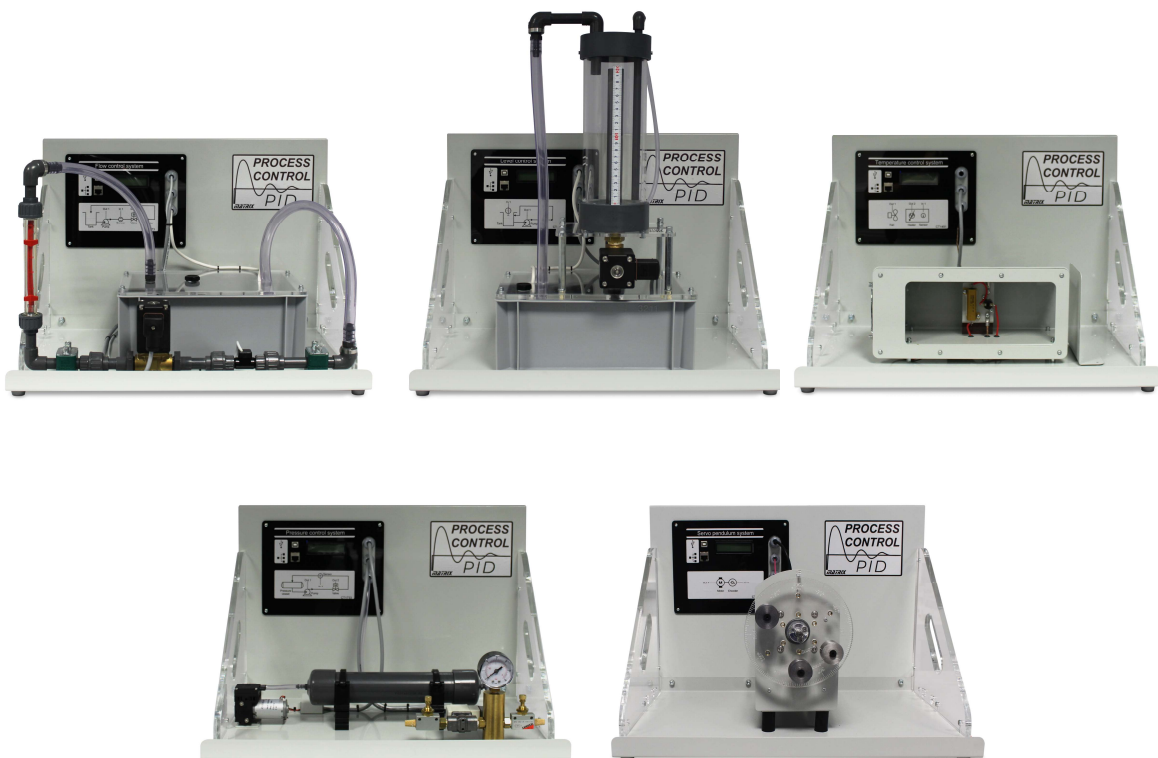




PROCESS CONTROL

PID

Process Control Reference Manual



CP5956

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Safety

During the design of these products we have paid considerable attention to the potential risks of studying process control. We believe that we have come up with the safest possible design. However there are still some risks that you need to be aware of. This page shows how we have considered each danger. You need to read this and make sure that your students are protected whilst using the equipment.

Electric shock

This is minimal: the output from the power supply is 24VDC. There are no electrical outputs on the unit.

Ensure that the equipment is sited away from the mains outlet or other mains equipment especially when filling it with water.

Do not operate mains devices with wet hands.

Physical shock

The equipment is heavy. As with other heavy lab. equipment, if a student drops a device on his foot, it could cause considerable damage. You need to decide on the level of responsibility that students take here.

You can reduce risk by having a technician lay the equipment out on benches and ensuring that students are seated at desks whilst using the equipment.

Ensure that the equipment is suitable sited so that it is stable and cannot be accidentally caused to fall.

Any spills of water either on the equipment, the work surface or the floor should be mopped up immediately to prevent damage,

slips or falls.

Please ensure that students are adequately supervised at all times.

Please:

Should an accident happen while the equipment is being used, please report it to us, at the address below, so that we can consider how to make the equipment even safer.

Design team

Matrix TSL

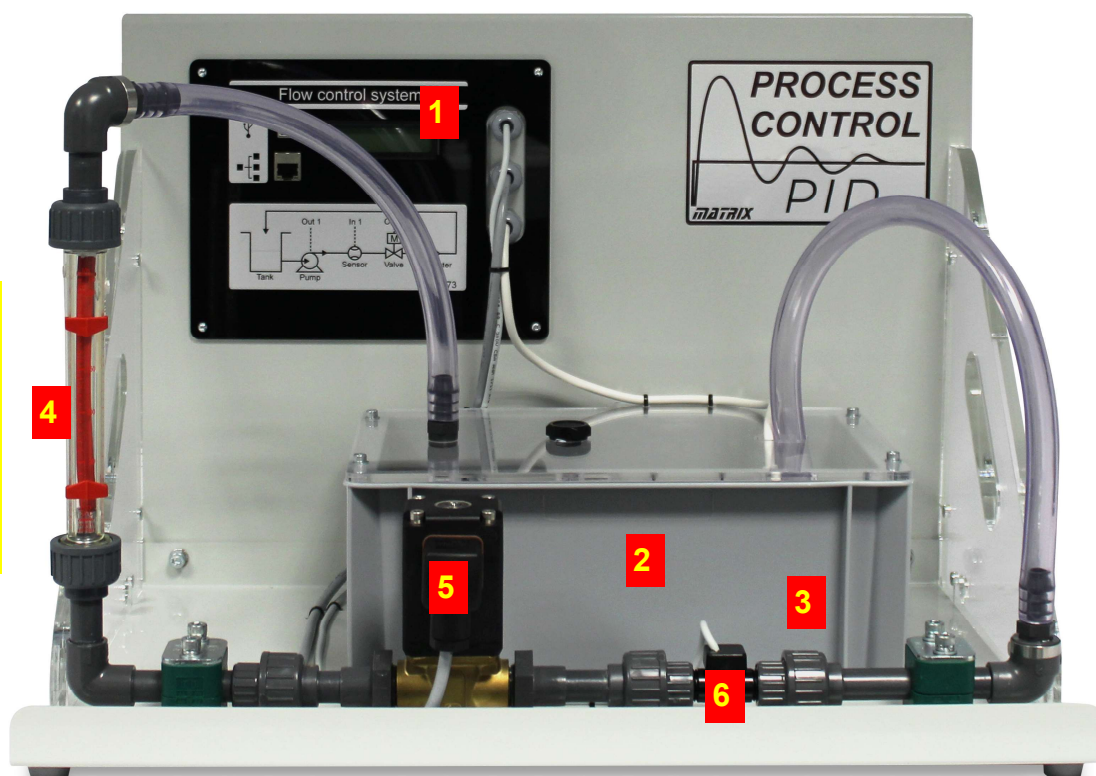
33 Gibbet Street

HX1 5BA

England

Flow control apparatus

Process Control Reference Manual



**Remove
Rotameter
shipping plug
before using**

About the unit

The photograph above shows the Flow Control apparatus. The numbered items are:

- 1) Controller circuit board .
- 2) Reservoir
- 3) Submerged pump
- 4) Rotameter flow gauge - shows shipping plug in place
- 5) Proportional valve
- 6) Flow sensor

Instructions for use

- 1) Site the equipment on a suitable bench, the water will be contained within the equipment during normal use, but the surface should be able to resist spills of water when the equipment is filled or drained. You should decide the final position of the equipment before filling it with water to avoid splashes and spills due to it being moved. A

suitable mains outlet should be within easy reach but should not be able to be splashed with water when the unit is filled with water or drained.

- 2) The flow control unit is shipped fully assembled, however the rotameter has been removed for shipping to prevent damage. Fit it as shown above ensuring that the O rings are in place and that the unions are finger tight. **Do not use tools on the unions**, finger tight is enough.
- 3) Note that for shipping the Rotameter may have a red plastic insert to stop the eight moving during transport. This should be removed.
- 4) The unit should be filled with clean mineral free fresh water (preferably de-ionised water), do not allow any debris to be present in the water. NB the use of dirty, mineralised or

Flow control apparatus

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otherwise poor quality water may cause damage to the transducers and in the long term will impair the appearance of the clear parts of the equipment.

- 5) Remove the filler plug from the reservoir lid and fill the reservoir to around 50mm from the top. You cannot do any damage by over filling the reservoir, but over filling increases the chances of splashes and spills.
- 6) To prevent the potential of growth of algae in the water the unit is supplied with barley straw extract. This is a completely natural non-toxic environmentally friendly additive. Pour half a capful into the reservoir. **Do not use any other additives, they may harm the equipment function or material finishes**
- 7) Referring to the outlets in the lab fit the appropriate mains plug adaptor to the power supply.
- 8) Connect the power supply low voltage plug to the socket on the side of the controller rear cover (on the right of the unit). Plug the unit into the mains supply with the switch in the "off" position.
- 9) Switch the mains plug on and the display on the unit should light up and confirm the unit has power.
- 10) Follow the instructions in the section on setting up the software application for the Flow control unit and getting the drivers on your computer.
- 11) You can use the unit with USB, Bluetooth or LAN connection. The details of how to set up each are included below. If this is the first time you have used the unit we recommend you start with USB and verify the functionality of the unit controller.

- 12) Open the 'Open_Flow_Manual.bat' app on your PC.
- 13) Using the controller app select manual control of both the proportional valve and the pump. Ensure that the pump setting is at zero and the valve is fully open (100%). Gradually increase the speed of the pump to maximum observing the flow of water back into the reservoir, leave the pump running for a few minutes to expel any trapped air in the system. Return the pump back to zero ready to begin experiments.
- 14) NB if the pump is heard to run, but no flow is observed, firstly make sure that the proportional valve is fully open. If after this no flow is observed, then there may be an "air lock" in the lower pipe. In this case reduce the pump setting to zero and place an absorbent cloth below the bottom union of the rotameter. Loosen the union to help the air escape, running the pump gradually increasing the speed. Once the flow is observed, the re-tighten the unit **finger tight only**. Mop up any splashes and spills.

Draining the equipment

If the unit will not be used for more than a month or more, or the water is seen to be dirty or contain debris then it is advisable to drain the unit of water. To do this:

- 1) Switch off the mains supply and disconnect the low voltage connector.
- 2) Remove the reservoir filler plug
- 3) Drain the majority of the water from the reservoir by inserting the drain tube into the self-sealing fitting at the bottom right corner of the reservoir.

