QUANSER
INNOVATE. EDUCATE.

USER MANUAL

Couple Tank Experiment

Set Up and Configuration

CAPTIVATE. MOTIVATE. GRADUATE.

Quanser Inc.
119 Spy Court
Markham, Ontario
L3R 5H6
Canada
info@quanser.com
Phone: 1-905-940-3575
Fax: 1-905-940-3576

Printed in Markham, Ontario.

For more information on the solutions Quanser Inc. offers, please visit the web site at:
http://www.quanser.com

Waste Electrical and Electronic Equipment (WEEE)

This symbol indicates that waste products must be disposed of separately from municipal household waste, according to Directive 2002/96/EC of the European Parliament and the Council on waste electrical and electronic equipment (WEEE). All products at the end of their life cycle must be sent to a WEEE collection and recycling center. Proper WEEE disposal reduces the environmental impact and the risk to human health due to potentially hazardous substances used in such equipment. Your cooperation in proper WEEE disposal will contribute to the effective usage of natural resources. For information about the available collection and recycling scheme in a particular country, go to ni.com/citizenship/weee.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

CE Compliance CE

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EC; Electromagnetic Compatibility Directive (EMC)

CONTENTS

1 PRESENTATION

1.1 Coupled-Tank: System Description

The typical Coupled-Tank plant is depicted in the Figure 1.1. The Coupled-Tank specialty module is a bench-top "Two-Tank" plant consisting of a pump with a water basin and two tanks of uniform cross sections. Such an apparatus forms an autonomous closed and re-circulating system. The two tanks, mounted on the front plate, are configured such that flow from the first (upper) tank can flow into the second (lower) tank. Flow from the second tank flows into the main water reservoir. In each one of the two tanks, liquid is withdrawn from the bottom through an outflow orifice (i.e. outlet). The outlet pressure is atmospheric. Both outlet inserts are configurable and can be set by changing inserts that screw into the tapped holes at the bottom of each tank. In order to introduce a disturbance flow, the first tank is also equipped with a drain tap so that, when opened, flow can be released directly into the water basin. The pump thrusts water vertically to two quick-connect orifices "Out1" and "Out2", which are **normally closed**. For configurability purpose, these two orifices, or inlets, have different diameters. Rubber tubing with appropriate couplings is supplied to enable the pump to feed water into one or both tanks. The selection of outputs from the pump controls the flow ratio between the two outlets "Out1" and "Out2". The water level in each tank is measured using a pressure-sensitive sensor located at the bottom of the tank. As detailed later in this manual, both offset and gain potentiometers of each pressure sensor are readily available for proper calibration.

Additionally, a vertical scale (in centimeters) is also placed beside each tank for visual feedback regarding each tank's water level.This single system can be configured into three main types of experiments, as listed in Table 1.1 below. Each of which can be configured with diverse parameter values (e.g. outlet diameters).

This single system can be configured into three main types of experiments, as listed in Table 1.1 below. Each of which can be configured with diverse parameter values (e.g. outlet diameters).

Figure 1.1: Coupled Tanks Plant

1.2 Coupled-Tank: Control Challenges

As illustrated in Figure 1.1, the purpose of the coupled-tank experiment is to design a control system that regulates the water level in a multiple coupled-tank system. The controller can then track the liquid level to a desired trajectory.

The system is supplied with different feedback-plus-feedforward controllers tuned through pole placement but, of course, you may design any other controller you wish. The complete mathematical modelling and system parameters are provided to streamline the implementation of the control theory of your choice. A single Coupled-Tank system can be configured into three types of experiments, as illustrated and described in Table 1.1, below. Each of the resulting control challenges can then be configured with various system parameters.

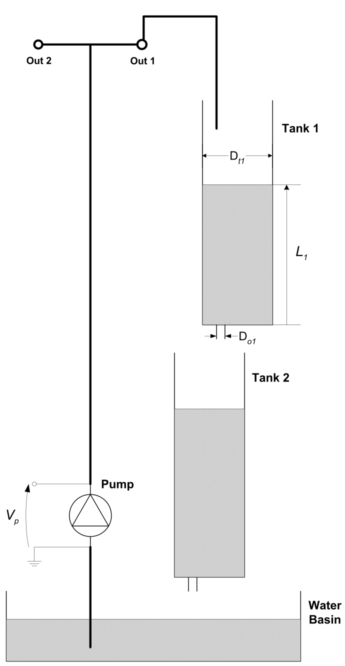
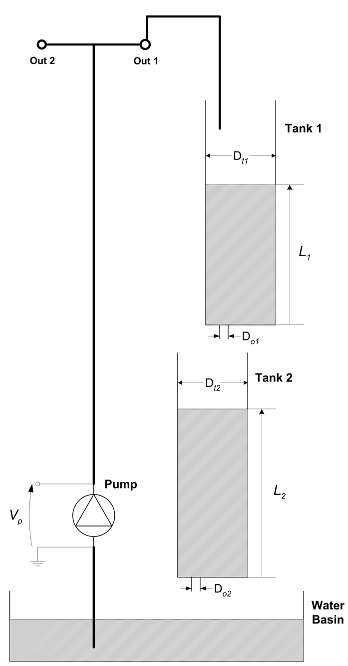
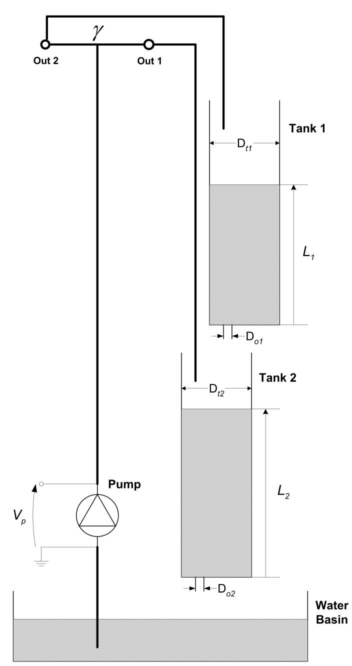
Configuration #1	Configuration #2	Configuration #3
Single Input Single Output (SISO) system.	State-coupled SISO system.	State-coupled and input-coupled SISO system.
The pump feeds into Tank 1. Tank 2 is not used at all.	The pump feeds into Tank 1, which in turn feeds into Tank 2.	The pump feeds into Tank 1 and into Tank 2 using a split flow. Tank 1 also feeds into Tank 2
A controller is designed to regulate or track the level in Tank 1.	A controller is designed to regulate or track the level in Tank 2.	A controller is designed to regulate or track the level in Tank 2.
Different inlet and outlet diameters in Tank 1 can be set up and tried.	Different inlet and outlet diameters in Tank 1 and Tank 2 can be set up and tried.	Different inlet and outlet diameters in Tank 1 and Tank 2 can be set up and tried.
 (a) Configuration #1	 (b) Configuration #2	 (c) Configuration #3

