

Kobuki User Guide



i c l e b o
Kobuki

Version 1.1.0
2017/03/15

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About

Introducing Korea's first robotic turtle.

kobuki [거북이] n. turtle

Kobuki is robotically engineered to be long-lived, tough and fast. With high performance batteries, Kobuki will tirelessly work alongside you through those long coffee-powered nights. He'll also happily burden himself with your modded array of sensors, actuators, laptops, embedded boards, portside cannons and do it all at a speed that makes his real world cousins seem like ... well, turtles.

Use him for serving 차|맥 (chi-mek), chasing your neighbour's kids or simply, to make your own robot ideas become reality.

Kobuki is still young, don't expect him to remain as he is . Kobuki's development has already been significantly influenced by the community and as he marches towards old age, we will continue to work with the community and you to ensure he becomes better with time.

Sincerely,
Kobuki Team.

Basic Usage

Make sure be aware of the [safety guidelines](#).

Charging

Connect the power adapter to Kobuki or dock Kobuki in the docking station. If Kobuki is turned on, you will hear a short sound when charging starts and the LED will light up appropriately.

- Green : fully charged
- Blinking Green : charging
- Orange : low battery

Tip: the battery still charges if Kobuki is off, but you will not see the LED, nor hear sounds

First Run

You want to see Kobuki in action without further ado? Kobuki has a special random walker mode embedded into the firmware which you can activate on start-up:

1. Turn on Kobuki.
2. Within the first 3 seconds press the B0 button and hold for 2 seconds.
3. LED2 will start blinking and Kobuki wander around.

Tip: this was introduced to the firmware in v1.1.0. In case your kobuki is not running this or a later version, please refer to the section about [updating the firmware](#).

Software

In order to gain access to all of Kobuki' s features, you will need an external computing unit (pc/laptop/tablet/embedded board) with software which communicates with Kobuki. Officially supported systems include:

Build Your Own Kobuki Driver	Linux C++ Application	Kobuki for ROS
Use the Serial Protocol	Use the Kobuki C++ Driver	Use the Kobuki ROS World

Alternatively, you can get started with the [Turtlebot 2 Platform](#) which runs on a Kobuki base.

Info: other platforms have had experimental support at one stage or another (windows/arduino/android).

Problems

Reach out on the following channels:



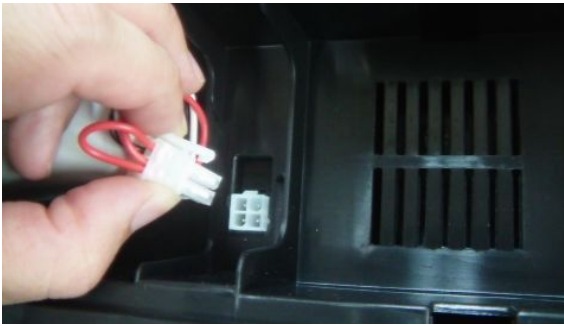
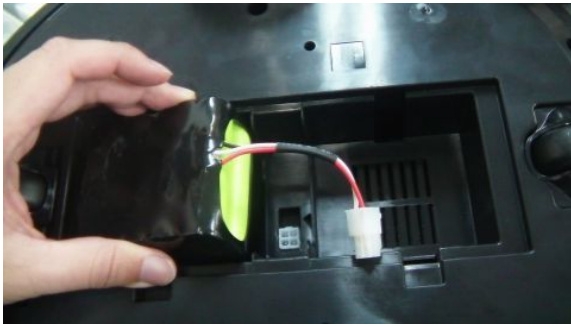


- Kobuki User's Mailing List: kobuki-users@yujinrobot.com
- ROS Community Answers: <http://answers.ros.org/questions/tags%3Akobuki>
- Yujin Sales Support: kobuki@yujinrobot.com

Note: Kobuki comes with a 1 year warranty. In case you bought Kobuki from another one of Yujin Robot's distributors, please contact them, otherwise email Yujin Sales Support.

Advanced Usage

Replacing Batteries

Warning: the electronics does not support the use of multiple battery packs at the same time!

	
Flip the kobuki	Open the case
	
Unplug	Swap batteries
	
Replug	Replace the case

Updating Firmware

If you have a ROS installation, you can find the current version by running:

```
$ rosrn kobuki_driver version_info
# Version Info:
* Hardware Version: 1.0.4
* Firmware Version: 1.2.0
* Software Version: 0.7.7
* Unique Device ID: 97713968-842422349-1361404194
```

Alternatively you can compile [version_info.cpp](#) (no ROS) to create your own version checker.

Linux

The Flashing Utility

```
# Download & build the flashing utility
$ wget http://files.yujinrobot.com/kobuki/firmware/stm32flash-0.4.tar.gz
$ tar -xvzf stm32flash.tar.gz
$ cd stm32flash
$ make
```

Download the Firmware

```
# choose the firmware version from http://files.yujinrobot.com/kobuki/firmware
# e.g. latest
$ wget http://files.yujinrobot.com/kobuki/firmware/kobuki\_firmware-latest.hex
```

Identify the ttyUSBx Port

If you have a udev rule installed, it will show up as `/dev/kobuki`, but if not, you can typically find it under one of the ttyUSB ports, e.g. `/dev/ttyUSB0`. If you are not sure, type `dmesg` into a terminal, unplug and replug the robot and type `dmesg` again. You should now be able to see which port is assigned to the robot (more precisely the FTDI USB to serial converter).

Switch to Download Mode

1. Connect the robot to your PC using the USB cable
2. Turn off the robot (switch on the side)
3. Switch from normal runtime mode to firmware download mode

This simply changes the type of data that is sent back and forth along the usb connection. You can do this by moving the switch illustrated below into the 'download' (up) position. Note that this switch is embedded into the robot cover so it isn't easily thrown by accident – you may need thin plyers or some similar tool. You can find the mode switch mechanism on the right side of the control panel - see the image below.



Flashing

Note: The following instructions assume flashing of `kobuki_firmware-latest.hex` and port `/dev/ttyUSB0`. Modify these if necessary.

Warning: you need to execute the flashing command IMMEDIATELY after turning the robot on!