Flow control apparatus

Process Control Reference Manual

- 4) Transfer the unit to a sink or draining board, and tilt it up at the left hand end to remove as much water as possible.
- 5) Place an absorbent cloth and the two unions and shown and loosen them to drain the water from the lower pipe section. Ensure the unions are re-tightened (**finger tight only**)
- 6) If desired the base of the reservoir can then be dried with a lint free cloth by firstly removing the reservoir lid. This can be removed by removing the four securing screws, washers and nuts. Carefully lift the lid avoiding straining any electrical cables or pipes.
- 7) Mop up any spills on the unit and work surfaces, replace the reservoir filler plug to avoid its loss.

Maintenance

Caution

All Maintenance should be completed by a competent person.

Spare and replacement parts may be obtained from Matrix TSL. When contacting Matrix TSL for spares or replacements then please give as much detail as you can, including, if possible, the serial number and date of purchase.

General

The flow control unit is designed to be maintenance free, however the following checks should take place:

Check the equipment for any signs of damage.

Replace any parts if required with an equivalent part of the same type and rating.

Check the tightness of fasteners and fittings

Clean the equipment using a damp clean cloth, do not use any other cleaning products as they may damage the equipment working parts, surfaces or finishes

If the unit is to be left for any length of time

Drain the unit as described above.

Store it a dry dust free environment, either in a cupboard or covered over.

Power supply

The power supply contains no serviceable parts. If for any reason it gets broken or fails to operate the unit then **do not attempt to repair it**. Contact Matrix TSL for a replacement.

Fusing

The Controller has an onboard resettable Fuse that is not user serviceable. Should it fail and reset continuously then seek the advice of a qualified engineer, or preferably contact Matrix TSL .

Testing your Flow control apparatus

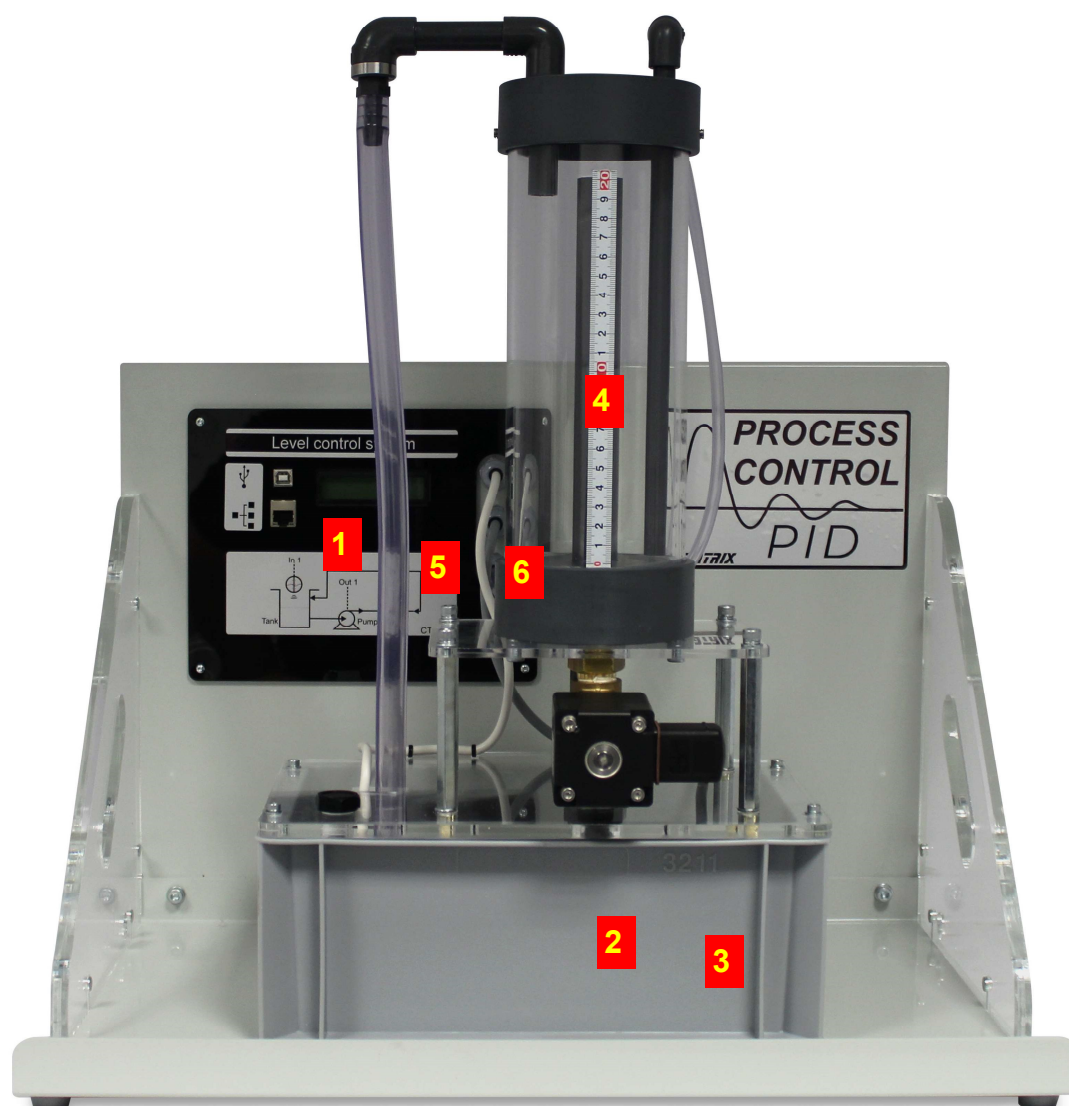
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- 1) Make sure there is enough water in the tank
- 2) Load the App 'Open Manual Control.BAT'
- 3) Under Properties...Application select Flow
- 4) Under Input scaler on Properties enter 0.52
- 5) Under Input calibration on Properties enter 0.9. This is an approximation to calibration and you will calculate this in more detail in the worksheets.
- 6) Press Go at top left of App
- 7) Set Load to 100% - this is the valve fully open.
- 8) Set drive to 80%
- 9) Click RUN. The pump should activate and water fill flow round the system. The LCD screen will show the number of litres per hour flowing.
- 10) Check that the rotameter and the flow reading on the screen are the same. If not repeat the step above. The unit is now calibrated.
- 11) Push the LOAD up to 100% and verify the valve is connected properly. 0% is closed, 100% is open.
- 12) Push the DRIVE up to 100% and check that the flow works. Try several values of flow. Try several values of valve.
- 13) Quit

- 1) Load 'Open PID Control.bat'
- 2) Under Properties...Application select Flow
- 3) Enter the following values under Properties:
 - Set Control frequency to 500
 - Set Input scaler to 0.52
 - Set Input calibration to 0.9.
 - Set output scaler to 0.4
 - Set the Kp setting to 2.4
 - Set the Ki setting to 0 .056
 - Set the Kd setting to 25.5
- 4) Go
- 5) Open the Load Valve to 100%
- 6) Set a Flow rate of 200 litres per hour
- 7) RUN
- 8) Choose several values for the Drive and the Load and make sure your system is now exhibiting PID characteristics.
- 9) You can improve the accuracy of your system by working through the worksheets to get more exact values.

Level control apparatus

Process Control Reference Manual



About the unit

The photograph above shows the Level Control apparatus. The numbered items are:

- 1) Controller circuit board .
- 2) Reservoir
- 3) Submerged pump
- 4) Level gauge
- 5) Proportional valve
- 6) Level sensor

Instructions for use

- 1) Site the equipment on a suitable bench, the water will be contained within the equip-

ment during normal use, but the surface should be able to resist spills of water when the equipment is filled or drained. You should decide the final position of the equipment before filling it with water to avoid splashes and spills due to it being moved. A suitable mains outlet should be within easy reach but should not be able to be splashed with water when the unit is filled with water or drained.

- 2) The level control unit is shipped partially assembled. You will need to reassemble the

Level control apparatus

Process Control Reference Manual

main level chamber. See separate instructions below. Fit it as shown above ensuring that the O rings are in place and that the unions are finger tight. **Do not use tools on the unions**, finger tight is enough.

- 3) The unit should be filled with clean mineral free fresh water (preferably de-ionised water), do not allow any debris to be present in the water. NB the use of dirty, mineralised or otherwise poor quality water may cause damage to the transducers and in the long term will impair the appearance of the clear parts of the equipment.
- 4) Remove the filler plug from the reservoir lid and fill the reservoir to around 50mm from the top. You cannot do any damage by over filling the reservoir, but over filling increases the chances of splashes and spills.
- 5) To prevent the potential of growth of algae in the water the unit is supplied with barley straw extract. This is a completely natural non-toxic environmentally friendly additive. Pour half a capful into the reservoir. **Do not use any other additives, they may harm the equipment function or material finishes**
- 6) Referring to the outlets in the lab fit the appropriate mains plug adaptor to the power supply.
- 7) Connect the power supply low voltage plug to the socket on the side of the controller rear cover (on the right of the unit). Plug the unit into the mains supply with the switch in the "off" position.
- 8) Switch the mains plug on and the display on the unit should light up and confirm the unit has power.
- 9) Follow the instructions in the section on

setting up the software application for the Flow control unit and getting the drivers on your computer.

- 10) You can use the unit with USB, Bluetooth or LAN connection. The details of how to set up each are included below. If this is the first time you have used the unit we recommend you start with USB and verify the functionality of the unit controller.
- 11) Open the 'Open ManualControl.bat' app on your PC.
- 12) Using the controller app select manual control of both the proportional valve and the pump. Ensure that the pump setting is at zero and the valve is fully open (100%). Gradually increase the speed of the pump to maximum observing the flow of water back into the reservoir, leave the pump running for a few minutes to expel any trapped air in the system. Return the pump back to zero ready to begin experiments.
- 13) NB if the pump is heard to run, but no flow is observed, firstly make sure that the proportional valve is fully open. If after this no flow is observed, then there may be an "air lock" in the lower pipe. In this case reduce the pump setting to zero and place an absorbent cloth below the bottom union of the rotameter. Loosen the union to help the air escape, running the pump gradually increasing the speed. Once the flow is observed, the re-tighten the unit **finger tight only**. Mop up any splashes and spills.

Draining the equipment

If the unit will not be used for more than a month or more, or the water is seen to be dirty

Level control apparatus

Process Control Reference Manual

or contain debris then it is advisable to drain the unit of water. To do this:

- 1) Switch off the mains supply and disconnect the low voltage connector.
- 2) Remove the reservoir filler plug
- 3) Drain the majority of the water from the reservoir by inserting the drain tube into the self-sealing fitting at the bottom right corner of the reservoir.
- 4) Transfer the unit to a sink or draining board, and tilt it up at the left hand end to remove as much water as possible.
- 5) Place an absorbent cloth and the two unions and shown and loosen them to drain the water from the lower pipe section. Ensure the unions are re-tightened (**finger tight only**)
- 6) If desired the base of the reservoir can then be dried with a lint free cloth by firstly removing the reservoir lid. This can be removed by removing the four securing screws, washers and nuts. Carefully lift the lid avoiding straining any electrical cables or pipes.
- 7) Mop up any spills on the unit and work surfaces, replace the reservoir filler plug to avoid its loss.