Table 1.1: Coupled-Tank Water Level Control Configuration

Additionally, two Two-Tank plants can also be used simultaneously and coupled to obtain more complex Multi-Input-Multi-Output (MIMO) experiment. For example, Figure 1.2 below illustrates the quadruple-tank process described in the following publication: K. H. Johansson. The Quadruple-Tank Process: A Multivariable Laboratory Process with an Adjustable Zero. IEEE Transactions on Control Systems Technology, 8(3):456-465, 2000 ([**?**]) Appendix A describes how to setup two Coupled-Tank systems to be used in a quadruple-tank experiment. It can be shown that the four-interconnected-tank system has an adjustable zero, which can be moved along the real axis in the left- or right-hand-side of the s-plane. Therefore by changing the system parameters, the multivariable zero dynamics can be configured to be either minimum phase or non-minimum phase.

Caution: This equipment is designed to be used for educational and research purposes and is not intended for use by the general public. The user is responsible to ensure that the equipment will be used by technically qualified personnel only.

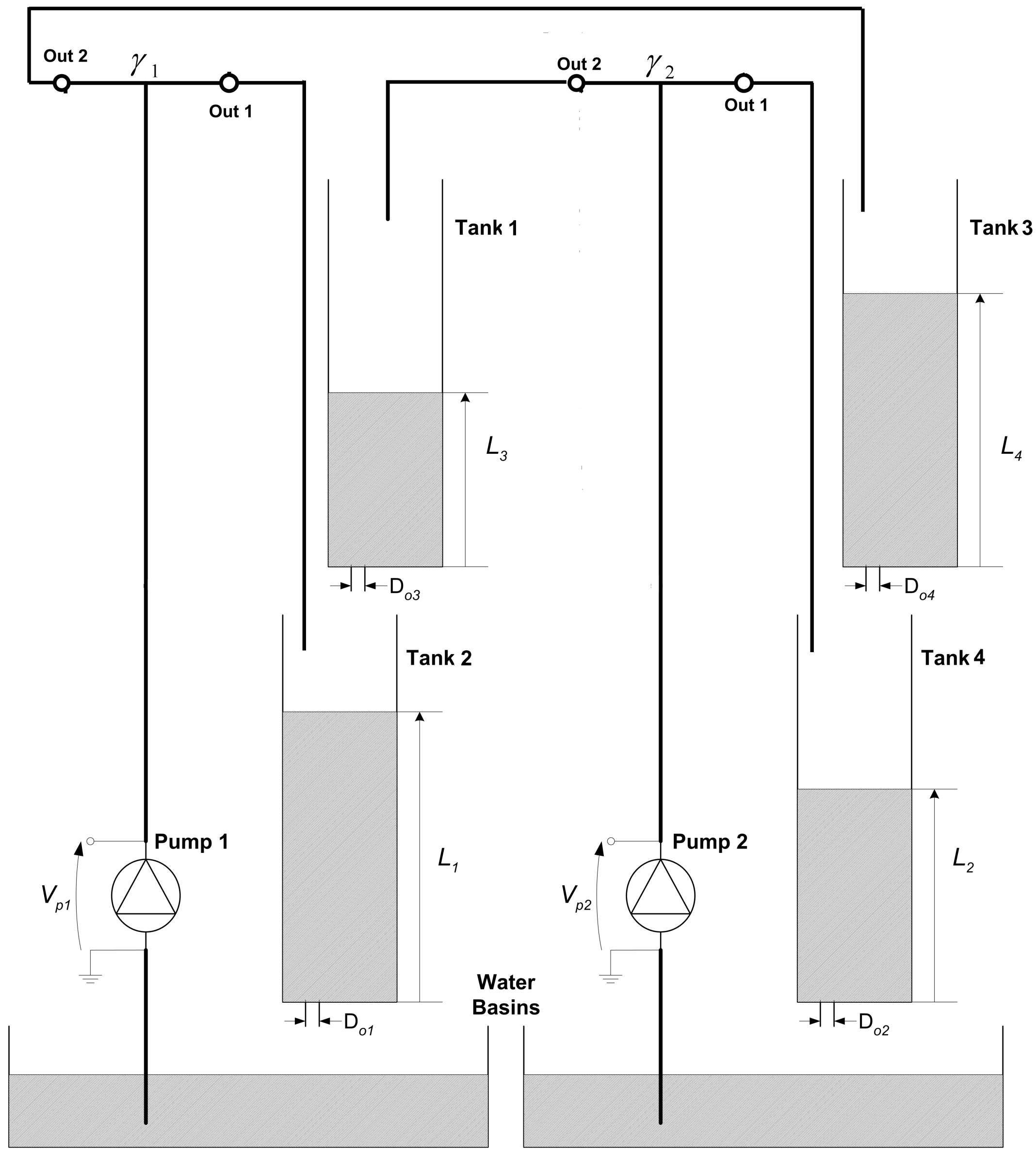


