Pybricks Modules and Examples

Version v3.1.0

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Pybricks is Python coding for smart LEGO® hubs. Run MicroPython scripts directly on the hub, and get full control of your motors and sensors.

Pybricks runs on LEGO® BOOST, City, Technic, MINDSTORMS®, and SPIKE®. You can code using Windows, Mac, Linux, Chromebook, and Android.

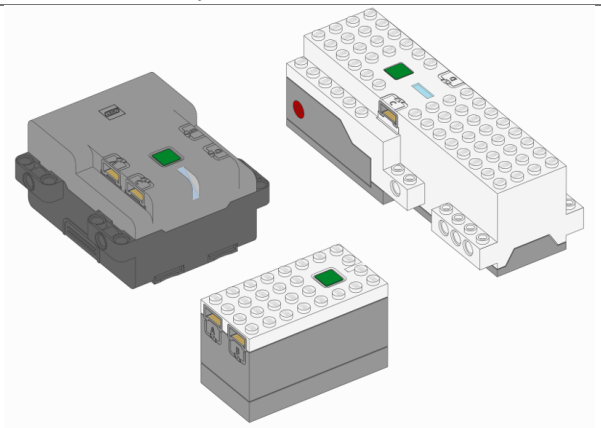
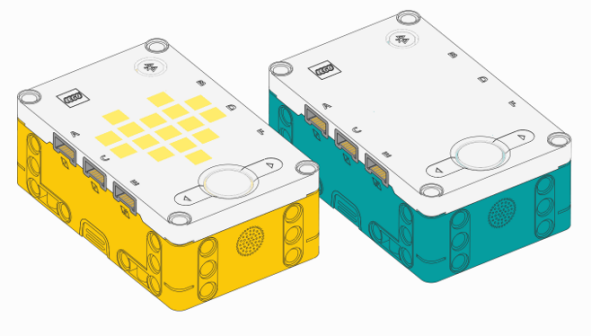
What's on this page?

This page provides API documentation and short example snippets. If you're new to Pybricks, or if you're looking for bigger example projects, check out the Pybricks website instead.

Note: Are you using LEGO MINDSTORMS EV3? Check out the EV3 documentation instead.

Installation

To run Pybricks MicroPython scripts, you must update the firmware on the hub. To get started, click one of the platforms below.

Technic Hub, City Hub, BOOST Move Hub	SPIKE Prime Hub / MINDSTORMS Inventor Hub
	

Once installed, Pybricks works the same for all hubs. check out the Pybricks modules in the left hand menu to see what you can do.

Get involved!

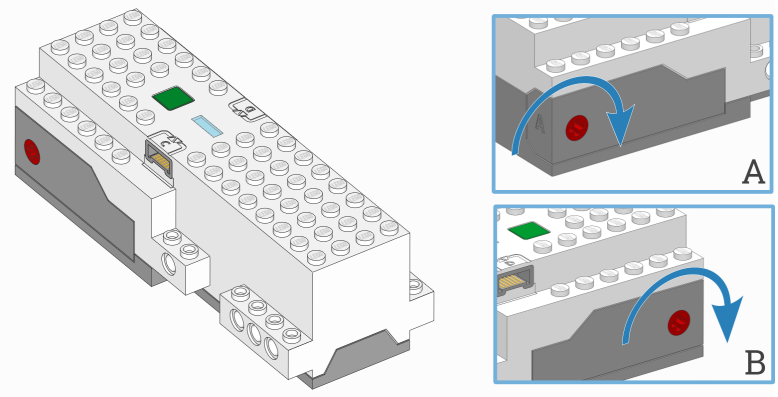
Got questions or issues? Please share your findings on our support page so we can make Pybricks even better. *Thank you!*

CHAPTER

ONE

HUBS – PROGRAMMABLE HUBS

1.1 Move Hub



class MoveHub

LEGO® BOOST Move Hub.

Using the hub status light

light.**on**(*color*)

Turns on the light at the specified color.

Parameters **color** (Color) – Color of the light.

light.**off**()

Turns off the light.

light.**blink**(*color*, *durations*)

Blinks the light at a given color by turning it on and off for given durations.

The light keeps blinking indefinitely while the rest of your program keeps running.

This method provides a simple way to make basic but useful patterns. For more generic and multi-color patterns, use `animate()` instead.

Parameters

- **color** (Color) – Color of the light.
- **durations** (list) – List of (*time: ms*) values of the form `[on_1, off_1, on_2, off_2, ...]`.

`light.`**`animate`**`(`*colors*, *interval*`)`
Animates the light with a list of colors. The next color in the list is shown after the given interval.

The animation runs in the background while the rest of your program keeps running. When the animation completes, it repeats.

Parameters

- **`colors`** (`list`) – List of *`Color`* values.
- **`interval`** (*time: ms*) – Time between color updates.

Using the IMU

`imu.`**`up`**`()`
Checks which side of the hub currently faces upward.

Returns `Side.TOP`, `Side.BOTTOM`, `Side.LEFT`, `Side.RIGHT`, `Side.FRONT` or `Side.BACK`.

Return type *`Side`*

`imu.`**`acceleration`**`()`
Gets the acceleration of the device.

Returns Acceleration along all three axes.

Return type tuple of *linear acceleration: m/s/s*

Using the battery

`battery.`**`voltage`**`()`
Gets the voltage of the battery.

Returns Battery voltage.

Return type *voltage: mV*

`battery.`**`current`**`()`
Gets the current supplied by the battery.

Returns Battery current.

Return type *current: mA*

Button and system control

`button.`**`pressed`**`()`
Checks which buttons are currently pressed.

Returns Tuple of pressed buttons.

Return type Tuple of *`Button`*

`system.`**`set_stop_button`**`(`*button*`)`
Sets the button or button combination that stops a running script.

Normally, the center button is used to stop a running script. You can change or disable this behavior in order to use the button for other purposes.

Parameters **`Button`** – A button such as *`Button.CENTER`*, or a tuple of multiple buttons. Choose `None` to disable the stop button altogether.

system.**name**()
Gets the hub name. This is the name you see when connecting via Bluetooth.

Returns The hub name.

Return type *str*

system.**shutdown**()
Stops your program and shuts the hub down.

system.**reset_reason**()
Finds out how and why the hub (re)booted. This can be useful to diagnose some problems.

Returns Returns `0` if the hub was previously powered off normally. Returns `1` if the hub rebooted automatically, like after a firmware update. Returns `2` if the hub previously crashed due to a watchdog timeout, which indicates a firmware issue.

Return type *int*

1.1.1 Status light examples

Turning the light on and off

```
from pybricks.hubs import MoveHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub.
hub = MoveHub()

# Turn the light on and off 5 times.
for i in range(5):

    hub.light.on(Color.RED)
    wait(1000)

    hub.light.off()
    wait(500)
```

Making the light blink

```
from pybricks.hubs import MoveHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub
hub = MoveHub()

# Keep blinking red on and off.
hub.light.blink(Color.RED, [500, 500])

wait(10000)
```

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```
# Keep blinking green slowly and then quickly.
hub.light.blink(Color.GREEN, [500, 500, 50, 900])

wait(10000)
```

1.1.2 IMU examples

Testing which way is up

```
from pybricks.hubs import MoveHub
from pybricks.parameters import Color, Side
from pybricks.tools import wait

# Initialize the hub.
hub = MoveHub()

# Define colors for each side in a dictionary.
SIDE_COLORS = {
    Side.TOP: Color.RED,
    Side.BOTTOM: Color.BLUE,
    Side.LEFT: Color.GREEN,
    Side.RIGHT: Color.YELLOW,
    Side.FRONT: Color.MAGENTA,
    Side.BACK: Color.BLACK,
}

# Keep updating the color based on detected up side.
while True:

    # Check which side of the hub is up.
    up_side = hub.imu.up()

    # Change the color based on the side.
    hub.light.on(SIDE_COLORS[up_side])

    # Also print the result.
    print(up_side)
    wait(50)
```

Reading acceleration

```
from pybricks.hubs import MoveHub
from pybricks.tools import wait

# Initialize the hub.
hub = MoveHub()

# Get the acceleration tuple.
print(hub.imu.acceleration())
```

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```
while True:
    # Get individual acceleration values.
    x, y, z = hub.imu.acceleration()
    print(x, y, z)

    # Wait so we can see what we printed.
    wait(100)
```

1.1.3 Button and system examples

Using the stop button during your program

```
from pybricks.hubs import MoveHub
from pybricks.parameters import Color, Button
from pybricks.tools import wait, StopWatch

# Initialize the hub.
hub = MoveHub()

# Disable the stop button.
hub.system.set_stop_button(None)

# Check the button for 5 seconds.
watch = StopWatch()
while watch.time() < 5000:

    # Set light to green if pressed, else red.
    if hub.button.pressed():
        hub.light.on(Color.GREEN)
    else:
        hub.light.on(Color.RED)

# Enable the stop button again.
hub.system.set_stop_button(Button.CENTER)

# Now you can press the stop button as usual.
wait(5000)
```

Turning the hub off

```
from pybricks.hubs import MoveHub
from pybricks.tools import wait

# Initialize the hub.
hub = MoveHub()

# Say goodbye and give some time to send it.
print("Goodbye!")
```

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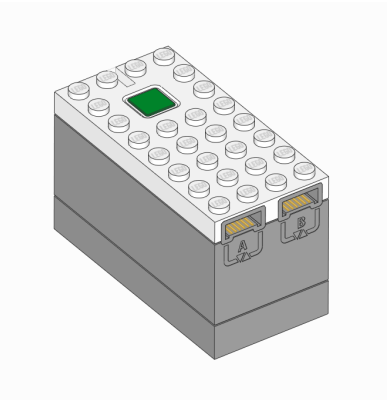
```
wait(100)

# Shut the hub down.
hub.system.shutdown()
```

1.2 City Hub



class CityHub
LEGO® City Hub.

Using the hub status light

light.**on**(*color*)
Turns on the light at the specified color.

Parameters **color** (Color) – Color of the light.

light.**off**()
Turns off the light.

light.**blink**(*color*, *durations*)
Blinks the light at a given color by turning it on and off for given durations.

The light keeps blinking indefinitely while the rest of your program keeps running.

This method provides a simple way to make basic but useful patterns. For more generic and multi-color patterns, use animate() instead.

Parameters

- **color** (Color) – Color of the light.
- **durations** (list) – List of (*time: ms*) values of the form [on_1, off_1, on_2, off_2, ...].

light.**animate**(*colors*, *interval*)
Animates the light with a list of colors. The next color in the list is shown after the given interval.

The animation runs in the background while the rest of your program keeps running. When the animation completes, it repeats.

Parameters

- **colors** (list) – List of *Color* values.
- **interval** (*time: ms*) – Time between color updates.

Using the battery

battery.**voltage**()
Gets the voltage of the battery.

Returns Battery voltage.

Return type *voltage: mV*

battery.**current**()
Gets the current supplied by the battery.

Returns Battery current.

Return type *current: mA*

Button and system control

button.**pressed**()
Checks which buttons are currently pressed.

Returns Tuple of pressed buttons.

Return type Tuple of *Button*

system.**set_stop_button**(*button*)
Sets the button or button combination that stops a running script.

Normally, the center button is used to stop a running script. You can change or disable this behavior in order to use the button for other purposes.

Parameters **Button** – A button such as *Button.CENTER*, or a tuple of multiple buttons. Choose None to disable the stop button altogether.

system.**name**()
Gets the hub name. This is the name you see when connecting via Bluetooth.

Returns The hub name.

Return type *str*

system.**shutdown**()
Stops your program and shuts the hub down.

system.**reset_reason**()
Finds out how and why the hub (re)booted. This can be useful to diagnose some problems.

Returns Returns 0 if the hub was previously powered off normally. Returns 1 if the hub rebooted automatically, like after a firmware update. Returns 2 if the hub previously crashed due to a watchdog timeout, which indicates a firmware issue.

Return type *int*

1.2.1 Status light examples

Turning the light on and off

```
from pybricks.hubs import CityHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub.
hub = CityHub()

# Turn the light on and off 5 times.
for i in range(5):

    hub.light.on(Color.RED)
    wait(1000)

    hub.light.off()
    wait(500)
```

Changing brightness and using custom colors

```
from pybricks.hubs import CityHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub.
hub = CityHub()

# Show the color at 30% brightness.
hub.light.on(Color.RED * 0.3)

wait(2000)

# Use your own custom color.
hub.light.on(Color(h=30, s=100, v=50))

wait(2000)

# Go through all the colors.
for hue in range(360):
    hub.light.on(Color(hue))
    wait(10)
```

Making the light blink

```
from pybricks.hubs import CityHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub
hub = CityHub()

# Keep blinking red on and off.
hub.light.blink(Color.RED, [500, 500])

wait(10000)

# Keep blinking green slowly and then quickly.
hub.light.blink(Color.GREEN, [500, 500, 50, 900])

wait(10000)
```

Creating light animations

```
from pybricks.hubs import CityHub
from pybricks.parameters import Color
from pybricks.tools import wait
from umath import sin, pi

# Initialize the hub.
hub = CityHub()

# Make an animation with multiple colors.
hub.light.animate([Color.RED, Color.GREEN, Color.NONE], interval=500)

wait(10000)

# Make the color RED grow faint and bright using a sine pattern.
hub.light.animate(
    [Color.RED * (0.5 * sin(i / 15 * pi) + 0.5) for i in range(30)], 40)

wait(10000)

# Cycle through a rainbow of colors.
hub.light.animate([Color(h=i*8) for i in range(45)], interval=40)

wait(10000)
```

1.2.2 Button and system examples

Using the stop button during your program

```
from pybricks.hubs import CityHub
from pybricks.parameters import Color, Button
from pybricks.tools import wait, StopWatch

# Initialize the hub.
hub = CityHub()

# Disable the stop button.
hub.system.set_stop_button(None)

# Check the button for 5 seconds.
watch = StopWatch()
while watch.time() < 5000:

    # Set light to green if pressed, else red.
    if hub.button.pressed():
        hub.light.on(Color.GREEN)
    else:
        hub.light.on(Color.RED)

# Enable the stop button again.
hub.system.set_stop_button(Button.CENTER)

# Now you can press the stop button as usual.
wait(5000)
```

Turning the hub off

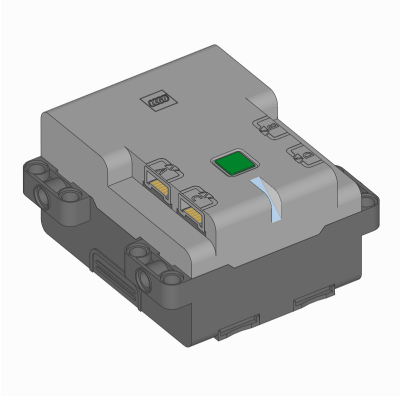
```
from pybricks.hubs import CityHub
from pybricks.tools import wait

# Initialize the hub.
hub = CityHub()

# Say goodbye and give some time to send it.
print("Goodbye!")
wait(100)

# Shut the hub down.
hub.system.shutdown()
```

1.3 Technic Hub



class TechnicHub(*top_side=Axis.Z*, *front_side=Axis.X*)

LEGO® Technic Hub.

Initializes the hub. Optionally, specify how the hub is *placed in your design* by saying in which direction the top side (with the button) and front side (with the light) are pointing.

Parameters

- **top_side** (Axis) – The axis that passes through the *top side* of the hub.
- **front_side** (Axis) – The axis that passes through the *front side* of the hub.

Using the hub status light

light.**on**(*color*)

Turns on the light at the specified color.

Parameters **color** (Color) – Color of the light.

light.**off**()

Turns off the light.

light.**blink**(*color*, *durations*)

Blinks the light at a given color by turning it on and off for given durations.

The light keeps blinking indefinitely while the rest of your program keeps running.

This method provides a simple way to make basic but useful patterns. For more generic and multi-color patterns, use `animate()` instead.

Parameters

- **color** (Color) – Color of the light.
- **durations** (list) – List of (*time: ms*) values of the form `[on_1, off_1, on_2, off_2, ...]`.

light.**animate**(*colors*, *interval*)

Animates the light with a list of colors. The next color in the list is shown after the given interval.

The animation runs in the background while the rest of your program keeps running. When the animation completes, it repeats.

Parameters

- **colors** (list) – List of *Color* values.
- **interval** (*time: ms*) – Time between color updates.

Using the IMU

imu.**up**()
Checks which side of the hub currently faces upward.

Returns Side.TOP, Side.BOTTOM, Side.LEFT, Side.RIGHT, Side.FRONT or Side.BACK.

Return type *Side*

imu.**tilt**()
Gets the pitch and roll angles. This is relative to the *user-specified neutral orientation*.

The order of rotation is pitch-then-roll. This is equivalent to a positive rotation along the robot y-axis and then a positive rotation along the x-axis.

Returns Pitch and roll angles.

Return type (*angle: deg*, *angle: deg*)

imu.**acceleration**(*axis=None*)
Gets the acceleration of the device along a given axis in the *robot reference frame*.

Parameters **axis** (Axis) – Axis along which the acceleration is measured.

Returns Acceleration along the specified axis. If you specify no axis, this returns a vector of accelerations along all axes.

Return type *linear acceleration: m/s/s*

imu.**angular_velocity**(*axis=None*)
Gets the angular velocity of the device along a given axis in the *robot reference frame*.

Parameters **axis** (Axis) – Axis along which the angular velocity is measured.

Returns Angular velocity along the specified axis. If you specify no axis, this returns a vector of accelerations along all axes.

Return type *rotational speed: deg/s*

imu.**heading**()
Gets the heading angle relative to the starting orientation. It is a a positive rotation around the *z-axis in the robot frame*, prior to applying any tilt rotation.

For a vehicle viewed from the top, this means that a positive heading value corresponds to a counterclockwise rotation.

Note: This method is not yet implemented.

Returns Heading angle relative to starting orientation.

Return type *angle: deg*

imu.**reset_heading**(*angle*)
Resets the accumulated heading angle of the robot.

Note: This method is not yet implemented.

Parameters **angle** (*angle: deg*) – Value to which the heading should be reset.

Using the battery

battery.**voltage**()
Gets the voltage of the battery.

Returns Battery voltage.

Return type *voltage: mV*

battery.**current**()
Gets the current supplied by the battery.

Returns Battery current.

Return type *current: mA*

Button and system control

button.**pressed**()
Checks which buttons are currently pressed.

Returns Tuple of pressed buttons.

Return type Tuple of *Button*

system.**set_stop_button**(*button*)
Sets the button or button combination that stops a running script.

Normally, the center button is used to stop a running script. You can change or disable this behavior in order to use the button for other purposes.

Parameters **Button** – A button such as *Button.CENTER*, or a tuple of multiple buttons. Choose None to disable the stop button altogether.

system.**name**()
Gets the hub name. This is the name you see when connecting via Bluetooth.

Returns The hub name.

Return type *str*

system.**shutdown**()
Stops your program and shuts the hub down.

system.**reset_reason**()
Finds out how and why the hub (re)booted. This can be useful to diagnose some problems.

Returns Returns 0 if the hub was previously powered off normally. Returns 1 if the hub rebooted automatically, like after a firmware update. Returns 2 if the hub previously crashed due to a watchdog timeout, which indicates a firmware issue.