Maintenance

Caution

All Maintenance should be completed by a competent person.

Spare and replacement parts may be obtained from Matrix TSL. When contacting Matrix TSL for spares or replacements then please give as much detail as you can, including, if possible, the serial number and date of purchase.

General

The flow control unit is designed to be maintenance free, however the following checks

should take place:

Check the equipment for any signs of damage.

Replace any parts if required with an equivalent part of the same type and rating.

Check the tightness of fasteners and fittings

Clean the equipment using a damp clean cloth, do not use any other cleaning products as they may damage the equipment working parts, surfaces or finishes

If the unit is to be left for any length of time

Drain the unit as described above.

Store it a dry dust free environment, either in a cupboard or covered over.

Power supply

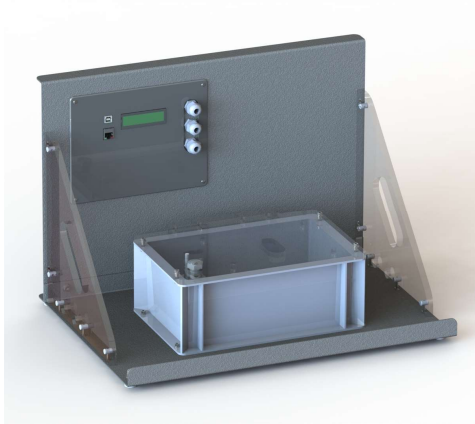
The power supply contains no serviceable parts. If for any reason it gets broken or fails to operate the unit then **do not attempt to repair it**. Contact Matrix TSL for a replacement.

Fusing

The Controller has an onboard resettable Fuse that is not user serviceable. Should it fail and reset continuously then seek the advice of a qualified engineer, or preferably contact Matrix TSL .

Level control apparatus Assembly

Process Control Reference Manual



Base tank



Level tank

On the right you can see the 2 modules that will require assembling. The level tank will be laid on top of the base tank with the wires connected. They are loose and have enough slack for the level tank to be moved around.

- 1) Step 1: insert the long M6 hexagonal spacers into the m6 threaded inserts in the tank lid. Make sure that you use a standard washer between the spacer and the clear plastic of the base tank lid.
- 2) Step 2: position the level tank above the base tank and use four M6 bolts with both a conventional washer and spring washer. Do not over tighten or the plastic will crack.
- 3) Step 3: Using the two cable ties provided gather the wires and pipes to that they are tidy.



Step 1



Step 2

Testing your Level control apparatus

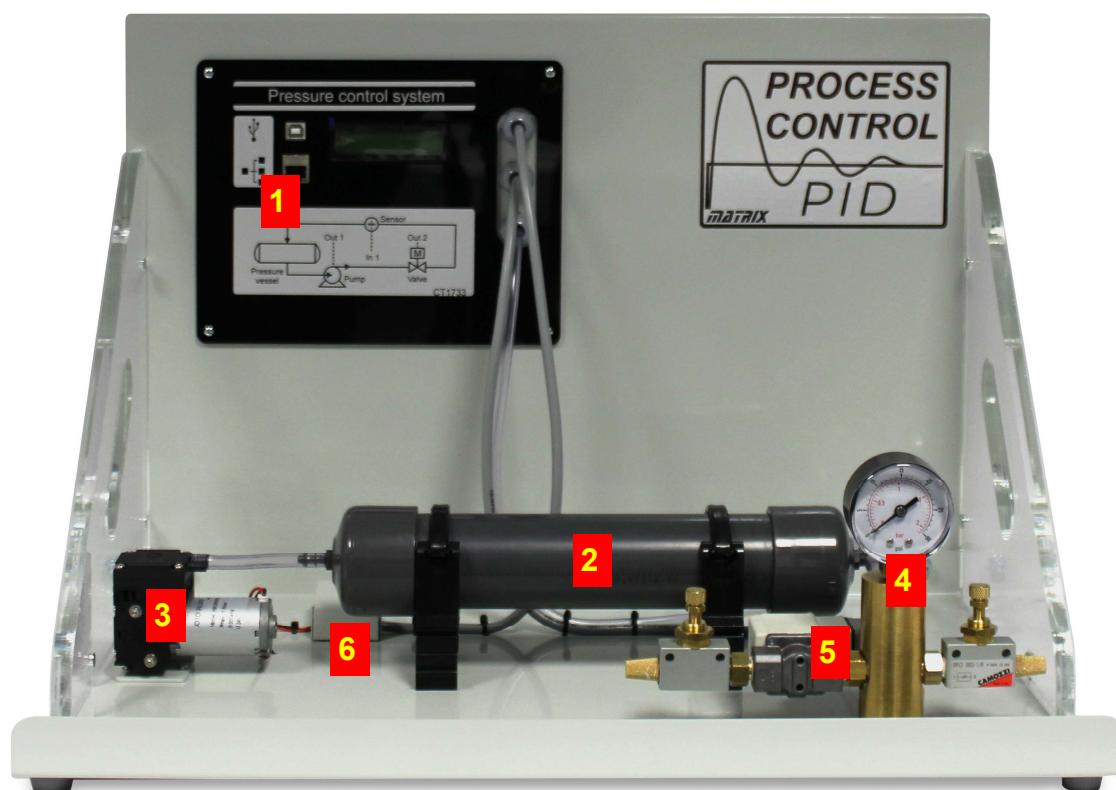
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- 1) Make sure there is enough water in the tank
- 2) Load the App 'Open Manual Control.BAT'
- 3) Under Properties...Application select Level
- 4) Enter the following values under Properties:
 - Set Input scaler to 0.001
 - Set input calibration to 0.5
- 1) Press Go at top left of App
- 2) Set Load to 0% - this is the valve fully closed.
- 3) Set drive to 80%
- 4) Click RUN. The pump should activate and water will flow into the tube. The LCD screen will show the water level and drive percentages of the motor and the valve.
- 5) Push the LOAD up to 100% and verify the valve opens. 0% is closed, 100% is open.
- 6) Push the DRIVE up to 100% and check that the pump works. Try several values of Drive and Load.
- 7) The reading on the display and in the software will not be accurate. You will learn how to calibrate the equipment in the worksheets.
- 8) Quit

- 1) Load 'Open PID Control.bat'
- 2) Under Properties...Application select Level
- 3) Enter the following values under Properties:
 - Set Control frequency to 20
 - Set Input scaler to 0.001
 - Set Input calibration to 0.5
 - Set output scaler to 1
 - Set the Kp setting to 18
 - Set the Ki setting to 2
 - Set the Kd setting to 40
- 4) Go
- 5) Open the Load Valve to 100%
- 6) Set a Drive level of 100mm
- 7) RUN
- 8) Choose several values for the Drive and the Load and make sure your system is now exhibiting PID characteristics.
- 9) You can improve the accuracy of your system by working through the worksheets to get more exact values.

Pressure control apparatus

Process Control Reference Manual



About the unit

The photograph above shows the Flow Control apparatus. The numbered items are:

- 1) Controller circuit board .
- 2) Air reservoir
- 3) Pump
- 4) Pressure gauge
- 5) Proportional valve
- 6) Pressure sensor

Instructions for use

- 1) Site the equipment on a suitable bench.
- 2) The Pressure control unit is shipped fully assembled and is ready to use 'out of the box'.
- 3) Referring to the outlets in the lab fit the appropriate mains plug adaptor to the power supply.
- 4) Connect the power supply low voltage plug to the socket on the side of the controller rear cover (on the right of the unit). Plug the

unit into the mains supply with the switch in the "off" position.

- 5) Switch the mains plug on and the display on the unit should light up and confirm the unit has power.
- 6) Follow the instructions in the section on setting up the software application for the unit and getting the drivers on your computer.
- 7) You can use the unit with USB, Bluetooth or LAN connection. The details of how to set up each are included below. If this is the first time you have used the unit we recommend you start with USB and verify the functionality of the unit controller.
- 8) Open the 'Open ManualControl.bat' app on your PC.
- 9) Using the controller app select manual control of both the proportional valve and the

Pressure control apparatus

Process Control Reference Manual

pump. Ensure that the pump setting is at zero and the valve is fully open (100%).

- 10) NB if the pump is heard to run, but no flow is observed, firstly make sure that the proportional valve is fully open.

Zeroing the apparatus.

Before using the apparatus you may need to zero the unit. To do this:

- 1) Load the 'Open ManualControl.bat' file, Run the program, Open the valve until pressure equalises with atmospheric pressure and adjust the valve for maximum loss.
- 2) Click on the Zero button on the screen.