1. Turn off the robot
2. Check that the switch is in download mode
3. Turn on the robot

```
$ ./stm32flash -b 115200 -w kobuki_firmware_firmware-latest.hex /dev/ttyUSB0
stm32flash 0.4

http://stm32flash.googlecode.com/

Using Parser : Intel HEX
Interface serial_posix: 115200 8E1
Version      : 0x22
Option 1     : 0x00
Option 2     : 0x00
Device ID    : 0x0414 (High-density)
- RAM        : 64KiB (512b reserved by bootloader)
- Flash      : 512KiB (sector size: 2x2048)
- Option RAM : 16b
- System RAM : 2KiB
Write to memory
Erasing memory
Wrote address 0x0800a3f0 (100.00%) Done.
```

Rebooting

- Turn off the robot power
- Flick the firmware switch back to 'Operation' mode.
- Turn on the robot power
- I'm happy, you should be too!

Windows

The Flashing Utility

- Download and install the [windows flashing utility](#)

Download the Firmware

Find and download the version of the firmware you wish to flash from the [Kobuki FW File Server](#).

Identify the COM Port

Usually if this will show up on COM1, but check to make sure.

Switch to Download Mode

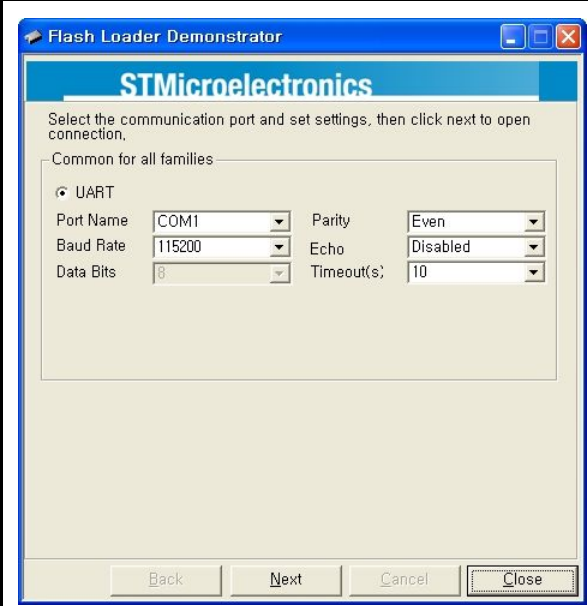
1. Connect the robot to your PC using the USB cable
2. Turn off the robot (switch on the side)
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This simply changes the type of data that is sent back and forth along the usb connection. You can do this by moving the switch illustrated below into the 'download' (up) position. Note that this switch is embedded into the robot cover so it isn't easily thrown by accident – you may need thin plyers or some similar tool. You can find the mode switch mechanism on the right side of the control panel - see the image below.



Flashing

1. Turn off the robot
2. Check that the switch is in download mode
3. Turn on the robot



Flash Loader Demonstrator

STMicroelectronics

Select the communication port and set settings, then click next to open connection.

Common for all families

☒ UART

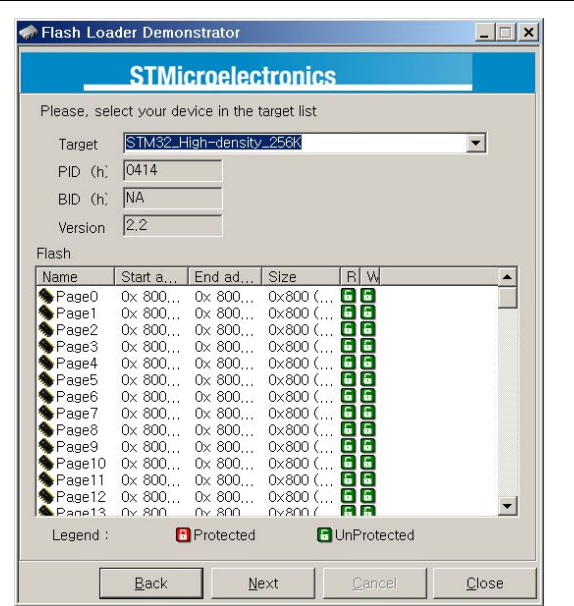
Port Name: COM1 Parity: Even

Baud Rate: 115200 Echo: Disabled

Data Bits: 8 Timeout(s): 10

Back Next Cancel Close

Configure Properties



Flash Loader Demonstrator

STMicroelectronics

Please, select your device in the target list

Target: STM32_High-density_256k

PID (h): 0414

BID (h): NA

Version: 2.2

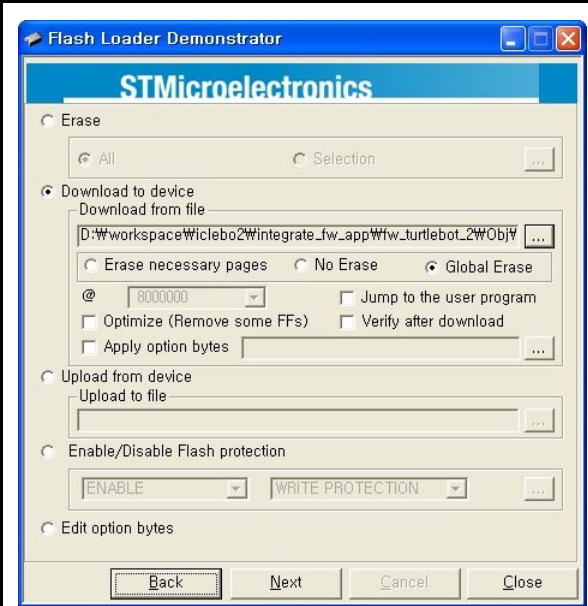
Flash

Name	Start address	End address	Size	R	W
Page0	0x 800...	0x 800...	0x800 (...)		
Page1	0x 800...	0x 800...	0x800 (...)		
Page2	0x 800...	0x 800...	0x800 (...)		
Page3	0x 800...	0x 800...	0x800 (...)		
Page4	0x 800...	0x 800...	0x800 (...)		
Page5	0x 800...	0x 800...	0x800 (...)		
Page6	0x 800...	0x 800...	0x800 (...)		
Page7	0x 800...	0x 800...	0x800 (...)		
Page8	0x 800...	0x 800...	0x800 (...)		
Page9	0x 800...	0x 800...	0x800 (...)		
Page10	0x 800...	0x 800...	0x800 (...)		
Page11	0x 800...	0x 800...	0x800 (...)		
Page12	0x 800...	0x 800...	0x800 (...)		
Page13	0x 800...	0x 800...	0x800 (...)		