Figure 1.2: Quadruple-Tank System consisting of two Coupled-Tank Plants

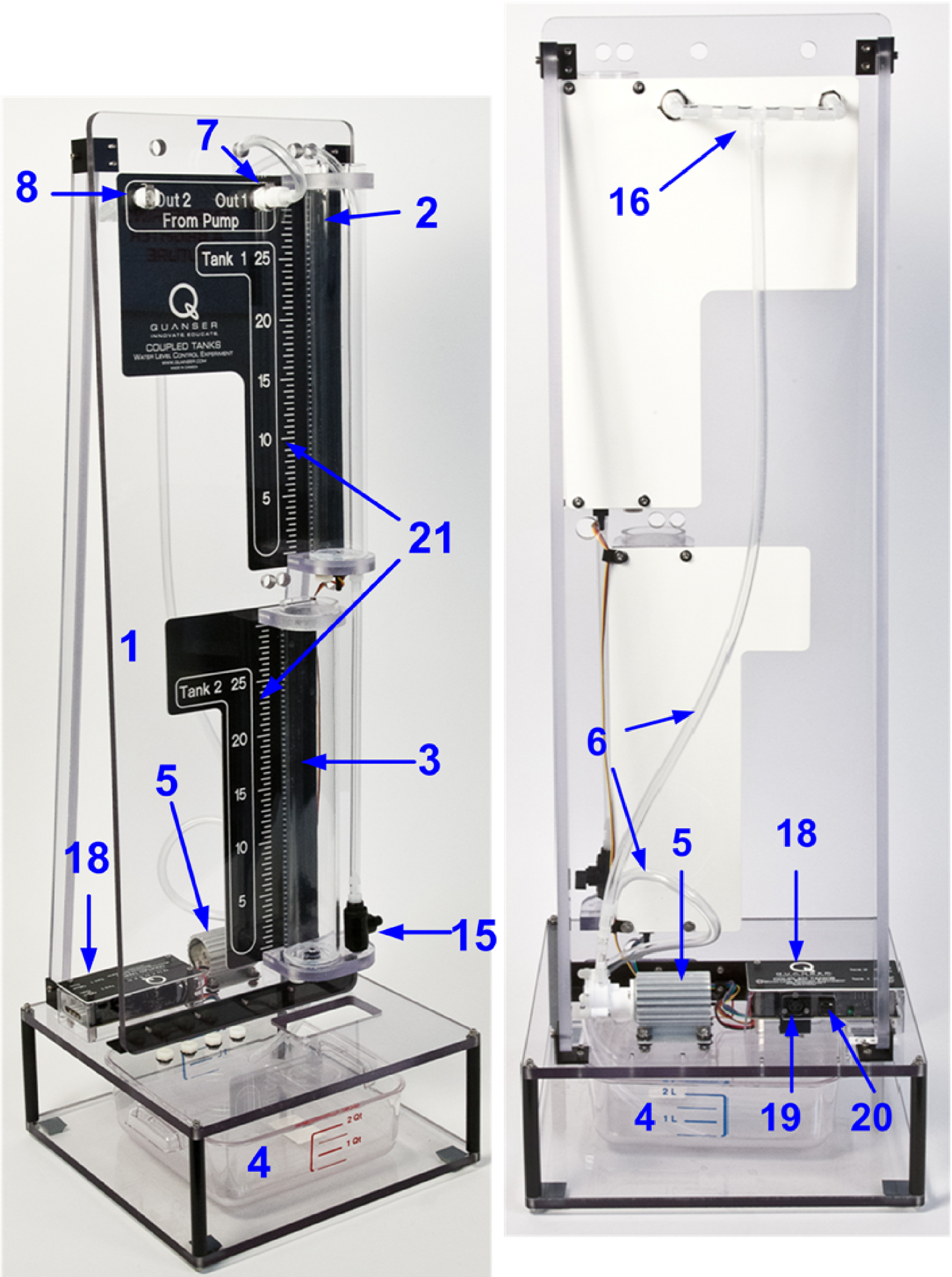
2 COUPLED-TANKS SYSTEM

2.1 Component Nomenclature

As a quick nomenclature, Table 2.1, below, provides a list of all the principal elements composing the Coupled-Tank Specialty system. Every element is located and identified, through a unique identification (ID) number, on the Coupled-Tank plant represented in Figure 2.1, Figure 2.2 and Figure 2.3, below.

ID	Component	ID	Component
1	Coupled-Tank Overall Frame	12	Medium Outlet Insert (9/16" Hexagonal Nut)
2	Tank 1	13	Large Outlet Insert (9/16" Hexagonal Nut)
3	Tank 2	14	Plain Outlet Insert (i.e. Plug)(9/16" Hexagonal Nut)
4	Main Water Basin (a.k.a. Reservoir)	15	Disturbance Tap
5	Pump	16	Flow Splitter
6	Flexible Tubing (in rubber)	17	Pressure Sensor
7	Quick-Connect Inlet Orifice "Out1"	18	Calibration And Signal Conditioning Circuit Board
8	Quick-Connect Inlet Orifice "Out2"	19	Pump Motor 4-Pin DIN Connector
9	Quick-Connect "Out1" Coupling And Hose	20	Pressure Sensors Cable 6-Pin-Mini-DIN Connector
10	Quick-Connect "Out2" Coupling And Hose	21	Tank Level Scale (in cm)
11	Small Outlet Insert (9/16" Hexagonal Nut)		

