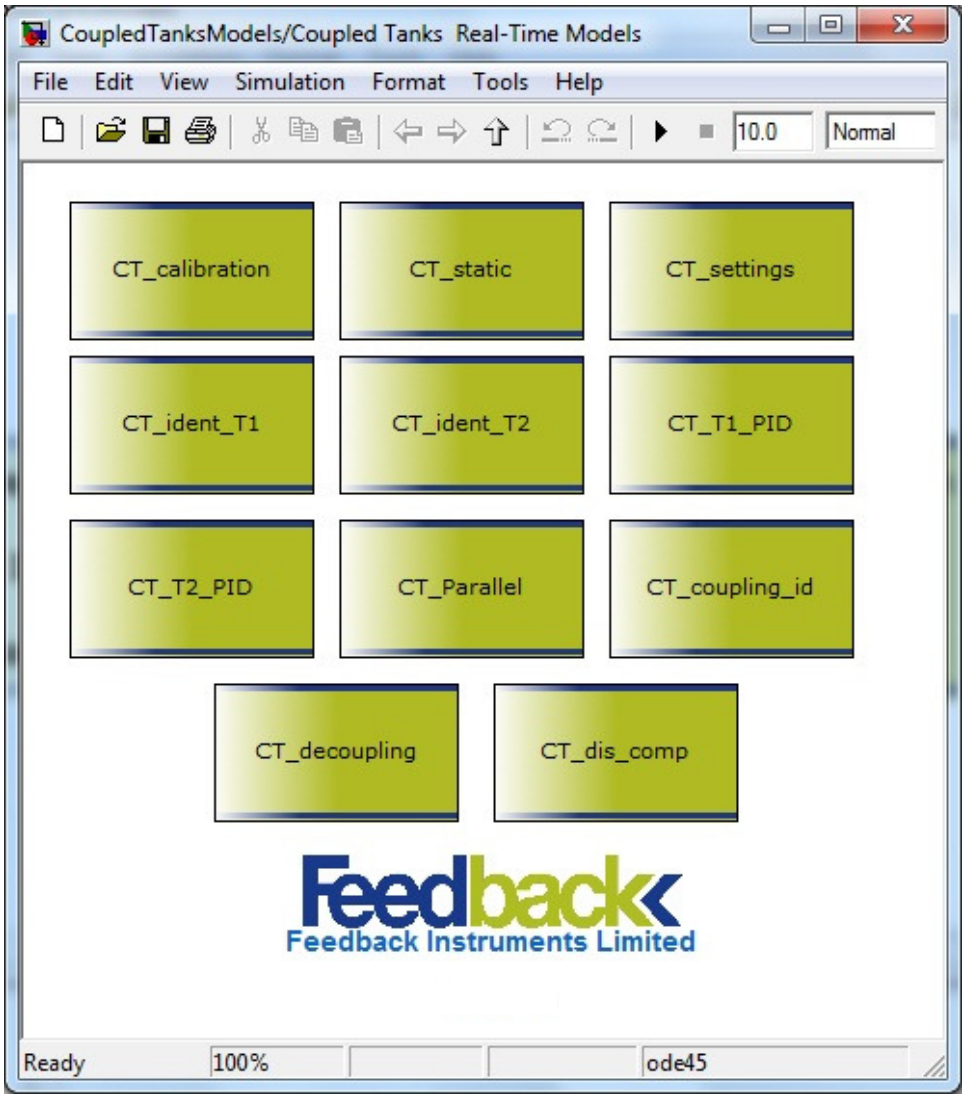

Figure 29 Real-time models menu

Double click the required model, for example *CT_callibration*. The Simulink model window will open Figure 30.

Sensor calibration

Each sensor has to be calibrated before any experiments are run. The calibration should be done periodically to ensure agreement between the real data and the

measured signal. With time passing the water might change its density, which might influence the level reading.