Legend: ■ Protected ■ UnProtected

Back Next Cancel Close

Check that the target is identified



Flash Loader Demonstrator

STMicroelectronics

☐ Erase

☒ Download to device

Download from file

D:\workspace\Wiclebo2\Integrate_fw_app\fw_turtlebot_2\Obj\...

☐ Erase necessary pages ☐ No Erase ☒ Global Erase

@ 8000000 ☐ Jump to the user program

☐ Optimize (Remove some FFs) ☐ Verify after download

☐ Apply option bytes

☐ Upload from device

Upload to file

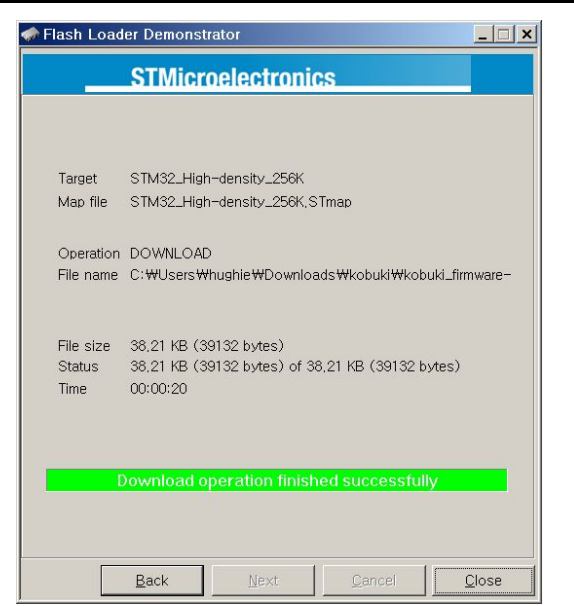
☐ Enable/Disable Flash protection

ENABLE WRITE PROTECTION

☐ Edit option bytes

Back Next Cancel Close

Enter the Download from file (your .hex)



Flash Loader Demonstrator

STMicroelectronics

Target: STM32_High-density_256K

Map file: STM32_High-density_256K.STmap

Operation: DOWNLOAD

File name: C:\Users\Whughe\Downloads\Wkobuki\Wkobuki_firmware-

File size: 38,21 KB (39132 bytes)

Status: 38,21 KB (39132 bytes) of 38,21 KB (39132 bytes)

Time: 00:00:20

Download operation finished successfully

Back Next Cancel Close

Success!

Rebooting

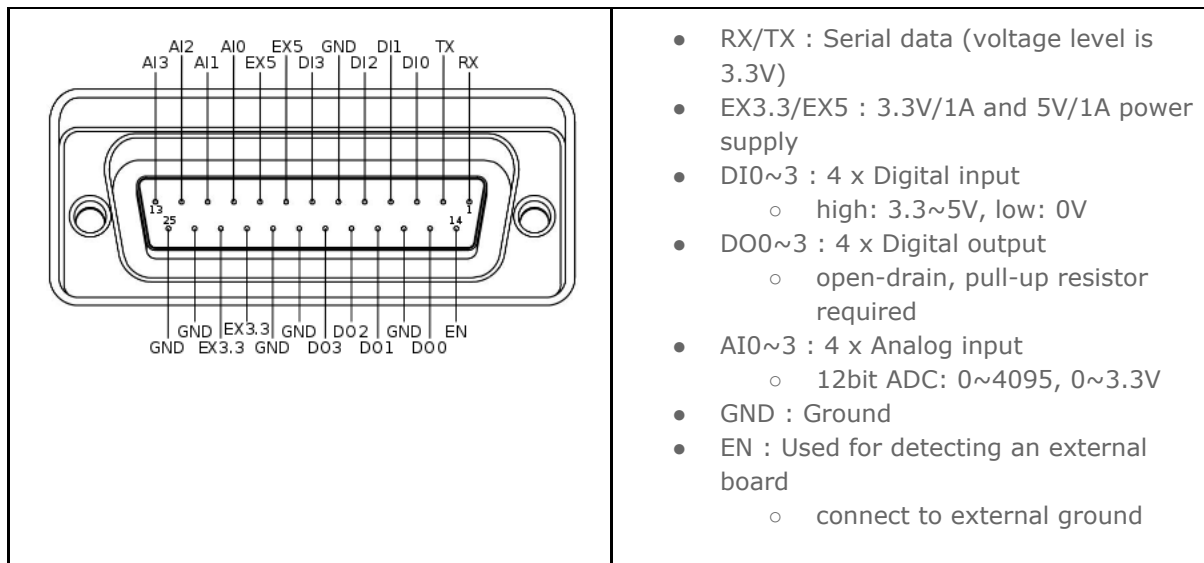
1. Turn off the robot power
2. Flick the firmware switch back to 'Operation' mode.
3. Turn on the robot power
4. I'm happy, you should be too!

Serial Port Connectivity

Many embedded boards do not have usb interfaces, or the embedded board doesn't have the necessary ftdi32 serial->usb support. In these cases it is simpler to utilise the serial port on Kobuki's expansion port to driving kobuki by serial interface instead of USB.

Pinouts

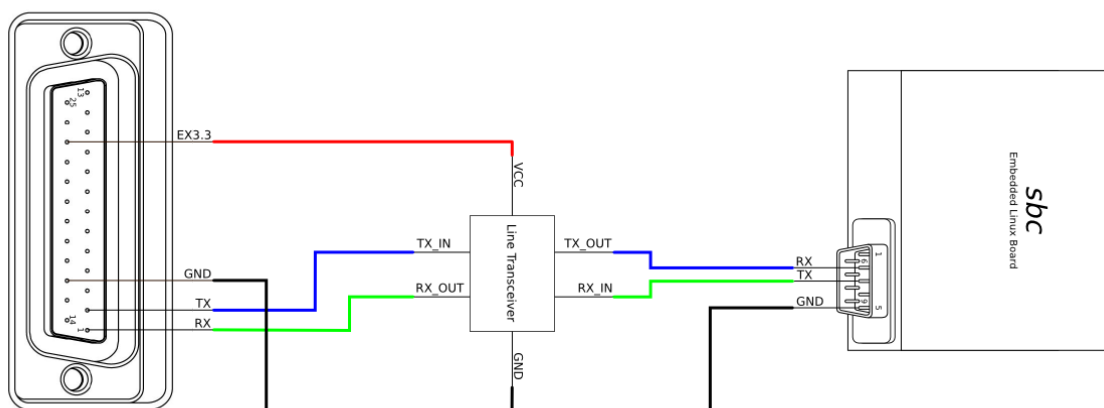
Pictured below are the pinouts of Kobuki's expansion port, include the serial pins. The minimum number of required pins for serial communication is three; TX, RX, and GND. Additionally EX3.3 or EX5 can be used for powering external devices, such as line transceiver.