Table 2.1: Coupled-Tank Component Nomenclature



(a) Front

(b) Back

Figure 2.1: Front Back and Base of the Coupled Tank

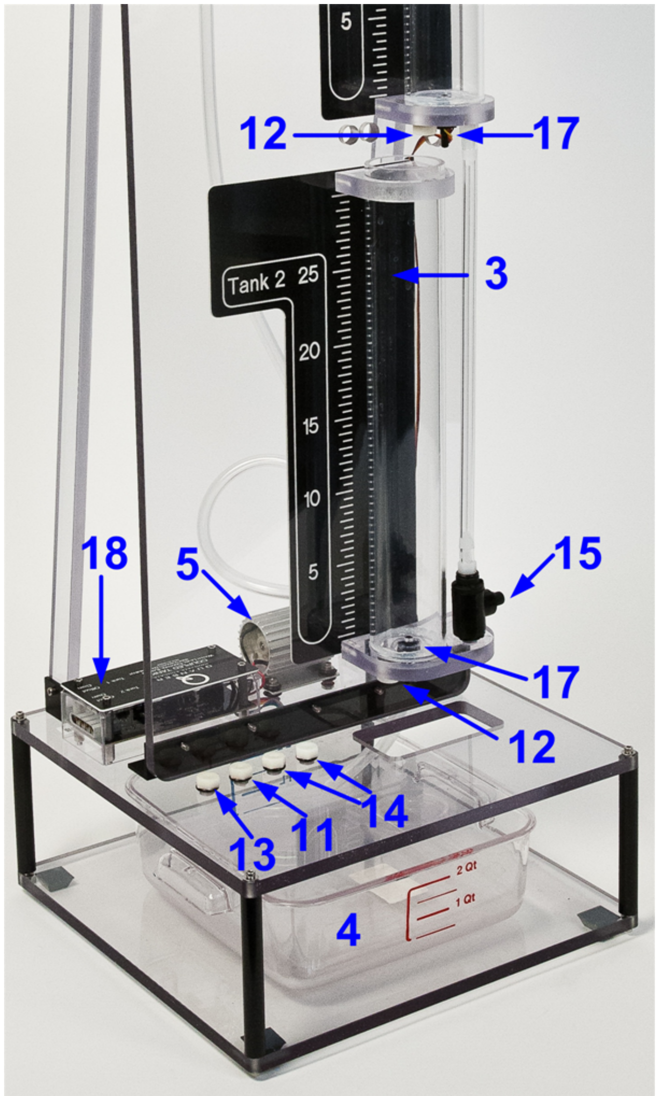
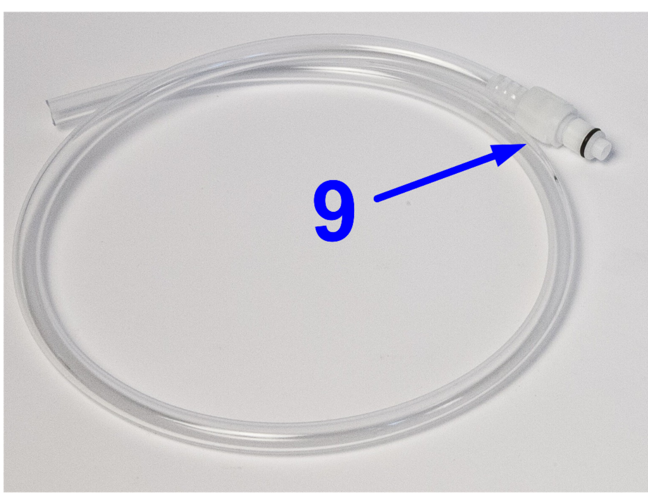
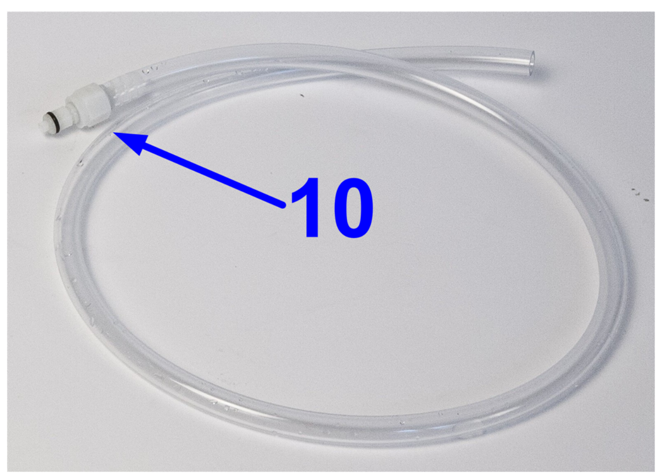


Figure 2.2: Base of the Coupled Tank



(a) Quick-Connect "Out1"



(b) Quick-Connect "Out2"

Figure 2.3: Quick Connect Couplings

2.2 Component Description

2.2.1 Overall Frame (Component # 1)

The Coupled-Tank overall frame is made of Plexiglas. Its external dimensions are shown in Table 2.2, below.

Description	Value	Unit
Overall Frame Height	0.915	m
Overall Frame Width	0.305	m
Overall Frame Depth	0.305	m

Table 2.2: Coupled-Tank Frame Overall Dimensions

2.2.2 Tanks (Component #2 and #3)

The system's two water tanks are made out of Plexiglas tubes of uniform cross section.

2.2.3 Pump (Component #5)

The Coupled-Tank pump is a gear pump composed of a DC motor rated for 12 V continuous and 22 V peak with heat radiating fins. The materials that come into contact with the fluid being pumped are: two molded Delrin gears in a Delrin pump body, stainless steel shafting, a Teflon diaphragm and a Buna N seal. It is also equipped with 3/16" ID hose fittings.

Caution: Input +/- 24 V, 5 A peak, 3 A continuous.

2.2.4 Pressure Sensor (Component # 17)

Each tank's actual liquid level is measured through a pressure sensor. Such a level sensor is located at the bottom of each tank and provides linear level readings over the complete liquid vertical level. In other words, the sensor output voltage increases proportionally to the applied pressure. Its output measurement is processed through a signal conditioning board (component #18) and made available as 0 to 5V DC signal. Its measurement sensitivity is given in Table 3.1, below. Moreover, as detailed in a following section, calibration of each pressure sensor's offset and gain potentiometers is required to keep level measurements consistent with the type of liquid used in the coupled-tank experiment.

Caution: Make sure the circuit board (component #18) does not get wet.

Caution: Depending on the duration of your experiment, the pump might get hot.

3 COUPLED-TANK MODEL PARAMETERS

Table 3.1, below, lists and characterizes the main parameters (e.g. mechanical and electrical specifications, convertion factors, constants) associated with the two-tank specialty plant. Some of these parameters can be used for mathematical modelling of the Coupled-Tank system as well as to obtain the water level's Equation Of Motion (EOM).

Symbol	Description	Value	Unit
K_P	Pump Flow Constant	3.3	$cm^3/s/V$
V_{Pmax}	Pump Maximum Continuous Voltage	12	V
V_{Ppeak}	Pump Peak Voltage	22	V
D_{Out1}	Out 1 Orifice Diameter	0.635	cm
D_{Out2}	Out 2 Orifice Diameter	0.47625	cm
L_{1max}	Tank 1 Height (i.e. Water Level Range)	30	cm
D_{t1}	Tank 1 Inside Diameter	4.445	cm
K_{L1}	Tank 1 Water Level Sensor Sensitivity (Depending on the Pressure Sensor Calibration).	6.1	cm/V
L_{2max}	Tank 2 Height (i.e. Water Level Range)	30	cm
K_{L2}	Tank 2 Water Level Sensor Sensitivity (Depending on the Pressure Sensor Calibration).	6.1	cm/V
L_{2max}	Tank 2 Height (i.e. Water Level Range)	30	cm
V_{bias}	Tank 1 and Tank 2 Pressure Sensor Power Bias	+/-12	V
P_{range}	Tank 1 and Tank 2 Sensor Pressure Range	0 - 6.89	kPa
D_{So}	Small Outflow Orifice Diameter	0.31750	cm
D_{Mo}	Medium Outflow Orifice Diameter	0.47625	cm
D_{Lo}	Large Outflow Orifice Diameter	0.55563	cm
g	Gravitational Constant on Earth	981	cm/s^2

Table 3.1: Coupled-Tank System Model Paremeters

4 WIRING PROCEDURE FOR THE COUPLED-TANK SYSTEM

This section describes the standard wiring procedure for the Coupled-Tank specialty plant. The following hardware, accompanying the Coupled Tanks, is assumed:

1. **Power Amplifier**: Quanser VoltPAQ, or equivalent
2. **Data Acquisition Board**: Quanser Q2-USB, Quanser Q1-cRIO, Q8-USB, QPID, or equivalent.