Testing your Pressure control apparatus

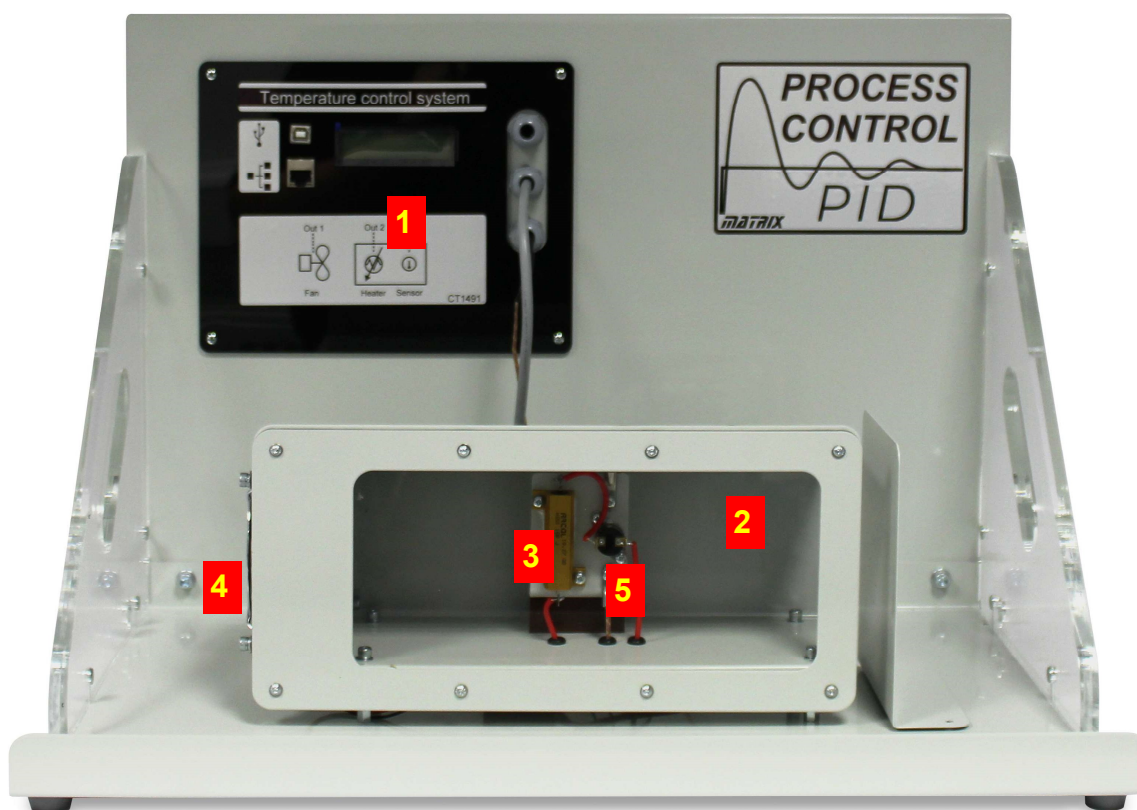
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- 1) Load the App 'Open Manual Control.BAT'
- 2) Under Properties...Application select Pressure
- 3) Enter the following values under Properties:
 - Set Input scaler to 0.001
 - Set input calibration to 0.006
- 1) Screw in the two leakage valves fully and then unscrew one turn.
- 2) Press Go at top left of App
- 3) Click RUN. The pump should activate and air will flow into the cylinder. The LCD screen will show the pressure and drive percentages of the motor and the valve.
- 4) Under LOAD close the valve.
- 5) Push the DRIVE up to 50% and verify the pressure increases.
- 6) Open the valve and try several different values of DRIVE.
- 7) The reading on the display and in the software will not be accurate. You will learn how to calibrate the equipment in the worksheets.
- 8) Quit

- 1) Load 'Open PID Control.bat'
- 2) Under Properties...Application select Pressure
- 3) Enter the following values under Properties:
 - Set Control frequency to 5
 - Set Input scaler to 0.0005
 - Set Input calibration to 0.006
 - Set output scaler to 4.4
 - Set the Kp setting to 7.2
 - Set the Ki setting to 0.8
 - Set the Kd setting to 16.2
- 4) Go
- 5) Open the Load Valve to 100%
- 6) Set the DRIVE to 7psi
- 7) RUN
- 8) Choose several values for the Drive and the Load and make sure your system is now exhibiting PID characteristics.
- 9) You can improve the accuracy of your system by working through the worksheets to get more exact values.

Temperature control apparatus

Process Control Reference Manual



About the unit

The photograph above shows the Flow Control apparatus. The numbered items are:

- 1) Controller circuit board .
- 2) Temperature chamber
- 3) Resistive heat generator on heatsink
- 4) Fan
- 5) Temperature sensor

Instructions for use

- 1) Site the equipment on a suitable bench.
- 2) The Temperature control unit is shipped fully assembled and is ready to use 'out of the box'.
- 3) Referring to the outlets in the lab fit the appropriate mains plug adaptor to the power supply.
- 4) Connect the power supply low voltage plug to the socket on the side of the controller rear cover (on the right of the unit). Plug the

unit into the mains supply with the switch in the "off" position.

- 5) Switch the mains plug on and the display on the unit should light up and confirm the unit has power.
- 6) Follow the instructions in the section on setting up the software application for the unit and getting the drivers on your computer.
- 7) You can use the unit with USB, Bluetooth or LAN connection. The details of how to set up each are included below. If this is the first time you have used the unit we recommend you start with USB and verify the functionality of the unit controller.
- 8) Open the 'Open ManualControl.bat' app on your PC.
- 9) Ensure that the fan and heater are functioning properly.

Testing your Temp. control apparatus

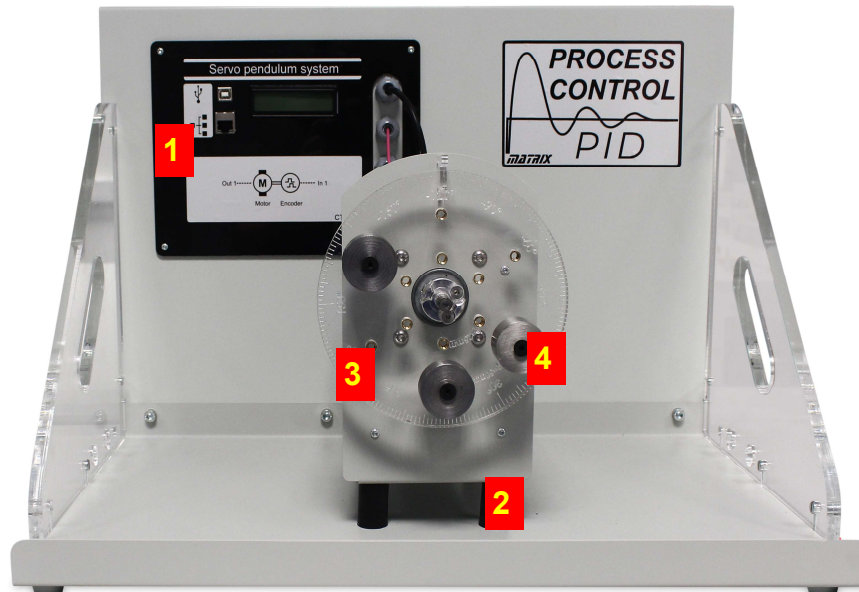
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- 1) Load the App 'Open Manual Control.BAT'
- 2) Under Properties...Application select Temperature
- 3) Enter the following values under Properties:
 - Set Input scaler to 1
 - Set input calibration to 1
- 1) Press Go at top left of App
- 2) Click RUN. The LCD screen will show the temperature and drive percentages of the heater and fan.
- 3) Push the DRIVE up to 100% and verify the temperature increases.
- 4) Try several values of LOAD. The fan should come on.
- 5) Try several combinations of DRIVE and LOAD. The temperature responds relatively slowly.
- 6) Quit

- 1) Load 'Open PID Control.bat'
- 2) Under Properties...Application select Pressure
- 3) Enter the following values under Properties:
 - Set Control frequency to 0.1
 - Set Input scaler to 1
 - Set Input calibration to 1
 - Set output scaler to 1
 - Set the Kp setting to 30
 - Set the Ki setting to 1.7
 - Set the Kd setting to 127
- 4) Go
- 5) Keep the LOAD fan at 0%
- 6) Set the DRIVE to 30C
- 7) RUN
- 8) Choose several values for the Drive and the Load and make sure your system is now exhibiting PID characteristics.
- 9) You can improve the accuracy of your system by working through the worksheets to get more exact values.

Servo pendulum apparatus

Process Control Reference Manual



About the unit

The photograph above shows the Servo pendulum apparatus. The numbered items are:

- 1) Controller circuit board .
- 2) Motor housing unit
- 3) Servo pendulum rotor
- 4) Weights on the rotor

Instructions for use

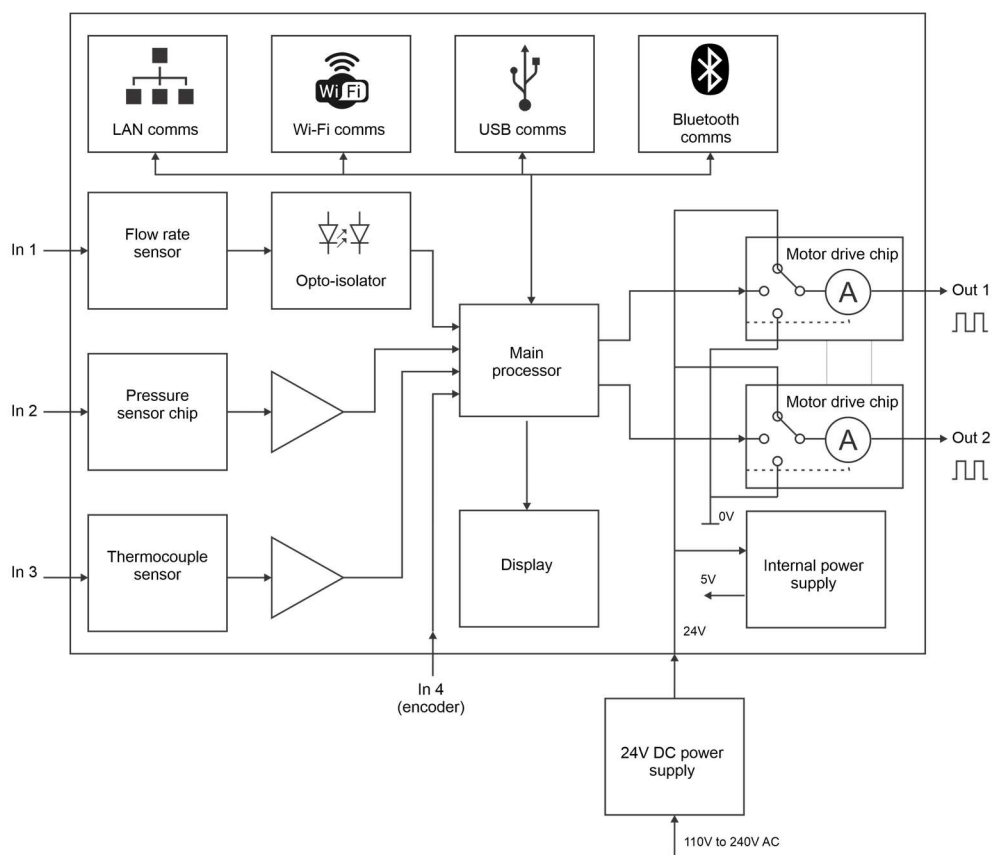
- 1) Site the equipment on a suitable bench.
- 2) The Servo pendulum control unit is shipped fully assembled and is ready to use 'out of the box'.
- 3) Referring to the outlets in the lab fit the appropriate mains plug adaptor to the power supply.
- 4) Connect the power supply low voltage plug to the socket on the side of the controller rear cover (on the right of the unit). Plug the unit into the mains supply with the switch in the "off" position.
- 5) Switch the mains plug on and the display on

the unit should light up and confirm the unit has power.

- 6) Follow the instructions in the section on setting up the software application for the unit and getting the drivers on your computer.
- 7) You can use the unit with USB, Bluetooth or LAN connection. The details of how to set up each are included below. If this is the first time you have used the unit we recommend you start with USB and verify the functionality of the unit controller.
- 8) Open the 'Open ManualControl.bat' app on your PC.
- 9) Use the drop down box on the properties to select 'Servo speed'.
- 10) Press the play button and select Run from the interface.
- 11) Increase the motor drive and make sure that the rotor turns.

