



# USER MANUAL

## Quanser AERO Experiment

Set Up and Configuration



CAPTIVATE. MOTIVATE. GRADUATE.

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# 1 PRESENTATION

The Quanser Quanser Aero, pictured in Figure 1.1, is a compact dual-rotor two degree-of-freedom aerospace system that can be used to perform a variety of actuator and flight control based experiments. The Quanser Aero can be configured with either the QFLEX 2 USB or QFLEX 2 Embedded interface modules. The QFLEX 2 USB allows control by a computer via USB connection. The QFLEX 2 Embedded allows for control by a microcontroller device such as an Arduino via a 4-wire SPI interface.

For all versions, the system is driven using two direct-drive 18V brushed DC motors. The motors are powered by a built-in PWM amplifier with built-in current sense. Single-ended rotary encoders are used to measure the angular position of the DC motors, and the speed of the motors can be measured with a software tachometer.

Main Quanser Aero features:

- Compact and complete aerospace control system
- 18V direct-drive brushed DC motors
- Encoders mounted on DC motors and support yolk
- DC motor tachometer output
- Built-in PWM amplifier with integrated current sense
- Built-in data acquisition (DAQ) device
- Low and High-efficiency propellers
- Lockable pitch and yaw axes
- Tri-color LED indicator lights



Figure 1.1: Quanser Aero



**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 HARDWARE

## 2.1 System Schematic

The Quanser Aero can be configured with one of two different I/O interfaces: the QFLEX 2 USB, and the QFLEX 2 Embedded. The QFLEX 2 USB provides a USB interface for use with a computer. The QFLEX 2 Embedded provides a 4-wire SPI interface for use with an external microcontroller board.

The interaction between the different system components on the Quanser Aero is illustrated in Figure 2.1. On the data acquisition (DAQ) device block, the motor position encoders are connected to Encoder Input (EI) channels #0 and #1. EI2 reads the pitch angle of the Aero body, and EI3 reads the yaw angle of the yoke. The Analog Output (AO) channels are connected to the power amplifier command, which then drives the DC fan motors. The DAQ Analog Input (AI) channels are connected to the PWM amplifier current sense circuitry. The DAQ also controls the integrated tri-colour LEDs via an internal serial data bus. The DAQ can be interfaced to the PC or laptop via USB link in the QFLEX 2 USB, or to an external microcontroller via SPI in the QFLEX 2 Embedded.

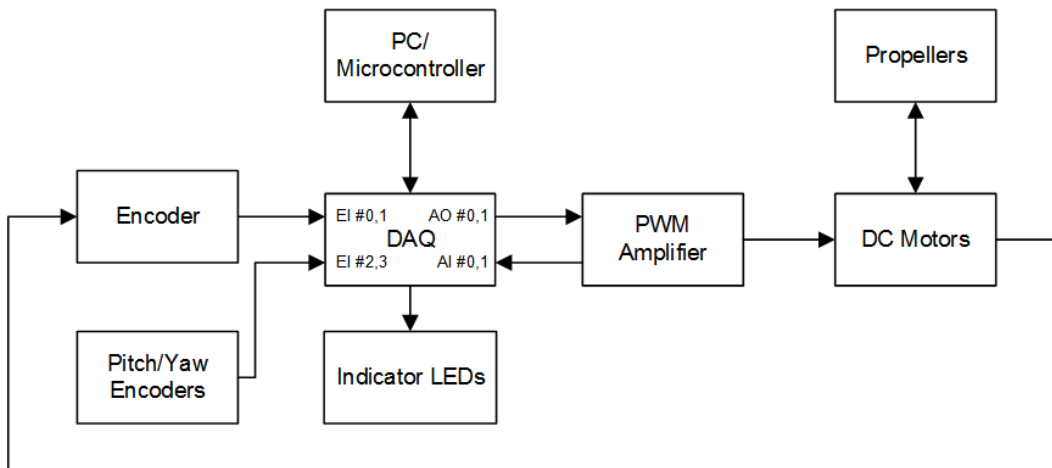


Figure 2.1: Interaction between Quanser Aero components.

The schematic given in Figure ?? illustrates the main Quanser Aero components and how they interact with a data acquisition (DAQ) device.