4.1 Cable Nomenclature

Table 4.1, below, provides a description of the standard cables used in the wiring of the Coupled-Tank system.

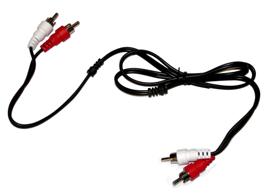
Cable	Type	Description
 (a) RCA Cable	2xRCA to 2xRCA	This cable connects an analog output of the Data Acquisition (DAQ) Device to the power module for proper power amplification.
 (b) "To Load" Cable	4-pin-DIN to 6-pin-DIN	This cable connects the output of the power module, after amplification, to the desired actuator (e.g. gear pump).
 (c) "From Analog Sensors" Cable	6-pin-mini-DIN to 6-pin-mini-DIN	This cable carries analog signals from one or two plant sensors (e.g. pressure sensors) to the amplifier, where the signals can be either monitored and/or used by an analog controller. The cable also carries a ±12VDC line from the amplifier in order to power a sensor and/or signal conditioning circuitry.
 (d) Analog-To-Digital" Cable	5-pin-DIN to 4xRCA	This cable carries the analog signals, previously taken from the plant sensors (e.g. pressure sensors), unchanged, from the amplifier to the Digital-To-Analog input channels on the Data Acquisition (DAQ) Device.

Table 4.1: Cable Nomenclature

4.2 Typical Connections

Table 4.2, below, sums up the electrical connections necessary to run the Coupled-Tank system.

Caution: If you are using the Quanser VoltPAQ, make sure the gain on the amplifier is set to 3!

Cable #	From	To	Signal
1	Analog Output **AO #0**	Amplifier **"Command"** connector	Control signal to the amplifier.
2	Amplifier **To Load** connector	Coupled-Tank's "Pump Connector" connector	Power leads to the gear pump.
3	Amplifier **"To ADC"**	Data Acquisition (DAQ) Device: 1. S1 (yellow) to Analog Input **AI #0** 2. S2 (white) to Analog Input **AI #1**	Tank 1 and tank 2 level feedback signals to the Data Acquisition (DAQ) Device, through the amplifier.
4	Coupled-Tank's "Pressure Sensors Connector" #1	Amplifier **"S1 & S2"**	Liquid level feedback signal to the amplifier.
5	Power Supply Outlet #1	Amplifier Power Socket	Amplifier Power Supply.

Table 4.2: Coupled-Tank Wiring Summary

Figure 4.1 shows the Data Acquisition Device, the back of the Coupled-Tank plant, and the amplifier, all connected with the necessary cabling to interface to and use the Coupled-Tank plant.

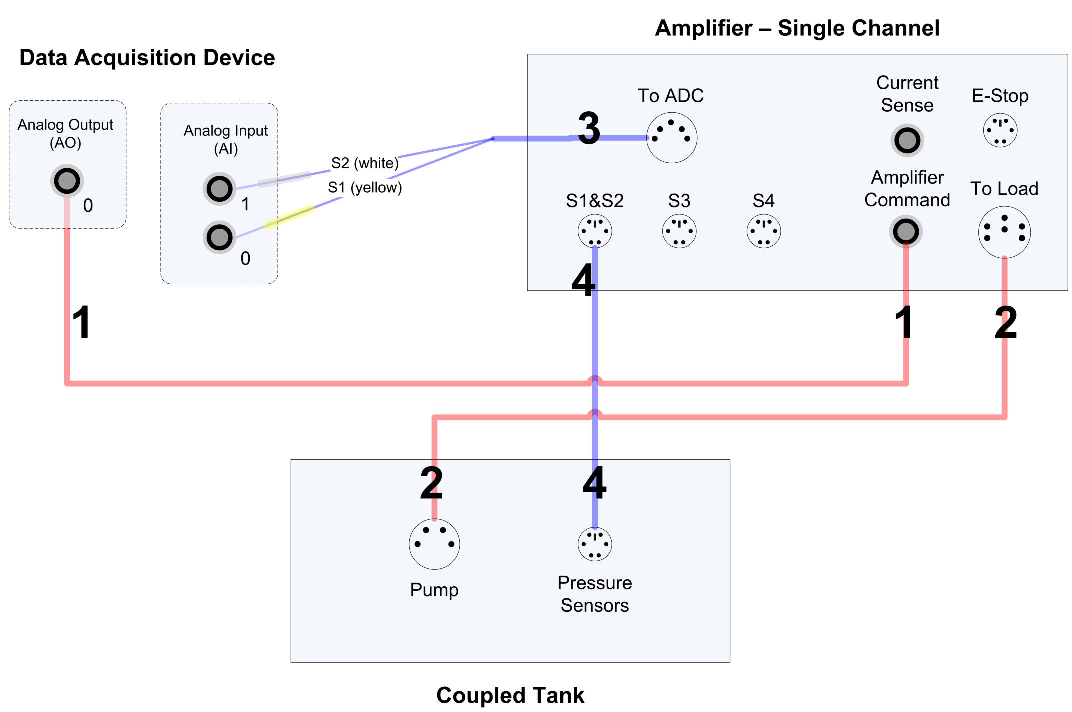


Figure 4.1: Coupled Tank Wiring Diagram

4.3 Wiring the Coupled Tanks

1. **Connect the "RCA Cable" #1**:
   Using the "RCA cable" cable described in Table 4.1, connect one end of this cable to the **Analog Output 0**(i.e. AO # 0) of your Data Acquisition (DAQ) Device and its other corresponding side to the socket labelled **"Command"** on the amplifier. These two connections are illustrated by cable #1 in Figure 4.1.