Return type *int*

1.3.1 Status light examples

Turning the light on and off

```
from pybricks.hubs import TechnicHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub.
hub = TechnicHub()

# Turn the light on and off 5 times.
for i in range(5):

    hub.light.on(Color.RED)
    wait(1000)

    hub.light.off()
    wait(500)
```

Changing brightness and using custom colors

```
from pybricks.hubs import TechnicHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub.
hub = TechnicHub()

# Show the color at 30% brightness.
hub.light.on(Color.RED * 0.3)

wait(2000)

# Use your own custom color.
hub.light.on(Color(h=30, s=100, v=50))

wait(2000)

# Go through all the colors.
for hue in range(360):
    hub.light.on(Color(hue))
    wait(10)
```

Making the light blink

```
from pybricks.hubs import TechnicHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub
hub = TechnicHub()

# Keep blinking red on and off.
hub.light.blink(Color.RED, [500, 500])

wait(10000)

# Keep blinking green slowly and then quickly.
hub.light.blink(Color.GREEN, [500, 500, 50, 900])

wait(10000)
```

Creating light animations

```
from pybricks.hubs import TechnicHub
from pybricks.parameters import Color
from pybricks.tools import wait
from umath import sin, pi

# Initialize the hub.
hub = TechnicHub()

# Make an animation with multiple colors.
hub.light.animate([Color.RED, Color.GREEN, Color.NONE], interval=500)

wait(10000)

# Make the color RED grow faint and bright using a sine pattern.
hub.light.animate(
    [Color.RED * (0.5 * sin(i / 15 * pi) + 0.5) for i in range(30)], 40)

wait(10000)

# Cycle through a rainbow of colors.
hub.light.animate([Color(h=i*8) for i in range(45)], interval=40)

wait(10000)
```

1.3.2 IMU examples

Testing which way is up

```
from pybricks.hubs import TechnicHub
from pybricks.parameters import Color, Side
from pybricks.tools import wait

# Initialize the hub.
hub = TechnicHub()

# Define colors for each side in a dictionary.
SIDE_COLORS = {
    Side.TOP: Color.RED,
    Side.BOTTOM: Color.BLUE,
    Side.LEFT: Color.GREEN,
    Side.RIGHT: Color.YELLOW,
    Side.FRONT: Color.MAGENTA,
    Side.BACK: Color.BLACK,
}

# Keep updating the color based on detected up side.
while True:

    # Check which side of the hub is up.
    up_side = hub.imu.up()

    # Change the color based on the side.
    hub.light.on(SIDE_COLORS[up_side])

    # Also print the result.
    print(up_side)
    wait(50)
```

Reading the tilt value

```
from pybricks.hubs import TechnicHub
from pybricks.tools import wait

# Initialize the hub.
hub = TechnicHub()

while True:
    # Read the tilt values.
    pitch, roll = hub.imu.tilt()

    # Print the result.
    print(pitch, roll)
    wait(200)
```

Using a custom hub orientation

```
from pybricks.hubs import TechnicHub
from pybricks.tools import wait
from pybricks.geometry import Axis

# Initialize the hub. In this case, specify that the hub is mounted with the
# top side facing forward and the front side facing to the right.
# For example, this is how the hub is mounted in BLAST in the 51515 set.
hub = TechnicHub(top_side=Axis.X, front_side=-Axis.Y)

while True:
    # Read the tilt values. Now, the values are 0 when BLAST stands upright.
    # Leaning forward gives positive pitch. Leaning right gives positive roll.
    pitch, roll = hub.imu.tilt()

    # Print the result.
    print(pitch, roll)
    wait(200)
```

Reading acceleration and angular velocity vectors

```
from pybricks.hubs import TechnicHub
from pybricks.tools import wait

# Initialize the hub.
hub = TechnicHub()

# Get the acceleration vector.
print(hub.imu.acceleration())

# Get the angular velocity vector.
print(hub.imu.angular_velocity())

# Wait so we can see what we printed
wait(5000)
```

Reading acceleration and angular velocity on one axis

```
from pybricks.hubs import TechnicHub
from pybricks.tools import wait
from pybricks.geometry import Axis

# Initialize the hub.
hub = TechnicHub()

# Get the acceleration or angular_velocity along a single axis.
# If you need only one value, this is more memory efficient.
while True:

```

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```
    # Read the forward acceleration.
    forward_acceleration = hub.imu.acceleration(Axis.X)

    # Read the yaw rate.
    yaw_rate = hub.imu.angular_velocity(Axis.Z)

    # Print the yaw rate.
    print(yaw_rate)
    wait(100)
```

1.3.3 Button and system examples

Using the stop button during your program

```
from pybricks.hubs import TechnicHub
from pybricks.parameters import Color, Button
from pybricks.tools import wait, StopWatch

# Initialize the hub.
hub = TechnicHub()

# Disable the stop button.
hub.system.set_stop_button(None)

# Check the button for 5 seconds.
watch = StopWatch()
while watch.time() < 5000:

    # Set light to green if pressed, else red.
    if hub.button.pressed():
        hub.light.on(Color.GREEN)
    else:
        hub.light.on(Color.RED)

# Enable the stop button again.
hub.system.set_stop_button(Button.CENTER)

# Now you can press the stop button as usual.
wait(5000)
```

Turning the hub off

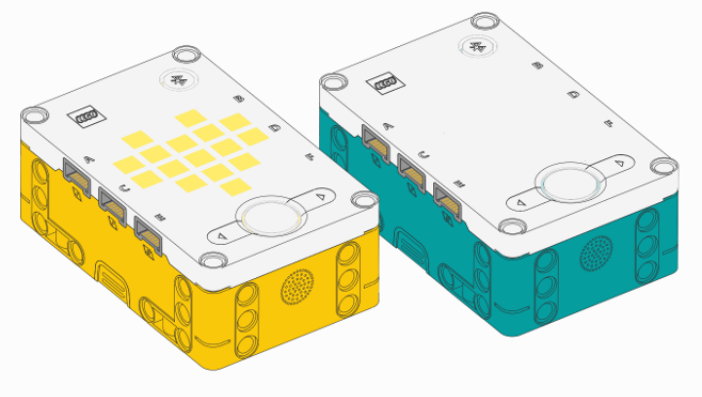
```
from pybricks.hubs import TechnicHub
from pybricks.tools import wait

# Initialize the hub.
hub = TechnicHub()

# Say goodbye and give some time to send it.
print("Goodbye!")
wait(100)

# Shut the hub down.
hub.system.shutdown()
```

1.4 Prime Hub / Inventor Hub



class InventorHub

This class is the same as the `PrimeHub` class, shown below. Both classes work on both hubs.

These hubs are completely identical. They use the same Pybricks firmware.

class PrimeHub(*top_side=Axis.Z*, *front_side=Axis.X*)

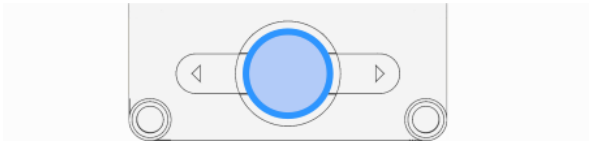
LEGO® SPIKE Prime Hub or LEGO® MINDSTORMS Inventor Hub.

Initializes the hub. Optionally, specify how the hub is *placed in your design* by saying in which direction the top side (with the buttons) and front side (with the USB port) are pointing.

Parameters

- **top_side** (`Axis`) – The axis that passes through the *top side* of the hub.
- **front_side** (`Axis`) – The axis that passes through the *front side* of the hub.

Using the hub status light



`light.`**`on`**(*color*)
Turns on the light at the specified color.

Parameters **`color`** (`Color`) – Color of the light.

`light.`**`off`**()
Turns off the light.

`light.`**`blink`**(*color*, *durations*)
Blinks the light at a given color by turning it on and off for given durations.

The light keeps blinking indefinitely while the rest of your program keeps running.

This method provides a simple way to make basic but useful patterns. For more generic and multi-color patterns, use `animate()` instead.

Parameters

- **`color`** (`Color`) – Color of the light.
- **`durations`** (`list`) – List of (*time: ms*) values of the form `[on_1, off_1, on_2, off_2, ...]`.

`light.`**`animate`**(*colors*, *interval*)
Animates the light with a list of colors. The next color in the list is shown after the given interval.

The animation runs in the background while the rest of your program keeps running. When the animation completes, it repeats.

Parameters

- **`colors`** (`list`) – List of *`Color`* values.
- **`interval`** (*time: ms*) – Time between color updates.

Using the light matrix display

`display.`**`orientation`**(*up*)
Sets the orientation of the light matrix display.

Only new displayed images and pixels are affected. The existing display contents remain unchanged.

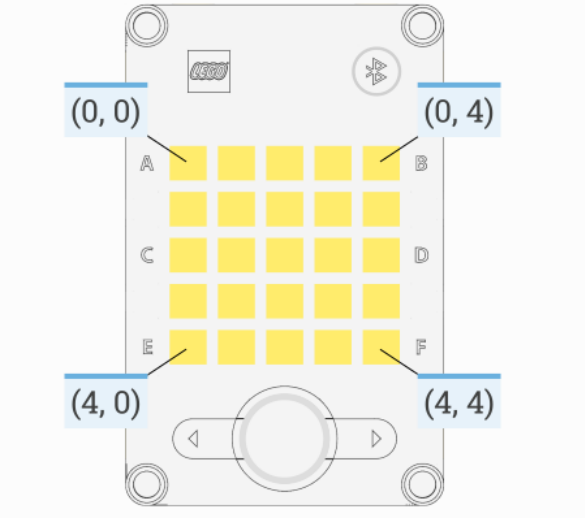
Parameters **`top`** (`Side`) – Which side of the light matrix display is "up" in your design. Choose `Side.TOP`, `Side.LEFT`, `Side.RIGHT`, or `Side.BOTTOM`.

`display.`**`off`**()
Turns off all the pixels.

`display.`**`pixel`**(*row*, *column*, *brightness=100*)
Turns on one pixel at the specified brightness.

Parameters

- **`row`** (`int`) – Vertical grid index, starting at 0 from the top.



- **column** (int) – Horizontal grid index, starting at 0 from the left.
- **brightness** (*brightness: %*) – Brightness of the pixel.

`display.`**`image`**`(`*matrix*`)`
Displays an image, represented by a matrix of *brightness: %* values.

Parameters **matrix** (Matrix) – Matrix of intensities (*brightness: %*). A 2D list is also accepted.

`display.`**`animate`**`(`*matrices*, *interval*`)`
Displays an animation made using a list of images.

Each image has the same format as above. Each image is shown for the given interval. The animation repeats forever while the rest of your program keeps running.

Parameters

- **matrix** (list) – List of Matrix of intensities.
- **interval** (*time: ms*) – Time to display each image in the list.

`display.`**`number`**`(`*number*`)`
Displays a number in the range -99 to 99.

A minus sign (-) is shown as a faint dot in the center of the display. Numbers greater than 99 are shown as >. Numbers less than -99 are shown as <.

Parameters **number** (int) – The number to be displayed.

`display.`**`char`**`(`*char*`)`
Displays a character or symbol on the light grid. This may be any letter (a–z), capital letter (A–Z) or one of the following symbols: `!"#$%&'()*+,-./:;<=>?@[\]^_`{|}`.

Parameters **character** (str) – The character or symbol to be displayed.

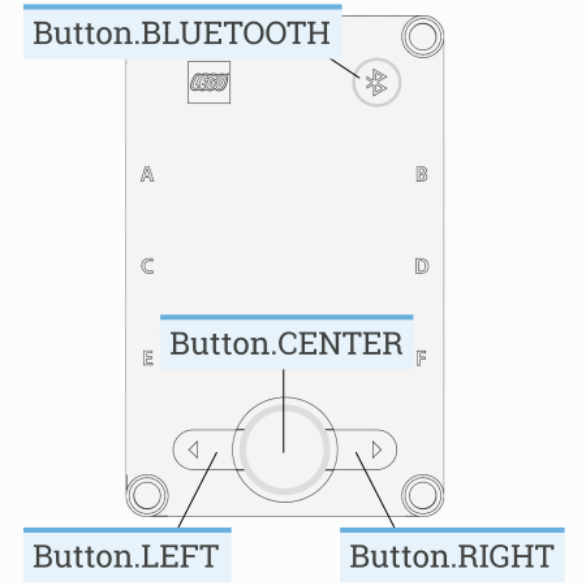
`display.`**`text`**`(`*text*, *on=500*, *off=50*`)`
Displays a text string, one character at a time, with a pause between each character. After the last character is shown, all lights turn off.

Parameters

- **text** (str) – The text to be displayed.
- **on** (*time: ms*) – For how long a character is shown.

- **off** (*time: ms*) – For how long the display is off between characters.

Using the buttons



buttons.**pressed**()
Checks which buttons are currently pressed.

Returns Tuple of pressed buttons.

Return type Tuple of *Button*

Using the IMU

imu.**up**()
Checks which side of the hub currently faces upward.

Returns Side.TOP, Side.BOTTOM, Side.LEFT, Side.RIGHT, Side.FRONT or Side.BACK.

Return type *Side*

imu.**tilt**()
Gets the pitch and roll angles. This is relative to the *user-specified neutral orientation*.

The order of rotation is pitch-then-roll. This is equivalent to a positive rotation along the robot y-axis and then a positive rotation along the x-axis.

Returns Pitch and roll angles.

Return type (*angle: deg*, *angle: deg*)

imu.**acceleration**(*axis=None*)
Gets the acceleration of the device along a given axis in the *robot reference frame*.

Parameters **axis** (Axis) – Axis along which the acceleration is measured.

Returns Acceleration along the specified axis. If you specify no axis, this returns a vector of accelerations along all axes.

Return type *linear acceleration: m/s/s*

imu.**angular_velocity**(*axis=None*)
Gets the angular velocity of the device along a given axis in the *robot reference frame*.

Parameters **axis** (Axis) – Axis along which the angular velocity is measured.

Returns Angular velocity along the specified axis. If you specify no axis, this returns a vector of accelerations along all axes.

Return type *rotational speed: deg/s*

imu.**heading**()
Gets the heading angle relative to the starting orientation. It is a a positive rotation around the *z-axis in the robot frame*, prior to applying any tilt rotation.

For a vehicle viewed from the top, this means that a positive heading value corresponds to a counterclockwise rotation.

Note: This method is not yet implemented.

Returns Heading angle relative to starting orientation.

Return type *angle: deg*

imu.**reset_heading**(*angle*)
Resets the accumulated heading angle of the robot.

Note: This method is not yet implemented.

Parameters **angle** (*angle: deg*) – Value to which the heading should be reset.

Using the speaker

speaker.**beep**(*frequency=500*, *duration=100*)
Play a beep/tone.

Parameters

- **frequency** (*frequency: Hz*) – Frequency of the beep. Frequencies below 100 are treated as 100.
- **duration** (*time: ms*) – Duration of the beep. If the duration is less than 0, then the method returns immediately and the frequency play continues to play indefinitely.

speaker.**play_notes**(*notes*, *tempo=120*)
Plays a sequence of musical notes. For example: `['C4/4', 'C4/4', 'G4/4', 'G4/4']`.

Each note is a string with the following format:

- The first character is the name of the note, `A` to `G` or `R` for a rest.
- Note names can also include an accidental `#` (sharp) or `b` (flat). `B#`/`Cb` and `E#`/`Fb` are not allowed.
- The note name is followed by the octave number `2` to `8`. For example `C4` is middle C. The octave changes to the next number at the note C, for example, `B3` is the note below middle C (`C4`).
- The octave is followed by `/` and a number that indicates the size of the note. For example `/4` is a quarter note, `/8` is an eighth note and so on.

- This can optionally followed by a `.` to make a dotted note. Dotted notes are 1-1/2 times as long as notes without a dot.
- The note can optionally end with a `_` which is a tie or a slur. This causes there to be no pause between this note and the next note.

Parameters

- **notes** (*iter*) – A sequence of notes to be played.
- **tempo** (`int`) – Beats per minute. A quarter note is one beat.

Using the battery

`battery.`**`voltage`**`()`
Gets the voltage of the battery.

Returns Battery voltage.

Return type *voltage: mV*

`battery.`**`current`**`()`
Gets the current supplied by the battery.

Returns Battery current.

Return type *current: mA*

System control

`system.`**`set_stop_button`**`(`*button*`)`
Sets the button or button combination that stops a running script.

Normally, the center button is used to stop a running script. You can change or disable this behavior in order to use the button for other purposes.

Parameters **Button** – A button such as *Button.CENTER*, or a tuple of multiple buttons. Choose `None` to disable the stop button altogether.

`system.`**`name`**`()`
Gets the hub name. This is the name you see when connecting via Bluetooth.

Returns The hub name.

Return type *str*

`system.`**`shutdown`**`()`
Stops your program and shuts the hub down.

`system.`**`reset_reason`**`()`
Finds out how and why the hub (re)booted. This can be useful to diagnose some problems.

Returns Returns `0` if the hub was previously powered off normally. Returns `1` if the hub rebooted automatically, like after a firmware update. Returns `2` if the hub previously crashed due to a watchdog timeout, which indicates a firmware issue.

Return type *int*

Note: The examples below use the `PrimeHub` class. The examples work fine on both hubs because they are the identical. If you prefer, you can change this to `InventorHub`.

1.4.1 Status light examples

Turning the light on and off

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Turn the light on and off 5 times.
for i in range(5):

    hub.light.on(Color.RED)
    wait(1000)

    hub.light.off()
    wait(500)
```

Changing brightness and using custom colors

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Show the color at 30% brightness.
hub.light.on(Color.RED * 0.3)

wait(2000)

# Use your own custom color.
hub.light.on(Color(h=30, s=100, v=50))

wait(2000)

# Go through all the colors.
for hue in range(360):
    hub.light.on(Color(hue))
    wait(10)
```

Making the light blink

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub
hub = PrimeHub()

# Keep blinking red on and off.
hub.light.blink(Color.RED, [500, 500])

wait(10000)

# Keep blinking green slowly and then quickly.
hub.light.blink(Color.GREEN, [500, 500, 50, 900])

wait(10000)
```

Creating light animations

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Color
from pybricks.tools import wait
from umath import sin, pi

# Initialize the hub.
hub = PrimeHub()

# Make an animation with multiple colors.
hub.light.animate([Color.RED, Color.GREEN, Color.NONE], interval=500)

wait(10000)

# Make the color RED grow faint and bright using a sine pattern.
hub.light.animate(
    [Color.RED * (0.5 * sin(i / 15 * pi) + 0.5) for i in range(30)], 40)

wait(10000)

# Cycle through a rainbow of colors.
hub.light.animate([Color(h=i*8) for i in range(45)], interval=40)

wait(10000)
```

1.4.2 Matrix display examples

Displaying images

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait
from pybricks.parameters import Icon

# Initialize the hub.
hub = PrimeHub()

# Display a big arrow pointing up.
hub.display.image(Icon.UP)

# Wait so we can see what is displayed.
wait(2000)

# Display a heart at half brightness.
hub.display.image(Icon.HEART / 2)

# Wait so we can see what is displayed.
wait(2000)
```

Displaying numbers

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Count from 0 to 99.
for i in range(100):
    hub.display.number(i)
    wait(200)
```

Displaying text

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Display the letter A for two seconds.
hub.display.char('A')
wait(2000)

# Display text, one letter at a time.
hub.display.text('Hello, world!')
```

Displaying individual pixels

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Turn on the pixel at row 1, column 2.
hub.display.pixel(1, 2)
wait(2000)

# Turn on the pixel at row 2, column 4, at 50% brightness.
hub.display.pixel(2, 4, 50)
wait(2000)

# Turn off the pixel at row 1, column 2.
hub.display.pixel(1, 2, 0)
wait(2000)
```

Changing the display orientation

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait
from pybricks.parameters import Side

# Initialize the hub.
hub = PrimeHub()

# Rotate the display. Now right is up.
hub.display.orientation(up=Side.RIGHT)

# Display a number. This will be shown sideways.
hub.display.number(23)

# Wait so we can see what is displayed.
wait(10000)
```

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Icon
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

while True:

    # Check which side of the hub is up.
    up_side = hub.imu.up()

    # Use this side to set the display orientation.
```

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```
    hub.display.orientation(up_side)

    # Display something, like an arrow.
    hub.display.image(Icon.UP)

    wait(10)
```

Making your own images

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait
from pybricks.geometry import Matrix

# Initialize the hub.
hub = PrimeHub()

# Make a square that is bright on the outside and faint in the middle.
SQUARE = Matrix([
    [100, 100, 100, 100, 100],
    [100, 50,  50,  50,  100],
    [100, 50,  0,   50,  100],
    [100, 50,  50,  50,  100],
    [100, 100, 100, 100, 100],
])

# Display the square.
hub.display.image(SQUARE)
wait(3000)

# Make an image using a Python list comprehension. In this image, the
# brightness of each pixel is the sum of the row and column index. So the
# light is faint in the top left and bright in the bottom right.
GRADIENT = Matrix([[(r + c) for c in range(5)] for r in range(5)]) * 12.5

# Display the generated gradient.
hub.display.image(GRADIENT)
wait(3000)
```

Combining images to make expressions

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Icon, Side
from pybricks.tools import wait

from urandom import randint

# Initialize the hub.
hub = PrimeHub()
hub.display.orientation(up=Side.RIGHT)
```

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```
while True:

    # Start with random left brow: up or down.
    if randint(0, 100) < 70:
        brows = Icon.EYE_LEFT_BROW*0.5
    else:
        brows = Icon.EYE_LEFT_BROW_UP*0.5

    # Add random right brow: up or down.
    if randint(0, 100) < 70:
        brows += Icon.EYE_RIGHT_BROW*0.5
    else:
        brows += Icon.EYE_RIGHT_BROW_UP*0.5

    for i in range(3):
        # Display eyes open plus the random brows.
        hub.display.image(Icon.EYE_LEFT + Icon.EYE_RIGHT + brows)
        wait(2000)

        # Display eyes blinked plus the random brows.
        hub.display.image(Icon.EYE_LEFT_BLINK*0.7 + Icon.EYE_RIGHT_BLINK*0.7 + brows)
        wait(200)
```

Displaying animations

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Icon
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Turn the hub light off (optional).
hub.light.off()

# Create a list of intensities from 0 to 100 and back.
brightness = list(range(0, 100, 4)) + list(range(100, 0, -4))

# Create an animation of the heart icon with changing brightness.
hub.display.animate([Icon.HEART * i/100 for i in brightness], 30)

# The animation repeats in the background. Here we just wait.
while True:
    wait(100)
```

1.4.3 Button examples

Detecting button presses

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Button, Icon
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Wait for any button to be pressed, and save the result.
pressed = []
while not any(pressed):
    pressed = hub.buttons.pressed()
    wait(10)

# Display a circle.
hub.display.image(Icon.CIRCLE)

# Wait for all buttons to be released.
while any(hub.buttons.pressed()):
    wait(10)

# Display an arrow to indicate which button was pressed.
if Button.LEFT in pressed:
    hub.display.image(Icon.ARROW_LEFT_DOWN)
elif Button.RIGHT in pressed:
    hub.display.image(Icon.ARROW_RIGHT_DOWN)
elif Button.BLUETOOTH in pressed:
    hub.display.image(Icon.ARROW_RIGHT_UP)

wait(3000)
```

1.4.4 IMU examples

Testing which way is up

```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Color, Side
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Define colors for each side in a dictionary.
SIDE_COLORS = {
    Side.TOP: Color.RED,
    Side.BOTTOM: Color.BLUE,
    Side.LEFT: Color.GREEN,
    Side.RIGHT: Color.YELLOW,
```

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```
    Side.FRONT: Color.MAGENTA,
    Side.BACK: Color.BLACK,
}

# Keep updating the color based on detected up side.
while True:

    # Check which side of the hub is up.
    up_side = hub.imu.up()

    # Change the color based on the side.
    hub.light.on(SIDE_COLORS[up_side])

    # Also print the result.
    print(up_side)
    wait(50)
```

Reading the tilt value

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

while True:
    # Read the tilt values.
    pitch, roll = hub.imu.tilt()

    # Print the result.
    print(pitch, roll)
    wait(200)
```

Using a custom hub orientation

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait
from pybricks.geometry import Axis

# Initialize the hub. In this case, specify that the hub is mounted with the
# top side facing forward and the front side facing to the right.
# For example, this is how the hub is mounted in BLAST in the 51515 set.
hub = PrimeHub(top_side=Axis.X, front_side=-Axis.Y)

while True:
    # Read the tilt values. Now, the values are 0 when BLAST stands upright.
    # Leaning forward gives positive pitch. Leaning right gives positive roll.
    pitch, roll = hub.imu.tilt()
```

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```
    # Print the result.
    print(pitch, roll)
    wait(200)
```

Reading acceleration and angular velocity vectors

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Get the acceleration vector.
print(hub.imu.acceleration())

# Get the angular velocity vector.
print(hub.imu.angular_velocity())

# Wait so we can see what we printed
wait(5000)
```

Reading acceleration and angular velocity on one axis

```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait
from pybricks.geometry import Axis

# Initialize the hub.
hub = PrimeHub()

# Get the acceleration or angular_velocity along a single axis.
# If you need only one value, this is more memory efficient.
while True:

    # Read the forward acceleration.
    forward_acceleration = hub.imu.acceleration(Axis.X)

    # Read the yaw rate.
    yaw_rate = hub.imu.angular_velocity(Axis.Z)

    # Print the yaw rate.
    print(yaw_rate)
    wait(100)
```

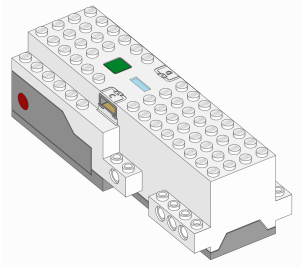
1.4.5 System examples

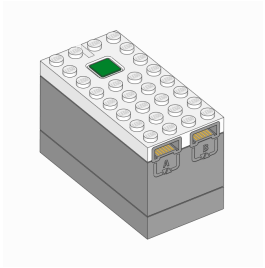
Changing the stop button combination

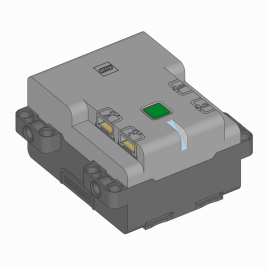
```
from pybricks.hubs import PrimeHub
from pybricks.parameters import Button

# Initialize the hub.
hub = PrimeHub()

# Configure the stop button combination. Now, your program stops
# if you press the center and Bluetooth buttons simultaneously.
hub.system.set_stop_button((Button.CENTER, Button.BLUETOOTH))

# Now we can use the center button as a normal button.
while True:

    # Play a sound if the center button is pressed.
    if Button.CENTER in hub.buttons.pressed():
        hub.speaker.beep()
```

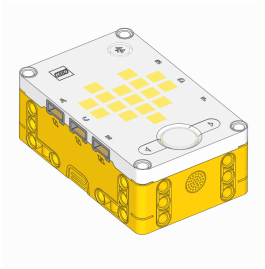
Turning the hub off

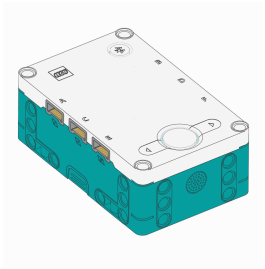
```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub()

# Say goodbye and give some time to send it.
print("Goodbye!")
wait(100)

# Shut the hub down.
hub.system.shutdown()
```











CHAPTER

TWO

PUPDEVICES – POWERED UP DEVICES

LEGO® Powered Up motor, sensors, and lights.