Connections

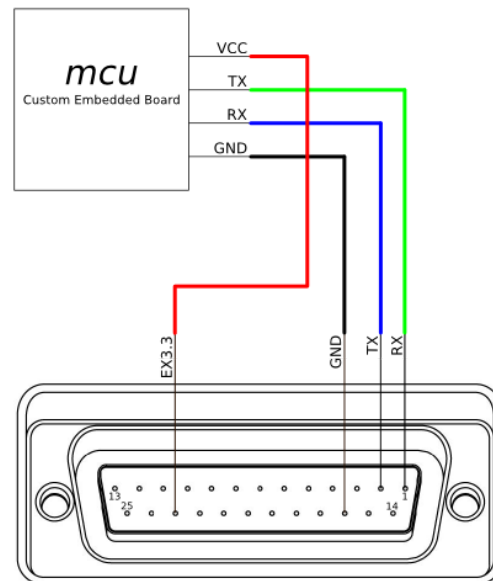
a) RS-232 Interface

The voltage level of serial port is 3.3V. To connect kobuki with the standard [RS-232](#) serial port, you should use line transceiver in the middle to convert voltage level. [MAX232](#) chip is typical solution for it. Below diagram show simplified typical example of connections between Kobuki and [SBC](#) (your embedded board, laptop or pc). EX3.3 pin is used to powering line transceiver. It can be EV5 pin or external power sources from outside.



b) Logic Level Interface

To connect kobuki with serial port of [MCU](#) directly, below is the simplest connection diagram can be used. Serial pins of kobuki are 5V-tolerant. It accepts 3.3V and 5V voltage levels typically used by integrated circuit. Connection with power pin(EX3.3 or EX5) is optional, if you powering MCU with independent sources, such as battery, or wall adaptor.



Building An Application

If you're using the ROS implementation, or building atop the kobuki c++ driver, simply re-configure the port string used for the application and everything should be ready to go.

If building an **experimental driver** from scratch (e.g. android driver), then you will need to implement the [Kobuki Protocol](#) specification.

Adding a Custom Sensor Array

Kobuki usually gets equipped with a 3d sensor. These typically have limitations as obstacle avoidance sensor:

- Narrow fov (58° x 43° horizontal x vertical)
- Death zone on the first 45 cm
- Cannot detect glass walls
- Cannot detect polished metallic surfaces

In one experiment an 11 IR sensors half ring, pointing 12 degrees downward was added to compensate.

- **Sensor model:** Sharp GP2Y0A21YK
- **Power supply:** Kobuki's 5V, 1A
- **Sensor reading:** Arduino MEGA 2560
- **PC interface:** Arduino custom firmware – Bosch adc_driver
- **Mounting:** 3D printed frame.

The analog output of sensors is read by the Arduino board, while for power and ground they are connected to Kobuki's 5V 1A power source. Connecting several sensors to the same power supply makes readings very noisy when there aren't obstacles. The solution was to put decoupling capacitors on each sensor. For interfacing Arduino, we use Bosch adc_driver. A funny problem comes sometimes when looking at corners in a particular angle (~30 degrees) : sensors get a spurious reading, no idea why. We just went on with this, as is not a common problem.

Different mounting frames are available for downloading and printing in our [file server](#):

- Horizontally mounted MaxBotix's LV-Maxsonars
- Horizontally mounted Sharp IR sensors
- 12 degrees downward pointing Sharp IR sensors

And the result:



Specifications

Safety Guideline

- Do not twist or subject the power cable to extreme pressure or weight weight.
- Keep the pin and interface of the power plug clean from dust or water.
- Do not pull the power cord or touch the power plug with wet hands.
- Do not use with a damaged power plug, power cord or loose outlet.
- Use Kobuki indoors only.
- Do not pour or spray water onto Kobuki.
- Do not use Kobuki to pick up anything that is burning or smoking.
- Always remove the battery before long-term storage or transportation.

Functional

- Maximum translational velocity: 70 cm/s

- Maximum rotational velocity: 180 deg/s (>110 deg/s gyro performance will degrade)
- Payload: 5 kg (hard floor), 4 kg (carpet)
- Cliff: will not drive off a cliff with a depth greater than 5cm
- Threshold Climbing: climbs thresholds of 12 mm or lower
- Rug Climbing: climbs rugs of 12 mm or lower
- Expected Operating Time: 3/7 hours (small/large battery)
- Expected Charging Time: 1.5/2.6 hours (small/large battery)
- Docking: within a 2mx5m area in front of the docking station