2. **Connect the "To Load" Cable #2**:
   The "To Load" cable is the 4-pin-DIN-to-6-pin-DIN cable described in Table 4.1. First, connect the cable 4-pin-DIN connector to the Coupled-Tank's **Pump** connector, which is shown as component #19 in Figure 2.1b and Figure 2.1a. Then connect the cable 6-pin-DIN connector to the amplifier socket labelled "To Load". The connection to the amplifier is illustrated by cable # 2 in Figure 4.1

3. **Connect the "Analog-To-Digital" Cable #3**:
   The "To Analog-To-Digital" cable is the 5-pin-DIN-to-4xRCA cable described in Table 4.1. First, connect the cable 5-pin-DIN connector to the amplifier socket labelled **"To ADC"**, as illustrated by cable #3 in Figure 4.1. The other end of the cable is split into four RCA connectors (yellow, white, red and black). This four RCA connectors correspond to the analog sensor signals passing through the amplifier, namely S1-yellow, S2-white, S3-red and S4-black. In order for the analog signals to be used in software, you should then connect the RCA connectors to the analog input channels of your Data Acquisition (DAQ) Device. Specifically, connect **S1 (yellow) to Analog Input 0 and S2 (white) to Analog Input 1**, S3 (red) and S4 (black) are not used in this experiment, but you can connect them to Analog Inputs 2 and 3 of your acquisition card terminal board, if it has that capability. See cable #3 in Figure 4.1.

4. **Connect the "From Analog Sensors" Cable #4**:
   The "From Analog Sensors" cable is the 6-pin-mini-DIN-to-6-pin-mini-DIN cable described in Table 4.1. First connect one end of the cable to the **Pressure Sensors Connector**, located at the back of the Coupled-Tank and which is shown as component #20 in Figure 2.1b. Then connect the cable's other end to the amplifier socket labelled **"S1 & S2"**, which is contained inside the amplifier "From Analog Sensors" front panel. These connections are illustrated by cable #4 in Figure 4.1.

In other words, the liquid level in tank 1 is sensed using A/D #0 through the amplifier analog channel S1, and the liquid level in tank 2 is sensed using A/D #1 through the amplifier analog channel S2.

⚠ **Caution:** If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

5 CONFIGURING THE COUPLED-TANK SYSTEM

5.1 Main Water Basin

1. Fill the Coupled-Tank water basin up to 3/4 of its height.
2. Insert the basin inside the bottom of the Coupled-Tank frame, as illustrated in Figure 2.2
3. Ensure that the pump inflow flexible tube is located inside the water basin.
4. Setup the configuration 1, 2, or 3. Table 5.1 details the inlet and outlet sizes for the three standard configurations.

Note: It is recommended to use distilled water (i.e. without mineral salts) to fill up the main basin. This is to avoid stains on the system's Plexiglas tubes and structure as the water dries out.

5.2 Flexible Tubing and Outlet Typical Setup

As previously mentioned, a single Coupled-Tank system can be configured into three different types of experiments, corresponding to the system's configurations #1, #2, and #3 as illustrated and described in Table 1.1, above. Each configuration results in a distinct control challenge and can also be modified by using different values for the system parameters. However, the default water level controllers supplied with the Coupled-Tank plant have been designed for the standard three system's configurations described hereafter.

A system configuration is defined in terms of each tank inflow and outflow characteristics, as well as the desired control variable. Table 5.1, below, details the Coupled-Tank setup for the three standard configurations.

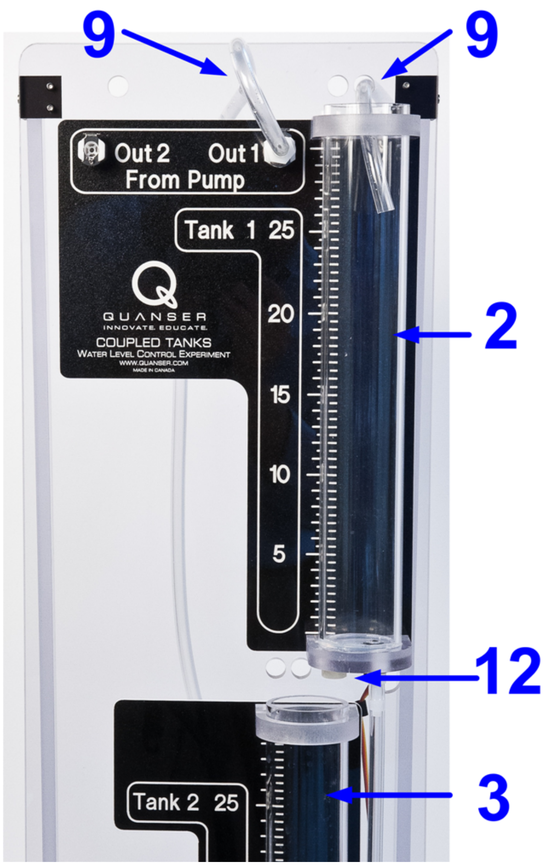
	Configuration #1	Configuration #2	Configuration #3
Tank 1 Inflow	From "Out 1".	From "Out 1"	From "Out 1"
Tank 1 Outlet Insert Size	**Medium**	**Medium.**	**Small**
Tank 2 Inflow	From Tank 1 Outflow.	From Tank 1 Outflow.	From Tank 1 Outflow and From "Out 1"
Tank 2 Outlet Insert Size	**Medium.**	**Medium.**	**Large .**
Control Variable	Tank 1 Level	Tank 2 Level	Tank 2 Level

Table 5.1: Coupled-Tank Default Setup For Configurations #1, #2, and #3

In other words, Table 5.1, above, indicates the appropriate exit orifice and the appropriate feed from the pump to use for the three configurations corresponding to different experiments.

For all three configurations make sure:

1. The disturbance tap, directly connecting tank 1 to the main water basin, is closed.
2. The drain tap is identified by component #15 in Figure 2.1a and Figure 2.2, above. For the tap to be closed, its flap should be horizontal.
3. **Configuration 1 and 2** Figure 5.1a, illustrates the Coupled-Tank system setup in configurations #1 and #2. Note that the quick-connect "Out 1" coupling and flexible hose, depicted by component #9, is used to transport the water from the inlet orifice "Out 1" to Tank 1.



(a) Coupled-Tank Configurations #1 and #2

(b) Coupled-Tank Configurations #3

Figure 5.1: Configurations 1, 2 and 3

4. **Configuration 3** Figure 5.1b, illustrates the Coupled-Tank system setup in configuration #3. This time note that the quick-connect "Out 1" coupling and flexible hose, depicted by component #9, is used to transport the water from the inlet orifice "Out 1" to Tank 2. Similarly, the quick-connect "Out 2" coupling and flexible hose, depicted by component #10, is used to transport the water from the inlet orifice "Out 2" to Tank 1.

Note: When putting the output tube from the pump into the water tank, ensure that the water discharge to the water column occurs at atmospheric pressure. In other words, the hose tip should stand above the tank water level (e.g. above the 25-cm mark).