2.1 Motors without rotation sensors

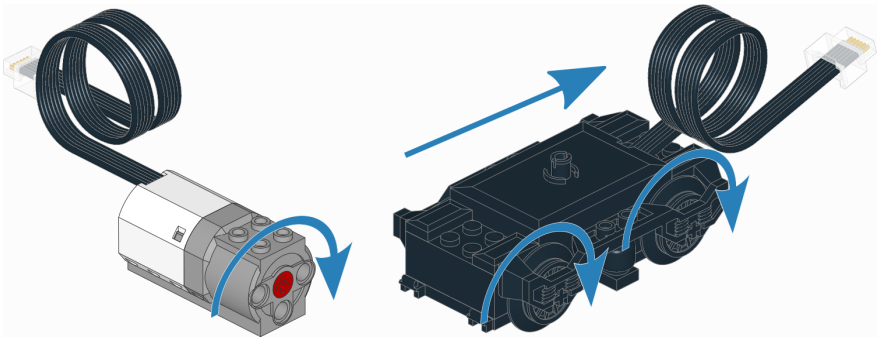


Figure 2.1: Powered Up motors without rotation sensors. The arrows indicate the default positive direction.

class DCMotor(*port*, *positive_direction=Direction.CLOCKWISE*)

Generic class to control simple motors without rotation sensors, such as train motors.

Parameters

- **port** (Port) – Port to which the motor is connected.
- **positive_direction** (Direction) – Which direction the motor should turn when you give a positive duty cycle value.

dc(*duty*)

Rotates the motor at a given duty cycle (also known as "power").

Parameters **duty** (*percentage: %*) – The duty cycle (-100.0 to 100).

stop()

Stops the motor and lets it spin freely.

The motor gradually stops due to friction.

brake()

Passively brakes the motor.

The motor stops due to friction, plus the voltage that is generated while the motor is still moving.

settings(*max_voltage*)
Configures motor settings. If no arguments are given, this returns the current values.

Parameters **max_voltage** (*voltage: mV*) – Maximum voltage applied to the motor during all motor commands.

2.1.1 Examples

Making a train drive forever

```
from pybricks.pupdevices import DCMotor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the motor.
train_motor = DCMotor(Port.A)

# Choose the "power" level for your train. Negative means reverse.
train_motor.dc(50)

# Keep doing nothing. The train just keeps going.
while True:
    wait(1000)
```

Making the motor move back and forth

```
from pybricks.pupdevices import DCMotor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize a motor without rotation sensors on port A.
example_motor = DCMotor(Port.A)

# Make the motor go clockwise (forward) at 70% duty cycle ("70% power").
example_motor.dc(70)

# Wait for three seconds.
wait(3000)

# Make the motor go counterclockwise (backward) at 70% duty cycle.
example_motor.dc(-70)

# Wait for three seconds.
wait(3000)
```

Changing the positive direction

```
from pybricks.pupdevices import DCMotor
from pybricks.parameters import Port, Direction
from pybricks.tools import wait

# Initialize a motor without rotation sensors on port A,
# with the positive direction as counterclockwise.
example_motor = DCMotor(Port.A, Direction.COUNTERCLOCKWISE)

# When we choose a positive duty cycle, the motor now goes counterclockwise.
example_motor.dc(70)

# This is useful when your (train) motor is mounted in reverse or upside down.
# By changing the positive direction, your script will be easier to read,
# because a positive value now makes your train/robot go forward.

# Wait for three seconds.
wait(3000)
```

Starting and stopping

```
from pybricks.pupdevices import DCMotor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize a motor without rotation sensors on port A.
example_motor = DCMotor(Port.A)

# Start and stop 10 times.
for count in range(10):
    print("Counter:", count)

    example_motor.dc(70)
    wait(1000)

    example_motor.stop()
    wait(1000)
```

2.2 Motors with rotation sensors

class Motor(*port*, *positive_direction=Direction.CLOCKWISE*, *gears=None*, *reset_angle=True*)

Generic class to control motors with built-in rotation sensors.

Parameters

- **port** (Port) – Port to which the motor is connected.
- **positive_direction** (Direction) – Which direction the motor should turn when you give a positive speed value or angle.
- **gears** (list) – List of gears linked to the motor.

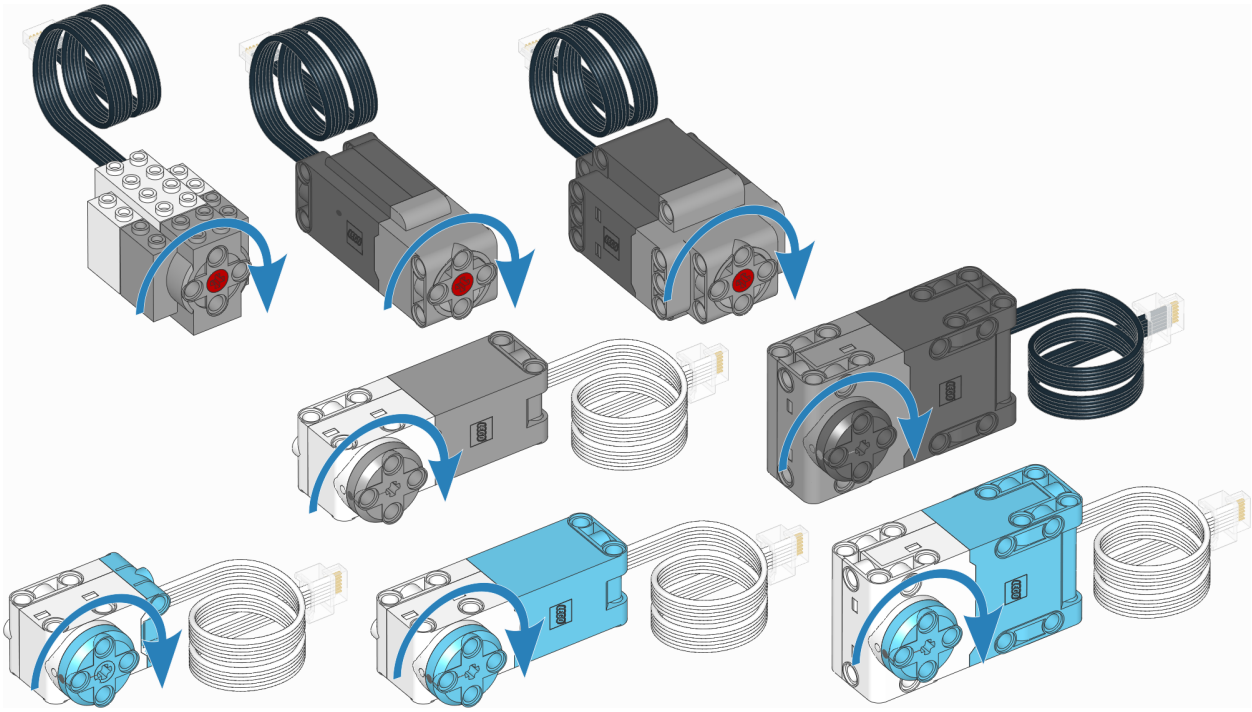


Figure 2.2: Powered Up motors with rotation sensors. The arrows indicate the default positive direction. See the *hubs* module for default directions of built-in motors.

For example: `[12, 36]` represents a gear train with a 12-tooth and a 36-tooth gear. Use a list of lists for multiple gear trains, such as `[[12, 36], [20, 16, 40]]`.

When you specify a gear train, all motor commands and settings are automatically adjusted to account for the resulting gear ratio. The motor direction remains unchanged by this.

- **`reset_angle`** (`bool`) – Choose `True` to reset the rotation sensor value to the absolute marker angle (between -180 and 179). Choose `False` to keep the current value, so your program knows where it left off last time.

Measuring

`speed`()
Gets the speed of the motor.

Returns Motor speed.

Return type *rotational speed: deg/s*

`angle`()
Gets the rotation angle of the motor.

Returns Motor angle.

Return type *angle: deg*

`reset_angle`(*angle=None*)
Sets the accumulated rotation angle of the motor to a desired value.

If you don't specify an angle, the absolute angle will be used if your motor supports it.

Parameters **`angle`** (*angle: deg*) – Value to which the angle should be reset.

Stopping

stop()
Stops the motor and lets it spin freely.

The motor gradually stops due to friction.

brake()
Passively brakes the motor.

The motor stops due to friction, plus the voltage that is generated while the motor is still moving.

hold()
Stops the motor and actively holds it at its current angle.

Action

run(*speed*)
Runs the motor at a constant speed.

The motor accelerates to the given speed and keeps running at this speed until you give a new command.

Parameters **speed** (*rotational speed: deg/s*) – Speed of the motor.

run_time(*speed*, *time*, *then=Stop.HOLD*, *wait=True*)
Runs the motor at a constant speed for a given amount of time.

The motor accelerates to the given speed, keeps running at this speed, and then decelerates. The total maneuver lasts for exactly the given amount of `time`.

Parameters

- **speed** (*rotational speed: deg/s*) – Speed of the motor.
- **time** (*time: ms*) – Duration of the maneuver.
- **then** (`Stop`) – What to do after coming to a standstill.
- **wait** (`bool`) – Wait for the maneuver to complete before continuing with the rest of the program.

run_angle(*speed*, *rotation_angle*, *then=Stop.HOLD*, *wait=True*)
Runs the motor at a constant speed by a given angle.

Parameters

- **speed** (*rotational speed: deg/s*) – Speed of the motor.
- **rotation_angle** (*angle: deg*) – Angle by which the motor should rotate.
- **then** (`Stop`) – What to do after coming to a standstill.
- **wait** (`bool`) – Wait for the maneuver to complete before continuing with the rest of the program.

run_target(*speed*, *target_angle*, *then=Stop.HOLD*, *wait=True*)
Runs the motor at a constant speed towards a given target angle.

The direction of rotation is automatically selected based on the target angle. It does not matter if `speed` is positive or negative.

Parameters

- **speed** (*rotational speed: deg/s*) – Speed of the motor.

- **target_angle** (*angle: deg*) – Angle that the motor should rotate to.
- **then** (Stop) – What to do after coming to a standstill.
- **wait** (bool) – Wait for the motor to reach the target before continuing with the rest of the program.

track_target(*target_angle*)

Tracks a target angle. This is similar to *run_target()*, but the usual smooth acceleration is skipped: it will move to the target angle as fast as possible. This method is useful if you want to continuously change the target angle.

Parameters **target_angle** (*angle: deg*) – Target angle that the motor should rotate to.

run_until_stalled(*speed*, *then=Stop.COAST*, *duty_limit=None*)

Runs the motor at a constant speed until it stalls.

Parameters

- **speed** (*rotational speed: deg/s*) – Speed of the motor.
- **then** (Stop) – What to do after coming to a standstill.
- **duty_limit** (*percentage: %*) – Duty cycle limit during this command. This is useful to avoid applying the full motor torque to a geared or lever mechanism.

Returns Angle at which the motor becomes stalled.

Return type *angle: deg*

dc(*duty*)

Rotates the motor at a given duty cycle (also known as "power").

This method lets you use a motor just like a simple DC motor.

Parameters **duty** (*percentage: %*) – The duty cycle (-100.0 to 100).

Motor status

control.**scale**

Number of degrees that the motor turns to complete one degree at the output of the gear train. This is the gear ratio determined from the `gears` argument when initializing the motor.

control.**done**()

Checks if an ongoing command or maneuver is done.

Returns `True` if the command is done, `False` if not.

Return type *bool*

control.**stalled**()

Checks if the controller is currently stalled.

A controller is stalled when it cannot reach the target speed or position, even with the maximum actuation signal.

Returns `True` if the controller is stalled, `False` if not.

Return type *bool*

control.**load**()

Estimates the load based on the torque required to maintain the specified speed or angle.

When coasting, braking, or controlling the duty cycle manually, the load cannot be estimated in this way. Then this method returns zero.

Returns The load torque. It returns 0 if control is not active.

Return type *torque: mNm*

Motor settings

You can only change these settings while the controller is stopped. For example, you can change them at the start of your program. Alternatively, first call `stop()`, and then change the settings.

settings(*max_voltage*)
Configures motor settings. If no arguments are given, this returns the current values.

Parameters **max_voltage** (*voltage: mV*) – Maximum voltage applied to the motor during all motor commands.

control.**limits**(*speed*, *acceleration*, *torque*)
Configures the maximum speed, acceleration, duty, and torque.

If no arguments are given, this will return the current values.

Parameters

- **speed** (*rotational speed: deg/s* or *speed: mm/s*) – Maximum speed. All speed commands will be capped to this value.
- **acceleration** (*rotational acceleration: deg/s/s* or *linear acceleration: mm/s/s*) – Maximum acceleration.
- **torque** (*torque: mNm*) – Maximum feedback torque during control.

control.**pid**(*kp*, *ki*, *kd*, *reserved*, *integral_rate*)
Gets or sets the PID values for position and speed control.

If no arguments are given, this will return the current values.

Parameters

- **kp** (int) – Proportional position control constant. It is the feedback torque per degree of error: μNm/deg.
- **ki** (int) – Integral position control constant. It is the feedback torque per accumulated degree of error: μNm/(deg s).
- **kd** (int) – Derivative position (or proportional speed) control constant. It is the feedback torque per unit of speed: μNm/(deg/s).
- **reserved** – This setting is not used.
- **integral_rate** (*rotational speed: deg/s* or *speed: mm/s*) – Maximum rate at which the error integral is allowed to grow.

control.**target_tolerances**(*speed*, *position*)
Gets or sets the tolerances that say when a maneuver is done.

If no arguments are given, this will return the current values.

Parameters

- **speed** (*rotational speed: deg/s* or *speed: mm/s*) – Allowed deviation from zero speed before motion is considered complete.
- **position** (*angle: deg* or *distance: mm*) – Allowed deviation from the target before motion is considered complete.

control.**stall_tolerances**(*speed*, *time*)

Gets or sets stalling tolerances.

If no arguments are given, this will return the current values.

Parameters

- **speed** (*rotational speed: deg/s* or *speed: mm/s*) – If the controller cannot reach this speed for some `time` even with maximum actuation, it is stalled.
- **time** (*time: ms*) – How long the controller has to be below this minimum `speed` before we say it is stalled.

2.2.1 Initialization examples

Making the motor move back and forth

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# Make the motor run clockwise at 500 degrees per second.
example_motor.run(500)

# Wait for three seconds.
wait(3000)

# Make the motor run counterclockwise at 500 degrees per second.
example_motor.run(-500)

# Wait for three seconds.
wait(3000)
```

Initializing multiple motors

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize motors on port A and B.
track_motor = Motor(Port.A)
gripper_motor = Motor(Port.B)

# Make both motors run at 500 degrees per second.
track_motor.run(500)
gripper_motor.run(500)

# Wait for three seconds.
wait(3000)
```

Setting the positive direction as counterclockwise

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port, Direction
from pybricks.tools import wait

# Initialize a motor on port A with the positive direction as counterclockwise.
example_motor = Motor(Port.A, Direction.COUNTERCLOCKWISE)

# When we choose a positive speed value, the motor now goes counterclockwise.
example_motor.run(500)

# This is useful when your motor is mounted in reverse or upside down.
# By changing the positive direction, your script will be easier to read,
# because a positive value now makes your robot/mechanism go forward.

# Wait for three seconds.
wait(3000)
```

Using gears

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port, Direction
from pybricks.tools import wait

# Initialize a motor on port A with the positive direction as counterclockwise.
# Also specify one gear train with a 12-tooth and a 36-tooth gear. The 12-tooth
# gear is attached to the motor axle. The 36-tooth gear is at the output axle.
geared_motor = Motor(Port.A, Direction.COUNTERCLOCKWISE, [12, 36])

# Make the output axle run at 100 degrees per second. The motor speed
# is automatically increased to compensate for the gears.
geared_motor.run(100)

# Wait for three seconds.
wait(3000)
```

2.2.2 Measurement examples

Measuring the angle and speed

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# Start moving at 300 degrees per second.
```

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```
example_motor.run(300)

# Display the angle and speed 50 times.
for i in range(100):

    # Read the angle (degrees) and speed (degrees per second).
    angle = example_motor.angle()
    speed = example_motor.speed()

    # Print the values.
    print(angle, speed)

    # Wait some time so we can read what is displayed.
    wait(200)
```

Resetting the measured angle

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# Reset the angle to 0.
example_motor.reset_angle(0)

# Reset the angle to 1234.
example_motor.reset_angle(1234)

# Reset the angle to the absolute angle.
# This is only supported on motors that have
# an absolute encoder. For other motors, this
# will raise an error.
example_motor.reset_angle()
```

2.2.3 Movement examples

Basic usage of all run methods

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# Run at 500 deg/s and then stop by coasting.
print("Demo of run")
example_motor.run(500)
```

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```
wait(1500)
example_motor.stop()
wait(1500)

# Run at 70% duty cycle ("power") and then stop by coasting.
print("Demo of dc")
example_motor.dc(50)
wait(1500)
example_motor.stop()
wait(1500)

# Run at 500 deg/s for two seconds.
print("Demo of run_time")
example_motor.run_time(500, 2000)
wait(1500)

# Run at 500 deg/s for 90 degrees.
print("Demo of run_angle")
example_motor.run_angle(500, 90)
wait(1500)

# Run at 500 deg/s back to the 0 angle
print("Demo of run_target to 0")
example_motor.run_target(500, 0)
wait(1500)

# Run at 500 deg/s back to the -90 angle
print("Demo of run_target to -90")
example_motor.run_target(500, -90)
wait(1500)

# Run at 500 deg/s until the motor stalls
print("Demo of run_until_stalled")
example_motor.run_until_stalled(500)
print("Done")
wait(1500)
```

Stopping ongoing movements in different ways

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# Run at 500 deg/s and then stop by coasting.
example_motor.run(500)
wait(1500)
example_motor.stop()
```

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```
wait(1500)

# Run at 500 deg/s and then stop by braking.
example_motor.run(500)
wait(1500)
example_motor.brake()
wait(1500)

# Run at 500 deg/s and then stop by holding.
example_motor.run(500)
wait(1500)
example_motor.hold()
wait(1500)

# Run at 500 deg/s and then stop by running at 0 speed.
example_motor.run(500)
wait(1500)
example_motor.run(0)
wait(1500)
```

Using the `then` argument to change how a run command stops

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port, Stop
from pybricks.tools import wait

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# By default, the motor holds the position. It keeps
# correcting the angle if you move it.
example_motor.run_angle(500, 360)
wait(1000)

# This does exactly the same as above.
example_motor.run_angle(500, 360, then=Stop.HOLD)
wait(1000)

# You can also brake. This applies some resistance
# but the motor does not move back if you move it.
example_motor.run_angle(500, 360, then=Stop.BRAKE)
wait(1000)

# This makes the motor coast freely after it stops.
example_motor.run_angle(500, 360, then=Stop.COAST)
wait(1000)
```

2.2.4 Stall examples

Running a motor until a mechanical endpoint

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# We'll use a speed of 200 deg/s in all our commands.
speed = 200

# Run the motor in reverse until it hits a mechanical stop.
# The duty_limit=30 setting means that it will apply only 30%
# of the maximum torque against the mechanical stop. This way,
# you don't push against it with too much force.
example_motor.run_until_stalled(-speed, duty_limit=30)

# Reset the angle to 0. Now whenever the angle is 0, you know
# that it has reached the mechanical endpoint.
example_motor.reset_angle(0)

# Now make the motor go back and forth in a loop.
# This will now work the same regardless of the
# initial motor angle, because we always start
# from the mechanical endpoint.
for count in range(10):
    example_motor.run_target(speed, 180)
    example_motor.run_target(speed, 90)
```

Centering a steering mechanism

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port

# Initialize a motor on port A.
example_motor = Motor(Port.A)

# We'll use a speed of 200 deg/s in all our commands.
speed = 200

# Run the motor in reverse until it hits a mechanical stop.
# The duty_limit=30 setting means that it will apply only 30%
# of the maximum torque against the mechanical stop. This way,
# you don't push against it with too much force.
example_motor.run_until_stalled(-speed, duty_limit=30)

# Reset the angle to 0. Now whenever the angle is 0, you know
# that it has reached the mechanical endpoint.
example_motor.reset_angle(0)
```