Control unit description

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Referring to the block schematic above:

This control board is used for all Matrix Process Control units:

- Temperature
- Flow control
- Pressure
- Level
- Servo pendulum

The unit is powered from an external 'plug top' power supply which delivers 24V at 2.5 amps. This is supplied with adaptors for US, Europe, UK and Australia and is 110 - 240VAC compatible.

Internally to the unit a small 5V regulator converts the 24V into 5V and 3.3V for all devices and modules on the board.

The unit is powered by a fast dsPIC type processor. This connects via an internal serial bus to communications chips, modules and connectors for Local Area Networks, Wi-Fi, USB

and Bluetooth. Instructions on setting up communications for each protocol are given below. The LAN connection allows the unit to be accessed by students when they are not physically attending their institution when used with a Flowcode App Developer program.

There are four inputs to the main processor board which measure the quantities from sensors in each of the Process Control rigs.

- 1) The sensor input is a digital electronic input. It feeds into an opto-isolator which ensures safety, and hence into the main processor. For the Flow and Level rigs this input is used to measure the flow input from the Flow rate sensor.
- 2) The main board contains a pressure sensor module which converts air pressure into an electronic signal. It requires that a plastic tube is passed through the control panel front plate and is plugged into a nipple on

Control unit description

Process Control Reference Manual

the sensor module on the bottom of the controller printed circuit board. The signal from the module is conditioned by an analogue electronics circuit to provide the main processor with an optimised input for pressure sensing.

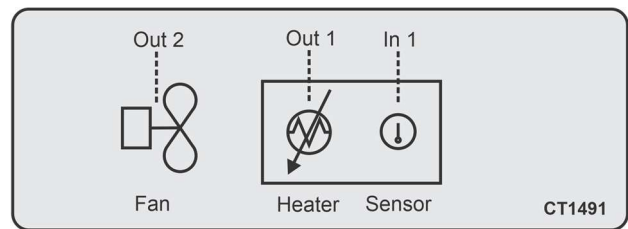
- 3) The thermocouple sensor is an analogue electronic input which is used for the temperature control rig. A sensor chip on the circuit board, and an analogue electronic circuit, converts the thermocouple input to a signal the main processor can read.
- 4) On the servo pendulum the encoder output is fed directly into the processor.

There are two outputs from the main processor that are passed into powerful FET power output devices. These supply 24V at up to 2A and both are fully short circuit protected. The main processor uses Pulse Width Modulation to provide variable output power from 0 % to 100% in 1024 separate steps. This gives great control over the power being delivered.

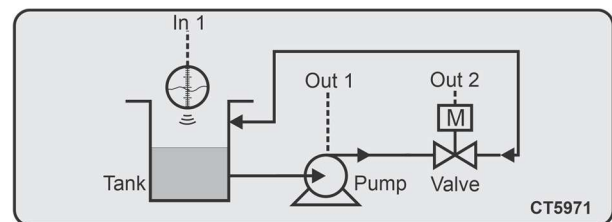
A 2 line 16 character liquid crystal display is used to provide basic indicators to the user of the Set point and feedback in the control program. None of the electronics signals are available to the user for examination by oscilloscope or multimeter - the software has been written in such a way that all necessary instrumentation values are available to the user on screen.

Connections of Process Control units

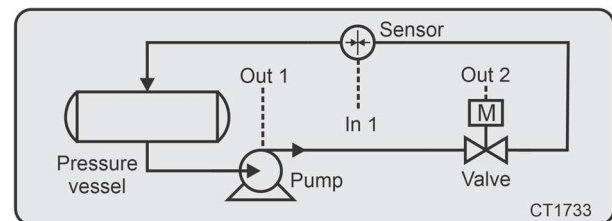
The images opposite show the connections of the controller and the system diagrams of the four rigs.



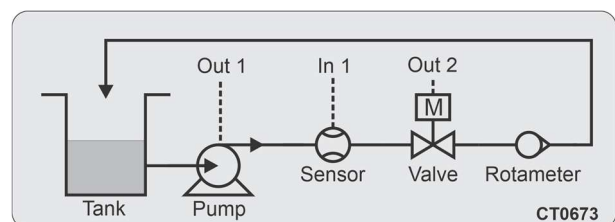
Temperature



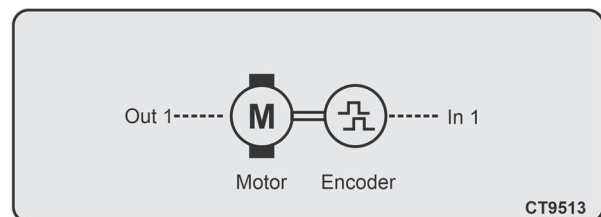
Level



Pressure



Flow



Servo pendulum

Sensors and their operation

Process Control Reference Manual

Flow rate

Sensor: FT110

Sensor scale factor

The flow rate is determined by the frequency of the pulses from the sensor. The manufacturer's datasheet states that there are 6900 pulses per litre for the flow meter we are using. The control system needs a conversion of frequency to litres per hour. This is $(F/6900) \times 3600$ or 0.52. So the Input Scaler factor here is 0.52.

Calibration

The sensors are not so accurate and vary from one to another. Because of this the sensor needs calibrating against the Rotameter. The software supplied allows users to determine the theoretical rate against practical rate and enter an Input calibration factor.

Zeroing

Not needed.

Temperature

Sensor: MAX 31855

Sensor scale factor

The temperature system uses a thermocouple that connects to a custom made device that gives a digital output in C. The sensor scale factor here is 1 as the source is digital.

Calibration

No calibration is needed here as the sensor is digital. A reference device is shipped with the unit to allow students to make sure that the sensor is accurate. The sensor calibration factor is 1.

Zeroing

Not needed.

Pressure

Sensor: Honeywell 26PC series

Scaling factor and Calibration factor

The sensor is at the end of a tube on the controller circuit board. The sensor has a Wheatstone bridge arrangement that feeds into an intelligent bridge amplifier into which you write a scale factor. This is a relative factor so the sensor needs scaling and calibrating on set up. To do this start with an approximate Input Scaler factor. E.g. 0.0001. Then set the pressure to a steady value using the software provided. Once the pressure is steady read the value from the software and the value from the gauge. Adjust the Calibration factor by the ratio of gauge to sensor reading and retest the software against the gauge to verify that the scaling factor and calibration factor are correct.

Zeroing

Needed at the start of each session. With the valve open the pressure equalises with atmospheric pressure. Run the 'Open ControlManual.bat' software and click on the 'Zero' button.

Level

Sensor: Honeywell 26PC series

Scaling factor and Calibration factor

The level is deduced using the same pressure sensor as for the Pressure equipment and Boyle's law: $P_1V_1 = P_2V_2$. A change in pressure in the vertical pipe in the Level tank can be used to deduce the height of the fluid in the tank. Water is allowed into the bottom of the tube and the level of the water in the tube is the same as the level of the water in the tank: as the level rises the air in the tube compresses producing a change in pressure proportional

Sensors and their operation

Process Control Reference Manual

to the change in level. The sensor is at the end of a tube on the controller circuit board. The sensor has a Wheatstone bridge arrangement that feeds into an intelligent bridge amplifier into which you write a scaling factor. As volume is proportional to height we can write in a single Scale factor which performs the function of scaling and calibration and gives a reading of liquid level in mm. To do this start with an approximate Input Scaler factor. E.g. 0.0001. Then set the water level to a steady value using the software provided. Once the level is steady read the value from the software and the value from the gauge. Enter the Input calibration factor of the ratio of gauge to sensor reading and retest the software against the gauge to verify that the scaling and calibration are correct.

Zeroing

Needed at the start of each session. With the valve open the pressure equalises with atmospheric pressure. Run the 'Open ControlManual.bat' software and click on the 'Zero' button.

Servo Pendulum

Sensor: US digital

Sensor scale factor

As this is digital the scaling factor is one.

Calibration

No calibration is needed here as the sensor is digital.

Zeroing

Not needed.

Software installation

Process Control Reference Manual

Copying over the software

There are 3 applications that allow you to operate the equipment in different ways. The software is available free of charge as a download from the Matrix web site. When you unpack the zip file you will see the following files:

Open ManualControl.bat

Open ONOffControl.bat

Open PIDControl.bat

Please copy these programs and directories into a suitable location on your hard drive. You can make short cuts to the *.BAT files if you wish.

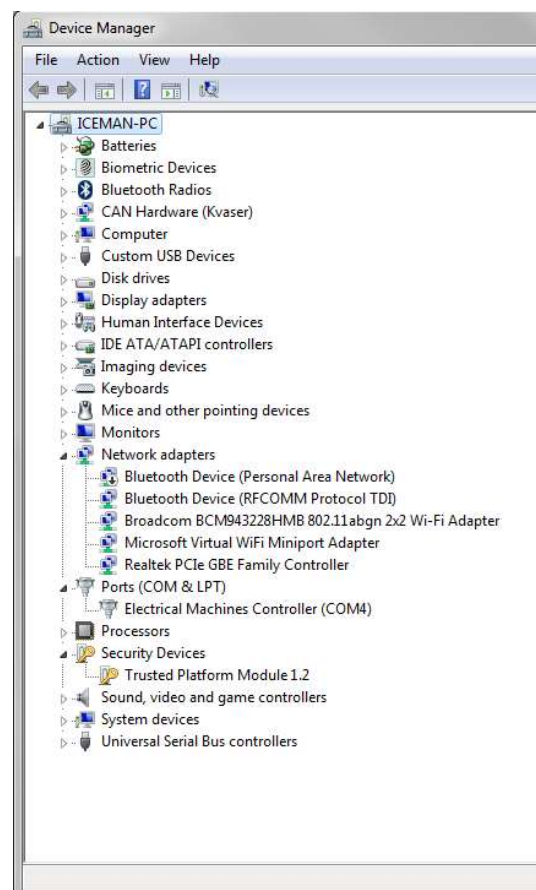
You can run each program by clicking on the '*.BAT' file.

You will also find a single application called 'Open Configure.bat' which allows you to configure the equipment for Web and Bluetooth use.

Installing drivers

Go into the USB drivers folder and run the 32 bit or 64 bit as appropriate for your computer. This should install the driver for the controller.

You can check the driver is installed properly by looking at Device Manager and checking that the controller appears under Ports - see opposite.