Hardware

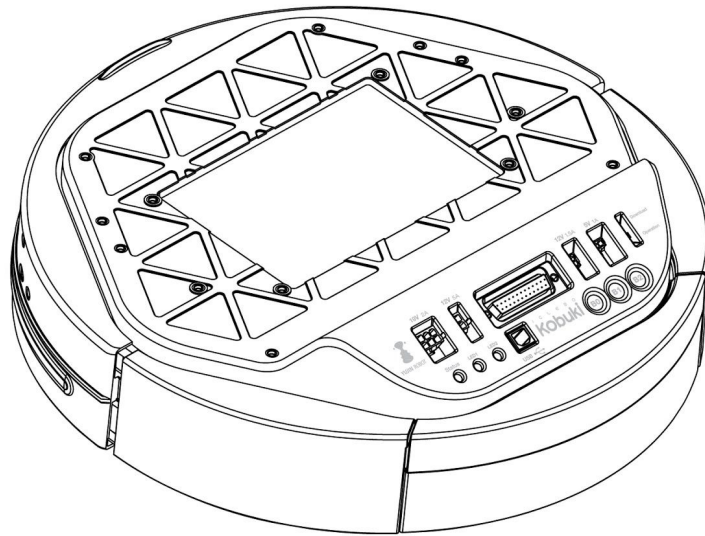
- PC Connection: USB or via RX/TX pins on the parallel port
- Motor Overload Detection: disables power on detecting high current (>3A)
- Odometry: 52 ticks/enc rev, 2578.33 ticks/wheel rev, 11.7 ticks/mm
- Gyro: factory calibrated, 1 axis (110 deg/s)
- Bumpers: left, center, right
- Cliff sensors: left, center, right
- Wheel drop sensor: left, right
- Power connectors: 5V/1A, 12V/1.5A, 12V/5A
- Expansion pins: 3.3V/1A, 5V/1A, 4 x analog in, 4 x digital in, 4 x digital out
- Audio : several programmable beep sequences
- Programmable LED: 2 x two-coloured LED
- State LED: 1 x two coloured LED [Green - high, Orange - low, Green & Blinking - charging]
- Buttons: 3 x touch buttons
- Battery: Lithium-Ion, 14.8V, 2200 mAh (4S1P - small), 4400 mAh (4S2P - large)
- Firmware upgradeable: via usb
- Sensor Data Rate: 50Hz
- Recharging Adapter: Input: 100-240V AC, 50/60Hz, 1.5A max; Output: 19V DC, 3.16A
- Netbook recharging connector (only enabled when robot is recharging): 19V/2.1A DC
- Docking IR Receiver: left, centre, right

Software

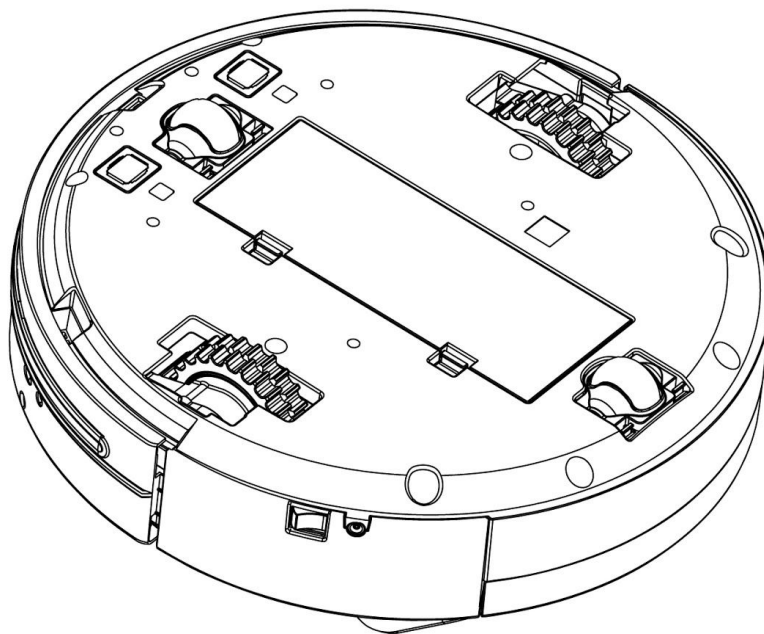
- C++ drivers for Linux
- ROS driver
- Gazebo simulation

Anatomy

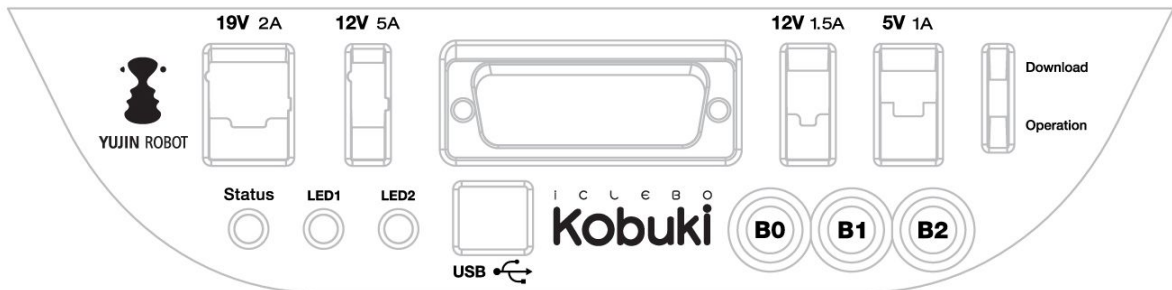
Top View



Bottom View



Control Panel



- 19V/2A: Laptop power supply
- 12V/5A: Arm power supply
- 12v/1.5A: Microsoft Kinect power supply
- 5V/1A: General power supply
- Status LED: Indicates Kobuki's status
 - Green: Kobuki is turned on and battery at high voltage level
 - Orange: On - Low battery voltage level (please charge soon)
 - Green blinking: On - Battery charging
 - Off: Kobuki is turned off.
- LED1/2: Programmable LEDs
- USB: Data connection
- BO/1/2: Buttons
- Firmware switch: Enable/disables the firmware update mode

Connectors

SOME NOTES ABOUT THE MOLEX PAGES BELOW

1. We do not actually use Molex connectors but we are supplied by a Korean vendor who produces connectors according to the Molex standard. These links will be more useful to internationals in helping them find a mating part that works for them.
2. The images on each page are representative of the series of connectors. Each series usually has a variety of connectors with a different number of pins. As a result, the pictures on some of the pages below may seem as though they have the incorrect number of pins, but do not worry about this – they are the correct links. Note that you can jump to different connectors in the series via the second part of their identification number (e.g. 43045-0224 for the 2-pin, 43045-0424 for the 4-pin).
3. If some linked connectors are listed as obsolete on the molex website, don't worry. The connector you are exactly requiring are those you can find under the 'Mates with Parts' link on each page. If these however should become obsolete as well, please let us know via email.