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```
# Now make the motor go back and forth in a loop.
# This will now work the same regardless of the
# initial motor angle, because we always start
# from the mechanical endpoint.
for count in range(10):
    example_motor.run_target(speed, 180)
    example_motor.run_target(speed, 90)
```

2.2.5 Parallel movement examples

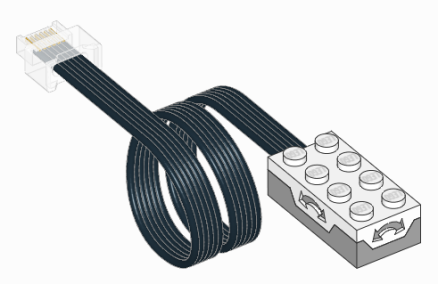
Using the `wait` argument to run motors in parallel

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port

# Initialize motors on port A and B.
track_motor = Motor(Port.A)
gripper_motor = Motor(Port.B)

# Make the track motor start moving,
# but don't wait for it to finish.
track_motor.run_angle(500, 360, wait=False)

# Now make the gripper motor rotate. This
# means they move at the same time.
gripper_motor.run_angle(200, 720)
```

Waiting for two parallel actions to complete

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize motors on port A and B.
track_motor = Motor(Port.A)
gripper_motor = Motor(Port.B)

# Make both motors perform an action with wait=False
track_motor.run_angle(500, 360, wait=False)
gripper_motor.run_angle(200, 720, wait=False)

# While one or both of the motors are not done yet,
# do something else. In this example, just wait.
while not track_motor.control.done() or not gripper_motor.control.done():
    wait(10)

print("Both motors are done!")
```

2.3 Tilt Sensor



class TiltSensor(*port*)

LEGO® Powered Up Tilt Sensor.

Parameters **port** (Port) – Port to which the sensor is connected.

tilt()

Measures the tilt relative to the horizontal plane.

Returns Tuple of pitch and roll angles.

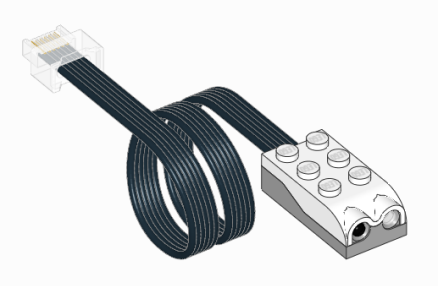
Return type (*angle: deg*, *angle: deg*)

2.3.1 Examples

Measuring pitch and roll

```
from pybricks.pupdevices import TiltSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
accel = TiltSensor(Port.A)

while True:
    # Read the tilt angles relative to the horizontal plane.
    pitch, roll = accel.tilt()

    # Print the values
    print("Pitch:", pitch, "Roll:", roll)

    # Wait some time so we can read what is printed.
    wait(100)
```

2.4 Infrared Sensor



class InfraredSensor(*port*)

LEGO® Powered Up Infrared Sensor.

Parameters **port** (Port) – Port to which the sensor is connected.

distance()

Measures the relative distance between the sensor and an object using infrared light.

Returns Relative distance ranging from 0 (closest) to 100 (farthest).

Return type *relative distance: %*

reflection()

Measures the reflection of a surface using an infrared light.

Returns Reflection, ranging from 0.0 (no reflection) to 100.0 (high reflection).

Return type *percentage: %*

count()

Counts the number of objects that have passed by the sensor.

Returns Number of objects counted.

Return type *int*

2.4.1 Examples

Measuring distance, object count, and reflection

```
from pybricks.pupdevices import InfraredSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
ir = InfraredSensor(Port.A)

while True:
    # Read all the information we can get from this sensor.
    dist = ir.distance()
    count = ir.count()
    ref = ir.reflection()
```

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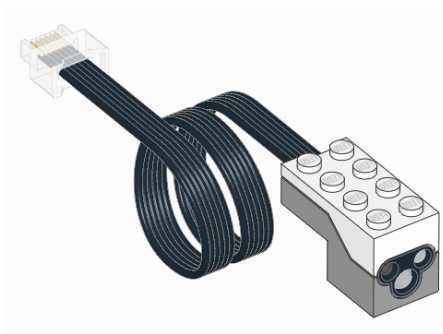
```
    # Print the values
    print("Distance:", dist, "Count:", count, "Reflection:", ref)

    # Move the sensor around and move your hands in front
    # of it to see what happens to the values.

    # Wait some time so we can read what is printed.
    wait(200)
```

2.5 Color and Distance Sensor



class ColorDistanceSensor(*port*)

LEGO® Powered Up Color and Distance Sensor.

Parameters **port** (Port) – Port to which the sensor is connected.

color()

Scans the color of a surface.

You choose which colors are detected using the *detectable_colors()* method. By default, it detects Color.RED, Color.YELLOW, Color.GREEN, Color.BLUE, Color.WHITE, or Color.NONE.

Returns Detected color.

Return type *Color*

reflection()

Measures the reflection of a surface.

Returns Reflection, ranging from 0.0 (no reflection) to 100.0 (high reflection).

Return type *percentage: %*

ambient()

Measures the ambient light intensity.

Returns Ambient light intensity, ranging from 0 (dark) to 100 (bright).

Return type *percentage: %*

distance()

Measures the relative distance between the sensor and an object using infrared light.

Returns Relative distance ranging from 0 (closest) to 100 (farthest).

Return type *relative distance: %*

hsv()
Scans the color of a surface.

This method is similar to *color()*, but it gives the full range of hue, saturation and brightness values, instead of rounding it to the nearest detectable color.

Returns Measured color. The color is described by a hue (0–359), a saturation (0–100), and a brightness value (0–100).

Return type *Color*

detectable_colors(*colors*)
Configures which colors the *color()* method should detect.

Specify only colors that you wish to detect in your application. This way, the full-color measurements are rounded to the nearest desired color, and other colors are ignored. This improves reliability.

If you give no arguments, the currently chosen colors will be returned as a tuple.

Parameters **colors** (list) – Tuple of *Color* objects: the colors that you want to detect. You can pick standard colors such as `Color.MAGENTA`, or provide your own colors like `Color(h=348, s=96, v=40)` for even better results. You measure your own colors with the *hsv()* method.

Built-in light

This sensor has a built-in light. You can make it red, green, blue, or turn it off. If you use the sensor to measure something afterwards, the light automatically turns back on at the default color for that sensing method.

light.**on**(*color*)
Turns on the light at the specified color.

Parameters **color** (Color) – Color of the light.

light.**off**()
Turns off the light.

2.5.1 Examples

Measuring color

```
from pybricks.pupdevices import ColorDistanceSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorDistanceSensor(Port.A)

while True:
    # Read the color.
    color = sensor.color()

    # Print the measured color.
    print(color)

    # Move the sensor around and see how
    # well you can detect colors.
```

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```
    # Wait so we can read the value.
    wait(100)
```

Waiting for a color

```
from pybricks.pupdevices import ColorDistanceSensor
from pybricks.parameters import Port, Color
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorDistanceSensor(Port.A)


# This is a function that waits for a desired color.
def wait_for_color(desired_color):
    # While the color is not the desired color, we keep waiting.
    while sensor.color() != desired_color:
        wait(20)


# Now we use the function we just created above.
while True:

    # Here you can make your train/vehicle go forward.

    print("Waiting for red ...")
    wait_for_color(Color.RED)

    # Here you can make your train/vehicle go backward.

    print("Waiting for blue ...")
    wait_for_color(Color.BLUE)
```

Measuring distance and blinking the light

```
from pybricks.pupdevices import ColorDistanceSensor
from pybricks.parameters import Port, Color
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorDistanceSensor(Port.A)

# Repeat forever.
while True:

    # If the sensor sees an object nearby.
    if sensor.distance() <= 40:
```

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```
        # Then blink the light red/blue 5 times.
        for i in range(5):
            sensor.light.on(Color.RED)
            wait(30)
            sensor.light.on(Color.BLUE)
            wait(30)
    else:
        # If the sensor sees nothing
        # nearby, just wait briefly.
        wait(10)
```

Reading hue, saturation, value

```
from pybricks.pupdevices import ColorDistanceSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorDistanceSensor(Port.A)

while True:
    # The standard color() method always "rounds" the
    # measurement to the nearest "whole" color.
    # That's useful for most applications.

    # But you can get the original hue, saturation,
    # and value without "rounding", as follows:
    color = sensor.hsv()

    # Print the results.
    print(color)

    # Wait so we can read the value.
    wait(500)
```

Changing the detectable colors

By default, the sensor is configured to detect red, yellow, green, blue, white, or no color, which suits many applications.

For better results in your application, you can measure your desired colors in advance, and tell the sensor to look only for those colors. Be sure to measure them at the **same distance and light conditions** as in your final application. Then you'll get very accurate results even for colors that are otherwise hard to detect.

```
from pybricks.pupdevices import ColorDistanceSensor
from pybricks.parameters import Port, Color
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorDistanceSensor(Port.A)

```

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```
# First, decide which objects you want to detect, and measure their HSV values.
# You can do that with the hsv() method as shown in the previous example.
#
# Use your measurements to override the default colors, or add new colors:
Color.GREEN = Color(h=132, s=94, v=26)
Color.MAGENTA = Color(h=348, s=96, v=40)
Color.BROWN = Color(h=17, s=78, v=15)
Color.RED = Color(h=359, s=97, v=39)

# Put your colors in a list or tuple.
my_colors = (Color.GREEN, Color.MAGENTA, Color.BROWN, Color.RED, Color.NONE)

# Save your colors.
sensor.detectable_colors(my_colors)

# color() works as usual, but now it returns one of your specified colors.
while True:
    color = sensor.color()

    # Print the color.
    print(color)

    # Check which one it is.
    if color == Color.MAGENTA:
        print("It works!")

    # Wait so we can read it.
    wait(100)
```

2.6 Power Functions

The *ColorDistanceSensor* can send infrared signals to control Power Functions infrared receivers. You can use this technique to control medium, large, extra large, and train motors. The infrared range is limited to about 30 cm, depending on the angle and ambient conditions.

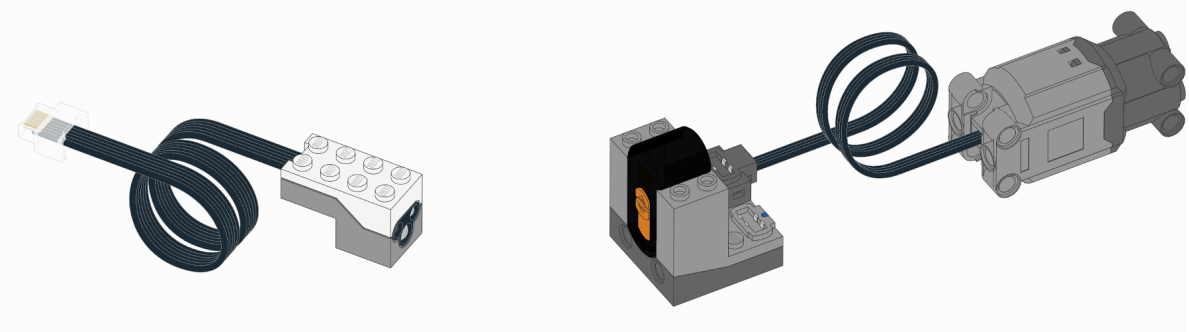


Figure 2.3: Powered Up *ColorDistanceSensor* (left), Power Functions infrared receiver (middle), and a Power Functions motor (right). Here, the receiver uses channel 1 with a motor on the red port.

class PFMotor(*sensor*, *channel*, *color*, *positive_direction=Direction.CLOCKWISE*)

Control Power Functions motors with the infrared functionality of the *ColorDistanceSensor*.

Parameters

- **sensor** (ColorDistanceSensor) – Sensor object.
- **channel** (int) – Channel number of the receiver: 1, 2, 3, or 4.
- **color** (Color) – Color marker on the receiver: *Color.BLUE* or *Color.RED*
- **positive_direction** (Direction) – Which direction the motor should turn when you give a positive duty cycle value.

dc(*duty*)

Rotates the motor at a given duty cycle (also known as "power").

Parameters **duty** (*percentage: %*) – The duty cycle (-100.0 to 100).

stop()

Stops the motor and lets it spin freely.

The motor gradually stops due to friction.

brake()

Passively brakes the motor.

The motor stops due to friction, plus the voltage that is generated while the motor is still moving.

2.6.1 Examples

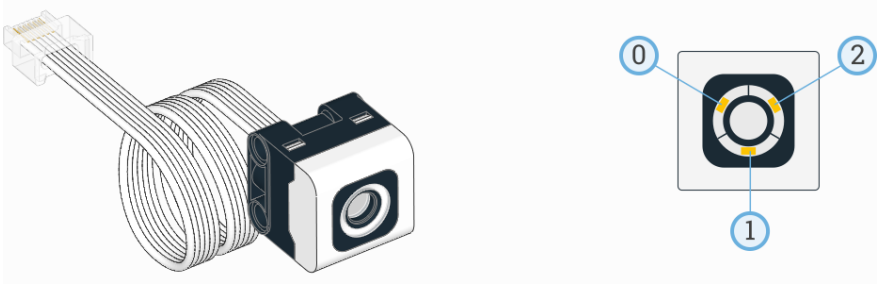
Control a Power Functions motor

```
from pybricks.pupdevices import ColorDistanceSensor, PFMotor
from pybricks.parameters import Port, Color
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorDistanceSensor(Port.B)

# Initialize a motor on channel 1, on the red output.
motor = PFMotor(sensor, 1, Color.RED)

# Rotate and then stop.
motor.dc(100)
wait(1000)
motor.stop()
wait(1000)

# Rotate the other way at half speed, and then stop.
motor.dc(-50)
wait(1000)
motor.stop()
```

Controlling multiple Power Functions motors

```
from pybricks.pupdevices import ColorDistanceSensor, PFMotor
from pybricks.parameters import Port, Color, Direction
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorDistanceSensor(Port.B)

# You can use multiple motors on different channels.
arm = PFMotor(sensor, 1, Color.BLUE)
wheel = PFMotor(sensor, 4, Color.RED, Direction.COUNTERCLOCKWISE)

# Accelerate both motors. Only these values are available.
# Other values will be rounded down to the nearest match.
for duty in [15, 30, 45, 60, 75, 90, 100]:
    arm.dc(duty)
    wheel.dc(duty)
    wait(1000)

# To make the signal more reliable, there is a short
# pause between commands. So, they change speed and
# stop at a slightly different time.

# Brake both motors.
arm.brake()
wheel.brake()
```

2.7 Color Sensor



class ColorSensor(*port*)

LEGO® SPIKE Color Sensor.

Parameters **port** (Port) – Port to which the sensor is connected.

color(*surface=True*)

Scans the color of a surface or an external light source.

You choose which colors are detected using the *detectable_colors()* method. By default, it detects `Color.RED`, `Color.YELLOW`, `Color.GREEN`, `Color.BLUE`, `Color.WHITE`, or `Color.NONE`.

Parameters **surface** (bool) – Choose `true` to scan the color of objects and surfaces. Choose `false` to scan the color of screens and other external light sources.

Returns Detected color.

Return type *Color*

reflection()
Measures the reflection of a surface.

Returns Reflection, ranging from 0.0 (no reflection) to 100.0 (high reflection).

Return type *percentage: %*

ambient()
Measures the ambient light intensity.

Returns Ambient light intensity, ranging from 0 (dark) to 100 (bright).

Return type *percentage: %*

Advanced color sensing

hsv(*surface=True*)
Scans the color of a surface or an external light source.

This method is similar to *color()*, but it gives the full range of hue, saturation and brightness values, instead of rounding it to the nearest detectable color.

Parameters **surface** (bool) – Choose `true` to scan the color of objects and surfaces. Choose `false` to scan the color of screens and other external light sources.

Returns Measured color. The color is described by a hue (0–359), a saturation (0–100), and a brightness value (0–100).

Return type *Color*

detectable_colors(*colors*)
Configures which colors the *color()* method should detect.

Specify only colors that you wish to detect in your application. This way, the full-color measurements are rounded to the nearest desired color, and other colors are ignored. This improves reliability.

If you give no arguments, the currently chosen colors will be returned as a tuple.

Parameters **colors** (list) – Tuple of *Color* objects: the colors that you want to detect. You can pick standard colors such as `Color.MAGENTA`, or provide your own colors like `Color(h=348, s=96, v=40)` for even better results. You measure your own colors with the *hsv()* method.

Built-in lights

This sensor has 3 built-in lights. You can adjust the brightness of each light. If you use the sensor to measure something, the lights will be turned on or off as needed for the measurement.

lights.**on**(*brightness*)
Turns on the lights at the specified brightness.

Parameters **brightness** (tuple of *brightness: %*) – Brightness of each light, in the order shown above. If you give one brightness value instead of a tuple, all lights get the same brightness.

lights.**off**()
Turns off all the lights.

2.7.1 Examples

Measuring color and reflection

```
from pybricks.pupdevices import ColorSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorSensor(Port.A)

while True:
    # Read the color and reflection
    color = sensor.color()
    reflection = sensor.reflection()

    # Print the measured color and reflection.
    print(color, reflection)

    # Move the sensor around and see how
    # well you can detect colors.

    # Wait so we can read the value.
    wait(100)
```

Waiting for a color

```
from pybricks.pupdevices import ColorSensor
from pybricks.parameters import Port, Color
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorSensor(Port.A)


# This is a function that waits for a desired color.
def wait_for_color(desired_color):
    # While the color is not the desired color, we keep waiting.
    while sensor.color() != desired_color:
        wait(20)


# Now we use the function we just created above.
while True:

    # Here you can make your train/vehicle go forward.

    print("Waiting for red ...")
    wait_for_color(Color.RED)

    # Here you can make your train/vehicle go backward.
```

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```
    print("Waiting for blue ...")
    wait_for_color(Color.BLUE)
```

Reading *reflected* hue, saturation, and value

```
from pybricks.pupdevices import ColorSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorSensor(Port.A)

while True:
    # The standard color() method always "rounds" the
    # measurement to the nearest "whole" color.
    # That's useful for most applications.

    # But you can get the original hue, saturation,
    # and value without "rounding", as follows:
    color = sensor.hsv()

    # Print the results.
    print(color)

    # Wait so we can read the value.
    wait(500)
```

Changing the detectable colors

By default, the sensor is configured to detect red, yellow, green, blue, white, or no color, which suits many applications.

For better results in your application, you can measure your desired colors in advance, and tell the sensor to look only for those colors. Be sure to measure them at the **same distance and light conditions** as in your final application. Then you'll get very accurate results even for colors that are otherwise hard to detect.

```
from pybricks.pupdevices import ColorSensor
from pybricks.parameters import Port, Color
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorSensor(Port.A)

# First, decide which objects you want to detect, and measure their HSV values.
# You can do that with the hsv() method as shown in the previous example.
#
# Use your measurements to override the default colors, or add new colors:
Color.GREEN = Color(h=132, s=94, v=26)
Color.MAGENTA = Color(h=348, s=96, v=40)
Color.BROWN = Color(h=17, s=78, v=15)
```

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```
Color.RED = Color(h=359, s=97, v=39)

# Put your colors in a list or tuple.
my_colors = (Color.GREEN, Color.MAGENTA, Color.BROWN, Color.RED, Color.NONE)

# Save your colors.
sensor.detectable_colors(my_colors)

# color() works as usual, but now it returns one of your specified colors.
while True:
    color = sensor.color()

    # Print the color.
    print(color)

    # Check which one it is.
    if color == Color.MAGENTA:
        print("It works!")

    # Wait so we can read it.
    wait(100)
```

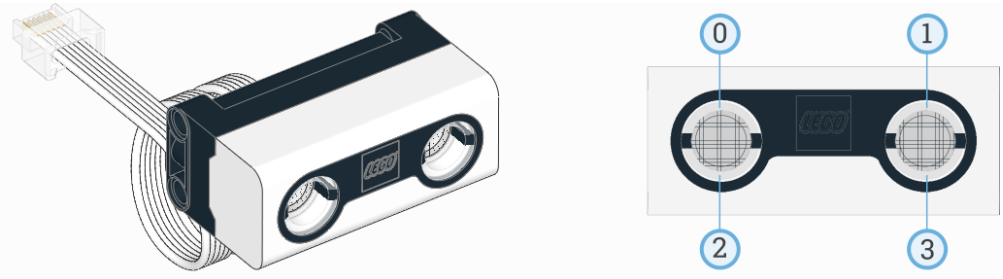
Reading *ambient* hue, saturation, value, and color

```
from pybricks.pupdevices import ColorSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorSensor(Port.A)

# Repeat forever.
while True:

    # Get the ambient color values. Instead of scanning the color of a surface,
    # this lets you scan the color of light sources like lamps or screens.
    hsv = sensor.hsv(surface=False)
    color = sensor.color(surface=False)

    # Get the ambient light intensity.
    ambient = sensor.ambient()

    # Print the measurements.
    print(hsv, color, ambient)

    # Point the sensor at a computer screen or colored light. Watch the color.
    # Also, cover the sensor with your hands and watch the ambient value.

    # Wait so we can read the printed line
    wait(100)
```

Blinking the built-in lights

```
from pybricks.pupdevices import ColorSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
sensor = ColorSensor(Port.A)

# Repeat forever.
while True:

    # Turn on one light at a time, at half the brightness.
    # Do this for all 3 lights and repeat that 5 times.
    for i in range(5):
        sensor.lights.on([50, 0, 0])
        wait(100)
        sensor.lights.on([0, 50, 0])
        wait(100)
        sensor.lights.on([0, 0, 50])
        wait(100)

    # Turn all lights on at maximum brightness.
    sensor.lights.on(100)
    wait(500)

    # Turn all lights off.
    sensor.lights.off()
    wait(500)
```

2.8 Ultrasonic Sensor



class UltrasonicSensor(*port*)

LEGO® SPIKE Color Sensor.

Parameters **port** (Port) – Port to which the sensor is connected.

distance()

Measures the distance between the sensor and an object using ultrasonic sound waves.