6 WATER LEVEL SENSOR CALIBRATION

The pressure-proportional water level voltage should be zero when the tank is empty, while it should be between 4.0 Volts and 4.2 Volts when the tank water level is at 25 centimeters (as seen on the tank scale).

Note: The pressure-sensitive water level sensor is calibrated at the factory but may need re-adjustment when you receive it, or under different water characteristics (depending on the kind of liquid used).

6.1 Calibration Circuit Board Nomenclature

To calibrate both pressure sensors signals, the bottom part of the Coupled-Tank apparatus houses a signal conditioning circuit board, depicted by component #18 in Figure 2.1, above. As a quick nomenclature, Table 6.1, below, provides a list of the different signal conditioning potentiometers to be tuned during sensors calibration. Additionally, every potentiometer is located and identified, through a unique identification (ID) number, on the circuit board close-up represented in Figure 6.1, below.

ID	Component
23	Tank 1 Sensor Offset Potentiometer
24	Tank 1 Sensor Gain Potentiometer
25	Tank 2 Sensor Offset Potentiometer
26	Tank 2 Sensor Gain Potentiometer

Table 6.1: Coupled-Tank Component Nomenclature

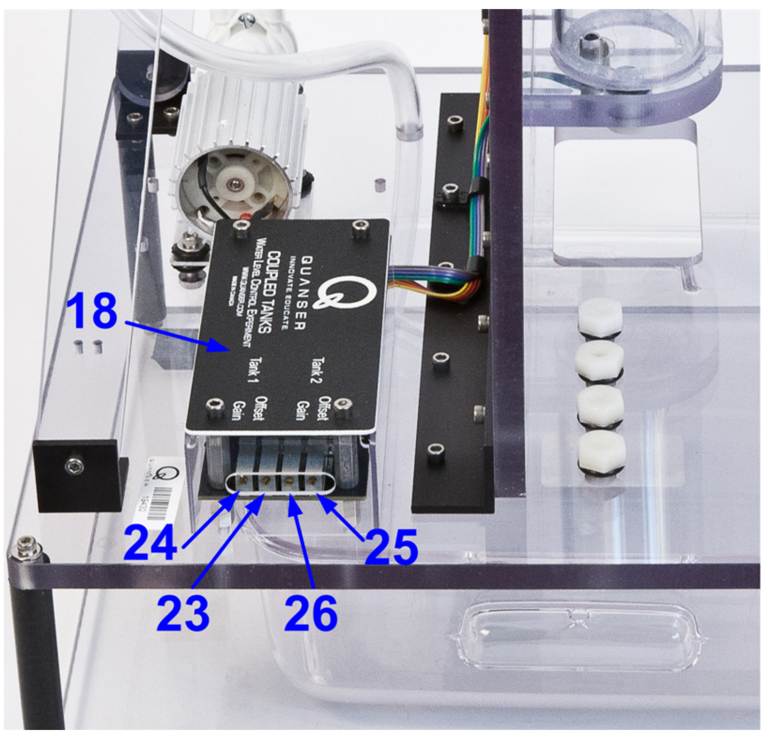


Figure 6.1: Coupled-Tank Calibration Potentiometer

6.2 Calibration Procedure

The calibration procedure detailed in the following subsections is to calibrate the circuit board's four potentiometers, which are namely "Offset 1", "Gain 1", "Offset 2", and "Gain 2", as depicted in Figure 6.1, above, as components #23, #24, #25, and #26, respectively.

In order to successfully run the calibration procedure:

1. Ensure that the Coupled-Tank system is wired as previously described.
2. Setup the Coupled-Tank apparatus to configuration #2 with the appropriate exit orifices and the appropriate feed from the pump, as previously summarized in Table 5.1 and illustrated in Figure 5.1a, above.
3. Power up the amplifier, you are now ready to proceed.

Note: Make sure the flexible tube from "Out 1" is inserted into tank 1. Do not connect a tube to "Out 2".

6.2.1 Zero "Offset" Potentiometer Calibration: With No Water

To calibrate the offset to zero to 0V for both tank pressure sensor readings do the following:

1. Ensure the Pump is **OFF** and tank is empty.
2. Run the supplied calibration software files keeping the Pump **OFF**.
3. Measure tank #1 voltage on Analog Input Channel #0. For tank #2, use Analog Input Channel #1.
4. Adjust the pots using a potentiometer adjustment tool (i.e. a small flat-end screwdriver), manually adjust tank 1 **Offset** potentiometer screw (i.e. components #23 and #25), if necessary, in order to obtain 0.0 Volts for both readings. Turning the **Offset** potentiometer screw clockwise increases the voltage and vice-versa.
5. This Voltage can be monitored in the display found in the calibration software.

When both zero-Volt offsets are achieved, you can move on the next section to calibrate the gain potentiometers.

6.2.2 "Gain" Potentiometer Calibration: At a 25-cm Water Level

The calibration of each one of the two gain potentiometers is performed with the corresponding tank containing water up to the 25-centimeter scale mark.

1. Fill up the water tank to the 25 cm mark. Plug the tank 1 outlet with your finger and apply a pump voltage using the supplied calibration software files.
2. When the 25-centimeter level mark is attained, stop the pump feed.
3. Measure tank #1 voltage on Analog Input Channel #0. For tank #2, use Analog Input Channel #1.
4. Using a potentiometer adjustment tool (i.e. a small flat-end screwdriver), manually adjust tank 1 **gain** potentiometer screw (i.e. component #24 in Figure 6.1) to obtain anywhere **between 4.0 and 4.2 Volts**. Turning the **gain** potentiometer screw clockwise increases the voltage and vice-versa.
5. This Voltage can be monitored in the display found in the calibration software.

Repeat procedure to tank 2.

7 TECHNICAL SUPPORT

To obtain support from Quanser, go to http://www.quanser.com/ and click on the Tech Support link. Fill in the form with all the requested software and hardware information as well as a description of the problem encountered. Also, make sure your e-mail address and telephone number are included. Submit the form and a technical support person will contact you.

Note: Depending on the situation, a support contract may be required to obtain technical support.

8 APPENDIX A. QUADRUPLE-TANK SETUP PROCEDURE

Figure 8.1 shows a generic Data Acquisition (DAQ) Device, the back of the Quadruple-Tank plant, and the amplifier, all connected with the necessary cabling to interface to and use the Quadruple-Tank plant.