Software Manual control

Process Control Reference Manual

The screenshot displays the 'ManualControl' software interface. The main window is titled 'ManualControl - powered by Flowcode App Developer'. The interface includes a menu bar (File, View, Control, Help), a status bar at the bottom, and a central control area. The control area is divided into several sections: a 'Run' button (3), status indicators for Application, Communications, and Auto Control (2), a 'DRIVE' section with a 'PUMP' gauge (4) showing 44.5%, a 'LOAD' section with a 'VALVE' gauge (5) showing 'OPEN', and a 'PRESSURE' section with a gauge (6) showing 4.79 PSI. A central graph (7) plots 'Pressure (PSI)' against 'Time (s)'. A 'Zero' button (8) is located near the graph. On the right, a 'Properties' panel (9) shows settings for 'COM Method' (USB (COM)), 'COM Port Settings' (Autodetect: Yes, COM Port: COM14), and 'Settings' (Application: Pressure, Input Scaler: 0.000010, Input Calibration: 0.250000).

The file name for this program is 'Open ManualControl.bat'.

The controls and displays are:

- 1) Program control - hit 'PLAY' to start
- 2) Flags for App running, communications working and App running.
- 3) RUN button
- 4) DRIVE output
- 5) LOAD output
- 6) System measured value
- 7) Graph area
- 8) Zero button (not all applications)
- 9) Properties

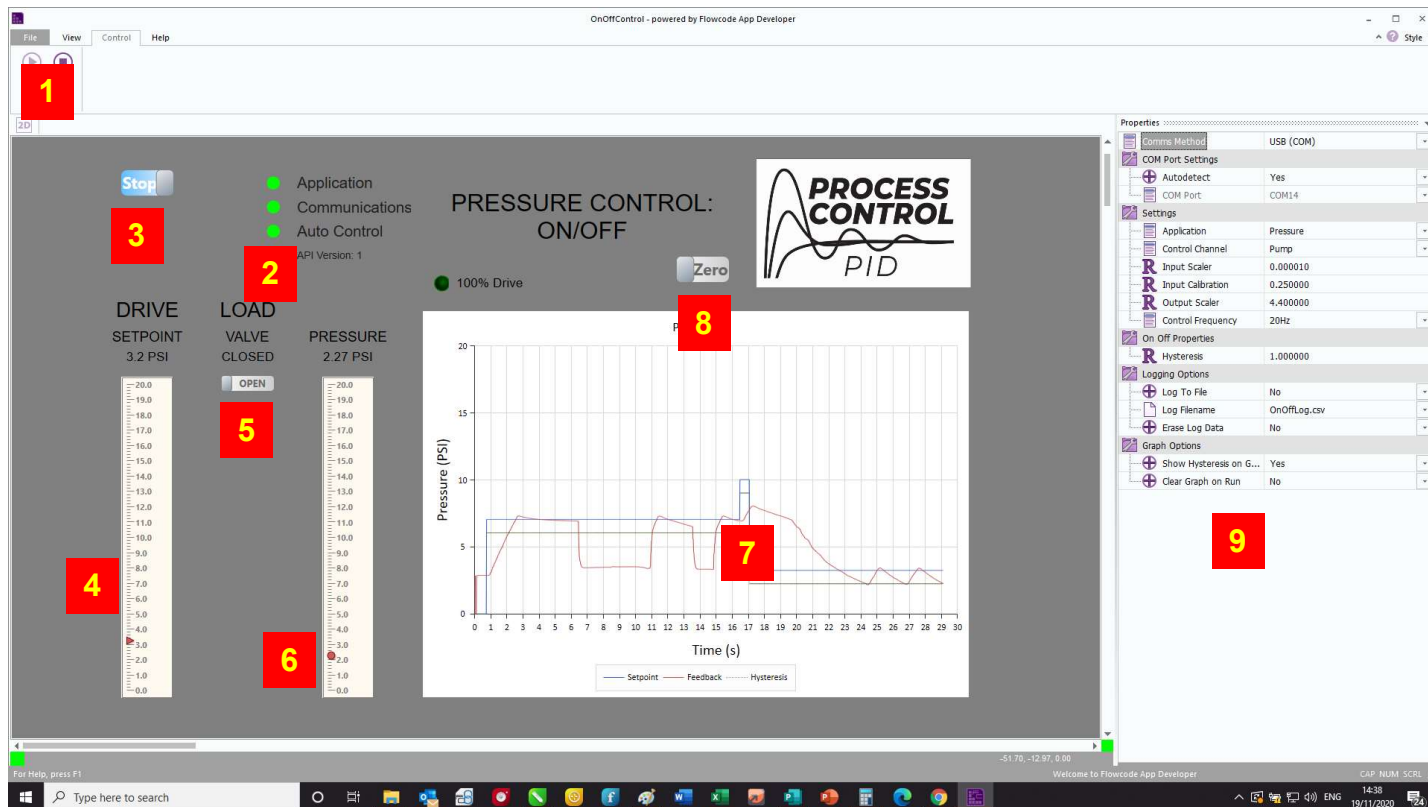
Before RUNNING please select the Process Control application you are using in the properties section.

Software

On Off control

Process Control

Reference Manual



The file name for this program is 'Open OnOff-Control.bat'.

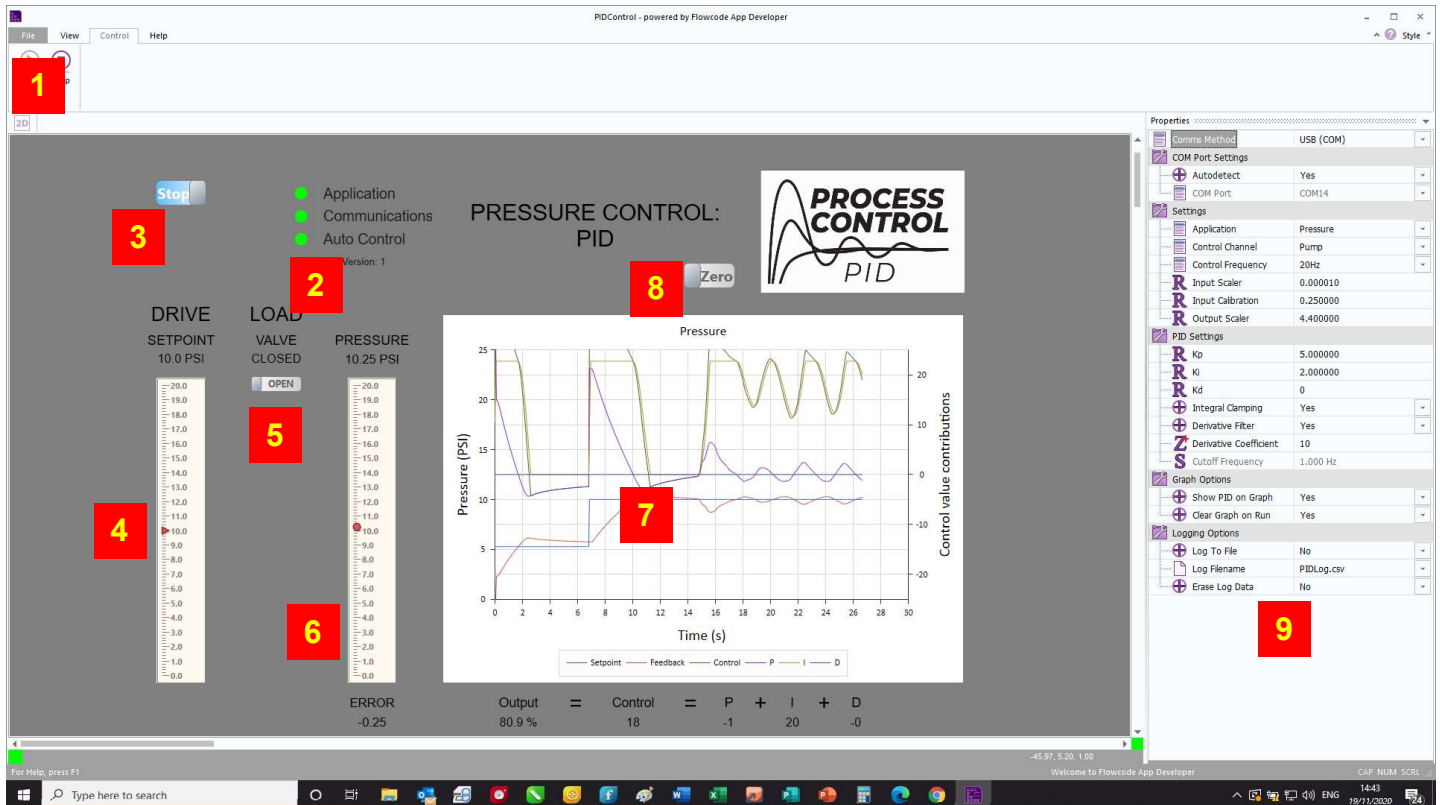
The controls and displays are:

- 1) Program control - hit 'PLAY' to start
- 2) Flags for App running, communications working and App running.
- 3) RUN button
- 4) DRIVE output
- 5) LOAD output
- 6) System measured value
- 7) Graph area
- 8) Zero button (not all applications)
- 9) Properties

Before RUNNING please select the Process Control application you are using in the properties section.

Software PID control

Process Control Reference Manual



The file name for this program is 'Open PID-Control.bat'.

The controls and displays are:

- 1) Program control - hit 'PLAY' to start
- 2) Flags for App running, communications working and App running.
- 3) RUN button
- 4) DRIVE output
- 5) LOAD output
- 6) System measured value
- 7) Graph area
- 8) Zero button (not all applications)
- 9) Properties

Before RUNNING please select the Process Control application you are using in the properties section.

Software Configure

Process Control Reference Manual



These products can be used on UAB, with Bluetooth, on LAN or Wi-fi.

If you are wanting to use Bluetooth, Wifi or LAN then the initial configuration should be carried out using USB.

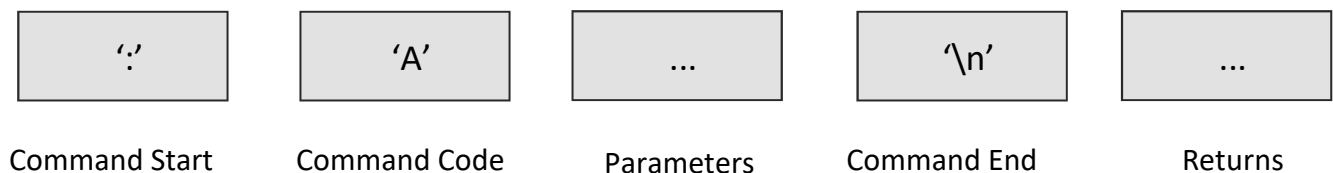
- 1) STOP/PLAY controls
- 2) WIFI config—Enables or Disables WIFI functionality, default Disabled.
- 3) WIFI Get IP—Gets the IP address of the WIFI.
- 4) Configure Ethernet
- 5) BT config—Enables or Disables Bluetooth functionality, default Enabled.
- 6) Bootloader - puts the unit into Bootloader mode for reprogramming.
- 7) Function indicators
- 8) Properties

Understanding the API

Process Control Reference Manual

As the API reacts to a simple byte-based protocol (as shown below) it means you have the freedom to use formal programming languages like C, C#, C++ or Python, or graphical or icon-based languages like Flowcode, App Inventor or LabView.