Returns Measured distance. If no valid distance was measured, it returns 2000 mm.

Return type *distance: mm*

presence()
Checks for the presence of other ultrasonic sensors by detecting ultrasonic sounds.

Returns `True` if ultrasonic sounds are detected, `False` if not.

Return type *bool*

Built-in lights

This sensor has 4 built-in lights. You can adjust the brightness of each light.

lights.**on**(*brightness*)
Turns on the lights at the specified brightness.

Parameters **brightness** (tuple of *brightness: %*) – Brightness of each light, in the order shown above. If you give one brightness value instead of a tuple, all lights get the same brightness.

lights.**off**()
Turns off all the lights.

2.8.1 Examples

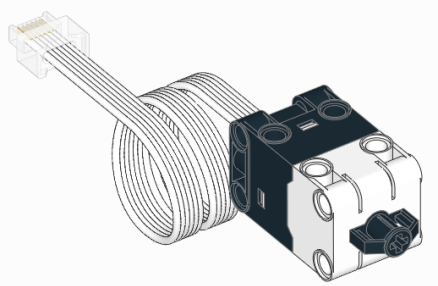
Measuring distance and switching on the lights

```
from pybricks.pupdevices import UltrasonicSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
eyes = UltrasonicSensor(Port.A)

while True:
    # Print the measured distance.
    print(eyes.distance())

    # If an object is detected closer than 500mm:
    if eyes.distance() < 500:
        # Turn the lights on.
        eyes.lights.on(100)
    else:
        # Turn the lights off.
        eyes.lights.off()

    # Wait some time so we can read what is printed.
    wait(100)
```

Gradually change the brightness of the lights

```
from pybricks.pupdevices import UltrasonicSensor
from pybricks.parameters import Port
from pybricks.tools import wait, StopWatch

from umath import pi, sin

# Initialize the sensor.
eyes = UltrasonicSensor(Port.A)

# Initialize a timer.
watch = StopWatch()

# We want one full light cycle to last three seconds.
PERIOD = 3000

while True:
    # The phase is where we are in the unit circle now.
    phase = watch.time()/PERIOD*2*pi

    # Each light follows a sine wave with a mean of 50, with an amplitude of 50.
    # We offset this sine wave by 90 degrees for each light, so that all the
    # lights do something different.
    brightness = [sin(phase + offset*pi/2) * 50 + 50 for offset in range(4)]

    # Set the brightness values for all lights.
    eyes.lights.on(brightness)

    # Wait some time.
    wait(50)
```

2.9 Force Sensor



class ForceSensor(*port*)

LEGO® SPIKE Force Sensor.

Parameters **port** (Port) – Port to which the sensor is connected.

force()

Measures the force exerted on the sensor.

Returns Measured force (up to approximately 10.00 N).

Return type *force: N*

distance()
Measures by how much the sensor button has moved.

Returns How much the sensor button has moved (up to approximately 8.00 mm).

Return type *distance: mm*

pressed(*force=3*)
Checks if the sensor button is pressed.

Parameters **force** (*force: N*) – Minimum force to be considered pressed.

Returns `True` if the sensor is pressed, `False` if it is not.

Return type *bool*

touched()
Checks if the sensor is touched.

This is similar to *pressed()*, but it detects slight movements of the button even when the measured force is still considered zero.

Returns `True` if the sensor is touched or pressed, `False` if it is not.

Return type *bool*

2.9.1 Examples

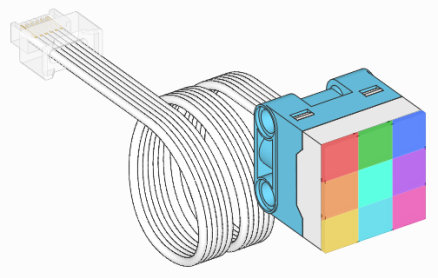
Measuring force and movement

```
from pybricks.pupdevices import ForceSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
button = ForceSensor(Port.A)

while True:
    # Read all the information we can get from this sensor.
    force = button.force()
    dist = button.distance()
    press = button.pressed()
    touch = button.touched()

    # Print the values
    print("Force", force, "Dist:", dist, "Pressed:", press, "Touched:", touch)

    # Push the sensor button see what happens to the values.

    # Wait some time so we can read what is printed.
    wait(200)
```

Measuring peak force

```
from pybricks.pupdevices import ForceSensor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the sensor.
button = ForceSensor(Port.A)


# This function waits until the button is pushed. It keeps track of the maximum
# detected force until the button is released. Then it returns the maximum.
def wait_for_force():

    # Wait for a force, by doing nothing for as long the force is nearly zero.
    print("Waiting for force.")
    while button.force() <= 0.1:
        wait(10)

    # Now we wait for the release, by waiting for the force to be zero again.
    print("Waiting for release.")

    # While we wait for that to happen, we keep reading the force and remember
    # the maximum force. We do this by initializing the maximum at 0, and
    # updating it each time we detect a bigger force.
    maximum = 0
    force = 10
    while force > 0.1:
        # Read the force.
        force = button.force()

        # Update the maximum if the measured force is larger.
        if force > maximum:
            maximum = force

        # Wait and then measure again.
        wait(10)

    # Return the maximum force.
    return maximum


# Keep waiting for the sensor button to be pushed. When it is, display
# the peak force and repeat.
while True:
    peak = wait_for_force()
    print("Released. Peak force: {0} N\n".format(peak))
```

2.10 Color Light Matrix



class ColorLightMatrix(*port*)

LEGO® SPIKE 3x3 Color Light Matrix.

Parameters **port** (Port) – Port to which the device is connected.

on(*colors*)

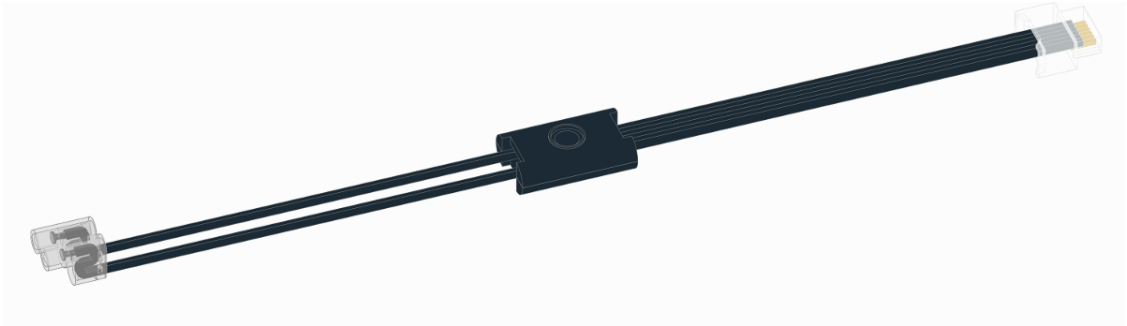
Turns the lights on.

Parameters **colors** (Color *or* list) – If a single *Color* is given, then all 9 lights are set to that color. If a list of colors is given, then each light is set to that color.

off()

Turns all of the lights off.

2.11 Light



class Light(*port*)

LEGO® Powered Up Light.

Parameters **port** (Port) – Port to which the device is connected.

on(*brightness=100*)

Turns on the light at the specified brightness.

Parameters **brightness** (*brightness: %*) – Brightness of the light.

off()

Turns off the light.

2.11.1 Examples

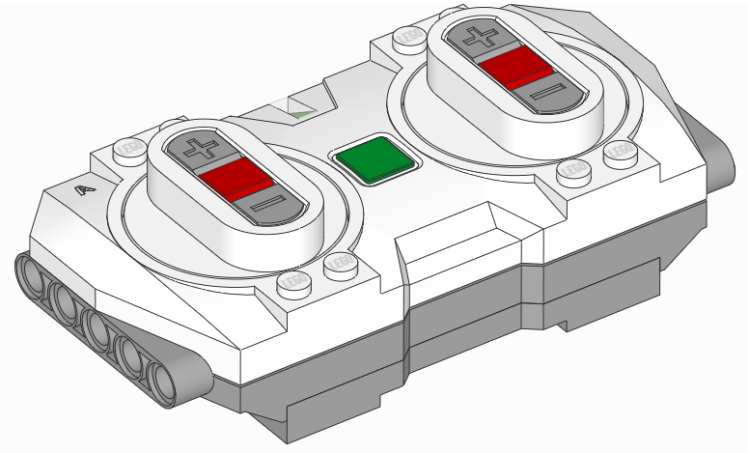
Making the light blink

```
from pybricks.pupdevices import Light
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the light.
light = Light(Port.A)

# Blink the light forever.
while True:
    # Turn the light on at 100% brightness.
    light.on(100)
    wait(500)

    # Turn the light off.
    light.off()
    wait(500)
```

Gradually change the brightness

```
from pybricks.pupdevices import Light
from pybricks.parameters import Port
from pybricks.tools import wait, StopWatch

from umath import pi, cos

# Initialize the light and a StopWatch.
light = Light(Port.A)
watch = StopWatch()

# Cosine pattern properties.
PERIOD = 2000
MAX = 100

# Make the brightness fade in and out.
while True:
    # Get phase of the cosine.
    phase = watch.time()/PERIOD*2*pi

    # Evaluate the brightness.
    brightness = (0.5 - 0.5*cos(phase))*MAX

    # Set light brightness and wait a bit.
    light.on(brightness)
    wait(10)
```

2.12 Remote Control



class Remote(*name=None*, *timeout=10000*)

LEGO® Powered Up Bluetooth Remote Control.

When you instantiate this class, the hub will search for a remote and connect automatically.

The remote must be on and ready for a connection, as indicated by a white blinking light.

Parameters

- **name** (str) – Bluetooth name of the remote. If no name is given, the hub connects to the first remote that it finds.
- **timeout** (*time: ms*) – How long to search for the remote.

name(*name=None*)

Gets or sets the Bluetooth name of the remote.

If no name is given, this method returns the current name.

Parameters **name** (str) – New Bluetooth name of the remote.

light.**on**(*color*)

Turns on the light at the specified color.

Parameters **color** (Color) – Color of the light.

light.**off**()

Turns off the light.

buttons.**pressed**()

Checks which buttons are currently pressed.

Returns Tuple of pressed buttons.

Return type Tuple of *Button*

2.12.1 Examples

Checking which buttons are pressed

```
from pybricks.pupdevices import Remote
from pybricks.parameters import Button
from pybricks.tools import wait

# Connect to the remote.
my_remote = Remote()

while True:
    # Check which buttons are pressed.
    pressed = my_remote.buttons.pressed()

    # Show the result.
    print("pressed:", pressed)

    # Check a specific button.
    if Button.CENTER in pressed:
        print("You pressed the center button!")

    # Wait so we can see the result.
    wait(100)
```

Changing the remote light color

```
from pybricks.pupdevices import Remote
from pybricks.parameters import Color
from pybricks.tools import wait

# Connect to the remote.
remote = Remote()

while True:
    # Set the color to red.
    remote.light.on(Color.RED)
    wait(1000)

    # Set the color to blue.
    remote.light.on(Color.BLUE)
    wait(1000)
```

Changing the light color using the buttons

```
from pybricks.pupdevices import Remote
from pybricks.parameters import Button, Color


def button_to_color(buttons):

    # Return a color depending on the button.
    if Button.LEFT_PLUS in buttons:
        return Color.RED
    if Button.LEFT_MINUS in buttons:
        return Color.GREEN
    if Button.LEFT in buttons:
        return Color.ORANGE
    if Button.RIGHT_PLUS in buttons:
        return Color.BLUE
    if Button.RIGHT_MINUS in buttons:
        return Color.YELLOW
    if Button.RIGHT in buttons:
        return Color.CYAN
    if Button.CENTER in buttons:
        return Color.VIOLET

    # Return no color by default.
    return Color.NONE


# Connect to the remote.
remote = Remote()

while True:
    # Wait until a button is pressed.
    pressed = ()
    while not pressed:
        pressed = remote.buttons.pressed()

    # Convert button code to color.
    color = button_to_color(pressed)

    # Set the remote light color.
    remote.light.on(color)

    # Wait until all buttons are released.
    while pressed:
        pressed = remote.buttons.pressed()
```

Using the timeout setting

You can use the `timeout` argument to change for how long the hub searches for the remote. If you choose `None`, it will search forever.

```
from pybricks.pupdevices import Remote

# Connect to any remote. Search forever until we find one.
my_remote = Remote(timeout=None)

print("Connected!")
```

If the remote was not found within the specified `timeout`, an *OSError* is raised. You can catch this exception to run other code if the remote is not available.

```
from pybricks.pupdevices import Remote

try:
    # Search for a remote for 5 seconds.
    my_remote = Remote(timeout=5000)

    print("Connected!")

    # Here you can write code that uses the remote.

except OSError:

    print("Could not find the remote.")

    # Here you can make your robot do something
    # without the remote.
```

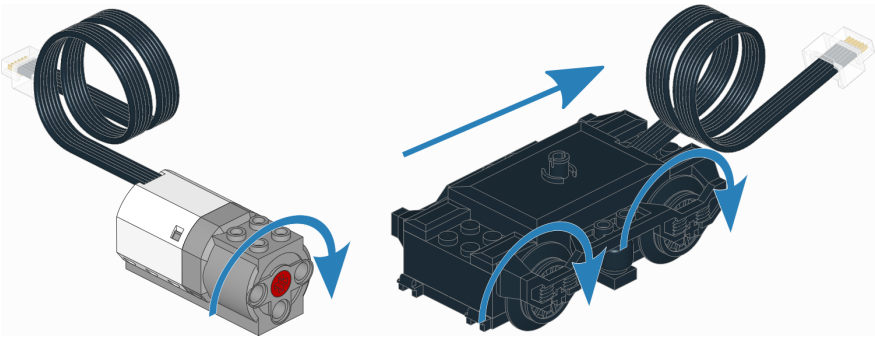
Changing the name of the remote

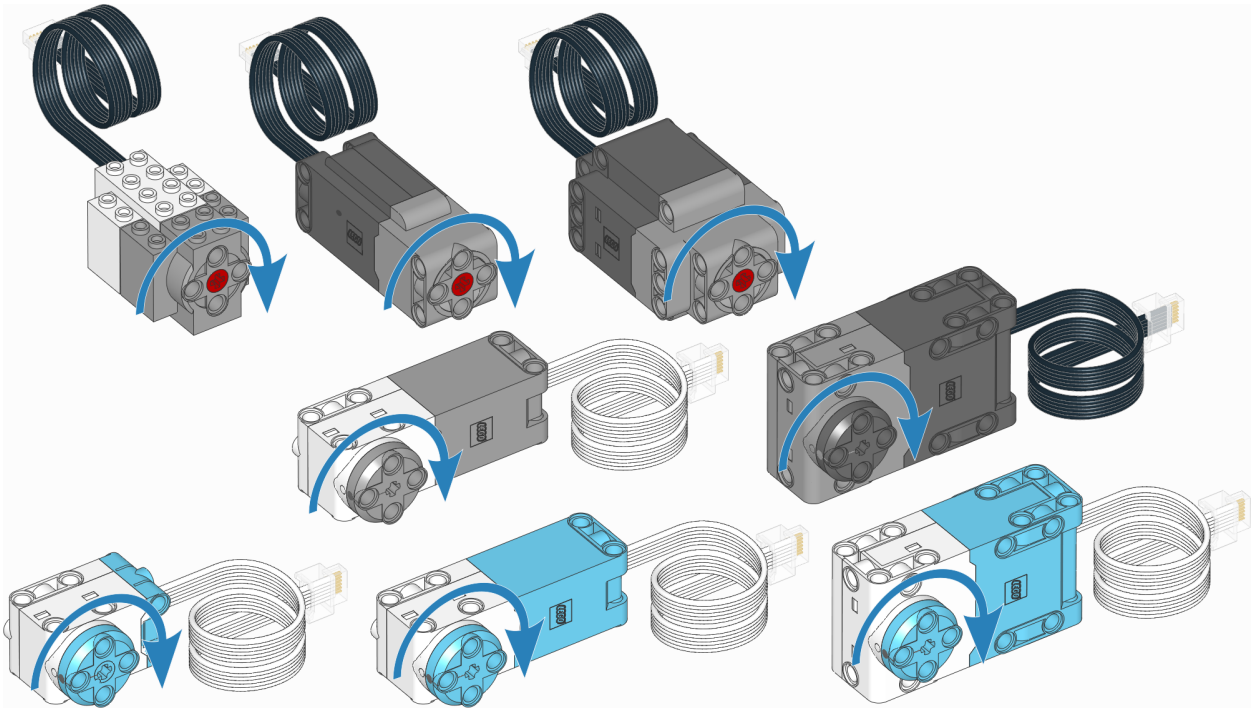
You can change the Bluetooth name of the remote. The factory default name is `Handset`.

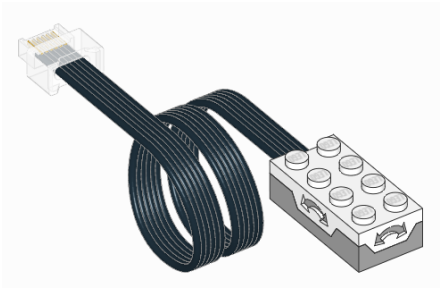
```
from pybricks.pupdevices import Remote

# Connect to any remote.
my_remote = Remote()

# Print the current name of the remote.
print(my_remote.name())

# Choose a new name.
my_remote.name('truck2')

print("Done!")
```

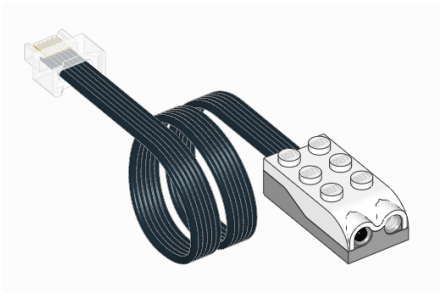
You can specify this name when connecting to the remote. This lets you pick the right one if multiple remotes are nearby.

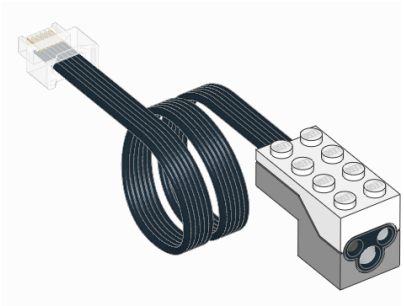
```
from pybricks.pupdevices import Remote
from pybricks.tools import wait

# Connect to a remote called truck2.
truck_remote = Remote('truck2', timeout=None)

print("Connected!")

wait(2000)
```

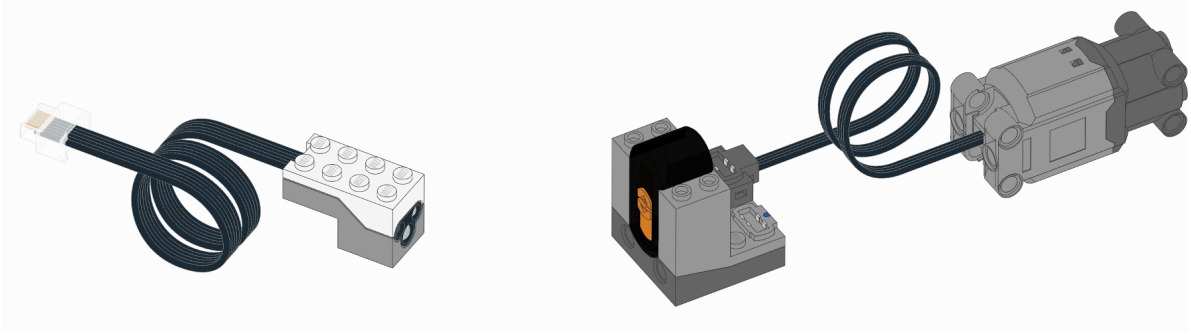


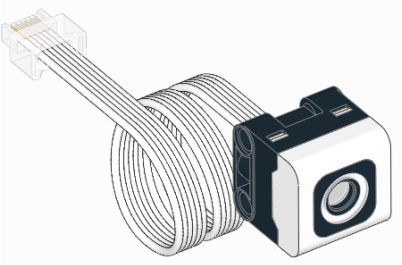


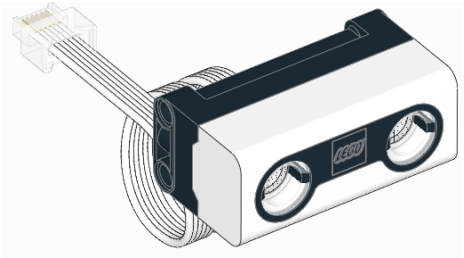


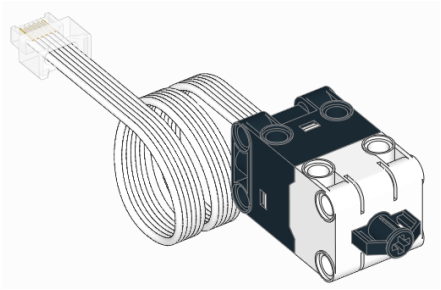


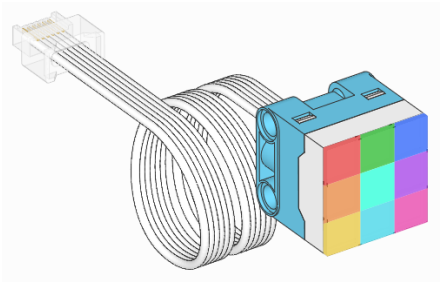


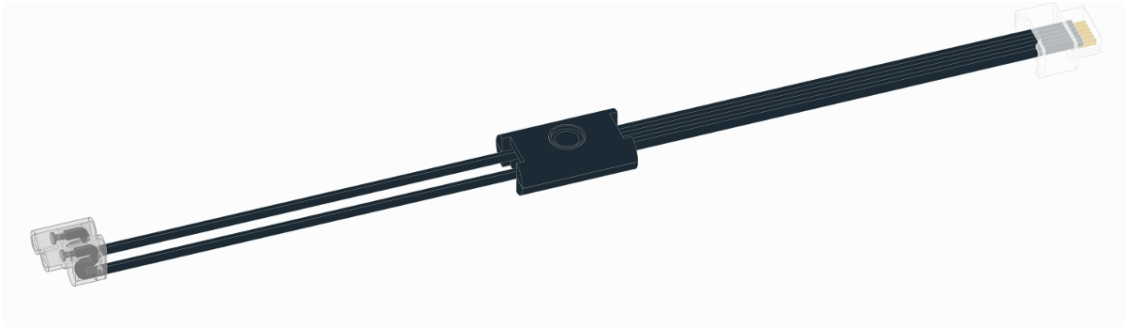


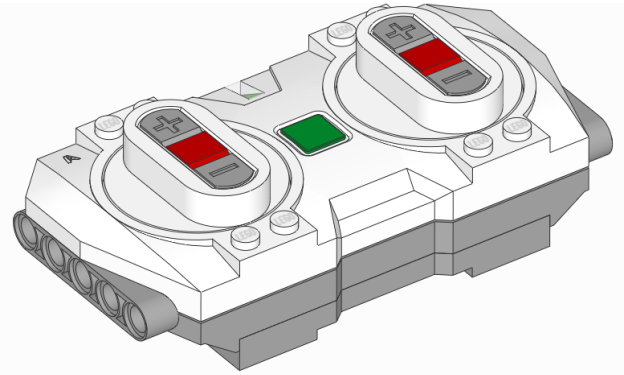










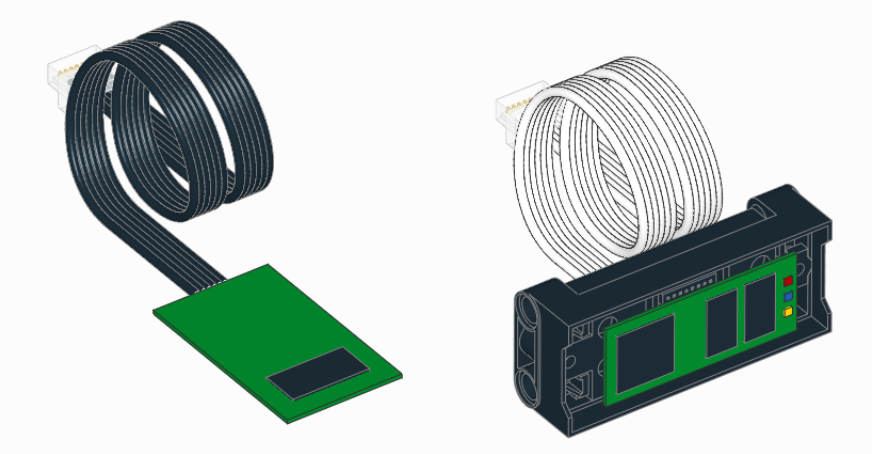


CHAPTER

THREE

IODEVICES – GENERIC I/O DEVICES

3.1 Powered Up Device



class PUPDevice(*port*)

Powered Up motor or sensor.