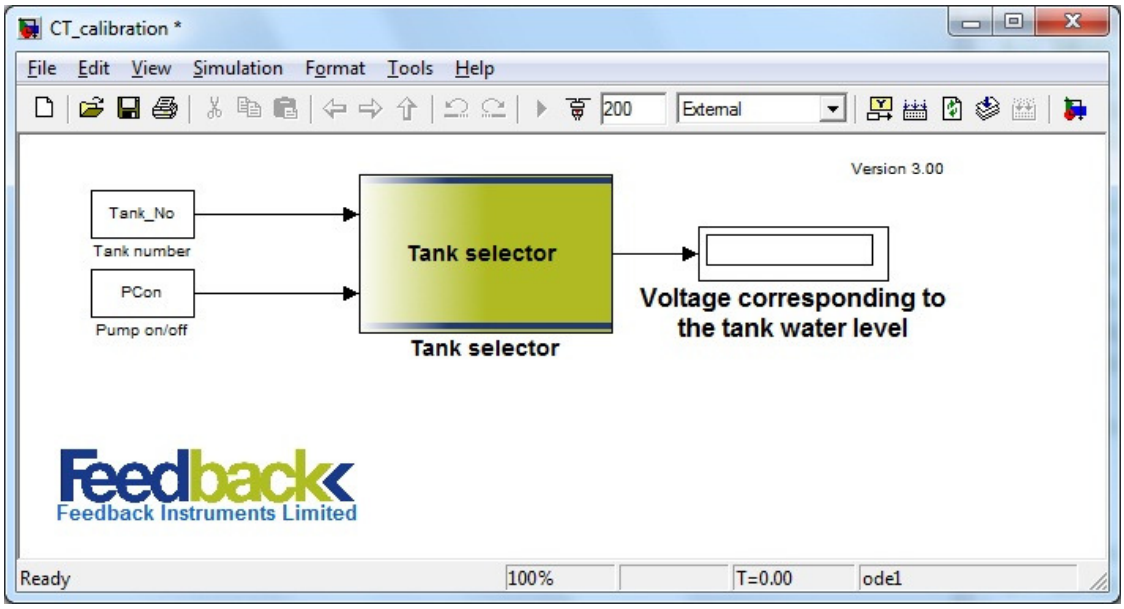

Figure 30 Coupled Tanks calibration window

Follow the instructions below to calibrate the sensors. The sequence has to be repeated for each sensor and tank.

1. Shut the outflow valves of the tank, in which you are going to perform calibration.

2. Open the proper pump output valve (valve **MVB** for tank T1 calibration, valve **MVA** for tank T2 calibration, valve **MVE** for tank T3 calibration, valve **MVD** for tank T4 calibration). Keep the other valves closed, so the water flows directly to the tank, which is being calibrated.

3. Empty the calibrated tank. Place a blocking plastic cap on the outflow pipe so the water cannot run out.

4. Run the *CT_calib.m* file. Follow the given instructions to perform calibration on all of the tanks. The files containing the calibration constants will be saved in the Real-Time models directory.

THE CALIBRATION HAS TO BE PERFORMED BEFORE ANY EXERCISES ARE RUN. CALIBRATION CONSTANTS WILL BE SAVED IN A FILE AND AUTOMATICALLY LOADED WHEN MODELS ARE RUN.

Coupled Tanks Mechanical Unit description

The Coupled Tanks Mechanical Unit consists of 4 tanks attached to the rig. At the bottom of the rig 5th tank is placed for water storage. Inside that tank 2 submersible pumps are placed. The water is pumped up to the top 2 tanks through the series of pipes and configuration valves named 'MV X' (X = {A,B,C,D,E,F,G}). From the top tanks the water flows freely to the 2 bottom tanks. The orifice size can be varied with 3 cap sizes available, which can be slid on the pipes coming from the bottom of the tanks. With the configuration valves it is possible to introduce coupling between the tanks. The water level can be read in each of the tanks using 4 pressure sensors.

