Quanser 3 DOF Hover

User Manual

3 DOF Hover

Quanser Inc.
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1 PRESENTATION

The Quanser 3 DOF Hover experiment, shown in Figure 1.1, consists of a helicopter model mounted on a fixed base with two propellers that are driven by DC motors. The front propeller controls the elevation of the helicopter nose about the pitch axis and the back propeller controls the side to side motions of the helicopter about the yaw axis.

The Quanser 3 DOF Hover system consists of a frame with four propellers. The frame is mounted on a three degree of freedom pivot joint that enables the body to rotate about the roll, pitch and yaw axes. Each propeller generates a lift force and the lift forces are used to control the pitch and roll angles. The total torque generated by the propeller motors causes the body to move about the yaw axis. One set of propellers in the system are counter-rotating propellers such that the total torque in the system is balanced when the thrust of the four propellers are approximately equal. The axes angles are all measured using high-resolution encoders. The encoder and motor signals are transmitted through a slip ring mechanism, which allows the yaw axis to rotate continuously about 360 degrees.

Figure 1.1: Quanser 3 DOF Hover

In Section 2 the components composing the Quanser 3 DOF Hover are described and the system specifications are given. Section 3 explains how to setup the system and gives the wiring procedure.

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.

2 SYSTEM DESCRIPTION

2.1 Components

Section 2.1.1 lists the components on the Quanser 3 DOF Hoverplant and 2.2 summarizes the system specifications.

2.1.1 Quanser 3 DOF HoverOverall Components

The components comprising the Quanser 3 DOF Hoversystem are labeled in Figure 2.1, Figure 2.2, and Figure 2.3, are described in Table 2.1. The motors, propeller assemblies, and encoders are described in more detail below.

ID #	Component	ID #	Component
1	Propeller shield	11	Base platform
2	Motor	12	Front motor connector
3	Clip	13	Right motor connector
4	Roll axis encoder	14	Back motor connector
5	Pitch axis encoder	15	Yaw motor connector
6	Yoke	16	Roll encoder connector
7	Encoder/motor circuit	17	Pitch encoder connector
8	Body frame	18	yaw encoder connector
9	Slip ring	19	Left motor connector
10	Propeller		