The other thing to note about the API is that some commands are bi-directional. This means that a command sent to the equipment could result in a value being returned. Shown below is the general format for the equipment's API.



Every command starts off with a ':' character, ASCII value 58 which is then followed by a command code byte that identifies what the robot should do. This may be followed by one or more parameters depending on the command issued. The command is completed with a '\n' characters, ASCII value 10 which executes the command.

For example to change the relay status you might send the following bytes:

```
':' , 'E' , <value> , '\n'
```

The numeric byte values for this would look like this.

```
58 , 69 , <value> , 10
```

Where <value> is a 1 or a 0 for ON or OFF respectively.

It should be noted that the API commands for a particular language might have some subtle differences. For example, Python will use something like "RA2.SetRelay(1)" whereas C# would look like "RA_DLL.RA_SetRelay(1); " and for App Inventor, Flowcode and LabView the appropriate icon would be selected.

Here's another example that shows how to control one of the motors on the equipment.

```
':' , 'I' , <motor> , <LSB> , <MSB> , '\n'
```

Understanding the API

Process Control Reference Manual

Below is a table showing the Application Programming Interface specification. This shows you the structure of each command.

	Cmd Code	Param Bytes	Param	Return Bytes	Return	Details
Get API Version	A	0		1	Version	Gets the API version Number
SetAutoPID	B	2	Channel, Enable	0		Controls if the Auto PID is running or not, default not running Channel: 0-1 Enable: 0=Off, 1=5Hz, 2=10Hz, 3=20Hz, 4=50Hz, 5=100Hz, 6=200Hz, 7=500Hz, 8=1000Hz
SetAutoPIDParam	C	5	Index, Value0, Value1, Value2, Value3	0		Sets one of the Auto PID parameters Index: 0=P, 1=I, 2=D, 3=IntegralClamping, 4=DerivativeFiltering, 5=Derivative Filter Coefficient
SetAutoPIDSetpoint	D	4	SP0, SP1, SP2, SP3	0		Control the setpoint value as a real world value
SetManualDuty	E	3	Channel, DutyMSB, DutyLSB	0		Sets one of the motor driver output duties Channel: 0=OP0, 1=OP1, Duty = 0-20000
SetFeedbackMethod	F	9	ControlType FBScaler0, FBScaler1, FVScaler2, FBScaler3 OPScaler0, OPScaler1, OPScaler2, OPScaler3	0		Sets which type of feedback to try and collect FBMethod: 0=Level Pressure, 1=Flow Rate, 2=Pressure Pressure, 3=Temperature Temp Also sets Feedback and Output Scalers
GetFeedback	G	0		4	FB0, FB1, FB2, FB3	Gets the Feedback Value as a Real World Value
GetOutput	H	0		1	Output	Gets the Scaled Output Value as an integer 0 - 100
SetAutoOnOff	I	2	Channel, Enable	0		Controls if the Auto On/Off is running or not, default not running Channel: 0-1 Enable: 0=Off, 1=5Hz, 2=10Hz, 3=20Hz, 4=50Hz, 5=100Hz, 6=200Hz, 7=500Hz, 8=1000Hz
SetAutoOnOffParam	J	4	Value0, Value1, Value2, Value3	0		Sets the On/Off hysteresis
GetPIDComponent	K	1	Index	4	Comp0, Comp1, Comp2, Comp3	Gets a component of the PID calculation in real world units, 0=P, 1=I, 2=D
ZeroSensor	L	0		0		Zeros the Pressure Sensors
SetAutoPIDFlip	M	1	Flip	0		Controls if the PID and On/Off control requires positive or negative feedback
GetDataArraySize	N	0		1	ArraySize	Returns the number of queued samples in the data array
GetDataArray	O	0		10	SPMSB, SPLSB FBMSB, FBLSB PMSB, PLSB IMSB, ILSB DMSB, DLSB	Returns a single queued sample from the data array
GetDataArray x 6	P	1	Count	60	6 x GetDataArray	Returns Count * 6 queued samples from the data array, sent in packets of 60 bytes
Set Wifi Mode	Q	1	Mode	0		Configures whether to host or join a network 0=Off / 1=Host / 2=Join
Set Wifi SSID	R	STR	STRING	0		Set the WIFI SSID - Max 32 Chars
Set Wifi Password	S	STR	STRING	0		Set the Password - Empty string leaves network open - Max 32 Chars
Set Bluetooth Mode	T	1	Mode	0		Configures whether to power up BT module 0=Off / 1=On
Set Bluetooth Name	U	STR	STRING	0		Set the BT Friendly Name
Set Bluetooth Key	V	STR	STRING	0		Set the BT Passkey
Set CAN ID	W	2	ID	0		Sets the CAN bus listen ID
Set CAN Mode	X	1	Mode	0		Configures whether to power up CAN module 0=Off / 1=On
Get Wifi IP	Y	0		STR	STRING	Collects the WIFI IP address if the WIFI is enabled
Set WIFI Port	Z	2	PortMSB, PortLSB	0		Sets the WIFI Port Number
Set Ethernet Mode	a	1	Mode	0		Configures whether to power up the Ethernet module 0=Off / 1=On
Set Ethernet IP	b	4	IP0, IP1, IP2, IP3			Sets the Ethernet IP address bytes
Set Ethernet Port	c	2	PortMSB, PortLSB	0		Sets the Ethernet Port Number
Set Auto Prescaler	d	1	Prescaler	0		Sets the auto mode prescaler to divide down the calculation frequency if required
Reset To Boot	z	0		0		Reset to Bootloader Mode

Reinstalling the API

Process Control Reference Manual

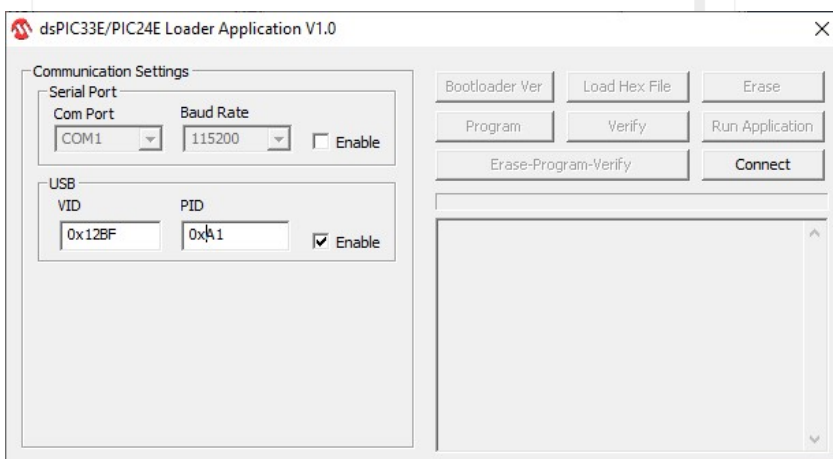
The Application Programming Interface is written in Flowcode and compiled to hex code. The microcontroller on the control board is a powerful 16 bit dsPIC microcontroller. This dsPIC contains a 'bootloader' program. This program resides permanently on the dsPIC. It communicates to a PC via USB and allows the hex code - or 'Firmware' - to be changed easily without the use of any special programming adaptor.

The default program is the Application Programming Interface. If any new firmware has been downloaded to the control board then the API will have been over written. This means that you will need to restore it for the next user. Alternatively if the API has ben updated or expanded then it will need downloading to the unit.

The process of restoring the API is exactly the same as the process for sending a hex program to the microcontroller.

To restore the API or change the firmware please follow the instructions below.

- 1) Run the PC Loader application from the resource files from the MatrixTSL.com website.
- 2) Click the Enable button in the USB section.
- 3) Change the VID to 0x12BF
- 4) Change the PID to 0xA1
- 5) Unplug the USB cable from the equipment.
- 6) Power up the equipment by connecting the power supply to the DC socket.
- 7) Connect the USB cable to the equipment
- 8) The display should cycle through the connection methods resulting in a green display saying: 'BOOTLOADER' to indicate that the equipment is in bootloader mode. Bootloader mode should last for approx. 10 seconds before reverting back into normal running mode.
- 9) While the equipment is in bootloader mode click the Connect button in the PC Loader application.
- 10) If the PC Loader failed to connect go back to step 5 and try again.
- 11) Click the Load Hex File button
- 12) Select the hex file to send, the API firmware is named ControlFW.hex
- 13) Click the Erase-Program-Verify button
- 14) Click the Run Application button to end the bootloader mode and run the new firmware.



Bluetooth setup

Process Control Reference Manual

The WIFI and Bluetooth communications are setup using the Configure software.

Configuring Bluetooth

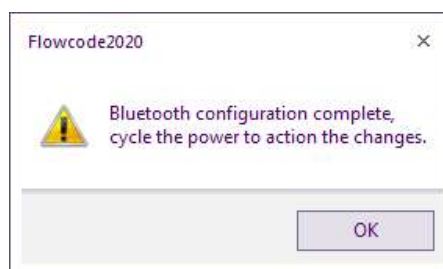
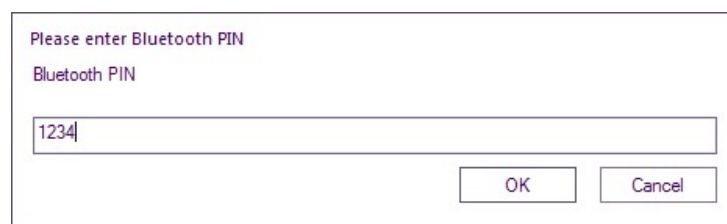
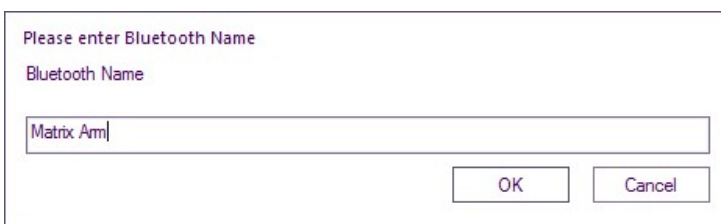
To configure the Bluetooth connection first connect to the hardware using a USB cable.