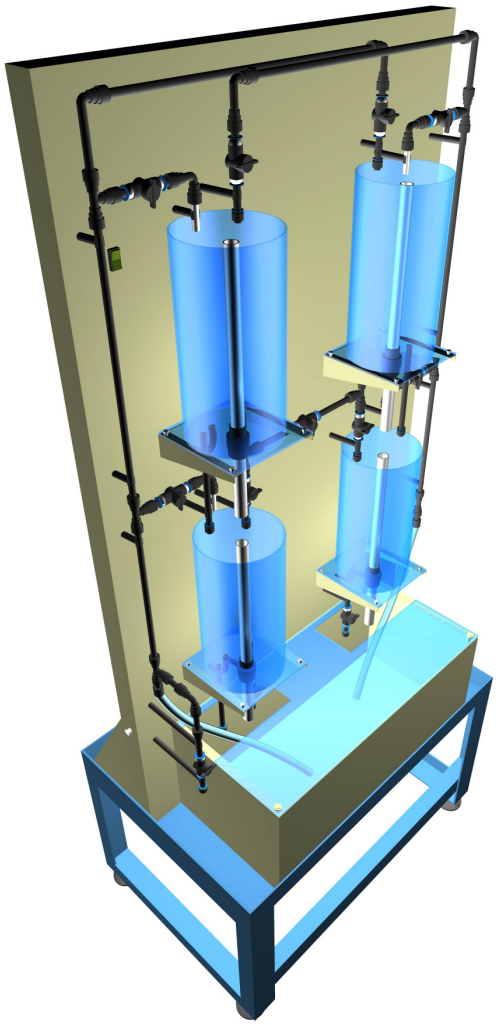

Figure 31 Coupled Tanks Mechanical Unit

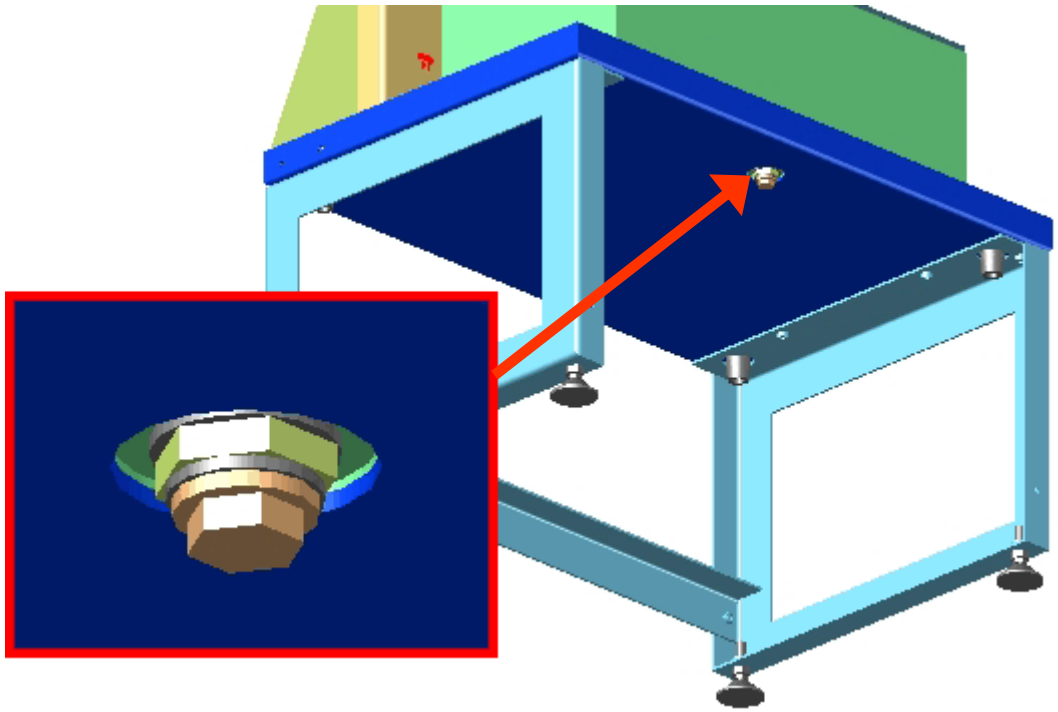

Figure 32 Main tank drain hole

A drain plug is provided at the base of the main tank as shown in Figure 32 which allows water to be fully drained from the system.

It is recommended that as much water as possible is first pumped out of the system via the drain pipe, as follows. The supplied PVC hose should be fitted to the open end of the drain pipe. The system is drained using the left-hand pump only. Valves MV A, MV B and MV C must be closed, the end cap must be removed from the drain pipe, and the drain shut-off valve must be open to allow drainage.

After pumping out as much water as possible, unscrew the nut on the underside of the main tank to empty the residual water from the system into a suitable container. Remember to replace the nut securely and close the drain shut-off valve before filling the system with water again.

WARNING: NEVER ATTEMPT TO TILT THE UNIT WHEN IT CONTAINS WATER.

The unit can be heavy when it contains water. Do not empty the tanks by tilting it. Attempting to do so could be hazardous.

Control system

The Coupled Tanks System is organized according to the schematic presented in Figure 33.