Table 2.1: Quanser 3 DOF Hovercomponents

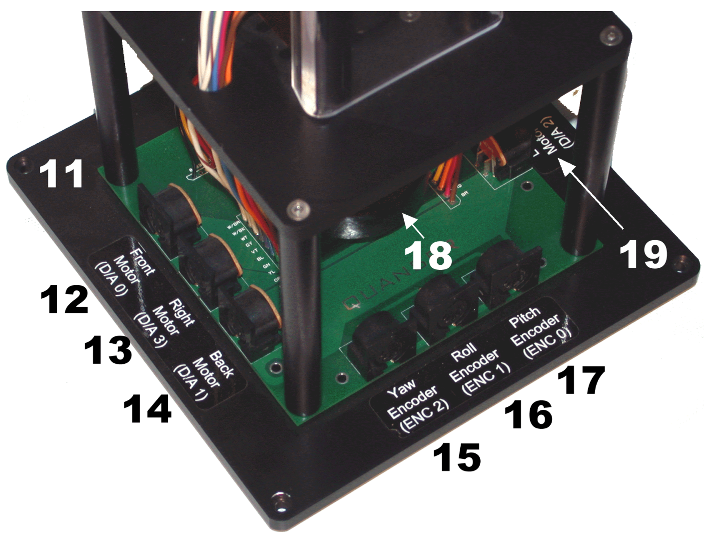

Figure 2.1: Quanser 3 DOF Hover base components

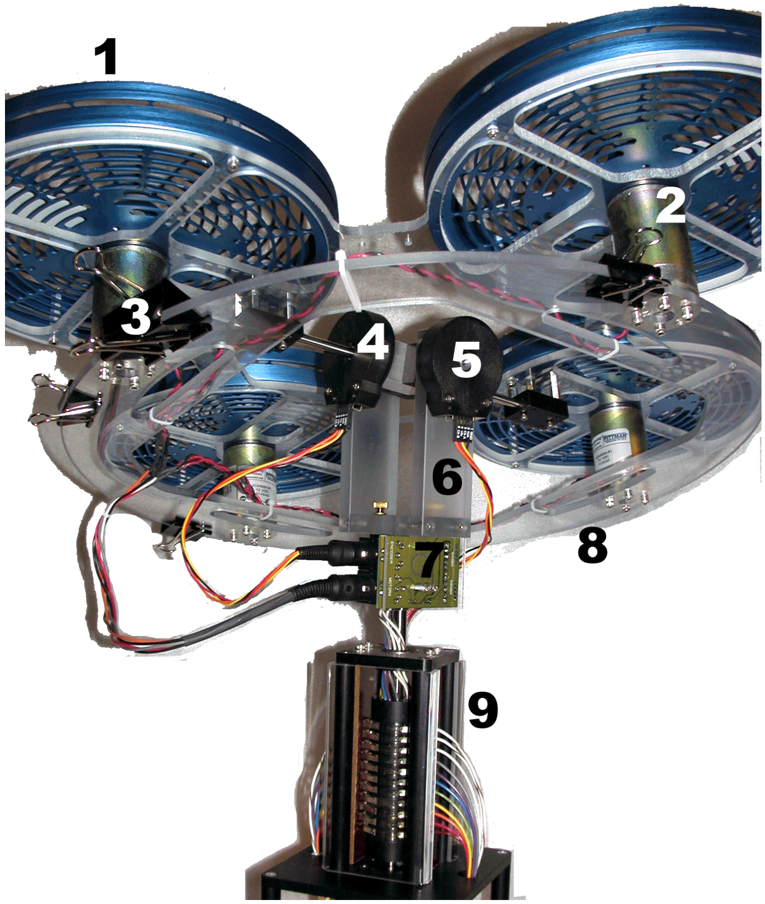

Figure 2.2: Quanser 3 DOF Hover plant components

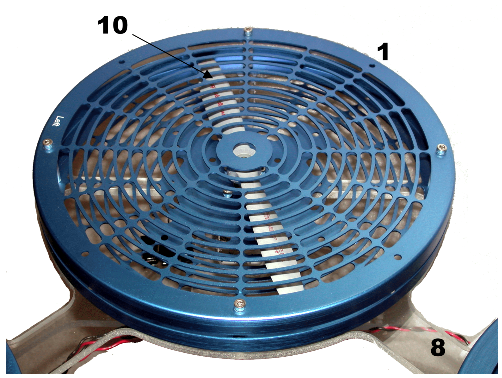

Figure 2.3: Quanser 3 DOF Hover propeller assembly components

2.1.2 DC Motors (Components #2)

The Quanser 3 DOF Hover has four DC motors: the front and back motors that mainly control the system about the pitch axis and the left and right motors that primarily move it about the roll axis.

Each DC motor is a Pittman Model 9234. It has an electrical resistance of 0.83 Ω and a current-torque constant of 0.0182 N.m/A. The rated voltage of the motor is 12 V but its peak voltage can be brought up to 22 V without damage. See [1] for the full specifications of this motor.

Caution: Pitch motor input: ±24V, 5A peak, 3A continuous.

2.1.3 Propellers (Components #10)

The pitch and yaw propeller assemblies are composed of the actual propeller, which is directly mounted to the motor shaft, and the aluminum propeller shield. The propellers used for both the pitch and yaw motors are Graupner 20/15 cm or 8/6". The pitch motor/propeller has an identified thrust-force constant of 0.119 N/V and a thrust-torque constant of 0.0036 N-m/V. The thrust-force constant describes the lifting force of propellers when working in the pitch and roll axes. The thrust-torque constant is used to determine the amount of voltage needed to rotate the hover system about its yaw axis.

