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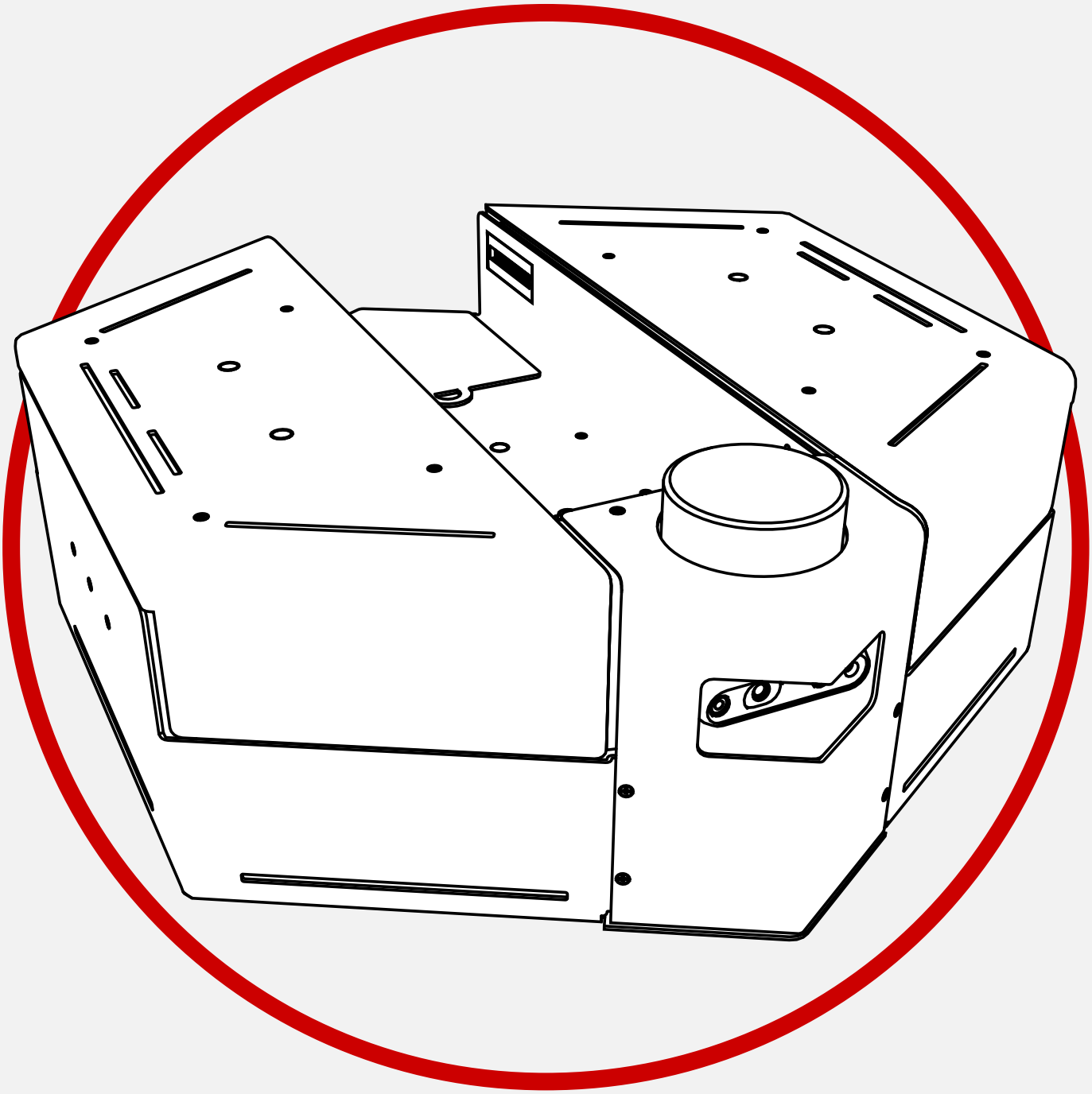

QBot Platform

User Manual – System Hardware

v 1.4 – 9*th Jan* 2025

For more information on the solutions Quanser offers,
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Caution

This equipment is designed to be used for educational and research purposes and is not intended for use by the public. The user is responsible for ensuring that the equipment will be used by technically qualified personnel only.
NOTE: While the GPIO, Ethernet and USB ports provide connections for external user devices, users are responsible for certifying any modifications or additions they make to the default configuration.