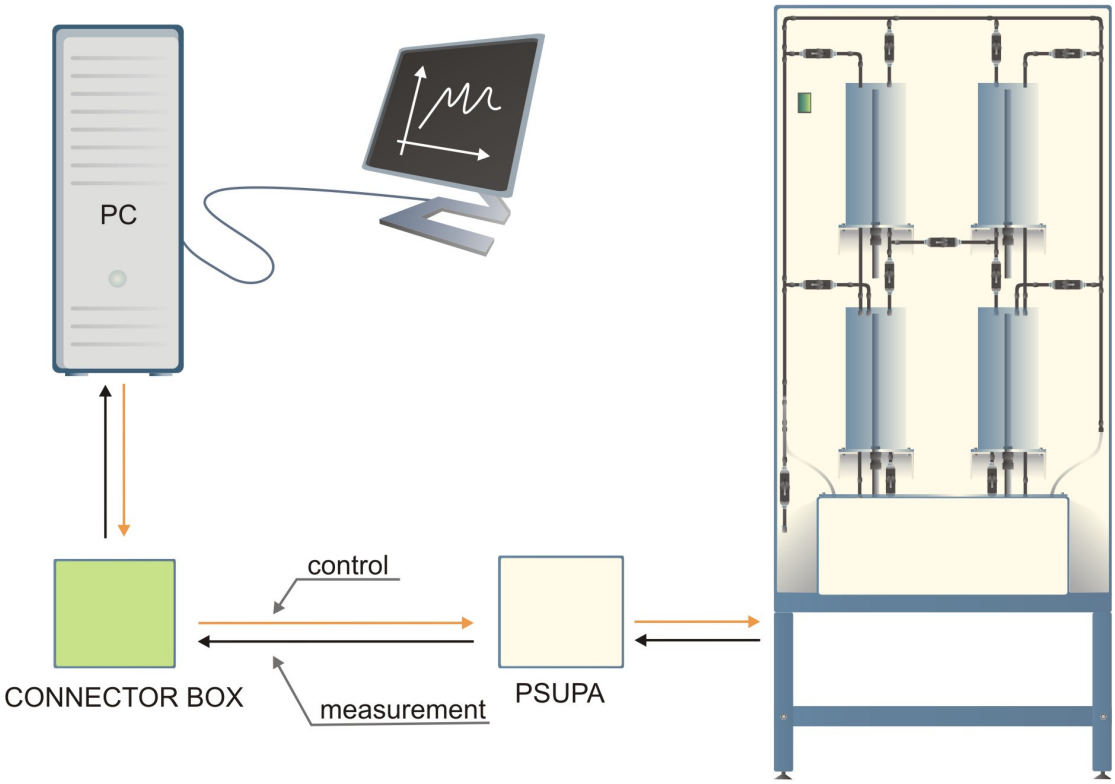

Figure 33 Control system schematic

The PC with Advantech card and Matlab and Simulink environment serve as the main control unit. The control signals, which are voltages between 0 V and 5 V, are transferred to the Power Amplifier where they are transformed into 24V dc signals driving the pumps.

The water level in the tanks is measured using pressure sensors. The water level information is transferred to the PC via the PSUPA. From the Simulink point of view the Coupled Tanks (single tank and pump) is seen as the following model presented in Figure 34.

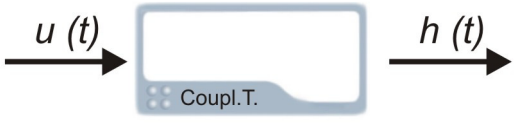

Figure 34 Coupled Tanks model

Computer control

Using MathWorks and Advantech software together simplifies the design of control systems for the Coupled Tanks unit. To design a controller you do not have to build a real-time application from the very beginning. It has been done for you. You can design arbitrary controllers in the Simulink environment and through the Real Time Kernel run them on an external process.

The digital control diagram presented in Figure 35 is used for that purpose.

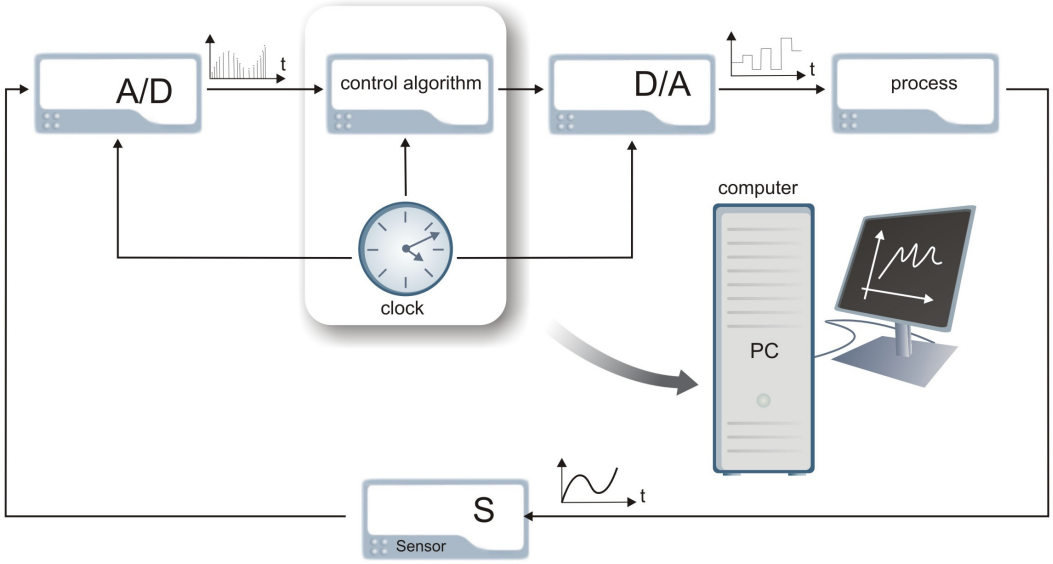

Figure 35 Computer control system diagram

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 an

interrupt service routine (ISR) is called. During the ISR routine an A/D converter delivers a discrete representation of the measurement returned by the sensor. Based on the measurement the control algorithm calculates the value of the control signal. At the end of the ISR the control signal 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 Coupled Tanks system.

Simulink Coupled Tanks control

After software installation two folders are created, which contain Simulink files. One of them contains files for simulation; the second folder contains files for real-time Coupled Tanks control.

The simulation only files can be used as normal Simulink experiments.

Real-time control

Real time control applications refer to an external source (external equipment). In Figure 36 an example position control application is presented.