Power

- 5V@1A Molex PN : 43650-0218 – for custom boards
- 12V@1.5A : Molex PN : 43045-0224 – specially supporting the kinect
- 12V@5A : Molex PN : 3929-9023 – for high powered accessories (e.g. robotic arm)
- 19V@2A : Molex PN : 3928-9068 – for recharging netbooks



Battery

- [4S1P/4S2P Battery Pack Connector](#)

I/O Port

- DB25 pin D-SUB Female connector that provides the following functionality ([pdf](#))

Cables

Note, if you click on the preceding links for the power connectors, under the heading 'Mates with Part(s)' you can find the compatible connector to use with each power source. The most important one being of course:

- 12V@1.5A : [Molex PN : 43025-0200](#) – specially supporting the kinect

Models & Drawings

The models and drawings include both the base and parts for the Turtlebot 2.

- [2D mechanical drawings](#) – DWG, PDF
- [3D models](#) – IGS, STEP

The inserts in the kobuki plate are M4 threads (metric, 4mm). If you wish to build standoffs compatible for these inserts, please reference the pole pdf's in the 2D mechanical drawings which are what we use for turtlebots.

Motors

Specifications

- Brushed DC Motor
- Motor Manufacturer: Standard Motor
- Part Name: RP385-ST-2060
- Rated Voltage: 12 V
- Rated Load: 5 mN·m
- No Load Current: 210 mA
- No Load Speed: 9960 rpm \pm 15%
- Rated Load Current: 750 mA
- Rated Load Speed: 8800 rpm \pm 15%
- Armature Resistance: 1.5506 Ω at 25°C
- Armature Inductance: 1.51 mH
- Torque Constant(Kt): 10.913 mN·m/A

- Velocity Constant(Kv): 830 rpm/V
- Stall Current: 6.1 A
- Stall Torque: 33 mN·m

Control Method

- Driven by voltage source(H-bridge)
- Controlled by Pulse-width modulation(PWM)

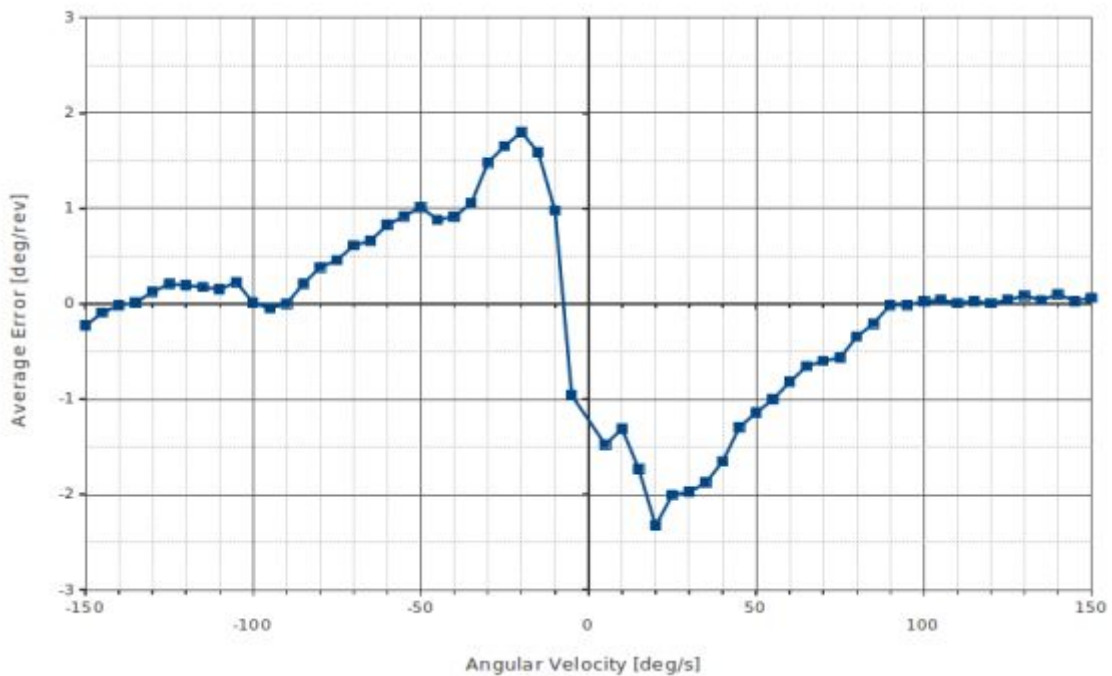
Gyro

Specification

- 3-Axis Digital Gyroscope
- Manufacturer : STMicroelectronics
- Part Name : [L3G4200D](#)
- Measurement Range: ± 250 deg/s
- Yaw axis is factory calibrated within the range of ± 20 deg/s to ± 100 deg/s