Caution: The propellers rotate at high speeds. Always make sure the propeller shields are installed when in operation and stay clear of the system.

2.1.4 Encoders (Components #4 and #5)

The Quanser 3 DOF Hover experiment has three encoders used to measure the angle of pitch, yaw, and roll axes. In quadrature mode, each encoder has a resolution of 8192 counts per revolution. Thus the effective position resolution is 0.0439 degrees about the yaw, pitch, and roll axes.

2.2 System Specifications

The main parameters of the Quanser 3 DOF Hover is summarized in Table 2.2. The motor and encoder specifications are listed in Table 2.3 below. Finally, Table 2.4 lists various dimensions, masses, and inertias of the Quanser 3 DOF Hover system.

Symbol	Description	Value	Unit
K_t	Torque thrust constant of motor/propeller	0.0036	N-m/V
K_f	Force-thrust constant of motor/propeller	0.1188	N/V
L	Distance between pivot to each motor	0.197	cm
m_{hover}	Total moving mass of the system (body, four propeller assemblies, etc.)	2.85	kg
J_y	Equivalent moment of inertia about yaw axis.	0.110	kg-m^2
J_p	Equivalent moment of inertia about pitch axis	0.0552	kg-m^2
J_r	Equivalent moment of inertia about roll axis.	0.0552	kg-m^2

Table 2.2: 3 DOF Hover model parameters

Symbol	Description	Value	Unit
R_m	Armature resistance of motor	0.83	Ω
K_t	Current-torque constant of motor	0.0182	N-m/A
J_m	Rotor moment of inertia of motor	1.91×10^{-6}	kg-m^2
m_m	Mass of DC motor	0.292	kg
K_{EC}	Encoder resolution (in quadrature mode)	8192	counts/rev
	Encoder sensitivity gain	7.67×10^{-4}	rad/counts

Table 2.3: 3 DOF Hover motor and encoder specifications

Symbol	Description	Value	Unit
m_{shield}	Mass of propeller shield	0.167	kg
m_{props}	Mass of propeller, propeller shield, and motor assembly	0.754	kg
m_{shaft}	Mass of metal shaft rotating about yaw axis	0.151	kg
L_{shaft}	Length of metal shaft rotating about yaw axis	0.280	m
J_{shaft}	Moment of inertia of metal shaft about yaw axis end point	0.0039	kg-m^2

Table 2.4: Various 3 DOF Hover mass, length, and inertia parameters

3 SYSTEM SETUP

3.1 Assembling the 3 DOF Hover

The Hover system comes partially disassembled and this section explains how to install the system and do some device-only wiring. Connecting the 3 DOF Hover to the amplifiers and the data acquisition device is explained in Section 3.3.

Follow these steps to setup the 3 DOF Hover system:

1. Place the base of the 3 DOF Hover, Component # 11 shown in Figure 2.1, on a table or on the floor.
2. Assemble the body to the main base by aligning the pitch/roll encoder frame, i.e., the yoke shown in Figure 2.2 as Component #6, with the top of the base and tighten the thumb screws.

   ⚠ **Caution:** Once the body is installed on the support base, do not lift the system from the helicopter body. Always carry from the base with one hand and stabilize the body with the other hand. Never apply extreme loads in the vertical direction!
3. Connect the flat 5-pin connector from the pitch encoder (Component #5 in Figure 2.2), i.e., the encoder that is labeled *Pitch*, to the 5-pin connector on the Encoder/Motor Circuit, Component #7 in Figure 2.2. Align the GND pin #1 on the cable to the BR pin on the Encoder/Motor circuit.
4. Connect the flat 5-pin to 5-pin-stereo-DIN cable from the roll encoder (Component #4 inFigure 2.2) to the 5-pin-stereo-DIN connector on the Encoder/Motor circuit board that is labeled *ENCODER*.
5. Connect the flat 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the four motors (Component #2 in Figure 2.2) to the 5-pin-stereo-DIN connector on the Encoder/Motor circuit board that is labeled *MOTORS*.