FCC Notice This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.
Contains FCC ID: SQG-60SIPT

Industry Canada Notice This Class A digital apparatus complies with CAN ICES-3 (A). Cet appareil numérique de la classe A est conforme à la norme NMB-3 (A) du Canada.
Contains IC: IC3147A-602230C

Waste Electrical and Electronic Equipment (WEEE)

This symbol indicates that waste products must be disposed of separately from municipal household waste, according to Directive 2012/19/EU 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.

CE Compliance CE

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

- 2014/35/EU; Low-Voltage Directive (safety)
- 2014/30/EU; Electromagnetic Compatibility Directive (EMC)
- 2014/53/EU; Radio Equipment Directive (RED)

Warning: This is a Class A product. In a domestic environment this product may cause radio interference, in which case the user may be required to take adequate measures.

Caution

The Leishen LiDAR M10P and the Intel RealSense D435 RGB-D camera are both classified as Class 1 Laser Products. The laser safety of both products meets the following standards:

- IEC 60825-1:2014
- 21 CFR 1040.10 and 1040.11 standards, except for conformance with IEC 60825-1 Ed. 3 as described in Laser Notice No. 56, dated May 8, 2019.

Do not power on the product if any external damage is observed. Do not open or modify any portion of any laser product as it may cause the emissions to exceed Class 1. Invisible laser radiation when opened. Do not look directly at the transmitting laser through optical instruments such as a magnifying glass or microscope. Do not update laser product firmware unless instructed by Quanser.

Caution

ESD Warning. The QBot Platform internal components are sensitive to electrostatic discharge. Before handling the QBot Platform, ensure that you have been properly grounded.

Table of Contents

A. Hardware Components

The main QBot Platform components are listed in Table 1. These components are ID marked in Figures 1 through 4, which present the front, back, top, and bottom views of the QBot Platform.

ID	Component	ID	Component
1	LeiShen LiDAR M10P	10	User LEDs
2	Magnetic Attachment Points	11	Base Camera OV9281-160
3	Expandable I/O	12	Embedded Computer
4	10/100/1000 Base-T Ethernet jack	13	Drivetrain
5	4 Port - USB3.0 Hub	14	Caster Wheels
6	HDMI connector	15	LFP batteries and battery bays
7	LCD display	16	LFP battery connector
8	Push Button Power Switch	17	Intel RealSense D435 RGBD camera
9	Landing Plate	18	QArm Mini Cover

Table 1. QBot Platform Components

	ESD WARNING	The QBot Platform internal components are **sensitive to electrostatic discharge**. Before handling the QBot Platform, ensure that you have been properly grounded.
	CAUTION	The QBot Platform has a **max payload of 20 kg**. Do not sit or stand on the robot.
	CAUTION	The QBot Platform is **not waterproof**.
	WARNING	Users are **advised against tilting the robot** on its side. Contact Quanser technical support for guidance if tilting is necessary.
	WARNING	Motors: Hot Surface! Wheel motors can exceed 50˚C/120˚F during operation. **Do not touch motors** until the unit has cooled down.