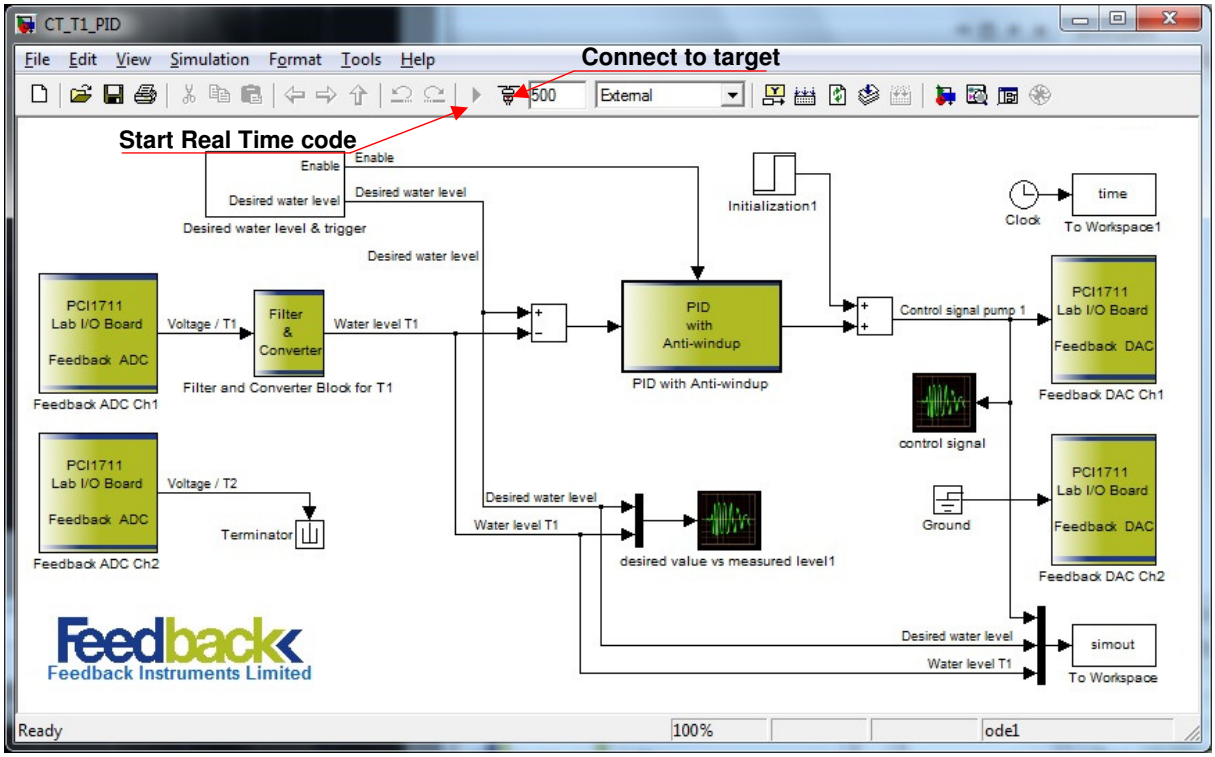

Figure 36 PID Tank1 water level control

The models can be run by navigating using either the Windows *start* menu:

Start menu → All Programs → Feedback Instruments → 33-041 Coupled Tanks Simulink Models

and category choice (Figure 37)

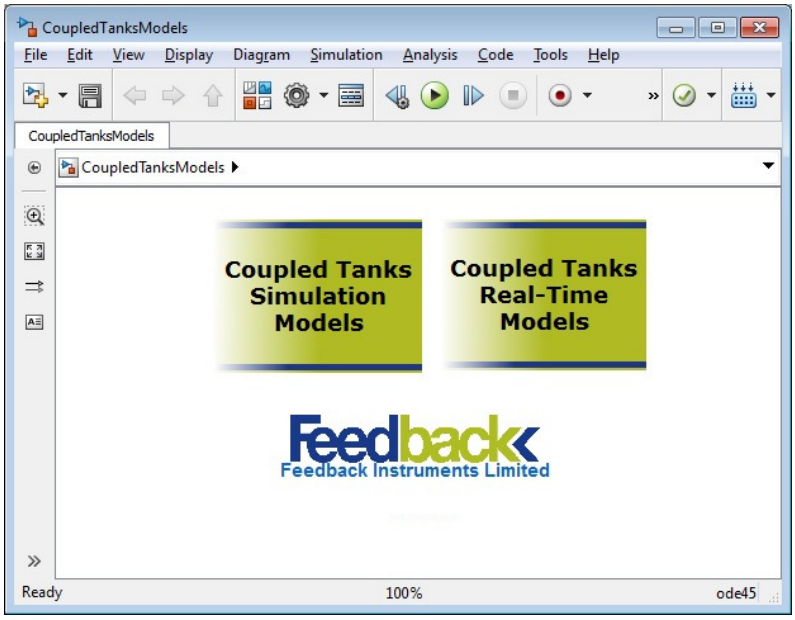

Figure 37 Model category window

or by loading Matlab then using the following path:

C:\ProgramData\Feedback Instruments\Coupled Tanks\Examples\Real-time models\

If you have two Matlab installations available, make sure that the Coupled Tanks software is installed for the Matlab that you want to use for Coupled Tanks. If it is the first time you are running real-time experiments on that version of Matlab type the:

rtwintgt -setup

command and execute it in Matlab.