⚠ **Caution:** Exposed moving parts. Ensure all obstructions that may interfere with the complete 360-degree axial motion of the helicopter are removed before performing any experiment.

3.2 Balancing the 3 DOF Hover

Before running the experiments, the frame of the 3 DOF Hover must be horizontal with the ground when the system is at rest.

1. Using the supplied with weight clips, Component #3 in Figure 2.2, move the clips around the edge of the circular frame until the frame is balanced, i.e., parallel with the floor.
2. The system is always balanced before being shipped. However, some re-adjustments to the weights may have to be made as the wires from the body to the base do affect the balance.

3.3 Typical Connections

This section describes the typical cabling connections that are used by default for the Quanser 3 DOF Hover system. The encoders are connected directly to the data-acquisition device and provide the necessary position feedback to control the helicopter. The data acquisition (DAQ) device outputs a control voltage that is amplified and drives the front, back, left, and right motors. Figure 3.1 illustrates the wiring between a generic data acquisition device, the Quanser 3 DOF Hover base, and a four-channel amplifier. These connections are described in detail in Section 3.3.1 and summarized in Table 3.1.

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

Note: Your configuration may be different. For instance, you may have a DAQ with more channels than the one presented in Figure 3.1 or have four single-channel amplifiers that do not require any Emergency Stop (in which case, you would omit connection #12).