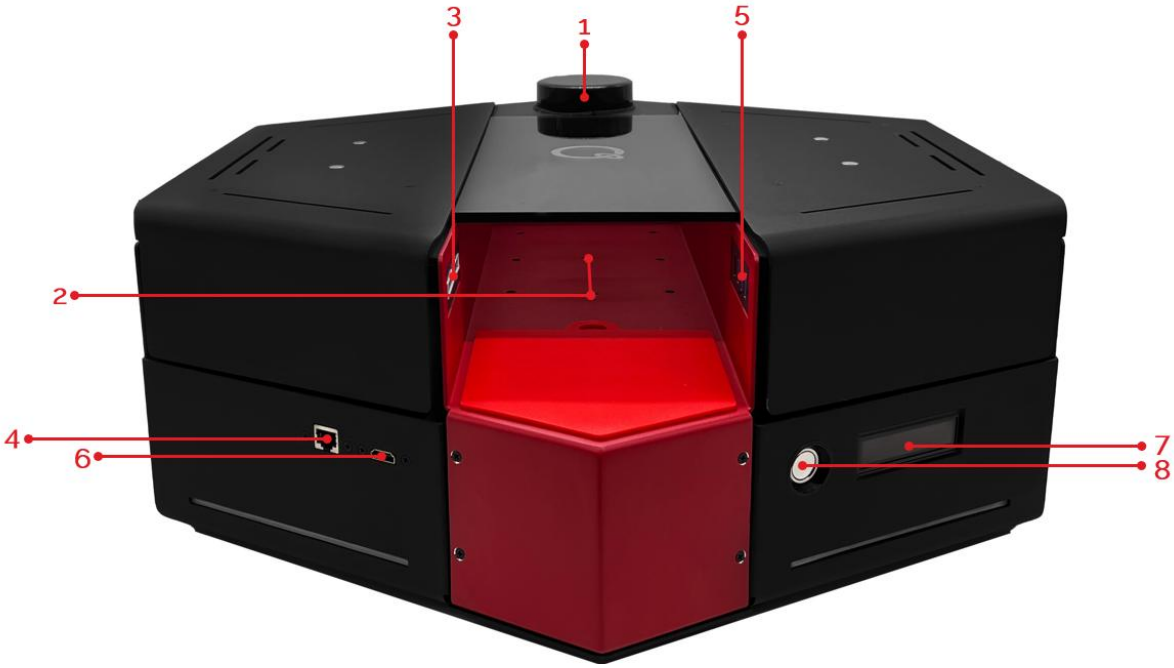


Figure 1: Back view

Figure 2: Front view

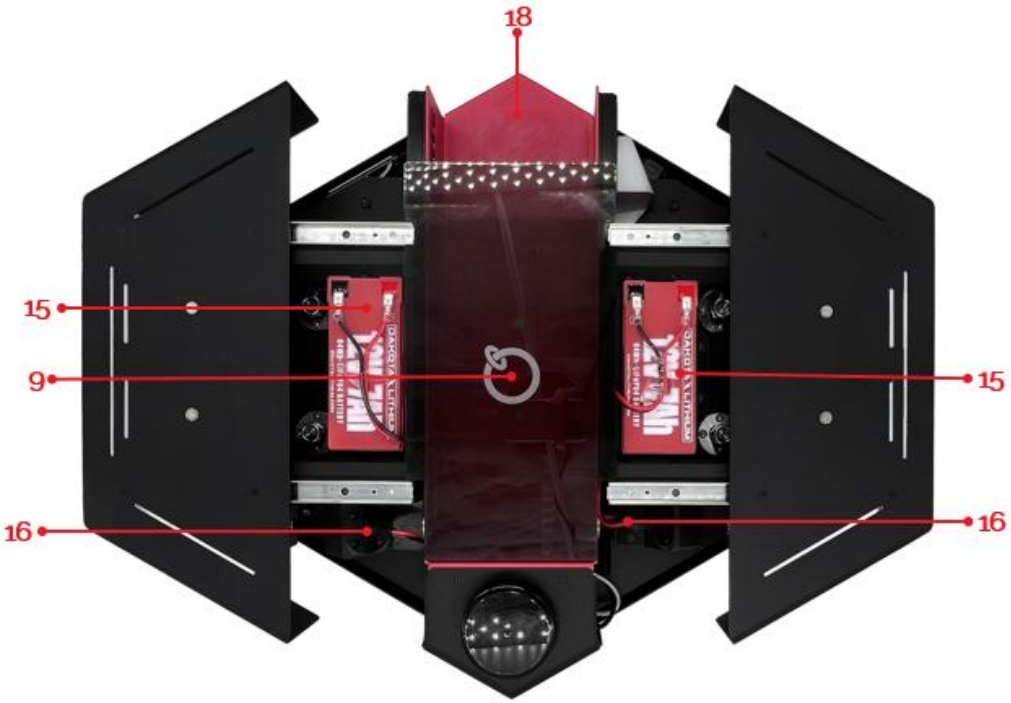


Figure 3: Top view

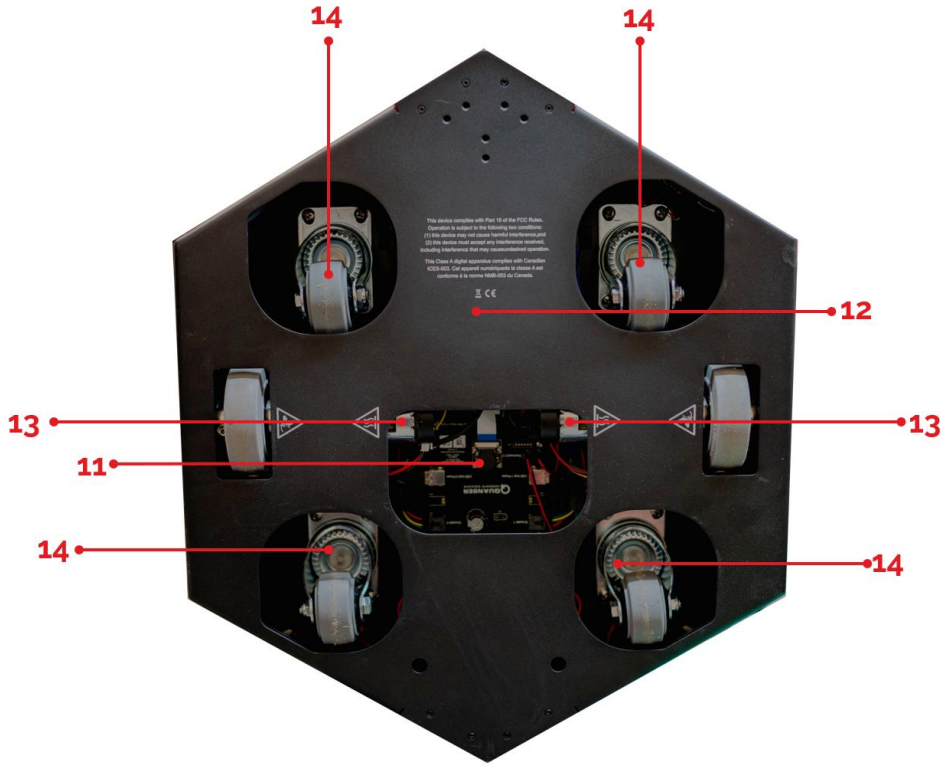


Figure 4: Bottom view

i. Embedded Computer

The QBot Platform is powered by an NVIDIA Jetson Orin Nano on an AverMedia D131-L carrier board. Please see the datasheets available in the ancillary materials directory.

Figure 5. NVIDIA Jetson Orin Nano

The NVIDIA module includes a 6-core ARM Cortex-A78AE v8.2 64-bit SCPU with 64-bit LPDDR5 memory as well as a 512-core NVIDIA Ampere architecture GPU. The carrier board provides numerous peripheral inputs/outputs to the user that are exposed at the QBot Platform's body surface for user interfacing. A heat sink and fan are also provided to cool the NVIDIA module appropriately. See section A.ix. for more details on available peripherals.

ii. LiDAR

The QBot Platform comes equipped with a Leishen LiDAR M10P as shown below. This 2D planar LiDAR supports 1680 points per sample for a revolution at 10 samples per second and has a sensing range of up to 10m. The scanning frame rate and corresponding samples per revolution are summarized in Table 2 below. More information on this LiDAR can be found in the attached datasheets. The LiDAR is Class I and eye-safe, with a wavelength of 905nm. The recommended operation parameters have been shown in Table 2.

Figure 6. Leishen LiDAR M10P

Frequency (Hz)	Samples per revolution	Angular Resolution (degrees)
10 Hz	1680	0.214°