## 2.2 Hardware Components

The main Quanser Aero components - for the USB and SPI embedded interfaces - are listed in Table 2.1. The components on the QFLEX 2 USB are labeled in Figure 2.2c, the components on the QFLEX 2 Embedded are shown in Figure 2.2d.



**ESD Warning:** Quanser Aero internal components are sensitive to electrostatic discharge. Before handling the Quanser Aero ensure that you have been properly grounded.

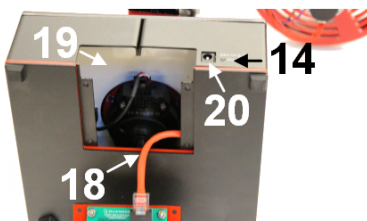
ID	Component	ID	Component
1	Aero base	11	Propeller guard screw
2	Yaw pivot	12	Propeller attachment hub
3	Support yolk	13	IMU (Internal to aero body)
4	Aero body	14	System Power LED
5	Pitch pivot	15	Interface Power LED
6	Pitch lock screws	16	SPI Data Connector*
7	Status LED strip	17	USB connector†
8	Thruster rotation locks	18	Quanser Aero internal data bus
9	Thruster 0	19	Quanser Aero DAQ/amplifier board
10	Thruster 1	20	Power Connector

Table 2.1: Quanser Aero Components

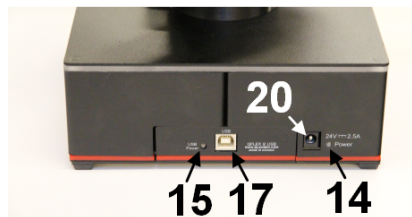
† only on QFLEX 2 USB  
 \*only on QFLEX 2 Embedded



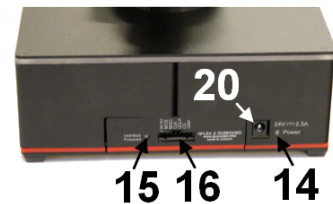
(a) Quanser Aero Top View



(b) Quanser Aero Interior



(c) Quanser Aero with QFLEX 2 USB



(d) Quanser Aero with QFLEX 2 Embedded

Figure 2.2: Quanser Aero components

## 2.2.1 DC Motor

The Quanser Aero includes two direct-drive 18V brushed DC motors. The motor specifications are given in Table 2.2.

The Quanser Aero incorporates the Allied Motion CL40 Series Coreless DC Motor model 16705. The complete specification sheet of the motor is included at: <http://alliedmotion.com/Products/Series.aspx?s=29>.



**Caution:** Max motor input  $\pm 18$  V, 2 A peak, 0.5 A continuous.



**Caution:** Exposed moving parts.



**Caution:** Holding the motor in a stalled position for a prolonged period of time at applied voltages of over 5V can result in permanent damage.

## 2.2.2 Thruster Assemblies

The Quanser Aero has two identical thruster assemblies which are attached to the Aero body. Thruster 0 can be identified by locating the pitch lock screws or the yaw lock magnets. Both of these items are on the side of the yolk facing thruster 0.

## 2.2.3 High-efficiency Propeller

The Quanser Aero ships with two counter-rotating APC 5.0x4.6 propellers, models LP05046E/EP. More information on the propellers can be found on the Advanced Precision Composites website ([www.apcprop.com](http://www.apcprop.com)).

## 2.2.4 Low-efficiency Propeller

The Quanser Aero ships with two eight-vane counter-rotating 3D-printed propellers.

## 2.2.5 Propeller Hub

The Quanser Aero propellers are connected to the DC motors with aluminum prop adapters with collets. The propeller adapters are E-flite part number EFLM1922.

## 2.2.6 Pitch and Motor Position Encoders

The encoders used to measure the pitch of the Aero body and the angular position of the DC motor on the Quanser Aero is a single-ended optical shaft encoder. It outputs 2048 counts per revolution in quadrature mode (512 lines per revolution).

The encoders used to measure the pitch of the Aero body, and angular position of the DC motors on the Quanser Aero is the US Digital E8P-512-118 single-ended optical shaft encoder. The complete specification sheet of the E8P optical shaft encoder is given in E8P Data Sheet.