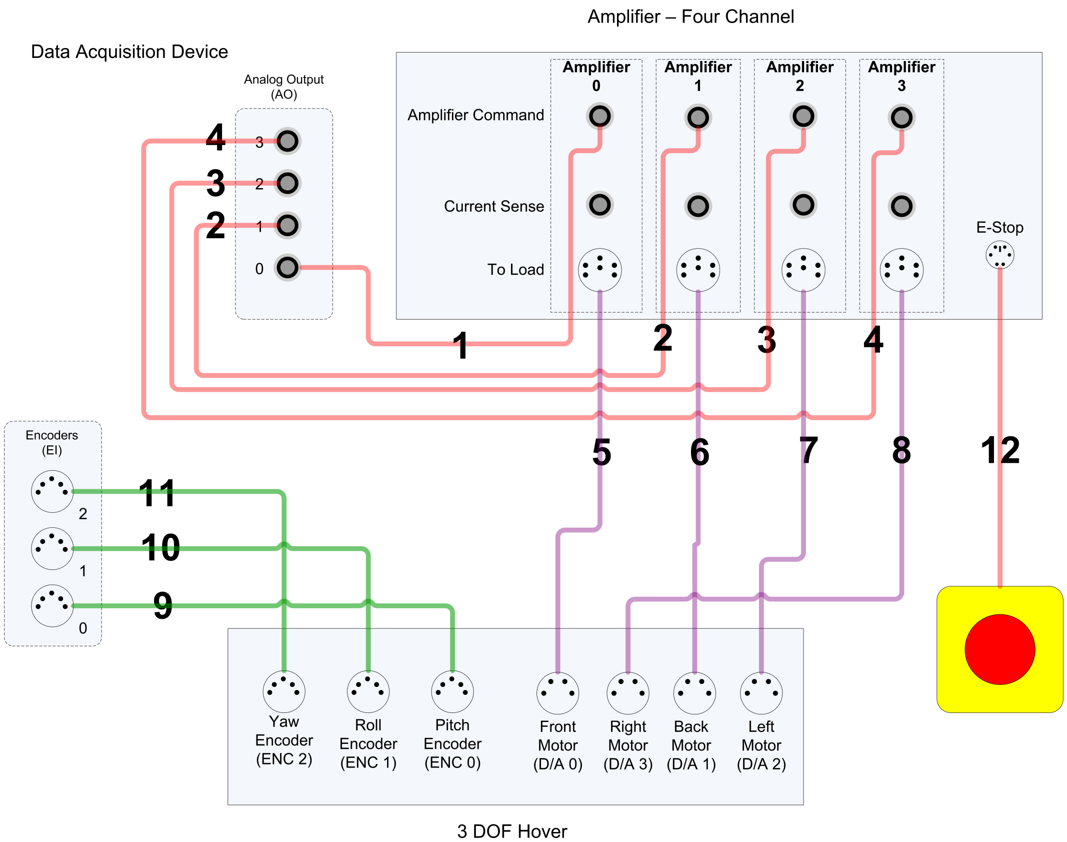

Figure 3.1: Typical connections of the 3 DOF Hover Experiment

Cable #	From	To	Signal
1	DAQ: *Analog Output #0*	Amplifier 0: *Command*	Command signal sent to amplifier for the front motor.
2	DAQ: *Analog Output #1*	Amplifier 1: *Command*	Command signal sent to amplifier for the back motor.
3	DAQ: *Analog Output #2*	Amplifier 2: *Command*	Command signal sent to amplifier for the left motor.
4	DAQ: *Analog Output #3*	Amplifier 3: *Command*	Command signal sent to amplifier for the right motor.
5	Amplifier 0: *To Load*	Quanser 3 DOF Hover: *Front Motor (D/A 0)*	Amplified voltage that is applied to the front DC motor.
6	Amplifier 1: *To Load*	Quanser 3 DOF Hover: *Back Motor (D/A 1)*	Amplified voltage that is applied to the back DC motor.
7	Amplifier 2: *To Load*	Quanser 3 DOF Hover: *Left Motor (D/A 2)*	Amplified voltage that is applied to the left DC motor.
8	Amplifier 3: *To Load*	Quanser 3 DOF Hover: *Right Motor (D/A 3)*	Amplified voltage that is applied to the right DC motor.
9	3 DOF Hover: *Pitch Encoder (ENC 0)* connector	DAQ: *Encoder #0*	Measured pitch angle.
10	3 DOF Hover: *Roll Encoder (ENC 1)* connector	DAQ: *Encoder #1*	Measured roll angle.
11	3 DOF Hover: *Yaw Encoder (ENC 2)* connector	DAQ: *Encoder #2*	Measured yaw angle.
12	*Emergency Stop* switch	Amplifier *E-Stop* connector	Disables the amplifier when the red button is pressed down. If the E-Stop switch is connected, the amplifier can only be enabled if the red knob is in the released position.

Table 3.1: Quanser 3 DOF Hover system wiring summary

3.3.1 Wiring Details

Follow these steps to connect the Quanser 3 DOF Hoversystem:

1. Make sure your data acquisition (DAQ) device has been installed and tested. See the specific DAQ documentation for details.
2. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the amplifier.
3. Connect one of the connectors on the 2x RCA to 2x RCA cable from the *Analog Output Channel #0* on the terminal board to the Amplifier 0 *Amplifier Command* connector. This is illustrated by connection #1 in Figure 3.1.
4. Connect the other line of the 2XRCA to 2XRCA cable from the *Analog Output #1* connector on the terminal board to the Amplifier 1 *Amplifier Command* connector. This is illustrated by connection #2 in Figure 3.1.

5. Connect a 4-pin-DIN to 6-pin-DIN cable from Amplifier 0 *To Load (3x Amplifier Command)* connector, to the *Pitch Motor (D/A 0)* connector on the Quanser 3 DOF Hoverplant. This is illustrated by connection #3 in Figure 3.1.
6. Connect another 4-pin-DIN to 6-pin-DIN cable from the Amplifier 1 *To Load (3x Amplifier Command)* connector, to the *Yaw Motor (D/A 1)* connector on the Quanser 3 DOF Hoverplant. This is illustrated by connection #4 in Figure 3.1.
7. Connect a 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder 0* connector on the terminal board, to the *Pitch Encoder (ENC 0)* connector on the Quanser 3 DOF Hoverplant. This is illustrated by connection #5 in Figure 3.1.
8. Connect another 5-pin-stereo-DIN to 5-pin-stereo-DIN cable from the *Encoder 1* connector on the terminal board to the *Yaw Encoder (ENC 1)* connector on the Quanser 3 DOF Hoverplant. This is illustrated by connection #6 in Figure 3.1.