Table 2. Achievable frame rates and samples per revolution for the Leishen LiDAR M10P

This LiDAR uses a 6-pin serial connector, that is connected to the NVIDIA carrier board via an OTS USB-to-serial connector.

iii. Intel RealSense D435 Camera

The QBot Platform comes equipped with an Intel RealSense D435 RGB-D camera. It includes an IR projector and two IR imagers, making this unit a stereo tracking solution. The FOVs have been summarized in Table 3. The camera can provide RGB, Infrared (left and right) and depth

streams of data at a variety of frame rates and resolutions, with the most common ones summarized in Table 4. For typical resolutions requested, it provides the maximum frame rate as well as the maximum resolution supported at that frame rate. More information can be found here.

Figure 7. Intel RealSense D435 RGBD camera

Camera	Horizontal	Vertical	Diagonal
RGB	69.4˚ ± 3˚	42.5˚ ± 3˚	77˚ ± 3˚
Depth	87˚ ± 3˚	58˚ ± 1˚	95˚ ± 3˚

Table 3: Field of Views (FOV)

RGB		Depth	
Typical (max) Resolution	Max Frame Rate	Typical (Max) Resolution	Max Frame Rate
640 x 480 (960 x 540)	60	848 x 100	100
1280 x 720 (1920 x 1080)	30	640 x 480 (848 x 480)	90
-	-	1280 x 720	30

Table 4: Intel RealSense resolutions and frame rates

iv. Downward Facing Global Shutter CSI Camera

The QBot Platform provides a grayscale global-shutter CSI camera (Figure 4 item 11 and Figure 8) underneath the robot at a slight offset towards the front of the robot for line following. The camera has a lens providing up to 160˚ Diagonal-FOV. See Table 5 for more information.