## 2.2.7 Yaw Encoder

The encoders used to measure the yaw of the support yolk on the Quanser Aero is an optical encoder. It outputs 4096 counts per revolution in quadrature mode (1024 lines per revolution).

The encoders used to measure the yaw of the support yolk on the Quanser Aero is the US Digital E3-1024-984 optical encoder. The complete specification sheet of the E3 optical shaft encoder is given in E3 Data Sheet.

## 2.2.8 Inertial Measurement Unit

The Quanser Aero includes an integrated IMU mounted within the Aero body. This module allows for real-time measurement of the angular position and velocity along all three of the primary axes of the Aero body.

The IMU incorporated into the Quanser Aero is the STMicroelectronics LSM6DS0 iNEMO inertial module. Further information on the module can be found in the LSM6DS0 data sheet.

## 2.2.9 Data Acquisition (DAQ) Device

The Quanser Aero includes an integrated data acquisition device with four 16-bit encoder channels with quadrature decoding and two PWM analog output channels. The DAQ also incorporates a 12-bit ADC which provides current sense feedback for the motors. The current feedback is used to detect motor stalls and will disable the amplifier if a prolonged stall is detected.

## 2.2.10 Power Amplifier

The Quanser Aero circuit board includes a PWM voltage-controlled power amplifier capable of providing 2 A peak current and 0.5 A continuous current (based on the thermal current rating of the motor). The output voltage range to the load is between  $\pm 24$  V.

## 2.2.11 Power Supply

The Quanser Aero is equipped with an external DC power supply which provides power for the sensors and motors. This supply is intended for use with 100-240 VAC at 50-60 Hz.

Only the provided power supply and AC cord should be used with the Quanser Aero. The included supply is an Adapter Technology Co Ltd model ATS065-P241.

## 2.2.12 Embedded System Connector

The SPI data connector pictured on the QFLEX 2 Embedded in Figure 2.2d allows an external microcontroller to set motor voltage and LED brightnesses, read and set encoder counters, and read motor speed and current flow. See the QFLEX 2 Embedded data sheet for information on connecting the SPI interface.

## 2.3 Environmental

The Quanser Aero is designed to function under the following environmental conditions:

- Standard rating
- Indoor use only
- Temperature 5°C to 40°C
- Altitude up to 2000 m
- Maximum relative humidity of 80% up to 31°C decreasing linearly to 50% relative humidity at 40°C
- Pollution Degree 2
- Mains supply voltage fluctuations up to  $\pm 10\%$  of nominal voltage
- Maximum transient overvoltage 2500 V



- Marked degree of protection to IEC 60529: Ordinary Equipment (IPX0)

## 2.4 System Parameters

Table 2.2 lists and characterizes the main parameters associated with the Quanser Aero.

Symbol	Description	Value
<b>DC Motor</b>		
$V_{nom}$	Nominal input voltage	18.0 V
$\tau_{nom}$	Nominal torque	22.0 mN-m
$\omega_{nom}$	Nominal speed	3050 RPM
$I_{nom}$	Nominal current	0.540 A
$R_m$	Terminal resistance	8.4 $\Omega$
$k_t$	Torque constant	0.042 N-m/A
$k_m$	Motor back-emf constant	0.042 V/(rad/s)
$J_m$	Rotor inertia	$4.0 \times 10^{-6}$ kg-m <sup>2</sup>
$L_m$	Rotor inductance	1.16 mH
<b>Aero Body</b>		
$M_b$	Mass of body	1.075 kg
$D_m$	Center of mass	-7.59 mm
$J_p$	Pitch inertia	$2.15 \times 10^{-2}$ kg-m <sup>2</sup>
$J_y$	Yaw inertia	$2.37 \times 10^{-2}$ kg-m <sup>2</sup>
$D_t$	Thrust displacement	15.8 cm
<b>Motor and Pitch Encoders</b>		
	Encoder line count	512 lines/rev
	Encoder line count in quadrature	2048 lines/rev
	Encoder resolution (in quadrature)	0.176 deg/count
<b>Yaw Encoder</b>		
	Encoder line count	1024 lines/rev
	Encoder line count in quadrature	4096 lines/rev
	Encoder resolution (in quadrature)	0.088 deg/count
<b>Amplifier</b>		
	Amplifier type	PWM
	Peak Current	2 A
	Continuous Current	0.5 A
	Output voltage range (recommended)	$\pm 18$ V
	Output voltage range (maximum)	$\pm 24$ V