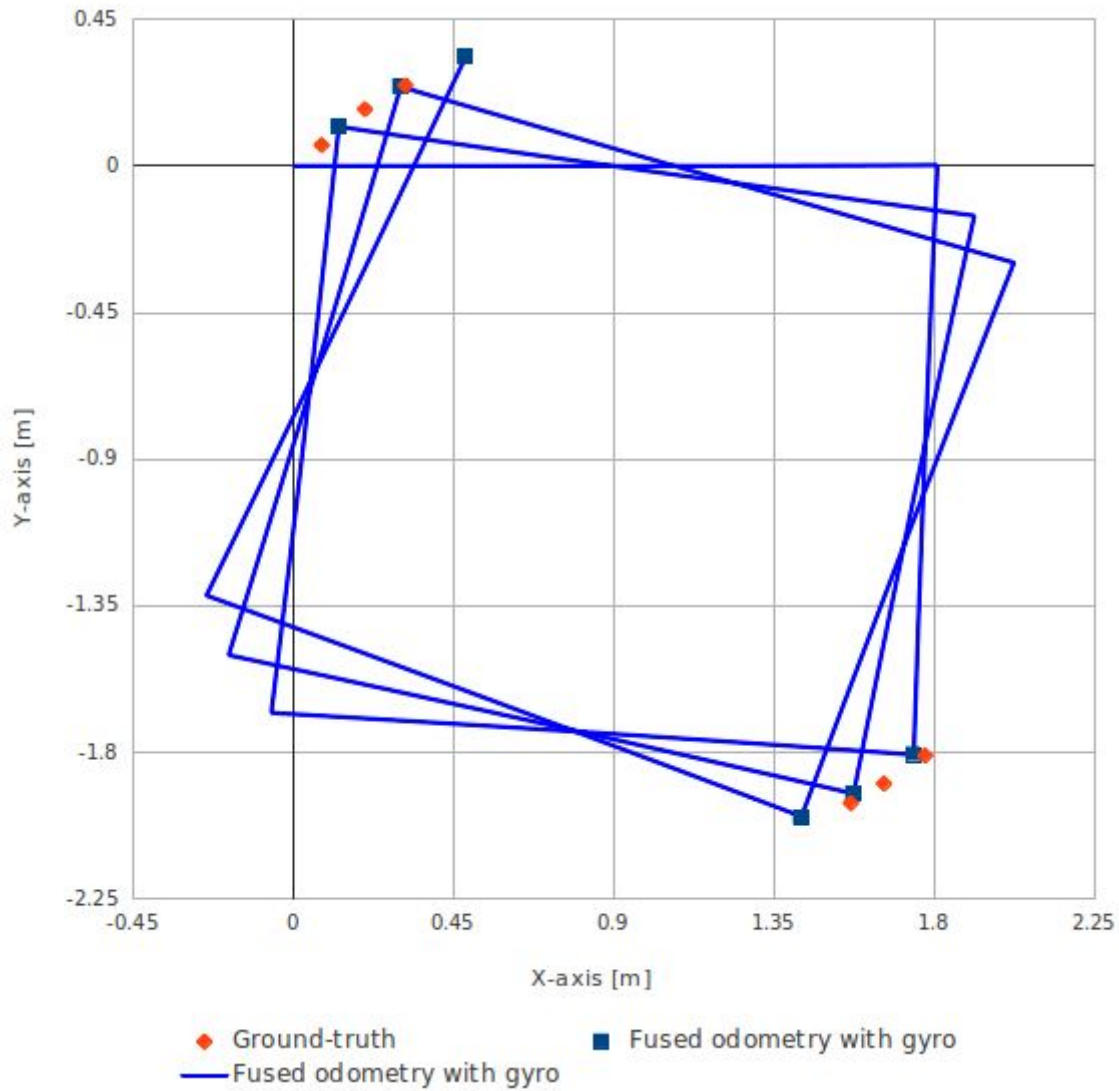
Performance

In-Place Rotation Test



This graph shows the average heading error per revolution of gyro, when robot rotates with a given velocity.

Square Path Test



This graph shows the position error of fused odometry with gyro, when robot moves along a square path. Robot moved with 0.1 m/s on the line segment and rotated with 30 deg/s on the corner.

Number of turns of square path	Angular Error [deg]
0.5	0.47
1.5	1.99
2.5	3.18

This table shows the calculated angular error, when robot arrived at the diagonally opposite corner from the starting point (0.0, 0.0).

Power Adapter

Input	Output	Other
<ul style="list-style-type: none"> Voltage: 100-240V Frequency: 50/60Hz Ampere: 1.5A Max 	<ul style="list-style-type: none"> Voltage: 19V Ampere: 3.16A 	<ul style="list-style-type: none"> Photo Specification 1 Specification 2

Batteries

Kobuki by the default ships with a small Lithium-Ion battery pack (4S1P, 2200mAh, 14.8V).

Tip: for extra long operation, a big battery pack (4S2P, 4400mAh, 14,8V) can be ordered as well.

Warning: the electronics does not support the use of multiple battery packs at the same time (even if there is room in the battery compartment)

Specifications

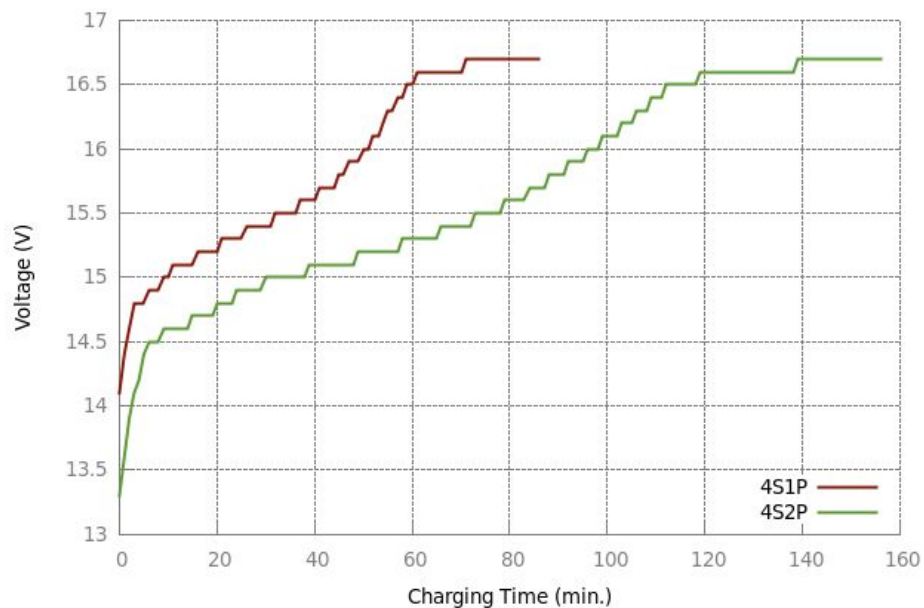
- [Data Sheet \(pdf\)](#)

Pinouts

- **Red:** battery (+), 9.6 V ~ 16.8 V
- **White:** NTC thermistor to ground, 10 k Ω \pm 1%
- **Black:** battery(-), Ground

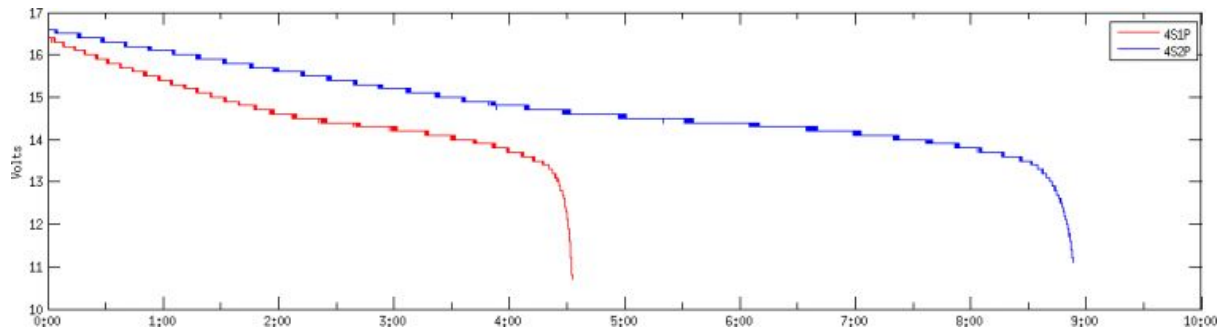
Charging Profile

This plot shows the voltages as measured by the robot's hardware. Both the standard 4S1P and the extra 4S2P batteries are compared. During the test, the robot was charging via adaptor.