Note: these resolutions are typically used for capture and processing. Consider reducing frame rates to 30Hz or lower when displaying images from remote targets such as the QBot Platform for Wi-Fi considerations. Image compression can also serve as a useful tool to reduce bandwidth impact.

Figure 8: Downward Facing CSI camera

Resolution	Max Frame Rate (FPS)
1280 x 800	120 fps
1280 x 720	130 fps
640 x 380	180 fps
640 x 400	210 fps

Table 5. Achievable frame rates and FOVs for CSI camera

v. Drivetrain

The QBot Platform comes equipped with two motors. The motor parameters are listed in Table 6. There are firmware velocity controllers implemented for both motors accepting velocity commands, with an option to bypass them for application velocity controllers. There is also firmware level protection implemented for Stall as well as Overcurrent.

The qbot_platform_driver_physical real-time application must be used with the QBot Platform. See the **Driver model** section in the Software User Manuals for Simulink and Python for more information.

Symbol	Description	Value
R_m	Terminal resistance	0.923 Ω
k_t	Torque constant	0.1397 Nm / A
k_m	Motor back-emf constant	0.1397 V/(rad/s)

Table 6: Drive motor parameters

Stall protection

If the PWM duty cycle commands **P** are greater than 25% (0.25) and the motor velocity is under 43 counts/sec (approximately $\pi/4$ rad/s), then a stall warning will be issued in the Digital channels through the HIL driver. If the stall warning is consistently held for **T** seconds, a stall error is triggered and both motor PWMs are disabled for safety, with the LCD showing a `Motor error: STALL` message. Ensure that the QBot Platform is not stuck behind any obstacles and can move freely and re-enable the motors. The duration **T** depends on the PWM **P** applied as below

PWM P (%)	Duration T (s)
≤ 25.0	∞
> 25.0	15.0
> 30.0	5.0
> 40.0	1.0
< 70.0	0.2

For PWM values in between, linear interpolation is used. As an example, applying a continuous PWM command of 0.35 (35%) while stalling the QBot Platform will trigger a stall in 3.0 seconds.

Note: The user cannot apply a PWM larger than 70%. A lower limit can be set in the HIL Initialize block in the qbot_platform_driver_physical.slx application.

Note: Any examples supplied with the QBot Platform do not move the robot at speeds under $\pi/4$ rad/s per wheel. This corresponds to an approximate body forward velocity of 3 cm/s and a body turn velocity of $\pi/20$ rad/s.

Overcurrent protection

Onboard overcurrent protection from the firmware will ensure that either motor enters an Overcurrent state if the following conditions are met,

1. current draw of 4 Amps continuously for 6 seconds
2. current draw of 6 Amps continuously for 4 seconds
3. current draw of 8 Amps continuously for 3 seconds
4. current draw of 10 Amps continuously for 2.4 seconds
5. current draw of 12 Amps continuously for 2 seconds

Once in the Overcurrent state, the LCD will show a `Motor error: OVERCURRENT` message and both motors PWMs are disabled for safety. Ensure that the QBot Platform can freely move and consider reducing the payload based on the desired trajectory/commands and re-enable the motors.

Encoder

The QBot Platform includes two pre-gear encoders used to measure the angular position of each motor. The encoders provide 17 counts per revolution with a gear ratio of 5:1 reducing speed and increasing torque. At the output shaft, this provides 85 counts per revolution in normal mode or 340 counts per revolution in quadrature mode.

A hardware encoder-based speed measurement is also available from the firmware on the Other channels in the HIL driver (channels 14000 and 14001). This is based on the time between encoder edges, and is considered a 'hardware velocity', available in counts/s. A version of this velocity in rad/s is also available in the other channels in the HIL driver (channels 3003 and 3004)

The motor and encoder's datasheet can be found in the supplementary manuals attached here.

vi. Battery

The QBot Platform uses a 12V 7Ah battery (84Wh) Lithium Iron Phosphate (LFP or LiFePO4) battery (Figure 9a). The battery can be charged using the provided Optimate lithium battery charger (Figure 9b). For more information, see the User Manual - Power document. We have included a firmware limit for the battery to protect the robot and battery for long term use. Current draws for various components have been listed in Table 7. For example, if both the LEDs are set to red ($0.33\ A$) and the robot is driving continuously while streaming both cameras and the LiDAR, the total current draw should be $3.50\ A$, which yields an estimate operation time of $2\ hrs$ for a $7Ah$ battery per battery.