Table 2.2: Quanser Aero System Parameters

# 3 SYSTEM SETUP



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

## 3.1 Components

To setup the Quanser Aero system, you need the following components:

1. Quanser Aero (USB or Embedded version)
2. High and low-efficiency propellers
3. Propeller adapters
4. Power supply with the following ratings:
  - Input Rating: 100-240 V AC, 50-60 Hz, 1.4 A
  - Output Rating: 24 V DC, 2.71 A

**Note:** Only the power supply provided (AC-DC adapter by Adapter Technology Co Ltd, model ATS065-P241) should be used with the Quanser Aero

5. Power cable

**Note:** Only the power cable provided should be used with the Quanser Aero

**Note:** Make sure that the power cable is accessible for disconnection in case of emergency.



**Caution:** Precaution must be taken during the connection of this equipment to the AC outlet to make sure the grounding (earthing) is in place, and that the ground wire is not disconnected

6. USB 2.0 A/B cable (for QFLEX 2 USB) or jumper wires (for QFLEX 2 Embedded)

## 3.2 QFLEX 2 USB Hardware Setup

To setup the QFLEX 2 USB follow these steps:

1. The Quanser Aero should have one of the included sets of propellers installed. If the other propellers are required, follow the procedure for exchanging propellers in Section ?? **before** connecting power.
2. Connect USB 2.0 cable from back cover of Quanser Aero to an enabled USB 2.0 port on your desktop PC or laptop.
3. Connect the **Power** connector on the Quanser Aero to the power supply. Ensure the power supply is connected to a wall outlet using the appropriate power cable.
4. The QFLEX 2 USB driver should install automatically. If not, then you may not have installed all the required software to support the device including either **QUARC®** or **Quanser Rapid Control Prototyping Toolkit®**.

## 3.3 QFLEX 2 Embedded Hardware Setup

This section describes how to connect the QFLEX 2 Embedded to an external microcontroller board. The connection procedure is given below, and summarized in Table 3.1. The wires required to connect the QFLEX 2 Embedded are not included with the unit, connections may be made with jumper wires or a custom wiring solution dependent on the external controller being used.

Follow these steps to connect the QFLEX 2 Embedded to your microcontroller device:

1. Before proceeding make sure your microcontroller device has been setup and successfully tested. Refer to the documentation supplied with your control system for set up and testing instructions.
2. Make sure everything is powered off before making any of these connections. This includes turning off the external microcontroller board.
3. Connect the GND pin on the QFLEX 2 Embedded to a digital ground connection on the microcontroller board.
4. Connect the MOSI, MISO, and CLK pins on the QFLEX 2 Embedded to the microcontroller board as outlined in the SPI interface documentation for your controller.
5. Connect the CS pin on the QFLEX 2 Embedded to a digital output on the microcontroller board.
6. Connect the 1.8V-5V pin on the QFLEX 2 Embedded to a signal level power pin on the microcontroller board in the 1.8V to 5V range.



**Caution:** Applying voltages in excess of 5V to the 1.8V-5V input on the QFLEX 2 Embedded may result in damage to the QFLEX 2 Embedded.

Cable #	From Microcontroller	To QFLEX 2 Embedded	Signal
1	VCC/VDD(1.8V-5V)	1.8V-5V	QFLEX 2 Embedded interface power.
2	MOSI/SDO/SO	MOSI	SPI master out, slave in data line.
3	MISO/SDI/SI	MISO	SPI master in, slave out data line.
4	SCLK/SCK	CLK	SPI clock line.
5	Digital output line	CS	SPI slave select line.
6	GND/DGND	GND	SPI digital signal ground.

Table 3.1: QFLEX 2 Embedded wiring summary

## 3.4 Exchanging QFLEX 2 Panels

Follow these steps to install the QFLEX 2 USB or QFLEX 2 Embedded panel in your Quanser Aero.