Parameters **port** (Port) – Port to which the device is connected.

info()

Returns information about the device.

Returns Dictionary with information, such as the device id.

Return type dict

read(*mode*)

Reads values from a given mode.

Parameters **mode** (int) – Device mode.

Returns Values read from the sensor.

Return type tuple

write(*mode*, *data*)

Writes values to the sensor. Only selected sensors and modes support this.

Parameters

- **mode** (int) – Device mode.

- **data** (tuple) – Values to be written.

3.1.1 Examples

Detecting devices

```
from pybricks.iodevices import PUPDevice
from pybricks.parameters import Port
from uerrno import ENODEV

# Dictionary of device identifiers along with their name.
device_names = {
    34: "Wedo 2.0 Tilt Sensor",
    35: "Wedo 2.0 Infrared Sensor",
    37: "BOOST Color Distance Sensor",
    38: "BOOST Interactive Motor",
    46: "Technic Large Motor",
    47: "Technic Extra Large Motor",
    48: "SPIKE Medium Angular Motor",
    49: "SPIKE Large Angular Motor",
    61: "SPIKE Color Sensor",
    62: "SPIKE Ultrasonic Sensor",
    63: "SPIKE Force Sensor",
    75: "Technic Medium Angular Motor",
    76: "Technic Large Angular Motor",
}

# Make a list of known ports.
ports = [Port.A, Port.B]

# On hubs that support it, add more ports.
try:
    ports.append(Port.C)
    ports.append(Port.D)
except AttributeError:
    pass

# On hubs that support it, add more ports.
try:
    ports.append(Port.E)
    ports.append(Port.F)
except AttributeError:
    pass

# Go through all available ports.
for port in ports:

    # Try to get the device, if it is attached.
    try:
        device = PUPDevice(port)
    except OSError as ex:
        if ex.args[0] == ENODEV:
```

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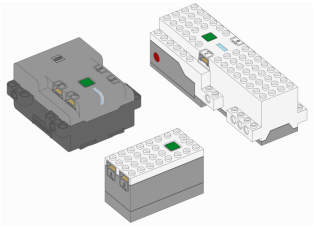
```
            # No device found on this port.
            print(port, ": ---")
            continue
        else:
            raise

    # Get the device id
    id = device.info()['id']

    # Look up the name.
    try:
        print(port, ":", device_names[id])
    except KeyError:
        print(port, ":", "Unknown device with ID", id)
```

3.2 LEGO Wireless Protocol v3 device

Warning: This is an experimental class. It has not been well tested and may be changed in future.



class LWP3Device(*hub_kind*, *name=None*, *timeout=10000*)

Connects to a remote hub running official LEGO firmware using the the LEGO Wireless Protocol v3

Parameters

- **hub_kind** (int) – The hub type identifier of the hub to connect to.
- **name** (str) – The name of the hub to connect to or None to connect to any hub.
- **timeout** (int) – The time, in milliseconds, to wait for a connection before raising an exception.

name(*name=None*)

Gets or sets the Bluetooth name of the remote.

If no name is given, this method returns the current name.

Parameters **name** (str) – New Bluetooth name of the remote.

write(*buf*)

Sends a message to the remote hub.

Parameters **buf** (bytes) – The raw binary message to send.

read()

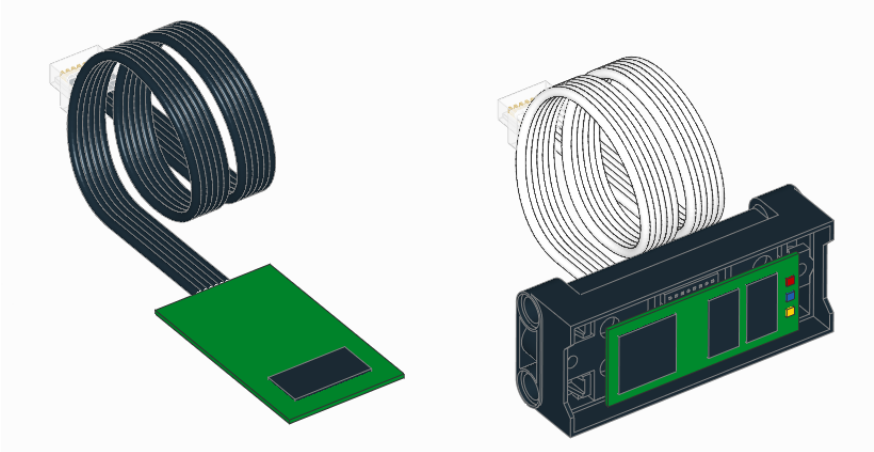
Retrieves the most recent message received from the remote hub.

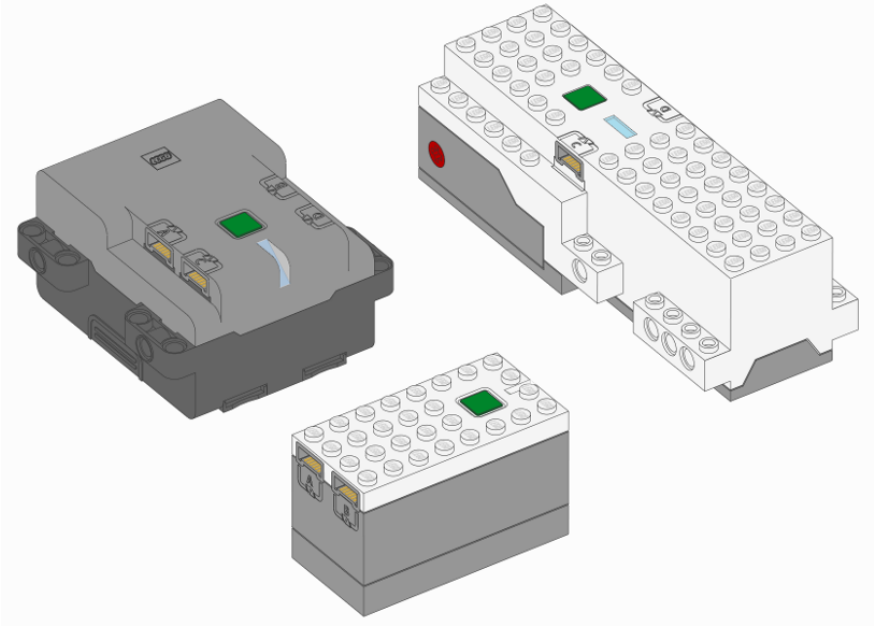
If a message has not been received since the last read, the method will block until a message is received.

Returns The raw binary message.

Return type *bytes*

This module has classes for generic input/output devices.





CHAPTER

FOUR

PARAMETERS – PARAMETERS AND CONSTANTS

Constant parameters/arguments for the Pybricks API.

4.1 Button

class Button

Buttons on a hub or remote.

LEFT_DOWN

LEFT_MINUS

DOWN

RIGHT_DOWN

RIGHT_MINUS

LEFT

CENTER

RIGHT

LEFT_UP

LEFT_PLUS

UP

BEACON

RIGHT_UP

RIGHT_PLUS

4.2 Color

class Color(*h*, *s=100*, *v=100*)

Light or surface color.

Saturated colors

These colors have maximum saturation and brightness value. They differ only in hue.

RED = Color(h=0, s=100, v=100)

ORANGE = Color(h=30, s=100, v=100)

YELLOW = Color(h=60, s=100, v=100)

GREEN = Color(h=120, s=100, v=100)

CYAN = Color(h=180, s=100, v=100)

BLUE = Color(h=240, s=100, v=100)

VIOLET = Color(h=270, s=100, v=100)

MAGENTA = Color(h=300, s=100, v=100)

Unsaturated colors

These colors have zero hue and saturation. They differ only in brightness value.

When detecting these colors using sensors, their values depend a lot on the distance to the object. If the distance between the sensor and the object is not constant in your robot, it is better to use only one of these colors in your programs.

WHITE = Color(h=0, s=0, v=100)

GRAY = Color(h=0, s=0, v=50)

BLACK = Color(h=0, s=0, v=10)
This represents dark objects that still reflect a very small amount of light.

NONE = Color(h=0, s=0, v=0)
This is total darkness, with no reflection or light at all.

Making your own colors

This example shows the basics of color properties, and how to define new colors.

```
from pybricks.parameters import Color

# You can print colors. Colors may be obtained from the Color class, or
# from sensors that return color measurements.
print(Color.RED)
```

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```
# You can read hue, saturation, and value properties.
print(Color.RED.h, Color.RED.s, Color.RED.v)

# You can make your own colors. Saturation and value are 100 by default.
my_green = Color(h=125)
my_dark_green = Color(h=125, s=80, v=30)

# When you print custom colors, you see exactly how they were defined.
print(my_dark_green)

# You can also add colors to the builtin colors.
Color.MY_DARK_BLUE = Color(h=235, s=80, v=30)

# When you add them like this, printing them only shows its name. But you can
# still read h, s, v by reading its attributes.
print(Color.MY_DARK_BLUE)
print(Color.MY_DARK_BLUE.h, Color.MY_DARK_BLUE.s, Color.MY_DARK_BLUE.v)
```

This example shows more advanced use cases of the `Color` class.

```
from pybricks.parameters import Color

# Two colors are equal if their h, s, and v attributes are equal.
if Color.BLUE == Color(240, 100, 100):
    print("Yes, these colors are the same.")

# You can scale colors to change their brightness value.
red_dark = Color.RED * 0.5

# You can shift colors to change their hue.
red_shifted = Color.RED >> 30

# Colors are immutable, so you can't change h, s, or v of an existing object.
try:
    Color.GREEN.h = 125
except AttributeError:
    print("Sorry, can't change the hue of an existing color object!")

# But you can override builtin colors by defining a whole new color.
Color.GREEN = Color(h=125)

# You can access and store colors as class attributes, or as a dictionary.
print(Color.BLUE)
print(Color["BLUE"])
print(Color["BLUE"] is Color.BLUE)
print(Color)
print([c for c in Color])