Please carefully review the safety guidelines for using Lithium Iron Phosphate batteries listed after Table 7 before using the product.

a. 12V 7Ah 84Wh LFP battery

b. Optimate lithium battery charger

Figure 9. LFP battery and charger provided with the QBot Platform

Component	Approx. Current Draw
RealSense camera	$0.700\ A$
Leishen M10P LiDAR	$0.400\ A$
Downward camera	$0.150\ A$
LEDs (per channel per side, e.g. x6 multiplier for white)	$0.165\ A$
Electronics current	$0.500\ A$
Both motors running at nominal speeds 0.7 m/s	$1.410\ A$

Table 7. Current draws for various components of the QBot Platform

Caution: Before using any batteries, chargers/balancers, or power supplies, users must first read the manuals packaged with their equipment. Quanser supplies these guidelines for charging batteries, but it is the users' responsibility to ensure they are operating their equipment safely and correctly. Quanser is not responsible for any damages resulting from use of batteries, power supplies, chargers, or balancers.

Caution: Prior to using the QBot Platform, visually check the battery for bloating or damage. If the battery exhibits bloating **DO NOT USE** it. Visual bloating of the battery is dangerous - discard it in accordance with your country's relevant recycling and disposal laws

⚠ **Caution**: Do not charge the battery under direct sunlight.

⚠ **Caution**: Keep LFP batteries away from children and animals.

⚠ **Caution**: Never charge a LFP battery or battery charger that has been punctured or damaged in a crash. After a crash, inspect the battery or charger for signs of damage. Protect your LFP batteries from accidental damage during storage and transportation. Do not put batteries in pockets or bags can encounter sharp or metallic objects.

⚠ **Caution**: Do not use batteries unless supplied by Quanser. If you require additional batteries, please contact Quanser.

⚠ **Caution**: A LFP battery left deep-discharged for an extended period may develop permanent damage in one or more cells. Such batteries may heat up excessively while charging. Always monitor battery temperature during the first hour, then hourly there-after. If at any time the battery is uncomfortably hot to touch or you notice any unusual signs, disconnect the charger immediately.

⚠ **Caution**: Do NOT attempt to disassemble, modify, or repair the LFP battery.

Note: When discarding a LFP battery, discard it in accordance with your country's relevant recycling and disposal laws.

vii. IMU

The QBot Platform includes a 6-axis IMU. There is a 16-bit accelerometer and gyroscope. The spec sheet for the part is attached here.

viii. Dimensions

Index	Item	Value
1	Length	$0.575\ m$
2	Width	$0.500\ m$
3	Height (with lidar)	$0.215\ m$
4	Wheelbase Width (tire center to center)	$0.393\ m$
5	Tire diameter	$0.0889\ m$