1. Disconnect the 24VDC power input from the Quanser Aero.
2. Disconnect any connections between the currently installed QFLEX panel and the computer or microcontroller board.



**ESD Warning:** The interior of the Quanser Aero contains components which are sensitive to electrostatic discharge. Before opening the Quanser Aero case, ensure that both you and the workspace are properly grounded.

3. Remove the four screws at the corners of the QFLEX panel to release the panel from the Aero chassis. The Quanser Aero is shown in Figure 3.1 below with the screws removed.

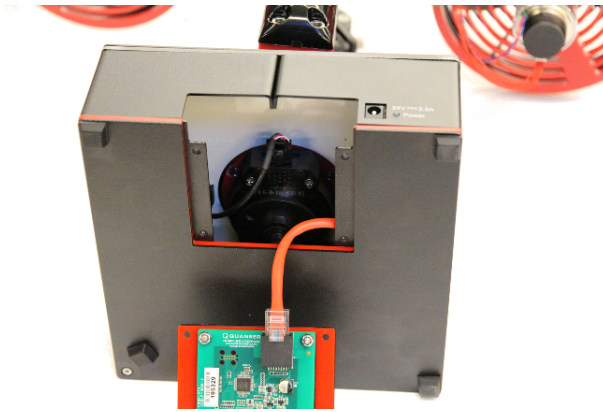


Figure 3.1: Quanser Aero with QFLEX panel detached.

4. Disconnect the Aero internal data cable from the QFLEX panel by depressing the latching tab.
5. Connect the Aero internal data cable to the QFLEX panel to be installed, pressing the connector into the socket until a click is heard and the connector latches in place.
6. Anchor the QFLEX panel in place using the four screws removed earlier.



**Caution:** Ensure that the Quanser Aero is completely reassembled, with all screws in place before connecting power or attempting operation.

## 3.5 Changing Thruster Orientation

Follow these steps to change the orientation of the thrusters on the Quanser Aero.

1. Use the included hex key to loosen the thruster rotation lock set-screw on the thruster you wish to rotate by one quarter turn as shown in Figure 3.2a



**Caution:** Do not loosen the set screws more than one half turn to prevent accidentally detaching the thruster assembly.

2. Rotate the propeller to the desired angle as shown in Figure 3.2b  
**Note:** Each thruster has a 90 degree range motion and will only rotate in one direction from either the vertical or horizontal positions.
3. Tighten the thruster rotation lock set-screw.

## 3.6 Exchanging Propellers

Follow these steps to change the propellers in the Quanser Aero.



**Caution:** The Quanser Aero is intended only for use with the included propellers. Operating the Quanser Aero with any other propellers may result in damage and/or injury.

1. Disconnect the 24VDC power input from the Quanser Aero.
2. Disconnect any connections between the currently installed QFLEX panel and the computer or microcontroller board.
3. Unfasten the propeller guard screws and remove the propeller guard.