When '*CT_T1_PID*' is selected the model presented in Figure 36 will open. 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 easier to use one of the existing applications and modifying it according to your needs 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 CT_T1_PID 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 38). Select yes.

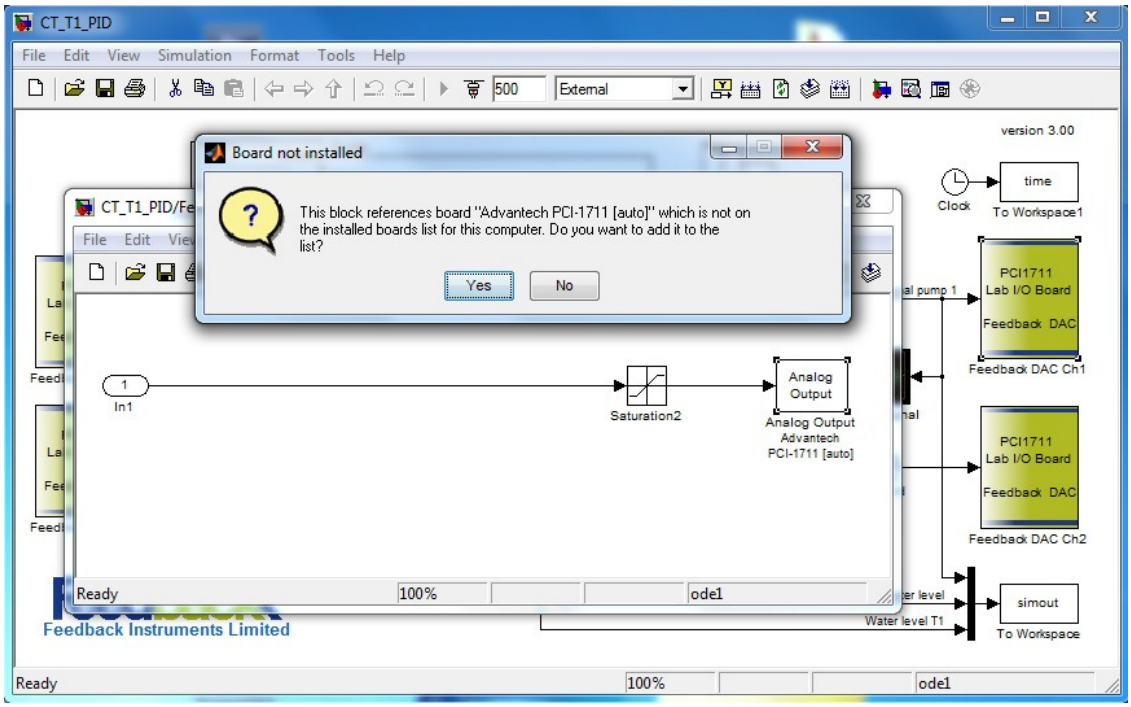

Figure 38 Adding an I/O Board to the Matlab Installed Boards List

The block parameter dialogue box for the PCI-1711 card will open. Cancel this dialogue then close the CT_T1_PID/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 33-041 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 CT_T1_PID model, select the *Tools* menu then *Real-Time Workshop* and *Build Model* (Figure 39).