Table 8. QBot Platform dimensions

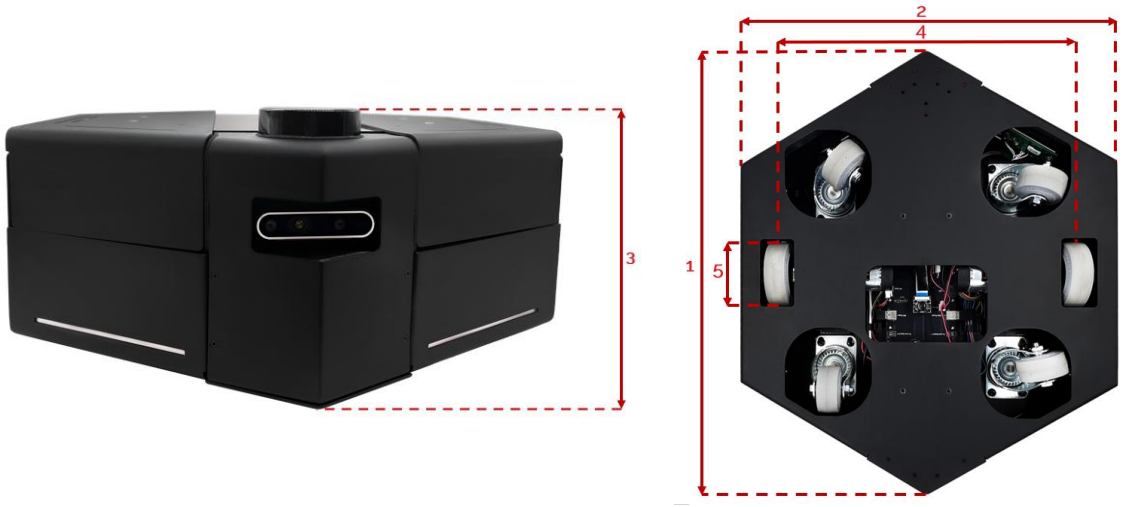


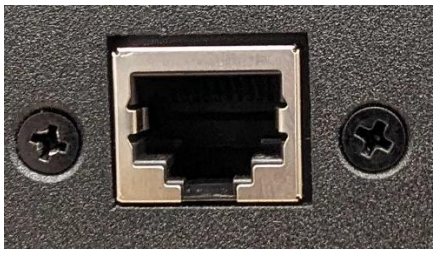
Figure 10. QBot Dimensions

ix. Peripherals

The QBot Platform features accessible ports, including HDMI and Ethernet, the 40-pin GPIO interface from the embedded computer, and a powered USB hub for additional peripheral connections. The top face of the QBot includes slots for convenient attachment of fiducial markers or custom solutions, while a centrally located slot hole on the side of the QBot Platform facilitates the neat routing of wires and cables.

Note: In figure 11c, the bottom left pin is pin #1

a. Powered USB Hub



b. Ethernet Port

c. GPIO pins from Embedded Computer

d. HDMI Port

Figure 11: Designated locations on the QBot Platform intended for the attachment of peripherals.

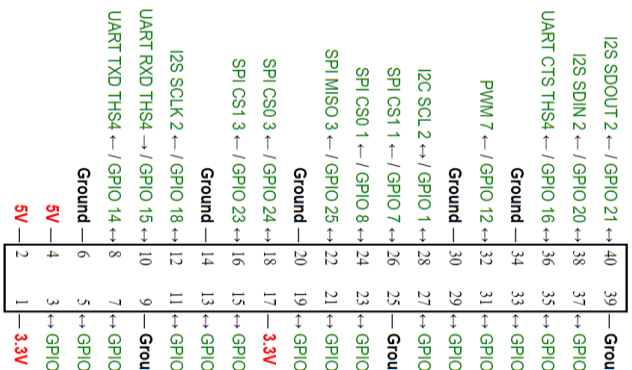


Figure 12: 40-pin GPIO configuration

x. Landing Plate

Each QBot Platform comes with its own landing plate. The landing plate can be removed or installed depending on your use. To install the landing plate simply open the wings and place down your landing plate snuggly around the rails and close the wings again. See Figure 13.

Figure 13: QBot Platform Landing Plate Installation Steps

xi. Environmental

The QBot Platform is designed to function under the following environmental conditions,

1. Standard rating
2. Indoor use only
3. Temperature range of 5°C to 40°C
4. Altitudes up to 2000 m
5. Maximum relative humidity of 80% up to 31°C decreasing linearly to 50% at 40°C
6. Pollution degree 2
7. Mains supply voltage fluctuations up to 10% of nominal voltage
8. Maximum transient overvoltage 2500 V
9. Marked degree of protection to IEC60529: Ordinary Equipment (IPX0)

B. Mats and Walls Setup

Each QBot Platform Bundle comes with a set of mats and walls for education and research purposes. In case you have not acquired the QBot Platform Bundle, each QBot Platform comes with a testing mat as shown in Figure 14. This mat is to be used as a guideline for building your own setup. The recommended setup is shown in Figure 15. The QBot Platform Bundle also contains walls (see Figure 16) for setting up a perimeter around the mats in challenging environments for the LiDAR (larger than 12 m in diameter or containing dark objects).