   ⚠ **Caution:** Encoders should be directly connected to the data acquisition device using a standard 5-pin DIN cable. DO NOT connect the encoder cable to the amplifiers!
9. Connect the emergency stop switch to the E-Stop connector on the amplifier. This is illustrated by connection #7 in Figure 3.1.
10. Connect the USB cable of the supplied joystick to a USB port on the PC. The system should detect the joystick and automatically install the driver (you will be prompted). See the corresponding joystick User Manual for more information on the setup procedure.
11. If your amplifier has a Gain setting switch, **make sure you set the amplifier Gain to 3 when using the Quanser 3 DOF Hoverexperiment**.
12. Turn ON the rear power switch of the amplifier.

4 TESTING AND TROUBLESHOOTING

This section describes some functional tests to determine if your system is operating normally. It is assumed that the Quanser 3 DOF Hoveris connected as described in Section 3.3. To carry out these tests, it is preferable if the user can use a software such as QUARC®or LabVIEW™ to read sensor measurements and feed voltages to the motor. Alternatively, these tests can be performed with a signal generator and an oscilloscope.

4.1 Motor

4.1.1 Testing

Ensure the motors are operating correctly by going through this procedure:

1. Apply approximately 4V to Analog Output Channel #0 on the DAQ to verify that the front propeller rotates.
2. Similarly, apply 4V to Analog Output Channel #1, 2, and 3 to verify that the back, left, and right motors, respectively, are rotating.

4.1.2 Troubleshooting

If the motor is not responding to a voltage signal, go through these steps:

- Review the RCA and motors connections in Section 3.3.
- Ensure the power amplifier is powered on and operational, e.g., when using the Quanser VoltPAQ-X4, verify that the green LED lit.
- Check that the data acquisition device is functional. Go through the DAQ User Manual for troubleshooting guidelines.
- Ensure the voltage is actually reaching the motor terminals (use a voltmeter or oscilloscope).
- If the E-Stop is connected, make sure the red button is in the upper, *released* position.

4.2 Encoder

4.2.1 Testing

Follow this procedure to test each encoder on their respective motors:

1. Measure Encoder Input Channel #0 and rotate the pitch angle, i.e., axis about the front and back propellers, up and down. Verify if any counts are being outputted.
2. Measure Encoder Input Channel #1 and rotate the roll angle, i.e., axis about the left and right propellers, up and down. Verify if any counts are being outputted.
3. Measure the Encoder Input Channel #2 and rotate the yaw angle. Rotate the hover about the yaw axis one full rotation and verify that 8192 is being measured (in 4x quadrature mode).

Note: Some data acquisition systems do not measure in quadrature and, in this case, one-quarter of the expected counts are received, i.e., 2048 counts. Make sure the details of the data-acquisition system being used is known. The counters on the Quanser DAQ boards measure in quadrature and therefore a total of four times the number of encoder lines per rotation, e.g., a 2048-line encoder results in 8192 integer counts for every full rotation.

4.2.2 Troubleshooting

If the encoder is not measuring properly, go through this procedure:

- Review the encoder connections in Section 3.3.
- Check that the data acquisition device is functional. Go through the DAQ User Manual for troubleshooting guidelines.
- Check that both the A and B channels from the encoder are properly generated and fed to the data-acquisition device. Using an oscilloscope, there should be two square waves, signals A and B, with a phase shift of 90 degrees. If this is not observed then the encoder may be damaged and need to be replaced. Please see Section 5 for information on contacting Quanser for technical support.

5 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 representative will contact you.

REFERENCES

[1] Pittman. *LO-COG DC Servo Motors 8000, 9000, 14000*, 2010.