1. With communications set to USB click the Play button at the top left of the screen to start the program running.
2. The communications icon should turn to a Green Tick to indicate comms to the arm have been established.
3. Click the Configure Bluetooth button. You will be asked to enable the Bluetooth device, then for a name for the arm you are connected to, then for a PIN.
4. Once you have configured the Bluetooth connection you will need to switch the hardware off and back on to allow it to setup the Bluetooth module as required.

Any details that you have setup using the configure software will be retained in non-volatile memory so you should only have to re-run the configure software if you want to edit the settings.

You will be able to run a number of systems in the same room.

Once you have done this you will need to pair the hardware with your computer and set the COM port.



Bluetooth set up on Windows

Process Control Reference Manual



A lot of Windows devices, especially laptops and tablets, have inbuilt Bluetooth functionality. If your PC does not, you will need to use a Bluetooth USB dongle.

Different versions of the Windows operating system use slightly different ways of connecting Bluetooth devices, but they all follow the same steps.

1) Turn on Bluetooth

Often, Bluetooth is enabled by default and you can usually ignore this step. However if it is not, it can be enabled in the Windows settings and/or control panel. Very occasionally, Bluetooth needs to be switched on using a special switch or function-key. Please consult your PC or Windows help for more information.

Manage Bluetooth devices

Bluetooth
 On

2) Pair the device

First switch on the control hardware and wait for Ready to appear on the LCD. If you don't know the Bluetooth name or Pair key then the defaults are Control and 1234. These defaults can be edited using the configuration tool and a USB connection to the Control Hardware.

Again, pairing works slightly differently on the various Windows versions and so it is difficult to give specific instructions here. The Windows help and website will have guides that explain how.

When pairing, you will be presented with a screen or list of available Bluetooth devices. Select the device with the name of your Control Hardware and click Next or Pair.

You will be asked to enter the pairing code. The Control Hardware uses the default code of 1234, although this can be changed to another code if you want to ensure no-one else can pair with your hardware.

Bluetooth set up on Windows

Process Control Reference Manual

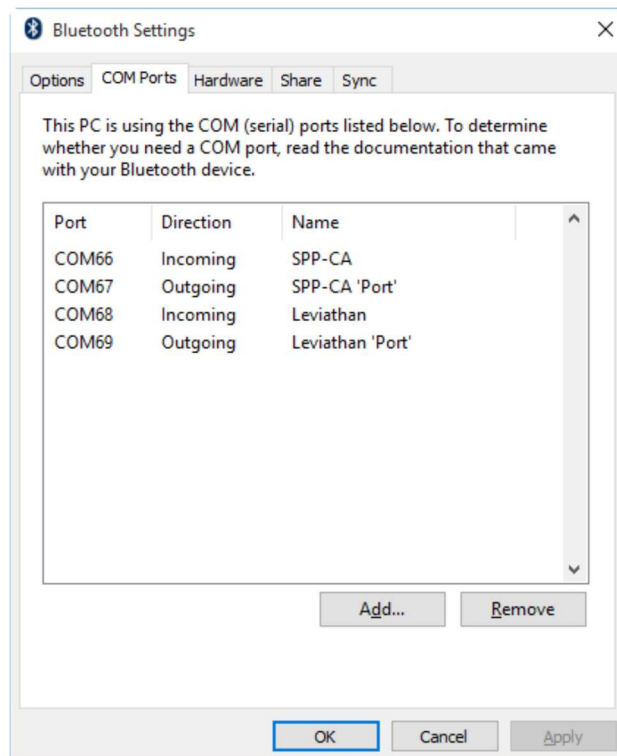
3) Determine the COM port number

You should get a popup balloon on the task bar saying device is ready to use. If you click this before it fades away then you can find out the COM port assigned to the robot.

You use this COM port number when communicating with the Control Hardware and this COM port number will stay the same as long as you do not remove or unpair the hardware from Windows.

If you did not see the COM port when the hardware was paired, you can find it in the Bluetooth Settings window, as shown on the right.

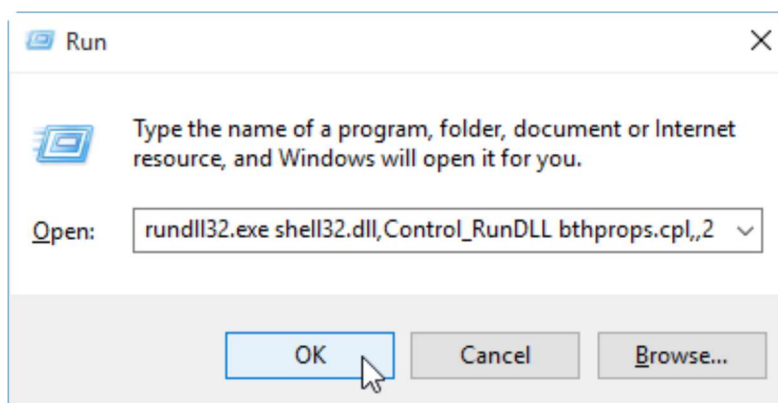
There are two COM ports listed for each hardware connection. Make sure you use the “outgoing” port number.



This window can be a bit hard to find on some versions of Windows. For example, on Windows 10 you can find this via the “More Bluetooth options” link on the Bluetooth settings screen.

If your having trouble finding the com ports list then you can open the “Run...” window by holding the Windows key and pressing R, then type (or copy and paste) the following command into the box and press “OK”:

`rundll32.exe shell32.dll,Control_RunDLL bthprops.cpl,,2`



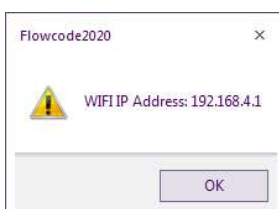
Wi-Fi setup

Process Control Reference Manual

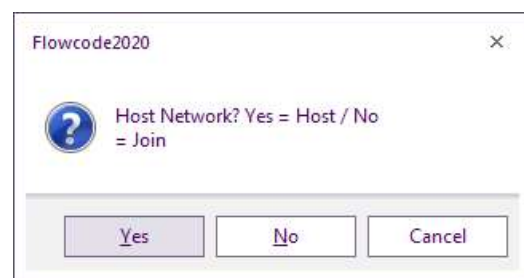
To configure the WIFI connection first connect to the hardware using a USB cable.

1. Click the Play button at the top left of the screen to start the program running.
2. The communications icon should turn to a Green Tick to indicate comms have been established.
3. Click on the Configure WiFi button. You will be taken through a number of dialogues as shows on the right.
4. Click the stop button at the top left of the screen.
5. Once you have configured the WIFI connection you will need to switch the system off and back on to allow it to setup the WIFI module as required.
6. Once the system has been switched back on click the Play button at the top left of the screen
7. Click the WIFI Get IP button to collect the IP address assigned to the system by the network

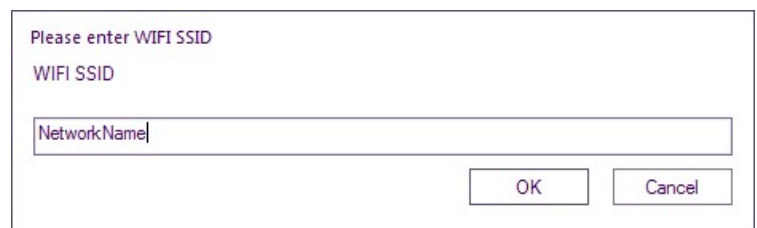
Any details that you have setup using the configure software will be retained in none volatile storage so you should only have to re-run the configure software if you want to edit the settings. If you want the equipment to be connected from the internet then you need to enable port forwarding on your router to forward any external requests on the specified port onto the local IP address of the equipment. You must then share the external IP address of the router as well as the port.



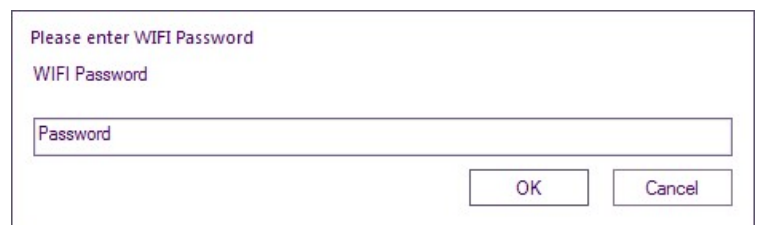
This is the address set by your router
You will need to enter this into the App.



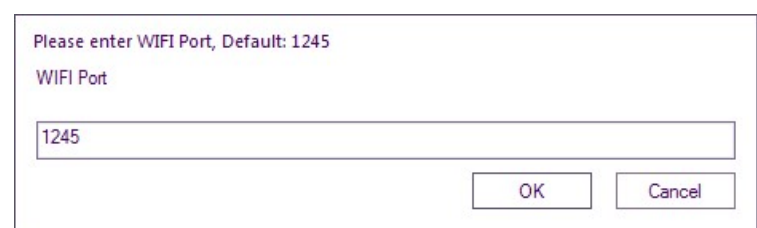
Select NO



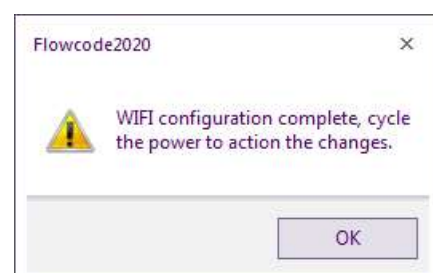
Enter the Wireless network same



Enter the Wi-Fi password



Use default 1245



Reference

Software: MATLAB integration

Process Control Reference Manual

The MATLAB software is available as a download from the Matrix web site.

The Control functionality is controlled via a USB COM port or Networked connection to the computer.

We have provided a library of functions to allow the various aspects of the Control Hardware to be investigated and controlled. The various function scripts can be found inside the Primitives folder. The scripts require a global variable to be declared in your project to set the COM port number or Network stream as shown opposite:

USB Communications

```
global Control_Comms;

% Find the COM port on your PC where the Matrix
control unit is plugged
% in and use it here instead of 'COM1'

Control_Comms = serial
('COM1','Baudrate',115200,'Databits',8);
fopen(Control_Comms);

% Main program resides here

fclose(EM_USB) % Close the COM port
```

Network Communications

```
global Control_Comms;

% Find the IP address and Port where the Matrix
control unit is plugged in and use it here in-
stead of '192.168.1.200'

Control_Comms = tcpclient("192.168.1.200",1245);

% Main program resides here

Clear Control_Comms % Close the TCP port
```

Version control

Process Control Reference Manual

19 11 20 First release

17 08 21 Servo Pendulum added.

05 01 22 Test instructions added.