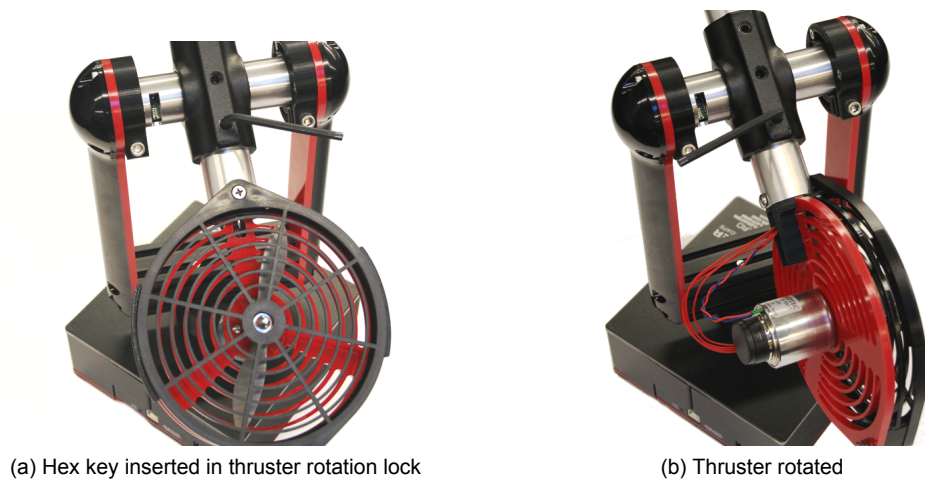


Figure 3.2: Quanser Aero propeller change steps

4. Insert a small hex key or similar object (not provided) through the cap of the propeller hub as shown in Figure 3.3a.
5. While holding the propeller still, loosen the collet in the propeller hub slightly by turning the cap counter-clockwise.
6. Pull gently on the propeller hub to slide the assembly off the motor shaft.
7. Disassemble the propeller hub as shown in Figure 3.3b



Figure 3.3: Quanser Aero propeller change steps

8. Identify the correct propeller from the counter-rotating pairs for the thruster being swapped. Under positive voltage, viewed from above, thruster 0 rotates counter-clockwise and thruster 1 rotates clockwise. Select the propeller such that positive voltage results in downward thrust. In the case of the high-efficiency propellers, the prop labeled 5x4.6E is intended for thruster 0, and that labeled 5x4.6EP is intended for thruster 1.
9. Slide the propeller assembly on to the motor shaft and tighten the cap.
10. Place the propeller cover back in position and replace the screws holding it in place.

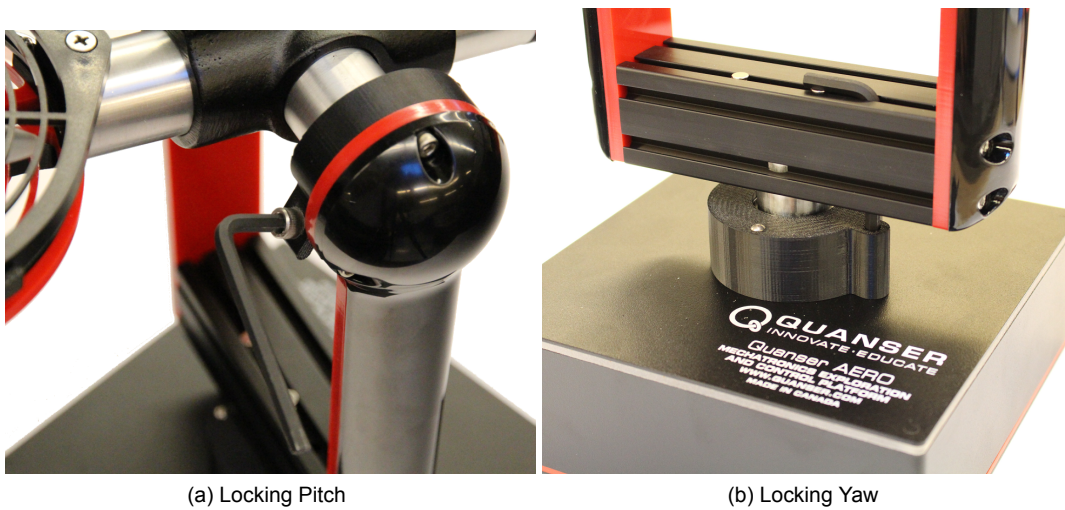


**Caution:** Ensure that the Quanser Aero is completely reassembled, with all screws in place before connecting power or attempting operation. The outer propeller guard screw must be fastened with the included lock nut. Improper assembly may result in damage and/or injury.

## 3.7 Pitch and Yaw Locks

To lock the pitch of the Aero body, use the included hex key to tighten the pitch lock screws as shown in Figure 3.4a

To lock the yaw of the yoke, remove the hex key from its storage location in the bottom of the yoke and reinsert it with the long arm of the key down as shown in Figure 3.4b. Once the key is inserted all the way and protruding from the bottom of the yoke, rotate the yoke clockwise until the key comes in contact with the magnetized stop on the yaw pivot.



(a) Locking Pitch

(b) Locking Yaw

Figure 3.4: Quanser Aero attitude locks

# Quanser aerospace and unmanned systems for teaching and research



These systems allow you to study or research traditional and modern controls applications relating to spacecraft, unmanned vehicles, rescue missions and autonomous control. For more information please contact [info@quanser.com](mailto:info@quanser.com)

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