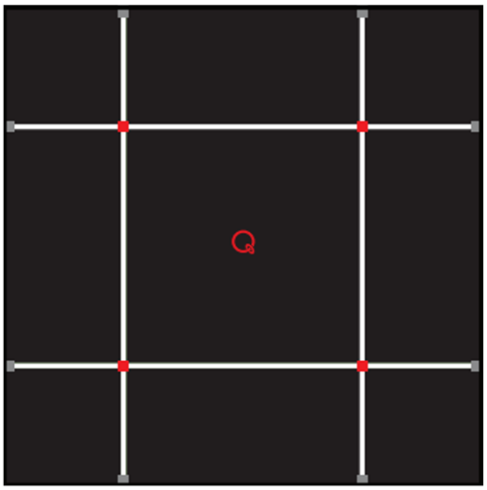


Figure 14: Testing Mat

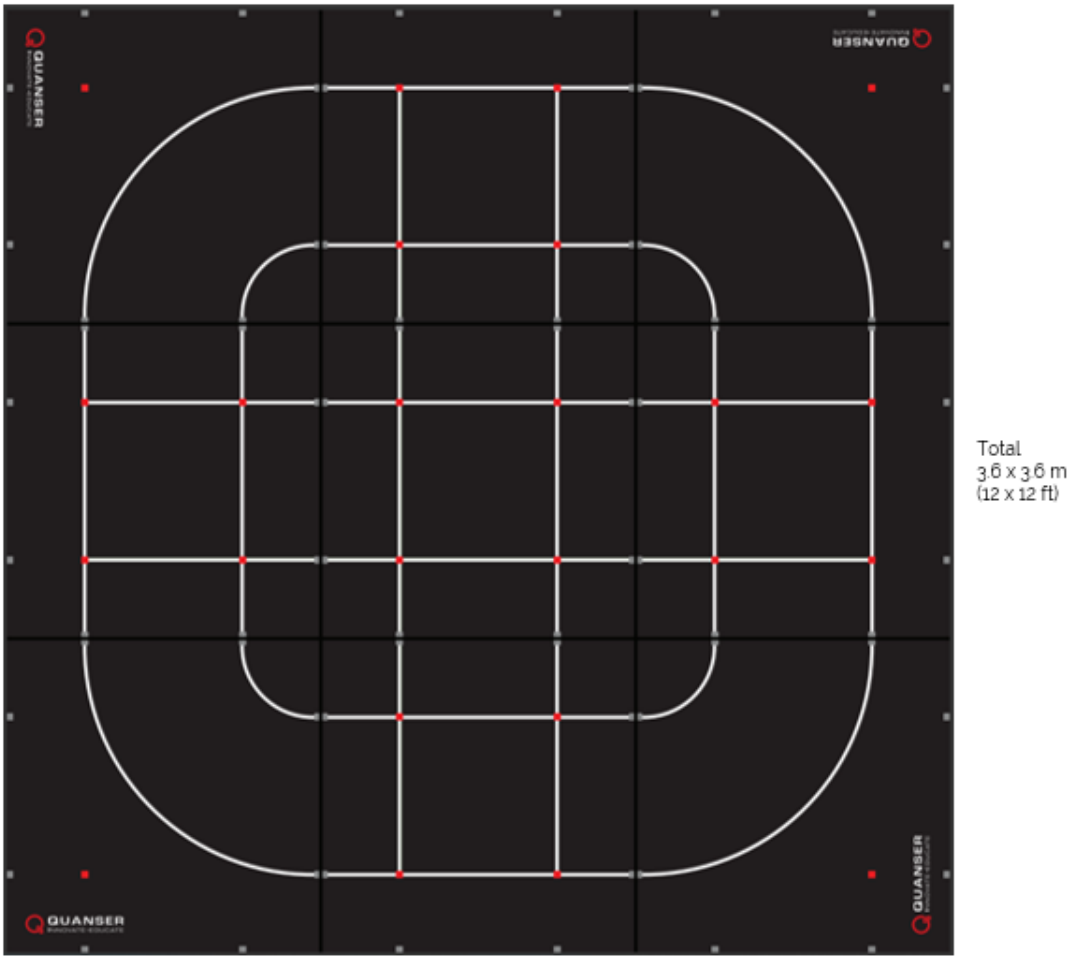


Figure 15: Recommend Mat Layout for the QBot Platform Bundle with dimensions.

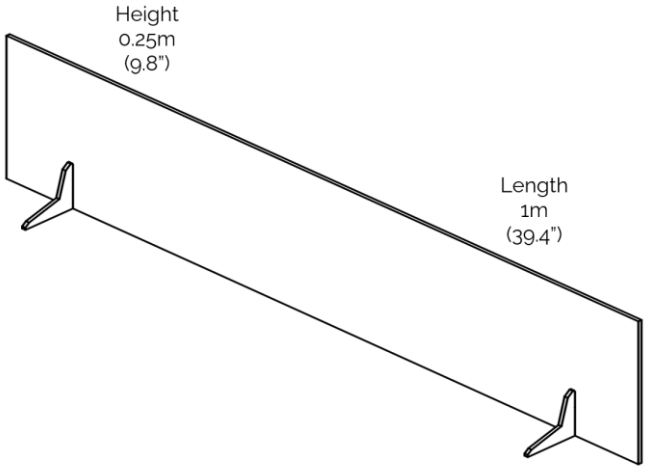


Figure 16: QBot System walls with dimensions

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