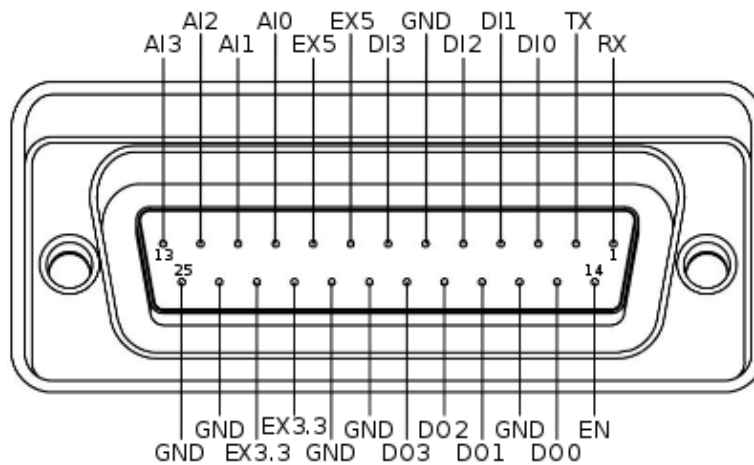


Discharging Profile

This plot shows the voltage as measured by the robot's hardware. Both the standard 4S1P and the extra 4S2P batteries are compared. During the test, the robot was continuously spinning, with the Kinect camera running.



Serial Port



- RX / TX: Serial data connection (RS232; used voltage level is 3.3V!)
- EX3.3 / EX5: 3.3V/1A and 5V/1A power supply
- DI0 - 3: 4 x Digital input (high: 3.3 - 5V, low: 0V)
- DO0 - 3: 4 x Digital output (open-drain, pull-up resistor required)
- AI0-3: 4 x Analog input (12bit ADC: 0 - 4095, 0 - 3.3V)
- GND: Ground
- EN: Used for detecting an external board (connect to external ground)

Firmware

Communication

- Baud rate: 115200 BPS, Data bit: 8 bit, Stop bit: 1 bit, No Parity
- Electronic protocol: USB / RS232 (@ DB25 connector)

Protocol Specification

The driver communicates with the robot by using predefined protocol. In general, the driver sends the commands to the robot and the robot sends some feedback data or sensor readings. This command and feedback data are converted into bytestreams for communication via serial interface. The protocol specifies that rules and forms of bytestream.

For more detailed information, visit:

- <http://yujinrobot.github.com/kobuki/enAppendixProtocolSpecification.html>

Version Checking

Every time the robot comes alive (because it is connected or powered on), the driver checks the compatibility between software (i.e. driver) and firmware. Firmware versions are of the form M.m.p, where:

- M(ajor) represents a deep rebuild of the code that almost surely breaks protocol compatibility. In consequence, if major version doesn't match, the driver will show an error, suggest the required update and shutdown.
- m(inor) represents a new feature that could not work if the driver is outdated, but the protocol itself is spared. In consequence, if minor version doesn't match, the driver will show a warning suggesting the required update and continue working.
- p(atch) represents a fix on the code and is not checked at all.

You can check which firmware version your robot is running on the log (check the first lines on stdout at driver startup), by running the version_info program included on the kobuki driver, or if you are using ROS, just echoing /mobile_base/version_info topic. Generally speaking, it's recommended to upgrade the firmware to the latest stable version.

Special Firmware Modes

Activating

Kobuki has some special firmware modes, which can be activated on startup. Currently implemented are:

- I. Random walker mode
- II. Arduino/Embedded board support mode

To activate one of them, follow these instructions:

1. Turn on Kobuki.

2. Within in the first 3 seconds press and hold button BO(I) / B1 (II) for 2 seconds.
3. If* you see LED2(I) / LED1(II) switching between red and green, your chosen mode is activated.

Note(*): These modes have been introduced to the firmware with version 1.1.0. In case your Kobuki is not running this or a later version, please refer to the section about [updating the firmware](#).

Random Walker Mode

In the random walker mode Kobuki is driving around until it hits an object with the bumper or a cliff is detected. In both cases, Kobuki will stop, turn by a random amount of degrees and continue driving .

Note: In this mode Kobuki's wheel drop sensors are not activated. So, be careful when lifting up Kobuki!

Arduino / Embedded Board Support Mode

In this mode the serial port (DB25 connector) gives access to basic controls of Kobuki. You can hook up the digital/analog inputs/output of your Arduino or other embedded boards and start writing simple control programs.

Below is the special pin setting listed. Please refer to the [serial port description](#) for the name to pin mapping.

- DI0: Not used
- DI1: Not used
- DI2: Not used
- DI3: Not used
- DO0: Bumper left (pressed/released)
- DO1: Bumper centre (pressed/released)
- DO2: Bumper right (pressed/released)
- DO3: Wheel drop sensors (at least one wheel is dropped / none is dropped)
- AI0: Wheel speed right (0V - full speed backward, 3.3V - full speed forward)
- AI1: Wheel speed left (0V - full speed backward, 3.3V - full speed forward)
- AI2: Not used
- AI3: Not used

All other pins (GND, RX, TX etc.) remain unchanged.

Note: To enable the motors you need to press button B0.

Resources

- [Kobuki Images & Renderings](#)
- [Turtlebot Images & Renderings](#)
- [Marketing Materials](#)

ChangeLog

- 1.0.0 : official release
- 1.0.1 : upgrading firmware link fix
- 1.0.2 : documentation link fix
- 1.0.4 : updating the spec. of serial communication
- 1.0.5 : fixing battey & connector link
- 1.0.6 : updating link after Kobuki web site revision
- 1.1.0 : reorganised and collapsed website howtos into the guide

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