# This allows you to update existing colors in a loop.
for name in ("BLUE", "RED", "GREEN"):
    Color[name] = Color(1, 2, 3)
```

4.3 Direction

class Direction

Rotational direction for positive speed or angle values.

CLOCKWISE

A positive speed value should make the motor move clockwise.

COUNTERCLOCKWISE

A positive speed value should make the motor move counterclockwise.

positive_direction =	Positive speed:	Negative speed:
Direction.CLOCKWISE	clockwise	counterclockwise
Direction.COUNTERCLOCKWISE	counterclockwise	clockwise

In general, clockwise is defined by **looking at the motor shaft, just like looking at a clock**. Some motors have two shafts. If in doubt, refer to the diagram in the Motor class documentation.

4.4 Port

class Port

Input and output ports:

A

B

C

D

E

F

4.5 Side

class Side

Side of a hub or a sensor. These devices are mostly rectangular boxes with six sides:

TOP

BOTTOM

FRONT

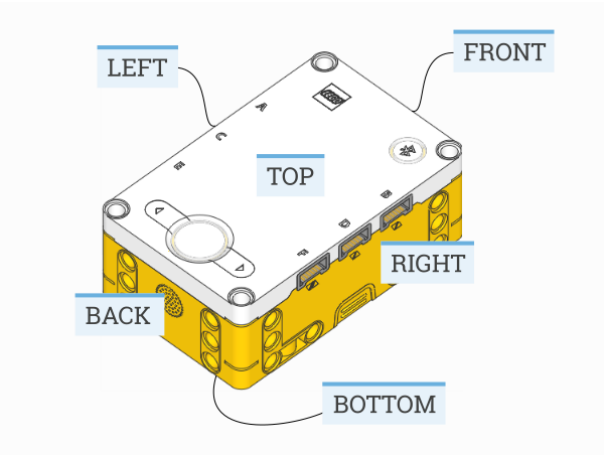
BACK

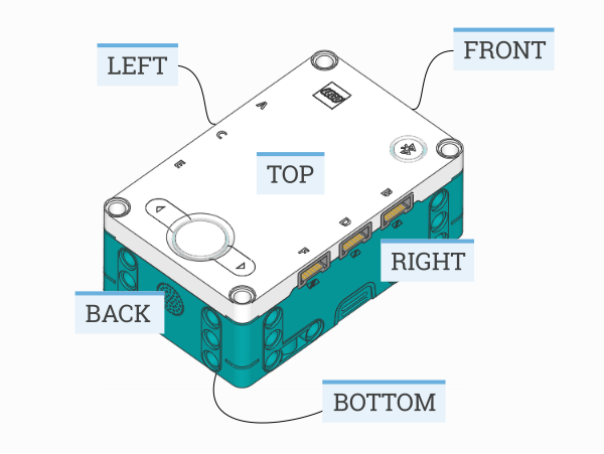
LEFT

RIGHT

Screens or light matrices have only four sides. For those, TOP is treated the same as FRONT, and BOTTOM is treated the same as BACK. The diagrams below define the sides for relevant devices.

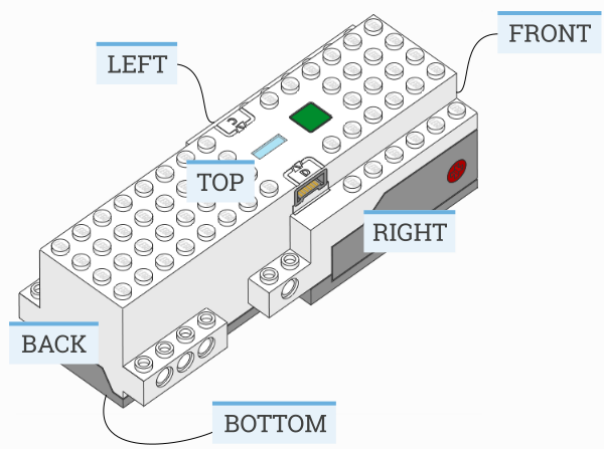
Prime Hub



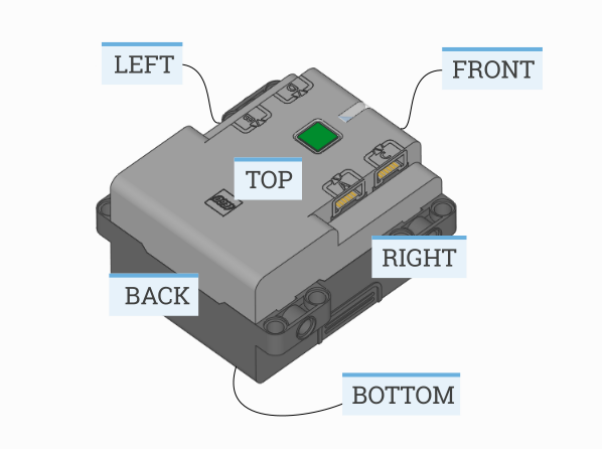


Inventor Hub

Move Hub



Technic Hub



Tilt Sensor

4.6 Stop

`class Stop`

Action after the motor stops.

`COAST`

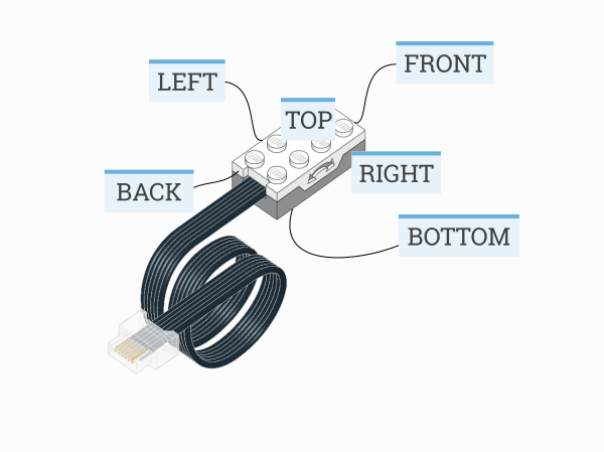
Let the motor move freely.

`BRAKE`

Passively resist small external forces.

`HOLD`

Keep controlling the motor to hold it at the commanded angle. This is only available on motors with encoders.



The following table shows how each stop type adds an extra level of resistance to motion. In these examples, `m` is a *`Motor`* and and `d` is a *`DriveBase`*. The examples also show how running at zero speed compares to these stop types.

Type	Friction	Back EMF	Speed kept at 0	Angle kept at target	Examples
Coast	•				`m.stop()` `m.run_target(500, 90, Stop.COAST)`
Brake	•	•			`m.brake()` `m.run_target(500, 90, Stop.BRAKE)`
	•	•	•		`m.run(0)` `d.drive(0, 0)`
Hold	•	•	•	•	`m.hold()` `m.run_target(500, 90, Stop.HOLD)` `d.straight(0)` `d.straight(100)`

CHAPTER

FIVE

TOOLS – GENERAL PURPOSE TOOLS

Common tools for timing and data logging.

wait(*time*)
Pauses the user program for a specified amount of time.

Parameters **time** (*time: ms*) – How long to wait.

class StopWatch
A stopwatch to measure time intervals. Similar to the stopwatch feature on your phone.

time()
Gets the current time of the stopwatch.

Returns Elapsed time.

Return type *time: ms*

pause()
Pauses the stopwatch.

resume()
Resumes the stopwatch.

reset()
Resets the stopwatch time to 0.

The run state is unaffected:

- If it was paused, it stays paused (but now at 0).
- If it was running, it stays running (but starting again from 0).

CHAPTER

SIX

ROBOTICS – ROBOTICS

Robotics module for the Pybricks API.

class DriveBase(*left_motor*, *right_motor*, *wheel_diameter*, *axle_track*)

A robotic vehicle with two powered wheels and an optional support wheel or caster.

By specifying the dimensions of your robot, this class makes it easy to drive a given distance in millimeters or turn by a given number of degrees.

Positive distances, radii, or drive speeds mean driving **forward**. **Negative** means **backward**.

Positive angles and turn rates mean turning **right**. **Negative** means **left**. So when viewed from the top, positive means clockwise and negative means counterclockwise.

Parameters

- **left_motor** (Motor) – The motor that drives the left wheel.
- **right_motor** (Motor) – The motor that drives the right wheel.
- **wheel_diameter** (*dimension: mm*) – Diameter of the wheels.
- **axle_track** (*dimension: mm*) – Distance between the points where both wheels touch the ground.

Driving for a given distance or by an angle

Use the following commands to drive a given distance, or turn by a given angle.

This is measured using the internal rotation sensors. Because wheels may slip while moving, the traveled distance and angle are only estimates.

straight(*distance*, *then=Stop.HOLD*, *wait=True*)

Drives straight for a given distance and then stops.

Parameters

- **distance** (*distance: mm*) – Distance to travel
- **then** (Stop) – What to do after coming to a standstill.
- **wait** (bool) – Wait for the maneuver to complete before continuing with the rest of the program.

turn(*angle*, *then=Stop.HOLD*, *wait=True*)

Turns in place by a given angle and then stops.

Parameters

- **angle** (*angle: deg*) – Angle of the turn.

- **then** (Stop) – What to do after coming to a standstill.
- **wait** (bool) – Wait for the maneuver to complete before continuing with the rest of the program.

curve(*radius*, *angle*, *then=Stop.HOLD*, *wait=True*)

Drives an arc along a circle of a given radius, by a given angle.

Parameters

- **radius** (*dimension: mm*) – Radius of the circle.
- **angle** (*angle: deg*) – Angle along the circle.
- **then** (Stop) – What to do after coming to a standstill.
- **wait** (bool) – Wait for the maneuver to complete before continuing with the rest of the program.

settings(*straight_speed*, *straight_acceleration*, *turn_rate*, *turn_acceleration*)

Configures the speed and acceleration used by *straight()*, *turn()*, and *curve()*.

If you give no arguments, this returns the current values as a tuple.

You can only change the settings while the robot is stopped. This is either before you begin driving or after you call *stop()*.

Parameters

- **straight_speed** (*speed: mm/s*) – Straight-line speed of the robot.
- **straight_acceleration** (*linear acceleration: mm/s/s*) – Straight-line acceleration and deceleration of the robot.
- **turn_rate** (*rotational speed: deg/s*) – Turn rate of the robot.
- **turn_acceleration** (*rotational acceleration: deg/s/s*) – Angular acceleration and deceleration of the robot.

Drive forever

Use *drive()* to begin driving at a desired speed and steering.

It keeps going until you use *stop()* or change course by using *drive()* again. For example, you can drive until a sensor is triggered and then stop or turn around.

drive(*speed*, *turn_rate*)

Starts driving at the specified speed and turn rate. Both values are measured at the center point between the wheels of the robot.

Parameters

- **speed** (*speed: mm/s*) – Speed of the robot.
- **turn_rate** (*rotational speed: deg/s*) – Turn rate of the robot.

stop()

Stops the robot by letting the motors spin freely.

Measuring

`distance()`
Gets the estimated driven distance.

Returns Driven distance since last reset.

Return type *distance: mm*

`angle()`
Gets the estimated rotation angle of the drive base.

Returns Accumulated angle since last reset.

Return type *angle: deg*

`state()`
Gets the state of the robot.

This returns the current *distance()*, the drive speed, the *angle()*, and the turn rate.

Returns Distance, drive speed, angle, turn rate

Return type (*distance: mm*, *speed: mm/s*, *angle: deg*, *rotational speed: deg/s*)

`reset()`
Resets the estimated driven distance and angle to 0.

Measuring and validating the robot dimensions

As a first estimate, you can measure the `wheel_diameter` and the `axle_track` with a ruler. Because it is hard to see where the wheels effectively touch the ground, you can estimate the `axle_track` as the distance between the midpoint of the wheels.

In practice, most wheels compress slightly under the weight of your robot. To verify, make your robot drive 1000 mm using `my_robot.straight(1000)` and measure how far it really traveled. Compensate as follows:

- If your robot drives **not far enough**, **decrease** the `wheel_diameter` value slightly.
- If your robot drives **too far**, **increase** the `wheel_diameter` value slightly.

Motor shafts and axles bend slightly under the load of the robot, causing the ground contact point of the wheels to be closer to the midpoint of your robot. To verify, make your robot turn 360 degrees using `my_robot.turn(360)` and check that it is back in the same place:

- If your robot turns **not far enough**, **increase** the `axle_track` value slightly.
- If your robot turns **too far**, **decrease** the `axle_track` value slightly.

When making these adjustments, always adjust the `wheel_diameter` first, as done above. Be sure to test both turning and driving straight after you are done.

Using the DriveBase motors individually

Suppose you make a *DriveBase* object using two `Motor` objects called `left_motor` and `right_motor`. You **cannot** use these motors individually while the DriveBase is **active**.

The DriveBase is active if it is driving, but also when it is actively holding the wheels in place after a *straight()* or *turn()* command. To deactivate the *DriveBase*, call *stop()*.

Advanced settings

The *settings()* method is used to adjust commonly used settings like the default speed and acceleration for straight maneuvers and turns. Use the following attributes to adjust more advanced control settings.

You can only change the settings while the robot is stopped. This is either before you begin driving or after you call *stop()*.

`distance_control`
: The traveled distance and drive speed are controlled by a PID controller. You can use this attribute to change its settings. See the *motor control* attribute for an overview of available methods. The `distance_control` attribute has the same functionality, but the settings apply to every millimeter driven by the drive base, instead of degrees turned by one motor.

`heading_control`
: The robot turn angle and turn rate are controlled by a PID controller. You can use this attribute to change its settings. See the *motor control* attribute for an overview of available methods. The `heading_control` attribute has the same functionality, but the settings apply to every degree of rotation of the whole drive base (viewed from the top) instead of degrees turned by one motor.

CHAPTER

SEVEN

GEOMETRY – GEOMETRY AND ALGEBRA

class Matrix(*rows*)

Mathematical representation of a matrix. It supports common operations such as matrix addition (+), subtraction (-), and multiplication (*). A *Matrix* object is immutable.

Parameters **rows** (list) – List of rows. Each row is itself a list of numbers.

T

Returns a new *Matrix* that is the transpose of the original.

shape

Returns a tuple (m, n), where m is the number of rows and n is the number of columns.

vector(*x*, *y*, *z=None*)

Convenience function to create a *Matrix* with the shape (3, 1) or (2, 1).

Parameters

- **x** (float) – x-coordinate of the vector.
- **y** (float) – y-coordinate of the vector.
- **z** (float) – z-coordinate of the vector (optional).

Returns A matrix with the shape of a column vector.

Return type *Matrix*

class Axis

Unit axes of a coordinate system.

X = vector(1, 0, 0)

Y = vector(0, 1, 0)

Z = vector(0, 0, 1)

ANY = None

7.1 Reference frames

The Pybricks module and this documentation use the following conventions:

- X: Positive means forward. Negative means backward.
- Y: Positive means to the left. Negative means to the right.
- Z: Positive means upward. Negative means downward.

To make sure that all hub measurements (such as acceleration) have the correct value and sign, you can specify how the hub is mounted in your creation. This adjust the measurements so that it is easy to see how your *robot* is moving, rather than how the *hub* is moving.

For example, the hub may be mounted upside down in your design. If you configure the settings as shown in Figure 7.1, the hub measurements will be adjusted accordingly. This way, a positive acceleration value in the X direction means that your *robot* accelerates forward, even though the *hub* accelerates backward.

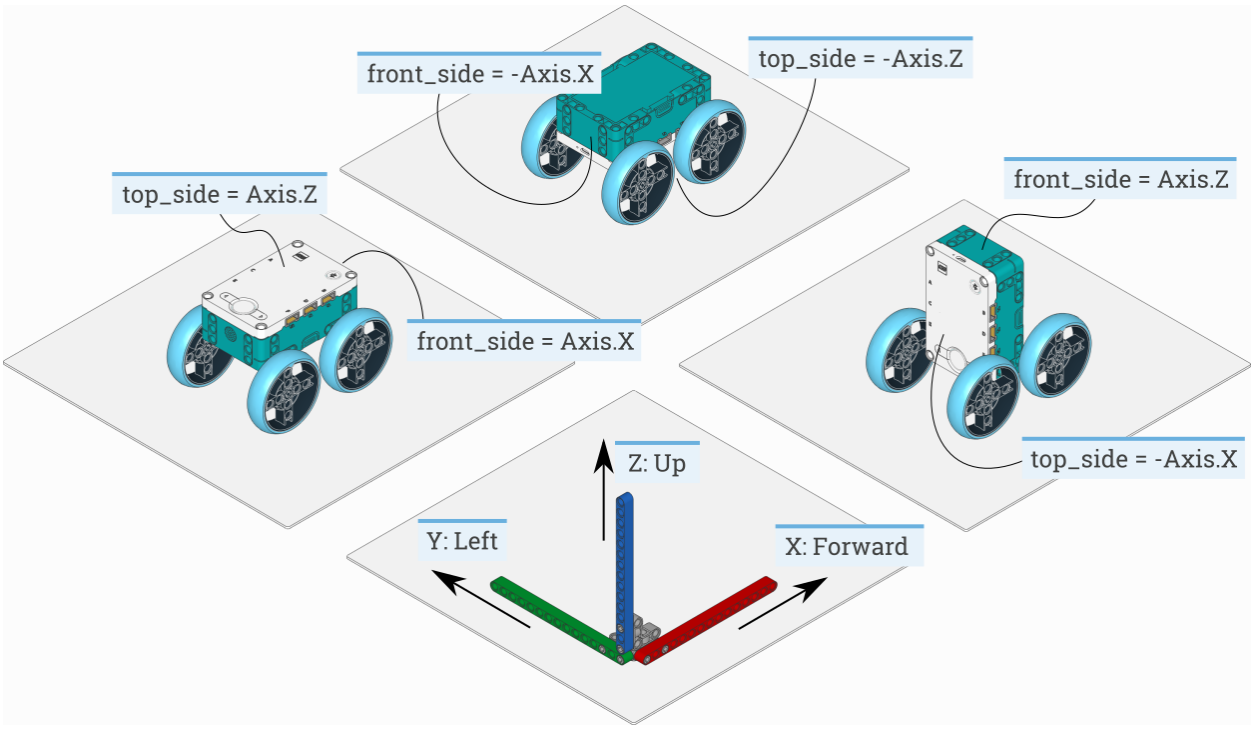


Figure 7.1: How to configure the `top_side` and `front_side` settings for three different robot designs. The same technique can be applied to other hubs and other creations, by noting which way the top and front *`Side`* of the hub are pointing. The example on the left is the default configuration.

CHAPTER

EIGHT

SIGNALS AND UNITS

Many commands allow you to specify arguments in terms of well-known physical quantities. This page gives an overview of each quantity and its unit.

8.1 Time

8.1.1 time: ms

All time and duration values are measured in milliseconds (ms).

For example, the duration of motion with `run_time`, and the duration of *`wait`* are specified in milliseconds.

8.2 Angles and angular motion

8.2.1 angle: deg

All angles are measured in degrees (deg). One full rotation corresponds to 360 degrees.

For example, the angle values of a `Motor` or the `GyroSensor` are expressed in degrees.

8.2.2 rotational speed: deg/s

Rotational speed, or *angular velocity* describes how fast something rotates, expressed as the number of degrees per second (deg/s).

For example, the rotational speed values of a `Motor` or the `GyroSensor` are expressed in degrees per second.

While we recommend working with degrees per second in your programs, you can use the following table to convert between commonly used units.

	deg/s	rpm
1 deg/s =	1	1/6=0.167
1 rpm =	6	1

8.2.3 rotational acceleration: deg/s/s

Rotational acceleration, or *angular acceleration* describes how fast the rotational speed changes. This is expressed as the change of the number of degrees per second, during one second (deg/s/s). This is also commonly written as deg/s^2.

For example, you can adjust the rotational acceleration setting of a `Motor` to change how smoothly or how quickly it reaches the constant speed set point.

8.3 Distance and linear motion

8.3.1 distance: mm

Distances are expressed in millimeters (mm) whenever possible.

For example, the distance value of the `UltrasonicSensor` is measured in millimeters.

While we recommend working with millimeters in your programs, you can use the following table to convert between commonly used units.

	mm	cm	inch
1 mm =	1	0.1	0.0394
1 cm =	10	1	0.394
1 inch =	25.4	2.54	1

8.3.2 dimension: mm

Dimensions are expressed in millimeters (mm), just like distances.

For example, the diameter of a wheel is measured in millimeters.

8.3.3 speed: mm/s

Linear speeds are expressed as millimeters per second (mm/s).

For example, the speed of a robotic vehicle is expressed in mm/s.

8.3.4 linear acceleration: mm/s/s

Linear acceleration describes how fast the speed changes. This is expressed as the change of the millimeters per second, during one second (deg/s/s). This is also commonly written as mm/s^2.

For example, you can adjust the acceleration setting of a *`DriveBase`* to change how smoothly or how quickly it reaches the constant speed set point.

8.3.5 linear acceleration: m/s/s

As above, but expressed in meters per second squared: m/s^2. This is a more practical unit for large values such as those given by an accelerometer.

8.4 Approximate and relative units

8.4.1 percentage: %

Some signals do not have specific units. They range from a minimum (0%) to a maximum (100%). Specifics type of percentages are *relative distances* or *brightness*.

Another example is the sound volume, which ranges from 0% (silent) to 100% (loudest).

8.4.2 relative distance: %

Some distance measurements do not provide an accurate value with a specific unit, but they range from very close (0%) to very far (100%). These are referred to as relative distances.

For example, the distance value of the `InfraredSensor` is a relative distance.

8.4.3 brightness: %

The perceived brightness of a light is expressed as a percentage. It is 0% when the light is off and 100% when the light is fully on. When you choose 50%, this means that the light is perceived as approximately half as bright to the human eye.

8.5 Force and torque

8.5.1 force: N

Force values are expressed in newtons (N).

While we recommend working with newtons in your programs, you can use the following table to convert to and from other units.

	mN	N	lbf
1 mN =	1	0.001	$2.248 \cdot 10^{-4}$
1 N =	1000	1	0.2248
1 lbf =	4448	4.448	1

8.5.2 torque: mNm

Torque values are expressed in millinewtonmeter (mNm) unless stated otherwise.

8.6 Electricity

8.6.1 voltage: mV

Voltages are expressed in millivolt (mV).

For example, you can check the voltage of the battery.

8.6.2 current: mA

Electrical currents are expressed in milliampere (mA).

For example, you can check the current supplied by the battery.

8.6.3 energy: J

Stored energy or energy consumption can be expressed in Joules (J).

8.6.4 power: mW

Power is the rate at which energy is stored or consumed. It is expressed in milliwatt (mW).

8.7 Ambient environment

8.7.1 frequency: Hz

Sound frequencies are expressed in Hertz (Hz).

For example, you can choose the frequency of a beep to change the pitch.

8.7.2 temperature: °C

Temperature is measured in degrees Celcius (°C). To convert to degrees Fahrenheit (°F) or Kelvin (K), you can use the following conversion formulas:

$$^\circ F = {}^\circ C \cdot \frac{9}{5} + 32.$$

$$K = {}^\circ C + 273.15.$$

8.7.3 hue: deg

Hue of a color (0-359 degrees).

TODO: diagram

CHAPTER

NINE

BUILT-IN CLASSES AND FUNCTIONS

The classes and functions shown on this page can be used without importing anything.

9.1 Input and output

input() → str
input(*prompt: str*) → str
Gets input from the user in the terminal window. This function waits until the user presses `Enter`. The input is returned as a string.

Parameters **prompt** – If given, this is printed in the terminal window first. This can be used to ask a question so the user knows what to type.

Returns Everything the user typed before pressing `Enter`.

print(**objects*)
print(**objects*, *sep: str = "' '"*, *end: str = "'\\n'"*, *file:* uio.FileIO = *'usys.stdin'*)
Prints text or other objects in the terminal window.

Parameters **args** – One or more objects to print.

Keyword Arguments

- **sep** – This is printed between objects, if there is more than one.
- **end** – This is printed after the last object.
- **file** – By default, the result is printed in the terminal window. This argument lets you print it to a file instead. This argument is not supported on the BOOST Move hub.

9.2 Basic types

class bool
class bool(*x: Any*)
Creates a boolean value, which is either `True` or `False`.

Parameters **x** – Value that is tested for being `True` or `False`. It is converted using the standard truth testing procedure.

Returns Result of the truth-test. If no object is given, it returns `False`.

class complex
class complex(*string: str*) → None

class complex(*a: Union[float, complex]*, *b: Union[float, complex] = 0*) → None
Creates a complex number from a string or from a pair of numbers.

If a string is given, it must be of the form `'1+2j'`. If a pair of numbers is provided, the result is computed as: `a + b * j`.

Parameters

- **string** – A string of the form `'1+2j'` .
- **a** – A real-valued or complex number.
- **b** – A real-valued or complex number.

Returns Complex number, obtained from the string or as the result of `a + b * j`.

class dict(**args*, ***kwargs*)
Creates a new dictionary.

class float
class float(*x: Union[int, float, str]*) → None
Converts the argument to a floating point number. If no argument is given, this returns `0.0`.

Parameters **x** – Number or string that will be converted.

Returns The input argument `x` converted to a floating point number.

class int
class int(*x: Union[int, float, str]*) → None
Converts the argument to an integer. If no argument is given, this returns `0`.

Parameters **x** – Number or string that will be converted.

Returns The input argument `x` converted to an integer.

to_bytes(*length:* int, *byteorder: Literal[little, big]*) → *bytes*
Returns a *bytes* object representing the integer.

Parameters

- **length** – How many bytes to use.
- **byteorder** – Choose `"little"` for little-endian encoding or `"big"` for big-endian encoding.

Returns The integer represented by a sequence of bytes.

classmethod from_bytes(*bytes: Union[*bytes, bytearray*]*, *byteorder: Literal[little, big]*) → *int*
Returns the integer represented by the given bytes.

Parameters

- **bytes** – The bytes to convert.
- **byteorder** – Determines the byte order used to represent the integer. If byteorder is `"big"`, the most significant byte is at the beginning of the byte sequence. If byteorder is `"little"`, the most significant byte is at the end of the byte sequence.

Returns The integer represented by the bytes.

class object
Return a new featureless object.

class type(*object: Any*)
With one argument, returns the type of an `object`.

9.3 Sequences

class bytearray
class bytearray(*source: int*)
class bytearray(*source: Union[bytes, bytearray, str, Iterable[int]]*)
Creates a new `bytearray` object, which is a sequence of integers in the range $0 \leq x \leq 255$. This object is *mutable*, which means that you *can* change its contents after you create it.

- If no argument is given, this creates an empty `bytearray`.
- If the `source` argument is an integer, this creates a `bytearray` of zeros. The argument specifies how many zeros.
- For all other valid `source` arguments, this creates a bytearray with the same byte sequence as the given `source` argument.

class bytes
class bytes(*source: int*)
class bytes(*source: Union[bytes, bytearray, Iterable[int]]*)
class bytes(*source: str*, *encoding: str*)
Creates a new `bytes` object, which is a sequence of integers in the range $0 \leq x \leq 255$. This object is *immutable*, which means that you *cannot* change its contents after you create it.

- If no argument is given, this creates an empty `bytes` object.
- If the `source` argument is an integer, this creates a `bytes` object of zeros. The argument specifies how many zeros.
- If `source` is a `bytearray`, `bytes` object, or some other iterable of integers, this creates a `bytes` object with the same byte sequence as the `source` argument.
- If `source` is a string, choose `'utf8'` as the `encoding` argument. Then this creates a `bytes` object containing the encoded string.

len(*s: Sequence*) → int
Returns the length (the number of items) of an object.

class list
class list(*iterable: Iterable*)
Creates a new list.

class slice(*stop: int*)
class slice(*start: int*, *stop: int*)
class slice(*start: int*, *stop: int*, *step: int*)
Returns a slice object representing the set of indices specified by `range(start, stop, step)`.

Slice objects are also generated when extended indexing syntax is used. For example: `a[start:stop:step]` or `a[start:stop, i]`.

class str(*object: Any = ''*)
class str(*object: bytes = b''*, *encoding: str = 'utf-8'*, *errors: str = 'strict'*)
Return a *str* version of object.

class tuple
class tuple(*iterable: Iterable*)
Rather than being a function, *tuple* is actually an immutable sequence type.

9.4 Iterators

all(*iterable: Iterable*) → bool
Returns `True` if all elements of the iterable are true (or if the iterable is empty).

Equivalent to:

```
def all(iterable):
    for element in iterable:
        if not element:
            return False
    return True
```

any(*iterable: Iterable*) → bool
Returns `True` if any element of the iterable is true. If the iterable is empty, returns `False`.

Equivalent to:

```
def any(iterable):
    for element in iterable:
        if element:
            return True
    return False
```

class enumerate(*iterable: Iterable*)
class enumerate(*iterable: Iterable*, *start: int*)
Returns an enumerate object.

Equivalent to:

```
def enumerate(sequence, start=0):
    n = start
    for elem in sequence:
        yield n, elem
        n += 1
```

iter(*object: Union[Iterable, Sequence]*) → Iterator
Returns an iterator object.

map(*function: Callable*, *iterable: Iterable*, **args: Any*) → Iterator
Returns an iterator that applies function to every item of iterable, yielding the results.

next(*iterator: Iterator*) → Any
next(*iterator: Iterator*, *default: Any*) → Any
Retrieves the next item from the iterator by calling its `__next__()` method. If `default` is given, it is returned if the iterator is exhausted, otherwise `StopIteration` is raised.

class range(*stop: int*)
class range(*start: int*, *stop: int*)
class range(*start: int*, *stop: int*, *step: int*)
Rather than being a function, `range` is actually an immutable sequence type.

reversed(*seq: Sequence*) → Iterator
Returns a reverse iterator.

sorted(*iterable: Iterable*, *key=None*, *reverse=False*) → List
Returns a new sorted list from the items in `iterable`.

zip(**iterables: Iterable*) → Iterable[Tuple]
Returns an iterator of tuples, where the i-th tuple contains the i-th element from each of the argument sequences or iterables. The iterator stops when the shortest input iterable is exhausted.

With a single iterable argument, it returns an iterator of 1-tuples. With no arguments, it returns an empty iterator.

Equivalent to:

```
def zip(*iterables):
    # zip('ABCD', 'xy') --> Ax By
    sentinel = object()
    iterators = [iter(it) for it in iterables]
    while iterators:
        result = []
        for it in iterators:
            elem = next(it, sentinel)
            if elem is sentinel:
                return
            result.append(elem)
        yield tuple(result)
```

9.5 Conversion functions

bin(*x: Any*) → str
Converts an integer number to a binary string prefixed with "0b". The result is a valid Python expression. If `x` is not a Python *int* object, it has to define an `__index__()` method that returns an integer.

chr(*i: int*) → str
Returns the string representing a character whose Unicode code point is the integer `i`. For example, `chr(97)` returns the string `'a'`.

This is the inverse of *ord()*.

hex(*x: int*) → str
Converts an integer number to a lowercase hexadecimal string prefixed with "0x".

oct(*x: int*) → str
Converts an integer number to an octal string prefixed with "0o".

ord(*c: str*) → int
Given a string representing one Unicode character, return an integer representing the Unicode code point of that character.

This is the inverse of *chr()*.

repr(*object: Any*) → str
Returns a string containing a printable representation of an object.

9.6 Math functions

See also *umath* for floating point math operations.

abs(*x: Any*) → Any
Returns the absolute value of a number. The argument may be an integer, a floating point number, or an object implementing __abs__().

divmod(*a: int*, *b: int*) → Tuple[int, int]
divmod(*a: float*, *b: float*) → Tuple[float, float]
Takes two (non complex) numbers as arguments and returns a pair of numbers consisting of their quotient and remainder when using integer division.

max(*iterable: Iterable*) → Any
max(*arg1: Any*, *arg2: Any*, **args: Any*) → Any
Returns the largest item in an iterable or the largest of two or more arguments.

min(*iterable: Iterable*) → Any
min(*arg1: Any*, *arg2: Any*, **args: Any*) → Any
Returns the smallest item in an iterable or the smallest of two or more arguments.

pow(*base: int*, *exp: int*) → Union[int, float]
pow(*base: int*, *exp: int*, *mod: int*) → Union[int, float]
Returns `base` to the power `exp`; if `mod` is present, returns `base` to the power `exp`, modulo `mod`.

The two-argument form `pow(base, exp)` is equivalent to using the power operator: `base ** exp`.

round(*number: float*) → int
round(*number: float*, *ndigits: int*) → float
Returns `number` rounded to `ndigits` precision after the decimal point. If `ndigits` is omitted or is `None`, it returns the nearest integer to its input.

Tip: To print a number use a format function instead. Since many floating point numbers don't have exact representations, *round()* often gives unexpected results!

Example:

```
# print two decimal places
print('my number: %.2f' % number)
print('my number: {:.2f}'.format(number))
```

---

sum(*iterable: Iterable*) → int
sum(*iterable: Iterable*, *start: int*) → int
Sums `start` and the items of an `iterable` from left to right and returns the total.

9.7 Runtime functions

eval(*expression: str*) → Any
eval(*expression: str*, *globals: dict*) → Any
eval(*expression: str*, *globals: dict*, *locals: Mapping*) → Any
The arguments are a string and optional globals and locals. If provided, `globals` must be a dictionary. If provided, `locals` can be any mapping object.

The return value is the result of the evaluated expression. Syntax errors are reported as exceptions.

exec(*object: Any*) → None
exec(*object: Any*, *globals: dict*) → None
exec(*object: Any*, *globals: dict*, *locals: Mapping*) → None
This function supports dynamic execution of Python code.

globals() → Dict[str, Any]
Return a dictionary representing the current global symbol table.

hash(*object: Any*) → int
Returns the hash value of the object (if it has one).

help() → None
help(*object: Any*) → None
Prints help for the `object`. If no argument is given, prints general help. If object is `'modules'`, prints available modules.

id() → int
Returns the "identity" of an object. This is an integer which is guaranteed to be unique and constant for this object during its lifetime.

locals() → dict
Updates and returns a dictionary representing the current local symbol table.

9.8 Class functions

callable(*object: Any*) → bool
Returns `True` if the object argument appears callable, `False` if not.

dir() → List[str]
dir(*object: Any*) → List[str]
Without arguments, return the list of names in the current local scope. With an argument, attempt to return a list of valid attributes for that object.

getattr(*object: Any*, *name: str*) → Any
getattr(*object: Any*, *name: str*, *default: Any*) → Any
Returns the value of the named attribute of object.

hasattr(*object: Any*, *name: str*) → bool
The result is `True` if the string is the name of one of the object's attributes, `False` if not.

isinstance(*object: Any*, *classinfo: Union[type, Tuple[type]]*) → bool
Returns `True` if the `object` argument is an instance of the `classinfo` argument, or of a subclass thereof.

issubclass(*cls: type*, *classinfo: Union[type, Tuple[type]]*) → bool
Returns `True` if `cls` is a subclass of `classinfo`.

setattr(*object: Any*, *name: str*, *value: Any*) → None
Assigns the value to the attribute, provided the object allows it.

This is the counterpart of *getattr()*.

super() → type
super(*type: type*) → type
super(*type: type*, *object_or_type: Any*) → type
Returns am object that delegates method calls to a parent or sibling class of `type`.

9.9 Method decorators

`@classmethod`
: Transforms a method into a class method.

`@staticmethod`
: Transforms a method into a static method.

CHAPTER

TEN

EXCEPTIONS AND ERRORS

This section lists all available exceptions in alphabetical order.

class ArithmeticError
The base class for those built-in exceptions that are raised for various arithmetic errors.

class AssertionError
Raised when an assert statement fails.

class AttributeError
Raised when an attribute reference or assignment fails.

class BaseException
The base class for all built-in exceptions.

It is not meant to be directly inherited by user-defined classes (for that, use *Exception*).

class EOFError
Raised when the *input()* function hits an end-of-file condition (EOF) without reading any data.

class Exception
All built-in exceptions are derived from this class.

All user-defined exceptions should also be derived from this class.

class GeneratorExit
Raised when a generator or coroutine is closed.

class ImportError
Raised when the `import` statement is unable to load a module.

class IndentationError
Base class for syntax errors related to incorrect indentation.

class IndexError
Raised when a sequence subscript is out of range.

class KeyboardInterrupt
Raised when the user hits the interrupt key (normally `Control-C`).

class KeyError
Raised when a mapping (dictionary) key is not found in the set of existing keys.

class LookupError
The base class for the exceptions that are raised when a key or index used on a mapping or sequence is invalid.

class MemoryError
Raised when an operation runs out of memory.

class NameError
Raised when a local or global name is not found.

class NotImplementedError
In user defined base classes, abstract methods should raise this exception when they require derived classes to override the method, or while the class is being developed to indicate that the real implementation still needs to be added.

class OSError
This exception is raised by the firmware, which is the Operating System that runs on the hub. For *example*, it raises an `OSError` if you call `Motor(Port.A)` when there is no motor on port A.

errno: *int*
Specifies which kind of `OSError` occurred, as listed in the *uerrno* module.

class OverflowError
Raised when the result of an arithmetic operation is too large to be represented.

class RuntimeError
Raised when an error is detected that doesn't fall in any of the other categories.

The associated value is a string indicating what precisely went wrong.

class StopIteration
Raised by built-in function *next()* and an iterator's `__next__()` method to signal that there are no further items produced by the iterator.

Generator functions should return instead of raising this directly.

class SyntaxError
Raised when the parser encounters a syntax error.

class SystemExit
Raised when you press the stop button on the hub or in the Pybricks Code app.

class TypeError
Raised when an operation or function is applied to an object of inappropriate type.

class ValueError
Raised when an operation or function receives an argument that has the right type but an inappropriate value. This is used when the situation is not described by a more precise exception such as *IndexError*.

class ZeroDivisionError
Raised when the second argument of a division or modulo operation is zero.

10.1 Examples

10.1.1 Debugging in the REPL terminal

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port
from pybricks.tools import wait

# Initialize the motor.
test_motor = Motor(Port.A)

# Start moving at 500 deg/s.
```

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```
test_motor.run(500)

# If you click on the terminal window and press CTRL+C,
# you can continue debugging in this terminal.
wait(5000)

# You can also do this to exit the script and enter the
# terminal. Variables in the global scope are still available.
raise KeyboardInterrupt

# For example, you can copy the following line to the terminal
# to get the angle, because test_motor is still available.
test_motor.angle()
```

10.1.2 Running code when the stop button is pressed

```
from pybricks.tools import wait

print("Started!")

try:

    # Run your script here as you normally would. In this
    # example we just wait forever and do nothing.
    while True:
        wait(1000)

except SystemExit:
    # This code will run when you press the stop button.
    # This can be useful to "clean up", such as to move
    # the motors back to their starting positions.
    print("You pressed the stop button!")
```

10.1.3 Detecting devices using `OSError`

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port

from uerrno import ENODEV

try:
    # Try to initialize a motor.
    my_motor = Motor(Port.A)

    # If all goes well, you'll see this message.
    print("Detected a motor.")
except OSError as ex:
    # If an OSError was raised, we can check what
    # kind of error this was, like ENODEV.
```

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```
    if ex.errno == ENODEV:
        # ENODEV is short for "Error, no device."
        print("There is no motor this port.")
    else:
        print("Another error occurred.")
```

CHAPTER

ELEVEN

MICROPYTHON – MICROPYTHON INTERNALS

Access and control MicroPython internals.

const(*value: int*) → int
: Declares the value as a constant. This value will be substituted wherever it is used, which makes your code more efficient.

  To reduce memory usage further, prefix its name with an underscore (`_ORANGES`). This constant can only be used within the same file.

  If you want to import the value from another module, use a name without an underscore (`APPLES`). This uses a bit more memory.

opt_level() → int
opt_level(*level: int*) → None
: Sets the optimization level for code compiled on the hub:

  0. Assertion statements are enabled. The built-in `__debug__` variable is `True`. Script line numbers are saved, so they can be reported when an Exception occurs.
  1. Assertions are ignored and `__debug__` is `False`. Script line numbers are saved.
  2. Assertions are ignored and `__debug__` is `False`. Script line numbers are saved.
  3. Assertions are ignored and `__debug__` is `False`. Script line numbers are *not* saved.

  This applies only to code that you run in the REPL, because regular scripts are already compiled before they are sent to the hub.

  If no argument is given, this function returns the current optimization level.

mem_info() → None
mem_info(*verbose: Any*) → None
: Prints information about stack and heap memory usage.

  If the `verbose` argument is given, it also prints out the entire heap, indicating which blocks are used and which are free.

qstr_info() → None
qstr_info(*verbose: Any*) → None
: Prints how many strings are interned and how much RAM they use.

  MicroPython uses string interning to save both RAM and ROM. This avoids having to store duplicate copies of the same string.

  If the `verbose` argument is given it also prints out the names of all RAM-interned strings.

stack_use() → int
: Returns the amount of stack that is being used. This can be used to compute differences in stack usage at different points in a script.

kbd_intr(*chr: int*) → None

Set the character that will raise a `KeyboardInterrupt` exception. By default this is set to `3` during script execution, corresponding to `Ctrl-C`. Passing `-1` to this function will disable capture of `Ctrl-C`, and passing `3` will restore it.

This function can be used to prevent the capturing of `Ctrl-C` on the incoming stream of characters that is usually used for the REPL, in case that stream is used for other purposes.

11.1 Examples

11.1.1 Using constants for efficiency

```
from micropython import const

# This value can be used here. Other files can import it too.
APPLES = const(123)

# These values can only be used within this file.
_ORANGES = const(1 << 8)
_BANANAS = const(789 + _ORANGES)

# You can read the constants as normal values. The compiler
# will just insert the numeric values for you.
fruit = APPLES + _ORANGES + _BANANAS
print(fruit)
```

11.1.2 Checking free RAM

```
from micropython import mem_info

# Print memory usage.
mem_info()
```

This prints information in the format shown below. In this example for the SPIKE Prime Hub, there are 257696 bytes (251 KB) worth of memory remaining for the variables in your code.

```
stack: 372 out of 40184
GC: total: 258048, used: 352, free: 257696
No. of 1-blocks: 4, 2-blocks: 2, max blk sz: 8, max free sz: 16103
```

11.1.3 Getting more memory statistics

```
from micropython import const, opt_level, mem_info, qstr_info, stack_use

# Get stack at start.
stack_start = stack_use()

# Print REPL compiler optimization level.
```

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(continued from previous page)

```
print("level", opt_level())

# Print memory usage.
mem_info()

# Print memory usage and a memory map.
mem_info(True)

# Print interned string information.
qstr_info()

# Print interned string information and their names.
APPLES = const(123)
_ORANGES = const(456)
qstr_info(True)


def test_stack():
    return stack_use()


# Check the stack.
print("Stack diff: ", test_stack() - stack_start)
```

CHAPTER

TWELVE

UERRNO – ERROR CODES

The `errno` attribute of an *OSError* indicates why this exception was raised. This attribute has one of the following values. See also *this example*.

EAGAIN: int
The operation is not complete and should be tried again soon.

EBUSY: int
The device or resource is busy and cannot be used right now.

ECANCELED: int
The operation was canceled.

EINVAL: int
An invalid argument was given. Usually `ValueError` is used instead.

EIO: int
An unspecified error occurred.

ENODEV: int
Device was not found. For example, a sensor or motor is not plugged in the correct port.

EOPNOTSUPP: int
The operation is not supported on this hub or on the connected device.

EPERM: int
The operation cannot be performed in the current state.

ETIMEDOUT: int
The operation timed out.

errorcode: Dict[int, str]
Dictionary that maps numeric error codes to strings with symbolic error code.

CHAPTER

THIRTEEN

UIO – INPUT/OUTPUT STREAMS

Note: This module is not available on the BOOST Move Hub.

This module contains additional types of `stream` (file-like) objects and helper functions.

class BytesIO
class BytesIO(*initial_bytes: bytes*)
class BytesIO(*alloc_size: int*)
A binary stream using an in-memory bytes buffer.

Parameters

- **initial_bytes** – Optional bytes-like object that contains initial data.
- **alloc_size** – Optional number of preallocated bytes.

class StringIO
class StringIO(*initial_value: str*)
class StringIO(*alloc_size: int*)
A binary stream using an in-memory string buffer.

Parameters

- **initial_value** – Optional string object that contains initial data.
- **alloc_size** – Optional number of preallocated bytes.

class FileIO
This is type of a file open in binary mode, e.g. using `open(name, 'rb')`. You should not instantiate this class directly.

CHAPTER

FOURTEEN

umath – MATH FUNCTIONS

This MicroPython module is similar to the math module in Python.

See also the *built-in math functions* that can be used without importing anything.

14.1 Rounding and sign

ceil(*x: float*) → int
Rounds up.

Parameters **x** – The value `x`.

Returns Value rounded towards positive infinity.

floor(*x: float*) → int
Rounds down.

Parameters **x** – The value `x`.

Returns Value rounded towards negative infinity.

trunc(*x: float*) → int
Truncates decimals to get the integer part of a value.

This is the same as rounding towards `0`.

Parameters **x** – The value `x`.

Returns Integer part of the value.

fmod(*x: float*, *y: float*) → float
Gets the remainder of `x / y`.

Not to be confused with *modf()*.

Parameters

- **x** – The numerator.
- **y** – The denominator.

Returns Remainder after division

fabs(*x: float*) → float
Gets the absolute value of `x`.

Parameters **x** – The value.

Returns Absolute value.

copysign(*x: float*, *y: float*) → float
Gets `x` with the sign of `y`.

Parameters

- **x** – Determines the magnitude of the return value.
- **y** – Determines the sign of the return value.

Returns `x` with the sign of `y`.

14.2 Powers and logarithms

e = 2.718282
The mathematical constant e.

exp(*x: float*) → float
Gets *e* raised to the power of `x`.

Parameters **x** – The exponent.

Returns *e* raised to the power of `x`.

pow(*x: float*, *y: float*) → float
Gets `x` raised to the power of `y`.

Parameters

- **x** – The base number.
- **y** – The exponent.

Returns `x` raised to the power of `y`.

log(*x: float*) → float
Gets the natural logarithm of `x`.

Parameters **x** – The value `x`.

Returns The natural logarithm of `x`.

sqrt(*x: float*) → float
Gets the square root of `x`.

Parameters **x** – The value `x`.

Returns The square root of `x`.

14.3 Trigonomety

pi = 3.141593
The mathematical constant .

degrees(*x: float*) → float
Converts an angle `x` from radians to degrees.

Parameters **x** – Angle in radians.

Returns Angle in degrees.

`radians`(*x: float*) → float
Converts an angle `x` from degrees to radians.

Parameters `x` – Angle in degrees.

Returns Angle in radians.

`sin`(*x: float*) → float
Gets the sine of the given angle `x`.

Parameters `x` – Angle in radians.

Returns Sine of `x`.

`asin`(*x: float*) → float
Applies the inverse sine operation on `x`.

Parameters `x` – Opposite / hypotenuse.

Returns Arcsine of `x`, in radians.

`cos`(*x: float*) → float
Gets the cosine of the given angle `x`.

Parameters `x` – Angle in radians.

Returns Cosine of `x`.

`acos`(*x: float*) → float
Applies the inverse cosine operation on `x`.

Parameters `x` – Adjacent / hypotenuse.

Returns Arccosine of `x`, in radians.

`tan`(*x: float*) → float
Gets the tangent of the given angle `x`.

Parameters `x` – Angle in radians.

Returns Tangent of `x`.

`atan`(*x: float*) → float
Applies the inverse tangent operation on `x`.

Parameters `x` – Opposite / adjacent.

Returns Arctangent of `x`, in radians.

`atan2`(*b: float*, *a: float*) → float
Applies the inverse tangent operation on `b / a`, and accounts for the signs of `b` and `a` to produce the expected angle.

Parameters

- `b` – Opposite side of the triangle.
- `a` – Adjacent side of the triangle.

Returns Arctangent of `b / a`, in radians.

14.4 Other math functions

isfinite(*x: float*) → bool
Checks if `x` is finite.

Returns `True` if `x` is finite, else `False`.

isinfinite(*x: float*) → bool
Checks if `x` is infinite.

Returns `True` if `x` is infinite, else `False`.

isnan(*x: float*) → bool
Checks if `x` is not-a-number.

Returns `True` if `x` is not-a-number, else `False`.

modf(*x: float*) → Tuple[float, float]
Gets the fractional and integral parts of `x`, both with the same sign as `x`.

Not to be confused with *fmod()*.

Parameters **x** – The value to be decomposed.

Returns Tuple of fractional and integral parts.

frexp(*x: float*) → Tuple[float, int]
Decomposes a value `x` into a tuple `(m, p)`, such that `x == m * (2 ** p)`.

Parameters **x** – The value to be decomposed.

Returns Tuple of `m` and `p`.

ldexp(*m: float*, *p: int*) → float
Computes `m * (2 ** p)`.

Parameters

- **m** – The value.
- **p** – The exponent.

Returns Result of `m * (2 ** p)`.

CHAPTER

FIFTEEN

URANDOM – PSEUDO-RANDOM NUMBERS

This module implements pseudo-random number generators.

Note: This module is not available on the BOOST Move Hub.

You can make your own random number generator like this instead:

```
_rand = hub.battery.voltage() + hub.battery.current()  # seed

# Return a random integer N such that a <= N <= b.
def randint(a, b):
    global _rand
    _rand = 75 * _rand % 65537  # Lehmer
    return _rand * (b - a + 1) // 65537 + a
```

seed(*a: Optional[int] = None*) → None
Initialize the random number generator.

Parameters **a** – Optional seed value. If `None`, the system timer will be used.

Tip: This is called when the module is imported, so normally you do not need to call this.

randrange(*stop: int*) → int
randrange(*start: int*, *stop: int*) → int
randrange(*start: int*, *stop: int*, *step: int*) → int
Returns a randomly selected element from `range(start, stop, step)`.

randint(*a: int*, *b: int*) → int
Returns a random integer *N* such that `a <= N <= b`.

getrandbits(*k: int*) → int
Returns a non-negative integer with `k` random bits.

choice(*seq: Sequence[Any]*) → Any
Returns a random element from the non-empty sequence `seq`.

If `seq` is empty, raises `IndexError`.

random() → float
Return the next random floating point number in the range [0.0, 1.0).

Tip: The interval notation indicates that this includes 0.0 and excludes 1.0.

uniform(*a: float*, *b: float*) → float

Returns a random floating point number *N* such that `a` <= *N* <= `b` for `a` <= `b` and `b` <= *N* <= `a` for `b` < `a`.

The end-point value `b` may or may not be included in the range depending on floating-point rounding in the equation `a + (b-a) * random()`.

CHAPTER

SIXTEEN

USELECT – WAIT FOR EVENTS

This module provides functions to efficiently wait for events on multiple streams.

Note: This module is not available on the BOOST Move hub.

POLLIN: int
Data is available for reading.

POLLOUT: int
More data can be written.

POLLERR: int
Error condition happened on the associated stream.

POLLHUP: int
Hang up happened on the associated stream.

poll() → *uselect.Poll*
Creates an instance of the Poll class.

class Poll

register(*obj: IO*) → None
register(*obj: IO*, *eventmask: int*) → None
Register *stream* `obj` for polling. `eventmask` is logical OR of:

- *POLLIN*
- *POLLOUT*

Note that flags like *POLLHUP* and *POLLERR* are *not* valid as input eventmask (these are unsolicited events which will be returned from *poll()* regardless of whether they are asked for). This semantics is per POSIX.

`eventmask` defaults to `POLLIN | POLLOUT`.

It is OK to call this function multiple times for the same `obj`. Successive calls will update `obj`'s eventmask to the value of `eventmask` (i.e. will behave as *modify()*).

unregister(*obj: IO*) → None
Unregister `obj` from polling.

modify(*obj: IO*, *eventmask: int*) → None
Modify the `eventmask` for `obj`. If `obj` is not registered, `OSError` is raised with error of `ENOENT`.

poll() → List[Tuple[IO, int]]

poll(*timeout: int*) → List[Tuple[IO, int]]
Wait for at least one of the registered objects to become ready or have an exceptional condition, with optional timeout in milliseconds (if `timeout` arg is not specified or -1, there is no timeout).

Returns list of (`obj`, `event`, ...) tuples. There may be other elements in tuple, depending on a platform and version, so don't assume that its size is 2. The `event` element specifies which events happened with a stream and is a combination of `POLL*` constants described above. Note that flags *POLLHUP* and *POLLERR* can be returned at any time (even if were not asked for), and must be acted on accordingly (the corresponding stream unregistered from poll and likely closed), because otherwise all further invocations of *poll()* may return immediately with these flags set for this stream again.

In case of timeout, an empty list is returned.

ipoll() → Iterator[Tuple[IO, int]]
ipoll(*timeout: int*) → Iterator[Tuple[IO, int]]
ipoll(*timeout: int*, *flags: int*) → Iterator[Tuple[IO, int]]
Like *poll()*, but instead returns an iterator which yields a *callee-owned tuple*. This function provides an efficient, allocation-free way to poll on streams.

If `flags` is 1, one-shot behavior for events is employed: streams for which events happened will have their event masks automatically reset (equivalent to `poll.modify(obj, 0)`), so new events for such a stream won't be processed until new mask is set with *modify()*. This behavior is useful for asynchronous I/O schedulers.

CHAPTER

SEVENTEEN

USYS – SYSTEM SPECIFIC FUNCTIONS

This MicroPython module is a subset of the sys module in Python.

stdin
: Stream object (*uio.FileIO*) that receives input from a connected terminal, if any.

  Writing may modify newline characters. Use `usys.stdin.buffer` instead if this is undesirable.

  Also see *micropython.kbd_intr()* to disable `KeyboardInterrupt` if you are passing binary data via `stdin`.

stdout
: Stream object (*uio.FileIO*) that sends output to a connected terminal, if any.

  Reading may modify newline characters. Use `usys.stdout.buffer` instead if this is undesirable.

stderr
: Alias for *stdout*.

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