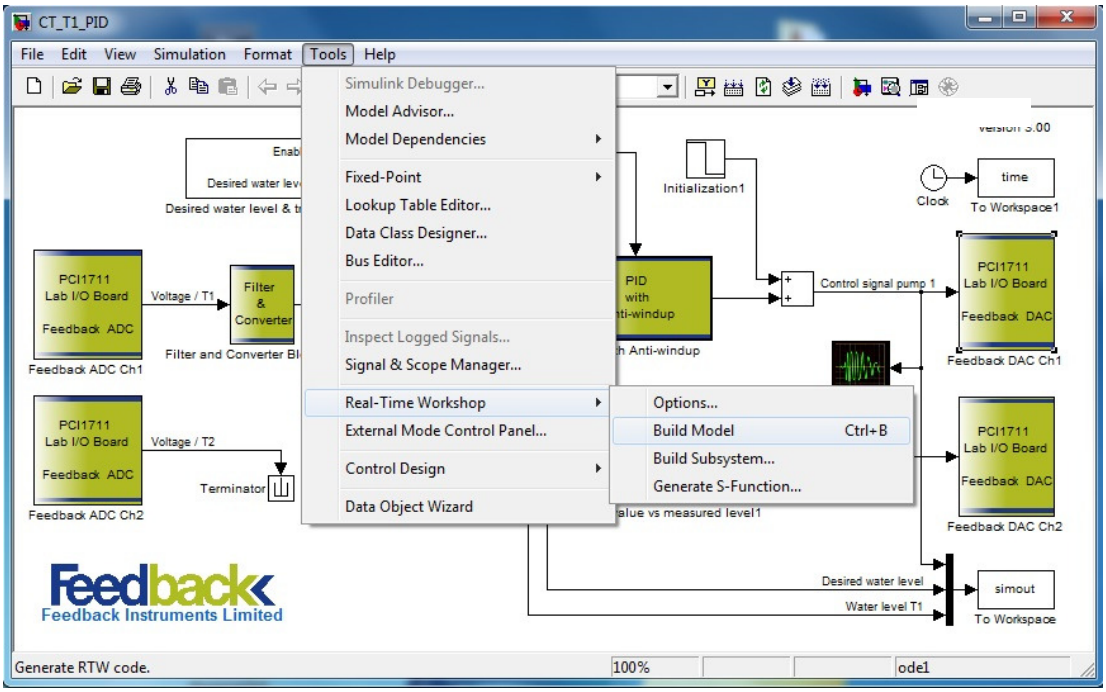

Figure 39 Building a model

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 CT_T1_PID application to test that the hardware and software has been installed correctly.

NOTE: The reservoir tank should be full with the pumps fully submersed in water. Make sure that the unit is calibrated and that static characteristic and working point is identified (see Control Experiments manual).

Connect the application with the PCI1711 card by pressing the CONNECT TO TARGET button. The application will not run yet. Now turn the Coupled Tanks power on.
You can start the application by pressing the START REAL TIME CODE button.

More information on '*CT_T1_PID.mdl*' is given in the '*Control Experiments*' manual.

New controllers design

It is best to start your own controller design by using the already made application and removing its content apart from two important blocks (Figure 40), which are the *'Feedback ADC block'* and the '*Feedback DAC block*' and Feedback logo block. This way all of the simulation parameters that are needed for the Real Time application will be set.

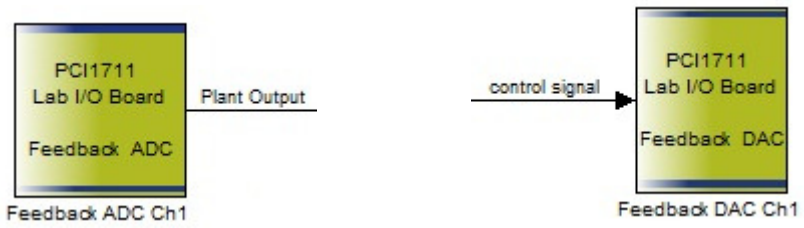

Figure 40 External equipment blocks

The '*Feedback ADC block'* has one output, which is the voltage corresponding to the water level in the tank. You do not need to modify these blocks. Modifications may cause serious problems with control applications. The '*Feedback DAC*' block has one input, which is the control voltage.
It is best if you start with existing control applications parameters' modifications or design very simple algorithms to get familiar with the Coupled Tanks setup.

PCI 1711 Lab I/O Block – Feedback DAC

- This is a universal Feedback block which sends the input value to *PCI-1711 analog output.*
- There is one input in this block and the block reads the value from this input and sends it to the analogue output of the PCI-1711 card (Figure 41).

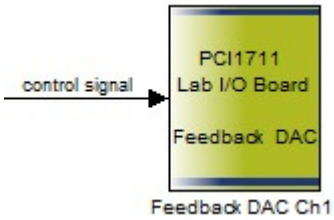

Figure 41 Feedback DAC Block – one input

- There are two parameters available: sample time and output channel. We can choose between 1 or 2 for output channels. This is because *PCI-1711 analog output* contains two channels.
- By double clicking on this block we can change the above parameters (Figure 42).

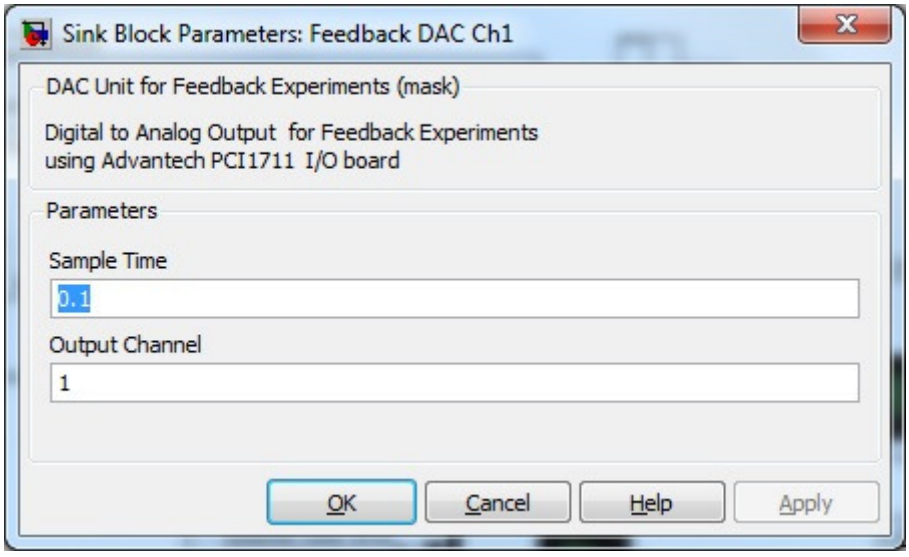

Figure 42 Feedback DAC Block – parameters

- The value, which is sent to the analogue output is the accepted range of 0V to 5V.
- Choose "*Look under Mask*" to view all of the subsystems (Figure 43). Before any experiments are run the PCI-1711 card has to be registered and set up. Double click on the Analog Output block and register the PCI-1711 card in Matlab environment (Figure 44).