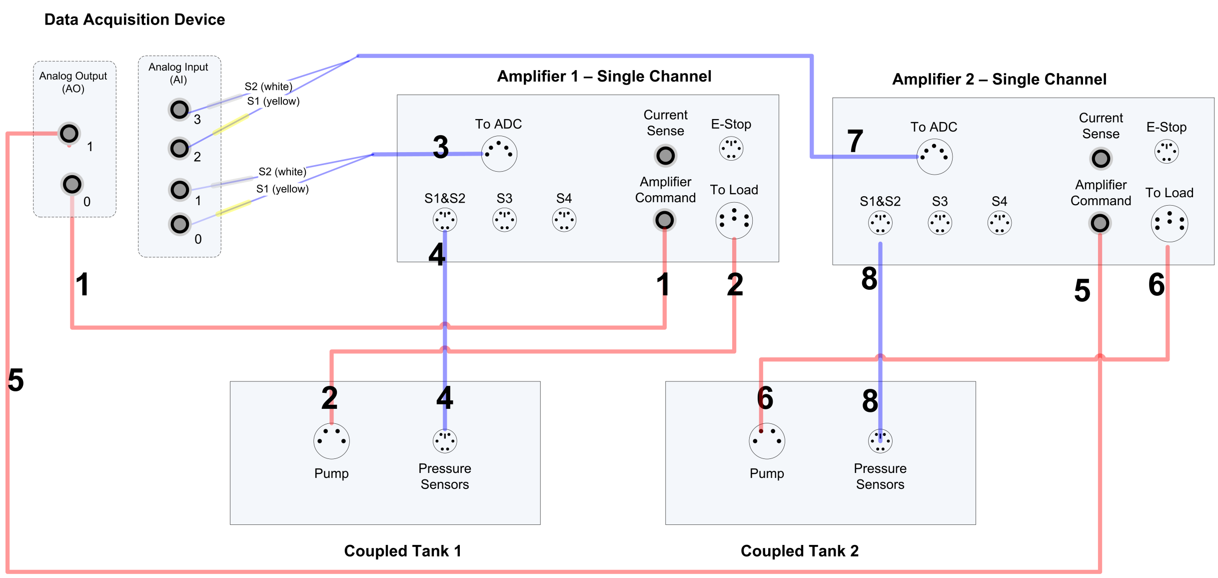


Figure 8.1: Quadruple Tank Wiring Diagram.

Table 8.1 sums up the electrical connections necessary to run the Quadruple-Tank system.

Cable #	From	To	Signal
1	Analog Output **AO #0**	Amplifier 1 **"Command"** connector	Control signal to the amplifier.
2	Amplifier 1 **To Load** connector	Coupled-Tank's "Pump" connector	Power leads to the gear pump.
3	Amplifier 1 **"To ADC"**	Data Acquisition (DAQ) Device: 1. S1 (yellow) to Analog Input **AI #0** 2. S2 (white) to Analog Input **AI #1**	Tank 1 and tank 2 level feedback signals to the Data Acquisition (DAQ) Device, through the amplifier.
4	Coupled-Tank's "Pressure Sensors" Connector #1	Amplifier 1 **"S1 & S2"**	Liquid level feedback signal to the amplifier.
5	Analog Output **AO #1**	Amplifier 2 **"Command"** connector	Control signal to the amplifier.
6	Amplifier 2 **To Load** connector	Coupled-Tank's "Pump" Connector	Power leads to the gear pump.
7	Amplifier 2 **"To ADC"**	Data Acquisition (DAQ) Device 1. S1 (yellow) to Analog Input **AI #3** 2. S2 (white) to Analog Input **AI #4**	Tank 3 and tank 4 level feedback signals to the Data Acquisition (DAQ) Device, through the amplifier.
8	Coupled-Tank's "Pressure Sensors Connector"	Amplifier 1 **"S1 & S2"**	Liquid level feedback signal to the amplifier.
	Power Supply Outlet #1	Amplifier Power Socket	Amplifier Power Supply.
	Power Supply Outlet #2	Amplifier Power Socket	Amplifier Power Supply.

Table 8.1: Quadruple-Tank Wiring Summary

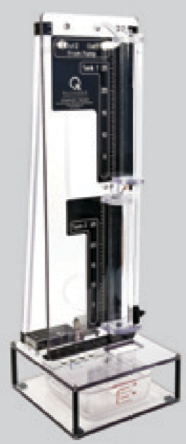
A system configuration is defined in terms of each tank inflow and outflow characteristics, as well as the desired control variable. Table 5.1 details the Coupled-Tank setup for the three standard configurations, whereas Table 8.2 indicates the appropriate exit orifice and the appropriate feed from the pump to use for the Quadruple-tank configuration.
Note: Ensure that the disturbance tap, directly connecting tank 1 and 3 to the main water basin, is closed. The drain tap is identified by component #15 in Figure 2.1a and Figure 2.2. For the tap to be closed, its flap should be horizontal.

	Configuration #4
Tank 1 Inflow	From **"Out 1"** of Pump 1
Tank 1 Outlet Insert Size	**Medium**
Tank 2 Inflow	From Tank 1 Outflow.
Tank 2 Outlet Insert Size	**Medium**
Control Variable	Tank 2 and 4 Level
Tank 3 Inflow	From **"Out 1"** of Pump 2
Tank 3 Outlet Insert Size	**Medium**
Tank 4 Inflow	From Tank 3 Outflow
Tank 4 Outlet Insert Size	**Medium**

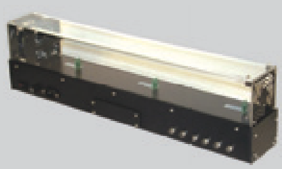
Table 8.2: Coupled-Tank Default Setup for Configurations #4

Full range of process control and mechatronic control plants for teaching and research

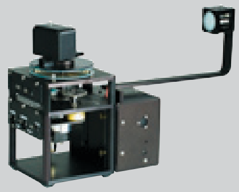
Coupled Tank



Heatflow Experiment

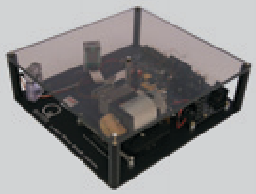


Solar Tracker



Magnetic Levitation

Laser Beam Stabilizer



These five plants allow you to study or research traditional and modern applications including laser stabilization, sensors and solar tracking. For more information please contact info@quanser.com

QUANSER
INNOVATE. EDUCATE.

INFO@QUANSER.COM +1-905-940-3575 QUANSER.COM

Solutions for teaching and research. Made in Canada.