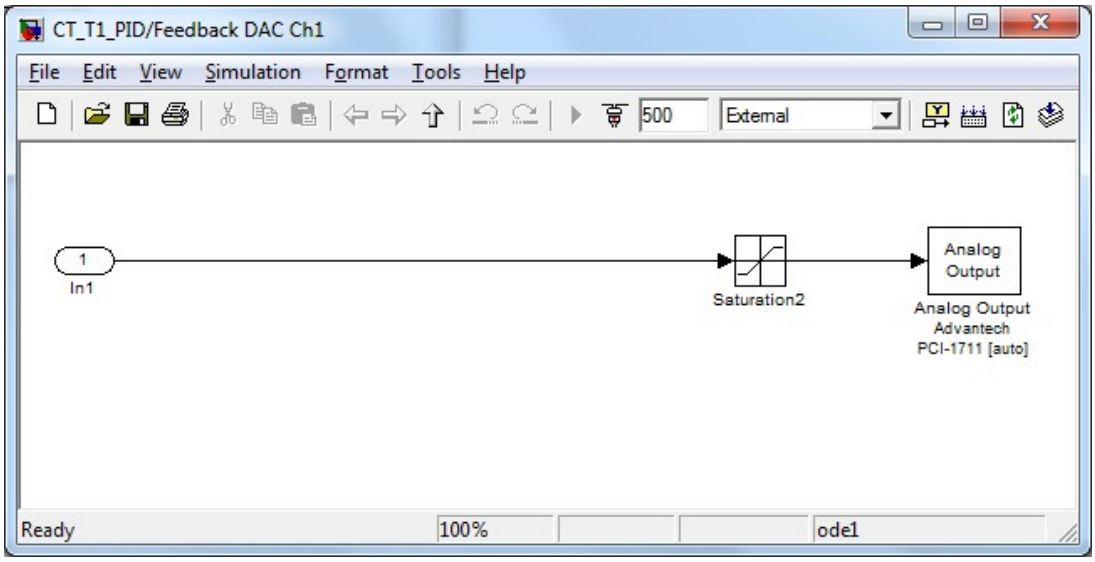

Figure 43 Feedback DAC Block –under mask

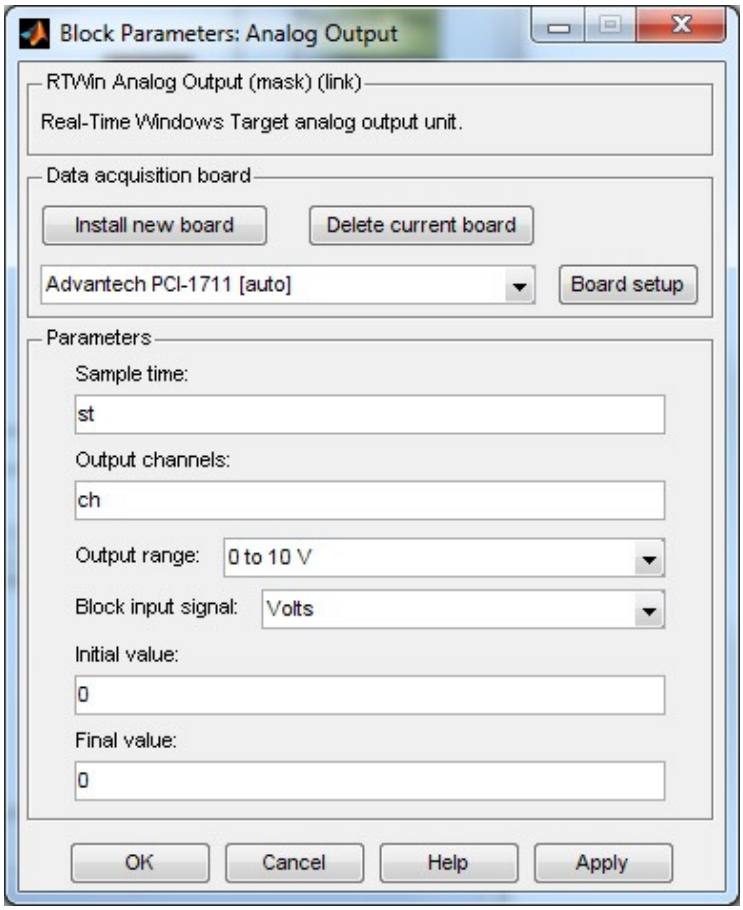

Figure 44 Feedback DAC Block – board setup